HIGHLIGHTS OF THE UNIQUE GEOLOGY OF THE FORT DODGE, IOWA, AREA

Ryan J. Clark

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Cover Photograph: Exposure along the north wall of the US Gypsum Company's Flintkote quarry. Note the slumping of overlying Wisconsin Des Moines Lobe till into the solutionally-enlarged fractures of the underlying gypsum of the Upper Jurassic Fort Dodge Formation. (Photo taken by Ryan J. Clark on 3/18/2014 and used with permission by the US Gypsum Company.)

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INTRODUCTION

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The Iowa Academy of Science annual meeting is at Iowa Central Community College in Fort Dodge, Iowa. Fortunately for the members of the Geological Society of Iowa (GSI), the Fort Dodge area hosts some of the most unique bedrock geology in the state; such as the basal limestone-clast conglomerates, economic gypsum beds, and desert red beds of the Jurassic Fort Dodge Formation. Previous geological field trips were centered in and around Fort Dodge in 1996 (Cody, et al., 1996, Geological Survey Bureau – Guidebook Series No. 19) and in 1999 (Anderson, et al., 1999, Geological Society of Iowa – Guidebook No. 67). Both trips visited the exposures along Soldier Creek that we will visit today as well as several area quarries.

Of the many things that have changed in the last 15 years or so, safety awareness in quarries has increased dramatically, partly due to the increased enforcement actions by the Mining Safety and Health Administration (MSHA). This, of course, is a much needed improvement to the mining industry; however, it seems to have a negative effect on the geology enthusiast industry. Access to quarries, whether for geologic mapping conducted by Iowa Geological Survey staff or for weekend fossil hunters trying to inflate their collections, is becoming increasingly difficult. Quarries simply cannot afford the risk. That is why I am delighted that one quarry in Fort Dodge allowed us access for the purposes of this field trip. We are very lucky.

The other thing that has changed over the last 15 years is the exposures themselves. For example, both of the previous field trips visited Snell Crawford Park, located along Soldier Creek. Just across the creek from a parking lot stood a ledge of gypsum about six feet (2 m) thick just above the creek level, with another 35 feet (10 m) of Fort Dodge Fm. red beds above it. Today, only three blocks of gypsum survive at creek level with a steep slope of dark red mud above it (Fig. 1). Needless to say, with the limited time we have for our trip, we will not be wasting any of it looking at the Snell Crawford Park section.


Figure 1. Snell Crawford Park section in 1999 (left) and 2014 (right). Note the white gypsum bedrock exposed just above creek level. Much of the gypsum ledge has slumped and been buried over the past 15 years.

The rocks of the Fort Dodge Formation (Upper Jurassic) are the most intensely quarried bedrock units in Iowa. The formation includes a locally-occurring basal conglomerate (Shady Oak Member) and an overlying dark gray claystone, followed by a thick gypsum unit (Gypsum Creek Gypsum Member), and an upper suite of sandstones and mudstones called the Soldier Creek Member (Fig. 2). The formation has an extremely restricted areal extent, with its only known occurrences in central Webster County, Iowa. The thick and exceptionally high quality gypsum unit that dominates the formation has been mined for a variety of economic products since the mid-1800's. Today we will not see the Shady Oak Member since its natural outcrops are very poor and we were not allowed access to the only other exposures in the Georgia Pacific quarry on the west bank of the Des Moines River, but we will examine the other two Fort Dodge Formation members, the Gypsum Creek Gypsum Member and the Soldier Creek Member. The formation was the target of several early geologic investigations in the late 1800's and early 1900's. While these early studies discussed many details of the lithology, structure, and economic features of these strata, especially the gypsum beds, they failed to adequately answer many basic questions, such as the age, depositional environments, and the mechanics of their preservation. The high quality gypsum in the formation has been intensely mined for over 125 years, making the Fort Dodge Formation the only bedrock unit in Iowa that could potentially be completely removed from the geologic record.

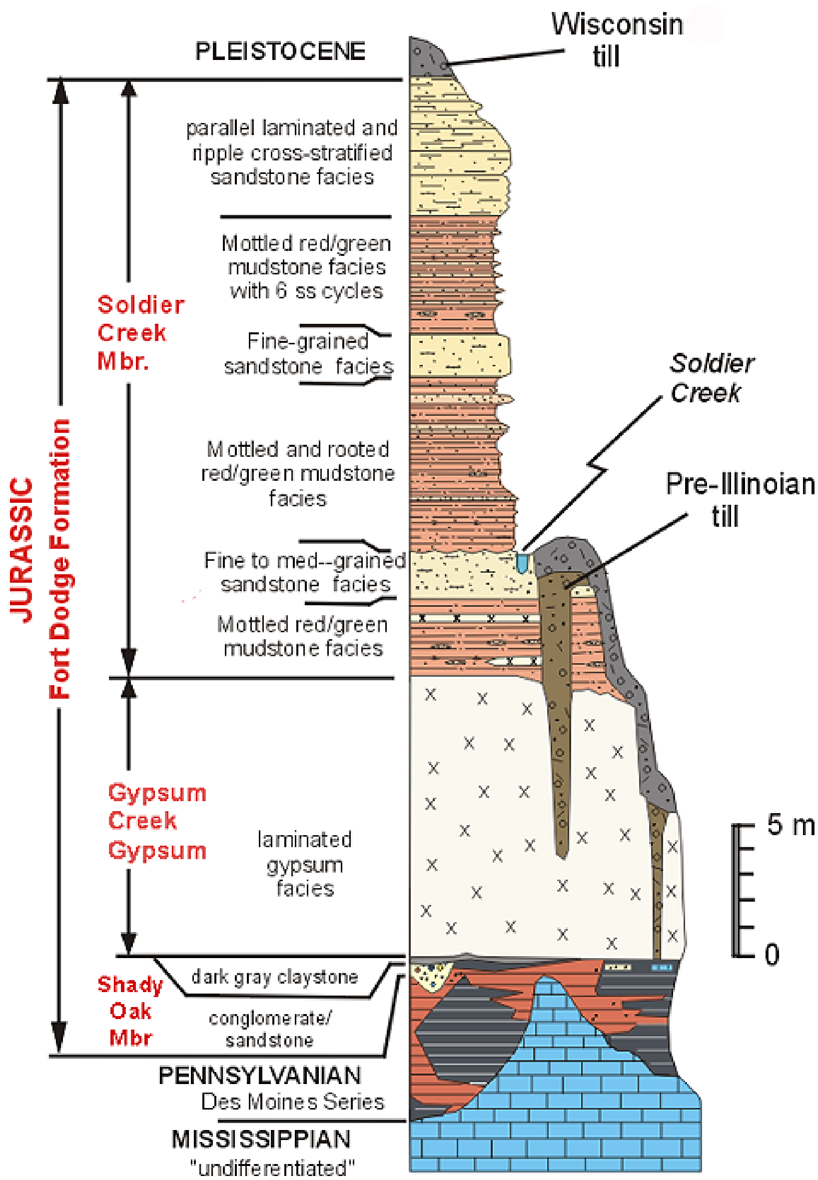

Figure 2. Composite stratigraphic section of the Fort Dodge Formation, from Anderson (unpublished).

