THE GEOLOGY AND ORE DEPOSITS OF

HILTANO CAMP, ARIZONA

by

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PREFACE.

The following report is patterned after the folios of the U. S. Geological Survey except that it has been slightly modified by the writer and follows the outline as given in Lahee's "Field Geology." The following are the headings:

1. Introduction.
2. Summary.
3. Topography and Physiography.
4. Descriptive Geology.
   a. Petrography.
   b. Structure.
5. Historical Geology
   a. Stratigraphy.
   b. Paleontology.
6. Mineralogy.
7. Economic Geology and Ore Genesis.
8. Photos.
9. Maps.

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INTRODUCTION.

The following report is submitted as a Master of Science Thesis at the University of Arizona, May, 1929, and describes the Hiltano mining district, 47 miles southeast of Tucson in Pima County, Arizona. The camp is reached by an old road directly south from Pantano, a small station on the Southern Pacific Railway, which is located on the main highway about 35 miles from Tucson on the Bisbee road. The camp is located on the south side of the Empire Mts., a low range between the Whetstone and Santa Rita Mts. The road through this range is usually in very poor condition. The Hiltano district occupies about two square miles of very rugged country but the area covered in this report is about one-half of this.

The district has been worked since 1880 and there have been several producing mines, the most important being the Total Wreck which is reported by Schrader to have yielded $450,000 worth of silver lead ore. In all there are perhaps fifteen claims that have produced, although none of them ever equaled the Total Wreck in output.

The mines of the Hiltano group, which comprised the Prince, Gopher, Chief and adjacent claims, were operated by the Hiltano Exploration Company, a subsidiary of the Calumet and Arizona Mining Company, until about the

middle of December, 1928, at which time the properties were leased. About eighty men, all Mexicans, were employed by J.B.Harper, mine manager. Exploration was carried on by shaft sinking, trenching, and near the end of the operations, by geophysical methods. Several truckloads of ore were shipped to Douglas before the closing of the camp, and at present, April, 1929, the Chief and Gopher are being operated by lessees on a small scale.

There is no permanent surface water supply in the camp. Water was struck at the Prince shaft at 450 feet. While the camp was in operation, this furnished an ample supply for well over a hundred people, but there is no other well nearer than a ranch house at Hilton's Ranch, two miles away. There is little or no vegetation other than the desert plants and a few live oak on the river bottoms. There are no flowing streams or springs, except during or immediately after rains.

SUMMARY.

The Empire Mts. are a small outlier of the larger ranges of the Santa Rita Mts. to the west. The range trends to the northeast for a distance of seven miles from Hiltano camp, and is perhaps four miles across from east to west. Structurally it consists of a southeastward dipping monocline of late Paleozoic limestones and quartz-

ites, which are underlain by intrusive granites and overlaid by Cretaceous sediments. The mineral deposits are all associated with intrusive rocks within the limestones.

The Hiltano district is composed entirely of Pennsylvanian and Permian limestones and quartzites and Cretaceous arkoses. These sedimentaries dip eastward at an angle around 65 degrees. The Paleozoic rocks have been extensively intruded by dikes of quartz porphyry, by sills, and to the northwest, by a stock of granodiorite. The rocks have been extensively faulted by, undoubtedly, post intrusive movement. There has been no folding on a large scale within the sedimentary rocks. There is considerable local metamorphism adjacent to intrusive contacts, especially along the stock well exposed on Empire Peak.

Ore deposits of small size occur as replacements of and fillings in cavities within the Permian limestone. The primary ore bodies were small sulphide masses which have been extensively oxidized to carbonate and sulphate ores.

TOPOGRAPHY AND PHYSIOGRAPHY.

The Hiltano district occupies a divide with two distinct drainage systems, one to the east down Cienaga Creek, and one to the west down Davidson Canyon.

The easterly half of the area consists of low rounded hills, seldom rising over 100 feet above the lower gulches. There is well developed radial drainage. Most of the small valleys, however, are determined by faults within the limestone. The Davidson Canyon area is distinctly more rugged, the canyon itself is over 800 feet below the divide, and Empire Peak on the north side reaching an altitude of 5480 feet, an elevation of over 1200 feet above the bottom of the canyon. The sides of this canyon are comparatively steep and somewhat cut by small gulches.

A level sight taken southward from the summit of Empire Peak looking over the plateau of valley fill to the south of the range, seems to indicate that possibly the Empire Mts. were once buried beneath the valley fill of Tertiary or Quaternary gravels, sands, and conglomerates. It appears as if this has been eroded back to the south forming the escarpment over which the present auto road climbs, on the way to Sonoita.

DESCRIPTIVE GEOLOGY.

Sedimentary Rocks.

The sedimentary rocks of the Hiltano district are limestones, quartzites, arkoses and some in-

terbedded shales. The older rocks are of Pennsylvanian and Permian age; these are capped by Cretaceous arkoses. The entire section is well exposed just to the north of the main camp, where the beds strike uniformly N. 60 E. and dip around 70 degrees to the S. S. E. The Paleozoics total around 2400 feet in thickness; the thickness of the Cretaceous is unknown. An exact measurement of the Cretaceous has not been made, but it extends some two miles east from Hiltano, with regularly dipping beds having the same strike as the earlier formations. The Cretaceous arkose is separated from the Paleozoic rocks by a bed of conglomerate, but there is no recognizable change in either dip or strike in the beds above or below the conglomerate.

Naco Limestone (Pennsylvanian).

The oldest formation in the immediate vicinity of Hiltano is the Naco limestone, approximately 1600 feet in thickness, which is well exposed on the ridges of Empire Peak. This limestone is very light grey in color, contains numerous quartzite beds, and a few thin bedded shales and argillites. In some places it is coarsely crystalline, in others, extremely fine in texture. There has been considerable local metamorphism within the formation near the stock at the summit of the main

peak, which has produced large masses of garnet, tremolite, marble, and epidote; the garnet and tremolite are frequently found in very large boulders. Whether or not the Escabrosa (Mississippian) limestone is represented in the series, the writer has been unable to determine, as the limestone is so highly altered near the contact that any fossil evidence has been destroyed.

Ransome in the Bisbee Folio places the Naco at 3000 feet in thickness, and at Tombstone slightly less. Therefore there is no reason to suppose that the exposure on Empire Peak is other than Naco, and as the limestones are terminated by the big fault system at the mouth of the east branch of Davidson Canyon, there is no reason to expect an exposure of the Escabrosa or Martin within the immediate district.

The limestone beds vary in thickness from a foot to five or six feet. There are numerous siliceous horizons within these beds and some of the silica zones contain abundant fossils. The presence of pyrite casts is suggestive of mineralization within the silica, but prospect pits fail to reveal any persistancy with depth.

Red Quartzite (Basal Snyder's Hill).

A quartzitic sandstone marks the border

between the Naco and the overlying Snyder's Hill formation. This is a massive brown rock weathering a brick-red color. The rock is fine grained, very compact, and shows good stratification. The beds vary from a few inches to a foot or more in thickness. It occupies the ridge between Empire Peak and South Mt., and extends in a fairly even manner, with strike conformable to the limestones. The rock weathers in cubical blocks which average two or three inches on a side. The sand grains are so well cemented that when the rock is broken, it breaks across the grain.

