Field Trip Guidebook

52nd Annual Meeting

Sedalia, Missouri

October 7-8, 2005
ASSOCIATION OF MISSOURI GEOLOGISTS

GUIDEBOOK TO FIELD TRIPS

52nd ANNUAL MEETING
OCTOBER 7-8, 2005
SEDALIA, MISSOURI

FIELD TRIP 1, FRIDAY, OCTOBER 7
Geology of the Valley Anticline beneath the Warrensburg Sandstone,
Warrensburg, Missouri

FIELD TRIP 2, SATURDAY, OCTOBER 8
Devonian and Mississippian Stratigraphy of the Sedalia-Otterville Area, Missouri.

Editors
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ASSOCIATION OF MISSOURI GEOLOGISTS

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OCTOBER 7-8, 2005
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Field Trip I:
Geology of the Valley Anticline beneath the Warrensburg Sandstone, Warrensburg, Missouri

John L. Nold and John W. Emerson
Central Missouri State University
VALLEY ANTICLINE ASSOCIATED WITH THE WARRENSBURG SANDSTONE IN MISSOURI

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ABSTRACT
The Warrensburg Sandstone, a Pennsylvanian alluvial valley-fill in Johnson County, Missouri, lies with angular unconformity on Desmoinesian Pennsylvanian marine strata comprised mainly of shales and thin limestones. These Desmoinesian shales and limestones generally dip away from the valley center, creating a valley anticline beneath the unconformity. Structural relationships reveal that the valley anticline formed contemporaneously with the incision of the deep valley in which the Warrensburg Sandstone was deposited. The structure formed primarily by toward-the-valley slumping of the valley walls. In addition, flow of Desmoinesian shales toward the valley as pressure was relieved by valley incision may have also contributed to the development of the valley anticline.

INTRODUCTION
In the Warrensburg, MO area, U.S. Highway 50 exposes a two mile wide cross-section of the north-south trending Pennsylvanian Warrensburg Sandstone as well as dipping layers of the older Marmaton limestones and shales on both the east and west margins of the sandstone body. These Marmaton Group strata along both edges of the Warrensburg Sandstone dip about 25-30 degrees away from the sandstone body on both sides, giving the impression that the sandstone was deposited along the axis of an eroded anticline (Emerson, 1975; Beall, 1975; Emerson and Nold, 1981; Nold and Emerson, 1989). This relationship extends for at least 6 mi (10 km) to the north and 12 mi (20 km) to the south of Warrensburg (Figure 1). More importantly, where Cenozoic erosion along the Blackwater River and its tributaries has cut through the bottom of the Warrensburg Sandstone, the same anticlinal dips are observed in the Desmoinesian rocks beneath the channel (Figures 2 and 3). Furthermore, where the Warrensburg Sandstone bifurcates south of Warrensburg, there is a valley anticline present along both branches (Figure 1). The coincidence between the branches of the Warrensburg Sandstone and the anticlinal structure within the pre-Warrensburg rocks implies some relationship between the two. In contrast, the regional subsurface structure in Johnson County is dominated by northwest and northeast trending faults and folds (McCracken, 1971). Structure contour maps of Ordovician and Mississippian rocks in the subsurface of Johnson County, based on dozens of well logs, show the northwest-southeast strike. The valley anticline in the Desmoinesian rocks beneath the Warrensburg Sandstone bears no relationship to regional structures.
Figure 1  Map showing the location of the Warrensburg Sandstone in Missouri and showing the valley anticlinal structures in Desmoinesian Series cyclothemic strata adjacent to the Sandstone. The north-south trend of the valley anticline is at variance with the dominant northwest-southeast tectonic structural trend in the underlying Paleozoic carbonates.
Figure 2  Geologic Map showing dipping Pennsylvanian Desmoinesian rocks adjacent to and beneath the Warrensburg Sandstone (stipple). In the southwest part of the City of Warrensburg, Cenozoic erosion has cut through the Sandstone exposing dipping strata beneath. The cross-Section shows the relationship of the Desmoinesian strata dipping away from the channel axis on both sides of the Sandstone. The depth to which the dipping layers extend is not known, but is not believed to be great.
STRATIGRAPHIC SETTING
The Warrensburg Sandstone is a north-south trending Pennsylvanian alluvial valley-fill which
crops out for more than 50 miles (80 km) in Lafayette, Johnson, and Henry Counties, Missouri
(Figure 1 and Emerson, 1979). The present maximum thickness of the Warrensburg Sandstone
is about 100 feet based on missile site cores. The original thickness is unknown as the
Warrensburg is the youngest formation exposed in the outcrop area. The Warrensburg
Sandstone has been assigned to the Pleasanton Group, Missourian Series, by the Missouri
Geological Survey (Howe and Koenig, 1961; Thompson, 1995). The Warrensburg
Sandstone lies with angular unconformity upon cyclothemic rock units belonging to the Desmoinesian
Series (Figures 3 and 4). The lower portion of the Desmoinesian, the Cherokee Group, consists
mainly of shales, claystones, coals, and thin sandstones, the total thickness of the Group ranging
from 200 to 300 feet thick within the region. The overlying Marmaton Group has a maximum
thickness of 100 feet and is composed mainly of shales and thin limestones.
The above thickness of the Desmoinesian rocks is taken from water well logs and missile site
cores. Both Groups are poorly exposed due to soil development and vegetative cover. Outcrops
in Lafayette County and northern Johnson County are further obscured by a mantle of glacial
deposits.

