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The copper deposits of Shannon County, Missouri

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Thesis

THE COPPER DEPOSITS OF SHANNON COUNTY, MISSOURI.

by

John H. Bowles, B.S. in 1908

and

L. E. Davidson, B.S. in 1920

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ACKNOWLEDGMENTS

The preparation of this report has been greatly facilitated by the courtesies shown by the various officials of the Casey Copper Mining Company and the Shannon County Copper Mining Company of Eminence, Missouri. The writers are especially indebted to Mr. John Denton, manager of the Casey Copper Company, who by his able assistance and by his intimate knowledge of the district furnished much valuable information.

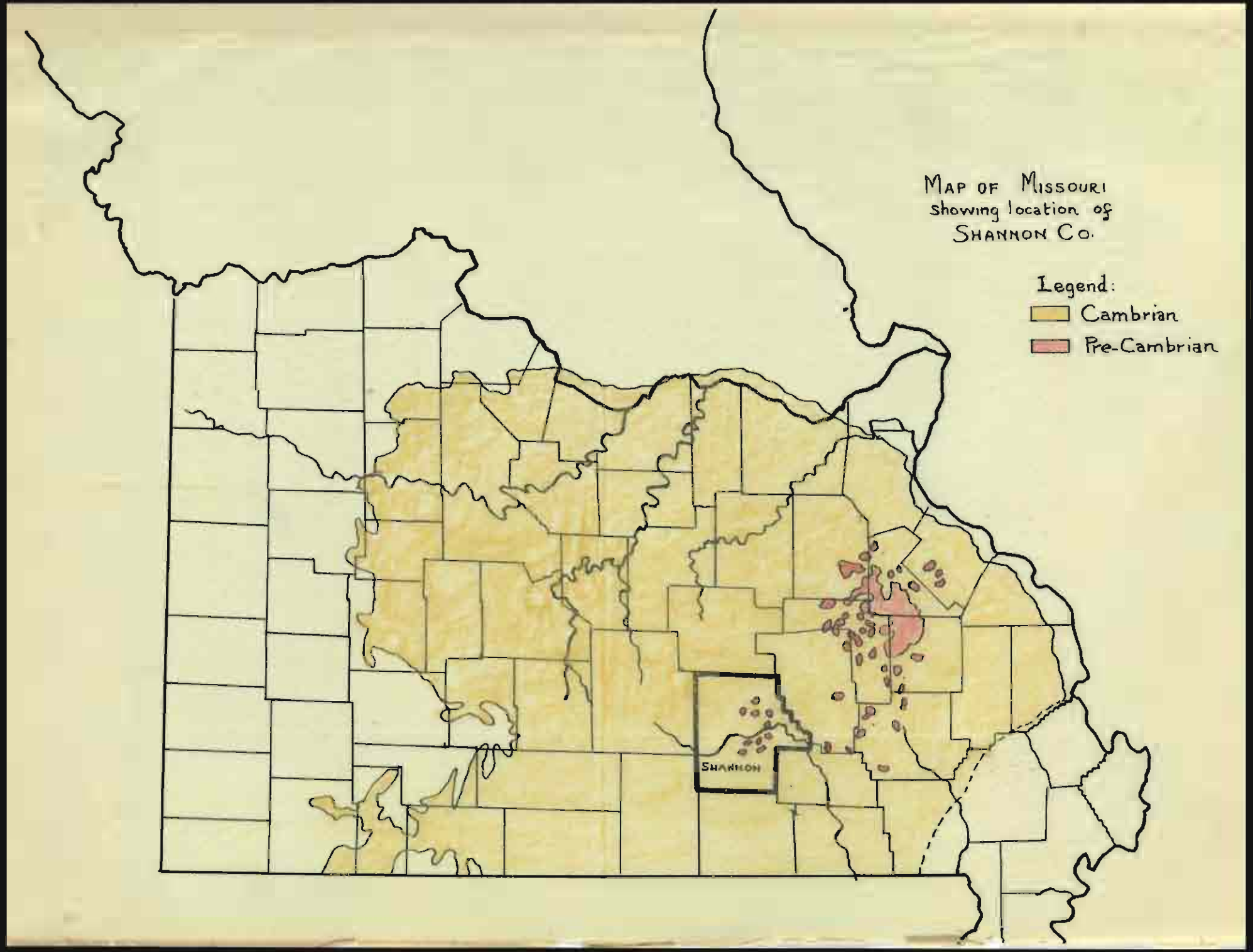
INTRODUCTION

The object of this report has been threefold. First, it has been deemed necessary to discuss the general geology of the area about Eminence, showing the distribution and character of the different formations. The distribution is shown on a topographic map of the Eminence Quadrangle. This sheet was prepared by the United States Geological Survey on a scale of one inch to the mile and with a contour interval of twenty feet. In places where the contacts were determined by actual observation, they are shown on the map by a solid black line, and where they were estimated according to the regional dip, the boundaries are shown by a black dotted line. The aneroid barometer was used for determining elevations in the field. The detailed field work was restricted to the area about Eminence, with the exception of occasional reconnaissance trips to more distant points. Part of the work of Professor Dake in mapping this area for the Missouri Bureau of Geology and Mines has been incorporated in this report. (The report on Professor Dake's

work has not been published, but is in manuscript form in the office of the Missouri Bureau of Geology and Mines.)

In the second place, it is intended to give a detailed account of the history, development, and extent of mining operations in Shannon County, with the amounts of production and the occurrence of the ore.

The third object of this report is to develop a probable theory for the genesis of the ore, and to discuss the most favorable horizon for further prospecting.


MAP OF MISSOURI
showing location of
SHANNON CO.
Legend:
Cambrian
Pre-Cambrian
SHANNON

CHAPTER I

GENERAL GEOLOGY

The map opposite page 6 gives an idea of the general distribution of the Cambrian and Pre-Cambrian rocks in Missouri. Structurally, the Ozark region, embracing the southern part of the State, consists of a large, slightly elliptical-shaped dome, the crest of which is situated near the Pre-Cambrian outcrops in Madison and St. Francois Counties. From this place the strata dip rather abruptly to the east, but gently to the north, west, and south. Very gentle anticlines and synclines on the flanks of this dome break the continuity of the regional dip. Occasional normal faults (of a hundred feet or so displacement) have been traced thru Washington and Crawford Counties; and faults of much greater magnitude (up to one thousand feet displacement) have been mapped in Iron, St.Francois, Madison and Ste.Genevieve Counties.

