

Geology and Ore Deposits of the Rosemont Area
Pima County, Arizona

By

Walter L. Thomas

-----:-----:-----:-----:-----:-----

Submitted in partial fulfillment of the
requirements for the degree of

Master of Science

College of Mines and Engineering of the

University of Arizona

1 9 3 1

*Approved
H. S. Butler*

-----:-----:-----

E9791
1931
31

C O N T E N T S

I. Summary-----	1
II. Introduction-----	3
Fieldwork-----	3
Previous Investigation-----	3
Bibliography-----	4
III. Superficial Features-----	4
Location-----	4
Topography-----	5
Climate and Vegetation-----	6
Physiography-----	6
IV. General Geology-----	9
Summary-----	9
Igneous Rocks-----	10
General Statement-----	10
Pre-Cambrian Granite-----	10
Post-Cretaceous Igneous Rocks-----	11
Granite-----	11
Aplite-----	12
Sedimentary Rocks-----	13
Summary-----	13
Paleozoic Sedimentary Rocks-----	14
Cambrian System-----	14
Abrigo Limestone-----	15
Quartzite Formation-----	15

C O N T E N T S

IV. General Geology continued.	
Devonian and Carboniferous Formations---	16
Cretaceous Formation-----	17
Metamorphism of Sediments-----	18
Factors Affecting Metamorphism-----	18
Metamorphism of Limestones-----	19
Metamorphism of Shales-----	20
Metamorphism of Quartzite-----	21
Metamorphism of Cretaceous Sedimentary Rocks--	21
V. Structure-----	23
General Statement-----	23
Folding-----	23
Faulting-----	24
Outline of Faulting-----	24
Overthrust Faults-----	25
Character of Thrust Outcrop-----	26
Forces and Movement of Thrusting-----	26
Associated Thrusting-----	27
Faulting Connected with Igneous Intrusion--	28
Late Faulting-----	28
Age of Faulting-----	29
Summary-----	29
VI. Geologic History-----	31
VII. Mineral Deposits-----	34
History of District-----	34

C O N T E N T S

VII. Mineral Deposits continued	
Production-----	36
General Character of Deposits-----	37
Description of Minerals-----	38
Iron Minerals-----	38
Copper Minerals-----	39
Gangue Minerals-----	42
Paragenetic Relation of Ores-----	46
General Statement-----	46
Classification of Metamorphic Zones-----	46
Significance of Zoning-----	48
Sequence of Mineralization-----	48
Relation of Ore Deposits to Structure-----	49
Age of Ore Deposits-----	51
Oxidation and Enrichment-----	51
VIII. Conclusion-----	54

ACKNOWLEDGMENTS

The writer is indebted to Dr. B.S. Butler for his advice given in connection with the fieldwork and for his valuable criticisms and assistance in the organization of the material.

Grateful acknowledgment is made for the field assistance of Dr. R.A. Wilson, R. M. Hernon and G. W. Peters without whose help the fieldwork would have been greatly hindered. To the members of the geology faculty appreciation is expressed for the sincere interest shown as the work progressed. To Mr. Holdren thanks is due for his interest and permission to work upon the property.

SUMMARY

The Rosemont Camp is one of Arizona's small mining areas located 45 miles southeast of Tucson. Since 1896 it has produced over 10,000,000 pounds of copper and small amounts of lead and zinc.

The oldest rock of the region is a basal pre-Cambrian granite. The sedimentary rocks of the area include the Paleozoic and Mesozoic systems, separated by a conspicuous angular unconformity. Those of Paleozoic age are composed of Cambrian basal quartzite, followed by interbedded shales and limestones, upon which lies Devonian and Carboniferous limestones. The Carboniferous limestone is overlain unconformably by a series of interbedded Cretaceous conglomerates, arkosic sandstones, shales and some thin limestone beds.

Following the deposition of the Paleozoic and Mesozoic sediments there was regional deformation of the strata with the formation of folds roughly parallel to the present trend of the northern Santa Rita Mountains.

Subsequent to the folding there occurred thrust faulting from the southwest which carried Paleozoic rocks over and upon Mesozoic formations. Closely associated with the thrusting were two periods of faulting, an earlier thrust and a later period of normal faulting.

Intruded into the lower part of this sed-

imentary series is a coarse-grained granite of post-Cretaceous age. This intrusion has metamorphosed a large part of the sedimentary series. The metamorphism recrystallized the limestones and converted portions of it and the calcareous shales into lime silicate minerals as garnet, wollastonite, epidote and others of related origin.

The ore deposits are of the pyrometasomatic or contact metamorphic type. Coincident with the intrusion there was faulting and displacement of the sedimentary rocks. The ore solutions rose along the channels opened by the faulting.

The ore deposits resulted from the replacement of limestones and calcareous shales. The principal ore minerals chalcopyrite, cuprite, chalcocite, malachite and azurite.

Oxidation and enrichment has been important in the concentration of certain ore bodies. The zone of oxidation is very shallow except along strong fault zones. In many areas it is lacking and secondary sulphides of the enriched zone outcrop at the surface.

INTRODUCTION

Fieldwork

The data presented in this report is based upon the work of the writer. The field work was carried on during the fall and spring of 1930-31 with the assistance of R.M. Hernon and G.W. Peters. The problem was under the supervision of Dr. B.S. Butler and the faculty of the geology department of the University of Arizona.

Previous Investigation

In the past there has been very little detailed geological work in the Rosemont Camp. The only previous published report is that of the United States Geological Survey Bulletin, by F.C. Schrader, dealing with the mineral deposits of the Santa Rita and Patagonia Mountains. This report includes a brief examination of the Rosemont Camp, with a general description of the geology of the neighboring Helvetia District.

J.E. Spurr examined the Helvetia District and some of his observations and conclusions are published in "The Ore Magmas", McGraw Hill Book Co., 1923.

BIBLIOGRAPHY

Schrader, F. C. Mineral deposits of the Santa Rita and Patagonia Mountains, Arizona, U. S. Geol. Survey Bull. 582, 1915.

Darton, N. H. A resume of Arizona geology, University of Arizona Bull. 119, pp. 276-77, 1925.

Spurr, J. E. The ore magmas, McGraw Hill Co., pp. 310, 330, 416, 637, 1923.

SUPERFICIAL FEATURES

Location

The area is situated on the east side of the Santa Rita Mountains at latitude $30^{\circ}51'$ north and longitude $111^{\circ}46'$ west. It comprises an area 3,000 feet square, or approximately the northern half of the Rosemont Mining Camp of southeastern Pima County, Arizona.

Rosemont is located 45 miles southeast of Tucson. It is situated within five miles of the state highway No. 80 at the head of McCleary Canyon. The Helvetia and Rosemont camps are connected by a pack trail over the high ridge which separates them. The Rosemont camp is considered part of the Helvetia Mining District, with which it is closely allied in geology, history and production. Vail, a small station of the Southern Pacific Railroad 28 miles north, is the nearest shipping point.

Topography

The topography of the camp is characteristic of the entire Santa Rita Mountains. This range is a single unbroken chain approximately 30 miles in length and varying from four to eight miles in width. It reaches a rather uniform elevation of about 3500 feet above the Santa Cruz Valley to the west and 1500 feet above its eastern base. The most notable exception to this almost uniform elevation is in the southern portion where Mt. Baldy, the single high peak of the range, reaches an elevation of 9432 feet.

