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GUIDEBOOK FOR THE

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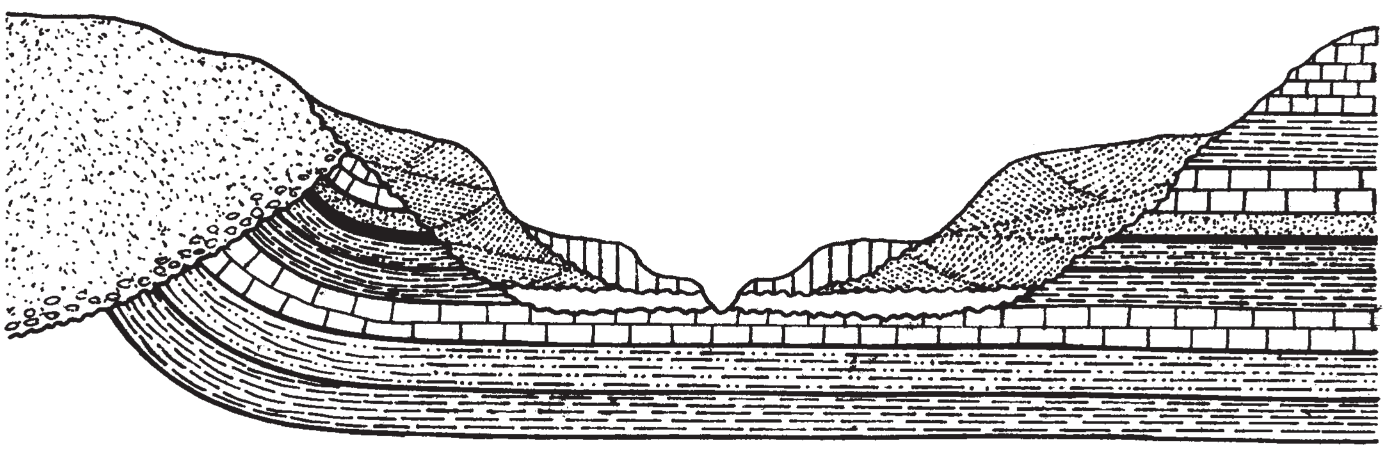

PENNSYLVANIAN-PLEISTOCENE CHANNEL FILL AND QUATERNARY GEOMORPHOLOGY NEAR WARRENSBURG, MISSOURI

ASSOCIATION OF MISSOURI GEOLOGISTS 1975

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PREFACE

The purpose of this field trip is to study the nature of stream channels and their deposits, both ancient and modern, in the vicinity of Warrensburg, Missouri. We will observe the geomorphic effects due to channelization of the Blackwater River; the Pennsylvanian Warrensburg Sandstone, its geometry and relationship to the enclosing rocks; and Quaternary deposits and landforms.

The Field Trip Committee wishes to thank Nan Cocke for typing the manuscript, and Dan Barber and Brad Brown (C.M.S.U. students) for field assistance and drafting.

MAN AS A GEOMORPHIC AGENT

John W. Emerson

Earth Science

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The process of straightening a stream by dredging a new channel has been practiced since Colonial days in the United States. When the forests and fields were cleared for farming, the greatly increased rate of erosion gradually silted up the once clear streams. The channel and floodplain sedimentation due to farming caused higher ground water tables, higher flood stages, and made the bottom land unsuitable for cultivation. The great increase in aggradation in and along stream courses due to early-day farming practices is well documented by Happ, Rittenhouse and Dobson (1940), Happ (1944), and Trimble (1969).

Channelization is a simple process. By dredging a shorter channel, the gradient of the stream is increased and the new gradient causes an erosional regime to commence. The new channel does not have to be as large as the former stream. Old time drainage engineers were delighted by the returns from such a small investment, and called them "self-digging" ditches. An example of such increase is provided by an engineering report on Big Creek in Cass County, Missouri, (Meyers, 1949), in which Big Creek's 2000 cubic feet per second flow capacity channel was to be supplanted with a new 700 cfs capacity ditch, which was expected to enlarge very rapidly to a size sufficient to carry a discharge of 5000 cfs without flooding.

The very rapid deepening and widening of streams due to channelization was documented by Ramser (1930), Daniels (1960), and Emerson (1971). The process is very effective in terms of drainage and flood control, as the enlarged channel can receive much higher discharges without overbank flow, and the ground water table is lowered so that drainage of nearby fields is more effective. The agencies involved in channelization are private drainage districts, the Army Corps of Engineers, the Bureau of Reclamation, the Soil Conservation Service, and State Highway Departments.

Although alluvial rivers make their own natural cut-offs, man has often lent a hand, and not always for the best of reasons as shown by this quote from Life on the Mississippi, (Clemens, 1874).

> "When the river is rising fast, some scoundrel whose plantation is back in the country, and therefore of inferior value, has only to watch his chance, cut a little gutter across the narrow neck of land some dark night, and turn the water into it, and in a wonderfully short time a miracle has happened: to wit, the whole Mississippi has taken possession of that little ditch, and placed the countryman's plantation on its band (Quadrupling its value), and that other party's formerly valuable plantation finds itself away out yonder on a big island; the old watercourse around it will soon shoal up, boats cannot approach within ten miles of it, and down goes its value to a fourth of its former worth. Watches are kept on those narrow necks at needful times, and if a man happens to be caught cutting a ditch across them, the chances are all against his ever having another opportunity to cut a ditch."

The Blackwater River was known in the 1800's as Blackwater Creek. It was a little meandering stream which had a north and south fork, both of which began in the northwest corner of Johnson County, and joined about 5 miles northwest of Warrensburg (Figure 1). It was a good sized creek with banks ranging from 40-100 feet wide. Old-timers in the county say the bottom was about 10-12 feet below bank level. Due to

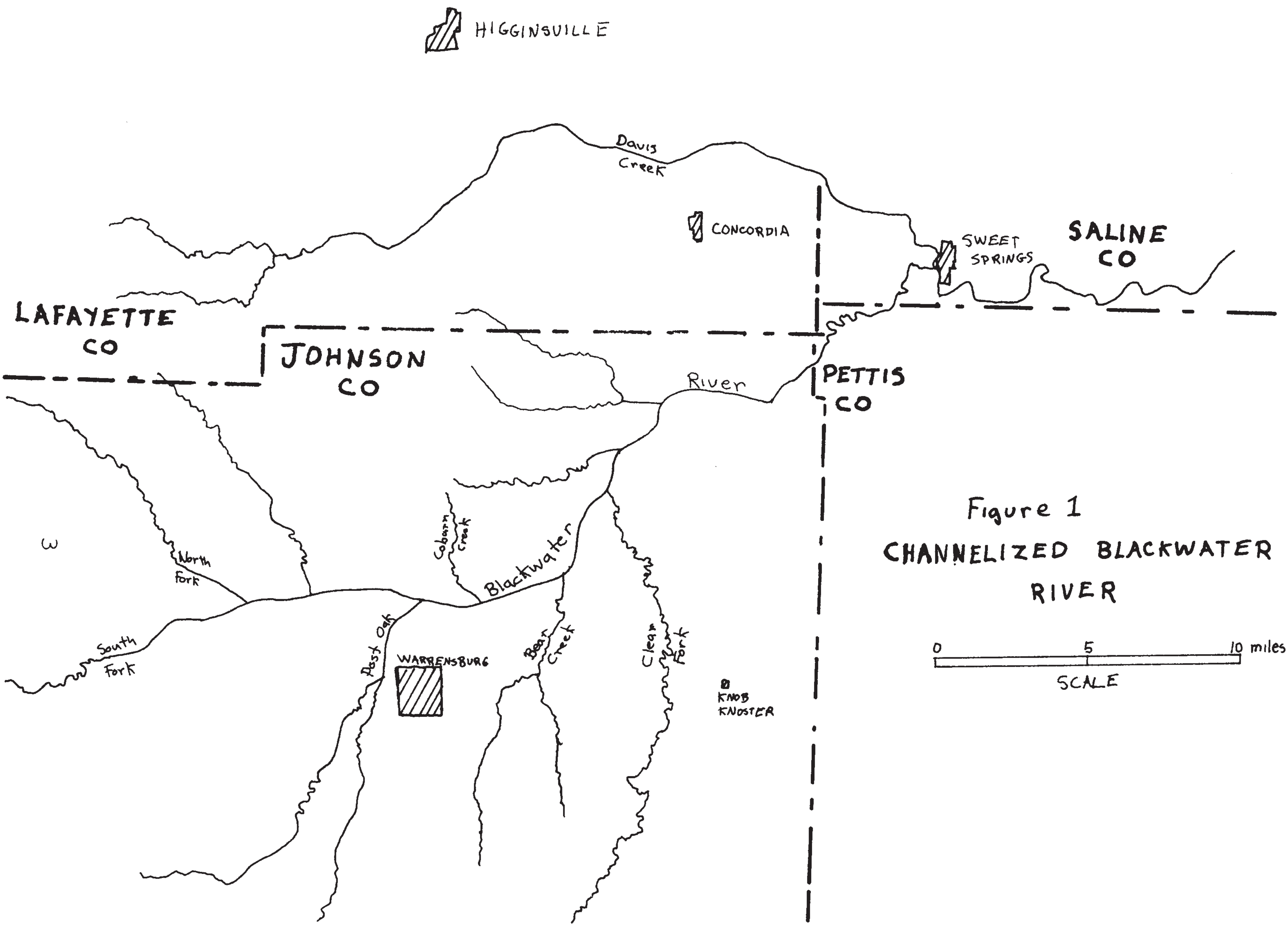

Figure 1
CHANNELIZED BLACKWATER RIVER

frequent flooding Blackwater Drainage District No. 1 was formed in 1909 and dredging continued for several years. Parts of both the north and south forks were straightened, as well as the main channel, nearly to the east county line. The lower reaches of the major tributaries were also diverted to lateral ditches. From the beginning of channelization on the south fork to the east county line, the original stream distance was 71.7 miles. The present ditch measures 29 miles for the same distance. The former gradient of .96 feet per mile was steepened to the present gradient of 2.3 feet per mile.

The drainage engineers' report called for a ditch about 30 feet wide, 12.5 feet deep, and 3 feet wide at the bottom, giving a cross section of about 200 square feet. The present channel of the Blackwater is 30-40 feet deep, 175-230 feet wide and has a cross sectional area ranging from 3000-5000 square feet in the central part of Johnson County.

The rate of downcutting in the alluvial deposits was rapid. The Blackwater River has cut down to bedrock a number of places near Warrensburg. Long-time county residents remember one of these bedrock riffles being exposed in the early 1930's, a period of only 15-20 years after channelization. The entrenchment was responsible for the equally rapid widening, due to slumping of the banks.