THE POST OAK CREEK CROSS-SECTION AT OLD HIGHWAY 13 NORTH
Figure 3 is a structural cross-section along Post Oak Creek showing the angular unconformity
between the horizontal Warrensburg Sandstone and an excellent section of underlying dipping
Desmoinesian Series sedimentary rocks. On Figure 1 the section is exposed about two miles
north of Warrensburg where Post Oak Creek has downcut through the Warrensburg Sandstone.
The section is 400 feet in length and, except for rocks covered by 44 feet of bridge abutment, has
nearly continuous exposure. The section is shown with west on the right and east on the left
because it is exposed on the south side of Post Oak Creek and is observed while facing toward
the south. The dip angle of the tilted rocks averages about 30 degrees on the west end of the
section and gradually changes to approximately 60 degrees on the east end of the section. The
tilted Demoinesian rocks are a series of shales, claystones, sandstones, coals, and limestones. No
attempt has been made to divide these rocks into individual Formations because when the
Pennsylvanian cyclothemic sedimentary rocks are structurally deformed and not in their normal
stratigraphic order, identification is nearly impossible. We are certain that the tilted rocks are
mostly Marmaton Group, with perhaps some underlying Cherokee Group rocks present as well.
Two normal faults are present within the tilted Demoinesian Series rocks, the west fault being at
45 feet and the east fault at 300 feet on the 400 foot section (Figure 3). The west fault strikes
north and dips about 60 degrees west and drag of beds on both sides definitely show it to be west
side down, east side up. The east fault strikes a little west of north and has a vertical dip; no
dragged beds are observed and the fault is inferred to have the same type of displacement as the
one on the west, that is west side down, east side up. Adjacent to the east fault is a small fault
that displaces coal and shale (Figure 3). The two normal faults are inferred to divide this section
into three slump blocks which are present in this portion of the east side of the valley anticline.
Inferences about the amount of displacement of the two normal faults are of considerable
interest. First, the west fault. If the sequence coal, shale, sandstone that is exposed between zero
and 30 feet is the same sequence, repeated by the west fault, as that exposed from 153-183 feet
(Figure 3), then the stratigraphic separation and the slip of the fault would be approximately 80
feet. Estimating the amount of movement of the east fault is more tenuous. If we are correct in
our inference that the fault is west side down, then a minimum of about 140 feet of stratigraphic
Figure 3  Cross-section along Post Oak Creek at the old Highway 13 bridge showing the angular unconformity between the horizontal Warrensburg Sandstone and the tilted undifferentiated Demonesian Series rocks below. The location of this section is about two miles north of Warrensburg, MO, where Post Oak Creek has eroded through the base of the Warrensburg Sandstone and exposed the underlying rocks (see Figure 1). The cross-section is shown as four 100 foot long portions which combine to be 400 feet in length of nearly continuous exposure, with west on the right and east on the left because the rocks are exposed on the south side of Post Oak Creek. Standard geologic symbols are used, that is stipple for sandstone, dashes for shale and claystone, and "brick" symbol for limestones. Mixtures of stipple and dashes are used for sandy shale and shaley sandstone. Coal beds are marked with "C". The dip angle of the tilted rocks averages 30 degrees on the west end of the section and gradually changes to approximately 60 degrees on the east end of the section. Two faults are shown. The west fault has dragged beds on both sides and is definitely west side down, east side up. No dragged beds are observed on the east fault and it is inferred to have the same type of displacement, west side down, east side up. Adjacent to the east fault there is a minor fault which displaces coal and shale. These faults are believed by the authors to divide the exposed tilted rocks into three slump blocks on the east side of the valley anticline.
Figure 4  Photograph of the angular unconformity between the Warrensburg Sandstone, above, and the dipping Demoinesian Series rocks below. Located in Post Oak Creek north of Warrensburg at the old Highway 13 bridge. The dark bed in this photograph is a 3 ft thick coal bed located at 195 feet on the Figure 3 cross-section. The coal bed is underlain and overlain by shales and claystones.

Figure 5  Cross-section from Hollingsworth et al. (1944) showing the deformation caused by flow of Upper Lias clays toward the axes of valleys in the Northampton Ironstone Field, England. Bulging of the valley floor is apparently due to flow caused by pressure relief resulting from valley incision. The bulging caused the valley walls to be tilted away from the axis, resulting in an anticlinal structure. Length of the longer cross-sections is approximately 5000 feet.
separation would be required in order for the three limestones in the east fault block to not be exposed in the central fault block.
The three limestone units in the east block are in themselves a stratigraphic problem. We suspect them to be Marmaton Group limestones but three limestones should not be present so close together within the Group. Perhaps there is faulting which is not exposed that is present between some of the limestones.

SIMILAR MIDWESTERN STRUCTURES
Hinds (1912), and Hinds and Greene (1915) mentioned several localities in east-central Missouri where the Moberly channel sandstone (Missourian Series) overlies dipping Cherokee Group and Marmaton Group rocks. Both Jackimovicz (1970) and Gentile (1976) found channel sandstones overlying tilted Marmaton limestones in Bates County, western Missouri. Unklesbay (1952) commented on a channel sandstone unconformable on a tilted Marmaton limestone in Boone County. The present authors did field work on the Moberly Sandstone and found that outcrops in that area, in comparison to the Warrensburg area, were extremely poor. In addition, several specific localities were visited that were described by Hinds (1912) and Hinds and Greene (1915), and it was found that the outcrops no longer existed.

In nearby eastern Kansas, dipping strata have been noted along the margin of the valley-fill Ireland Sandstone (Pennsylvanian System, Virgilian Series). In Franklin County, steeply dipping Robbins Shale is found below the Ireland Sandstone (Ball et al., 1963). O'Connor (1960) found undisturbed beds of Ireland Sandstone overlying steeply dipping Weston Shale and Stranger Formation in Douglas County.

Simmons (1966) describes valley anticlines formed during the Recent within Ordovician limestones and shales in central Kentucky.

UTAH VALLEY ANTICLINES
Huntoon (1982) discussed anticlinal river valleys in Utah. The Meander anticline in Utah, has its axial trace along the Colorado River for 41 km (25 mi) and on the southeast side of the river, eight tributary canyons also contain valley anticlines. Dips on the limbs of these anticlines range from a few degrees to more than 30 degrees. The rims of the canyons are tilted away from the river as much as a mile from the axis. These canyons are eroded to a depth between 122m (400 ft) and 548 m (1800 ft) into Permo-Pennsylvanian sedimentary rocks.

Harrison (1927), Shoemaker (1973), and Huntoon (1982) considered the Meander anticline an unloading feature and both Harrison (1927) and Huntoon (1982) believed that the Meander anticline is still growing. The mechanisms proposed for the origin of these features include salt flowage, salt solution, and brittle plate gliding.

