GEOLOGY AND RECLAMATION AT THE WATERLOO SOUTH QUARRY BLACK HAWK COUNTY, IOWA

prepared by: Ryan J. Clark



Geological Society of Iowa

April 22, 2017

Guidebook 94

Cover Image

BMC Aggregates L.C. geologist, Sherman Lundy, staring down the Hinkle Member. "It's basically a sandwich, with lithographic limestone on top and bottom, and shale in the middle." Photo by Ryan Clark.

GEOLOGY AND RECLAMATION AT THE WATERLOO SOUTH QUARRY

edited by:

Ryan J. Clark

Iowa Geological Survey University of Iowa Iowa City, IA 52242 ryan-j-clark@uiowa.edu Phil Kerr Iowa Geological Survey University of Iowa Iowa City, IA 52242 phillip-kerr@uiowa.edu Stephanie Tassier-Surine Iowa Geological Survey University of Iowa

Iowa City, IA 52242 <u>stephanie-tassier-</u> surine@uiowa.edu

with contributions by:

Bill J. Bunker

Iowa Geological & Water Survey (Retired) Iowa Dept. of Natural Resources Iowa City, Iowa 52242

Ryan J. Clark

Iowa Geological Survey University of Iowa Iowa City, IA 52242 ryan-j-clark@uiowa.edu

Paul L. Garvin

Cornell College (Retired) Mount Vernon, Iowa 52314

Chad Heinzel

Dept. of Earth & Env. Sciences University of Northern Iowa Cedar Falls, Iowa 50614 chad.heinzel@uni.edu

Sherman Lundy

BMC Aggregates L.C. Elk Run Heights, Iowa 50707 <u>sherml@bmcaggregates.com</u>

Brian J. Witzke

Iowa Geological & Water Survey (Retired) Iowa Department of Natural Resources Iowa City, Iowa 52242 and Dept. of Earth & Env. Science (Adjunct) University of Iowa Iowa City, IA 52242 brian-witzke@uiowa.edu

April 22, 2017 Geological Society of Iowa Guidebook 94

This and other Geological Society of Iowa guidebooks may be downloaded as pdf files, or printed copies may be ordered from the Iowa Geological Survey website at: <u>www.iowageologicalsurvey.com</u>.

TABLE OF CONTENTS

Field Trip Introduction	
by Ryan J. Clark	1
Beneficial Fill/Quarry Reclamation Project – Waterloo South Quarry	
by Sherman Lundy	9
Surficial Geology of Southern Black Hawk County	
by Chad Heinzel	11
Devonian Stratigraphy of the Waterloo South Quarry:	
Eagle Center Member – Iowa City Member	
by Brian J. Witzke and Bill J. Bunker:	
with contributions by Ryan J. Clark	17
Minerals of the Waterloo South Quarry, Black Hawk County, Iowa	
by Paul L. Garvin	25
Field Trip Stops	
by Ryan J. Clark	29

FIELD TRIP INTRODUCTION

By: Ryan J. Clark

The 2017 Iowa Academy of Science annual meeting is at the University of Northern Iowa in Cedar Falls, Iowa. After a one year hiatus, this year the meeting will be followed by a field trip organized under the auspices of the Geological Society of Iowa (GSI). The GSI may not be an official membership-granting organization, but it remains one of the primary bridges between the Iowa Geological Survey (IGS) and the citizens of Iowa. The only other time a GSI field trip ventured into this quarry was back in 1984 led by Wayne Anderson of UNI and Paul Garvin of Cornell College (GSI guidebook #42). Figure 1 is the map showing the notable features at the Waterloo South Quarry (WSQ) in southern Black Hawk County and the locations of the field trip stops we will make today.



Figure 1. Map of the WSQ.



Figure 2. Ryan Clark, IGS geologist, leaning on the contact between the Hinkle and Eagle Center members.

Stop #1 will provide participants an up-close look at the reclamation project that BMC has initiated at this quarry. Stop #2 will take us to the incline ramp leading to the former underground mine (now filled with water) to study the contact between the Hinkle and Eagle Center members (Fig. 2) as well as to view rare stromatolites in the upper Eagle Center Member. Stop #3, the final field trip stop, is where we will see the nearly full Eagle Center Member, for which the WSQ is section. discuss the type and the reorganization of the Devonian stratigraphic lexicon and its implications in correlating these units since the keystone publication by Witzke et al. in 1988. The trip will be highlighted by the opportunity to collect mineral specimens of calcite, pyrite, marcasite, and many others from rubble piles of the Hinkle Member!

We ask the field trip participants to use common sense and conduct themselves in a manner that will ensure their safety as well as the safety of those around them, so we can maintain a positive relationship with BMC for years to come!

ACKNOWLEDGMENTS

Today we thank BMC Aggregates L.C. (BMC) for their continued support and cooperation as they allow the 2017 GSI field trip into the Waterloo South Quarry (WSQ). Special thanks goes to BMC geologist, Sherman Lundy. Without his tireless support and cooperation, this GSI field trip would lack the educational value we desire to offer our participants.

The editor wishes to thank all of the contributing authors and those behind the scenes that helped with the compilation of this guidebook. The GSI appreciates the support from the leadership of IIHR-Hydroscience & Engineering and the IGS for allowing us the opportunity to continue this great tradition of joining the citizens of Iowa in our desire to embrace the geologic wonders in our backyard.

HISTORY OF THE WATERLOO SOUTH QUARRY

By: Sherman Lundy

According to historical aerial photography, quarry activity has occurred at this location since the 1930's and continues to the present. The unique feature here is a "mound," or rise, or perhaps an erosional feature

shaped by erosional events and Pleistocene Glaciation leaving this structure, consisting of the Coralville Formation, on top with low overburden thicknesses at the intersection of Quarry and Dysart roads.

Earlier operations by Concrete Materials Company, later Martin Marietta, mined limestone on the NW, NE, and SW corners before extending operations to the southeast corner at this location (Figs. 3-6). In 1982, Martin Marietta sold their operations in the Waterloo area to Basic Materials Corp, (later name change to BMC Aggregates) which the operators and owners of the quarry operation now refer to as "South Quarry."

Martin Marietta developed an underground mine in the southeast corner after the quarry operation moved to the south side of Miller Creek and expanded into what was the former Elliott Property. The underground mine targeted the upper Solon Member (now the Bassett Mbr.) in addition to the surface extraction of rock from the Coralville Formation. This was due in part to the need to secure additional concrete stone to supplement the limited surface area available for open pit mining and to maintain a Class 2 Concrete Source, which in the 1970's and early 80's was the principle concrete stone for highways. Prior to the acquisition of this location by BMC Aggregates, the IDOT had added two additional categories of concrete aggregate, Class 3 and Class 3i, whose characteristics (chemical and physical properties) exceeded the characteristics of the aggregate available from the Solon Ledge in the mine and underground mining ceased at South Quarry. Portions of the Coralville Formation and the upper beds of the old Rapid Member (now the Eagle Center Mbr.) in the open pit mine continue to be utilized today for commercial concrete stone, referred to as Class 1 Concrete stone, or primarily as the ³/₄" aggregate suitable for asphalt paving. Other beds are suitable for road stone and subbase production along with products including aglime, rip-rap, road stone, and erosion stone.