The engineer in charge of the project, apparently unaware of the propensity of drainage ditches to enlarge, planned 12 bridges across the new channel. The new bridges were of 50, 60, and 75 foot spans, similar to those across the old channel. Six of the 12 have been abandoned due to bed and bank erosion. The remaining six have either been replaced or have needed to be extended 40-60 feet on each end, and to have new vertical supports. A local farmer tells of one old bridge which collapsed and was replaced in 1930 by a chain bridge with a 90 foot span. That bridge was replaced in the early 1940's and again in 1947 by a bridge with a 245 foot span. This bridge, too, is now gone due to bank erosion.

Bridge and bank erosion problems are the usual occurrence along channelized streams. Ramser (1925) tells of a tiny ditch in Cape Giradeau County 4 feet deep and 16 feet wide at the top, which grew in two years to be 26 feet deep and 160 feet wide. Two successive railroad bridges were washed out due to the enlargement.

The dredged lower reaches of the tributary streams have also increased in size. Honey Creek, one such tributary, has gone from a cross-sectional area of 88 square feet when newly dredged to 2050 square feet today. Along the channelized portion of several tributaries, parts of the pre-dredging channels are preserved 8-12 feet above the present stream bed. In the unchannelized upper reaches of the tributaries, meanders have become entrenched. This condition is also evident in the unchannelized parts of the Blackwater.

Gully erosion adjacent to the entrenched streams is quite pronounced. One gully leading to a channelized Blackwater tributary, has eroded 75 feet headward since 1970.

Channelization did reduce flood stages and allow more bottomland to be utilized for farming. This benefit must be weighed against accelerated bank and gully erosion by the Blackwater and its tributaries, and the cost of bridge repairs. There are benefits from this change in stream regimen which accrue to the Quaternary geologist. Entrenchment to bedrock by the major streams in the county has exposed the Quaternary alluvial sequence in many places where these sediments would otherwise have been buried by recent alluvium.

The Blackwater Drainage Ditch was dredged nearly to the Johnson-Pettis County line. The Sweet Springs Drainage District attempted to continue the project eastward but with no success. At the Johnson-Pettis boundary and across into western Saline County, the flood plain is much more narrow due to a lithologic change from the dominantly clastic Pennsylvanian rocks to more resistant Mississippian carbonates. The channel sides change from Quaternary alluvium to limestone bedrock. The Sweet Springs district could not afford the cost of blasting a new channel so the project was abandoned. As a result, the Blackwater follows its old meandering course at the county line.

The combination of a meandering channel and a small cross-section cause a reduction in velocity which results in channel and floodplain sedimentation. The improved reach of the Blackwater has a capacity of 10,000-30,000 cubic feet per second, whereas the downstream reaches in Pettis and Saline Counties have a capacity of 6,000-9,000 cubic feet per second. (Army Corps of Engineers, 1960). The spring floods recorded by the Blackwater gage in northeast Johnson County have maximum discharges of 20,000-60,000 cubic feet per second. A number of public hearings held by the Corps of Engineers in the 1940's indicated that flooding in Saline County had greatly increased since channelization and that the lower end of the new channel is slowly being reduced in size by channel sedimentation which is progressing upstream. At present, about 45 miles of riparian property is affected by flooding.

The amount of floodplain deposition in adjacent parts of Johnson, Pettis, and Saline Counties has been considerable. A local farmer stated that during the 35 years he lived along the Blackwater in northeast Johnson County, two successive generations of fence posts were buried. A friend of his hunted that land in the early 1900's and often shot racoons from the crotch of a sycamore tree. That fork of the tree was 10-12 feet above the ground then, but is now only 2 feet above ground level due to floodplain aggradation.

The problem of flooding in the Sweet Springs area is exerbated by the fact that Davis Creek enters the Blackwater at Sweet Springs. Davis Creek was also channelized at its upper end, had a great increase in channel dimensions, and has deposited the results of this upstream erosion in the lower part of the channel near Sweet Springs.

To summarize, the Blackwater River has behaved just as channelized streams always do. It is attempting to re-establish a natural equilibrium which was upset when the gradient was steepened. It is going about this process by eroding in the upstream reaches and depositing in the downstream reaches and thereby attempting to achieve something like its former gradient.

When does the channel re-stabilize? Because the channel has been cut to bedrock near Warrensburg for many years, the gradient is not being changed appreciably in this portion. Is the river now trying to widen or resume meandering since it cannot deepen? Will the channel sedimentation continue to advance upstream? Fluvial geomorphologists are not yet able to answer such questions.

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DEFORMATION OF DESMOINESIAN STRATA ADJACENT TO THE WARRENSBURG CHANNEL-FILL SANDSTONE

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Recent field mapping of the Warrensburg Sandstone in the area adjacent to and south of Warrensburg has revealed some interesting features which have apparently escaped notice in the past. The Warrensburg Sandstone bifurcates to form two channels just south of Warrensburg (Figure 1). The east channel is apparently the one shown on the geologic map of Missouri. Whether these channels rejoin farther south is not presently known. Another interesting aspect discovered during field mapping is that the Desmoinesian strata truncated by the channel-fill sandstone are, in some areas, steeply dipping immediately adjacent to the sandstone.

Strata in the Warrensburg area have long been considered to be essentially horizontal. The only mention in the literature of steeply dipping beds in this area is by Hinds and Greene (1915) who reported seeing on the west edge of the town of Warrensburg (sec. 26, NW corner) ". . .two beds of limestone dipping at a high angle and overlain by arenaceous channel deposits." As shown in Figure 1 this is but one of several west dipping exposures striking essentially parallel to the north-south trend of the channel contact. This trend is continuous for at least three miles. Other structural trends bordering the channel sandstone are shown in Figure 1.

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*Presently employed by Phillips Geothermal Division, Del Mar, Calif.

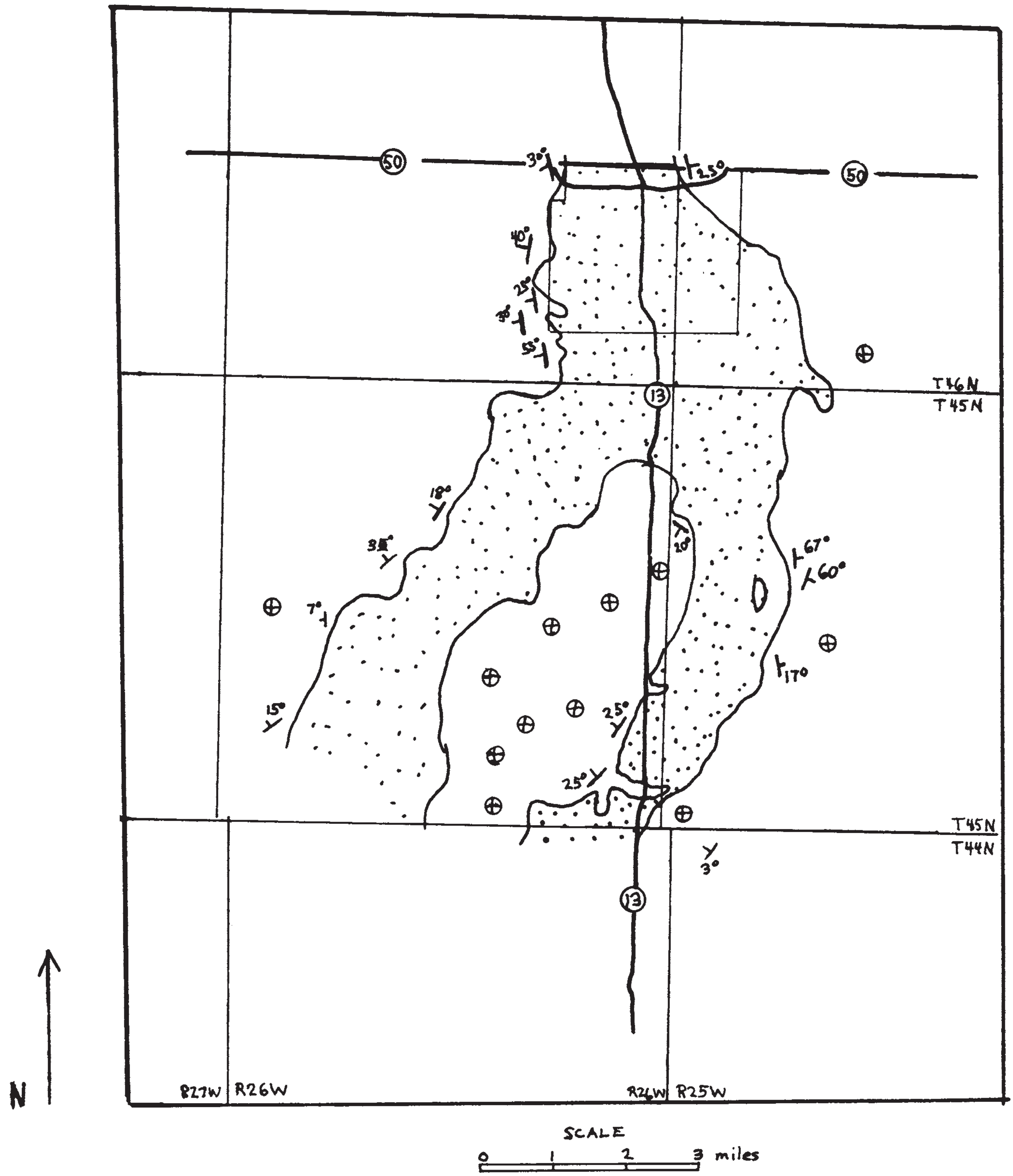

Figure 1 - STRUCTURES ADJACENT TO THE WARRENSBURG SANDSTONE

Any explanation for the origin of the deformation adjacent to the channel sandstone should be compatible with the following observations:

1. Steep dips in Desmoinesian strata are observed only near the contact with the channel sandstone and in several places the dip of the strata becomes progressively less steep away from the channel.

2. By far, most dips are away from the channel sandstone and resultant structures are therefore monoclinal.

3. The sandstone, where massive bedded, is essentially undeformed. Thin bedded sandstone (mainly near the base) is highly deformed in some places. Immediately east of the Holiday Inn (intersection of highway 13 and U.S. 50) thin bedded Warrensburg Sandstone is in vertical fault contact with Desmoinesian shales and coals. Both units are, at that location, highly incompetent and extremely deformed.

4. Within a very short distance from the sandstone contact, steep dips give way to regional structure. East of Warrensburg folds trend N to NNE with dips of 5^{o} or less. West of Warrensburg insufficient structural data have been accumulated to make any generalization except that dip angles are very slight.

One model which would seem to explain the above observations is shown in diagrammatic cross section in Figure 2. Regional compression with an east-west component produced broad open folds in this part of Missouri with maximum dips of about 5^{o}. The Desmoinesian strata cut by the channel sandstone are predominantly shales, coals and thin limestones, though some massive limestone units are present. The Warrensburg Sandstone, for the most part, acted as a rigid wedge and consequently underwent very little lateral shortening under regional compression. Deformation of Desmoinesian strata against the rigid sandstone acted to rotate upward the edges of the strata truncated by the channel sandstone as shown in Figure 2.

