UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 886-C

GEOLOGY AND ORE DEPOSITS OF THE SOUTHWESTERN ARKANSAS QUICKSILVER DISTRICT

BY

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Contributions to economic geology, 1937
(Pages 15-90)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1938

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - Price 75 cents

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ABSTRACT

Cinnabar was discovered near the southern border of the Ouachita Mountains, in southwestern Arkansas, in 1930. The belt in which cinnabar is now known has a length of more than 25 miles from east to west, and in most places is less than a mile wide, although it has a maximum width of about 6 miles.

The principal rocks exposed in the district are shale and sandstone of the Stanley, Jackfork, and Atoka formations, of Pennsylvanian age, which aggregate many thousands of feet in thickness. The three formations occupy several east-northeastward-trending belts and have been deformed by close folding and thrust faulting.

Most of the cinnabar deposits are in a northward-overriding thrust block that is cut by tear faults and is deformed and minutely fractured by cross folds. The cross folds and the tear faults appear to have been formed during the thrusting.

In the eastern part of the district the cinnabar is found in the Jackfork sandstone; throughout most of the rest of the district the ore occurs principally in the Gap Ridge sandstone member of the Stanley shale, but locally it is found at other horizons in the Stanley and in the overlying Jackfork sandstone.

Most of the cinnabar fills fractures related to the cross folds, but certain tear faults may also be worthy of prospecting. Locally cinnabar is disseminated through the sandstone. The cinnabar is invariably associated with the more widespread clay mineral dickite. The linear distribution of the ore deposits is believed to have been due to the ascent of mineralizing solutions along or just above the thrust faults until the solutions reached fractured sandstones of the Stanley or Jackfork, whence they followed these permeable beds toward the surface.

Because of the low relief, the scarcity of good outcrops, and the heavy brush cover, surface prospecting is difficult. Surface prospecting and especially underground prospecting are hampered by the irregularity of the fracture zones and the irregular distribution of the ore within the zones.

Geologic indications appear to warrant further prospecting and development in favorable areas. It seems likely that in a time of national emergency, when cost is no obstacle, the Arkansas district can produce a large amount of quicksilver. The metal probably can be produced at a profit under conditions similar to those of 1936 provided the enterprise is not burdened by too great an expense in the finding of ore bodies similar to some already mined.

INTRODUCTION

The United States ordinarily produces only about half of the quicksilver that it consumes. In the 11-year period 1924–34, the country produced 54.3 percent of its quicksilver consumption.[1] Any

[1] Furness, J. W., and Meyer, H. M., Mercury: U. S. Bur. Mines Minerals Yearbook, 1935, pt. 2, p. 441, 1935.

new source of this essential metal is therefore of relatively great importance. For this reason, and because of the possibility of financial gain attending the development of any new mining district, the Arkansas quicksilver district has attracted considerable attention from geologists, mining engineers, and others since its discovery in 1930.

An allotment of funds from the Public Works Administration enabled the United States Geological Survey to begin a detailed study of the district in March 1934. Field work continued until late November. The work in 1934 was under the direction of John C. Reed, assisted by J. M. Hansell, R. C. Becker, H. A. Millar, T. E. Jones, J. T. Young, John Wilson, Jr., and W. M. Plaster. Some of these men were employed for part of the time only. Mr. Reed was absent on another assignment for about 4 months, during which Mr. Hansell directed the field work.

Through an additional allotment of Public Works money, the investigation of the district was resumed in February 1935 and continued until the middle of May. This period of field work was directed by F. G. Wells, who was assisted by Messrs. Hansell, Young, Jones, and Wilson of the original field party, P. A. Shaw, and Howard Shoptaw. As before, some members of the party were not employed for the full period of the work. Mr. Reed was with the party for a week at the time Mr. Wells took it over in February and again for about 2 weeks as the work was winding up in May.

Mr. Wells visited the district for a few days in October 1935 to check up on developments during the summer. The district was again visited for about a week by Mr. Reed in March 1937.

FIELD METHODS

The field work was carried on under somewhat unusual conditions, and accordingly a method of operation was developed that differs considerably from ordinary field practice. The procedure is here briefly described as it may be applicable to further work in this or similar areas under similar conditions.

Many of the geologic features that are of economic importance, because of their control of ore deposition, measure only a few tens of feet. Thus at the outset it was apparent that the scale of the map should be large in order to show a great proportion of these features. The scale could not be made too large, however, for more time than was available would then be required for the field work. The small structural features, some of which controlled the ore deposition, are in many places reflected in the topography. It was therefore essential to make a topographic map and to choose for it a contour interval small enough to show considerable detail of form but large enough to prevent too great crowding of the contours on the map. A scale of 1 inch to 2,000 feet and a 20-foot contour interval were finally adopted (pl. 2).

The cinnabar-bearing area that has been mapped is long and narrow and essentially comprises a broad lowland and the flanks of the two bordering ridges, which for the most part rise less than 300 feet above the lowland. It is covered with second-growth forest or brush, at only a few places relieved by open farm land. The cultivated land is confined to the valleys. These conditions result in very restricted visibility for plane-table work, and consequently location by resection was almost everywhere impossible. Nevertheless the total lack of any reliable horizontal control made the expansion of a triangulation control net imperative. Points in treetops on the two ridges were therefore observed by plane table from a valley base line. The triangulation net was then expanded the long way of the area but with difficulty because of the impossibility of seeing along the occupied ridge or, in many places, into the valley and because of the large amount of brush-cutting necessary in many places to see across the valley to the other ridge. Two steel fire lookout towers in the area were very useful points in the net, as they were stable enough for plane-table occupancy.

The triangulation points were then used as starting and tie points for closely spaced interlocking lines of plane-table stadia traverse. This method entailed considerable ax work but was flexible enough to allow the use of many natural openings. Only the more obvious geologic features were mapped on the plane-table sheets, for the particular problem at that time was the making of an accurate topographic map. The mapping of the geologic features by instrumental methods would have greatly increased the time required and the amount of brush-cutting. The traverse turning points were marked on the ground by stakes, small piles of rock, blazes, or otherwise. Later the geologists went over the ground again and added the geologic features to the map. Full use was made of known location points, such as triangulation points, cut-out lines, turning points, buildings, and stream and trail intersections. Some small areas were covered for both topography and geology by pace and compass traverse, altitudes being determined by aneroid barometer. This method, although faster, was found to be unsatisfactory and was abandoned.

The problem of vertical control was simplified by a line of recent Coast and Geodetic Survey benchmarks that runs through the medial lowland.

The final map may be somewhat in error as regards the relative positions of its most easterly and its most westerly points, but it is probable that this extreme error is not greater than 300 feet. Within any relatively small area the map is believed to be as accurate as can be plotted on the scale used.

ACKNOWLEDGMENTS

The writers wish to acknowledge gratefully the spirit of hearty cooperation in which they were met during the field work by the local inhabitants and by others interested in the district. Although many more names could be added to the list of those who contributed aid and information, the following people were particularly helpful: Leo Yount and Ralph Cranston, both formerly of the Southwestern Quicksilver Co., and Mr. Yount now with the Mid-Continent Quicksilver Corporation; George C. Branner, State geologist of Arkansas; N. K. Clemmensen, district forester of the Arkansas State Forestry Commission; M. J. Eunson, formerly of Mercury Producers, Inc.; Wes. Russell; G. W. Shoptaw, of Arkadelphia; R. C. Rohrdanz, of the Mid-Continent Quicksilver Corporation; J. F. Funk and V. B. Lewis, formerly of the Mercury Mining Co.; N. H. Stearn, of the Southwestern Quicksilver Co.; and Walter F. Hintze, of Murfreesboro.

The writers had the advantage of discussing the problems involved in the area with several of their colleagues in the Geological Survey during visits made while field work was in progress, including A. A. Baker, H. G. Ferguson, T. A. Hendricks, E. T. McKnight, H. D. Miser, and C. P. Ross.

BIBLIOGRAPHY

The following publications deal with the quicksilver district or the area in which it lies:

Miser, H. D., and Purdue, A. H., Geology of the DeQueen and Caddo Gap quadrangles, Ark.: U. S. Geol. Survey Bull. 808, 1929. This bulletin describes in detail the geology and mineral deposits of two 30-minute quadrangles, one of which, the Caddo Gap, contains part of the quicksilver district. It contains colored geologic maps of the quadrangles and many other maps and geologic cross sections. Although its publication preceded the discovery of the quicksilver deposits, it has been the foundation for geologic work in the region.

Branner, G. C., A preliminary report on the discovery of quicksilver in Pike County: Arkansas Gazette, Aug. 30, 1931.

Weigel, W. M., New quicksilver discoveries: Eng. and Min. Jour., vol. 132, no. 11, pp. 495–497, Dec. 14, 1931. The author tells of the discovery of the Arkansas cinnabar district and early prospecting in it. He briefly describes the general geology of the region, largely after Miser and Purdue, and the occurrence of cinnabar at several localities.

Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Information Circ. 2, 1932. Branner points out that up to the time of publication of his report 34 occurrences of cinnabar had been discovered. Mining operations near the Little Missouri River and near Antoine Creek had produced nearly 2,000 pounds of quicksilver. He recognized the linear arrangement of the occurrences of cinnabar in a narrow belt whose structure he interpreted to be anticlinal, in accordance with the map by Miser and Purdue, which he reproduced in his report. This belt is now believed to be not anticlinal but to be related to thrust faults. He also stated his belief that the cinnabar is of hydrothermal origin.

Stearn, N. H., The new quicksilver district in Arkansas: Min. Jour., Phoenix, Ariz., vol. 16, no. 2, pp. 3, 4, June 1932. This paper includes a short history of the discovery of quicksilver in Arkansas, a description of mining development in the area, a synopsis of the general geologic setting and of the occurrence of the ore, and a paragraph on the significance of the discovery of the new district in which the possibility of commercial mines is predicted.

Stearn, N. H., Mining and furnacing quicksilver ore: Eng. and Min. Jour., vol. 134, no. 1, pp. 22–24, January 1933. The geology in the vicinity of the Parnell Hill mine is described. Four different types of structural control of ore deposition are recognized. The mining and furnacing methods of the Southwestern Quicksilver Co. are described.

Sohlberg, R. G., Cinnabar and associated minerals from Pike County, Ark.: Am. Mineralogist, vol. 18, pp. 1–8, 1933. A description of the minerals and their paragenesis in a suite of ores from Pike County. Crystallographic measurements of the cinnabar crystals are given as well as data concerning optical and X-ray studies of the dickite.

Sohlberg, R. G., Petrographic study of quicksilver ores and associated minerals from Pike County, Ark. [abstract]: Geol. Soc. America Bull. vol. 44, pt. 1, pp. 158–159, Feb. 28, 1933.

Stearn, N. H., Structure from sedimentation, Parnell Hill quicksilver mine, Ark.: Econ. Geology, vol. 29, no. 2, pp. 146–156, March-April 1934.

Hansell, J. M., Mining development of the Arkansas quicksilver district to July 1, 1934; bound in the back of some later copies of Arkansas Geol. Survey Inf. Circ. 2. This paper is a summarized account of the development of the various prospects in the district.

Stearn, N. H., Stibnite in quartz: Am. Mineralogist, vol. 20, no. 1, pp. 59–62, Jan. 1935. Numerous small quartz crystals containing stibnite and cinnabar have been found in the Parnell Hill and Gap Ridge mines in the southwestern Arkansas quicksilver district. The habit of the stibnite inclusions differs in different crystals, but the acicular form is the most common. A few crystal faces on quartz crystals are etched and pitted with finely granular pyrite, thus indicating that the quartz was not deposited by meteoric waters but by sulphide-bearing hydrothermal solutions. The sequence of minerals from older to younger is stibnite, cinnabar, quartz, pyrite, and dickite.

Hansell, J. M., and Reed, J. C., Quicksilver deposits near Little Missouri River, southwest Arkansas: Am. Inst. Min. and Met. Eng. Tech. Pub. 612, 1935. This report covers a 12-mile segment of the district that includes the three mines of the Southwestern Quicksilver Co., from which came most of the production of the district prior to 1935.

Reed, J. C., and Hansell, J. M., Quicksilver deposits near Little Missouri River and near Antoine Creek, southwestern Arkansas: U. S. Dept. Interior Press Mem. 99554, Apr. 30, 1935. This paper is similar to the preceding one by the same authors but covers a larger area. It contains additional material on structural geology and structural control of mineralization.

Reed, J. C., Hansell, J. M., and Wells, F. G., in Furness, J. W., and Meyer, H. M., Mercury: U. S. Bur. Mines Minerals Yearbook, 1935, pp. 443–449, 1935. The authors describe the development work on the principal properties in the Arkansas quicksilver district.

Stearn, N. H., [Discussion of Tech. Pub. 612]: Am. Inst. Min. and Met. Eng. Trans., vol. 115, pp. 244–246, 1935. Stearn indicates his essential agreement with most of the interpretations of geologic features as described in Technical Publication 612. He differs on some points, however. He believes that the formation that lies to the north of the major thrust—the Cowhide thrust—is Atoka and not Jackfork, that the cross folding took place during a period of east-west compression between two periods of thrusting from the south, and that the deposits are more likely late Paleozoic than Upper Cretaceous. The writers now agree that the deposits are probably of late Paleozoic age. (See pp. 51–53.) In this discussion Stearn names the Gap Ridge sandstone member of the Stanley shale.

Stearn, N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, no. 1, pp. 1–28, 1936. (For discussion see Reed, J. C., idem, vol. 31, no. 3, pp. 314–317, 1936. This paper is a somewhat more elaborate presentation of the ideas set forth by Stearn in his papers already cited. It contains considerable new material, among which are hitherto unpublished data on the tenor of the ore mined by the Southwestern Quicksilver Co.

The preliminary results of the Geological Survey's work in the district have been summed up in Technical Publication 612 of the American Institute of Mining and Metallurgical Engineers, the Department of the Interior Press Memorandum 99554, the section entitled "Mining development of the Arkansas quicksilver district to July 1, 1934", bound in Information Circular 2 of the Arkansas State Geological Survey, and the statement on the district in the United States Bureau of Mines Minerals Yearbook for 1935, under "Mercury."

GEOGRAPHY

LOCATION, ROADS, AND CLIMATE

The quicksilver district lies in southwestern Arkansas. (See fig. 3.) Cinnabar has been found in a narrow belt about 26 miles long and about 6 miles in maximum width that extends from sec. 13, T. 7 S.,

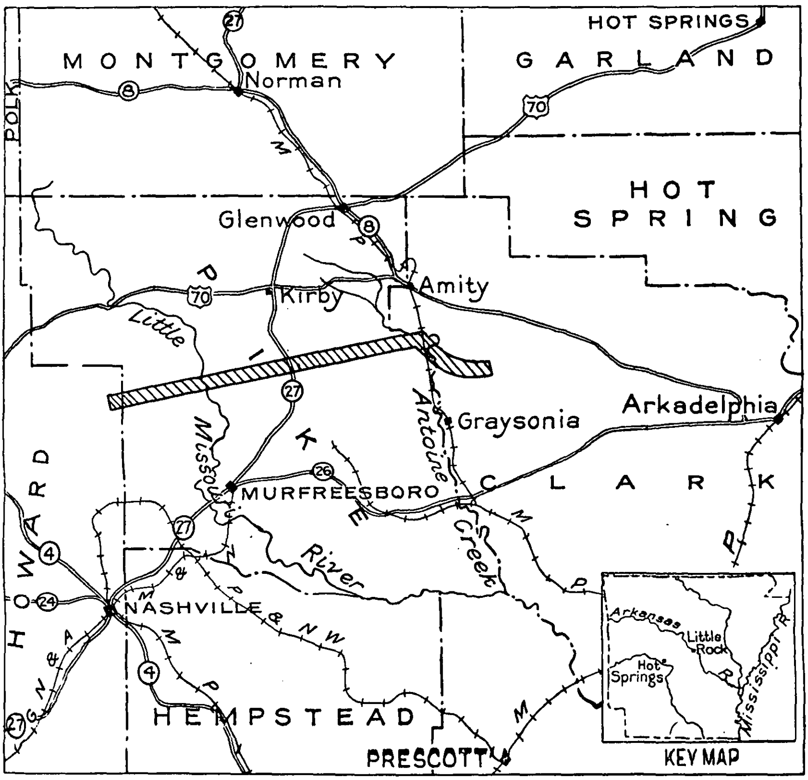


FIGURE 3.—Index map showing location and extent of the southwestern Arkansas quicksilver district (shaded area).

R. 27 W., in eastern Howard County, east by north across Pike County into sec. 5, T. 7 S., R. 22 W., in western Clark County (pl. 7). Hot Springs, with a population of 20,238, lies some 50 miles to the northeast of the district, and Arkadelphia, which has a population of 3,380 and is the county seat of Clark County, lies about 20 miles to the east. No town or village lies within the district. Amity, 5 miles north of the east end of the district, is a town of 608 population. The central and western parts of the district are more accessible from Murfreesboro, the county seat of Pike County, population 733, which lies 7 miles south of the district. Though the villages of Kirby, Nathan, and Graysonia are nearer to parts of the district than either Murfreesboro or Amity, they are too small (population less than 300) to offer many conveniences. Within the district human activities other than mining are confined to a few farms in the medial lowland, the hills being forested with second growth.

Most of the district is well served by roads. State Highway 27 crosses the middle of the district from north to south. The west end of the district is accessible by county roads from both Murfreesboro and Nashville. A road, in part improved by the Civilian Conservation Corps, runs through the western part of the district from east to west, connecting Highway 27 with the county roads to the west. This east-west road is passable except in times of high water, when the fords across the streams cannot be used.

The eastern part of the district near Antoine Creek is accessible by road from Amity or by the Graysonia road, which leaves State Highway 8 about 15 miles northwest of Arkadelphia, or some 8 miles southeast of Amity (pl. 7). From the Graysonia road three roads built by the Civilian Conservation Corps enter the district. Both the Amity and Graysonia routes cross Antoine Creek on low-water bridges and are impassable during high water. The country between Highway 27 and the Antoine Creek area is traversed by a farm road only, which becomes impassable during wet weather.

A branch line of the Missouri Pacific Railroad crosses the eastern part of the district.

The average annual precipitation for 38 years at Amity was 49.68 inches, most of it falling in the winter and spring. The heavy precipitation of these seasons interferes with open-cut mining and often makes fords and low-water bridges impassable. As run-off is rapid, all but the major streams are dry during the hot summer, and consequently the development of water for mining is difficult. In other respects the climate is on the whole favorable to efficient operation, the temperature being moderate and snow almost unknown. Timber for building and for use in the mines is still plentiful in the surrounding neighborhood.

TOPOGRAPHY

RELIEF

The quicksilver district lies within the Athens Plateau just north of its boundary with the Gulf Coastal Plain. The plateau is a hilly country characterized by long, narrow east-west ridges whose gently undulating crest lines range from about 750 to 1,100 feet above sea level, separated by narrow valleys that are in most places less than 350 feet below the general level represented by the ridge tops.[1a] The master streams flow southeastward, transverse to the ridges, through which they have cut narrow gaps, and the topography contiguous to the gaps is rugged. In the interstream areas, however, the slopes are gentle and the country open. The maximum relief in the area mapped (pl. 2) is 560 feet, from 350 feet above sea level where Antoine Creek leaves the area to 910 feet on the south ridges in sec. 31, T. 6 S., R. 24 W.

The salient topographic features of the area mapped are two long, narrow ridges trending east by north, separated by a median lowland that extends from the western extremity of the area eastward into the western part of T. 6 S., R. 23 W., where the north ridge bends southward, causing the two ridges to converge and form a rugged tract of hills just west of Antoine Creek. East of the gap made by Antoine Creek the north-south ridges resume an eastward but divergent course. Both ridges maintain a general altitude of 750 feet above sea level, and each rises to a summit altitude of about 900 feet. The highest points are commonly natural walls of heavy sandstone beds that project as much as 30 feet above the general ridge level and extend along the ridges for considerable distances. Such a feature gives the name of Wall Mountain to the south ridge (sec. 32, T. 6 S., R. 23 W.). The crests of the ridges are everywhere higher than 650 feet above sea level, but they are trenched by Stony, Buck, South Woodall, Wall, and Antoine Creeks and the Little Missouri River.

The medial lowland is divisible into three parts—South Woodall Valley, the valley of Cowhide Creek, and Couch Valley. South Woodall Valley at its east end includes the headwaters of Wall Creek and extends westward to a low divide 660 feet above sea level near Highway 27. The valley of Cowhide Creek extends westward from the divide near Highway 27 to Little Missouri River. Couch Valley is formed by the valleys of Redding Creek and its main southern tributary and by those of lateral tributaries of Buck and Stony Creeks near the west end of the area.

The lowland has a maximum width of 1 mile in sec. 25, T. 6 S., R. 24 W., but is commonly less than half a mile wide. Where obstructed

[1a] U. S. Geol. Survey topographic map of Caddo Gap quadrangle, Arkansas, 1928.

by transverse ridges—for example, Mill Mountain, in sec. 12, T. 7 S., R. 26 W.—or by protruding flatiron-shaped segments of the south ridge, it is constricted to a ravine. The lowland includes an east-west chain of elongate hills which extends throughout its length. Where erosion has been most active these hills rise out of the valleys as steep ridges or hogbacks—for example, the ridge on which is located the Gap Ridge mine (pl.2); elsewhere they are less prominent and at the drainage divide crossed by State Highway 27 are elongate swells. Their general crest line is about 600 feet above sea level; and though they rise above this altitude locally, they nowhere attain the height of the main ridges to the north and south. A similar medial ridge is found east of Antoine Creek.

A broad, relatively flat, low area lies north of the east end of the district. About 3 square miles of this lowland is included in the area mapped. The lowland ranges in altitude from a little below 400 feet to about 500 feet above sea level.

DRAINAGE

The Little Missouri River is the major stream of the district and flows southward in a meandering course across its western part. Cowhide Creek, one of its tributaries, rises just east of State Highway 27 and flows westward in a broad valley. Redding and Wild Cat Creeks are tributary to the Little Missouri River from the west. About 2 square miles in the western part of the area is drained by southward-flowing Buck and Stony Creeks.

All of the area east of State Highway 27 except about a quarter of a square mile at the head of Cowhide Creek is drained by Antoine Creek and its tributaries. The longest of these, South Woodall Creek, rises just west of Highway 27 and, after flowing east by north for 5 miles, turns sharply north to gain Woodall Creek through a narrow ravine. Wall Creek and its tributaries drain the east end of South Woodall Valley. Like South Woodall Creek, Wall Creek cuts through the northern ridge and empties into Antoine Creek. Antoine Creek enters the mapped area in sec. 24, T. 6 S., R. 24 W. After flowing southeastward against the end of the north ridge, it makes a big loop before turning south to cut through both the north and the south ridges in a meandering course. Wherever it has encountered less resistant rocks it has widened its bed and has built a small flood plain, but it crosses the sandstone ridges through steep ravines. In this area two short brooks, Suck Hollow and White Oak Creeks, are tributary to Antoine Creek from the west; from the east two others and Caldwell Creek enter the major stream. The Little Missouri River and Antoine Creek are usually the only perennial streams in the area, but even Antoine Creek was dry in the summer of 1934, a year with unusually low precipitation.

GEOLOGY

AGE AND ATTITUDE OF THE ROCKS

Three formations,[2] the Stanley shale, Jackfork sandstone, and Atoka formation, all of Pennsylvanian age,[3] have been recognized on the Athens Plateau. These rocks have been greatly folded and faulted, and as a result they dip steeply and are exposed in several belts with an east-northeast trend. The folding and faulting of the rocks of the Athens Plateau and of the Ouachita Mountain anticlinorium, just to the north, were the result of mountain-making forces that produced compression from the south in middle Pennsylvanian time.[4]

The sandstone and shale surface of the Athens Plateau passes southward beneath the gently southward-dipping Lower Cretaceous sediments of the Gulf Coastal Plain. The Cretaceous sediments of the Coastal Plain were laid down on the Ouachita peneplain, which now dips southward at about 80 feet to the mile.[5] A younger erosion surface, the Hot Springs peneplain, forms much of the Athens Plateau except for the Jackfork sandstone ridges that project above the peneplain.[6] The Hot Springs peneplain cuts the present contact of the Cretaceous on the Pennsylvanian rocks.

DISTRIBUTION AND CHARACTER OF THE ROCKS

The areal distribution of the rocks of the district is shown on plate 2.

CARBONIFEROUS ROCKS

STANLEY SHALE

The Stanley shale underlies the east-west lowland that extends from the western limit of the mapped area eastward within about 4 miles of its east end. Stanley shale also occupies about 3 square miles in the northeastern part of the district, in the vicinity of Antoine Creek. This area of 3 square miles is but a very small part of a large area of Stanley shale, outside of the quicksilver district, that extends many miles both to the east and to the west.[7]

The maximum exposed thickness of the Stanley shale in the medial lowland is about 4,000 feet near the east end of the lowland, between Wall Mountain and Bare Rock. At most places in the lowland the exposed thickness is less than 3,000 feet, or less than half the normal thickness of the formation on the Athens Plateau.[8] The Stanley

[2] Miser, H. D., and Purdue, A. H., Geology of the DeQueen and Caddo Gap quadrangles, Ark.: U. S. Geol. Survey Bull. 808, pp. 59–79, 1929.

[3] Miser, H. D., Carboniferous rocks of Ouachita Mountains: Am. Assoc. Petroleum Geologists Bull., vol. 18, pp. 971–993, 1934. White, David, Age of Jackfork and Stanley formations of Ouachita geosyncline, Arkansas and Oklahoma, as indicated by plants: Idem, pp. 1010–1017. Harlton, Bruce, Carboniferous stratigraphy of the Ouachitas, with special study of the Bendian: Idem, pp. 1018–1037.

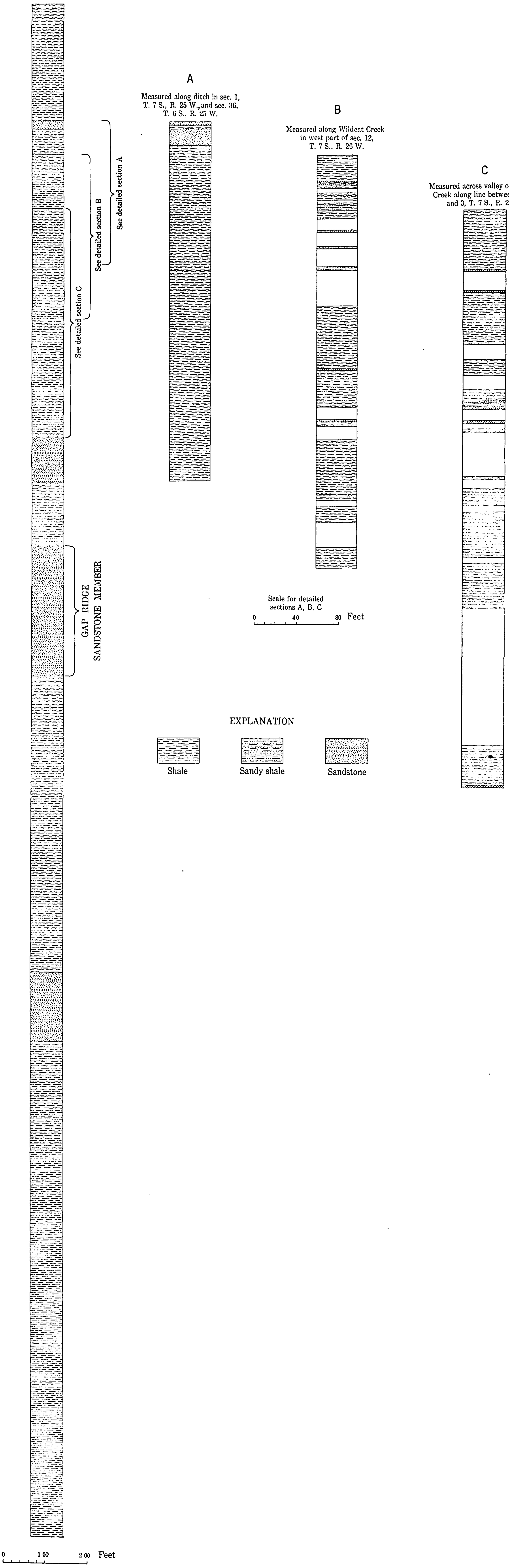
[4] Miser, H. D., Structure of the Ouachita Mountains of Oklahoma and Arkansas: Oklahoma Geol. Survey Bull. 50, p. 26, 1929.

[5] Miser, H. D., and Purdue, A. H., op. cit. (Bull. 808), p. 137.

[6] Idem, pp. 144–146.

[7] Idem, pl. 3. Branner, G. C., Geologic map of Arkansas, Arkansas Geol. Survey, 1929.

[8] Miser, H. D., and Purdue, A. H., op. cit., p. 60.



COMPOSITE COLUMNAR SECTION OF STANLEY SHALE EXPOSED IN THE SOUTHWESTERN ARKANSAS QUICKSILVER DISTRICT, WITH MORE DETAILED SECTIONS OF PARTS OF THE FORMATION.

shale east of Bare Rock along the northeast edge of the mapped area is apparently more than 6,000 feet thick across the strike, but exposures are generally poor in that vicinity and, although more of the section is probably present there, the true thickness could not be reliably determined because of the possibility of repetition of beds by folding or faulting or both.

The formation is dominantly a grayish-black clay shale, locally containing many beds half an inch to 6 inches thick of fine-grained impure sandstone and a few beds of fine- to medium-grained quartzitic sandstone. Where weathered, the shale has a characteristic greenish-brown color, and the sandstone has become yellowish or gray white and soft. Three sandstone members were recognized in the part of the formation exposed in the medial lowland.