Figure 3. Map showing the vicinity of stops #1 and #2.

The field trip will begin on the campus of Iowa Central Community College at parking lot L5 just south of the Bioscience and Health Science Building (see map on back cover). Drive out to Highway 169 and turn right (north) and continue to 2nd Avenue S. Turn right (east) on 2nd Avenue S and continue to N 3rd Street. Turn left (north) on N 3rd Street then turn right (east) on Haskell Street. Then turn left (north) on N 5th Street. Once you get to 5th Avenue N, turn left (west) and go around the building (Humes Distributing, Inc.) to the parking lot by the trail. We will assemble there and walk to stops #1 and #2.

Stop 1 – Soldier Creek Member Exposure – Soldier Creek Nature Trail / 5th Avenue North

****Please do not attempt to cross the creek and do not attempt to climb on the exposure, it is very slippery and unstable!****

The type section exposure of the Soldier Creek Member is located on the west bank of Soldier Creek (Fig. 4) approximately where; 5th Avenue North would intersect the creek, if it were extended west. The name "Soldier Creek Beds" was first applied to the units at this location by Zaskalicky (1956) in an unpublished report on the gypsum resources of the area prepared for the U.S. Gypsum Company. More recently, the name Soldier Creek Member was applied to the unit by Anderson (personal communication), however the earlier assignment of a similar name in Iowa, the Soldier Creek Shale Member of the Bern Limestone, Pennsylvanian Wabaunsee Group, may force this name to be changed.

Figure 4. Soldier Creek Member exposed at the 5th Avenue North section on the west bank of Soldier Creek.

Approximately 50 feet (15 m) of Soldier Creek Member red, tan, and green mudstones, claystones, and highly calcareous sandstones/siltstones are exposed at this section (Fig. 5). Thirteen beds were described and tentatively grouped into five informal units. Comparing the rocks at the 5th Avenue North section with the section at Snell Crawford Park (~ 0.5 miles up Soldier Creek) and a section at the Kohl Brewery (~ 0.4 miles down Soldier Creek) published by Wilder (1919, p. 137-138), an additional 10 to 13 feet (3 – 4 m) of Soldier Creek Member strata are present in the subsurface. This constitutes the entire Soldier

Creek Member section in the Gypsum Basin Facies Tract[1]. At this section, the Soldier Creek Member rests on at least six feet (2 m) of gypsum (as seen at Snell Crawford Park) and up to more than 30 feet (10 m), the maximum observed gypsum thickness in the area.

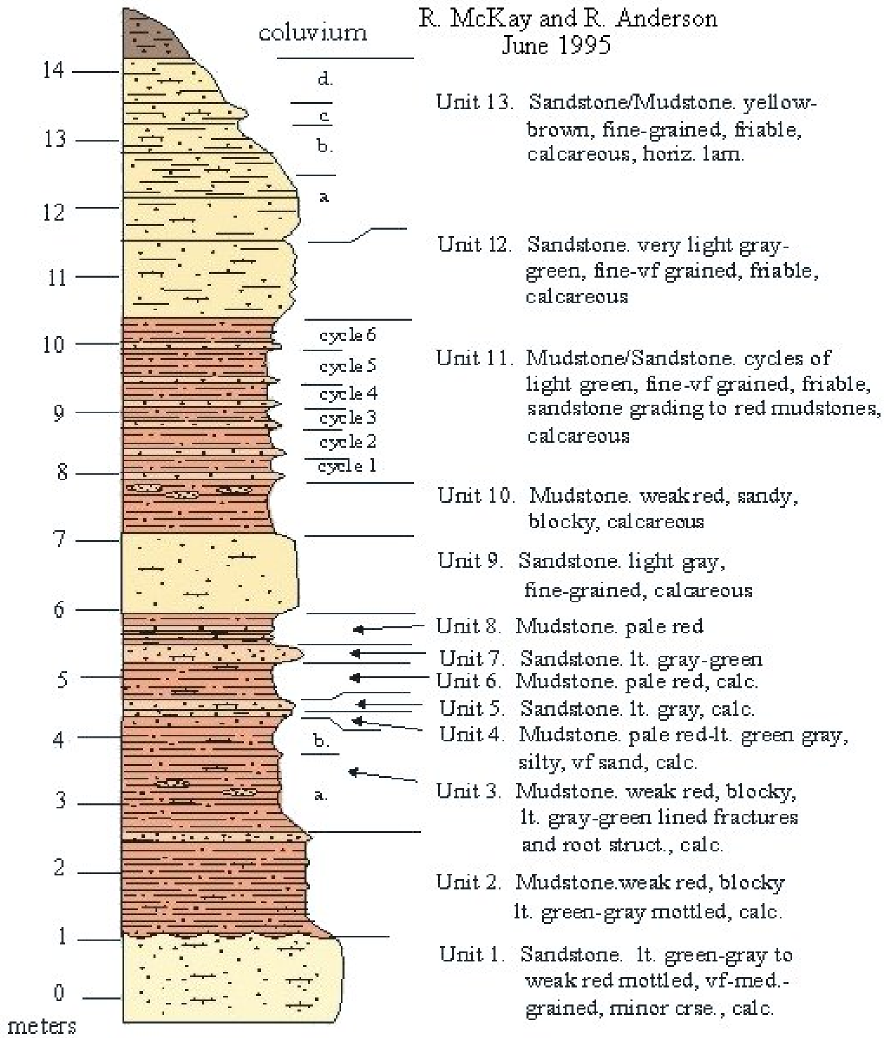

Figure 5. Measured section of the Soldier Creek Member exposed at the 5th Avenue North section on the west bank of Soldier Creek (McKay and Anderson, 1995, unpublished).