The relief in the north end of the range is controlled by differential erosion of a steeply dipping sedimentary series, intruded by a granitic mass. The hard Cambrian quartzite forms a sharp, irregular ridge. On the east the ridge is bordered by limestones and less resistant shales and on the west by easily weathered granite. The more gentle slopes of the shales and arkosic sandstones are interrupted by numerous ledges of quartzite, silicified zones and fault breccia.

Faulting and folding have been important in the development of the structure. Many of the topographic features owe their location to structural control.

The drainage is mainly by short draws at right angles to the axis of the range. These soon converge into canyons that lead into Davidson Canyon, the principal

drainage course of the region.

Climate and Vegetation

The climate is moderate the entire year. In the winter, however, the snow often reaches a depth of 15 inches upon the higher elevations. The average rainfall as determined by the Forest Service for a period of 34 years from 1896-1928 is slightly over 15 inches per year. The greatest precipitation and most rapid erosion occurs during the summer months.

The Santa Rita Mountains which are almost encircled by arid valleys show with increasing altitude a gradual change of vegetation. This is due primarily to the decrease in temperature and the increase in rainfall with rise in elevation.

On the lower elevations the typical plants are greasewood, mesquite, paloverde, catclaw, ocatilla and cacti. At approximately 5000 feet elevation black oak and pinon pine appear. There is practically no undergrowth, except an occasional catclaw, stunted mesquite or bear grass.

Of particular note is the selective preference of the brush and pinon pine for the limestone areas. The contacts of the formations are generally in sharp relief and well defined by the preferential habit of the vegetation.

Physiography

The mountains have been carved from a series

of steeply tilted westerly dipping formations of varying resistance to erosion. The more resistant formations have formed an erosional barrier characterized by a narrow winding and precipitous quartzite ridge that extends roughly parallel to the general structural trend of the region. The hard rocks occupy the higher and the soft rocks the lower areas.

The angle of slope varies with the composition and character of the formations. The relatively insoluble quartzite forms broken cliffs, below which abundant talus collects. Limestones in desert regions are usually characterized by strong relief because of insufficient rainfall and organic acids to cause rapid solution. This is indicated throughout the region. The shales develop the more gentle slopes, the angle depending upon the amount of rainfall and its ability to transport the decomposed material.

In the marbled limestone, steep and narrow canyons are developed up to 50 feet in depth. These have resulted from a combination of corrasion and solution in a homogeneous material. The sides of the canyons are composed of material of sufficient strength to resist slumping.

On the upper slopes of the range, erosion has laid bare most of the formations, except those locally covered with talus. Deposition by the streams has been in their lower parts away from the steep slopes. There has been a sequence of physiographic events, outward from the range,

beginning with the filling of a structural basin by the continued deposition of debris from the ridges, the streams later cutting through this alluvium and into the bedrock.

This erosional history would require either an uplift of the area or an increase of rainfall for the region. The known geological events of post-Cretaceous time clearly show deformation has in places uplifted the region and this resulted in renewed erosion.

GENERAL GEOLOGY

Summary

The oldest rock of the Rosemont District is a pre-Cambrian granite. It is exposed about one half mile south of the area. Here it forms a sedimentary contact with the Bolsa quartzite.

The rock formations of the Paleozoic include a basal Cambrian quartzite overlain by interbedded calcareous shales and limestones, Devonian limestone, Mississippian limestone, Pennsylvanian limestone and Cretaceous conglomerates, arkosic sandstones and shales.

The Paleozoic rocks rest with apparent conformity upon each other, but the Paleozoic and Mesozoic is separated by an angular unconformity which approximates fifteen degrees.

The structural relations of the area are so complex that it is not possible to correlate the complete stratigraphic relations of the sedimentary rocks. Metamorphism has destroyed the lithological character of the beds and the traces of the fossils.

Intruded into the sediments is a later granite and closely related aplite which are post-Cretaceous in age.

IGNEOUS ROCKS

General Statement

The principal igneous rocks of the Rosemont area are an older pre-Cambrian granite and a younger intrusive granite and associated aplite. The ore deposits bear no relation to the older igneous rocks but are genetically related to the younger granites and aplites.

The younger igneous rocks of granite and aplite are probably related to a single period of igneous activity. These intrusives have been determined as post-Cretaceous in age because of their relations to the sedimentary series.

Pre-Cambrian Granite

Pre-Cambrian rocks do not outcrop within the area mapped. However, they are found in the southern part of the Rosemont District where the Bolsa quartzite (Cambrian) rests upon a pre-Cambrian granite.

This pre-Cambrian granite varies in color and texture. The prevailing color is pinkish from the color of the predominating feldspar. In texture it varies from an even grained rock in which the crystals of quartz and feldspars range from small crystals to those approximating one half inch in diameter or that of a porphyritic nature.

Post-Cretaceous Igneous Rocks

Granite

The late granite is well exposed in the southwest portion of the area. This intrusion is post-Cretaceous in age. In some parts of the region it cuts through the Paleozoic section and into the Cretaceous sediments. The Paleozoic sedimentary series dips steeply west with this intrusion lying irregularly along the contact with the quartzite and in places is intruded higher into the section.

The intrusion appears to increase laterally in depth. There are very few dikes and those which are developed are apophyses that are only found developed in the quartzite.

Where the granite has intruded, portions of the quartzite there are large engulfed blocks of quartzite within the granite.

Silicification has been very intense within the granite. The mass as a whole has been intensely fractured after cooling. This silicification has developed along the fractures with the deposition of veins of quartz ranging from minute veinlets to those fifteen inches wide. These veins persist for hundreds of feet and strike in all directions.

The general color of the granite is a light gray but upon close examination the color is due to a large amount of hornblende. The feldspars are usually a light pink

but the color of the hornblende predominates, giving the rock its darker hue.

The rock is decidedly porphyritic with phenocrysts of feldspar and quartz developed up to three fourths of an inch in diameter. Hornblende also shows a porphyritic development with the crystals averaging one fourth of an inch in diameter. Biotite is only noticed in minor amounts.

Under the microscope large orthoclase, quartz, and hornblende crystals are surrounded by a matrix which is chiefly finely crystalline quartz and orthoclase. The feldspars were determined to be essentially orthoclase and microcline with minor amounts of acid oligoclase.

The granite is very susceptible to decomposition upon the surface, evidently because of the large amounts of ferromagnesium minerals present. It is difficult to secure a specimen which does not show a large development of kaolin and sericite in the feldspars and epidote in the hornblende.

Aplite

In the northern part of the area is a prominent exposure of an aplitic intrusion. It is elliptical in shape and averages about twelve hundred feet long and five hundred feet wide trending east and west.

This aplite has partially replaced a quartzite series and parallels the stratification of the original beds.

The dip and strike is continuous throughout the mass dipping 82 degrees NE and striking N 62 degrees W. Large unreplaced masses of quartzite still remain as isolated bodies within the aplite.

The rock is fine grained with a sugary texture. The color is almost white, but weathers to a brown color. The aplite probably represents the last phase of the post-Cretaceous intrusions.

