Karstification on the Silurian Escarpment *in* FAYETTE COUNTY, NORTHEASTERN IOWA

by

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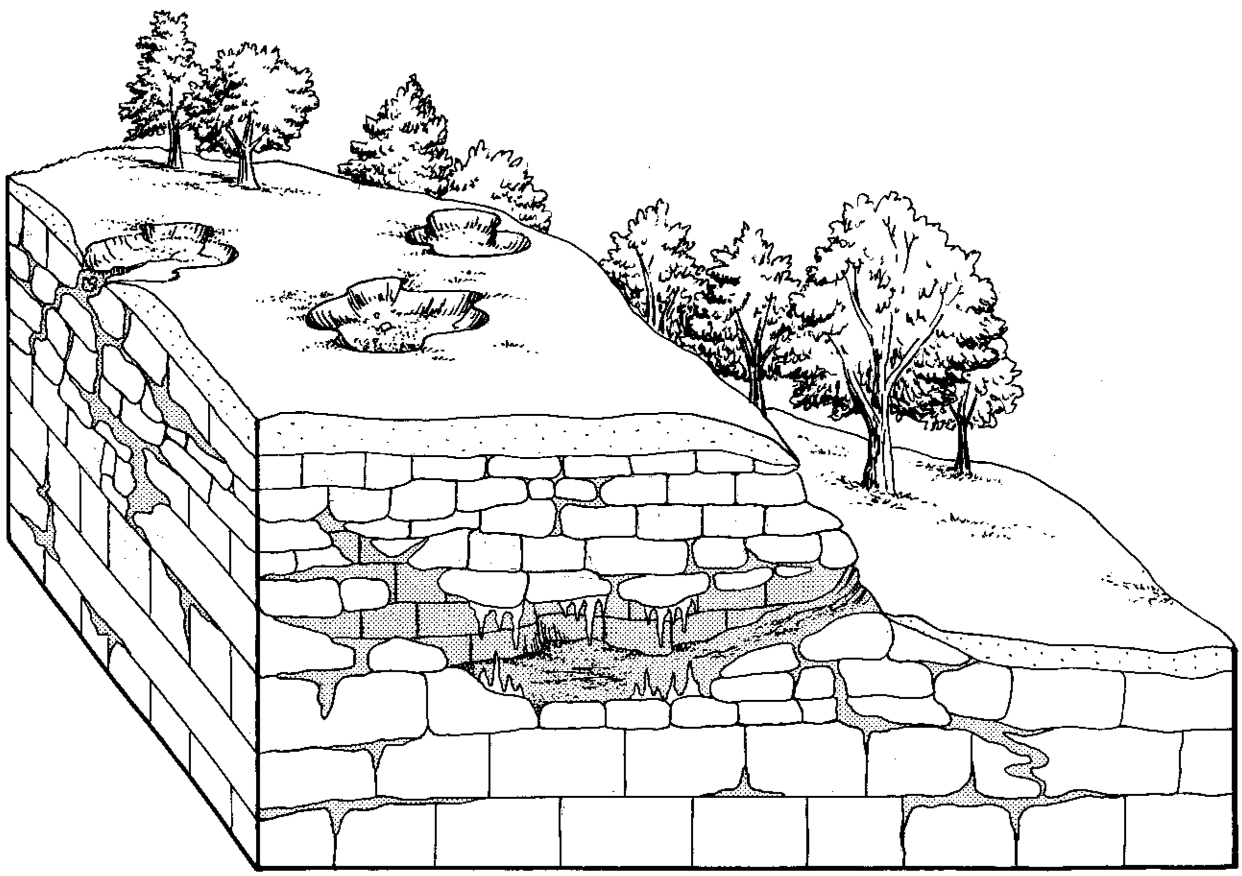

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KARSTIFICATION OF THE SILURIAN ESCARPMENT IN FAYETTE COUNTY, NORTHEASTERN IOWA

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INTRODUCTION

The Silurian Escarpment is a prominent northwest-trending physiographic feature in northeast Iowa, which marks the updip erosional edge of resistant Silurian carbonates, and their contact with the underlying Upper Ordovician Maquoketa shales.

The area of the Silurian Escarpment in Fayette County is host to a hydrologically active solutional karst system, which is recharged by sinkholes located on the upland areas to the south and west. Much of this karst is expressed as springs and caves at the base of the escarpment, commonly occurring at the upstream margins of narrow, steep-sided and deep ravines that dissect the escarpment.

LOCAL GEOLOGY

The local stratigraphy consists of, in ascending order, the Clermont Shale, Ft. Atkinson Limestone, and Brainard Shale Members of the Upper Ordovician Maquoketa Formation. The Brainard is unconformably overlain by the Silurian Waucoma Limestone, (Fig. 1) a thickly bedded to massive limestone and dolomite unit with minor chert. This unit grades southward into the Tete des Morts, Blanding, and Lower Hopkinton Formations (Witzke, 1981). The Silurian carbonates are in turn unconformably overlain by the Spring Grove Member, a petroliferous coarse-grained dolostone, and the Davenport Member, a sublithographic limestone to brecciated unit, both of the Middle Devonian Wapsipinicon Formation. The Wapsipinicon Formation is overlain by the Solon Member of the Middle Devonian Cedar Valley Limestone. The Spring Grove and Davenport Members were deposited by a transgressing Middle Devonian sea, which onlapped and

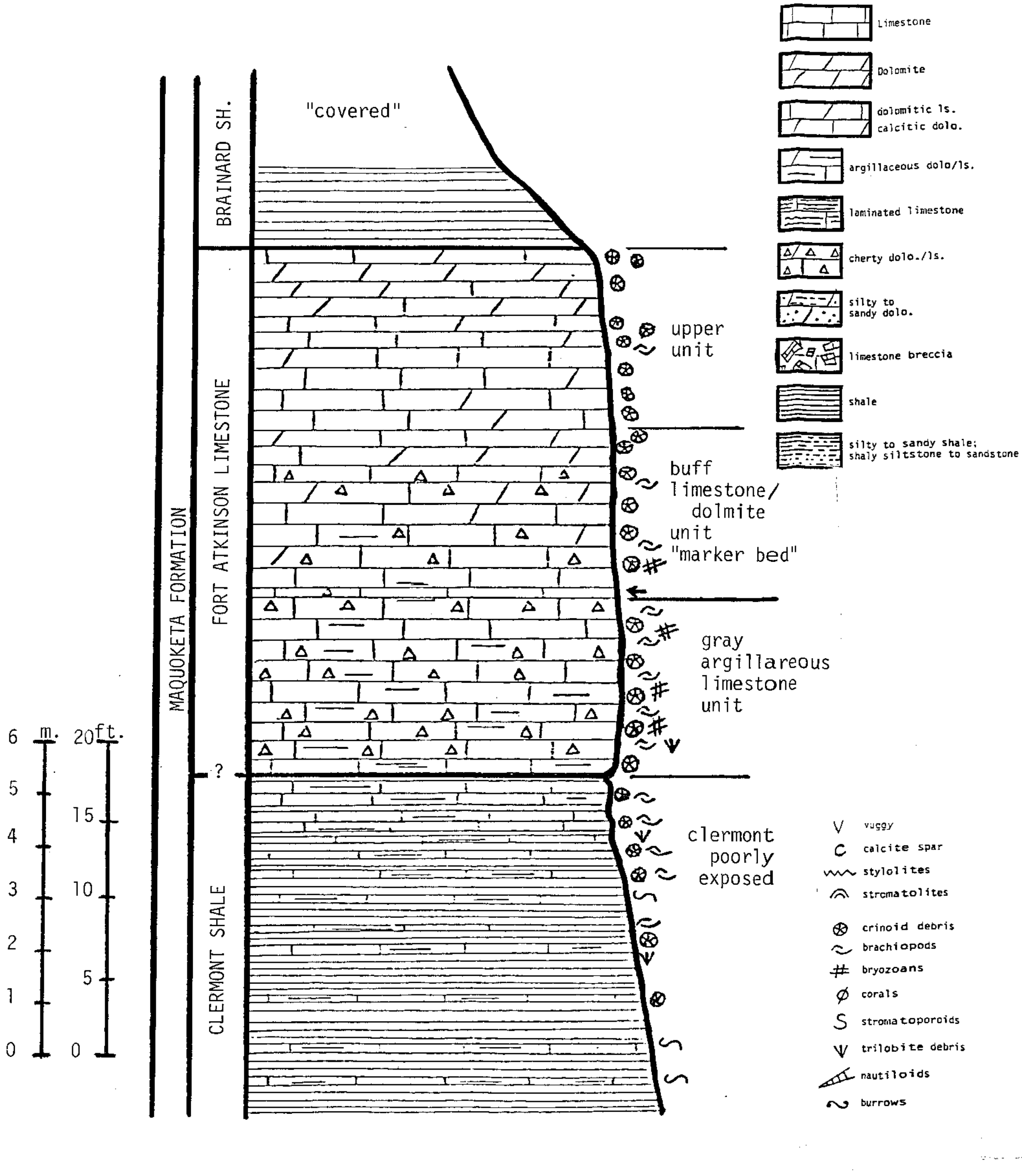

Figure 1. Highway 150 road cut, Eldorado, Fayette County (Bunker et al., 1983).

