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REPORT OF INVESTIGATIONS NUMBER 49

STRUCTURAL FEATURES OF MISSOURI

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STRUCTURAL FEATURES OF MISSOURI

Mary H. McCracken

ABSTRACT

Study of the structure of the rocks of Missouri began with interest in the metallic ores of the state in the 1700's, grew with the establishment of the State Geological Survey in the mid-1800's, and is summarized with the compilation of this report. Missouri is part of the stable Mid-continent, containing the deeply eroded Ozark uplift which has undergone repeated mild uplift since Precambrian time, exposing rocks ranging in age from Precambrian to late Paleozoic. To the northwest of the domal Ozark uplift lies the Forest City basin, containing late Paleozoic sedimentary rocks, and southeast of the uplift is the Mississippi embayment, a seismically-active region containing sediments of Cretaceous and younger age. The western edge of the Illinois basin borders the Ozark area in the region extending from St. Louis to Cape Girardeau. Most of the nearly 100 named anticlines in Missouri are in the western and northern parts of the state in basinal areas containing Pennsylvanian rocks. Some of the gentle anticlines in western and northern Missouri produce oil and gas.

The more competent pre-Pennsylvanian rocks tend to fail by fracturing and faulting. About 200 named faults, many of which are accompanied by extensive brecciation, have displacements averaging about 100 feet. Faulting follows the Precambrian pattern of northwest-southeast trends with secondary northeast-southwest and east-west faulting. A nearly east-west zone of disturbance crossing the state near the 38th parallel contains several cryptoexplosive structures which occur at the intersections of Precambrian structural lineaments.

Jointing is present in all rocks in the state, but is most pronounced in massively bedded Cambrian and Ordovician dolomites, which also are the most cavernous rocks and contain most of the large springs of the state. Numerous miscellaneous structural features, some productive of oil and gas, occur throughout Missouri. Pseudo-structures formed by collapse of overlying beds into cavernous bedrock, and other solution-caused structural features are common in central and southern parts of the state.

At least six episodes of deformation have occurred in Missouri, beginning with intense faulting and volcanic activity in the Precambrian followed by intermittent but persistent uplift of the Ozark region during the Paleozoic and Mesozoic. Sharp rejuvenation of the Mississippi embayment took place in post-Paleocene-pre-Pliocene time. Pleistocene stream terraces, entrenched meanders, and seismic activity all indicate that uplift is continuing.

A summary of the structural features and structural history of the state precedes a listing of more than 450 named and described structures which are indexed alphabetically and by county. This material accompanies and complements a map (scale 1:500,000) showing known structural features of Missouri. The map includes structural contours on the base of the Roubidoux Formation, plus supplementary detailed maps illustrating a variety of features not depicted on the principal map.

INTRODUCTION

Study of the structure of the rocks of the State of Missouri has followed closely the mapping of the rock units within the state. Early interest in the metallic ores, with the first lead mining in 1719, created interest in the study of the geology of the state. Reconnaissance surveys by Schoolcraft in 1821 and Featherstonhaugh in 1835 were not detailed enough to show much of the geologic structure, although they served to stimulate interest in Missouri geology.

Henry King, M. D., was hired in 1839 to make a geological survey along the Osage River. He wrote a report to the Chief Engineer of Missouri (1840) in which he called attention to the gentle dip (2 or 3 degrees) of strata from the Osage River (in what is now the Lake of the Ozarks area) north toward the Missouri River.

The appointment of G. C. Swallow as State Geologist in 1853 resulted in the publication in 1855 of a report of his first two years of study. In it (p. 136), he describes the structure of the state as follows:

". . . . it will appear that the stratified rocks of the State lie in a position nearly horizontal. There are, however, a few important variations. The strata rise and form a geological ridge, which commences on Salt River, in Ralls County, and extends through Pike, Callaway, Franklin, and Washington to the Iron Mountain. Springfield, is also, on an elevation of the strata, which, probably extends to the Iron Mountain. There is another elevation in the valleys of the Osage and the Niangua. Depressions, also, exist: one in the strata at St. Louis, and another, doubtless, still more important in the South-East. But there are numerous undulations, which produce axes of elevation and depression in various parts of the State.

After passing the mouth of the Osage, in ascending the Missouri River, the strata are found dipping gradually beneath the surface, until, at the Iowa line, a part only of the Upper Coal Series remains above the surface; the Silurian, Devonian and nearly all of the Carboniferous rocks have disappeared below the river. On the Osage, also, the Silurian, Devonian, and Lower Carboniferous rocks successively dip below the surface, and leave the Coal Measures only exposed, in the western part of Henry County."

From 1855 to the present, much information has been collected pertaining to the structural geology of Missouri. Many people have contributed to this knowledge; prominent among them have been Broadhead, Keyes, Meek, Shumard, Winslow, Buckley, Buehler, Shepard, Hinds, Greene, Dake, Bridge, Hughes, St. Clair, Weller, Flint, McQueen, James, Hayes, Rutledge, Clark, and Beveridge.

In 1945 and 1946 Charles L. Bieber spent the summer months working on the structure and stratigraphy of the Mississippian rocks of southwestern Missouri. His work was continued in the summer seasons of 1956 and 1957. During 1956 and 1957 Mrs. DeJean Weldon Stevens worked part-time assisting Bieber in compiling structural data south of the 38th parallel in Missouri. Following the resignation of Mrs. Stevens in March of 1958 and the death of Bieber at a later date, the author was asked by Thomas R. Beveridge to compile a map showing structural features for the entire state with accompanying text. In doing this, the Bieber material has been checked and brought up to date, and mapped, named, and described structural features have been added for the entire state.

The named structural features are briefly described with locations in section, township, and range where possible. The author and the date of work done in the area are given in the text. Structures are alphabetized by name and a county index of structures is also included. The accompanying map, scale 1:500,000, depicts faults, anticlines, synclines, and other structural features which have been described or mapped to date. It is also contoured on the base of the Roubidoux Formation with 250-foot contour intervals. In areas where the Roubidoux Formation is absent due to erosion, contours are dashed and are reconstructed. Areas of Precambrian outcrop are delineated. In the northwest quarter of the state, the base of the Kansas City Group is contoured to show the extent and depth of the Forest City basin. In the Mississippi embayment region, the top of the Paleozoic is contoured to show the slope and shape of that structural feature. This is shown on an inset map as are basic structural features of the Precambrian. Some features worthy of mention but too small or otherwise unsuitable for representation on the map are discussed in the text but are not shown on the map.

A compilation of the structural features of Missouri is, of course, only a progress report and is incomplete in many areas. Some parts of the state (in general those with the largest population or greatest accumulation of mineral wealth) have been adequately mapped while others have had only reconnaissance mapping. Therefore, the number of named structural features is unequally distributed. Further detailed geologic mapping will increase the number of features, particularly the number of faults, in the southern Ozark region.