In the thin section the aplite is composed mainly of quartz and orthoclase with acid plagioclase (oligoclase-andesine) characteristically present in small amounts. Quartz is the most abundant of the minerals present. Biotite is sparsely developed but is very characteristic mineral.

SEDIMENTARY ROCKS

Summary

The sedimentary rocks consist mainly of widely distributed Cambrian quartzites, shales and limestones, Devonian limestone, Mississippian limestone and Cretaceous sandstone, shale and thin bedded limestone.

The Paleozoic rocks rest unconformably upon a granite that has been classified as pre-Cambrian.

The only Paleozoic formations in the area whose age may be certainly determined are those of Cambrian age.

Metamorphism has greatly changed the lithology and destroyed the character of the fossils so that the possible Devonian, Mississippian and Pennsylvanian formations are correlated upon minor characteristics and their sequence. Even though based upon minor characteristics the correlations are in all probability accurate.

PALEOZOIC SEDIMENTARY ROCKS

Cambrian System

The Bolsa quartzite occurs as a well defined exposure along the main ridge of the district. It varies very little in its lithological character. The rock is of uniform texture and fine grain, which under the microscope shows individual grains of interstitial quartz, subangular in outline, with no feldspathic material.

About one and one half miles north of Helvetia, Wilson⁽¹⁾ has measured the normal thickness of the Paleozoic section and found the Bolsa quartzite to average about five hundred feet thick. It is lenticular in nature as most basal conglomerates are.

Shale and Limestone Formation

This formation is probably better known as the Cochise, named by Stoyanow. It lies with apparent conform-

1. Personal communication.

ity upon the Bolsa quartzite. It is composed of about 150 feet of interbedded limestones and calcareous shales. The formation is continuous almost throughout the entire area. The average thickness of both the limestone and calcareous shales is three feet throughout the section.

The limestone layers are very thin bedded and weather upon the surface to a dark gray. The shales are calcareous, thin bedded and greenish-yellow to brown in color. Toward the base of the formation the shales grade into arkosic grits.

Abrigo Limestone

Only a small exposure of Abrigo limestone is found. This small area outcrops where erosion has cut back into the thrust plane and exposed a faulted portion. It is recognized by its laminated structure composed of alternating thin bands of chert and limestone.

In the unaltered Abrigo limestone the layers are usually parallel but because of metamorphism many of the cherty bands are badly twisted and the limestone is recrystallized. In the normal section the Abrigo limestone was measured as 250 feet.

Quartzite Formation

In the southern part of the area the top of

the Cambrian is characterized by a thin bedded pinkish formation of variable thicknesses from 150 to 200 feet. Continuing north the quartzite lenses out. In the northern portion it is again present as a shaly bed in contact with the aplite intrusion.

Upon the surface this quartzite weathers into occasional cliffs, showing the different phases of metamorphism within it. Under the microscope it is composed of small angular fragments of quartz and feldspar with a predominance of the former.

Devonian and Carboniferous Formations

Overlying the Cambrian with apparent conformity is a thick section of metamorphosed limestones. These limestones have been altered so as to destroy the greater part of their lithological character and any fossils.

Without doubt the Martin limestone or Devonian, the Escabrosa or Mississippian, and the Naco or Pennsylvanian are present in the district. Even with metamorphism there are certain faint lithological, and depositional characteristics which show three types of limestone formations.

The portion called Martin limestone is the lower member of the metamorphosed series which is composed of moderately thick beds and shows faint remains of corals and

other fossils in the upper portion.

Overlying this formation is a thicker bedded metamorphosed limestone within which no traces of fossils have been found. This formation has been assigned as Mississippian or Escabrosa.

Where the Cretaceous formations have been deeply eroded there is exposed a window of thin bedded metamorphosed limestone underlying the Cretaceous. This limestone is thin bedded and shows none of the characteristics of the other two limestones. To this limestone has been assigned Pennsylvanian age or the Naco Limestone.

In the normal section measured north of Helvetia the following thicknesses have been determined: Devonian, 200 feet; Mississippian, 600 feet; and Pennsylvanian, 300 feet.

Cretaceous Formation

The Cretaceous is a very characteristic, persistent and easily distinguished formation. In the normal section it lies unconformably upon the Paleozoic at a low angle.

It is composed of conglomerate, shale, thin beds of limestone and arkosic sandstones. The strata are light gray in color and in many places are red from oxidation.

The lower member is a basal conglomerate composed principally of quartzite fragments within an arkosic

matrix, which in many places is essentially altered to a quartzite.

The basal conglomerate grades into an arkosic sandstone of almost uniform texture. The rock is fine grained and gray in color. Under the microscope it is composed of a predominance of feldspars and minor amounts of quartz. No other accessory minerals other than hematite are present. The feldspars are orthoclase and microcline with occasional fragments of plagioclase. The plagioclase was determined to be basic oligoclase and acid andesine.

Interbedded in the arkosic sandstone are occasional beds of shale and impure limestone which have shown a preference to metamorphism and replacement.

The accurate thickness of the Cretaceous has not been measured in the area but is known to be up to 12,000 feet thick in some parts of Southern Arizona.

METAMORPHISM OF SEDIMENTS

Factors Affecting Metamorphism

The intensity of the metamorphism decreases with the distance from the igneous activity. However, the distance of metamorphism is controlled by other factors than igneous intrusion. The strong faults show a development of thick gouge which has acted as a barrier to extensive alteration.

The most important control of metamorphism is the character of the bed. Metamorphism is most intense in limestone or calcareous beds. The greatest changes in the rocks have been the addition of iron and silica, and the typical metamorphic minerals developed are wollastonite, epidote, garnet and chlorite.

Except where replacement is controlled by structural conditions the governing factors have been the chemical composition of the strata and the character of the solutions.

Metamorphism of the Limestones

Except for a very small portion in the southern edge of the area, the limestones are metamorphosed to some degree. The changes in the limestone do not seem to be controlled by the proximity to the outcropping igneous body. This suggests vertical as well as horizontal movement of the metamorphosing agents. Some of the metamorphism may be attributed to a rather shallow body of igneous rock that is not exposed.

The marble constitutes a large portion of the area. Conditions of metamorphism were almost uniform through large areas with very little mineralogical changes. Some parts of these formations retain a distinctive bedding after marmorization, the character of which is controlled by

the composition and structure of the original limestone.

Garnetization of the limestone is very extensive locally in the district. A large portion of the marmorization preceded garnetization. A major portion of the garnet is found near the contact of the igneous intrusion, where it occurs as massive beds up to 300 feet in width.

Between the marmorized areas and the massive garnet is a zone composed partly of marble and garnet. This zone indicates the beginning of the deposition of the garnet.

Metamorphism of the Shales

The more intense metamorphism and mineralization is associated with the intrusion of a coarse grained granite in the southwest part of the district. Along the northern edge there is very little metamorphism or mineralization connected with the intrusion of the aplite.

In many places the shales are changed essentially to argillite, showing dehydration and crystallization of the colloidal matter present. The most common metamorphism is garnetization of large areas, which show selective replacement according to the nature of the bed or physical condition of deposition.

Where the intrusion has broken through the quartzite to the base of the Cambrian shales, the formations are converted into pyritiferous layers. These zones are developed where the metamorphism has been more intense. The veins

occur along the bedding of the shales and vary in thickness from small veinlets to those of one inch wide.