In effect, today's operation extracts rock from the Coralville Formation for road stone and subbase along with asphalt stone. The upper beds of the former Rapid Member, now part of the Little Cedar Formation, are utilized for road stone products and some subbase materials. Plans are being considered for possible deeper excavation to open the Solon Ledge up in a surface mining operation in the east part of the operation to produce asphalt stone as the Coralville beds thin toward the south part of the east pit.

The operations in this southeast corner of the Dysart Road and Quarry Road intersection are by far the larger of the previous operations at this location. Over 400 acres have been or are part the aggregate operation with around another 90+ acres of potential reserves left to be uncovered. Of that 400 acres in the southeast corner, 70 acres have been reclaimed for farming and about 30 acres have been reforested. Exploration around the perimeter of the site suggest rising bedrock to the south where the Coralville section is thinning and other properties surrounding this area have 60+ feet of overburden and probably bedrock erosional surfaces where the Coralville Formation has been eroded away.



Figure 3. 1930's aerial photo of the WSQ.

Figure 4. 1960's aerial photo of the WSQ.

Figure 5. 1980's aerial photo of the WSQ.

Figure 6. 2005 aerial photo of the WSQ.

BENEFICIAL FILL/QUARRY RECLAMATION PROJECT – WATERLOO SOUTH QUARRY

By: Sherman Lundy

Nearly 12 years ago, BMC was approached by the University of Iowa regarding the possible acceptance of the fly-ash product from the coal combustion power plants as a beneficial fill material for quarry reclamation. Working with the Solid Waste Section of the Iowa Department of Natural Resources (IDNR), BMC and the University of Iowa, went through the process of examining the physical and chemical character of the fly ash as a possible resource and not a solid waste. This process, referred to as a BUD (Beneficial Use Determination), involved not only the character of the ash but also included the placement and management of the ash as a reclamation material.

Fly ash was, and still is, utilized as an additive in cement and asphalt with other uses as a fill material for highway and road construction. The University fly ash as processed also contains remnants of slaked lime which had been added as part of the University program to control sulfur oxides (SOx) emissions from the power plant. There were and are several concerns for consideration of the fly ash as a beneficial fill material. Some of the major concerns involved in the BUD of the ash material include placement of the ash above the level of water supply wells in the area, out of any flood plain issues, within a closed area to prevent any spillage or leakage from the site, and an annual (or more frequent if necessary) chemical analysis of the ash materials for the presence of 18 heavy metal concentrations, with reference to groundwater and drinking water standards.

The BMC management considerations for placement of the ash as a reclamation material included a pugging process (where the ash is mixed with water) which was implemented to produce a product for final placement of the material in an older abandoned section of the quarry (Figs. 7 & 8). Another important issue was the recognition that the ash from the Power Plant was highly alkaline and that the ash after pugging and periodic mixing with aglime from the quarry would be placed in an alkaline, limestone, location. This is important as heavy metals, while highly soluble in acidic solutions, are minimally or nearly insoluble in alkaline solutions. Even with the presence of very low concentrations of heavy metals below any thresholds of concern, this was further evidence of virtually no leaching of any heavy metals from the ash which would cause problems with groundwater. Also, the pugging or mixing of the alkaline ash with water further generated an exothermic reaction whereby a newer product was formed and instead of the ash, a harmless calcitic slilicate material was generated as the final fill product. As a condition of the BUD approval, BMC also implemented the establishment of several monitoring wells, which are sampled periodically for the presence of any heavy metal concentrations of concern. To date, after a decade of sampling and analysis, complex reviews of the testing results indicate no issues with any transmissivity of any heavy metals or ash particles. Later, the University of Northern Iowa and Iowa State University became involved with this reclamation project. Currently, the Iowa State material is no longer brought to the BMC facility and is used as a daily cover at the Des Moines Area Metro Landfill.

Shortly after this BUD approval for the fly ash from the three State Universities, the John Deere Foundry located in Waterloo asked to be involved in this reclamation project and underwent a similar BUD review

by the IDNR for their foundry sand. Today, the Deere Foundry sends one half of their foundry sand product to BMC's South Quarry and the other half goes to the Lehigh Cement plant in Mason City.

The use of the fly ash from the Universities along with the John Deere foundry sand as a resource and not a waste product is helping to turn abandoned limestone quarry areas into productive farm land with no impact or adverse concerns regarding water resources or other environmental issues.

Figure 7. Fly ash fill material in the old Waterloo South Quarry pit. (photo by Ryan Clark)

Figure 8. Containment structure where fly ash is dumped into the pug mill located below. (photo by Ryan Clark)

SURFICIAL GEOLOGY OF SOUTHERN BLACK HAWK COUNTY

By: Chad Heinzel

Basic Materials Corporation (BMC) owns and operates the Waterloo South Quarry (WSQ), located in southcentral Black Hawk County Iowa. The surficial geology surrounding this quarry contains an opulent history of Quaternary events. Black Hawk County and much of northeast Iowa fall within an area classified as the Iowa Erosion Surface (IES) (Prior, 1991). The IES is one of ten landform regions currently recognized in our state and is sometimes referred to as the Iowan Surface (Fig. 9). A landform region/physiographic province is a product of an area's geology and predominant surficial processes (weathering, erosion/transportation, and deposition) over recent geologic time, comprising the past two million years.

Figure 9. Landform Regions of Iowa, identifying the location of the BMC Waterloo South Quarry within the Iowan (Erosion) Surface.

The Iowan Erosion Surface (IES) is characterized by complex sediment assemblages of glacial, periglacial, eolian/wind, fluvial/river and pedisediment/gravity deposits. Geologic interpretations of this landscape date back 100 years and continue to change as new scientific techniques and data inform our understanding of the area's development. A foundation of Pre-Illinoian glacial sediments (approx. 1.2 Ma to 550,000 y.b.p) set the stage for subsequent periods of intense weathering and erosion (Ruhe, 1969; Hallberg et al., 1978). Current research suggests the IES was greatly impacted by the development of periglacial environments during the Middle to Late Wisconsin stages (approx. 85,000 to 25,000 y.b.p.) (Bettis and Autin, 1997, Mickelson and Colgan, 2004, Kerr et al., 2017). Prominent periglacial features within the IES include sediment-filled ice-wedge casts, polygonal patterned ground and a distinctive stone line separating underlying pre-Illinoian till and overlying loess to pedisediment (Walters, 1994; Davidson & Walters, 2010; Matzke et al., 2013). Distinctive northwest to southeast trending eolian features, paha and sand stringers, pepper the surface of the IES. These loess to sand deposits mark an active period of wind-driven sedimentation (approx. 28,000 to 14,000 y.b.p) (Halberg et al., 1978; Zanner, 1999). Two and half miles south of the quarry on HWY 21 is an area called Hickory Hills. The primary landform features responsible for this beautiful area of raised topography are Casey's Paha and Wolf Creek Drainage to the south (Halberg et al., 1978).