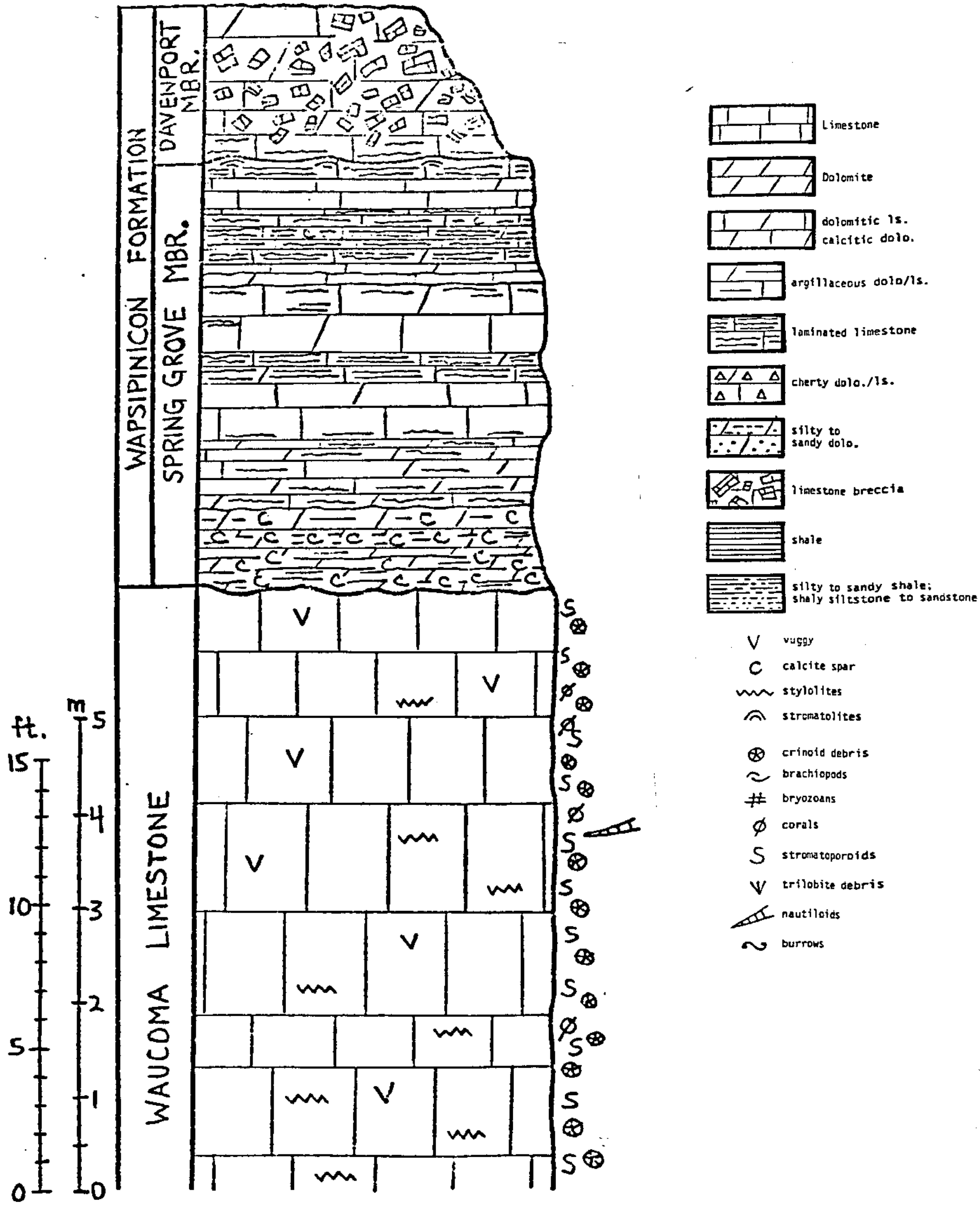

Figure 1(a). Highway 150 road cut, Eldorado, Fayette County (Bunker et al., 1983). Section above Maquoketa Formation.

buried an exposed ridge of northeastward-trending Silurian strata (Bunker *et al.*, 1983). To the north of Fayette County, the Silurian strata were completely removed by pre-Middle Devonian erosion, and in that area Ordovician and Middle Devonian rocks are in control (ibid.).

The Brainard Shale and underlying members of the Maquoketa commonly underlie the floors of the deep valleys which indent the Silurian Escarpment and much of the Turkey and Little Turkey River valleys. The overlying Silurian Waucoma Limestone forms the majority of the steep escarpment walls, while the overlying Devonian rocks underlie the relatively low relief uplands to the south of the escarpment. To the west-northwest of the study area, where the Silurian strata were erosionally truncated prior to Middle Devonian deposition, the Devonian rocks form an erosional escarpment morphologically similar to, although somewhat more subdued than that of the Silurian.

GENERAL THEORY OF CAVE DEVELOPMENT

(adapted from Bounk, 1983)

Although many caves are now within the vadose zone and thus no longer play an active role in the hydrologic system, most were formed under phreatic conditions. Bretz (1942) suggested that caves of shallow phreatic origin are usually linear in form, often with side passages. Picknett *et al.* (1976) suggested that this form is related to: 1) the increased solutional potential of descending groundwater, where it mixes with water in the saturated zone; and 2) the uppermost portion of the saturated zone, being the first locus of prolonged contact between the descending water of any given stratum. Solutional openings tend to develop at or near the top of the phreatic zone, resulting in relatively rapid groundwater movement at this level. This further accentuates solution at the expense of deeper levels (Davis, 1960). In contrast, caves of deep phreatic origin tend to be irregular in shape (Bretz, 1942).

Shallow phreatic cave formation is influenced by the relationship between jointing and preferred direction of groundwater flow. Preferred directions of groundwater flow may be determined through the use of potentiometric surface (or water table) maps. Average flow paths are perpendicular to contour lines, proceeding from areas of high gravitational head (upland recharge areas) to low gravitational head (discharge areas; e.g., streams). Most carbonate strata have little intergranular porosity, and secondary features such as fractures and joints serve as primary routes of groundwater flow. This implies that groundwater may not always occur at right angles to the water-table slope. Groundwater will flow from joint to joint in a general downgradient direction. Cavern development will occur along those joints subparallel to the major flow lines. Groundwater will utilize those joints and bedding planes that allow it to follow the highest pressure gradient downhead (Bogli, 1980). The details of passage morphology are influenced by other factors, including joints at other orientations. Davis (1960), noted in his studies of Appalachian cave systems that many caves appear to be formed just below the water table, which they follow downhead toward major river valleys.

The relationship between the present potentiometric surface and the orientation of shallow phreatic caves indicates that these caves originated in groundwater flow systems oriented similarly to those at present, although with initial higher water-table levels. This suggests that these caves were formed after the last major glaciation in this area (Pre-Illinoian; Hallberg, 1980) and development of drainage on the drift surface. Although landscape development on the Pre-Illinoian deposits has been complex, present-day drainage has been evolving since at least Late Sangamon time, with extensive erosion in Wisconsinan time (Hallberg, 1979, pers. comm.). This brackets cave genesis somewhere between Late-Sangamon time and the lowering of the phreatic zone to a level below those caves. This is not meant to imply that all shallow phreatic caves in the Silurian of Iowa are of this age, as many are known for which the above relationship has not been demonstrated.

KARST SYSTEMS OF THE SILURIAN ESCARPMENT

This area is underlain by a solutional karst system, which is indicated by the presence of seeps, springs, and caves that commonly are located at or near the valley heads. Groundwater recharges from these features are fed by recharge to blind valleys, sinkholes (dolines), and some caves on the uplands. These upland caves end in either sumps (flooded passage) or impassable passages, as do the upstream ends of those caves located in the valleys.

This relationship is in contrast to the condition of karst systems along the escarpment to the east and south, in Clayton and Dubuque Counties, which are generally characterized by mechanical karst development (Hansel, 1976). Examples of the solutional karst of northern Fayette County are discussed below.

Sowards Cave

Sowards Cave (Fig. 2) is developed in the Waucoma Limestone and consists of three levels. The uppermost level is a maze of fracture-controlled passages, which has been largely filled by clay and speleothems, and disseted by the development of the middle level.

The middle level of Sowards extends to the south for about 50 m to a point where it is presently terminated by a clay and silt fill. This passage varies in height from 1.7 to 3 m over a clay and breakdown fill of unknown depth. The passage width, although varying from 1 to 3 m is generally about 2.5 m.