* * * * *

ACKNOWLEDGMENTS

Credit for information is given with the written descriptions of the structural features. These are keyed to the references which include both published and unpublished sources.

Thanks are due Thomas R. Beveridge, former State Geologist, who initiated the study in 1962; William C. Hayes, State Geologist, who made possible the completion of the project and who made many helpful comments; Wallace B. Howe, Assistant State Geologist; and the staff of the Survey who helped to make this study complete. Jerry D. Vineyard critically read the manuscript and prepared it for publication following Mrs. McCracken's retirement in February 1970. Douglas R. Stark supervised the preparation of the structural features map.

PRINCIPAL STRUCTURAL FEATURES

UPLIFTS AND BASINS

Missouri is part of the stable Midcontinent area of the United States. It is of interest to structural geologists because it contains an old positive area, the Ozark uplift, an area of repeated mild uplift since Precambrian time which is eroded deeply enough to expose formations ranging in age from Precambrian through Pennsylvanian.

The main northwest-southeast structural pattern of the state is the most apparent. It is reflected in the pattern of the outcrops of older rocks along anticlinal axes on the Geologic Map of Missouri (McCracken, M. H., 1961). Prominent among these are: (1) the Farmington anticline which passes northward into the Mineola dome, an anticlinal fold which may become the Browns Station anticline as it is deflected westward; (2) the Lincoln fold of northeast Missouri which plunges northwestward but seems to be reflected in the subsurface as far north as the Iowa state line; (3) the Saline County arch which passes northward into the Livingston County fold; and (4) the Proctor anticline in Camden and Morgan Counties.

A basinal area in the northwestern quarter of the state has trapped and preserved sediments of Paleozoic age. This, the Forest City basin, contains a well-developed and thick sequence of Siluro-Devonian and early Pennsylvanian rocks. It appears to have had its inception as part of a larger basin in post-Canadian time. Missouri also contains, within its extreme southeastern section, a portion of the northern tip of the Mississippi embayment with sediments of Late Cretaceous and Early Tertiary age as well as a thick section of Pleistocene and Holocene alluvium. The embayment and the eastern and southern borders of the Ozark uplift are active seismic zones where earthquakes occur with moderate frequency.

FOLDS

In general, the rocks of Missouri which fail by folding are of Pennsylvanian age. A few of the large structures, however, show gentle folding in the more competent pre-Pennsylvanian sediments which are predominantly limestones or dolomites with minor amounts of sandstone and only a small percentage of shale. The Pennsylvanian rocks, containing a large percentage of clastics and only thin and minor amounts of limestone, tend to produce gentle folds.

The fact that much of Missouri is a stable area, moving generally as a block, has kept folding to a minimum and no Alpine structures or tightly folded rocks occur. Steeply dipping beds are restricted to the immediate vicinity of faults; whereas, over most of the state, the regional dip is only a few degrees in magnitude. The dip of strata is quaquaversal with respect to the St. Francois Mountain area, with steeper dips on the south and east flanks of the Precambrian outcrop area. The general dip is well illustrated by the structure contour map with the base of the Roubidoux Formation as a datum.

Folding, in many cases, may not be so much a result of lateral stress as it is a result of sedimentary rocks draping over a block-faulted Precambrian basement of competent crystalline rocks.

FAULTS

Faulting is prevalent in the pre-Pennsylvanian strata of the state because the brittle carbonate and sandstone beds tend to fail primarily by fracture rather than by folding. Many of the faults are not of great throw, but average about 100 feet of displacement. In some instances, faults are accompanied by brecciation of the limestone or dolomite beds which appears to be out of proportion to the throw of the faults.

Faulting follows the old Precambrian pattern of predominant northwest-southeast trends with secondary northeast-southwest and east-west trending faults. Many of these faults have had repeated movement. From the southern third of Missouri northward, the trend is predominantly northwest-southeast, with some of the larger fault systems crossing the entire state.

Anticlinal structures and faulting in extreme southern Missouri are aligned northeast-southwest. These structural features extend trends present in Oklahoma and Arkansas. The prominence of these northeast-southwest trends is reduced sharply along a line just south of the 37th parallel where the east-west trending Ritchey fault crosses Newton and Lawrence Counties. This fault apparently passes into an anticline to the east and, where it passes across the southern extension of the Chesapeake fault and the northern extension of the Ten O'Clock Run, obliterates these faults. It is interesting to note that the throw of the Chesapeake fault is exactly opposite to that of the Ten O'Clock Run fault. East-west trends continue in Greene and Webster Counties with the Valley Mills fault zone of Beveridge and Clark (1952). There has been little except reconnaissance work done in Missouri east of this area, but detailed work may show that the trend continues to the east. In fact, it may be responsible in part for the northern boundary of the Mississippi embayment.

Another east-west structural disturbance related to faulting passes through Missouri at about the 38th parallel. This is the dominant east-west structural zone within the state. It has also been studied the most. It was recognized as the Bourbon arch in Kansas (Jewett, 1951); Earl McCracken (1952) shows its reflection in his pre-St. Peter map of western Missouri; Denison (1966) shows some Precambrian change along the same line; and the Weaubleau Creek disturbance of Beveridge (1951) in St. Clair County is part of it. It passes through the Decaturville dome area in Camden County, through some east-west faults mapped by Wallace Lee in the Rolla quad rangle, and joins the Palmer fault system at the Crooked Creek disturbance in Crawford County. This continues eastward as a major fault system to join the Ste. Genevieve fault system and thence to the Rough Creek fault zone of southern Illinois and Kentucky (Heyl and Kiilsgaard, 1963; Snyder and Gerdemann, 1963; and McCracken and McCracken, 1965).

This zone shows a change in the alignment of most of the major northwest-southeast anticlinal structures which cross it. These are bent northwesterly north of the east-west axis, particularly in the lower Paleozoic rocks (McCracken and McCracken, 1965), and possibly even more so in the Precambrian (Denison, 1966). This would indicate an east-west shearing action continuing over a long period of time with lateral displacement of beds and may account for the disturbed structures at Weaubleau, Decaturville, and Crooked Creek. These three unusual structural complexes occur at or near the junction of northwest-southeast structural features (Hayes' lineaments, 1962) with the east-west axis (here called the Decaturville-Crooked Creek axis).

One other noteworthy feature is that the steep limbs of anticlinal and synclinal axes are reversed in passing over this axis. The chief anticlinal structures in northern Missouri have their steep limbs to the southwest. South of this axis most of the anticlines have their steep limbs to the northeast. This would appear to be a result of shearing stresses.

Another less apparent east-west axis crosses the state on an approximate line between Kansas City and the Cap au Gres fault near Winfield, Missouri. This causes an increase in the westward and northwest-southeast structures, again bending them to the northwest. This has caused possible offsetting of the Precambrian along the Cap au Gres fault of 30 miles (Cole, 1961). Structure maps show more offsetting of older Paleozoics than of the younger rocks in the area. This may have a bearing on the peculiar relationships of the Silurian, Devonian, and early Mississippian (Kinderhookian) formations in the vicinity of the Lincoln fold. It would appear that some of the Illinois Silurian and Devonian had been displaced westward north of the Cap au Gres fault line.

