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GEOLOGY OF THE COPPER DEPOSITS IN THE EMINENCE REGION
SHANNON COUNTY, MISSOURI

BY

LANNY L. EVANS

A

THESIS

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the

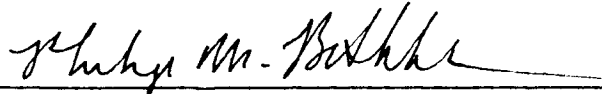
Degree of

MASTER OF SCIENCE, GEOLOGY MAJOR

Rolla, Missouri

1959

Approved by -



Assistant Professor of Geology

ABSTRACT

Copper has been known to occur in Shannon County, Missouri since the early 1830's. A number of small deposits in an area around Eminence has been worked intermittently up to the present day. Little detailed geologic information is available on these deposits.

The geology of the Eminence region consists of Precambrian rhyolite porphyry knobs projecting through dolomites and sandstones of Upper Cambrian and Ordovician age. A conglomerate of limited horizontal extent overlying the Precambrian is found at certain localities within the region. The only structures noted are the structural highs formed where the Paleozoic sediments lap upon the knobs.

The copper deposits occur as irregular replacement type bodies within the conglomerate overlying the Precambrian basement. The copper minerals present are chalcopyrite, chalcocite, covellite, malachite, azurite, and chrysocolla with hematite, limonite, calcite, and dolomite occurring as gangue material. The deposits appear to be structurally controlled as all but two of the seven known deposits occur at the head of buried Precambrian valleys.

The most favorable area for future exploration for copper and other base metal deposits within the Eminence region is in the Bonneterre formation near the pinch-out line of the Lamotte where it overlies the porphyry knobs in the southwest portion of the Eminence region. Ore bodies at this locality would not be expected to crop out at the surface.

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INTRODUCTION

The Problem

Shannon County, Missouri contains a number of small copper deposits, the majority of which are in the central portion of the county, near Eminence. These copper deposits were discovered in the early 1800's, and prospecting and development have gone on intermittently up to the present time.

A previous study of the literature pertaining to these deposits revealed how very little information is available, although, a very good description of the geology of the quadrangle containing the deposits was published by Josiah Bridge⁽¹⁾ in 1930. Several mining and

(1) Bridge, Josiah, The Geology of the Eminence and Cardareva Quadrangles: Missouri Bureau of Geology and Mines, 2d ser., Vol. 24, 228 pp., 1930.

exploration companies have been active within the area in the last several years, and as this is the only known occurrence of base metal mineralization on the south side of the Ozark Dome the great need for a detailed study of these deposits was realized.

The purpose of the present investigation was to describe the copper deposits as completely as possible, to determine the factors controlling their localization and to apply the information so gained to an evaluation of the possibilities of locating significant base metal mineralization in the area.

Acknowledgments

This investigation is a cooperative project of the Geology Department of the Missouri School of Mines and Metallurgy and the Missouri Geological Survey and Water Resources. The Missouri Geological Survey and Water Resources provided the funds for field expenses, and for making the thin sections.

The writer wishes to express his appreciation to Dr. P. M. Bethke of the Missouri School of Mines and Metallurgy, the advisor in charge of this investigation, for his aid, guidance, and suggestions during the course of the study. The writer is also indebted to Dr. T. R. Beveridge, State Geologist, for making available the facilities and files of the Missouri Geological Survey and Water Resources.

Thanks are also due to the various staff members of the Missouri Geological Survey and Water Resources and the Geology Department of the Missouri School of Mines and Metallurgy for their valuable assistance in making the completion of this thesis possible. Dr. W. C. Hayes aided on various parts of the study and visited the thesis area. Mr. D. Stark assisted with the illustrations. Miss Mable Phillips did the spectrographic analysis, and Mr. Henry Groves aided with the photography. Dr. G. C. Amstutz gave valuable assistance when needed, particularly on the mineragraphy involved in this investigation.

Previous Work

The literature relating to the copper mines in the Eminence region is very limited. None of the published accounts give a detailed description of the deposits, and as a result very little is known about them at the present time.

(2)
In 1841 J. T. Hodge visited the Eminence region and published

(2) Hodge, J. T., On the Wisconsin and Missouri Lead Region: (Silliman's Journal) Amer. Jour. Sci., Vol. 43, 1842.

the first account of the copper mines in the area. His paper, published just after mining operations had been discontinued, included a brief description of the Slater and Jerktail Mines. C. P. Williams (3) Director

(3) Williams, C. P., Industrial Report on Lead, Zinc, and Iron together with Notes on Shannon County and its Copper Deposits: Geol. Survey of Missouri, pp. 157-168, 1877.

of the Missouri School of Mines and Metallurgy, and ex-officio State Geologist of Missouri published a brief account of his visit to the Slater Mine in 1876. A map of the mine workings is included in his report.

(4)
Bain and Ulrich published a very brief report in 1904 on the

(4) Bain, H. Foster, and Ulrich, E. O., Contributions to Economic Geology, The Copper Deposits of Missouri: U. S. Geol. Survey Bull. 260, pp. 233-235, 1904.

copper deposits in this region, and followed this with a more detailed account a little later in the year (5). Bain and Ulrich's latter paper

(5) Bain, H. Foster, and Ulrich, E. O., The Copper Deposits of Missouri: U. S. Geol. Survey Bull. 267, 52 pp., 1905.

also introduced a new classification of the formations of the "Ozark series" in Missouri. In 1911 Ulrich (6) altered this classification in

(6) Ulrich, E. O., Revision of the Paleozoic Systems: Bull. Geol. Soc. Amer. Vol. XXII, pp. 627-678, 1911.

a brief publication.

(7)
In 1895 Haworth published his account on the "Crystalline

(7) Haworth, E., Crystalline Rocks of Missouri: Missouri Geol. Survey Vol. 8, p. 207, 1894.

Rocks of Missouri", in which he included a brief description of the lithology of the igneous rocks in the Eminence region.

(8)
Josiah Bridge spent the summers of 1922, 1923, and 1924 doing

(8) Bridge, Josiah, op. cit.

the field work on the geology of the Eminence Quadrangle, which he combined with the geology of the Cardareva Quadrangle and published in 1930. He gives detailed accounts of the Slater, Jerktail, Sutton, and Casey Deposits. Mining operations were resumed at the Sutton Mine during the time Bridge was doing his field work in the region.

The above publications comprise all the major accounts that have been published on the copper deposits in this region. Two unpublished theses have been written on this region by students of the Missouri School of Mines and Metallurgy. The first of these was written in
(9)
1876 by Greason, which contains a very brief account of the copper

(9) Greason, Arthur, Copper Ores and Deposits of Shannon County, Missouri: unpublished thesis, Missouri School of Mines and Metallurgy, Rolla, Missouri, 1876.

deposits, and chemical analyses of a few of the ores and rocks. The
(10)
other thesis was written by Bowles and Davidson who spent several

(10) Bowles, J. H., and Davidson, L. E., Copper Deposits of Shannon County, Missouri: unpublished Master's thesis, Missouri School of Mines and Met., Rolla, Missouri, 1921.

weeks in the region in 1920-21 during the time all the mines were in operation. Their work contains information in connection with the mining operations in the region. Ore genesis is also discussed in their thesis. They believe that the deposits are of supergene origin, the copper having been derived from erosion of the overlying Jefferson City formation.

There are also many reports by geologist and mining engineers that were submitted to various companies over a long period of time. A few of these are on file at the Missouri Geological Survey and Water Resources at Rolla, Missouri. While some of these reports contain much accurate and valuable information, many of them were written for promotional purposes and are of little value to the geologist.

GEOGRAPHY

The Eminence region, as defined in this report, consists of the area bounded on the east by the $91^{\circ} 15'$ longitude, the west by the $91^{\circ} 23'$ longitude, the north by the $37^{\circ} 14'$ latitude, and on the south by the $37^{\circ} 5'$ latitude. The region contains about 75 square miles, all of which are within the Eminence Quadrangle. The location of the region in relation to other areas in the Ozark region is shown in Figure 1. The Eminence region is readily accessible by State Highway 19 which runs north and south through the west edge of the area, and State Highway 106 which runs east and west through the center of the region. The portions of the region away from the highways are very difficult of accessibility as the area is very hilly and wooded, and few good roads exist. Several of the mines and prospects are accessible only by old lumbering roads that are inadequate for conventional cars and can only be reached by pick-up trucks and jeeps.

The Eminence Quadrangle lies wholly within Shannon County, the second largest county in the state of Missouri. Shannon County is located on the southeastern slope of the Ozark Mountains. The northern and central portions of the county, in which the Eminence region lies, are very heavily wooded and hilly exhibiting relief up to 700 feet. The town of Eminence, on the Jacks Fork River lies at an elevation of about 650 feet. The southern portion of the county consists of elevated table lands. There are three principal towns in Shannon County; Eminence, the county seat, Winona, and Birch Tree.

INDEX MAP of the EMINENCE REGION, MISSOURI

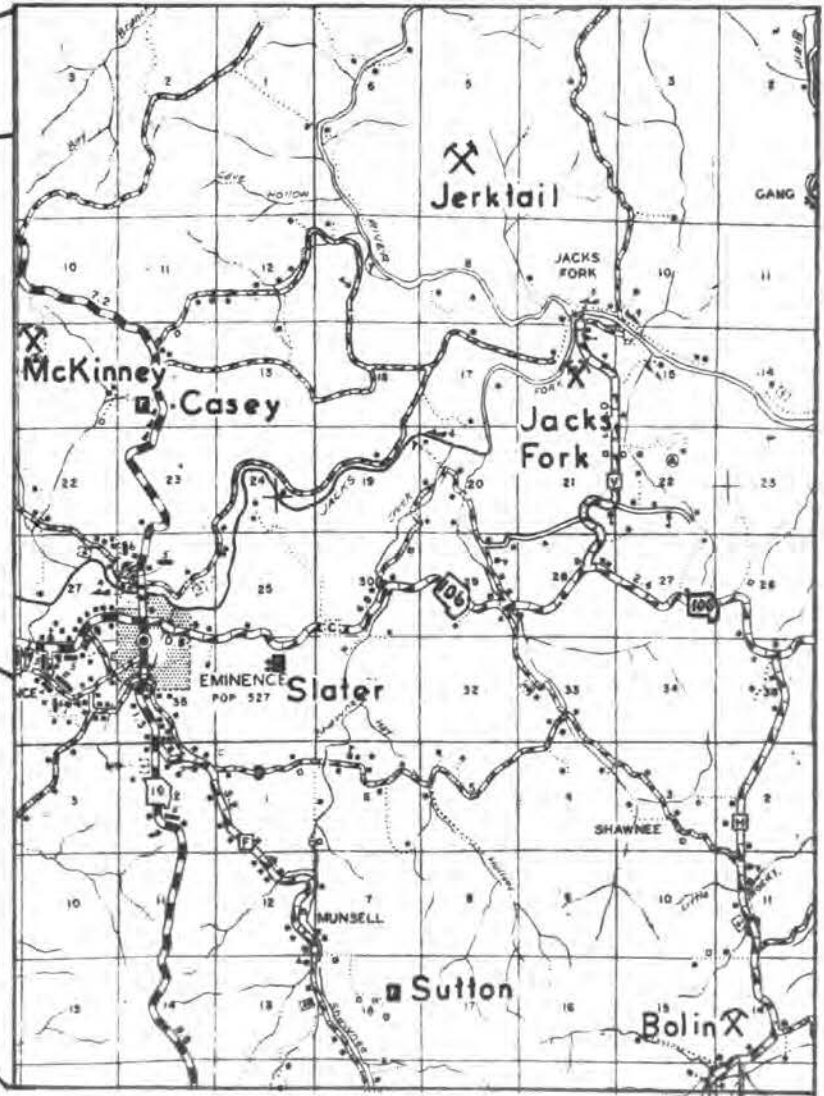
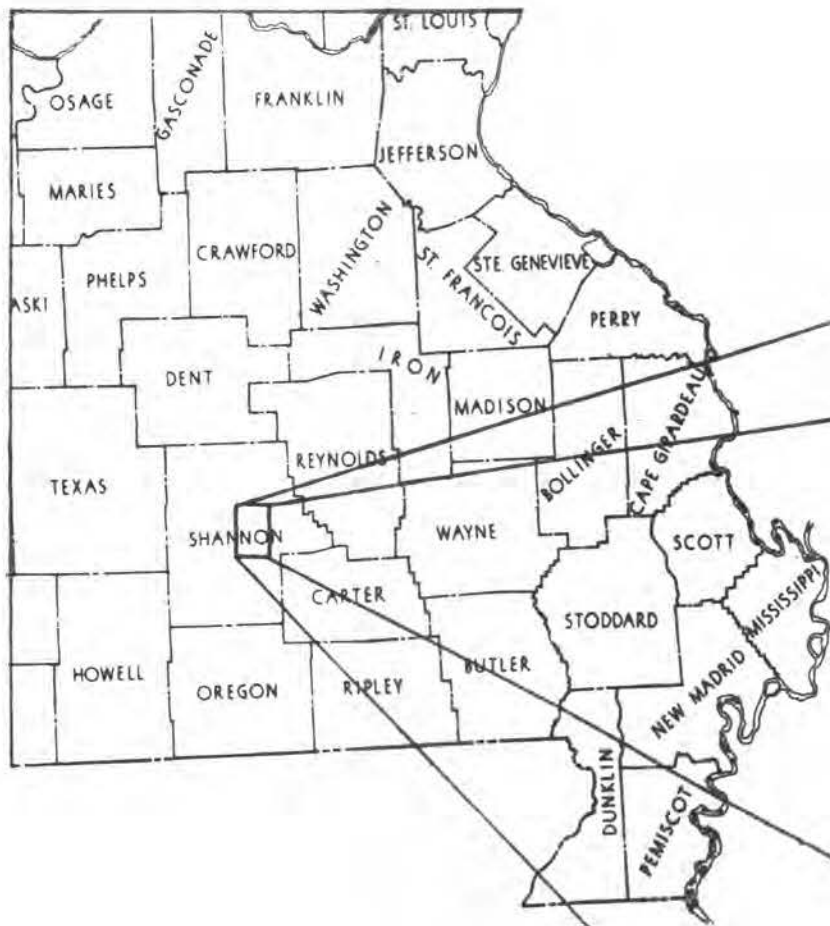




Figure 2. View of the Eminence region looking east from Missouri State Highway 19, 3 miles north of Eminence.

Population and Industries

The region is sparsely populated, with an estimated rural population of 10 persons per square mile ⁽¹¹⁾. According to the 1950 census Eminence

(11) Bridge, Josiah, op. cit., p. 23.

had a population of 527 people. A large portion of the population of the county lives on small farms on the flood plains.

Agriculture and stock raising are the major industries of the region at the present time. Lumbering was the major industry about 40 years ago, but the region was throughly cut-over by the lumbering operation, which was exclusively an extractive process. The land then became practically valueless as it is too steep and rocky to farm. About 72.3% of the land is designated as non-agricultural and recommended ⁽¹²⁾ to be returned to forest cover.

(12) Coors County Study, Missouri State Planning Board, 1937.

Railroads

The closest railway shipping point for the Eminence region is Winona which is 11 miles south of Eminence. The Current River Branch of the St. Louis and San Francisco Railway, passing through Winona, traverses the county east to west. This branch has its west terminal at Willow Springs where it connects with the main line of the St. Louis and San Francisco Railway between Kansas City, Missouri and Birmingham, Alabama. It also connects with the Missouri Pacific's

Iron Mountain route at Williamsville, Missouri. To the east it leads to the Mississippi River at Cape Girardeau.

