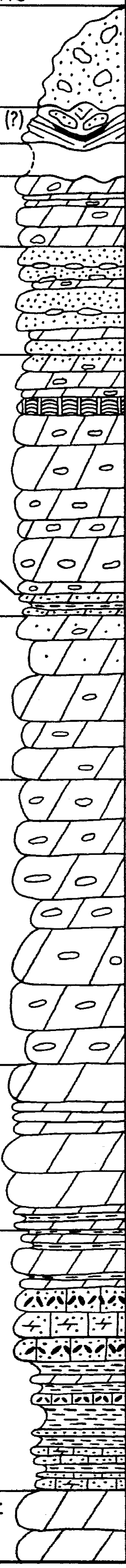
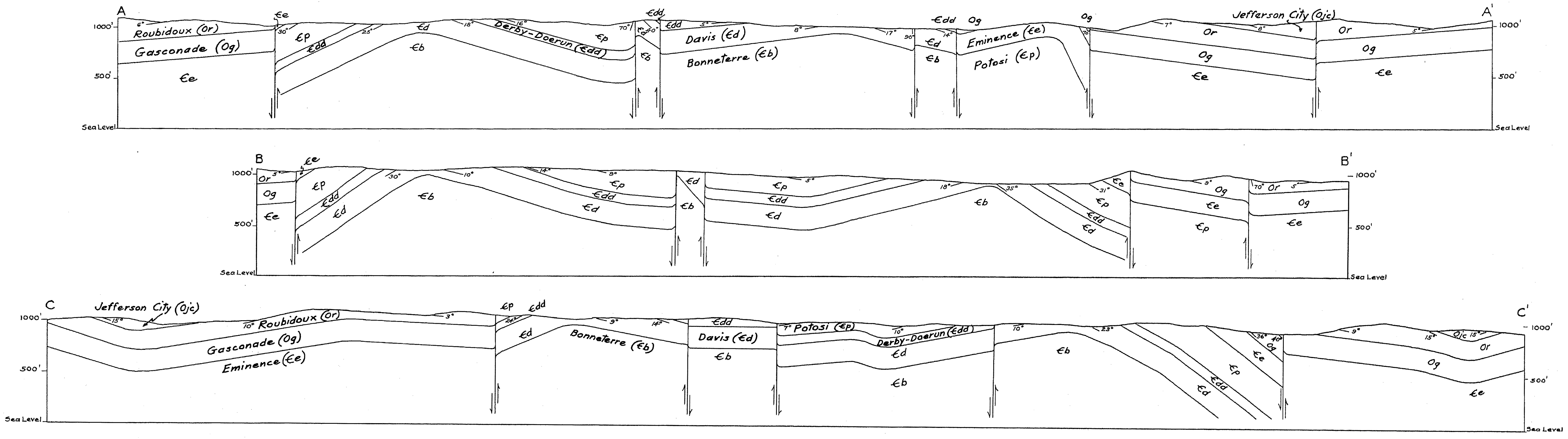
COLUMNAR SECTION



ERA	PERIOD (SYSTEM)		EPOCH (SERIES)	STRATIGRAPHIC UNITS	LITHOLOGY
CENO.	PLEISTOCENE		RECENT	ALLUVIUM RESIDUUM	*Residual soils, chert and sandstone boulders and alluvium.*
PALEOZOIC	PENN.		MIDDLE	KREBS GROUP (?) 25' ±	*Massive sandstone, fire clay and coal preserved in sinks.*
PALEOZOIC	MISS.		?	?	*One chert fragment with Fenestella and fragment of Schizophoria swallowi ? (Hall)*
PALEOZOIC	CANADIAN (ULRICH)	ORDOVICIAN	LOWER ORDOVICIAN	JEFFERSON CITY FORMATION 80' ±	*Earthy, light-buff to gray, fine to medium crystalline, thin to well-bedded dolomite with several ledges of massive, pitted dolomite.*
PALEOZOIC	CANADIAN (ULRICH)	ORDOVICIAN	LOWER ORDOVICIAN	ROUBIDOUX FORMATION 120' ±	*Massive to well-bedded sandstone composed of medium to fine, angular to rounded grains.* *Beds of light-gray, argillaceous and cherty dolomite intercalated through the sandstone.*
PALEOZOIC	OZARKIAN (ULRICH)	ORDOVICIAN	LOWER ORDOVICIAN	GASCONADE FORMATION 195' ± *Gunter Member*	*Slightly sandy, coarsely crystalline, evenly bedded dolomite. Calcite-filled vugs common.* *Cryptozoon reef, massive chert.* *Light-gray, medium to coarse crystalline, well-bedded to massive, cherty dolomite.* *Thin and well-bedded dolomite with gray-brown, oolitic chert.* *Well-bedded to massive dolomite with dolomoldic chert.* *Well-bedded to massive dolomite with white porcelaneous chert.* *Massive, drusy dolomite with much gray chert.* *Thin beds of sandy dolomite, green shale and sandstone.*
PALEOZOIC	OZARKIAN (ULRICH)	CAMBRIAN	UPPER CAMBRIAN	EMINENCE FORMATION 185' ±	*Slightly sandy, light, bright gray, irregularly mottled green, buff and pink, well-bedded to massive dolomite. Weathers to low, blocky crags. Contains blue-gray, granular oolitic chert.* *Well-bedded to massive, brown and gray, coarsely crystalline dolomite. Weathers to massive craggy pinnacles. Contains white to brown, finely granular and oolitic chert.*
PALEOZOIC	OZARKIAN (ULRICH)	CAMBRIAN	UPPER CAMBRIAN	POTOSI FORMATION 300' ±	*Drusy, light-gray to brown, coarsely crystalline, well-bedded to massive dolomite.* *Drusy, light- to dark-brown, fine to medium crystalline, massive dolomite with a petroliferous odor.* *Drusy, light- and dark-gray to brown, finely crystalline, well-bedded to massive dolomite with a petroliferous odor.*
PALEOZOIC	CAMBRIAN (ULRICH)	CAMBRIAN	UPPER CAMBRIAN	DERBY-DOERUN FORMATION 70' ±	*Dendritic, light-gray, finely crystalline and dense, massive dolomite with calcite-filled vugs. Weathers punky.* *Argillaceous, gray-buff, thin-bedded dolomite.* *Light-gray and buff, finely crystalline, well-bedded dolomite with calcite-filled vugs.* *Shaly, gray to buff, thin-bedded dolomite.*
PALEOZOIC	CAMBRIAN (ULRICH)	CAMBRIAN	UPPER CAMBRIAN	DAVIS FORMATION 220' ±	*Gray, buff and brown, coarsely crystalline, thin-bedded to massive dolomite interstratified with blue-green, fissile shale.* *Sandy, dove-gray, fine-grained, well-bedded, dolomitic limestone with intercalated beds of edgewise conglomerate.* *Gray-green, fissile shale interstratified with beds of fine-grained, glauconitic sandstone, gray, thin-bedded, slabby dolomite and beds of edgewise conglomerate.* *Brown, sandy and shaly dolomitic limestone with coarse grains of glauconite at base.*
PALEOZOIC	CAMBRIAN (ULRICH)	CAMBRIAN	UPPER CAMBRIAN	BONNETERRE FORMATION 50' ±	*Gray-brown, coarsely crystalline, massive dolomite with calcite-filled vugs.*

CROOKED CREEK AREA
STRUCTURE SECTIONS



STATE OF MISSOURI
DEPARTMENT OF BUSINESS AND ADMINISTRATION

DIVISION OF
GEOLOGICAL SURVEY AND WATER RESOURCES

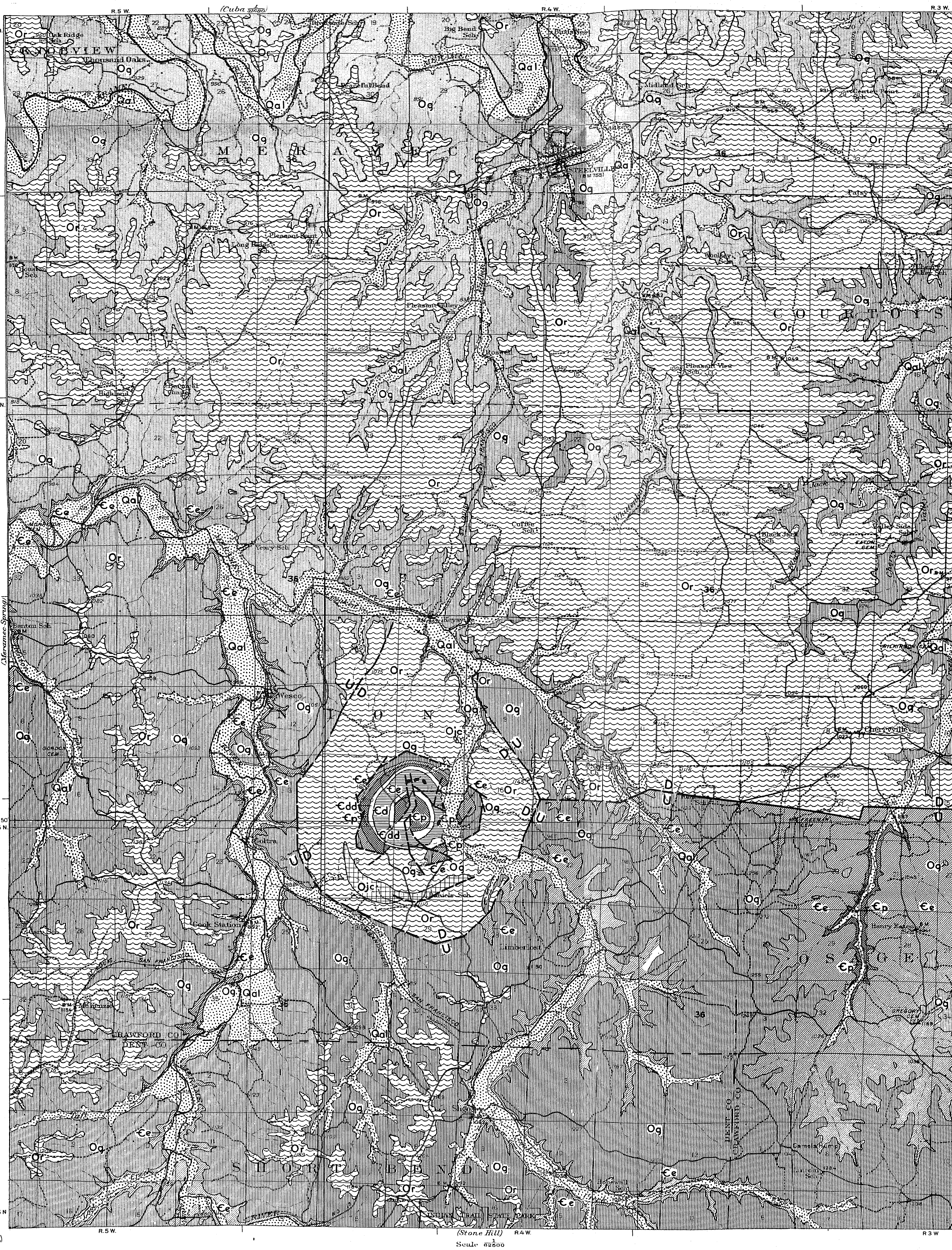
GEOLOGIC MAP
OF
THE STEELVILLE QUADRANGLE, MISSOURI

BY
HERBERT E. HENDRIKS

1949

VOL. XXXVI, 2nd SERIES

PLATE VII



Scale $\frac{1}{62500}$

LEGEND

ERA	SYSTEM PERIOD	SERIES EPOCH	FORMATION
CENOZOIC	QUAT	RECENT	ALLUVIUM
PALEOZOIC	ORDOVICIAN	LOWER	JEFFERSON CITY
			ROUBIDOUX
			GASCONADE
	CAMBRIAN	UPPER	EMINENCE
			POTOSI
			DERBY-DOERUN
			DAVIS
			BONNETERRE

HIGH ANGLE FAULT
DASHED WHERE APPROXIMA
LOCATED

APPROXIMATE MEAN
DECLINATION, 1933

SCALE

1 0

STATE OF MISSOURI
DEPARTMENT OF BUSINESS AND ADMINISTRATION

DIVISION OF
GEOLOGICAL SURVEY AND WATER RESOURCES

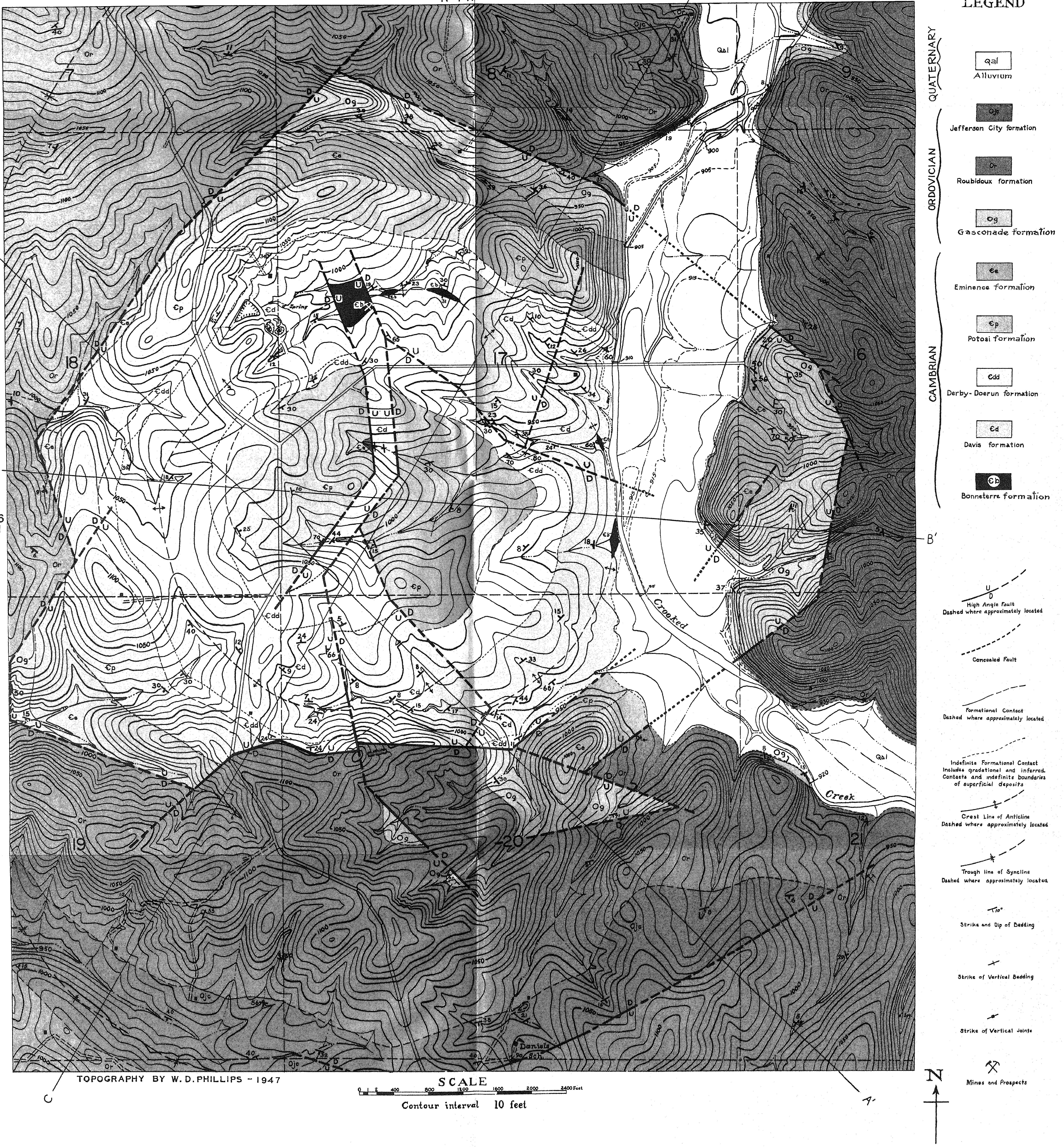
GEOLOGIC MAP
OF
THE CROOKED CREEK AREA

A PORTION OF THE STEELVILLE QUADRANGLE, MISSOURI

BY
H. E. HENDRIKS
1947

VOL, XXXVI, 2ND SERIES

PLATE VIII



THE GEOLOGY OF THE STEELVILLE QUADRANGLE MISSOURI

HERBERT E. HENDRIKS

Vol. XXXVI, Second Series

1954

STATE OF MISSOURI
DEPARTMENT OF BUSINESS AND ADMINISTRATION
Division of
GEOLOGICAL SURVEY AND WATER RESOURCES
EDWARD L. CLARK, *State Geologist*
Rolla, Missouri

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ILLUSTRATIONS

LETTER OF TRANSMITTAL

Rolla, Missouri
October 25, 1954

Honorable Phil M. Donnelly
Governor of Missouri
Jefferson City, Missouri

Dear Governor Donnelly:

I have the honor and pleasure to transmit herewith a report on THE GEOLOGY OF THE STEELVILLE QUADRANGLE, MISSOURI, by Herbert E. Hendriks.

Within the Steelville quadrangle is an area of geologic complexity which has long been of interest to geologists throughout the United States. This report goes far in setting forth the basic geologic conditions and possible explanations of the series of events that have taken place.

No recent comprehensive geologic report has been published within or near the Steelville quadrangle and this area will serve as a key for further detailed studies in several counties.

Respectfully submitted,

EDWARD L. CLARK
State Geologist

The Geology of the Steelville Quadrangle, Missouri

Herbert E. Hendriks

ABSTRACT

The formations exposed in the Steelville quadrangle are of Upper Cambrian, Lower Ordovician, Mississippian, and Pennsylvanian age. Pleistocene residuum and alluvium compose the mantle.

The dominant geologic feature in the Steelville quadrangle is the Crooked Creek structure. The essentially circular deformed area of intensely folded, faulted, and shattered rock is approximately three miles in diameter. It is a collapsed dome with the depressed apical area forming a shallow basin which is encircled by a ring anticline. In many respects the structure resembles the cryptovolcanic structure of the Steinheim Basin in southern Germany, Serpent Mound in Adams County, Ohio, and other structures in Kentucky, Tennessee, and Ohio. The Crooked Creek structure may have been produced by a subterranean explosion or by the impact and explosion of a meteorite. The Palmer fault extends eastward from the Crooked Creek area into Washington County.

INTRODUCTION

Introductory statement.—This investigation of the geology of the Steelville quadrangle was done primarily to determine the structural details of the Crooked Creek area and their relationships to the regional structure of the Ozarks. The investigation included the identification and correlation of recognizable lithologic units exposed in the quadrangle. The Crooked Creek area warranted study because of its location at the western end of the Palmer fault, its extraordinary structural features, and its deposits of barite, lead, fire clay, coal, and iron ore.

Most of the field work for this report was done during the summers of 1942 and 1947 to provide data for a doctoral dissertation at the State University of Iowa (Hendriks, 1949). Further field work during the summer of 1949 completed the mapping of the Steelville quadrangle. The present report which was written in 1950 is a modification and an expansion of the original dissertation. Staff members of the Missouri Geological Survey made slight changes in the manuscript immediately prior to publication.

ACKNOWLEDGEMENTS

This study was partially financed by the Missouri Geological Survey. The members of the Survey gave technical assistance, information, advice, and criticism during the course of the investigation. The writer is especially indebted to Wendell Phillips, deceased, who made the topographic map of the Crooked Creek area. Earl McCracken verified many field determinations of stratigraphic zones by a study of insoluble residues, which were prepared by the members of the subsurface laboratory. Edward L. Clark, John Grohskopf, and Jack A. James arranged an instructive field conference through the Cambro-Ordovician section of southeastern Missouri.

Especial thanks is due the faculty of the Department of Geology of the State University of Iowa, who supervised the preparation of this report in its preliminary form. The writer received pertinent information from John Mickelson, who mapped the northern half of the Steelville quadrangle in 1947.

The hospitality of the residents of the area, particularly Mr. and Mrs. M. E. Beers, was greatly appreciated. Their cooperation and friendly assistance facilitated the field work.

PREVIOUS WORK

The first reference to the area under consideration was made in 1873 by Shumard (p. 225), who described two irregular deposits of coal near Crooked Creek in Crawford County. Nason (1892, p. 139) mentioned a coal deposit three miles from Cook Station on the Sligo branch of the St. Louis and San Francisco Railroad. Two years later, Winslow (1894, p. 685) gave the location of several lead prospects in Crawford County, one of which was the Arthur mines, later known as the Metcalf diggings. Wheeler (1896, p. 230) noted a fire clay deposit near

Sligo furnace. Gallaher (1900, p. 104) reported exposures of the Cambrian near Cook Station and Sligo.

The Crooked Creek structure was discovered in 1910 by a reconnaissance field party of the Missouri Geological Survey. Hughes (1911, pp. 48-54) published a brief description of the formations involved, along with a generalized geologic map.

Crane (1911, pp. 205-232) described briefly the iron ore deposits in Crawford County in his report of 1911. Hinds (1912, p. 161) mentioned the occurrence of Pennsylvanian coal deposits in sinks in southern Crawford County, between Sligo and Keysville. He observed that " . . . their slight extent and their crushed and disturbed condition make most of them of doubtful value."

During the summers of 1923 and 1924 Dake (1930, p. 132) and Bridge studied the geology along Missouri Highways 8 and 19 for their road profile from Potosi to Eminence, Missouri. Dake (p. 132) also mentioned collecting fossils from the Eminence, about one-fourth of a mile south of Wesco.

During the summer of 1926 Bridge mapped the Palmer fault and made a geologic map of a part of the Crooked Creek area for a mining company.

GEOGRAPHY

Location of area.—The Steelville quadrangle is in southwestern Crawford County and northeastern Dent County on the northwestern flank of the Ozark province. The quadrangle is bounded by parallels 37° 45′ and 38° 00′ north latitude, and by meridians 91° 15′ and 91° 30′ west longitude, an area of 235 square miles. In 1932 and 1933 the area was topographically mapped by the United States Geological Survey in cooperation with the Missouri Geological Survey.