In general there is considerable contortion along faults and in several places the formation has been slightly folded. There is a well developed system of joints at right angles to the bedding. This formation is considered basal Permian in various parts of the state, but it cannot be definitely placed stratigraphically, due to lack of fossil evidence.

Snyder's Hill Limestone (Permian).

The Snyder's hill limestone is the most characteristic rock in the vicinity and is found outcropping all along the ridges to the west of Hiltano camp. The

ore deposits occur within this limestone. The rock is grey, is extremely dense, in fact, almost lithographic in character. It is never crystalline, except around solution cracks. Some of the beds contain considerable chert, and within these beds have been found numerous specimens of silicified coral. Corals are very common throughout the formation. The chert is usually grey or white and sometimes shows iron stain. The formation is well stratified with beds varying in thickness from a foot to five or more feet. Jointing is well developed at right angles to the strike and there is considerable fissuring parallel to the strike. It weathers by typical limestone solution and some of the dissolved carbonate is reprecipitated in cavities underground, as aragonite. This is well shown at the Chief Shaft.

The presence of typical index fossils of Permian age, place this limestone as the Snyder's Hill formation as stated verbally by Prof. A.A.Stoyanow of the University of Arizona. The type locality is Snyder's Hill, some 12 miles west of Tucson, on the Ajo road.

Conglomerate (Basal Cretaceous).

At the base of the Cretaceous is a bed of conglomerate which separates the Snyder's Hill formation from the arkose. It is well exposed in the gulch below the

bridge on the way up to the Prince Shaft and is readily traced northward all along the foot of the Empire Mts. It consists essentially of limestone pebbles cemented by a calcareous material. The pebbles vary considerably in size, some are as much as a foot or more in diameter, others are much smaller. The pebbles are well rounded and the cementing material is suggestive of caliche. The pebbles are made up of fragments of the Snyder's Hill formation, as is shown by the presence of chert nodules and fossils of that age. The bed appears to be conformable with the underlying Permian and overlying Cretaceous, but nowhere has there been found any signs of stratification.

Arkose (Cretaceous).

A few feet below an old office shack, represented now only by an old water line, there outcrops the lowest of a great series of Cretaceous (?) sediments. These rocks extend for a distance of over two miles at right angles to their strike. The arkose in the immediate vicinity of the camp is deep red in color, rather hard, and regularly stratified in beds from five to six feet in thickness. At the camp, the arkose is fine grained and

composed of orthoclase cemented by lime carbonate, with a few quartz pebbles in places, as well as some conglomerate beds near the base of the section. It weathers a rusty brown color and shows a distinct tendency towards spheroidal weathering along well defined joint planes at right angles to the plane of stratification. Farther eastward these arkoses are interbedded with shales, conglomerates, and some limestones. There has been no exact correlation of this formation due to lack of fossil evidence. Darton places it in the Comanchean but recent discussion on the subject tends to place it in the Cretaceous.

METAMORPHIC ROCKS.

There are no regionally metamorphosed rocks within the area. There is, however, considerable local alteration due to the numerous intrusive bodies. Masses of marble are exposed on Empire Peak where they occur as roof pendents; also there is a small area of marble along the northern extremity of the quartz porphyry dike that cuts through the Snyder's Hill formation. The Naco formation has several beds of hornfels and quartzite at one point, but, in general, all the alteration is of purely local character, not very persistent, and consists of small masses of garnet tremolite principally.

IGNEOUS ROCKS.

The igneous rocks within the area are entirely intrusive and for the most part of acid composition. The main intrusive body of the district is a large stock of granodiorite which outcrops along the summit ridges of Empire Peak, on the northern side of Davidson Canyon. Numerous small dikes cut through the limestones on the lower slopes, and there is also one fair sized sill of basic composition.

Granodiorite.

The large stock on Empire Peak, the main intrusive body of the district is, according to Schrader, in U.S.G.S. Bulletin 582, a granite of probable Mesozoic age. Microscopic examination of numerous samples from this intrusive tend to show that it is a granodiorite.

The rock, where exposed on Empire Peak, is white in color, has a typical granitic texture, and weathers slightly brown, due to the presence of magnetite and some pyrite. The essential primary minerals, as revealed by the microscope, are quartz, orthoclase, and plagioclase; the latter ranging from acid labradorite to basic

andesine. Primary rock-forming minerals are: hornblende, titanite, magnetite, and apatite. There is considerable secondary sericite and chlorite.

Slight variations in color are due to the presence of more or less hornblende, but, in general, the rock is of the same composition throughout. At the bottom of Davidson Canyon there is a small outcrop of the rock, but beyond the fact that this contains biotite, it is essentially similar to the rest.

The granodiorite tends to break down to a fine white sand and shows typical spheroidal weathering. Jointing is well shown at the lower outcrops where the rock weathers in large blocks several feet across.

Just when this granodiorite was intruded is subject to question. Schrader states that it is probably Mexozoic. The writer is of the opinion that it is at least post-Cretaceous, due to the fact that the Cretaceous sediments are conformable to the underlying Paleozoics and that the entire section was undoubtedly tilted to near its present dip before intrusion by the stock.

Quartz Porphyry.

Quartz porphyry dikes are extremely common throughout the area and, although they vary somewhat in color and texture, microscopic examination reveals

them all to be of the same composition. The dike which has determined the ore deposits at Hiltano camp is the largest exposed and extends N. 70 E. from the Chief shaft, approximately along the strike of the limestone. This dike is about a quarter of a mile in length and varies in width from five to fifteen feet. It is terminated by a fault near the north end of the Permian beds and displaced westward a distance of about 1600 feet, where it outcrops along the east slope of Empire Peak, extending north in the same direction as before. The color is white or cream, the texture typically fine-grained felsitic, with small quartz phenocrysts scattered throughout. In places there are a few phenocrysts of orthoclase. Microscopic examination fails to reveal any unusual associations; the groundmass is entirely cryptocrystalline.

At some places, notably near the Chief Shaft, this dike apparently produced a great deal of alteration within the adjoining limestone. Here for some distance along the dike, the limestone is altered to marble within ten feet or more on either side of the intrusive. At other points, however, notably at the prospect pits along Dike Hill, there is no alteration whatsoever.

This dike cuts vertically through the limestones at all points observed. It is very resistant to the hammer, but seems to weather at about the same speed as the limestone, as it seldom projects over a foot above the softer rock.

To the south and around the slope of South Mt. there is a darker colored dike which tends to weather green. It is very compact, very hard to break and appears to be quite different from the other quartz porphyries to the north. Microscopic examination shows that it is essentially the same, the greenish tinge being due to minute crystals of hornblende within the groundmass. The rock itself is chiefly orthoclase and quartz, the latter readily visible with a hand lens. This dike is about 15 feet wide and strikes due north. Its dip is impossible to determine. The rock weathers to a greenish sand, the weathering speed being about the same as the limestone. There is no evidence of alteration in the vicinity of the contact.