The whole exposed part of the Stanley could not be measured in detail because of the lack of sufficiently complete outcrops. The composite section in plate 3 was compiled from the three detailed partial sections measured near the top of the formation, from small but good exposures such as mine openings and road cuts, and from more general information elsewhere.

The 300-foot sandstone 1,250 feet below the top of the Stanley, together with the 150-foot shale bed above it and the still higher 100-foot sandstone, has been called the Gap Ridge sandstone member by Stearn,[9] after the Gap Ridge mine, which is opened in it. The name is retained here but is used in a more restricted sense, being applied to the 300-foot lower sandstone only. The reason for the restriction is that the upper 100-foot sandstone cannot be differentiated throughout the district, although it is unquestionably present at many places. The Gap Ridge sandstone is more resistant to weathering than the more shaly parts of the formation above and below it, and consequently it forms a distinct but disconnected ridge, traceable, with a few breaks, throughout the length of the medial lowland.

The sandstone zone 160 feet thick in the Stanley shale 2,240 feet below its top has been shown on the map from a point near the northeast corner of sec. 5, T. 7 S., R. 25 W., eastward for about 3 miles into the southern part of sec. 35, T. 6 S., R. 25 W. Stearn[10] believes this zone to be the same as that at the Parker Hill mine, just west of the Little Missouri River, and therefore calls it the "Parker Hill member." This correlation across an interval of about 2½ miles may well be the correct interpretation, but as the structure of the region is so complex it may also be erroneous and therefore has not been adopted.

Neither of the sandstone members just described was differentiated in the Stanley area east of Bare Rock. The formation there contains

[9] Stearn, N. H., [Discussion of Am. Inst. Min. Met. Eng. Tech. Pub. 612]: Am. Inst. Min. Met. Eng. Trans., vol. 115, p. 245, 1935.

[10] Stearn, N. H., idem, p. 245; The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, no. 1, p. 8, January-February 1936.

sandy zones, but the exposures were so poor that none of them could be traced for more than a short distance. Any or all of the zones described above may well be present there.

Stearn[11] has described plant fossils from the Parnell Hill mine, in his Gap Ridge sandstone member. He found two specimens of *Calamites stanleyensis* and other fragmentary plant remains. Similar material was observed at Parnell Hill during the course of this investigation.

A thin section from a sandstone bed exposed in a trench on the Funderburk property, in the NW¼NW¼ sec. 3, T. 7 S., R. 25 W., which is in the 160-foot sandstone zone 2,240 feet below the top of the formation, is made up of about 80 percent of clean angular to subrounded quartz grains and 20 percent of fine-grained clay minerals. The clay minerals fill the irregular interstices between the sand grains. The rock carries accessory titanite, tourmaline, muscovite, limonite, cinnabar, and zircon(?). The cinnabar and titanite are associated in the clay minerals.

Under the microscope the Gap Ridge sandstone member is seen to be composed predominantly of a mosaic of subrounded to angular quartz grains whose mean diameter may be about 0.5 millimeter. Ordinarily 80 to 90 percent of the rock is made up of this mosaic. The rest is composed largely of isolated grainlike masses and interstitial fillings of clay minerals. Common accessories include titanite and its alteration products, sericite, muscovite, zircon, tourmaline, and apatite.

A thin section from the 710-foot shale zone, the top of which is about 285 feet below the top of the formation, is made up of material so fine-grained that individual mineral grains could not be studied. The section shows marked aggregate orientation of the shale particles.

Microscopic examination of a thin section from a sandy bed in the upper 290-foot zone of the Stanley shows it to be composed principally of quartz grains between 0.25 and 0.75 millimeter in diameter. The grains are rounded to angular, and most of them are surrounded by a matrix of clay minerals. The clay minerals have replaced some of the quartz. Some of the masses of clay minerals, however, may have replaced albite, as a few residuals of that mineral still remain. Some goethite and limonite are present in the clay mass. Sericite, muscovite, chlorite, and a very little biotite were observed.

JACKFORK SANDSTONE

The higher land lying both to the north and to the south of the medial lowland of Couch Valley, the valley of Cowhide Creek, and South Woodall Valley, is underlain by the rocks of the Jackfork sandstone. This formation overlies the Stanley shale. The northern and the southern band of Jackfork join near the southwest corner of

[11] Stearn, N. H., Structure from sedimentation at Parnell Hill quicksilver mine, Ark.: Econ. Geology, vol. 29, pp. 149–155, 1934.

sec. 29, T. 6 S., R. 23 W., thus terminating South Woodall Valley on the east. Jackfork sandstone continues eastward from that locality, south of the large Stanley shale area to and beyond the eastern limits of the district mapped (pl. 7).

Stearn [12] is of the opinion that the ridge lying to the north of the medial lowland is composed of rocks of the Atoka or a still higher formation. The writers feel, however, partly on structural evidence that will be considered in the section on "Structure" but principally because of lithologic similarity between the rocks of the two ridges, that the northern ridge is underlain by rocks that definitely belong to the Jackfork sandstone.

Reliable determinations of the thickness of the Jackfork sandstone are difficult because of the presence, almost everywhere in the district, of complicated structural features. The 5,000- to 6,600-foot thickness found by Miser and Purdue [13] in the Caddo Gap and DeQueen quadrangles, in the former of which the quicksilver district lies, coincides very well with the 6,000-foot thickness as measured in the quicksilver district. At least as far as the district under consideration is concerned, 6,000 feet should be taken as the maximum exposed thickness, because structural deformation of the type actually present would apparently increase the true thickness. An example of the unreliability of the determination of thicknesses is illustrated in plate 4, *A*.

In general the Jackfork sandstone is made up of about 80 percent sandstone and 20 percent shale. The sandstone beds range from a few inches to 20 feet in thickness and the intercalated beds of gray to gray-black clay shale from an inch to more than 100 feet. Locally the shale of the Jackfork consists of a series of layers, ordinarily less than an inch across, that are alternately colored light brown or yellow and gray or gray black and give the shale a distinctive ribbonlike appearance (pl. 4, *B*). The weathered sandstone is ordinarily soft and brown. The formation contains a few conglomeratic beds, principally in the upper half. All the pebbles seen are quartz. Most of them are about the size of rice grains, though a few pebbles as much as half an inch in diameter were seen. At a few places conglomeratic beds were observed in the northern band of Jackfork sandstone, but their more common presence in the southern band is distinctive. In dealing with a much larger area Miser and Purdue [14] found that in general the conglomeratic beds are more common near the base of the formation.

A marine invertebrate fossil was found in the Jackfork in the SW¼ sec. 23, T. 6 S., R. 24 W. Girty [15] describes it as "a concentrically

[12] Stearn, N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, no. 1, fig. 3 and p. 7, January-February 1936.

[13] Miser, H. D., and Purdue, A. H., op. cit. (Bull. 808), pl. 4 and p. 75.

[14] Idem, p. 76.

[15] Girty, G. H., memorandum to J. C. Reed, April 10, 1936.

coiled, rather strongly involute discoidal shell, evidently a cephalopod and more probably an ammonoid than a nautiloid. The sculpture is rather well preserved, but not a trace of suture can be seen. The generic position is therefore indeterminable."

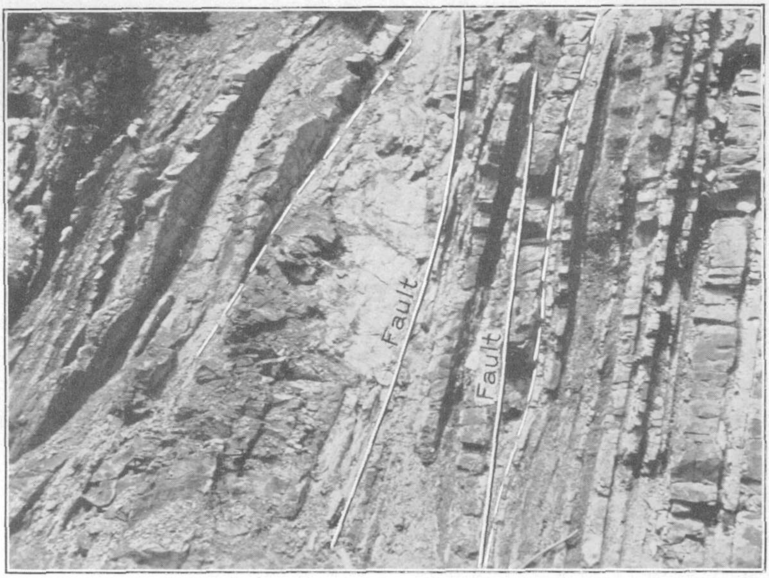
At several places in the southern belt of Jackfork sandstone, mostly south of the mapped area, erosion along strike valleys has formed a lowland in the interior of the belt. This, together with the soft, crumbly character of the poorly exposed rocks, indicates for the formation a more easily eroded middle part between relatively resistant upper and lower parts unless this feature is the result of unrecognized thrust faulting. Resistant beds that rise as much as 20 feet above the surrounding surface and trend across the country like giant walls are relatively common in the upper third of the formation south of the less resistant interior zone.

Exposures were not good enough to compare in detail the stratigraphy of the northern and southern bands of the Jackfork. Apparently the northern band is characterized by the relative scarcity of conglomeratic beds, the absence of strike valleys in the interior of the belt, and the presence at many places of color banding of the sandstone beds. The color bands are ordinarily less than half an inch thick and may be due partly to differences in grain size.

Plate 5 gives a composite columnar section of the Jackfork sandstone constructed from several detailed columnar sections, which are included in the plate, and from more general observations; it gives also a partial section measured along the Missouri Pacific Railroad in sec. 4, T. 7 S., R. 23 W.

Under the microscope the Jackfork sandstone is seen to be made up of a mosaic of rounded to angular quartz grains whose mean diameter may approach 0.5 millimeter. No feldspar grains were seen in any of six thin sections of Jackfork from widely separated localities within the district, nor in three sections from two localities in the Jackfork south of the district, but feldspar has been recognized in it elsewhere.[16] The rocks from which some of the thin sections were cut have been crushed to a fine-grained mass of irregularly interlocking sutured quartz grains. Some of the rocks that have been less intensely crushed have a network of fine-grained crushed quartz surrounding uncrushed grains. All the sections show some fine-grained clay mineral, presumably dickite, but some have much more of this material than others. Common accessories are zircon, muscovite, sericite, limonite, and titanite and its alteration products. One slide contains fine shreds and plates of a yellow nonpleochroic mineral that may be alunite. Some of these minerals and cinnabar are considered in more detail in the section on "Ore and gangue minerals."

[16] Miser, H. D., and Purdue, A. H., op. cit, (Bull. 808), p. 76.



A. EXPOSURE OF JACKFORK SANDSTONE IN RAILROAD CUT IN NE¼NE¼ SEC. 4, T. 7 S., R. 23 W.

Looking west. Stratigraphic position 500 feet below top of Jackfork. Thrust fault near middle of exposure and parallel to underlying beds on right cuts out massive sandstone bed in overriding block on left, as indicated by dashed line. Sandstone bed 1 foot thick about 3 feet below thrust fault is repeated just below center of exposure by smaller related fault. Such features could not be recognized except in artificial cuts.

B. EXPOSURE OF "RIBBON" SHALE IN JACKFORK SANDSTONE IN RAILROAD CUT IN SW¼NE¼ SEC. 4, T. 7 S., R. 23 W.

Looking west. Banded appearance is caused by alternating layers of light and dark shale.

ATOKA FORMATION

Large areas of the Atoka formation, which overlies the Jackfork sandstone, lie both to the north and to the south of the quicksilver district as mapped. The map was not extended far enough to include any of the Atoka except a few small patches along its northern and southern margins. In a general way, the formation is less resistant to erosion than the Jackfork but more resistant than the Stanley.

The Atoka is composed of about equal parts of sandstone and shale. The sandstone is grayish brown, is ordinarily micaceous, and breaks along bedding planes into slabs 1 to 6 inches thick. Much of the shale is black and breaks into smaller fragments than the shale of the Stanley and the Jackfork.

It is difficult or impossible to distinguish specific outcrops of this formation from either the Stanley or the Jackfork. In general, however, when large areas are mapped the Atkoa can be readily identified. Miser and Purdue,[17] in this connection, say:

> The usual color of the exposed sandstone [Atoka] is brown. This color, together with the large content of shale, makes the formation easily distinguishable from the Jackfork sandstone. * * * It [the shale of the Atoka] differs from the shale of the formations beneath [Stanley and Jackfork] in being exposed in fewer places, in having a more basic appearance, and in breaking down into small splinters and granular fragments instead of flakes.

Miser and Purdue [18] also note that fragments of plants and fossil wood are common in the formation. Some of this material was found in the Atoka in the vicinity of the quicksilver district.

The constitution of the sandstone of the Atoka formation as revealed by two thin sections, one from rock near Antoine Creek and one from rock near the west end of the district, is apparently similar to that of the Jackfork. The Atoka may be distinguished from the Jackfork by a greater proportion of feldspar, a more dirty appearance, more muscovite and biotite, and less zircon and titanite. The sections studied contain considerable limonite, but this may be a local feature. In the section from the Atoka near Antoine Creek the larger quartz grains are surrounded by a groundmass of finer quartz grains. This is probably the result of crushing during structural deformation.

LOWER CRETACEOUS ROCKS

PIKE GRAVEL MEMBER OF TRINITY FORMATION

As stated by Miser and Purdue,[19]

> The Trinity formation [part of the Comanche series, of Lower Cretaceous age] is exposed in a belt which trends eastward along the southern boundary of the DeQueen and Caddo Gap quadrangles and hence lies within the northern border of the Gulf Coastal Plain. This belt has irregular north and south boundaries, is narrowest on the east, and is continuous except where the formation is concealed by surficial deposits of alluvium and terrace remnants along the streams that cross the belt.

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[17] Miser, H. D., and Purdue, A. H., op cit. (Bull. 808), pp. 77–78.

[18] Idem, p. 77.

[19] Idem, p. 80.

The formation is separated from the Pennsylvanian rocks by a profound unconformity; it dips to the south at about 100 feet to the mile.

According to Miser and Purdue [20] the Trinity formation ranges in thickness from 70 to more than 600 feet. The Pike gravel member is the basal member of the formation and its thickness ordinarily ranges between 20 and 50 feet, although near Pike, a few miles south of the quicksilver district, it may attain 100 feet.

The southwestern part of the quicksilver district is partly covered by the Pike gravel member; and a few miles west of the mapped area the district is terminated by a continuous overlapping blanket of the gravel. Within the area mapped exposures of Pike gravel are confined to the southern Jackfork ridge west of the Little Missouri River. Some pebbles and cobbles, presumably from the gravel, were found at a few places in Couch Valley and on some of the southern ridges in the eastern part of the district. These are either remnants of larger areas of the gravel or have been transported by erosion from areas of the gravel to their present position. The thickest development of the gravel in the district is about 50 feet thick.

The Pike gravel is poorly indurated, clay-bound, and made up of well-rounded pebbles of novaculite and sandstone in a ratio of about 9 to 1. Cobbles as much as 10 inches in diameter lie near the base of the member, but most of the pebbles are about 2 inches in diameter.

RECENT SEDIMENTS

ALLUVIUM

Within the quicksilver district alluvium of Quaternary age is found along the valleys of Buck and Stony Creeks, the Little Missouri River, South Woodall Creek from a point about 1½ miles east of State Highway 27 to the point where the creek turns northward and enters the northern band of Jackfork sandstone, Wall, and Antoine Creeks. It extends for a little more than a mile up Cowhide Creek from its mouth and for shorter distances up some of the other tributaries of the Little Missouri River and Antoine Creek. At most places the alluvium does not reach altitudes of more than 30 feet above the adjacent stream, but along the Little Missouri River some terrace gravel and finer alluvial material that attain altitudes of nearly 80 feet above the river have been included with the alluvium. All the streams flow on bedrock.

The alluvium is composed principally of fine sand and silt and ordinarily makes the best soil in the district. The terrace material and locally even the alluvium is in places made up of gravel, the pebbles of which may reach 6 inches in diameter. Most of the pebbles and cobbles are novaculite, but some are sandstone.

[20] Miser, H. D., and Purdue, A. H., op. cit. (Bull. 808), pp. 80–81.

STRUCTURE

The rocks of the Athens Plateau were originally laid down in a horizontal or nearly horizontal position. Miser and Purdue [21] have shown that the folding and faulting of the rocks of the plateau and of the Ouachita Mountain anticlinorium just to the north were produced by mountain-making forces in the form of thrusting from the south in middle Pennsylvanian time. The action of these forces resulted in the repetition of bands of the Stanley, Jackfork, and Atoka formations across the Athens Plateau. Regarding this plateau [22] they say, "The general structure of the Athens Plateau is that of a southward-sloping monocline corrugated with many minor folds. These folds are nearly parallel and have a general south of west trend."

In a general way the quicksilver district may be considered as including three of the east-west bands of rocks that traverse the plateau, a northern and a southern band of Jackfork and a central band of Stanley. A thrust fault, the Cowhide fault, separates the northern band of Jackfork sandstone from the Stanley shale, which lies south of it. This and another thrust fault, the Amity fault, together with numerous tear faults, constitute the principal structural features of the district.

Plate 2 shows some of the structural features of the district. The general trend of the rocks in all but the easternmost 6 miles of the district is about N. 75° E. The strikes in that area are not very uniform, and it is difficult to determine the general trend, though the ordinary range is from about N. 45° W. to east-west, and N. 75° W. may approach the mean.

Except for a small area in which several folds were recognized (see p. 32) southerly dips prevail throughout the district. Northerly dips have been found in a few places, but they are very local. Again except in the area of the folds, the tops of the beds in the district were found, wherever tops could be determined, to face the south. In other words, the rocks are not overturned.

DETERMINATION OF TOPS OF BEDS

Observations on beds that result in a definite conclusion as to which side is the top are possible only at exceptional localities within the district. The best places were found along State Highway 27 and in some of the mine openings. Of particular value is a feature common in the DeQueen and Caddo Gap quadrangles which Miser [23] has termed "rubbly bottom." Wide experience has convinced Miser that this phenomenon is developed only on the bottoms of the beds. It consists of hummocky, irregular surfaces, with sharp indentations about

[21] Miser, H. D., and Purdue, A. H., op. cit. (Bull. 808), pp. 117-126. Miser, H. D., Structure of the Ouachita Mountains of Oklahoma and Arkansas: Oklahoma Geol. Survey Bull. 50, 1929.

[22] Miser, H. D., and Purdue, A. H., op. cit. (Bull. 808), p. 123.

[23] Miser, H. D., personal communication.

three-fourths of an inch deep between flat-surfaced hummocks that reach a maximum diameter of 2 feet. Other valuable criteria for the determination of tops in the district have been described by Stearn.[24] He lists the following five criteria: (1) Wave marks; (2) cross laminations; (3) fossils; (4) gradations; and (5) pitted upper surfaces. The pitted upper surfaces (pl. 6, *B*) are described in detail by Stearn.

The stratigraphic sequence, plus the fact that the tops of the beds face south, constitute the principal evidence for the thrust fault along the north side of the medial Stanley lowland.

PARALLEL FOLDS

Tightly compressed synclinal folds essentially parallel to the general trend of the rocks are not common in the quicksilver district. Two relatively large synclinal folds of this nature were recognized, and the noses of at least a dozen small folds, both anticlinal and synclinal, were observed but could not be followed for more than a few hundred feet on either limb. Probably the lack of sufficiently good outcrops prevented the recognition of other folds.

The folds just mentioned, with one exception, lie in the northern band of Jackfork sandstone in the eastern half of the district, from a point about 3 miles east of State Highway 27 in the southeastern part of sec. 29, T. 6. S., R. 24 W., eastward nearly to the center of sec. 29, T. 6 S., R. 23 W. The exception consists of a small fold in the southwestern part of sec. 33, T. 6 S., R. 23 W.

The most extensive synclinal fold occupies the eastern 2½ miles of the zone of folding just described. It is bounded on the northeast by the Amity fault, which there separates the Jackfork from the Stanley, and on the south by the Cowhide fault, which trends east through sec. 25, T. 6 S., R. 24 W., and secs. 30 and 29, T. 6 S., R. 23 W. The trend of the axial plane of the fold is nearly east in sec. 24, T. 6 S., R. 24 W., but is about S. 62° E. from that locality eastward. The fold is open and asymmetrical, the northern limb in most places having a steeper dip than the southern. The fold appears to be more tightly compressed toward the east, near the intersection of the two bounding faults. In that area also the fold pitches as much as 60° W., whereas farther west, where it is not so tightly compressed, the westerly pitch is only about 35°.

The other relatively large synclinal fold can be traced for about 1½ miles from the southeastern part of sec. 29, T. 6 S., R. 24 W., to a point near the northeast corner of sec. 28, T. 6 S., R. 24 W. Its axial plane strikes about N. 65° E. and appears to be nearly vertical. This syncline is not overturned, but it is tightly folded. The average dip of both limbs may approach 65°.

[24] Stearn, N. H., Structure from sedimentation at Parnell Hill quicksilver mine, Arkansas: Econ. Geology, vol. 29, pp. 146-156, 1934.

An anticlinal nose that is complicated by minor crumples is exposed in the SW¼ sec. 23, T. 6 S., R. 24 W. A more simple but otherwise similar one has been mapped in the northeastern part of sec. 28, T. 6 S., R. 24 W. These two noses trend toward each other and appear to be on the same fold. Several other small folds are present in the part of the area of folding south of the last-described syncline and the two anticlinal noses.

Projected trend lines seem to indicate that the large eastern syncline lies south of the anticline, marked by the two exposed noses, which in turn lies south of the western syncline. In an area of such complicated structure, however, where exposures are poor or lacking, projection of trend lines gives results that must be considered possibilities only, rather than established facts.

The folds described above and many others on the Athens Plateau are regarded as being some of the earlier results of the compression of the Ouachita geosyncline in the form of thrusting from the south in middle Pennsylvanian time. Continued application of these compressive forces resulted in the thrust faults described below.

THRUST FAULTS

Thrust faults that trend in general about parallel to the strike of the rocks and dip to the south are the most conspicuous structural features of the quicksilver district and are of paramount importance in connection with the deposition of the ore.

COWHIDE AND OTHER FAULTS

The most extensive thrust fault in the district, which is here named the Cowhide fault, has been mapped, with only minor offsets, from one end of the district to the other. Its line of outcrop is slightly wavy. From the west end of the mapped area to the southwestern part of sec. 29, T. 6 S., R. 23 W., the fault and its southern branch bound the north side of the Stanley shale belt. Near the center of sec. 30, T. 6 S., R. 23 W., the fault splits. The main Cowhide fault continues eastward along the south side of the syncline already described and joins the Amity fault near the center of sec. 29, T. 6 S., R. 23 W. The southern branch follows down Suck Hollow, extends up the small valley southwest of Bemis Hill, and joins the Amity fault near the southeastern tip of Bemis Hill, in the NE¼ sec. 33, T. 6 S., R. 23 W.

Two smaller thrust faults are mapped in the southern part of the district in the vicinity of Antoine Creek. One of these was identified for a little less than a mile along the north side of the alluvial flat that extends up the small creek along the south line of sec. 34, T. 6 S., R. 23 W. The other, which was mapped for a longer distance, lies still farther south and trends northwestward from the eastern edge of the district through the southwest corner of sec. 34, T. 6 S., R. 23 W., and was traced for about two-thirds of a mile beyond.

The contact that trends southwest from the north branch of the Cowhide thrust fault in the SW¼ sec. 29, T. 6 S., R. 23 W., for about half a mile into the NE¼ sec. 31, T. 6 S., R. 23 W., and thus bounds a part of the east end of South Woodall Valley, is probably best interpreted as a thrust contact. Similarly the northern boundary of the promontory of Jackfork sandstone that juts out from the south across the Stanley shale lowland nearly as far as the Gap Ridge sandstone member in the southeastern part of sec. 31, T. 6 S., R. 24 W., and extends for a short distance eastward into sec. 32 is mapped as a thrust.

A thrust fault diverges from the Amity fault north of Bare Rock, in the northern part of sec. 24, T. 6 S., R. 24 W., and extends thence southwestward along the northern boundary of the northern band of Jackfork, between that formation and the Atoka. The fault between the Jackfork and Atoka in the southern part of secs. 22 and 23 and the northern part of sec. 27, T. 6 S., R. 24 W., is probably part of the same thrust, but the area between was not mapped far enough north to show it continuously. The thrust fault farther west, near the northern edge of the district, in the vicinity of the Little Missouri River, may also be part of the one just described.

Thrust faults other than those mapped and described probably exist in the district. It does not seem likely that all the thrust movement would have been taken up along the few definite planes mentioned. Where thrust zones nearly parallel the bedding planes in a region of thick sandstone and shale sequences almost totally lacking in horizon markers, a large amount of thrusting probably would take place along bedding planes and would be most difficult to identify. Some evidence of this type of yielding to thrust forces has been recognized and is considered in the section on "tear faults" (p. 38). It is felt that the aggregate thrust movement between bedding planes may be of the same order of magnitude as that along the thrusts mapped—probably several thousand feet.

Although the strikes of the thrust faults and the rocks are nearly parallel, there are some divergences between the two in both the overriding and the overridden blocks. The Stanley shale at the east end of South Woodall Valley is completely cut out by the south branch of the Cowhide fault and the fault that meets it in the SW¼ sec. 29, T. 6 S., R. 23 W. East of that point the Jackfork sandstone of the overriding block lies against Jackfork sandstone of the overridden block. Another example of truncation of the rocks of the upper block is furnished by the 160-foot sandstone zone 2,240 feet below the top of the Stanley (Stearn's Parker Hill member), which in the northern part of sec. 3, T. 7 S., R. 25 W., lies about 900 feet above the Cowhide fault, but which in the northeastern part of sec. 5, less than 2 miles distant, is cut out by the fault.

Truncation in the lower or northern block apparently is not as great as in the upper block. At one place west of State Highway 27 a sandstone bed crops out at the fault. The bed was followed eastward for 600 feet, and at that distance it lay 150 feet north of the Cowhide fault.

A maximum of 4,800 feet of the Stanley shale is exposed in South Woodall Valley. In most parts of the medial lowland the exposed thickness is much less. As Miser gives 6,000 feet as the thickness of the formation on the Athens Plateau, a minimum of 1,200 feet and a maximum of the full 6,000 feet plus an undetermined thickness of Jackfork east of the east end of South Woodall Valley has been cut out by the thrust faulting in the district.

At no place was a major thrust plane actually observed. The rocks on the south sides of the thrust faults are at many places greatly contorted. The extremely intricate and complicated minor structural features of Bemis Hill and Hill 2 west of it between the two branches of the Cowhide fault well exemplify this condition. The contrast between the structure of the hills just mentioned and the relatively simple synclinal fold adjacent on the north across the Cowhide fault is striking. Contorted Stanley shale is well exposed, especially at times of low water, along the east side of the Little Missouri River where it crossses from sec. 1, T. 7 S., R. 26 W., to sec. 6, T. 7 S., R. 25 W. A small overturned fold, exposed along a small creek a short distance south of the fault about 1,000 feet northeast of the Old Argentine prospect, shows movement up the dip from the south. Its axial plane conforms approximately with the general strike and dip of the rocks in the vicinity.

The traces of the thrusts on the surface are in most places only slightly wavy. This feature indicates that the thrust planes are steep, at least near the surface.

Certain cross folds and tear faults, which are related to the thrust faults, are more numerous in the overriding blocks not far from the outcrops of the thrust-fault planes than elsewhere. This distribution of such structural features helps to locate the thrust faults in the field. These cross folds and tear faults are considered in detail beyond.

As might be expected from the structural interpretation described above, the hydrothermal minerals are distributed close to the fault in the upper block of the Cowhide thrust throughout the district. The hydrothermal minerals include quartz in thin veins, widespread dickite, cinnabar, and others. The mineralization is also discussed beyond (pp. 45–53).

AMITY FAULT

The Amity fault (fig. 4) is one of the major structural features of the eastern part of the quicksilver district. It is described separately because in its major features it differs from all other faults in the district. This fault was described by Miser and Purdue [25] but not named by them. It appears on the geologic map of Arkansas and was named by Branner [26] in his circular on the quicksilver district. The fault runs northwestward from its intersection with the Cowhide fault near the southeastern tip of Bemis Hill (pl. 2 and fig. 10), in the NE¼ sec. 33, T. 6 S., R. 23 W., to the point where it leaves the mapped area, in the northern part of sec. 24, T. 6 S., R. 24 W., and for several miles beyond. No observations on the dip of the fault plane were obtained. Locally the trace of the fault on the surface is meandering, and a flat southwestward dip is indicated. The fault forms the boundary between the Stanley shale area on the northeast and the Jackfork sandstone and Atoka formation on the southwest.

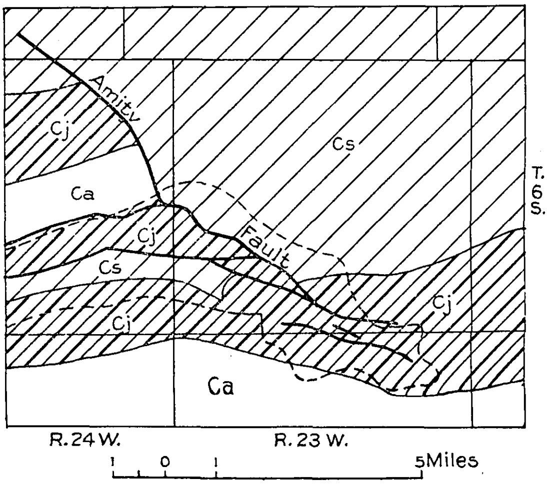


FIGURE 4.—Sketch illustrating relation of the Amity fault to other thrust faults (mapped area outlined by dashed line; areal geology outside of mapped area modified from Arkansas State geologic map). Cs, Stanley shale; Cj, Jackfork sandstone; Ca, Atoka formation.