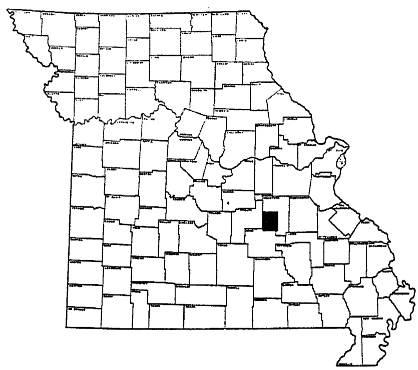


Fig. 1. Index map showing location of Steelville quadrangle.

The quadrangle is readily accessible. Missouri Highway 19 crosses the northeastern and southeastern portions of the area. Missouri Highway 8 extends across the northern part and Crawford County Road M. serves the western side of the area. The quadrangle is traversed by the Salem branch of the St. Louis and San Francisco Railroad which operates through Steelville, Keysville, Wesco, and Cook Station.

Drainage and relief.—The area is drained by the Meramec River and its tributaries: Crooked Creek, Benton Creek, Yankee Branch, Dry Creek, Yadkin Creek, Whittenburg Creek, and Cherry Valley Creek. The drainage basins of these tributaries are separated by long, irregularly bifurcating, sinuous divides. These ridges are dissected by innumerable V-shaped ravines with high gradients. During most of the year, these ravines are dry. Their floors are covered with boulders, pebbles, and chert fragments. During the spring and summer occasional torrents make additions to and redistribute this accumulation of rock debris.

The highest point in the Steelville quadrangle is Camel's Hump, with an altitude of 1349 feet, in the SE¼ NE¼ sec. 7, T. 35 N., R. 3 W. The lowest point is near Birds Nest Lodge, in the NW¼ SW¼ sec. 22, T. 38 N., R. 4 W., where the flood plain of the Meramec River is at an altitude of 675 feet. The maximum relief of 674 feet is misleading. Local relief, the difference in altitude between adjacent ridges and valleys, is nowhere more than 250 feet. Notwithstanding this comparatively low relief, the region has a rugged appearance, and it is in the mature state of dissection.

Geomorphic development.—The divides between the major drainage basins are essentially flat-topped ridges with accordant summits. These flat ridge tops are the remnants of the oldest erosional surface (peneplain?) in the Steelville quadrangle. The streams which developed this surface probably had courses which were essentially the same as that of the present day streams. Camel's Hump, and possibly the Crooked Creek area, stood above the general level of this erosional surface, as monadnocks.

Following the development of this erosional surface, the Ozark area in the vicinity of the Steelville quadrangle was uplifted approximately 100 feet. The existing streams became entrenched in their courses, eventually cut their channels to grade, and then developed extensive valley flats and flood plains, about 100 feet below their former erosional surface. Remnants of the lower surface are the benches, covered with alluvial material, on the sides of broad interstream divides and near the ends of narrow spurs.

Before the streams could develop extensive flood plains at this lower level, this part of the Ozark area was again uplifted about 200 feet. Following this uplift, the streams have not only cut down to near grade, but have developed narrow flood plains, as well. Locally, more resistant bedrock has restricted the development of the flood plains. This is particularly well-shown in the Crooked Creek structure where Crooked Creek crosses the outcrop of the Roubidoux formation in the eastern and northeastern parts of the encircling graben. There its valley is much narrower than it is to the southeast or upstream, where it flows on the Eminence. The central part of the Crooked

Creek structure, which is not protected by the resistant Roubidoux, has been eroded more rapidly than has the surrounding area. Consequently, it has developed as a topographic basin rimmed by the escarpment of Roubidoux which crops out in the encircling graben.

Adjacent to the streams with their narrow flood plains are the flat-topped ridges and intervening divides. The Ozark province in the vicinity of the Steelville quadrangle is in the early mature stage of topographic development.

STRATIGRAPHY

General statement.—Neither the pre-Cambrian nor the Lamotte sandstone, the basal formation of the Cambrian, is exposed in the Steelville quadrangle. The overlying Bonneterre is concealed, except for the upper 30 or 40 feet which is exposed in the Crooked Creek area. The Davis, Derby-Doerun, Potosi, and Eminence formations, also of the Upper Cambrian age, are exposed within the area. The lower Ordovician is represented by exposures of the Gasconade, Roubidoux, and Jefferson City formations. One fragment of chert, containing fossils of Mississippian age, was found in the Crooked Creek area. Residual sandstone boulders, probably of Pennsylvanian age (Krebs?), are scattered over the area. Extensive areas are mantled with residual soils and chert, and the river valleys are floored with alluvial deposits (pl. I).

CAMBRIAN SYSTEM

UPPER CAMBRIAN SERIES

BONNETERRE FORMATION

Name.—The name Bonneterre was first used in 1901, when Nason (1901a, p. 396) applied it to the beds between what is now called the Lamotte and an edgewise conglomerate in what is now called the Davis. His failure to designate which one of the many edgewise conglomerate horizons he meant left the top of the Bonneterre uncertain. Buckley (1909, pp. 26-44) was the first to establish the top of the Bonneterre as now defined.

Distribution.—Outcrops of the Bonneterre are limited to the axial portion of the ring anticline which encircles the central part of the Crooked Creek structure in secs. 17, 18, 19, and 20, T. 36 N., R. 4 W. (pl. VIII). Six small, lenticular-shaped outcrops occur, mostly in stream beds. The largest and most prominent exposure is in the bed of the small stream just north of the old Metcalf diggings, near the east center, SW¼ NW¼ sec. 17, T. 36 N., R. 4W. Other small outcrops are exposed at the following localities: 650 feet east and 480 feet south of the NW corner, SE¼ NW¼ sec. 17, T. 36 N., R. 4 W.; in the bed of a small stream about 100 feet west of Crooked Creek, 250 feet west and 400 feet north of the SE corner, NW¼ SE¼ sec. 17,

T. 36 N., R. 4 W.; and in the bed of the small stream where it enters Crooked Creek near the east center of the SW¼ SE¼ sec. 17, T. 36 N., R. 4 W.

Thickness.—The small isolated outcrops of Bonneterre dolomite expose only the upper 30 to 40 feet of the formation. Drill holes (Missouri Geol. Survey and Water Resources well log nos. 2168, 2169, 2187, 2983, and 3367) outside the area of the Crooked Creek structure, where the sedimentary formations are nearly horizontal, penetrate an average of 288 feet of Bonneterre, whereas those in the Crooked Creek area penetrate an average of 407 feet (Missouri Geol. Survey and Water Resources well log nos. 2167, 2668, 2669, 2671, and 2672). Either the dips of 30° to 50° or the duplication of beds due to faulting observed in the area may account for this apparent greater thickness.

Lithology.—The upper Bonneterre exposed in the Crooked Creek area is massive, gray-brown, coarsely-crystalline dolomite. It contains many calcite and dolomite-lined vugs which range in size from one-fourth inch to two inches in diameter. The accumulation of dolomite crystals on the dark chocolate brown colored, deeply pitted weathered surface commonly produces a deceptive sandy texture. The upper Bonneterre resembles the upper Eminence in many respects. However, chert which is so characteristic of the Eminence is not present in the Bonneterre.

Topographic expression.—The exposures of the Bonneterre in the Crooked Creek area are too limited to have any control over the topography. Chocolate red soil characteristically mantles the outcrops of the Bonneterre in this area. Typical Bonneterre soil is found on the hillside between the old Metcalf lead prospect and the small creek near the east center of the SW¼ NW¼ sec. 17, T. 36 N., R. 4 W.

Paleontology.—No fossils were found in the Bonneterre of the Steelville quadrangle.

Stratigraphic relations.—The base of the Bonneterre is not exposed in the Steelville quadrangle. It is generally believed that the contact of the Lamotte and Bonneterre is conformable. Dake (1930, p. 50) found no evidence of an erosional break between the Lamotte and the Bonneterre within the

Potosi and Edgehill quadrangles, nor did he observe " . . . any evidence for a break elsewhere in southeast Missouri between these two units."

DAVIS FORMATION

Name.—Prior to 1908 the beds now referred to as the Davis formation were variously designated as parts of the St. Joseph limestone (Winslow 1894, p. 331), the Fredericktown formation (Keyes, 1895, pp. 48-52), the Potosi (Nason, 1901b, pp. 358-361), and the Elvins (Bain and Ulrich, 1905, pp. 21-26; Weller and St. Clair, 1928, p. 45). The accepted definition of the Davis formation was first proposed by Buckley (1909, pp. 33-34) in 1908. The type section of the Davis formation is in St. Francois County, Missouri, along Davis Creek, a tributary of Flat River.

Distribution.—The Davis formation forms a rudely circular outcrop along the axial portion of the inner and outer flanks of the ring anticline which encircles the central part of the Crooked Creek structure (pl. VIII). The only other sizeable area of outcrop of the Davis is the horst-like block which extends from the north center of the SE ¼ NW ¼ sec. 17, T. 36 N., R. 4 W., to the SE corner of the NW ¼ SW ¼ sec. 17, T. 36 N., R. 4 W., thence in a southwesterly direction to the SW corner of sec. 17, T. 36 N., R. 4 W.

Thickness.—A complete section of the Davis formation is not exposed in the Steelville quadrangle. Drill holes (Missouri Geol. Survey and Water Resources well log nos. 2169, 2170, 2178, 2983, and 3367) outside the area of the Crooked Creek structure, where the sedimentary formations are nearly horizontal, penetrate an average of 220 feet of Davis.

Lithology.—The Davis formation consists of a complex succession of thin-bedded, commonly dolomitic limestone; green and brown plastic shale; thin slabby beds of calcareous, fine-grained sandstone or siltstone; and many beds of edgewise and limestone pebble conglomerate.

The lower 50 to 60 feet is predominantly shale interstratified with thin slabby beds of dolomitic limestones, lenses of edgewise conglomerate, and thin beds of fine-grained sandstone. Disseminated throughout the sandstone are small, rounded, light olive-green particles of glauconite, commonly called "salt and pepper glauconite." The shale is generally blue green to gray, finely-stratified and fissile, and locally somewhat calcareous. The lower Davis formation in some places shows vertical intervals of as much as 10 to 15 feet of unbroken shale. The sand is very fine-grained, sub-angular quartz. The dolomite is dense, medium crystalline, and slabby in appearance. Some weathered outcrops show broken fossil fragments, most of which appear to be trilobite remains, too fragmentary for identification. The glauconite of the Davis is most noticeable in the lower 50 to 60 feet, where it is chiefly "salt and pepper glauconite." In the basal 15 feet of the Davis, the glauconite is exceedingly abundant, occurring as rounded to irregularly botryoidal, dark green masses, some of which are as much as one-eighth inch in diameter. This occurrence of glauconite is a valuable marker for the base of the Davis.

The middle 100 feet of the Davis is predominantly dolomitic limestone. Most of the beds range from a few inches to a foot in thickness. The color varies from dove gray to dull gray on fresh exposures, and from buff to reddish brown on weathered surfaces. The dolomitic limestone of the middle Davis is generally fine to medium crystalline and contains a rather large amount of very fine-grained, angular sand or silt which is less abundant in the upper middle portion. In fact, the lower 50 or 60 feet of the middle Davis appears to be thin-bedded, fine-grained sandstone, because much of the calcium carbonate has been removed by leaching. Edgewise and flat-pebble conglomerates occur in the lower two-thirds of the middle Davis and in the shaly beds of the lower Davis. These conglomerates contain thin, flat, angular to rounded limestone fragments, the largest of which have a maximum diameter of six inches. However, those of a maximum diameter of two to three inches are more numerous. Generally, the pebbles range from one-fourth inch to one inch in thickness. The various edgewise conglomerates are almost everywhere associated with beds of blue-green to gray, plastic, sandy and thinly-laminated shale. Generally, the conglomerates are sandwiched between the shale beds, but locally the shale is found only beneath the conglomerate, and rarely it is found only above. Although the conglomerates crop out persistently, they are too discontinuous for correlation. Dake (1930, p. 82) found this to be true in the Potosi and Edgehill quadrangles. These conglomerates seem to represent previously consolidated, thin-bedded limestone, which was broken and incorporated in an accumulating, sandy calcareous ooze. Insoluble residues show a higher silica sand concentration in the matrix than in the pebbles. All the conglomerate horizons of the lower half of the Davis are not of the edgewise variety. Many of them are "flat-pebble conglomerates", the thin, flat, angular to subrounded pebbles of limestone lying essentially parallel to the bedding.

The upper 30 to 40 feet of the Davis consists of thin to massive-bedded dolomite interstratified with shale. The dolomite beds are predominantly thin-bedded and slabby, dense to coarsely crystalline, ranging in color from buff to gray. It should be noted that the thin, platy dolomite of the upper Davis resembles the lower Bonneterre, although the lower thin-bedded limestone of the Bonneterre is softer and more argillaceous than the upper Davis. The middle portion of the Derby-Doerun is a thin-bedded dclomite sequence which may also be confused with the upper Davis, though it lacks the numerous shale seams so characteristic of the older formation. The shale of the upper Davis is almost invariably bluish or greenish on fresh surfaces, but weathers to bright gray, yellow, and brown. Generally the shale appears thin-bedded and fissile on the outcrop. However, rare fresh exposures appear massive.

Topographic expression.—Although the Davis is exposed on a pronounced structural high, the outcrop is expressed as a topographic depression, because the Davis is the least resistant of the Cambro-Ordovician formations. Tension fracturing facilitated the rapid weathering and erosion of the Davis which was exposed on the crest of the ring anticline. It is interesting to note that in the older plats of the land survey of Crawford County, the area of the Davis outcrop is designated as "open prairie". This area is still an open meadow in a vast woodland of oak-covered hills.

The soil which develops upon the Davis is characterized by an ashy or flaky texture and a gray-green to buff color. An abundance of fine gray-green shale flakes in the soil, in the absence of outcrops, is fairly indicative of the presence of the formation.

Paleontology.—Some poorly preserved and fragmentary trilobite remains were collected from the lower to middle portion of the sandy middle Davis, in the SE¼ SE¼ NE¼ sec. 18, T. 36 N., R. 4 W. Most of the fragments seem to be referable to the genera *Elvina*, *Camaraspis* and *Burnetia*.

The *Hypseloconus recurvus* fauna which was identified by Bridge (1927, p. 231) and Dake (1930, p. 88), as occurring in the basal Davis in the Potosi and Edgehill quadrangles, was not found in the Crooked Creek area.

The generally fossiliferous *Eoorthis* zone, which occurs within the top 30 to 40 feet of the formation at the type locality is also missing from this area. It must be remembered that the section involved has undergone considerable deformation and alteration, especially by leaching, which may account for the paucity of fossils.

Stratigraphic relations.—There are few exposures of Bonneterre in the Steelville quadrangle, and the contact is everywhere concealed. The distinctive heavy glauconite zone of the basal Davis is exposed a few feet above massive Bonneterre dolomite, resembling the contact found in other parts of southeastern Missouri and in the subsurface.

DERBY-DOERUN FORMATION

Name.—The beds which comprise the Derby-Doerun formation were included successively in the St. Joseph limestone (Winslow, 1894, p. 231), the Fredericktown (Keys, 1895, pp. 45-52), the Potosi (Nason, 1901b, pp. 358-361), and the Elvins (Bain, 1905, pp. 21-26). The present definition of the individual formations was first proposed by Buckley (1909, pp. 44-49). The formations were named separately for the Derby mine on Harris Branch about two miles south of Elvins, Missouri, and the Doe Run Lead Company mine which is situated along the Gumbo Branch of the Mississippi River and Bonneterre Railroad, near Elvins, Missouri. Present Missouri Geological Survey usage combines the two units into one formation to which the name Derby-Doerun is applied.

Distribution.—The outcrop pattern of the Derby-Doerun forms two roughly concentric belts on the flanks of the ring anticline of the Crooked Creek structure. These belts are separated by the Davis formation which crops out along the axis of the anticline (pl. VIII).

Thickness.—A complete section of the Derby-Doerun is not exposed in the Steelville quadrangle. The erratic dips and limited number of exposures prevent a satisfactory estimate of the thickness from the outcrop area. Drill holes (Missouri Geol. Survey and Water Resources well log nos. 2168, 2169, 2170, 2187, 2983, and 3367) outside the area of the Crooked Creek structure, where the sedimentary formations are nearly horizontal, penetrate an average of 70 feet of Derby-Doerun.

Lithology.—The lower 20 to 30 feet of the Derby-Doerun in the Crooked Creek area is composed essentially of thick-bedded, massive, non-cherty, finely arenaceous, dense, light buff-tinted gray dolomite. The denser beds are finely crystalline and generally contain small calcite-lined vugs. In contrast, a few beds are distinctly calcareous and earthy in texture. The lower beds of the Derby-Doerun crop out typically as low, rounded or knobby, much-pitted exposures, the surfaces of which exhibit only traces of bedding.

The best exposures of the lower 20 to 30 feet are as follows: in the bed of a drain, 175 feet west of the SE corner, NE¼ NE¼ sec. 18, T. 36 N., R. 4 W.; in a drain bed in an open field, 395 feet east and 525 feet north of the SW corner, SE¼ sec. 17, T. 36 N., R. 4 W.; in the bed of a small intermittent stream, 80 feet east, 325 feet south of the NE corner, SW¼ NE¼ sec. 20, T. 36 N., R. 4 W.; and in the bed of a small stream, 260 feet east, 400 feet north of the SW corner, NE¼ NE¼ sec. 19, T. 36 N., R. 4 W.

The middle 25 to 30 feet of the Derby-Doerun in the Crooked Creek area is thin-bedded, argillaceous, light gray-buff, pink-tinted dolomite. These beds weather into thin wavy plates with an earthy texture and a buff color. This phase is well-exposed in the nearly vertical beds of an outcrop in the bed of a tributary stream of Crooked Creek, 20 feet east and 260 feet north of the SW corner, NW¼ SE¼ sec. 17, T. 36 N., R. 4 W.; in a gully 150 feet west and 450 feet south of the NE corner, NE¼ NW¼ sec. 20, T. 36 N., R. 4 W.; in the bed of an intermittent stream 270 feet west and 630 feet north of the SE corner, NE¼ SW¼ sec. 17, T. 36 N., R. 4 W.; and in a small gully 140 feet west and 245 feet south of the NE corner, SE¼ NE¼ sec. 19, T. 36 N., R. 4 W.

The upper Derby-Doerun is dense, hard, gray, finely crystalline massive dolomite, which is commonly dendritic, and generally contains numerous small, vug-like inclusions of calcite, and scattered cubes of pyrite. Weathered surfaces are "punky," that is, they have a dead or cushioned feel when hit with the hammer. Weathering also produces a patchwork of rectangular buff and gray mottling, due to oxidation along the planes of a rectangular joint system.

The upper Derby-Doerun of the Crooked Creek area, which crops out on the inner flanks of the ring anticline, has undergone much brecciation and crushing. Many exposures are so intensely shattered that the outcrop has the appearance of crushed rock. As a result, leaching has been very effective and the beds are much lighter in color than is the normal Derby-Doerun. The upper Derby-Doerun is well-exposed in the bed of a drain 400 feet east and 165 feet south of the NW corner, SW¼ sec. 17, T. 36 N., R. 4 W.; 295 feet east, 370 feet south of the NW corner, SW¼ NW¼ sec. 20, T. 36 N., R. 4 W.; in the bed of an intermittent stream 110 feet east and 415 feet north of the SW corner, SW¼ SE¼ sec. 17, T. 36 N., R. 4 W.; in the bed of a small stream 420 feet east and 600 feet north of the SW corner, sec. 17, T. 36 N., R. 4 W.; on the hillside 110 feet west and 520 feet north of the SE corner, SW¼ sec. 17 T. 36 N., R. 4 W.; and 500 feet west and 530 feet north of the SE corner, SW¼ SW¼ sec. 17, T. 36 N., R. 4 W.

Topographic expression.—The Derby-Doerun forms gentle slopes down to the outcrop of the Davis. The steeper slopes of the Derby-Doerun are due partly to the overlying, resistant Potosi which forms the higher topographic areas of the Crooked Creek structure. The Derby-Doerun and Potosi formations form a poorly-defined, low, gently-sloping, outward facing escarpment on the inner flanks of the circular anticline, and a similar inward-facing escarpment on the outer flanks.

Paleontology.—No fossils were found in the Derby-Doerun in the Steelville quadrangle. Dake (1930, p. 107) noted the presence of only a few very poorly-preserved forms which he could not identify with certainty. Buckley (1909, p. 49) reported the occurrence of *Finkelnburgia osceola* Walcott from the Derby-Doerun of the type area.

Stratigraphic relations.—The contact between the Davis and the Derby-Doerun is not exposed in the quadrangle. From a study of beds which may belong in either the upper Davis or the Derby-Doerun, it is believed that there is a gradual transition from the shale and slabby limestone of the upper Davis to the massive, argillaceous dolomite of the Derby-Doerun. Dake (1930, p. 84) in his extensive studies in southeastern Missouri, could find no evidence of unconformity. Evidently Ulrich (in Bain and Ulrich, 1909, pp. 23-26) considered the beds of the Davis and Derby-Doerun to be conformable, for he placed them together in his Elvins formation.

POTOSI FORMATION

Name.—The term Potosi was first used in 1894 by Winslow (1894, p. 331) who applied it to the series of beds which are well-exposed near the town of Potosi in Washington County, Missouri. These beds are now called Potosi and Eminence. He erroneously correlated these beds with the Moreau (Roubidoux) and the Jefferson City formations of the central Ozarks. Nason (1901b, pp. 358-361) defined the base of the Potosi to include all of the Davis as it is now known, but he failed to delimit the top of the formation. Bain and Ulrich (1909, pp. 26-28) defined the "Potosi Group" as lying between the Elvins below and the St. Peter above. Local usage soon restricted the term Potosi to the drusy and cherty beds above the non-drusy and non-cherty Elvins. Buckley (1909, pp. 51-58) limited the use of the term to those beds, which contain the abundant "mineral blossom" of the local miners.