The shales are intensely altered throughout the area but the degree of metamorphism decreases away from the points of deepest intrusion into the various members. In close connection with the development of pyrite is the occurrence of chlorite which occurs as fine crystalline veinlets paralleling the pyritic veins.

Metamorphism of the Quartzite

The Bolsa quartzite is very resistant to the action of the metamorphosing solutions. It forms a well defined boundary to replacement and alteration. The only mineralization has been a slight development of scattering crystals of pyrite near its contact with the igneous body.

Metamorphism of the Cretaceous Sedimentary Rocks

The least amount of metamorphism is registered in the Cretaceous sediments. This is due primarily to the character of the beds, which are in the main, arkosic sandstones, conglomerates and shales.

These types of clastic sediments have been relatively inert to replacement by iron, copper and silica rich

solutions. In the calcareous horizons there is a development of garnet, but this is a preferential replacement due to their composition.

Later than the garnet is vein quartz which cuts at angles across the bedding. Many of these veins show crystal growths outward from the walls. In close association with the quartz veins are other veins of quartz showing a platy development. These plates of silica are the result of replacement of calcite along cleavage planes. Through the solution of the remaining calcite, parallel plates of silica have resulted with intervening open spaces formerly occupied by the calcite.

This shows that the earlier stages of deposition were solutions essentially containing calcite. As metamorphic conditions changed, there was deposition of garnet, showing additions of iron and silica. The introduction of iron became gradually less until the solutions were almost entirely silica.

STRUCTURE

General Statement

The structure of the area is complex and records a varied tectonic history. Paleozoic and Cretaceous rocks were regionally folded. This was followed or accompanied by strong thrust faulting from the southwest which carried Paleozoic rocks over and upon Cretaceous rocks. Associated with the major thrusting were minor thrusts in the overthrust block.

This was followed by the intrusion of a granitic mass which has partly assimilated and displaced the sediments. Two later stages of reverse and normal faulting are recognizable from their relation to the granite porphyry stock with stresses operating from the south.

FOLDING

Regional folding is discernible throughout the Santa Rita Mountains. In the southern portion of the range, as shown on F. C. Schrader's map, the regional folding was almost obscured by pre-Cretaceous intrusives. The intrusives in the Rosemont region have been determined to be post-Cretaceous in age. Northward and away from the larger igneous bodies the folding of the strata becomes more evident. Anticlinal folding of the Cretaceous rocks

is clearly outlined on Mt. Fagan, four miles northeast of Rosemont.

The Whetstone Mountains twelve miles east of Rosemont also show anticlinal structure with the sediments dipping southwest on their west slope. The intervening valley is covered with alluvium but the formations on the western margin of the valley dip to the east. This indicates the possibility of a synclinal basin or a series of folds under the Quaternary alluvium.

From evidence observed in the mapped area the regional pitch of the folds appears to be gently south. The trend of the folds is almost constant, varying within the narrow limit of $N10^{\circ} - 20^{\circ}E$. Local dips at Rosemont show the structure to be monoclinal with westerly dips. This interpretation may be misleading because of the later complex thrusting and faulting. Folded strata north of Rosemont, however, show symmetrical folds.

FAULTING

Outline of Faulting

The periods of faulting may be grouped progressively as follows:

1. Major overthrusting and accompanying faults in the overthrust block;
2. Steep faults which are connected

with the intrusion and displace the thrust plane;

3. Late block faulting due to stresses from the south and which displace the igneous stock;

4. Recent normal faulting trending E-W and associated with pre-existing planes of weakness.

Overthrust Faults.

Paleozoic formations rest upon Cretaceous formations throughout the mapped area. This resulted from a strong thrust that caused the Paleozoic formations to move northeastward along a break which will be hereafter referred to as the Rosemont thrust fault. See sections for further details.

In the southern portion of the area the thrust has moved the Carboniferous limestones upon the Cretaceous. Continuing north erosion has cut back along the fault exposing the Cambrian thrust upon the Cretaceous.

At the surface reliable dips are not obtained on the fault, the dips varying from 15° to 45° west. Underground the fault seems to approximate a dip of 15° west and a strike of $N10^{\circ}E$ which corresponds to the regional trend of the folds.

The foot wall of the thrust is composed of Cretaceous arkosic beds. These dip 55° southwest and strike $N55^{\circ}W$. Underground, both the hanging and foot wall are intensely fractured. The Paleozoic rocks dip from 60°

to 80° southwest and strike from north to $N40^{\circ}W$. The change of dip is due to a secondary thrust which was developed coincident with the major thrust and has further inclined the strata.

Character of Thrust Outcrop

The nature of the thrust fault zone varies considerably according to the character of the strata severed by the thrust. The fault zone is composed of crushed rock fragments. The trace of the fault is well marked by a wide brecciated zone varying from 20 to 100 feet.

The outcropping fault breccia of the Cambrian shales is denoted by a resistant band of angular broken rock, cemented by later minerals. Through this breccia two diamond drill holes were driven into the underlying Cretaceous rock. This was evidently done on the assumption that the fault was vertical rather than a low angle thrust.

The thrust zone in the Cretaceous and Paleozoic limestones is composed of a crushed mass of limestone fragments. These fragments have been subsequently disintegrated by solutions and are now reprecipitated as finely crystalline calcite.

Forces and Movement of Thrusting

The stresses which caused the major faults were exerted from the southwest. These forces overturned the folds and thrust the rocks for a considerable distance to the

east..

The distance of thrusting is not discernible by a comparison with the formations lying to the west as recent alluvial deposits cover most of the older sedimentary formations. In the Helvetia District, west of Rosemont, the rocks have undergone complex thrusting and faulting. This has isolated and distorted the formations making it practically impossible to correlate the amount of movement.

The movement, however, is known to be considerable because of the sequence of formations. Those of the thrust block are in the reverse order as compared with the underlying rigid mass.

Two miles northwest of Rosemont there is a continuous sedimentary section forming the regional dip and strike of the eastern limb of an anticline. On the basis of the section the movement of the thrust has been apparently two miles from the west.

Associated Thrusting

In close connection with the major movement there are minor thrusts in the overthrust block. Only one such minor thrust has been recognized. This fault occurs between the Cambrian and Carboniferous limestones. Starting at the southern part of the area it extends north almost parallel to the major thrust and finally disappears beneath a heavy talus, either dying out or joining the major thrust.

A large amount of fracturing occurs in the overthrust block and in places these fractures have developed into a series of small faults which strike parallel to the thrust fault.

Faulting Connected with Igneous Intrusion

Warping and displacement of the lower quartzite is associated with the major igneous intrusion. Where the quartzite is thin or has been assimilated, faults radiate into the sediments. The faults invariably have steep dips varying from 70 to 90 degrees. In some places they cut and displace the major thrust plane, indicating a later age than the principal thrusting. These faults have been the main arteries of the mineralizing solutions.

Late Faulting

The third period of faulting followed the intrusion of the granite porphyry. The faults are reverse with dips to the south at angles approximating 60°. The granite porphyry stock to the north is faulted and displaced by the third system of faulting which forms a large fault zone. Within this fault zone are fragments of Cretaceous shales, aplite and altered Paleozoic limestones indicating the strata that were severed by the shear.