The Soldier Creek Member occurring above the gypsum is much thicker and more widely distributed than the basal claystone, conglomerate, and sandstone units (Fig. 2). They were apparently overlying the gypsum at all locations, but have subsequently been eroded from many areas. Additionally, the Soldier Creek Member is present in areas outside of the gypsum basin where they rest directly on Pennsylvanian and Mississippian strata (Fig. 6). For a detailed description of the Soldier Creek Member at this location, see pages 69 – 71 of Anderson, et al., 1999, GSI Guidebook No. 67.

[1] For more information on the two primary facies tracts, the Gypsum Basin and the Western, see pages 16 – 19 of Anderson, et al., 1999, GSI Guidebook No. 67.

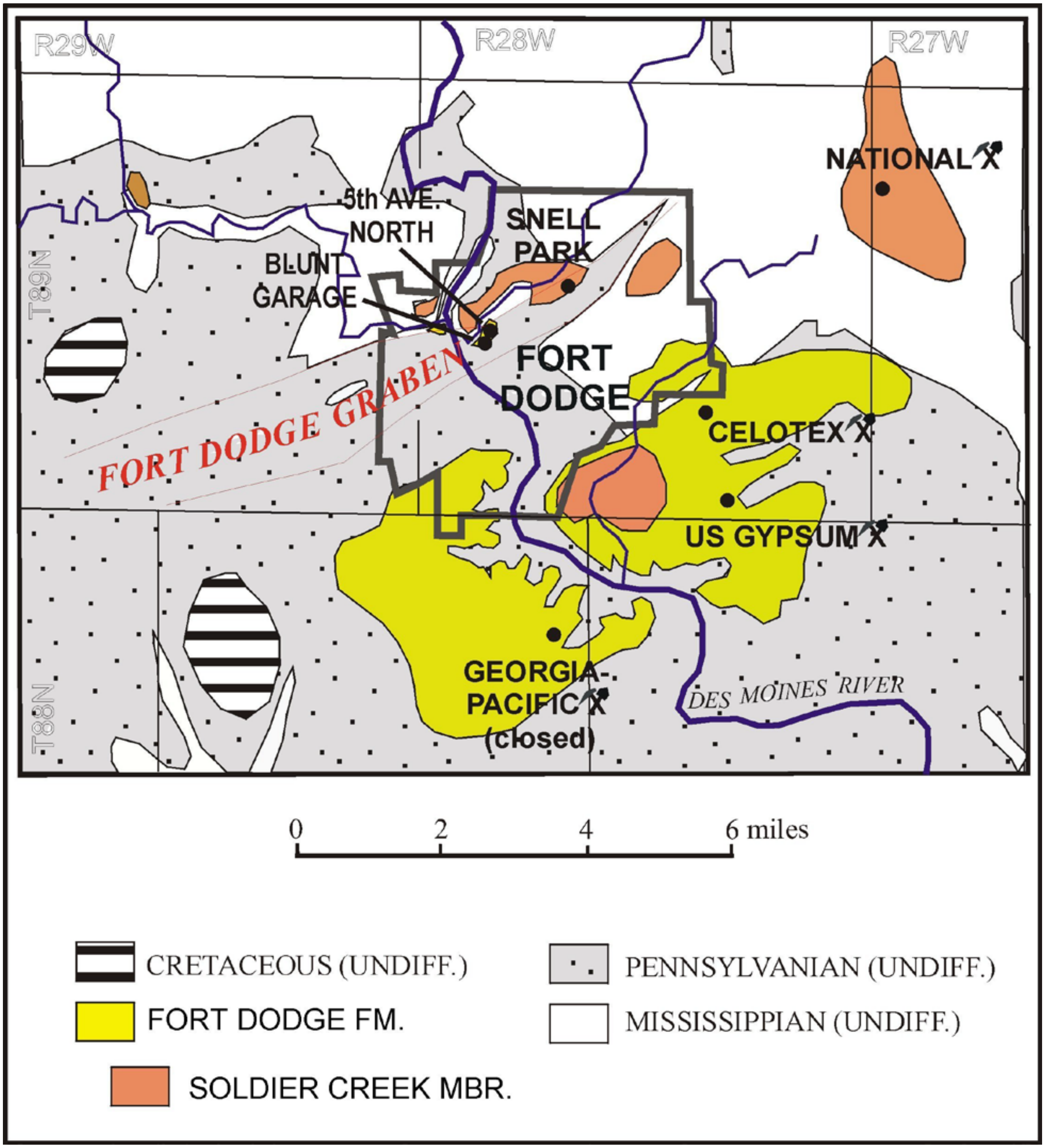

Figure 6. Distribution of the Soldier Creek Member in the Fort Dodge Formation (modified from Anderson, et al., 1999, GSI Guidebook No. 67, p. 15).

Stop 2 – Fort Dodge Fault Zone and Mississippian Bedrock Exposure – Soldier Creek Nature Trail / Skateboard Park

****Please do not attempt to cross the creek and do not attempt to climb on the exposure, it is very slippery and unstable!****

About ¼ mile up Soldier Creek from the 5th Avenue North section is an excellent exposure of Mississippian bedrock of the St. Louis Formation (Fig. 7). At this stop the presence of the Fort Dodge Fault is demonstrated by the exposure of Mississippian carbonates and sandstones at similar elevations and within about 100 feet (30 m) of the Jurassic Soldier Creek Member. St. Louis Formation strata on the up-thrown block form a low waterfall and a high bluff on the west bank of Soldier Creek. The fault zone lies somewhere between stops 1 and 2 in this area.

Figure 7. View looking up stream (north) at Mississippian strata exposed on the west bank of Soldier Creek, just northwest of the Fort Dodge Fault.

The carbonates of the Croton Member are overlain by Yenrougis Member sandstone and Verdi Member limestone (see the graphic section in Fig. 8). Minor satellite faults to the main Fort Dodge Fault can be observed producing tilted and slickensided St. Louis strata on the east bank of the creek. The strata within the Fort Dodge Graben appears to dip to the west (likely the result of a series of step faults paralleling the Fort Dodge Fault), with displacement of approximately 55 feet (17 m) observable in the elevation of the gypsum from the mouth of Soldier Creek to the main gypsum district southeast of Fort Dodge. Faulting at the waterfall was observed to strike 176° and dip at 58° east. Vertical fractures near the fault display a strike azimuth of 53°, dipping 79° to the northwest.