These structural trends could have been formed by forces from the southwest abutting against the stable Canadian shield area with a secondary stable area in the Ozarks (Beveridge, 1951). Apparently volcanism in late Precambrian and early Cambrian was concentrated in this central east-west zone (Snyder and Gerdemann, 1965). Post-Middle Devonian diatremes are present in Ste. Genevieve County near the fault zone, and an active seismic belt lies along the Ste. Genevieve fault system.

JOINTS

Some jointing is present in all consolidated rocks of the state. Graves (1938), who has studied joints in the Precambrian, notes four directions of jointing: north-south, east-west; northwest-southeast; and southwest-northeast. Dip is usually vertical.

Jointing in the Cambrian and Ordovician rocks is best developed in the massive dolomite of the Eminence, Potosi, and Gasconade formations. Incidentally, these also are the best cave formers and the host of many of the large springs. Ball and Smith (1903, p. 131) measured direction and dip of joints in these rocks in Miller County and spoke of them as essentially vertical, with directions of N. 25° W. and N. 70° E. being the dominant strikes. Barnholtz (1961) related Ball and Smith's joint pattern to cavern development and orientation.

Van Horn (1905, p. 46) measured many joints in his study of Moniteau County. Among others he noted four sets of joints in the Burlington limestone of Mississippian age. These are N. 25° W., N. 60° E., and minor north-south and east-west.

Hinds and Greene (1915, p. 206) noted joints in the Pennsylvanian limestones (fig. 1) and in some of the Pennsylvanian sandstones. Dip is vertical. The most common strike is N. 62° E., with almost as many N. 3° W. joints. Minor sets strike N. 45° E. and N. 45° W.

Bretz (1956, p. 44-56) mentioned jointing as influencing the development of many caves including Cameron and Mark Twain Caves in Marion County and Bluff Dwellers Cave in McDonald County.

Figure 1

Jointing in the Farley Limestone exposed in a streambed near Parkville. Photo from Hinds and Greene (1915, p. 206).

MISCELLANEOUS STRUCTURES

Several types of structural features that occur in Missouri are difficult to classify. One group consists of locally downdropped blocks in areas of Pennsylvanian rocks. These are discussed in more detail elsewhere. In general, rocks near these structures dip steeply with the center containing beds younger than the periphery. They are not associated with regional structures but are thought to be formed by the collapse of large pre-Pennsylvanian caverns developed in calcareous sediments beneath the clastic Pennsylvanian.

Other downdropped blocks of younger sediments occur in association with the Ste. Genevieve fault system in Jefferson, Bollinger, and Cape Girardeau Counties. Disturbed areas identified as the Marble Hill and Scopus structures are examples. The processes by which these are developed are not thoroughly understood. They have been thought to be the result of faulting,

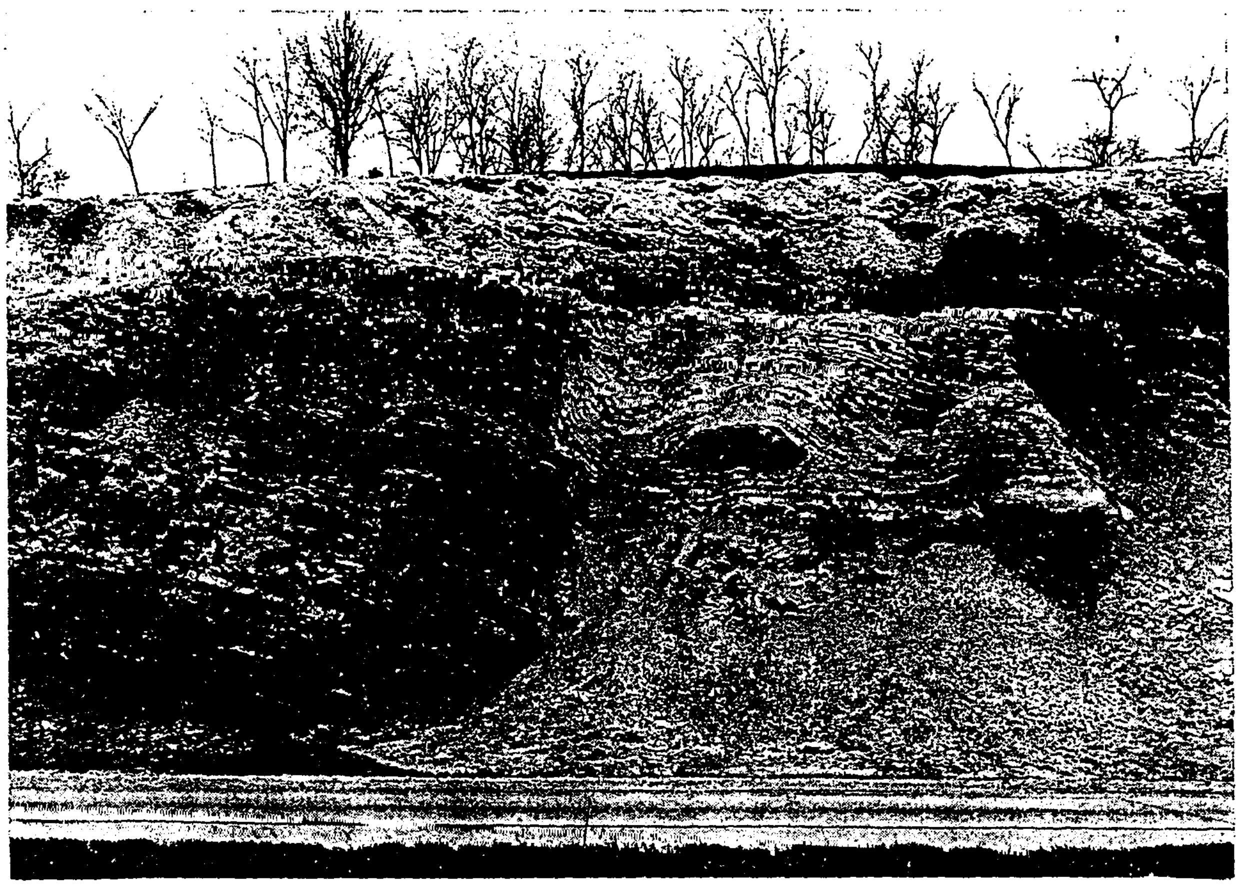


Figure 2
Pennsylvanian shales filling an old sink structure in Jefferson City strata along Interstate 44 in the north edge of Rolla (Vichy Road overpass). Sec. 2, T. 37 N., R. 8 W., Phelps County. Photo by H. M. Groves.

several ages of faulting, or of solution and collapse on a grand scale. They remain of interest to the structural geologist.