Dake (1930, p. 110) defined the Potosi adequately in these words: "As the term is defined at present, it includes the brownish, very drusy, almost unfossiliferous dolomite lying above the Derby-Doerun, and below the Eminence, which is lighter in color, more cherty than drusy, and carries an abundant fauna."

Distribution.—Two outcrop areas of the Potosi in the central basin of the Crooked Creek structure are separated by the narrow horst of nearly vertical beds of Davis shale described earlier in this report. The eastern outcrop area is in the SW¼ NE¼ and in the SE¼ SW¼ sec. 17, T. 36 N., R. 4 W., with small portions of this area extending into the SW corner, NW¼, and the NW corner of the SW¼ SE¼ sec. 17, T. 36 N., R. 4 W. There is also a small extension into the NW part of the NE¼ NW¼ sec. 20, T. 36 N., R. 4 W. The western outcrop area lies mostly in the W½ SW¼ sec. 17, T. 36 N., R. 4 W., and along the eastern edge of the SE¼ sec. 18, T. 36 N., R. 4 W. A Potosi outcrop of variable width is exposed on the north and west sides of the outer flank of the ring anticline. Small outcrop areas of the Potosi are located near the east center, SE¼ SE¼ sec. 17, T. 36 N., R. 4 W., and just west cf the center of the NE¼ sec. 20, T. 36 N., R. 4 W. (pl. VIII).

Outside the Crooked Creek area, the upper 25 feet of Potosi is exposed in T. 36 N., R. 3 W., along both sides of Dry Creek, between the Palmer fault on the north and the Dillard road on the south (pl. VII).

Thickness.—The thickness of the Potosi in the Steelville quadrangle is difficult to determine. The massive character of the formation prevents accurate measurement of dip and strike. Outcrops are small and isolated, and no complete section is exposed. Near the SE corner, NE¼ NW¼ sec. 17, T. 36 N., R. 4 W., where a small stream crosses the Potosi outcrop in the direction of dip, is the only place within the area where it is possible to obtain by calculation a reliable determination of thickness. From the average dip of 38° at this locality, and the outcrop width of 475 feet, a thickness of about 300 feet is calculated. This figure is comparable to the average thickness for the Potosi penetrated by deep wells in the southern half of Crawford County (Missouri Geol. Survey and Water Resources well log nos. 2168, 2169, 2170, 2187, 2983, and 3367).

Lithology.—The Potosi is one of the most distinctive formations in the whole Cambro-Ordovician section of Missouri. Characteristically, it is a massive, poorly-bedded, fine to medium crystalline, light to dark brown dolomite which has a typical petroliferous odor on fresh breaks. However, the chief diagnostic feature of the Potosi is the abundant quartz druse associated with it at nearly every outcrop. The druse consists of microscopic to macroscopic quartz crystals on botryoidal laminations of white, gray or brown quartz. The laminations, when examined under a microscope, are found to consist of many finer laminations of chalcedony separated by very fine layers of quartz crystals oriented normal to the botryoidal surfaces. The convex sides of these botryoidal surfaces are covered with fine to medium, clear to milky, pink, buff, or brown tinted quartz crystals. The concave sides of the larger surfaces are characteristically chalky, white to buff in color, with abundant dolomolds which are rarely more than a millimeter in size. Small, dead white to gray and brown oolites occur commonly on the concave side, as isolated oolites, in clusters, or in association with the dolomolds.

Generally the darker phases of the rock have more abundant druse, a characteristic more common outside the area of the structure, where the dolomite has not been so altered by deformation and leaching. It should also be noted that on steep slopes and in cliff exposures, druse is not so well developed as on gentle slopes or where weathering has produced a deep residual soil. Thoroughly decayed Potosi dolomite is honeycombed, and almost completely replaced by great masses and ledges of druse.

All outcrops of the Potosi in the Crooked Creek area are intensely fractured, the fractures having later been filled with secondary quartz and banded chalcedony in a relationship similar to that found in the druse. The Potosi of the Crooked Creek area is not as dark as the Potosi southeast of Cherryville, where it is brought to the surface on the upthrown side of the Palmer fault.

Although no complete section of the Potosi is exposed in the quadrangle, the field relationships of the various outcrops enable one to ascertain certain differences in lithology. The lower one-third consists essentially of massive, finely crystalline, light to medium gray-buff dolomite. The weathered surfaces of this lower portion are smooth, finely granular, slightly earthy in appearance, and dark gray brown. This particular phase is perhaps best exposed in the bed of a small drain 510 feet south of the NW corner, SW¼ sec. 17, T. 36 N., R. 4 W., and on a hillside 480 feet west and 590 feet south of the NE corner, SE¼ SE¼ sec. 18, T. 36 N., R. 4 W.

The middle 150 feet comprises the "typical Potosi" of Dake (1930, p. 113). It is massive, poorly-bedded, fine to medium crystalline, light to dark brown, very drusy dolomite with a pronounced petroliferous odor on freshly broken surfaces. This portion of the Potosi is well-exposed in the bed of an intermittent stream 630 feet east and 265 feet south of the NW corner, SE¼ SW¼ sec. 17, T. 36 N., R. 4 W.; in a small drain 150 feet south and 150 feet east of the NW corner, SW¼ SW¼ sec. 17, T. 36 N., R. 4 W.; 235 feet east and 340 feet south of the NW corner, SW¼ SW¼ sec. 17, T. 36 N., R. 4 W.; in a drain 580 feet west and 570 feet north of the SE corner, NW¼ SW¼ sec. 17, T. 36 N., R. 4 W.; and in the bed of a creek 275 feet east and 240 feet north of the SW corner, NE¼ SW¼ sec. 17, T. 36 N., R. 4 W.

In some exposures, the upper 40 to 80 feet of the Potosi resembles the middle Potosi. In others, it is a well-bedded, coarsely crystalline, bright gray, cherty dolomite which resembles the Eminence. However, most exposures show a variable vertical gradation from one to the other.

Topographic expression.—The Potosi underlies much of the higher area of the central portion of the Crooked Creek structure, and it also forms the prominent, inward-facing escarpment on the north and west sides of the structure. Most of the outcrop supports a growth of oak timber, with a small portion having been cleared for pasture. The drusy, dark red, very sticky, residual clay soil is characteristic of the formation and a definite aid in areal mapping. The soils of the Bonneterre and Eminence are brownish red, and they lack the abundant druse fragments which are invariably present in the Potosi soil.

Paleontology.—No fossils were found in the Potosi exposed in the Steelville quadrangle. However, Bridge (1930, p. 73) reported three gastropods in decayed chert from the interior of a large Potosi druse found east of the Steelville quadrangle, near Davisville in Crawford County.

Stratigraphic relations.—The character of the Derby-Doerun and Potosi contact could not be determined, because it is covered by the abundant drusy, red clay residuum of the Potosi. Therefore, the approximate position of most of this contact was mapped on float and soil characteristics. Ulrich (1911, pp. 614-616; 1938, pl. 58) stated that an unconformity exists between the Derby-Doerun and the Potosi. He used this break to separate his Cambrian and Ozarkian systems in Missouri. Farther to the east, in the St. Francois Mountain area, Dake (1930, pp. 104-106) found evidence for the existence of an unconformity at the base of the Potosi. Bridge (1930, pp. 68-72) also reported an unconformity in the Eminence region. However, this is a local unconformity, for in the deeper basins of sedimentation, away from the porphyry knobs, wells and deep valleys which cut through the contact show the Potosi on Derby-Doerun, with little, if any, of the section missing.

EMINENCE FORMATION

Name.—The beds which now comprise the Eminence have been included in the Third Magnesian Limestone (Swallow, 1855, pp. 126-128), the Gasconade (Nason, 1892, pp. 114-115), and the Potosi (Winslow, 1894, p. 331; Nason, 1901a, p. 396).

In 1907 Buckley (p. 286) published a geologic column in which he used the term Eminence without defining it. In 1909 Buckley (pp. 33-49) again mentioned the Eminence, saying that it had been recognized above the Potosi in Shannon County, by Ulrich, but that he (Buckley) was not familiar with it.

Ulrich (1911, pp. 630-631) had used the name Eminence for several years prior to 1911, when he published a description of the formation. He named the formation for numerous exposures in the vicinity of Eminence, Shannon County, Missouri. Ulrich originally defined the formation as a very cherty dolomite that overlies the Potosi, apparently unconformably, and underlies the Proctor. Branson, in 1918 (pp. 40-49), stated that the Eminence overlies the Potosi and unconformably underlies the Gasconade formation. The Proctor has been proved to be the Eminence and the name has been suppressed by the Missouri Geological Survey.

Distribution.—The Eminence is exposed in the valley of Yankee Branch from near the west center of the SE¼ sec. 24, T. 36 N., R. 4 W., northwest to where the Palmer fault crosses Yankee Branch (pl. VII). It is also well-exposed along the valley of Dry Creek from near Camel's Hump on the south to the Palmer fault on the north. A narrow, irregular outcrop of upper Eminence is exposed below the overlying Gasconade along Crooked Creek from the southern border of the quadrangle, downstream to near the north center of the SE¼ sec. 21, T. 36 N., R. 4 W. The upper Eminence is exposed along both sides of the Meramec River in the southern half of the Steelville quadrangle. The only other outcrops are those which extend from Keysville westward one mile, on the north side of the valley of Crooked Creek.

Within the area of the Crooked Creek structure, a small exposure of the lower Eminence occurs in the stream bed west of the horst of Davis formation, 330 feet west and 400 feet north of the SE corner, NW¼ SW¼ sec. 17, T. 36 N., R. 4 W. (pl. VIII). Other exposures of the Eminence occur in a narrow belt which extends northeast from the SW corner, NW¼ SE¼ sec. 18, T. 36 N., R. 4 W., to the NE corner of sec. 18, T. 36 N., R. 4 W. At this point the outcrop belt swings east by southeast to Crooked Creek near the center of the NE¼ sec. 17, T. 36 N., R. 4 W. Other outcrops are on the west and north sides of the hill in the east center of the SE¼ sec. 17 and the west center of sec. 16, T. 36 N., R. 4 W.; on the top and east side of the hill in the N½ SW¼ NE¼ sec. 20, T. 36 N., R. 4 W.; on the south side of the hill just south of the center of the NE¼ sec. 19, T. 36 N., R. 4 W.; and on the west side of the valley in the W½ NW¼ NE¼ sec. 19, T. 36 N., R. 4 W.

Thickness.—The Eminence dolomite is about 180 feet thick where it is well-exposed along both sides of Dry Creek in the southeastern portion of the quadrangle. A study of well logs from the Steelville quadrangle shows that, in the subsurface, the Eminence is 170 to 200 feet thick.

Lithology.—The Eminence, as exposed in the Steelville quadrangle, is essentially massive to well-bedded, coarsely crystalline, bright-gray, cherty dolomite.

The formation is generally more coarsely crystalline than is the underlying Potosi or the overlying lower portion of the Gasconade. The upper Eminence is very coarsely crystalline, as are portions of the Gasconade. This characteristic of the Eminence is perhaps best revealed on deeply weathered surfaces, which commonly look "sandy" because of the abundance of loosely-aggregated, coarse dolomite crystals.

The color of the Eminence is distinctive, for no other formation of the Cambro-Ordovician section presents such a wide stratigraphic expanse of clean, bright, light-gray dolomite. However, the basal beds are somewhat interbedded or mottled with brown dolomite, like the Potosi, whereas the upper beds are irregularly mottled with green, buff, or pink.

The lower Eminence is more massively bedded than is the rest of the formation, cropping out as rugged, pitted, and cavernous pinnacles or crags. The upper portion is more regularly bedded than the lower Eminence. Beds from eight inches to three feet or more in thickness are common. In this respect, it somewhat resembles the massive beds found in both the lower and the upper Gasconade. In contrast, parts of the lower Gasconade are much more thinly-bedded than the Eminence. In comparison with the rugged crags of the lower portion, the upper Eminence crops out as low, blocky, roughly-pitted hummocky crags.

Within the area of the Crooked Creek structure, the lower Eminence is well-exposed in a stream bed 150 feet north and 640 feet west of the SE corner, NW¼ NE¼ sec. 17, T. 36 N., R. 4 W.; in a small drain 330 feet west and 400 feet north of the SE corner, NW¼ SW¼ sec. 17, 36 N., R. 4 W.; and along the east side of the road, 460 feet west and 325 feet south of the NE corner, SE¼ SE¼ sec. 17, T. 36 N., R. 4 W.

Along Dry Creek, south of the Palmer fault for a distance of three miles, there are also many good exposures of the lower Eminence above the Potosi.

The upper Eminence is well-exposed in the Crooked Creek area on the outer flanks of the ring anticline at the following localities: in the bed of a stream near the west-bounding fault, 145 feet west and 410 feet north of the SE corner, NW¼ SW¼ sec. 18, T. 36 N., R. 4 W.; on the side of a hill just north of an old house 160 feet east and 250 feet south of the NW corner, SW¼ sec. 16, T. 36 N., R. 4 W.; on the north side of the small gully 390 feet east and 470 feet south of the NW corner, SW¼ sec. 16, T. 36 N., R. 4 W.; in the bed of a stream 190 feet east and 430 feet north of the SW corner, NE¼ sec. 20, T. 36 N., R. 4 W.; and along the road in the SE corner, NE¼ SE¼ sec. 17, T. 36 N., R. 4 W.

Outside the Crooked Creek area, the upper Eminence is exposed in the bed of a small stream just west of Lost Mountain Ranch near the SE corner, NW¼ NE¼ sec. 13, T. 36 N., R. 5 W.; in the north bank of a drain near the NW corner, SE¼ SW¼ sec. 28, T. 36 N., R. 4 W.; along both sides of Missouri Highway 19, just east of Crooked Creek, near the SE corner of sec. 22, T. 36 N., R. 4 W.; along both sides of the same highway east of Yankee Branch in the SW corner of sec. 13, T. 36 N., R. 4 W.; and along the east side of the road just south of Wesco, near the center of the NW¼ sec. 12, T. 36 N., R. 5 W.

The Eminence of the Steelville quadrangle, particularly the upper part, is sandy. The sand occurs as disseminated, rarely clustered particles of quartz. The most abundant grains are from 1/16 to 1/8 millimeter in diameter, sub-angular to well-rounded, clean, and generally frosted. A few well-rounded, frosted and pitted, medium-sized grains were observed in most samples studied.

The chert of the Eminence is nearly as diagnostic of that formation as the druse is of the Potosi. This chert occurs as seams, ledges, and irregular masses. Fresh, unweathered Eminence chert is usually gray, blue gray, gray brown, or brown. Rarely is it white, as are the cherts of the lower Gasconade. Also diagnostic of the Eminence chert are its finely granular texture, oolites, and dolomolds. The oolites occur singly or in clusters. They are usually white and coated with very fine quartz crystals. The dolomolds in the chert are small, the intervening walls, thin, giving the chert a fine lacy appearance. The weathered chert occurs as porous, rusty-brown, very irregular, ropy masses.

Hill and ridge tops underlain by the Eminence are thickly mantled with sandy, reddish-brown clay, and large, irregular boulders, up to five feet in diameter, of rusty-brown, porous, deeply weathered chert.

Stratigraphic sections.—Section of lower Eminence and upper Potosi exposed along northwest bank of Dry Creek, west from center of SW¼ SW¼ sec. 16, T. 36 N., R. 3 W. to top of hill in NW corner, SW¼ SW¼ sec. 16, T. 36 N., R. 3 W.

	Thickness Feet	Thickness Inches
Cambrian System		
Upper Cambrian Series		
Eminence formation		
6. Covered interval to top of hill; irregular masses of rusty brown, porous, ropy chert and reddish brown soil cover the hillside	110	0
5. Dolomite; fresh exposures are bright, light gray and weathered surfaces are dull, dark gray; coarsely crystalline; fresh exposures are massive, weather into craggy pinnacles with deeply-pitted, rough surfaces	5	0
4. Covered interval; rusty, porous, drusy, and oolitic chert float	6	0
3. Dolomite; fresh surfaces are light gray, weather to dull, dark gray; coarsely crystalline; well-bedded to massive, weathers into rows of low craggy pinnacles along the hillside; gray, oolitic chert weathers to rusty red, porous irregular masses	25	0
2. Covered interval; rusty chert float	4	0

	Thickness Feet	Inches
Cambrian System—Continued		
Upper Cambrian Series		
Potosi formation		
1. Dolomite, drusy; medium to dark gray brown; coarsely crystalline........................	25	0
Base of section is stream bed		

Section of upper Eminence and lower Gasconade exposed along Missouri Highway 19, beginning one-tenth of a mile east of Yankee Branch where the highway crosses a small draw, northeast along both sides of the highway to the top of the hill in sec. 24, T. 36 N., R. 4 W.

	Thickness Feet	Inches
Ordovician System		
Lower Ordovician Series		
Gasconade formation		
8. Covered interval to top of hill; finely angular fragments of china-white chert..............	20	0
7. Dolomite, "cotton rock" argillaceous; light gray; weathers dark gray; finely crystalline; massive and well-bedded..................	12	0
Gunter member		
6. Dolomite, arenaceous and drusy; light gray, weathers dull, dark gray; medium to coarsely crystalline; massive; weathered surfaces mantled with rusty, porous chert................	3	0
5. Dolomite, arenaceous; light gray; finely crystalline; thin and irregularly bedded; intercalated, greenish gray shale seams..................	1	9
4. Dolomite, arenaceous; dark buff to brown; finely crystalline; thin-bedded; thin seams and small flat, lenticular nodules of white chert....	3	0
Unconformity		
Cambrian System		
Upper Cambrian Series		
Eminence formation		
3. Dolomite; light gray, weathers dark gray; coarsely crystalline; thin to thick-bedded; weathers to thin beds with pitted surfaces; small vugs lined with pink dolomite crystals are abundant............................	15	0
2. Dolomite, contains nodular, white, granular chert; light gray, weathers dark gray; fine to medium crystalline; massive; rare thin stringers of gray shale............................	12	0
1. Dolomite; light gray; coarsely crystalline; massive beds weather into low, blocky crags with deeply pitted surfaces.....................	30	0
Alluvium in bed of draw.		

Topographic expression.—The Eminence, as well as the Potosi, underlies the more rugged and higher portions of the Crooked Creek area. Characteristically it forms steep slopes or low, bluff-like exposures. Outside the Crooked Creek area, where the beds are essentially horizontal, the Eminence crops out in bluffs or steep hillsides. Good examples of this may be observed at numerous places along the Meramec River from a few miles south of the Crawford-Dent County line, downstream to two miles north of Wesco.

The residual soils of the Eminence are commonly brownish red. In contrast, the soils of the Gasconade are orange or yellow brown.

Paleontology.—A rather extensive fauna has been collected from the Eminence in Missouri, mostly from residual chert. The collection reported here is small, for the writer collected only those specimens found in place.

A few poorly-preserved specimens, including a cephalon fragment of the trilobite, *Plethopeltis*, ? and fragments of several gastropods, *Rhachopea*, were found in chert in place in the upper Eminence along the east side of the road near the east center, NE¼ SE¼ sec. 17, T. 36 N., R. 4 W.

The largest collection was obtained from the upper Eminence near the head of a large gully just north of the center of the NW¼ SW¼ NW¼ sec. 22, T. 36 N., R. 4 W. Fragments of several gastropods, *Rhachopea* and *Dirhachopea*, and one good cephalon fragment of the trilobite, *Plethopeltis*, were found. This locality also yielded a large number of fragments of gastropods and trilobites, all too poorly-preserved to be of any value.

Dake (1930, p. 132) mentions a collection, apparently from near the top of the Eminence, in the vicinity of a small spring near the center of the NW¼ sec. 12, T. 36 N., R. 4 W., about one-fourth mile south of Wesco. A thorough search of this locality, now heavily overgrown, failed to reveal a single specimen.

Stratigraphic relations.—The Potosi grades into the overlying Eminence. The best exposure of the gradational beds is along the northwest bank of Dry Creek, west of the center of the SW¼ SW¼ sec. 16, T. 36 N., R. 4 W. At this locality the lower 25 feet consists of typical dark-brown, massive, finely crystalline Potosi dolomite. Above this zone the lithology changes gradually through 30 feet to bright, light-gray, coarsely crystalline, well-bedded, non-drusy dolomite, which contains the gray, granular, frequently oolitic chert typical of the Eminence. This zone can also be seen in steeply dipping beds along the east side of the road, 420 feet west and 520 feet south of the NE corner, SE¼ SE¼ sec. 17, T. 36 N., R. 4 W. At this point the dolomite is massive to well-bedded, medium crystalline, dense, somewhat drusy and bright, light gray. Approximately 30 feet higher on the hillside there are isolated pinnacles of the bright-gray, coarsely crystalline Eminence dolomite. The surface of the hillside is mantled with the rusty, porous, ropy masses of chert so characteristic of the Eminence. Outside the Crooked Creek area, the best exposure of the Potosi-Eminence gradational beds is along the northwest bank of Dry Creek, west of the center of the SW¼ SW¼ sec. 16, T. 36 N., R. 4 W. At this locality, the basal 25 feet consists of typical dark-brown, massive, finely crystalline Potosi dolomite. Above this zone the lithology changes gradually through 30 feet of beds to bright, light-gray, coarsely crystalline, well-bedded, non-drusy dolomite which contains gray, granular, commonly oolitic chert.

ORDOVICIAN SYSTEM
LOWER ORDOVICIAN SERIES
GASCONADE FORMATION

Name.—The type area of the Gasconade formation is along the Gasconade River in east central Missouri. Nason in 1892 (pp. 114-115), was the first to apply the name Gasconade to " . . . the great series of limestone beds, interstratified with thin beds of sandstone, which underlie the Roubidoux." Nason thought that the Roubidoux and Crystal City (St. Peter) sandstones were equivalent, but in his mapping of the Gasconade, he placed the top at the base of the Roubidoux. Nason did not define the base of the Gasconade. Winslow (1894, p. 331) placed everything between the Iron Mountain conglomerate (basal Lamotte) and the Crystal City (St. Peter) sandstone in the Gasconade. Winslow, as Nason, correlated the Roubidoux with the St. Peter, and in his mapping he also delimited the top of the Gasconade at the base of the Roubidoux.