The Geology of the Eminence Quadrangle

Location and Topography.

The Eminence Quadrangle contains an area of 245

sq. mi., 17 1/2 mi. north and south by 14 mi.east and west, in the east central part of Shannon County. Shannon County is located in the southeast part of the State of Missouri. (See map opposite page 6).

In no part of the State, perhaps, are the surface features more rugged, or is the local relief much greater. Current River and Jack's Fork, with their tributaries, dissect the country with a network of drainage, forming steep slopes and sharp divides with many isolated hills. Limestone bluffs of four hundred feet in height are not uncommon along Current River. Coot Mountain furnishes a good example of local relief. This mountain is an exposed porphyry peak that rises about seven hundred feet above the water-level of Current River in secs. 15 and 22, T.29N.,R.3W.

Stratigraphy.

The classificiation shown in the geologic section below is the one accepted by the Missouri Bureau of Geology and Mines. E. O. Ulrich of the United States Geological Survey has,however, suggested a revision of this classification, in which

he has divided the Cambrian shown in the section below into three coordinate systems: the "Cambrian restricted", which is not represented in the section given below; the "Ozarkian", in which he includes the Potosi, Eminence, Proctor, and Gasconade; and the "Canadian" system, composed here of the Roubidoux and Jefferson City formations.

Geologic Section showing the formations represented in the Eminence Quadrangle.

	Jefferson City
	Roubidoux
	unconformity(?)
	Gasconade
	unconformity
Upper Cambrian	Proctor
	unconformity
	Eminence
	great unconformity
Pre-Cambrian -	Rhyolite porphyry

Distribution and Description of Formations

The Jefferson City Formation

The Jefferson City formation has been almost entirely removed by erosion from the area included in the Eminence Quadrangle. There are, however, occurrences of nodular chert float in the NE. part of T.27N., R.5W. The formations are here concealed by large amounts of residual material covering the

slopes, but the chert float resembles very much that described in other localities as being quite typical of the Jefferson City formation. The maximum estimated thickness of this formation within the area of this quadrangle is 50 feet. In Cole County the best exposures of the Jefferson City formation occur. There the formation has an exposed thickness of at least 350 feet and consists of alternate beds of fine-grained cotton-rock and pitted dolomite, the cavities of which are often lined with drusy quartz.

The Roubidoux Formation

The Roubidoux formation outcrops on the high ridges north and south of Jack's Fork, its lower contact having an average elevation of 900 to 1000 feet above sea-level. Thruout T.29N., R.4W, the exposures consist essentially of outliers capping only the highest points, and there possibly only as residual material. It was noted that the Roubidoux comes in contact with the porphyry on the highest porphyry knobs. The Roubidoux consists chiefly of a well stratified, tho sometimes thickly bedded, sandstone member. The

float often contains much dense, iron-stained chert, and a quartzite which is apparently the result of silicification of the sandstone by weathering. No quartzite beds were observed in place, Altho limestone members are known to be interstratified with the sandstone beds in other localities, no evidence of such conditions were found in this area. It is possible that they occur; but on account of the rapid weathering of the limestone and the more resistant nature of the sandstone and chert, they are concealed by float. It is also possible that limestone, belonging to the Roubidoux and resting below the thick sandstone member, was mistaken for Gasconade. The maximum thickness of the Roubidoux in this area is about 130 feet. In Bollinger County it has a thickness of about 90 feet and consists of three members, the lowest of which is a wavy, thin bedded limestone from 10 to 25 feet thick; the middle one a sandstone varying from 10 to 30 feet in thickness; and the upper member a coarse grained dolomite from 20 to 30 feet thick. In the area of the Rolla Quadrangle the Roubidoux is reported as having a maximum thickness of 160 feet and consisting of seven members of alternate sandstone and dolomite.

The Gasconade Formation

This formation outcrops along the valley sides of Jack's Fork and Current River and in the valleys of their tributaries. The upper contact follows roughly the 900-foot contour,altho exceptions to this were noted. Just west of Eminence in the S. 1/2 of sec.27,T.29N.,R.4W. two thin sandstone beds, separated by only a few feet of limestone, outcrop at about the 800-foot contour. From the character of the formation below these beds, it is believed that the sandstone represents the base of the Gasconade. This would place the top of this formation at an elevation of at least 1000 feet above sea level. This sandstone,believed to be the Gunter and to mark the base of the Gasconade, is not continuous,but seems to be present in lenses. On Current River in the S.1/2 of sec. 6,T.29N.,R.3W, over 400 feet of dolomite are exposed. In this exposure there are no sandstone beds to mark the lower contact of the Gasconade, but it is believed that the formation does not attain such thicknesses in this district. The lower 100 feet of this outcrop show a dolomite

which exhibits different characteristics of weathering and color from the upper part. For this reason the lower contact of the Gasconade has been taken at the point where the character of the rock seems to change.

The dolomite of this formation resembles that of the Proctor and Eminence in texture and crystallinity. The most noticeable differences are in the weathered surfaces. The Gasconade weathers in cavernous, pinnacled and craggy surfaces. The chert of the formation is quite typical. It consists of a very open, porous, honeycomb chert, which in places is fossiliferous. The approximate thickness of the Gasconade in this area is 300 feet. In other parts of the State it is known to be 400 feet thick.

The Proctor Formation

Lying beneath the Gasconade and separated from it by an unconformity is the Proctor formation. In some places the Proctor is found below the Gasconade; in others it appears to be absent, with the Eminence coming directly in contact with the Gasconade. On account of the discontinuity

of the formation its contacts have been drawn in on the map only where they were observed in the field. The Proctor was noted by the writers as occurring along Current River in the south part of sec.6,T.29N.,R.3W. Mr. St. Clair, in his reconnaissance work in this county,noted the occurrence of this formation along Shawnee Creek in sec.7 and 18,T.28N.,R.3W.,and near the center of the S. line of sec.27,T.29N.,R.3W.

The Proctor formation consists of a grey, coarsely crystalline,non-cherty dolomite. It is massively bedded,and where it is exposed in cliffs weathers to high, slightly convex surfaces. Such surfaces at a distance seem very regular and smooth, but upon closer observation reveal small pits, the result of differential weathering. The maximum thickness of the Proctor was nowhere observed to exceed 100 feet. In Camden and Miller Counties,in the central part of the State, the Proctor formation is exposed, and there it possesses the same lithologic and weathering characteristics described above.