Roads

There are few good roads in the Eminence region at the present time. These are composed of the two state highways and several good farm-to-market roads. The logging operation that previously existed in the region covered the wooded areas, and particularly the ridges, with a network of old wagon trails. Many of these old wagon trails can still be used today by pick-up trucks and jeeps. No map of these "jeep-roads" exists, but they can often be located on aerial photographs. The road system on the 1915 edition of the Eminence Quadrangle topographic map does not show many of the roads now present, and many of the roads shown on the map do not exist at the present time. State Highways 19 and 106 are not shown on the map.

Rivers and Springs

The main river in the region is Current River. Its head is at Montauk Springs in Dent County. The many large and small springs and Jacks Fork River, which empties into Current River about 5 miles northeast of Eminence, empty approximately 600,000,000 gallons of water into Current River daily. The Jacks Fork River has its source in Howell County north of Willow Springs.

There are many large springs in Shannon County, and a few of them rank among the largest in the state. Slater Springs are the largest permanent springs in the Eminence region. They are of historical interest in connection with the Slater Copper Mine. The combined flow of

the springs is around 65,000 gallons per day ⁽¹³⁾ . No other springs of

(13) Beckman, H. C., and Hinchey, N. S., The Large Springs of Missouri: Missouri Geol. Survey and Water Resources, Vol. XXIX, 2d ser., p. 121, 1944.

this magnitude were observed in the region, although numerous smaller springs were found.

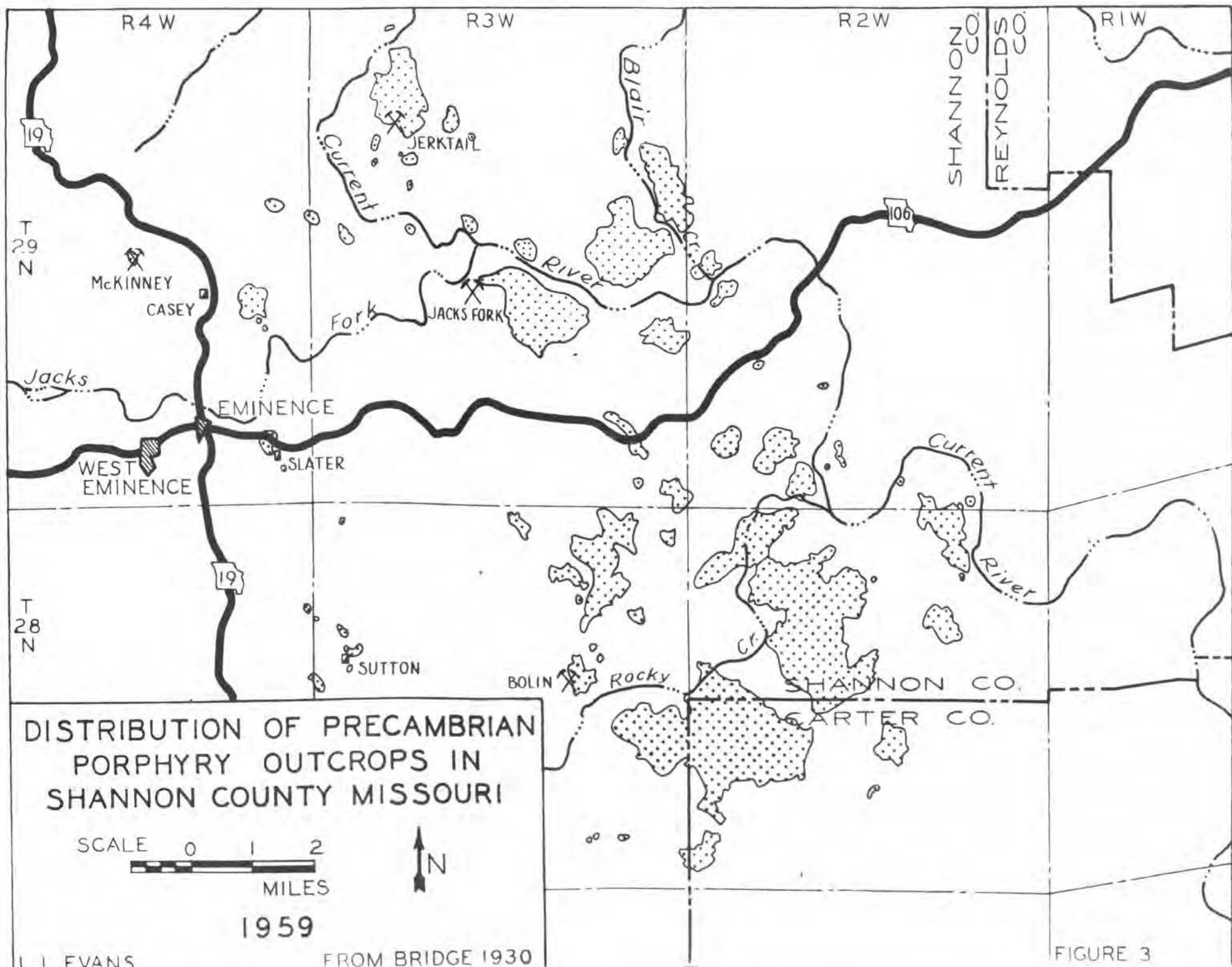
REGIONAL SETTING

The Eminence region is in the southeastern portion of the region broadly known as the Ozark Uplift. This is an elliptical, warped plateau having a major northeast axis of about 300 miles. Its geologic center is to the east, in Iron, Madison, St. Francois, and surrounding counties, where the Precambrian crystalline rocks project through the nearly horizontal strata of Cambrian and Ordovician age to form the St. Francois Mountains. In the Eminence region, the Precambrian rocks crop out as isolated knobs projecting through dolomite, sandstone, and conglomerate strata of Upper Cambrian and Ordovician age.

Precambrian Rocks

The oldest rocks exposed in the Eminence region are porphyries and tuffs of Precambrian age. These rocks crop out in the east-central part of Shannon County in an area delineated by a rectangle approximately 13 miles by 8 miles with the longer side trending to the northwest. The northwestern portion of this area composes the Eminence region. The exposures range in size from several square yards in Lick Log Hollow to about 5 square miles on Thorny Mountain. Many of the higher hills in the region are formed by these igneous knobs.

These exposed Precambrian knobs are portions of a topography that was carved out of the igneous rocks in Precambrian and early Cambrian time. This topography developed on the Precambrian surface possesses a considerable relief. A broad saddle was formed between this region and the St. Francois Mountains to the northeast where the



DISTRIBUTION OF PRECAMBRIAN
PORPHYRY OUTCROPS IN
SHANNON COUNTY MISSOURI

SCALE 0 1 2
MILES



1959

L.L. EVANS

FROM BRIDGE 1930

FIGURE 3

peaks have a slightly higher elevation, and are much more exposed. The highest Precambrian peaks in the Eminence region penetrate the lower part of the Roubidoux formation. There may be a number of buried peaks of this magnitude.

The porphyry is cut by two major systems of fractures which are in general perpendicular and nearly vertical. Their strikes are essentially parallel to the sides of the imaginary rectangle enclosing the porphyry outcrop area. Two other less prominent fracture systems were also noted. One is horizontal and the other strikes west-northwest. All of the igneous outcrops visited showed fracturing except in the large outcrop in the northern portion of the region in the center of sec. 5, T. 29 N., R. 3 W.

A number of the porphyry outcrops visited showed a well developed flow structure. The strike of the flow in almost every case was observed to be west-northwest. The magnitude of the dip varies from about 60° to 90° in both directions perpendicular to the strike of the flow. Flow banding is contorted in some areas.

Lithologically the Precambrian rocks are dark reddish brown to purple porphyritic felsites with associated tuffs. There are a number of different varieties of porphyries that crop out throughout the Eminence region. To examine, in detail, each of these would be beyond the scope of this report, although, they are certainly worthy of further study. As this report is primarily concerned with the copper deposits in the region, only the Precambrian rocks directly associated with the deposits will be described in detail.

The various types of Precambrian porphyries that crop out throughout the region are all somewhat similar in appearance, but exhibit some variation in coloration, percentage of phenocryst, grain size, and flow banding. Fresh surfaces of the rocks are darker than the weathered surfaces. Flow structure is suggested by the alternating light and dark color bands of variable thickness. The phenocryst are almost entirely feldspar less than 4 mm. across. No mafic minerals were observed as phenocryst.

The percentages of orthoclase to plagioclase phenocryst were determined with the Wentworth Micrometer after staining the thin-sections. The method used to stain the sections is that described by (14) Heinrich . The Precambrian rocks were identified microscopically

(14) Heinrich, E. W., Microscopic Petrography: McGraw-Hill Book Company, Inc., New York, p. 8, 1956.

as rhyolite porphyries, because staining the orthoclase revealed that the groundmass is composed almost entirely of orthoclase and quartz. A detailed description of the rocks examined follows:

Rock Name: Rhyolite Porphyry. This specimen was obtained from the SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 18, T. 29 N., R. 3 W., from an outcrop in the ditch about 100 feet north of the Sutton Mine shaft.

Megascopically the rock is a dark reddish brown, aphanitic rock with rectangular phenocrysts of pink orthoclase and gray plagioclase up to $\frac{1}{4}$ inches long. The larger phenocrysts are plagioclase. Flow structure is very well developed by alternating gray and dark brown bands of varying widths up to about 1/8 inch (Fig. 4). The feldspar

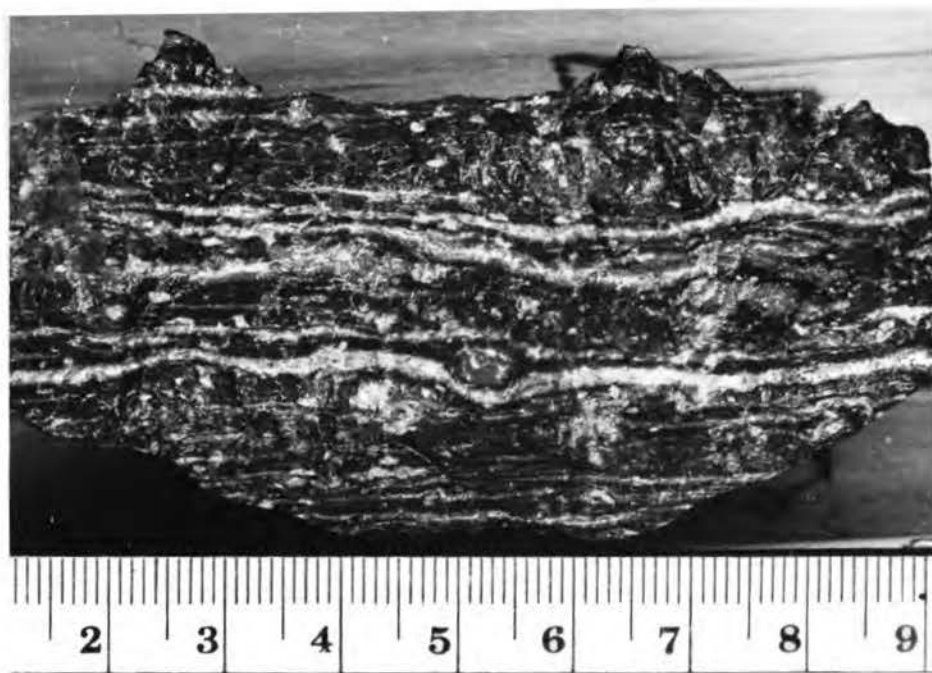


Figure 4. Flow structure in rhyolite porphyry.

phenocrysts are aligned with the flow. The weathered surface contains small pits which were probably formed by weathering of the feldspar phenocrysts.

The holocrystalline groundmass, comprising about 90% of the rock, consists of a very fine grained mosaic of quartz and feldspar with indistinct boundaries. Within this groundmass are subhedral to euhedral phenocrysts of feldspar up to 2 mm. long. About 61% of the feldspar phenocrysts are plagioclase of the oligoclase variety, while the remaining 39% is orthoclase. The plagioclase phenocrysts are the larger. Some of the orthoclase phenocrysts contain a perthitic texture (Plate 1). The plagioclase grains are badly corroded and include some quartz. Flow is very well developed by alternating bands of different sized groundmass (Plate 2). Minute grains of iron oxide in the larger sized groundmass cause the different colors seen megascopically. Several minute grains of zircon can be seen. Badly corroded grains of magnetite composes about 2.9% of the rock. The rock also contains thin, granular quartz veinlets, which often parallel the flow foliation.

Rock Name: Rhyolite. This specimen was obtained from an outcrop at the Slater Mine in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T. 29 N., R. 4 W.

This aphanitic rock is very dark red in color. It is unusual for the Eminence region in that it contains no visible phenocrysts. The rock has a very dense appearance, and its color is very uniform. The rock possesses a conchoidal fracture.

Microscopically the rock is a very fine grained holocrystalline mixture of feldspar and quartz with indistinct boundaries. The grains of the groundmass are about 0.01 mm. across. Few subhedral to euhedral

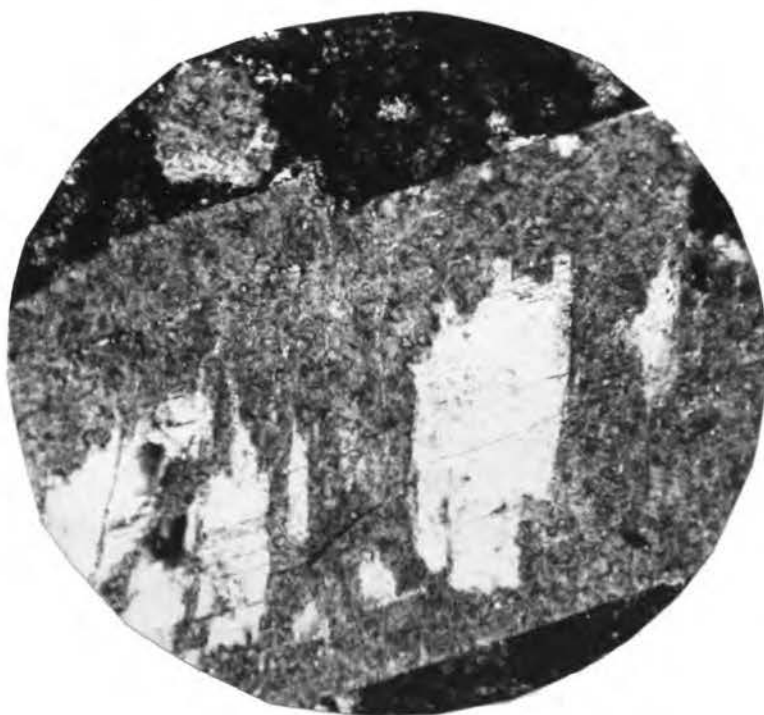


Plate 1. Perthitic texture in an orthoclase phenocryst.

X 130



Plate 2. Flow structure in rhyolite porphyry.
X 45

phenocryst of strained quartz up to 2 mm. across are present in the rock. The rock has been sericitized.

Rock Name: Rhyolite Porphyry. This rock was obtained from an exposure in the center of the SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 16, T. 29 N., R. 4 W., on top of the porphyry hill about 250 yards west of the McKinney Prospect.

This rhyolite porphyry is a very dark, slightly reddish brown rock with an aphanitic groundmass containing anhedral phenocrysts of a pink feldspar up to 1.0 cm. across that composes about 5% of the rock. Flow is very well developed by the alternating dark brown and almost black parallel bands with few light bed brown bands. The feldspar crystals are aligned with the flow. The weathered surface is lighter in color, and exhibits minute ridges where the more resistant flow bands occur.

Microscopic examination of a thin section shows that it is a holocrystalline, porphyritic rock composed of a very fine grained groundmass of intergrown quartz and orthoclase with indistinct boundaries. Phenocrysts of feldspar compose about 7% of the rock. Approximately 61% of these are subhedral to euhedral grains of oligoclase possessing albite twinning. The feldspars are slightly altered to sericite and quartz, the orthoclase being the more altered. Some of the orthoclase phenocrysts possess a perthitic texture. Alternating bands of different sized grains are suggestive of flow. The rock has been silicified, and the strained quartz occurs as veins of granular quartz up to 2.5 mm. across often with small needles of orthoclase within the quartz near the edges of the veins where they widen into pods (Plate 3).