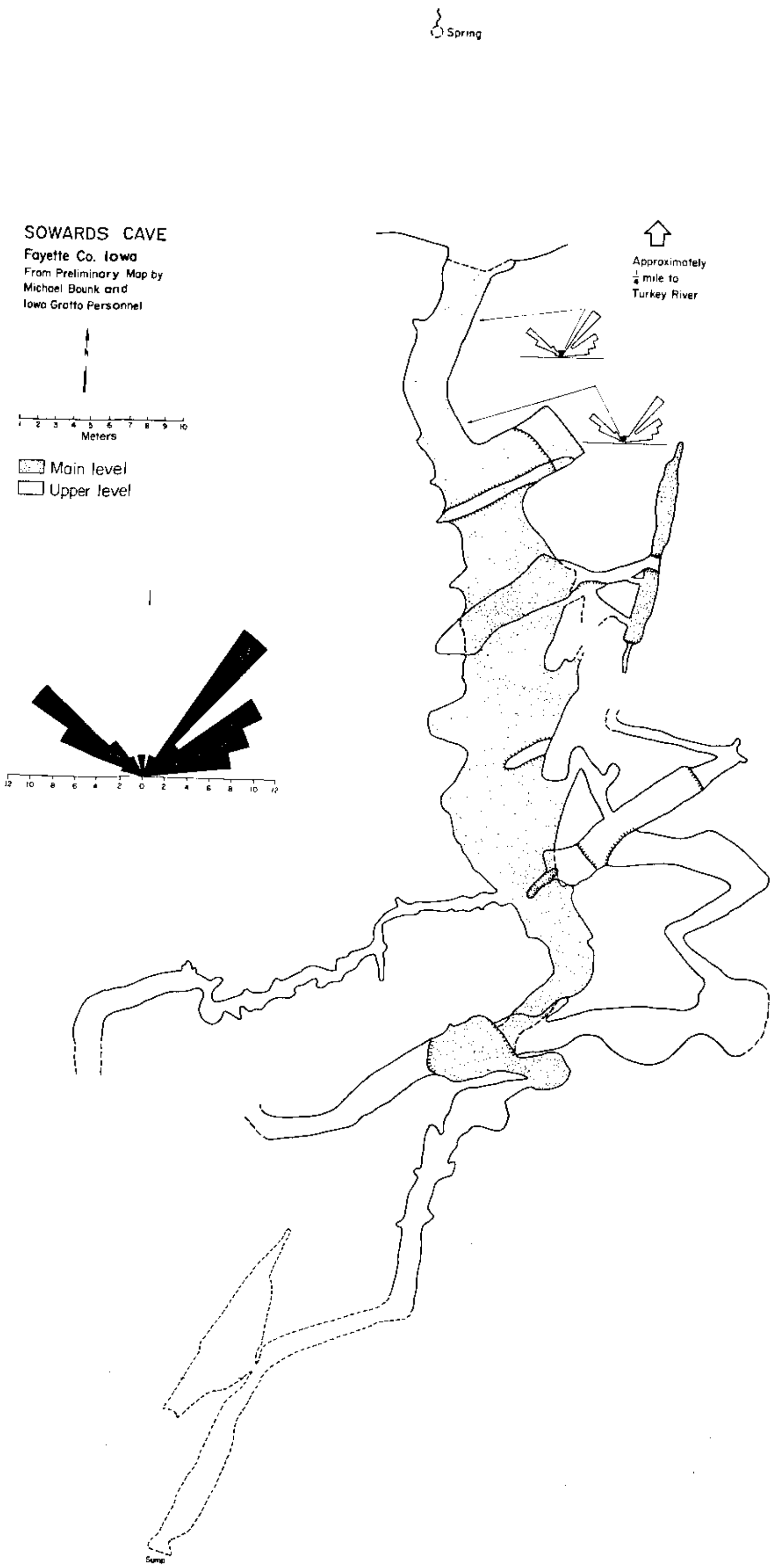

Figure 2. Map of Soward's Cave, Fayette County, with rose diagram.

The lowest level, which is entered at the south end of the middle level, consists of an estimated 35 m of hydrologically-active stream passage. At its upstream end, this stream flows from an impassable slot (Jagnow, 1968). At the downstream end, it flows into an impassable hole. During wet weather, this passage fills completely with water, and the middle level serves as an overflow. The lower level has been traced to a spring about 10 m north of the cave entrance (Jagnow, 1968).

As discussed by the author in an earlier paper (Bounk, 1983), the middle level of this cave is developed primarily along N20°-30°E trending fractures, probably in response to northward flowing groundwater. The alignment of valley segments downstream from this cave parallel the major rock fracture and cave passage trends. The valley's relative narrowness and steep sides also indicate that it follows the trend of a downstream extension of the cave to the Turkey River.

Duttons Cave

Duttons Cave is located about three miles to the southeast of Sowards and consists of a breakdown floored level through which the cave is entered (Fig. 3), and a lower main level. The lower main level consists of about 100 m of oneflow passage and extends from its entrance to the southwest where it joins a hydrologically-active passage flowing from a sump. This passage flows into an impassable segment to a series of springs in the talus slope below the entrance. Our understanding of the upstream sump has been extended by diving (McCarty, 1979) to and through a second sump to a third. During high water, the overflow passage fills with water, which then flows out of the cave entrance. Although an upper level occurs beyond the second sump, this cave consists primarily of one level. From its entrance to the first sump, the

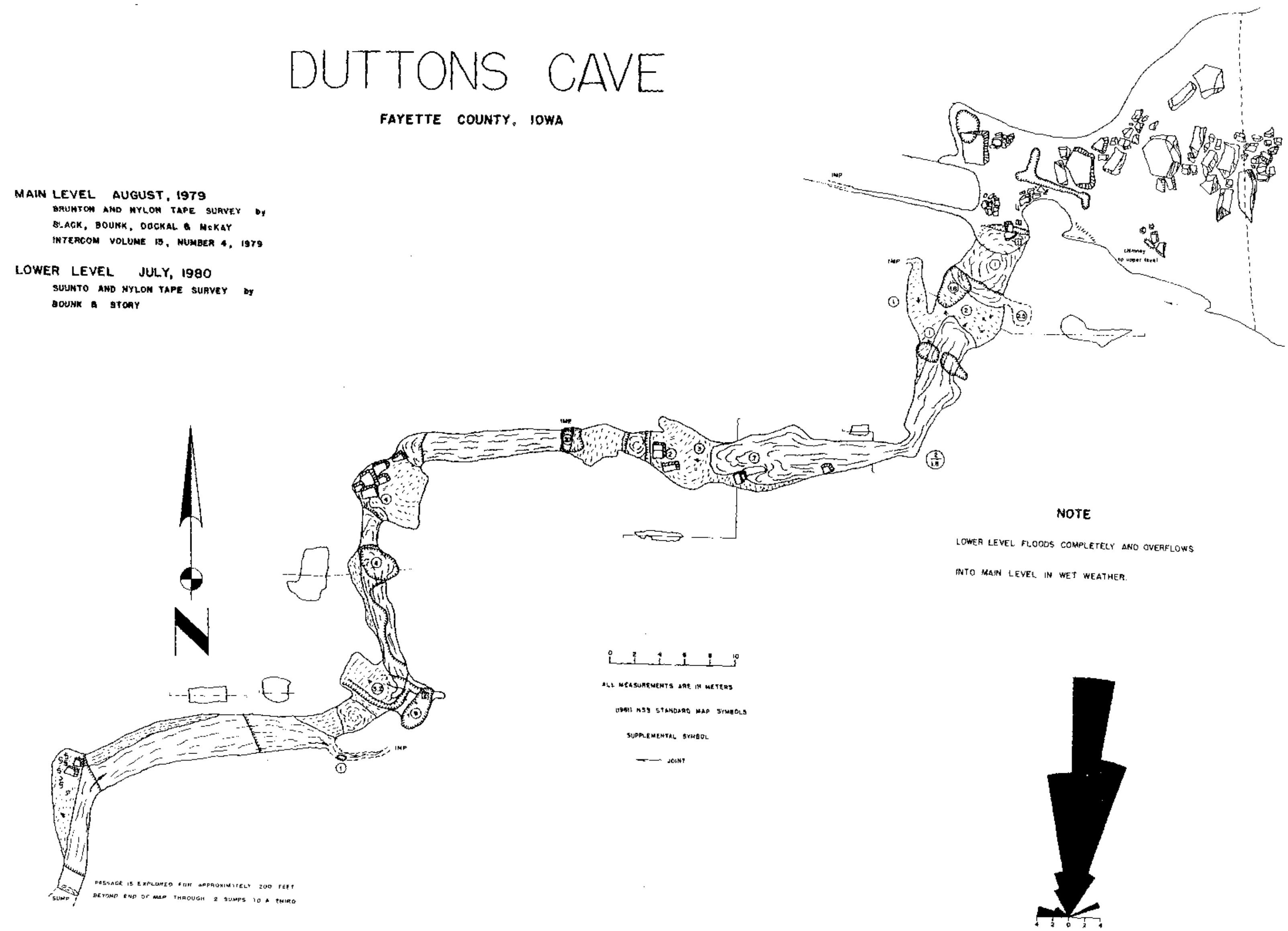

Figure 3. Map of Dutton's Cave, Fayette County, with rose diagram.

cave follows a series of N0°-10°E and E-W fracture trends which link developments along a third N60°-70°E trend (Fig. 3). This trend, if extended to the southwest, passes through Mittlestadt Cave (Fig. 4), an upland "feeder" cave of high relief, which sumps and finally cuts across the north edge of a complex of sinkholes on the Clarence Cannon farm which drains a blind valley.