The last period was one of normal faulting,

primarily along pre-existing planes of weakness. This shows possibly a reversal of earlier faulting. The gouge and breccia of the reverse and normal faults are not mineralized and apparently post mineral in age.

Age of Faulting

The thrust faulting was later than the Cretaceous, but how much later is not known. It is probably late Eocene or early Oligocene because rocks of post-Cretaceous age are found faulted in nearby areas. These age relations are based upon folding, with which the thrust faulting bears a close relationship.

Faults caused by igneous intrusion displace all formations up to and including the Cretaceous. The thrusting was earlier than the igneous intrusion. The post-thrust faulting may be divided into three periods. Each of these periods show relations to the overthrusting and the granite porphyry intrusion. These conditions make it possible to determine the relative age of practically all the faulting within the area.

Summary

The region as a whole was folded in Paleozoic and post-Cretaceous times. This statement is

based on local and regional structural conditions in and around the Helvetia District. In the Rosemont area the Paleozoic formations are resting upon Cretaceous sedimentary rocks which fact indicates thrust faulting.

This structural history has been complicated by later movements connected with the igneous intrusion. Post-intrusion there was a period of reverse faulting followed by normal faulting.

GEOLOGIC HISTORY

The following summary of geological history is arrived at from the interpretations of the regional and local conditions.

Preceding Cambrian time the region was intruded by large masses of porphyritic granite. The coarse texture of this intrusion indicated deep seated conditions. A long period of erosion followed, exposing the batholithic masses of granite and eventually developing a peneplained surface in the region.

Subsidence of the land mass caused the invasion of the seas from the Pacific region in Cambrian time. This sea invasion was characterized by the deposition of a quartzitic sand with minor amounts of feldspar. These sediments later consolidated to form the Bolsa quartzite. Sinking continued with a change to off-shore conditions. During this period the interbedded shales and limestones of Cambrian age were deposited.

In Ordovician and Silurian times emergent conditions prevailed. The region stood very little above sea level and did not undergo strong erosion, and if there was any deposition of continental deposits they were removed before Devonian time.

During early Devonian times emergent conditions still prevailed, but in the later Devonian submergence

became very general. This invading sea deposited thick Devonian limestones with apparent conformity upon Cambrian limestones. Land conditions probably existed again for a short period following the Devonian.

In early Mississippian marine conditions soon prevailed with deposition of thick bedded limestones. After a short emergence there was further deposition of thick limestones in the Pennsylvanian.

The termination of this period of deposition came at the close of the Permian with rising of the land. From the evidence of an unconformity between the Paleozoic and the overlying sediments this period was a time of folding and mountain making. The rugged and mountainous conditions continued far into the Triassic.

Triassic and Jurassic formations are notably absent throughout this region. However, the deposits of these two periods may have been laid down but were soon eroded with no traces of their deposition now evident.

Toward the end of the Jurassic there were decided crustal movements and active deformations. During this period probably the greatest amount of Triassic and Jurassic sediments were eroded, if they were ever deposited. The Commanchean is thought also to be missing in this region.

These conditions continued into the Cretaceous with a continuation of active erosion. In many places erosive conditions were so vigorous as to expose pre-Cambrian

formations upon which the Cretaceous was deposited.

The Cretaceous marked a time of deposition of thick beds of conglomerates, arkosic sandstones and shales. These formations rest with angular unconformity upon the eroded surface of the Paleozoic formations.

During early Tertiary a period of folding, thrusting and faulting began. Following this folding and faulting there were intrusions of stock like masses of granitic rock.

Mineralizing solutions associated with these igneous intrusions rose along the faults and deposited the primary ores where favorable conditions existed. As erosion progressed, oxidized and enriched zones were produced on or near the surface from the primary ores.

MINERAL DEPOSITS

History of District

The possibilities of the Rosemont Camp as a producing area were recognized at an early date. Copper stains were visible upon the cliffs and leached outcrops and oxidized cappings were abundant in the area. Chalcocite was found on the steep slopes.

The earliest claims were located about 1870. Production was started after the advent of transportation and the erection of smelters.

The Rosemont Copper Company, headed by L. J. Rose, started the development of the southern part of the camp on the Chicago claims in September 1894. A crew of 40 men was employed at that time. Toward the end of the year a 60 ton blast furnace was constructed at the town of Rosemont.

Production continued until 1896 when the claims were bonded by the owner, L. J. Rose, to the Lewishon Brothers of New York, who have since held the property.

The Lewishon Brothers acquired control of the Narragansett Mine in 1897 from J. J. Brown who had located the claim in 1879. He had worked the mine intermittently and produced some rich ore. At this time a shaft was down 115 feet and a fairly large body of 20 percent copper

ore was blocked out.

The Lewishons operated the mines until 1900. During 1907 the mines were again operated. The combined production of the Tip Top and the Narragansett mines totaled 200,000 pounds of copper valued at \$45,000.

Mining was discontinued again until 1913, in which year 62,805 pounds of copper, 10,392 pounds of lead and 235,117 pounds of zinc was produced from the Rosemont camp and the Cuprite Mine. Operations ceased in 1914, but were resumed in 1915 and a steady output maintained until the depression of 1921.

Production

The yield from the Rosemont District for the period 1915 to 1930, inclusive, is shown in the following table:

Late Production by Years

<u>Year</u>	<u>Tons Ore</u>	<u>Copper lbs.</u>	<u>Lead lbs.</u>	<u>Value</u>
1915	2,506	349,945		\$ 63,161
1916	14,609	1,958,825	71,903	499,820
1917	18,499	2,615,613		
1918	16,303	2,156,486		
1919	3,357	414,320	58,432	86,607
1920	2,516	401,244		80,988
1921	(No production--camp inactive)			
1922	(Small production)			
1923	683	68,633	40,590	17,360
1924	202	33,585		6,130
1925	319	40,000		8,300
1926	(No production)			
1927-28-29-30	(Small Production)			

General Character of the Deposits

The primary ores of the district are of the typical contact metamorphic or pyrometasomatic class of deposits. This type is formed by the intrusion of an igneous body into a series of sedimentary rocks. They are essentially metasomatic deposits, and because of their formation at high temperatures from magmatic emanations have been termed pyrometasomatic by Lindgren.

The deposits have been formed as a result of the replacement of limestone and calcareous sediments. They occur as irregular lode-like bodies on the limestone side of the metamorphic area because of the limestone's greater susceptibility to alteration.

The ore deposits consist of pyrite, chalcopyrite, chalcocite, cuprite, copper carbonates, tenorite and chryscolla associated with other metallic minerals, mainly magnetite and hematite. The two most important gangue minerals are garnet and calcite, with minor amounts of kaolin, sericite, chlorite, and epidote.

Oxidation has produced most of the commercially important ore bodies. The depth of oxidation is very shallow, due to rapid erosion. The oxidized minerals cuprite, tenorite, chryscolla and copper carbonates have been derived from chalcopyrite and pyrite. The depth of oxidation is very shallow except along the faults, fissures, and the

porous strata.

The only mineral of the secondary sulphide zone is chalcocite. It outcrops upon the surface in many places and has a very shallow extension downward. Over most of the district chalcocite is entirely missing.