Recent geologic mapping efforts by the Iowa Geological Survey (STATEMAP) and University of Northern Iowa (EDMAP) have characterized the surficial deposits of Black Hawk County (Tassier-Surine *et al.*, 2013; Heinzel *et al.*, 2012). The area surrounding the Waterloo South Quarry contains the following mappable surficial geology units: Qwa2 (Shallow loam to sand over till), Qnw2 (Sand and gravel), Qal (Recent alluvial/stream sediment), and Qpq (Pits and quarries) (Fig. 10). The two primary features of this landscape are loam covered glacial uplands (Qwa2) that are dissected by Miller Creek (Qal). The soil series surrounding the Waterloo South Quarry are commonly classified as Dinsdale or Kenyon on the uplands and Sawmill or Nevin in the lowlands. The approximate ranges of depth to bedrock are zero to 35 feet for the glaciated uplands (Qwa2) and one to three hundred feet within and adjacent to the stream drainages (Qal to Qnw2). A relatively shallow depth to bedrock within the Waterloo South Quarry area makes it economically feasible to extract natural resource/limestone.

The Waterloo South Quarry falls within the Miller Creek Watershed that drains into the Cedar River between Glibertville and La Porte City, Iowa. This area drains 42,461 acres of land and is made up of two Hydraulic Unit Code (HUC) 12 classified areas (Headwaters Miller Creek and Miller Creek) (Fig. 11). Like much of Iowa, the Miller Creek Watershed contains a productive agricultural system (mainly corn and soybeans). An estimated 200 tons of phosphorous-rich sediment per year runs off of fields and through Miller Creek's drainage network. Local farmers and Basic Materials Corporation (BMC) are working with the Black Hawk Soil and Water Conservation District as well as the National Resources Conservation Service (NRCS) to reduce nutrient runoff and improve the overall water quality flowing through Miller Creek.

Surficial Geology of the Waterloo South Quarry

Figure 10. Map exhibiting the surficial geology surrounding the WSQ in southern Black Hawk County.

Miller Creek Watershed

Figure 11. The Miller Creek Watershed, inset with the location of the WSQ.

REFERENCES

- Bettis, E.A. and W.J. Autin, 1997, Complex response of a midcontinent North America drainage system to Late Wisconsinan sedimentation: Journal of Sedimentary Research, vol. 67, no. 4, p. 740-748
- Davidson, J. and Walters, J.C., 2010, Ventifacts on the stone line of the Iowan Surface of Northeast Iowa: Proceedings and Abstracts of the Annual Geologic Society of America Meeting, Denver, Colorado, Vol. 42, no. 5, p. 285.
- Hallberg, G.R., Fenton, T.E., Miller, G.A., and Luteneggar, A.J., 1978, The Iowan Erosion Surface an Old Story, an Important Lesson and some New Wrinkles: 42nd Annual Tri-State Geological Field Conference Guidebook, Kirkwood Community College, Oct. 13-15, p. 2-1/2-94.
- Heinzel, C.E., Bosshart, N. Shultz, J., and Lenth, Z., 2012, The surficial geology of the Waterloo South Quadrangle (7.5'), Black Hawk County, Iowa: United States Geological Survey (EDMAP).
- Kerr, P., Tassier-Surine, S., Streeter, M., Liu, H., Clark, R., 2017, Surficial Geology of the Orchard 7.5' Quadrangle, Iowa: Proceedings and Abstracts, Iowa Academy of Science Meeting, University of Northern Iowa, April 21-22, p. ?
- Matzke, J., Bettis III, E.A., Wierich, F., Vogelgesang, J., 2013, A new view of the stone zone on the Iowa Erosion Surface: Proceedings and Abstracts of the Northcentral region, Geologic Society of America Meeting, Kalamazoo, MI, vol. 45, no. 4, p. 17.
- Mickelson, D.M., and Colgan, P.M., 2004, The southern Laurentide Ice Sheet, in The Quaternary Period in the United States, Gillespie, A.R., Porter, S.C. and Atwater, B.F. (eds.): Developments in Quaternary Science, vol. 1, p. 1-16.
- Prior, J., 1991, Landforms of Iowa, University of Iowa Press, 168p.
- Ruhe, R.V., 1969, Quaternary Landscapes in Iowa: Iowa State University Press, 255p.
- Tassier-Surine, S., Quade, D., Rowden, R., McKay, R., Huaibao, L., and Giglierano, J., 2013, Surficial Geology of Black Hawk County, Iowa, Iowa Geologic Survey, Open File Maps (OFM)-13-4, STATEMAP, U.S.G.S. #G12AC20280.
- Walters, J.C., 1994, Ice-Wedge Casts and Relict Polygonal Patterned Ground in Northeast Iowa, USA: J. of Permafrost and Periglacial Processes, v. 5, p. 269-282.
- Zanner, C.W., 1999, Late Quaternary landscape evolution in southeastern Minnesota Loess, eolian sand, and the periglacial environment: Dissertation, University of Minnesota, 381p.

DEVONIAN STRATIGRAPHY OF THE WATERLOO SOUTH QUARRY: Eagle Center Member – Iowa City Member

By: Brian J. Witzke and Bill J. Bunker

with contributions by:

Ryan J. Clark

INTRODUCTION

Unraveling the Devonian System of Iowa was more than a century in the making before retired Iowa Geological Survey (IGS) geologists Brian Witzke and Bill Bunker took on the challenge. Previous geologist's attempts at correlating the vast Devonian exposures throughout eastern Iowa, and eventually incorporating data from the ever increasing number of boreholes throughout the state, relied upon characterizing the lithological and faunal relationships observed in the rocks. However, due to the extreme lateral variations and facies changes displayed by the Devonian sequence in Iowa, much confusion remained. Brian and Billy provided much needed clarity by building on the work of those previous geologists. Only after their diligent work, using primarily conodont biostratigraphy, were they able to reliably redefine and correlate the stratigraphic nomenclature that geologists use in Devonian carbonate work to this day. Their efforts were expertly synthesized in Witzke *et al.* (1988) which provides the majority of the unit descriptions that follow in this section of the guidebook.

As part of their work, Witzke *et al.* realized that correlation of the Cedar Valley Group across the outcrop belt was not possible given the formational groupings at the time. They identified the need to separate the members found in north-central Iowa from those at similar stratigraphic horizons in southeastern Iowa. Thus, one of the major improvements borne out of the 1988 paper was the introduction of the Little Cedar Formation. This formation encompasses four distinct members in north-central Iowa that were all newly defined in the 1988 paper (in ascending order: Bassett, Chickasaw Shale, Eagle Center, and Hinkle) and two distinct members in southeastern Iowa that carried the original unit names (in ascending order: Solon and Rapid). The Waterloo South Quarry (WSQ) was designated as the type section of the Eagle Center Member by Witzke *et al.* (1988).

CEDAR VALLEY GROUP STRATIGRAPHY: OLD VS. NEW

Owen (1852) termed the Middle Devonian carbonate sequence of eastern Iowa the "limestones of Cedar Valley," and McGee (1891) formally designated this interval the "Cedar Valley limestone." Subsequent definition of the Wapsipinicon Formation restricted the Cedar Valley Limestone to the interval above the Wapsipinicon and below the Upper Devonian shales of the Sweetland Creek and Lime Creek formations. Prior to the 1980's, the Cedar Valley Formation was split into three members: Solon, Rapid, and Coralville (Fig. 12). The use of conodonts as biostratigraphic markers enabled geologists to more accurately dissect the Cedar Valley into groupings based on individual transgressive-regressive cycles, thus refining the

thickness and extent of formations. The Cedar Valley attained official group status encompassing four formations, in ascending order, the Little Cedar, Coralville, Lithograph City, and Shell Rock (Fig. 12).