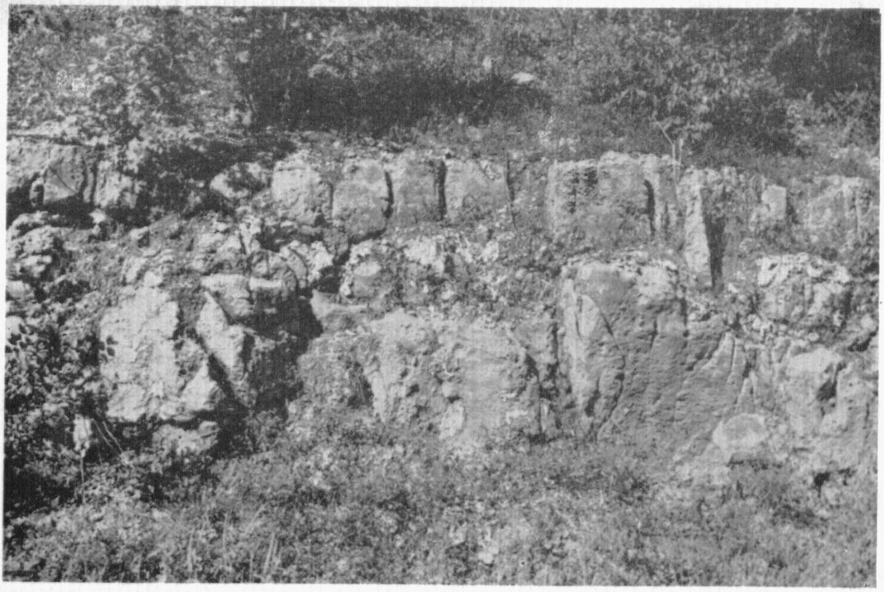
Ball and Smith (1903, pp. 30-50) defined the Gasconade as lying above the Gunter sandstone and beneath the St. Elizabeth (Roubidoux) formation. Marbut (1907, pp. 26-32) followed Ball and Smith, except he placed the base of the Gasconade at the base of the Gunter sandstone. Marbut was followed in this definition for more than 20 years by Buckley (1909, pp. 59-60), Ulrich (1911, pp. 631-632), Lee (1913, pp. 12-20), Tarr (1919, p. 51), and Branson (1918, p. 49).

Bridge (1930, pp. 98-99, 109) defined the formation as the cherty beds of dolomite lying between the Roubidoux formation above and the Van Buren formation below. This restricted definition was followed by Dake (1930, pp. 127-129) and McQueen (1931, p. 119). No satisfactory regional subsurface (Grohskopf, Personal communication, June 1947) or field (Clark, Personal communication, August 1949) criteria have been found for the separation of the Van Buren and the Gasconade (restricted). The Gasconade as used in this report includes those beds between the top of the Eminence dolomite and the base of the Roubidoux formation. This is the unrestricted definition of Marbut (1907, pp. 26-32).

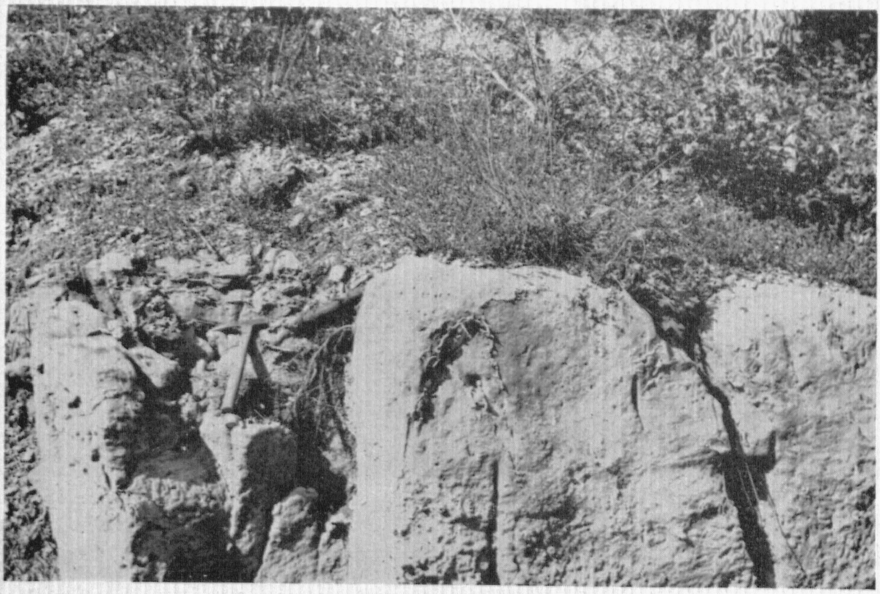
Distribution.—The Gasconade has a limited outcrop on the outermost flank of the Crooked Creek ring anticline (pl. VIII). It is widely exposed in the southwestern part of the quadrangle where it underlies all but the higher ridge crests and the deeper valley floors. In the northern part of the quadrangle the Gasconade is extensively exposed along the valley walls of the Meramec River and its tributaries (pl. VII).

Thickness.—The Gasconade is unusually thin over the southern part of Crawford County and the northern part of Dent County. This is well-shown by unpublished isopach maps of the Missouri Geological Survey. Dake (1930, p. 153) noted that the Gasconade is 150 to 180 feet thick near Scotia, Wesco, and Steelville.

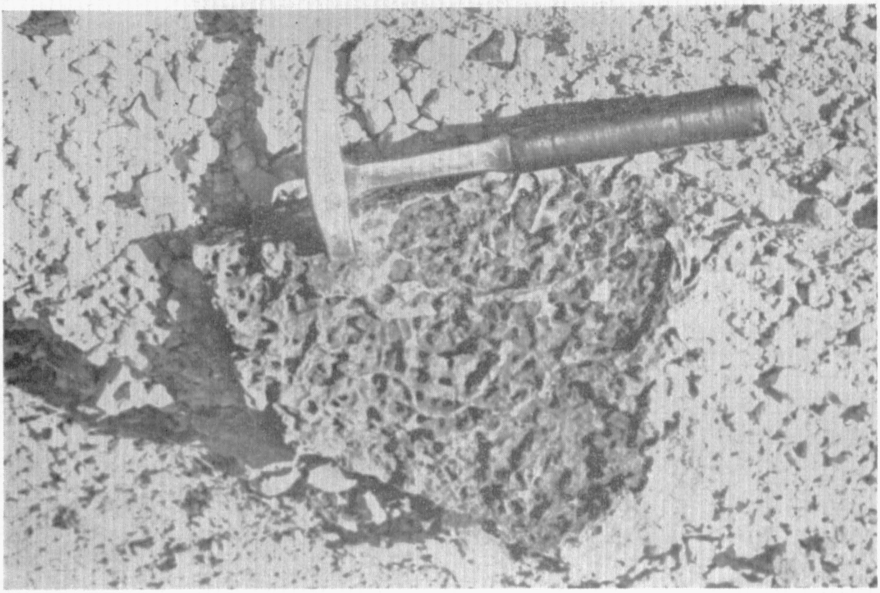
The average thickness of the Gasconade in the Steelville quadrangle is 190 to 200 feet. A section of 195 feet of Gasconade is exposed from the road level to the top of the hill on the west side of the road immediately south of Cook Station in the SE¼ NE¼ sec. 26, T. 36 N., R. 5 W. Another section of 193 feet, most of which is covered, occurs beneath the Roubidoux above the Eminence in the NW¼ NE¼ sec. 25, T. 36 N., R. 5 W.



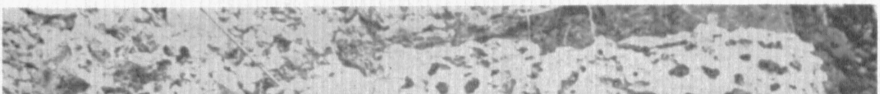
A. Thick-bedded upper Eminence, NW¼ SE¼ sec. 31, T. 37 N., R. 4 W. On north side of road one mile west of Keysville.



B. Closeup view of same showing shelly druse.



A. Ropy chert just above the *Cryptozoon* reef (Gasconade) along the east side of Crawford County Road M, near the north center, SE¼ NE¼ sec. 36, T. 37 N., R. 5 W.



B. Cellular chert in the lower Eminence along the north side of the Dillard Road in the SE¼ NE¼ SW¼ sec. 32, T. 36 N., R. 3 W.

Lithology.—The dolomite of the Gasconade is generally well-bedded, medium crystalline, light gray, and very cherty. In contrast to the Eminence, it is darker, with a dull luster, not so coarsely crystalline, nor so massive. The upper Gasconade is coarser in texture and not so thin-bedded as is the lower Gasconade. The weathered surface of the coarsely crystalline upper Gasconade is rough and pitted, as is the weathered surface of similar dolomite in the Eminence formation. The craggy pinnacles, so typical of the Eminence, are not developed; instead, the formation is exposed in step-like ledges.

Parts of the Gasconade are well-exposed in the Steelville quadrangle. A complete section is nowhere well-exposed, because heavy chert residuum covers the less resistant beds.

In this report the 150 feet of Gasconade below the top of the *Cryptozoon* reef is referred to as the lower Gasconade and the 40 to 50 feet above the *Cryptozoon* reef is called the upper Gasconade.

The lowermost Gasconade, the Gunter member, is an arenaceous dolomite. The upper extent of the sand grains can be determined only from insoluble residues.

The Gunter member is best exposed half a mile east of Sligo, in the road cut on the north side of the road, 40 feet above Crooked Creek. The outcrop consists of six inches of sandstone between the bright, light gray, well-bedded, coarsely crystalline Eminence dolomite and the buff, argillaceous, thin-bedded, lower Gasconade dolomite. The lower two inches of the Gunter sandstone consists of gray, white, and brown chert fragments in a quartzitic sandstone matrix. The upper four inches is composed of 95% fine quartz grains and 5% medium quartz grains. The fine grains are angular to sub-rounded, commonly frosted, and iron-stained. About 20% of these fine grains are secondarily enlarged. The medium-sized grains are generally well-rounded, frosted and pitted, and few are secondarily enlarged. This zone is also exposed one mile west of Keysville along the north side of the road, along the St. Louis and San Francisco Railroad, half a mile north of Wesco; in a road cut along the Cook Station-Sligo road in the SW¼ NE¼ sec. 25, T. 36 N., R. 5 W.; half a mile southeast of Goltra, along the abandoned Sligo spur of the St. Louis and San Francisco Railroad; and along the west bluff of the Meramec River in the NE¼ SW¼ sec. 11, T. 36 N., R. 5 W.

Above the Gunter sandstone is five feet of thin and wavy-bedded argillaceous and arenaceous, light-gray to buff, finely crystalline, cherty dolomite. These dolomite beds range from one-half inch to one foot in thickness. Thin seams of green shale and lenses of fine-grained sandstone commonly alternate with the dolomite beds. The sand is similar to that of the Gunter. Between the thin beds of shale, sand, and dolomite are stringers or lenses of dense, white, porcelaneous and tripolitic chert.

Above the thin-bedded zone is a single bed of massive, coarsely crystalline, light-gray dolomite, which averages five feet in thickness. This dolomite crops out in blocky pinnacles. The weathered surfaces have a sandy appearance caused by the accumulation of dolomite rhombs. Anastomosing stringers or veinlets of fine quartz druse, which mark the weathered surfaces, are more resistant to weathering than the dolomite, and stand out in bold relief. Extreme weathering of this bed produces a massive ledge of white to gray, finely granular, drusy chert, the surface of which resembles the rusty, porous, ropy masses of chert in the Eminence (pl. III). Outcrops of this bed on gentle hillsides are covered by a heavy residuum of finely angular, gray-white, drusy chert fragments. From this bed and from beds immediately above it, most of the Van Buren fauna has been collected. This bed is well-exposed along the St. Louis and San Francisco Railroad, three-fourths of a mile north of Wesco; in a road cut along the Cook Station-Sligo road in the SW¼ NE¼ sec. 25, T. 36 N., R. 5 W.; about half a mile southeast of Goltra, along the abandoned Sligo spur of the St. Louis and San Francisco Railroad; and along the west bluff of the Meramec River in the NE¼ SW¼ sec. 11, T. 36 N., R. 5 W.

Above this heavy druse and chert is a zone consisting of 30 to 40 feet of well-bedded to massive, medium crystalline, light-gray, cherty dolomite. These beds, where deeply weathered, are mantled with dense, finely angular, china-white, porcelaneous chert, with conchoidal fracture. This chert is most abundant on gently-sloping hillsides, where it produces the characteristic "snow hillsides" of the lower Gasconade outcrops. This chert is not discolored by weathering as are the rusty cherts of the Potosi, Eminence, or upper Gasconade. Dolomolds typical of the lower Gasconade are contained in the chert near the top of this zone. The dolomold horizon is 30 to 35 feet above the top of the Eminence. This relationship is as constant in the subsurface (Grohskopf, Personal communication, June 1947) as it is on the outcrop, and its recognition is an aid in mapping the Gasconade-Eminence contact. The dolomolds, which are coarse and widely spaced, are contained in white or buff, rarely gray, chert. This chert in the upper part of the dolomold horizon is vitreous, non-granular, oolitic, and oomoldic. The oolites resemble grains of rice in size and shape, and are irregularly spaced. The dolomold horizon is exposed along the south side of Missouri Highway 19, east of Crooked Creek near the SE corner, NE¼ SW¼ sec. 23, T. 36 N., R. 4 W.; near Gregory Cemetery at an altitude of 1180 feet, in the center of the NW¼ NE¼ sec. 33, T. 36 N., R. 3 W.; and near the head of a ravine in the SE ¼ SW¼ sec. 30, T. 36 N., R. 3 W.

Above the dolomold horizon are 20 to 30 feet of beds which grade from massive to well-bedded, cherty dolomite below to thin and well-bedded, less cherty dolomite above. The rock is finely crystalline, light-gray, argillaceous, "cotton rock" dolomite. The small amount of chert in this zone is gray and buff, oolitic, rarely dolomoldic, and not so finely angular as in the chert in the zone below. The top six to eight feet of this zone consists of two massive beds, each three to four feet thick, of finely crystalline, dense, light-gray, non-cherty dolomite. The weathered beds are dull, dark gray and have a rough, pitted surface. In contrast to much of the Gasconade, they are very resistant, forming conspicuous ledges along the hillsides. These two massive beds can easily be identified in the field. Above them the residual chert is gray, vitreous, and sparingly drusy. It tends to segregate into distinct concentric-banded nodules. These gradational beds crop out about 70 feet above the north side of the road, one mile west of Keysville; immediately south of Cook Station in the SE¼ NE¼ sec. 26, T. 36 N., R. 5 W.; and about one mile south of Wesco, 90 feet above the east side of the road in the S½ NW¼ sec. 13, T. 36 N., R. 5 W.

The zone above the two massive, resistant beds consists of 30 to 40 feet of well-bedded, light-gray, moderately crystalline, sparingly cherty dolomite. Weathered surfaces are generally smooth, and have an earthy texture. These beds crop out as low, widely spaced, step-like ledges. Smooth, elliptical nodules of white and gray-banded, finely granular chert are abundant. The maximum diameter of these nodules is six inches. Where these beds underlie gentle slopes, the surface is mantled with orange and buff stained, sharp, angular, broken fragments of chert. Stringers of white, porous, tripolitic chert near the top of this zone contain the gastropod, *Euomphalopsis*. Most outcrops of this zone are deeply covered by chert float from the higher strata of the Gasconade. Isolated small outcrops are exposed along Missouri Highway 19 near the east center of the SW¼ sec. 23, T. 36 N., R. 4 W.; along the east side of the road, SE¼ NE¼ sec. 31, T. 36 N., R. 4 W.; along the road near the SW corner, NW¼ SE¼ sec. 21, T. 36 N., R. 4 W.; and on the nose of a hill near the west center, NE¼ SW¼ sec. 34, T. 36 N., R. 5 W.

The next higher zone consists of 40 to 50 feet of medium to coarsely crystalline, light-gray dolomite, which contains abundant chert and some quartz druse. The dolomite is well-bedded to massive, in beds two to four feet thick. These beds are exposed as low, rounded pinnacles, which are not so rough, rugged, or craggy as are the pinnacles of the Eminence. The chert of this zone is white to light gray, finely granular, locally oolitic and drusy. The oolites are oval to spherical in outline, but they lack the uniformity of size and shape which is so characteristic of the Eminence oolites. The druse consists of fine quartz crystals on banded white and gray chert. This zone of the Gasconade is exposed near the head of a hollow in the extreme SE corner, sec. 29, T. 36 N., R. 4 W.; on the steep north side of a deep hollow in the SE¼ NE¼ sec. 1, T. 35 N., R. 5 W.; about half a mile southwest of Cook Station in a ravine near the NW corner NW¼ SE¼ sec. 26, T. 36 N., R. 5 W.; and on the hillside near the NE corner, NW¼ SE¼ sec. 16, T. 36 N., R. 5 W.

Immediately above this zone is the large *Cryptozoon* reef, consistently found at this horizon in the Gasconade. The top of the reef marks the base of the upper Gasconade. The *Cryptozoon* reef is the one which Bridge (1930, p. 113) refers to as *Cryptozoon ozarkensis*. In the Steelville quadrangle, it is approximately 150 feet above the base of the Gasconade, and 40 to 50 feet beneath the base of the Roubidoux. It crops out as a resistant ledge, from two to five feet thick, of massive, generally oolitic, slightly drusy, granular, white to gray chert. It breaks into large, blocky fragments which can always be recognized in the Gasconade chert residuum. Its most distinctive characteristic is the pattern formed by the *Cryptozoon* colonies. This pattern consists of parallel, vertical columns, usually from one to one and one-half inches in diameter, which are separated by a space of six to eight inches, bridged by thin, parallel, arched plates, convex upward. Notable exposures of this reef occur on the east side of Crawford County Road M, near the north center of the SE¼ NE¼ sec. 36, T. 37 N., R. 5 W.; along Missouri Highway 19, near the NW corner, SW¼ NE¼ sec. 18, T. 35 N., R. 4 W.; along the road in the SW corner, NE¼ SW¼ sec. 31, T. 36 N., R. 4 W.; and near the road junction in the south center, NW¼ SE¼ sec. 21, T. 36 N., R. 5 W.

The upper Gasconade is 40 to 50 feet thick. It consists of medium to coarsely crystalline dolomite in beds two to four feet thick which weather with a coarsely pitted surface and form massive ledges (pl. IV-B). Small vugs of calcite are abundant in the more massive beds. The dolomite is noticeably sandy near the top of the Gasconade. The sand is fine to medium-grained, angular to well-rounded, and commonly frosted. The angularity of most of the grains is due to secondary enlargement. The chert of the upper Gasconade distinguishes it from the rest of the formation. The chert resembles that of the upper Eminence. It is gray and brown, rarely greenish gray, finely granular, and locally drusy and oolitic. Immediately above the *Cryptozoon* reef there are irregular stringers or seams of gray to brown, granular chert. It weathers into ropy-appearing masses of rusty and porous chert, similar to that immediately above the lower drusy zone of the Gasconade, and in the Eminence (pl. III-A). This chert zone is generally very fossiliferous. The chert near the top of the Gasconade is commonly brown and oolitic.

Stratigraphic sections.—Section exposed between railroad track and top of hill on Wesco-Cook Station road, one mile south of Wesco, S½ NW¼ sec. 13, T. 36 N., R. 5 W.

	Thickness Feet	Inches
Ordovician System		
Lower Ordovician Series		
Gasconade formation		
17. Covered interval to top of hill; abundant Gasconade chert float	40	0
16. Dolomite; medium gray, weathers dark gray; dense, fine-grained; massive; weathered surfaces pitted	4	0

Ordovician System—Continued	Thickness	
Lower Ordovician Series	Feet	Inches
Gasconade formation		
15. Covered interval; gray and brown chert float	2	6
14. Dolomite; light gray, weathers dark gray; coarsely crystalline; massive; weathered surfaces pitted	2	8
13. Covered interval; buff chert float	5	0
12. Dolomite, drusy; light gray, buff mottled, weathers dull, dark gray; fine to medium crystalline; massive	1	4
11. Covered interval; buff chert float	6	0
10. Dolomite; light gray buff, weathers dark gray; medium crystalline; beds 2 to 4 inches thick	1	6
9. Dolomite; buff, weathers dark brown; coarsely crystalline; massive; weathered surfaces pitted	4	6
8. Dolomite, cherty; buff, weathers gray brown; finely crystalline; thin-bedded	2	0
7. Covered interval; small, angular fragments of white, porcelaneous chert float	30	0
6. Dolomite; buff, weathers gray brown; fine-grained; massive	1	6
5. Dolomite; buff, weathers brown; finely crystalline; thin-bedded	1	6
4. Covered interval	3	0
3. Dolomite, cherty and drusy; light gray, weathers dark blue gray; finely crystalline; massive	1	6
2. Covered interval; small, angular fragments of white chert and flakes of fissile green shale in soil	10	0
Unconformity		
Cambrian System		
Upper Cambrian Series		
Eminence formation		
1. Dolomite, sandy and cherty; bright, light gray, weathers dull, dark gray; coarsely crystalline; massive	12	0
Base of section at railroad tracks.		

Section exposed from road level to top of hill along west side of road, south of Cook Station, in the SE¼ NE¼ sec. 26, T. 36 N., R. 5 W.