The Eminence Formation

Resting unconformably below the Proctor is the Eminence formation. It outcrops near Eminence along Jack's Fork, along Swanee Creek in sec.18, T.28N.,R.3W., along Jack's Fork in sec.24,T.29N., R.4W., and in the valley bottom near the center of the N. line of sec.34,T.29N.,R.3W.

The best exposures occur along Jack's Fork near the center of the W. line of sec.26,T.29N., R.4W.,where fresh surfaces have been exposed by road excavations. Here the formation contains a bed of decomposed chert about thirty inches thick and many small solution cavities that have been filled with calcite. The formation, upon weathering, exhibits vertical jointing in places,resembling the basaltic jointing of igneous rocks.

The Pre-Cambrian Rhyolite-Porphyry

The Cambrian sediments are underlain by Rhyolite-porphyry. Only in protected cup-shaped basins in the porphyry is there a basal conglomerate separating the Cambrian from the Pre-Cambrian. Over the greater part of the area where the porphyry outcrops, the Eminence, Proctor, and Gas-

conade dolomites and occasionally the Roubidoux sandstone come into direct contact with the porphyry. The porphyry presents the usual uneven features of high isolated knobs with deep and irregular intervening valleys. From the relation of surrounding formations it is believed that the Cambrian sea entirely covered the highest points of porphyry, and that they have since been exposed by the erosion of the overlying sediments.

STRUCTURE

No evidence of faulting of any magnitude was noted in this district. At the Casey Prospect a few faults which had a throw of from 8 to 10 feet were noted. These faults are believed to be the result of solution and not of dynamic forces. On Sutton Creek near the E. line of sec.12,T.29N.,R. 4W., there appears to be a shear zone where the dolomite is greatly fractured. The axis of this disturbance has a NW.-SE. bearing, with the eastward side downthrown. Whether this was a fault or a very steep monoclinal fold was not determined. The maximum vertical displacement of the beds is

perhaps less than 50 feet.

Initial dips as high as 15 degrees were noted where the dolomite had been deposited on the flanks of porphyry mountains. The regional dip is to the south, averaging for the quadrangle about 5 feet per mile. A gentle unwarping of the sediments culminates near Eminence, where the contacts are relatively higher than they are a few miles to the north or south of this place.

CHAPTER II

LOCATION, HISTORY, DEVELOPMENTS, AND PRODUCTION

The Eminence district embraces an area of approximately sixty square miles. It extends from northeast to southwest a distance of ten miles and has an average breadth of six miles. Altho ore mineral in varying amounts is found scattered over the entire district, the best known and most thoroughly prospected properties are near Eminence. Eminence is the county seat of Shannon County, Missouri. It is located near the confluence of Jack's Fork and Current River in a very rugged, heavily timbered portion of the Ozark Mountains.

The Eminence district was discovered by Joseph Slater in 1830,or at a slightly later date. It is known that mining had been done in the district as early as 1840. The earliest Government surveys of the land in this area show the location of the Slater property on the original plats. Slater built a smelter on Shawnee Creek where he reduced the ore obtained from the mines. The product of the smelter was transported on flat boats down the river to New Orleans and there marketed. Tradition varies

as to the amount of copper produced, but probably not more than $50,000 was realized from the sale of this product. Shortly after the land was laid off in sections, a man named Chilton preempted the land, thus ousting Slater. Litigation followed, which was not settled until shortly before the Civil War. During the war and the period of reconstruction which followed, no attempt was made to operate the property. In 1876 Col. Biser of St.Louis purchased the property and began operations. Altho some ore was mined and shipped, this mining venture proved a failure and the land was sold to the Current River Land and Cattle Company. In 1892 F.M. Rogers leased the land from the owners and did some prospecting. Six years later action was brought by Rogers against the owners of the land for non-fulfillment of the contract. This litigation was continued until 1917. The foregoing paragraph is a brief history of the Slater property, now under lease to the Shannon County Copper Mining Company.

Other properties of the district have early histories, but none so varied as that of the Slater. The Jerktail was operated at an early

date and some ore no doubt was produced,altho no estimate of the amount could be obtained. Prospecting has been carried on in a desultory manner over the mineralized area for many years,but in most places it has been confined to superficial surface workings.

In 1843 Silliman's Journal of Science published an article by Professor J.T.Hodge on the occurrence of ore at the Slater Mine. According to this report Hodge believed that the ore in the conglomerate was practically exhausted,but that prospecting in the porphyry would likely reveal ore-bodies. It appears that at the time of the report no prospecting had been done in the porphyry.

In 1853 Stephen Baldwin gave a glowing account of his findings on the Slater property. This report contains mention of a shaft in the porphyry to a depth of 100 feet. Baldwin reported this shaft sunk on a heavily mineralized, true fissure vein and recommended the mining of 1000 tons of ore as preliminary work in locating the walls of the vein.

John Van Cleve Phillips made a report on the Slater mine in 1874. According to this report no

work had been done for some time. Phillips' report is not exhaustive as only surface workings were examined, the various shafts and pits being filled with water.

The report of Ulrich and Bain is a very conservative one. Prospecting in both the Slater and the Casey has proved that their theories are logical.

The latest report available is one made by Thos. Michner in 1918. Michner has evidently mistaken Pre-Cambrian porphyry for dikes of more recent age, and has reported the existence of metamorphosed limestones and quartzites where only crystalline dolomites exist.

With the exception of the report of Ulrich and Bain, all reports examined seem to be overdrawn. In some of these reports facts have been misrepresented, while in others conclusions were drawn which facts do not justify.

1. U.S.Geological Survey Bulletin No.267, page 40

The Casey Prospect

(S.1/2 of SW.1/4 of sec.14, T.29N., R.4W.)

The depth of the porphyry contact at the Casey

Prospect is not known. It is believed that the dolomite here fills a broad porphyry basin, the outer edge of which is marked on the northwest by the outcrop of the high porphyry peak near the northwest corner of sec.15, T.29N., R.4W., and on the east by an outcrop in the SE.1/4 of sec.14, T.29N., R.4W.