←────NORTHERN IOWA ─────>							EAST-CENTRAL IOWA →													
STAINBROOK (1935) Dorheim & Klapper & Barrick (1983) Koch (1965) Kettenbrink (1972) Kettenbrink (1972)																				
NORA MBR.		NORA MBR-		Nora Mer+		FM.	Nora Mer-													
ROCK	Rock Grove Mer-		ROCK		Rock Grove Mer-		ROCK	Rock Grove Mbr.												
HASON CITY		BR-		SHELL	MASON CITY MER-	1	SHELL	MASON CITY MBR.		STAINBROOK (1935, 1941a)				THIS REPORT						
				UNIT C	SROUP MAIN	GRAPH CITY FM.	IDELWILD MBR- THUNDER WOMAN SH-		STATE QUARRY FM.			ITY FM.	STATE QUARRY MBR-							
CEDAR VALLEY FM.	Coralville Mbr.		DAR VALLEY		LWR	ΓE	LITHO	Osage Springs Mbr+				LEY GROUP	10							
					UPR	JAR VAL	ALVILLE FM.	IOWA CITY MBR-		Coralville Mbr-			ALVILLE FM.	Iowa City Mbr-						
			CEI	5	LWR	CEL	COR	GIZZARD CREEK MBR+	VALLEY FM.			EDAR VALI	COR	Cou Falls Mbr-						
					UPR		FM.	HINKLE MBR-					FM.							
	RAPID									UNIT A	"RAPID" Sh•		E CEDAR	CHICKA- CENTER SAW SH- MBR-	CEDAR	RAPID MBR.		5	CEDAR	RAPID Mar-
	MBR-			-		LWR		רודון	BASSETT MBR-		Sa	LON MBR.		LITLE	Solon Mer.					
			MO		DAVENPORT-		DGE	DAVENPORT-	-	Dav	VENPORT MBR.	-	DGE	DAVENPORT MBR.						
			IPINI	E.	SPRING GROVE UNDIFF.	SROVE UNDIFF.		SPRING GROVE		SPRING GROVE MBR.		6P.	FM.	SPRING GROVE MBR-						
			WAPS		Kenwood Mbr.		PINIC	Kenwood Mer-	VICON	Kenwood Mbr.		IICON	PINIC	Kenwood Mbr.						
	Solon Mrr-		SPILL		ILLVILLE FM.			SPILLVILLE FM.		OTIS MBR-		ILLIS	FM.	CEDAR RAPIDS MER-						
						WAP		LAKE MEYER MBR-				WAP	1	BERTRAM FM.						

Figure 12. Historical summary of the stratigraphic nomenclature of the Middle and lower Upper Devonian rocks of northern and east-central Iowa. (from Witzke *et al.*, 1988, figure 1, page 222)

The immense amount of data collected and distributed by the Iowa Geological Survey (IGS) reflects the changes in stratigraphic nomenclature over time. This data needs to be updated whenever possible, which can be a daunting task. For example, with recent mapping efforts in north-central Iowa, geologists at the IGS have been updating the lithologic descriptions of well logs that pre-date the 1988 changes. Since the stratigraphic boundaries were changed (rather than simply changing the name of a unit and keeping the contact the same), hundreds of well logs housed in the IGS well database (GeoSam) had to be restudied to verify the correct correlations and stratigraphic descriptions in the system.

CEDAR VALLEY GROUP - INTRODUCTION

The Cedar Valley Group is a widespread interval of limestone and dolomite strata, in places with evaporite (gypsum-anhydrite) beds, that occurs across most of Iowa and adjoining areas of Illinois, Minnesota, Missouri, and Nebraska. It reaches a maximum thickness of about 180 ft (55 m) in Black Hawk County where it includes three formations, in ascending order: Little Cedar, Coralville, and Lithograph City (Fig. 13). The highest strata of the group, the Shell Rock Formation, are not recognized in Black Hawk County. The reader is referred to additional publications for regional stratigraphic, biostratigraphic, and depositional

Geological Society of Iowa

summaries (e.g., Witzke *et al.*, 1988; Witzke and Bunker, 2004; Day *et al.*, 2013). In Black Hawk County, the Cedar Valley Group is dominantly composed of Middle Devonian age rocks (Givetian), with erosional outliers of lower Upper Devonian (lower Frasnian) strata, the Lithograph City Formation. Although the Bedrock Geologic Map of Iowa (Witzke *et al.*, 2010) notes outliers of even younger Devonian rocks of the Lime Creek Formation, subsequent detailed mapping as part of the STATEMAP program revealed that no Lime Creek Formation rocks exist in Black Hawk County (Rowden *et al.*, 2013). Unlike the underlying Wapsipinicon Group, the Cedar Valley Group is richly fossiliferous, and numerous studies have documented much (although not all) of the diverse marine fossil faunas that these strata have yielded to paleontologists and fossil collectors through the years.

Figure 13. Generalized stratigraphic cross-section from north-central to extreme east-central Iowa, showing interpreted stratigraphic relationships of the various units of the Wapsipinicon and Cedar Valley groups (from Witzke *et al.*, 1988).

The section we will see today includes the upper half of the Eagle Center Member of the Little Cedar Formation through the lower part of the Gizzard Creek Member of the Coralville Formation (Fig. 14). The following descriptions of these units are from Witzke *et al.* (1988).

Figure 14. Bedrock section seen at the Waterloo South Quarry. (photo by Ryan Clark)

LITTLE CEDAR FORMATION

The Little Cedar Formation includes lower Cedar Valley strata which are bounded below by the Wapsipinicon Group (or Ordovician-Silurian rocks where the Wapsipinicon is absent) and above by the Coralville Formation. The type locality is at the Chickasaw Park Quarry (Witzke *et al.*, 1988) adjacent to the Little Cedar River in southwestern Chickasaw County, Iowa; this locality exposes one of the most complete sections (55 ft [17 m]) of the formation in northern Iowa. The Little Cedar Formation ranges from 50 to 120 feet (15 – 37 m) in thickness; it is thinnest in southeastern Iowa and thickest in northern and central Iowa. The Coralville overlies a disconformity or discontinuity surface at the top of the Little Cedar Formation in parts of Johnson County and the Sweetland Creek Shale overlies the formation at a few localities in southeastern Iowa. The Little Cedar Formation at a few localities in southeastern Iowa. The Little Cedar Formation is interpreted to have been deposited during a large-scale transgressive-regressive (T-R) cycle (part of cycle IIa of Johnson *et al.*, 1985), the Taghanic Onlap (Johnson, 1970). The formation is subdivided into three to four members in northern and central Iowa (in ascending order, Bassett, Chickasaw Shale, Eagle Center, and Hinkle) and two members in southeastern Iowa (Solon and Rapid). Subsequent discussion of the constituent members present at the WSQ follows.

Eagle Center Member

The Eagle Center Member consists of an interval of argillaceous and generally cherty, laminated dolomite below the Hinkle Member and above the Chickasaw Shale or Bassett Member. The member is dominated by sparsely fossiliferous to unfossiliferous burrowed argillaceous dolomite and contains prominent chert nodules and bands in the lower one-half to seven-eighths (Fig. 15). Faint to prominent laminations, in part

Geological Society of Iowa

disrupted by scattered burrow mottles, characterize much of the member at most sections; some laminations are pyritic (Anderson and Garvin, 1984). Thin dolomitized or silicified fossiliferous calcilutite and calcarenite beds are interspersed locally within the generally unfossiliferous sequence. The Eagle Center is not dolomitized to the southeast of the type area, where it is dominated by sparsely fossiliferous to unfossiliferous, burrowed, cherty, argillaceous calcilutite, in part laminated, and contains thin skeletal calcarenite beds. Upward it becomes dominantly finely calcarenitic. Upper Eagle Center strata, primarily in areas where the member overlies the Chickasaw Shale, contain stromatoporoids or corals and are locally biostromal. The Eagle Center Member ranges in thickness from 26 to 36 feet (8 - 11 m) where it overlies the Bassett Member, and is 5 to 14 feet (1.4 - 4.2 m) thick where it overlies the Chickasaw Shale Member.