Ordovician System	Thickness	
Lower Ordovician Series	Feet	Inches
Roubidoux formation		
13. Covered interval to top of hill; abundant sandstone float	25	0
Unconformity		

	Thickness	
	Feet	Inches
Ordovician System—Continued		
Lower Ordovician Series		
Gasconade formation		
12. Covered interval; large masses of finely granular, oolitic, blue-gray chert float	86	0
11. Dolomite; light gray, buff mottled, weathers dull, dark gray; medium crystalline; massive; outcrops as resistant ledges along the hillside	10	0
10. Covered interval; Gasconade chert float	15	0
9. Dolomite; light gray, weathers dark gray; finely crystalline; massive	10	0
8. Covered interval; smooth, gray and white chert float	2	0
7. Dolomite; light gray, weathers dark gray; dense, finely crystalline; massive; outcrops as resistant ledges	5	9
6. Covered interval	3	0
5. Dolomite, cherty and drusy; light gray, weathers dark gray; medium crystalline; beds one to two feet thick	5	3
4. Dolomite; light gray, weathers dull, dark gray; coarsely crystalline; massive; outcrops as resistant ledges	11	10
3. Covered interval; dolomoldic chert float near top of interval	37	0
2. Dolomite, cherty; light gray, weathers dark gray; medium crystalline; massive	5	0
1. Dolomite; buff and gray; finely crystalline; thin-bedded; intercalated stringers and seams of gray green shale, fine-grained quartz sand, and tripolitic chert	4	2
Base of section at road level.		

Section exposed in valley wall west of Meramec River, just north of Crawford-Dent County line in the S½ sec. 34, T. 36 N., R. 5 W.

	Thickness	
	Feet	Inches
Ordovician System		
Lower Ordovician Series		
Roubidoux formation		
6. Covered interval; Roubidoux float to top of hill	40	0
Unconformity		
Gasconade formation		
5. Dolomite, calcite vugs; buff, light gray mottled, weathers dull dark gray; coarsely crystalline; massive; weathered surfaces deeply pitted; outcrops as ledges	45	0

Ordovician System—Continued	Thickness Feet	Inches
Lower Ordovician Series		
Gasconade formation		
4. Covered interval; large masses of gray blue, granular chert which weathers rusty red....	6	0
3. *Cryptozoon* chert; white to gray; finely granular; oolitic; outcrops as massive ledge......	4	6
2. Dolomite, cherty; light gray, weathers dark gray; medium crystalline; massive; weathered surfaces pitted; outcrops as resistant ledges..................................	44	0
1. Dolomite; light gray, weathers dark gray; medium crystalline; thin to medium-bedded; chert, nodular, white and gray, weathers buff..................................	30	0
Base of section 35 feet above Meramec River.		

Topographic expression.—The Gasconade is extensively exposed on the sides of the larger valleys, but rarely forms broad uplands. Where the Gasconade underlies ridge crests, the ridges are narrow, sinuous, and generally steep-sided. They are capped by a deep residuum of chert fragments. Where erosion is not so active, the Gasconade outcrops as ledges widely separated by grassy, chert-covered slopes.

The Gasconade residual soils are clayey and stony. The color is reddish orange or yellow, not nearly so dark as the red soils of the Bonneterre, Potosi, or Eminence.

Paleontology.—The Gasconade cherts are normally fossiliferous, but as in the case of the older formations, most of the collections reported from the Gasconade have come from residual chert. The writer collected only those fossils found in place, hence the collection reported here is small.

A mold of the umbilical portion of the gastropod, *Sinuopea*, was collected from the drusy zone of the lowermost Gasconade, 330 feet east and 170 feet north of the SW corner, NW¼ sec. 16, T. 36 N., R. 4 W. Fragments of gastropods, too poorly preserved to identify, were collected from the same horizon in the head of a hollow near the north center of the NW¼ SW¼ NW¼ sec. 22, T. 36 N., R. 4 W. A fragment of the outer whorl of the gastropod, *Sinuopea*, was collected along the east side of the road, just south of the road junction in the NW corner of the SW¼ sec. 16, T. 36 N., R. 4 W.

Three fragmentary external molds of *Ophileta* were collected from widely separated localities. Two of these specimens are from the middle Gasconade and were collected near the road junction in the NW¼ SE¼ sec. 23, T. 36 N., R. 4 W. and in a small valley half a mile east of Keysville, north of the center, NW¼ NW¼ sec. 4, T. 36 N., R. 4 W. The other, from just above the cryptozoon reef, was collected just east of the road fork in the NW¼ SE¼ sec. 21, T. 36 N., R. 5 W.

No identifiable specimens of cephalopods were found in the Steelville quadrangle. A fragment of the external mold of a cephalopod was found in the chert of the lower Gasconade, along with the fragmentary molds of gastropods, on the hillside near the north center, NW¼ SW¼ NW¼ sec. 22, T. 36 N., R. 4 W.

Cryptozoa are common at many localities, particularly in the drusy dolomite and heavy chert zone near the base of the Gasconade and at the top of the lower Gasconade. These are poorly defined forms of doubtful affinities.

Stratigraphic relations.—In the St. Francois Mountain area, Dake (1930, pp. 127-129) found evidence of a conspicuous unconformity between the Eminence and the Gasconade. In the Steelville quadrangle the best evidence for this unconformity is the presence of small, apparently water-worn chert pebbles in the Gunter sandstone of the lowermost Gasconade. These pebbles are disseminated, giving a conglomeratic appearance to the beds immediately above the contact. At every exposure of the contact in this quadrangle, the Eminence and Gasconade exhibit parallel bedding. The contact relief is less than a foot. The contact is best-exposed in a road cut on the north side of the road, three-fourths of a mile east of Cook Station, near the SW corner, NW¼ NE¼ sec. 25, T. 36 N., R. 5 W.

ROUBIDOUX FORMATION

Name.—The early geological reports of the Geological Survey of Missouri (Swallow, 1855, pp. 61-62, 126-128; Williams, 1877) referred to the Roubidoux as the Second sandstone, in contrast to the First sandstone (St. Peter) and the Third sandstone (Gunter).

Nason (1892, pp. 114-115) proposed the name Roubidoux in 1892, for the great series of chert, dolomite, and sandstone which caps the ridges of the central Ozarks and which overspreads the " . . . Ozark region from Cabool to Gasconade City and from Salem to Doniphan." He concluded that " . . .

it embraces much, if not all of what has been called the Second sandstone, and will undoubtedly include the area of the so-called First sandstone as well." From the localities which he cites in his text, he meant to apply the term to the Second sandstone only. He was wrong in assuming that the First sandstone (St. Peter) was the equivalent of his Roubidoux.

Bain and Ulrich (1909, pp. 12, 18) stated that the Roubidoux overlies the Gasconade and underlies the Jefferson City. This is the accepted definition of the stratigraphic limits of the Roubidoux.

Distribution.—The Roubidoux crops out in the syncline which surrounds the central part of the Crooked Creek structure (pl. VIII). In the southern half of the Steelville quadrangle, it caps only the higher ridges, whereas in the northern half of the quadrangle, it is widely exposed over extensive uplands (pl. VII).

Thickness.—Northeast of Yankee Branch there is 120 to 150 feet of Roubidoux above the Gasconade. In addition to this thickness, residual Roubidoux sandstone mantles the hilltops. Approximately two miles southwest of Cook Station 80 to 100 feet of Roubidoux is exposed above the Gasconade.

Within the Rolla quadrangle, 15 miles west of the Steelville quadrangle, Lee (1913, p. 21) reports a thickness of 115 to 150 feet for the Roubidoux. Dake (1930, p. 163) estimates the thickness of the Roubidoux to be 100 to 120 feet in the Potosi and Edgehill quadrangles, and Bridge (1930, p. 119) thought it might be as much as 200 feet thick in the southwestern part of the Eminence quadrangle.

Lithology.—The Roubidoux is an extremely variable complex of sandstone, chert, and dolomite. To the west, in the vicinity of Rolla, approximately one-half the thickness is sandstone (Lee, 1913, pp. 21-30). To the northwest in Morgan (Marbut, 1907, pp. 33-39) and Miller (Ball and Smith, 1907, pp. 50-68) counties, and also to the southeast in Ste. Genevieve County (Weller and St. Clair, 1928, pp. 69-74), chert and dolomite constitute the bulk of the formation. In the Potosi quadrangle (Dake, 1930, p. 163), sandstone is the dominant constituent, as it is in the Steelville quadrangle.

A complete section of the Roubidoux is not exposed in the quadrangle. Most of the outcrops are near the ridge crests where solution and slumping have been active. Where the Roubidoux has been little affected by solution and slump, the sandstone is well-bedded, individual beds varying from a few inches to a few feet thick (pl. V). Cross-bedding, mudcracks, and current and oscillation ripple marks are abundant. The sandstone is composed of angular to rounded quartz grains, more than 90% of which are less than one-fourth millimeter in diameter.

In fresh exposures, such as recently-opened quarries, the sandstone is friable. More of the sand grains are round than angular, and only a few of them are coated with buff to red iron oxide. In sharp contrast are the deeply weathered exposures, and large float boulders which have been subjected to extensive weathering. These are either case-hardened, or quartzitic. The grains are angular and have well-defined crystal faces, formed by secondary enlargement. Most of them are coated with red, brown, or yellow iron oxide.

Certain beds of sandstone contain angular to round pieces of chert in a quartzitic to sandy chert matrix. Many of the round pieces are concentrically banded, suggesting that they may be concretions rather than pebbles. The surfaces of many angular fragments cut directly across the laminations of the chert, indicating the formation and fracture of the chert occurred prior to its incorporation into the sandstone. These pieces of chert are most abundant in residual float boulders lying on Gasconade ridge tops, which suggests that this may be a conglomerate in the basal Roubidoux. These conglomeratic sandstone boulders are abundant north of New Home Church, along the road in the SW¼ SE¼ SE¼ sec. 10, T. 36 N., R. 4 W.

The dolomite of the Roubidoux varies from coarsely crystalline, gray to buff, cherty, rough-weathering, massive-bedded dolomite like that of the Gasconade, to the finely crystalline, argillaceous, thin and well-bedded, sparingly cherty, "cotton rock" dolomite like that of the Jefferson City formation.

Chert is more abundant in the dolomite beds than in the sandstone. The Roubidoux chert is more sandy than that of the older formations. It varies from sandy chert to cherty sandstone. The chert is usually cream or buff, but may be brown, gray, blue gray, or flat white. The texture may be granular, glassy, or porcelaneous. Most of the Roubidoux chert is oolitic. Dark colored, spherical to elliptical oolites, of variable size, enclosed in lighter colored matrix, are abundant. In contrast, the oolites of the Gasconade chert are lighter than the matrix.

Topographic expression.—Northeast of Yankee Branch, where the Roubidoux is widespread, its resistant character has impeded erosion so that it forms gently rolling uplands, in contrast to the more rugged topography carved in the weaker, older dolomites. Around the Crooked Creek structure, the Roubidoux forms gently rolling to moderately rugged topography. Throughout the remainder of the southern half of the Steelville quadrangle, it caps only the higher ridges and hill tops.

The soil of the Roubidoux is loose and porous, has an ashy and sandy texture, and is generally too stony for extensive cultivation. Over much of the area, the Roubidoux outcrop is covered with oak timber or prairie grasses.

Palentology.—No fossils were found in the Roubidoux of the Steelville quadrangle. According to Bridge (1930, pp. 123-124), fossils are rare in the Roubidoux, except in two horizons. The lower one, near the base, carries *Syntrophina campbelli* (Walcott) and a large trochoid shell which Bridge and Cloud (1947, pp. 545-559) designated *Rhombella umbilicata.* The other faunal zone occurs near the middle of the Roubidoux, and is characterized by various species of the genus *Lecanospira.*

Heller (1950) has studied the fauna of the Roubidoux on a regional basis and reported fifteen described species and twelve undescribed species.

Stratigraphic relations.—There are no good exposures of the Gasconade-Roubidoux contact in the Steelville quadrangle. Solution of the upper Gasconade, especially on the narrow ridges, has allowed the more resistant Roubidoux to slump down over the contact. There is no definite proof of the existence of a sub-aerial erosional surface at the top of the Gasconade, as postulated by Ulrich (1924, pp. 103-104). According to Bridge (1930, p. 115), "There is a marked faunal break between the Gasconade and the Roubidoux, for no trace of the Tribes Hill-Stonehenge fauna which intervenes between the Gasconade and the Roubidoux faunal zones in the Appalachian trough has been found in Missouri."

It should be noted that the residues of the upper Gasconade show an increasing amount of sand which closely resembles the sand of the Roubidoux. It is quite possible that Ulrich's unconformity is nothing more than a gradational change from predominantly limestone deposition of the Gasconade seas, through increasingly sandy phases to the beds of pure sandstone, dolomitic sandstone, and Gasconade-type dolomite of the Roubidoux. The chert of the upper Gasconade also resembles that of the Roubidoux.

JEFFERSON CITY FORMATION

Name.—The Jefferson City formation was orginally designated (Swallow, 1855, pp. 61-62, 121-125) along with the overlying Cotter and Powell, as the Second magnesian limestone, underlain by the Second sandstone (Roubidoux) and overlain by the First sandstone (St. Peter).

Nearly 40 years later, Winslow (1894, pp. 331, 373, 375) proposed the term Jefferson City limestone for the upper part of his Gasconade. It was defined as the 175 feet of limestone which underlies the Roubidoux or Saccharoidal sandstone (not Roubidoux, but St. Peter sandstone) and overlies the Moreau sandstone (Roubidoux formation) in central Missouri.

Keyes (1898, p. 60) used the term Winfield limestone for what is a part of the Jefferson City or Cotter or both, as those formations are now defined.

Until 1911, the name Jefferson City limestone was used to designate the beds between the Roubidoux and the St. Peter sandstones (Ball and Smith, 1903, pp. 69-78; Shepard, 1904, pl. 1, p. 42; Bain and Ulrich, 1909, pp. 33-35; Van Horn and Buckley, 1905, pp. 23-33; Marbut, 1907, pp. 40-46; Buckley, 1909, pp. 61-62; Lee, 1913, p. 35). In 1911, Ulrich (1911, pl. 27) divided the beds previously called the Jefferson City into Everton, Yellville limestone, and Jefferson City, which he placed immediately above the Roubidoux. In 1915, Ulrich (pl. 2) modified his earlier division of the Jefferson City for the central Ozarks by dividing the original Jefferson City into three formations which, in ascending order, are the Jefferson City (restricted), the Cotter, and the Powell.

Cullison (1944) elevated the term Jefferson City to group rank and proposed four formations including the Rich Fountain, Theodosia, Cotter, and Powell. No attempt was made in this study to differentiate the Jefferson City of Ulrich into the Rich Fountain and Theodosia of Cullison.

Distribution.—The Jefferson City formation has a limited distribution in the area of the Crooked Creek structure (pl. VIII). The largest outcrop forms a crescentric area in the southern part of the encircling syncline, which extends south and east from the north center of the NW¼ sec. 19, T. 36 N., R. 4 W., to near the SE corner of the same section, thence east and northeast to near the center of sec. 21, T. 36 N., R. 4 W. The only other outcrop is a small lenticular area in the northeastern part of the encircling syncline, in the north center of the SE¼ SE¼ sec. 8, T. 36 N., R. 4 W.

Thickness.—Computation based on the dip, and on the width of outcrop between its contact with the Roubidoux and the axis of the syncline, indicates a thickness of approximately 80 feet for the Jefferson City in this area.

In the Rolla quadrangle, about 20 miles to the west, Lee (1913, p. 35) assigned a maximum thickness of 240 feet to the Jefferson City, in which he included all the beds between the Roubidoux and the St. Peter. Cullison (1930, pp. 10-16) believes that in the vicinity of Rolla the top of the Jefferson City should be drawn at a thin sandstone horizon about 30 feet above the pitted dolomite member which constitutes the lower 80 feet of the formation. This gives a thickness of 110 feet for the Jefferson City, which is close to the maximum for that formation.

Lithology.—The basal portion of the Jefferson City formation is 20 to 25 feet thick in the Steelville quadrangle. It consists of "cotton rock" which is light-gray to buff, very finely crystalline to earthy, argillaceous, thin to massive-bedded dolomite (pl. IV-A). The thin-bedded dolomite is interstratified with thin seams of finely oolitic, finely granular, and light-gray to buff chert. The massive beds of dolomite contain small nodules of white to gray, tripolitic, finely granular chert. The massive beds also have a petroliferous odor when freshly broken. The basal zone is exposed in the bed of an intermittent stream in the SE¼ NE¼ SE¼ sec. 20, T. 36 N., R. 4 W.; in the roadside ditch northeast of Daniels School in the SE¼ SE¼ SW¼ sec. 20, T. 36 N., R. 4 W.; and in the roadside ditch in the NE¼ SE¼ SE¼ sec. 8, T. 36 N., R. 4 W.

Six to eight feet of finely crystalline, dense, medium-gray dolomite crops out as a persistent ledge immediately above the basal zone of the Jefferson City. This ledge is quarried at many places for building stone, and contains the characteristic "quartz roses." These are irregularly distributed clusters of small, pink-stained quartz crystals. The rough and scoriaceous weathered surface is pitted and nodose. Exposures of this resistant ledge are at the road corner near the north center of the SE¼ SE¼ sec. 8, T. 36 N., R. 4 W.; in the south bank of a small intermittent stream just west of Daniels School, 330 feet west and 310 feet north of the SE corner, SE¼ SW¼ sec. 20, T. 36 N., R. 4 W.; and in the south bank of the stream, 530 feet east and 30 feet north of the SW corner, NE¼ SW¼ sec. 19, T. 36 N., R. 4 W.

The zone above the resistant beds is 20 to 30 feet thick, and consists of thin-bedded, "cotton rock" dolomite, and more massive beds of medium crystalline, light-gray-buff dolomite. These beds contain tripolitic white chert and finely granular, oolitic light-gray-brown chert. This zone is exposed in the roadside ditch in front of Daniels School, 350 feet west and 30 feet south of the NE corner, NW¼ sec. 29, T. 36 N., R. 4 W.

Stratigraphic section.—Section exposed in ditch along west side of road, W½ NE¼ SE¼ SE¼ sec. 8, T. 36 N., R. 4 W. Base of section at altitude of 920 feet, and top of section at altitude of 960 feet.

		Thickness Feet	Inches
Ordovician System			
Lower Ordovician Series			
Jefferson City formation			
	Top of section, 960 feet altitude.		
11.	Covered interval; float fragments of sandstone, fine to medium, well-rounded, frosted grains; soil, red plastic clay with chert fragments....	4	6
10.	Dolomite, "cotton rock," argillaceous; light buff; very finely crystalline; thin-bedded; chert, nodular, light gray brown, finely granular, oolitic..............................	5	6
9.	Dolomite; arenaceous, clusters of small, pink-stained quartz crystals; medium gray; finely crystalline; well-bedded, beds 10 to 14 inches thick; weathered surfaces rough and scoriaceous; outcrops as resistant ledge...........	8	0
8.	Covered interval........................	2	0
7.	Dolomite, "cotton rock," arenaceous; light buff; finely crystalline; thin-bedded; thin seams of white to gray, finely granular chert..	2	6
6.	Dolomite; steel gray, weathers dark gray; finely crystalline; massive................	6	6
5.	Dolomite, arenaceous; light buff, weathers gray; finely crystalline; very thin-bedded; interbedded thin layers of white to gray chert..	4	0

	Thickness Feet	Inches
Ordovician System—Continued		
Lower Ordovician Series		
Jefferson City formation		
4. Dolomite, arenaceous; buff; finely crystalline; massive; chert, nodular, white to gray, finely granular	3	0
3. Dolomite, "cotton rock," arenaceous; light gray, weathers buff; finely crystalline; thin-bedded; chert, nodular and in thin seams, white tripolitic	2	6
2. Covered interval	4	0
Roubidoux formation		
1. Sandstone; dark red to brown; fine to medium, sub-angular to rounded, frosted grains; loosely consolidated; massive	3	6
Base of section, 920 feet altitude.		

Paleontology.—The Jefferson City formation is apparently unfossiliferous in the Crooked Creek area, as it is in the Eminence region (Bridge, 1930, p. 128). In the Rolla area, Lee (1913, pp. 37-39) reported a fossiliferous horizon about six feet above the quarry ledge, but he did not state what forms are present. He also mentioned the presence, in the chert near the top of the formation, of an abundant fauna of cephalopods, gastropods, trilobites, and a few brachiopods.

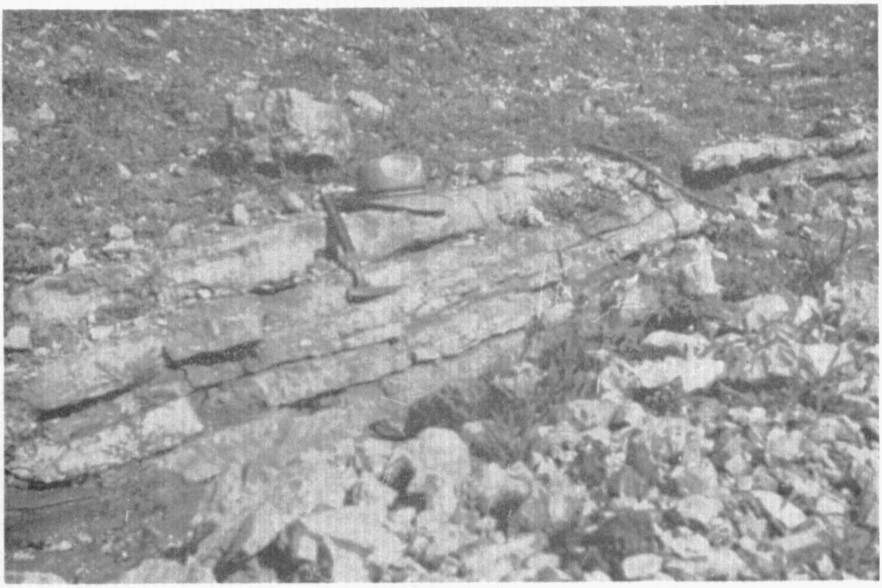
Cullison (1944) has made the most recent comprehensive study of the fauna of the Jefferson City. He listed 43 species from the Rich Fountain formation which is believed to be that portion of the Jefferson City described in this report.

Stratigraphic relations.—The Roubidoux-Jefferson City contact is concealed in this area. An unconformable surface is said to mark the top of the Roubidoux; however, there is little evidence to support this conclusion (Lee, 1913, pp. 22, 35; McQueen, 1931, pl. 3; Bridge, 1930, p. 123; Buehler, 1939).