Two types of perhaps pseudo-structure are the production of false folding by solution draping of insoluble chert and sandstone beds over soluble dolomites (Grawe, 1945), and the erosional excavation of old filled caverns known as "filled sinks" (fig. 2).

Finally, Missouri has some most interesting problematical structures, the so-called "crypto-explosion structures" at Decaturville and Crooked Creek. Described in more detail elsewhere, these consist of more or less circular disturbed areas in which the rocks are raised in a central area well above their original location. Forces causing this type of structure are thought to have been either from cryptovolcanic or astrobleme events. Smaller subcircular areas containing basic igneous rock and associated with brecciated sediments of several ages are described in southeast Missouri as diatremes.

STRUCTURAL HISTORY

At least six episodes of major deformation have occurred. In general, this deformation has resulted from renewal of the uplift of the positive Ozark area. The chief periods of deformation occurred as follows:

1. Precambrian
2. Post - Canadian — pre - Champlainian (St. Peter-Everton)

3. Post-Lower Devonian — pre-Mississippian (may be pre-Upper Devonian)
4. Post-Mississippian—pre-Pennsylvanian
5. Post-Pennsylvanian
6. Tertiary (post-Paleocene—pre-Pliocene)

The Precambrian structural framework of Missouri has become better known through outcrop and subsurface studies made within the last 30 years. The Precambrian grain is aligned northwest-southeast with a subordinate northeast-southwest pattern, and with jointing and some fracturing, both east-west and north-south (Graves, 1938; Meyer, 1939; and Tolman and Robertson, 1969).

Probably the most intense structural deformation occurred in the Precambrian when there was considerable faulting along the lineaments as shown by Hayes (1962). This was preceded by late Precambrian igneous activity which produced flows of rhyolite, tuffs, and ignimbrites in the Shannon County and St. Francois Mountain areas. The large structures trend northwest-southeast. These may be block-faulted structures in the Precambrian with the Paleozoic sediments draped over them producing anticlinal and synclinal structures which persist to the surface. Further deep drilling in the state will add to the picture, since only a small part of the Precambrian is exposed at the surface.

Isopach and structural maps (McCracken and McCracken, 1965) show that from late Cambrian to middle Ordovician time sediments were essentially conformable, being deposited in a stable structural environment on a gently tilted surface and thickening from northwest to southeast Missouri. At the close of Early Ordovician time, the area was subjected to stresses which caused uplift in the Ozark area as well as along an arch extending to the west and passing into Kansas at the west edge of Vernon County, Missouri. The entire area was subjected to erosion at this time and the beginning of Middle Ordovician (Champlainian) time saw the structural picture materially changed. Uplift was especially important in an east-west zone from northern Vernon County to the St. Francois Mountain area. Uplift in the Ozark area was accompanied by the development of a basin in northwestern Missouri which Lee (1943) named the North Kansas basin. This continued and culminated in Pennsylvanian time as the Forest City basin.

The structurally positive Ozark region restricted sedimentation in Middle and Late Ordovician, Silurian, and Early Devonian time to the east, north and northwest flanks of the uplifted area. The close of Early Devonian time brought widespread uplift, faulting (especially in southeastern Missouri), erosion, and beveling of beds.

Koenig (1967) suggests a tilting of the Ozark area to the northwest in post-Early Devonian time, accounting for the thick section of Lower Devonian south and southeast of the St. Francois Mountain area, but with Middle Devonian absent in this area. The Ste. Genevieve fault system also shows post-Early Devonian movement. Weller and St. Clair (1928) postulate two ages of faulting: one in post-Devonian time to account for the complex faulting in that area, and the other in post-Mississippian time. It is hard to determine the original extent of these Lower Devonian rocks. It should be noted that remnants are preserved in downdropped blocks well beyond the present outcrop area into the Ozark uplands. This would indicate a larger original area of sedimentation which has been stripped away by post-Early Devonian—pre-Mississipian erosion. Strata ranging in age from Middle Devonian to Early Mississippian overlap the eroded beds, bringing Mississippian beds in contact with Canadian rocks in some areas.

Mississippian deposits were probably laid down across the state under stable structural conditions. At the close of Mississippian time another uplift in the Ozark area resulted in widespread erosion and stripping of the Mississippian rocks from the uplift, and beveling of Mississippian rocks over the rest of the state.

Few structures can be definitely dated as post-Mississippian—pre-Pennsylvanian. One of these is the Chesapeake fault which is crossed by an undeformed channel sandstone of Pennsylvanian (Cherokee) age. However, in the northern part of Missouri the Mississippian rocks show a pattern of thinning by erosion over old high areas along anticlinal axes which are probably developed over Precambrian lineaments. It is, therefore, apparent that uplift, faulting, and beveling over either gently folded beds or draped beds over Precambrian structures took place in post-Mississippian time.

The Pennsylvanian sea advanced over the state with oldest Pennsylvanian beds being deposited in the Forest City basin and in southwestern Missouri adjacent to the Cherokee basin in Kansas and Oklahoma. The Ozark area was probably only briefly covered at this time. Post-Pennsylvanian structural movements again accented uplift of the Ozark area and this was followed by erosion over the entire state.

The last sea invasion of Missouri was in latest Cretaceous and earliest Tertiary (Paleocene) time. The area must have been essentially a peneplain before Cretaceous and Tertiary sedimentation and remained stable until after Paleocene time. Sharp rejuvenation of the uplift of the Ozarks with differential depression of the Mississippi embayment took place in post-Paleocene—pre-Pliocene time.

Continued intermittent movement of the Ozark area seems to have gone on until the present. Pleistocene terraces, entrenched meanders, and recent earthquakes all point to continuing uplift of the Ozarks.

INDIVIDUAL STRUCTURAL FEATURES

Locations, references, and descriptions of individual structural features follow:

Ackerman structure

Location: *NE¼ sec. 9, T. 38 N., R. 33 W., Bates County, Missouri.*

Reference: *Greene (1933, p. 23).*

This small structure covers less than 160 acres. It has a northeast dip of 14 feet in a quarter mile in contrast to the regional northwest dip; closure to the southeast is not determined. Gas was produced from several horizons in Cherokee Group (Pennsylvanian) rocks.

Adams Cemetery anticline

Location: *Northern part of T. 47 N., R. 30 W., and southern part of T. 48 N., R. 30 W., Jackson County, Missouri.*

Reference: *Clair (1943, p. 55).*

A small anticline irregularly elongated northeast-southwest, this structure has a closure of 40 feet. It is part of the larger Lees Summit nose which, in turn, is the southern part of the East Grandview anticline.