DESCRIPTION OF MINERALS

Iron Minerals

MAGNETITE, ferrous ferrite, ($\text{FeO} \cdot \text{Fe}_2\text{O}_3$).

Magnetite is the most abundant of the metallic minerals. It occurs mainly as irregular contact replacements. These masses are usually fine grained or granular.

The massive fine grained magnetite in many places is fractured and the fractures filled with dolomite. This dolomite has been partly replaced with malachite. Where these two minerals have been dissolved cavities are formed, and frequently contain small amounts of native copper.

Microscopic magnetite is disseminated in the limestone near the larger magnetite bodies. It is often developed in the garnet showing a close association with pyrite and chalcopyrite.

HEMATITE, iron sesquioxide, (Fe_2O_3).

Specularite is not as common as hematite and never is found in large bodies. However, veins up to one half inch are found in conjunction with the magnetite.

Hematite of supergene origin is very abundant. It is found as the oxidation product of magnetite on or near the surface and on exposure to the air is decomposed to form a red earthy variety. Underground the hematite in some places is developed in the magnetite bodies.

PYRITE, iron disulphide, (FeS_2).

Pyrite is the second most abundant metallic mineral. It is found irregularly distributed throughout the strongly metamorphosed rocks in varying proportions. Its most widespread occurrence is in the shales, forming segregations or veins.

Microscopic examination shows it is the earliest sulphide formed and later partly replaced by chalcopyrite. In many bodies it is completely replaced by chalcopyrite which is in turn partly replaced by chalcocite.

Copper Minerals

NATIVE COPPER, (Cu).

Native copper is rare. It is often found in solution cavities in magnetite where it is a secondary mineral after malachite. Polished sections show small areas of native copper in calcite veinlets.

CHALCOPYRITE, copper iron sulphide, (CuFeS_2).

Chalcopyrite accompanies pyrite as a primary mineral. It is found unevenly distributed in garnet masses. Chalcopyrite has served as the principal replacement

for chalcocite. Microscopically the chalcopyrite is usually surrounded or cut with veinlets of secondary chalcocite.

CHALCOCITE, cuprous sulphide, (Cu_2S) .

Chalcocite is found entirely as a secondary mineral, which has been deposited from supergene waters as a replacement of chalcopyrite and pyrite.

Shallow deposits worked in previous years formed outcrops of chalcocite upon the surface. Below the surface it occurs principally as a replacement of chalcopyrite and of lesser amounts of pyrite.

MALACHITE, basic cupric carbonate, $(\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2)$.

Malachite is common in the oxidized zone and is most abundant in the limestone. It occurs as globular masses and irregular veins in calcareous formations. These occurrences are probably due to copper sulphate solutions mixing with those containing acid carbonate.

AZURITE, basic cupric carbonate, $(2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2)$.

Azurite, although of lesser importance than malachite, is found associated with malachite. In a three inch vein of malachite, azurite and tenorite were found successively outward from the center. Examination showed the sequence to be tenorite, malachite and azurite.

CUPRITE, cuprous oxide, (Cu_2O) .

Cuprite is observed near the surface with

tenorite. Commercial ore bodies of shallow depth contain cuprite as the most abundant mineral and have some associated magnetite. The cuprite occurs as crystal growths, which line or fill cavities and is the principal ore mineral.

CHRYSCOLLA, $(\text{CuSiO}_3 \cdot 2\text{H}_2\text{O})$.

Chryscolla is not very abundant. It occurs in small areas as irregular cavity fillings with spherulitic structure and also as massive aggregates. When found with hematite it appears to have filled small cavities. In other places it is only a coloration of kaolin. Its most frequent association is with malachite and azurite.

Scattered through the chryscolla are segregations of quartz showing the ore bearing solutions were apparently rich in silica.

TENORITE, cupric oxide, (CuO) .

Tenorite, the black oxide of copper, is found in small quantities in the upper part of the oxidized zone. It is not as common as cuprite. This mineral is the most stable surface ore and appears to be the ultimate product formed from the oxidation of the copper minerals, including the sulphides, native copper, cuprite and the copper carbonates.

CHALCANTHITE, (blue vitriol), $(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})$.

Chalcanthite is frequently found in the underground workings along the secondary fractures as fibrous

fillings at right angles to the walls. It is associated with the bodies of sulphides and oxides above the upper limit of secondary sulphides.

The formation of chalcantite has resulted from the leaching of copper sulphate solutions and their subsequent evaporation along fractures and openings.

GANGUE MINERALS

WOLLASTONITE, calcium metasilicate, (CaSiO_3) .

Wollastonite appears to be mainly formed as a replacement of limestone. It has a fibrous development often showing a radiating structure. In places the limestones are almost completely altered to wollastonite. Underground, wollastonite is often found as a replacement surrounding chert nodules. The conditions have been favorable for the formation of the calcium silicate due to the presence of calcium in the marble and the silica in the chert.

ANDRADITE, calcium iron garnet, $(\text{CaO.Fe}_2\text{O}_3.\text{SiO}_2)$.

The garnet found in the area is andradite. It represents the most common mineral. It is found entirely as a replacement in calcareous beds.

The most common variety is a massive dark mineral which shows very little crystal outline. Upon examination it is noted that all the garnets are dark green. The massive garnet shows interstitial iron discolorations due to

disseminate magnetite.

Qualitative analysis of this type shows a high iron and calcium content, with only a trace of magnesium.

Another type in the formation of the andradite is the development of apple green crystals as large as one half centimeter. The specific gravity of these crystals is 3.70, showing it to be andradite. Theoretically andradite has a specific gravity of 3.75, but being an isomorphous mixture it may vary within narrow limits. Qualitative analysis of the purer garnet shows a high iron-calcium content and only a trace of manganese.

Under the microscope the massive and large crystalline garnets are the same apple green. Close observation has revealed no other variety of garnet within the district.

EPIDOTE, $(\text{H}\text{Ca}_2(\text{Al},\text{Fe})_3\text{Si}_3\text{O}_{13})$.

Epidote is abundant in the Cambrian and Cretaceous shales. Here it occurs as rounded irregular light green patches, appearing to replace the more calcareous shales.

QUARTZ, (SiO_2) .

One of the most abundant non-metallic minerals is quartz. The principal occurrence is as silicification due to the large additions of silica. It also occurs as veins ranging from small stringers to veins one foot in width.

Some of the quartz no doubt represents extensive crystallization of the silica previously present in the

rocks. The greater part, however, has been simultaneous with and following the introduction of the sulphides.

CALCITE, (CaCO_3) .

Calcite is noticed as a vein mineral in minor quantities closely associated with the primary deposits. The most common occurrence is vein filling and crystals lining solution cavities.

In the secondary ores calcite is found interstitially among the sulphides and oxides, and was among the latest minerals to form. The limestones are mainly quite pure calcium carbonate.

DOLOMITE, $(\text{Ca,Mg})\text{CO}_3$.

The only known occurrence of dolomite is in veins and cavity fillings in magnetite. Often it consists of irregular patches separated by brown rims, due to iron rich portions.

The dolomite may have been formed as a result of magnesium that was set free during the replacement of the limestones by magnetite or magnesium may have accompanied the mineralizing solutions.