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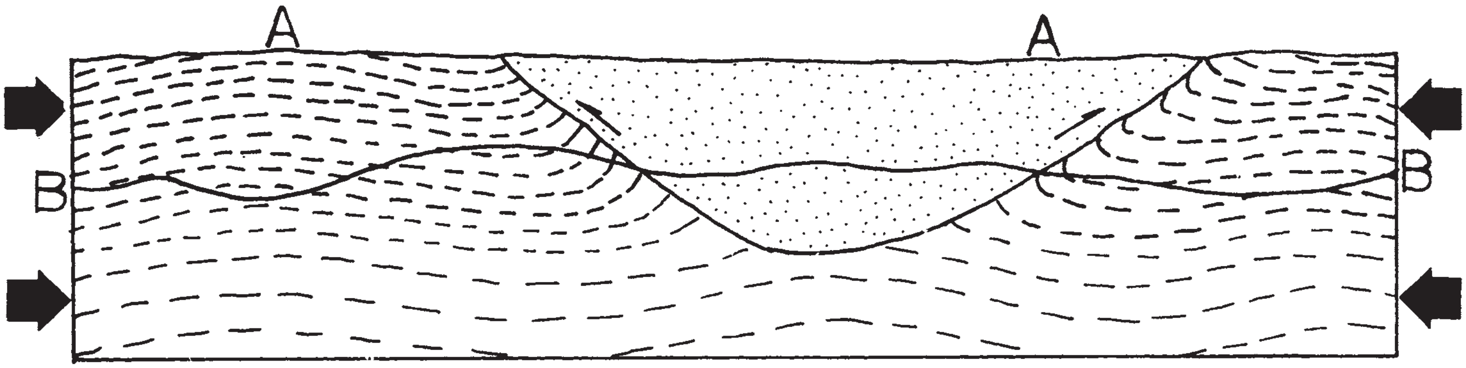

Figure 2 - DIAGRAMMATIC CROSS SECTION SHOWING PROPOSED MECHANISM OF DEFORMATION AT THE MARGINS OF THE CHANNEL SANDSTONE.

"A" - indicates former land surface.
"B" - indicates present land surface.
Arrows indicate direction of compression.

WARRENSBURG SANDSTONE REVISITED

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General Statement

The Warrensburg Sandstone is a Pennsylvanian channel-fill deposit which crops out from the Missouri River southward for over 50 miles in Lafayette, Johnson, and Henry Counties (Figure 1). Its outcrop width is about 5 miles at the Missouri River and generally 1-1.5 miles elsewhere. Numerous investigators have considered the Warrensburg to be a part of the river system which deposited the east-west trending Moberly channel in Chariton, Randolph, and Monroe Counties.

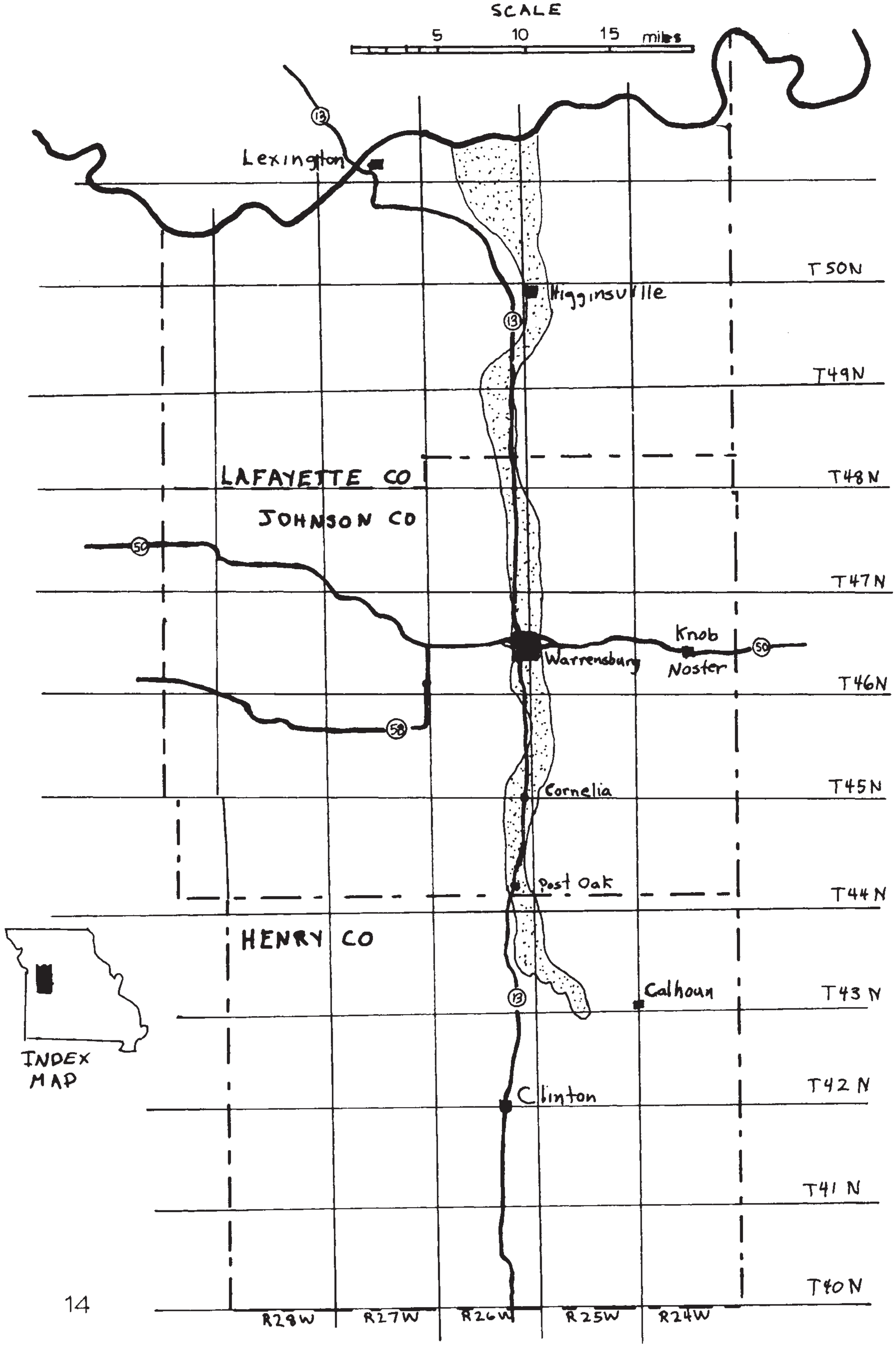
Previous Studies

The Warrensburg Sandstone was named by Winslow (1896) in his report on the Higginsville Sheet. He considered it a channel-fill on the basis of: a. great thickness; b. long narrow outcrop pattern; c. superposition on the middle coal measures; d. inclusion of fragments of adjacent rocks. He noted that the channel bifurcated at the Missouri River and formed an island of Middle Coal Measures surrounded by arenaceous deposits. The Warrensburg was noted in earlier reports by Swallow (1855) and by Broadhead (1873) but its channel-fill nature was not recognized.

Marbut (1898) in his report on the Calhoun Sheet (Henry Co.) described Warrensburg outcrops but did not use the name or map it as

Figure 1 - WARRENSBURG SANDSTONE OUTCROP

(From Geologic Map of Missouri, 1961)



a separate unit. He did recognize and map the Warrensburg Sandstone in his geologic studies of the Lexington Sheet, and the Ray and Carroll County Sheets (1896). Hinds and Greene (1915) studied the Warrensburg Sandstone and defined the approximate southern limit of outcrop as shown on the 1912 Geologic Map of Missouri. As the present State Geologic Map has the same outcrop pattern, I presume most of the areal mapping was done in the early 1900's. The formation was studied in Johnson County by Kos (1942) and Bowman (1962). Warrensburg Sandstone petrology was examined in detail by Rayl (1952), Doty (1960), and Doty and Herbert (1961).

Age Assignment

The Warrensburg Sandstone, Moberly Sandstone, and numerous other channel sandstones were assigned to the Pleasanton Group (Lower Missourian) by Hinds and Greene (1915). Howe (1948) and Greene and Searight (1949) considered channel sandstones in Jackson County a part of the Marmaton Group (Upper Desmoinesian) and designated them equivalent to the Warrensburg. Currently Howe (1961) has assigned the Warrensburg Sandstone to the lower part of the upper unnamed formation of the Pleasanton Group.

The problem of exact age assignment is extremely difficult because both the Desmoinesian and Missourian Series contain numerous channel deposits. Rock has not been found overlying the Warrensburg Sandstone in Lafayette, Johnson, and Henry Counties, therefore an upper age limit is difficult to assess. The channel deposits in Johnson County are disconformable with Cherokee and Marmaton (Desmoinesian) strata.

Similar Deposits in Other Parts of Missouri

Other channel sandstones considered by Hinds and Greene (1915, p. 103-106) to be Pleasanton in age are described from Schuyler, Boone, Monroe, Macon, Lynn, Livingston, Mercer, Grundy, Adair, Platte, Randolph, Sullivan, and Vernon Counties. They also mentioned channel sandstones in older Desmoinesian strata from Howard, Lawrence, Christian, Greene and Dade Counties. Gentile (1965) mapped two Pennsylvanian valley-fill deposits in Bates and Vernon Counties and found that they trended north-south with a south paleocurrent direction. Jackimovicz (1970) found these two channels to be similar to the north-south trending Englevale (Pennsylvanian) Sandstone in Vernon County, Missouri, and Bourbon and Crawford Counties, Kansas.

Current Studies

This section is something of a plea for a consideration of "old time" areal mapping, which has been rather in disrepute as a thesis and dissertation subject. To prepare for this meeting, I examined a number of theses and dissertations, in the areas of stratigraphy and sedimentation, done in and around Johnson County by students from the University of Iowa and the University of Missouri. None of these studies noted the field relationships between the particular rock unit(s) they were interested in and the adjoining rocks and nearly all samples were taken at road cuts, roadside gullys, or in quarrys. There is a lot of interesting geology these fellows missed by not walking cross-country between the section-line roads.

The west branch of the Warrensburg Sandstone in Johnson County was first noted in an undergraduate term paper (Edgar, 1967). This western channel had not been reported in other studies even though one of them (Bowman, 1958) contained a geologic map of the Centerview Quadrangle which is traversed by the west branch. Current mapping clearly demonstrates that the main channel bifurcates south of Warrensburg (Figure 2), and that the west (Centerview Quadrangle) channel is as thick and extensive as the east (Cornelia Quadrangle) channel. Both channels are obviously valley-fills deposited in wide bedrock valleys. It is apparent that many of the modern streams are excavated in the old channel fills. The deeper of the modern streams have cut through the Warrensburg Sandstone and exposed the underlying strata. Geologic cross-sections show that the western valley was entrenched to a lower elevation than was the eastern one (Figure 3). The southern limit of the west channel has not been mapped yet but it appears that it may rejoin the main channel a short distance north of the Johnson-Henry County line.