The Gasconade is the only formation that outcrops in the immediate vicinity of the workings. One high point a few hundred feet east of the shaft shows Gasconade dolomite to the crest, which has an elevation of 1050 feet above sea level. Gasconade is exposed as low as the 750-foot contour in the valley to the west, giving the formation a thickness of 300 feet at this point. Interbedded with the dolomite is a thin shale member 4 to 12 inches thick, together with a few dense chert members varying in thickness from 2 to 6 inches. Large amounts of a very porous, honeycomb chert occur in the upper part of the formation.

Altho Roubidoux sandstone does not outcrop on the high hills at the mine, it is found in massive boulders three-fourths of a mile to the

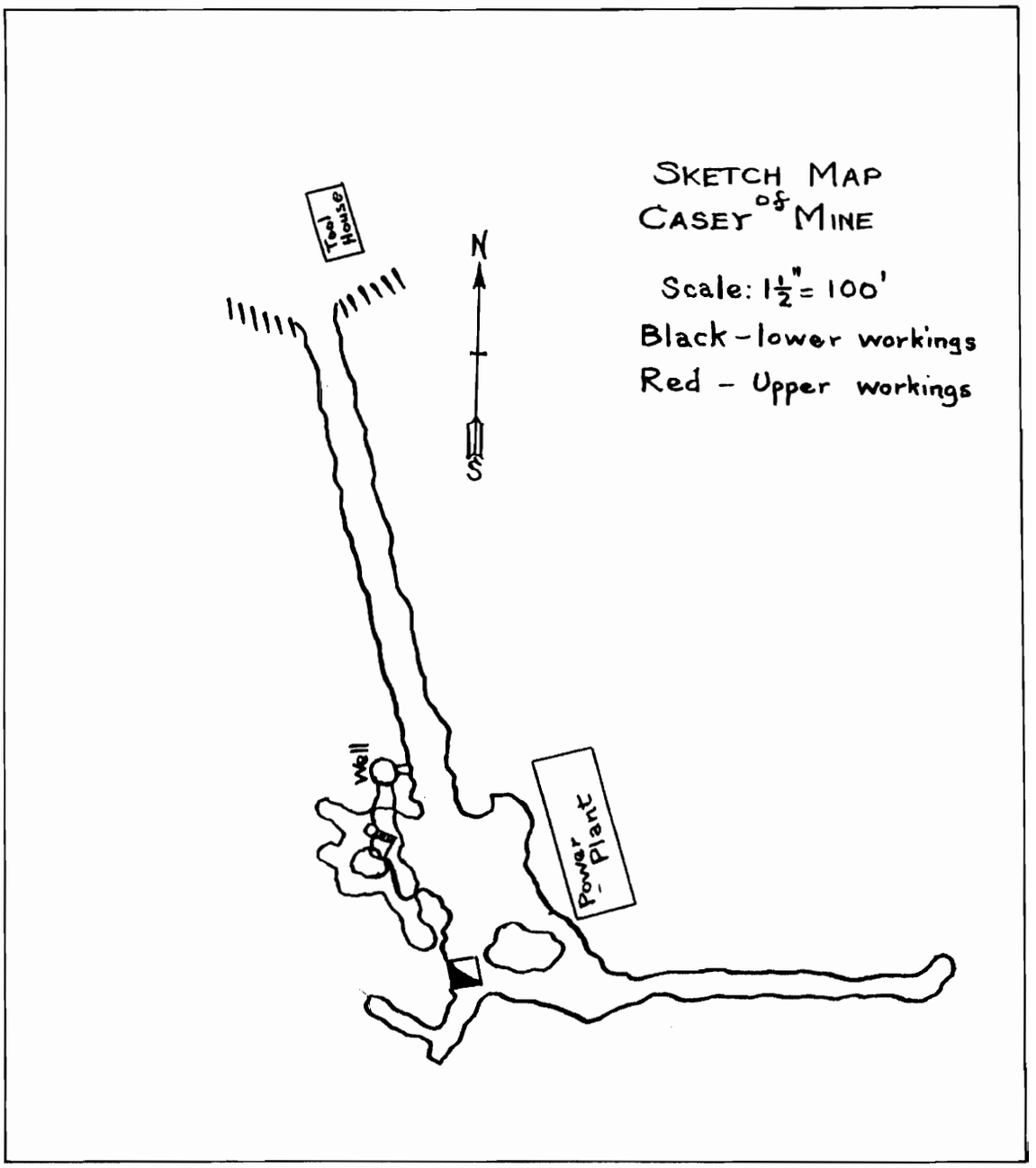


Fig. No. 3

southeast and southwest. The size and number of these boulders indicate that these hills are capped by sandstone in place.

The beds are all practically flat lying, tho in a few places local dips of two or more degrees were noted. These dips vary in direction and extend for only short distances. Three faults of from 5 to 10 feet displacement are exposed in the Casey workings. As the Gasconade dolomite is relatively very soluble, these faults are believed to be the result of solution and not of dynamic stresses.

Development

The accompanying sketch (Fig.3) shows a plan of the Casey mine. The lower workings are about 50 feet below the saddle between the two hills previously mentioned. These workings are connected with the surface by a shaft and an adit. The shaft has been sunk several feet below these workings, but at the time of examination was filled with water. There is in all approximately 450 feet of drift. Near the shaft, as shown in the sketch, an irregular room about 60 feet across has been stoped out. This room is connected to the

stope on the 26-foot level. Excavated material from the drifts and stopes has been removed thru the adit by means of a small tram car.

Operations were suspended at the time of the examination, awaiting the arrival of a pump and hoist. It is the intention of the management to reopen the shaft and drift north from the bottom. In pursuance of this idea a substantial headframe has been erected over the main shaft. The surface equipment consists of dwellings for the miners and manager, a blacksmith shop, and power house. The power house contains a gas engine and a belt-driven compressor. The compressor has been used only to furnish air for the operation of a Sullivan jack-hammer drill, but it is to be used to supply air for the hoist in further operations.

Occurrence of the Ore

The essential mineral found at the Casey prospect is the carbonate of copper, altho small amounts of chalcocite are found embedded in the carbonate. A heavily mineralized, tho rather small, vein is connected with all the mineralized bodies exposed in the workings. For this reason

it is believed to be the channel thru which the mineralizing solutions were introduced. From this vein carbonate of copper extends in all directions for a distance of 50 feet or more along the under side of a dense, persistent chert member. Where the faults intercept the chert member no mineralization along the fault plane has taken place. This shows that the mineralization was subsequent to the faulting. At the point where the chert member intercepts the mineralized fissure, mineralization occurs above and below but not in the chert. This condition is more clearly presented by the accompanying sketch. (Fig.4).

