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GEOLOGY OF THE SAN XAVIER DISTRICT
Pima County

BY

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SUMMARY

The oldest rock exposed in the San Xavier district is the basal pre-Cambrian granite. The limestones of determinable age are Permian. Whether or not any of the Carboniferous horizons are represented is unknown. The Permian strata constitute the most widespread sedimentary rocks mapped. They were deposited under a variety of conditions, as shown by the interstratified beds of limestone, quartzite, shale, and gypsum. Some thin layers of conglomerate are present near the base of the quartzite. The permian beds rest unconformably upon the pre-Cambrian granite, and are themselves overlain unconformably (?) by the Cretaceous (?) arkosic sedimentary series.

The sedimentary rocks are intruded and cut by a dark, coarse to fine grained diorite which consists essentially of hornblende, andesine, and some free quartz. A few dikes of granite occur, mainly within the Cretacous (?) rocks.

The broadest structure is a monocline in which the beds strike east-west and dip to the south from twenty to about twenty-five degrees. Folding is the most extensive type of minor deformation with a great number of small faults.

The ore deposits, regarded as the last stage of the magmatic activity, are almost wholly confined to the Permian limestones. They are localized mainly along fractures and under the somewhat impervious arkose and quartzite beds. The orebodies

are small and are somewhat scattered in occurrence. They nearly all outcrop at the surface and afford good opportunity to study gossans.

GEOLOGY OF THE SAN XAVIER DISTRICT

INTRODUCTION

The mining district of San Xavier was mapped during the autumn of 1928 and the spring of 1929. The work was undertaken as a partial requirement for the degree of Master of Science in Geology at the University of Arizona. The writer is grateful to the geological faculty of the University and especially to Professor B. S. Butler. Acknowledgment is also made to Mr. E. B. Eckel for his assistance in the field.

LOCATION

The San Xavier district is about twenty miles southwest of Tucson, Pima County, Arizona. The closest railroad is a branch from the Southern Pacific line, which terminates several miles to the southeast of the district. This railroad is in good condition and at the time of writing, March, 1929, there is some work being done on an extension to the Twin Buttes property, south of the area mapped. The metallized portion of the district is about a mile wide and extends from the Mineral Hill property on the north to the Twin Buttes mines on the south, a distance of approximately four miles. The mapping has been confined to a portion of the mineralized area roughly one mile in an east-west direction by three quarters of a mile in a north-south direction.

TOPOGRAPHY

The area mapped has as its outstanding topographical feature an east-west spur of the Sierrita Mountains. In the western part of the district this spur rises to a peak which is about five hundred feet above the level of the flats. The flats are gentle undulating plains, covered more or less with talus which extends both north and south from the spur. They show little variation in topography and are essentially a succession of abrupt but shallow arroyas, the main ones of which extend in an east-west direction along easily eroded rocks, arkosic, gypsum-bearing, or igneous.

VEGETATION AND RAINFALL

The vegetation is of the typical semi-arid type, consisting of mesquite, palo verde, and various kinds of cacti. Rainfall averages about ten inches a year, a large share of which is precipitated during the wet season, from June to August.

GENERAL GEOLOGY

The geology of this district may be generalized as a series of sedimentary rocks resting upon pre-Cambrian (?) granite, and the whole mass lifted and intruded by post-Cretaceous (?) igneous rocks.

The granite outcrops to the west for several miles and makes up most of the main Sierrita range. Within this range it contains some small areas of schist and the granite itself shows some gneissic structure. In the area mapped there is no evidence that this granite is of pre-Cambrian age. It is definitely of a period previous to the latest igneous activity, as evidenced by its faoulted nature in addition to its being cut and intruded by later rocks. It resembles, strikingly, the other granites in the Southwest that are attributed to pre-Cambrian age, and as all previous work in the district has assigned it to this period the present report will consider it as such.

The sedimentary rocks are of Permian and Cretaceous age. The Permian rocks consist of limestones, quartzites, shales, and gypsum beds. They rest unconformably upon the older granite and are themselves overlain unconformably (?) by the Cretaceous (?) beds. The Cretaceous (?) beds are mainly shales, arkosic sandstones, and conglomerates. The sedimentary rocks have been intruded and uplifted by the post-Cretaceous (?) igneous rocks and are in reality but a small fragment, surrounded on the west and north by intrusive, by some sedimentary and igneous rocks to the south, and by granite and talus to the east.