DEFORMATION DUE TO VALLEY INCISION - EXAMPLES FROM CIVIL ENGINEERING
The terms stress release, rebound, unloading, shale flow, and bulging have all been used by civil engineers and engineering geologists to describe the formation of upraised valley floors and tilted valley margin rocks developed after stream incision or after excavation. One of the earlier references to the formation of valley margin anticlines and valley axis bulges is by Hollingworth et al. (1944). This study of the Middle Jurassic age Northampton Ironstone Field in England found that upward movement of valley floors, composed of Upper Lias clay, caused high dips on rocks of the valley margin. Steep dips on valley side limestones are shown in cross sections (Figure 5), with dips from 10 degrees up to 80 degrees found in one valley for more than a kilometer. Contorted valley floor clays and marginal limestones which dip away from the axis
are confined to valleys. Cross sections of Lias clay exposed in dam trench excavations for large reservoirs show highly contorted and thrust faulted layers. Lydekker (1883) stated that broken, contorted, and steeply dipping strata adjacent to the valley bottom have been recognized in England since the last century. Valley floor rebound due to stream incision in Tertiary and Cretaceous siltstones, clay shales, and sandstones of the Great Plains of Canada and the western United States is well documented in engineering literature concerning damsite investigations. These valley anticlines have been studied by several investigators (Crandell, 1958; Peterson, 1958; Matheson, 1972; Matheson and Thompson, 1973). Similar structures in Romania were described by Zaruba (1956). All described raised, tilted valley rims and contorted valley floor rocks. Ferguson (1967) found that in the Allegheny Plateau, that the valley bottoms were deformed by arching and thrust faulting, apparently caused by stress release during valley incision. Nichols (1980) reviewed the literature concerning valley-floor expansion in terrains composed of clay, clay shale, and shales interbedded with limestones and dolomites. These studies from the United States, Canada, and western Europe indicated that unloading response begins at the time of incision and is continuous over long periods of time. Long-term valley floor uplift may be up to ten percent of valley depth. Rebound of .01 m (.04 ft) per year has been measured at Fort Peck Dam, Montana, since 1937 (Matheson and Thompson, 1973). Unloading response can be rapid in both competent and incompetent rocks. Legett (1973) described a newly excavated limestone quarry floor in St. Louis County, Missouri, which overnight developed a ridge 60 cm (2 ft) high and 90 m (300 ft) long. Hollingworth et al. (1944) noted that Sir Malcolm Watson visited the Panama Canal in 1913 and observed bulging in the floor of the Culebra Cut. At one place a steam shovel working the Cut had been raised and tilted so that it fell over.

INCISION OF THE WARRENSBURG VALLEY AND FORMATION OF THE VALLEY ANTICLINE

The Warrensburg Sandstone has a maximum present day thickness of 100 feet as shown by missile site cores and by water well logs. The maximum thickness before surface erosion is unknown. The outcrop is 2-3 miles wide in the Warrensburg area (Figures 1 and 2). For comparison, a nearby reach of the Missouri River, with a channel of similar width, has incised its bedrock channel about 300 feet below the bluffs and presently contains more than 100 feet of Quaternary alluvium. The deep incision of the Warrensburg valley was probably due to the rapid Carboniferous drops in sea level documented by Vail et al. (1977) and similar to valley incision caused by Early Cretaceous rapid lowering of sea level (Weimer, 1982). Heckel (1986) presented a Late Pennsylvanian glacial-eustatic sea level curve for the midcontinent. A major sea level drop at the Desmoinesian-Missourian boundary correlates well with the time of incision of the Warrensburg valley. The only known fossil age assignment was obtained from a thin coal in the basal conglomerate of the Warrensburg Sandstone collected by Emerson (1988). An age assignment of latest Desmoinesian by Palinex International for the basal Warrensburg fits well with the observed stratigraphy. The very coarse boulder conglomerate derived from erosion of the Marmaton Group limestone beds and contained in the basal Warrensburg Sandstone in Johnson and Henry Counties is evidence of steep valley sides and of mass movement to introduce this material as channel lag deposits (Emerson, 1975, 1977). The incision of the valley in which the Warrensburg Sandstone was deposited apparently allowed the development of the valley anticlinal structure. Two possible mechanisms for
development of this structure are suggested. The first method is slumping of large blocks of steep valley sides. Bristol and Howard (1974) studied the sub-Pennsylvanian unconformity in the Illinois Basin. A Late Mississippian (Upper Chesterian Series) sea level drop (Vail et al., 1977) recognized in the Illinois Basin and southern Appalachians, caused entrenchment of a system of valleys in the Chesterian marine limestones and shales followed by alluvial valley-fill of Pennsylvanian Caseyville Formation clastics. Electric logs and cross-sections from drill holes show great slump blocks of Chesterian strata arranged en echelon along the sides of the valley bottoms (Figure 6). Each block has rotated along the curved plane of a listric normal fault, so that the dip of the displaced strata is away from the valley axis. The slump blocks range from 10 to 125 feet in thickness and the maximum vertical displacement is 200 feet. Individual blocks are several hundred to 3000 feet long and up to several hundred feet wide. The northward advance of the Pennsylvanian sea across the area caused the streams that had been actively downcutting to begin aggrading and filling their valleys with the Caseyville alluvial sediments. We believe that the rapid sea level drop (Heckel, 1986) at the end of Pennsylvanian Desmoinesian time caused the incision of the Warrensburg valley system and slumping of blocks of Marmaton (Upper Desmoinesian) limestones and shales along the valley sides. Subsequent sea level rise and alluviation during Missourian time deposited the Warrensburg Sandstone in this valley. Post-Paleozoic erosion of the land surface in this area has exposed the lower part of the Warrensburg valley fill sandstone underlain and flanked by the tilted slump blocks. The slump blocks tilted backwards as they moved downward into the valley giving the appearance of an anticline caused by structural deformation.