The nature and extent of the movement along the Amity fault are somewhat obscure. Several interpretations are possible. Miser and Purdue [27] say that it is "a cross fault, having a northwesterly trend and with its upthrow on the northeast side. * * * Although the hade was not observed, the fault is thought to belong to the thrust variety because of the almost exclusive occurrence of this type in most of the Ouachita region. Much of the displacement may have been horizontal—that is, in a southeastward direction on the northeast side of the fault and in a northwestward direction on the southwest side."

Branner [28] says that the Amity fault "represents a tear movement having a vertical component in the order of several miles and a northwest-southeast movement of perhaps equal or greater magni-

[25] Miser, H. D., and Purdue, A. H., Geology of the DeQueen and Caddo Gap quadrangles, Ark.: U. S. Geol. Survey Bull. 808, p. 125, 1929.
[26] Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Inf. Circ. 2, p. 11, 1932.
[27] Miser, H. D., and Purdue, A. H., op. cit., p. 125.
[28] Branner, G. C., op. cit., p. 11.

tude. The magnitude and character of the movement have not been determined in detail."

Figure 4 illustrates the writers' interpretation of the Amity fault as a flat thrust fault. It differs from other thrust faults in the district in having a northwesterly trend, diagonal to the other major structural trends, a flat southwestward dip, and a large horizontal displacement, which cannot be less than 2 miles and may be as much as 7 miles, depending on whether the Jackfork ridge east of the fault is to be correlated with the Jackfork ridge west of the fault along the northern edge of the mapped area or with the one farther north beyond the band of Atoka (fig. 4). The rocks southwest of the fault have moved northwestward relative to those northeast of the fault.

TEAR FAULTS

FAULTS OF NORTHEASTWARD TREND

Tear faults having a northeasterly trend are common in the part of the district west of the central part of sec. 32, T. 6 S., R. 24 W. Sixteen faults of this class are mapped. These faults appear to be confined to the southern or overriding block of the Cowhide fault. Only two of them clearly cut the Cowhide fault—the western branch of the tear fault that cuts off the east end of Parnell Hill near the center of sec. 6, T. 7 S., R. 25 W., and the tear fault that extends from sec. 31, T. 6 S., R. 24 W., into the NW¼ sec. 32, T. 6 S., R. 24 W. The first offsets the Cowhide fault about 350 feet, and the second about 300 feet. The fault west of the Little Missouri River, which is mapped as far as the north boundary of sec. 12, T. 7 S., R. 26 W., may cut the Cowhide fault in sec. 1, T. 7 S., R. 26 W., beneath the alluvium along the river.

Four of the faults of this group are of relatively small displacement and were recognized only where they cut the Gap Ridge sandstone member of the Stanley shale. Two of them are west of State Highway 27 and within a mile of it. The other two are near the west end of the mapped area. The rest all offset not only the Gap Ridge sandstone member but the Stanley-Jackfork contact as well. The two largest ones, one about 1½ miles west of State Highway 27 and the other just west of the Little Missouri River, displace the top of the Jackfork and extend southward into the Atoka.

FAULTS OF NORTHWESTWARD TREND

East of the central part of sec. 32, T. 6 S., R. 24 W., the tear faults in general trend northwest instead of northeast. They are not as numerous as the northeastward-trending faults farther west. Nine were mapped in the upper block of the Cowhide fault. Of these, only one cuts the thrust. This fault displaces the Cowhide thrust about 500 feet in the northwestern part of sec. 33, T. 6 S., R. 24 W.

The southern limb of the large syncline (p. 32) north of the Cowhide thrust, south of Bare Rock, is broken by at least three northwestward-trending tear faults having displacements of about 100 feet each. Two similar faults were recognized in the NW¼ sec. 26, T. 6 S., R. 24 W. A tear fault runs northwest across the SW¼ sec. 27, T. 6 S., R. 23 W.

DISPLACEMENT ON THE TEAR FAULTS

The tear faults appear to be nearly vertical. The relative importance of the horizontal and vertical components of the movements along them is not known.

On all but four of the sixteen northeastward-trending faults the southeast side has moved northeastward relative to the northwest side. Three of the four exceptions are on the faults of relatively small displacement, which were recognized only where they cut the Gap Ridge sandstone. The other exception is on the fault just east of the Little Missouri River. The west branch of that fault shows the usual northeast displacement of the southeast block. Similarly, the Jackfork-Stanley contact is offset in the usual direction by that fault, but the block east of Parnell Hill has moved southwestward relative to the Parnell Hill block.

On all the northwestward-trending faults except two—the one in the northeastern part of sec. 31, T. 6 S., R. 23 W., and the one in the SW¼ sec. 27, T. 6 S., R. 23 W.—a northwesterly displacement of the southwest block is indicated.

The offsets along the tear faults are less in the Stanley shale than in the Jackfork sandstone, apparently because much of the displacement has been absorbed by the shale between the Jackfork and the Gap Ridge sandstone member of the Stanley. Possibly some of the movement absorbed by the shale has been taken up by thrusting along the shale bedding planes. Quantitatively, the amount of movement absorbed by the shale between the Gap Ridge sandstone and the top of the Stanley is indicated by a measurement of the aggregate northeasterly displacement of the Jackfork-Stanley contact along all the northeastward-trending faults as compared to the aggregate northeasterly displacement of the Gap Ridge sandstone member. The first is about 15,600 feet, and the second about 9,350 feet. Thus about 6,250 feet has been absorbed by the intervening shale. Between the Gap Ridge sandstone and the Cowhide thrust fault all of the 9,350-foot displacement has been absorbed with the following exceptions: The horizontal component of displacement along the thrust fault itself is 650 feet, as shown by its exposures north of the east end of Parnell Hill and in the NE¼ sec. 32, T. 6 S., R. 24 W.; it may also be somewhat displaced along the tear fault under the alluvium of the Little Missouri River.

Thus it is obvious (1) that, with the exception of a few minor faults, the tear faults are localized in the overriding block of the major thrust fault, (2) that the tear faults trend northeastward in the portion of the district west of the central part of sec. 32, T. 6 S., R. 24 W., and northwestward in the eastern portion of the district, and (3) that, with a few minor exceptions, the beds along the tear faults are displaced to the northeast on the southeast sides of the faults that run northeastward and to the northwest on the southwest sides of the faults that run northwestward.

CROSS FOLDS

In addition to the thrusting and tear faulting, deformational activity has produced an east-west crustal shortening that has resulted in small, sharp folds whose axes plunge about parallel to the steeply southward-dipping rocks and whose axial planes, in general, are about parallel to the trend of the tear faults in their vicinity. Many of these folds are too small to show on the map, but the structural symbols indicate some of them—for example, in the southwestern part of sec. 10 and the northwestern part of sec. 15, T. 7 S., R. 26 W., along the Little Missouri River below the mouth of Cowhide Creek; in the southern part of sec. 5 and the northern part of sec. 8, T. 7 S., R. 25 W.; and near the Palmer prospect in sec. 26, T. 6 S., R. 24 W. A typical cross fold (pl. 6, *A*) has been well exposed by mining operations near the center of Parnell Hill. This fold has been described in detail by Stearn.[29]

The cross folds are present in both the Stanley and the Jackfork south of the Cowhide thrust fault but are not important structural features of the Jackfork north of that fault, although some are present there. The cross folds in the overridden block north of the Cowhide fault are probably related to the thrust fault that lies still farther north and has been mapped in a few places along the northern border of the district. Where this northern thrust was observed, numerous cross folds were found adjacent to it. There are more cross folds in the northern overridden block of the thrust in the eastern part of the district than in the western part. The folds die out in number and intensity southward from the Cowhide fault and are not very numerous along the southern border of the mapped area. In the eastern part of the district, south of the thrust, the cross folds are more numerous and complicated than elsewhere. This is particularly true of the area between the two branches of the Cowhide thrust. In the eastern part of the district there also are more exceptions to the general rule that the axial planes of the folds trend about parallel to nearby tear faults. Only a few cross folds were seen in the large Stanley shale area northeast of the Amity fault. The exposures in that area, however, are so poor and scarce that many such small folds may have been overlooked.

A genetic connection between the thrust faulting, tear faulting, and cross folding is indicated by the facts that (1) the southern overriding

[29] Stearn, N. H., Mining and furnacing quicksilver ore: Eng. and Min. Jour., vol. 134, p. 23, 1933; The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, pp. 19–20, 1936.

block of the major thrust fault is principally affected by the cross folding and tear faulting, (2) the number and intensity of the cross folds decrease with increased distance from the underlying thrust, (3) the tear faults themselves are not greatly deformed, and (4) the trends of the tear faults and the axial planes of the cross folds are in general accord. The map indicates that the cross folds were not caused by drag along the tear faults.

The amount of east-west crustal shortening due to the cross folding is difficult to determine accurately, principally because of the numerous small cross folds that cannot be shown on a map of the scale used. A minimum figure for the amount of shortening due to cross folding not far south of the thrust fault can be obtained from a study of the Gap Ridge sandstone. The horizontal distance from the west end of the district to the east end of South Woodall Valley is 94,200 feet. From the map (pl. 2) it is seen that the aggregate crustal lengthening of the Gap Ridge sandstone member in this distance due to the tear faulting is 4,955 feet. The difference between these two distances is 89,245 feet and is the horizontal distance over which the Gap Ridge sandstone is exposed. The measured length of outcrop of the Gap Ridge sandstone, measuring around all the mapped cross folds, is 94,730 feet. The difference between the measured length of outcrop and the direct horizontal distance over which the sandstone is exposed is 5,485 feet ($94,730-89,245=5,485$). This figure for the amount of shortening due to cross folding is a minimum because of the many folds, too small to show on the map, that could not be included in the measured length of the Gap Ridge sandstone outcrop. The length of the outcrop minus the direct horizontal distance equals the total shortening of 530 feet ($94,730-94,200=530$). Thus it is seen that the lengthening due to tear faulting nearly equals the shortening due to cross folding, the difference being only 530 feet.

Thrusting from the south, resulting in close folds and thrust faults that trend east-west, would not ordinarily be considered a process that would result in east-west crustal shortening such as is indicated by the cross folds in the district. Gilluly [30] has suggested that greater thrust movement in the central part of the district than either east or west from that part might develop tear faults such as those found (fig. 5). Furthermore, these tear faults would tend to converge toward the zone of greatest thrust movement, and movements along them would result in east-west compression that might produce cross folds or buckles like those present in the district.

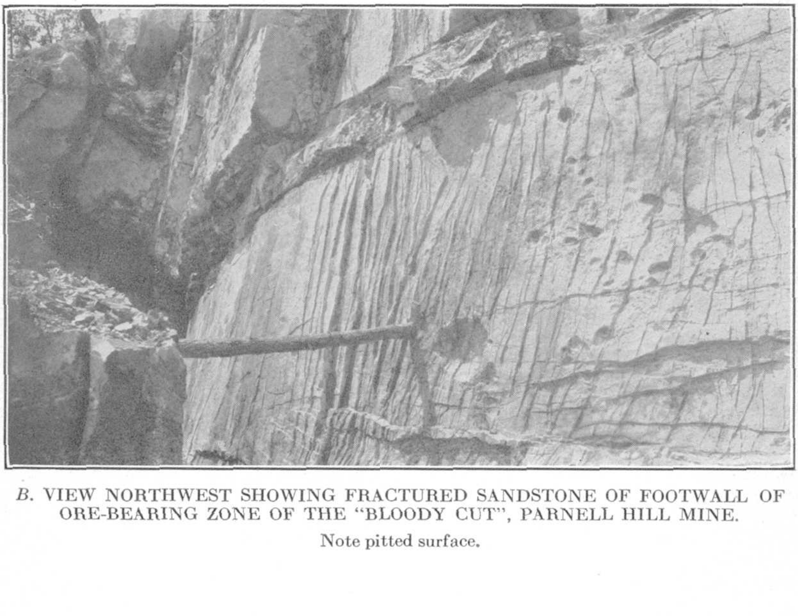
Stearn [31] believes that the cross folding took place by east-west compression after initial compression from the south and that the east-west compression was in turn followed by another period of

[30] Gilluly, James, personal communication.

[31] Stearn, N. H., op. cit., p. 11.

A. AIRPLANE VIEW OF PARNELL HILL, SHOWING CROSS FOLD EXPOSED BY MINING OPERATIONS.

The open cut shown in the upper left part of the photograph nearly follows the axial plane of the fold.



B. VIEW NORTHWEST SHOWING FRACTURED SANDSTONE OF FOOTWALL OF ORE-BEARING ZONE OF THE "BLOODY CUT", PARNELL HILL MINE.

Note pitted surface.

thrusting from the south during which the tear faults developed. He says:

> During the period of buckling the already partially up-ended beds in the cinnabar district were subjected to east-west shortening which produced cross folding and faulting. Especially susceptible to the east-west stresses were the Stanley and Jackfork facies which lay along the south edge of the regional thrust fault. * * * During and after the period of yielding to the east-west stress the continued thrusting from the south seems to have pushed northward along the thrust-fault plane irregular segments of the crumpled formations which lay along its south edge. At this time the steep southward dip of the up-ended beds may have been increased to the present nearly vertical attitude.

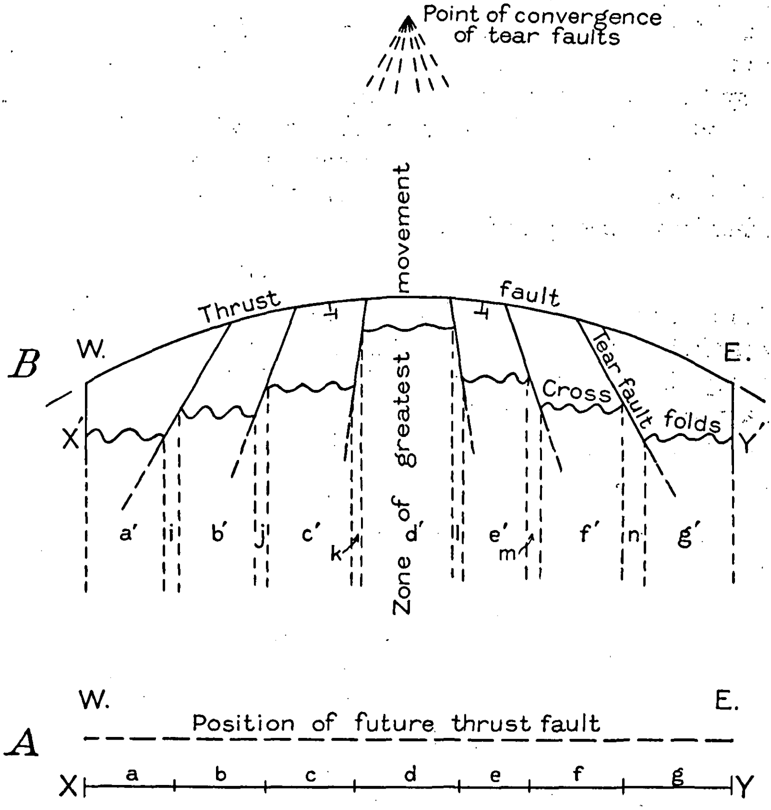


FIGURE 5.—Plan sketches illustrating manner in which tear faults and cross folds may have developed in the Arkansas quicksilver district. *A*, Area of steeply folded rocks that strike east-west, parallel to xy, before thrusting. A single horizon (xy), such as the Gap Ridge sandstone member, running through the area, is indicated. *B*, Same area after thrusting northward, with greater forward movement in the central part, although a large component of the movement probably was upward.

A: $a+b+c+d+e+f+g=xy$. *B*: Owing to shortening by cross folding, $a'<a$, $b'<b$, $c'<c$, etc. $(a'+i)+(b'+j)+(c'+k)+(d'+l)+(e'+m)+(f'+n)+g'=x'y'$. $x'y'=xy$. Therefore the lengthening ($i+j+k$, etc.) due to tear faulting equals the shortening ($a-a'$, $b-b'$, $c-c'$, etc.) due to cross folding.

Thrust movements from the south, without an independent and intermediate period of east-west compression, appear to be adequate to produce the structural features of the district. One difficulty with a hypothesis involving the intermediate east-west compression is the localization of the cross folds and tear faults in the overriding block close to the major thrust.

FRACTURES

The relatively incompetent shales of the district appear to have responded to the severe structural deformation largely by rock flowage, complicated crumpling, and bedding-plane thrusting. The sandstones yielded partly in the same manner as the shales, but, being more competent, they ultimately were locally fractured and even brecciated. Complicated fracture systems formed along shear zones and faults and are particularly well developed on the noses and limbs of the cross folds. Well-fractured sandstone has been found associated with cross folds that deflect the beds a few inches only. Wherever a fracture system can be made out, it is nearly vertical and about parallel to the plunging axis of the cross fold with which it is associated. Plate 6, *B*, illustrates the fractures developed on some cross folds. The fractures have opened somewhat since they were exposed to the weather by mining operations.

STRUCTURE OF THE CRETACEOUS ROCKS[32]

The Pike gravel member of the Trinity formation was deposited in Lower Cretaceous time on the flat surface of the Ouachita peneplain. The only structural movements that have affected it have been uplift and a gentle tilting toward the south. This tilting has resulted in the southerly dip of the Pike gravel, which ranges from about 60 to 100 feet to the mile.

SUMMARY

The bedrocks of the quicksilver district were laid down in a nearly horizontal position in a broad geosyncline. In middle Pennsylvanian time the rocks were compressed during a long period of thrusting from the south. The initial result of the compression was the formation of broad folds with east-west axes. As deformation continued the folds were tightly compressed, and finally the rocks began to yield by the formation of thrust faults. Near the central part of the district thrust movement was greater than elsewhere, perhaps owing to the greater resistance offered by the crust near the ends of the district. The greater movement in the central part of the district resulted in the formation of tear faults and cross folds in the overriding block of the principal thrust fault and locally elsewhere.

DEVELOPMENT OF TOPOGRAPHIC FEATURES

Cretaceous deposits of gravel, sand, and clay once covered this area.[33] They were deposited on a surface of low relief that sloped southward about 80 feet to the mile when the Gulf of Mexico covered most of the south-central United States. As the waters of the Gulf

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[32] Miser, H. D., and Purdue, A. H., op. cit. (Bull. 808), p. 126.
[33] Idem, pp. 136–145.

withdrew, streams developed on the southeastward-sloping surface, trenching themselves rapidly through the unconsolidated formations to the underlying hard rocks, where, confined by their valleys, they were constrained to continue in their southeast courses, cutting across both the hard and soft layers of the underlying formations. Erosion has since removed all the Cretaceous formations except along the southern edge of the west end of the area mapped, but the master streams—the Little Missouri River and Antoine Creek—still follow their old southeasterly courses. Such streams are called superimposed. It should be pointed out, however, that Antoine Creek follows a major fault across the sandstone formations, a zone of weakness that would naturally be sought out by any stream seeking egress to the southeast. The writers have not made a study of a sufficiently wide area to determine whether structure or superposition was the controlling factor in its localization.

The perfection of the trellised pattern of the drainage of the area shows a remarkable adjustment of the tributaries of Antoine Creek and the Little Missouri River to the rock structure of steeply southward-dipping formations of shale and sandstone. The valleys of the tributaries are in the easily eroded shales and follow their strike; the sandstones form the ridges. The tributaries, flowing down the ridges along lines of weakness, joints, and faults, soon developed both east and west laterals in the shale layers. These laterals rapidly cut headward, thus giving the trellis pattern and developing the flatiron topographic forms so characteristic of the region.

The fact that South Woodall Valley drains northward instead of eastward needs explanation. Obviously the massive sandstone beds at the east end of the valley were a barrier to any stream, but the north ridge offered as great an obstacle. Furthermore, an eastward-flowing stream would have a shorter course to Antoine Creek, therefore a steeper gradient and greater eroding power. Hence it seems probable that early in the present erosion cycle South Woodall Valley was drained by a stream flowing southward across Wall Mountain, possibly in sec. 35, T. 6 S., R. 24 W., to empty into Cany Creek (pl. 7). The massive sandstone beds impeded erosion, so downcutting was slow, but to the east Antoine Creek occupied a crushed zone, hence was able to lower its course rapidly across the ridge. Upper Antoine Creek and its tributary, Woodall Creek, flowed over easily eroded shale and were able to grade their beds as fast as Antoine Creek lowered its course. A northward-flowing tributary of Woodall Creek and a northeastward-flowing tributary of Antoine Creek cutting headward reached South Woodall Valley. As the north ridge was more easily eroded than Wall Mountain, they captured the south drainage.

ORE DEPOSITS

DISTRIBUTION OF METALLIC MINERALS IN THE OUACHITA REGION

Metalliferous deposits, including minerals of antimony, copper, lead, zinc, manganese, iron, and quicksilver, have been found throughout the southern Ouachita Mountains from McCurtain County, Okla., to western Hot Spring County, Ark.[34] Most of these are merely reported occurrences, but in a few localities there has been a small production. Stibnite deposits, some of which are richly argentiferous, argentiferous lead-zinc deposits with a little copper, and quicksilver deposits have been described.

Known quicksilver deposits are limited to a narrow belt in southwestern Arkansas about 26 miles long and about 6 miles in maximum width, extending in a direction north of east from sec. 13, T. 7 S., R. 27 W., to sec. 5, T. 7 S., R. 22 W. (pl. 7). Reports, as yet unsubstantiated, of quicksilver occurrences to the east and west along the same trend may extend the present limits. The discovery of quicksilver more than a short distance south of the present southern limit is precluded by the Cretaceous overlap. A detailed discussion of the quicksilver occurrences is given on pages 64–88.

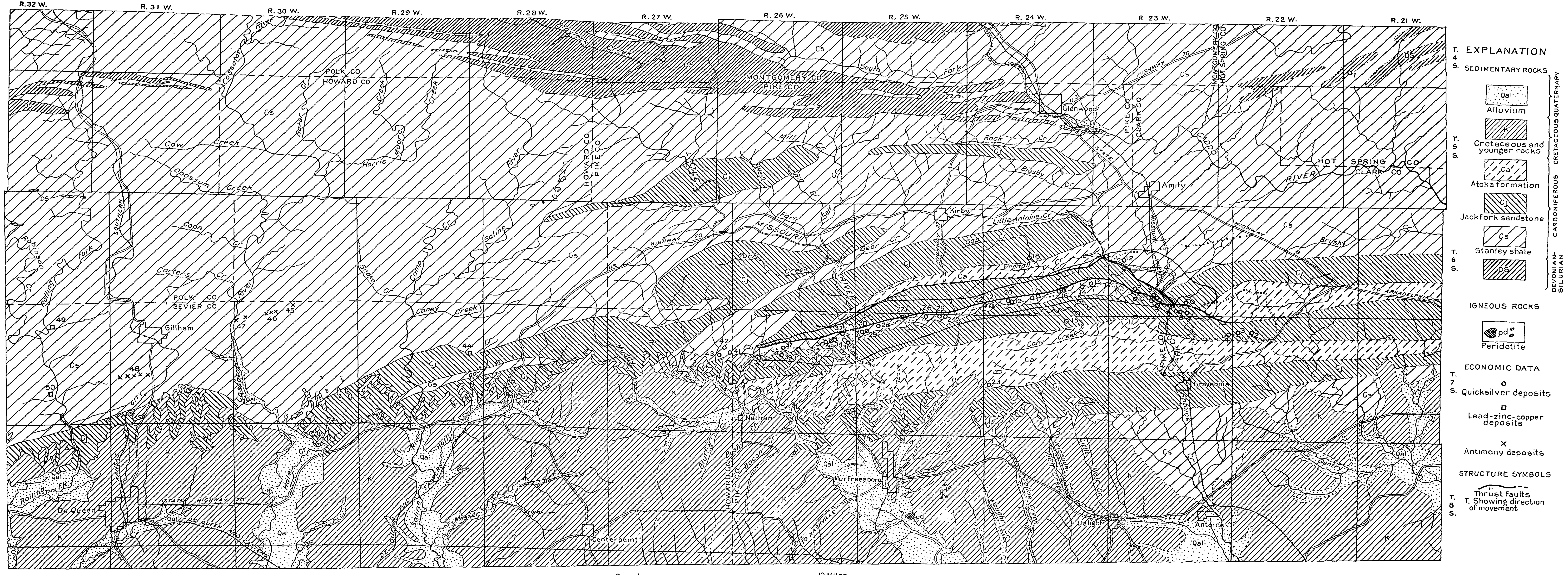
A small amount of stibnite has been found in the western part of the quicksilver belt (pp. 48, 79, 86). The antimony deposits, however, are about 20 miles to the west, in Sevier County. They extend from the May shaft (45, pl. 7), in sec. 4, T. 7 S., R. 30 W., about 10 miles south of west, to and beyond the Otto mine (48, fig. 17), in sec. 20, T. 7 S., R. 31 W.

The lead-zinc-copper deposits have the widest distribution. They extend from the Housley mine (1, pl. 7), in western Hot Spring County, to an outcrop [35] in the SE¼SE¼ sec. 14, T. 5 S., R. 23 E., in McCurtain County, Okla. The Housley mine lies in sec. 31, T. 4 S., R. 21 W., 13 miles north of the east end of the quicksilver district, and the Buzbee prospect (44, pl. 7) is 12 miles west of the Rock Fence quicksilver prospect (43, pl. 7). The antimony and lead-zinc deposits are closely associated. Sulphantimonides of lead—zinkenite ($PbS.Sb_2S_3$), and jamesonite ($2PbS.Sb_2S_3$)—have been found in the Stewart mine.[36] It seems probable that the cinnabar, antimony, and lead-zinc deposits were formed during the same period of ore deposition, because they all occur in the same formations, occupy structural features formed by the same diastrophism, and have related mineral assemblages.

[34] Hess, F. L., The Arkansas antimony deposits: U. S. Geol. Survey Bull. 340, pp. 241–252, 1908. Honess, C. W., Geology of the southern Ouachita Mountains of Oklahoma: Oklahoma Geol. Survey Bull. 32, pt. 2, pp. 35–42, 1923. Miser, H. D., and Purdue, A. H., op. cit. (Bull. 808), pp. 150–176.

[35] Honess, C. W., op. cit., pp. 39–40, 1923.

[36] Hess, F. L., op. cit. (Bull. 340), p. 248.



LIST OF MINES AND OCCURRENCES

1. Housley mine, N½SE¼NW¼ sec. 31, T. 4 S., R. 21 W.
2. Cinnabar in SE¼ sec. 6, T. 7 S., R. 22 W.
3. Cinnabar in SW¼ sec. 6, T. 7 S., R. 22 W.
4. Cinnabar in SE¼ sec. 1, T. 7 S., R. 23 W.
5. Cinnabar in NW¼ sec. 35, T. 6 S., R. 23 W., and NE¼ sec. 34, T. 6 S., R. 23 W.
6. Cinnabar in SE¼ sec. 34, T. 6 S., R. 23 W.; S½ sec. 34, T. 6 S., R. 23 W.; and SW¼ sec. 34, T. 6 S., R. 23 W.
7. Hill 3, NW¼ sec. 33, T. 6 S., R. 23 W.
8. Bemis Hill, northern part of sec. 33, T. 6 S., R. 23 W., and SW¼ sec. 28, T. 6 S., R. 23 W.
9. Hill 2, NW¼ sec. 33, T. 6 S., R. 23 W., and S½ sec. 29, T. 6 S., R. 23 W.
10. Prospect in NW¼ sec. 32, T. 6 S., R. 23 W.
11. Cinnabar in sandstone in SW¼ sec. 32, T. 6 S., R. 23 W.
12. Amity Quicksilver Corporation, NE¼ sec. 19, T. 6 S., R. 23 W.
13. Atoka Quicksilver Co., SW¼NW¼ sec. 25, T. 6 S., R. 24 W.
14. Palmer prospect, NW¼ SE¼ sec. 26, T. 6 S., R. 24 W.
15. Wall Mountain shaft, Wall Rock shaft, and prospects between, SE¼ sec. 35, T. 6 S., R. 24 W., and NE¼ sec. 3, T. 7 S., R. 24 W.
16. Cinnabar in SE¼ sec. 27, T. 6 S., R. 24 W.
17. Cinnabar in NE¼ sec. 33, T. 6 S., R. 24 W., and NW¼ sec. 33, T. 6 S., R. 24 W.
18. Cinnabar in NW¼NW¼ sec. 21, T. 6 S., R. 24 W.
19. Mac-Holmes Mining Co., SE¼NW¼ sec. 32, T. 6 S., R. 24 W.
20. Mine in SW¼NW¼ sec. 32, T. 6 S., R. 24 W.
21. Cinnabar near center of sec. 31, T. 6 S., R. 24 W.
22. Cinnabar in NW¼ sec. 31, T. 6 S., R. 24 W.
23. Southern Kraft Corporation, SW¼ NW¼ sec. 19, T. 7 S., R. 24 W.
24. Prospect in northern part of sec. 2, T. 7 S., R. 25 W.
25. Cox prospect, NE¼NE¼ sec. 3, T. 7 S., R. 25 W.
26. Funderburk prospect, NW¼NW¼ sec. 3, T. 7 S., R. 25 W.
27. Old Argentine prospect, NW¼NW¼ sec. 4, T. 7 S., R. 25 W.
28. Isbell prospect, N½SE¼ sec. 6, T. 7 S., R. 25 W.
29. Yenglin prospect, SE¼SW¼ sec. 6, T. 7 S., R. 25 W.
30. Parnell Hill and Bell prospect, SW¼ SW¼ sec. 6, T. 7 S., R. 25 W.
31. Mill Mountain, SW¼NE¼ sec. 12, T. 7 S., R. 26 W.
32. Parker Hill, SE¼SW¼ sec. 1, T. 7 S., R. 26 W.
33. Parker prospect, SE¼SW¼ sec. 12, T. 7 S., R. 26 W.
34. Eastern part of Gap Ridge, SW¼ NW¼ sec. 12, T. 7 S., R. 26 W.
35. Gap Ridge, NE¼ sec. 11, T. 7 S., R. 26 W.
36. Ridge west of Gap Ridge, SE¼NW¼ sec. 11, T. 7 S., R. 26 W.
37. Cinnabar south of center of sec. 9, T. 7 S., R. 26 W.
38. Hudgins prospect, SE¼SW¼ sec. 9, T. 7 S., R. 26 W.
39. Prospect in NE¼NW¼ sec. 16, T. 7 S., R. 26 W.
40. Cinnabar in sec. 36, T. 7 S., R. 26 W.
41. Pyle prospect, NE¼NE¼ sec. 13, T. 7 S., R. 27 W.
42. Floyd prospect, SW¼SE¼ sec. 12, T. 7 S., R. 27 W.
43. Rock Fence prospect, NE¼NW¼ sec. 13, T. 7 S., R. 27 W.
44. Buzbee prospect, NE¼ sec. 13, T. 7 S., R. 29 W.
45. May mine, NE¼NE¼ sec. 4, T. 7 S., R. 30 W.
46. Conboy shaft and tunnel, NE¼NW¼ sec. 5, T. 7 S., R. 30 W.
47. New Discovery shaft, NE¼SE¼ sec. 6, T. 7 S., R. 30 W.
48. Otto and Valley mines, SE¼ sec. 20, T. 7 S., R. 31 W.
49. Davis mine, NW¼NW¼ sec. 10, T. 7 S., R. 32 W.
50. Bellah mine, NW¼NW¼ sec. 27, T. 7 S., R. 32 W.