The present attitude of the rock is attributed to the mountain making epoch at the close of the Cretaceous and during early Tertiary times. The topography and physiography are of the typical desert range type. The drainage is controlled mainly by soft beds, and the dry stream courses occur along the strike of the formation. Faulting, usually of minor importance so far as the drainage is concerned, does seem to be the dominant factor in some places in determining stream location.

STRATIGRAPHY

No satisfactory columnar section was obtained because of the complicated structure. The country within a radius of fifteen to twenty miles was examined and no section of value for measurement was found. The closest available area is in the Empire Mountains, about twenty to twenty-five miles to the east.

If the dip of the pre-Cambrian (?) granite continues to the south at the same inclination as where mapped to the north, the stratigraphic thickness of the beds to the Cretaceous (?) is 1650 feet. This estimate of thickness is, however, of little value, as repetition of the beds by strike faulting undoubtedly occurs.

AGE OF SEDIMENTARY ROCKS: Most of the sedimentary rocks mapped are assigned to Permian age. The fossils found in the limestones correspond with those of the Snyder Hill formation, as determined by Dr. A.A. Stoyanow. Composita Mexicana and Bellerophon are especially abundant. The southern group of the sedimentary rocks is composed chiefly of rounded grains of quartz and feldspar. Some shale is present but is subordinate to the arkosic material. The whole formation has a reddish color which grades into reddish yellow. A thin layer of conglomerate is present in many places at the base, but may be absent. No fossils have been found in any of this material, but it is arbitrarily assigned to the Cretaceous. The reason for doing this is the resemblance to other known sediments of this age.

CHARACTER OF SEDIMENTARY ROCKS: The sedimentary rocks of Permian age are chiefly limestones, quartzites, and shales, with beds of gypsum abundant in places. The limestones occur in massive beds, blue in color and in places cherty. The chert locally is missing, and in its place are blotches of white calcite that represent recrystallized fossils.

The quartzites, in some beds, are almost a conglomerate; in others they are very fine; and some few beds grade into almost unconsolidated sandstone. The color varies from a bright red to a rusty brown. The quartzites are cross-bedded and are regarded as irregular lenses of varying dimensions. In the west-central part of the mapped area the quartzite is almost entirely missing.

The shales grade in color from red to green near the tops of some beds and near the bottoms of others. This change of color depends, to a large extent, upon the degree of weathering and possibly on alteration by mineralizing solutions. The green shade is formed by the removal or chemical reduction of the ferric iron in the original reddish material.

Gypsum deposits are extensive throughout the area and especially in the central part east of the main Twin Buttes road. They appear at first to be replacement bodies within the limestone and along fracture zones. Nodules of "cherty" looking material are very prominent along the supposed bedding planes. This "chert" has many of the physical appearances of true silica, but it is somewhat soft. Chemical analysis shows it to be a very compact mass of gypsum with minor amounts of calcium carbonate. Several specimens suggest anhydrite, but they are too soft and in all cases contain water. No data are available regarding the possible transition to anhydrite at depth. The rocks near the gypsum beds have all of the physical appearances of limestone but grade gradually into gypsum. All of the limestone adjacent to the gypsum is softer than normal limestone; wherever it has weathered, even slightly, the surface may be scratched by the finger nail. Several attempts have been made to find sulphate in this material but without success. The gypsum everywhere contains some calcite and grades from almost pure calcium sulphate into pure limestone. The significant points concerning the origin of these gypsum beds are the facts that they are somewhat regular in form and in places seem to lie directly below a quartzite horizon. This may be interpreted to mean a localization below the quartzite; but until more satisfactory evidence is obtained, they are considered to be of a true sedimentary type. Some local trenching by one of the mining companies has disclosed a narrow stratum of gypsum distinctly of a bedded character. This tends to support the idea of a sedimentary origin for the larger deposits.