Adams County terrace

Location: *Lewis and Clark Counties, Missouri.*

Reference: *Krey (1924, p. 49).*

This structure is named for Adams County, Illinois, being the northwestern extension of the Pittsfield-Hadley anticline. The western part crosses the Mississippi River entering Missouri midway between Gregory Landing and Canton and continuing across northeastern Lewis and southwestern Clark Counties.

Alba-Neck City structures

Location: *Secs. 8 and 16, T. 29 N., R. 32 W., Jasper County, Missouri.*

References: *Smith and Siebenthal (1907), Clark (1946), and Bieber (1955).*

This is an area of complex minor flexures, brecciation, chertification, and minor faulting. The structures are on the east flank of the Galesburg-Pittsburg anticline.

Albright Creek fault

Location: *SE¼ SW¼ sec. 12, T. 29 N., R. 14 E., Scott County, Missouri.*

References: *Stewart, McManamy, and McQueen in Kansas Geol. Survey 13th Annual Guidebook (1939), and Grohskopf (1955).*

This fault is exposed at the mouth of Albright Creek about 2½ miles south of Commerce, Scott County. The faulting brings Devonian and Silurian rocks against the Thebes (Ordovician). The strike is N. 22° E. and the throw is estimated at 400 feet, downthrown to the southeast.

Alice Mine structure

Location: *NW¼ NE¼ sec. 12, T. 22 N., R. 11 W., Ozark County, Missouri.*

Reference: *Kidwell (1946).*

This is described as a collapse structure elongated N. 70° to 80° W. Brecciation and mineralization (principally sphalerite) are associated with it. Vertical displacement is small (18 feet maximum). It is possible that this is an essentially east-west strike-slip fault with much brecciation.

Anomalous structures in Pennsylvanian rocks

Location: *a list of occurrences of steeply dipping, downwarped Pennsylvanian rocks, with local faulting, follows:*

1. Allendale structure, *Secs. 21 and 28, T. 66 N., R. 30 W., Worth County, Missouri.*

associated with shattering, shearing, and mineralization of Mississippian rocks. The youngest rocks affected are of Meramecian (Warsaw) age. The complex is a portion of the larger Galesburg-Pittsburg anticline (Bieber, 1955).

Cassville anticline

Location: *Sec. 21, T. 23 N., R. 27 W., Barry County, Missouri (extends north for 1½ miles).*

Reference: *Clark (1941).*

Mapped north of Cassville along Flat Creek, this minor anticlinal structure has a north-south axis with dips of 3° to 11°. It apparently flattens to a terrace to the north.

Cedar Creek fault

Location: *Sec. 26, T. 36 N., R. 2 E., Washington County, to Sec. 21, T. 35 N., R. 4 E., St. Francois County, Missouri.*

References: *Buckley (1909) and James (1951).*

Buckley describes this fault as paralleling the Irondale and Valles Mines faults. It has a general northwest strike with some portions approaching an east-west strike; it is downthrown to the northeast approximately 400 feet. James (1951) includes the Cedar Creek fault in his Palmer fault system.

***Cedar Point anticline**

Location: *Secs. 29, 30 and 31, T. 37 N., R. 22 W., Hickory County, Missouri.*

Reference: *Schroeder (1950).*

This is a small anticlinal structure in the east-central part of the Hermitage Quadrangle. The limbs dip ½° to 1° from the axis which strikes N. 50° W. It appears to plunge both northwest and southeast.

Centerview-Kansas City anticline

Location: *Southeast from Kansas City, Jackson County, through Centerview, Johnson County, Missouri.*

References: *Hinds and Greene (1915) and Clair (1943).*

This is the dominant structural feature of Jackson County. It is flanked on either side by synclinal structures. Clair (1943) has identified a number of smaller named structures along the larger structure. These are the Martin City anticline, Lees Summit nose, Indian Creek dome, and the South Kansas City dome.

Central anticline

Location: *Crosses Cass County, Missouri from northwest to southeast.*

Reference: *Clair (1943).*

**Structure does not appear on the map (pl. 1).*

The Central anticline corresponds to Hinds and Greene's La Due-Freeman anticline but appears to be slightly north of the trend as originally mapped by Hinds and Greene. It is a composite structure containing the following smaller elements as named and mapped by Clair:

1. Prettyman anticline, *the dominant minor feature, extending from Sec. 23, T. 45 N., R. 32 W. to Sec. 12, T. 43 N., R. 32 W., consisting of a long irregular anticline with four small domes and a terraced nose developed along it. These are as follows: (a) Barton Station dome to the north (b) Cressman nose (a terracing on the main anticline), (c) Lanahan dome, (an elongated dome with 30 feet of closure), (d) Anderson dome, and (e) Hess dome (the last two being smaller, rather regular domes).*
2. Pearson anticline, *a continuation of the Central anticline south of the Prettyman anticline, separated by a low saddle from the Harrisonville anticline to the south.*
3. The Harrisonville anticline, *which is elongated north-south, is narrow and contains two flat domes: (a) Van Horn dome, the smaller of the two, in the S½ sec. 5, T. 44 N., R. 31 W., and (b) Wright dome in the SW¼ sec. 8, and Sec. 16, T. 44 N., R. 31 W.*
4. The Merrill depression *bounds the Central anticline to the northeast in Secs. 25, 26, 35, 36, T. 46 N., R. 31 W.*

Centropolis dome

Location: *Secs. 6 and 7, T. 49 N., R. 32 W., Jackson County, Missouri.*

Reference: *Clair (1943).*

This is a comparatively flat-topped structure defined by subsurface control and lying entirely in the valley of the Big Blue River.

Chalk Bluff fault

Location: *NW¼ SE¼ sec. 13, T. 29 N., R. 14 E., Scott County, Missouri.*

References: *McQueen et al. (1939) and Grohskopf (1955).*

Exposed in the bluffs of the Mississippi River, this fault is 1.25 miles north of Commerce in what is known as the "Chalk Bluff." The throw is approximately 400 feet. Faulting has brought lower Devonian rocks (Bailey) against upper Ordovician (Thebes). The strike of the fault is N. 15° E. with the southeast side downthrown.

Cheltenham syncline

Location: *City of St. Louis, Missouri.*

Reference: *Fenneman (1911).*

northeast. Maximum displacement is at the point where the St. Francis River crosses the fault in Sec. 29, T. 35 N., R. 6 E. Here the Potosi Dolomite is faulted against the Lamotte Sandstone indicating a throw of over 600 feet. There is a strong possibility that this fault system extends southeast to join the Jackson fault.

Dogwood fault

Location: *Secs. 16, 21, 22, 26 and 36, T. 28 N., R. 18 W., and Secs. 5 and 6, T. 27 N., R. 17 W., Webster and Douglas Counties, Missouri.*

References: *Geologic Map of Missouri (1939, 1961), Bieber (1955), and Hayes (1960).*

Bieber named this fault which had previously been located by reconnaissance geology for the 1939 Geologic Map of Missouri. Additional field mapping by Hayes (1960) for the 1961 Geologic Map of Missouri delineated the fault trace more precisely and extended the fault 2 miles northwest of its previously known limits.