Plate 3. Orthoclase pods within a quartz vein.
X 130

Introduced anhedral quartz grains about 0.12 mm. across are disseminated throughout the slide. These grains contain the matrix and are indistinguishable except under crossed nicols, and tend to concentrate along the introduced quartz veins. About 2% of the rock contains badly corroded ilmenite grains that are commonly associated with the fractures. Some of the ilmenite grains appear to be replacing the phenocrysts.

Rock Name: Rhyolite Porphyry. This specimen was taken from an outcrop on the logging road about 300 yards north of the Jerk tail Prospect in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 5, T. 29 N., R. 3 W.

This rhyolite porphyry is a dark reddish brown rock with an aphanitic groundmass with phenocrysts of a gray plagioclase and pink orthoclase. The plagioclase phenocrysts are the larger and range in size up to about $\frac{1}{4}$ inches across. The phenocryst are randomly oriented and compose about 20% of the rock. Small phenocrysts of badly fractured and corroded ilmenite are present. No flow structure is present.

Thin sections show that the rock contains a holocrystalline groundmass of quartz and feldspar with indistinct boundaries, composing about 79% of the rock, with phenocrysts of feldspar up to 2.6 mm. long. Approximately 36% of the feldspar phenocrysts are oligoclase, and the remaining 64% is orthoclase. All the feldspar phenocrysts are somewhat altered to sericite and quartz. Orthoclase rims a few of the plagioclase phenocryst. This rock has been silicified in that it contains granular quartz veinlets. Minute grains of zircon are observed, and ilmenite makes up about 7% of the rock, occurring in very small badly corroded, fractured grains that are commonly distributed near fractures.

Rock Type: Rhyolite Porphyry. This specimen was obtained from the outcrop at the Bolin Prospect in the NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 14, T. 28 N., R. 3 W.

This rhyolite porphyry is a light brown rock with an aphanitic groundmass of quartz and feldspar. Anhedral to Subhedral feldspar and quartz phenocrysts compose about 10% of the rock. The feldspar phenocrysts range in size up to about $\frac{1}{2}$ inch long, but the smaller phenocrysts are the more abundant. All the voids in the rock are filled with quartz. No flow structure was observed.

Microscopically the rhyolite is a holocrystalline rock with a slightly larger groundmass than the rocks previously described and phenocrysts of quartz and feldspar. The groundmass consists of intergrown quartz and feldspar with indistinct boundaries which has been recrystallized on the introduction of later quartz to a coarser aggregate of anhedral quartz and orthoclase laths. Quartz is predominant in the groundmass. Approximately 59% of the feldspar phenocrysts are plagioclase up to about 2.3 mm. long. All the feldspars in the groundmass and as phenocryst are partially altered to sericite and quartz. Resorbed quartz phenocryst that range in size up to about 1.7 mm. across are present. Many of the orthoclase phenocryst possess a perthitic texture. Ilmenite composes less than 1% of the rock.

A very fine grained, dense, felsitic rock with no phenocryst or flow texture was found associated with the Precambrian porphyries in several localities within the region. The rock was found as float on the porphyry knobs, but was nowhere found in place. The most

abundant occurring on the east side of the knob at the Slater Mine. The rock is dull red in color and possesses a cherty-like appearance. It also occurs with well defined alternating light red and light gray color bands with varying widths averaging about 1.5 mm. wide (Fig. 5). An examination of the rock with a hand lens showed that the color bands grade into one another. Several of these bands contain shallow depressions that are very similar to rain-drop depressions. These felsites are only found on one side of an individual knob.

Microscopic examination of the rock shows it to be a volcanic tuff that is composed of very fine grains of quartz and feldspars (Plate 4). Staining the feldspars reveals that they are predominantly orthoclase. The feldspars are altered to sericite. The rock appears to be devitrified as it shows aggregate polarization.

A coarse breccia composed of angular tuff fragments that range in size from about one foot to less than one inch across with possibly a pyroclastic matrix were observed as float on the porphyry knobs associated with the Bolin, Sutton, and Jerktail deposits and on the east side of Coot Mountain. This breccia was found in place in contact with the Precambrian porphyry and the Eminence dolomite on the west side of a small porphyry outcrop in Lick Log Hollow in the center of the NW $\frac{1}{4}$ sec. 24, T. 29 N., R. 3 W.

The tuff may be of value in interpreting the Precambrian stratigraphy of the region because of its possible vast horizontal extent and limited time range.

There has been almost no work done on the Precambrian of this region to date, although, the problem certainly warrants further study.

A profound unconformity separates the Precambrian rocks from

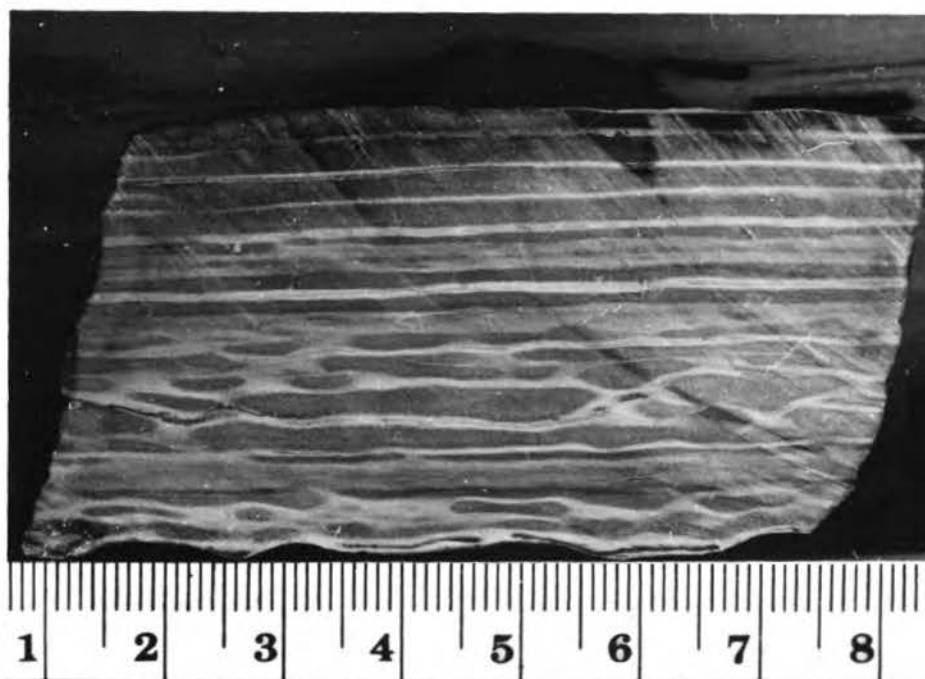


Figure 5. Banding in tuff from Sutton Mine Area.

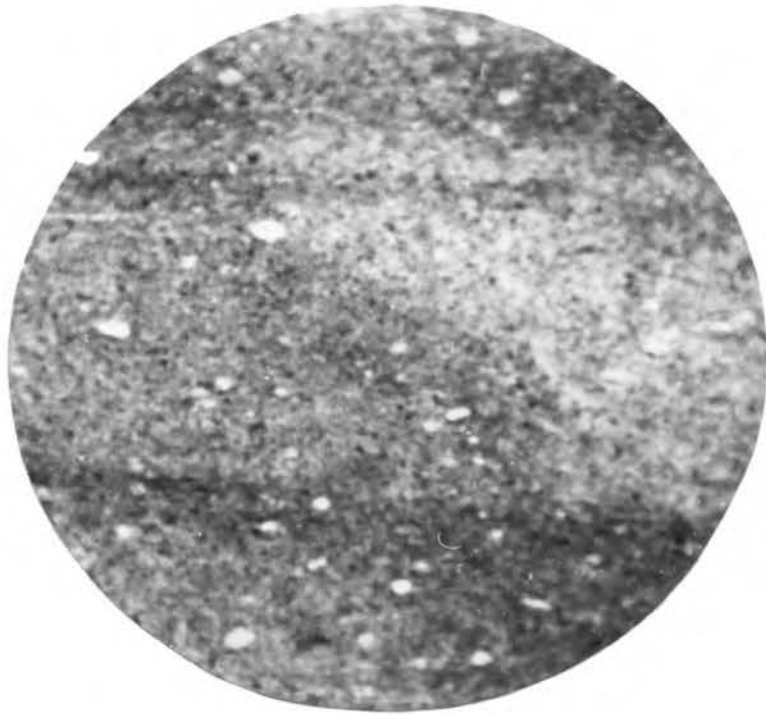


Plate 4. Microphotograph of the volcanic ash
from the Sutton Mine area.

X 45

the overlying Paleozoic sediments. The almost perpendicular flow foliation of the porphyries, and the occurrence of tuffs on only one side of the knobs suggest a period of deformation in Precambrian time that tilted the igneous rocks. A perpendicular contact between two flow rocks on the northwest side of Coot Mountain a few yards to the east of State Highway V near the culvert in the NW $\frac{1}{4}$ sec. 16, T. 29 N., R. 3 E., also lends some support to the tilting of the Precambrian rocks. This deformation was followed by an extensive period of erosion during the later Precambrian and early Cambrian time which carved the knobs and ridges out of the igneous rocks.

The material resulting from the breaking up of the Precambrian rocks formed a conglomerate that erratically overlies the porphyry at the base of the Paleozoic sediments. It is not limited to any one horizon, but occurs in all horizons from the Bonneterre to the Van Buren where they are in contact with the Precambrian. The conglomerate consists of angular to subrounded porphyry and tuff fragments with a dolomitic matrix. The size of the igneous material grades vertically and horizontally from fragments about one foot in diameter at the base to grains that can only be seen with the aid of a lens. The best exposure of this size grading is found in the ditch at the McKinney Prospect in the NW $\frac{1}{4}$ sec. 14, T. 29 N., R. 4 W.

The conglomerate is not found everywhere the Precambrian and Paleozoic contact occurs, but is developed near the head of the Precambrian valleys where the slope was such as to allow accumulation of the clastic material, and where the amount of water runoff was insufficient to remove the material. This conglomerate is an im-

portant ore horizon.

The absence of sandstones and the limited extent of the basal conglomerate, along with the present relief of the now exposed Precambrian rocks, indicates that the basal Paleozoic sediments were deposited on a surface with a high relief. It is believed that the relief was at least 1500 feet ⁽¹⁵⁾. This Precambrian surface

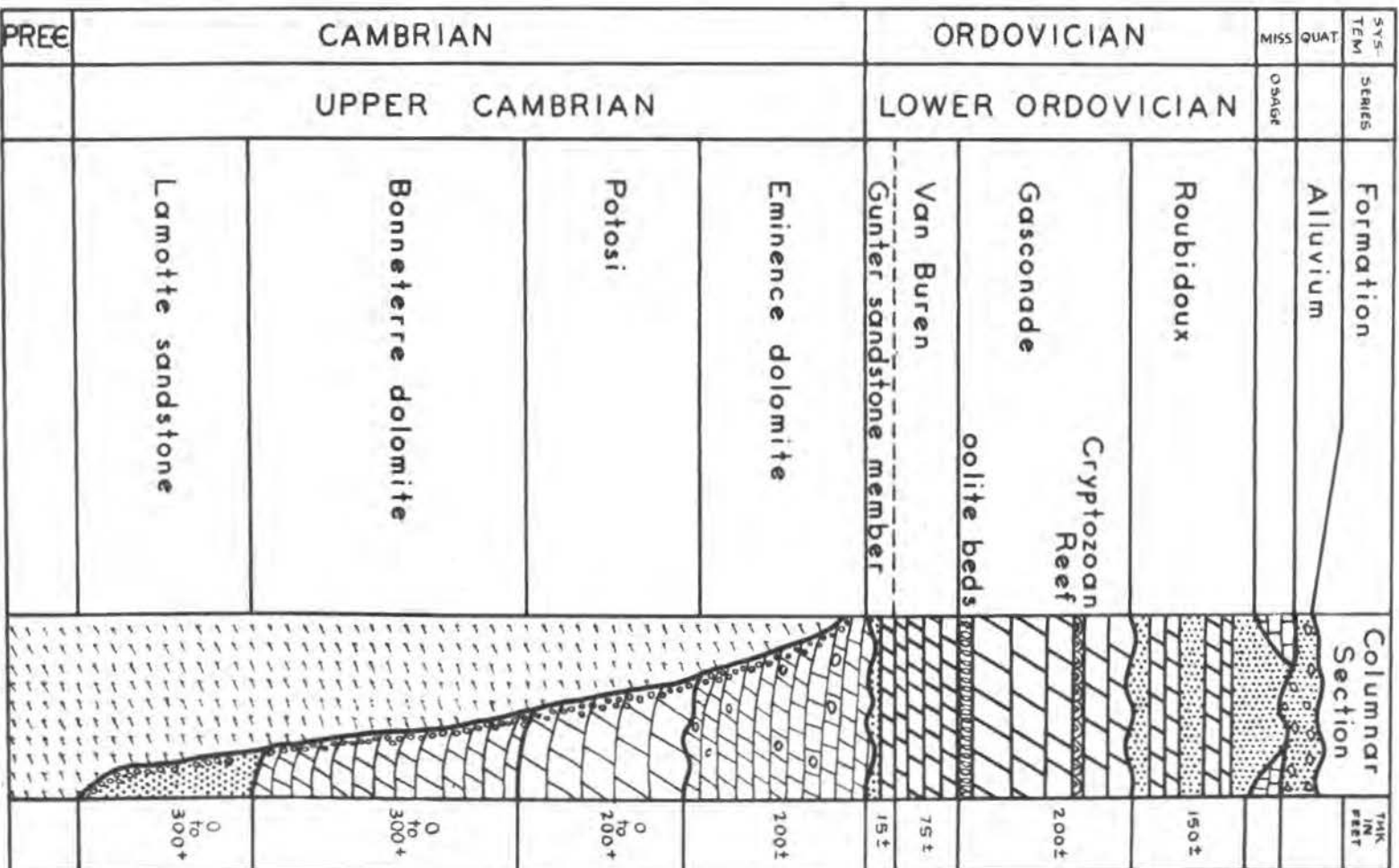
(15) Bridge, Josiah, op. cit., p. 60.

has been the chief factor in determining the structure of the overlying Paleozoic sediments.

Paleozoic Rocks

Most of the Paleozoic sediments in the Eminence region range in age from Upper Cambrian to Ordovician. Some residual Mississippian sediments are also present. The sediments are essentially horizontal dolomites with a few sandstone beds. A deepening of the seas resulted in the deposition of younger sediments overlapping the older sediments and resting directly upon the Precambrian peaks. This resulted in a structural high within the region.

Lamotte formation. The Lamotte sandstone crops out only on the northeast side of the St. Francois Mountains in St. Francois and surrounding counties. Deep well logs on file at the Missouri Geological Survey and Water Resources give well sections that show 265 feet of Lamotte at a depth of 1400 feet in the City of Ellington well, which is 20 miles northeast of Eminence, Missouri, and 262 feet of Lamotte at a depth of 2500 feet in a well in central Howell County, about 35 miles southwest of Eminence. Because of this, the writer feels that



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FIGURE 6

the Lamotte also occurs within the Eminence region, at depth, covered by younger sediments that overlap the formation where it pinches out against the Precambrian peaks. Erosion has not proceeded so far as to expose the Lamotte in this region as in the higher St. Francois Mountains. There is no drill hole information available on the Lamotte in the region at the present time. The configuration of the Lamotte-porphry contact might be of considerable interest in the exploration for base metal deposits in the area.

The Lamotte formation is a well bedded sandstone composed largely of medium grained quartz grains varying in color, with shale layers throughout.