Downstream of its entrance, the Duttons valley like the Sowards valley, is relatively steep and narrow. This valley is controlled to a great extent by the N60°-70°E trend mentioned previously, and a N20°-30°E trend, which is prominent in the main level of Sowards, suggesting that Duttons Cave once extended through the modern valley to the Turkey River flood plain. This relationship was originally proposed by Hedges in 1967.

Dye Tracing

During the summer of 1981, as a portion of an Iowa Geological Survey karst study, three dye trace were conducted in this area (Fig. 5), using Fluorescein dye (Hallberg and Hoyer, 1982). The dye was collected by means of activated charcoal packets and analyzed according to the method discussed by Aley and Fletcher (1976). All three dye injection points: Mittelstadt Cave (Trace #1); the Cannon Farm sinkhole complex (Trace #2); and another sinkhole located about 6 km to the north (Trace #3), are located in separate surface drainage basins, but were traced to the springs of Duttons Cave, thus demonstrating the existence of an extensive karst system diverting the flow from several surface drainage systems. The injection site in the Cannon Farm sink complex was later excavated, revealing an enterable cave in the Middle Devonian Spring Grove Member of the Wapsipinicon Formation, thus demonstrating the hydrologic connection between the Silurian and Middle Devonian carbonates in the study area.

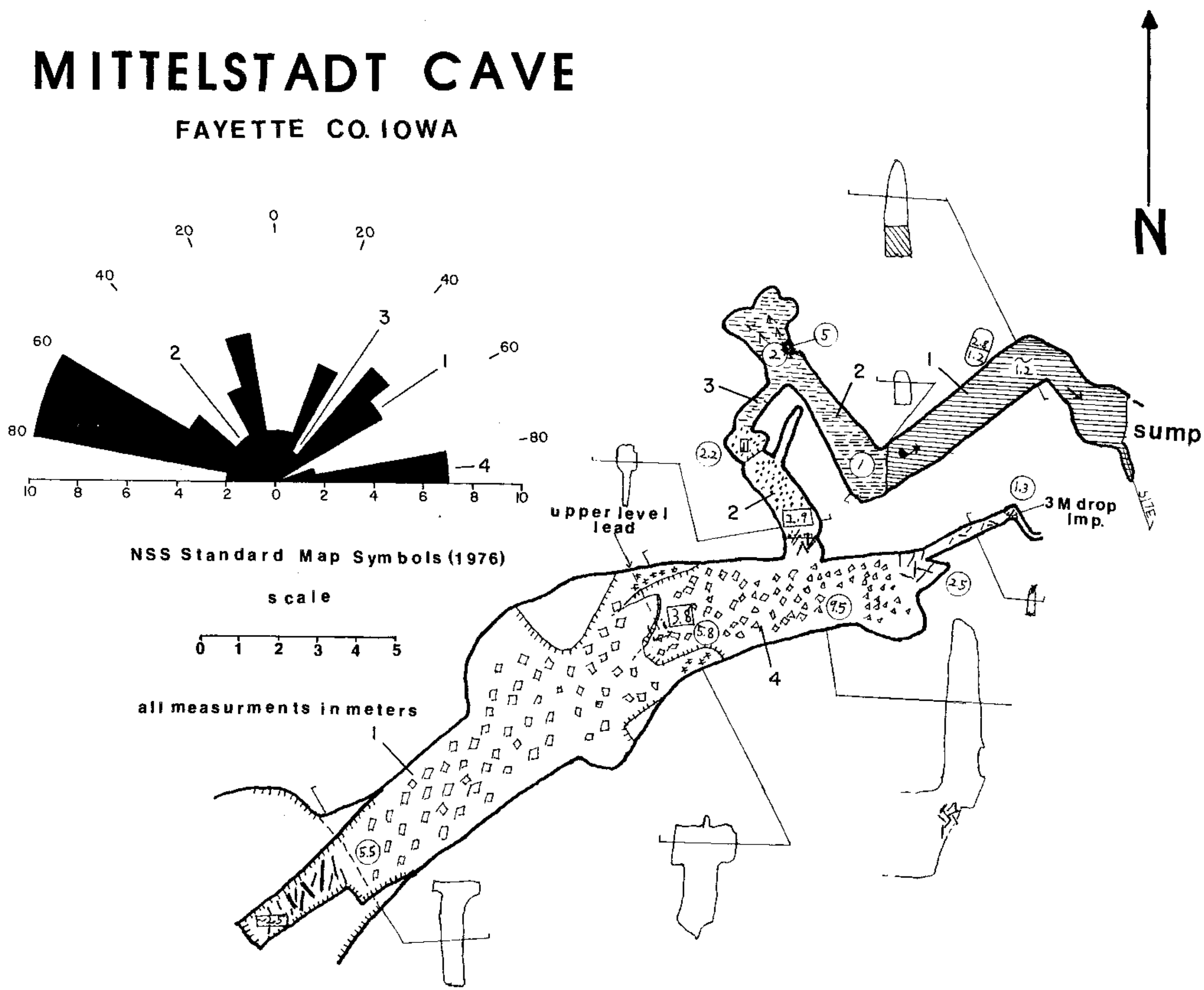

Figure 4. Map of Mittelstadt Cave, Fayette County, with rose diagram.

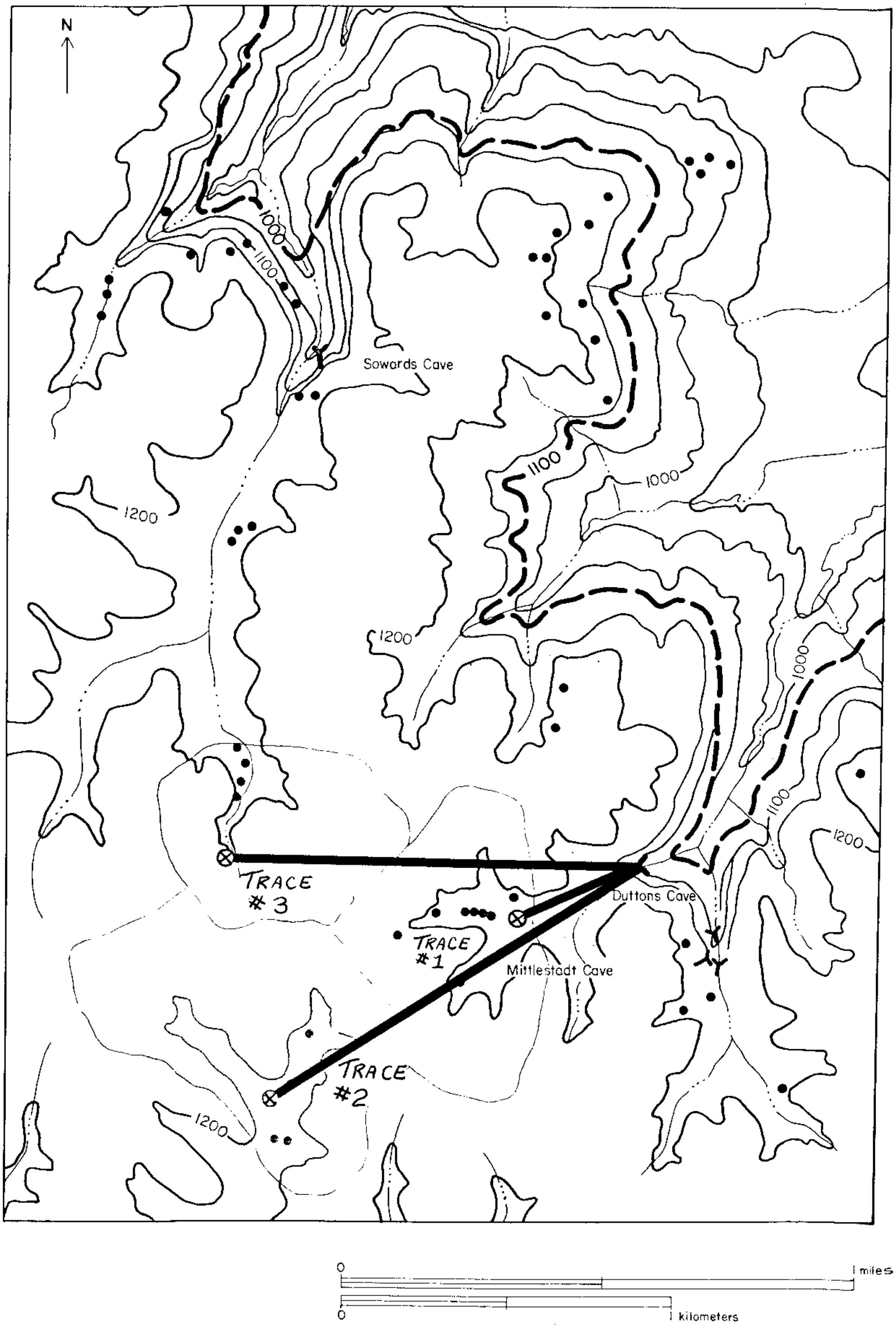

Figure 5. Dye traces near Dutton's Cave, 1981.