Gabbro.

There are two sills of hornblende-gabbro outcropping at Hiltano, one at the Prince Shaft, and the other at the bottom of Davidson Canyon. They are similar in composition and texture. The sill at the Prince Shaft strikes N. 70 E. with the limestone formation and dips around 60 degrees to the S.S.E. The rock is dark greenish-black in color and varies in texture from coarse crystalline to comparatively fine granitic. The longer hornblende crystals reach a length of a quarter of an inch. The

feldspar is basic labradorite. The rock weathers to a green-black sand and contains considerable pyrite. Numerous fissures in the rock are filled with small veins of calcite; these are well seen along the pits back of the Prince Shaft. The exact age of the sill cannot be determined.

STRUCTURAL GEOLOGY.

The Empire Mts. are a large tilted block which dips to the south-east and is terminated on the northwest by the fault system of Davidson Canyon. The complete series dips 60 to 70 degrees to the south-southeast, and strikes N. 70 E. There are some local variations due to faulting and the intrusive bodies, but, on the whole, the dip is uniform.

In the northwest section of the area, the beds have been intruded and slightly contorted by a granodiorite stock which forms the main mass of Empire Peak. Roof pendant structure is well shown by limestone on the summit of the peak, where it is surrounded by granite on three sides.

The tilted sedimentary rocks have been intruded by porphyry dikes and sills; the dikes were probably intruded after tilting, but the age of the sills is subject to question. The dikes all cut vertically through

the limestone and are offset at slight angles from the strike. The sills are extremely regular and are distinctly parallel to the bedding at all points observed.

There are numerous faults in the area, the majority of them trend east-west; the strike of the faults being about thirty degrees east of the formational strike. The faults range in throw from a few feet to a quarter of a mile. Depressions and irregularities within the Snyder's hill limestone suggest strike faulting, but this is difficult to determine. Due to the lack of key horizons within the limestone itself, faulting within the Snyder's Hill formation is somewhat obscure and data can only be obtained from the borders. Most of the faulting is post intrusive, as is well shown by the displacement of the quartz porphyry dike near the Chief Shaft, and at the northern end of the area. The sill, however, shows no displacement, despite the fact that a very large fault cuts directly across the body in the gulch north of the Prince Shaft. At the south end of this sill, there is some small faulting with displacements of a few feet.

In all cases the sediments are conformable with each other. The contact of the Naco and red quartzite, red quartzite and Snyder's Hill, and Snyder's Hill and arkose, shows no angular variation. The presence of the conglomeritic layer between the

Snyder's Hill limestone and Cretaceous arkose undoubtedly denotes a hiatus, but the arkoses are angularly conformable to the limestone at six points measured.

There has been considerable fissuring in the limestone along the strike, and this has undoubtedly influenced the ore deposition at Hiltano. There are also numerous silica bodies which outcrop at numerous points, sometimes in circular form and often in long dike-like masses. These occur in many places, some of them extending well into the ground to the 650-foot level of the Prince Shaft, and others seem to be merely surface phenomena. Investigation has disclosed no visible relation of these silica veins and pipes to the deposits.

HISTORICAL GEOLOGY.

Just what the geological history of the region was prior to the Pennsylvanian period is obscure, due to the complete absence of any earlier rocks. It is perfectly possible that earlier periods such as the Mississippian, Devonian, and Cambrian were at one time well represented within the region, as they are elsewhere in the southern part of Arizona. However, there has not been found any Martin, Abrigo, or Bolsa quartzite within the dis-

trict, so this information is lacking completely.

During the Pennsylvanian, the area was probably covered by a shallow sea, as is shown by marine fossils of typical shallow water type. This sea must have been of long duration, as indicated by the great thickness of the Naco. Deposition of limestone, however, was not continuous throughout the period, since it contains interbedded quartzites, argillites, and shales. Possibly these represent littoral or delta phases.

At the end of the Pennsylvanian there evidently was a change, as represented by the red quartzite member which is about 800 feet thick. This is possibly a change to littoral conditions. At the conclusion of this stage, deposition of marine limestones opened the Permian period. Probably warm, shallow seas were general throughout this time, as is shown by the presence of corals.

There is a great hiatus at the termination of the Permian, and at this time there appears to have been chiefly terrestrial sedimentation. The Triassic and Jurassic periods are completely missing, and a limestone conglomerate at the top of the Snyder's Hill beds serves to mark the unconformity and indicate that from the Permian on the ocean floor was probably uplifted and erosion started. The arkoses of the Cretaceous, which were then deposited on this old land surface, seem to indicate a somewhat arid climate and suggest a country

very similar to southern Arizona today.

Probably at the end of the Cretaceous, the whole region was uplifted by the Laramide Revolution which affected the entire Rocky Mountain chain. Possibly at this time, the beds were tilted to near the steep angle they now occupy and erosion set in which has continued to the present day. After this tilting, the sediments were intruded by a stock of granodiorite and complimentary dikes and sills. The exact age of the intrusion is questionable. It is undoubtedly post-tilting and may have been the last phase of the Laramide Revolution, marking the close of the Cretaceous. Probably at this time, the ore deposits were formed although they undoubtedly did not reach their present condition until a later date as is well shown by the fact that a large part of the ore bodies is secondary carbonate and oxide. Sometime after the intrusive, the country was faulted and the limestones slightly folded in places with the resulting formation of small fissures.

It appears that the range was buried beneath the valley fill of the Whetstone and Santa Rita Mountains during the Tertiary and early Quaternary. The plateau between Davidson Canyon and Sonoita appears to have extended over the highest point of the Empire Mts., and present erosion is wearing it southward towards

Sonoita. Therefore it is perfectly possible that the entire range has been buried since the Mesozoic in a mass of valley fill, and it has only recently been stripped by erosion, due to uplift.

STRATIGRAPHIC SECTION.

Age	Thickness	Rock
Quaternary	10-20'	Alluvium, conglomerate, fill, gravels, caliche.
Tertiary	?	Sands and gravels, etc.
Cretaceous (?)		Intrusives
Cretaceous	Over 1000'	Arkoses, arkosic conglomerates.
Hiatus	- - -	- -
?	15-30'	Conglomerate
Permian	800'	Snyder's Hill Limestone.
Permian (?)	200'	Quartzitic sandstone
Pennsylvanian	1600'	Naco Limestone.

PALEONTOLOGY.

Within the Pennsylvanian series there has been found two distinct fossil horizons. In these, one of the Derbya sp. has been found, as well as a small

brachiopod that has not been identified. Within the Snyder's Hill Bellerophon, Productus semiraticulatus, Campophyllum torquium, Pugnax pugnus, Composita subtilita, and one unidentified brachiopod have been found abundantly. Derbya has been classified as a Pennsylvanian fossil but it also extends into the Permian. Accordingly, the correlation of the Naco is based on the lithology as compared with F.L.Ransome's section at Bisbee. The remaining fossils are typical Snyder's Hill fauna and are an excellent index horizon.

MINERALOGY.