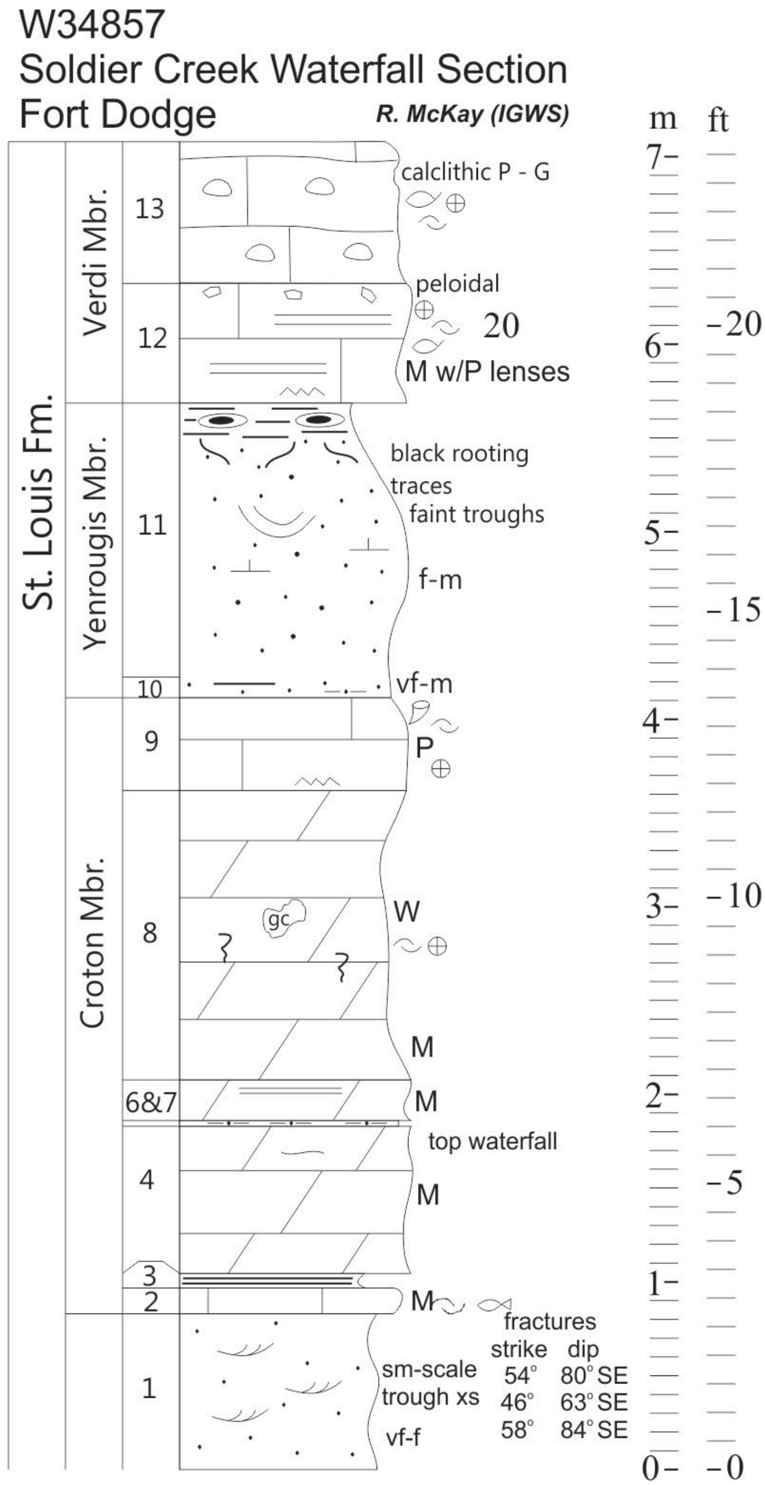

Figure 8. Graphic section of the Mississippian rocks exposed along Soldier Creek on the up-thrown block of the Fort Dodge Fault (Anderson, et al., 1999, GSI Guidebook No. 67, p. 74).

Stop 3 – Gypsum Creek Gypsum Member at the United States Gypsum Company

To reach Stop 3, go back around the way you came into the parking lot and turn right (south) on N 5th Street continuing to 1st Avenue N and turn left (east). Continue to N 8th Street and turn right (south). Drive south on N 8th Street (it will become S 8th Street after you cross Central Avenue). Take a left on Kenyon Road (aka Hwy 169/20) and drive east for 3 miles (see map on back cover). Turn right (south) on Quail Avenue and drive 1.8 miles south to the US Gypsum office, which is just past the railroad tracks on the left (east) side of Quail Avenue. The US Gypsum office address is 2200 Quail Avenue. Please park your vehicles in the office parking lot and we will transport people to the selected stop(s) as needed.