HISTORY OF THE DUTTONS-SOWARDS CAVE SYSTEM

Based on the previously discussed data, conclusions regarding the history of the Duttons and Sowards Cave Systems can be summarized as follows:

In Late Sangamon time (Hallberg, 1979, pers. comm.), after the last glaciation of this area, but before the incision of the Turkey River, the upper level of Sowards Cave was developed at or near the local base level. During high water inflow, backflooding would occur, forcing water under high hydrostatic head into all available openings forming a fracture-controlled maze system.

Later incision of the Turkey River permitted this system to drain and the underlying level to develop. Water flowing towards the Turkey River under hydrostatic pressure used those fractures, which best facilitated downhead flow, dissolving them out to form the main levels of both Duttons Cave and the middle level of Sowards Cave under shallow phreatic conditions. At this time, these caves extended to the Turkey River where they emerged as seeps and springs. Upstream, the Sowards cave system extended south (Fig. 6) to drain the area where dye Trace #3 was injected (Fig. 5). Later development of Duttons Cave, extending southwestward along the N60°-70°E fracture trend, provided a high gradient pathway for water from this area to the Turkey River. The main passage of Sowards Cave south of the present-day cave was drained, became inactive, and was plugged with clay and silt (Fig. 7). This conclusion is based upon the observations that if: 1) Sowards Cave was continued southward along the trend of the known cave, it would intersect the area of dye injection point Trace #3, and 2) that although the passages of the middle level of Sowards Cave and the main level of Duttons Cave are about the same width, Sowards ends in fill. Based on the passage dimensions, this piracy is

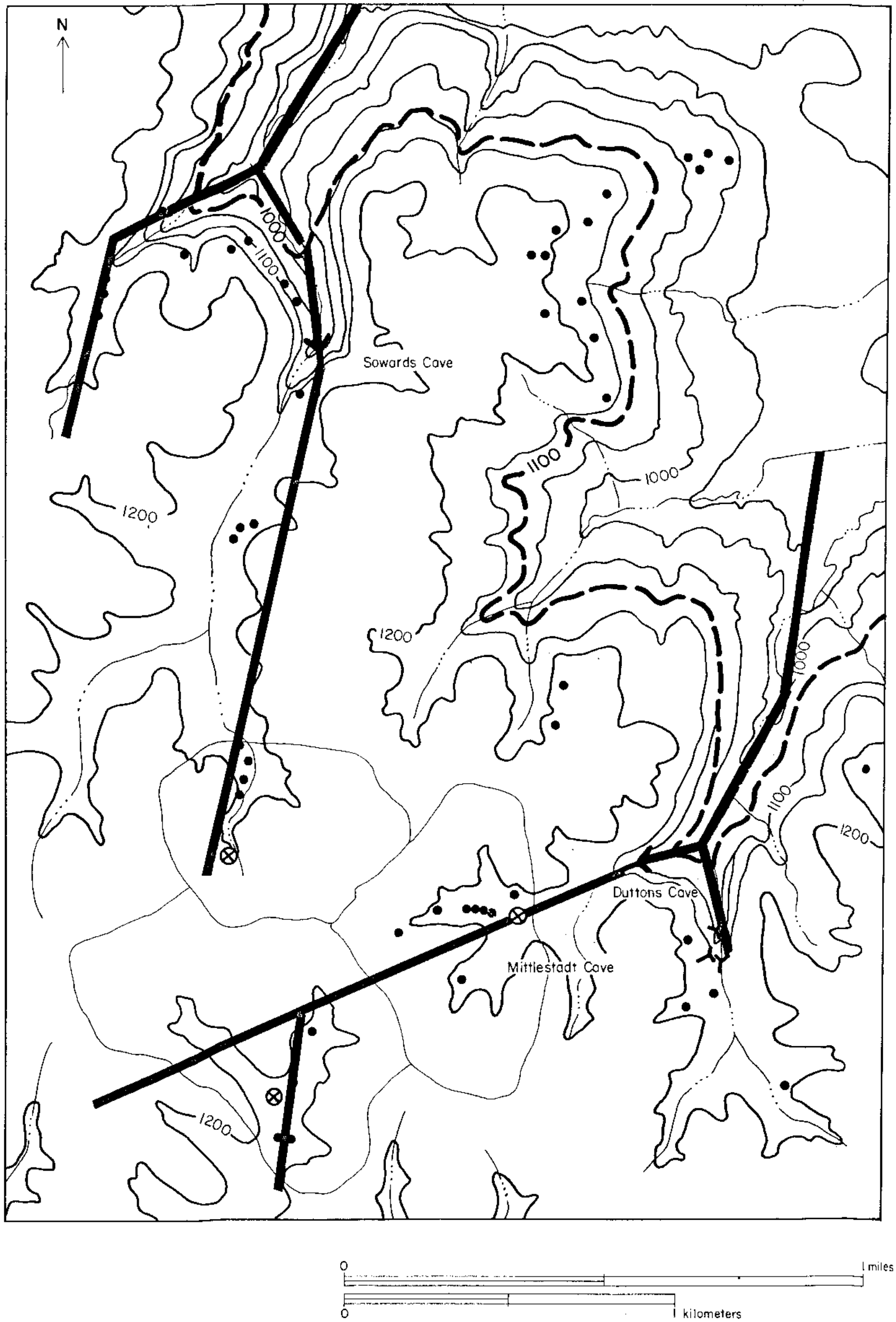

Figure 6. Map of the Soward's/Dutton's cavern system--pre-piracy.

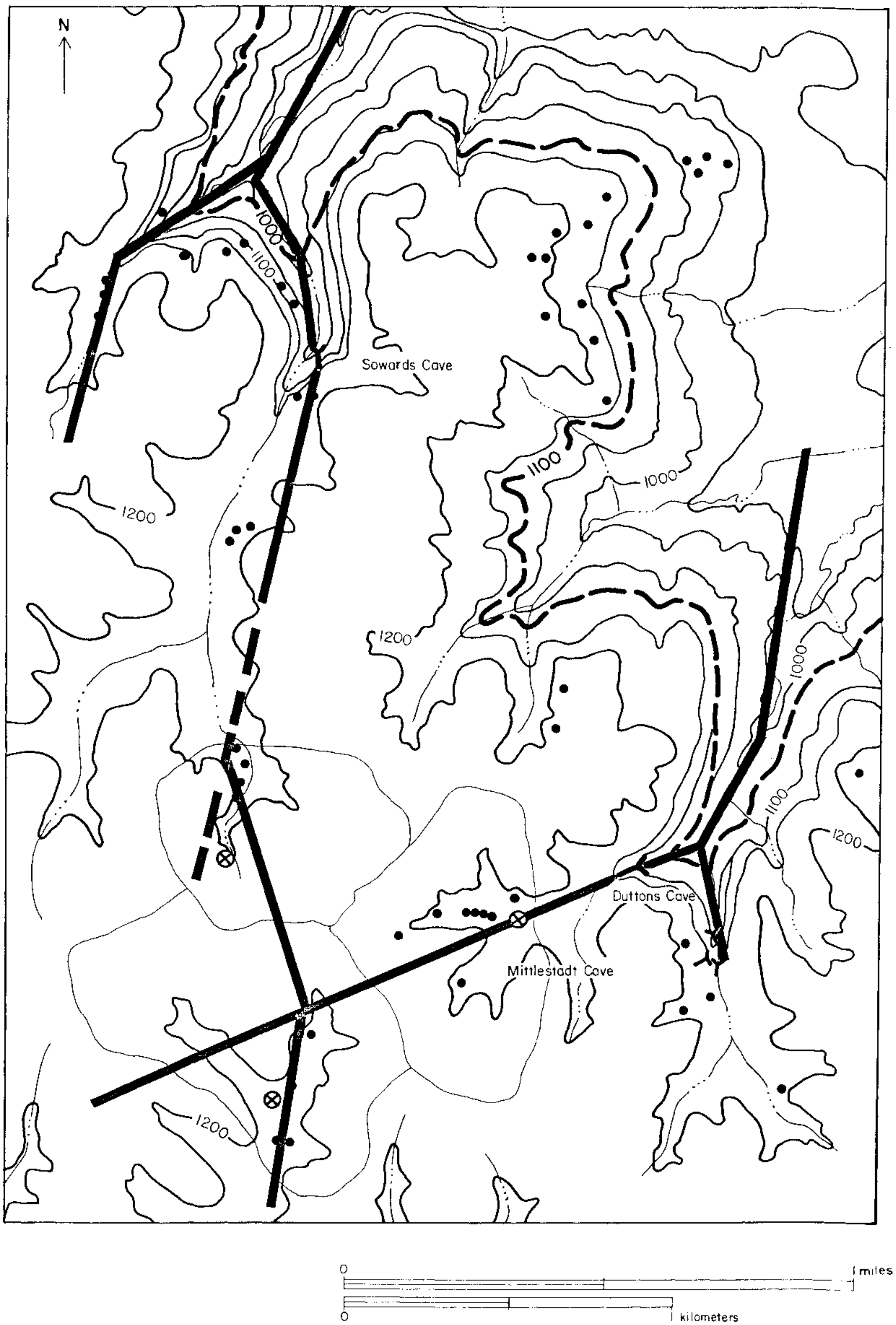

Figure 7. Map of the Soward's/Dutton's cavern system--post-piracy.

believed to have occurred after Sowards Cave had evolved to the vadose or partly air-filled stage.