The following minerals have been identified at Hiltano:

ANGLESITE $PbSO_4$. Contains sulphur trioxide 26.4% and lead oxide 73.6%. Anglesite is found throughout the Prince, Gopher, and Chief deposits. It has been the most important ore of the district and is frequently pseudomorphic after galena, with which it is extensively associated.

ARAGONITE $CaCO_3$. Radiated and stalactitic masses of aragonite are extremely common throughout the Prince, Chief, and Gopher deposits, where it is found in caves and small cavities in the limestone.

AURICHALCITE $2(Zn,Cu)CO_3.3(Zn,Cu)(OH)_2$. This basic

carbonate of zinc and copper has been found in very few localities and is rare at Hiltano. It is found at the Prince shaft above the primary ore in small blue crystals. It is of no economic importance.

AZURITE $2CuCO_3.Cu(OH)_2$. Carbon dioxide 25.6%, cupric oxide 69.2% and water 5.2%. Considerable azurite has been found in the Gopher shaft and some from the Prince. As there is only a very small quantity, none has been shipped to the smelter.

BIOTITE. Essentially $(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4$. Biotite mica is found chiefly in the stock to the northwest of the area, where it occurs within the granodiorite.

CALCITE $CaCO_3$. Calcite is found throughout the district as a cavity filling, or in the form of marble along dikes.

CERUSSITE $PbCO_3$. Cerussite is very common at the Prince and Gopher shafts, where it occurs with anglesite and aragonite in numerous cavities within the limestone. It contains 83.5% lead oxide and the remainder is CO_2. The cerussite is usually found as a white crust coating the anglesite; it has been of considerable value at the Gopher mine.

CHLORITE. Normally $H_8Mg_5Al_2Si_3O_{18}$. Occurs within the granodiorite.

CHRYSOCOLLA. $CuSiO_3.2H_2O$. Silica 34.3%, copper oxide 45.2% and water 20.5%. Of no importance in the district. Found associated with the other copper minerals at the Gopher and Chief shafts.

COVELLITE. CuS. Copper 66.4%, sulphur 33.6%. Chiefly microscopic fillings of cracks and cavities at the Prince shaft.

EPIDOTE. Essentially $HCa_2(Al,Fe)_3Si_3O_{13}$. Found as a contact metamorphic mineral on Empire Peak adjoining the stock and within the limestone. The epidote is the green variety.

GALENA PbS. Lead 86.6%, sulphur 13.4%. Is the primary lead mineral of the Prince shaft and has furnished most of the values of the mine. The galena from Hiltano contains no silver.

GARNET. Andradite variety. $Ca_3Fe_2(SiO_4)_3$. Occurs as a contact mineral on Empire Peak along the limestone bordering on the intrusive.

HEMATITE. Fe_2O_3. Is found in the primary ores at the Prince Shaft, but is of no economic importance. It is the probable source, along with pyrite, of the large masses of limonite in the oxide zone.

HORNBLENDE. $RSiO_3$. Is found in the gabbro sill and is the ordinary green-black sodic variety.

JAROSITE. $K_2Fe_6(OH)_{12}(SO_4)_4$. Found in the gossan at the Prince.

LIMONITE. Approximately $2Fe_2O_3.3H_2O$. Found throughout the ore bodies and especially within the oxide zones.

MAGNETITE. Fe_3O_4. Found within the granodiorite stock and also in the primary ores of the Prince shaft. Here

it is associated with quartz and pyrite.

MALACHITE. $CuCO_3.Cu(OH)_2$. Contains 71.9% cupric oxide, 19.9% carbon dioxide and 8.2% water. Malachite is very common in the Gopher deposit, also there is a small outcrop containing malachite, where it is associated with calcite and some silica. It has been of no value to date.

ORTHOCLASE. $KalSi_3O_8$. Found in the main stock and is the essential mineral of the dikes in the limestones.

PYROLUSITE. (?) MnO_2. Manganese outcrops occur to the north of the Chief incline.

PLAGIOCLASE. $NaAlSi_3O_8$. A basic andesine found within the granodiorite intrusive on Empire Peak.

PYRITE. FeS_2. The primary sulphide is found throughout the area, where it is extensively associated with quartz and limonite.

QUARTZ. SiO_2. Found in both cryptocrystalline high temperature veins and crystalline masses within the limestone. Quartz is also an essential mineral of the acid intrusives.

SIDERITE. $FeCO_3$. Siderite is found extensively associated with calcite along the upper levels of the Chief shaft.

SMITHSONITE. $ZnCO_3$. Contains carbon dioxide 35.2%, and zinc protoxide 64.8%. Some of this ore has been shipped from the Chief and has run fairly high in zinc. It is associated with aragonite, calcite, and siderite within a hundred feet of the surface.

SPHALERITE. ZnS. Sphalerite was undoubtedly the primary ore at the Chief and Gopher but at present only residual

grains of microscopic size can be found. These grains contain the usual minute specks of chalcopyrite ($CuFeS_2$). There are traces of primary sphalerite within the protore of the Prince shaft, where it is associated with cryptocrystalline quartz, pyrite, hematite, galena and magnetite.

TREMOLITE. $CaMg_3(SiO_4)_3$. Found along the contact of the granodiorite stock and limestone.

WULFENITE. $PbMoO_4$. Molybdenum trioxide 39.3%, lead oxide 60.7%. Has been the chief ore at the Prince, occurring with limonite and Jarosite within the gossan.

ECONOMIC GEOLOGY

History and Production.

According to Schrader, the Empire Mountain district has been producing since 1879 at which time the Total Wreck mine was discovered. In 1881 the Empire Mining and Development Company installed a 70-ton mill and operated for over a year and a half on rich surface ore. It has been estimated that $450,000 worth of ore was shipped. Since that time, the mine has been inoperative.

The mines at Hiltano have been more or less intermittently operated for the last twenty years by lessees. There has been some production from the Lone

Mountain and Forty-Nine mines, but figures are not available. The Hiltano Exploration Company, a subsidiary of the Calumet and Arizona Company leased the Hiltano group from M.P.Hilton, a pioneer resident of the camp, about two years ago. After exploration work and the shipment of small quantities of ore during the past year, the leases were disposed of and the camp closed. At present there is some ore being shipped from the Chief, by two men who have leased the property from Hilton.

Mineralization

Contact Metamorphis Deposits.

There has been considerable mineralization along the contact of the Naco limestone and the granodiorite stock to the northwest along Empire Peak. Numerous prospect holes and pits have been excavated, but beyond disclosing very small masses of pyrite, nothing of importance has been discovered. The local alteration at the contact is well shown by large masses of andradite garnet, tremolite, and epidote; the garnet and tremolite frequently occur in very large massive boulders. Alteration of the limestone to marble extends over an area of about a quarter square mile to the west of Empire Peak.

Replacement Deposits.

The replacement ore deposits of the area are comparatively small and, as far as present developments have shown, occur within 700 feet of the surface. All this mineralization occurs within the Permian limestone, where it is undoubtedly connected with the intrusive rock, altho in just what manner is rather doubtful. In general the outcrops have all been carbonate ore, although at the Chief some galena was found on the surface. The ore bodies are undoubtedly supergene, the ore that is now being mined and which has been mined in the past being the result of an oxidized sulphide protore.