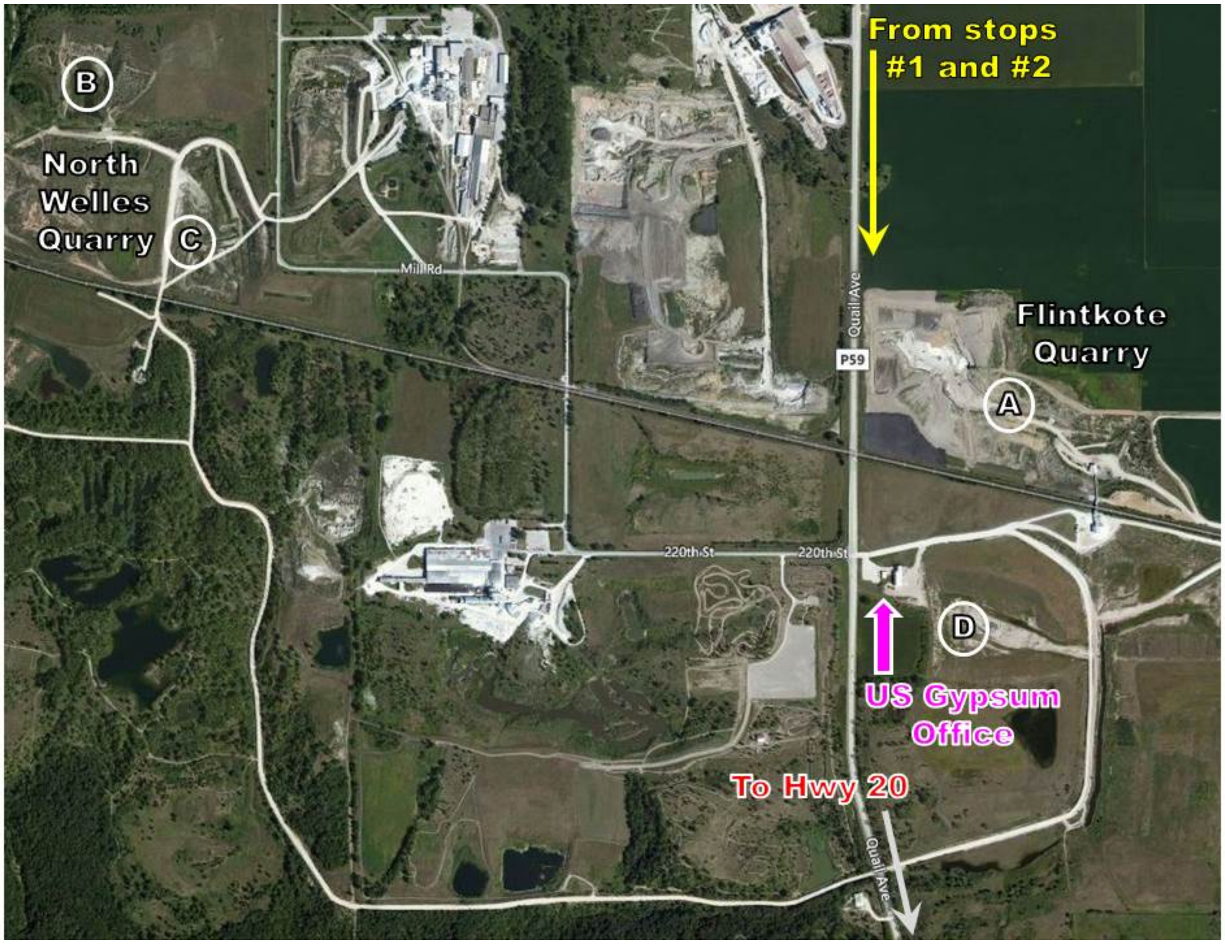

Figure 9. Map showing the vicinity of Stop #3.

Due to the uncertainty of weather conditions leading up to and including the day of the field trip, we have identified four possible locations (Fig. 9 A-D) on US Gypsum Co. property in which to view the bedrock gypsum present in this area. The two previously mentioned field trips that visited this area in 1996 and 1999 accessed several of the area quarries including the US Gypsum – Collins quarry (now called the Flintkote quarry), so the geology in this area is well understood.

HARDHATS MUST BE WORN AT ALL TIMES INSIDE THE QUARRY!
STAY AWAY FROM HIGHWALLS AND STEP CAREFULLY!

The US Gypsum Company produced approximately 450,000 tons of raw gypsum per year from its quarries up to 2008. Now production has reduced to approximately 125,000 tons annually. This is due, in part, to the downturn of the construction industry and closure of the wallboard plant. Mining the gypsum bedrock involves removing the glacial sediments overlying the bedrock and stockpiling it until the quarry is closed. Once the gypsum bedrock is exposed, it is drilled, blasted, and transported by large dump trucks to the processing plant. After a pit has exhausted its gypsum deposits, the glacial overburden is pushed over the highwalls to mimic the natural cover as much as possible and to create gradual slope angles to minimize erosion.

Figure 10. Photo of the working face looking northeast from inside the US Gypsum Flintkote quarry. Note the thickness of the glacial sediment package overlying the gypsum and the irregular bedrock surface. (Photo taken by Ryan J. Clark on 3/18/2014 and used with permission by the US Gypsum Company.)

Gypsum Creek Gypsum Member

The Gypsum Creek Gypsum Member, the major gypsum-bearing unit of the Fort Dodge Formation, is generally bright white with gray banding. The gypsum is of remarkably pure quality, between 89% and 96% $CaSO_4 \cdot 2H_2O$ (Bard, 1982). The distinctly bedded deposit consists of layers ranging from two inches (5 cm) to 10 inches (25cm) thick, separated by thin clay bands along which it is easily parted. The upper surface of the gypsum is highly variable due to extensive dissolution along preferential fractures in the rock. This surface is most notably eroded in areas where the overlying Soldier Creek Member is absent and the gypsum is directly overlain by glacial deposits (Fig. 10).

The white bands are of three types. The first is comprised of approximately horizontal laminations of single-tiered, vertically-oriented, elongate gypsum crystals. The second type appears to result from the coalescence of small nodules concentrated in horizontal planes. The third and last type of light/dark banding results from intercalation of marl layers within the gypsum (Fig. 11). The dark bands appear to be composed of mineral impurities, but only discontinuous stringers of accessory mineral inclusions are visible in thin-sections. Major impurities are quartz, iron oxide, clay, and calcite/dolomite. Further study of the mineral impurities found in the Gypsum Creek gypsum by Hayes (1986) revealed pyrite, limonite, and possibly tourmaline. Mineral impurities were found to constitute between 1.0% and 3.5% of the rock.

Figure 11. Banding in hand specimen of Gypsum Creek Gypsum Member.

Jurassic Strata of the Midcontinent

The Jurassic was marked with the beginning of the breakup of the Pangean supercontinent. In general, the Jurassic is characterized by significant marine transgressions on a world-wide scale, with seaways advancing into the heartlands of the existing continents. Seas transgressed onto the North American craton from three sides during the Jurassic, the north, the west, and the south. From the north the Western Interior Seaway, known as the Logan or Sundance sea, extended southwards as far as New Mexico and Arizona along the trend of the modern Rocky Mountains (Sellards et al., 1981). Periodic transgressions of these seas were followed by regressions and erosional episodes that divide the three major subdivisions of the Jurassic, the Lower, Middle, and Upper. Surviving strata show progressive overlap by each successive sequence.