GEOLOGIC MAP OF SOUTHWESTERN ARKANSAS SHOWING DISTRIBUTION OF DEPOSITS OF QUICKSILVER, LEAD-ZINC-COPPER, AND ANTIMONY.

THE QUICKSILVER DEPOSITS

ORE AND GANGUE MINERALS

Quicksilver deposits everywhere are characterized by few ore and gangue minerals. The deposits described herein are no exception to the rule, although a number of the quicksilver minerals have been recognized in the district. A list of the hypogene ore and gangue minerals includes barite, cinnabar, calomel, dickite, egglestonite, livingstonite, pyrite, quartz, siderite, stibnite, and native quicksilver (?). The supergene minerals found are hydrated iron oxides, metacinnabar, native quicksilver, opal, and stibiconite.

BARITE

Veinlets of coarsely crystalline barite ($BaSO_4$) cutting sandstone were found on the Will Pyle property, in the SE¼SE¼ sec. 12 and NE¼NE¼ sec. 13, T. 7 S., R. 27 W. (41, pl. 7). Within the barite are specks of cinnabar.

CINNABAR

Cinnabar (HgS), the chief ore mineral of quicksilver, ordinarily occurs either close to or associated with quartz, dickite, and, in one or two places, stibnite and pyrite as incrustations on the surfaces of joints, cracks, bedding planes, and cavities or completely filling these openings. The cinnabar crystals in the drusy openings are commonly twinned and more or less malformed. The crystals range in length from 1 to 7 millimeters. Perfect doubly terminated crystals of cinnabar are commonly found entirely surrounded by dickite. Where associated with stibnite the cinnabar occurs as grains completely surrounded by stibnite and as veinlets cutting stibnite. Cinnabar in many places completely surrounds quartz crystals. At other places cinnabar crystals are completely enclosed in quartz crystals. In some places fine veinlets of cinnabar cut grains of vein quartz. A specimen from the Gap Ridge mine (pl. 8, *A*) clearly shows a set of branching cracks in shattered sandstone completely filled with cinnabar.

In some places—for example, on the ridge in the southern part of sec. 34, T. 6 S., R. 23 W.—cinnabar occurs as elongate crystals scattered through the sandstone (pl. 8, *B*). It can be determined under the microscope that the cinnabar has replaced the quartz sand grains (pl. 9, *A*, *B*). Such sandstone shows signs of crushing. A few miles farther east, in sec. 6, T. 7 S., R. 22 W., tiny specks of cinnabar are distributed through sandstone. Cinnabar is found in shale partings in the sandstone in a very few places. Cinnabar was deposited during the same time interval as dickite and quartz.

OTHER QUICKSILVER MINERALS

Livingstonite (a sulphantimonide of mercury), calomel (the chloride), and egglestonite (the oxychloride) have been reported from the district.[37]

In places cinnabar has been thinly coated with metacinnabar, the black secondary sulphide of mercury. Small globules of native quicksilver have been reported from the Old Argentine prospect, the Arkansas Cinnabar Mining Co. prospect, and the Parker Hill mine (pl. 10,*B*). Though most of the native quicksilver was found near the surface, a little was found at a depth of 113 feet in the Parker Hill mine. Where the native quicksilver is present the cinnabar has wholly or partly disappeared, leaving open fractures with limonite, or pockets in dickite either with or without limonite.

DICKITE

Dickite,[38] one of the clay minerals ($Al_2O_3.2SiO_2.2H_2O$), is the most widely distributed of the hydrothermal minerals. Not only is it found throughout the quicksilver belt, but it is widespread in the rest of the Ouachita Mountains.[39] Dickite is normally white and powdery or, where smeared, hornlike. It is commonly stained yellow to brown by iron oxide. Where best developed, it is an aggregate of small plates as much as one-sixteenth of an inch in diameter. Dickite is found between the quartz crystals, in the quartz veins, and along fractures and bedding planes. It is present in nearly every thin section studied from the district. It surrounds quartz grains, their mutual boundaries being ragged, or it occurs as very small plates within the quartz. All the cinnabar is associated with dickite. Veinlets of cinnabar contain patches of dickite, and some cinnabar veinlets merge into dickite veinlets. Commonly the cinnabar is scattered through the dickite as subhedral to euhedral crystals. From these relations it seems probable that dickite, quartz, and cinnabar are essentially contemporaneous, though the formation of quartz and dickite continued longer than the formation of cinnabar, and some very late quartz may have followed dickite.

PYRITE

Pyrite (FeS_2) is found throughout the district, but it is very small in amount and inconspicuous. It appears to be particularly abundant at the mine in sec. 32, T. 6 S., R. 24 W. All the pyrite seen by the writers was in the form of small cubical crystals, less than 1 millimeter square, encrusting cavities and crystals of clear quartz or coating fracture and shear surfaces. On one specimen minute grains of

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37 Sohlberg, R. G., Cinnabar and associated minerals from Pike County, Ark.: Am. Mineralogist, vol. 18, p. 4, 1933. Stearn N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, p. 24, 1936.

38 Ross, C. S., and Kerr, P. F., The kaolin minerals: U. S. Geol. Survey Prof. Paper 165, pp. 158-160, 1931.

39 Miser, H. D., personal communication.

cinnabar were observed on the pyrite cubes. According to Stearn,[40] a sample of pyritiferous rock when assayed yielded 0.02 ounce of gold and 0.4 ounce of silver to the ton and a small amount of arsenic.

In addition to the cubical pyrite, Stearn reports "small irregular masses of sugary pyrite, which were probably originally present in the dark shales of the country rock, particularly the carbonaceous ones."

QUARTZ

Quartz (SiO_2), like dickite, everywhere forms part of the hydrothermal group of minerals. Thin quartz veins cut both the shale and the sandstone throughout the district. Microscopic examination of the sandstone usually reveals introduced quartz. The vein quartz associated with the ore is of three varieties—milky quartz, smoky quartz, and glassy quartz crystals. The glassy crystals occur in druses, with occasional large crystals, coating the walls of cavities, some of which are now filled with dickite (pl. 10, *A*). The stibnite and cinnabar [41] observed in some of the quartz crystals (pl. 11) suggest a later age for the quartz. According to Stearn, the smoky quartz is probably discolored by local inclusions. It is intimately intergrown with dickite and cinnabar and appears to have crystallized at about the same time. The milky quartz generally adheres to the wall rock. According to Sohlberg,[42] it is partly replaced by dickite and in places is surrounded by cinnabar. In a table of mineral sequence Stearn [43] shows that the deposition of milky quartz began as the first product of mineralization and ended before the deposition of dickite, cinnabar, and smoky and glassy quartz began. To the writers the different types of quartz appear to have no general chronologic significance.

SIDERITE

Stearn [44] found some siderite ($FeCO_3$) at a depth of about 120 feet in the Gap Ridge mine. His description follows:

> Siderite was found * * * near a shale-sandstone contact, surrounding fragments of a brecciated rock, followed by massive dickite. The siderite layers show crystal terminations, indicating deposition in open space; these are covered by dickite, indicating its later development. A similar occurrence was observed from Parker Hill, where siderite appeared to be replaced by dickite.

Siderite is also present at the Mac-Holmes mine in sec. 32, T. 6 S., R. 24 W., and at the east end of Hill 2, near Suck Hollow Creek, in sec. 33, T. 6 S., R. 23 W.

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[40] Stearn, N. H., The cinnabar deposits of southwestern Arkansas: Econ. Geology, vol. 31, p. 23, 1936.
[41] Stearn, N. H., Stibnite in quartz: Am. Mineralogist, vol. 20, no. 1, pp. 59-62, 1935.
[42] Sohlberg, R. G., Cinnabar and associated minerals from Pike County, Ark.: Am. Mineralogist, vol. 18, p. 6, 1933.
[43] Stearn, N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, no. 1, fig. 11, p. 25, 1936.
[44] Idem, p. 24

STIBNITE

Stibnite (Sb_2S_3) has been found only in the western part of the quicksilver district. Stibnite deposits occur farther west, in Sevier County,[45] but the nearest of these—the May prospect, east of Gillham, in the NE¼ sec. 4, T. 7 S., R. 30 W.—lies 24 miles west of the Gap Ridge mine. Stearn[46] was present when stibnite was found at the Gap Ridge mine, and his description of the mineral follows:

Stibnite occurs in small amounts at Parnell Hill near the surface and at Gap Ridge about 180 feet below the surface. It has been noted in shale gouge, in distorted acicular crystals; in open fractures with the bladed crystals at right angles to the walls and bent by movement along them; and plastered on fracture walls in radiating rosettes. Within the masses of stibnite, crystals of cinnabar are common. Cinnabar, quartz (chalcedony or opal), and dickite all replace and are pseudomorphous after stibnite, which, therefore, must have been formed before the main metallization. Rarely inclusions of stibnite are observed in cinnabar crystals.

Stibnite has been observed as thread-like inclusions in quartz crystals (pl. 11).

A sample of the mineral from the Gap Ridge mine was assayed for silver and arsenic, and traces of both metals were found.

Stibiconite ($H_2Sb_2O_5$), an oxidation product of stibnite, has been reported by Stearn.[47]

HYDRATED IRON OXIDES

Hydrated iron oxide staining is common throughout the district. The stain ranges in color from black through scarlet to pale yellow and in texture from massive to earthy. The scarlet iron oxide is easily mistaken for cinnabar. The origin of the hydrated iron oxide is not definitely known. Several possibilities suggest themselves—deposition from meteoric solutions or hydrothermal solutions, or local alteration of pyrite and siderite.

A distinctive form is found at various places in the Jackfork sandstone—for example, in the eastern part of sec. 19, T. 7 S., R. 24 W. (pl. 7). It consists of dark-brown bands of iron-stained material as much as 1 inch thick that follow the reticulate joint planes in the sandstone. The joint may be empty or occupied by goethite ($Fe_2O_3.H_2O$), dickite, or cinnabar. The crystalline character of the goethite, as well as the fact that it replaces quartz, can be readily seen under the microscope. All stages of replacement of sand grains are present from solid goethite to sand grains with a few goethite crystals around their margins. The goethite is later than dickite or cinnabar. Similar "iron ribs" have been described from quicksilver deposits in Oregon.[48] In Oregon the alteration of siderite in place has furnished the iron oxide, but the "iron ribs" here described were probably

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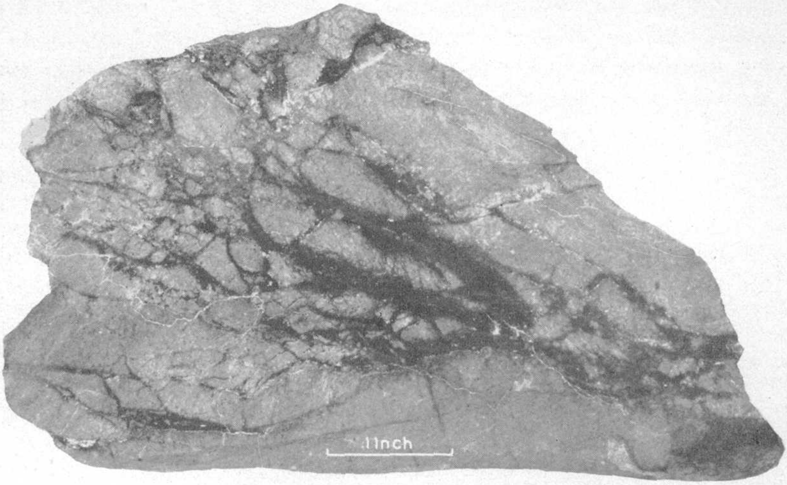
[45] Hess, F. L., The Arkansas antimony deposits: U. S. Geol. Survey Bull. 340, p. 249, 1908. Miser, H. D., and Purdue, A. H., op. cit., pp. 150–153.

[46] Stearn, N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, p. 23, 1936.

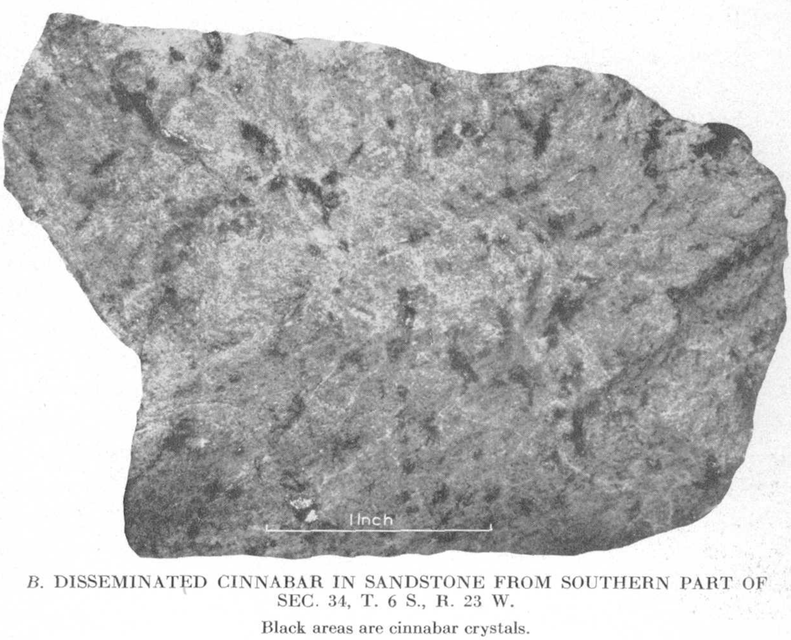
[47] Idem, p. 24.

[48] Wells, F. G., and Waters, A. C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey Bull. 850, pp. 31, 32, 1934.



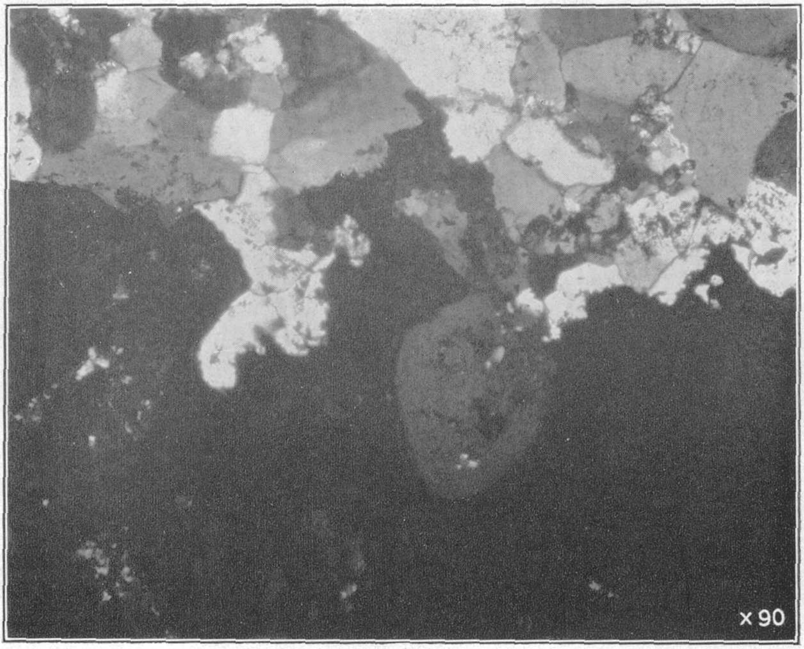
A. SPECIMEN FROM GAP RIDGE MINE SHOWING BRANCHING CRACKS FILLED WITH CINNABAR IN SHATTERED SANDSTONE.

Cinnabar is dark.

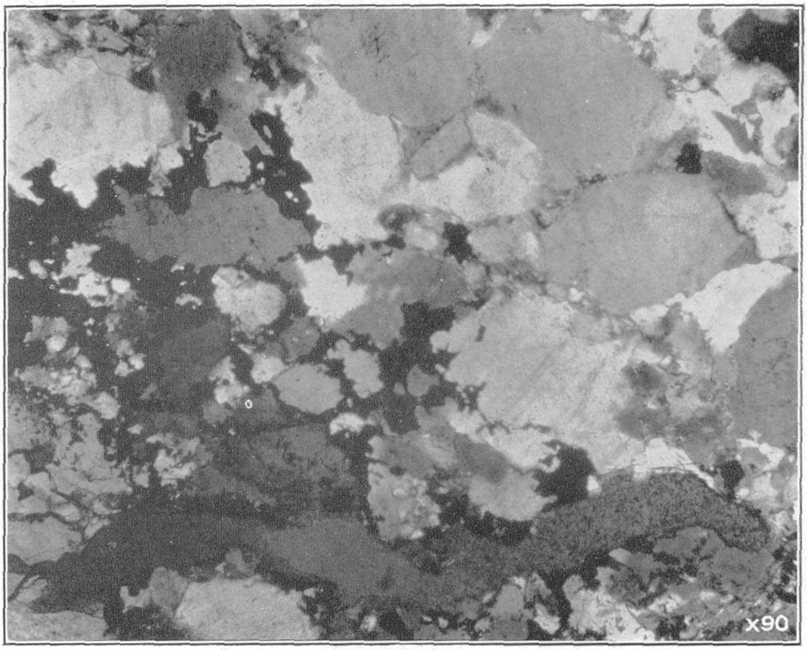


B. DISSEMINATED CINNABAR IN SANDSTONE FROM SOUTHERN PART OF SEC. 34, T. 6 S., R. 23 W.

Black areas are cinnabar crystals.

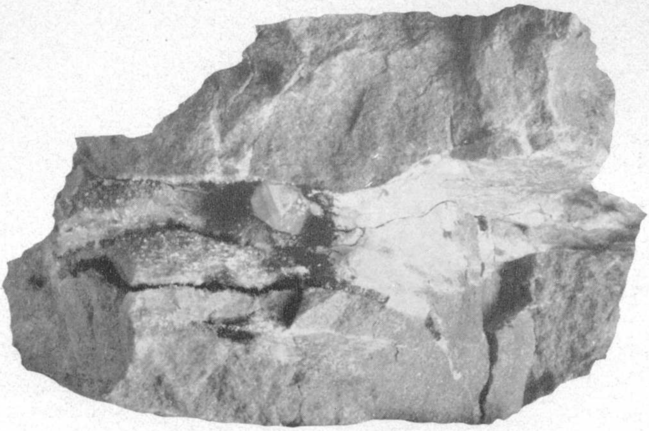


A



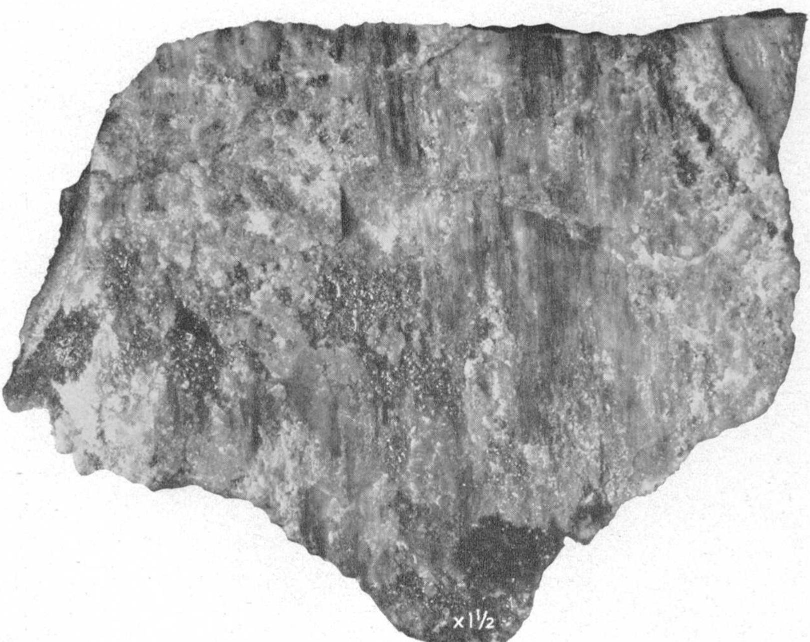
B

A and *B*. PHOTOMICROGRAPHS OF SPECIMENS FROM SEC. 34, T. 6 S., R. 23 W.
Show cinnabar (black) replacing quartz sand grains (white and gray).



A. VUG IN SANDSTONE LINED WITH DRUSY QUARTZ FROM HUDGINS PROSPECT.

One large quartz crystal in vug. Dickite partly fills vug. Natural size.



B. NATIVE QUICKSILVER FROM PARKER HILL MINE.

The native metal forms small droplets near the center and left of the sandstone face photographed.

STIBNITE NEEDLES AND CINNABAR IN QUARTZ CRYSTAL.

formed largely by introduced material, because siderite is only sparingly present in the district.

STRUCTURAL CONTROL OF MINERALIZATION

The distribution of the cinnabar deposits in a narrow belt more than 25 miles long and a study of the deposits suggest that the ore-bearing solutions came up in fractured zones which developed above the Cowhide and Amity faults and, as they approached the surface, made their way into the fractured and faulted sandstone beds of the Stanley shale and, where it lay close enough, into the Jackfork sandstone.

Most of the localities at which cinnabar has been found lie south and within a mile of the Cowhide or Amity faults (pls. 2 and 7) and are therefore in the upper or overriding blocks of the faults. Only 10 of the many quicksilver occurrences known do not fit this general rule. Other exceptions no doubt exist. Of the 10 known, 4 are north of one or both thrust faults, and 6 are south of them but more than a mile distant. At the prospect of the Amity Quicksilver Corporation in the NE¼ sec. 19, T. 6 S., R. 23 W., cinnabar is found in Stanley shale northeast of the Amity fault. Cinnabar has been reported from time to time from other places in southwestern Arkansas, but its presence has not been confirmed at any visited by the writers. Thrust faults similar to those in the mapped area are probably present at other places on the Athens Plateau. It is suggested that the apparently anomalous presence of cinnabar at localities where it cannot be tied structurally to the Cowhide or Amity faults may imply a structural relation to other thrust faults not yet recognized.

It has been shown that throughout most of the quicksilver district the Stanley shale lies adjacent to and above the Cowhide thrust. In this part of the district the Gap Ridge sandstone member of the Stanley crops out within 2,000 feet of the fault. The shales above and below the Gap Ridge sandstone apparently were largely impervious to the mineralizing solutions. The Gap Ridge member itself, however, was a favored path for the solutions, and many of the cinnabar deposits are in it. Locally other sandy beds in the shale, particularly the 160-foot bed or member that lies 2,240 feet below the Gap Ridge sandstone, are mineralized. In the part of the district east of the east end of South Woodall Valley, where the Stanley shale is cut out by the faulting and where the Jackfork sandstone of the overriding block rests against Jackfork sandstone of the overriden block, the cinnabar is deposited in the Jackfork. This is also true at a few places farther west, where tear faulting has set blocks of Jackfork sandstone relatively close to the thrust fault. The Wall Mountain deposits in sec. 35, T. 6 S., R. 24 W., and sec. 3, T. 7 S., R. 24 W. (pl. 7), are in Jackfork sandstone between 1 and 2 miles south of the Cowhide thrust at places where tear faulting is not conspicuous. Although this area has not been mapped in detail, reconnaissance work indicates that another thrust fault may lie between them and the Cowhide fault.

The cinnabar is commonly found filling fractures and disseminated through the rock near fractures in well-fractured or even brecciated sandstone on the noses and limbs of the cross folds. The fracture zones are largely confined to the relatively brittle sandstone beds as distinguished from the more plastic shale. Individual fractures and fracture zones are extremely irregular, and attempts to classify them into definite systems during the present investigation were unsuccessful. Stearn,[49] however, has made a classification based on careful and repeated observations during mining operations on the properties of the Southwestern Quicksilver Co. His classification follows:

> Three dominant sets of fractures occur in the district, complicated by many shatter cracks that defy general classification:
>
> 1. A system with nearly horizontal attitude or with dips of 10° to 20° either east or west and with strikes normal to the bedding. These fractures were probably developed during the north-south shortening that up-ended the beds and are complementary to the bedding planes.
> 2. A system striking N. 4° to 30° E. and dipping from 60° to vertical.
> 3. A system striking N. 10° to 20° W. and dipping from 75° to vertical. These are complementary to those in system 2 and were probably developed during the east-west shortening period.
>
> Fractures belonging to system 1 are found to interrupt and offset fractures belonging to systems 2 and 3, and vice versa, so that it seems possible that system 1 fractures developed both before and after those of systems 2 and 3. Systems 2 and 3 are much more abundant than system 1. Mineralization is rarely found in system 1. In fact, fractures belonging to system 1 have been observed to cut off mineralization in fractures of system 2.
>
> Single fractures belonging to systems 2 and 3 are habitually discontinuous from bed to bed, although rarely they cut a thick series of beds, and fracture zones that cut several beds are common.

The cross folds range in size from those that buckle the beds only a few inches to those that deflect them as much as 200 feet. Even very small folds are well fractured in some places. For example, at the Gap Ridge mine each one of a series of tiny cross folds deflects a group of beds a few inches (fig. 14). Nevertheless, the cross folds are well fractured and now contain ore shoots.

Most of the mineralized fracture zones are relatively narrow and extend across one sandstone bed or a group of several sandstone beds separated by thin shale layers. Well-mineralized beds are commonly found close to equally well-fractured barren beds. Apparently the mineralizing solutions did not have access to some fractured zones, possibly because the fractures were sealed from the solutions by shale or fault gouge or because they did not extend to a channel that carried the solutions. Measured horizontally the longest continuous mineralized zone so far opened is about 150 feet long. Mineralization throughout most of this zone stopped at a horizontal fracture 15 feet below

[49] Stearn, N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, p. 12, 1936.

the surface. Other ore zones have been followed to depths of more than 200 feet.

A type of deposit structurally distinct from that associated with cross-fold fracture zones is that associated with tear faults. This type includes ore bodies formed in the tear faults and ore bodies in fractures related to the tear faults. Very little development work has been done on ore bodies of this type, and consequently there are few data on it. At the Parker Hill mine a mineralized minor tear fault that strikes about N. 9° E. and dips 60° E. has been opened by mining operations. Fractures on the west side of the fault and probably related to the faulting have been mineralized also. A fault near the northwest corner of sec. 33, T. 6 S., R. 23 W., contains boulders of cinnabar-bearing sandstone that have been rolled in the fault and are now completely surrounded by tight envelopes of shale. Some shale in this fault is also locally mineralized.

A third type of ore is locally called "shale ore." This type consists of cinnabar between shale layers or between shale and sandstone. It is quantitatively unimportant. A considerable amount was found at Parnell Hill and at Bemis Hill. It was apparently deposited in actual or potential open spaces formed by the separation of shale layers during structural deformation.

The channels through which the ore-bearing solutions moved and the sites of deposition were undoubtedly controlled by the preexisting structural features (thrust faults, tear faults, cross folds, and fractures) that have been described. In addition, the solutions had the power to penetrate unfractured sandstone, as is shown by the presence of disseminated cinnabar in most of the specimens examined. Such disseminated cinnabar is commonly found only a fraction of an inch from the fractures along which the ore solution probably traveled. At a few places, such as the SW¼ sec. 34, T. 6 S., R. 23 W., an unusual amount of disseminated cinnabar is found.

ORIGIN AND AGE OF MINERALIZATION

Since the classic study by Becker [50] quicksilver deposits have been considered to be formed by hot waters derived from cooling igneous rocks. The close association of cinnabar deposits with volcanic phenomena [51] and the presence of cinnabar in hot-spring deposits give ample proof that the solutions which deposited the cinnabar had their origin in igneous rocks. For these reasons it might be argued that the Arkansas cinnabar deposits are related to the igneous activity that took place in Arkansas in early Upper Cretaceous time.[52] The

[50] Becker, G. F., Geology of the quicksilver deposits of the Pacific slope: U. S. Geol. Survey Mon. 13, 486 pp., 1888.

[51] Lindgren, Waldemar, Mineral deposits, 4th ed., pp. 471–473, 1933.

[52] Miser, H. D., and Ross, C. S., Diamond-bearing peridotite in Pike County, Ark.: U. S. Geol. Survey Bull. 735, pp. 311–312, 1923

writers feel, however, because of evidence that is given below, that these deposits are more probably of middle Pennsylvanian age.