Figure 7 is an interpretive cross-section showing the Warrensburg river valley and the Warrensburg Sandstone during Pennsylvanian time. Also shown are the rotated slump blocks which have caused the tilting of the bedding away from the channel axis resulting in the valley anticlinal structure. This mechanism also explains the apparently excessive stratigraphic thickness for the tilted Desmoinesian strata beneath and adjacent to the Warrensburg Sandstone by repetition in individual slump blocks. The Marmaton Group is the only part of the Desmoinesian Series containing distinctive limestones more than 4 feet thick. These limestones are, in ascending order, the Blackjack Creek, the Higginsville, the Myrick Station, and the Coal City. Well logs and missile site cores from the area show that these four limestones occur in no more than 70 feet of stratigraphic section (Thompson, 1995, p.104). The north-south striking belts of tilted Marmaton strata (and perhaps some underlying Cherokee Group strata) beneath and adjacent to the sandstone body appear to make up at least several hundred feet of stratigraphic thickness. Repetition of the 70-100 foot thick Marmaton strata is the most logical explanation for this anomalous thickness. The Post Oak Creek cross-section at old Highway 13 north (Figure 3) shows two of the faults on the east side of the valley anticline which repeat the Marmaton strata within individual slump blocks. In general, relatively poor exposures within the area have allowed the inference of other faults between the slump blocks in only a few localities. The alternative mechanism for the development of the valley anticline is that of tilting of the strata on the valley sides from bulging due to flow of the Cherokee Group shale and claystone toward the axis of the developing valley. This flow would be due to a pressure gradient caused by valley incision. This mechanism would be similar to that suggested by Hollingsworth et al. (1944) for Jurassic strata in England (Figure 5). Though exposures are poor in the area, exposures of shale beneath the Sandstone do not show the types of internal deformation that would be expected to be present if the structure was caused principally by shale-flow. Perhaps if this mechanism was operative, it was minor in importance compared to slumping.
Figure 6  Cross-section from Bristol and Howard (1974) showing the development of valley-side slump blocks within an Illinois valley incised into Mississippian Chester strata. The incision was caused by a Late Mississippian sea level drop (Vail et al., 1977). Later alluviation filled the valley with Caseyville Formation clastic sediment during Early Pennsylvanian time.

Figure 7  Interpretive cross-section showing the Warrensburg river valley as it was filling with the Warrensburg Sandstone during Pennsylvanian time. Shown also are Demoinesian limestones and shales within the rotated slump blocks responsible for tilting the bedding away from the center of the valley on both sides creating the valley anticline. This mechanism explains the excessive apparent stratigraphic thickness for the tilted Desmoinesian strata beneath and adjacent to the Warrensburg Sandstone by repetition in individual slump blocks. Arrows in the Cherokee Group indicate the possibility of shale flow from pressure release due to valley incision.
SUMMARY AND CONCLUSIONS

Detailed field mapping of the structures under and adjacent to the Warrensburg Sandstone shows that the Desmoinesian strata have been deformed into a valley anticlinal structure. Analysis of our field maps and structural cross-sections indicates that the tilted Desmoinesian strata adjacent to and beneath the Sandstone have an excessive thickness that is probably due to repetition. The valley anticlinal structure and the amount of repetition can best be explained by the breaking up of the valley walls into numerous slump blocks which moved toward the axis of the valley, the resulting tilt of the bedding being caused by rotation of the blocks. In addition, a pressure gradient within the underlying Cherokee Group shale and claystone may have caused flow toward the developing valley which resulted in thickening of the shales and tilting of the valley sides away from the center.

Lastly, examination of the literature leads us to believe that valley anticlines are a widespread phenomenon but, with a few notable exceptions, they are not well known to a majority of the geologic profession other than those involved in dam construction.

REFERENCES CITED


ACKNOWLEDGMENTS
We acknowledge D. Barber and J. Beall for assistance in mapping.
Road Log

0.0 mi.  Road log starts at the intersection of U.S. Highway 50 and State Highway 13. Westbound on U.S. 50 from Sedalia, exit on Highway 13 and turn right (north). Continue north on Highway 13 past Wal Mart and at 0.6 miles turn left (west), and then immediately right (north) on old Highway 13, now county NW21. Continue north 1.1 miles to the bridge over Post Oak Creek (slowly, the bridge is closed and has a chain across it). Park for Stop 1.

1.9 mi.  Stop 1  Post Oak Creek outcrop. We will walk across the bridge and make our way down into the creek and examine the east-dipping pre-Warrensburg strata and the overlying Warrensburg Sandstone in angular unconformity on the east side of the bridge abutment. Figure 3 on p.6 in the previous article on the valley anticline is a cross-section of this outcrop, and the section of the article entitled "The Post Oak Creek Cross-section at Old Highway 13 North", on p.5 describes the geology. That description is not repeated here. After examining this portion of the east-dipping stratigraphic section, we will make our way to the portion of the section to the west of the bridge abutment, probably by climbing back out of the creek, re-crossing the bridge and making our way down to the creek on the other side. We will examine the east-dipping rocks and the angular unconformity west of the abutment.

We will then work our way upstream to the west where the pre-Warrensburg strata are horizontal in relation to the overlying Warrensburg Sandstone basal conglomerate. These outcrops are separated from the outcrops near the bridge by several hundred feet and are not shown on the Figure 3 cross-section. Nold and Emerson are of the opinion that these horizontal pre-Warrensburg strata are toward the middle of the ancient valley and as a result, did not slump into the developing valley. The basal conglomerate is abnormally thick here, for which we have no explanation.

We will then make our way back to the bus. Please use care; we only have permission to cross the lower part of the James Clear-Bryn Myers lot. We will reverse our path to the south, taking Highway 13 south past Highway 50 through Warrensburg.

4.9 mi.  Turn right (west) on South Street at the northeast corner of the campus of Central Missouri State University, and continue west to Warren Street.

5.4 mi.  Turn left (south) on Warren Street, continue south to where Warren Street swings right and becomes Southwest Boulevard. Continue on Southwest Boulevard, and stop on the shoulder, and disembark.
6.1 mi. Stop 2 We will walk across a small creek on the edge of Culp Park, proceed through the woods and examine 3-4 outcrops in and near the Park. In this area we are on the west side of the valley anticline and the outcropping limestones are striking a little west of north and dipping west. These pre-Warrensburg outcrops were originally underneath the Warrensburg Sandstone on the west side of the Warrensburg valley, but Cenozoic erosion through the Sandstone has exposed the dipping layers.
Proceed back to the bus and go to Stop 3, if time.

Continue southwest on Southwest Boulevard, turn left on south Main Street after about 0.1 mi. After another tenth of a mile, note the large outcrop of Warrensburg Sandstone on left, across from the shelterhouse on Lions Lake. Another tenth of a mile takes you to the stop sign at Hale Lake road, turn right and continue about 0.3 mi., turn left on Live Oak Lane, continue south along the west edge of the Pertle Springs golf course. Turn right on SW 51 road and park on right hand edge of road.