Bonneterre formation. The Bonneterre formation underlies a large area of the younger sediments in the Eminence region, although, the only outcrop is a single area where the formation overlaps a Precambrian knob in the NW $\frac{1}{4}$ sec. 5, T. 29 N., R. 3 W., about $\frac{1}{4}$ mile north of the northern boundary of the region.

The thickness of this single Bonneterre outcrop near the region is 60 feet. Overlap on the Precambrian knobs resulted in a great variation in thickness. Branson ⁽¹⁶⁾ states that the normal thickness

(16) Branson, E. B., The Geology of Missouri: Univ. of Missouri Studies, Vol. 19, No. 3, p. 18, 1944.

of the Bonneterre formation is 375 feet, but this figure applies to the area north of the Ozark Dome.

The lithology of the outcrop noted above is a light gray, medium to coarsely crystalline, non-cherty dolomite. According to Branson ⁽¹⁷⁾

(17) Branson, E. B., op. cit., p. 18.

the lower part of the formation consists of alternating beds of a calcareous sandstone and a sandy dolomite. The outcrop contains a basal conglomerate.

The Bonneterre dolomite is Upper Cambrian in age and is very similar lithologically and stratigraphically to the Bonneterre in the Lead Belt area north of the Ozark Dome. A paraconformity exists between this formation and the overlying Potosi formation.

Davis and Derby-Doe Run formations. The Davis and Derby-Doe Run formations crop out in the deeper basins of the Ozarks and around the St. Francois Mountains. There is no record of their having been deposited in the Eminence region. A pronounced erosion occurred in the Ozarks after this period of deposition, and much of the Davis and Derby-Doe Run formations were eroded off of the higher areas. It is quite possible that these formations do occur in the deeper valleys in the Eminence region, but there is no drill hole data available to confirm this. A deep well at Pomona, in Howell County, about 40 miles southwest of Eminence, gives a section that contains 260 feet of these formations. Another deep well about 10 miles southwest of the Eminence region at the Melton Mine in sec. 10, T. 26 N., R. 6 W., gives a section that contains 14 feet of Derby Doe Run. From this it seems possible that the Davis and Derby-Doe Run formations do occur around the margins of the Eminence region.

The Davis and Derby-Doe Run formations, as they occur around the St. Francois Mountains, contain beds of shale, sandstones, edge-wise conglomerates, and considerable limestone having a total thickness of about 260 feet.

The Potosi formation. The Potosi formation crops out in the northern part of the Eminence region. The outcrops are small in extent and occur in the deeper valleys in the region. All but a few of the

outcrops occur in contact with a Precambrian knob. The Potosi underlies much of the younger sediments in the region.

The thickness of the Potosi at the only place where its contact with the older formations is exposed is about 60 feet. This outcrop is where the previously described Bonneterre outcrop occurs. The higher Precambrian knobs were still not covered by sediments and caused an uneven surface upon which the Potosi was deposited, resulting in a great variation in thickness. The section in the deep well at the Melton Mine described above contains 205 feet of Potosi.

A massive, finely crystalline, pale to dark chocolate brown dolomite characterizes the Potosi formation in this region. The quartz druse typical of the Potosi in southeastern Missouri are not well developed here. The formation is poorly bedded, although vertical jointing is well developed.

The Potosi formation is Upper Cambrian in age, and the Lower Ozarkian of Ulrich's classification. The contact between the Potosi and the overlying Eminence is one of transition, although, insoluble residue studies of the formations suggest an unconformity exists between them. The tops of the higher Precambrian peaks remained emergent during deposition of the Potosi.

The Eminence formation. The Eminence formation is found in numerous places in the Eminence region and around the St. Francois Mountains. In this region the formation crops out in the Jacks Fork and Current River valleys and their tributaries. The formation crops out over about 50% of the region.

The Eminence is made up almost entirely of massively bedded,

very cherty, coarsely crystalline dolomite with some shale and irregular sand beds. The lithology of the formation is very similar throughout its thickness, so no beds within it can be used as marker horizons. The formation weathers to jagged, deeply pitted pinnacles averaging about one foot high. It is also a cliff former in this region.

The average thickness of the formation is about 200 feet. The thickness varies considerably because of the irregularities of the surface during deposition, and because of the upper layers being removed by the pronounced post-Eminence erosion. The Eminence seas were much more extensive than any previous seas and covered even the highest Precambrian peaks in the region with sediments.

This formation is the youngest Cambrian formation in Missouri. The Gunter sandstone member of the Van Buren overlies the formation unconformably throughout the Eminence region.

Unconformity at Base of the Ordovician Rocks. An unconformity of considerable extent and magnitude separates the Cambrian from the overlying Ordovician rocks. During this period of erosion the Ozarks was uplifted. This was accompanied by faulting in the St. Francois Mountains. There is no evidence that faulting occurred in the Eminence region at this time.

Erosion removed much of the top of the Eminence formation in the region. The overlying Van Buren formation does not contain any Precambrian material. It is only in contact with the Precambrian at one locality in this area. This is on the north side of Stegall Mountain about two miles east of the southeast corner of the region.

A thin, persistent conglomerate in the base of the Gunter member of the Van Buren is the only evidence of the unconformity in the Eminence region. The conglomerate consists of small, rounded, waterworn pebbles of Eminence and porphyry.

The Van Buren formation. The Van Buren crops out in most of the major river valleys in southeastern Missouri and in the area adjacent to the St. Francois Mountains. It crops out in numerous places throughout the entire Eminence region.

The Van Buren is composed of two members, the basal Gunter sandstone, and a dolomite member. Two or three beds of a white sandstone interbedded with a dolomite and a thin conglomerate at the base make up the Gunter sandstone member. This member averages about 15 feet thick. The dolomite member consists of a light gray, fine to medium grained, well bedded dolomite with some thin green shale partings. The average thickness of the dolomite member is about 75 feet.

The Van Buren formation rests upon the Eminence formation unconformably. Its relationship to the overlying Gasconade is not clear.

(18)
 Bridge prepared a structural contour map of the top of the

(18) Bridge, Josiah, op. cit., Figure 9.

Gunter sandstone member. The configuration of the Gunter is probably determined by the configuration of the Precambrian surface and the initial dip of the sediments that overlie the knobs. Therefore, the map is useful as a guide in interpreting the topography of the buried Precambrian.

The Gasconade formation. The Gasconade crops out in numerous places throughout the Ozarks; however, there are no outcrops outside the state of Missouri. In the Eminence region the Gasconade crops out along the upper slopes of the valleys. It covers approximately 35% of the region.

Much of the formation consists of a light gray, cherty, massively bedded, medium to coarsely crystalline dolomite. A conspicuous, silicified, cryptozoan reef 2 to 3 feet thick is present about 70 feet below the top of the formation.

The average thickness of the Gasconade in the Eminence region is about 200 feet. The thickness of the formation is variable because of the removal of much of the soluble material by groundwater.

The Gasconade formation is in the Canadian Series of the Ordovician. In this region it rests on the Van Buren, and is overlain by the Roubidoux. A thin conglomerate in the basal member of the Roubidoux suggests the presence of a slight unconformity.

The Roubidoux formation. The Roubidoux crops out over a large portion of southern Missouri. It forms a plateau surface over much of this area. The Roubidoux outcrops occur in a rough, broken circle around the Eminence region with only a few outcrops capping the higher divides within the region.

The formation is made up of interbedded sandstones and cherty dolomites. It is variable in character occurring from mainly dolomite in some places to entirely sandstones in others. It is about 50% dolomite in and around the Eminence region. The Roubidoux has a basal member which is a thin sandstone less than a foot thick

in this region.

The thickness of the Roubidoux is not known in the region as it is the youngest formation exposed and the top of the formation is missing. Outcrops of the Roubidoux southwest of the Eminence region show that the formation is between 150 and 200 feet thick.

The Mississippian formation. Several small patches of Mississippian chert boulders occur in the upland areas within the Eminence region. These residual deposits seem to have formed by accumulating in ancient sink holes of considerable depth and escaped erosion. Erosion has carried all the finer material away leaving the residual chert boulders. These residual boulders are quite fossiliferous, containing numerous disks of crinoid stems.

Structure. The Eminence region is located within a structural high on the southwestern flank of the Ozark Uplift where the essentially horizontal formations overlap the Precambrian peaks. The only prominent structures observed in the region are those controlled by the Precambrian surface. A broad saddle is formed between this region and the St. Francois Mountains to the northeast where the peaks are higher in elevation and much more exposed.

The structure in the Eminence region is directly related to the configuration of the Precambrian erosional surface. Previous to the initial sedimentation, a very rugged topography existed on the Precambrian rocks. The valleys were filled by increments of successive layers that eventually buried the highest Precambrian peaks during the deposition of the Eminence formation. Each succeeding younger formation overlapped the preceding one, but the areal extent is

limited to the valleys except where the thickness of the sediments exceed the depth of the valley and the strata spread over the dividing ridge or knob.

The sediments were carried up the valley walls by current and wave action, and later compacted to produce what is recognized today as initial dip. The initial dip is developed more strongly in the older formations that extend over the knobs and ridges, and gradually lessens in succeeding younger formations. This affect causes the beds near the flanks of the knob or ridge to form a structural high.

The sediments which overlie the knobs and ridges possess an initial dip as high as 30° where deposited on the flanks of the peaks. The regional dip is to the south, averaging about 5 feet per mile. The contacts are higher in elevation in this region than a few miles further north or south because of the gentle upwarping of the sediments which reaches its summit near Eminence.

No faulting of any magnitude is found within the region, however, it is quite possible that faulting does exist. A fault was observed about $\frac{1}{2}$ mile south of Round Springs on State Highway 19, which is about 3 miles northwest of the Eminence region. A possible fault in the Eminence formation, which crops out over a large portion of the region would be very difficult to observe as the lithology of the formation is fairly uniform throughout its entire thickness and contains few fossils. These criteria certainly offer no proof, or even an indication, that faulting exists in the region, but only serves to demonstrate the possibility of faulting which may have escaped observation in earlier geologic mapping.

MINERAL DEPOSITS

History of Mining

Prospecting and development of the copper in the Eminence region has been going on at different intervals for over a century. There are very few records available on the discovery and early development of the area.

Copper was first discovered in the Eminence region in the early 1800's by hunters and trappers. About 1837 the news of the discovery reached a group of French settlements along the Mississippi River. The settlers at Ste. Genevieve, Missouri sent an experienced miner named Joseph Slater to develop these copper deposits. This region was composed primarily of unsurveyed government land at that time. Slater purchased the mining rights from George Smith, a hunter who claimed the deposits by right of discovery.

Slater established a small settlement near Shawnee Creek in the NW $\frac{1}{4}$ of sec. 6, T. 28 N., R. 3 W., by a spring that now bears his name. This settlement consisted of his cabin, a boarding house for the miners, a store, and a blacksmith shop. He also erected a small smelter on Shawnee Creek near the settlement (Fig. 10). Sometime later Slater built a second and larger smelter a few hundred yards downstream from the first smelter.

Most of the ore obtained by Slater was from the locality now known as the Slater Mine in the NE $\frac{1}{4}$ sec. 26, T. 29 N., R. 4 W. He obtained a small amount of ore from the Jerktail Mine in the NE $\frac{1}{4}$

sec. 5, T. 29 N., R. 3 W.

Slater acquired all of his ore at the Slater property from shallow pits in the Eminence dolomite and conglomerate on the east side of the porphyry hill. Hodge ⁽¹⁹⁾ states that the diggings

(19) Hodge, J. T., op. cit., p. 66.

extended to an average depth of about 10 feet. Williams ⁽²⁰⁾ reported

(20) Williams, C. P., op. cit., p. 164.

that Slater produced about 1500 tons of copper ore.

This region was surveyed by the government in 1840. John Cowan, a speculator, took the land away from Slater by preemption. Slater took the case to the Supreme Court but he lost. Cowan then sold the land to the Aberdeen Mining Company. This company possibly started the shaft at the mine which eventually reached a depth of 200 feet. The company soon discontinued all mining operations, thinking the region was **too** far from a market to be worked profitably. In 1848 they transferred the land to Thomas Primrose, a member of the Current River Mining Company.

Operations at the Slater Mine was not resumed until 1872 when the Current River Mining Company sold the property to the Consolidated Land Company of Missouri. This company shipped about 36,000 pounds of ore that they obtained by cleaning up the mine and by exploration. Shortly thereafter the mine was visited by Mr. C. P. Williams of the Missouri Geological Survey. **Much information on the condition**

of the mine at that time was included in the report ⁽²¹⁾.

(21) Williams, C. P., op. cit.

Williams included a map of the Slater property in his report which gives the location of four shafts.

In 1876 Charles T. Biser purchased a considerable amount of land in Shannon County, including the Slater property. Mr. Biser shipped only a few carloads of copper before selling all his holding to the Current River Land and Cattle Company.

Operations at the Slater Mine again stopped and were not resumed until 1892. The mine was leased by Mr. F. H. Rodgers for a period of 99 years. He lost the lease a few years later for non-fulfillment of the terms of the lease. The lease then came into the hands of the Slater Copper Company of Winona, Missouri in 1917.

In 1918 the advancing price of copper revived interest in the district and operations were resumed in all the deposits within the region. The mining operations stopped just four years later. There has been very little activity at the Slater and Jerktail deposits since that time. Most of the recent activity has been at the Sutton property in sec. 18, T. 28 N., R. 3 W.

The Sutton property was acquired by the Shawnee Copper Company of Eminence, Missouri in 1924. Tom Knobel drilled 7 test holes at the Sutton property in 1943. The logs of these holes are on file at the Missouri Geological Survey and under Well Log No. 8759 through 8765. In 1955 a promoter named E. G. Welker leased the property from this

company and drilled 10 holes. A report by G. Weaton, Jr. (22) to E. G.

(22) Weaton, G., Jr., Report on the Sutton Copper Area Southeast of Eminence, Missouri and Appraisal Report of Estimated Tonnage of Ore Reserve: unpublished report, Missouri Geol. Survey, Rolla, Missouri 1955.

Welker on the drilling operation is on file at the Missouri Geological Survey. Several years later the Phelps Dodge Corporation drilled two holes on the property. There are no records available on these holes.

The most recent activity at the Sutton property has been by the American Exploration and Mining Company of Tuscon, Arizona. They acquired a 2-year lease from the Sutton Copper Company, whose president is Mr. W. E. Stevens of Eminence, Missouri. Three churn drill holes were drilled under the direction of Joseph Aide, geologist, during the summer of 1958. No data is available on their findings at this time.

The Bear Creek mining Company has been active in the region for the past several years. They have drilled a number of test holes over the region. The results of this work are not available at this time.

Mineralogy

The minerals directly related to the copper deposits are described below. The copper and associated minerals are grouped according to their origin. The mineralogy of the copper deposits in the Eminence region is not complex. The mineral deposits contain mainly malachite, chalcocite, chalcopyrite, and small amounts of pyrite, marcasite, covellite, chrysocolla, and azurite. The gangue minerals are dolomite, calcite, siderite, limonite and hematite.

Chalcopyrite, CuFeS₂. Chalcopyrite is present in the Sutton,

Slater, Casey, and Jerktail deposits. It is the only primary copper mineral in these deposits with the possible exception of the Casey Mine. Chalcopyrite usually occurs as massive ore in voids in the limestone and conglomerate, and as replacement of the calcareous matrix in the conglomerate. Chalcopyrite was found as veinlets in the porphyry at the Jerktail Prospect where it is the predominant copper mineral. Small chalcopyrite pseudo-tetrahedrons were also found in voids in the limestone at the Jerktail Prospect. In the Sutton and Casey Mines the chalcopyrite occurs as remnants within the center of massive oxidized minerals where the chalcopyrite has not been completely oxidized. In these cases the ore possesses an exploded-bomb texture (Plate 5).