The Cretaceous (?) rocks vary considerably in composition and physical appearances. In greatest part they consist of a rock resembling a granite, with large corroded and rounded crystals of two colors of quartz, gray, and white. The rest of the rock is composed of weathered feldspars. Biotite and hornblende, which characterize the igneous rocks of the district, are entirely wanting. Some or nearly all of the quartz grains are rounded, and are apparently pebbles included in the rock. This pebble mixture is thought at present to be a sedimentary rock, but there is also a possibility that it may represent a stage of decomposition of a binary granite, although this does not appear to be probable. Some quartzite is present in the Cretaceous (?) and some smaller areas of red shale may be encountered.

All of these arkosic sedimentary rocks are cut by dikes and irregular intrusive bodies of basic igneous rocks, near diorite in composition. Some small dikes of granite composed of quartz, orthoclase, and biotite are of common occurrence, although much less abundant than the dark rock. Several of these dark dikes are composed of an igneous breccia cemented by more of the diorite.

IGNEOUS ROCKS

The main intrusive rock in the northern and western parts of this district is a granitic type of probable pre-Cambrian age. It is a coarse-grained holo-crystalline rock, with only two major constituents, orthoclase, feldspar, and quartz. The feldspar is much altered, kaolinized, and frequently coated with limonitic stains. Individual specimens show considerable chlorite, resulting from the decomposition of former biotite "pencils." The biotite may have been an important constituent of the original rock but has been so largely altered and removed that only a few specimens contain the recognizable mineral. The granite shows considerable evidence of having been subjected to stress and strain. Individual crystals of all types are shattered and cut by fractures of all sizes, varying from minute cracks to well definable fissures.

As stated under the heading of general geology there is no very definite reason for attributing this granite to the pre-Cambrian age. It contains a few small areas of schist near Helmet Peak, and some considerably larger areas in the Sierrita Mountains. The rock is somewhat gneissic in places. From its appearance in San Xavier, the intrusive could be assigned to the late Cretaceous or Tertiary, but as definite evidence is lacking and the area under discussion has previously been mapped as pre-Cambrian, there is nothing to be gained by assuming it otherwise without definite evidence. Whatever its age, it underlies the ore horizons in the limestones at no great depth.

This granite has been intruded and cut by many dark dikes and irregular fine grained intrusive bodies. This cross-cutting intrusive is post-Cretaceous (?) in age, as shown by the fact that it intrudes the Cretaceous (?) sedimentary rocks. This rock is very dark in color and has a dioritic composition. From thin sections it is seen to be composed mainly of hornblende, andesine feldspar and a surprisingly large amount of quartz. The rock in places is almost completely chloritized and epidotized.

In the area to the south of the main range mapped, there are many intrusive bodies and dikes that are not outlined on the map. These were purposely left out as the contacts are very irregular and obscured by talus. There are two types of igneous rocks represented, the quartz diorite described above and a biotite granite, of probable pegmatitic origin. The diorite is not nearly as fresh as that obtained on the north side of the range, and free quartz is entirely missing in the sections examined.

GENERAL STRUCTURE

The general structure is a monocline dipping to the south. Crenulations and folds, from minute size to over one hundred feet across, are common. This folding, combined with many faults, complicates the structure and makes careful detailed study essential to an understanding of the features. Dissolving of the gypsum beds, which are locally of considerable thickness, and the subsequent collapse of the overlying strata may account for some of the smaller structural features.

FOLDING: The tilting of the strata was probably caused by the post-Cretaceous intrusive in the northern part of the district. With subsequent erosion, this resulted in a range made up of hills of resistant Permian limestone with southerly dips of twenty to twenty-five degrees.

In the extreme eastern part of the area a major combined fold and fault displacement culminates in Helmet Peak to the southeast. These combine to form the most prominent structural feature of the district. The folding has been the main cause of deformation, with the faulting subordinate. The main system of fracturing coincident with this fold has a general strike of N 25-35 W and a dip varying from 85 degrees west to vertical.