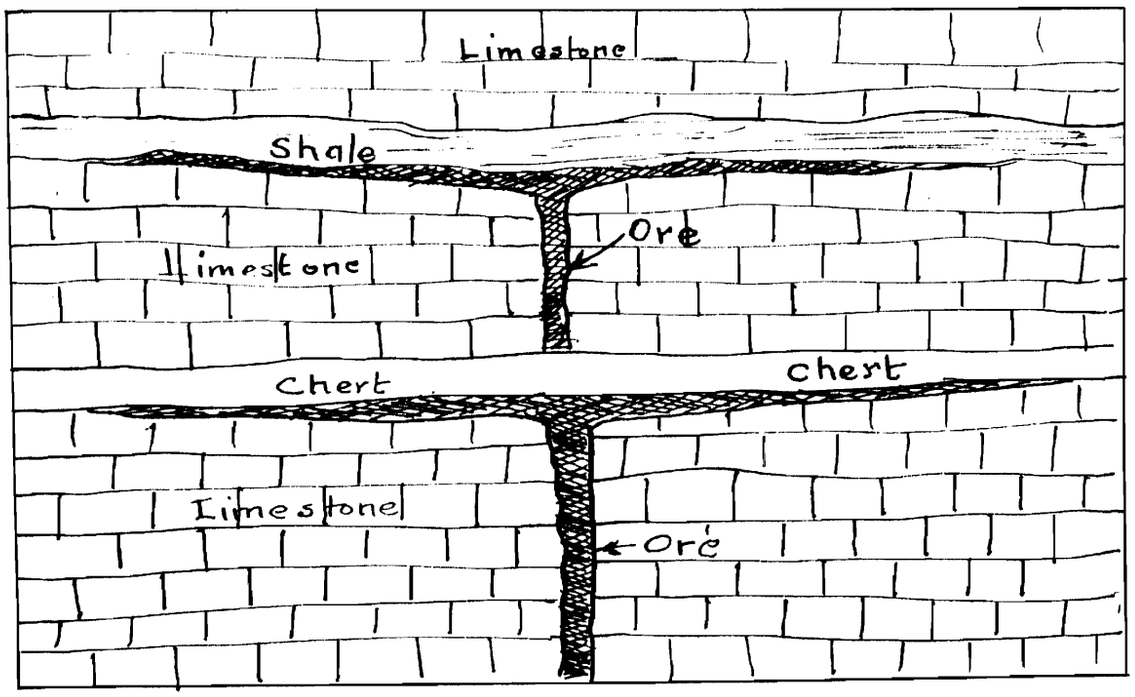


Fig. No. 4.

The ore mineral along the under side of the chert bed has a thickness of from 6 to 8 inches near the fissure but thins to a mere seam at a distance of 50 feet from the opening. Apparently there has been a small amount of replacement of the chert by minerals of copper, but such replacement seems to be confined to the walls of small fractures developed in this member. In places where the small fractures extend entirely thru the chert, mineralization has taken place along the upper side of it; but in all cases it is of very limited extent and considerably thinner than that occurring below.

Fig. 4 also shows the mineralizing fissure extending to a point where it is intercepted by the shale member heretofore mentioned. This shale member apparently prevented the further upward migration of the mineralizing solutions, as no mineral is found above the shale. Ore mineral occurs along the under side of this shale and in some places impregnates it. The copper blanket lying below the shale is not so extensive as that lying below the chert member. An attempt to

explain these rather peculiar phenomena as shown in Fig. 4 is undertaken in the genesis of the ore given in a special chapter.

Production.

No shipments of ore have been made from this property. We were informed by Mr. Denton, manager for the company, that his best extraction of ore in one day was 860 pounds of hand-sorted malachite, averaging about 20 % copper. This ore was taken from the under side of the chert member near the vertical fissure. From 3 to 5 tons of ore have been sorted and stored in a small bin.

The Slater Prospect
(N.1/2 of sec.36, T.29N., R.4W.)

The Slater mine is located in the central portion of the mineralized area. Surrounding the mine are heavily wooded hills from which the supply of timber used about the mine has been taken. An abundance of wood for fuel in the power plant is available.

Geology

The portion of the property where prospecting has been done lies on the north side of a low saddle formed by a porphyry and limestone hill. Res-

idual material here covers the surface to a considerable depth, so that the contact of the lime and porphyry was located only at one place. The basin-shaped depression on the north side of the saddle is filled with lime-pophyry conglomerate. This basal conglomerate is not wide spread over the area,but rests generally in basin-shaped depressions favorable for its accumulation. The Gasconade dolomite,which forms the hill to the west of the prospect,has been fully described in the paragraph on the general geology of the district and,as at this point it has no peculiarities, further description is unnecessary. The porphyry hill forming the east flank of the basin differs from the other porphyry of the region. This difference consists in the number and extent of joint or fracture planes,which occur in all the shafts and drifts on the property. The persistence of these fracture planes,which extend the entire depth of the main shaft,has led previous examiners to the belief that the fractures constitute a shear zone resulting from dynamic streeses. The evidence, as a whole, tends to prove that such

is not the case. The limestone hill, under which the porphyry containing these fractures dips, is neither faulted nor fractured. The entire absence of gouge or selvage in any of the fractures, the absence of any quartz in the vein fillings, and the presence of good columnar jointing on the 190-foot level, has led us to believe that these are closely spaced joint planes due to contraction on cooling; and not to dynamic forces. Roubidoux sandstone caps the higher hills to the south of the property.

Developments.

The basin in which the present workings are located shows evidence of previous operation. In all probability Slater secured the ore for his early smelting operations from the numerous shallow pits and cross-cuts in this basin. The more recent workings consist of two shallow shafts and one deep shaft. The two shallow shafts have been sunk thru the conglomerate and a short distance into the porphry. The deep shaft is 200 feet from the collar to the bottom of the sump and is the deepest shaft in the district. This shaft has been driven at an angle of eighty degrees for the first 100 feet and

vertically the remaining 100 feet. From the 190-foot level, drifts have been driven approximately east and west. The west drift has been driven on an incline and is filled with water. The east drift has been cross-cut 24 feet from the shaft. This cross-cut has been driven parallel to the joint system for a distance of 100 feet or more. The deep shaft is equipped with a headframe and power house. The power house contains a boiler, a small bucket-hoist, and an air compressor.