Throughout the area around the Prince shaft, there have been numerous silica injections or "intrusions" within the Permian limestone. These appear to be in the form of pipes, veins, or plugs, varying considerably in shape but in general following the strike of the limestone. These silica bodies have been very carefully mapped in an attempt to connect them with the ore deposits. In addition, there has been considerable prospecting along the outcrops and beneath them. So far no relation has been established and at one point under ground, in the Prince shaft, it would appear that the silica is post-mineral as it cuts directly through a small vein of sulphide ore.

Prince Shaft.

The Prince shaft is located on the east slope of South Mountain, beyond the main office of Hiltano camp. The shaft is vertical to 450 feet. From this level there is a small winze to the 500-foot level. Although several truck-loads of ore have been shipped, the mine was never profitable to the Calumet and Arizona Company.

The lead minerals are chiefly anglesite, wulfenite, cerussite, and some galena. In general all of the ore contains a large amount of limonite. Anglesite was mined between the 350 and 400-foot levels; there was practically none below the 450-foot level. Wulfenite is present throughout the deposit and does not seem to be characteristic of any special zone, although it was particularly abundant on the 400-foot level. The anglesite ore contained more than 60% lead, and where galena was also present the lead content was still higher. In general, the anglesite replaces the galena throughout the deposit.

The sulphide protore is found at the bottom of the winze at the water table on the 500-foot level and consists of pyrite, galena, hematite and some magnetite, in a quartz gangue. This protore is of too

low grade to yield a profit. Above the water level, the galena has been oxidized to anglesite and there are large masses of limonite and jarosite. This zone has furnished most of the ore from the Prince shaft.

The ore bodies occur as pockets in the limestone, most of them being very small. In the Prince, the ore is found in solution cavities largely adjoining a gabbro sill. The ore occurs in fissures and cavities which are determined by jointing in the limestone and the fact that the sill itself is mineralized with pyrite and magnetite, seems to point to a definite relationship of the intrusive to the ore bodies.

Microscopic study of the ores from the various levels of the Prince shaft, has failed to disclose any unusual occurrences or associations as far as paragenesis is concerned.

As has been previously stated, the primary ore is pyrite and galena within a quartz gangue. The galena is very typical, showing regular cubical habit and in some places having the so-called "flow structure." The pyrite is usually found as residual grains within the galena or as crystals within the quartz gangue. In some sections, euhedral crystals of pyrite appear to have been directly replaced by the galena as is shown by encroachment of galena into the pyrite crystals. At the very lowest level, (750 ft.) most of the pyrite has been oxidized to

hematite, the latter bordering on the pyrite crystals and in turn is altered to limonite. The secondary hematite is distinctly massive and shows no crystal structure.

Scattered throughout the limonite are numerous patches of covellite which are microscopic in size, and, in places, show the characteristic radiated crystalline form. For the most part, however, the covellite is amorphous and full of minute specks of chalcopyrite. The presence of these specks may suggest the replacement of sphalerite by covellite. This mineral is found only along minute replacement fissures.

The oxidation of galena to anglesite by supergene agencies has taken place on a considerable scale. The anglesite clearly replaces the galena along crystallographic lines and cleavage cracks; in some cases forming excellent pseudomorphs. Many of the cracks in the anglesite are filled or bordered with cerussite.

Sphalerite is present in small patches in the galena and is readily recognized by small blebs or dots of chalcopyrite which are scattered through the mineral. It has been suggested by Van Der Veen that a series of solid solutions that are stable at high temperature, may, at lower temperatures, split up into various components; this is the phenomena of unmixing. The chalcopyrite may form along crystal lines, cleavage cracks or twinning planes. Another theory is that these blebs are

residual, showing direct replacement of chalcopyrite by the sphalerite.

Gopher Deposit.

The Gopher deposit is essentially similar to the Prince except that there are considerable masses of zinc and copper carbonates on the higher levels. These are completely lacking in the Prince although zinc and copper sulphides are present microscopically. The outcrop of the Gopher shows considerable malachite and azurite within a siliceous gangue. The deposit is within the Permian limestone and a few hundred feet west of the end of the Prince workings.

Chief Deposit.

The Chief shaft is located on a low hill directly back of Mr. Harper's house on the summit of the slope. The shaft is an incline about 600 feet deep and is at present being operated by lessees. The shaft is parallel to a quartz porphyry dike. This dike has altered the lime-

stone on the south and near the dike to marble and the ore is found within this marble. Smithsonite, calcite, aragonite, azurite, malachite, and siderite are all abundant. None of the ore, however, is at the dike limestone contact or within thirty feet of it. There is no pyrite present and the deposit appears to be essentially supergene. However, large masses of limonite from the lower levels, seems to point towards the oxidation of a sulphide body and the presence of jarosite with the hydrous oxides of iron further supports this hypothesis. As at the Prince, there is wulfenite present and some oxide of manganese in the gossan ore.

Forty-Nine.

The Forty-Nine claim is similar to the Chief in that it is along the same dike, within the same formation and only over the next ridge to the north. As yet this deposit has not been thoroughly investigated, but the dump material contains carbonates of copper as the chief ore mineral. The outcrop was a small vein of malachite along the contact of the quartz porphyry dike and the limestone.

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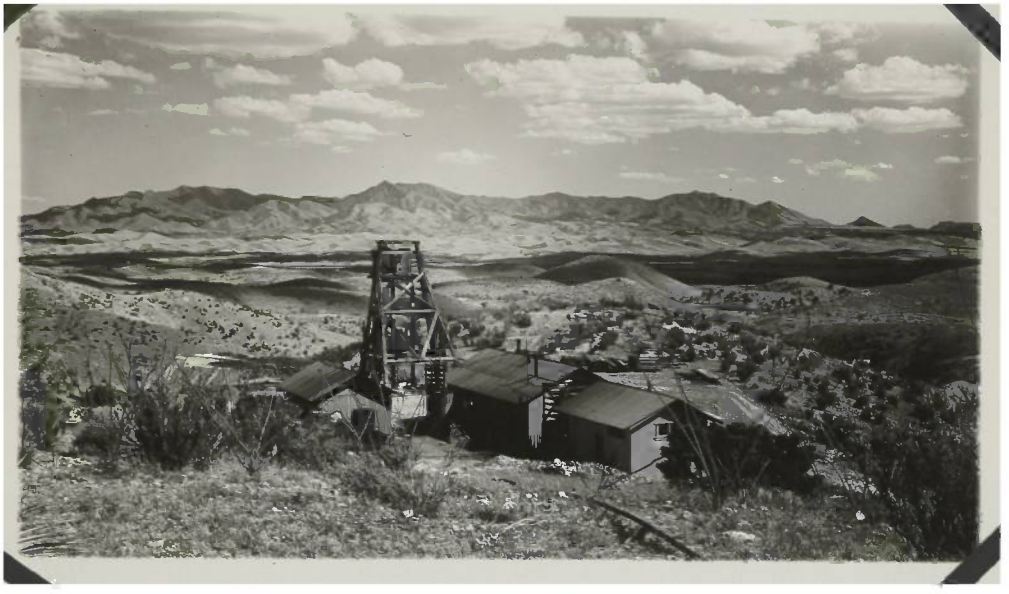
Bisbee Folio (F.L.Ransome) U.S.G.S. 1914. (#112).