FAULTING: There is some evidence of east-west faulting all along the Cretaceous (?) and Permian contact. This evidence, however, is not sufficient to prove that a fault of appreciable size is present. There has undoubtedly been some slight movement, possible a dip slip,or adjustment of the beds due to tilting. (See cross-sections). Breccia is nearly everywhere present at this contact and seems to have been formed by the cementing of detritus in the erosion though present along the contact. The cementing material is caliche, which is abundant at many places. The contact is mineralized, and breccia occurs at places in depth. The main reason for thinking that the Cretaceous-Permian contact may be a fault, is that the basal conglomerate is thinner here than at other localities where the Cretaceous (?) conglomerate is known in the state. In places in this district the conglomerate is entirely missing. The most logical way to explain its absence is by a fault parallel to the contact. Cross faulting does not seem to be adequate to account for the conditions. However, until better evidence is obtained no fault of definite displacement is assigned parallel to this contact.

Several minor faults with a measurable offset have been followed. Two of these occur in the eastern half of the area and are roughly parallel, striking about N 45 W. and tending to converge toward the Helmet Peak fold-fault. In the western half of the area there is a possibility of an east-west break, although it is not definite enough for exact location. Shearing is very common, and the limestones and silicified shale are badly jumbled.

The structure in the central part of the area is not as clear as might be desired, chiefly because of talus and detrital material. It was thought at first that the Permian quartzites formed persistent beds, broken by faults, but more work gives the impression that they are present as lenses. If this is true, the lack of continuity of quartzite beds in the area under discussion may be accounted for without faulting. The Permian-Cretaceous (?) arkose contact was followed through and showed no sign of cross faulting or significant structural features. From the evidence at hand, the only structural difference in this west-central area is the result of the lower level of the surface due to softer rocks.

CONTACT ALTERATION

The limestones, at and near the contact with the intrusive rock in the northern part of the district, are very coarsely recrystallized, the crystals in places attaining a length of about an inch. In nearly all places observed this recrystallization was the only effect produced, the contact being otherwise tight and unmineralized. It is thought that the ore forming solutions were distinctly later than the latest intrusive. Where this intrusive makes a comparatively tight contact with the limestones, conditions have not been favorable for deposition by later solutions.

From one old mine working, at present inaccessible considerable garnet rock and some ore have been removed, as evidenced by the material left on the dump. Here, however, there is considerable fracturing and brecciation at the contact of the sedimentary rocks with the granitic intrusive body. This has left an open porous zone which allowed subsequent solutions a relatively free movement.

Along many faults and fractures, away from any exposed igneous rock, there is garnet and some silicification of the limestone. Minor quantities of pyroxene and magnetite are usually present. The whole character of the mineralized and metallized zones resembles contact metamorphosed rock. These areas have no definite connection with the outcropping igneous masses. The facts point toward an intrusive in depth, and at a relatively shallow depth. If the pre-Cambrian intrusive in the northern part of the area continues at its known dip at the surface, the contact will underlie the Cretaceous (?) beds at a depth of about two thousand feet. The quartz diorite and some later granitic pegmatites probably come much nearer to the mineralized areas than appears from surface outcrops.

HYDROTHERMAL ALTERATION

General hydrothermal alteration is so obscured by local contact metamorphism that its effects are not very noticeable. Some widespread silicification has occurred. This is best shown by the extensive areas of former shale, now intensely silicified.

MINERALOGY

The mineral deposits of the district as a whole are of the typical contact metamorphic class. They are concentrated along fractures and at the contacts of different sedimentary rocks, as described under localization. The mineral species will be described in detail, briefly.

COPPER MINERALS: Chalcopyrite $CuFeS_2$ 34.5% Cu. Chalcopyrite is present in nearly all polished specimens in minute relict grains and also in many places in veinlets.

Chalcocite Cu_2S 79.8% Cu. Chalcocite was observed as a thin black powder, coating pyrite.

Bornite Cu_5FeS_4 63.3% Cu. Bornite was observed in several specimens on dumps, but nowhere in place.

Covellite CuS 66.5% Cu. Covellite was found with bornite, but is rare in the district.

Tetrahedrite $Cu_6Sb_2S_6$ 52.1% Cu. Tetrahedrite occurs in specimens from the Helmet Peak mine, south of the area mapped.

Malachite $CuCO_3.Cu(OH)_2$ 55.1% Cu. Malachite is common and widespread throughout the district as an oxidation product of sulphides.

Azurite $2CuCO_3.Cu(OH)_2$ 55.1% Cu. Azurite is widespread but in smaller quantities than malachite, with which it occurs.

Chrysocolla $CuSiO_3.2H_2O$ 36.0% Cu. Chrysocolla is common as an oxidation product of the sulphides.