7.1 mi. Stop 3 Disembark bus, and walk south on road off of which we have just turned (Live Oak Lane), to end of the Lane and examine more west-dipping outcrops in creek on last lot, near the corner of the golf course.
In the creek just west of the chain link fence of the golf course is the basal conglomerate of the Warrensburg Sandstone. To the west, down the creek, are two west-dipping limestone beds, the stratigraphically lower one being about six feet thick and the upper one being about 10 feet thick. We believe these to be the Blackjack Creek Limestone and the Higginsville Limestone, based on color, thickness, plus bedding character and thickness. These outcrops would have been under the western side of the original Warrensburg valley and have been uncovered by Cenozoic erosion.
Proceed back to bus.
Field Trip II
Devonian and Mississippian
Stratigraphy and Structural Geology
of the
Sedalia-Otterville Area, Missouri

Carl Priesendorf
Longview Community College
Lee’s Summit, Missouri
DEVONIAN AND MISSISSIPPIAN STRATIGRAPHY AND STRUCTURAL GEOLOGY
OF THE SEDALIA-OTTERVILLE AREA, MISSOURI.

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ABSTRACT
The Paleozoic strata near Sedalia, Missouri in West-Central Missouri consist of numerous
dolostone, limestone and sandstone formations ranging in age from lower Ordovician to middle
Pennsylvanian. The strata are generally horizontal and are relatively undeformed. Locally, the
limestone and dolomite formations exhibit extensive paleokarst features. Karst features are
found in the Burlington Limestone of Mississippian age, indicating a post-Osagean time of karst.
To the east of the Sedalia area, numerous paleokarst structures are found in the underlying
Jefferson City Dolomite and Cedar Valley Limestone formations.

INTRODUCTION
In the region near Sedalia, Missouri, the surface bedrock consists of a variety of rock formations,
ranging in age from lower Ordovician to Pennsylvanian. Overlying the Paleozoic rocks in the
northern and western parts of Pettis County, are Pleistocene lake sediments. South of Sedalia,
the Jefferson City Dolomite is the dominant formation exposed. The northern half of the county
is primarily covered by Burlington Limestone and Chouteau Group Formations, both of
Mississippian age. Rocks of Devonian age are found primarily along the eastern margins of the
county and in adjacent Cooper and Morgan counties.

The bedrock geology of the area has been described by numerous past investigators. One of the
earliest to study the bedrock in the area was G. C. Swallow, who in 1855 described the rocks
near Chouteau Springs, and was the first to describe the rocks that eventually became known as
the Chouteau Group. R. C. Moore (1928) described rocks in the vicinity of Clifton City (Cooper
County) and subdivided the “Chouteau Limestone” into a lower unit he called the “Chouteau
Limestone restricted,” and an upper unit called the Sedalia Formation. Clark and Beveridge
(1952) were the first to conduct an organized field trip into the area by a group of professional
geologists (Kansas Geological Society). In their field trip guidebook, several bedrock exposures
were described, some of which were used as the basis for this study. Sleeman (1964)
investigated the Cedar Valley Formation lithofacies relationships, while Fraunfelter (1964)
investigated the biofacies stratigraphy of the same formation. Thompson (1986) described the
Mississippian strata north of Sedalia and the Devonian bedrock in the vicinity of Otterville,
Missouri (1993). Emerson (1982) described several “Pennsylvanian” sandstones in northwest
Pettis County and in neighboring Johnson County as well as the Pleistocene lake sediments
(1975).

The Paleozoic strata in the Sedalia area are generally relatively undeformed, and show little
evidence of karst development. Locally however, a variety of paleokarst features are found, and
clearly indicate a time of karst development that took place during the Pennsylvanian Period.
Other localities however, give possible evidence to an earlier time of karst that may have
occurred earlier in the Paleozoic.
FIGURE 1
Map of Sedalia Area Field Trip Stops, Pettis County, Missouri (Stops 1 – 4)
FIGURE 2

Map of area near Otterville, Cooper and Morgan Counties of Missouri.
(Stops 5 and 6)
ROAD LOG
(Distances in Miles)

0.0  Road log starts at Hotel Bothwell (intersection of Ohio Avenue and East 4th Street). Proceed south on Ohio Street to Highway 50.

0.25  Turn right (west) on Highway 50.

0.70  Intersection with Grand Avenue.

1.40  Intersection with Highway 65 (Limit Avenue).

2.20  Intersection with Thompson Boulevard.

3.20  Intersection with Main Street.

4.40  Abandoned quarry on south side of highway. Reverse fault visible in quarry wall from highway. Exposed in quarry are Burlington, Pierson, Northview and Sedalia Formations.

4.80  Bridge over Muddy Creek.

5.20  Road cut with exposure of Burlington, Pierson, Northview and Sedalia formations on both sides of road.

5.40  County Road MM intersection. Turn right.

5.55  Intersection of Whitfield Road and County Road MM. Turn right on County Road MM.

5.90  Railroad crossing. Turn left onto Menefee Road, immediately after crossing railroad tracks.

6.50  Intersection with Snow Road. Turn right.

6.60  STOP 1. Sedalia Quarry Office on left side of road.

6.70  Leave Sedalia Quarry by proceeding south to Menefee Road.

6.80  Intersection with Menefee Road. Turn Left.

7.50  Proceed to County Road MM (Oak Grove Lane). Turn right, crossing railroad tracks.

7.80  Intersection of Whitfield Road and MM Highway. Turn left. Proceed to Highway 50.
8.00   Intersection with Highway 50. Turn Left.

8.20   **STOP 2.** Exposure of Burlington, Pierson, Northview and Sedalia formations.

8.50   Muddy Creek Bridge.

12.0   Intersection with Highway 65. Turn Left (north).

12.60  Bridge over Main Street (Highway 765).

13.70  North Grand Avenue intersection.


15.20  County Roads H & HH intersection.

16.20  Burlington Limestone along both sides of highway.

16.60  Cedar Creek Bridge.

16.85  Burlington Limestone along both sides of highway.

17.40  Burlington Limestone exposed in road cuts along west side of highway.

18.0   Burlington Limestone along both sides of highway.

18.20  Bothwell Park Road.

18.90  **STOP 3.** Exposure of Chouteau Group, Bachelor Sandstone, and Cedar Valley Limestone formations.