The abundant structural deformation of Cherokee and Marmaton rocks along the Warrensburg outcrop belt in Johnson County has likewise been ignored: "Dips of Pennsylvanian strata due to tectonic structural movements are so low that they rarely are measurable in any one locality" (Doty and Herbert, 1962, p. 11). Hinds and Greene (1915, p. 96) are apparently the only geologists to have noticed steep dips adjacent to the Warrensburg Sandstone in Johnson County. Hinds and Greene (1915, p. 202-206) commented on the very general nature of their structure contour map showing the very large northwest-southeast trending folds and stated that these folds are so gentle they do not have definite axes. They did say, however, that "many small areas may show marked folding and faulting. Faulted, slickensided, and steeply dipping

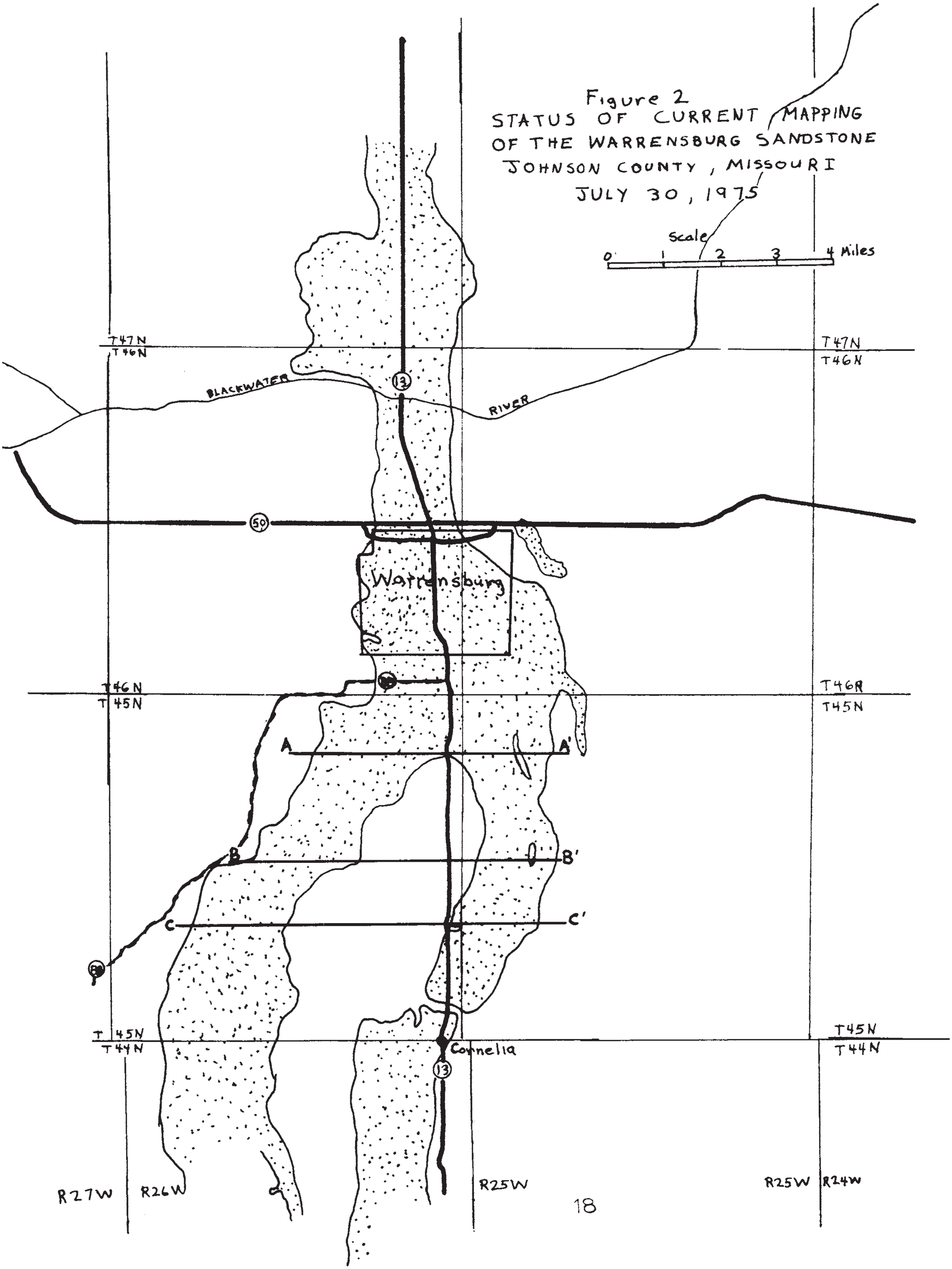


Figure 2
STATUS OF CURRENT MAPPING
OF THE WARRENSBURG SANDSTONE
JOHNSON COUNTY, MISSOURI
JULY 30, 1975

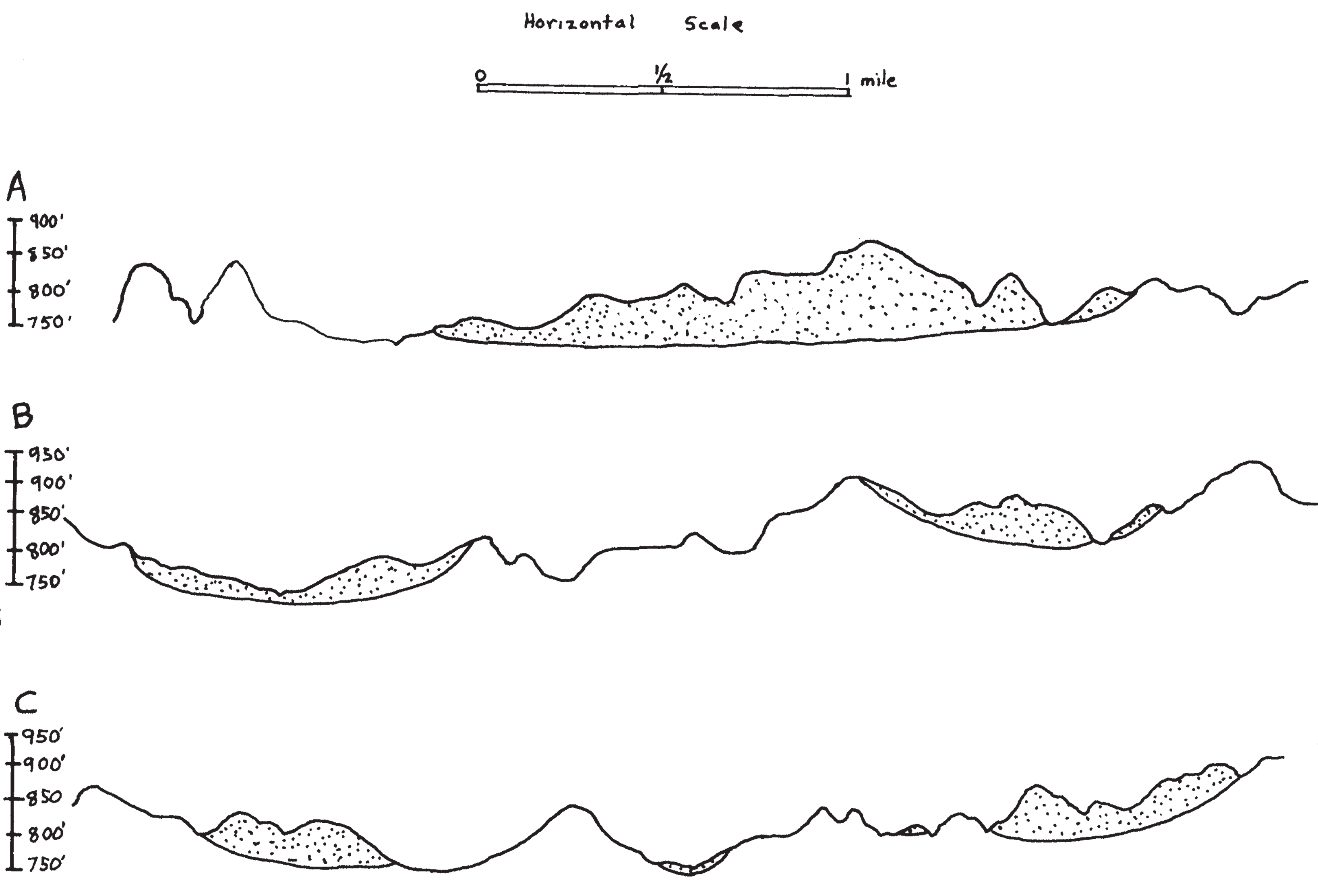


Figure 3 - CROSS SECTIONS OF WARRENSBURG SANDSTONE

Pennsylvanian coal, shale, and limestone are common in Missouri and have been noted in Bates County (Gentile, 1968), Miller County, (Ball and Smith, 1903), Moniteau County (VanHorn, 1905), Morgan County (Marbut, 1907), and Boone County (Unklesbay, 1952).

Current mapping has covered the Warrensburg East, Warrensburg West, Cornelia, Centerview, and part of the Chilhowee 7.5 minute quadrangles. In all these quadrangles, deformation of Desmoinesian strata adjacent to the Warrensburg Sandstone is very marked. Both folding and faulting are the rule rather than the exception along the contact between the approximate east and west boundaries of the Warrensburg channel deposits and the older rocks. In all places observed, the older rocks dip away from the Warrensburg most steeply near the contact and dip less at greater distances from the channel deposits.

Field observations have caused me to concur with the opinion of Beall, (1975, this Guidebook), that the channel-fill acted as a rigid block during regional compression and that only the thin outer edges of the Warrensburg were deformed. Thrust faults and faulted chevron folds in the Mississippian rocks of the Weableau area demonstrate Late Paleozoic tectonic compression in western Missouri, (Beveridge, 1951). In numerous places in Johnson County, the Warrensburg is faulted against older rocks so at least part of the deformation occurred after deposition of the valley-fill deposits. The four-mile long, north-south contact zone along the west side of Warrensburg is marked by faulted, westward dipping limestones and shales and many spring areas, among them Pertle Springs, Spring Valley, Spring Ridge, Spring Branch, and Electric Springs. The first and last of these springs were resort areas in the early 1900's.

A search of the Missouri geological literature revealed areas where deformation similar to that in Johnson County has been reported. Just east of Butler, Bates County, valley-fill sandstone and conglomerate unconformably overlies the Higginsville Limestone. The valley-fill deposits are almost horizontal whereas the Higginsville Limestone dips about 23 degrees southward (Jackimovicz, 1970). Hinds and Greene (1915, p. 104) noted an outcrop of conglomeratic sandstone unconformably overlying Desmoinesian rocks near Woodland Mills, Lynn County. A few hundred yards southeast there are beds of limestone and sandstone dipping at 80 degrees. They also observed channel sandstones involved in folding with Missourian limestones in Livingston County. Unklesbay (1952) remarked on a channel sandstone which overlay the upturned edges of the Myrick Station Limestone (Upper Marmaton) in Boone County.

It seems possible that the authors of the numerous papers on Oklahoma, Kansas, Missouri, and Illinois channel deposits have noted such deformation but did not include that information because the papers deal primarily with sedimentation and paleogeography.