The Magnet Cove igneous rocks, the syenites south of Little Rock, and the diamond-bearing peridotite plugs near Murfreesboro were introduced in early Upper Cretaceous time. The acidic tuffs and conglomerates north of Nashville are of the same age.[53] The peridotite plugs near Murfreesboro are about 9 miles south of the quicksilver district, and the acidic tuffs and conglomerates north of Nashville are about 16 miles distant. No definite evidence tying the mineralization to this igneous activity was recognized in the district.

The mineralized boulders or "niggerheads" of hard silicified sandstone that have been found in a fault zone, mentioned on page 51, are as much as 18 inches in largest dimension. They are well rounded and enveloped in shale. Considerable movement would be necessary to round the "niggerheads", and the sandstone must have been sufficiently indurated to withstand rolling and crushing. Hence it seems probable that the "niggerheads" were formed during the major thrusting and that the hardening due to silicification, with the concurrent formation of cinnabar, took place either prior to or before the end of this deformation. Corroborative evidence is found in the extensive slickensided surfaces that cut and polish previously mineralized fractures present throughout the district. Although slickensiding can be caused by movements of a few inches, such widespread slickensiding is most probably related to the major deformation.

Undisturbed cinnabar crystals are common on the slickensided surfaces, and some cinnabar was seen in shale in faults and indicates that either there was more than one surge of mineralization or that the mineralization was prolonged. Structural evidence alone does not preclude the possibility that some mineralization followed the structural deformation, but other evidence, including the absence of cinnabar in the Cretaceous rocks and its probable relation to deposits of other sulphides, makes it appear unlikely.

As the major thrusting is of middle Pennsylvanian age (p. 31), and as there is no evidence of folding or major faulting during or since Cretaceous time, it seems probable that the mineralization took place during the mountain-building movements of the Pennsylvanian epoch.

Careful search has failed to reveal any cinnabar in the Cretaceous sedimentary rocks that overlap the western part of the district. If the mineralization were younger these permeable rocks might be at least locally mineralized.

The presence of stibnite in the quicksilver deposits strongly suggests a genetic relationship between these deposits and the deposits of antimony, lead, and zinc to the west (pl. 7). Though the age of

[53] Ross, C. S., Miser, H. D., and Stephenson, L. W., Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas: U. S. Geol. Survey Prof. Paper 154, p. 189, 1928.

these deposits is not known, they are believed to have been formed during the period of ore formation in the Ouachita Mountains of Oklahoma. Referring to these, Honess [54] writes:

> It is my opinion that the date of folding of the Ouachita Mountains of Oklahoma and Arkansas is middle Pennsylvanian. * * * I am of the opinion, further, that as the folding of the mountains progressed intrusions occurred. Among the deposits introduced at this time (middle Pennsylvanian) in Oklahoma are (1) lead, zinc, and copper sulphides in a quartz-carbonate gangue; (2) large quartz-vein and quartz-orthoclase pegmatites; (3) carbonate, chiefly siderite replacements, and (4) large asphalt dikes.

If, as there seems reason to believe, the lead, zinc, antimony, and cinnabar were formed during one period of mineralization, then the cinnabar was deposited during middle Pennsylvanian time. Erosion has not uncovered the igneous source of the metallization in the environs of the deposits.

ECONOMIC POSSIBILITIES OF THE DISTRICT

As the Arkansas quicksilver district is so new and so little developed, it is impossible to make an accurate prediction of its possibilities. The area is more than 25 miles long, and cinnabar has been observed at many places within it. However, only a few of these occurrences have been prospected even slightly, and at less than 25 places has more than a few tons of rock been moved.

The following table shows the amount of waste and the amount of ore of a specified tenor that has been taken from 15 mines and prospects within the district:

Waste and ore of specified tenor from mines and prospects in the Arkansas quicksilver district

Mine or prospect	Waste	Ore	Tenor of ore
	Tons	*Tons*	*Pounds per ton*
Gap Ridge mine [1]	3,730	2,250	22
Parker Hill mine [1]	[2] 3,150	850	22
Wall Rock shaft	750	275	5–8
Wall Mountain shaft	2,650	400	10–12
Prospect on Wall Mountain near Wall Mountain shaft	450	50	15–18
Cuts in sec. 32, T. 6 S., R. 23 W	1,530	40	7–9
Hill 2, cut 1	425	115	17–20
Hill 2, cut 2	2,500	315	15–18
Hill 2, cut 3 and cut 5 combined	1,000	95	14–16
Hill 2, cut 4	100	20	12–15
Hill 2, cut 6	400	55	10–12
Hill 3, cut near center of sec. 33, T. 6 S., R. 23 W	350	75	12–14
Hill 3, cut a short distance north of last-mentioned cut	525	140	10–12
Sec. 34, T. 6 S., R. 23 W., large cut near west end of hilltop	3,260	1,350	8–10
Sec. 34, T. 6 S., R. 23 W., shaft near east end of hilltop	660	180	12–15

[1] Figures from Stearn, N. H., Econ. Geology, vol. 31, no. 1, 1936; all others from R. C. Rohrdanz, of the Mid-Continent Quicksilver Corporation.
[2] 1,800 tons of the waste came from preliminary stripping operations.

It should be emphasized that the figures in the table include prospecting as well as mining and do not include the quicksilver in the

[54] Quoted in Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Inf. Circ. 2, p. 28, 1932.

rock discarded as waste. At Bemis Hill, according to reports, 11,000 pounds of quicksilver was recovered by the Arkansas Quicksilver Co. from a glory hole from which 2,500 tons was mined, or a recovery of 4.4 pounds to the ton. Here also the waste dump contains considerable cinnabar.

The surface showings at the localities that have yielded most of the ore so far found were not appreciably better than many other showings within the district that are as yet untested. The low relief of the region, the scarcity of good outcrops, and the heavy brush cover combine to make surface prospecting difficult. Underground prospecting is hampered by the irregularity of the fracture zones in which the cinnabar is found and by the irregular distribution of the ore within the zones. As more mining is done in the district and the geologic principles that controlled the deposition of the ore become better understood, it will probably be possible to make more and better use of geology in guiding development work. The nature of the deposits, however, necessarily imposes a high cost of prospecting and development relative to operations on ore bodies of more regular shape.

The experience of the district so far has been that small-scale operations, using home- or factory-made retorts to recover the metal, are ordinarily unsuccessful. Occasionally one may run for a time at a profit, but never at a large profit, because the tenor of the ore and the capacity of the retort both tend to prevent it. To increase the tenor of the ore means to increase labor and mining costs, as the ore must be more carefully hand-sorted. It would also increase the amount of rock discarded as waste and the proportion and amount of cinnabar lost in the waste.

The two greatest drawbacks of a furnace for recovering quicksilver in the Arkansas district are the relatively high initial cost and the doubt of an insured supply of ore after it begins operating. The furnace gives quicker, cheaper recovery on large amounts of ore than the retort. It permits the treatment of lower-grade ore, thus decreasing sorting costs and waste rock. But it must be remembered that the only really blocked-out ore in the district is the ore in the bins and that actually showing on the working faces. Thus, to insure the continuous operation of a furnace, ore should be drawn from enough different localities so that when unproductive prospecting is under way at some places, ore for the furnace can still come from the rest. This means either that an organization must control a large number of the cinnabar occurrences or that a furnace must be operated on a custom basis.

The geologic features described in this report indicate that the ore deposits will probably be terminated in depth by the Cowhide thrust zone. Too little is known of the attitude of this thrust fault to predict its depth below the surface at any place. However, where it crops out it apparently dips so steeply southward that even a rather abrupt flattening would leave it far below the depth yet reached by any mining operations. There is the alternative possibility that the ore zone may accompany the thrust zone down and southward. Possibly, with increased depth, sulphides of metals other than mercury will become more conspicuous.

In summation, the geologic indications appear to warrant further prospecting and development in favorable areas. It seems likely that in a time of national emergency, when cost is no object, the Arkansas district could produce a large amount of quicksilver. Recent operations in the district indicate that quicksilver can be produced there at a profit under conditions similar to those of 1936, provided production can be maintained over a period long enough to insure the amortization of a relatively large capital investment.

SUGGESTIONS FOR PROSPECTORS

The only thrust faults at present known to exist on the Athens Plateau are those of the quicksilver district. The regional structural relations and the presence of a few cinnabar localities outside the mapped area suggest the existence of others at least in and near the quicksilver district. By analogy with the structural relations in the quicksilver district, prospecting in a mile-wide zone south of these postulated thrust faults might disclose other occurrences of quicksilver. Within the district cinnabar can be seen at many places in rock outcrops. It would seem reasonable to suppose that any other well-defined area, if it exists, would long since have been discovered. On the other hand, it should be remembered that the known district was not discovered until 1931, in spite of the fact that the region had been settled for many years previously. It is felt, however, that in the present state of knowledge of the geology of the region prospecting in the belt of known mineralization is more likely to prove profitable than a search for new cinnabar-bearing areas.

Within the district the prospector should search for well-fractured sandstone relatively close to and south of the thrust fault. Where the Stanley shale is present south of the fault most efforts should be confined to the Gap Ridge sandstone member or to other sandy zones in the shale. The cross folds are good guides to many fracture zones. East of the east end of South Woodall Valley, where the Stanley is cut out, the greatly deformed belt of Jackfork lying between the two branches of the thrust fault appears to be structurally an unusually favorable area.

Structurally the vicinities of the tear faults appear to be favorable places to prospect. It has been pointed out that to date very little development work has been done on them. There is a good opportunity for fracture zones to develop along the tear faults, and also a relatively good chance that some of these faults penetrate to solution channels in depth.

Once cinnabar in place has been found, the only way it can be safely opened is to "stay with the ore", which, because of the low relief throughout the district, generally means relatively expensive working downward from the surface. It is not safe to run adits with the idea of intersecting an ore zone even a short distance away. The irregular nature of the fracture zones and of the ore within the zones makes it difficult to block out ore in advance of stoping. This is a great handicap to prospecting and to later mining operations.

Large, well-financed organizations might find it feasible to prospect likely fracture zones even where no cinnabar appears at the surface. They also should probably consider prospecting deeper along well-defined fracture zones, even if the ore body being worked is terminated. There is no reason to suppose that all the ore bodies in the district are confined within a few hundred feet of the surface.

The nature of the ore zones and of the rocks also discourages extensive prospecting by drilling. The ore shoots are so irregular in size, shape, and attitude that even closely spaced holes might not reveal the presence of a good ore shoot, and conversely, there is a slight chance that drill holes might cut an ore zone in such a way as to make it appear much larger and better than it really is. Furthermore, only a little "shale ore" has been found, and drills penetrating nearly vertical rocks composed of thin beds of alternating sandstone and shale would tend to follow the shale strata rather than the sandstones. The use of short drill holes, however, may be of great use in conjunction with other work in determining the extent of ore bodies that have been partly opened.

HISTORY

It has been reported [55] that the courthouse at Mount Ida, Montgomery County, Ark., contains the record of the filing on a cinnabar claim in southwestern Montgomery County around 1880. If cinnabar was actually found there, it was the first, so far as is known, that was ever found in Arkansas. According to Branner,[56] on October 4, 1897, four claims were filed in the Pike County courthouse at Murfreesboro on the "Quicksilver lode" in sec. 25, T. 6 S., R. 27 W., but an attempt to find these old claims in 1934 resulted in placing their location in secs. 24 and 25, T. 5 S., R. 27 W., not far from Langley. Copies of the claim descriptions, received in February 1936 by the writers from Dr. Branner, to whom they were furnished by Howard A. Millar, of Murfreesboro, show that six claims actually were located in secs. 24 and 25, T. 5 S., R. 27 W. According to local reports metallic mercury was found in a spring, and the legend is that it was unwittingly dropped

[55] Weigel, W. M., New quicksilver discoveries: Eng. and Min. Jour., vol. 132, no. 11, p. 495, Dec. 14, 1931.

[56] Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Inf. Circ. 2, p. 3, 1932.

there by an old prospector, one of a number who were searching for gold in the vicinity at that time.

Parks [57] states that cinnabar was first discovered in the district now under consideration by D. F. Short near Antoine Creek in 1927. Mr. Short, thinking the mineral was ruby silver, made a working agreement with the Ozan-Graysonia Lumber Co., which owned the property. A piece of the ore was placed on display in Caddo Gap, where it was noticed and recognized as cinnabar by Moritz Norden in July 1931. W. N. Bemis, of the Ozan-Graysonia Lumber Co., and Norden then organized the Arkansas Quicksilver Co.

The Arkansas Quicksilver Co. installed a 2-tube type "D" Gould retort at Graysonia, about 8 miles south of the district, in November 1931. The company operated, with some shut-downs, and produced considerable quicksilver until May 1934.

In July 1930 [58] Crown Cox, a local man, picked up a specimen containing cinnabar in sec. 1, T. 7 S., R. 26 W. This place is near the Little Missouri River, about 16 miles west of the location of the Antoine Creek discovery. Cox showed his specimen to W. F. Hintze, of Murfreesboro, who submitted it to W. M. Weigel [59] for identification. A report stating that the mineral was cinnabar was sent to Hintze on July 14, 1931.

Leo Yount began prospecting for cinnabar near the Little Missouri River in the summer of 1931. In the fall of that year he operated a small 3-tube retort near what is now the Parker Hill mine and produced several flasks of quicksilver. Yount optioned a considerable block of ground containing the best showings in the Little Missouri River area, and on February 19, 1932, he and W. C. McBride, Inc., of St. Louis, Mo., formed the Southwestern Quicksilver Co. Until it ceased operations this company was the largest producer in the district.

In April 1932 the Southwestern Quicksilver Co. installed a Gould rotary furnace on Parnell Hill. After that the ore from all three principal mines, Gap Ridge, Parker Hill, and Parnell Hill, was treated in that furnace. All the company's production in 1934 came from the Gap Ridge and Parker Hill mines, and nothing was done at Parnell Hill except a little small-scale work done on a share basis by about six men. Owing to increased expenses, the Southwestern Quicksilver Co. ceased operations in September 1934.

Mercury Producers, Inc., later took an option to purchase the holdings of the Southwestern Quicksilver Co., and on June 15, 1935, began to operate under the terms of the option. This company produced considerable quicksilver before the lease and option were given up, according to reports, sometime in the summer of 1936. Most of the

[57] Parks, Bryan, personal communication.
[58] Stearn, N. H., The new quicksilver district in Arkansas: Min. Jour., vol. 16, no. 2, p. 3, June 15, 1932.
[59] Weigel, W. M., op. cit., p. 495.

work of Mercury Producers, Inc., was done on Parnell Hill, but some was done at Parker Hill and at the Bell prospect, on ground not controlled by the Southwestern Quicksilver Co., at the west end of the hill.

The Mid-Continent Quicksilver Corporation (incorporated in the State of Arkansas) was formed on March 15, 1935, and took over from the Arkansas Quicksilver Co., 1,935 acres in secs. 28 to 33, T. 6 S., R. 23 W., owned by the Ozan-Graysonia Lumber Co. Since then the Mid-Continent Quicksilver Corporation has leased a large part of the holdings of the Ozan-Graysonia Lumber Co. and the Ozan Investment Co., mostly in Pike County (pl. 13) and has thereby increased its holdings to about 9,000 acres. The corporation started mining in March 1935 and has been operating since. During the first 3 months of operation the ore was furnaced at the plant of the Southwestern Quicksilver Co. In December 1935 a 50-ton Nichols-Herreshoff furnace was put into operation on Bemis Hill. To the time of writing (April 1937) this corporation has been the largest producer of quicksilver in the district.

In 1935 the Mercury Mining Co. was organized and leased the extensive holdings of the Southern Kraft Corporation, a subsidiary of the International Paper Co. (pl. 13). It is understood that this lease was terminated early in 1936.

In addition to the operations described above, about 20 small companies and individuals have carried on prospecting and mining at different times at widely separated localities in the district. A number of them are now active. These operations, so far as they are known, are described under individual headings in the section on the mines and prospects. In the aggregate they have produced considerable quicksilver.

PRODUCTION

The writers estimate that the district has produced, through 1936, at least 3,960 flasks of quicksilver (76 pounds to a flask). This estimate is probably a few flasks too low because of unreported production from some small mines and prospects.

The production from properties of the Southwestern Quicksilver Co. by years is given in the following table.

Quicksilver produced from properties of Southwestern Quicksilver Co., 1931–35 [59a]

	Flasks
1931	10
1932	271
1933	281
1934	391
1935	16
Total	969

[59a] Buchner, C. F., vice president of W. C. McBride, Inc., letter to John C. Reed, dated Feb. 29, 1936.

According to Branner,[60] the experimental 3-tube retort produced 688 pounds (9 flasks plus 4 pounds) of quicksilver from October 30, 1931, to November 29, 1931. The 72-pound difference between this figure and Buchner's figure of 10 flasks for 1931 may have been produced during December 1931. Stearn [61] has published the total production from the Gap Ridge and Parker Hill mines and gives for them 651.3 flasks and 246.1 flasks respectively.

It is assumed that Stearn's figures do not include the earlier retort production—the 10 flasks reported by Buchner for 1931. The 16 flasks reported by Buchner for 1935 is believed to be the result of the work done on a share basis at Parnell Hill (see section on history, p. 57), and therefore is not included in Stearn's figures. Thus:

	Flasks
From Gap Ridge and Parker Hill mines	897. 4
1931 retort production	10
1935 Parnell Hill production before property was taken over by Mercury Producers, Inc	16
	923. 4

The difference of 45.6 flasks between Buchner's total of 969 flasks and the figure given above should equal the total Southwestern Quicksilver Co.'s production from Parnell Hill. In view of the large amount of work done on Parnell Hill (pl. 16) and the reported grade of the ore mined, this figure of 45.6 flasks seems far too small and seems to indicate that Buchner's total of 969 flasks is a minimum figure and might be increased by perhaps 100 flasks.

Mercury Producers, Inc., is said to have produced 70 flasks of quicksilver from Parnell Hill and Parker Hill and about 100 flasks from the Bell prospect between June 1935, when it took over the properties of the Southwestern Quicksilver Co., and the summer of 1936.

The production of the Arkansas Quicksilver Co. is not known with certainty. Estimates range from 211 to 650 flasks. The higher figure is thought to be more nearly the correct one, and 500 flasks is arbitrarily used in estimating total production from the district. The Mid-Continent Quicksilver Corporation produced 1,251 flasks of metal up to March 1937. This includes 79 flasks produced in the Southwestern Quicksilver Co.'s furnace at Parnell Hill in the fall of 1935, before the Mid-Continent's new plant at Bemis Hill went into operation in December 1935. Much of the ore resulting in this production was mined and furnaced by the Mid-Continent Quicksilver Corporation according to the terms of a contract between the Mid-Continent and the Mercury Mining Co. The Mercury Mining Co. is reported to have made a total production of about 850 flasks.

[60] Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Inf. Circ. 2, pp. 34, 39, 1932.

[61] Stearn, N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, pp. 14, 15, 19, January 1936.

According to reports about 60 flasks of quicksilver has been recovered from the retort of the Mac-Holmes Mining Co. at the Caponetto property, in South Woodall Valley. Reports from various sources indicate the following production from less productive prospects: Rock Fence prospect, 11 flasks; Parker prospect, 21 flasks; Bell prospect, 15 flasks (in addition to the 100 flasks already credited to Mercury Producers, Inc.); and Isbell prospect, 13 flasks.

The following table summarizes production figures for the district so far as they are known:

Reported production of various properties in the southwestern Arkansas quicksilver district

	Flasks
Southwestern Quicksilver Co. (including a little production before the formation of the company, a little produced on a share basis by individuals, and an estimated production of 100 flasks from Parnell Hill above Buchner's total (see pp. 57, 58, 59)	1, 069
Mercury Producers, Inc	170
Mid-Continent Quicksilver Corporation	1, 251
Arkansas Quicksilver Co	500
Mercury Mining Co	850
Mac-Holmes Mining Co	60
Rock Fence prospect	11
Parker prospect	21
Bell prospect	15
Isbell prospect	13
Total	3, 960

TREATMENT OF THE ORE

The treatment of cinnabar is in general a relatively simple process, involving only (*a*) the heating of the ore to a temperature high enough to cause combustion of the sulphur in the cinnabar to sulphur dioxide and the liberation of metallic quicksilver vapor and (*b*) the condensation of the vapor to liquid quicksilver. This treatment is accomplished in either retorts or furnaces. The difference between a retort and a furnace is that the operation of the retort is a discontinuous process, in which the combustion of the fuel does not take place in the same chamber as that in which the ore is placed, and the operation of the furnace is a continuous process, in which the ore travels through the combustion chamber. Practically, many problems and difficulties arise in the operation of either a retort or a furnace. A furnace is capable of effectively handling larger quantities of lower-grade ore than a retort, which, because of higher costs per ton of ore, to operate successfully must use ore of relatively high grade.

There are two furnaces of different types in the Arkansas district and more than half a dozen retorts have been operated there from time to time. Only two of the retorts have produced any considerable quantity of quicksilver.

RETORTS

The tenor of most of the Arkansas ores is so low that retort operation has not been generally successful. Hand sorting of ore to a tenor high enough to permit successful operation of a retort results in a greatly increased ratio of waste to ore and in increased loss of quicksilver in the cinnabar discarded in the waste. Retort operation, relative to furnace operation, involves higher labor and fuel costs per ton of ore treated. The operation of a retort may also result in losses of metal, through leaks in the system, at times when charges of burned ore are removed, and through an inefficient condensing system.

The retort of the Arkansas Quicksilver Co. at Graysonia has produced more quicksilver than any other retort in the district. This retort is not now in operation. It was a 2-tube type "D" Gould retort, and the average tenor of the ore put through it is reported to have been 40 pounds of quicksilver to the ton.

The retort of the Mac-Holmes Mining Co. had been in almost continuous operation since January 1936 and was in operation in March 1937. It is a 15-tube "drafted retort" and was built by the company. It has a capacity of 3 tons a day and is reported to have treated ore from which was recovered about 12 pounds of quicksilver to the ton.

Mr. Yount operated a 3-tube retort near the present site of the Parker Hill mine for a few months in 1931 and recovered from it about 10 flasks of quicksilver.

Two or three flasks of metal was recovered from a small retort at the Rock Fence prospect in 1932. Another 2-tube Gould retort produced about eight flasks of quicksilver there in 1934.

In June 1934 a locally built 24-tube retort replaced a former 2-tube retort at the Hudgins prospect. The older retort had a reported capacity of 1,200 pounds of ore a day. Neither the tenor of the ore put through nor the amount of quicksilver produced by either retort is known.

Other small, locally constructed retorts have produced small quantities of quicksilver at different localities in the district.

FURNACES

Southwestern Quicksilver Co.—The following description of the plant of the Southwestern Quicksilver Co. is taken from Stearn.[62]

> It [the plant] consists of a Gould Improved quicksilver furnace, the rotary kiln of which is 35 feet long and 2 feet in inside diameter, equipped with automatic ore feed and dust chamber, and a fuel-oil burner. The kiln rotates at 1¼ revolutions a minute. The plant is powered by a 25 Y Fairbanks-Morse semi-Diesel

[62] Stearn, N. H., Mining and furnacing quicksilver ore: Eng and Min. Jour., vol. 134, p. 24, 1933.

engine, which drives a 25-kilowatt generator, supplying power to a 10-horsepower motor for the crusher, a 2-horsepower motor for the ore feed, a 5-horsepower motor for the compressor, a 1½-horsepower motor for the fuel feed, a 3-horsepower motor for the blower, and a 2-horsepower motor for the kiln rotator, as well as lights and electric refrigeration for the plant and staff house. The condensing system consists of 200 feet of 12-inch cast-iron pipe, arranged in four pairs of vertical stands with four drips to return the quicksilver, a redwood air chamber, and a 20-foot redwood stack.

Because the cinnabar is not associated with any complicating minerals, extraction is simple. From the track level the high-grade ore direct from the mining faces is dumped into a 60-ton coarse-ore bin. Through a gate in the bottom of this bin the ore passes across a 1-inch grizzly, the coarse ore going through a jaw crusher set to crush to 1 inch, and drops into a 45-ton crushed-ore bin. A short chute from this bin leads directly to the automatic feeder, and thence into the rotary kiln, where it encounters a temperature of about 1,600° F. during the 35 minutes required for passage. From the lower end of the kiln the burnt rock drops into a bin that can be emptied into a tram car running to a burnt-rock dump just below the plant.

The water, mercury, and sulphur dioxide vapors from the kiln are boosted into the condensing system by a blower. They enter the cast-iron pipes at a temperature of about 400° F.; so to insure complete quicksilver recovery, as quick and as complete a cooling as possible must be effected. The condensing system when installed was equipped with a water spray inside the second stand of the cast-iron condensing system. Only about 5 percent of the recovered quicksilver was delivered by the first return, 80 percent came from the second and third returns, 15 percent from the fourth return and the tank, and the gas was about 25° above summer atmospheric temperature when it issued from the stack. Almost all the quicksilver came out as flour mercury, which was so fine and so mixed with soot that extraction on the hoeing table was difficult, even with the use of much unslacked lime.

Ralph Cranston, plant superintendent, and Mr. Yount succeeded in overcoming these difficulties by eliminating the inside spray, and substituting an outside drip on the first five stands, which kept the outside surface of the iron pipes covered by a thin film of water. Also, an inside spray was installed in the base of the stack. The beneficial effects of these alterations on the cooling curve of the gases can be seen in the fact that the gases drop 90 percent of their quicksilver in the first two returns, 5 percent in the third, 4 percent in the fourth, the remainder in the air chamber, and issue from the stack at a temperature only about 1° above summer atmospheric temperature. The quicksilver is returned almost entirely in liquid form rather than as flour mercury, and much less unslacked lime and labor are required to clean it. * * *

Its [the plant's] average throughput is 12 tons of ore per day, at a plant cost of $0.942 per ton. This figure does not include depreciation and overhead charges but includes the following items:

	Per ton	Per day
Labor (crushing and furnacing)	$0. 552	$6. 63
Fuel (furnace and engine)	. 233	2. 80
Lubricating oil	. 092	1. 10
Water (pumping cost)	. 035	. 42
Lime	. 01	. 12
Miscellaneous	. 02	. 24
Total	. 942	11. 31

Mid-Continent Quicksilver Corporation.—The Nichols-Herreshoff furnace of the Mid-Continent Quicksilver Corporation went into operation at Bemis Hill in December 1935. This furnace has a treating capacity of 50 tons a day.

A brief description and flow sheet of the plant follows. Ore is hauled to the plant by trucks which dump into a 650-ton rough-ore bin (pl. 12). From this bin the ore passes through a Rogers jaw breaker that has a capacity of 80 tons per 10-hour day and crushes to about ¾ inch. Ore from the breaker goes into a 250-ton crushed-ore bin. From the crushed-ore bin the ore is elevated about 5½ feet by a car on a track to the drying hearth on top of the furnace. The top one of a series of rabble arms feeds the ore into the furnace, which comprises six hearths. The furnace is fired by three burners, one each on hearths 3, 5, and 6. The rabble arms move the ore successively from one hearth to that below it. The rabble arms are hollow and are cooled internally by a draft of cold air. Part of the air, warmed by passing through the rabble arms, is returned to the burners as preheated air and is used for carbureting the Diesel fuel oil used for heating the furnace. The fuel consumption is about 11 gallons to the ton of ore.

The volatile products from the furnace pass through a dust collector and thence to a twin-unit condenser, which is much larger than the condenser ordinarily used with a furnace of this size. Each unit is composed of 19 10-inch cast-iron tubes 16 feet high, a redwood tank 20 feet high and 7 feet in diameter, and a stack 18 inches in diameter and 30 feet high. Fumes leave the stacks only a few degrees above atmospheric temperature.

It is thought that no quicksilver is lost as vapor through the stacks or in the burned ore, which is reported to be entirely barren. Some may be lost through the stacks, however, as fine globules attached to particles of soot and perhaps also in other ways. The whole furnace system is furnished with a draft provided by a suction fan, so that any leaks allow no loss of volatile materials.

The plant is powered by a 37½-horsepower Fairbanks-Morse semi-Diesel engine and an alternate 75-horsepower semi-Diesel engine of the same make. The plant is housed in an 80-foot by 30-foot corrugated-metal building. The furnace and the condensing system are on a concrete floor surrounded by a curb. The floor drains into a concrete trap in which eventually collects all the quicksilver unavoidably lost around the plant.

The following reduction costs per ton of ore were furnished by the Mid-Continent Quicksilver Corporation: Labor, \$0.742; fuel and lubricants, \$0.854; supplies and upkeep, \$0.389; total, \$1.985.

The recovery per ton from all ore so far run through the plant, including some low-grade dumps and more than 1,500 tons run for experimental purposes, ranged from 3 pounds to 46 pounds. The average recovery per ton, exclusive of the ore from low-grade dumps and experimental ore, has been 16.2 pounds.

MINES AND PROSPECTS

On the following pages are described all the mines and prospects within the area mapped, as well as a few outside the area. In addition, many of the localities where cinnabar has been found in place but where little or no development work has been done are described briefly.

Most of the prospects and the productive mines lie within a zone about a mile wide that borders the Cowhide and Amity faults on the south. The deposits are described in order from the east end of the district westward, and the locality numbers in parentheses in the headings correspond to the locality numbers in plates 2 and 7.