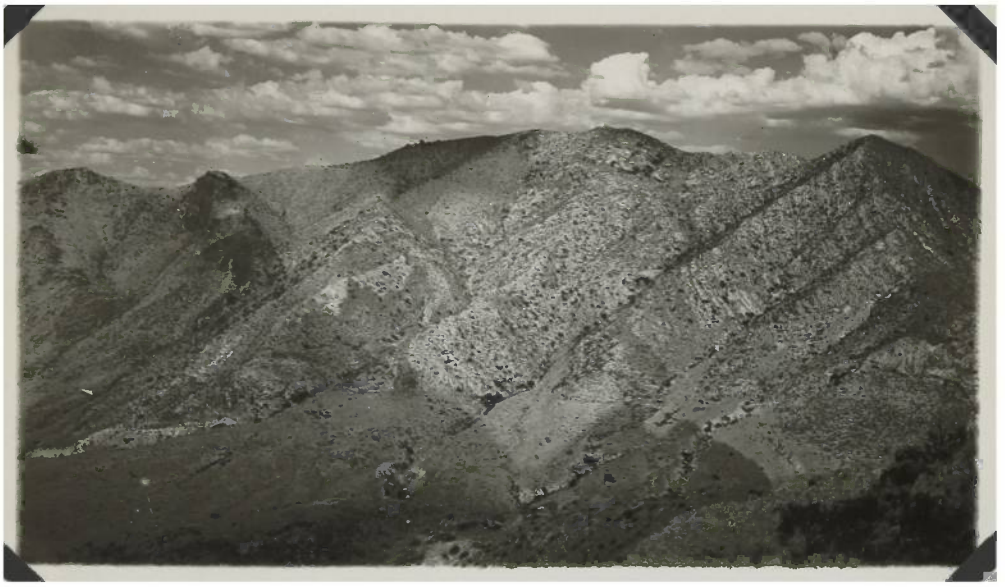
View east from the Prince shaft across the Cretaceous section towards the Whetstone Mountains.

The Empire Mountains as seen looking north from the plateau south of Davidson canyon.



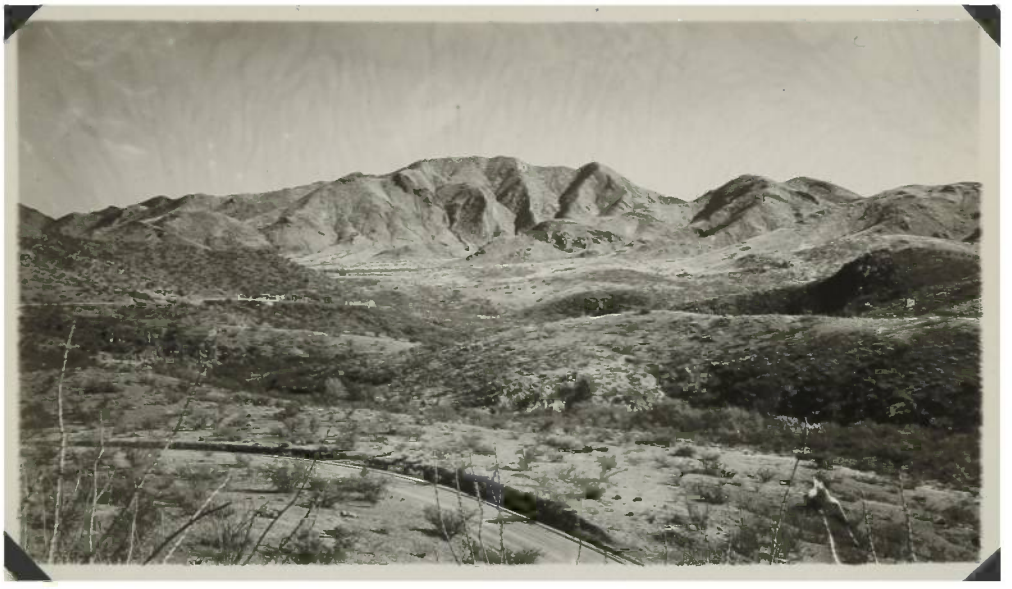
A view of the south side of Empire Peak showing uptilted Naco beds and the intrusive at the left of the picture.

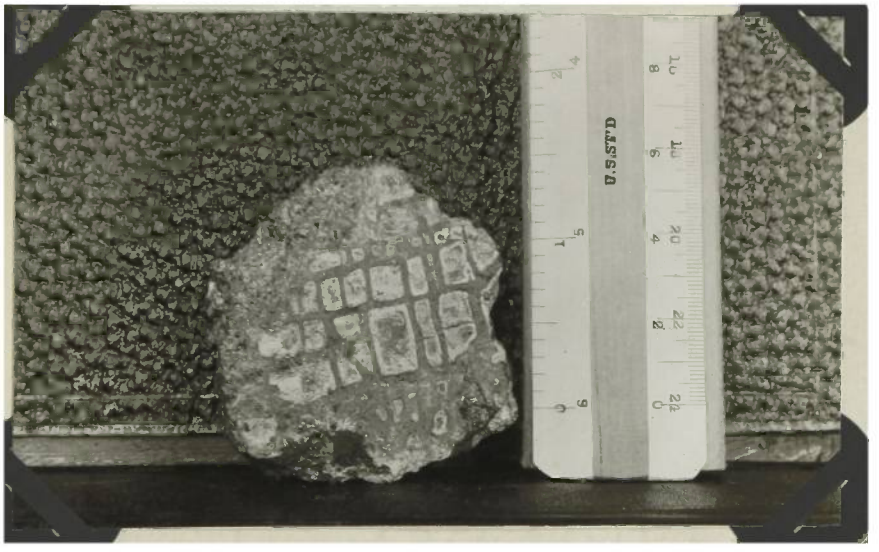
Looking south from the Davidson Canyon divide. The formation in the foreground is the basal Permian quartzite. The rise to the left is in the Snyder's Hill Limestone, the valley marking the contact. The Prince shaft is located in the middle distance and the Gopher is to the right. The great plateau of gravels and conglomerates can be seen in the distance.