Warrensburg Sandstone Petrology

The Warrensburg Sandstone is a typical fluvial deposit in that it contains quartz, mica, clay, and organic debris. It can be classified as a subgraywacke or quartz wacke.

A basal conglomerate is usually found. The clasts range from granule to boulder size and are composed of pieces of siltstone, coal, sandstone, and especially large blocks of limestone with abundant *Chaetetes*. Ironstone concretions are plentiful, and pea-sized, white quartz pebbles are not uncommon. Some outcrops contain several conglomerate layers. These coarse conglomerate deposits are quite similar to the coarse sediments found in modern gravel bars along the Blackwater and its tributaries wherever these streams are undercutting ledges of Cherokee or Marmaton limestones.

Very-fine to medium-grained sandstone makes up the bulk of the Warrensburg. It is commonly cross-bedded and also has current ripple marks, although the latter are not as abundant. The cross-beds generally dip towards the south, southwest or southeast. Flattened clay balls, minute coal fragments, and ironstone concretions are common along bedding planes. The principal cements are calcite and iron oxide although siliceous cement is not uncommon; matrix is clay and iron oxide. Marcasite concretions and silicified wood are abundant in the Warrensburg area.

Quartz is the principal mineral (50-85 %) of the sandstone. Doty (1961) reported up to 10% muscovite, and up to 10% feldspar, principally orthoclase. Both Doty (1961) and Rayl (1952) reported tourmaline, zircon, garnet, and rutile to be the common accessory minerals. Opaque minerals comprise from 5-15% of the sandstones.

Siltstones and shales are common in the Warrensburg channel deposits although they are not as well exposed due to their greater susceptibility to weathering.

Thickness of the Warrensburg Sandstone in Johnson County is variable. Richard Gentile (U.M.K.C.) logged a missile site core 5 miles north of Warrensburg which showed 102.5 feet of sandstone and bottomed in conglomerate. The several sandstone quarrys north of Warrensburg are water filled now but had working faces of 45-55 feet.

One small quarry at a lower elevation, is dry, has a 15 foot working face, and a limestone base at about 720 feet elevation. Three miles southeast of Warrensburg, Gentile logged 45 feet of Warrensburg in a missile site core. This location was at the west edge of the east branch of the Warrensburg channel (Cornelia Quadrangle). A measured section one-half mile east of the missile site has 13 feet of conglomerate overlain by 45 feet of sandstone. The maximum thickness found in the west channel (Centerview Quadrangle) is 80 feet. Maximum thickness of the sandstone in the Warrensburg area apparently ranges from less than 50 to more than 100 feet.

Conclusion

The present study of the Warrensburg Sandstone in Johnson County encompassed the period May-July, 1975 and has uncovered a number of interesting facets of: Warrensburg areal distribution and geometry; structural geology of Johnson County; and local variations in the Desmoinesian stratigraphic section. The stimulus provided by discoveries made during preparation of this guidebook will result in continued study of Pennsylvanian strata by Central Missouri State University staff and students.

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QUATERNARY STRATIGRAPHY AND GEOMORPHOLOGY OF NORTHEASTERN JOHNSON COUNTY, MISSOURI

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General Statement

The Blackwater drainage basin in Johnson County covers 600 square miles. It contains 1333 first order streams, 290 second order, 50 third order, 14 fourth order, 2 fifth order, and the Blackwater becomes a sixth order stream where joined by Clear Fork (Figure 1). The north and south forks originate at 1050 feet elevation and the stream leaves the county at elevation 650 feet. Floodplain width is .5-2miles for the Blackwater and a maximum of 1 mile for its largest tributaries. Channelization of the Blackwater in the early 1900's (Emerson, 1971) caused entrenchment to bedrock in the drainage basin.

Topographic Surfaces and Stream Terraces:

The highest surface in this area, from 900-940 feet elevation, is carried along the Clear Fork and Bear Creek divides by long narrow ridges. This surface is preserved in the two monadrocks for which Knob Noster is named. Generally this surface is underlain by limestone of the Marmaton Group (Higginsville or Pawnee), although a small area is formed on Warrensburg Sandstone. A second surface (elevation 840-880 feet) is formed on Warrensburg Sandstone or limestone. There is a third at 790-820 feet elevation which is also underlain by either

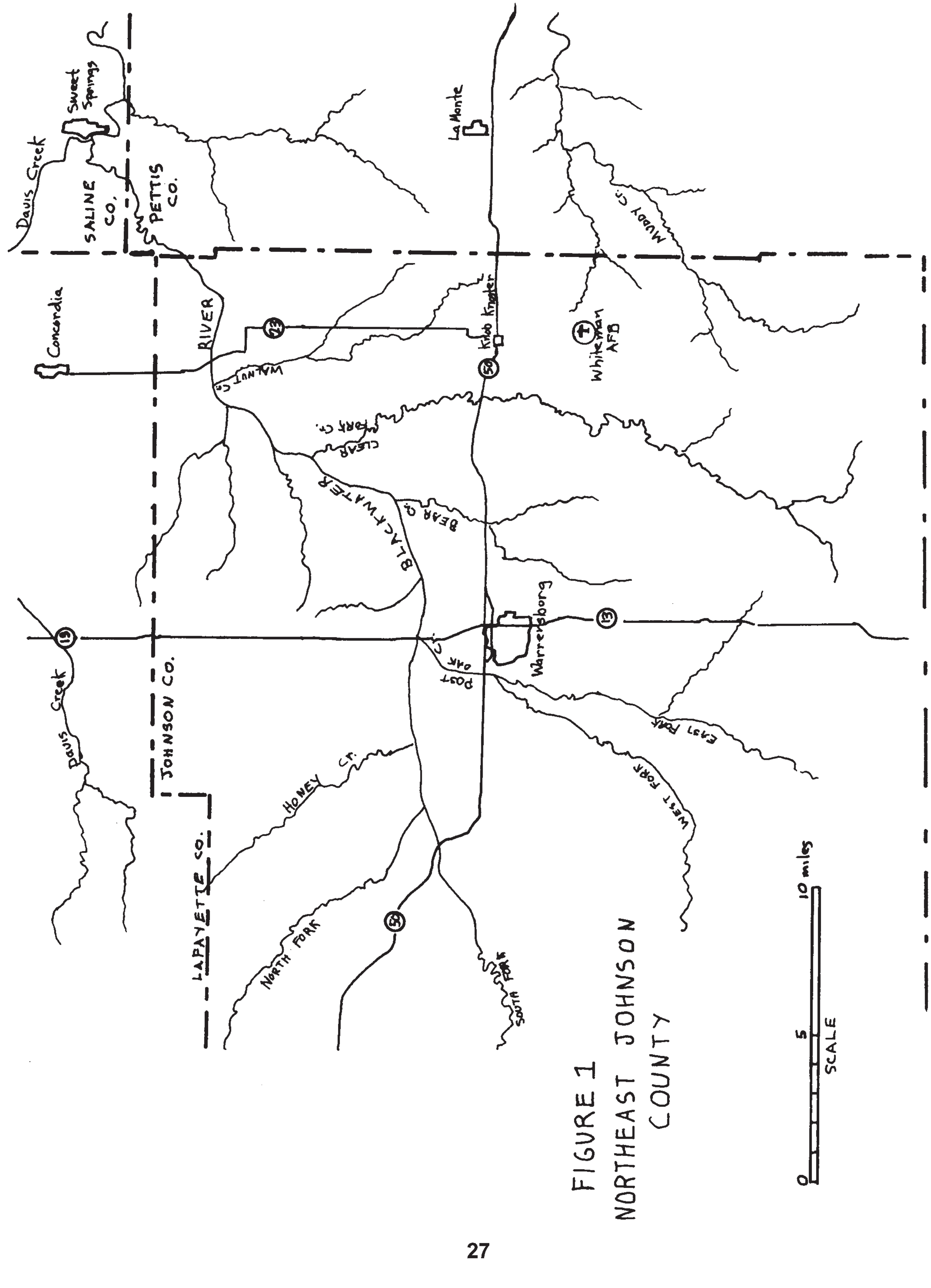

FIGURE 1
NORTHEAST JOHNSON
COUNTY

Warrensburg Sandstone or Marmaton limestones.

There are generally 3 alluvial terraces preserved. The first terrace (T_o) is formed by the pre-dredging channel of the streams and is preserved in many places along the Blackwater River and its tributaries. The distance from the streambed to T_o is 8-12 feet for the tributaries and more than 20 feet for the master stream. A second terrace (T_1) is formed by the present broad floodplains, 6-10 feet above T_o. A third alluvial terrace (T_2) is 15-30 feet above the floodplain.

In studying the stream terraces, I came to the conclusion that streams of similar order and local geology respond in a similar manner to base level changes. Two examples will illustrate this point. Two Bear Creek second order tributaries, a township apart, each have three alluvial terraces with a T_o height of 3 feet, T_o-T_1 of 6 feet, T_1-T_2 of 6-7 feet, and 28-29 feet to a surface formed on Warrensburg Sandstone. A second example involves a former channel of the South Fork of the Blackwater. It has an 11 foot deep channel incised in T_o and the T_o-T_2 distance is 7 feet, T_1-T_2, 6.5 feet. Colburn Creek, at its dredged lower end has similar distances; stream bed - T_1 11 feet, T_o-T_2 6.2 feet, T_1-T_2 5.9 feet.

In summary, this area has 3 Quaternary alluvial terraces and 3 topographic surfaces of unknown age. Undoubtedly there are other buried bedrock surfaces and alluvial terraces covered by the present floodplains. I would hesitate to call the 3 surfaces peneplains although they do meet the criteria required by Thornbury (1954, p. 184) that "its low relief surface truncate strata of varying resistance to weathering and erosion." Bretz (1965, p. 53, 125) correlated the highest surface (900-940 feet elevation) with the Springfield peneplain, the lower surface (790-820 feet elevation) with the Ozark peneplain, and the Blackwater floodplain (650-700 feet elevation) with the Osage strath.

<u>Bedrock Channels</u>

Bedrock is exposed 30-50 feet below the floodplain along the Blackwater River in the Warrensburg area. These observed depths are somewhat misleading in that seismic refraction profiles on the floodplain indicate the presence of channels incised as much as 25 feet below the general bedrock level. Six bridge sounding logs for the new Highway 13 bridge over the Blackwater all indicate a bedrock elevation of 650 feet. Soundings for the Highway 50 bridge over South Fork 6.5 miles west of Warrensburg show a different picture. Bedrock elevation on the west end of the 300 foot bridge is 695 feet and is 675 feet on the east end. Soundings for a tributary bridge on the same floodplain indicate bedrock elevation of 670 feet. Floodplain elevation here is 720-730 feet. The Highway 23 bridge soundings show a range of bedrock elevation from 600 feet to 637 feet and a 660 feet floodplain elevation. These 20-37 foot differences in bedrock elevation in horizontal differences of only 300-400 feet indicate considerable relief on the bedrock floor.