Figure 15. Chert nodules in the Eagle Center Member. (photo by Ryan Clark)

Conodonts from the Eagle Center Member (Icriodus subterminus and Polygnathus xylus xylus) are assigned to the Lower subterminus Fauna (Witzke *et al.*, 1988; Rogers, 1990). Macrofauna is sparse in the member, but scattered fish debris (placoderm and shark) is noted in the laminated dolomites. Thin fossiliferous beds within the laminated sequence have yielded brachiopods (Neatrypa waterlooensis, Orthospirifer, Cranaena, and "Cupularostrum"), bryozoans, and crinoid debris (Anderson and Garvin, 1984). Upper strata are locally biostromal, primarily in the northern sections, and have yielded corals (Hexagonaria, solitary rugosans, and favositids), domal stromatoporoids, brachiopods, crinoid debris, and rostroconchs. The fauna and stratigraphic position indicates correlation of the Eagle Center with upper Rapid strata.

Hinkle Member

The Hinkle Member is the uppermost member of the Little Cedar Formation in northern and central Iowa, where it conformably overlies the Eagle Center or Bassett members and is disconformably overlain by the Coralville Formation. It conformably overlies the upper Rapid Member along its southernmost extent. The Hinkle Member is characterized by dense unfossiliferous "sublithographic" limestone and dolomitic limestone, in part with laminated, pelletal, intraclastic, and "birdseye" fabrics. Similar fabrics are noted at all known sections, but the member is partially to completely dolomitized over most of north-central and central Iowa. Hinkle strata are generally unfossiliferous, but burrows, ostracodes, and sparse brachiopods have been noted locally. The member is commonly fractured to brecciated (Fig. 16), and argillaceous beds

Figure 16. Brecciated "sublithographic" limestone in the Hinkle Member. (photo by Ryan Clark)

and minor shale (locally carbonaceous) are present at many sections. Laminated carbonates are petroliferous in part, and desiccation cracks and minor erosional disconformities occur within some Hinkle sequences. Gypsum molds are present locally (e.g., Klug, 1982, p. 47), and the member includes extensive evaporites (gypsum and anhydrite) in central Iowa. The Hinkle changes character near its eastern margin where faintly laminated limestones are interbedded locally with thin fossiliferous limestone beds containing brachiopods, echinoderm debris, favositids, and domal stromatoporoids. The Hinkle Member averages about 8 feet (2.5 m) in thickness and is known to vary between 1 to 13 feet (0.4 - 4.1 m). Erosional relief, locally to 3 feet (1 m), is evident below the Coralville Formation at some localities.

CORALVILLE FORMATION

In an 1866 lecture at the University of Iowa, the internationally famous geologist Louis Agassiz emphasized the significance of fossil coral accumulations in the Iowa City area. Several months later, abundant corals were encountered in limestone layers during the construction of a mill along the Iowa River west of Iowa City (now the Iowa River Power Restaurant). The State Press (December 19, 1866) gave an account of this and of the subsequent naming of a new town, Coralville, for these coral accumulations. Keyes (1912) proposed the term Coralville for these coral-bearing rocks, and included it as a stratigraphic unit within the Cedar Valley Limestone. Stainbrook (1941a) designated the type section at the Conklin Quarry, adjacent to the city of Coralville, Johnson County, Iowa. In 1988, Witzke et al. designated the Coralville as a formation within the Cedar Valley Group. The Coralville Formation includes a lower fossiliferous carbonate member with an abundant marine fauna (Cou Falls or Gizzard Creek members) and an upper carbonate-dominated unit with laminated, brecciated, or evaporitic textures and some restricted-marine faunas (Iowa City Member). The Coralville Formation was deposited during a single T-R depositional cycle and is bounded above and below by disconformities or discontinuity surfaces. The formation overlies the Little Cedar Formation at all known localities, and where capped by younger Devonian strata is variably overlain by the Lithograph City, Sweetland Creek, or Lime Creek formations. The Coralville Formation varies greatly in thickness across Iowa, reaching a maximum thickness of 65 to 82 feet (20 - 25 m) in areas of central and northern Iowa. It is as thin as 12 feet (3.9 m) in parts of southeastern Iowa.

Geological Society of Iowa

Gizzard Creek Member

The Gizzard Creek Member is dominated by dolomite, generally medium- to thick-bedded in the lower part and medium- to thin-bedded in the upper part, but dolomitic limestones and calcite-cemented (poikilotopic sparites) dolomites are present. The Gizzard Creek Member is slightly argillaceous in part, and calcite-filled vugs are common (Fig. 17). Intraclasts are present locally in some beds. The member contains scattered to abundant fossil molds, locally with calcitic fossils, and displays wackestone (calcilutite) to rare packstone fabrics, in part burrow mottled. The Gizzard Creek Member disconformably overlies the Hinkle Member at all localities, and is conformably overlain by the Iowa City Member at most localities. The Gizzard Creek Member ranges from 12 to 23 feet (3.7 - 7 m) in thickness.

Conodonts of the Gizzard Creek Member include Icriodus subterminus, Mehlina gradata, and Polygnathus angustidiscus (Witzke *et al.*, 1988; Rogers, 1990) which are assigned to the Upper subterminus Fauna. Faunas of the Gizzard Creek are generally of low diversity and are characterized by sparse to abundant crinoid debris and brachiopods (Independatrypa, Athyris, and rare Tecnocyrtina; Day, 1988). Rare gastropods and bryozoans have been noted, and branching stromatoporoids and favositids are present locally near the southern limits of the member in the outcrop belt.

Figure 17. Calcitefilled vugs in the Gizzard Creek Member. (photo by Ryan Clark)