Occurrence of the Ore

Two horizons of mineralization are found on this property. The upper horizon occurs in the conglomerate and in the porphyry near the conglomerate contact. The ore mineral occurring here is completely oxidized. It has replaced the cementing material in the conglomerate and filled the joint planes in the porphyry. Chalcopyrite associated with calcite fills the joint planes in the porphyry below the oxidized zone. Copper mineralization has taken place only in the larger crevices and in these it is not persistent, cal-

cite being greatly in excess. Mineralization seems to be almost entirely confined to the replacement of the lime cement in the basal conglomerate and to the filling of fracture plants in the porphyry.

The Jerktail Prospect
(S.1/2 of sec.5,T.29N.,R.3W.)

The Jerktail property is located about 1 1/2 miles east of Current River in the valley head of a small tributary of that stream. The mineralization occurs just south of, and about 250 feet below the crest of a high porphyry peak. This prospect marks the north end of the mineralized area and is some distance from any other property.

Like the Slater, the Jerktail occupies a basin-shaped depression at the limestone-porphyry contact. Conglomerate similar to that at the Slater occurs at this point, but is apparently of less extent. As no prospecting has been done in the porphyry on this property, it is impossible to determine whether fracture planes in the porphyry are as numerous as they are at the Slater. It is believed,however, on account of the apparent

impervious nature of the porphyry basement, which holds the water table at a high elevation at this point, that they are not so well developed.

The workings on this property consist of surface cuts and conglomerate strippings done in the early prospecting days, and a shaft and drift of recent date. The shaft has been sunk to a depth of 16 feet, from the bottom of which a short drift has been driven. The workings are entirely in the lime-porphyry conglomerate. The shaft and drift were filled with water, so that only the excavated material on the dump could be examined. This material revealed a great variety of sulphides and a small amount of carbonate. The sulphides consisted of bornite, chalcopyrite, chalcocite and covellite. Mr. Denton informed us that a sample, very carefully taken across the face of the drift, gave an analysis of 2.3% copper. In the surface workings, ore occurs as residual material associated with clay, chert, lime, and porphyry pebbles. These old dumps would probably analyze 1.5% copper. As in the other properties heretofore described, mineralization seems entirely confined to a replacement of the cementing material in the conglomerate by copper. No replace-

ment of the porphyry was noted. The occurrence of sulphides so near to the surface probably results from the imperviousness of the porphyry basement. No other place in the district shows so much water at a high elevation in the abandoned workings.

Production.

Reports of ore shipped from this property are numerous, altho no reliable data as to the amounts of production could be obtained. Surface indications give evidence that some ore has been produced from this property.

The McKinney Prospect.

(NW.1/4 of sec.15,T.29N.,R.4W.)

This prospect lies north and west of the Casey property approximately 1 1/2 miles, at the base of a high porphyry peak in a bed of heavy conglomerate. The cove features illustrated by the Slater and Jerktail prospects do not seem to exist here. From the very steep dip of a prominent ledge of Gasconade dolomite outcropping just south and west of the shaft, we are led to

believe that this shaft is on the edge of a very thick conglomerate, dipping under the dolomite of the Gasconade formation. The shaft has been sunk 35 feet in the conglomerate and has not reached the porphyry contact. The conglomerate is highly impregnated with green ferrous silicate, but very little copper is contained. This may be due to the fact that descending solutions have leached the copper from the exposed conglomerate and carried it further down the pitching strata.

Mr. Denton informs us that he intends to prospect the conglomerate southeast of the present shaft with a churn drill. Should this conglomerate become more heavily mineralized as followed down the dip it might provide a paying mine, as the conglomerate here has all the evidence of existing in large quantities, which could be mined at very small cost.

The Sutton Prospect.

(NE 1/4 of sec. 18, T. 28N., R. 3W.)

This property lies south and east of Eminence a distance of 6 miles. Like the surface workings of the Slater, it lies at the base of a porphyry outcrop in the basal conglomerate. No estimate of

the thickness of the conglomerate could be obtained, because the old shafts and cross-cuts had caved in. A shaft has recently been sunk in the limestone about 200 yards south of the old workings, but as this was filled with water only the excavated material on the dump could be examined. Examination of this material revealed no mineralization whatever. The material consisted entirely of limestone, showing that the conglomerate had not been reached. The excavated material on the dump of the old workings to the north showed malachite intermingled with porphyry pebbles and limestone.

There was no evidence that any ore had ever been produced at this prospect.

CHAPTER III.

GENESIS OF THE ORE.

In reports made by various engineers for the Shannon County Copper Mining Company, present leasers of the Slater property, it has been stated that the veins in the porphyry were the result of ascending thermal solutions and that these veins should increase in richness with depth. It has also been stated that porphyry dikes were present and that contact metamorphism of the limestones had taken place. A close examination of the Slater property in particular and the whole district in general failed to reveal intrusions of any kind; nor could any evidence be found which would lead us to believe that the district was mineralized by thermal waters. The evidence, which will be submitted in the following paragraphs, points to the theory of mineralization by meteoric waters.

Previous Reports.

In Bulletin No. 267 of the United States Geological Survey, Ulrich and Bain have described the copper deposits of this district. They have

not gone into the theory of origin of the ores, but have considered only a possible explanation; that is, that the copper was originally in the porphyry which outcrops in this district. This copper was contained as finely disseminated particles in the porphyry and as small vein fillings, which were formed previous to the deposition of the overlying sediments. During the process of erosion, these minerals were taken into solution by meteoric waters, transported to favorable horizons, and there precipitated by the reduction of the solution by organic matter in the limestone or by the action of feldspar contained in the basal conglomerate and porphyry. The porphyry, which outcrops in this district and which has been exposed to weathering, is not believed to be of sufficient extent to account for all the copper deposits of the district as resulting from a leaching of the copper from the porphyry and a consequent reprecipitation and concentration. Another point bearing on this subject is that in case of the high porphyry peaks of the district there is almost without exception a mineralization of the conglomerate or residual material at the base.

In no case were the extremely low points mineralized at the base, and in only two cases were those of intermediate height found to contain ore mineral. If the copper was contained in the porphyry of this district, the relative elevations of outcrops should not control the distribution of copper.