Pyrite, FeS₂. Pyrite is found in the Sutton, Casey, and Jerktail deposits normally as minute irregular shaped grains. In the Sutton Mine euhedral cubic and pyritohedral crystals of pyrite have been almost completely replaced by hematite (Plate 6). Minute grains of pyrite occur as small very irregular shaped islands in the hematite. Pyrite more commonly occurs in the deposits as small anhedral grains associated with chalcopyrite and showing mutual boundaries with it. In these cases the pyrite is partially replaced by chalcotite as is the chalcopyrite. Pyrite is also found within the malachite.

Marcasite, FeS₂. Only one globular grain of marcasite, about $\frac{1}{2}$ inch in diameter, was found on the dump at the Jerktail Prospect. It is rimmed by limonite, which is replacing it. No. copper minerals were associated with the specimen.

Chalcocite, Cu₂S. Secondary chalcocite occurs as small veinlets

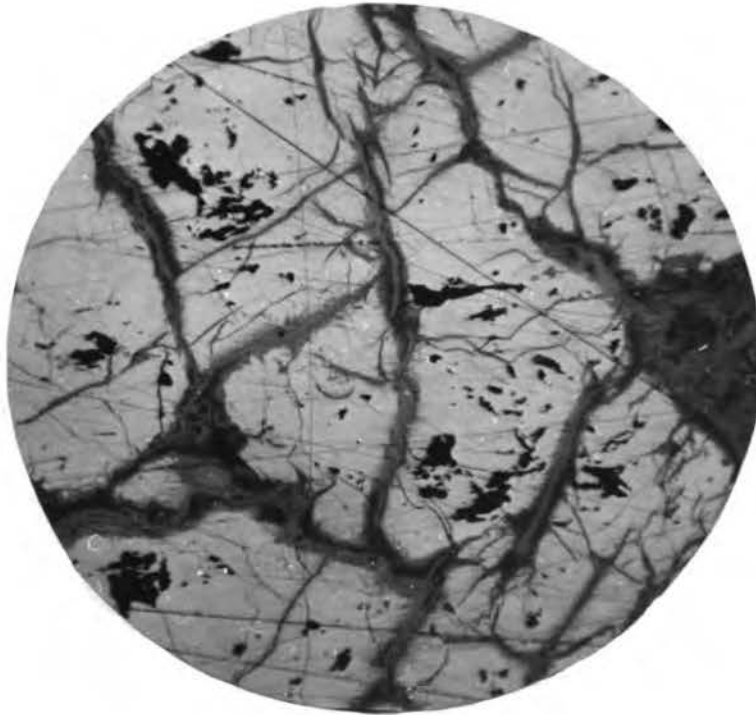


Plate 5. Initial stage of exploded-bomb texture
developing in chalcopyrite.

X 130



Plate 6. Pseudomorph of hematite after a pyrite pyritehedron.

X 130

in and as thin film around grains of chalcopyrite in the Sutton, Slater, Casey, and Jerktail deposits (Plate 7). Crystalline chalcocite appears to be the primary copper mineral in the 60-foot level of the Casey Mine where it is replacing the oolitic chert. Chalcocite is the chief copper mineral in the Casey Mine. Chalcocite is being replaced by malachite and limonite in all the deposits in the region. Small irregular shaped grains of chalcocite are finely disseminated throughout the malachite that is replacing it (Plate 8). The chalcocite grains present imparts a black color to the malachite in the Sutton and Casey deposits.

Covellite, CuS. Covellite is found in very small amounts in the Sutton and Casey deposits. It occurs as very small veinlets in and partially enveloping a few of the chalcocite grains. Where the covellite is found it appears to be replacing the chalcocite; although, one specimen from the tailings at the Sutton Mine revealed covellite replacing chalcopyrite with no chalcocite present (Plate 9).

Malachite, $\text{Cu}(\text{OH})_2\text{CuCO}_3$. Malachite is common in all the oxidized parts of all the deposits in the region. It is the most abundant copper mineral in all the deposits, and is the only copper mineral found at the Bolin, Jacks Fork, and McKinney Prospects. Malachite occurs as a very fine grained crystalline material replacing chalcocite and the calcareous matrix of the conglomerate, and as much coarser grained long bladed, commonly twinned crystals, with a radial structure, that is found as open space filling in the dolomite, conglomerate, and porphyry. Malachite envelopes the chalcocite where it replaces it, and is itself enveloped by limonite. As mentioned above, some of the

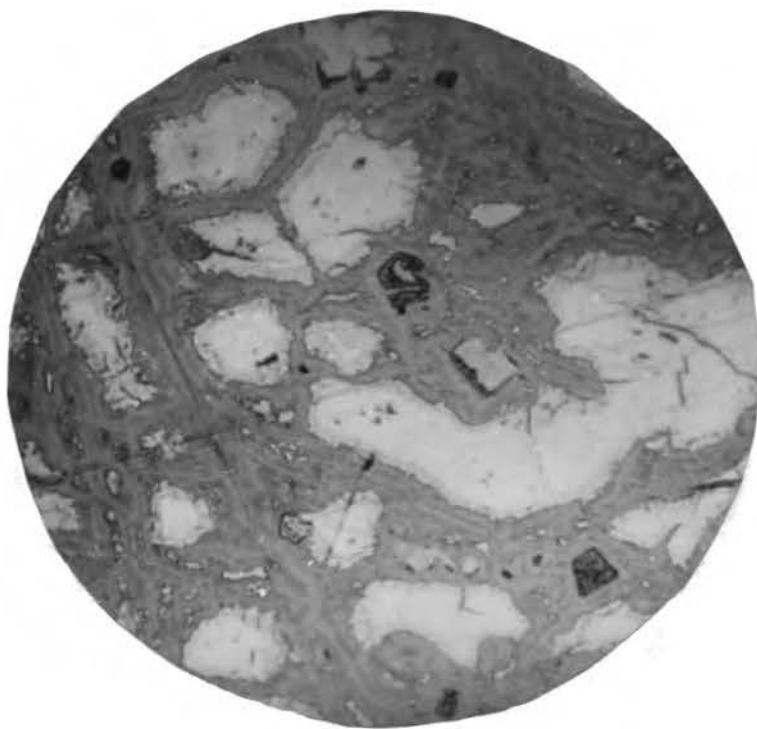


Plate 7. Chalcocite rims around chalcopyrite
remnants in limonite.

X 130

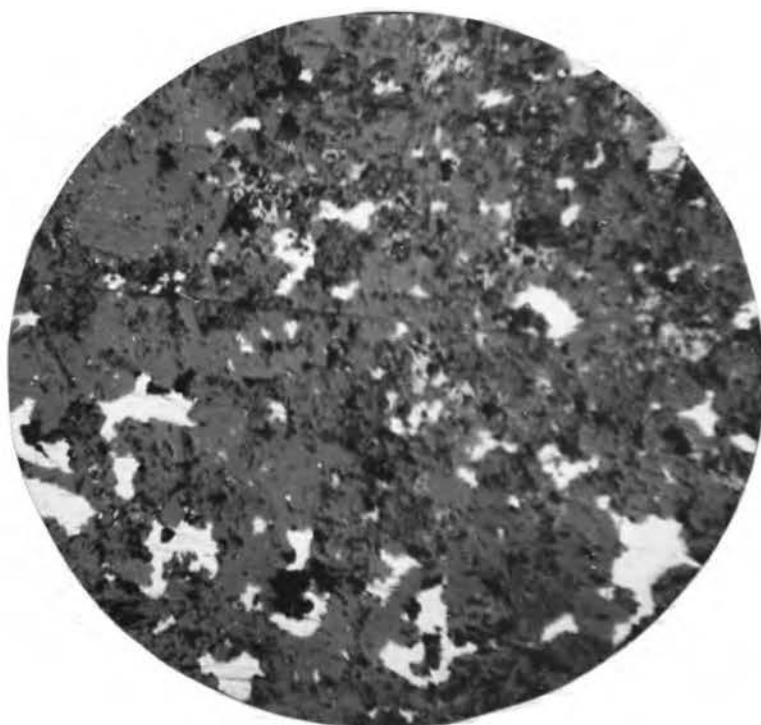


Plate 8. Relics of chalcocite in malachite.
X 130

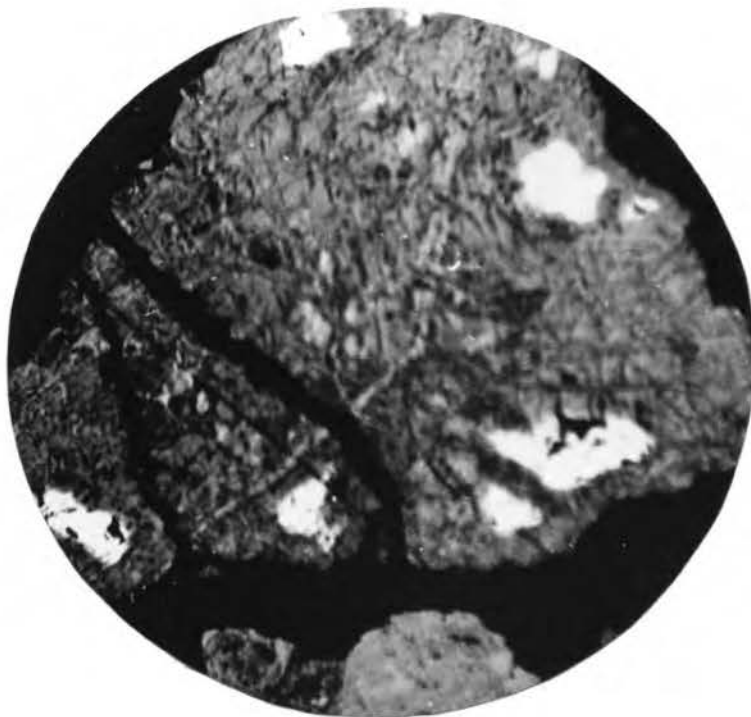


Plate 9. Remnants of chalcopyrite in covellite
from the Sutton Mine.

X 130



Plate 10. Zonal texture consisting of progressive replacement of chalcopyrite by limonite with malachite.

X 130

fine grained malachite possesses a black color that is due to the chalcocite it is replacing.

Azurite, $\text{Cu}_3(\text{OH})_2\text{CO}_3$. Azurite is absent in all the deposits with the exception of the Sutton and Jerktail. It is very rare in these two deposits. It only occurs as small patches of crystalline material within a few malachite veins.

Chrysocolla, $\text{CuSiO}_3 \cdot n\text{H}_2\text{O}$. Secondary chrysocolla is only found in the oxidized part of the Sutton Mine. It commonly occurs in earthy masses with malachite associated with the weathered porphyry pebbles in the conglomerate.

Limonite, hydrated iron oxide. This term is used in this report for the ferric oxide that contains varying amounts of water and occurs in yellow and brown colors. Porous limonite is the principal gangue mineral in all the deposits, with the exception of the Bolin, McKinney, and the Jacks Fork. These three deposits also contain no chalcopyrite which is believed to be the source of the iron oxide. Limonite is very abundant in all the remaining deposits. It occurs in both botryoidal form and in earthy masses, and also as pseudomorphs after chalcopyrite at the Jerktail Prospect. It is found replacing all of the copper minerals in the deposits.

Hematite, Fe_2O_3 . Hematite occurs in earthy masses in the Jerktail and Sutton deposits. It is the principal mineral replacing the pyrite crystals in the Sutton deposit.

Siderite, FeCO_3 . Siderite is a minor gangue mineral found only in the conglomerate at the Sutton Mine. It is present in veinlets and small irregular patches within the calcareous matrix of the

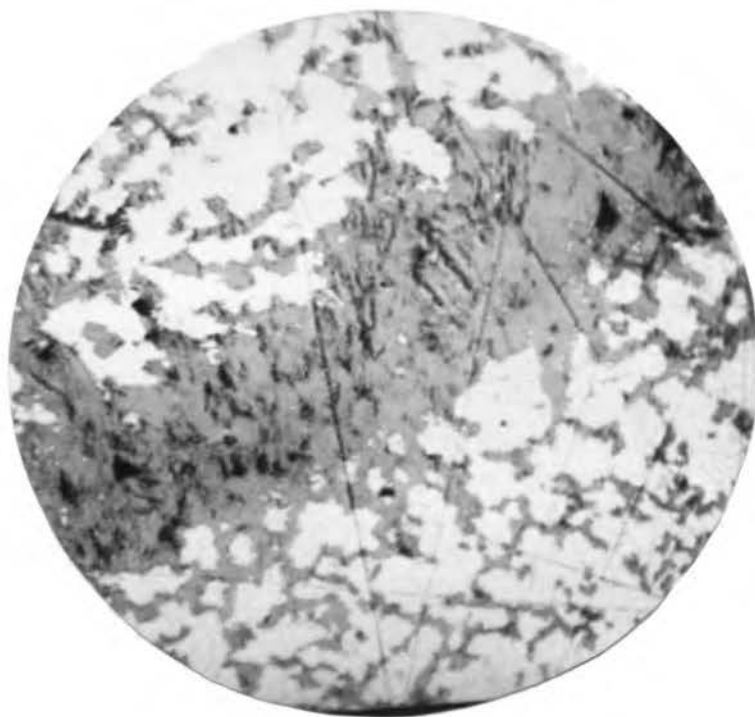


Plate 11. Vermicular texture resulting from malachite replacing chalcocite at the Casey Mine.

X 130

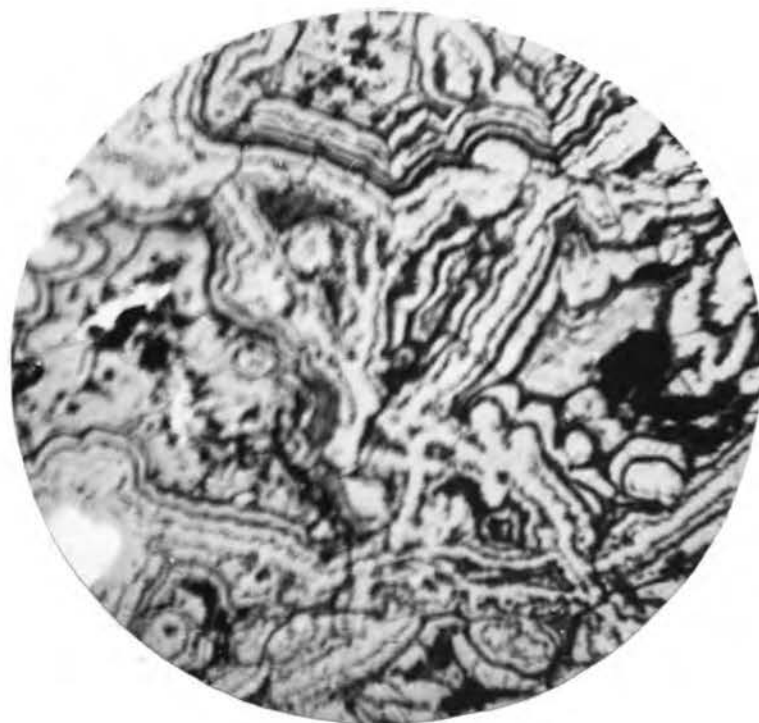


Plate 12. Zonal texture consisting of bands of limonite resulting from progressive replacement of chalcopyrite.

X 130



Plate 13. Remnants of chalcopyrite and pyrite in
limonite from the Jerktail Prospect.

X 130

conglomerate.

Aragonite, CaCO₃. A small amount of medium to coarse grained aragonite is found at the Sutton Mine. It occurs as radial aggregates in vugs in the calcareous matrix of the conglomerate. Calcite is much more abundant than aragonite in the deposits.

A spectrographic analysis of selected copper minerals from all the deposits, with the exception of the McKinney Prospect, was made to determine their trace element content. As siegenite is a common mineral associated with the chalcopyrite in the Fredericktown area, the principal elements sought were cobalt and nickel. The results of the analyses is enclosed in Table I.

The paragenesis of the copper minerals was determined chiefly from microscopic examination of many specimens from the dumps of all the deposits, but principally from the dump of the Sutton deposit. This paragenetic sequence is given in Table II.