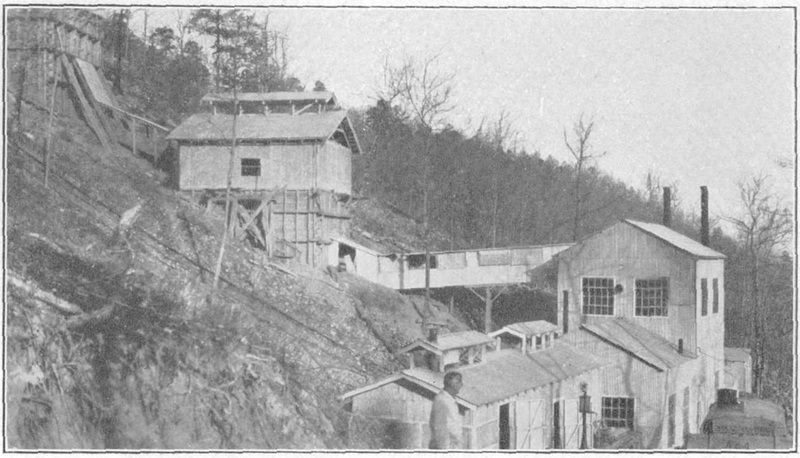
Plate 13 is a property ownership map which was prepared by Howard A. Millar, of Murfreesboro, in 1934, principally from records in the courthouses of Clark, Pike, and Howard Counties. It was brought up to date in 1936 from data furnished by Leo Yount. The map shows that a large proportion of the district and vicinity is owned by the Southern Kraft Corporation, the Ozan-Graysonia Lumber Co., and the Ozan Investment Co. The property of the first-named company is distributed over the entire area. The holdings of the second are principally in the eastern part of the district; and those of the third in the western part.

An ownership map of so large an area with so many owners is necessarily out of date before it is printed, but it is believed that plate 13 is correct in most places. Some inconsistencies are known to appear partly because of certain ambiguous property descriptions, particularly some of those dealing with irregular fractions, and partly because of failure to find many of the land lines on the ground. According to local reports, much of the subdivision of tracts was done by fast, inaccurate compass and pace methods.

SECS. 5 AND 6, T. 7 S., R. 22 W., AND SEC. 1, T. 7 S., R. 23 W. (2, 3, AND 4)

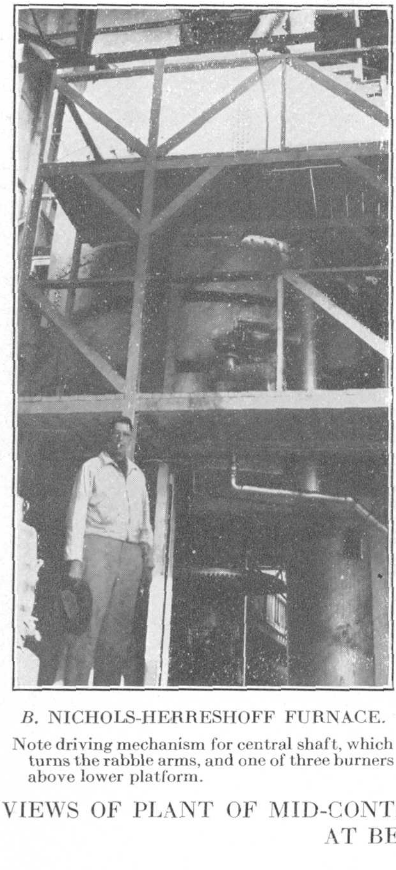
Cinnabar has been found at several places over a horizontal extent of about 1¾ miles along the north side of a prominent ridge of Jackfork sandstone north of the Ashbrook trail, which is on the ridge, in secs. 5 and 6, T. 7 S., R. 22 W., and sec. 1, T. 7 S., R. 23 W. The cinnabar in sec. 5 is the farthest east of all known.

Most of the cinnabar seen in these sections is of the disseminated type in sandstone. Some fills fractures and is associated with a little dickite. The deposit in sec. 5 is in rocks that trend about N. 35° E., considerably more northerly than the general trend. This indicates the presence there of a cross fold. A small cross fold is exposed and some cinnabar was seen a short distance west of the Okalona road in sec. 6.



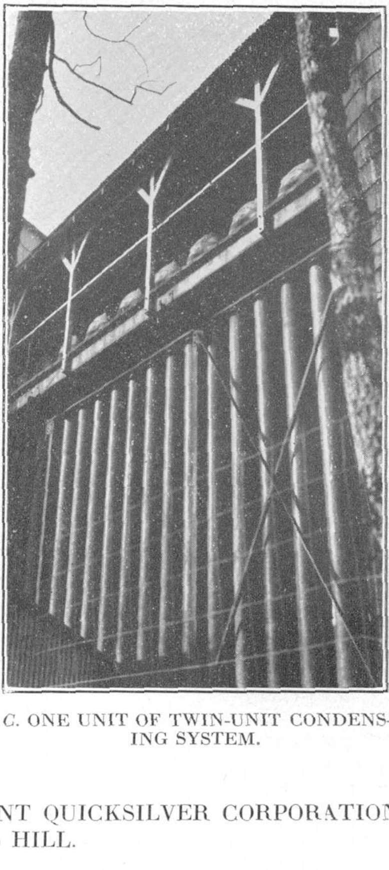
A. REDUCTION PLANT ON EAST SLOPE OF HILL.

From upper left to lower right: Coarse ore bin, crusher house above fine ore bin, and furnace room. The condensers are concealed by furnace room.



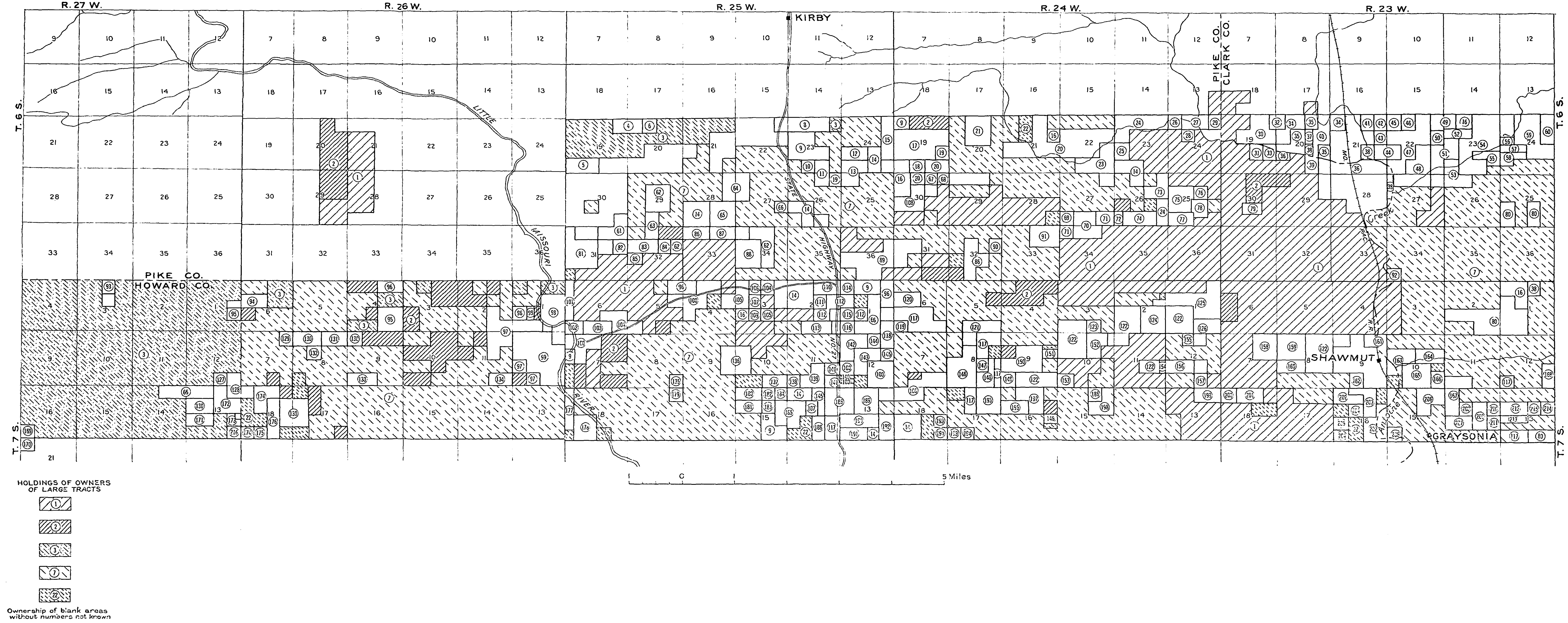
B. NICHOLS-HERRESHOFF FURNACE.

Note driving mechanism for central shaft, which turns the rabble arms, and one of three burners above lower platform.



C. ONE UNIT OF TWIN-UNIT CONDENSING SYSTEM.

VIEWS OF PLANT OF MID-CONTINENT QUICKSILVER CORPORATION AT BEMIS HILL.



PROPERTY OWNERSHIP MAP OF THE ARKANSAS QUICKSILVER DISTRICT AND SURROUNDING TERRITORY.

LIST OF OWNERS OF TRACTS SHOWN ON MAP BY CORRESPONDING NUMBERS IN CIRCLES

1. Ozan-Graysonia Lumber Co.
2. Ozan Investment Co.
3. Dierks Lumber & Coal Co.
4. Campbell, J. L.
5. Mack, J. B.
6. Gregory, W. O.
7. Southern Kraft Corporation.
8. Wagley, J. G.
9. United States.
10. McCormack, G. W.
11. Adams, W. P.
12. Winford, L. M.
13. Ashby, Betty.
14. Featherstone, Albert.
15. Reynolds, F. C.
16. Hays, W. C.
17. Murfreesboro Lumber Co.
18. Knighten, Hosea.
19. Holcomb, Lee.
20. Holcomb, W. C.
21. Barnett, T. J.
22. State.
23. Marshall, H. C.
24. Palmer, T. B.
25. Kyle, W. D.
26. Widner, W. P.
27. Sliegh, G. E.
28. Sliegh & Widner.
29. Garner, G. M.
30. Dearing, W. L.
31. Foshee & Tolleson.
32. Lyons, L.
33. Williams, W. L.
34. Trammel, V. E.
35. Williams, N.
36. Hethcock, A. L.
37. Kress, W.
38. Giles, W. A., estate.
39. Davidson, J. W.
40. Williams, L. W.
41. Wheeler, W. O.
42. Rowe, Paul.
43. Trammel, A. D.
44. Richardson, W. D.
45. Richardson, George.
46. Shaka, J. J.
47. Trout, J. M.
48. Trout, J. G.
49. Rice, B. F.
50. Myers, Elmira.
51. Kendrick, R. M.
52. Fox, Dale.
53. Gibson, Charles.
54. Golner, C. J.
55. Pinney, W. R.
56. Pittman, W. J.
57. Delamar, F. S.
58. Davis, W. H.
59. East, A. H.
60. Robertson, C. N.
61. Mitchell, M. V.
62. Stewart, R. D.
63. Buie, M. C.
64. Hamilton, C. F.
65. Tolleson, M. E.
66. Copeland, Z. A.
67. Nelms, W. H.
68. Anthony, J. W.
69. Cox, Mart.
70. Marino, Louis.
71. Woodal, W. M.
72. Woodal, W. N.
73. Tolleson, G. W.
74. Woodal, Kurt.
75. Oliver, H. W.
76. Philips, Elmer.
77. Woodal, Luther.
78. Woodal, John.
79. Davidson, W. B.
80. Gunter, Felix, trustee.
81. Carroll, M. L.
82. Skelton, J. P.
83. Skelton, J. F.
84. Skelton, J. E.
85. Pomroy, D. B.
86. Caponetto, Cirino.
87. Dansberry, J. P.
88. Garner, R. L.
89. Irwin, B. J. and C. R.
90. Townsend, M.B.
91. Nieman, W. G.
92. Mock, Wilson.
93. Williams & Henderson.
94. Reese & Barton.
95. Barton, M. C.
96. Meeks, O. O.
97. Parker, G. J.
98. Cox, A. J.
99. Arkansas Power & Light Co.
100. Parnell & Carroll.
101. Bell, W. R.
102. Parnell, D. L.
103. Hopkins, Mrs. Amont.
104. Bell, Lulu.
105. Funderburk, J. H., estate.
106. Bell, R. N.
107. McNaughton Mercury Co.
108. Spencer, B. L.
109. Farror, D. J.
110. Hicks, D. E.
111. Cox, W. E.
112. Scudamore, W. D.
113. Anderson, W. N.
114. Hicks, D. J.
115. Henderson, B. F.
116. Schwanda, Thomas.
117. Federal Land Bank.
118. Anderson, J. M.
119. Cox, J. H.
120. F. C. Stearns Hardware Co.
121. Pike City O. & L. S. Co.
122. Wright, J. B.
123. Simmons, E. B.
124. Cox, Otis.
125. Pennix, J. C., trustee.
126. Gatliff, G. C.
127. Brown, O.
128. Pyle, William.
129. Gross, P. C.
130. Henry, C. J.
131. Sweeden, J. W.
132. H. & F. Land Co.
133. Russell, S. W.
134. Terrell Bros.
135. Eckerson, Harry.
136. Clark, James G.
137. Townsend, R. R., and Kempner, I.
138. Townsend, R. R.
139. Musgrove, Ed.
140. Chambers, Eliza.
141. Duggar, J. G.
142. Detroit Timber & Lumber Co.
143. Anderson, B. F.
144. Anderson, J. H.
145. Johnson, Harry.
146. Patterson, W. M.
147. Hardy, A. A.
148. Stiles, Bessie.
149. McSpadden, O. H.
150. Land Tracts.
151. Holder, D. V.
152. Wright, E. T.
153. Worthey, W. C.
154. Reynolds, H. L.
155. Burleson, J. J.
156. Wilson, Luther.
157. Haynes, E. N.
158. Stinson, J. M.
159. Cox, D. B.
160. Trout, J. R.
161. Kelley, D. H.
162. State and R. J. Green.
163. Story, I. S.
164. Wood, Henry.
165. Frazier, C. M.
166. Frazier, S. F.
167. Couch, A. L.
168. Haynes, Minnie.
169. Blackwood, J. W.
170. Blackwood, G. C.
171. Russell, T. W.
172. Stone, J. L.
173. McRae, W. J.
174. Shute, John.
175. Bowers, Ben L.
176. Henderson, T. L.
177. Clark, James.
178. Simpson, W. B.
179. Brown, F. C.
180. Ashby, George.
181. Hicks, Mattie E.
182. Kempner, I.
183. Brown, A. F.
184. Antony, G.
185. Anderson, J. L.
186. Marks, Leon.
187. McNab, T. F.
188. Wagner, Giles.
189. Sanders, T. J.
190. Self, R. E.
191. Skelton, B. F.
192. Redding, Mary.
193. Shafer, W. H.
194. Harris, L. M.
195. Fuller, S. A.
196. Walker, J. R.
197. Wheelis, A. J.
198. Reynolds, T. J.
199. Haynes, M. D., and Witt, J. M.
200. Haynes, M. D.
201. Meats, Harry.
202. Lee, R. M.
203. Green, R. J.
204. Green, B. E.
205. Green, B. F.
206. Huffmann, T. D.
207. Meeks, Harvey.
208. Cally, J. B.
209. Johnson, Jewell.
210. Cason, J. T.
211. Garrett, F. A.
212. Johnson, Ester.
213. Couch, J. H.
214. Huffman, M. L.
215. Mauldlin, W. L.
216. Polk, Nettie.

Practically no development work has been done on any of these deposits, and there has been no production from them.

HILL IN SOUTHERN PART OF SEC. 34, T. 6 S., R. 23 W. (6)

Development work.—The hill in the southern part of sec. 34, T. 6 S., R. 23 W., commonly called Hill 34, is on land of the Southern Kraft Corporation. Cinnabar has been known on this hill since soon after the discovery of the mineral in the district. Considerable prospecting and mining have been done there by the Mercury Mining Co. and, under contract, by the Mid-Continent Quicksilver Corporation. The principal openings are a shaft on the top of the hill south and east of the haulage road and a cut at the sharp western angle in the haulage road on the top of the hill. Many smaller openings along the ridge have produced in the aggregate considerable quicksilver. The shaft is 6 by 12 feet and is 60 feet deep. It is reported to have produced 180 tons of 12- to 15-pound ore. The cut is about 150 feet long and at its face is about 35 feet below the surface. A shaft sunk near the face of the cut reaches a depth of 110 feet below the surface (fig. 6). This cut and shaft are reported to have produced 1,350 tons of 8- to 10-pound ore.

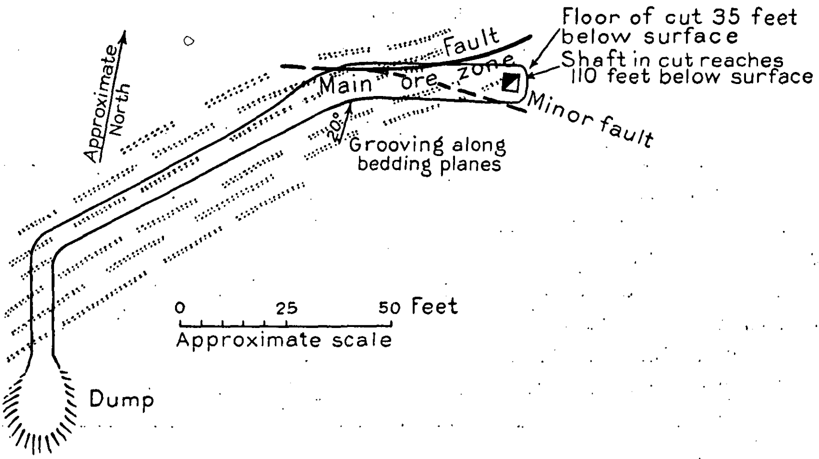


FIGURE 6.—Geologic sketch plan of principal cut on hill in southern part of sec. 34, T. 6 S., R. 23 W.

Geology.—Hill 34 lies between the Amity fault on the north and another thrust fault on the south. The rocks are Jackfork sandstone. Their trend on the hill is northwest, and the general dip is toward the south. The structure of the hill is very complex in detail, probably because it constitutes a narrow slice between two thrust faults. There are many cross folds and small thrust and tear faults.

At the shaft near the east end of the top of the hill the rocks trend parallel to the hill and are vertical. There is no faulting or folding there, but the walls exposed in the shaft are grooved. The sandstone beds are fractured, and no shale was seen. The beds were mineralized to a depth of 40 feet over the 6-foot width of the shaft and along the beds for about 12 feet. Beginning at a depth of 40 feet there was less cinnabar and the shoot was not as large. The last 10 feet of the shaft was sunk through barren rock. About three-fourths of the cinnabar taken out was in fractures, and about one-fourth was disseminated through the sandstone.

At the cut farther east the beds strike about N. 80° E. and are nearly vertical. At a little more than 100 feet in the cut a vertical fault is exposed, which splits a little farther in. The larger branch curves into the north wall, and the smaller one into the south wall. Many of the beds are deeply grooved in the plane of the bedding. Most of the grooves pitch about 20° E. The ore zone lies south of the larger fault. The last 15 feet of the shaft—that is, from about 95 feet below the surface—was in leaner ore than that higher up, but the bottom of the shaft (now partly full of water) is reported to be in ore (fig. 6).

Ore disseminated in sandstone is more common on Hill 34 than it is at many other places in the district.

HILL 3 (7)

Hill 3 is on property of the Mid-Continent Quicksilver Corporation and lies south of Bemis Hill and Hill 2, on the south side of the south branch of the Cowhide fault. Many openings were made near the east end of Hill 3 by the Arkansas Quicksilver Co., and three or four have been opened or enlarged by the Mid-Continent. One of these near the foot of the hill yielded 75 tons of 12- to 14-pound ore, and another farther up the hill produced 140 tons of 10- to 12-pound ore.

The cut near the foot of the hill is about 60 feet long and is driven westward into the hill. It exposes three pronounced folds in the interbedded sandstone and shale of the Jackfork. The ore occurred largely in closely spaced fractures near the axial planes of the folds in a bed that ranges from 6 to 30 inches in thickness. Some ore was found in other beds.

The cut that has produced 140 tons of ore is a short distance north of the cut just mentioned and about 30 feet above it. This cut is driven northward into Hill 3 and exposes a thick thrust zone. The ore was found in brecciated zones related to the thrust fault. The average tenor of the ore is said to be about 10 pounds to the ton.

Another cut about 100 feet higher on the hill is about 65 feet long and at the face is about 40 feet below the surface. About 30 feet of shale beds near the start of the cut appear to form the sole of a thrust zone, and the relatively undisturbed massive sandstone beds farther in are in the block underlying this zone. Cinnabar filling fractures in slightly fractured sandstone appears to be associated with a small tear fault that cuts the massive beds.

BEMIS HILL (8)

Development work.—Bemis Hill lies west of Antoine Creek in the northern part of sec. 33 and the SW. ¼ sec. 28, T. 6 S., R. 23 W. It is on ground controlled by the Mid-Continent Quicksilver Corporation and was the site of the principal mining efforts of the Arkansas Quicksilver Co. The furnace of the Mid-Continent Quicksilver Corporation is on the eastward-facing slope of the hill.

The workings on Bemis Hill consist of many test pits scattered over the hill, a glory hole, and five adits aggregating about 850 feet. This work was done partly by the Arkansas Quicksilver Co. and partly by the Mid-Continent Quicksilver Corporation. The location of some of these workings is shown on plate 14, but the map was made before the plant was built and before much of the more recent work was done. The glory hole is an open pit and shaft about 50 feet deep on the top of the hill. The hole produced about 145 flasks of quicksilver from about 2,500 tons of ore for the older company and has been greatly enlarged by the Mid-Continent. A large low-grade dump left by the Arkansas Quicksilver Co. was recently furnaced and yielded about 7 pounds to the ton. An adit connects the bottom of the glory hole with the surface.

A plan of the haulage tunnel, formerly tunnel 2, is shown in plate 14. The tunnel was driven from the east slope of the hill along the strike of some sandstone beds for the first 100 feet. Here the strike of the sandstone beds changed, and a few laterals were driven where a little mineralization was observed. The remainder of the work was carried on with the purpose of mining from the glory hole. Some ore was found in the southeast lateral in thin sandstone beds (less than 4 inches thick) in shale. The last 250 feet of tunnel to the west portal was driven during the summer of 1935 to make a haulageway. It is all in shale, and no cinnabar was observed.

At 33 feet from the west portal a drift was driven 56 feet toward the northwest for the purpose of mining a richly mineralized sandstone bed on which trenching had been done. The bed trended nearly east, almost at right angles to the bedding of the shale exposed in the main adit. Mining revealed that the sandstone bed had been torn from its original position and now lay completely surrounded by contorted shale.

The Black tunnel, about 30 feet long, was driven eastward from Suck Hollow into Bemis Hill, and a little cinnabar was found.

Short descriptions of the other adits are given in a report by Branner.[63]

[63] Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Inf. Circ. 2, pp. 44–45, 1932.

A new cut on the east side of Bemis Hill about 150 feet east of and 40 feet below tunnel 1 of the Arkansas Quicksilver Co. exposes a sharp drag fold in massive sandstone beds to the south along the Amity fault. About 100 tons of ore carrying 8 pounds of metal to the ton has come from this cut. The ratio of ore to waste has been about 1 to 2.

Geology.—Bemis Hill lies between the Amity fault and the south branch of the Cowhide fault. It forms the sliver end of a block of Jackfork sandstone that has been thrust northward completely over the Stanley shale until it abuts against the northern band of sandstone (pl. 2). As would be expected, the rocks in this block have suffered extreme deformation. An examination of the structure shown on plate 14 reveals the complexity of some of the folding and faulting. More detailed mapping of Bemis Hill, particularly some of the more recent openings, would reveal many more complex structural details. An idea of the complexity of some of the small structural features can be gained by a study of figure 7.

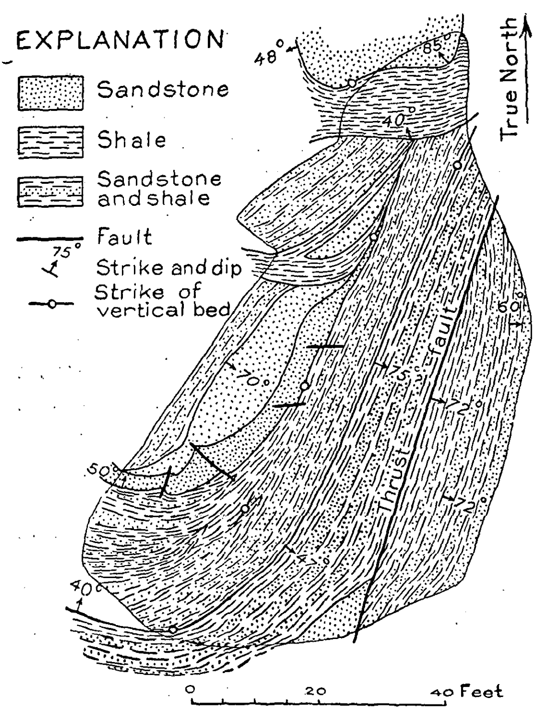


FIGURE 7.—Geologic sketch plan, projected to the plane of the surface, of the glory hole on Bemis Hill.

On the northeast slope of Bemis Hill (pl. 14) the sandstone beds trend in general about east; along the crest of the hill the trend is in general northwest; on the southwest slope most of the sandstone beds deviate but slightly from an east-west trend. In some places the change in strike is due to folding—for example, in the eastern part of the haulage tunnel—but in others the sandstone beds are faulted off and abut against beds striking across them. In still other places slabs of sandstone many feet long have been torn loose and completely isolated from their parent beds and now lie surrounded by shale. An example of this has been described above. As the exposures are poor, the true nature of many of these structural features will be revealed only when mining has exposed them more completely.

As is explained on pages 50 and 55, places showing such structure are favorable for the localization of ore. Furthermore, their proximity to the Cowhide and Amity thrusts, up which the mineralizing solutions came, makes this area an exceptionally favorable one for metallization. Though ore has been mined here over a vertical range of 250 feet, no single fold or fault has been mined for a depth of more than 50 feet. This is due partly to the difficulties of mining open pits and partly to the termination of ore. At the Gap Ridge mine, near the Little Missouri River, an ore shoot was mined to a depth of 225 feet. The structure of the sandstone at this mine is much simpler than at the Mid-Continent Quicksilver Corporation's property. Possibly mineralization may be more continuous where it is limited to fewer structural features. Nevertheless, it seems probable that ore will persist down some of the folds and faults on Bemis Hill to greater depths than they have yet been mined. Local lean zones may be encountered, but if evidence of mineralization persists, ore may be found below such lean zones.

HILL 2 (9)

Hill 2 lies west of Bemis Hill and is separated from it by the valley of Suck Hollow Creek. Hill 2 is on land controlled by the Mid-Continent Quicksilver Corporation. The hill is spotted with many prospects, on several of which a large amount of work has been done. These prospects have yielded a considerable quantity of quicksilver. The more important ones are described after the following short paragraph on the geology of the hill.

Hill 2 constitutes a large block of Jackfork sandstone that lies south of the Amity and Cowhide faults and north of the south branch of the Cowhide fault. As at Bemis Hill and Hill 34, the block is caught between relatively major thrust faults and is intensely deformed. Small thrust faults, tear faults, and cross folds are all common. Cinnabar has been found at many places on the south side of the hill, but so far as known has not yet been found on the north side.

Cut 1.—Cut 1 is near the east end of Hill 2, in the NW¼ sec. 33, T. 6 S., R. 23 W. It is close to Suck Hollow Creek, at an altitude of about 480 feet. The cut has so far produced about 115 tons of 17- to 20-pound ore.

Work done before 1936 opened up a wedge-shaped mass of intricately folded and contorted shale in which were round "niggerheads" of rich ore as much as 1½ feet in diameter and large slabs of highly mineralized sandstone. This is bounded on the northeast by a thrust-fault plane that strikes N. 74° W. and dips 64½° SW., against which lay 2 feet of ore. The footwall of the fault plane is massive sandstone. The south side of the wedge is bounded by an irregularly curved slickensided wall of sandstone. About 80 feet higher on the hill two beds of mineralized sandstone in contorted shale were opened by a trench. The ore extended through what is apparently the fault plane.

More recent work at cut 1, nearer the creek and only a few feet above it, shows sandstone and shale, in the upper block of the minor thrust fault mentioned above, folded into an overturned anticline and cut off against the thrust plane. This minor thrust projected should intersect, according to plate 2, the south branch of the Cowhide fault in a short distance (fig. 8). Some cinnabar has been found about where the minor fault should intersect the larger one.

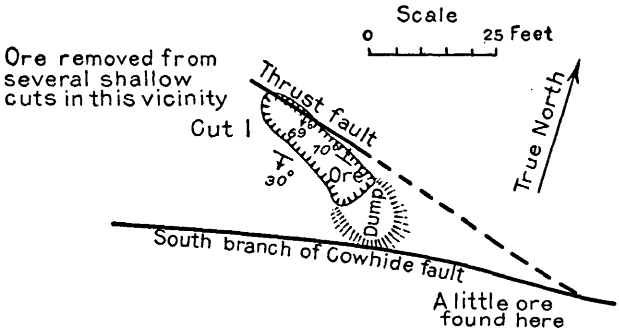


FIGURE 8.—Geologic sketch plan of vicinity of cut 1, Hill 2, Pike County, Ark.