Source of Ore Mineral

A general consideration of copper occurrences thruout the State offers suggestions as to the possible source of the mineral. Copper occurs locally concentrated over widespread areas in the Gasconade, Roubidoux, and Jefferson City formations. In Ste. Genevieve County the Cornwall mine has produced some ore from the Jefferson City formation. In most of the sink deposits of iron ore, north of the Eminence area, copper minerals have been found. Occurrences have also been noted in Benton, Crawford, Dallas, Dent, Franklin, Greene, Jefferson, Maries, Phelps, and Washington counties. These deposits lie at or above the horizon at which mineralization occurs in the Eminence district and are far removed

from any igneous rock outcrops. In the vicinity of the Pre-Cambrian igneous rocks of the St.Francois Mountains, copper has been found in Madison, Iron,and St.Francois counties.

The igneous rocks of these mountains are known to contain copper, lead, zinc, iron,and other minerals. It is logical then to presume that the erosion of sufficient amount of these rocks to account for much of the clastic material of the Cambrian sediments, as well as the large quantities of lead, zinc, and iron ore of the Ozarks, must have liberated considerable quantities of copper, sufficient, in fact, to account for all the occurrences of copper in the Ozark region.

The fact that the deposits of copper are distributed vertically from the basal porphyry to the Jefferson City formation irrespective of faulting precludes the theory of transportation by artesian circulation. It is known that copper minerals occur locally concentrated in the Jefferson City formation. This formation is a very shaley dolomitic limestone and the organic matter contained in the shale may account for the precipitation there in locally concentrated bodies. In the case of the

sink deposits of iron ore which contain copper and which usually occur in the Gasconade dolomite the mineral has been leached from the Jefferson City formation by the action of meteoric waters, carried downward and reprecipitated with or below the iron in these structures.

It is believed that the copper minerals of the Eminence deposits were once contained in the Jefferson City formation overlying that area. The formation has since been completely removed. The meteoric waters charged with copper from the erosion of this formation have circulated downward to the porous Roubidoux sandstone just below. This sandstone furnished an excellent passageway for the circulation of the mineralizing solutions.

A careful study of the geologic map opposite page 48 will show that the highest peaks of porphyry penetrate the lower part of the Roubidoux formation, or are of sufficient elevation to have come in contact with that formation before it had been removed by erosion. The mineralizing solutions,circulating thru the sandstone,came in contact with the porphyry and descended along the slopes of the then buried

porphyry peaks, and thru the conglomerate. The impervious nature of the porphyry prevented the further downward migration of solutions, except in fracture planes in the porphyry. As explained by Ulrich and Bain, the feldspar of the porphyry-lime conglomerate or of the porphyry may have been the precipitating agent for the deposition of the copper. This explanation will account for the mineralization of the McKinney and Jerktail prospects and the mineralization at the base of Coot and Stiegal Mountains.

At the Casey mine the ore mineral evidently has been deposited by upward circulating waters. This is attested by the fact that mineralization occurs along the underside of the chert and shale members of the ore-bearing formation. Where the chert has been fractured pressure has forced the solutions into the openings, resulting in the deposition of mineral in such openings. Where the fractures extend thru the chert, mineralization has taken place thru and slightly above this member. The fact that the main vertical fissure, which connects with all the deposits of mineral, is intercepted by the chert member indicates two

periods of mineralization. During the first period, the fissure was partly mineralized and copper was deposited along the under side of the shale. This shale member formed an impervious layer and prevented the mineralization of any of the formation above. This period of copper deposition was followed by the silicification of the dolomite, forming the chert member which closed the fissure and prevented further mineralization above this bed. Following the formation of the chert came another period of copper deposition in which the chert formed the upper limit for the ascending solutions. The solutions coming in contact with this bed of chert moved laterally, depositing copper along the under side of the chert and in the small cracks which were open to the circulating solutions. Just what could have caused this succession of events is not clearly understood, yet these conclusions are offered as a possible explanation of existing conditions.

The foregoing statements point to the fact that the copper deposits of the Casey prospect resulted from upward circulating solutions. In

the first part of the discussion of the Casey property on page 20, it was mentioned that the porphyry probably formed a cup-shaped depression with the high point of porphyry outcropping in the NW. 1/4 of sec.15,T.29N.,R.4W.,forming the outer edge of the basin. At this point the Roubidoux is found resting on the porphyry. It is not improbable that the solutions which mineralized the conglomerate at that point circulated downward along the porphyry contact until they reached the lowest point of the basin. The map shows the elevation of this Roubidoux-porphyry contact to be 150 feet higher than the ore horizons at the Casey mine. Under this head of pressure the solutions would be forced up thru any opening in the overlying sediments.

Altho no direct evidence could be obtained that the porphyry peak occurring at the Slater property had come in direct contact with the Roubidoux sandstone, it is believed that the mineralization at the Slater is the result of solutions carried by this sandstone. These solutions might easily have percolated thru the

thin and probably open layer of Gasconade dolomite existing between the top of this peak and the sandstone.

In places where the lime-porphyry conglomerate offered favorable conditions for the precipitation, there resulted a mineralization by the replacement of the lime cement by the sulphides of copper. Examples of this type of deposit are to be seen on the Slater and Sutton properties.

A shaft 200 feet deep in the porphyry at the Slater mine shows mineralization along the fracture planes. Solutions which mineralized the conglomerate descended thru these fractures in the porphyry, precipitating copper and iron sulphide and calcite. The calcite was probably derived from the overlying limestone or from the cement in the lime-porphyry conglomerate.

It is probable that the copper was originally precipitated as the sulphide. Since the precipitation, erosion has removed not only the most of the Roubidoux, but much of the Gascon-

ade and some of the Proctor and Eminence dolomite. Deep valleys have been eroded, lowering the water table, and thus exposing the minerals to oxidation. At points where the water table has remained sufficiently high, there still remain some unoxidized sulphides. Examples of this occur at the Jerktail, where the mineral-bearing conglomerate lies in a small impervious porphyry basin, and in the deep shaft of the Slater where the mineral lies below the water table.

Resume

A brief summary of our theory is as follows:

1. That the mineral was contemporaneously deposited in the Jefferson City either as minute disseminations or as local concentrations.
2. That these minerals were leached from the Jefferson City during the destruction of that formation.
3. That the underlying Roubidoux sandstone afforded an excellent passageway for receiving and distributing the mineralbearing solutions.
4. That the Roubidoux-porphyry contact furnished an outlet for the solutions.