General Characteristics

The copper deposits within the Eminence region are all small irregular or bedded replacement type bodies. They occur as shallow, thin, fan shaped deposits that extend vertically through three stratigraphic horizons. The first horizon is at the base of the dolomite where the mineralization occurs as open space filling in solution channels and voids along the bedding planes. The second and most important horizon is the basal conglomerate at the contact of the Precambrian porphyry

TABLE I

SPECTROGRAPHIC ANALYSIS OF COPPER MINERALS

Missouri Geological Survey and Water Resources Analysis Number 3497

	Sutton Mine (Chalcopyrite)	Sutton Prospect (Malachite)	Jacks Fork Prospect (Malachite)	Bolin Prospect (Chalcopyrite)	Slater Mine (Chalcopyrite)	Casey Mine (Chalcocite and Malachite)	Jerktail Prospect (Chalcopyrite)
Co	----	----	Trace	Trace	Trace	Trace?	----
Ni	----	----	Approx. 0.1%	0.1 (0.01)	Approx. 0.1%	Trace?	----
Ag	Trace	----	Trace	----	Trace	Trace	Trace
Cu	High	High	High	High	High	High	High
Si	Low	Low	High	Present	High	Present	Low
Al	Low	Low	Present	Low	Present	Low	Trace
Fe	Present	Low	Low	Low	Present	Low	Present
Mn	----	Low	Low	Trace	Present	Low	----
Ti	Low	Low	Low	Low	Low	Low	Trace
Ca	Low	Present	Low	Low	High	Low	Present
Mg	Trace	Low	Present	Low	Present	Low	Trace
Na	----	----	Trace	----	Trace	Trace	----
K	----	----	Trace?	----	Trace	----	----
Cr	Trace	----	----	----	----	Trace	----
Zr	----	----	Trace	----	Trace	----	----
V	----	----	Trace	----	----	Trace	----
In	----	----	----	----	----	----	----
Zn	----	----	----	----	Trace	Trace	----
Pb	Trace	Trace	Trace	----	Low	Trace	Trace
As	----	----	Trace	Trace	Trace	Trace	----
Sb	----	----	----	----	----	Trace	----
B	----	----	Trace	----	----	Trace	----

Sn, Bi, An, Hg, Tl, W; not detected in any.
 ---- indicates not detected.

M. E. Phillips, Analyst, 12-17-58

TABLE II
PARAGENESIS OF COPPER MINERALS

Pyrite	_____		
Chalcopyrite	_____		
Brecciation			
Chalcocite	_____		
Covellite	?	_____	
Malachite		_____	
Azurite		?	_____?
Chrysocolla		?	_____?

and the Eminence dolomite where the mineralization is chiefly replacing the calcareous matrix. The third and least important horizon occurs where the copper mineralization has invaded fractures in the porphyry.

The copper deposits have such a limited vertical extent that they cannot be divided into the zones of oxidation, secondary enrichment, and primary ores. The deposits are so shallow that they appear to be partially oxidized throughout their entire depth.

The localization of the mineral deposits appears to be primarily one of structural control. Two factors are important in this localization. One is the sedimentary structural highs formed on the flanks of the buried Precambrian knobs and ridges, and the other is the presence of the conglomerate. Both of these factors are directly dependent upon the configuration of the Precambrian erosional surface. The conglomerate formed from the breaking up of the Precambrian rocks was developed on the sides of the valleys where the slope was such as to allow accumulation of the material, and where the amount of water runoff was insufficient to remove the material.

With the exception of the Casey Mine and the Jacks Fork Prospect all the known copper deposits on the flanks of buried ridges or knobs near the head of the valleys of exposed igneous rocks. The structural contour map on the Precambrian basement of the Sutton Mine area (Fig. 7) illustrates this localization of the ore bodies.

An examination of the location of the shafts with respect to the areal geology and the shape of the Precambrian outcrop of the Slater (Fig. 10), Jerktail (Fig. 13), and the McKinney (Fig. 15) deposits

also shows that the deposits are all located on similar positions on the flanks of the Precambrian knobs and ridges at or near the head of buried valleys. The Precambrian valleys are indicated by the V's at the contact of the Precambrian porphyry and the Eminence formation.

There appears to be no apparent relationship between the fractures in the Precambrian rocks and the copper deposits. Copper mineralization was found in these fractures, but they are probably open space filling from above. Several of these fractures were followed during the early mining of the deposits to locate the "true fissure vein" and they all disappeared at depth. One of these shafts was sunk 160 feet deep at the Slater Mine following such a malachite vein where it disappeared ⁽²³⁾. These veins were all only one to two

(23) Bain, H. Foster, and Ulrich, E. O., op. cit., p. 64.

inches in width.

The Casey and Jacks Fork deposits are exceptional among the deposits in the Eminence region in that they do not occur in the conglomerate overlying the porphyry. They are situated higher in the stratigraphic column, in the Eminence formation.

Mines and Prospects

The locations of the various copper deposits in the Eminence region are shown on the map of the distribution of Precambrian outcrops in Shannon County (Fig. 3). The geologic setting of many of the deposits is more clearly shown on the large scale maps of the individual areas

(Figs. 8, 10, 12, 13, and 14).

The deposits are all situated within the area where the Precambrian rocks are exposed. A line drawn through the Slater Mine striking N. 45° W. passes within one-half mile of four of the seven deposits and within one mile of a fifth, the Sutton Mine. This line very closely approximates the western edge of the Precambrian outcrop area. These five deposits are distributed over a distance of ten miles along this line. A second line parallel to, and three and one-half miles north-east of the first passes between, and within one-half mile of the two remaining deposits, the Jerktail and the Jacks Fork.

The mines and prospects are described individually on the following pages. All of the workings with the exception of the Casey have been inaccessible for many years, and many of the descriptions are summaries of a combination of published descriptions, information obtained locally from residents, and the results of the writer's field observations. The author has drawn much from the mine descriptions of Bridge⁽²⁴⁾.

(24) Bridge, Josiah, op. cit., pp.

In the description of some of the mines it will be noted that the ore and gangue minerals are presented with no specific statements regarding the character of the typical ore that has in the past yielded the profits. The omission is due to the absence of definite data from these deposits. The mineralogy has been determined largely from material collected from the mine dumps and it should be recognized that these data may not reflect the typical mineralogy of the ore bodies

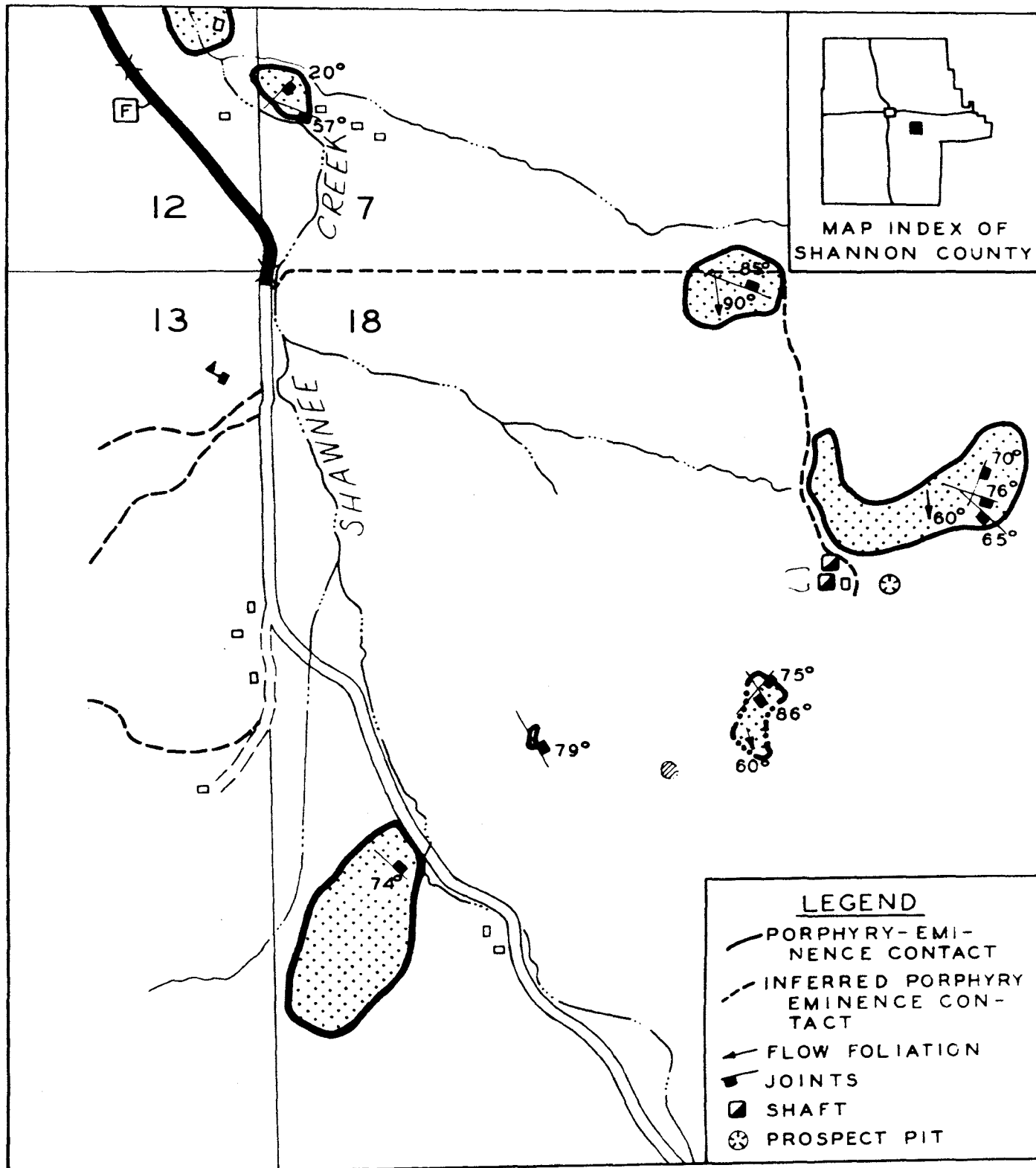
that were once mined.

Sutton Mine. The Sutton Mine is owned by the Sutton Copper Company of Eminence, Missouri. The mine is located in the SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 18, T. 28 N., R. 3 W. The mine has been inactive since 1955. Work was started on the mine by the Shawnee Copper Company of Eminence, Missouri in 1924. The deposit was developed by a shaft 36.5 feet deep and two drifts extending off of the shaft to the north and south. The Shawnee Copper Company leased the property to a company who started a second shaft about 100 yards east of the first shaft. The shaft reached a depth of about 90 feet and was still in dolomite of the Eminence formation. Examination of the material on the dump reveals no conglomerate or porphyry, therefore, it is quite likely that the shaft never reached the conglomerate. In 1955 the Shawnee Copper Company leased the land to George Welker. At this time the workings consisted of the original shaft with a 70 foot drift extending from it to the south, and a 110 foot drift extending to the north from this shaft to another shaft 32 feet deep sunk by Welker. At a point 60 feet north of the original shaft, a cross-cut extended approximately 45 feet to the east and west from the main drift. The main workings are inaccessible at the present time as the mine is filled with water.

The Shawnee Copper Company produced two shipments of ore. The first shipment of 44,390 pounds of ore netted the company a profit of \$935.40⁽²⁵⁾ while the second shipment of ore shipped over a year

(25) Bridge, Josiah, op. cit., p. 178.

later consisting of a much poorer grade of ore resulted in a loss of

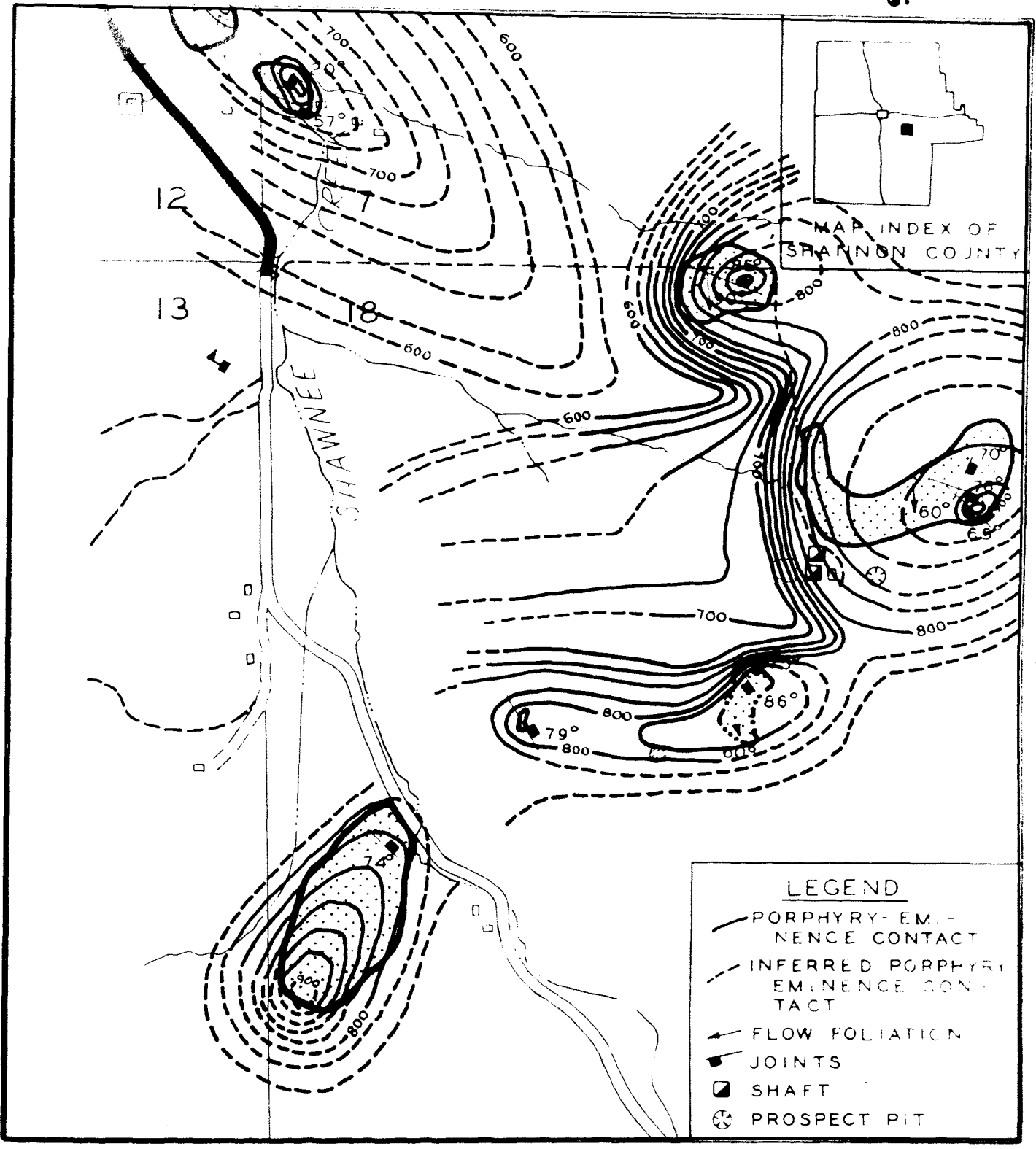


IGNEOUS OUTCROP LOCATION MAP OF SUTTON MINE AREA

SCALE IN FEET
 0 400 800 1200
 1959



FIGURE 8



Structure contour map of the Sutton Mine area drawn on top of Precambrian Porphyry
 Contour interval 20 feet



Figure 9. View of the Sutton Mine area as seen today.

\$66.73 to the company. These two shipments comprise the total production of the Sutton Mine to date.

The ore in the Sutton Mine occurs as an irregular replacement deposit in the conglomerate at the contact of an exposed Precambrian knob and the Eminence dolomite. Bridge⁽²⁶⁾ states that "The majority

(26) Bridge, Josiah, *op. cit.*, p. 178.

of it (ore) came from solution channels at the contact of the dolomite and the conglomerate, and from the interstices in the later".