The climate in central North America appears to have been relatively uniform throughout the 64 million years of the Jurassic (208 – 144 Ma). Circulation through the oceans that lay at both the north and south polar regions probably prevented the formation of polar ice caps accounting for this general climatic amelioration (Sellwood, 1978). However, the onset of the Late Jurassic was marked by a significant climatic change, expressed by overall warming of the climate in the Northern Hemisphere (Vakhrameev, 1988). Vast areas of the continent were flooded by shallow epicontinental seas during the Middle and Late Jurassic, but the seaways regressed from continental interiors by end of the period. Evaporite deposition was extensive in North America in the areas marginal to the inland seas (Brenner, 1983).

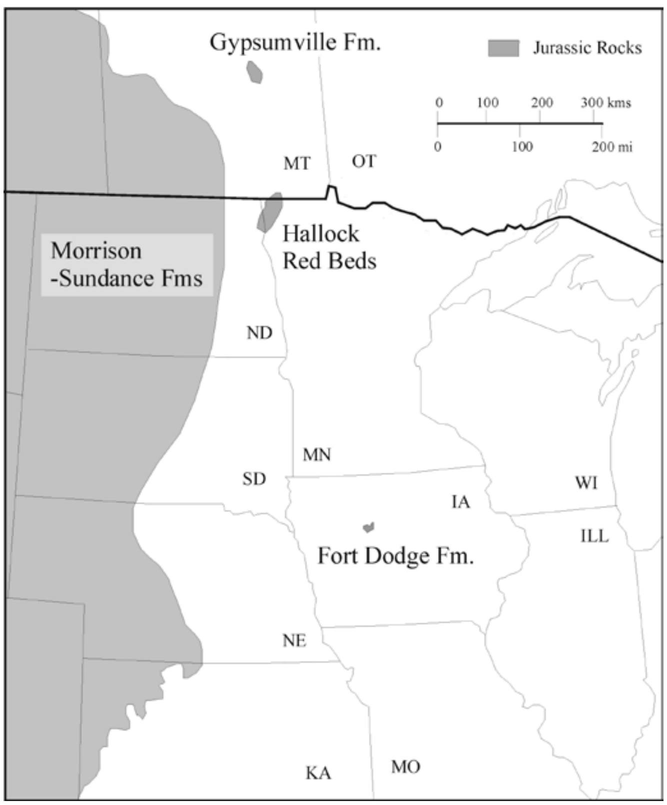

Figure 12. Location of Jurassic rocks in the Midcontinent.

The maximum limits of the Jurassic marine transgressions are not known due to extensive post-Jurassic erosion. However, the presence of a limited number of outliers of Jurassic evaporites and other strata provides minimum limits. The Fort Dodge beds are one of only a few of the remnants of these formerly extensive evaporite deposits to survive subsequent erosion. Others include the Hallock Red Beds (Mossler, 1978) in northwestern Minnesota, and the Gypsumville Gypsum (Banatynee, 1959) in east-central Manitoba (Fig. 12). These outliers are located hundreds of kilometers east of the main body of North American Jurassic strata in the western plains states and Rocky Mountains (Bunker et al., 1988; Brenner, 1983). The Fort Dodge Formation was probably deposited contemporaneously with the vast, dinosaur-bearing strata of the Morrison-Sundance formations of the western interior.

Origin of the Fort Dodge Gypsum

Some aspects of the deposition of the Fort Dodge Gypsum are fairly well understood and are not controversial. It is clear that the gypsum was deposited in a closed or restricted basin or basins in an arid climate where evaporation exceeded precipitation. Beyond those generalities, however, many aspects of the history of the Fort Dodge gypsum are not unambiguous. Was it a marine or inland continental lake deposit, and was the evaporite basin originally much larger than the gypsum's currently known extent or did it approximately coincide with the present-day extent of gypsum?

Among the difficulties in trying to answer these questions are: (1) the lack of autochthonous marine or continental fossils; (2) the complete lack of time-related strata in nearby areas, the nearest being in the subsurface of central Nebraska, Michigan, or northwest Minnesota; (3) unconformable upper and lower surfaces; (4) underlying shale and basal conglomerate and overlying 'Soldier Creek beds' also lack autochthonous fossils and other marine/continental indicators; (5) pervasive gypsum recrystallization; (6) near absence of primary structures and textures, even in relict form.

In contrast with these problems, several known features place restrictions on proposed hypotheses. These are: (1) purity of the gypsum; (2) apparent lack of lateral facies differences from one gypsum location to another; (3) near absence of vertical facies changes, with the exception of shallow water indicators in upper one-third of the section; and (4) similarity of sulfur isotope $\delta^{34}S$ ‰ values to those of the marine Jurassic isotope age curve (Claypool et al., 1979; Hansen, 1983).

Marine or Continental Deposit?

Probably the fundamental question relating to the deposition of the Fort Dodge gypsum is whether the deposit originated in a marine or continental environment. A marine gypsum deposit would utilize ocean water as the source of calcium sulfate. Deposition would have occurred in an evaporite basin with restricted connection to an open ocean, presumably to the west in the case of the Fort Dodge gypsum, or in a deep open sea basin with poor circulation. If the Fort Dodge gypsum was of marine origin, then the Late Jurassic shorelines must have been farther to the east than is indicated by the current main body of preserved Jurassic strata (Fig. 12). If the Fort Dodge gypsum was deposited in an inland continental lake, then calcium sulfate must have been derived from dissolution of older nearby evaporites. Both Devonian and Mississippian gypsum/anhydrite deposits occur in southern Iowa (McKay, 1985). South of Fort Dodge, gypsum/anhydrite deposits occur in Devonian rocks that lie about 650 to 1,300 feet (200 – 400 m) below the Fort Dodge beds, but shallower Mississippian gypsum may have once been present and subsequently disappeared through dissolution. Widespread brecciation of buried Mississippian limestones may be evidence of collapse resulting from subsurface evaporite dissolution.

Deposition probably occurred in a large evaporite basin, but there is no evidence available to confirm the geometry of the gypsum basin or the lateral extent of evaporite deposition. The purity of the gypsum and the lack of preserved lateral facies change support the contention that gypsum deposition was once more widespread than its present-day occurrence alone would suggest. Both factors argue against an inland continental lake setting. In inland continental lakes distant from an ocean, evaporite deposition utilizes groundwater supplemented by $CaSO_4$-bearing surface water as a source for the $CaSO_4$. Gypsum precipitation would be relatively slow, and wind-derived and seasonal river clastic input would prevent pure gypsum from being deposited. Fort Dodge gypsum contains wind-blown silt as a minor component, but no larger silicate particles that might have been transported by rivers. The silt usually constitutes < 4% of the rock, and seems insufficient in concentration for a continental groundwater-fed evaporite lake with slowly precipitating gypsum.