<u>IRON AND MANGANESE MINERALS:</u> Pyrite FeS_2. Pyrite is very common and is probably the most abundant sulphide in the district.

Magnetite Fe_3O_4. Magnetite is common throughout the area near the contacts of sedimentary and intrusive rocks and along faults in the sedimentary rocks.

Hematite Fe_2O_3. Hematite is closely associated with magnetite.

Limonite. No attempt has been made to differentiate the various constituents of this minera. It is observed as an alteration product from other iron-bearing minerals and is occasionally seen as pseudomorphs after pyrite.

Siderite $FeCO_3$. Siderite occurs in several places as fissure filling.

Manganosiderite (Ankerite). This mineral is found in association with siderite.

Marcasite FeS_2. Several specimens of sulphide having a structure similar to marcasite were observed.

Jarosite $K_2Fe_6(OH)_2\ (SO_4)_4$. Jarosite is present in a few places in the oxidized zones.

Pyrolusite (Wad). These indefinite hydrous manganese oxide minerals occur as oxidation products of the ankerite and form black crusts and dendrites.

<u>LEAD MINERALS:</u> Galena PbS 86.6% Pb. Galena is the only primary lead mineral observed. It is widespread, but usually in small quantities and associated with zinc sulphide.

Cerissite $PbCO_3$ 77.5% Pb. Cerussite is common in the oxidized zone as typical sand carbonate.

Anglesite $PbSO_4$ 68.3% Pb. Anglesite is noticed as an intermediate stage in the oxidation of galena to cerussite.

Plumbojarosite $PbO.3Fe_2O_3\ 4SO_3.\ 6H_2O$. 19.7% Pb oxide. Plumbojarosite occurs in several places with limonite.

Wulfenite $PbMoO_4$ 60.7% PB. Several specimens of this mineral were obtained from a dump. The material appears to be part of a fissure filling.

Cuprodescloizite (Pb,Zn,Cu) $(OH)VO_4$. Several specimens of a mineral answering all of the characteristics of cuprodescloizite were obtained from a prospect hole in very highly altered clayey material, probably an altered dike. Some pieces gave good tests for zinc, while others, with a slightly greener tint, may be psittacinite or a similar zinc free vanadium mineral.

ZINC MINERALS: Sphalerite ZnS 67% Zn. Sphalerite occurs as small replacement deposits in limestone, also in veinlets and fillings in breccia zones. The mineral is dark and contains several percent of iron.

Smithsonite $ZnCO_3$ 52.1% Zn. This mineral is fairly common as "drybone" along fissures and as replacement bodies in limestones.

Calamine $2ZnO.H_2O.SiO_2$ 54.2% Zn. Calamine occurs with smithsonite and is present in ferruginous clays.

Aurichalcite $2(Zn,Cu)\ CO_3.3\ (Zn.Cu)(OH)_2$. Only two specimens of this mineral were obtained. They were both from pipe-like structure and formed part of a fissure filling in the garnetized limestone.

GANGUE AND NON-METALLIC MINERALS Calcite $CaCO_3$. This mineral forms the beds of limestone, and in addition is very common in stringers and veins. It is present as thin coatings and cementing material. As caliche, it forms a solid layer as much as several feet in thickness in the northern part of the area, making mapping difficult.

Gypsum $CaSO_4$. Gypsum is very abundant and forms massive beds in several places. Whether or not these beds change to anhydrite in depth was indeterminable, although some of the material suggests this.

Garnet. Complex calcium and iron silicate. Garnet is abundant near the contacts of limestone and igneous rocks and apparently is formed in both. It is close to andradite in composition.

Hedenbergite $CaFe(SiO_3)_2$. Some highly altered specimens of a magnesium iron pyroxene were obtained. They contain a small percentage of manganese, and resemble hedenbergite in appearance. This mineral is fairly common as gangue and is usually closely associated with the ore.

Tremolite $CaMg_3(SiO_4)_3$. This mineral was found along one fracture surface, as a thin fibrous coating.

Epidote $HCa_2(Al, Fe)_3Si_3O_{13}$. Epidote is common as an alteration product in dikes and contact materials.