The sulfide minerals occur as massive ore that has replaced the calcareous matrix and filled open spaces in the conglomerate and the overlying dolomite. The ore minerals also occur as small fracture filling veins of slight vertical extent within the porphyry.

The ore body is located on the flank of a knob at the head of a buried valley. This can be seen by examining the structure contour map drawn on top of the Precambrian (Fig. 7). This map was prepared from data taken from an unpublished report by G. Welker⁽²⁷⁾ on file at the

(27) Welker, G., Jr., *op. cit.* 1955.

Missouri Geological Survey and Water Resources.

Casey Mine. The Casey Mine is located in the SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 14, T. 29 N., R. 4 W., about two miles north of Eminence, Missouri just north of Highway 19.

There is very little information available on the early history of the Casey Mine. The mine consists of a 26-foot level, a 60-foot level, and a 100-foot shaft. The 60-foot level is

the larger, and is connected to the surface by a drift about 200 feet long. This drift connects with a stope, approximately 50 feet by 100 feet across that extends northward from the shaft. A drift extends off this stope to the east for a distance of 150 feet. The smaller 26-foot level connects with the 60-foot level in the stope. A sketch map of the mine is included in a thesis by Bowles and Davidson (28).

(28) Bowles, J. H., and Davison, L. E., op. cit., Fig. 3.

Mr. Spurgeon of Eminence, Missouri, the present owner of the mine, constructed a small dam at the entrance of the adit causing water to fill the adit to a depth of about 2½ feet. The shaft has collapsed, but both levels are accessible by wading the water in the adit.

A drill hole was put down at the property to a depth of 577 feet in 1919. A log of the hole is on file at the Missouri Geological Survey and Water Resources under Well Log. No. 3008. The following log was compiled:

Gasconade and Van Buren formations -----	0' to 100'
Eminence formation -----	100' to 425'
Potosi formation -----	425' to 577'

No copper mineralization was indicated in the log.

From 3 to 5 tons of hand-sorted copper ore was taken out of the mine, but no shipment was ever made from this property.

The Casey Mine is exceptional among the Eminence region copper deposits in that the ore does not occur in the conglomerate at the contact of the Precambrian porphyry and the Eminence dolomite. The

mineralization occurs as a small bedded replacement deposit in a broad saddle between two exposed knobs. One knob is exposed in Lick Log Hollow about $\frac{1}{4}$ mile east of the mine and the second knob is about $1\frac{1}{2}$ miles northwest of the mine. The McKinney prospect is located in the conglomerate on the southeast side of this second knob.

The Casey copper deposit is situated in the lower Gasconade and upper Van Buren formations. Mineralization at the 60-foot level occurs beneath an impervious oolitic chert layer. This heavily mineralized nearly horizontal layer varies in thickness from about 6 inches to a thin seam over a distance of about 50 feet. Mineralization has filled small fractures in the chert. In places where these small fractures extend entirely through, the chert mineralization has taken place to a very limited extent along the upper side of the chert.

The mineralization in the 26-foot level is of much less extent. As in the 60-foot level, the copper minerals occur beneath an impervious layer. This layer consists of a thin shale lens. The mineralization possesses the shape of a lens having a maximum thickness of 6 inches and a horizontal extent of about 3 feet. Copper minerals were only found in two such small pockets in the upper level. The mineralization appears to be an open-space filling in a solution channel.

The principal copper minerals found in the Casey Mine are crystalline malachite in the 60-foot level and chalcopryrite in the 26-foot level. The malachite is replacing massive crystalline chalcocite which appears to have replaced the oolitic chert as the oolitic structure is retained in the chalcocite. There is a very small

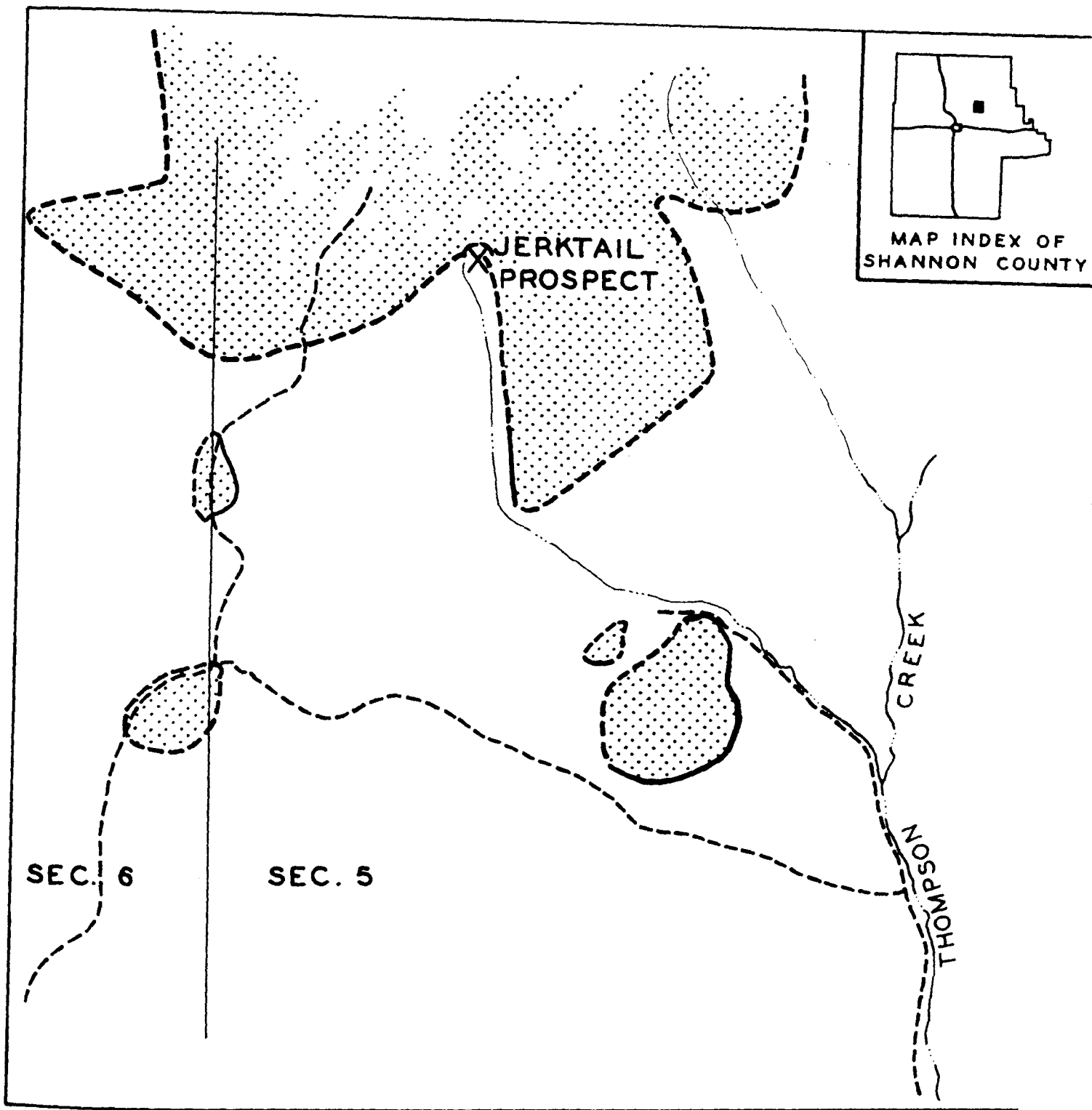
amount of covellite present associated with the chalcocite where in contact with malachite. Examination of the minerals under oil emersion revealed small pyrite grains are disseminated throughout the malachite.

The mineralization in the 26-foot level is of the massive sulfide type with chalcopyrite, the primary mineral, being replaced along grain boundaries by chalcocite. This in turn is replaced by limonite veining throughout the sulfides giving it the typical exploded bomb texture. This sequence is followed by small veins of fine to medium grained radially crystalline malachite. Hematite and limonite are abundant as gangue minerals.

Jerktail Prospect. The Jerktail Prospect is located in the center of the SW $\frac{1}{4}$ sec. 5, T. 29 N., R. 3 W., at the head of a small tributary of Thompson Creek. The prospect is very difficult of access, and is most easily reached by an old logging road that connects with State Road V 2.9 miles north of the ferry on Current River. This old logging road is not capable of access by conventional cars, but it is accessible to jeeps or pick-up trucks.

There is practically no information available on the early history of the Jerktail Prospect. It is perhaps the oldest prospect in the Eminence region as Joseph Slater did some work on the prospect in the early 1840's while operating the Slater Mine. This prospect was often called his "New Diggings". It is said to have been worked again in 1870, although, no record of this can be found. No figures on the production of the prospect are available.

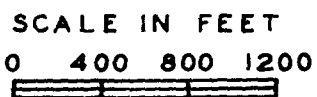
The prospect consists of a number of small test pits in the area,



IGNEOUS OUTCROP LOCATION MAP OF JERKTAIL PROSPECT AREA 1959

LEGEND

- PORPHYRY-EMINENCE CONTACT
- - - INFERRED PORPHYRY-EMINENCE CONTACT
- X PROSPECT



L.L. EVANS

FIGURE 10

all of which have caved, and a 16-foot shaft that is filled with water at the present time. The shaft was sunk through 10 feet of dolomite, 4 feet of conglomerate, and bottomed in the porphyry.

Similar to the Slater Mine, the prospect is situated at the head of a well developed Precambrian valley at the contact of the Eminence dolomite (Fig. 10). It is reported that Slater obtained most of his ore from the conglomerate at the Eminence-Precambrian contact ⁽²⁹⁾.

(29) Bridge, Josiah, op. cit. p. 175.

Very little conglomerate exists on the dump at the present time. An examination of the material on the dumps revealed that the copper minerals consist primarily of small thin crusts of primary chalcopyrite having a variable thickness up to $\frac{1}{4}$ inch and possessing a roughly pitted surface. All these crusts of chalcopyrite found in the material on the dumps are free of any wall rock material. These appear to the writer to be formed by open space filling along the bedding planes in the Eminence dolomite immediately overlying the conglomerate. It is quite likely that Slater shipped all of the richer ore found in the conglomerate, and the minerals now present on the dumps were taken out of the lower grade horizon at some later date, and were never shipped.

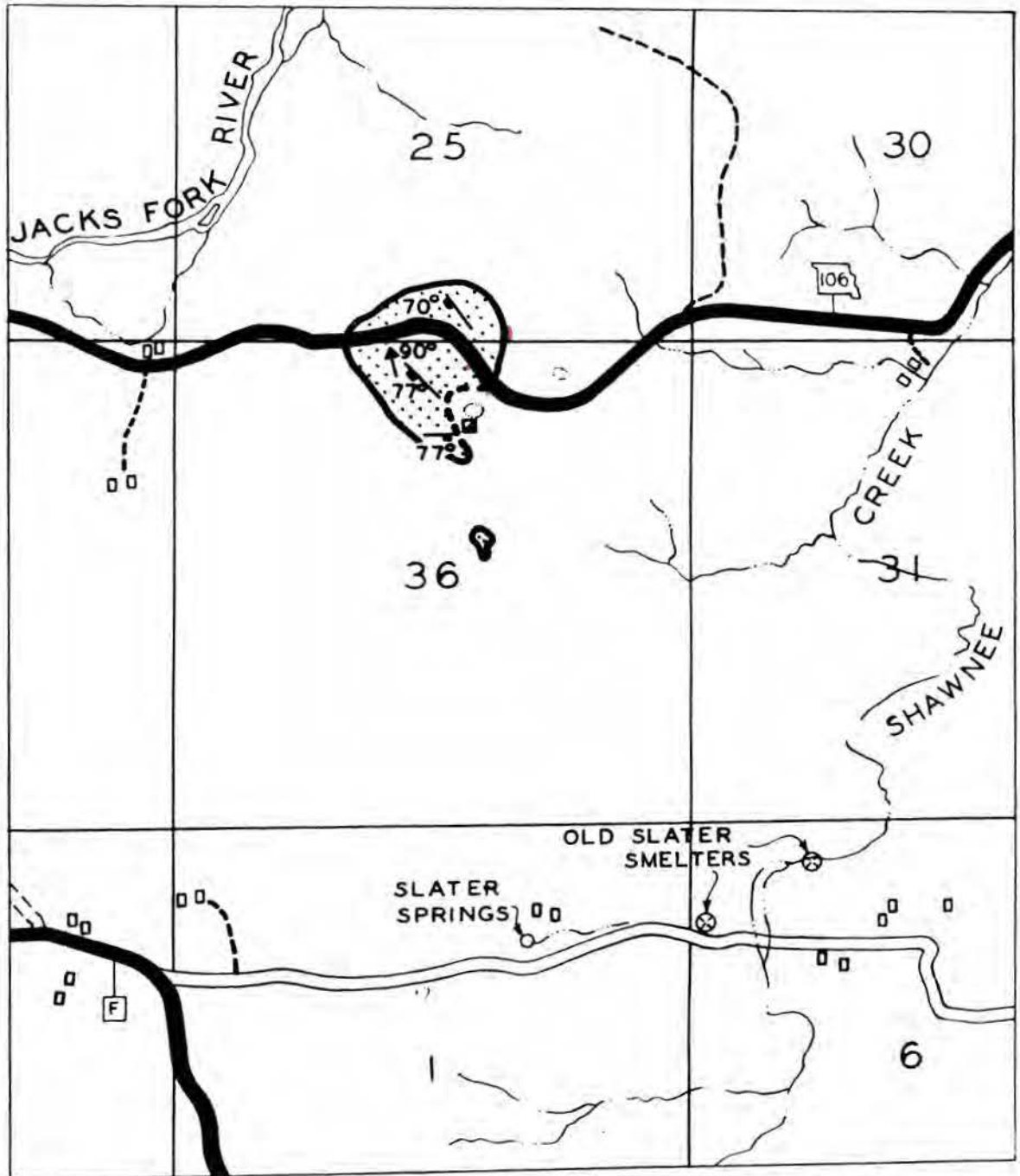
Slater Mine. The Slater Mine is owned by the Sutton Copper Company of Eminence, Missouri. The mine is located approximately 2 miles east of Eminence about 50 yards south of State Highway 106, in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T. 29 N., R. 4 W. This is the mine which was originally worked for copper in the Eminence region by Slater in the late 1830's.

Slater obtained the ore from numerous shallow pits and cross-cuts on the property. The property was developed by three short shafts through the conglomerate to the porphyry and one deep shaft. The deep shaft was 200 feet deep. It was driven at an angle of 80° for the first 100 feet and vertically the remaining 100 feet. Drifts were driven to the northeast and southwest at the 190-foot level. The drift to the northeast was driven a distance of 35 feet where another drift was driven at right angles to it parallel to the joint system of the porphyry. This drift was about 66 feet long. The ground at the Slater Mine has been worked for agricultural purposes so it is impossible to tell the location of any of these shafts at the present time. A stock pond that now exists in the area possibly covers the location of the deep shaft. The dumps have been carried off a specimen at a time by geologists, prospectors, and souvenir hunters, until there is very little evidence of any copper mineralization on the property today.

The only reported shipments made from the mine were approximately 1500 tons of ore by Slater, and 18 tons of ore obtained by the Consolidated Land Company of Missouri in 1872.

From the very limited evidence available at the mine property, it is concluded that this deposit is of the irregular replacement type. The mineralization replaced the calcareous cementing material in the conglomerate and filled the larger joint planes in the porphyry.