It is interesting to speculate on the gradient of the stream (Pleistocene?) which carved the bedrock channel. The minimum elevation at both bridges gives a relief of 70 feet. Present valley distance is 18.7 miles; present stream distance 19.7 miles, and the old Blackwater distance was 46.2 miles between bridges. It is unlikely that this ancient river would have been as straight as the present ditch and probable that a glacier-fed stream would have had a greater discharge, a larger meander radius, and therefore be shorter than the old Blackwater between these two points. It is suggested that the ancient river may have had a gradient between 2-3 feet per mile. The present ditch has a 2.2 feet per mile gradient for the same distance. Modern Blackwater gravel bars contain pebble-to-cobble size rocks and it is likely that the ancient stream had the same or even greater competence. Most bridge sounding logs report "boulders" at the base of the channel fill. The maximum thickness of Blackwater alluvium shown by logs is 60 feet. Seismograph investigation of the floodplain is now being conducted to ascertain if even thicker deposits exist in deep bedrock channels.

Floodplain Deposits

Riffles in the present streams run over Pennsylvanian bedrock or a dense gray, silty Pleistocene clay which is resistant to erosion and contains many potholes similar to those formed in hard rock. This basal Pleistocene deposit is 0-10 feet thick in tributary valleys. Bridge sounding logs from the Blackwater floodplain indicate 10-20 feet of this basal clay; adjacent seismic profiles show even thicker deposits of this very distinctive unit (seismic velocity 4500 feet per second). Munsell color is medium light gray (5Y 6/1) to light olive gray (5Y 6/2) when wet; light gray (5Y 7/1 dry). It contains 10-15% very fine sand, 20-35% silt, and the remainder is clay. Along the tributary streams, laminations of sand-sized coal flakes are the only bedding structure apparent. Abundant bright blue nodules are present at one locality on the Blackwater. The texture and geometry of the basal "blue clay" led me to believe it is lacustrine and was formed by glacial ice damming the Blackwater downstream and ponding the river and its tributaries.

The "blue clay" may not be present locally due to stream erosion after the lake deposits had been formed. Along the valley sides the "blue clay" is unconformably overlain by a thick sequence of cross-bedded alluvial sands and gravels. Numerous channels incised in the "blue clay" have been observed. This second Pleistocene deposit is called the yellow banks locally due to its color (brownish yellow, 10YR, 6/6), and the fact that it forms a distinctive terrace 15-30 feet above the present floodplains. This terrace is carved into a series of valley spurs projecting into the floodplain and grading upward into bedrock interfluves. This formation is characteristically extremely well indurated and both the sands and the gravels resist a normal mattock blow. The sand layers are largely fine-medium, sub-angular quartz. They are cross-bedded and range in thickness from .5-5 feet (At one locality on Bear Creek, a second, 2 foot thick blue-gray clay is conformable between sand layers.) The gravels are composed of locally derived pebbles and cobbles of siltstone, sandstone, shale, coal, and limestone, abundant Chaetetes fragments and ironstone concretions. These gravels may be stained black by iron and manganese oxides. The gravels display cut-and-fill structure and steep cross-bedding which generally dips in the direction of present stream flow. The upper portion of the Yellow Banks is generally composed of loess or loess-like sediment. Maximum observed thickness of this unit is 40 feet.

The lower slopes of the valley spur terraces (T_2) are overlapped by the dark-to-brown alluvium which comprises the present floodplains. The recent alluvium is 8-20 feet thick.

Yellow banks alluvium has a seismic velocity ranging from 1300-1800 feet per second and can be distinguished in subsurface from the younger alluvium which has a velocity of 700-1300 feet per second.

Lithic artifacts ranging from Paleo-Indian through Recent are often found on the yellow bank terraces adjoining the streams.

Quaternary Fossils

Although vertebrate fossils are undoubtedly abundant in Johnson County they have been reported from only a few localities. A fossil bison atlas vertebrae was found on a Blackwater gravel bar. There are three spring bog sites known from Blackwater terraces. Two sites near the Pettis County line were excavated deeper during a dry summer in the early 1930's and mastodon bones, teeth, and other "strange" bones were discovered. The teeth are now in the State Museum in Jefferson City. The other site, west of Warrensburg is a spring bog on a high Blackwater terrace. Large bones were discovered during excavation in the late 1930's. Vertebrate fossils in spring deposits are very common in this region. Broadhead (1881) described the excavation of a spring near Sedalia which yielded 8 mastodon skeletons. Meek (1873) stated that abundant bones and teeth of mastodons were found in springs along the banks of a Blackwater tributary near Sweet Springs.

These spring bog sites on terraces of the Blackwater and its tributaries are similar to springs excavated in the Pomme de Terre valley. King (1973) reported fossil horse, giant beaver, mastodon, deer, and tapir from these deposits. Haynes (In press) described three alluvial terraces on which these springs were located. The highest terrace was radiocarbon dated between 40,000-30,000 B.P.; the lowest terrace contained spruce logs dated 16,600 B.P.; and mastodon tusks dated 13,500-13,700 B.P.

Fossil wood is very common along the streams. Branches and logs up to 1 foot in diameter occur from 5-20 feet below present floodplain levels. The lowest occurrences are in the dark blue-gray, very dense clay. The wood has not been dated yet, but is believed to be late Pleistocene or Recent. No wood has been found in the higher terrace (yellow banks) although it is undoubtedly present.

Whiteman Uplands

Whiteman Air Force Base is south of Knob Noster adjacent to the Johnson-Pettis County line. The base site is very low relief; more than one square mile is between 830-840 feet elevation. The base is rimmed on the north, south and west by low hills rising to a maximum 900 feet elevation. The natives called the area "Old Blue Flats" before the base was constructed. The very level portion is underlain by 20-40 feet of silty clay which is light olive gray (5Y 6/2) when wet and light gray (5Y 7/2) dry. The average of 10 hydrometer analyses gives a composition of 22% sand, 30% silt, and 48% clay. This clay has been reported in borings and was studied in a drainage ditch, 20 feet deep, along the southwest base perimeter. The ditch continues east from the base and becomes a tributary to Muddy Creek. Fifteen feet of clay was observed on the west perimeter of the base (elevation 825 feet), during construction of a new sewer line.

A section measured at another site on the west side of the base where a west flowing tributary of Clear Fork Creek has entrenched to limestone bedrock (elevation 790 feet). The bedrock surface is disconformably overlain by 15 feet of well indurated sand and gravel similar in texture and composition to the yellow banks deposits. The sands and gravels were overlain by gray silty clay.

Seismic refraction profiles on the south side of the base indicated the average velocity of the clay was 4700 feet per second; depth to limestone bedrock was 46 feet.

This silty clay deposit is considered to be a Pleistocene lake deposit. It resembles upland clays described in Saline County by Meek (1873), similar deposits on the Sedalia West Quadrangle noted by Agee (1954), and the Ferrelview Formation described by Howe and Heim (1968). The very low relief upland topography underlain by Quaternary deposits continues from Whiteman northeast through the La Monte area in Pettis County. Preliminary seismic and sedimentologic studies are now being made on Quaternary deposits on the La Monte Uplands. Well logs from the city of La Monte show 25-30 feet of yellow silt and clay on Pennsylvanian bedrock.

Johnson County in Relation to the Glacial Margin

The 1961 Geologic Map of Missouri indicates the southern limit of glaciation a short distance north of the Johnson-Lafayette County line. C. D. Holmes (written communication, 1974) was informed of glacial erratics being found near Concordia. I have examined striated limestone bedrock 1 mile south of Concordia (4 miles north of the Blackwater). An Army Corps of Engineers log from a well 1 mile east of Concordia indicates 10-18 feet of Quaternary deposits. The lower portion is residual, the upper is glacially associated material.

Summary of Quaternary Alluvial History

The sequence of Quaternary events as presently interpreted by me is as follows:

1. Carving of the bedrock valleys
2. Ponding of the Blackwater and its tributaries; deposition of the "blue clay"
3. Entrenchment to bedrock by streams which flowed across the basal clay
4. Aggradation of more than 40 feet of yellow banks alluvial and colluvial sands and gravels grading upward into loess
5. Stream and gully erosion; carving of sloping valley spurs from the yellow banks by meandering streams. Possible entrenchment to bedrock again
6. Aggradation of alluvium to present floodplain levels. The basal part of the yellow banks spurs were buried by the alluvium except where meanders cut against the banks.
7. Channelization caused entrenchment to bedrock once more and exposed the Quaternary alluvial sequence.

The deposits in the valleys of the Blackwater River system in Johnson County may be as young as Wisconsin or as old as Kansan. Due to the high level of the Quaternary deposits near Whiteman Air Force Base, a Kansan age appears more likely. Obviously much work remains to be done in this region.

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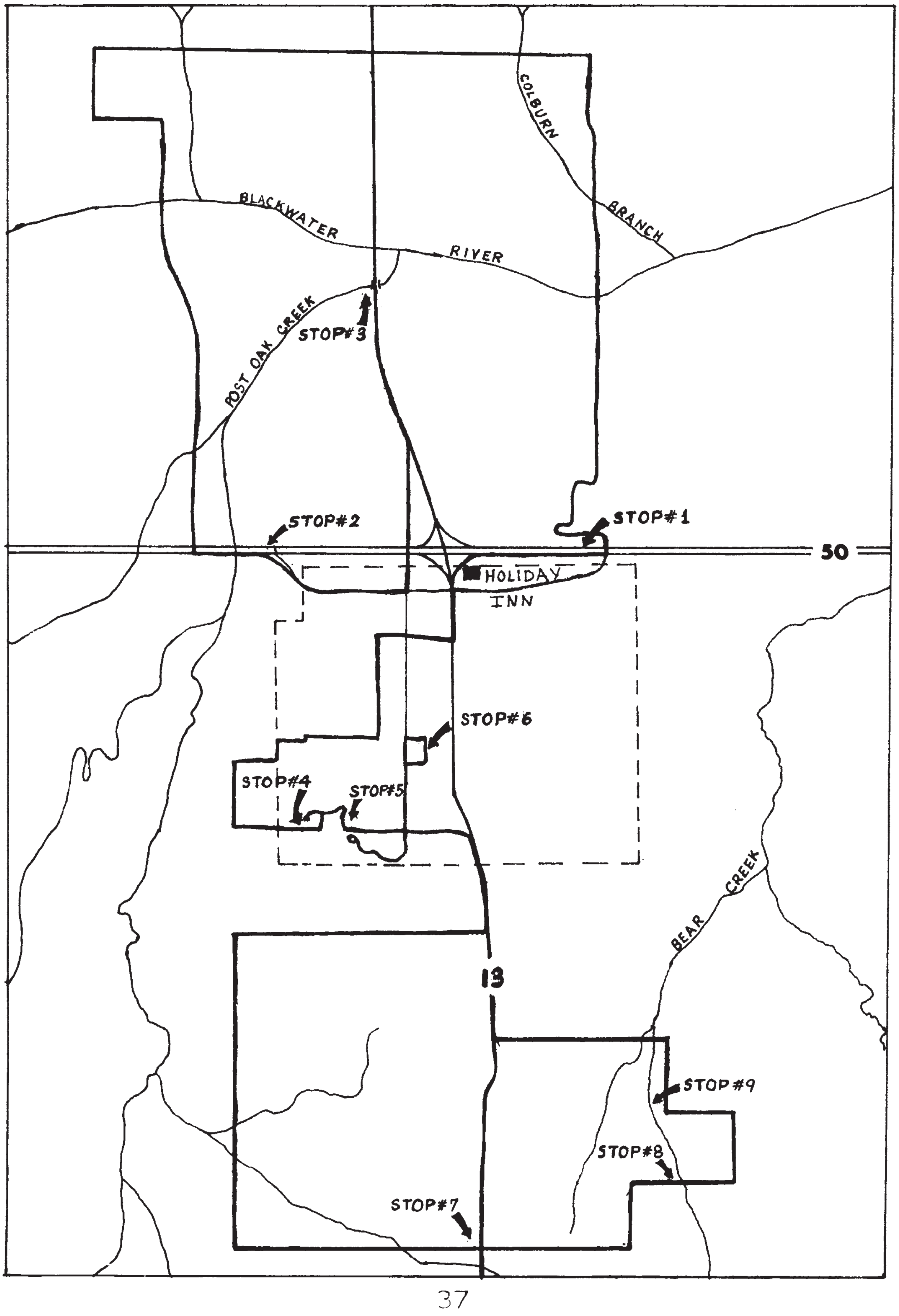
FIELD TRIP ROUTE MAP