19.40  Muddy Creek Bridge

19.60  Burlington, Pierson, Northview and Sedalia formations exposed in road cut along both sides of highway.

19.90  **STOP 4.** Exposure of Burlington Limestone with numerous paleokarst fill structures.

20.20  Turkey Creek Bridge.

20.30  Exposures of Burlington Limestone, Pierson, Northview and Sedalia Formations along both sides of highway.

20.60  Turn around using median, and proceed south on Highway 65.
23.10 Intersection with Bothwell Park Road. Turn left, and proceed to Bothwell Lodge State Historic Site.

23.40 Park Entrance. Turn left and proceed to Picnic Area.

24.00 Picnic Area and Shelter House. Turn left.

24.20 Lunch at Picnic Area and Shelter House.

24.20 Leave Picnic Area after lunch, and proceed to Highway 65.

25.20 Intersection with Highway 65. Turn left and proceed to Sedalia.

29.10 Intersection with Highway 765 (Ohio Avenue). Turn south on Highway 765. Proceed through downtown Sedalia.

30.30 Railroad crossing.

30.35 Intersection with Main Street. Continue south on Ohio Avenue.

30.55 Hotel Bothwell on left.

30.80 Intersection with Highway 50. Turn left (east).

31.05 Railroad overpass (Katy Trail State Park).

31.60 Intersection with Engineer Street.

33.10 Railroad overpass.

35.0 County Road TT intersection.

36.50 County Road O intersection

38.00 County Road W intersection.

39.20 Highway 135 (north) intersection.

40.00 Morgan County Line.

40.50 Exposures of Sedalia Formation-Burlington Limestone along both sides of highway.

41.00 County Road A intersection.

41.50 Highway 135 (south) intersection.
STOP 5. Road cut along both sides of Highway 50. Exposure of Cedar Valley Limestone and Jefferson City Dolomite. Extensive paleokarst locality.

Intersection with Morgan County Street. Turn left, and proceed to Otterville.

Railroad tracks. Turn right on Old Highway 50 in Otterville.

Lamine River Bridge.

Exposures of St. Peter Sandstone and Jefferson City Formation along both sides of road.


Turn around and proceed back (west) to Otterville.

Intersection of Morgan County Street in Otterville. Turn left and proceed to Highway 50.

Intersection with Highway 50. Turn right and proceed to Sedalia.

Intersection of Ohio Street. Turn right and proceed to Hotel Bothwell.

Hotel Bothwell. End of Field Trip.

STOP 1 Sedalia Quarry, (NE ¼, SE ¼, Sec. 23, T 46 N, R 22 W)

In this part of the quarry, approximately 25 feet of lower Burlington Limestone is exposed. Above the Burlington Limestone is nearly 8 feet of micaceous cross-bedded Pennsylvanian sandstone, and four feet of Pleistocene silty clay (Figure 3). Of particular interest in this quarry are the numerous paleokarst structures, including filled-sink, and joint fill structures (Figures 4, 5, 6). The paleokarst structures are filled with shaley sandstone, crinoidal debris and a combination of boulders of chert and limestone (Figure 6). The crinoidal debris has undergone secondary lithification after weathering of the Burlington Limestone that likely took place during the Pennsylvanian Period (Figures 4, 5, 6).

The sandstone above the Burlington Limestone is lithologically different than the sandstone found in the paleokarst structures. It is a fine-medium grained, subangular - subrounded, micaceous quartz sandstone with thin layers of ironstone. The sandstone exhibits distinct cross-bedding indicating a paleocurrent direction to the south (Figures 3, 7). The sandstone is believed to from Pennsylvanian Period, however its relationship to other Pennsylvanian strata is yet to be determined. A number of studies have attempted to demonstrate the stratigraphic relationships of the sandstones in this part of Missouri (Marbut, 1898; Hinds and Greene, 1915; Searight and Howe, 1961; Emerson, 1982). Lithologically, the sandstone at this locality is quite similar to the Warrensburg Sandstone, and Emerson’s “Type C” sandstone (1982), where he describes a channel sandstone that has a linear trend from Saline County to southeastern Henry County.
According to Emerson, this is possibly the same sandstone as that found by Gentile in the 1960’s, when he logged three Pettis County missile site cores. Gentile described the sandstones as being “fine-grained, arkosic, micaceous, cross bedded sandstone.” Above the sandstone at this locality is a four foot thick silty-clay layer that is likely the same as that described by Emerson (1975) (Figure 8). He describes a “gray silty clay” that is found in the uplands of Johnson County, western Pettis County and Saline counties of Missouri. His interpretation of the silty-clay is a Pleistocene lake deposit, possibly formed by the build-up of glacial melt-water caused by ice damming of the Missouri River. The exact age of the silty clay is undetermined. Similar silty clay sediments containing the remains of a mammoth and other vertebrates found near Grain Valley, Missouri may be of similar origin (Dort, 2004).

Figure 3. Exposure of strata in western part of Sedalia Quarry (STOP 1).
Figure 4. Shaley-sandstone (Pennsylvanian) in filled-sink structure within Burlington Limestone (Mississippian).

Figure 5. Solution channel in Burlington Limestone filled with shaley sandstone.
Figure 6. Paleokarst fill composed of chert and limestone boulders with crinoidal detritus from weathered Burlington Limestone.
Figure 7. Close-up view of Pennsylvanian sandstone, showing cross-bedding (above rock hammer).