Later collapse and valley head erosion has dissected and destroyed much of these caves. Part of this collapse in Duttons Cave blocked the entrance, resulting in development of the bypass to the spring. The fact that much of the post cave valley floors are now cut into Brainard Shale means that these caves have been removed from the immediate influence of the Turkey River. Further cave development has included the partial drainage of Duttons Cave to the early vadose stage, although phreatic sections remain, and at times of high water much of the cave floods. This flooding is largely attributed to the talus dam at the cave entrance. In Sowards Cave, a lower vadose/phreatic level is currently developing in response to hydrostatic pressure.

In the western part of the study area, a similar situation exists at Wet and Falling Springs Caves (Fig. 8), which were once branches of a much larger cavern system that flowed to the Little Turkey River, as originally proposed by Hedges (1967).

RELATIONSHIP TO MECHANICAL KARST

Much of the Niagaran Escarpment in Iowa is characterized by a mechanical karst resulting from the slippage and rotation of blocks of Silurian carbonates on the underlying Brainard Shale (Hansel, 1976). Observations of mechanical karst in road cuts in Clayton County to the east show not only pure mechanical karst, but examples of combined mechanical and solutional karst.

Northern Fayette County is one area where the escarpment has not been eroded back from the Turkey River, the local base level. Possibly a similar solutional karst once was developed along the entire escarpment, in conjunction with stream incision. As the caverns were destroyed by headward erosion,

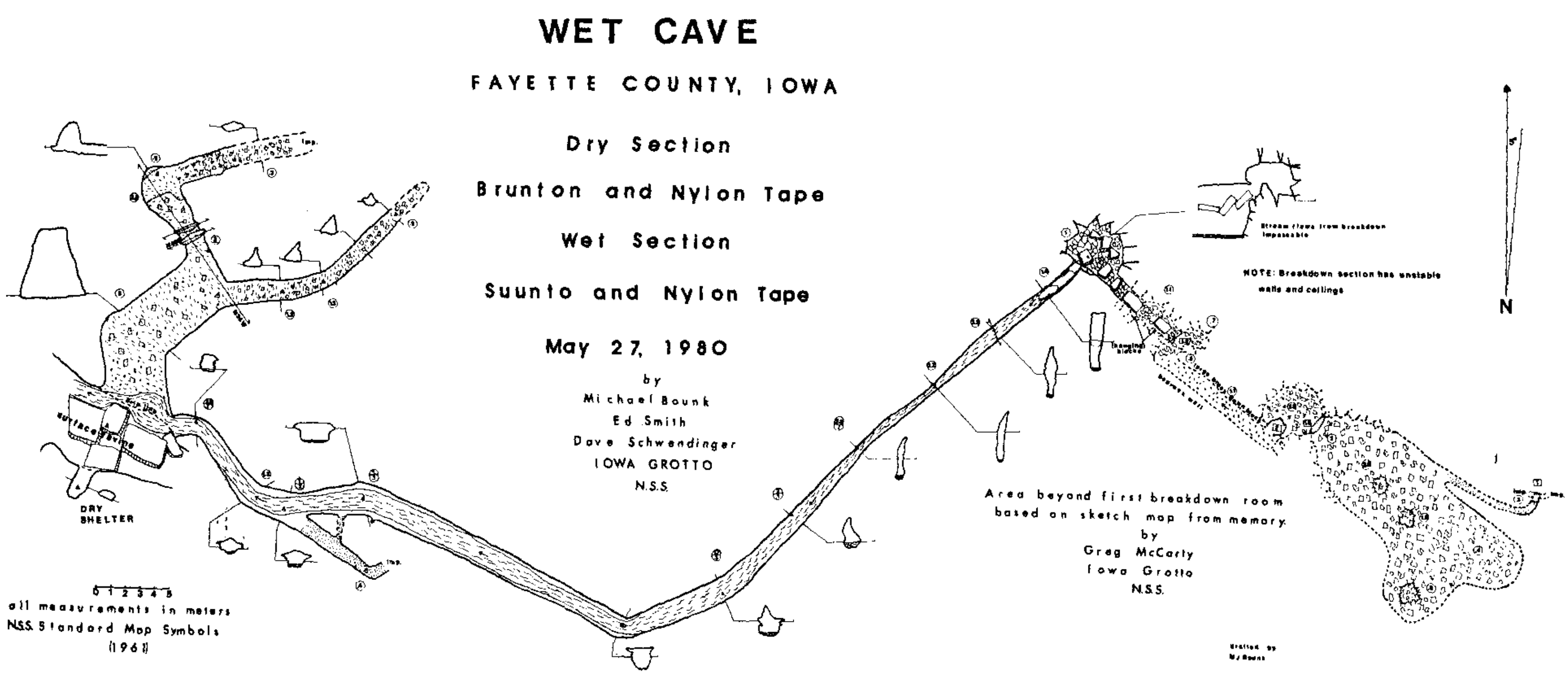

Figure 8. Map of Wet Cave, Fayette County.

mechanical karst developed, diverting surface waters rapidly downward to the Brainard Shale, preventing the formation of more solutional karst. This resulted in the present-day escarpment with relatively little solutional karst of any size.

An alternate possibility of cavern development is that due to the greater solubility of calcite in groundwater than dolomite, such an extensive karst would be much more likely to develop in a limestone terrane. This, coupled with the greater porosity and thus more diffuse flow in dolomite may be the cause of the rarity of such cavern systems elsewhere along the escarpment in Iowa, although as evidenced in the Dancehall Cave System, a dissected cavern system in Jackson County (Hedges, 1967), such systems can form in dolomites.

CONCLUSIONS

The caves and karst present along the Silurian Escarpment in northern Fayette County are remnants of a once more extensive series of cavern systems, which developed during post glacial incision of the Turkey River. These caverns have been destroyed to a great extent by valley head erosion and collapse.

Possibly such karst developed along the entire escarpment, but as this karst was destroyed, it was replaced by a mechanical karst, which inhibited solution. An alternate possibility is that karst development in the limestones of northern Fayette County were in preference to the dolomite which comprise the rest of the escarpment.

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ROAD LOG AND STOP DESCRIPTION

Mileage	Description
0.0	STOP 1. Goeken Park. This locality (Fig. 1) was recently described by Bunker, Klapper, and Witzke (1983). The slopes below the prominent north-facing ledges are underlain by the poorly-exposed gray-green dolomitic upper Ordovician Brainard Shale. This is unconformably overlain by the limestone of the Silurian Waucoma Limestone. These thickly-bedded limestones vary from crinoidal wackestone to packstones. The unit is in part styolitic, vuggy with some calcite spar void fillings. Fossils include cup corals, colonial corals, brachiopods, and nautiloids. The Waucoma is unconformably overlain by the Spring Grove Member of the Middle Devonian Wapsipinicon Formation. This unit consists of an argillaceous dolomite overlain by interbedded laminated and non-laminated petroliferous limestones. The Spring Grove is overlain by the Davenport Member of the Wapsipinicon Formation, which includes dolomitic limestone and limestone breccias. Clasts consist of laminated limestone and lithographic limestone.
0.1	Turn right (south) onto Hwy. 150.
2.1	Turn left onto gravel road.
3.8	Turn left onto county road W43.
4.8	Turn right onto gravel road.
5.3	Crossing the approximate location of the presumably filled conduit of Sowards Cave.
5.4	Turn right.
5.7	Note sinks on the west side of the road. This is the site of dye Trace #3. Water from this area once probably flowed to Sowards Cave but now flows to Duttons Cave.
6.1	Turn left.
6.8	Turn left.
7.0	Turn right and enter Duttons Cave Park. At the Y, turn right.
7.1	Park along the side of the road.

STOP 2. Duttons Cave Park.