Doniphan fault

Location: *Sec. 24, T. 23 N., R. 1 E., Ripley County, Missouri.*

References: *Dake (1923) and Williams (1966).*

As mapped by Dake (1923) this fault strikes east-west with the south side downthrown bringing Jefferson City beds opposite the Roubidoux. Williams (pers. comm.) recently extended the fault to Sec. 24, T. 23 N., R. 1 W., southwest of Briar, Missouri.

Dry Creek anticline-Dry Creek fault complex

Location: *Northwest from Sec. 26, T. 29 N., R. 18 W., Webster County, Missouri.*

Reference: *Jeffries (1955).*

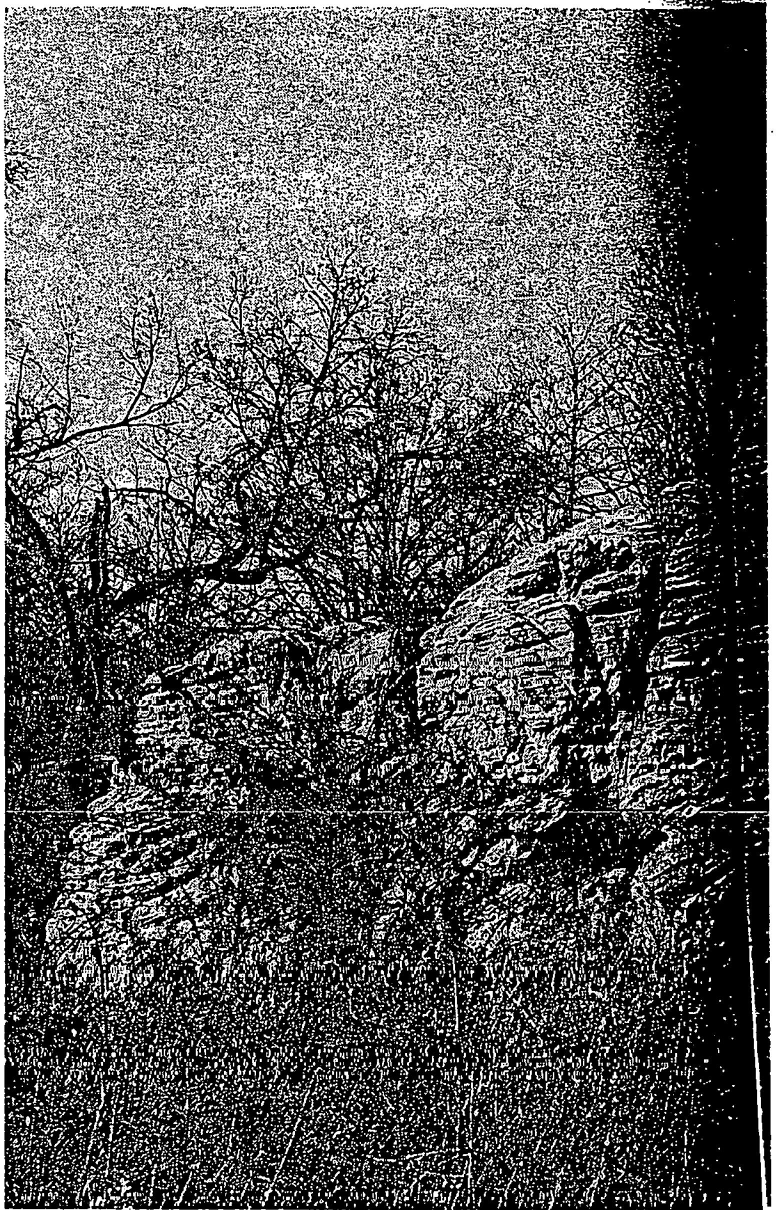
This structure was mapped by data on the top of the Northview Formation. It is dome-like, plunging northwest and cut off by faulting at the northeast edge.

***Duenweg-Webb City-Carl Junction minor flexures**

Location: *Jasper County, Missouri near the towns named above.*

References: *Smith and Siebenthal (1907) and Fowler (1939).*

These are small localized faults and flexures occurring in mines and associated with mineralization. They strike from east-west to northwest-southeast and are associated with shearing, tearing, and fracturing which may, in part, be a



result of slumping from the solution of carbonate material. Mineralization is commonly associated with them. Smith and Siebenthal describe the Duenweg fault as having a displacement of 30 feet down to the north along an east-west axis. It is observable only in the mine workings in Sec. 4, T. 27 N., R. 32 W.

Dupo anticline

Location: *From Sec. 25, T. 2 S., R. 10 W., Monroe County, Illinois slightly west of north through Dupo, Illinois, crossing the Mississippi*

**Structure does not appear on the map (pl. 1).*

fact that the loess is affected by the fault shows late movement in the area. This remains an active seismic area.

***Enon faults**

Location: *NE¼ sec. 31, T. 43 N., R. 14 W., Moniteau County, Missouri.*
Reference: *Van Horn (1905).*

Along the railroad northeast, probably should be southwest, as the railroad is southwest, of Enon four faults have been observed with a throw of 15 or 20 feet. There is no other description and the map accompanying the report does not show the faults. Van Horn's map shows this location as being southwest of Enon. If the faulting is northeast of Enon it would be in Sec. 20 (this could possibly be a collapse structure).

Esther fault

Location: *Sec. 12, T. 36 N., R. 5 E., northwest to the south line of Sec. 33, T. 37 N., R. 5 E., St. Francois County, Missouri.*
Reference: *Weller and St. Clair (1928).*

This is described as a normal fault, downthrown to the northeast with Derby-Doerun faulted against Bonneterre.

Eureka-House Springs anticline

Location: *Crest of the anticline passes from House Springs, Sec. 3, T. 42 N., R. 4 E., northwestward through Sec. 21, T. 43 N., R. 4 E., Jefferson County, through Eureka, Sec. 36, T. 44 N., R. 3 E., St. Louis County, thence northwestward.*
References: *Gleason (1935), Engle (1939), Good (1948), and M. H. McCracken (1966).*

The structure is best developed between Eureka and House Springs and appears to plunge both to the southeast in Jefferson County and to the northwest in St. Louis County. It continues northwest in two segments. Good (1948) mentions that the more prominent branch extends to Sec. 8, T. 44 N., R. 3 E. and continues northwest across the Missouri River near St. Albans.

The Eureka-House Springs anticline is part of the anticlinal structure that extends from near Riverside in Jefferson County on the Mississippi River through the House Springs-Eureka area, thence northwest across the Missouri River to a window of Ordovician rocks north of New Melle on Dardenne Creek. The structure persists in a northwest direction in several outcrops of the Chouteau Group in St. Charles County on Peruque Creek between Wentzville and Wright City. This same trend picks up again at Laddonia, where wells drilled in the town encounter Mississippian strata immediately under a thin veneer of drift or alluvium. While not one of the larger structures of the state, the persistence of this and other northwest-southeast structures has been determined by the predominant grain of structure within the state. Many of these have higher areas as domes which show up like beads on a string. Sometimes these nodes or domes occur at junctions of main northwest-southeast structures with less well developed northeast-southwest structural trends.