Figure 8. Close-up view of silty-clay, interpreted as Pleistocene lake deposit.
STOP 2 Location along Highway 50, immediately northwest of Muddy Creek
(SW ¼, Sec. 26 T 46 N, R 22 W).
Exposed at this locality are the Sedalia and Northview Formations, Pierson Limestone
and Lower Burlington Limestone (Figure 9). The Kinderhookian/Osagean Series
Boundary is found at the base of the Pierson Limestone. Beneath this boundary is the
Chouteau Group (Kinderhookian). From top – bottom, the Chouteau Group consists of
the Northview Formation, Sedalia Formation, an “Unnamed Limestone, and the Compton
Limestone (Figure 11). At this locality, only the Northview and Sedalia Formations are
present. The Northview Formation, is a greenish-gray dolomitic siltstone approximately
two – three feet thick. The formation becomes progressively thicker to the south, and in
Greene County is over 75 feet thick. East of the Missouri River in central Missouri, the
Northview is absent (Thompson, 1986). The Sedalia Formation is “typically a medium-
to-thick-bedded finely crystalline dolomitic and siliceous limestone (Thompson, 1986).”
Chert nodules and chert layers are common. Overlying the Chouteau Group at this
locality is the Pierson Limestone. The Pierson Limestone is a tan-colored dolomitic-silty
limestone, approximately 2 –3 feet thick. Like the Northview, the Pierson Limestone
also thickens to the south, eventually attaining a thickness of over 40 feet near the
Arkansas border (Thompson, 1986). At the top of the exposure is the abundantly
fossiliferous crinoidal Burlington Limestone.

Figure 9. Bedrock exposure of Mississippian strata exposed northwest of Muddy Creek.
Kinderhookian-Osagean boundary is at base of Pierson Limestone.
STOP 3  Road cut along eastern side of Highway 65 approximately 6 miles north of Sedalia (SE ¼, NE ¼, Sec. 4, T 46 N, R 21 W).
Exposure of Compton Limestone in road cut (Figure 10). The Compton Limestone is the lowest member of the Chouteau Group. The formation is a finely crystalline, wavy-bedded, gray to buff, fossiliferous limestone. Above the Compton Limestone at this locality are the overlying members of the Chouteau Group (poorly exposed). The Bachelor Sandstone and Cedar Valley Formations are exposed at the base of the south facing cliff. The Bachelor Formation is a poorly-cemented greenish gray phosphatic sandstone that forms a prominent reentrant at the base of the Chouteau Group. In west-central Missouri, the Bachelor Formation rests unconformably on the Cedar Valley Formation (Devonian), however south of Sedalia, the Bachelor Formation lies on the Jefferson City Formation.

Figure 10. Exposure of Compton Limestone (lower Chouteau Group) along east side of Highway 65.
13. Limestone, gray, coarsely crystalline, crinoidal; with zones of interbedded chert nodules. (3 ft)
12. "Rubble zone"; chert and weathered limestone. (2 ft 6 in.)
11. Limestone, dark-blue-gray, medium- to coarsely crystalline, very fossiliferous, crinoidal; single bed. (5 ft)
10. Dolomite, gray, coarsely to very finely crystalline, very dense, fossiliferous; single bed. (2 ft 6 in.)
9. Siltstone, dolomitic, dark-blue-gray to green, blocky; single uneven continuous bed of silty dolomite in upper part. (8 ft)
8. Dolomite, silty, dark-blue-gray, single bed, laminated; phosphatic zones. (2 ft 6 in.)
7. Dolomite and dolomitic limestone, silty, dark-gray-brown; scattered fossils. Chert (25%) as nodules and beds, dark-gray-black; scattered calcite-filled vugs (Sedalia and "Chouteau chert"). (9 ft)
6. Limestone ("Chouteau"), light-gray, lithographic, fossiliferous; irregular beds with silty dolomitic partings. Chert (5-10%), as irregular masses and nodules within limestone beds. (5 ft)
5. Dolomite and limestone, as alternating zones or beds; lateral facies. Dolomite ("Sedalia"), buff, silty, calcitic, very finely crystalline. Limestone ("Chouteau"), dark-blue-gray, lithographic; beds 1-2 ft thick. (10 ft)
4. Limestone, dark-gray to buff, finely crystalline, very fossiliferous; incipient nodular bedding very prominent in lower part; very even major beds. (3 ft)
3. Limestone, light-gray to green-gray; even, medium beds with incipient nodular bedding when weathered; very finely crystalline matrix, scattered fossils. (7 ft)
2. Sandstone, light-gray-green; calcite cement, very irregular base, even top. (0 ft 3-6 in.)
1. Dolomite, buff, dense.

Figure 11. Generalized Columnar Section representative of strata north of Sedalia, along U. S. Highway 65 (Adapted and modified from Thompson, 1986).
STOP 4  Road cut ½ mile north of Muddy Creek (NE ¼, Sec. 33, T 47 N, R 21 W). Road cuts on both sides of highway expose Burlington Limestone that has undergone extensive dissolution, exhibiting an abundance of paleokarst fill structures (Figures 12, 13). Limestone and chert boulders fill most of the paleokarst structures, however several are filled with a fine-grained quartz sandstone of unknown age (Pennsylvanian ?) (Figure 14). The sandstone at this locality is distinctly different than either of the sandstones observed at STOP 1. This sandstone is finer-grained, composed of angular nearly pure quartz sand grains, lacking micas, or any of the thin shale units found in the paleokarst fill structures of STOP 1.

Figure 12. Filled-sink structure in Burlington Limestone along west side of highway.
Figure 13. Close-up view of paleokarst fill in Burlington Limestone.

Figure 14. Quartz sandstone in filled-sink structure along east side of highway.
STOP 5  Road cut along both sides of Highway 50, (center sec. 9, T 45 N, R 19 W), Morgan County, Missouri. Numerous paleokarst structures are found along both sides of highway for several hundred feet. At this locality, the Jefferson City Dolomite (Ordovician) is overlain by Cedar Valley Formation (Devonian), Bachelor, Chouteau Group, Pierson Limestone and Burlington Limestone (Mississippian) (Figure 15). In central Missouri, the Cedar Valley Limestone consists of three distinct facies (Thompson, 1993): Callaway, Cooper and Mineola. At this locality, only the Cooper and Mineola Facies are present (Figure 15). Koenig (1961) describes the Cooper Facies as “a light to medium brownish-gray, dense to finely crystalline limestone which in some places is very fossiliferous.” The Mineola Facies consists of “two significant rock types, sandstones (principally orthoquartzites) and biosparites (Sleeman, 1967).” The sandstone within the Mineola Facies is primarily orthoquartzite, however locally (especially at the base), it is friable, and is quite similar to the St. Peter Sandstone. Koenig (1961) describes the carbonate member of the Mineola as “a light to medium brown, coarsely crystalline limestone which is locally very fossiliferous and is cross-laminated in some exposures.” Upon weathering, the Mineola Facies resembles the Burlington Limestone. The Mineola however, is dominantly composed of brachiopod fragments, with lesser amounts of crinoid fragments, whereas the Burlington is almost entirely crinoidal. Above the sandstone member (orthoquartzite) of the Mineola Facies is the Bachelor Sandstone, Chouteau Group and Pierson/Burlington Limestones. The Mississippian Formations are exposed at east end of road cut along both sides of highway.