The Roubidoux-Jefferson City contact, because it is mostly concealed, is difficult to map. A very resistant dolomite ledge (the so-called "Quarry Ledge") crops out 20 to 25 feet above the base of the Jefferson City. The contact has been mapped above the highest Roubidoux sandstone float or ledges, and approximately 25 feet beneath the base of the "Quarry Ledge".

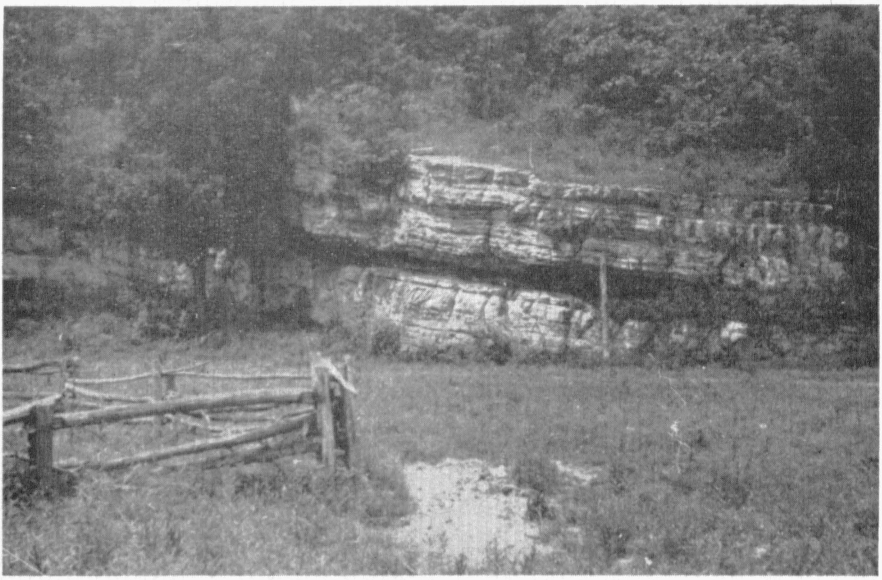
MISSISSIPPIAN SYSTEM

Residual chert of Mississippian age is abundant over the Ozark province. Only one fragment which could be identified

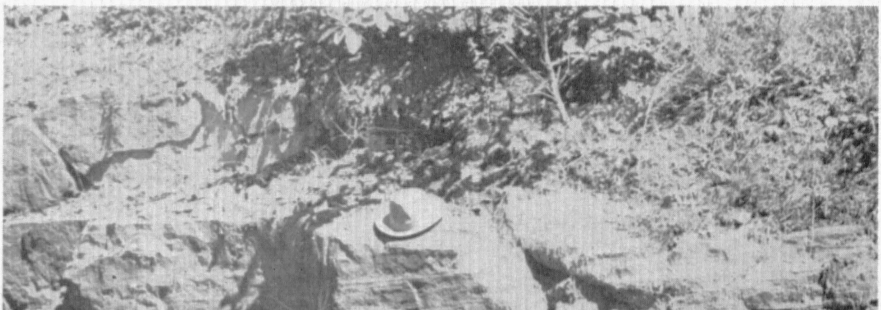


A. "Cotton rock" of the Jefferson City in the road ditch, 250 feet south and 650 feet east of the NE corner, SE¼ SE¼ sec. 8, T. 36 N., R 4 W.

B. Upper Gasconade along Dry Creek in the SE¼ SE¼ sec. 9, T. 36 N., R. 3 W.



A. Roubidoux sandstone in the extreme SE. corner, NE ¼ SE ¼ sec. 8, T. 36 N., R. 4 W.



B. Lower Roubidoux sandstone on small hill north of the center of sec. 33, T. 37 N., R. 5 W.

as possible Mississippian chert was found in the Crooked Creek area, in a small hollow, 150 feet east and 385 feet south of the NE corner, NW¼ SW¼ sec. 21, T. 36 N., R. 4 W. This chert fragment contains two incomplete specimens of *Fenestella*, and a fragment of a brachiopod, *Schizophoria swallowi* ? (Hall). The chert is hard, dense, buff gray, stained reddish brown in places, and closely resembles some of the lower Gasconade chert. This fragment is probably residual, for it is not rounded, as are pebbles from Tertiary gravels.

PENNSYLVANIAN SYSTEM
MIDDLE PENNSYLVANIAN SERIES
KREBS GROUP (?)

General statement.—The Pennsylvanian System is represented in the Steelville quadrangle by slumped beds of coal, masses of fire clay, and sandstone boulders preserved below the present erosional surface, in remnants of sinks. There are four deposits of coal and many pockets of fire clay in the Crooked Creek area. There are also carbonaceous films on the imprints of plant tissue in sandstone boulders.

Evidence from Pennsylvanian deposits in sink structures elsewhere in Missouri indicate that most, if not all of the coal, sandstone, and clay deposits are older than the Seville limestone and therefore belong in the Krebs group of early Desmoinesian age. These deposits are therefore referred tentatively to that group (Searight, personal communication, May 1954).

Sandstone.—Small patches and individual boulders of sandstone are scattered over the area. Some of these boulders are doubtless residual from the Roubidoux. Those which are regarded as Pennsylvanian differ from Roubidoux sandstone boulders in grain size, color, and texture. The quartz sand grains of the Pennsylvanian boulders are coarse (½-1 mm. in diameter), well-rounded, frosted and pitted grains, in a matrix of very fine to fine (— ¼mm. in diameter) sandstone. Only a few of these grains are secondarily enlarged, whereas most of the grains of Roubidoux sandstone boulders are secondarily enlarged. Sand grains of the Pennsylvanian sandstone boulders are uniformly stained dark-brown, red, or purple, whereas the grains of the Roubidoux are variably stained. Consequently, Pennsylvanian sandstone boulders are more uniformly colored than the mottled or streaked Roubidoux boulders. The texture of the Roubidoux is more uniform, and the grains are more compactly arranged than in the more porous Pennsylvanian sandstone.

Both the Roubidoux and Pennsylvanian boulders are more or less cemented by silica, some to quartzite; but it appears that recementation is more complete in the younger sandstone, perhaps because of its greater porosity. The Pennsylvanian sandstones generally weather into larger and more massive, more rounded boulders than do the Roubidoux sandstones. Many of the boulders exceed six feet in diameter and exhibit no trace of bedding.

The most convincing proof of the Pennsylvanian age of these boulders is the presence in the sandstone of imprints of plant tissues covered with carbonaceous film. The fragments of these impressions are less than an inch in length. Examination of these imprints with a hand lens reveals a woody, cellular structure with a surface pattern much like that of *Calamites.*

These sandstone boulders occur at a great many localities in the Crooked Creek area. The more prominent are on a small bench on the hillside, 500 feet north and 400 feet east of the center, sec. 17, T. 36 N., R. 4 W.; on the nose of a hill, just southeast of the center, sec. 17, T. 36 N., R. 4 W.; along the north bank of an intermittent stream, 200 feet north and 160 feet east of the SW corner, NW¼ NW¼ sec. 20, T. 36 N., R. 4 W.; at several points along the hillside in the E½ SW¼ SE ¼ sec. 18, T. 36 N., R. 4 W.; and in the vicinity of the old coal prospect on the west side of the hill, near the west center, NE¼ SW¼ sec. 21, T. 36 N., R. 4 W.

Coal.—Four small pockets of coal occur along the southern side of the Crooked Creek structure. Here the Roubidoux and Jefferson City are far below their normal level for this part of the Ozarks. This depression has prevented the destruction, by erosion, of the Pennsylvanian sinks in this area. The outcrops of these coal beds have been masked by mining operations of the last century and subsequent heavy growth of vegetation. Hence, the character of the deposits could not be determined.

Fire clay.—The middle Pennsylvanian of Missouri contains much fire clay. It occurs in isolated sink-hole type deposits.

The physical and chemical properties of the clay are remarkably consistent over a wide area. Several deposits of fire clay occur along the southern and western sides of the Crooked Creek structure. Most of the clay is of the white flint and plastic varieties; but some of it is stained a peculiar reddish or purple color that seems to be characteristic of many of the Pennsylvanian deposits of the northeastern Ozarks. This clay is associated with all of the coal deposits and, in some localities, with the sandstone boulders.

Stratigraphic relations.—The Pennsylvanian deposits of this area lie unconformably upon the Cambro-Ordovician rocks. The distribution of these Pennsylvanian outliers over all the formations exposed in the Crooked Creek structure suggests the development of an extensive erosional surface prior to Pennsylvanian times. In the bank of an intermittent stream, 535 feet east and 560 feet north of the SW corner, NW¼ SW¼ sec. 16, T. 36 N., R. 4 W.; gently northeast-dipping beds of the Eminence have been irregularly beveled. Lying nearly horizontal upon these beveled beds is a ledge of sandstone very similar to that described as Pennsylvanian. The character and relationship of the upper surface of the sandstone is concealed by the alluvium of the creek bank.

CENOZOIC

General statement.—The exact age of the residuum and alluvium which mantle large portions of the Ozark province is not known. However, some of the residuum and alluvium is Pleistocene in age (Dake, 1930, pp. 173-176; Bridge, 1930, p. 133).

Residuum.—Residual products of weathering have accumulated upon the formations exposed in the quadrangle. The thicker and more distinctive accumulations are on the outcrops of the Potosi and younger formations, which are essentially cherty dolomitic limestones. Solution has been more active than mechanical erosion in the removal of the soluble portions of these formations, causing relatively insoluble chert to accumulate on the surface.

Alluvium.—The broad flood plains and terraces in the quadrangle are covered with silt and sand, whereas the narrow valleys and ravines are floored with chert gravel and scattered boulders, which came from the adjacent hillsides.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Steelville quadrangle lies 30 miles northwest of the St. Francois Mountains. The regional dip is about 15 feet per mile to the northwest. Within the Steelville quadrangle this gentle dip is disrupted by the complex Crooked Creek structure, the Palmer fault, and small domal structures.

THE CROOKED CREEK STRUCTURE

GENERAL STATEMENT

The dominant geological feature of the Steelville quadrangle is the Crooked Creek structure south of Keysville, Missouri, in the northwestern part of T. 36 N., R. 4 W. (Pls. VII and VIII). This structure consists of an essentially circular highly deformed, uplifted central area, inside a peripheral series of high-angle, normal faults that form the inner margin of an encircling synclinal graben. In this structure, which is three to four miles in diameter, the oldest beds exposed are about 1000 feet above their normal position.

THE UPLIFTED CENTRAL AREA

Structural elements.—The uplifted central area is approximately one and one-half miles in diameter. It is a domal structure with the apical area slightly depressed to form a shallow basin and surrounding ring anticline, the axial trace of which is about midway between the peripheral faults and the center of the structure. The beds on the outer flank of the ring anticline dip steeply outward and end against the upthrown side of the peripheral faults. The beds on the inner flank of the ring anticline dip gently inward and form a shallow structural basin. Faults, drag folds, and small irregular undulations cause many local variations in the direction and amount of dip. These are particularly numerous in the shales of the Davis formation. The uplifted central area is broken by an essentially radial pattern of normal faults and by a north-south, narrow horst block.

The ring anticline.—The Davis formation is exposed on the upper part of both flanks and along the crest of the ring anticline in a nearly circular belt from 700 to 1600 feet wide. Four small, elliptical areas of Bonneterre dolomite are exposed within the Davis outcrop belt. These Bonneterre exposures occur where intermittent streams have eroded the basal Davis from the crest of the ring anticline. Two of the exposures are on the northern portion of the anticline and the other two are on the eastern portion. Along a part of the southern side of the uplifted central area, only the Davis is exposed on the outer flank of the ring anticline between its axis and the southern peripheral fault. Around the remainder of the central area the Davis, Derby-Doerun, Potosi, and locally the Eminence and lower Gasconade, dip steeply outward and form successive, concentric, arcuate outcrop belts on the outer flank of the ring anticline between its axis and the peripheral faults.

On the inner flank of the ring anticline, beds of the Davis and Derby-Doerun formations dip gently inward from the axis and beneath the Potosi formation which occupies the center of the basin formed by the converging flanks of the ring anticline. One small exposure of the basal Eminence occurs above the

Potosi. The Derby-Doerun and Potosi formations in the basin are extensively fractured and brecciated, and in places they are so thoroughly pulverized that no trace of bedding remains. At the junction of two intermittent streams in the SW¼ NE¼ SW¼ and in the NW¼ SE¼ SW¼ sec. 17, T. 36 N., R. 4 W., shatter cones occur throughout the intensely fractured Potosi. These are similar to the shatter or pressure cones of the Steinheim basin described by Branca and Fraas (1905, pp. 36-38, figs. 7 and 8). Shatter cones are formed by incipient fractures arranged in the form of cones with an apical angle of about 45°. The fractures are inbricate and form a nest of cones which resembles a stack of conical drinking cups. In the field, only the top or outer cone is visible. (Pl. VI-A and B). The sides of the cones, that is, the fractures, bear grooves which radiate from the apexes. A study of the bases of the cones and the grooves upon their sides indicates that the outer or overlapping cone has been displaced toward the base, away from the apex. The shatter cones of the Crooked Creek structure range from about one inch in height and basal diameter to nearly three inches in height and diameter. The apexes are oriented upward and the axes of the cones generally plunge in a south to southeasterly direction and form angles of approximately 70° with the recognizable bedding.

The horst block.—A narrow, "dog-leg" shaped horst crosses the central uplift from north to south. The northern part of this horst is about 400 feet wide, and the southern part is about 200 feet wide. The northern end of the horst terminates in a complex and intricately folded area of the Davis on the outer flank of the ring anticline. The largest area of Bonneterre in the Crooked Creek area is exposed where the horst crosses the northern side of the ring anticline. Here the horst has a displacement of about 40 feet. Where the horst crosses the center of the uplift, the displacement is about 400 feet and the shale beds of the Davis are vertical and have a strike parallel to the bounding faults. About 300 feet northwest of the SE corner of the SW¼ NW¼ sec. 17, T. 36 N., R. 4 W., the shale beds of the Davis exposed in the horst are so intricately crenulated that the strike and dip vary as much as 90° within a few square yards. South of the center of the uplift, the horst trends northeast-southwest where it crosses the southwestern inner flank of the ring anticline. In the southern part of the horst the displacement decreases to less than 100 feet, the strike of the included Davis and Derby-Doerun formations is normal to the bounding faults, and the dip decreases to approximately 45°.

Normal faults.—Some of the numerous fractures which break the Derby-Doerun and Potosi exposed in the center of the uplift are probably small faults. However, the shattered condition of the bedrock, the absence of bedding, and the lack of recognizable lithologic zones prevent the identification of any of these fractures as faults. Six faults large enough to displace recognizable lithologic zones break the central uplift.

The most evident fault is a southeasterly continuation of the one which forms the east side of the horst. This fault crosses the southern part of the central uplift, and on both the inner and outer flanks of the ring anticline it displaces beds of the Davis and of the Derby-Doerun. It has a throw of approximately 40 feet and is downthrown to the east. Where it crosses the axis of the ring anticline, the axial trace is offset approximately 350 feet. This fault also breaks and offsets the peripheral fault on the south side of the central uplift. It extends beyond the central uplift, southeastward into the encircling synclinal graben where locally the Gasconade is upthrown against the Roubidoux.

A second fault, northeast of the one previously described, is a branch of the fault which forms the east side of the horst. This fault has a maximum throw of about 100 feet and is downthrown to the northeast. It throws lower Potosi against upper Davis, and offsets the axial trace of the ring anticline about 650 feet. The southern end is deflected to the southwest and ends against the peripheral fault on the south side of the central uplift.

Another fault crosses the northeastern part of the ring anticline. It has about 40 feet of throw and displaces Davis against Derby-Doerun and Derby-Doerun against Potosi. The axial trace of the ring anticline is offset approximately 200 feet by this fault.

The remaining three faults are strike faults. Two of these are on the southeastern outer flank of the ring anticline and are separated by the alluvium of Crooked Creek. Because the projections of their traces are very close together, and because they both have a maximum throw of approximately 150 feet, they may be two exposures of the same fault. A strike fault eliminates a small amount of upper Davis and lower Derby-Doerun throughout most of its length, on the northeastern inner flank of the ring anticline. The eastern end of this fault has a very small displacement in the Davis formation.

THE ENCIRCLING SYNCLINAL GRABEN

The uplifted central area is surrounded by a graben from one to two miles wide. It lies between the peripheral series of high-angle normal faults that bound the uplifted central area, and the high-angle normal faults that separate the Crooked Creek structure from the essentially horizontal bedrock of the surrounding area. The Roubidoux dips gently inward from the sides of the graben and forms a shallow syncline. However, along the margins of the graben, the Roubidoux has been intensely fractured and dragged up, and in places it dips as much as 70° to 80° away from the faults. The fractures have been filled with quartz and granular chert veins, and the intervening sandstone has been firmly recemented. This recemented sandstone is very resistant and crops out persistently. In places along the margins of the graben, the underlying Gasconade has been dragged up high enough to be exposed. The largest such exposure is along the west side of Crooked Creek, in the NE¼ NW¼ NE¼ sec. 17, T. 36 N., R. 4 W.

Locally, the gentle dips of the synclinal flanks are interrupted by low, broad undulations or subsidiary folds. These are well-exposed in the bluff along the west side of Crooked Creek, in the NE¼ SE¼ sec. 8, T. 36 N., R. 4 W.; in the SE¼ SW¼ SW¼ sec. 9, T. 36 N., R. 4 W.; and in the bluff along the south side of Crooked Creek, near the center of the SW¼ NW¼ sec. 21, T. 36 N., R. 4 W.

A normal fault along the southeastern part of the synclinal axis is downthrown to the north and brings the Jefferson City down against the Roubidoux. On the upthrown side the Roubidoux dips gently toward the fault, and on the downthrown side, the Jefferson City dips steeply toward the fault. Both ends of the fault die out gradually along the synclinal axis. The Jefferson City outcrop north of the fault continues to the west and northwest along the trough of the syncline. A very small outcrop of the Jefferson City is exposed on the synclinal axis in the E½ SW¼ sec. 8, T. 36 N., R. 4 W.

Beyond the outer flanks of the encircling graben, the country rock is essentially horizontal. The Roubidoux within the graben is downthrown against the upper Gasconade on the hilltops and the lower Gasconade and upper Eminence in the valleys.

TYPE OF STRUCTURE

Structure similar to that of the Crooked Creek area may be produced by: (1) the intrusion of a salt plug; (2) intrusions of magma such as ring-dikes, cone sheets, plugs, and stocks; (3) a subterranean explosion; and (4) the impact and explosion of a meteorite. There is no conclusive evidence that the Crooked Creek structure was formed in any one of these ways. For such structures of uncertain origin the term cryptovolcanic was proposed by Branca and Fraas (1905, pp. 1-64) in their description of the Steinheim Basin in southern Germany. Sixteen years later, Bucher (1921, pp. 74-75) used the term to describe the Serpent Mound structure in Adams County, Ohio and in 1925 (pp. 193-237), he published his studies of Jeptha Knob, Kentucky, which was also described as cryptovolcanic. Other structures within the United States which have been described as cryptovolcanoes are the Upheaval Dome (Prommel, 1927, pp. 809-820), San Juan County, Utah; the Wells Creek Basin (Bucher, 1932, pp. 147-148), Stewart County, Tennessee; the Kentland Dome (Schrock and Malott, 1933, pp. 337-370), Newton County, Indiana; the Flynn Creek disturbance (Wilson and Born, 1936, pp. 815-835), Jackson County, Tennessee; the Howell structure (Born and Wilson, 1939, pp. 371-388), Lincoln County, Tennessee; and the Decaturville dome (Bucher, 1936, p. 1071), Camden and Laclede counties, Missouri.

The most extensive study of cryptovolcanic structures has been made by Bucher, who has defined the structural type

> ". . . as characterized by a nearly circular outline a central uplift with intense structural derangement; and a marginal, ring-shaped depression with irregular and local faulting. Evidence of explosive action is seen in the intensely disordered structure and local brecciation of the central, uplifted portion; the presence (in the Kentland and Wells Creek structures) of peculiar fracture patterns, the 'shatter cones'; and the presence and character of folding in the marginal zone. Correspondingly, these cryptovolcanic structures are thought to be the result of a sudden liberation of pent up volcanic gases, which had accumulated near the surface, the explosion having been too weak to produce a shallow explosion crater . . ." (1936, p. 1055).

However, there is no evidence of igneous materials or thermal action in or adjacent to these structures (Bucher, 1936, p. 1071).

COMPARISON WITH CRYPTOVOLCANIC STRUCTURES

The central uplift.—The central uplift of the Crooked Creek structure is nearly circular, approximately one and one-half miles in diameter, and bounded by high-angle, normal faults. This portion of the structure is comparable in size to the central uplift of the Steinheim Basin. It is somewhat larger than those of Jeptha Knob and Serpent Mound, which are about one mile in diameter, and smaller than Upheaval Dome and Wells Creek Basin, which have central uplifts nearly two miles in diameter. Only in Jeptha Knob do we find the central uplift so completely bounded by normal faults as is the Crooked Creek structure. The central uplifts of the Steinheim Basin, Upheaval Dome and the Wells Creek Basin merge outward into encircling synclines. The Serpent Mound structure is different from the others in that the central portion consists of irregular, angular fault blocks which give that part of the structure a very angular outline.

The uplifted central area of the Crooked Creek structure is not a simple dome, as it is in other cryptovolcanic structures. It is a collapsed dome. The center of the uplift is slightly depressed and forms a shallow structural basin, about one mile in diameter, formed by beds dipping inward on the flank of a ring anticline, the crest of which delimits the basin. On the outer flank, beds dip radially outward and end against the peripheral faults which bound the uplifted central area.

The Potosi exposed on the inner flank of the ring anticline is about 350 to 400 feet above its normal level. The Bonneterre and upper Davis which crop out on the crest of the ring anticline are nearly 1000 feet above their normal levels. The Eminence and Gasconade exposed on the outer flank of the ring anticline are at, or slightly above, their normal levels. In contrast, the beds of the central dome of Jeptha Knob and the Serpent Mound structures are 200 to 400 feet above their normal levels; those in the Steinheim Basin, approximately 500 feet above their normal levels; and the beds in the center of the Wells Creek Basin and Upheaval Dome are 1000 to 1200 feet above their normal levels.