The only 90%+ pure gypsum lake deposits we know of occur in a few, relatively small, sea-marginal lakes. Thick, relatively pure, laminated gypsum deposits occur in the sea-marginal dune lakes of South Australia (Warren, 1982, 1989). In sea-marginal Lake MacLeod in northwest Australia (Logan 1987), halite deposits are relatively clean because the NaCl concentration in seawater seeping through permeable coastal sediments requires that relatively small volumes of water evaporate to produce thick salt deposits. Rapid precipitation of halite, therefore, easily overwhelms clastic input from wind and other sources. In comparison to halite, seawater contains relatively small amounts of $CaSO_4$, so that large amounts of seawater must evaporate to form thick pure gypsum deposits (Fig. 13). This process can be relatively rapid in sea-marginal lakes supplied by seawater flowing through permeable coastal sand dunes, but gypsum in these lakes is not always of high purity. Lake MacLeod gypsum is mixed with clay and aragonite (Logan, 1987).

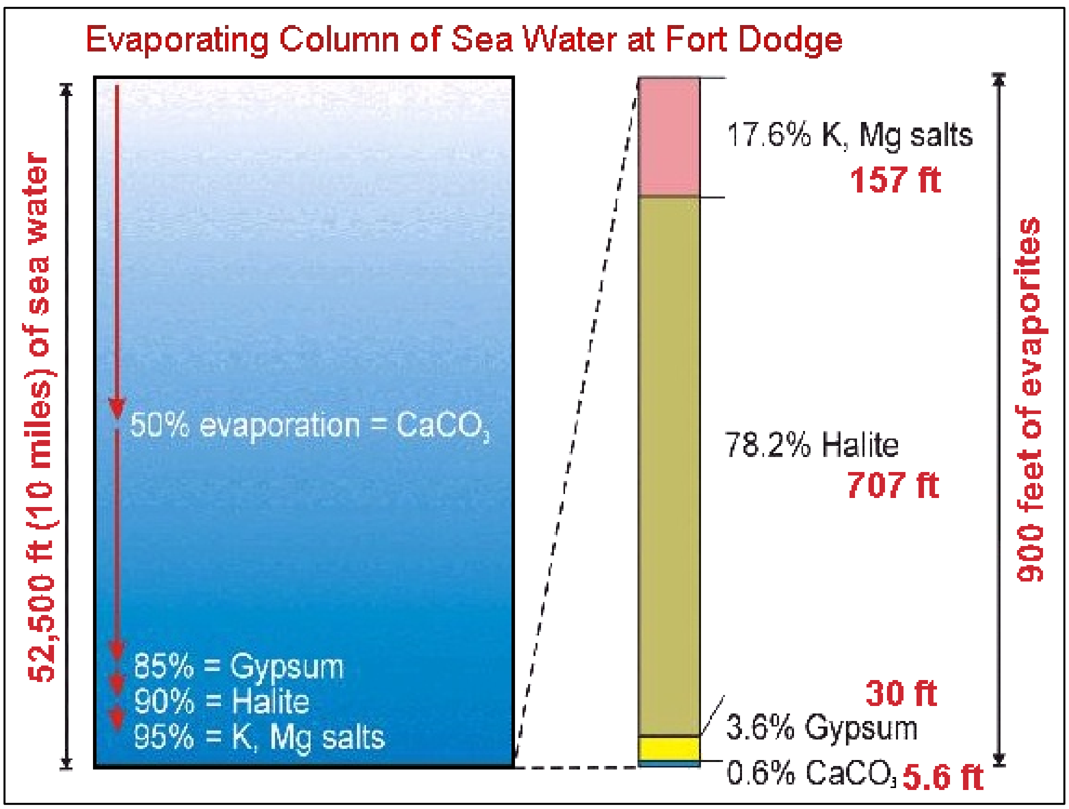

Figure 13. Diagram showing amount of sea water necessary to produce the same thickness of Fort Dodge gypsum.

Other problems related to a continental lake origin are the absence of carbonates which would be expected in lakes fed largely by groundwater. Fort Dodge area Devonian and Mississippian gypsum was closely associated with limestone/dolomite, and groundwater rich in calcium sulfate would be expected to carry abundant carbonates in solution. Carbonates are abundant in both the underlying conglomerate and in the Soldier Creek Member however, lake margin carbonate deposits may have once been present but might have been eroded in pre-Pleistocene times.

The similarity of $\delta^{34}S$ ‰ of the Fort Dodge gypsum to marine Jurassic values seems surprising if the sulfate were derived from buried Devonian or Mississippian gypsum, but this evidence could be stronger because sulfur isotope values of both Devonian and Mississippian Iowa sulfates overlap those of the Jurassic (Hansen, 1983).

Deposition of the Fort Dodge gypsum in a deep-sea basin with poor circulation and vertical communication with surface waters is ruled out by reconstructions of Late Jurassic paleoenvironments. The Fort Dodge area lay at the eastern-most limits of the Sundance Sea, as indicated by the very limited number of preserved outliers, the characteristics of the rock in these outliers and the main body of Jurassic strata, and the lack of evidence of a Jurassic structural basin in the region. All these data indicate that the Sundance Sea of the central midcontinent transgressed eastward over a very flat, very low-relief surface, reaching its maximum transgression somewhere in the Iowa area. There is no evidence that its depth in the area reached hundreds of meters or that any significant basins were present.

In summary, lithologic features and regional interpretations suggest that the Fort Dodge gypsum was deposited in a relatively large sea-marginal lake or restricted marine evaporite basin. However, the lack of marine palynomorphs in the gypsum, place some major constraints on the configuration of the depositional basin. The basin must have been large enough to trap any sediment contributed by rivers and most other terrestrial sources near its margins (now lost to erosion.) Also, some barrier must have restricted or very seriously limited the direct communication of water from the open sea to the west and the gypsum basin. Normal surface circulation of water, as would occur over a submarine barrier, would allow for the movement of planktonic and other shallow water palynomorphs into the basin. The barrier separating the Fort Dodge gypsum basin from the Sundance Sea may have risen above the surface of the water, and recharge of $CaSO_4$ -rich water may have been by percolation through a permeable barrier such as an along-shore sand bar (Fig. 14).