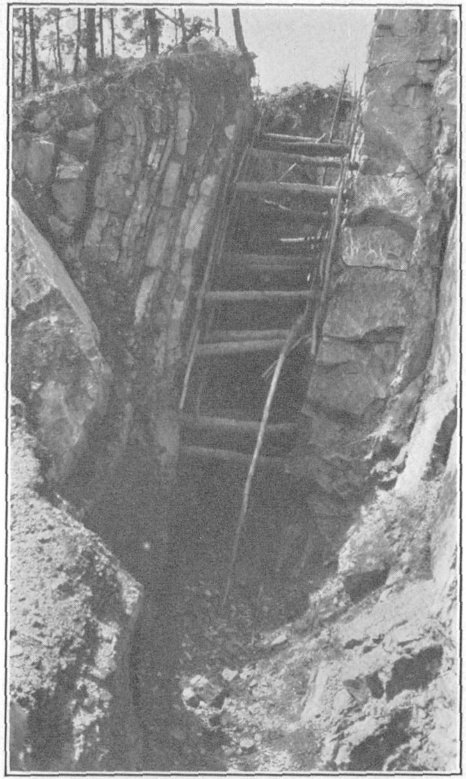
Cut 2.—An open stope near the mouth of a small creek in the SE¼ SW¼ sec. 29, T. 6 S., R. 23 W., from which about 2,800 tons of ore and rock has been taken, has yielded 315 tons of 15- to 18-pound ore. The mined beds aggregate about 6 feet in thickness, and the stope is about 80 feet long. The stope, at its deepest place, reaches a depth of about 45 feet below the surface (pl. 15, *A*).

The beds at cut 2 are deflected to the left about 80 feet by a faulted cross fold. The stope is on the fold where the beds strike about N. 55° E. and dip about 72° SE.

Cuts 3 and 5.—Cuts 3 and 5 on Hill 2 are near the head of a small valley at about the southeast corner of the NE¼SW¼ sec. 29, T. 6 S., R. 23 W. Cut 3 is on the southeast side of the valley, and cut 5 is just across the valley from it. About 1,100 tons of material has been removed from these cuts, of which about 95 tons was ore of a tenor between 14 and 16 pounds to the ton.

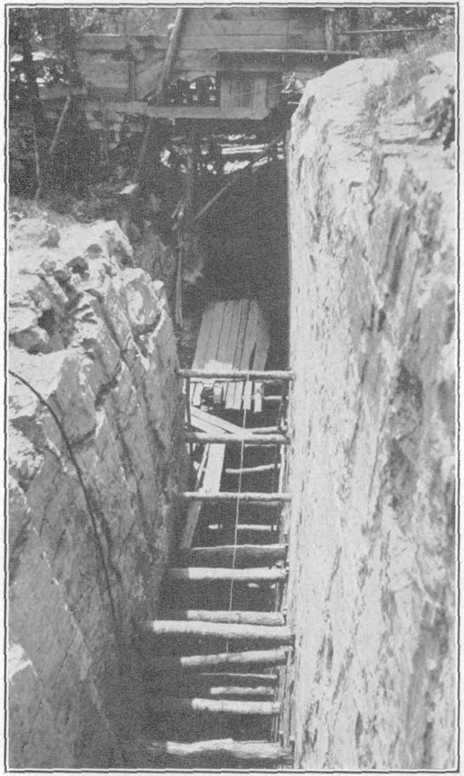
Cut 3 is a pit about 10 feet square and 30 feet deep. The pit is on a sharp flexure in sandstone and shale beds, shown diagrammatically in figure 9. Cinnabar was found at the surface in several beds but near the bottom of the pit was confined to a 6-inch bed.

At cut 5, which is an open cut about 35 feet long and 30 feet high at the face, the rock is greatly contorted. Boulders of ore lie in shale in a fault zone. The shale carries some cinnabar. Part of the cinnabar at cut 5 occupies small quartz veinlets.



A. VIEW S. 55° W. ALONG CUT 2, HILL 2.

Sharp folds that do not show in the photograph at each end of the stope turn the beds into their normal trend. A fault that dips steeply toward the northwest cuts off some beds in the hanging wall.



B. STOPE AT GAP RIDGE MINE FROM THE EAST.

Note offsets along fractures in left or hanging wall and steep westward pitch of fractures.

Cut 4.—Cut 4 is in the SE¼SW¼ sec. 29, T. 6 S., R. 23 W. About 20 tons of 12- to 15-pound ore has been mined there. A shaft about 25 feet deep was sunk in loose shale that was moved without blasting. Diamond drilling reveals a sandstone nose just east of the shaft and indicates that the ore continues in that direction. Most of the ore at cut 4 was found as loose bits of sandstone and shale containing cinnabar.

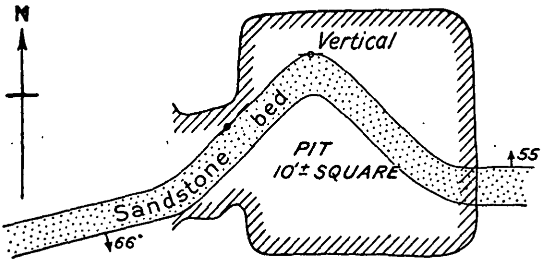


FIGURE 9.—Diagrammatic sketch plan of structure in pit at cut 3, Hill 2.

Cut 6.—Cut 6, which is a few hundred feet northwest of cut 5, has yielded 55 tons of ore that carried between 10 and 12 pounds of quicksilver to the ton. Cut 6 is in massive sandstone beds, but the structure is obscure.

NW¼ SEC. 32, T. 6 S., R. 23 W. (10)

On the hillside south of some of the openings in sec. 29 on Hill 2 but not far distant from them some prospecting was done by the Arkansas Quicksilver Co. This work may have yielded about 13 tons of 20-pound ore. Some ore of very high grade was found there, and a little native quicksilver has been reported.

More recently the Mid-Continent Quicksilver Corporation has done some more work at the old prospect, a short distance east of it on a sharp cross fold, and several hundred feet farther east across a small valley. The newer work recovered 40 tons of 7- to 9-pound ore from 1,570 tons of rock.

The old prospect was opened on a sandstone bed 2 feet thick which lies between beds of ribbon shale and which pinches out at the east end of the prospect trench. The bed strikes N. 75° W. and dips 69° S. Cinnabar was found in fractures, mostly in sandstone but partly in shale for a short distance each way from the sandstone bed.

A few feet east of the east end of the old prospect the beds make a bend and strike S. 10° E. for 20 feet, to a point where they resume the general strike. A trench along this portion of the beds failed to recover ore.

The eastern prospect is a cut about 75 feet long with a maximum depth of about 20 feet. The cut followed a group of sandstone beds between 4 and 8 feet thick. The beds strike N. 87° W. and dip 68° S. A small fault, covered when visited during this survey, is reported to trend about parallel to the beds but to dip south at a low angle. The upper block, as would be expected, is reported to have moved north. The ore in this eastern cut has been in general of low grade, but good ore is reported in the bottom, which when visited was covered.

NE¼ SEC. 19, T. 6 S., R. 23 W. (12)

Development work.—The prospect of the Amity Quicksilver Corporation lies near the center of the NE¼ sec. 19, T. 6 S., R. 23 W. According to reports the ground is owned by Warner L. Deering (see pl. 13), of Amity, Ark., and the company leases from him. This place has been variously known as the property of Deering, the Exploration Co., Schwartzberg, the Amity Quicksilver Co., the Amity Quicksilver Corporation, and the Antoine Quicksilver Co. When last visited, in the fall of 1935, the work appeared to be under the direction of R. E. Vandruff.

The lease is supposed to cover an area of 220 acres. The property was first opened in 1932 by the Exploration Co., which dug a trench 30 feet long, 12 feet wide, and 3 feet deep. In January 1934 the trench was widened 3 feet and deepened to 15 feet at its northwest end by M. Schwartzberg. When visited in July 1934 the lessees were reported to be R. B. Martin and O. W. Wheeler. The property was visited again in May 1935, when it was controlled by the Amity Quicksilver Corporation. At that time an inclined shaft 20 feet long and 8 feet wide had been sunk down the dip to a depth of about 40 feet, a few feet northwest of the older pit. No quicksilver has been produced from this property.

Geology.—The development work has been done a few hundred feet southwest of the top of a low ridge that runs northwestward through the NE¼ of the section. The country rock has been assigned to the Stanley shale. Fragments of vein quartz are common in the vicinity. The shaft and the trench have been opened in a massive 12-foot bed of sandstone, which is immediately overlain along the southwest side of the excavations by 3 feet of shale and thin-bedded sandstone. The sandstone is light gray, fine-grained, and has a dirty appearance. The strike and dip of the beds are somewhat variable but may average about N. 33° W. and 72° SW.

The beds are cut by a series of cross fractures whose strikes range from N. 69° E. to N. 81° E. and whose dips range from 67° SE. through vertical to 79° NW. The fractures are spaced from 6 inches to 5 feet apart, and movements along them have displaced the beds on the southeast side to the northeast. Most of the displacements do not exceed 3 inches, but two displacements each about a foot in magnitude were observed. A small, steeply dipping fracture crosses the shaft diagonally in a northwesterly direction near its bottom. At the southwest side of the shaft the fracture curves and continues in a southwesterly direction. Cinnabar and dickite were observed in several of the fractures, among them the curving one near the bottom of the shaft. Some of the fracture surfaces are coated with a cinnabar veneer about $\frac{1}{32}$ inch thick. This property and the Mac-Holmes mine, in the SE¼NW¼ sec. 32, T. 6 S., R. 24 W., are the only places where cinnabar mineralization of this type was observed. Some of this cinnabar crust is itself coated with a thin black film which may be metacinnabar.

SW¼NW¼ SEC. 25, T. 6 S., R. 24 W. (13)

A few prospect pits in the Gap Ridge sandstone member in the SW¼NW¼ sec. 25, T. 6 S., R. 24 W., are reported to have disclosed some cinnabar. In October 1935 this ground was said to have been leased by the Atlas Quicksilver Co., which planned to start prospecting. Later reports indicate that the pits are on ground now controlled by the Atoka Quicksilver Corporation.

PALMER PROSPECT (14)

The prospect of T. B. Palmer is in the NW¼SE¼ sec. 26, T. 6 S., R. 24 W. The Atoka Quicksilver Corporation was reported, early in 1937, to hold the property under lease. Several trenches and pits were opened on the property in 1934, 1935, and 1936. The two largest trenches are crosscuts, each about 100 feet long, near the hilltop. A shaft at the end of one trench has a reported depth of about 52 feet.

The Palmer prospect is in the Gap Ridge sandstone. The two largest trenches expose a section nearly 200 feet thick, which is largely light-colored quartzitic sandstone with some shale. The detailed structure of the hill is complex, with many small cross folds and tear faults. Because of the number and complexity of the minor structural features the rocks are locally greatly fractured. A broken cross fold is well exposed at the south end of the most southerly prospect trench.

Much of the shattered rock appears to be impregnated with hydrothermal quartz, which partly fills the numerous vugs. Crystalline dickite and a large amount of limonite are present also. Some of the dickite is stained brown or red with hydroxides of iron. A bright-red amorphous-appearing mineral, thought in the field to be a hydrated oxide of iron, was shown by laboratory tests to contain considerable cinnabar. It is probably contaminated with iron compounds.

WALL MOUNTAIN SHAFT, WALL ROCK SHAFT, AND PROSPECTS BETWEEN (15)

Two shafts have been sunk by the Mid-Continent Quicksilver Corporation on the south slope of Wall Mountain, outside the area mapped in detail, and the same company has opened more than half a dozen prospects between them. The Wall Mountain shaft is in the SE¼ sec. 35, T. 6 S., R. 24 W., and the Wall Rock shaft is in the NE¼ sec. 3, T. 7 S., R. 24 W., about a mile distant.

The general trend of the rocks in this vicinity indicates that all these Wall Mountain openings are in the same general stratigraphic position in the Jackfork sandstone. All these deposits are more than a mile south of the Cowhide thrust fault and therefore are farther away from the fault than most of the deposits in the district. The area between the Wall Mountain deposits and the southern edge of the mapped area has been studied in a reconnaissance way only, but the unusually wide band of Jackfork sandstone present there, the position and trend of a long east-west valley, and the occurrence of the deposits on Wall Mountain indicate the possible presence of another thrust fault between the Wall Mountain deposits and the Cowhide fault.

The Wall Mountain shaft is 110 feet deep and when visited in March 1937 was nearly full of water. The massive Jackfork sandstone beds there strike N. 85° W. and dip 73° S. A vertical fault of unknown displacement cuts off the beds at the east end of the shaft. Most of the cinnabar mined filled fractures in the sandstone, but some was disseminated. Some of the fractures contained solid cinnabar as much as 2 inches thick. The beds mined aggregate about 8 feet in thickness, and the footwall is shale. Many of the fractures that carry the cinnabar strike across the beds and dip about 45° E. Near the bottom of the shaft the ore is reported to be relatively lean. Some cinnabar was found to a depth of about 30 feet east of the fault mentioned above that cuts off the main ore-bearing beds at the east end of the shaft. This shaft has produced 400 tons of ore carrying 10 to 12 pounds of quicksilver to a ton.

The Wall Rock shaft is about 70 feet deep and was partly full of water in March 1937. Beds similar to those at the Wall Mountain shaft are cut by a tear fault that trends northward across the beds and that has practically no displacement at the surface. The displacement on the fault increases with depth at the rate of about 6 inches to 10 feet of depth. The beds are displaced to the left—that is, to the north on the east side of the fault. The ore shoot followed a breccia zone along the tear fault, and ore is reported at the bottom of the shaft. About 275 tons of 5- to 8-pound ore was taken from this shaft.

A prospect pit 8 feet long, 5 feet wide, and about 25 feet deep has been dug in massive sandstone beds about 600 feet southwest of and about 50 feet below the Wall Mountain shaft. The pit is just west of a small tear fault that displaces the beds about 2 feet to the left. About 50 tons of 15- to 18-pound ore has been taken from this pit.

About halfway between the two shafts on Wall Mountain a trench 80 feet long, 8 feet wide, and 6 feet in average depth is terminated at each end by a small tear fault. The pit has yielded about 15 tons of 8-pound ore.

Other small prospects between the shafts, each on a small tear fault, have produced in aggregate about 25 tons of 4- to 8-pound ore.

MAC-HOLMES MINE (19)

The Mac-Holmes mine of C. E. Holmes and R. B. McElwaine is in sec. 32, T. 6 S., R. 24 W., on ground owned by C. Caponetto and operated under lease by Holmes and McElwaine. The retort at this mine is briefly described in the section on "Treatment of the ore."

Former workings at this place, before the property was leased by Holmes and McElwaine in January 1936, include a shaft and some trenches. The shaft, commonly called the Caponetto shaft, is about 40 feet deep. At the bottom of the shaft is a drift about 35 feet long and a crosscut (fig. 10). Both drift and shaft are in thick sandstone

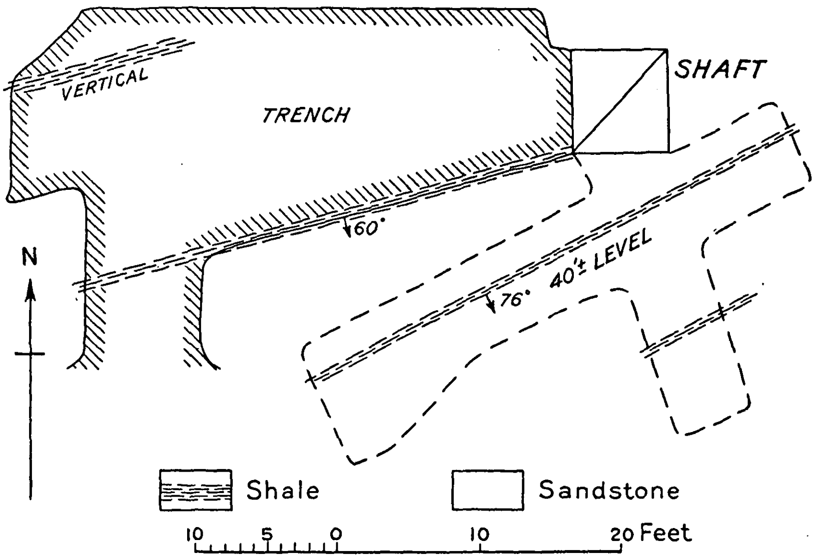


FIGURE 10.—Plan of Caponetto shaft at the Mac-Holmes mine.

beds separated by shale partings that strike N. 74° E. and dip 76° S. The sandstone is silicified, and siderite and a very little smeared cinnabar were seen on some joint surfaces.

Since January 1936 Holmes and McElwaine have sunk a shaft at a point about 30 feet southwest of the old Caponetto shaft, to a depth of about 90 feet. From this shaft drifts have been driven eastward about 100 feet on the 55- and 85-foot levels. The upper drift has been connected with the Caponetto shaft. Considerable stoping has been done between the levels. The relatively rich ore shoots appear to be localized by small cross folds whose axes pitch about 30° W.

At the shaft the beds are cut by a nearly vertical tear fault of unknown displacement. None of the ore shoots have yet been followed to the point of intersection with the tear fault.

Considerably more pyrite and siderite are associated with the cinnabar in quartz veinlets here than at any other place yet found in the district. The better ore obtained at this mine has been retorted, but according to an estimate of one of the operators a dump contains nearly 1,000 tons of ore that carries between 5 and 9 pounds of quicksilver to the ton.

The Mac-Holmes mine is in the Gap Ridge sandstone member of the Stanley shale.

At another place in the SE¼NW¼ sec. 32 a trench has been dug on a sharp elbow in the sandstone. The beds change from a strike of N. 60° E. with a dip of 66° S. to a strike of N. 20° E. with a dip of 73° W. The beds are silicified, carry much dickite and some cinnabar, and are vuggy, leached, and stained with hydrated iron oxides. Much slickensiding is in evidence. This pit is also in the Gap Ridge sandstone.

SW¼NW¼ SEC. 32, T. 6 S., R. 24 W. (20)

An open stope was sunk on some rich ore in South Woodall Creek in the SW¼NW¼ sec. 32, T. 6 S., R. 24 W., in the summer of 1935 by the Mercury Mining Co. When the property was visited in October 1935 this pit was 40 feet long, 40 feet deep, and about 3 feet in average width. Forty tons of ore had been mined, which yielded 35 flasks of mercury. The ore was a mineralized sandstone bed striking east, flanked by shale on the south wall. A shaft was being sunk on top of the ridge about 100 feet east of the west end of the pit.

NORTHERN PART OF SEC. 2, T. 7 S., R. 25 W. (24)

About a dozen small trenches and pits were opened in 1932 by the Arkansas Cinnabar Mining Co. (not to be confused with the Arkansas Quicksilver Co.) on property of J. J. Cox in the NW¼NW¼ sec. 2, T. 7 S., R. 25 W. The ground is reported to be owned now (1937) by Albert Featherstone. This locality is not far east of the Cox prospect, which is next described, and is at about the same horizon in the Gap Ridge sandstone member of the Stanley shale. According to Branner,[64] native quicksilver has been reported here.

COX PROSPECT (25)

The two shafts, each about 30 feet deep, and the 20-foot trench that constitute the developments at the J. J. Cox prospect, in the NE¼NE¼ sec. 3, T. 7 S., R. 25 W., were dug in 1932 by D. O. Roller, C. H. Lumin, and I. J. Brooks. No work has been done since 1932, but the land is reported to belong now (1937) to Albert Featherstone. A 1-tube retort near the shafts shows evidence of having been operated, but no production has been reported. The prospect is in the Gap Ridge sandstone member of the Stanley shale.

FUNDERBURK PROSPECT (26)

The Funderburk prospect, on land of the J. H. Funderburk estate, is in the NW¼NW¼ sec. 3, T. 7 S., R. 25 W. The main development

[64] Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Inf. Circ. 2, p. 47, 1932.

consists of a trench 75 feet long, 10 feet wide, and 20 feet deep at its north end. This trench was opened in 1932 by C. I. Barfield.

The Funderburk prospect is in the same sandstone member of the Stanley shale (Stearn's Parker Hill member) as the Old Argentine prospect, about a mile farther west.

The sandstone beds exposed in the trench are 9 feet in maximum thickness. They strike N. 78° E. and dip 77° S. Most of the fractures strike N. 20° E. and dip 60° SE. The beds have been offset about 18 inches along a fracture that strikes about parallel to the others but dips 38° W. The top has moved northward relative to the bottom.

Cinnabar was observed in the fractures, together with an unusually large amount of dickite.

OLD ARGENTINE PROSPECT (27)

The Old Argentine prospect is in the NW¼ sec. 4, T. 7 S., R. 25 W. In the later part of 1932 and the early part of 1933 a shaft 30 feet deep was sunk by C. Caponetto, who then held a lease on the property. A few other small prospect pits have been dug.

The Old Argentine prospect is in the 100-foot sandstone member (Stearn's Parker Hill member) of the Stanley shale, beneath the Gap Ridge sandstone. Native quicksilver is reported to have been found at a depth of 15 feet.

ISBELL PROSPECT (28)

The Fletcher F. Isbell holdings include the N½SE¼ sec. 6 and the SW¼SW¼ sec. 5, T. 7 S., R. 25 W. The fee owner is Mrs. Lulu Bell. The developments consist of about 20 prospect pits and one shaft about 12 by 14 feet and 50 feet deep. The property produced about 3.3 flasks of quicksilver in 1934, which was recovered from ore treated in Yenglin's retort. The production of 9.7 flasks in 1935 came from 52.75 tons of hand-sorted ore that was furnaced in the plant of the Southwestern Quicksilver Co. Practically all the ore came from the shaft, near the east line of sec. 6. The Isbell prospect suspended mining operations in June 1935, when the Southwestern plant was taken over by Mercury Producers, Inc., and became unavailable for customs treatment. Since then prospecting has been carried on at the property. It is reported that the mine will reopen whenever furnace facilities become available.

The shaft is near the top of the Gap Ridge sandstone, a few hundred feet east of a tear fault of considerable displacement and a few hundred feet west of a large and tightly compressed cross fold.

YENGLIN PROSPECT (29)

Otto Yenglin began prospecting in May 1934 in the SW¼SE¼ and SE¼SW¼ of sec. 6, T. 7 S., R. 25 W., on land which was reported to belong to W. R. Bell and which now (1937) is said to belong to Mrs.

Amont Hopkins. One pit has reached a depth of 20 feet, and another 10 feet. In addition, several small prospect pits have been dug on the property. One of the main pits is on the faulted segment of the Gap Ridge sandstone east of the staff house of the Southwestern Quicksilver Co.; the other is north of the new C. C. C. road and east of the Parnell Hill mine. A small retort has been installed.

PARNELL HILL (30)

Parnell Hill is principally in the SW¼SW¼ sec. 6, T. 7 S., R. 25 W., and its west end is in a fractional 40-acre tract farther west. The principal developments on the hill are the Parnell Hill mine and associated prospects, on ground reported to be owned by D. L. Parnell, and the Bell prospect, on the fractional tract west of the Parnell Hill mine, which is said to belong to W. R. Bell.

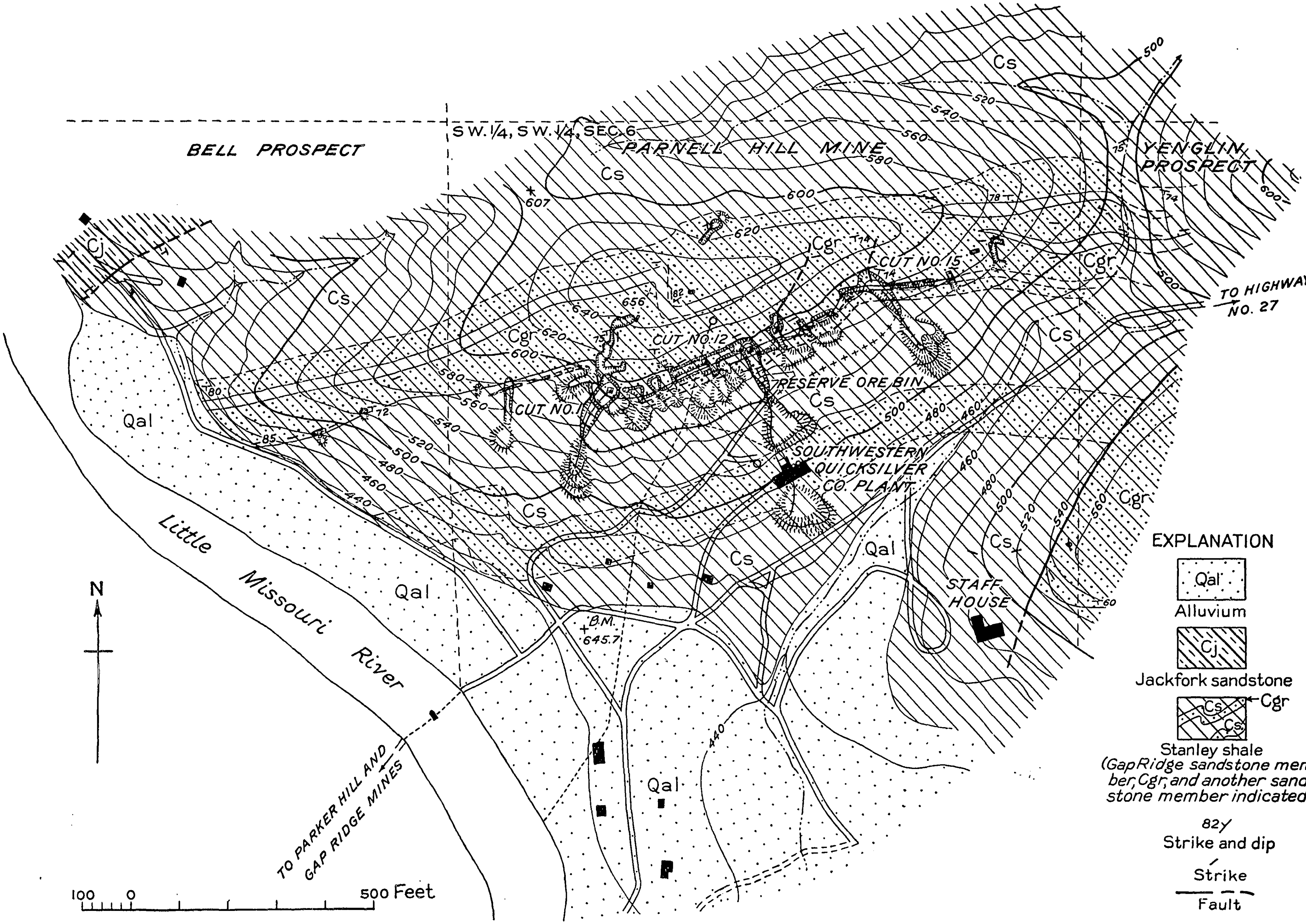
PARNELL HILL MINE

Development work.—The Parnell Hill mine was developed principally by the Southwestern Quicksilver Co., and the furnace of that company is located on Parnell Hill. The experience gained by early work at Parnell Hill has resulted in the development of a prospecting procedure used widely in the district. Cuts are made into the sides of the hills toward places where cinnabar is known. The hill slopes allow faces 30 to 40 feet high to be exposed within horizontal distances of 50 to 75 feet. From these cuts it is possible, where desired, to work laterally along the strike of the rocks. After such preliminary work the openings that expose the best showings of cinnabar are used as sites for sinking on the ore. During the prospecting the mineralized rock is sorted by hand and the waste discarded in the openings as the work progresses.

Most of the prospecting and mining on Parnell Hill was done prior to 1934. Plate 16 shows the extent of the work there in the spring of 1934. The principal openings are cuts 1, 12, and 15. The bottom of cut 1 attains a depth of about 60 feet below the surface at the back of the cut. A shaft has been sunk about 14 feet below the floor of the cut. From cut 12 an ore shoot was followed by an incline that pitches steeply to the east to a depth of 87 feet below the floor of the cut, or 122 feet below the surface outcrop. Cut 12 extends about 150 feet westward from the entry but has not been opened below the floor of the entry and in most places not even that deep. East of cut 12 a shoot was mined to a depth of 187 feet below the surface.

The ore was trammed to the plant for crushing and furnacing. Stearn [65] reports that the ore from the Parnell Hill mine on which the furnace was started ran 12 to 15 pounds to the ton, but that later its tenor was increased by hand sorting to about 38 pounds to the ton.

[65] Stearn, N. H., Mining and furnacing quicksilver ore: Eng. and Min. Jour., vol. 134, no. 1, p. 24, January 1933.



TOPOGRAPHIC AND GEOLOGIC MAP OF PARNELL HILL MINE.

Since the reopening of the property in June 1935, Mercury Producers, Inc., has driven several hundred feet of tunnels and has sunk a new shaft in cut 12. It is understood that much of the tunnel work has been east of the old Parnell Hill workings and at a lower level.

Geology.—The Parnell Hill mine is opened near the top of the Gap Ridge sandstone. The principal structural features are the well-exposed cross fold near the middle of the hill (pl. 6, *A*) and the large tear fault that terminates the hill on the east. The tear fault has offset the Gap Ridge sandstone east of the fault about 600 feet south and 1,500 feet west.

The shattered sandstone along the axis of the cross fold contains some cinnabar all the way across the hill, but ore has been found only near the upper sandstone-shale contact. The ore shoot, which pitches steeply eastward from cut 12, lies along the sandstone-shale contact. This ore contains some stibnite. Westward from the entry to cut 12 cinnabar mineralization appears to have stopped at a horizontal fracture about 15 feet below the surface. The west end of this cut (pl. 6, *B*) supplied some rich ore and gave rise to its name, "Bloody Cut." The ore shoot east of cut 12, which was followed to a depth of 187 feet, lay along a small tear fault. Another small fault in cut 15 strikes N. 5° W. and dips 75° E.

BELL PROSPECT

Several trenches and pits have been dug on the W. R. Bell property. Work in 1933 and part of 1934 was under the direction of H. E. Smith. A 1-tube retort was built. Late in 1934 and in 1935 the work was directed by R. C. Rohrdanz. Mr. Rohrdanz reports a production of about 15 flasks from 102 tons of ore. The ore was furnaced in the plant of the Southwestern Quicksilver Co. Operations were discontinued by Mr. Rohrdanz in April 1935. It is reported that Mercury Producers, Inc., has since sunk a 60-foot shaft at this prospect.