The exposures of the Potosi and Derby-Doerun formations in the uplifted central area of the Crooked Creek structure are extensively fractured, brecciated, and pulverized, as are the rock exposures in the central uplift of the Steinheim Basin, the Wells Creek Basin, and the Kentland Dome. Discussing the center of the Wells Creek structure, Bucher says,

> "The structure here is extraordinarily confused. The whole formation (Wells limestone) seems to be broken up into blocks, large and small, which are tilted and twisted into all sorts of positions. . . . At two points breccias are exposed made up of irregular fragments of dolomite and limestone ranging from blocks over two feet in diameter down to the granular matrix that fills the spaces between the large blocks . . . The whole character of the breccia suggests violent action." (1936, p. 1068).

In the Kentland structure, the rocks in the central uplift are intensely pulverized and brecciated. The St. Peter sandstone has undergone such intense deformation that most of the quartz grains have been cracked into fragments or crushed into powder. John L. Rich is quoted by Bucher (1936, p. 1071) as likening " . . . this internal brecciation to the effect of the sudden release of highly compressed steam on grains of rice, utilized in the manufacture of 'puffed rice'."

The shatter cones in the uplifted central area of the Crooked Creek structure are similar to those in the Kentland Dome which were described by Dietz (1947, pp. 42-43). The Crooked Creek shatter cones are similar to those described from the Steinheim Basin by Branca and Fraas (1905, pp. 36-38, figs. 7 & 8), who interpreted them as pressure phenomena. Kranz (1924, fig. 12, p. 100) called the peculiar texture produced by the points of many shatter cones and the intervening depressions, "strahlenkalk". He attributes shatter cones to stress resulting from sudden release of gases under high pressure, and is of the opinion that they may have an origin similar to that of stylolites, in which solution is a factor.

Bucher has observed shatter cones in the central uplift of the Wells Creek Basin, Tennessee where

> "The axes of the cones run obliquely across the bedding planes and traverse several layers with a continuity entirely impossible in true cone-in-cone structure. That they are due to mechanical shattering and are not of the nature of cone-in-cone is evident, especially when they are studied in the field." (1936, p. 1070).

W. A. Tarr (in Twenhofel, et al., 1932, pp. 721-722) writing on cone-in-cone structure in the Second Edition of the Treatise on Sedimentation, mentions the well-known percussion marks or cones which often develop in quartzite pebbles or boulders, which strike against each other or other solid objects as they are carried along stream beds. The essential difference between cone-in cone and shatter cones is that in the latter, " . . the apices and not the bases are at the surface (of the beds)."

Dietz (1947, pp. 42-43) believes that the converging, imbricated, grooved fractures are normal faults. The inner, or overlapping surface is the hanging wall and the outer, or overlapped surface is the foot wall. These features reveal that each cone is displaced relatively downward, away from the apex with respect to the inner cone. By applying Hartman's law, which states in part that under nonrotational forces the acute angle formed by shear planes in brittle material is bisected by the axis of maximum stress, it is apparent that the axis of such a series of cones is also the axis of maximum stress. An examination of many shatter cones at Kentland revealed that the axes of the cones are invariably oriented normal to the bedding and the apexes point toward the top of the bed. The common orientation of the apexes indicates that the deforming stress was unidirectional. A consideration of the mechanics of this type of deformation shows that the outer cones were active and the inner cones passive, and that the shock was applied from the direction in which the apexes point. Assuming that the beds were essentially horizontal prior to deformation, the orientation of the shatter cones suggests that the force was applied from above the beds rather than from below. W. A. Tarr (in Twenhofel, et al., 1932, pp. 721-722) also emphasizes the fact that the apex of a shatter cone points toward the direction from which the stress was applied. If Tarr and Dietz are correct in their interpretation of shatter cones, then in both the Kentland and the Crooked Creek structures the deforming stresses would necessarily have been applied from above.

Local irregularity of direction and amount of dip, similar to that in the Davis shale, was noted by Bucher (1936, p. 1059) in the central uplift of Jeptha Knob. Bucher states that " . . . irregular and inconstant dips . . . prevail in these shaly beds (Eden), suggesting 'wrinkling' of the shales rather than actual folding." The local "wrinkling" of shale or thin limestone beds, which results in erratic dips and rapidly changing strike, has also been noted by Bucher in the Serpent Mound structure (1936, p. 1062) and in the Upheaval Dome, Utah (1936, p. 1064).

The narrow, "dog-leg" shaped horst of nearly vertical or steeply dipping beds of the Davis formation does not have a counterpart in any of the other structures which have been described as cryptovolcanoes, unless it be the more simple expression of the jumbled blocks which occur in the central uplifts of the Serpent Mound structure, the Wells Creek Basin, and the Kentland Dome.

The ring depression.—Each of the aforementioned cryptovolcanic structures has a well-defined ring syncline or depression surrounding the central uplift. However, only Jeptha Knob has the central uplift set off from the encircling depression by normal faults. The Wells Creek Basin, Serpent Mound structure, and the Steinheim Basin exhibit faulting around the outer periphery of the ring depression. Consequently, the Crocked Creek structure is unique in that both the inner and outer margins of the ring syncline are normal faults which create an encircling graben. The maximum depression in the Crooked Creek encircling graben is in the northeastern and southern portions where the Jefferson City is exposed. In contrast, the eastern and western segments of the encircling graben exhibit a minimum of subsidence. This feature of the ring depression is duplicated in the depression which surrounds Jeptha Knob, where the two points of greatest depression " . . . lie opposite each other on the north and south sides of the structure. On the east and west sides, however, the depth of the ring depression reaches a minimum" (1936, p. 1059). The ring depression surrounding Serpent Mound is most depressed in the eastern and western portions and least depressed in the northern and southern parts (p. 1063).

Surrounding area—Beyond the encircling graben of the Crooked Creek structure, the bedrock is essentially undisturbed. The Roubidoux and Gasconade formations immediately underlie the surface of the surrounding area, except south of the Palmer fault where the lower Gasconade, the Eminence, and in a few places the Potosi, are exposed at the surface. The structure is surrounded by a series of concentric, discontinuous, low, broad swells, and shallow depressions. These are common in the Roubidoux in this part of the Ozark province, and are probably caused by irregular subsidence of the sandstone, where portions of the underlying Gasconade have been removed by solution.

ORIGIN OF CROOKED CREEK STRUCTURE

General statement.—The origin of the Crooked Creek structure, and of the cryptovolcanic structures which it resembles, may possibly be attributed to one of the following causes: (1) salt-dome intrusion; (2) igneous intrusion; (3) subterranean explosion; (4) meteoritic impact and explosion. It is believed that horizontal stresses would be incapable of producing the Crooked Creek structure.

Salt-dome intrusion.—Washburne (1937, pp. 629-630) believes that the chief difference between salt-dome structures and cryptovolcanic structures is the greater number of faults associated with the latter. He states that both types of structure require local concentration of vertical stresses but that " . . . neither requires the violent explosive action inferred by Bucher." This belief is not shared by Dietz (1947, p. 42) who states, "The application of a sudden shock in the formation of the Kentland disturbance is indicated in part by the jumbling of the strata, the shattering of the limestone, and the pulverization of the sand grains of the St. Peter sandstone." Boon and Albritton (1936, p. 7), who have made rather exhaustive studies of American cryptovolcanoes, are convinced that a violent explosion is necessary for the formation of such a structure. Shand (1916, p. 219) in his discussion of the Vredefort Dome, a possible cryptovolcanic structure located in the northern part of the Orange Free State, Africa, believes that a shock caused by a "gigantic impulse or series of impulses" caused the vast amount of shattered materials found in the central portion of this structure. Born and Wilson (1939, p. 387) are of the opinion that cryptovolcanic structures with their associated breccias and powdered limestones, " . . . require extremely violent explosive action." In their discussion of the Kentland Dome, Shrock and Mallott (1933, p. 369) state that " . . . the deformation was rapid and violent." Thus, the prevailing opinion of those who have studied cryptovolcanic structures favors explosive stresses. Certainly the slow, upward intrusion of salt does not cause rapid and violent deformation. Furthermore, salt beds do not occur in the subsurface of this part of Missouri, a factor which excludes the possibility of a salt-dome origin for the Crooked Creek area.

Igneous intrusion.—Circular structures of a few miles in diameter, with peripheral and cross-cutting faults, and encircling folds, are associated with ring-dikes (Clough, Maufe, and Bailey, 1909, pp. 611-678; Modell, 1936, pp. 1885-1932), cone sheets (Richey, 1932, pp. 42-140), and some stocks (Knopf, 1936, pp. 1734-1735), and other igneous bodies (Foye, 1916, pp. 783-791). Igneous rocks or other evidence of thermal activity are generally associated with these structures. In the Crooked Creek area there is no visible proof of igneous activity. The small amount of lead and barite associated with the Crooked Creek structure is not indicative, for farther east in Missouri where they occur abundantly, the origin of these minerals is uncertain. There is no magnetic anomaly within the area of the structure (Grohskopf and Reinoehl, 1933, pp. 1-20), and no igneous materials are exposed or have been encountered in test drilling. The orientation of the shatter cones indicates that the deforming force was applied from above. Nevertheless, there are structures of igneous origin, such as Crook Mountain and Elkhorn Peak in the Black Hills, in which there are no visible igneous materials, and the presence of igneous bodies is not always indicated by magnetic anomalies. It is possible that deeper drilling in the Crooked Creek area may reveal the presence, at depth, of some igneous materials, though such is not indicated by the available evidence.

Subterranean explosion.—Branca and Fraas (1905, pp. 1-64), Kranz and Gottschick (1925, pp. 37-65), Schrock and Malott (1933, p. 368), Bucher (1936, p. 1074), and Wilson and Born (1936, p. 835) all favor the subterranean explosion of gas and/or steam associated with volcanism as the most probable explanation of the origin of such a structure as that of the Crooked Creek area. According to Bucher (1936, pp. 1075-76),

> ". . . cryptovolcanic structures . . . form part of a natural series of disturbances which mark the beginning or the attempted beginning of volcanism in a region, and which may be classified as follows:
>
> 1. Disturbances produced by the explosive release of gases under high tension, without the extrusion of any original

magmatic material, at points where there had previously been no volcanic activity ('abortive volcanism'): Cryptovolcanic structures.

(a) The explosion, too deep-seated, too weak, or too unconcentrated ('muffled'), results in the more or less circular dome and ring structure . . . (Upheaval Dome, Jephtha Knob)

(b) The explosion, shallow and strong enough, blows out a shallow more or less circular explosion basin filled with a jumble of disordered blocks and surrounded by a zone of materials blown or pushed out from it . . . (Steinheim Basin, Serpent Mound)

2. Features produced largely by the explosive release of gases under high tension, with magmatic materials more or less subordinate to fragments of the overlying rocks, at points where there had previously been no volcanic activity ('embryonic volcanism'): 'Funnels,' 'chimneys,' 'pipes' filled with volcanic breccias or tuffs."

If the Crooked Creek structure be the result of subterranean explosion, then it must be the result of an explosion somewhat stronger than that described by Bucher in 1.(a) above, but not as strong as those explosions described in 1.(b). Such an explosion, followed by general subsidence, would explain the following features of the Crooked Creek area: (1) the central uplift and the faults at its periphery; (2) the collapse of the center of the uplift; (3) the uplift and collapse of the central area, possibly accounting for the rotation of the slice of Davis which forms the horst that cuts across the central basin; (4) the brecciation and shattering of the Potosi and Derby-Doerun in the central uplift; (5) the nearly circular shape of the structure; (6) the ring depression; and (7) the rude radial faulting of the central uplift. The cryptovolcanic origin does not explain: (1) the orientation of the shatter cones; (2) the maximum and minimum depressions of the ring syncline; and (3) the irregular faulting of the southern border of the central uplift.

Meteoritic impact and explosion.—The fall of meteorites and the craters thereby formed have been observed and recorded (Wylie, 1933, pp. 211-214). Burns (1933, pp. 477-479), and later Kulik (1937, pp. 559-562), have described the fall of a large meteorite in central Siberia at 7:00 A.M. on June 30, 1908. The impact and resulting explosion of this meteorite was heard at a distance of more than 600 miles, raised a column of fire seen at a distance of 250 miles, threw great quantities of rock flour into the air, and felled trees radially outward for a distance of 40 miles from the point of impact. The disintegration of the meteorite formed a number of craters which range up to 150 feet in diameter and average 30 feet deep.

The association of craters and meteoritic material is not likely to be fortuitous, and on this basis the Odessa Crater in Texas (Bibbins, 1926, p. 932; Barringer, 1929, pp. 307-311), the Henbury Craters in Australia (Alderman, 1932, pp. 19-32), the Haviland Crater, in Kansas (Nininger and Figgins, 1933, pp. 9-15), and others (Spencer, 1933, pp. 307-325) have been identified as meteorite craters. Meteor Crater, a crater nearly three-fourths of a mile in diameter and 600 feet deep, is near Flagstaff, Arizona, on an extensive plateau underlain by horizontal sedimentary formations. These beds are domed beneath the crater and dip away from it at angles of 25° to 90° on the west side, 25° to 50° on the east side, 5° to 20° on the north side, and 10° or less on the south side. A crater rim is formed by the upturned edges of these beds which are about 150 to 300 feet above their normal level. Large masses of fragmented limestone and sandstone ejecta, weighing as much as 5,000 tons, mantle an area 12 miles in diameter. Near the crater this material is 120 to 160 feet deep. With the ejecta have been found thousands of pieces of meteoritic iron, some weighing as much as 1000 pounds. Over 20 tons of this iron has been collected, but very little of it has been found in the bottom or walls of the crater (Barringer, 1906, pp. 861-866; Lobeck, 1939, p. 712). In the bottom of the pit is 600 to 900 feet of crushed and pulverized rock flour. According to Tilghman, the silica powder of this mass

> ". . . . cannot be imitated by grinding the sand grains in a mortar, as the edges and points of the powder thus produced are more blunted and rounder and broken than those of the silica. But it is very closely duplicated by the finest powder produced by firing a high power rifle bullet against a block of sandstone." (Tilghman, 1906, pp. 890-891).

Many holes have been drilled in the base of the crater (Barringer, 1927, p. 45). These revealed, at approximately 1000 feet below the floor of the crater, undisturbed bedrock lying under the broken and pulverized material of the crater floor.

Meteor Crater was first described by Gilbert (1896, pp. 1-13), who dismissed the meteoritic impact origin on the basis that dip needle surveys did not indicate the presence of a large body of iron in the near vicinity. He was of the opinion that the concentration of smaller meteorites about the rim was probably fortuitous, and he was particularly impressed by the scarcity of meteoritic material in the base of the crater. Gilbert explained the origin of the crater as a steam or gas explosion in the Coconino sandstone. Darton (1915, pp. 112-113) was of the same opinion, and he stated, " . . . the hole is due to an explosion of steam from volcanic sources below, accumulating in the pores of the sandstone and finally reaching the limit of tension."

Gilbert's theory of a steam explosion in the Coconino is discounted by Fairchild who stated:

> "The white sandstone (Coconino), nearly 1000 feet thick and underlying all the country, is very porous and would contain a large volume of water. The pressure of any heated water or vapor sufficient to throw the mass of rock out of the pit must have existed through an immense horizontal extent of strata, and a long time would have been required for entire relief of the pressure through the vent, and with decided hot spring or fumarolic or sulfataric phenomena. With all the careful study, there has not been found the least evidence of any volcanic or igneous activity of any kind." (1907, pp. 493-504).

Tilghman (1906, pp. 887-889) presents evidence to prove that the meteorite was not a solid body, but a closely packed cluster of smaller meteorites. Some of these were strung out as a tail, covering a large crescentric area to the north of the crater with meteoritic material. Of the remainder, some buried themselves deeply as discrete particles; others exploded and were widely scattered over the surrounding area; and still others were vaporized by the impact. Tilghman (1906, p. 889) conducted a series of experiments which demonstrated that a mass of pulverized iron would " . . . form a series of closed magnetic circuits with practically no external field whatever." In these experiments, two cubes of magnetite, one-half of an inch on a side, were used. The two cubes exerted nearly equal pulls on a magnetic needle. The one with the stronger pull was crushed to particles the size of coarse sand and packed into a paper cube slightly larger than the original sample. The pulverized mass had to be brought within one-eighth of an inch of the needle to exert the same pull that the original cube had produced at eight inches. It is thought that these experiments explain the negative character of Gilbert's dip needle surveys.

The association of meteoritic fragments with the ejecta, the undisturbed beds at 1000 feet beneath the crater, and the investigations of Fairchild (1907, pp. 493-504), Barringer (1906, pp. 861-866), and Tilghman (1906, pp. 887-889) indicate a meteoritic origin for the Arizona crater. According to Lobeck (1939, p. 712), "It is conceded by virtually all who have investigated Meteor Crater that it was formed by the explosion of a great meteorite."

If meteorite craters are being produced at the present and have been produced in the relatively recent past, where is the evidence for meteoritic impacts during geologic time? Oliver (1925, p. 251) has questioned this apparent absence of meteorite craters or scars in the geologic record. If relatively shallow topographic craters were the only results of such impacts, our search would necessarily be limited to the present landscape. However, meteorite craters, such as the one in Arizona, show deformed rock. It is not unreasonable to suppose that, long after the superficial topographic crater is destroyed by erosion, lower parts of the underlying structure will be exposed.

Boon and Albritton (1936, pp. 1-9) have considered the possibility that cryptovolcanic structures may be the roots or scars of meteorite craters. Later Born and Wilson (1939, p. 387), while favoring the subterranean gas explosion origin, admit that these structures may be the result of meteoritic impact. Dietz (1947, pp. 42-43), in his studies of the Kentland Dome, states very definitely that structures of the Kentland type (cryptovolcanic of Bucher) are due to meteoritic impact.

Deformation is produced by the impact and explosion of a rapidly moving object, such as a bullet or meteorite, when it strikes another body, such as the earth. Wylie (1934, p. 470) has shown that a rifle bullet traveling at a speed of 0.66 miles per second explodes and is shattered to bits when it strikes its target. If a bullet is shattered by impact at velocities of less than a mile per second, certainly meteorites traveling at a much higher velocity must also explode. Tilghman (1906, p. 902), Moulton (1931, p. 305), Spencer (1933, pp. 322, 325), Wylie (1934, p. 470), and Boon and Albritton (1936, p. 1) are all of the opinion that a meteorite 100 feet in diameter should produce Meteor Crater. A meteorite of this size would lose very little velocity as it plunges through the atmosphere. Fath (1928, p. 201) stated that the direct measurement of meteor velocities has given figures as high as 50 miles per second. Hence a meteorite 100 feet in diameter, traveling at a rate of 40 miles per second, would strike the earth with its velocity practically undiminished. According to Wylie (1933, p. 213), such a meteorite would possess potential energy of approximately 306 times that of an equal weight of nitroglycerin. The weight in tons of such a meteorite is equal to approximately the cube of the radius in feet (Wylie, 1933, p. 213). Thus a meteorite 100 feet in diameter would weight 125,000 tons and have the energy of 38,250,000 (125,000 x 306) tons of nitroglycerin. Were such a meteorite to strike the surface of the earth it would instantaneously form an impression in the earth's crust, and compress the crust beneath it, thereby explosively expending its tremendous energy. This explosion would exert, on the rocks beneath the point of impact, a pressure approximating 30,000,000 atmospheres (Moulton, 1931, p. 305), further compressing the rocks below. Such great compression of the rocks beneath the point of impact would cause shearing stresses to be developed within them. Bridgeman (1935, pp. 825-847) has shown that many substances, when subjected to pressures of 40,000 to 50,000 atmospheres, explode upon application of shearing stresses. Therefore, the explosion of the meteorite would be instantly followed by the explosion of the compressed rocks below the point of impact. These explosions would shatter and disperse the meteorite, form an explosion crater, and pulverize, brecciate and deform the rock beyond the crater. The rocks of the earth's crust are elastic, and would rebound following these explosions, generating a series of concentric elastic waves traveling out in all directions. These waves would be strongly damped by the overburden and by friction along faults, joints, and bedding planes. The damped waves would be preserved as ring anticlines and synclines. If the amount of vertical rebound were to exceed the elastic limits of the bedrock involved, nearly vertical normal faults would break the flanks of the major folds. The locus of impact would tend to rebound to a point higher than its position prior to compression, largely due to the removal of load from the explosion crater, and to the dissipation of the original deforming force. If this central rebound be completely damped by tension fractures, such as peripheral, high-angle normal faults, it would become fixed as a central dome, with or without slight subsidence of the apical area.

Therefore, the general type of structure to be expected beneath large meteorite craters would be a central dome, with or without an apical depression, surrounded by a ring anticline and possibly another ring of folds, which might be broken along their flanks by normal faults, the whole resembling a group of damped waves. Such a structure would not be radially symmetrical unless the meteorite struck the surface of the earth at nearly right angles. Meteor Crater shows this lack of symmetry (Barringer, 1915, pp. 556-565, and pl. 21). Test drilling and the work of D. M. Barringer, Jr. (1927, p. 145) show that the meteorite approached from the north at a rather low angle, and the partial remains now lie buried to a depth of approximately 1300 feet beneath the south rim of the crater.

It is believed that the structural pattern of the Crooked Creek area and other cryptovolcanic structures is similar to that which may be expected beneath a large meteorite crater. Features of the central uplift which are in accord with a meteoritic origin are: (1) the circular shape; (2) the size comparable to the dome under Meteor Crater; (3) the jumbled, brecciated, and shattered character of the rock; and (4) the upward orientation of the shatter cones. The character of the encircling synclinal graben, with its two areas of maximum depression, could be the result of the meteorite striking the earth at an angle of less than 90°, as was probably the case at Meteor Crater. A meteoritic impact origin does not have to explain the lack of magmatic materials or the lack of evidence for hydrothermal action. The absence of meteoritic material is to be expected, as the explosion of the meteorite would scatter it over the adjacent area, where it would be removed by erosion.