GYPSUM, $(\text{CaSO}_4 \cdot 2\text{H}_2\text{O})$.

Gypsum is abundant in the oxidized zone. Here it is usually associated with pyrite and other sulphides. It is formed during the oxidation of sulphides where they were

in contact with lime-bearing solutions, or acid solutions generated by the oxidation of pyrite reacted with the calcareous wall rock with the formation of gypsum. Its most common occurrence is in the shale where the largest pyrite bodies have developed.

PARAGENITIC RELATION OF ORES

General Statement

The formation of the primary minerals is due to replacement of the sediments or recombination of the minerals of the sediments. The sediments show a varying degree of susceptibility to replacement by the solutions. The calcareous sediments are the most replaced while the aluminous rocks and shales are less attacked and the purer quartzitic rocks are very stable.

Outward from the intrusion there are three zones within the sediments which are distinctive in their character of metamorphism. These zones show the intensity of the changes and the varying permeability of the sediments to solutions.

Classification of Metamorphic Zones

1. Early stage--Recrystallization
 - a. Marmorization
 - b. Recrystallization of original constituents
 - c. Very slight introduction of new elements
2. Intermediate stage
 - a. Introduction of iron and silica with formation of garnet and magnetite
 - b. Partial replacement

3. Late stage--Metallization

- a. Introduction of sulphides
- b. Complete replacement

Zones of Metamorphism

The outer and most extensive zone shows changes which have been the result of recrystallization of the original substances present with very little addition of outside constituents. This zone includes part of the Cretaceous sediments and Carboniferous limestones.

The principal metamorphic minerals developed have been calcite and wollastonite. The calcite is the result of recrystallization of the limestones. Wollastonite, the calcium silicate, is found disseminated throughout a large portion of the marmorized areas and in places the sediments are almost completely altered to wollastonite. This is due to the cherty, or siliceous parts of the limestone, recrystallizing under high temperatures with the escape of the carbon dioxide gas and the recombination of the calcium and silica to form wollastonite.

The second zone is composed almost entirely of garnet and marble in about equal amounts. Approaching the intrusive mass there is an increase in the amount of metamorphic minerals. Within the second zone most of the blanket ore bodies are formed. Very few sulphides are deposited within this zone, the main deposition is oxides and silicates.

The third zone shows the greatest amount of metamorphism in the limestones which are entirely replaced with

lime silicates and sulphides. The deposition has been sulphides and pyrite in massive garnet followed by intense silicification along minute fractures.

Significance of Zoning

There are two major periods of metamorphism. The first immediately followed the intrusion of the granitic mass and was due largely to the heat given off by the cooling mass. This process resulted in recrystallization of the material of the sediments.

The second period probably followed the partial solidification of the igneous mass and was caused by solutions escaping from the solidifying granite along fractures and partially or largely replacing the sedimentary rocks over limited areas.

Sequence of Mineralization

After a microscopic examination of specimens and verification of their field relations, the order of deposition of the minerals has been determined as follows:

- | | |
|-----------------|-----------------|
| 1. Wollastonite | 5. Pyrite |
| 2. Epidote | 6. Chalcopyrite |
| 3. Magnetite | 7. Quartz |
| 4. Garnet | 8. Calcite |

Wollastonite was among the first of the minerals which formed. According to the consensus of author-

ities wollastonite is a high temperature mineral, but has a long range of formation.

Epidote is found entirely localized in the cherty beds of the Abrigo limestone and Cretaceous shales. Its formation and mineralogical relation to the igneous body shows a high temperature of deposition. The preference of epidote for shaly beds is probably because they contain the the necessary elements for its formation.

Pyrite is intimately associated with the granular bodies of magnetite. Here it is found intergrown with magnetite showing a close relation in deposition. This shows the overlapping of the magnetite and pyrite deposition. Pyrite has a long range in its temperature of formation from magnetite to that of moderate temperature.

Most of the pyrite was precipitated almost in the same period as the massive garnet. Except for smaller disseminations pyrite is strictly confined to the massive garnet zone.

Sulphides are found interstitially in many places between the garnet crystals. In some specimens that were examined microscopically small veinlets of sulphides were detected cutting through the garnet crystals.

Relation of Ore Deposits to Structure

The geologic structure had a very important bearing upon the deposition of both the primary and

secondary ore deposits. Only by a careful study of these conditions may intelligent prospecting be carried on while exploring for new ore bodies in a region like Rosemont.

The deposits are closely related to the faulting and fissuring. The faulting has occurred before, during and following intrusion and a clear recognition of these general periods is necessary. The larger ore bodies which are genetically connected with the intrusion are on or near the intersection of faults or fracture systems with the more impervious strata.

These impervious strata may be either non-reactive fault gouge or the intersection of a fault with a relatively impermeable or inert stratum.

Faults and fracturing have allowed passageways and consequently greater areas for the radiation of the solutions into the walls. Along many of the veins which traverse unfavorable beds, the replacement and precipitation has been essentially within or near the fissure itself.

The most important ore bodies have formed along the Rosemont thrust fault, where it is cut by later nearly vertical fissures or faults. This fault zone was evidently favorable to mineralization because the limestone gave both permeability and a large surface for replacement.

The solutions traveled along the cross breaks until the permeable zone was reached, where replacement occurred outward from the fissures. This resulted in ore

bodies that in general follow the intersection of the fissures and the Rosemont fault.

The essential cause in the variation of the depth of oxidation has been due primarily to faulting. Where there is strong faulting it has resulted in large bodies of primary ore, which in turn has usually been oxidized and enriched with later supergene solutions. The depth of oxidation is variable, but in general the larger oxidized bodies may be expected along the major fracture systems.

Age of Ore Deposits

The earliest of the plutonic rocks which invaded the region was a coarse grained granite of post-Cretaceous age. The ore deposits owe their origin to this intrusion. This was followed by a later aplitic intrusion. No extensive mineralization has resulted from the later intrusion as indicated by the development work. No dikes are found associated with the intrusives, the mineral deposition is in close relation to the earlier igneous body.

The age of the intrusion is post-thrusting, which is post-Cretaceous. The mineralization is one of the latest geological events, post-dating everything except the later minor faulting.

Oxidation and Enrichment

Oxidation and enrichment of the deposits

has not been carried to great depths, but the major portion of the commercial ores have come from this type. Primary ores have not been important.

The strong relief and the consequent rapid erosion has denuded the area of most of the oxidized zones. This degradation has proceeded so rapidly in places that residual primary and secondary ores occasionally outcrop and lie upon the surface.

The principal minerals in the oxidized zone are tenorite, cuprite, chryscolla, azurite, malachite and the iron oxides. Masses of nearly pure koalin are often formed in this zone along the fractures.

Magnetite is the most stable of the metallic minerals. It changes to hematite only near the sulphide bodies. The alteration of magnetite is apparently brought about by the solutions generated from the oxidation of sulphides.

There has been extensive leaching near the surface in the more open calcareous beds. In these strata are found a mixture of calcium, ferric and aluminum sulphates. Scattered through the sulphates are crystal skeletons of pyrite, showing the generation of sulphate solutions and sulphuric acid, which has hastened the formation of these compounds.

Gypsum is the most common sulphate in the oxidized zone, near the surface. Its presence shows very little downward migration of solutions, because they have been unable to dissolve and remove such a soluble compound.