Dolomite $(Ca,Mg)CO_3$. Dolomite is common as a fissure filling. It is very coarsely recrystallized.

Aragonite $CaCO_3$. This mineral is fairly common as a fissure filling and is usually stained by copper.

HISTORY

Detail records of production from the district are not available. The chief metallic output has been in copper, zinc, and lead, with minor quantities of iron.

In the early days of the Southwest the Spanish Fathers are reported to have mined with profit several pockets of silver ore. Some years later two smelters were built and operated intermittently for several years. Maximum production was obtained during the world war, but production since has been practically negligible. Recent operations have been confined to the efforts of a few small companies and prospectors. Some attempts have been made recently to mine the magnetite and hematite in the eastern end of the district. This may at some time be of value as a smelter flux.

The main difficulties of the district in the past seem to have been inadequate transportation facilities, lack of efficient milling equipment, scarcity of water, low grade of the primary ores, which is partly due to the amount of wall rock it is necessary to mine and finally, the spotty character of the ore is unfavorable to cheap production.

CHARACTER OF THE ORE DEPOSITS

The commercial deposits all occur as small replacement shoots and pipes in limestone. Most of the copper output has been from replacement bodies along fissures and faults and almost wholly within the oxidized zones. In addition to being small, the ore deposits are discontinuous and frequently widely separated. In order to keep any reserve in sight this last feature makes extensive development necessary and is a lare factor in the final cost analysis.

Most of the evidence points toward contact metamorphism as the type of deposit, and it seems probable that an intrusive rock is relatively close to the surface throughout nearly all of the district. The fact that the granitic intrusive is dipping under the limestones at approximately forty degrees tends to substantiate this conclusion.

LOCALIZATION

DIKES: Dikes are commonly encountered but are greatly altered both from weathering and from the original mineral-bearing and associated solutions. The chief value of these dikes has been to help shatter the enclosing rocks. They thus render the country rock more pervious and facilitate the movement of solutions.

FAULTS: Throughout the district faults and fractures have been the main feature controlling mineralization. The white recrystalline limestone does not appear to be as well mineralized as the granular, sometimes massive blue limestone. The latter, while probably not as completely shattered, contains most of the well definable fissure zones. Where these fissure zones intersect the contact of limestone with the Cretaceous sedimentary rocks or the Permian quartzites, they furnish the most favorable conditions for ore localization.

SEQQUENCE OF DEPOSITION

The sequence of mineral deposition, as far as is determinable, is as follows. Quartz and garnet, magnetite and some hematite (see the discussion later), hedenbergite, pyrite, chalcopyrite, sphalerite, and galena. This order of formation is in general substantiated by field evidence. Chalcopyrite was observed in stringers through magnetite and also around the edges of corroded pyrite. The ore minerals are distinctly later than and apparently replacing most of the gangue minerals, more especially the hedenbergite.

MICROSCOPIC DATA: As determined by microscopic examination, quartz and garnet were the first minerals to cyrstallize and at nearly the same time. They furnish, together with hedenbergite in varying quantities, the main groundmass for the ores. Corroded pyrite crystals are common, in many places surrounded and penetrated by chalcopyrite, which in turn is cut by minute sphalerite veinlets. Numerous microscopic spots of chalcopyrite are present, surrounded and intimately mixed with sphalerite. This may be thought of as unmixing or the tendency for individual species to segregate by itself. Sooty chalcocite coating grains of pyrite, chalcopyrite, and sphalerite were observed in several specimens, as were also a few spots of bornite and covellite, probably alteration products from chalcopyrite. In several specimens a second generation of chalcopyrite is in evidence, cutting sphalerite. This was nowhere observed in contact with galena; hence the relative ages of the two species is in doubt.

Magnetite is a common constituent of the ores, and wherever observed, has a bladed structure usually characteristic of hematite. Both of these minerals are present; the magnetite is by far the more abundant. They are intimately mixed and intergrown, and may be interpreted to mean either a simultaneous deposition of the two minerals, or a change from original hematite to later magnetite.