REFERENCES

- Anderson, W.I., and Garvin, P.L., 1984, The Cedar Valley Formation (Devonian), Black Hawk and Buchanan counties: carbonate facies and mineralization: Geological Society of Iowa, Guidebook no. 42, 47 p.
- Day, J.E., 1988, The brachiopod succession of the Late Givetian-Frasnian of Iowa: *in* McMillan, J.J., Embry, A.F., and Glass, D.J. (eds), Devonian of the World, Canadian Society of Petroleum Geologists, Memoir 14, Volume III: Paleontology, Paleoecology, and Biostratigraphy, p. 303-325.
- Day, J.E., Witzke, B.J., and Lundy, S., 2013, Aspects of the Paleozoic History of Epeiric Seas of the Iowa Basin: Iowa Geological and Water Survey, Guidebook Series no. 29, 124 p.
- Johnson, J.G., 1970, Taghanic Onlap and the end of North American provinciality: Geological Society of America Bulletin, v. 81, p. 2,077-2,106.
- Johnson, J.G., Klapper, G., and Sandberg, C.A., 1985, Devonian eustatic fluctuations in Euramerica: Geological Society of America Bulletin, v. 96, p. 56-587.
- Keyes, C.R., 1912, Sundry provincial and local phases of the general geologic section of Iowa: Proceedings of the Iowa Academy of Science, v. 19, p. 147-151.
- Klug, C.R., 1982, Devonian stratigraphy and conodont biostratigraphy from portions of two cores in central Iowa: Iowa Geological Survey, Open File Report 82-2, 56 p.
- McGee, W.J., 1891. The Pleistocene history of northeastern Iowa. United States Geological Survey, 11th Annual Report, part 1, p. 199-577.
- Owen, D.D., 1852. Report of a geological survey of Wisconsin, Iowa and Minnesota. Lippencott Gambo and Co., Philadelphia.
- Rogers, F.S., 1990, Stratigraphy, depositional history, and conodonts of the Little Cedar and lower Coralville formations of the Cedar Valley Group (Middle Devonian) of Iowa: unpublished Ph.D. thesis, University of Iowa, 97 p.
- Rowden, R., McKay, R., Liu, H., Tassier-Surine, S., Quade, D., and Giglierano, J., 2013, Bedrock Geology of Black Hawk County, Iowa: Iowa Geological and Water Survey, Open File Map OFM-13-3.
- Stainbrook, M.A., 1941, Biotic analysis of Owen's Cedar Valley Limestone: Pan-American Geologist, v. 75, p. 321-327.
- Witzke, B.J., Bunker, B.J., and Rogers, F.S., 1988, Eifelian through lower Frasnian stratigraphy and deposition in the Iowa area, Midcontinent, U.S.A., in McMillan, N.J., Embry, A.F., and Glass, D.J., (eds.), Devonian of the World: Canadian Society of Petroleum Geologists, 2nd International Symposium on the Devonian System, v. 1, p. 221-250.
- Witzke, B.J., and Bunker, 2004, An Upper Middle Through Lower Upper Devonian Lithostratigraphic and Conodont Biostratigraphic Framework of the Midcontinent Carbonate Shelf Area, Iowa, *in* Walters, J.C., Groves, J.R., and Lundy, Sherman, (eds.), From Ocean to Ice: An examination of the Devonian bedrock and overlying Pleistocene sediments at Messerly & Morgan Quarries, Black Hawk County, Iowa: Geological Society of Iowa, Guidebook no. 75, p.3-23.
- Witzke, B.J., Anderson, R.R., and Pope, J.P., 2010, Bedrock Geologic Map of Iowa (1:500,000): Iowa Geological and Water Survey, Open File Map OFM-2010-01.

MINERALS OF THE WATERLOO SOUTH QUARRY, BLACK HAWK COUNTY, IOWA

By: Paul L. Garvin

INTRODUCTION

Several quarries in Black Hawk County are well known among collectors and rock hounds for their unique mineral specimens. Many descriptions of such minerals are scattered throughout the landscape of past GSI and IGS guidebooks, as well as other publications. Probably the most comprehensive publication regarding minerals is "The Minerals of Iowa" by Paul J. Horick of the IGS (1974). The following description of the minerals hosted at the Waterloo South Quarry (WSQ) is found in GSI guidebook no. 42 (Anderson and Garvin, 1984, p. 37-40).

A unique feature of the geology at the WSQ is the presence of solution-enlarged joints. These joints (called mud seams by the miners because they contained clay fillings) are most numerous in the area of the underground workings and die out to the north and south. They are readily visible in the incline and in the mine back. The strike of the joints ranges from N42° to 63°E, with near vertical dips (Fig. 18).

Mineralization at the WSQ is localized along joint and bedding plane fractures, in subspherical to irregularshaped vugs, and in areas of brecciation. Vug mineralization appears to be the dominant type. Vugs are more concentrated in certain stratigraphic horizons, suggesting that distribution is controlled by bed permeability. Distribution is not predominantly controlled by fossils, as at Pint's Quarry (nine miles northeast of the WSQ); at least, fossil remains are rare. Mineralization occurs in all members of the Cedar Valley Group, but is most varied and abundant in the Bassett Member.

MINERALOGY

Minerals occurring at the quarry are pyrite, marcasite, chalcopyrite, fluorite, calcite, barite, and quartz.

Pyrite

Pyrite occurs as crusts on fracture walls and breccia clasts, and as inclusions in calcite crystals. Crystals are typically combinations of octahedron, cube, and pyritohedrons (Fig. 19). They are generally not more than a few millimeters across.

Figure 18. Map showing distribution of joints at the WSQ. (Figure 10 in GSI guidebook no. 42)

Figure 19. Pyrite and calcite in a vug formed in the "sublithographic" limestone of the Hinkle Member. (photo by Ryan Clark)

Marcasite

Marcasite occurs as thin blades and capillary crystals. It is commonly perched on pyrite crystals, suggesting a genetic relationship between the two minerals. A single specimen of chalcopyrite is known from the quarry. It occurs as tiny pseudotetrahedral crystals on calcite.

Fluorite

Fluorite is quite common. It is very similar in appearance to the fluorite from Pint's Quarry. It ranges in color from pale transparent yellow to root beer brown. Locally, it is a nearly opaque tan. The tan variety appears to have undergone some kind of alteration, however, its X-ray diffraction pattern is identical with that of "fresh" fluorite. In long wave ultraviolet light (356 nm), the tan variety is intense yellowish white, whereas the translucent root beer variety fluoresces yellowish gray. Crystals are simple cubes, commonly with slightly curved or parqueted faces. Individual crystals may reach 2 cm across.

Calcite

Calcite is by far the most abundant epigenetic mineral at the quarry. It is prominent in vugs and accentuates bedding plane and cross fractures. It ranges in color from brownish yellow (always early) to white or colorless. The early calcite fluoresces creamy white in long wave ultraviolet light, while the later calcite is non-fluorescent or fluoresces dull pink. Prism and scalenohedron are the dominant crystal forms (Fig. 19). These are generally truncated by positive and negative rhombohedra and a second scalenohedron. Some late calcite is sparry. Crystal lengths may reach several centimeters.

Barite

Barite is uncommon at the WSQ. Where present, it occurs as white, almost opaque blades, which are often in radial clusters. Blades are generally less than 2 cm in length.

<u>Quartz</u>

Quartz is rare. In the single specimen I (Paul Garvin) collected, it occurs as a fine druse in association with fluorite. Quartz crystals are transparent and doubly terminated, and appear to replace tabulate coral.

COMMENTS ABOUT THE ORIGIN OF THE MINERALIZATION AT PINT'S AND WATERLOO SOUTH QUARRIES

Minor sulfide mineralization occurs in several localities in eastern Iowa in host rocks ranging in age from Ordovician to Devonian (Heyl *et al.*, 1959; Heyl and West, 1982; Brown, 1967; and Garvin, 1983 & 1984a,b). Some, like the Mineral Creek deposit (Allamakee County) and the Martin-Marietta deposit (Linn County), on the basis of structure, mineralogy, paragenesis, and temperature of formation, strongly resemble upper Mississippi Valley (now known as Mississippi Valley Type [MVT]) zinc-lead deposits (Heyl *et al.*, 1959 and Garvin, 1983 & 1984a,b). Mineralization at Pint's and WSQ resembles MVT mineralization in that all minerals found in these two quarries have also been reported from the MVT district (Heyl *et al.*, 1959). There are, however, two important differences: 1) form of deposits, and 2) mineral paragenesis. MVT deposits are fracture controlled. The pitch-flat deposits, vertical gash veins, and breccia fillings are examples. At Pint's and WSQ, although vertical and bedding plane fractures were important in controlling fluid migration, most mineralization is contained in vugs. Regarding paragenesis, MVT deposits are characterized by early iron sulfide and late calcite; whereas at Pint's and WSQ, calcite is early and most sulfides are late. Recently, Heyl (written communication) has discovered rare early calcite in the main district.