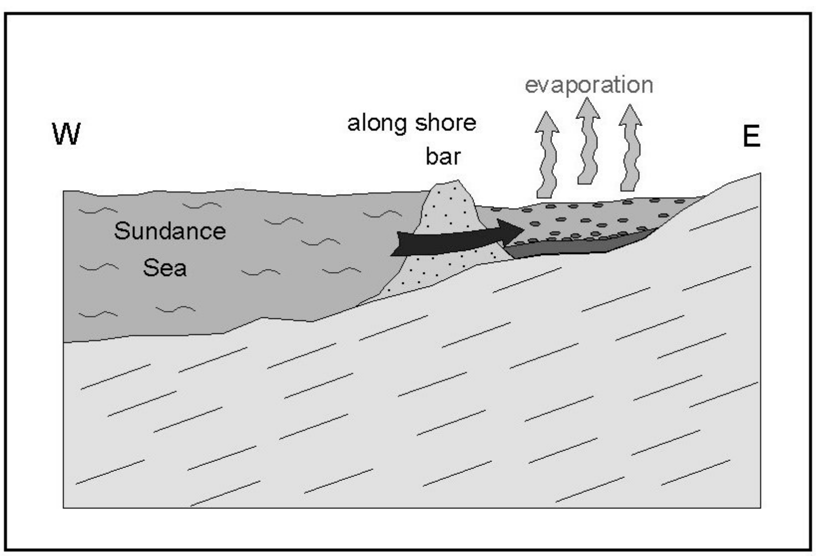

Figure 14. Possible model for recharge of brines in the Fort Dodge Gypsum basin.

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109 Trowbridge Hall
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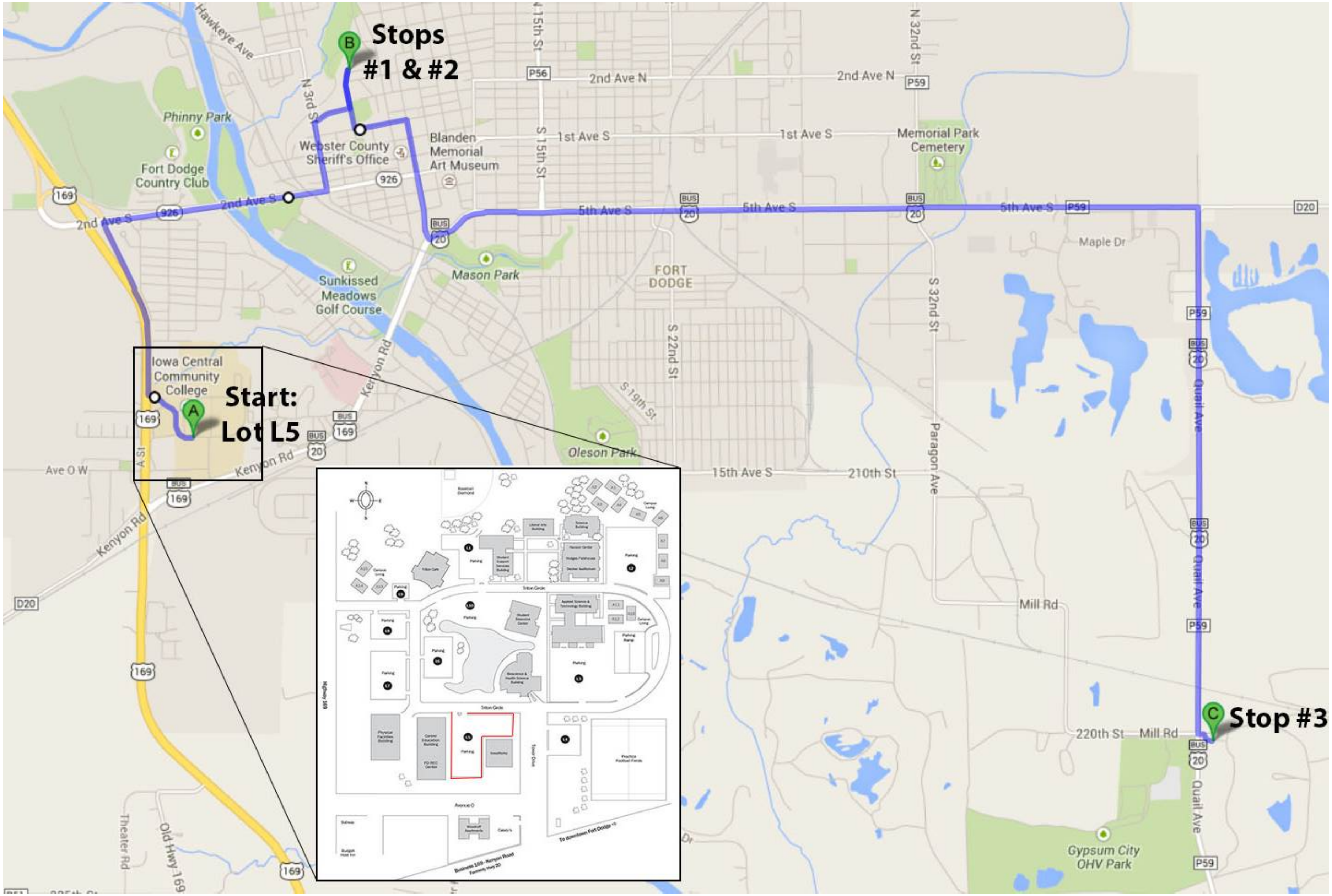

Stops
#1 & #2
Start:
Lot L5
Stop #3
Iowa Central
Community
College
Webster County
Sheriff's Office
Blanden
Memorial
Art Museum
Phinny Park
Fort Dodge
Country Club
Sunkissed
Meadows
Golf Course
Mason Park
Oleson Park
Memorial Park
Cemetery
Gypsum City
OHV Park
FORT
DODGE
Hawkeye Ave
N 3rd St
2nd Ave S
2nd Ave N
1st Ave S
5th Ave S
S 15th St
S 22nd St
S 19th St
N 32nd St
S 32nd St
Paragon Ave
15th Ave S
210th St
Maple Dr
Mill Rd
220th St
Quail Ave
Kenyon Rd
A St
Ave O W
Theater Rd
Old Hwy 169