Numerous paleokarst features are present along both sides of highway (circle deposits, filled-sinks, solution channels, paleocollapse structures, etc.). The following are selected paleokarst structures found at this locality:

**Filled-sink structures**  
Along the south side of the highway is a prominent filled-sink structure in the Jefferson City Dolomite (Figure 16). The sink is filled primarily with chert breccia and sandstone, and is “capped” by the Cedar Valley Limestone. Slabs of bedrock from the base of the Cedar Valley Formation are found in the chert breccia and is evidence for ceiling collapse into the structure. A variety of bedrock types are found as fill in the numerous filled-sink deposits, including limestone and sandstone from the overlying Cedar Valley Limestone (Figure 19).

**Paleocollapse structures**  
Several of the filled-sink structures are associated with faulting, likely due to karst-related collapse of the underlying strata. Along the north side of highway, the Cooper Facies (Cedar Valley Formation) is faulted, into a graben-like paleocollapse structure (Figure 18). Displacement along the fault is approximately 3 feet. The fault plane, can be recognized by the occurrence of a well-cemented fault breccia(?) (Figure 20). Another of the paleocollapse features exhibits “deformed bedding” at base of Cedar Valley Limestone (Figure 17). The “deformed bedding” and thinning of the limestone along the margins of the structure may be due to compaction and brecciation of the limestone into the filled-sink structure.  
Along the south side of highway near the west end of road cut, the Cedar Valley Limestone is laterally adjacent to the Jefferson City Dolomite due to paleocollapse.
Vertical displacement is approximately 15 feet. Within the collapse structure is sandstone from the overlying Mineola Facies, which resembles the St. Peter Sandstone. The occurrence of the sandstone within the sink structure indicates a paleocollapse after deposition and lithification of the Cedar Valley Formation (Devonian). The largest of the paleocollapse structures is found at the east end of road cut. Exposed along highway at the same level as the Mineola are tilted Burlington and Pierson Limestone Formations, Northview, and upper Sedalia Formations. The paleocollapse displacement within structure is approximately 30 - 35 feet.

Another road cut approximately ¼ mile to the east also exhibits numerous paleokarst features, however on a smaller scale. Circle deposits and solution channels occur within the Cooper Facies of the Cedar Valley Limestone. The paleokarst structures are filled with thinly-bedded fine-grained sandstone and dolomitic laminae (Figure 21). The solution channels follow along bedding planes and joints in the limestone (Figure 22). Fossils within the Cooper Facies of the Cedar Valley Formation are relatively rare, however at this location, stromatoporoids are common. The stromatoporoids are found fragmented (intraclasts) along with colonial corals including *Hexagonaria* and *Thamnopora* (Figure 23.).

**Age of Paleocollapse event**
The age and relationship of the paleocollapse structures at this locality are difficult to determine. Assuming that all of the paleokarst features occurred at the same time, it is evident that the age of the paleokarst event(s) is post-Osagean (Burlington Limestone), because the Burlington Limestone is the youngest formation affected by the paleokarst processes.
Figure 15. Composite columnar section of strata exposed along both sides of Highway 50 near Otterville, Missouri (STOP 5). Adapted and modified from Thompson (1986, 1993).
Figure 16. Filled-sink structure in Jefferson City Dolomite. Structure is overlain by Cedar Valley Limestone.

Figure 17. Paleocollapse structure (deformed bedding?) of Cooper Facies of Cedar Valley Limestone into underlying Jefferson City Dolomite.
Figure 18. Exposure of Cooper Facies (Cedar Valley Formation) into graben-like paleocollapse feature.

Figure 19. Boulders of Cedar Valley Limestone in filled-sink structure beneath “deformed bedding” (base of Cedar Valley Limestone).
Figure 20. Limestone breccia in Cooper Facies of Cedar Valley Limestone.

Figure 21. Circle-deposit filled with thinly bedded fine-grained sandstone. Width of structure is approximately 4 feet (at base).
Figure 22. Solution channel in Cedar Valley Limestone filled with thinly bedded, fine-grained sandstone and laminae of dolostone.

Figure 23. Brecciated Stromatoporoid and Hexagonaria fragments in Cedar Valley Limestone.
STOP 6. Brownfield Roadside Park, approximately 1.5 miles east of Otterville, Missouri, along “old” Highway 50. Immediately to the west of roadside park is one of the largest St. Peter Sandstone exposures in west-central Missouri. The St. Peter Sandstone overlies the Jefferson City Dolomite. Approximately 200 feet west of roadside park is the “Otterville Filled Sink” (SW ¼, Sec. 36, T 46 N, R19 W). The sink is filled with approximately 30 feet of St. Peter Sandstone within the Jefferson City Dolomite. The origin of many of the filled sinks in the region has been a matter of debate for years. Bretz (1950) suggested that many of the filled sinks of the northern and western flanks of the Ozark Dome were the “products of slow, compressional subsidence, under a former load into enlarging solution cavities in subjacent beds of limestone and dolomite.” “Deformed bedding” is found within the Jefferson City Dolomite adjacent to the sink structure (Figure 24). The deformation within the Jefferson City Dolomite may have been caused by the same processes responsible for the formation of the filled-sink structure.

![Figure 24. “Soft-sediment deformation” exposed in Jefferson City Dolomite.](image)
SUMMARY AND CONCLUSION
The exposed bedrock of west-central Missouri consists primarily of Ordovician dolostones, Devonian and Mississippian limestones. Generally, the strata are nearly horizontal, and are relatively undisturbed. In some areas, however, significant evidence of paleokarst exists. The paleokarst structures are believed to have formed during the Pennsylvanian Period. Evidence includes, Pennsylvanian age sandstones in filled-sink and joint fill structures within the Burlington Limestone of the Mississippian Period. At some localities, however evidence suggests the possibility of earlier paleokarst events. Further investigations, within the Ordovician and Devonian age strata of the area, will help resolve the issue.

REFERENCES CITED