Temperature data for Pint's and WSQ mineralization are lacking. Homogenization temperatures for fluid inclusions from the Conklin Quarry (Johnson County), with which Pint's and WSQ deposits are quite similar, range from 74 to 144°C (Garvin, 1984a). Temperatures of mineralization in minor sulfide-bearing mineral occurrences in the general midcontinent area range from 56 to 144°C (Coveney and Goebel, 1983).

The greater abundance of mineralization in the Solon Member (now Bassett Member), compared to the Rapid and Coralville members (now Eagle Center Member and Coralville Formation, respectively), is in part due to the greater abundance of vugs in the Solon (Bassett), which in turn is due (at least at Pint's) to dissolution of fossils. The higher concentration of sulfides in the Solon (Bassett) at Pint's may be related to the high organic content of the Solon limestone (Bassett), evidenced by the general brown color and presence of black bituminous partings. Pyrite and marcasite from all three members were analyzed for Ni, Cu, and Co using atomic absorption spectrophotometry (Garvin, unpublished data). The results are summarized in Table 1. Note that there is definite enrichment of these metals in iron sulfides in the Solon (Bassett) beds by circulating hydrothermal fluids. It is also possible that chemical reduction of these fluids by carbonaceous material caused precipitation and concentration of sulfides in the Solon (Bassett) (Krauskopf, 1979, pp. 253-256). Mineralized vertical fractures (especially prominent at WSQ), and mineralization in all units exposed in both quarries evidences fluid migration along a vertical plumbing system. Evidence for vertical fluid movement elsewhere in the MVT district is discussed in Ludvigson *et al.*, (1983).

Table 1. Ni, Cu, and Co Contents of Pyrite and Marcasite From Pint's Quarry, Black Hawk County Iowa. Values in parts per million)										
Rock Unit	No. of Analyses	N Ave	i (Range)	(Ave	Cu (Range)	(Ave	Co (Range)			
Solon	20	202	(23 - 830)	21	(8-66)	28	(8-56)			
Rapid	2	90	(40-141)	9	(9-10)	21	(18-25)			
Coralville	10	26	(14-41)	19	(13-44)	12	(6-27)			

REFERENCES

- Anderson, W.I. and Garvin, P.L., 1984, The Cedar Valley Formation (Devonian), Black Hawk and Buchanan Counties: Carbonate Facies and Mineralization: Geological Society of Iowa, Guidebook 42, p. 37-40.
- Brown, C.E., 1967, Fluorite in crystal-lined vugs in the Maquoketa Shale at Volga, Clayton County, Iowa: American Mineralogist, v.52, p. 1,735-1,750.
- Coveney, R.M. and Goebel, E.D., 1983, New fluid inclusion homogenization temperatures for sphalerite from minor occurrences in the mid-continent area: *in* Proceedings of the International Conference on Mississippi Valley-Type Lead-Zinc Deposits, G. Kisvarsanyi, S.K. Grant, W.P. Pratt, and J.W. Koenig, (eds), University of Missouri-Rolla, p. 234-242.
- Garvin, P.L., 1983, Sulfide mineralization at Mineral Creek Mines, Allamakee County, Iowa: Iowa Academy of Science, Proceedings v.90, p. 44-49.
- Garvin, P.L., 1984a, Mineralization at Conklin Quarry: *in* Underburden-Overburden: An examination of Paleozoic and Quaternary Strata at the Conklin Quarry near Iowa City: Geological Society of Iowa, Guidebook 41, p. 19-20.
- Garvin, P.L., 1984b, Hydrothermal mineralization of the Mississippi Valley Type at the Martin-Marietta Quarry, Linn County, Iowa: Iowa Academy of Science, Proceedings v.91, p. 70-75.
- Heyl, A.V., Agnew, A.F., Lyons, E.J., and Behre, C.H., 1959, The geology of the Upper Mississippi Valley Zinc-Lead District: U.S. Geological Survey, Professional Paper 309, 310p.
- Heyl, A.V. and West, W.S., 1982, Outlying mineral occurrences related the Upper Mississippi Valley Mineral District, Wisconsin, Iowa, Illinois, and Minnesota: Economic Geology, v.77, p. 1,803-1,817.

```
Krauskopf, K.B., 1979, "Introduction of Geochemistry", 2<sup>nd</sup> Edition McGraw-Hill, 617p.
```

- Ludvigson, G.A., Bunker, B.J., Witzke, B.J., and Garvin, P.L., 1983, Burial diagenetic model for the emplacement of zinc-lead sulfide ores in the upper Mississippi Valley, U.S.A.: *in* Proceedings of the International Conference on Mississippi Valley-Type Lead-Zinc Deposits, G. Kisvarsanyi, S.K. Grant, W.P. Pratt, and J.W. Koenig, (eds), University of Missouri-Rolla, p. 497-515.
- Tourtelot, E.B., 1970, Selected annotated bibliography of minor-element content of marine black shales and related sedimentary rocks, p. 1,930-1,965: U.S. Geological Survey, Bulletin 1293, 118p.

FIELD TRIP STOPS

By: Ryan Clark

Though the Waterloo South Quarry (WSQ) yields similar bedrock sections as seen in other area quarries such as at Raymond (nine miles northeast of the WSQ), the location of this quarry is conspicuous due to a seemingly unique bedrock high compared to the surrounding area (Figs. 20 & 21).

Figure 20. Map of the WSQ area showing the line of cross-section illustrated in figure 21.

STOP #1: WSQ Beneficial Use Fill and Reclamation – Sherman Lundy

The first stop today will be at the location of the old pit where fly ash and foundry sand is being placed as beneficial fill that will eventually bring the pit up to pre-quarrying grade, topped with clay and topsoil, and returned to farmland. Sherman Lundy will discuss the process that is described earlier in this guidebook and answer questions from the audience.

Approximate stop duration: <u>30 minutes</u>

Figure 21. Geologic cross-section of the WSQ area.

STOP #2: Incline Ramp to Old Underground Mine

The second stop on this field trip takes us to a rather unique feature at the WSQ, the incline ramp to the old underground mine area. As mentioned previously in this guidebook, underground mining took place here during the 1970's and 1980's when the Bassett Member of the Little Cedar Formation was harvested (Figs. 20 & 21). The Bassett is no longer exposed here due to groundwater inundation, however this is an excellent location to view the upper Eagle Center Member and the entire Hinkle Member.

Eagle Center Member

Although we will see the majority of the Eagle Center Member at Stop #3, this location is ideal for viewing the upper contact with the Hinkle Member (Fig. 22). The dolomitic limestones of the Eagle Center Member here are variably argillaceous with faint laminations. Apparent bioturbation is evidenced by the mottled gray-tan fabric seen on fresh surfaces.