5. That from this outlet the mineralizing solutions circulated down the impervious porphyry basement to points favorable for precipitation.

6. That in some cases hydrostatic pressure forced the solutions upward thru openings in the overlying sediments.

7. That the process of weathering has oxidized the mineral, except where it has been protected by underground waters.

We believe that the foregoing report contains sufficient evidence to warrant the statement that beyond the reasonable question of a doubt the district under discussion has been mineralized by meteoric waters rather than by thermal solutions. As the replacement of the porphyry is of insignificant occurrence, the only source of ore in the porphyry would be the small veins and joint fillings. These veins and joint planes near the surface, being closest to the source of mineralization, should contain as much, if not more, ore mineral than those at greater depth. That these conditions would become more favorable in the porphyritic body seems improbable. The deductions

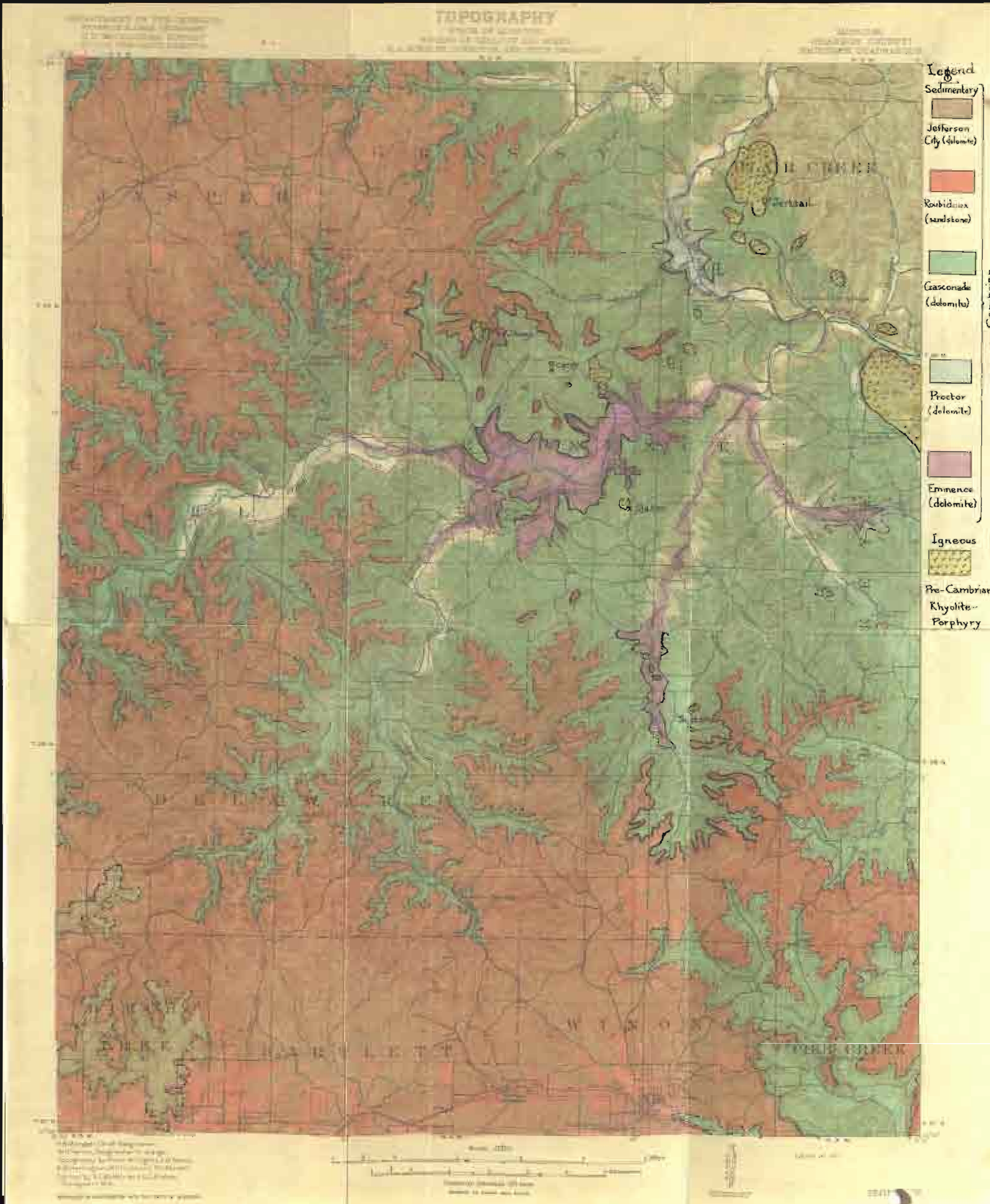
from the evidence in hand lead us to believe that continued prospecting in the porphyry is not justified.

The mineralized conglomerate which has been the source of ore in the past is, to all appearances, the most favorable horizon for profitable operation. The conglomerate would of necessity have to be of sufficient richness to bear the cost of smelting direct, as in all probability a body large enough for profitable operation would contain an excess of carbonate ore which would be lost in concentration. Successful operation would require an ore-body of conglomerate which seemed to be extensive enough to contain such deposits we observed was at the McKinney, and here the copper content in present workings is exceedingly low. Whether this may be due to the leaching of the more exposed portion of the conglomerate with a chance of a secondary enriched zone farther down the slope is problematical.

Deposits in limestone, as at the Casey, seem to require very favorable horizons for deposition. The deposits which have been opened

are of such limited extent that the question arises as to whether more favorable horizons occur at greater depth. As the mineralizing solutions at the Casey have undoubtedly circulated upward under hydrostatic pressure, it may be that larger deposits occur nearer the bottom of the basin or nearer the source of mineralization. A shaft has been sunk several feet below the present workings from which a drift could be driven that would cut the mineralized fissure at greater depth.

Considering the district as a whole, it has few features which recommend further prospecting.



TOPOGRAPHY
Legend
Sedimentary
Jefferson City (dolomite)
Roubidoux (sandstone)
Gasconade (dolomite)
Proctor (dolomite)
Eminence (dolomite)
Cambrian
Igneous
Pre-Cambrian Rhyolite-Porphyry