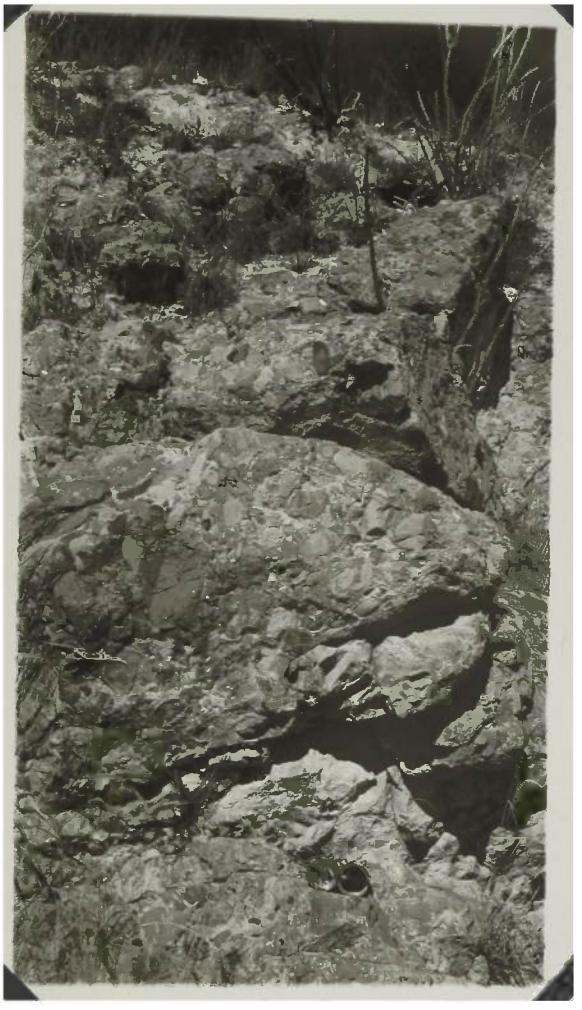
The Empire Mountains as seen from the Patagonia road to the west. The altitude of the Naco formation is readily seen on the main peak to the right center of the photograph.

The pseudomorphs of anglesite after galena as found at the Prince shaft.



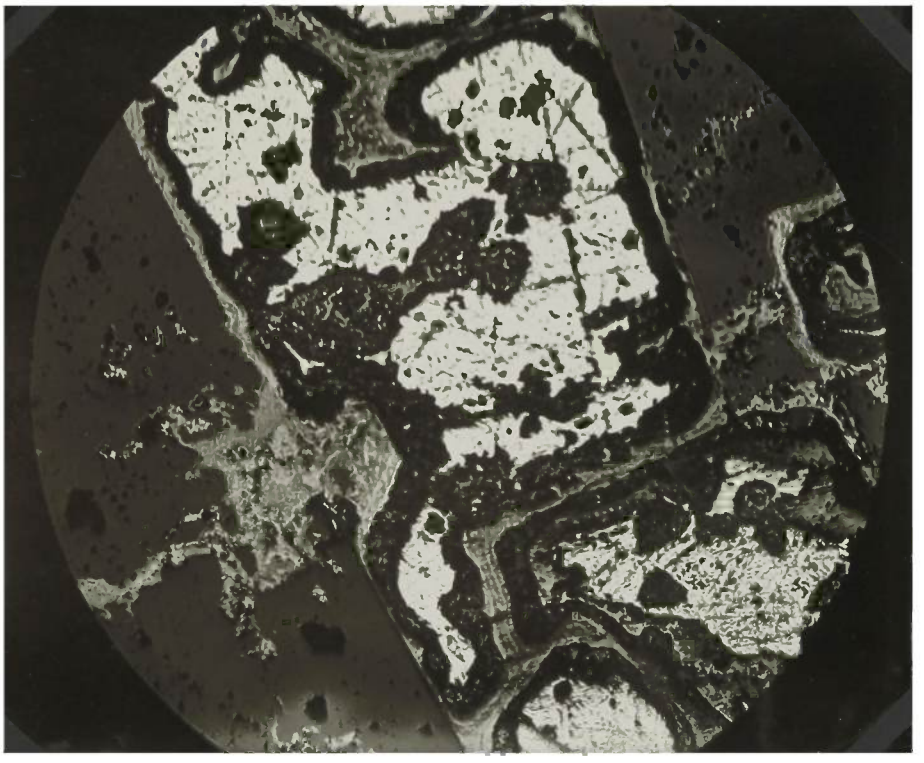

U.S.S.T.D

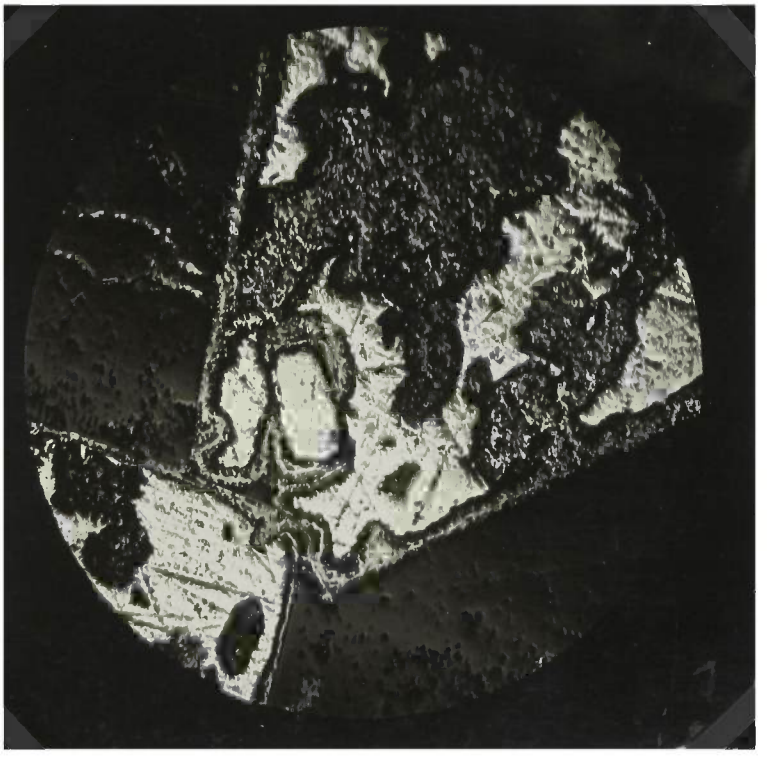
The basal Cretaceous conglomerate as seen in the draw back of the old office.



Cretaceous arkose east of Hiltano.

Microphotograph of ore from the Prince Shaft showing euhedral pyrite crystals bordered with limonite, the whole within a quartz and limonite gangue.





SEDIMENTARY ROCKS

COMANCHEAN
- ARKOSE
- CONGLOMERATE

PERMIAN
- LIMESTONE (Snyder's Hill)
- QUARTZITE

PENNSYLVANIAN
- LIMESTONE (Naco)

IGNEOUS ROCKS

TERTIARY(?)
- QUARTZ-PORPHYRY (Dyke)
- GABBRO (Sill)

- SILICA OUTCROP
- ORE ZONES

SCALE: 1" = 100'