Tenorite occurs in the upper oxidation zone, although it is not as common as cuprite. It appears to be one of the ultimate products of oxidation of the copper sulphides.

The zone of enrichment is very irregular and is not sharply separated from the zone of oxidation. Chalcocite has been formed at the expense of primary chalcopyrite. The chalcopyrite occurs in the main as a primary mineral, and rarely as a secondary mineral.

CONCLUSION

Although a few of the problems have been solved, the investigation has only summarized the great amount of geology as exemplified in the Rosemont and Helvetia areas. There still remains a great deal of detailed geological work to be done upon the stratigraphy and structure in their relations to the ore deposits.

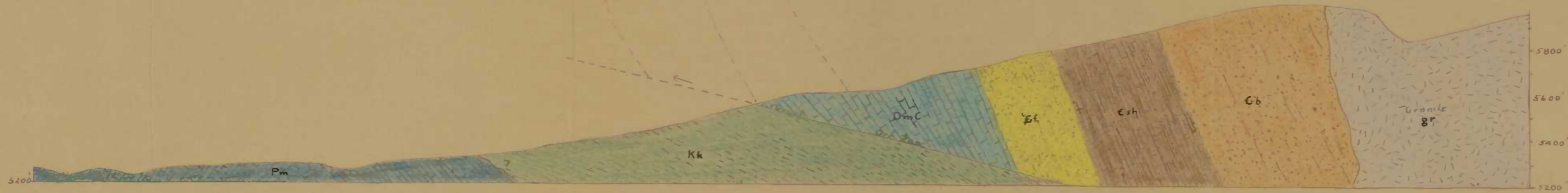
The future of the district is limited as far as a large producer is concerned. The primary commercial ores bottom at shallow depths. This sudden drop in values is exemplified by a change from chalcopyrite and pyrite to massive primary magnetite and pyrite. This mineralogical change in depth shows very unfavorable conditions for future developments of primary ores.

The abundance of reactive gangues near the surface will be favorable toward the formation of shallow oxidized and enriched zones.

The development of new ore bodies lies entirely in the recognition of favorable structural relations for deposition, especially those conditions which show favorable physical and chemical conditions for depositions.

INDEX MAP





Cross Section A-A'

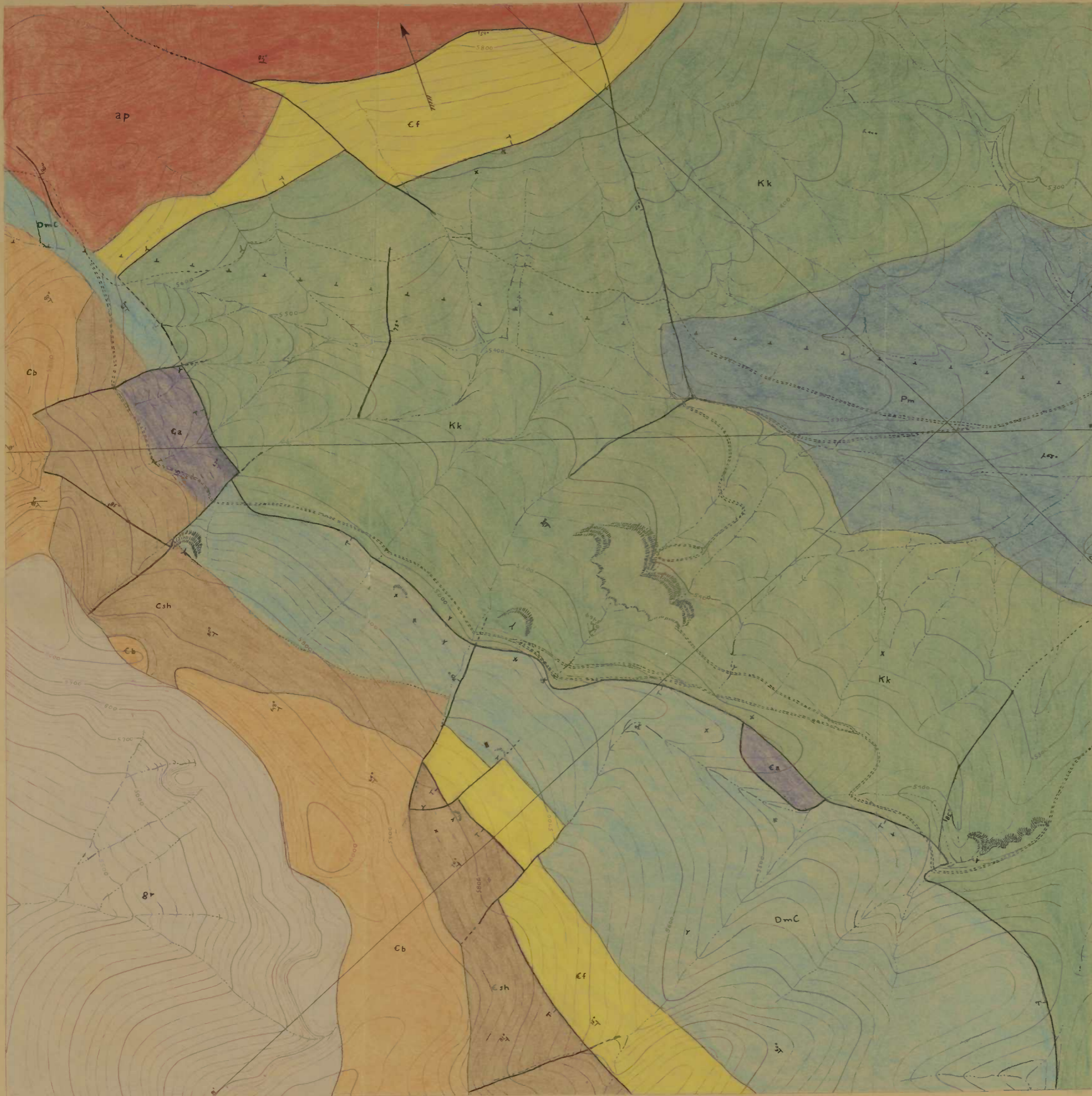


Cross Section B-B'



Cross Section C-C'

GEOLOGIC SECTIONS
H. Allen Thomas
 Scale 1" = 200'



- LEGEND
- SEDIMENTARY ROCKS
- Kk** CRETACEOUS
Ss + Shale.
- Pm** PENNSYLVANIAN ?
LIMESTONE
- DmC** DEVONIAN + CARBONIFEROUS
LIMESTONE
- ca** ABRIGO LI. }
cf QTZTE. SH. } CAMBRIAN
Csh LI-SHALE }
cb BOLSA QTZTE }
- IGNEOUS ROCKS
- gr** GRANITE }
ap APLITE } POST-CRETACEOUS
- FAULT
- COVERED FAULTS
(Concealed by alluvium)
- PROBABLE FAULTS
- THRUST SIDE OF THRUST FAULT
- DROPPED SIDE OF NORMAL FAULT
- STRIKE AND DIP

GEOLOGIC MAP OF THE ROSEMONT DISTRICT, ARIZONA

Scale 1 inch = 200 feet
Contour interval 20 feet
1931

Walter Thomas