FIELD TRIP LOG
27 September, 1975

Holiday Inn Area Stop 1	Begin field trip in front of Holiday Inn. Walk to west side of lake in front of Inn. Warrensburg Sandstone unconformably overlying coal and gray shales. Strike is N 55° W, dip is 30° to the southwest. No basal conglomerate at this outcrop. Contact between sandstones and underlying rocks dips to the south. Faulted north end of outcrop has the coal bed dipping 70° southwest.
	Walk back from lake to Holiday Inn starting point, then proceed east along power line road. Stop at end of blacktop road and follow the gully immediately behind Walmart store.
Stop 2	Warrensburg Sandstone overlies a coal bed which strikes north 25° west, dips 55° northwest. Follow the gully east to the first nick point. In this outcrop coal, shale, and limestone underlie the Warrensburg Sandstone. Strike of the underlying layers is north 60° west, dip 9° to the southwest. Cross-bedding in the Warrensburg dips east at this outcrop. At this point a 1 foot coal bed at the top of the sequence is underlain by 8 feet of gray weathered shale, 1 foot of dark shale and a gray nodular limestone in the bottom of the gully.
Stop 3	Return to power line road. Walk 50 yards east and stop at first large tree. Observe the large blocks of conglomerate. This general area exposes well the basal conglomerate of the Warrensburg Sandstone. The conglomerate is composed of large ironstone concretions, large blocks of fossiliferous limestone with abundant <u>Chaetetes</u>, crinoid stems, and pea sized, white quartz grains. Conglomerate extends down the slope towards the east. Follow the small gully south from this outcrop to intersection with main gully.
Stop 4	Nick point in the deep gully exposes a fault zone; Warrensburg Sandstone is faulted against older rocks. Strike of the fault is north 42° west, dip 80° southwest. Warrensburg Sandstone is the downthrown block, the upthrown block contains coal and claystone. Twenty feet down gully from this nick point, a purple fossiliferous limestone with abundant brachiopods strikes north 40° west, dips 70° east. Continuing down gully on steeply dipping shale beds, there is a layer of sandstone 2 feet thick which strikes north 40° west and dips 26° southeast.

Return to power line road. Observe conglomerate exposed in road. Follow road east down slope. Nick point in slope is the approximate lower boundary of conglomerate layer. Continue east down slope on power line road. Observe steeply dipping coal bed in gully on north side of road. The coal bed strikes north 35 degrees west, dips 16^{o} to the west. Continue east on power line road, walking on exposures of thinly bedded siltstones and massive sandstones, which strike north 20^{o} west, dip 35^{o} to the southwest. Warrensburg conglomerate is again exposed at the base of the road. Follow road down slope (east) and across a large gully. Observe coal and shale beds in gully to your right (south). Follow road uphill and note black shale and thin limestones in gullies, and a slope covered with float from the Warrensburg Sandstone.

Follow power line east over the crest of the hill, walking on Warrensburg Sandstone. Looking east from crest of the hill observe a north-south valley. This valley is the approximate contact between Warrensburg east depositional edge and older sedimentary rock. This valley trends north-south for more than a mile and many fault zones can be observed by walking the creek which follows the valley. Walk down the hill east toward the valley . . . observe flat area to your left (north), which was a sewage lagoon. Follow trail to your right (south), walk downslope through cross bedded Warrensburg Sandstone and cross the creek. After crossing, walk south on the creek bank about 100 yards.

Stop 5

To your right (west) observe basal contact of Warrensburg Sandstone in bluff along creek. The Warrensburg has a thin basal conglomerate overlain by crossbedded, laminated sandstone layers with carbonaceous materials along laminations. Note that the Warrensburg Sandstone dips west on the west side of creek and dips east on the east side of creek.

Walk north from basal Warrensburg outcrop and around lagoon, northeast to the power line road. Walk up to power line, continue to crest of hill where the bus will be waiting. This hillside contains horizontally bedded sequence of limestones and shales overlain by the thin edge of the Warrensburg Sandstone. The bus will return on Business 50 to front of Holiday Inn. Trip log mileage starts from the Holiday Inn.

Cumulative
Mileage

0.0 Begin at Warrensburg Holiday Inn. Drive north on 13, turn right on Highway 50 and drive east. Observe radio station on the left (north side of road). Hills on either side of the road have outcrops of limestone, shale, and siltstone dipping 25° to 30° east. Turn left at blinker light and cross highway. Turn left immediately after crossing highway and follow road west to radio station.

1.7 STOP 1. Pause briefly at crest of hill in front of radio station. Observe steeply dipping strata. Continue north on blacktop road past Northfield addition, north on gravel road. Northfield addition is underlain by a faulted limestone and shale sequence. Limestone beds can be seen in stock pond on the left.

2.3 Turn left. Continue north on gravel road toward Blackwater River. Road goes through a sequence of horizontally bedded Desmoinesian limestones, shales and siltstones. Hilltop on the skyline is Monkey Mountain which is supported by Desmoinesian limestones.

3.2 Crest of Monkey Mountain. Descend hill toward former course of Blackwater River and its floodplain.

3.4 Old Blackwater Bridge - notice very small dimensions of former channel - not more than 50 ft. wide, 10-12 ft. deep. Continue north across Blackwater floodplain to new bridge placed there after 1910 dredging.

3.7 New Blackwater bridge - notice large increase in channel dimensions, both width and depth, and that a lateral extension has been added to the south end of the bridge to allow for the large amount of bank erosion. Continue north on gravel road.

4.4 Bridge across Colburn Creek. This is the lower, channelized end of Colburn Creek. Upstream (west) many pre-dredging meanders of the channel are apparent as you walk along this stream. The pre-dredging stream level was 8 to 12 feet above the present dredged lower end. Upstream gully erosion leading to Colburn Creek is extremely pronounced. Continue north on gravel road.

5.4 Stop at Highway V blacktop. Turn left and go west on Highway V. Crest of the hill above stream valley of Colburn Creek is the approximate contact between limestones and Warrensburg Sandstone. Limestone beds to your right (north), dip 45° east. Continuing west on Highway V, Warrensburg Sandstone outcrops along the roadside.

6.9 Intersection with Highway 13, continue west on blacktop road OO. Warrensburg Sandstone outcrops on either side of Highway OO. Going downhill into valley of Walnut Creek, there are good exposures of Warrensburg Sandstone north and south of the highway.

8.2 Cross bridge and ascend hill which is composed of Warrensburg Sandstone on lower slopes and formed of limestone near the hilltop. Sandstone is dipping 16^{o} to east.

8.7 Crest of hill; limestone layers dipping west. Continue to intersection, turn left (south) on gravel road. Drive south on gravel road ¼ mile to intersection, turn left (east).

9.8 Turn right at road intersection, go south on gravel road and descend onto floodplain of the Blackwater River.

10.4 Blackwater Bridge across new Blackwater ditch. Gravel bars in the stream are lying on basal Pleistocene blue-gray clay. Continue south across floodplain.

11.1 Approaching old Blackwater Bridge. Notice small size of this stream and bridge as opposed to the bridge we just traversed. Continue south on gravel road to intersection with Highway 50. Drive east on 50. Cross the bridge across Post Oak Creek and turn right at Business 50.

13.2 STOP 2. Observe the west dipping (20^{o}-25^{o}) limestone, shale, and siltstone sequence exposed in the roadcut. Dip is less steep at the west end. One hundred yards east of this outcrop, a roadside gully exposes horizontal Desmoinesian rocks overlain by Warrensburg Sandstone. Continue east on Business 50 to first stop sign, intersection with North Holden Street.

OPTIONAL TRIP (Depending on time and river stage)

00.0 Begin at intersection of Business 50 and North Holden Street. Drive north across overpass (Highway 50) and continue north as Holden Street becomes old Highway 13.

2.4 STOP 3. Bridge across Post Oak Creek. Cross-bedded Warrensburg Sandstone is exposed in road cut. Walk west on the trail adjacent to the creek on the south side. Descend to stream level about 100 yards west of bridge. Near the bridge foundation, east dipping, cross-bedded sandstone is unconformably overlain by horizontal conglomerate and sandstone. Walking southwest (upstream) two distinctive types of lithology can be observed.

On the south bank, limestone on the stream bottom is overlain by gray shale and coal. Very fine exposures of Warrensburg basal conglomerate are unconformable on the shale. Note coal beds in the conglomerate.

The north bank is alluvial. The basal sediment is the Pleistocene gray clay. Holocene alluvium is unconformable on the basal clay. Observe the abundant fossil wood and large logs in the Holocene deposits. Return to bus and drive south to the intersection of Business 50 and Highway 13.

4.6 Intersection of 13 and 50.

0.0 Start again at intersection of Highway 13 and Business 50. Heading south on Hwy. 13, turn right at first stoplight, corner of Hwy. 13 and Gay Street. Go west on Gay Street for 3 blocks, turn left (south) on Washington Street. Continue south on Washington Street to football stadium.

1.2 Turn right on King Street between Residence Hall and new Multi-purpose Building. Continue west on King Street after jog in road, past the baseball diamond to the intersection of King and Old Main Streets. Turn left (south) on Old Main Street. Take the first right, on Clark Street. Warrensburg Sandstone outcrops on the hillside to your right.

2.1 Road turns south, downhill, through Warrensburg Sandstone outcrop. At the base of the hill is Spring Ridge addition. Turn right onto the gravel road and drive west.

2.7 Turn south on the gravel road. Go across the creek and flood-plain past Springbranch Mobile Homes.

3.1 Hilltop just south of Springbranch Mobile Home Estates contains beds of shale, coal, and limestone. Continue south on gravel road.