Fair Grove fault

Location: *Sec. 22, northwest to Sec. 16, T. 31 N., R. 20 W., Greene County, thence northeast to Sec. 2, T. 31 N., R. 20 W., Polk County, Missouri.*
Reference: *Russell and Knight (1955).*

This fault brings the Roubidoux Formation into contact with the Cotter Dolomite. The upthrown side is to the east; throw is approximately 150 feet. It is in the northeast part of the Strafford Quadrangle near Fair Grove.

Fair Play fault

Location: *From Sec. 21, T. 34 N., R. 24 W., to Sec. 11, T. 32 N., R. 22 W., Polk County, Missouri.*
References: *Newton (1894), Dake (1923), Bieber (1955), and T. K. Searight (1961).*

This fault is well developed about 1½ miles east of Fair Play. It is a high-angle, normal fault downthrown to the northeast. It trends northwest, but curves east-west just south of Bolivar. It is part of the larger Bolivar-Mansfield fault system.

Farmington anticline

Location: *Western Ste. Genevieve County and eastern St. Francois County, Missouri.*
References: *Weller and St. Clair (1928), James (1951), and Kidwell (1947).*

The anticlinal axis trends N. 30° W., with a length of 15 to 20 miles. The northeast limb is steeper with dips up to 4°; dip on the gentle southwest limb is 1°. The crest of the anticline brings Lamotte Sandstone and Precambrian

**Structure does not appear on the map (pl. 1).*

igneous rocks to the surface. Faulting cuts off both the north and south ends of the doubly plunging structure. Weller and St. Clair (1928) considered the anticline to be of Bonneterre age; Kidwell (1947) concluded it to be no older than Devonian because of the presence of Devonian rocks in the intrusive diatremes in the southern part of the structure. Recent age dating of the igneous rock of the diatremes showed a Devonian age (Zartman, Brock, Heyl, and Thomas, 1968).

Federal fault

Location: *Central St. Francois County, passing through the towns of Elvins and Federal.*

References: *Buckley (1909), James (1951), Ohle and Brown (1954), Davis (1960) and Snyder and Gerdemann (1968).*

This is a part of the larger Schultz-Federal fault system (see that heading). It is a series of faults striking northwest with some east-west components; the northeast side is downthrown. The rocks involved are of Cambrian age. The fault is named for the Federal Mine. Davis (1960) felt that the fault played an important role in mineralization of the area.

Fillmore structure

Location: *Secs. 7 and 12, T. 60 N., R. 36 W., Andrew County, Missouri.*

Reference: *Greene, Clair, and McQueen (1937).*

Mapping on the middle limestone member of the Deer Creek Formation indicated an anticlinal nose in the vicinity of Fillmore. Some closure was suggested in Sec. 7, T. 60 N., R. 36 W.; there is no record of drilling on this structure.

Fish Creek anticline

Location: *Northeast Saline County, east of the Saline City fault.*

Reference: *Miller (1967).*

This is a northwest-trending structure. Chouteau rocks are exposed along the crest in T. 51 N., R. 18 W., along Fish Creek and in the Gilliam rock quarry. Closure is 100 feet (see Saline City fault).

The southeastward extension of the Fish Creek anticline (in Howard County) was noted in reports by Meek (in Broadhead, 1873) and by Marvin (1950).

***Flat River structural block**

Location: *Between the Farmington anticline and the Simms Mountain fault system, eastern St. Francois County, Missouri.*

Reference: *James (1951).*

Regional dip in this area is northeast, but in the Flat River block this dip is reversed so that the sediments now dip gently southwest. James believed that the combination of the 600-foot throw on the Simms Mountain fault together with upfolding along the Farmington anticline produced this reversal of normal radial dip off the Ozark uplift. It is also possible to postulate the main Ozark uplift (St. Francois Mountain area) as an anticline, gentle to the southwest and steep, and downfaulted to the east along the Simms Mountain fault. The Flat River structural block then becomes the gentle southwest limb of the Farmington anticline.

Florissant dome

Location: *Sec. 6, T. 47 N., R. 7 E., St. Louis County, Missouri.*

Reference: *E. McCracken (1956).*

Missouri's most productive oil field is located on this somewhat circular closed structure developed on the larger northwest-southeast trend passing through eastern St. Louis County from the Cap au Gres fault southeast to Dupo and Waterloo, Illinois (see Dupo anticline). Closure of 100 feet on the Kimmswick Formation is present. The structure has produced oil since the discovery well was drilled in July 1953; production being over 732,000 barrels through 1969. The structure is being used as an underground gas storage facility by the Laclede Gas Company of St. Louis. Gas is stored in the St. Peter Sandstone of Middle Ordovician age; production of oil is from the Kimmswick Formation of Middle Ordovician age.

Fordland anticline

Location: *From Sec. 35, T. 29 N., R. 18 W., westward to Sec. 34, T. 29 N., R. 19 W., Webster County, Missouri.*

Reference: *Jeffries (1955).*

Fordland is on the crest of this anticline which plunges west; the south flank is gentle and the north flank is broken by the Fordland fault, which is downthrown to the north. The structure is about 6 miles long.

Fordland fault

Location: *From Sec. 35, T. 29 N., R. 18 W., westward to Sec. 35, T. 29 N., R. 19 W., Webster County,*

**Structure does not appear on the map (pl. 1).*

North St. Louis syncline

Location: *City of St. Louis, north from the vicinity of McKinley Bridge.*

References: *Frank (1944) and Brill (1960).*

Pennsylvanian sediments are preserved above Ste. Genevieve limestone in this synclinal structure.

North West Line syncline

Location: *Secs. 12 and 1 through 6, T. 44 N., R. 33 W., Cass County, Missouri.*

Reference: *Clair (1943).*

The North West Line syncline borders the Freeman-West Line anticline on the north. It trends east-west and is a western extension of the Main City-Belton syncline.

Omete Creek fault

Location: *W½ sec. 14, northwest to Sec. 9, T. 35 N., R. 12 E., Perry County, Missouri.*

Reference: *Flint (1925).*

This is a high angle thrust fault produced by thrust from the west which produced contortion and fracture with reverse movement on the fault plane. It extends from the horseshoe bend on Omete Creek to Doodlebug Branch. Rocks involved are Middle Ordovician (Plattin, Joachim, and St. Peter beds). Displacement is small. This fault is west of and parallel to the Red Rock thrust.