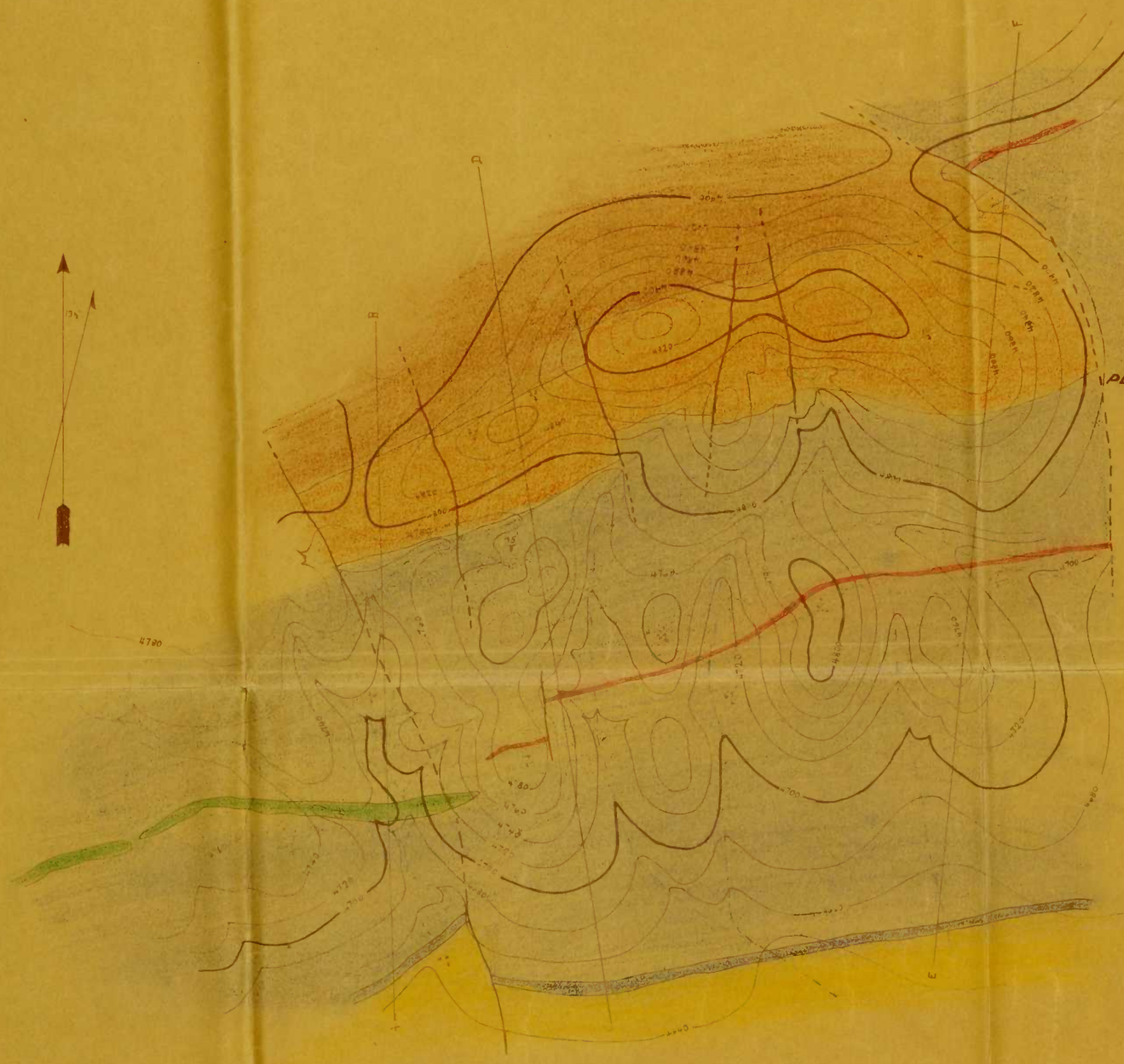
100 50 0 100 200 300 400

CONTOUR INTERVAL: 10'

TOPOGRAPHY & GEOLOGY of the HILLTANO MINING DISTRICT

EMPIRE MOUNTAINS
PIMA COUNTY, ARIZONA

To accompany M.S. Thesis
J. Wm. Feiss



SEDIMENTARY ROCKS

- COMANCHEAN
  - ARKOSE
  - CONGLOMERATE
- PERMIAN
  - LIMESTONE (SNYDER'S HILL)
  - QUARTZITE
- PENNSYLVANIAN
  - LIMESTONE (NACO)

IGNEOUS ROCKS

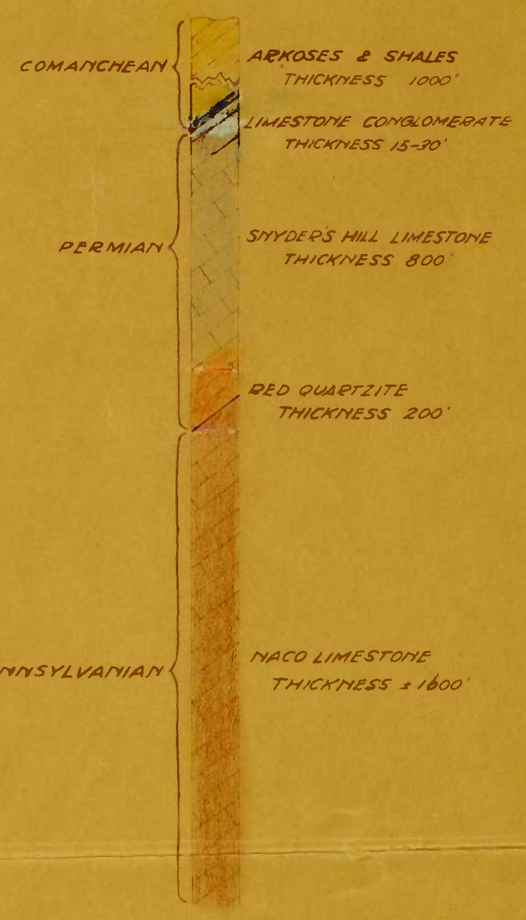
- TERTIARY(?)
  - QUARTZ-PORPHYRY (Dyke)
  - GABBRO (Sill)

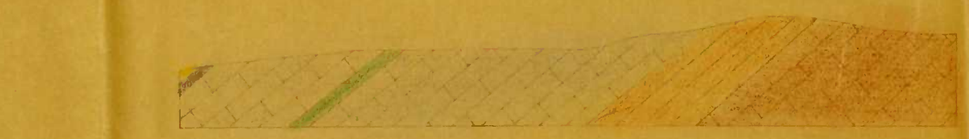
FAULT

SCALE: 1" = 400'

200 100 0 200 400 600 800

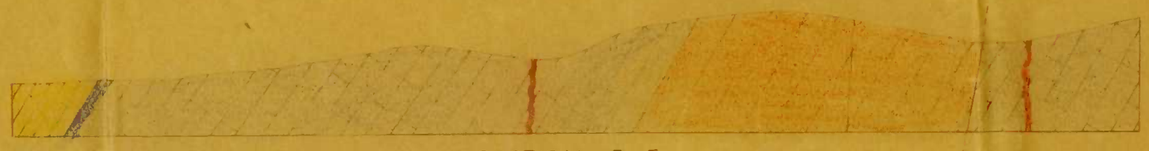
CONTOUR INTERVAL 20'





SECTION A-B

SECTION C-D



SECTION E-F

TOPOGRAPHY and GEOLOGY
of the
HILLTANO MINING DISTRICT
EMPIRE MOUNTAINS
PIMA COUNTY, ARIZONA

To accompany M.S. Thesis

J. Wm Feiss