The cinnabar at the Bell prospect is in the same zone near the top of the Gap Ridge sandstone as that at the adjacent Parnell Hill mine.

MILL MOUNTAIN (31)

In late 1931 and early 1932 George Bell and W. F. Hintze opened a trench 40 feet long, 7 feet wide, and 10 to 25 feet deep on property of the Arkansas Power & Light Co. on Mill Mountain, on the ridge in the SW¼NE¼ sec. 12, T. 7 S., R. 26 W. This is in the Jackfork sandstone but considerably lower in the formation than the Parker prospect, father southwest in the same section, although about the same distance east of the tear fault that trends northeast through the section. The sandstone in the vicinity is buckled complexly and fractured. No cinnabar was seen in the trench or on the dump, but some is reported to have been found there. The sandstone is in places brilliantly stained with hydrated oxides of iron.

In March 1937 two prospect pits, in both of which good ore showed, were being opened by the Cinnabar Mining Co. on ground leased from the Arkansas Power & Light Co. near the foot of the northeast slope of Mill Mountain, northeast of the prospect just described. These pits are in a buckle in sandstone beds near the base of the Jackfork sandstone.

PARKER HILL (32)

Development work.—Parker Hill is a small hill in the SE¼SW¼ sec. 1, T. 7 S., R. 26 W., on ground owned by G. J. Parker. The original discovery of cinnabar in the western part of the district was made on the southwest side of the hill. Subsequently the Parker Hill mine was opened there by the Southwestern Quicksilver Co. (fig. 11). A shaft was sunk to a depth of 75 feet on the nose of a cross fold, and a stope was opened for 27 feet east of the shaft. Trouble in retaining the shale hanging wall caused the shaft to be abandoned. A second shaft was sunk about 30 feet east of the original one (fig. 12), using the east side of the former opening as much as possible. This shaft is 129 feet deep. At a depth of 113 feet a drift runs west for 30 feet. The bottom of the shaft is 70 feet below ground-water level, and when it was closed the opening was making about 350 gallons of water an hour. According to Stearn,[66] 4,000 tons of rock has been moved at the Parker Hill mine.

It has been reported that since the mine was visited Mercury Producers, Inc., has run a 40-foot tunnel at Parker Hill.

Geology.—The Parker Hill mine is in a sandstone member of the Stanley shale, which lies below the Gap Ridge sandstone. It may be, as Stearn believes, the same sandstone member that he calls the Parker Hill member, which is cut off by the main thrust fault about halfway between State Highway 27 and the Little Missouri River.

The mine lies about 400 feet northwest of a large tear fault and a few hundred feet south of the Cowhide fault (pl. 2). The mine openings are near the upper contact of the sandstone member. At Parker Hill the sandstone, which is about 100 feet thick, has been bent into a tight cross fold, which deflects the beds about 150 feet (fig. 11). The main stope extends eastward from the nose of the cross fold. The best ore has been found in shattered sandstone on the nose of the fold and along a small tear fault about 90 feet farther east. The small tear fault strikes N. 5°–8° E. and dips 60° E. The east side has been offset 8 to 10 feet north with respect to the west side. The original 75-foot shaft and stope was in good ore all the way. The drift runs westward from the 129-foot shaft at a depth of 113 feet and was in good ore 6 to 8 feet wide for the entire distance of 30 feet.

[66] Stearn, N. H., The cinnabar deposits in southwestern Arkansas: Econ. Geology, vol. 31, p. 19, January-February 1936.

The mineralization produced the typical association of cinnabar, dickite, and quartz in fractures. Native quicksilver was found in

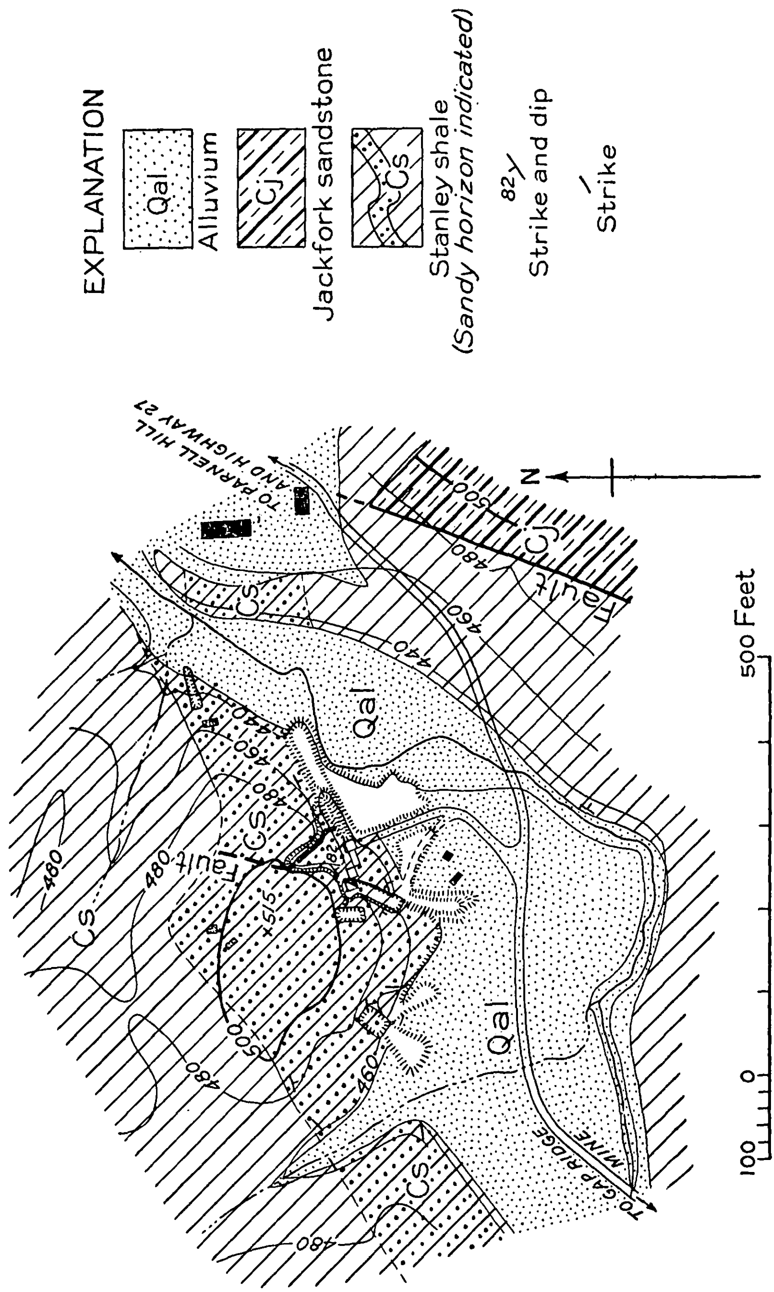


FIGURE 11.—Topographic and geologic map of the Parker Hill mine.

the discovery pit on the southwest side of Parker Hill and in the drift at a depth of 113 feet.

PARKER PROSPECT (33)

The G. J. Parker prospect is in the SE¼SW¼ sec. 12, T. 7 S., R. 26 W. According to reports, men named Scott and Otto brothers leased the land from Parker about May 1933 and worked the prospect until September of that year. They are said to have produced several flasks of quicksilver in a small retort at the property. Development when the prospect was visited in 1934 consisted of a prospect pit about 15 feet deep. The McNaughton Mercury Co. is reported to have done some subsequent work at the prospect and to have increased the total production to about 21 flasks.

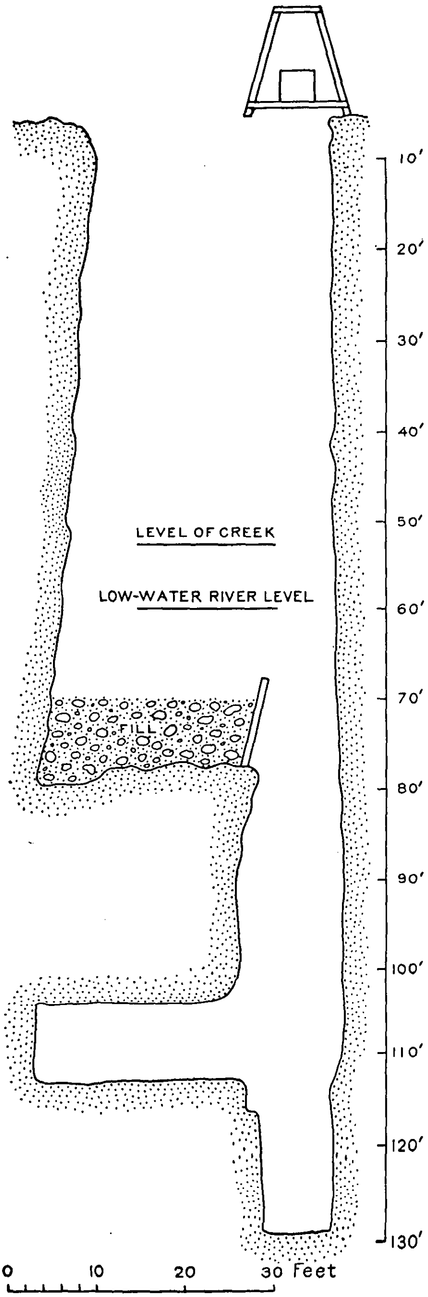


FIGURE 12.—Longitudinal section, looking N. 25° W., of stope at the Parker Hill mine.

The Parker prospect is in the Jackfork sandstone and is nearer the top of that formation than the bottom. It is considerably farther south than most other showings of cinnabar in the district. A reason for this may be that the prospect is not far east of one of the largest tear faults of the area. Fracturing associated with the tear faulting possibly afforded channels for the cinnabar-bearing solutions. The sandstone at the pit strikes N. 43° W. and dips 70° SW. Fracture surfaces in the light-gray sandstone are coated with crusts of quartz and cinnabar crystals. Cinnabar in place is reported from two neighboring localities, but these places were not found.

EASTERN PART OF GAP RIDGE (34)

Cinnabar has been observed in float and in place at several localities near the east end of Gap Ridge, in sec. 12, T. 7 S., R. 26 W., on ground of the Arkansas Power & Light Co. The Cinnabar Mining

Co., which holds this ground under lease, was prospecting there in March 1937. Considerable ore was stacked at the prospect, and it is reported that this company has rented the furnace of the Southwestern Quicksilver Co. to furnace this ore and ore from the new prospects on Mill Mountain. When visited in March 1937 two pits, 15 and 30 feet deep, had been sunk, and work was progressing in both of them.

The pits are in the Gap Ridge sandstone member of the Stanley shale not far west of a large tear fault that has been mentioned in the descriptions of several other prospects. The ore-bearing bed is apparently at about the same horizon as that of the Gap Ridge mine, farther west.

GAP RIDGE (35)

Location and development.—The Gap Ridge mine is near the west end of Gap Ridge in the SW¼NE¼ sec. 11, T. 7 S., R. 26 W. The fee owner is G. J. Parker.

The open stope from which the production of the Gap Ridge mine has come and neighboring smaller prospect openings are shown in plate 17. The stope is about 55 feet long and a little more than 6 feet wide, and has been sunk to a depth of about 225 feet. Figure 13 is a longitudinal section, slightly modified from one of Stearn's illustrations [67] and from a profile kindly furnished by Mr. Yount. Figure 14 is a plan sketch of the stope at the surface. Material was taken from the stope by a hoist at the west end. The stope is vertical. When the mine was closed in September 1934 water was entering the stope at an estimated rate of 500 gallons an hour. The bottom of the stope is about 125 feet below ground-water level. According to Stearn,[68] 5,980 tons of rock has been taken from the stope.

According to reports a little ore has been taken from the Gap Ridge mine by men working on a share basis since the mine was shut down by the Southwestern Quicksilver Co.

Geology.—The Gap Ridge mine is opened near the southern or upper contact of the Gap Ridge sandstone member of the Stanley shale (pls. 2 and 17). The detailed section at the stope (fig. 14), from the top down, is as follows:

Section at stope in Gap Ridge mine

		Ft.	in.
Shale	Hanging wall	100±	
Sandstone		4	
Shale	Stope	---	2
Sandstone		---	10
Shale		---	2–4
Sandstone		3	
Shale		---	2
Sandstone		---	8
Alternating sandstone and shale		1	
Massive sandstone footwall.			

[67] Stearn, N. H., op. cit., fig. 5, p. 14.

[68] Idem, p. 14.

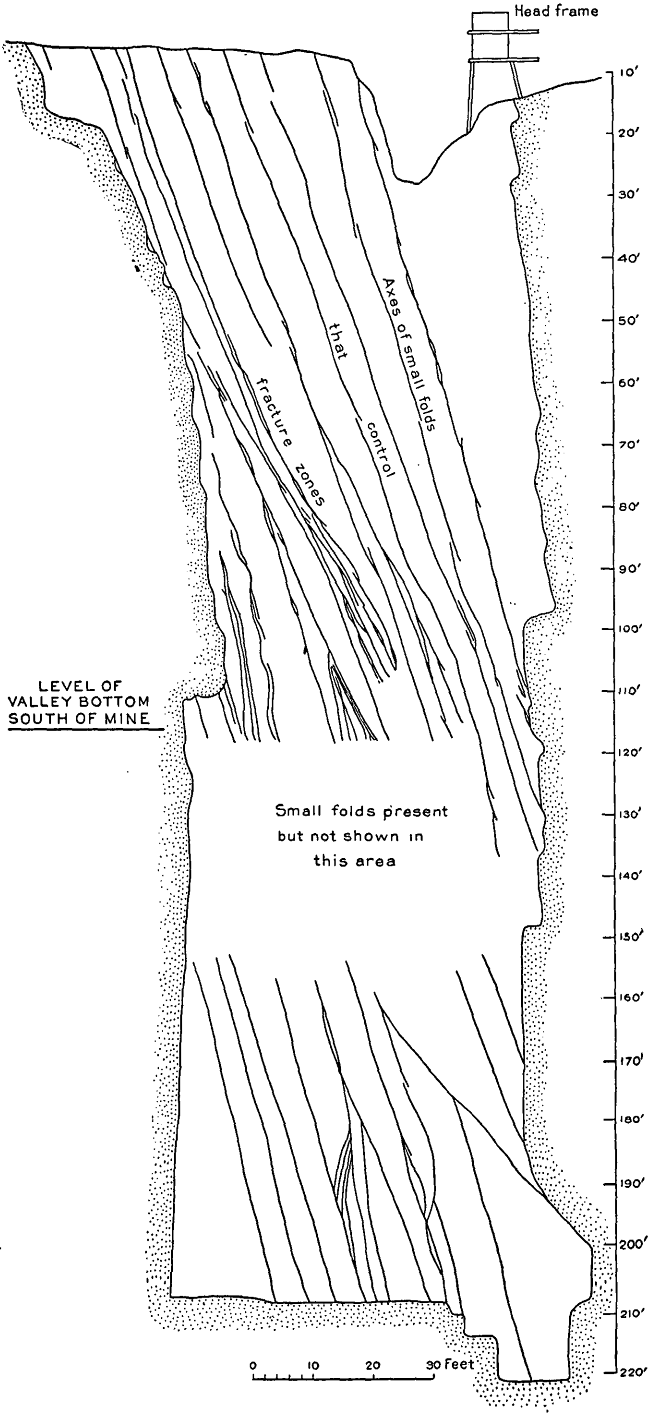
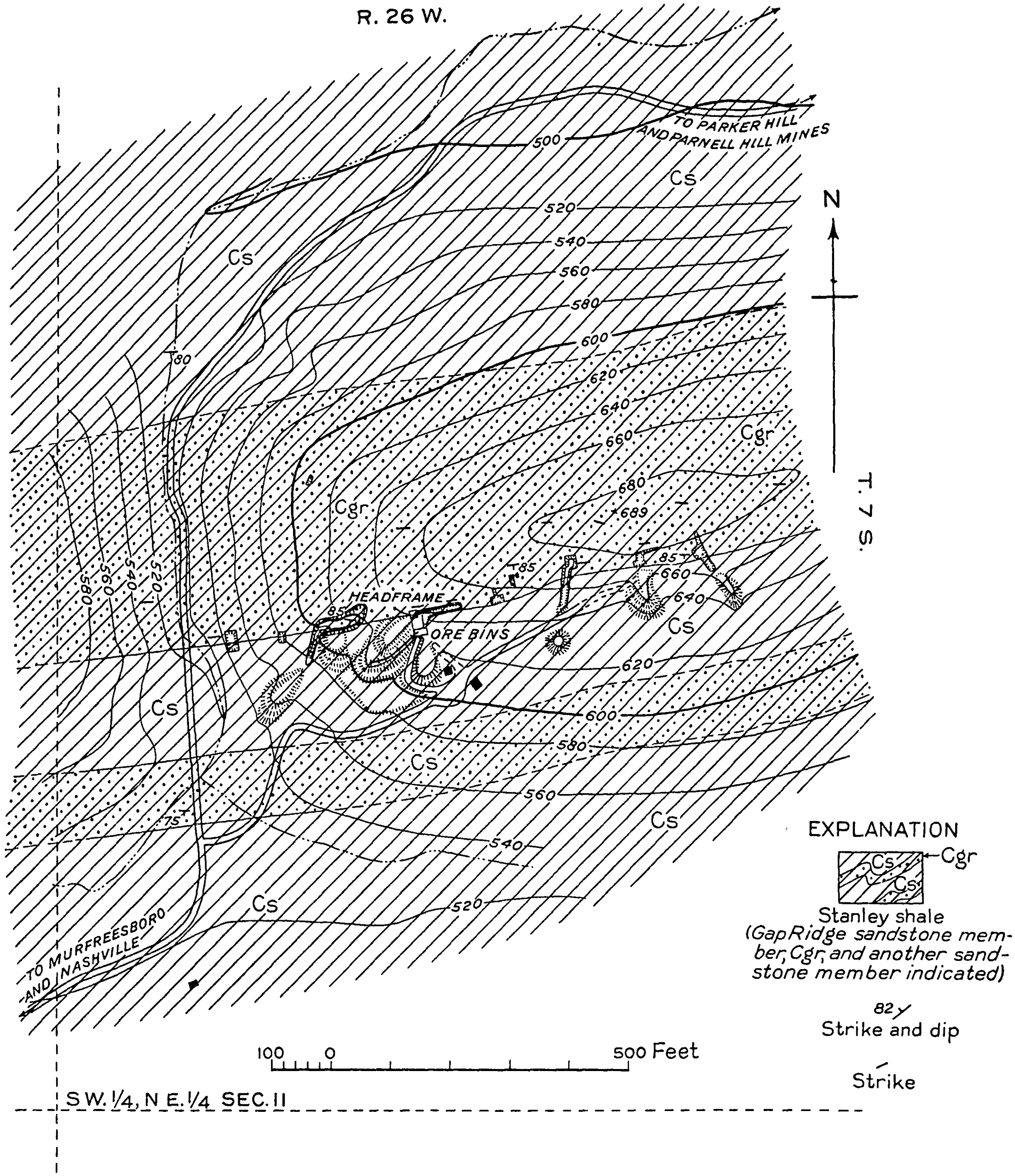


FIGURE 13.—Longitudinal section, looking south, of stope at the Gap Ridge mine.



TOPOGRAPHIC AND GEOLOGIC MAP OF GAP RIDGE MINE.

The rocks are not tightly compressed into cross folds as large as those at the Parker Hill and Parnell Hill mines, but they are crinkled in the main stope and are slightly warped where exposed in the prospect openings east of the stope. At the stope a series of steplike mineralized fractures (figs. 13, 14, and pl. 15, *B*), which strike N. 8° E. and dip 65°–70° W., offset the hanging-wall sandstone, which is mineralized but has been left to hold the overlying shale. The fractures extend north across the sandstone beds of the stope interval, but they offset each bed successively smaller amounts and do not offset the footwall sandstone at all. Most of the fractures are spaced between 3 and 6 feet apart. On the hanging-wall side of the stope the offsets along them range from 3 to 8 inches. On each offset the southeast side has moved northeastward relative to the northwest side, and the fractures therefore can be considered tiny cross folds such as the larger ones described in the section on "Structure" (pp. 39–42).

Cinnabar deposition apparently was controlled by the fractures, and the ore is found in them and in the closely associated broken rock which resulted from movements along the fractures. Individual shoots are tabular and are ordinarily richer on their south sides, where displacements are greater and where there is more brecciation. The shoots dip steeply to the west, with the fractures. The ore body as a whole is nearly vertical; thus, although the fractured zones continue upward east of the east end of the stope and downward west of its west end, they are not extensively mineralized outside the ends of the stope. In addition to

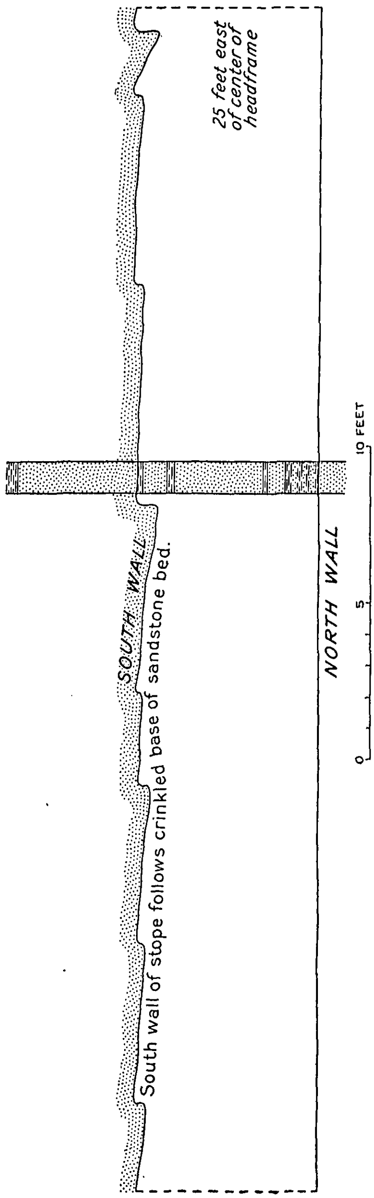


FIGURE 14.—Plan drawing showing small folds or crinkles in south wall of stope at the Gap Ridge mine and section across beds.

the common hydrothermal minerals of the district (cinnabar, dickite, and quartz), stibnite has been found at several places in the stope.

RIDGE WEST OF GAP RIDGE (36)

On the ridge west of Gap Ridge, in the SE¼NW¼ sec. 11, T. 7 S., R. 26 W., cinnabar with dickite and quartz is found along two sets of fractures in the Gap Ridge sandstone. This place is on land belonging to the Southern Kraft Corporation. The sandstone beds strike N. 75° E. and dip 83° S. The fractures of one set strike N. 20° E. and dip 41° NW.; those of the other, more irregular and indefinite set strike N. 5° W. and dip 62° E. In 1935 the Mercury Mining Co. drove an 85-foot tunnel here and found some cinnabar. Near the face the beds strike N. 80° W. and dip 78° S.

SE¼SW¼ SEC. 9, T. 7 S., R. 26 W. (37)

Fractures in the Gap Ridge sandstone carry cinnabar near the northeast corner of the SE¼SW¼ sec. 9, T. 7 S., R. 26 W., and between that point and the small creek that cuts the Gap Ridge sandstone a few hundred feet to the east. This occurrence was pointed out by F. S. Blount and is on land of the Southern Kraft Corporation.

HUDGINS PROSPECT (38) AND PROSPECT IN NE¼NW¼ SEC. 16, T. 7 S., R. 26 W. (39)

Development work.—The W. O. Hudgins prospect lies near the southwest corner of the SE¼SW¼ sec. 9, T. 7 S., R. 26 W., on ground owned by S. W. Russell.

Development was started in September 1933, and a 2-tube retort with a reported capacity of 1,200 pounds of ore a day was built. This retort was replaced in June 1934 by a 24-tube retort. Steam power was used, and the scarcity of water caused shut-downs during dry times. Crushing to about half an inch was effected in a jaw breaker.

When last visited, in the fall of 1934, the largest opening was a shaft 7 feet square and 30 feet deep. Several smaller pits had been dug in the vicinity.

Just south of the Hudgins prospect, on ground of the Southern Kraft Corporation, a small pit in the NE¼NW¼ sec. 16, T. 7 S., R. 26 W., discloses a considerable amount of cinnabar.

Geology.—The Hudgins prospect is in the Jackfork sandstone near its contact with the underlying Stanley shale. It lies a few hundred feet east of one of the northeastward-trending tear faults (pl. 2). In the shaft the beds strike E. and dip about 75° S. A gouge seam 6 inches thick and parallel to the bedding is exposed in the shaft. The rock is traversed by two distinct groups of joints. The joints of the principal group cross the bedding in a direction about N. 15° E. and dip 80° E. The joints of the other group strike parallel to the bedding and dip 26° N. Most of the cinnabar occupies the joints of the principal group but some is found along joints of the other set.

Locally the rock is brecciated, and cinnabar, dickite, and quartz partly or entirely fill the interstices between the sandstone fragments.

PYLE PROSPECT (41)

The Will Pyle prospect, in the SE¼SE¼ sec. 12, and the NE¼NE¼ sec. 13, T. 7 S., R. 27 W., was originally opened by F. A. Copeland in 1932. Brown & Rison did further prospecting in 1933. In 1934 the lessees were C. E. Holmes and C. Q. Schow.

When visited in April 1934, the principal development consisted of a trench 40 feet long and 10 feet deep at the deepest place. In lower ground north of the trench two other pits had been dug to depths of 20 feet and 10 feet.

The rock at the trench is clean light-gray sandstone that trends about N. 49° E. The sandstone is fractured and contains dickite, barite, and some cinnabar. Small cinnabar crystals were observed in larger crystals of barite.

The rock at the deeper of the two pits is principally a dirty dark crushed sandstone that contains many flat shale pellets about a quarter of an inch across. Considerable dark, locally carboniferous shale is present also. The pit is nearly full of water, but near the top the strike on the north side is N. 36° E. and the dip 85° S. At the south side, 15 feet away, the strike is N. 62° E. and the rocks are vertical. The rock is fractured, and dickite, limonite, and a little cinnabar were seen in the fractures.

The shallower pit is 25 feet long and is in light-gray sandstone. The bedding is obscure here, but a fault trending N. 81° E. and dipping 80° SE. is exposed. Considerable cinnabar is present in the fractured sandstone.

FLOYD PROSPECT (42)

The S. N. Floyd prospect is in Howard County, in the SW¼SE¼ sec. 12, T. 7 S., R. 27 W. According to plate 13 the property is in the name of O. Brown. Several prospect holes on the property, the largest a shaft about 10 feet square and about 35 feet deep, are reported to have been dug by Brown & Rison in 1933. A small 1-tube retort was also constructed. No production has been reported from the Floyd prospect.

The rock in this vicinity is a light-gray, locally fractured sandstone. The strike is about N. 72° E., and the dip approaches 87° S. Some of the prospect pits disclose considerable cinnabar in fractures.

ROCK FENCE PROSPECT (43)

Development work.—The Rock Fence property is in Howard County, in the NE¼NW¼ sec. 13, T. 7 S., R. 27 W. It is farther west than any other known locality where cinnabar has been found and is about 1½ miles west of the western limit of the mapped area. In April 1934, when the property was first visited, J. B. Floyd was reported to be the owner of the land. However, plate 13 shows that fraction of sec. 13 to be owned by Z. A. Copeland. Branner[69] also gives Copeland as the fee owner.

The property was opened by Z. A. Copeland in the summer of 1932, and a home-made retort is reported to have produced 2 or 3 flasks of metal. When visited in April 1934, the development consisted of a cut about 85 feet long, 2½ feet wide, and 4 feet deep. Near its center the trench had been deepened to about 25 feet. In the summer of 1934 C. Q. Schow and C. E. Holmes, lessees, erected a 2-tube Gould retort and began further development work. The property was visited again in the fall of 1935, a few days before operations were discontinued. Between the summer of 1934 and the fall of 1935 the lessees had excavated at the site of the older work an open stope, 50 feet long at the top, 40 feet long at the bottom, and 2½ feet wide, to a depth of 75 feet. Mr. Schow writes that the stope was started on a small showing of cinnabar at the top, that ore ceased at a depth of about 20 feet, and that cinnabar was again found at a depth of 50 feet. At the 50-foot level cinnabar was present in both ends of the stope, with a barren zone more than 20 feet long between. With increased depth the barren zone shortened, so that at the bottom of the stope it is only 8 feet long and is within 4 feet of the east end of the stope. Cinnabar was noted also in both walls of the stope.

The operators recovered 8 flasks of quicksilver from the retort in 1934. Twenty-five tons of ore was taken from the bottom 25 feet of the stope. The work in 1935 resulted in no production, as it was development work entirely and was done largely to improve the dangerous working conditions in the stope.

Geology.—The trend of the rocks at the west end of the mapped area is directly toward the Rock Fence and indicates that the prospect is in the Gap Ridge sandstone, but this has not been definitely established. The hill near the top of which the work has been done appears to be largely sandstone. The stope is in sandstone beds ranging between 6 inches and 2 feet in thickness. A thin shale stratum occupies a position at the south side of the stope. The beds strike about N. 70° E., and the dip is vertical. The sandstone is light-gray and clean. Locally it appears to be silicified.

No tear faults or cross folds were observed, but the walls of the stope are slickensided, indicating movement. The sandstone taken from the stope is greatly fractured and in places is a breccia. Many open cavities separate fragments of the broken rock. Cinnabar, dickite, and quartz partly fill some of the cavities and are found also in thin seams and fractures. Crusts of tiny quartz crystals coat some fracture surfaces. The cinnabar is distributed throughout the rock in the ore-bearing parts of the stope but is largely concentrated near both walls.

[69] Branner, G. C., Cinnabar in southwestern Arkansas: Arkansas Geol. Survey Inf. Circ. 2, p. 51, 1932.

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