SUPERGENE ALTERATION

Of the primary ore minerals zinc sulphide is the most readily oxidized and removed. It does not travel far, but is left in the limestones as the carbonate, smithsonite, or the silicate, calamine. Some high grade pockets of this material have been mined, and other, low grade oxidized products occur, usually mixed with limonite to form the red or brown clayey mass found at the outcrop. The residual gossan, left after the removal of the zinc sulphide, depends largely upon the character of the other minerals present. The main characteristics of the material are its porous, spongy, and brittle nature, combined with a reddish brown appearance. The gossan is occasionally strong enough to remain in large pieces and does not collapse or disintegrate to a fine powder.

Copper apparently does not migrate far, because of the calcareous nature of the greater part of the gangue. The metallic content of the former sulphides or silicate. Some migration and secondary deposition has occurred, as shown by the presence of sooty chalcocite and secondary covellite and bornite. The main enrichment is along fractures and breaks containing a higher percentage of silica than the limestones. These limestones are characterized by the presence of malachite, azurite, and chrysocolla. The enriched areas are associated with fracture zones and rocks relatively rich in silica. The copper gossans are a yellowish red color and are loose but not spongy. The mass appears to have collapsed after leaching, and leaves a very fine, soft material.

Lead remains in the outcrop as either the "sand" carbonate or, in a few places, as plumbojarosite. Pyrite is probably the most important single factor in determing which of the above minerals shall remain. The extent of iron removal depends to a large extent upon the type of material that constitutes the gangue: where the gangue is of such a nature that the iron remains as a residual product, leaching is reduced to a minimum. Limestone, relatively free from silica, would thus seem to be the most favorable background for the formation of the limonite group of minerals and also for plumbojarosite. Field conditions leave the impression that little, if any, plumbojarosite is formed from transported iron. The carbonate, cerussite, forms from oxidation of galena where the gangue is siliceous and iron minerals are scarce or easily removed. Plumbojarosite seems to be relatively stable under the conditions at present existing in this district.

"Pyrite gossan" is in evidence in several localities. Some silica skeletons forming a sponge-like mass were noticed. The iron is completely leached from this material and has left a series of hard siliceous chambers, the former habitat of pyrite cubes. In another place pseudo-morphs of "limonite" after pyrite are found in abundance. These pseudomorphs are mainly found in shales and arkosic beds. Other outcrops contain relatively small amounts of silica or siliceous minerals. The true pyrite gossan containing the "limonitic" residue tends to compact itself and form massive dark brown material resembling goethite in physical appearances.

<u>GENERAL STATEMENT:</u> In all cases of oxidation the type of gossan left in the former metal containing rock depends upon several factors. First, is the amount of pyrite present, and second, is the abundance of silica or the relative inertness of the gangue. Both of these factors are of prime importance and everything else is very much subordinate, except for a few possible minor places.

GENESIS OF THE ORES

As stated previously most of the facts collected point toward an intrusive body at a relatively shallow depth. Mineralization has been noticed in all types of rocks outcropping at the surface, independent of type or locality. The sediments in general are very much squeezed, folded and faulted. The mineral-bearing solutions are considered as the last phase of the magmatic materials resulting from the crystallization of the intrusive. These solutions have penetrated the strata through numerous channels, and deposited their loads under a variety of physical and chemical conditions.

Limestone was the most favorable rock for the formation of commercial orebodies, so received a greater percentage of metal than the other rocks. Localization has been influenced to a great extent by the relatively impervious nature of the arkosic and quartzitic sedimentary beds. These arkosic and quartzitic strata, especially where badly shattered, are somewhat mineralized.

CONCLUSIONS

The main structure of the San Xavier district is a steeply dipping monocline, striking in general east-west and dipping to the south. This major structure is considerable modified by folds and faults of various sizes. The primary ore deposits were formed by ascending solutions coming from a parent magma which at present is not far below the mineralized horizons. The ore bodies of commercial size were deposited in the most favorable strata of limestone. Localization has been determined by the degree of fracturing and the presence of impermiable beds. These causes are in addition to possible chemical causes.

Although furnishing an interesting structural problem, this area has also provided some intriguing questions. More work concerning the gypsum deposits in particular is needed, as the data obtained are somewhat conflicting. The greatly shattered condition of the ore bearing horizons, in addition to the spotty character of the bodies of commercial size, makes more geological detail almost an essential for the future prospecting of the district.

BIBLIOGRAPHY

No literature on this district is known.