Osage anticline

Location: *From southwest corner Sec. 26, T. 18 N., R. 26 W., Carroll County, Arkansas to cross the Missouri line in T. 21 N., R. 25 W., Barry County, then north-northwest to Verona in Lawrence County.*

References: *Purdue and Miser (1916) and Theil (1924).*

The structure was named and described in Arkansas as the Osage anticline (Purdue and Miser, 1916). Theil (1924) described the anticline, in part, as the Verona anticline (see additional discussion under that heading).

Ozark escarpment fault zone

Location: *From Sec. 33, T. 22 N., R. 3 E., Ripley County northeast to T. 30 N., R. 14 E., at the south edge of Cape Girardeau County, Missouri.*

References: *Bucher (1936) and Fisk (1944).*

The junction of the Paleozoic rocks with the alluvial material along the west edge of the Mississippi embayment forms a relatively straight line. It forms an escarpment similar to the bluff line along the Mississippi River farther to the north which has long been thought of as an erosional feature. However, Fisk (1944), noting fracture patterns in the alluvial valley of the Mississippi, believed that the Ozark escarpment was fault controlled. Previously Bucher (1936) had postulated a fault at this point which controlled the boundary between the Ozark uplift and the Mississippi embayment.

Ozark uplift (Ozark dome)

Location: *Southern Missouri.*

References: *Swallow (1855), Keyes (1894), Dake (1930), Graves (1938), and M. McCracken (1967).*

The Ozark uplift or dome, which is the major structural feature of the state, is a broad, slightly asymmetrical, quaquaversal fold. The topographic axis extends from Barry County to Iron County. Taum Sauk Mountain in Iron County with an elevation of 1,772 feet is the highest point in the state, closely followed by Lead Hill in the Cedar Gap Quadrangle, Wright County with an elevation of 1,744 feet. The structural center of this uplift is in Iron County. The topographic high to the west is generally due to preservation of younger formations west of the Precambrian core in the St. Francois Mountain area. The slope is steep to the south and east of the structural center, but is more gentle to the west and north. Swallow (1855) mentioned "an elevation of the strata" both north and west toward Springfield from "the Iron Mountain." Keyes (1894) described the Ozark uplift as follows:

> *"The popular designation, Ozark Mountains, is a name which has clung to the district ever since its earliest exploration. Although much of the area possesses a mountainous physiography, the appellation Ozark uplift has recently been proposed as a more expressive and a more appropriate title, geologically speaking."*

Keyes further described the Ozark uplift as a canoe-shaped elevation, broad and dome-like, dying away to the east in Illinois and to the west in Indian Territory. Dake (1930) indicated that the structural axis of the Ozark uplift was in Iron County in the St. Francois Mountains. Graves (1938, p. 141-142) referred to the structure as the Ozark dome. He pointed to a straight boundary between the uplift and the Illinois basin along the Ordovician-Mississippian boundary in eastern Missouri, and also along the south boundary between the Mississippi embayment and the Paleozoics between Cape Girardeau and Batesville, Arkansas. Westward, the boundary is garten graben by Meents and Swan. It is a long, narrow block of Jefferson City formation surrounded by older rocks.) The entire system may be tensional, developed by the rising Ozark mass against the sinking Illinois basin. Brock (1962) pointed out that the fault system is associated with one of the great fracture patterns of the continent where it is carried to the east through Illinois and Kentucky toward the Appalachians. The faulting may have a lateral component making it, in part, a wrench fault.

St. Francois Mountain block

Location: *Iron, Madison, and St. Francois Counties, Missouri.*
Reference: *Graves (1938).*

An uplifted area, roughly rhomboidal in form, this block is bordered on the northeast by the Irondale fault (Simms Mountain fault system). Faulting at Doe Run and Mine LaMotte also outline this side of the block. To the southeast, granite outcrops in the vicinity of Coldwater and along Bear Creek line up to form the St. Francois Mountain block boundary. The southwest side of the block is parallel to, and southwest of, the Black fault. Beyond the fault, the middle fork of Black River follows essentially a straight line for 10 miles. The northwest side of the fault follows the Big River branch of Dake's Palmer fault system (Big River fault system) and the straight valley of Big River. The block is primarily composed of igneous rocks and forms the chief core of the Ozark uplift.

***St. Francois thrust**

Location: *Precambrian area in Madison, Iron, Washington, and St. Francois Counties, Missouri.*
References: *Wheeler (1965) and Wheeler, et al. (1966).*

The Precambrian outcrop area in the central St. Francois Mountains is postulated as a thrust sheet, in part, which has been thrust northeastward from the root area in Oklahoma and Arkansas. Wheeler points to breccias in Paleozoic rocks and a difference in rock types between allocthonous felsites and autochthonous granites.

The paper by H. E. Wheeler (1965) produced much discussion. Refutations by R. R. Wheeler, Franks, Muehlberger, and Hayes and Gerdemann have been published. These point to a wealth of drillhole data, literature, and geologic mapping to support the theory that the Precambrian of southeast Missouri is indeed an outcrop of exhumed Precambrian mountains and that thrusting is not involved.

St. Louis depression

Location: *St. Louis and St. Charles Counties, Missouri.*
Reference: *Searight and Searight (1961).*

This is an area south of the Lincoln fold and Cap au Gres fault in which Pennsylvanian beds were preserved in a predominantly Mississippian area. The boundaries are vague and are described as ". . . the elongate St. Louis depression which lies immediately south and southwest of the Lincoln fold in Missouri." This includes Rubey's Troy-Brussels syncline and Fenneman's Cheltenham syncline in St. Louis County.

St. Louis fault

Location: *N. 5° E. from 4528 South Broadway, City of St. Louis, Missouri, for 15 miles north and 30 miles south.*
References: *Frank (1948) and Brill, et al. (1960).*

The fault zone strikes N. 5° E. with a width of several hundred feet. Two vertical fault planes, with a net throw of 10 feet, are visible in an abandoned quarry at 4528 South Broadway, St. Louis, Missouri. Sphalerite occurs on or near the fault planes. Frank (1948) traced the fault by geophysical methods for 45 miles north and south of the outcrop.

***St. Marys fault**

Location: *On Kaskasia Island, in Illinois northeast of St. Marys, Ste. Genevieve County, Missouri.*

Reference: *Tikrity (1968).*

Tikrity has described a fault trending N. 26° E. occurring about 3 miles north of St. Marys which was traced from gravity data by Mateker. It is thought to be a northeast extension of the Ste. Genevieve fault system. Tikrity's structural mapping indicates the throw to be from 200 to 400 feet down to the southeast toward the Illinois basin.

Saline City fault-Saline City anticline-Saline County arch-Fish Creek anticline

Location: *Northeast Saline County, Missouri, T. 52 N., R. 20 W., and T. 51 N., R. 19 W.*
References: *Meek (1873), McQueen and Hinchey (1941), Ellis (1948), Dwight (1950), Marvin (1950),*

**Structure does not appear on the map (pl. 1).*

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