3.2 Turn left (east). As the road crosses the creek, thin siltstones and shales are exposed on either side of road. Driving uphill (east) the exposures are composed of colluvial and alluvial deposits derived from the Warrensburg Sandstone.

3.5 Road traversing Warrensburg Sandstone. Pertle Springs golf course on your right. Take first left down a steep hill carved from Warrensburg Sandstone.

3.8 Base of hill, Pause. To your right is Lake Lyon, a city fishing lake. A Warrensburg Sandstone outcrop is exposed on the other side of the lake. On the left is the old city concrete reservoir, which was fed by the Pertle Springs, and was the source of city drinking water in the 1800's. Also, immediately north opposite the reservoir are 2 old well houses from early Warrensburg wells. Continue north across the dam and turn left (west). Drive past old reservoir to the baseball diamond and turn south onto the field.

STOP 4. Get out of bus, walk west along the backstop. Note limestone in the creek bed. At the west end of the baseball diamond, strike of these limestone beds is north 10° west, dip is 22° southwest. Walk east along the backstop parallel to the creek until you reach the intersection of this creek with the gully about 200 yards east of the first outcrop. Exposed in the creek is a layer of sandstone which strikes north 10° west and dips 45° to the southwest. In the south bank of the creek, adjacent to this outcrop, is a coal layer which is dipping at about the same angle. Cross the creek and continue east along the bluff. 50 yards east of the last outcrop, observe limestone dipping at a very high angle, overlain by Warrensburg Sandstone. Board the bus and return to gravel road adjacent to baseball field. Hill immediately north is composed of limestone 3/4 of the way to the top, then is capped by Warrensburg Sandstone. Spring Branch addition is located on this hill. The limestone layers strike north 30° east and dip 50° northwest. Drive east on the gravel road along the north side of Lake Lyon.

STOP 5. Turn south on blacktop. Stop at Warrensburg outcrop adjacent to pavillion on Lake Lyon. At this outcrop basal Warrensburg is exposed, resting unconformably on gray claystones. A basal conglomerate grades upward into crossbedded sandstones, and another conglomerate near the top is overlain by sandstone. Continue east on blacktop, around the lake to road junction.

4.6 Turn left and drive east to intersection. Intersection of Hale Lake Road with Pertle Drive. Turn right (south) into Pertle Springs. Pertle Springs was a resort area in the early 1900's and many people came here to drink the spring waters and take mineral baths. There was a rail line from Warrensburg to Pertle Springs. The Pertle Spring lodge on your right is built on Warrensburg Sandstone. Descend the hill, curving around past the lodge through Warrensburg Sandstone into outcrops of limestone. On the left is a sheltered spring which is in limestone. Road junction, continue right, observe limestone at base of roadcut. Limestone strikes north 10° west, dips 23° southwest. Continue on road around Lake Cena, the largest of the lakes in Pertle Springs. Limestone on right, on the north side of the road, adjacent to picnic area. Driving east towards the dam, Warrensburg Sandstone is exposed along the side of the road. Circle drive around end of Lake. At end of lake note claystones and shales exposed along the road. Sandstone along south side of lake is badly faulted and fractured, with anomalous dips trending in different directions. Coals and shales at the base of the sandstone are also involved in the faulting. Across the lake at water level are limestone beds overlain by Warrensburg Sandstone. Drive west along the shore of Lake Cena, turn right at hill going up toward golf course and pool.

6.1 Drive uphill toward swimming pool. Observe on the left beds of shale, coal, and limestone overlain by Warrensburg Sandstone. Descend hill from pool and continue back to the entrance of Pertle Springs. Drive north on south Holden Street; outcrops of Warrensburg Sandstone along both sides of the road.

7.2 Continue north on Holden Street, turn right on Clark Street, then turn left on College Street. University Union is on your left.

7.6. STOP 6. Lunch downstairs in the Union.

0.0 Begin afternoon field trip. Turn left at north end of the Union, go ½ block to Holden Street. Turn left (south) on Holden Street.

1.0 Intersection of Holden Street and Hale Lake Road. Turn left (east) on Hale Lake Road and continue to Highway 13. Observe crossbedded Warrensburg Sandstone on north side of road. Drive south on Highway 13 to Highway BB.

2.1 Turn right (west) on Highway BB.

3.0 Large house on left. Continue ahead on BB; in next ridge Warrensburg Sandstone overlies limestone exposed in gullies on south side of road.

3.3 Gully running north has limestone at base, Warrensburg Sandstone on top. This gully extends north to Pertle Springs golf course. Exposures of limestone dip nearly 90° beneath the Warrensburg Sandstone. Continue west on Highway BB, turn left (south).

4.0 Leave BB and continue going south on gravel road which traverses the west branch of the Warrensburg Sandstone.

5.2 Bridge across Fletcher Creek. Hill directly ahead to the south and bluffs trending the southeast are composed of the west branch of the Warrensburg Sandstone - more than 50 feet of sandstone is exposed along the creek banks to the southeast. Continue south up the hill.

6.0 Turn left on gravel road. Drive east on gravel road, still on Warrensburg Sandstone. As we approach crest of hill outcrop changes from sandstone to limestone.

6.4 Crest of hill is on limestone. Both shale and limestone are exposed. From this point east on gravel road to Highway 13.

7.2 Cross Fletcher Creek. Fletcher Creek to the right (south) side of road, Quaternary gravels and sand are overlying limestone and shale outcrops at base of creek.

7.8 STOP 7. Intersection of gravel road with Highway 13. Briefly note adjacent outcrops. To your left in a stockpond is the Blackjack Creek Limestone; the same Formation is exposed to the south along the highway. High hill immediately south, on the west side of the highway is composed of the Higginsville Limestone, Labette Formation, and Myrick Station Formation. Several large quarries are located on the hill crest and have excavated these limestones. At the base of the hill on the south side adjacent to the creek, is a deposit of Pleistocene yellow banks overlapped on either side by gray Holocene alluvium. Continue east on blacktop Highway.

7.9 Small quarry and pond on left excavated in Blackjack Creek Limestone, continue east on Highway Y.

8.4 East channel of the Warrensburg Sandstone. Missile site on left, core logged by Richard Gentile indicates 45 feet of Warrensburg Sandstone. Leave Highway Y, continue east on gravel road. Turn left and drive ¼ mile north along Warrensburg Sandstone outcrop. Road intersection, turn right. Proceed (east) downhill. Descend hill, and stop at the driveway on right side of the road.

9.6 STOP 8. Stop, leave bus. Walk back west across gully which is tributary to Bear Creek. Limestone in base of gully overlain by thin shales and siltstones. Ascending hill, note outcrop of Warrensburg conglomerate which grades upward into Warrensburg Sandstone on the north side of the road. To your left, on the south side of the road, note the stream terraces adjacent to the small gully. This outcrop has four terraces beginning at the stream level and going to the outcrop (level) of Warrensburg Sandstone at the top of the hill. Continue east across the west branch of Bear Creek. Warrensburg Sandstone is exposed along the creek to the south. Continue east across the Bear Creek floodplain and ascend a hill of Warrensburg Sandstone.

9.9 Dip in road. Next hill going toward dwelling is composed of limestone beds which extend across road and to the northeast.

10.1 Road intersection. Turn left (north) on gravel road. To the right limestone beds strike north 20° east and dip 25° southeast. Thin deposit of Warrensburg Sandstone on the left. Only limestone and shales outcropping on right (east) side of road. Continue north ¼ mile past apartment house to road intersection, still traversing limestone. Turn left at road intersection.

10.6 Limestone outcrop. At crest of hill, limestone outcrop gives way to Warrensburg Sandstone. Descending hill, going west, road is cut through Warrensburg Sandstone. Low terrace adjacent to Bear Creek floodplain is composed of Warrensburg Sandstone. Stop at right turn in road.

11.0 STOP 9. At this stop is the so called Grand Canyon of Bear Creek. Looking across the valley to your right, is a terrace cut partly on Warrensburg Sandstone and partly on fluvial and colluvial gravels eroded from the Warrensburg Sandstone. Cross field and walk north along fence line. About 100 yards from gate, cross wire fence and descend onto terrace below floodplain level. This terrace marks the former channel of the Bear Creek before channelization caused entrenchment. Bear Creek is flowing on the Pleistocene basal clay or on bedrock. On the west side of the creek, the high cut-bank is composed of up to 8 feet of basal Pleistocene dark blue gray silty clay, overlain by more than 20 feet of gravels and sands with crossbedding dipping to the north, in the direction of present stream flow. Notice that the surface contact between the basal clay and the overlying sands and conglomerates is very irregular. A thin zone of crossbedded sand and conglomerates is succeeded by another layer of clay at the south end of this outcrop. Cut and fill deposition is very marked. The gravels are very well consolidated and are stained black; composition of the clasts is similar to those in the modern gravel bars. This yellow bank deposit is considered to be Late Pleistocene. The highest level in this outcrop is composed of loess. Some of the Blackwater tributary streams have as much as 20 feet of loess deposited on Pleistocene alluvium. This particular terrace contains a thicker sequence of alluvial sediments and thinner loess deposits than do similar terraces exposed along Bear Creek north of Highway 50. At north end of the outcrop note that this valley spur composed of high level alluvial terrace deposits is overlain by Holocene alluvium forming the terrace which is part of the old channel of Bear Creek. At the north end of this outcrop you can see both T_0, the terrace formed by the pre-dredging channel of Bear Creek and T_1, the present floodplain level, both below the surface T_2 formed on the yellow banks, or ancient Quaternary alluvium. Cross fence and cross meadow to bus. Continue north on gravel road. Note low terraces on both sides of the floodplain.

11.6 Road intersection. Pause and note that the terrace continues north along the floodplain. On the right side of the road, this terrace is composed of Pleistocene alluvium, overlying the Warrensburg Sandstone. Turn left at road intersection. Drive on Bear Creek floodplain across 2 bridges crossing Bear Creek and its tributary. Notice on the right, the floodplain, T_1 and the terrace (T_2) which has the farmhouse, Mockingbird Hill on top. Driving uphill (west), we are crossing the yellow banks alluvial and colluvial deposits and we will ascend the hill into Warrensburg Sandstone bedrock. At the entrance to the subdivision on your right (north) we are again in Warrensburg Sandstone at elevation 800 feet. Continue west on gravel road to Highway 13 traversing Warrensburg Sandstone outcrop all the way. This is the south end of the zone where Warrensburg Sandstone is continuous from the east side of the Cornelia Quadrangle, west into the Centerview Quadrangle. Road intersection.

12.6 Road intersection. One-half mile south from this intersection, the Warrensburg Sandstone outcrop ends against limestones and shales. Continue east on this road to Highway 13.

12.8 Intersection of gravel road with Highway 13. One-half mile south of this point the Warrensburg Sandstone bifurcates into the east and west channel and only limestone and shale are exposed for several miles along Highway 13. Turn north on Highway 13 and return to Holiday Inn.

16.3 END FIELD TRIP. Holiday Inn.