Follow the trip leader from the parking area down into the cave ravine to the north. (Watch your step on the trails and around the bluff edge!) The floor of the ravine is underlain by the Brainard Shale, which is overlain by alluvium, and talus at the present cavern entrance. The Brainard can be seen to the east in a side ravine. Notice the springs flowing from the talus. This talus currently blocks the cave entrance to a level several feet above stream level. During high runoff, the lower level fills completely, and water flows from the cavern mouth. At one time, this cave continued for about 1 km down valley to the Turkey River. Upstream from the entrance, at least 116 linear km of passage is intact. The next two stops will examine feeders to this cave system.

The entrance area of Duttons Cave can be investigated with the use of a flashlight. (Watch your step!) Note the solutional features, the breakdown, and the vertical shaft. (DON'T ATTEMPT TO ENTER THE LOWER LEVEL!)

In the ravine, observe the thickly-bedded Waucoma Limstones including the stromatoporoid zone (Fig. 9). The exposed section is 16.5 m thick, consisting of in ascending order: A) calcareous dolomite, yellow orange, massive; B) calcareous dolomite, light yellow orange, massive; C) calcarenite, brown-gray, massive; D) dolomitic calcarenite with scattered chert, light brown-gray; E) dolomitic calcarenite, light brown-gray; F) calcarenite, cherty, light brown-gray; G) calcarenite, light brown-gray, chert layer at base; H) limestone, brown-gray, with scattered chert nodules, wavy bedded; I) calcarenite, brown-gray, wavy bedded; J) calcarenite, very light gray with abundant stromatoporoids in upper part; K) calcarenite, light brown-gray, irregularly bedded; L) calcarenite, light brown-gray; M) calcarenite, light brown-gray, massive to wavy bedded; N) calcarenite, light brown-gray, irregularly bedded; O) calcarenite, light brown-gray, very dense. These units are overlain by a covered interval containing float blocks of Spring Grove and Davenport lithologies (Witzke and Bounk, 1983, field work).

7.1 Follow road.

7.2 Upon leaving park, turn left.

7.4 Turn right.

7.6 Park along road. (Watch ditch but pull off as far as possible.)

STOP 3. Mittelstadt Cave.

Follow the trip leader through the farmyard to the cave. (On this and following stops, please respect private property including fences. Special arrangements have been made to visit many of

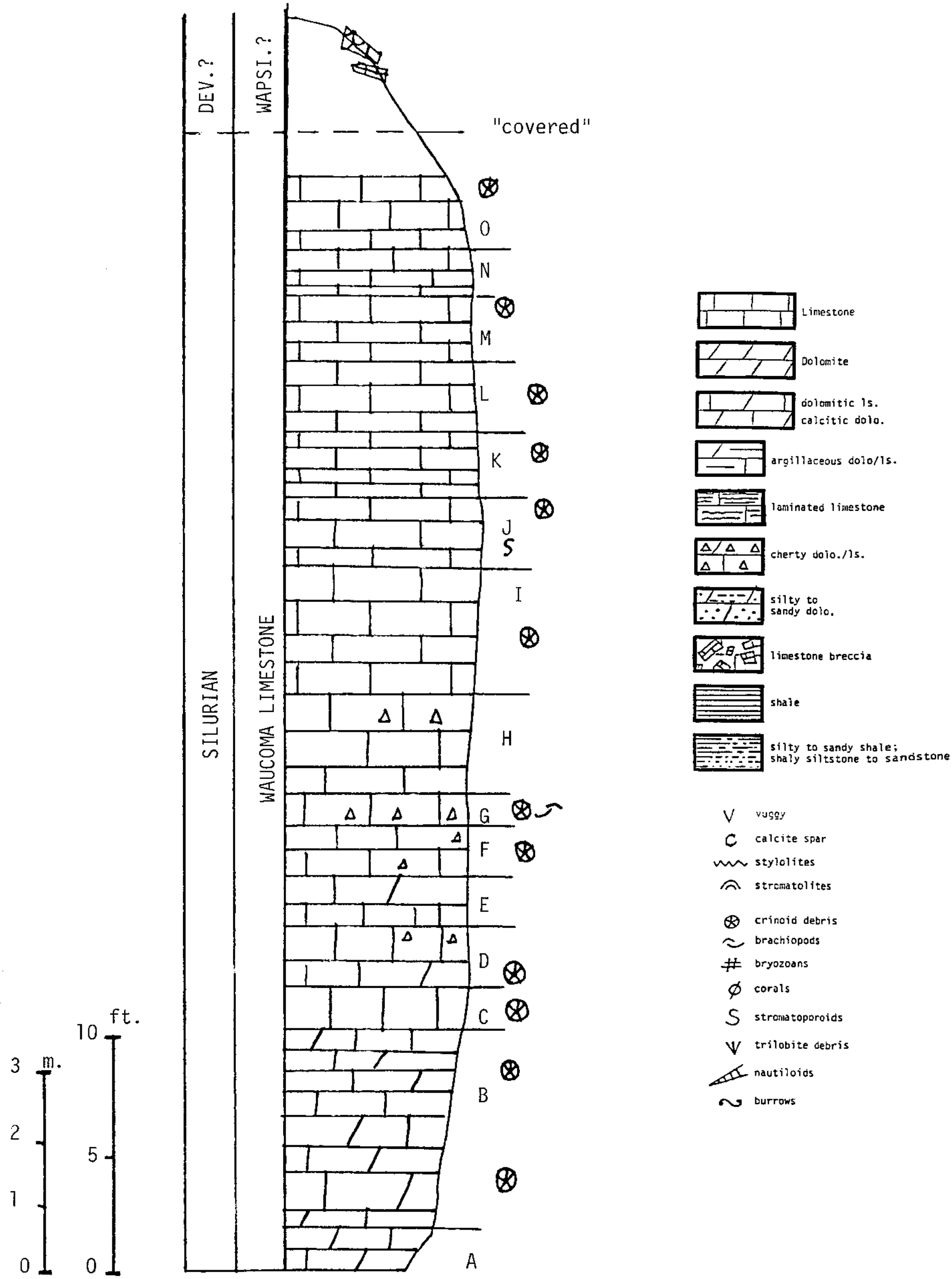

Figure 9. Dutton's cave section (Stop No. 2).

these sites. If you wish to revisit a site please check with the author.)

Mittelstadt Cave is an upland feeder developed in the Waucoma Limestone. As you approach the cave, notice the fractures in the stream bed,which were used for the fracture analysis (Fig. 4). At the cave, notice the stromatoporoid bed. (Don't enter the cave!) This cave, which drains about .5 square km is the site of dye Trace #1.

7.6 Continue east.

8.1 Turn left.

8.5 Park along road as before.

STOP 4. Common sinkhole complex (Lunch Stop!)

This sinkhole complex, which drains about .75 square km, is the site of dye Trace #2. Observe the numerous inactive sinkholes, and the Davenport breccia. Note the solution sculpting of the blocks of Davenport. (Please do not break up these blocks.) At the trace site, observe the petroliferous Spring Grove Member.

8.5 Continue to south.

9.2 Turn right.

11.1 Cross Hwy. 150 and continue west.

13.7 Turn right.

14.4 Turn right.

15.1 Park along road as before.

STOP 5. Wet Cave and Falling Spring.

Follow the trip leader into the valley and to the east to Wet Cave. As with Duttons Cave, this valley was developed along a major cavern system, which flowed to the local base level, in this case, the Little Turkey River. Wet Cave and Falling Spring are developed on separate branches of this system. This valley is floored by the Brainard Shale. At Wet Cave, note the position of the cave in the Waukoma Limestone. At this site, this unit is overlain by the Spring Grove and Davenport Members of the Wapsipinicon Formation and the Cedar Valley Limestone (Fig. 1). The exposed section is 4.6 m thick consisting of in ascending order; A) Silurian dolomite, buff, bedding approximately 4-10 cm thick, finely crystalline; B) dolomite, very light gray, with echinoderm debris, irregular bedding, beds approximately 6-14 cm thick; D) calcarenite as below with dispersed echinoderm debris in a calcilutite matrix, becoming tan-brown upward, beds are about 15 cm