The mine is situated in the head of a buried Precambrian valley on the east contact of the knob and the Eminence dolomite. The basal conglomerate overlying the porphyry at the property is at least 30



IGNEOUS OUTCROP LOCATION MAP OF SLATER MINE AREA



MAP INDEX OF SHANNON COUNTY



LEGEND

- PORPHYRY-EMINENCE CONTACT
- INFERRED PORPHYRY-EMINENCE CONTACT
- CONGLOMERATE
- JOINTS
- FLOW FOLIATION
- MINE



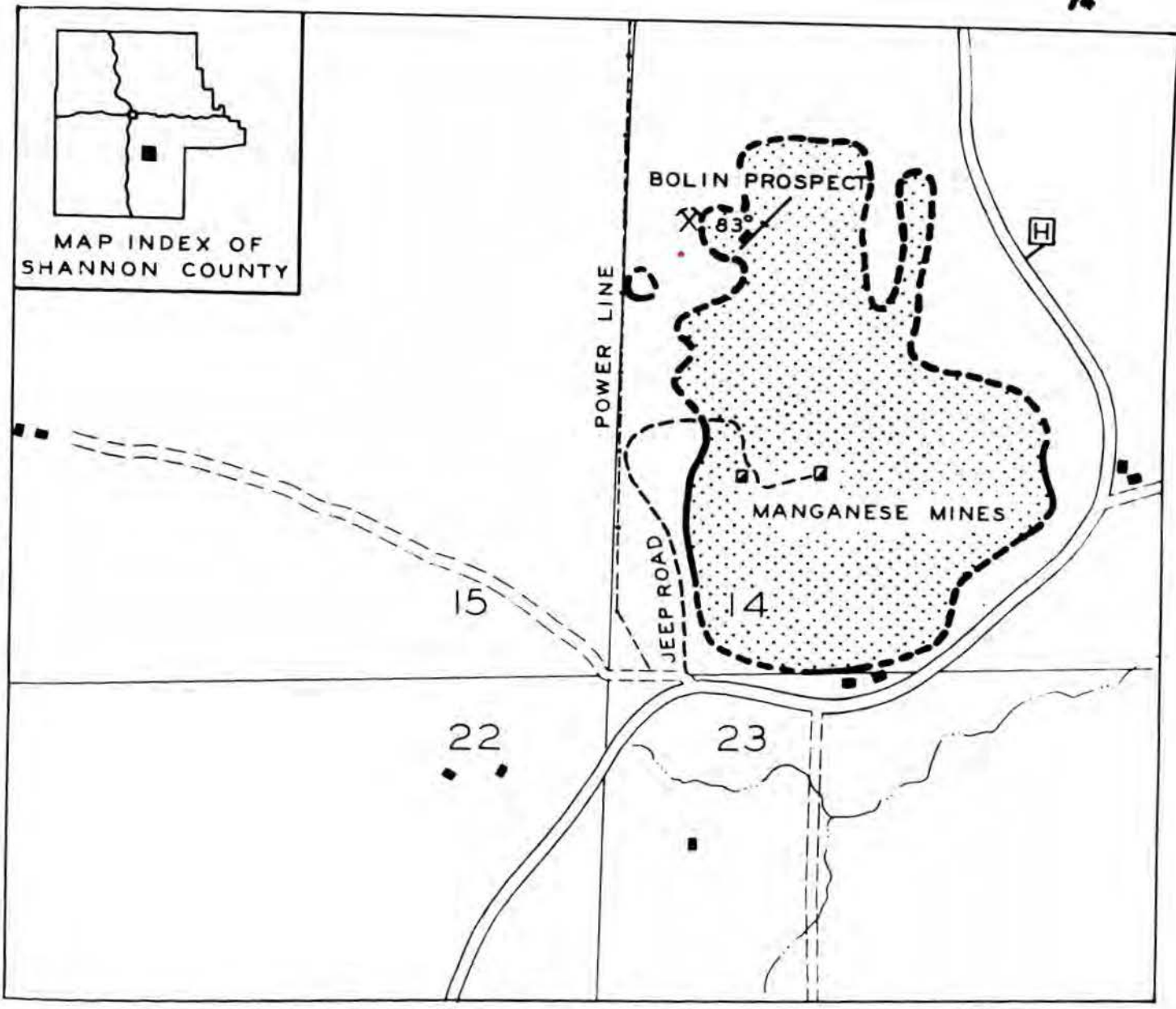
Figure 12. View of the Slater Mine area as seen today.

feet thick, and probably much thicker than this figure. It is exposed in two places in the ditch on the south side of State Highway 106 adjacent to the mine property. The lower exposure is in the small ditch at the culvert where the ditch crosses under the highway. The second outcrop is 30 feet vertically up the section in a small exposure in the bottom of the ditch. A very good outcrop of the conglomerate is also present on the northeast side of the Precambrian knob in the ditch at the contact of the porphyry and the Eminence dolomite approximately 100 yards from the highway. No mineralization was observed in any of these three conglomerate outcrops.

The Precambrian rock at the mine and the volcanic ash found as float on the east side of the knob, is previously described on pages 17 and 23 .

Bolin Prospect. The Bolin Prospect is located in the NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 14, T. 28 N., R. 3 W. This prospect is the southeastern most extent of the copper deposits in the Eminence region. There are no records available on the workings of this prospect. Mr. Lou Norris of Winona, Missouri related to the writer that he sunk a 23-foot shaft on the property around 1908. Mr. Norris reported that several tons of copper ore was taken out but never shipped. This ore has now been all but completely carried off. The deposit consists of malachite veins in the porphyry.

An examination of the prospect showed that the deposit was located at the contact of the Eminence dolomite and the Precambrian porphyry (Fig. 13). There are about 6 test pits in the immediate area, all of which have caved. A pit was situated in the porphyry



IGNEOUS OUTCROP LOCATION OF BOLIN PROSPECT AREA



- LEGEND**
- PORPHYRY-EMINENCE CONTACT
 - INFERRED PORPHYRY-EMINENCE CONTACT
 - CONGLOMERATE OUTCROP
 - SHAFT
 - PROSPECT
 - JOINTS

which is possibly the shaft Mr. Norris sunk. A very small outcrop of conglomerate was found in the shallow drainage channel about 30 yards S. 15° W. of the prospect pits. A green copper stain is present on the chert and quartz pebbles in the conglomerate.

Very few copper minerals were found in what was left of the dump material. The material on the dump consisted entirely of porphyry and quartz crystals with malachite, little azurite, and limonite. The copper minerals appear to be open space filling in narrow fractures in the porphyry. The porphyry was unaltered, except for a slight bleaching on the surface caused by weathering. Vein quartz is very abundant on the dump. The porphyry outcrop at the prospect possess very little fracturing.

Jacks Fork Prospect. The Jacks Fork Prospect is located at the base of a small dolomite ledge in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16, T. 29 N., R. 3 W., about 100 yards south of an old abandoned logging road.

The prospect was worked in 1931 and 1932. The workings consist of one shaft of unknown depth that is now filled with mud and large boulders. No shipment was ever made from this prospect.

The prospect is situated in the Eminence dolomite about 200 yards southwest of a porphyry outcrop that extends off of the very large porphyry outcrop that comprises Coot Mountain. The only copper mineral found on the dump of the prospect is earthy to very fine grained crystalline malachite. This occurs as roughly spherical masses averaging less than $\frac{1}{2}$ inch in diameter and possessing botryoidal structure. These malachite masses in the dump are free of any wall rock material and were probably formed by open space filling of voids

in the dolomite. No mineralization was observed in the accessible portion of the shaft.

It is quite possible that a much larger copper deposit exists in the conglomerate overlying the porphyry at depth.

McKinney Prospect. The McKinney Prospect is located in the SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 15, T. 29 N., R. 3 W., on the east bank of a drainage channel that follows the porphyry-Eminence contact. This prospect is the northwestern most copper deposit in the Eminence region.

The workings consist of one shaft that is now filled with water. No records are available on the depth of the shaft or any work that was done on the prospect.

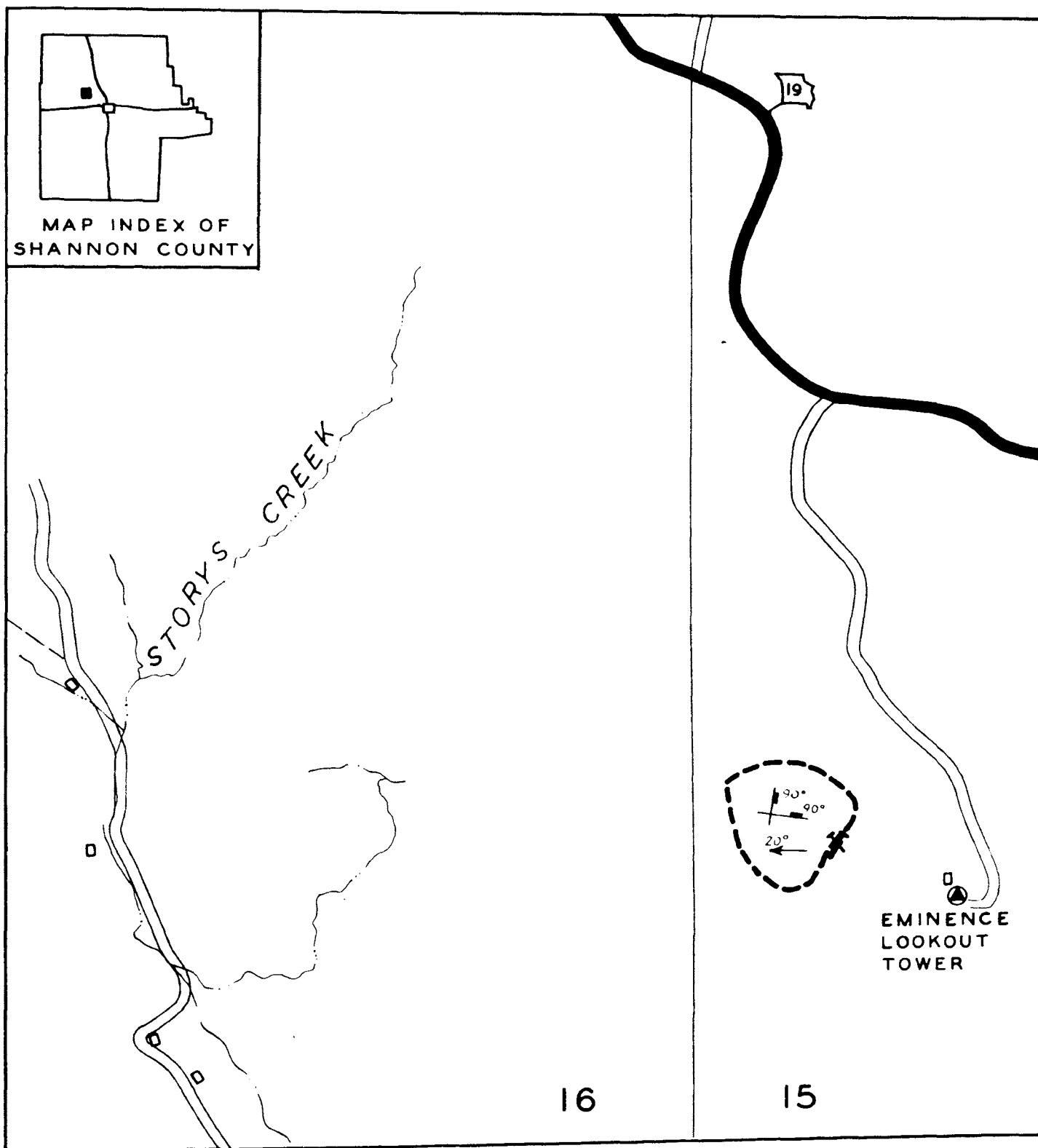
The McKinney prospect is similar to the larger deposits in the region in that it is situated in the conglomerate overlying the Precambrian porphyry at the head of a buried valley. The conglomerate is very well exposed in the bottom of the drainage channel at the prospect (Fig. 14).

The only mineralization found at this prospect is a green copper stain present on the porphyry fragments in the conglomerate and in the matrix.

Favorable Areas for Future Prospecting

As a result of the study made in the Eminence region, several areas appear promising for discovery of base metal deposits. The most striking features noted from this study are the structural control and the linear distribution of the mineral deposits.

A detailed study of the mineralogy and nature of the deposits gave no conclusive evidence as to the genesis of the deposits. The



MAP INDEX OF SHANNON COUNTY

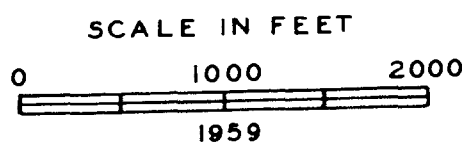
STORYS CREEK

EMINENCE LOOKOUT TOWER

16

15

IGNEOUS OUTCROP LOCATION MAP OF M^cKINNEY PROSPECT AREA



- LEGEND**
- - - INFERRED PORPHYRY-EMINENCE CONTACT
 - CONGLOMERATE
 - X PROSPECTS
 - OUTCROP
 - JOINTS
 - FLOW FOLIATION

linear distribution of the deposits as previously described on page
 can be attributed to two entirely different origins of the solutions.
 Atmospheric water may have acquired copper from the weathering of
 overlying formation. These supergene solutions passed through the
 sediments to the Precambrian knobs. They then followed the flanks
 of the knobs until they reached the conglomerate where the copper
 precipitated out. The linear outline of the Precambrian area may
 have been the principal factor controlling the linear distribution
 of the deposits. Another possibility is that hypogene solutions
 ascending from deeply buried faults in the Precambrian basement
 followed the buried valleys at the contact of the Paleozoic sediments,
 and were then deposited in the favorable conglomerate. The writer
 favors the latter explanation.

It is noted how the structural control of these deposits are
 very similar to the structural control of the ore deposits in the
 (30)
 Fredericktown area . The mineralogy is also quite similar to

(30) James, Jack A., Geologic Relationships of the Ore Deposits
 in the Fredericktown Area, Missouri: Missouri Geol. Survey, R. I.
 8, 1949.

the copper deposits in the Mine Lamotte except for the absence of
 siegenite in the Eminence region, although cobalt and nickel were
 found as trace elements in several of the deposits in this region
 (Table I).

(31)
 James pointed out that the ore deposits in the Fredericktown

(31) James, Jack A., op. cit., p. 21.

area are restricted to the lower 50 feet of the Bonneterre and closely related to the Lamotte sandstone pinch-out line against the buried Precambrian knobs. It is possible that this is also a favorable horizon in the Eminence region. James H. Davis (32) stated

(32) Davis, James H., Distribution of Copper, Zinc, and Minor Metals in the Southeast Missouri Lead District: Paper submitted for the Geological Society of America Meeting in St. Louis, Missouri, November 6-8, 1958.

that chalcopyrite is the latest mineral in the paragenetic sequence of the ore minerals in the Fredericktown area. It is common in ore deposits that ore minerals are zoned radially outward in direct relation to their paragenetic sequence; therefore, it is possible that perhaps lead and zinc may also occur in the Eminence region, in the Bonneterre dolomite near the pinch-out line of the Lamotte sandstone against a Precambrian knob near the head of a buried valley, as in the Fredericktown area. As the copper deposits in the Eminence region are larger and more numerous on the southwest side of the porphyry outcrop zone, this side would be the most favorable area for exploration. This area certainly warrants further exploration with these geologic considerations in mind.

A suggested method of approach would be to first prepare a detailed structure contour map of the surface of the Gunter sandstone member of the Van Buren formation to locate buried knobs. These buried knobs may also be located by studying the drainage pattern on aerial photographs. This method has been tested in an area to the east of the Eminence region in Reynolds and Wayne Counties

(33)
by Zarzavatjian .

(33) Zarzavatjian, Papkin, Detection of the Buried Basement Highs by Airphoto Drainage Pattern Analysis, Reynolds and Wayne Counties, Missouri: unpublished Master's thesis, Missouri School of Mines and Met., Rolla, Missouri.

Areas favorable for further explorations should then be selected by determining the position of the pinch-out line of the Lamotte sandstone against the Precambrian porphyry knobs. These areas should then be explored by drill holes.

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