Summary of possible modes of origin.—The Crooked Creek structure is not the result of the intrusion of a salt plug, as no source of salt exists in the subsurface of this part of southeastern Missouri. The structure may be the result of some form of igneous intrusion, but available evidence does not indicate such an origin. Either a subterranean explosion or the impact of a meteorite and the resulting explosion seem to be plausible explanations. Either would explain the following features: (1) the central uplift, either with or without an apical depression; (2) the encircling folds resembling damped waves; (3) the faulting of the central uplift and its periphery; and (4) the evidence of violent explosion (breccias and pulverized rock). The meteoritic impact origin would explain better: (1) the orientation of the shatter cones; and (2) the bilateral symmetry caused by maximum and minimum depression of the encircling syncline. It does not have to explain the absence of volcanic, magmatic, or hydrothermal materials, either at the surface or in depth, as does the subterranean explosion hypothesis. Finally, the meteoritic impact hypothesis partially answers the astronomers who have long questioned the apparent absence of evidence of meteorite falls in the geologic past.

Date of origin.—Certainly the Crooked Creek structure came into existence following the deposition of the Jefferson City (Lower Ordovician), for Jefferson City beds are involved in the disturbance. Unfortunately, the sedimentary record between the Jefferson City and the Pennsylvanian, is missing from this area. The residual sandstone boulders of Pennsylvanian age lie with equal distribution over the entire structure. There is also an outcrop of Pennsylvanian sandstone in place, lying horizontally, and with angular unconformity, upon dipping Eminence dolomite. These occurrences indicate the origin of the structure after the deposition of the Jefferson City and prior to Desmoinesian time. Closer dating of the structure is not possible at present.

THE PALMER FAULT

The Palmer fault zone extends eastward from the Crooked Creek area a distance of approximately 36 miles to a point nine miles south of Potosi, where it branches. The northern branch, the Big River fault, extends northeast to the vicinity of French Village, in St. Francois County, where possibly it becomes a part of the great Ste. Genevieve fault system. The southern branch extends southeast into St. Francois County (Buehler, 1939).

The north side of the fault is the downthrown side. At its western termination, on the east side of the Crooked Creek area, basal Roubidoux on the north side of the fault is against basal Gasconade or uppermost Eminence on the south side. Therefore, the throw of the fault at its western termination is approximately 200 feet. Near the eastern side of the quadrangle, where the Palmer fault crosses Dry Creek in sec. 16, T. 36 N.,

R. 3 W., Roubidoux on the north is against uppermost Potosi on the south, a throw of approximately 400 feet. Fourteen miles farther east, on the west side of the Potosi quadrangle, the throw is about 400 feet; 28 miles east, on the east side of the Potosi quadrangle, the throw is approximately 800 feet (Dake, 1930, p. 182).

The fault is best followed by the mapping of float and rare outcrops of the relatively displaced beds of the upper Potosi and Eminence against those of the upper Gasconade and Roubidoux. Exposures of steeply dipping and brecciated beds are rare. The best exposure is on the northwest side of Dry Creek in the north center of the SW¼ sec. 16, T. 36 N., R. 3 W. Here the fractured Roubidoux dips steeply to the north, resting against the upthrown Potosi and Eminence to the south.

Nowhere in the Steelville quadrangle is there any evidence for pre-Gasconade faulting as described by Dake (1930, p. 122). The writer doubts that the forces which formed the Crooked Creek structure were localized by the weakened rocks of the earth's crust at the western end of the Palmer fault. If the fault zone were a factor in the control of the forces which created the structure, then it would seem likely that those forces would have acted at one of the weaker points, such as the intersection of the Berryman-Leasburg and Palmer faults. Early in the course of the field work, the possibility of the localization of the Crooked Creek structure at the intersection of the Cuba and Palmer faults was considered. However, detailed work in the northern half of the Steelville quadrangle and the southern part of the Cuba quadrangle to the north failed to reveal a southern extension of the Cuba fault into the Crooked Creek area.

Field evidence also fails to indicate that the Palmer fault was formed at the same time as the Crooked Creek structure. Along the south and west bounding faults of the Crooked Creek structure, more active solution in Desmoinesian or pre-Desmoinesian time resulted in the development of sinks, in which the Pennsylvanian sediments were preserved. If the Palmer fault were a part of the geological structure in Desmoinesian time, sinks should have formed along the Palmer fault just as they did along the Crooked Creek bounding faults. However, along the western end of the Palmer fault there are no such sinks. Also, if the two structures were contemporaneous, the possibility of the Crooked Creek structure being the cause of the Palmer fault is more likely than is the possibility that the Palmer fault is the cause of the Crooked Creek structure. In either case, the greatest displacement along the Palmer fault should be in the near vicinity of the structure. Such is not the case, for near the structure the displacement of the Palmer fault is 200 feet or less; 10 to 20 miles east, it is approximately 400 feet; and 20 to 30 miles east, it is approximately 800 feet.

The Palmer fault was probably formed after the deformation of the Crooked Creek area. The locus of the forces which caused the Palmer fault system must have been to the east of the Crooked Creek area, as indicated by the increased throw toward the east. As the western extension of the fault developed, the rupture undoubtedly extended toward a pre-existing point of weakness, such as the Crooked Creek structure, where the residual movement was distributed along pre-existing fractures.

DOMAL STRUCTURES

Low, broad domal structures are common in the Cambro-Ordovician beds of the Steelville quadrangle. There are two notable examples. One is centered about two miles northwest of Keysville and the other near Camel's Hump (pl. VII). Similar domal structures have been explained by Bridge and Dake (1929, pp. 93-99), Dake (1930, pp. 185-191), and Bridge (1930, pp. 151-164) as reflections of the irregular pre-Cambrian topography in the overlying sedimentary beds. However, these two structures are probably diastrophic because initial dips will not persist as high as the Eminence from a normal pre-Cambrian surface. There is no evidence that the pre-Cambrian is close enough to the surface to account for these structures (Clark, personal communication, February, 1953).

ECONOMIC GEOLOGY

GENERAL STATEMENT

The Steelville quadrangle has deposits of fire clay, coal, iron ore, barite, lead, and copper. During the latter half of the past century and the first decades of the present century, iron ore, fire clay, coal, and lead were produced on a small scale. Barite was mined in 1937-1938.

FIRE CLAY

The largest of the fire clay deposits is the L. C. Taff "bank" on the ridge crest in the W ½ SW ¼ SW ¼ sec. 18, T. 36 N., R. 4 W. where gray to white fire clay crops out over an area of approximately one-half square mile. The whole ridge top is pock-marked by irregular pits, trenches, and shallow shafts dug during the first decade of the present century in search of fire clay. The deposit is in a sink, the periphery of which is defined by inward-dipping beds of Roubidoux sandstone.

A smaller fire clay deposit is exposed in a water-filled pit located near the NW corner, SW ¼ NW ¼ sec. 29, T. 36 N., R. 4 W. This deposit of white, purple and red-mottled flint fire clay has been worked sporadically during the past forty years, and apparently is nearly worked out. Roubidoux sandstone covers the ridge and sides of the hill about the pit. Another small pit is near the NE corner, SW ¼ NE ¼ sec. 30, T. 36 N., R. 4 W. The material is sandy, gray, flint clay associated with fragments of chert and boulders of Roubidoux sandstone.

Test pits have been dug near the old coal mine just south of the center of the NW ¼ SE ¼ sec. 21, T. 36 N., R. 4 W. Here sandstone boulders are irregularly dispersed through gray, flint fire clay. This clay is probably part of the same sink fill which contains the coal.

Other exposures of fire clay are in a ravine near the NE corner, sec. 29, T. 36 N., R. 4 W.; along the ridge top in the NW ¼ sec. 24, T. 36 N., R. 5 W.; on the ridge just south of the center, sec. 29, T. 36 N., R. 4 W.; and near the N center, NW ¼ NW ¼ sec. 18, T. 36 N., R. 4 W.

COAL

Coal is found as sink-hole fillings at four localities in the southern part of the encircling graben of the Crooked Creek structure. These were worked between 1880 and 1900. The shafts have caved in and the dumps are thickly overgrown with trees, some more than a foot in diameter. The small extent of these deposits, their jumbled arrangement, their crushed and brecciated condition, and the mixture of the coal with sandstone and clay prevent extensive development (Nason, 1892, p. 139). However, a good grade of blacksmith coal was obtained for local consumption from the small deposit just south of the center of the NW¼ SE¼ sec. 21, T. 36 N., R. 4 W. The other abandoned prospects are as follows: near the south center of the SW¼ SW¼ sec. 19, T. 36 N., R. 4 W.; near the NE corner of the NE¼ NW¼ sec. 29, T. 36 N., R. 4 W.; and in the NE¼ SW¼ NE¼ sec. 30, T. 36 N., R. 4 W.

IRON ORE

The deposits of limonite, hematite, and pyrite in the Steelville quadrangle are sink-hole deposits (Crane, 1911, pp. 98-99), most of which have been worked out.

The now idle Cherry Valley Mines are near the head of a large valley, five and one-half miles east-southeast of Steelville, Missouri. The ores consisted of soft, red hematite, smaller amounts of soft brown ore (limonite), scattered boulders of hard, blue, specular hematite, and some pyrite. These were mixed with clay and sandstone which filled two large sinks. Most of the ore was removed by open-pit methods; however, a small amount was mined from short, shallow drifts (Crane, 1911, pp. 205-209).

The Cherry Valley no. 1 mine is in the S½ NE¼ SW¼ sec. 4, T. 37 N., R. 3 W. It is an oval pit 460 feet long, 200 to 270 feet wide, and 40 to 80 feet deep. On the north, west, and east sides the sink is rimmed by the Roubidoux sandstone, which dips toward the pit at angles of 5° to 45°. The rim on the south side has been breached by headward erosion of a large ravine. According to analyses made by the Sligo Blast Furnace Company, the ore averaged 57.98% iron, 9.37% silica, and 1.60% alumina (Crane, 1911, p. 209).

The Cherry Valley no. 2 mine is in the W½ SW¼ SE¼ sec. 4, T. 37 N., R. 3 W. It was the largest and most productive of all sink structures in the central Ozark region. The oval pit is 900 feet long, 500 feet wide, and 60 to 150 feet deep. On the north, northwest, and southwest sides the sink is rimmed by the Roubidoux sandstone, which dips toward the pit. The rim on the east side has been breached by erosion. Test drilling has shown that the sink fill extends downward through the Gasconade and Eminence into the Potosi. In addition to the soft red and hard blue iron ore, about 26,000 tons of pyrites with an average sulphur content of 48% have been taken from the pit (Grawe, 1945, pp. 240-253). This ore consisted of loose, granular, brassy marcasite coated with pyrite druse. In places it was so loose that it flowed into the drift like sand.

According to Grawe (1945, pp. 252-253) who gives year by year production figures for the mines, nearly one million tons of iron ore valued at nearly $2,300,000 has been mined. Oxide and sulphide ores still remain in the southwestern and northeastern parts of the no. 1 pit and in the eastern and southeastern parts of the no. 2 pit (Grawe, 1945, p. 248).

The Marsh Mine, one mile southwest of Steelville in a ravine in the NE¼ NE¼ sec. 5, T. 37 N., R. 4 W., produced 41,000 tons of soft red hematite before it was abandoned in 1910. The ore, mixed with sandstone and red clay, filled a small sink which is rimmed on three sides by inward-dipping beds of Roubidoux sandstone (Crane, 1911, pp. 217-218).

Soft red and hard blue, specular hematite was mined from a sink south of Daniels School near the SE corner, SW¼ NW¼ sec. 29, T. 36 N., R. 4 W. The pit is about 100 feet long, 40 feet wide, and 10 feet deep. The property is now abandoned and very little ore can be seen, because the faces of the cut are concealed by slump. Several carloads of ore were shipped from this mine (Crane, 1911, p. 205).

Several hundred tons of red hematite ore was produced from the pit on the east bank of Crooked Creek north of Missouri Highway 19 in the SW¼ SE¼ sec. 22, T. 36 N., R. 4 W., and sent to the Sligo furnace prior to 1910. This pit is about 100 feet long, 50 feet wide, and 15 feet deep. Its proximity to Crooked Creek resulted in serious water seepage into the pit, which has been flooded since 1910. Several attempts have been made to pump the water out of the pit. During 1936 and 1937 it was pumped dry and a shallow shaft, sunk at the north end, revealed some soft red and hard blue, specular hematite. A prospect hole drilled 100 feet north of the pit encountered no ore. This sink fill is in the Eminence dolomite.

The so-called "Vaughn Bank" is an iron ore prospect on a low hill in the NE¼ sec. 13, T. 36 N., R. 5 W., about two miles southeast of Wesco. Two shallow trenches reveal very sandy, low-grade, red and blue hematite. Outcrops are concealed by chert mantle.

The James mine, abandoned since 1900, is about half a mile south of Wesco in the center of sec. 12, T. 36 N., R. 5 W. According to Crane (1911, p. 216), 2100 tons of iron ore was shipped from this mine prior to 1892. The pit walls expose basal Gasconade and the bottom must be in the Eminence. The contact is concealed beneath slumped material.

A relatively large producer of iron ore was the old Craig mine near the SW corner, SE¼ NW¼ sec. 24, T. 36 N., R. 5 W. Prior to 1892, more than 10,000 tons of red and specular hematite, and some soft, red ochre was produced (Nason, 1892, p. 218). The deposit is a sink fill. Beds of Roubidoux sandstone dip steeply toward the mine. The base of the sink is undoubtedly in the Eminence, with the body of the sink in the lower Gasconade.

The Thompson mine, just SE of the center of sec. 26, T. 36 N., R. 4 W., has produced several hundred tons of red and blue hematite. The ore is mixed with chert and sandstone, and required considerable hand picking. This sink fill is in the lower Gasconade.

Surface boulders and fragments of soft red hematite and specular hematite are found on the ridge crest about two miles east of Sligo near the NW corner, sec. 10, T. 35 N., R. 4 W.; on the knob of a hill in the NW¼ SE¼ sec. 17, T. 36 N., R. 3 W., on the Roubidoux outcrop just north of the Palmer fault; and at various points along the ridge crest in the W½ sec. 2, T. 35 N., R. 4 W.

An irregular concentration of limonite fragments occurs on the ridge in the W½ SW¼ NW¼ sec. 34, T. 36 N., R. 4 W. About 100 tons of this ore, the larger boulders of which contain cores of unaltered pyrite, was shipped to the Sligo furnace in the 1900's.

Near the SE corner of the NE¼ NW¼ sec. 10, T. 36 N., R. 4 W., pyrite, mostly altered to limonite, occurs in a sink in the Gasconade. This sink has a well-defined rim of Roubidoux sandstone which dips steeply toward the center.

BARITE

Barite ($BaSO_4$), variously known as barytes, heavy spar, or tiff, has been produced from the now idle Jonas mine located near the east center, SE¼ SE¼ NE¼ sec. 18, T. 36 N., R. 4 W. The barite occurs as irregular boulders and fragments in residual red clay, and as veins and lenses in the bedrock. It is clean, light gray and pink in color, and relatively pure. According to Mr. Reuben Jonas of Steelville, Missouri, who operated the mine under lease from R. O. Scott, also of Steelville, analyses of the barite by the Baroid Sales Division of the National Lead Company ran as high as 95% barium sulphate. During the years 1936-1940, Mr. Jonas produced more than 5,000 tons of barite by hand methods. The washed ore was trucked to Wesco and thence shipped by rail to the Fountain Farm Plant of the Baroid Sales Division of the National Lead Company near Potosi, Missouri.

Barite mining has resulted in the removal of the eastern end of a hill, creating a northwest-trending rock face, in which are exposed closely folded beds of the middle sandy Davis. Numerous thin stringers, veins, and irregular lenses of barite are exposed between the beds and along joint planes. This barite is probably a replacement deposit of the Davis. Weathering produced a secondary residual deposit, associated with red clay, which has been largely removed by mining.

LEAD

The Metcalf diggings, on the north slope of a hill in the east center, SW¼ NW¼ sec. 17, T. 36 N., R. 4 W., is the only locality within the area from which lead has been produced. These were surface diggings consisting of numerous "gouges" or pits which range up to 10 feet in depth and diameter. According to Winslow (1894, p. 685), these diggings were opened in 1863 and a total of 65 tons of lead was produced. The lead occurred in the red residual clay of the upper Bonneterre, which crops out in the Crooked Creek area where the narrow horst cuts across the axis of the ring anticline. A thorough search of the Bonneterre in the vicinity of the diggings failed to reveal any lead in place in the dolomite. Apparently weathering concentrated the lead in the residual clay. Likewise, a search of the bed of the small stream which drains east from the old diggings to Crooked Creek failed to reveal any fragments of lead lodged in potholes or behind obstructions. This absence indicates that very little, if any, residual lead is contained in the red clay soil of the Bonneterre which is being eroded by the stream.

Small cubes of galena were noted in the Derby-Doerun dolomite in the bed of the stream 250 feet north and 170 feet east of the SW corner, NW¼ SE¼ sec. 17, T. 36 N., R. 4 W.

The presence of this lead in a complex structural area encouraged the drilling of a number of tests between 1910 and 1920. Incomplete records of several of these tests, which are on file at the Missouri Geological Survey, indicate traces of lead. The great number of prospect pits and trenches scattered over the area indicate the interest that has been shown.

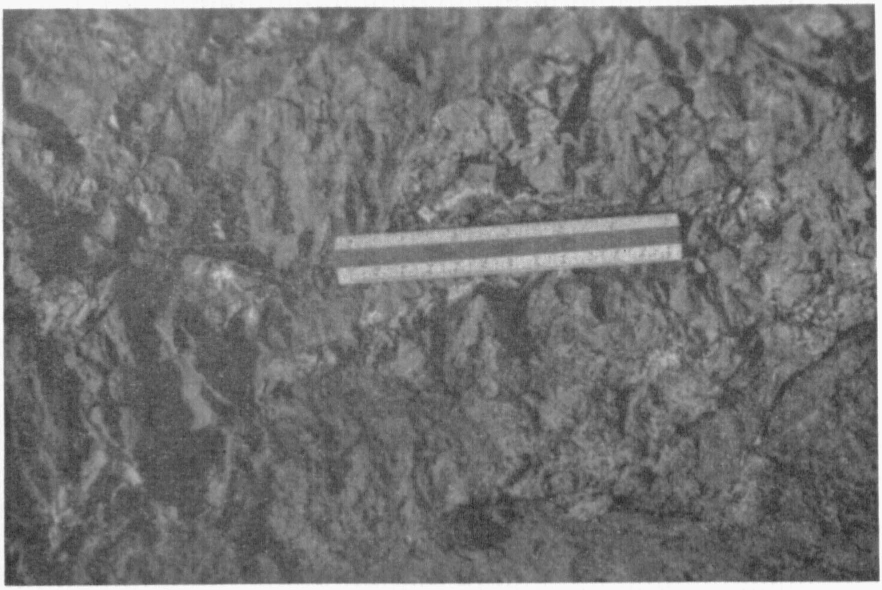
Lead prospects were noted at the following localities: half a mile southeast of Gregory Cemetery, in a small stream valley in the Eminence, in the N½ SW¼ SW¼ sec. 34, T. 36 N., R. 3 W.; near the Eminence-Gasconade contact, on the north side of Missouri Highway 19, near the east center, NE¼ NW¼ sec. 24, T. 36 N. R. 4 W.; and in the Gasconade on the side of a small stream in the S½ NE¼ SW¼ NW¼ sec. 20, T. 37 N., R. 3 W.

COPPER

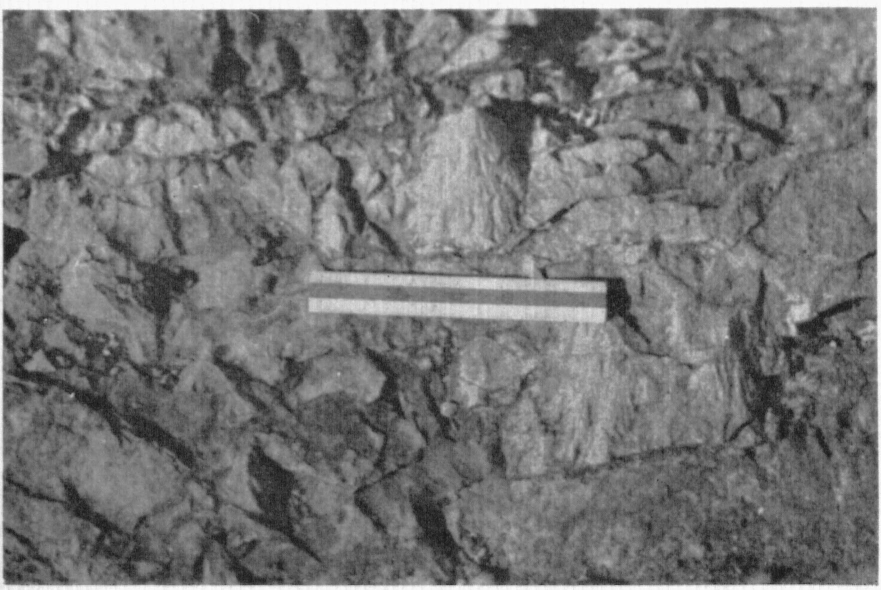
The local inhabitants report that two copper prospects have been worked at various times in the past century. These prospects are in the NW¼ sec. 6, T. 36 N., R. 4 W., and just south of the center of sec. 23, T. 36 N., R. 4 W. The writer visited both of these localities, but he found no trace of copper minerals in or about the abandoned prospects.

OTHER ECONOMIC PRODUCTS

The Roubidoux sandstone is used locally for building stone. Quarries can be conveniently located at almost any place over the extensive outcrop of the formation. Agricultural limestone is obtained from the Gasconade and the Jefferson City. The chert gravel of the many streams is used as road material.



A. Shatter cones in the Potosi in the stream bed 205 feet north and 390 feet east, SW. corner, NE¼ SW¼ sec. 17, T. 36 N., R. 4 W.



B. Shatter cones in the Potosi in the stream bed 250 feet north and 170 feet east, SW. corner, NE¼ SW¼ sec. 17, T. 36 N., R. 4 W.

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