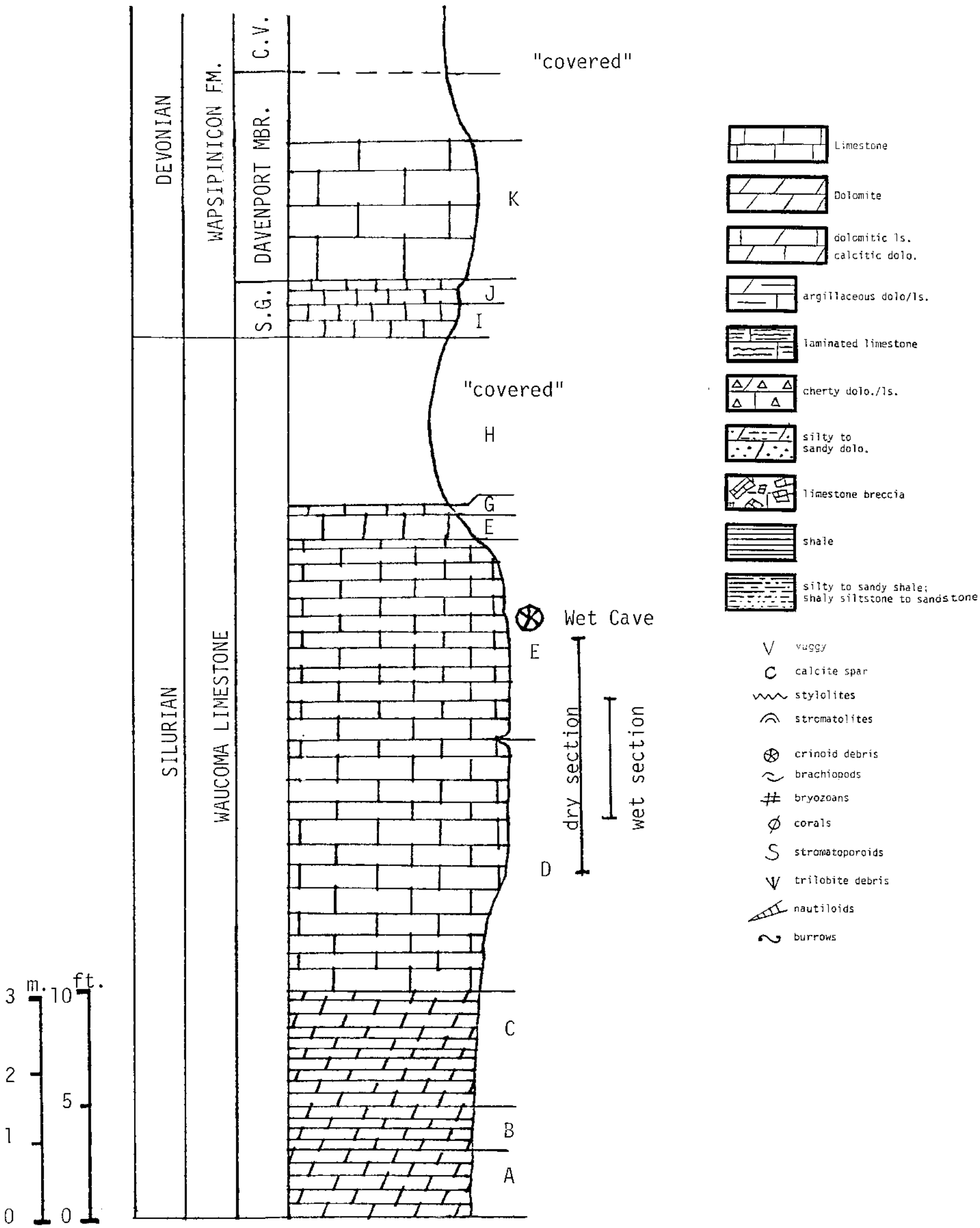

Figure 10. Wet Cave section (Stop No. 5).

thick; E) calcilutite, light gray, lithographic, orange mottling, dispersed echinoderm grains, beds about 7-8 cm thick, bedding planes irregular; F) calcarenite, gray and orange, massive; G) calcilutite, very light gray to pink with orange mottling, echinoderm debris; H) covered; I) Spring Grove, calcilutite, orange to light gray, massive, petroliferous odor; J) calcilutite, orange, thinly bedded; K) Davenport, calcilutite, very light gray with orange mottling, thickly bedded to massive; L) calcilutite, very light gray and orange, pinpoint porosity. This section is overlain by about 1 meter of covered interval with Davenport float, above this there is an estimated 10 meters of Cedar Valley Limestone (Fig. 10). (DON'T ATTEMPT TO ENTER THE CAVE!)

Falling Spring

From Wet Cave follow trip leader back down the valley to the junction with the Falling Spring ravine and up to Falling Spring.

Falling Spring flows from the Waucoma Limestone, as do the other springs visited on this trip.

At this point, you can either retrace your route to the vehicle, or climb the path to the west to the road and walk north to the vehicles. If you do the latter, note the large blocks of Davenport breccia along the route. (Watch your step.)

15.1 Continue north.

16.2 Turn right, east on county road B44.

18.7 Intersection with Hwy. 56. Turn right.

24.0 West Union.

24.9 Junction with Hwy. 18.

25.7 Intersection with Hwy. 56. Turn right.

Follow Hwy. 56 for about 24 miles to Hwy. 13. At the time of this trip, Hwy. 56 may be closed, in that case, follow detour to Hwy. 13.

Hwy 56 follows a re-entrant of the Silurian Escarpment known as Chicken Ridge for much of the way to Elkader.

app. 48.5 Elkader.

app. 50.0 Intersection with Hwy. 13. Turn right (south).

app. 53.5 Brainard Shale overlain by the Blanding Formation (Silurian).

app. 54.0 STOP 6. Crest of Chicken Ridge.

Park on shoulder of highway or on side roads. At this point, the Silurian ridge consisting of the cherty Blanding Formation has narrowed to about 100 meters in width. Notice the mechanical karst resulting from movement downslope of carbonate blocks on the underlying Brainard Shale. Note that a number of these blocks display greater or lesser amounts of solution.

End of trip.

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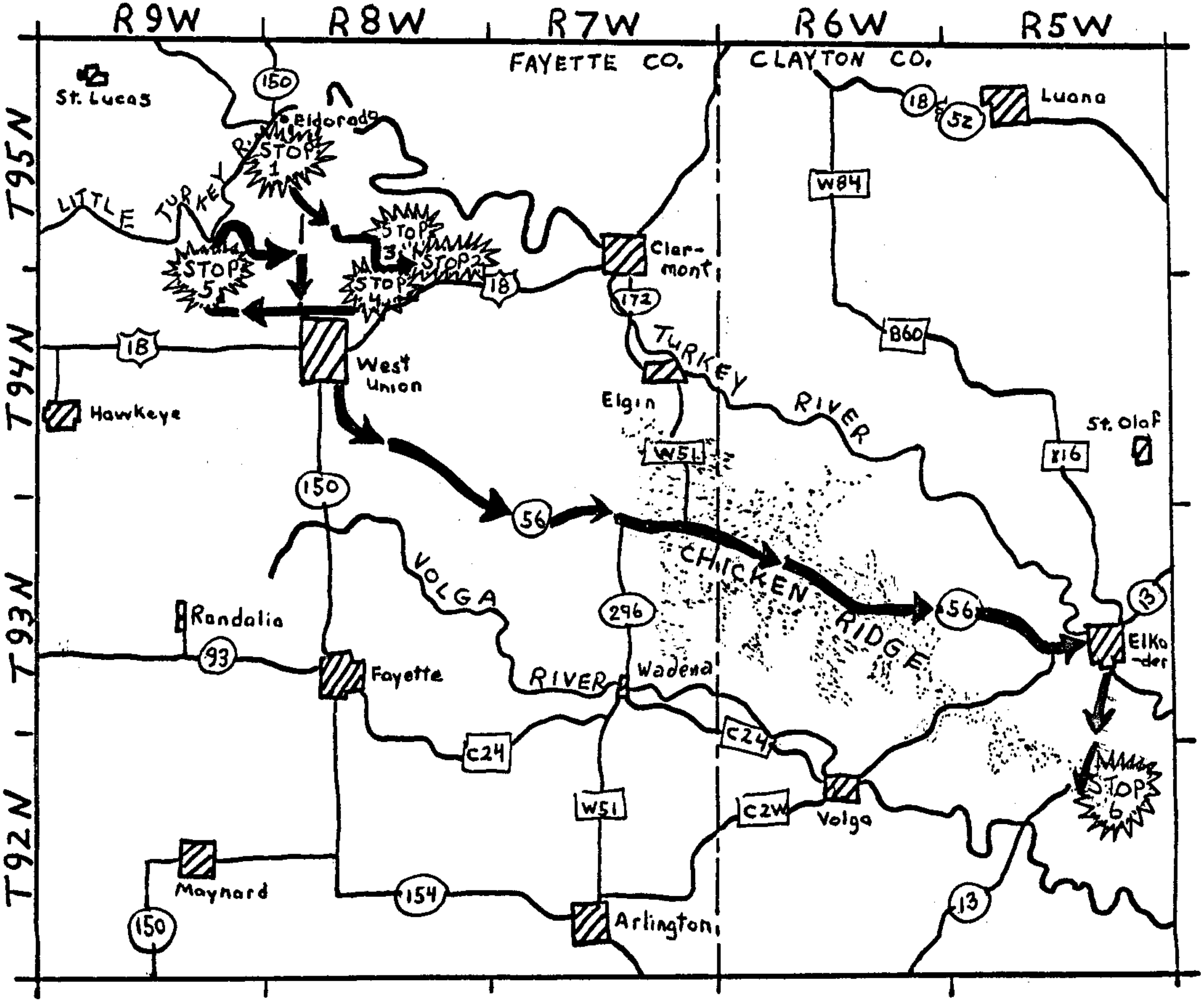
Karstification on the Silurian Escarpment in Fayette County, Northeastern Iowa



GSI Field Trip Route Map