Figure 22. Contact between the Hinkle and Eagle Center members at the incline ramp. (photo by Ryan Clark)

Occasional fossils and molds can be found here with minor chert. More prominent chert nodules and bands will be easier to find at Stop 3. The unique feature at this location is the presence of stromatolites in the uppermost part of the Eagle Center Member (Figs. 23 & 24). Although the upper Eagle Center Member is locally biostromal in northern Iowa (Witzke *et al.*, 1988), the stromatolite fauna seen here is not noted anywhere else and is in need of further investigation. Diligent study of these strata may reveal brachiopod and crinoid remains as well as the occasional coral.

Figure 23. Stromatolite mound in the upper Eagle Center Member. (photo by Ryan Clark)

Figure 24. Stromatolitic lamination (close up of previous figure). (photo by Ryan Clark)

Hinkle Member

Here we will see the "lithographic limestone sandwich" in full view (Fig. 25). The buff, sub-lithographic to lithographic limestone is approximately 6 ft (2 m) thick with a thin, gray shale seam in the middle that is

Geological Society of Iowa

less than a foot (0.3 m) thick. This association is persistent throughout the quarry area. Brecciation is common within the limestone, most prominently in the limestone below the shale. Fossils are sparse to absent. Mineralized vugs and veins are not as common here as elsewhere in the quarry.

Figure 25. "Sub-lithographic" limestone with interbedded shale of the Hinkle Member. Rock hammer is placed near the basal contact with the Eagle Center Member. (Photo by Ryan Clark)

The Hinkle Member represents the end of the regressive phase of the T-R cycle that encompasses the Little Cedar Formation. The fine-grained, micritic texture of the Hinkle Member suggests a mudflat facies with the intervening shale representing a brief influx of terrigenous sediment or perhaps a short-lived period of relative deeper water deposition.

STOP #3: Main Quarry Pit

The final stop for the trip is to the main working pit. The strata being removed at this quarry is the upper half of the Eagle Center Member, Hinkle Member, Gizzard Creek Member, and (where present) the Iowa City Member (Fig. 26). The floor of the pit is within the Eagle Center Member and the first bench is at the contact between the Hinkle and Gizzard Creek members. We will spend our time viewing the Eagle Center Member in place and rummaging through the rock piles for mineral specimens from the overlying Hinkle Member.

Waterloo South Quarry

Figure 26. Stratigraphic section of the units present at the WSQ. (modified from Witzke *et al.*, 1988, figure 8A, page 230)

Geological Society of Iowa

The Eagle Center Member displays scattered to abundant chert nodules and boudins within an argillaceous dolomitic limestone lithology. Bioturbation, fossil molds, and sparse fossil remains are also apparent. Another noteworthy feature of the Eagle Center Member seen here is the presence of vertical and horizontal jointing that has been highlighted by groundwater leaching the rock from gray to tan (Fig. 27). This wonderfully illustrates the movement of groundwater within a carbonate aquifer system.

Figure 27. Jointing surfaces within the Eagle Center Member that show zones of leaching by groundwater movement. (photo by Ryan Clark)

CORE DESCRIPTION – NEWTON QUARRY CORE W-27560 Described by Ryan Clark in March 2017

Today, weather permitting, we will look a section of the core that was drilled close to the location of the rock faces we will be inspecting (Figs. 20 & 21). The core begins in the Iowa City Member and continues into the Silurian System. The description given below reflects the units that have been mined at the WSQ, historically and currently. This core was likely drilled in the 1970's, prior to underground mining, however, it falls within the section of the quarry that eventually was mined underground during the 1970's and 1980's. Below is a general description of this core (depths are in feet below ground surface).

Devonian System

Cedar Valley Group

Coralville Formation

Iowa City Member

- 0.6 1.5' Limestone, tan-brown, "sub-lithographic", laminated, iron-oxide (liesegang) banding.
- 1.5 5.5' Limestone, tan-gray, dolomitic, mottled, bioturbated, finely crystalline, possible chert stromatoporoid at 5.2'.
- 5.5 6.2' Limestone, dark chocolate brown, lithographic, laminated.
- 6.2 7.6' Breccia, tan-gray, dolomite and limestone clasts in calcite matrix.
- 7.6 10.6' Dolomite, gray-tan, micro-crystalline, argillaceous, tan leached mottles, calcite veins, partly bioturbated, partly laminated.
- 10.6 15.1' Dolomite, buff, dull, calcite veins, partly wavy laminated, few oxidized pyrite crystals, partly intraclastic to brecciated. Minor interbedded gray, fine grained limestone.

Gizzard Creek Member

- 15.1 23.1' Limestone, brown, crystalline, intraclastic, calcite veins, oxidizes to light brown, ironmanganese oxide residue. Zone of very dark brown, dense, limestone with poikilotopic calcite cement.
- 23.1 26.0' Dolomitic limestone, light tan, micro-crystalline, micro-fossil molds, porous, small (1-3mm) calcite-filled vugs.
- 26.0 31.3' Limestone, light tan, dense to "sub-lithographic", scattered to abundant calcite-filled vugs (up to 3cm) and calcite veins, traces of sphalerite and marcasite, brachiopods and crinoid fossils (more abundant towards base).
- 31.3 36.8' Limestone, gray-brown, slightly dolomitic, very bioturbated, upper contact is argillaceous and laminated and possible fish debris, rare fish debris scattered throughout, scattered phosphatic brachiopods, few micro-fossil molds (crinoids?).

Little Cedar Formation

Hinkle Member

36.8 – 43.0' Limestone, light gray-light brown, lithographic to "sub-lithographic", laminated, shaly in upper 0.3', calcite veins, partly intraclastic, basal contact is brecciated with tan dolomitic cement. Grading to limestone breccia, gray, argillaceous, shale seam at 41.9', partly bioturbated.

Geological Society of Iowa

Eagle Center Member

- 43.0 46.0' Dolomitic limestone, gray with tan mottles and lenses, dense, chert (gray-brown, smooth) bands and nodules, breccia zone 45.7 46.0' with chert clasts.
- 46.0 48.8' Dolomitic limestone, tan, poikilotopic, calcite veins, chert nodules, breccia zone at base.
- 48.8 57.9' Dolomite, tan, fine grained, dull, calcite-filled vugs and veins, chert (cream-tan, tripolitic) nodules and bands, minor liesegang banding, ~54' irregularly grades to dolomite, gray, fine grained, argillaceous with black specks, laminated, bioturbated, back to tan dolomite, bioturbated, tripolitic chert nodules, chert brachiopods in lower 2'.
- 57.9 61.5' Dolomite, gray, slightly calcareous, argillaceous, fine grained, upper 0.5' is laminated to shaly, chert nodules and beds (up to 4cm), partly bioturbated, black fossil debris (fish?).

61.5 – 121.3' GAP: Eagle Center – Bassett contact is estimated at ~70'

Bassett Member

121.3 – 156.5' Limestone, gray, mottled, argillaceous, bioturbated, scattered calcite-filled vugs (up to 5cm), scattered brachiopods and fish(?).

124.6' – Zone of micro-fossils (brachiopods and ostracodes) and euhedral pyrite crystals. 144.5' – Becomes more fossiliferous with brachiopods, crinoids, bryozoans, and fish debris, some phosphatic fossils.

149' – Core split: Limestone, dark brown-gray, crystalline, glauconitic, fish scales, crinoids, brachiopods, calcite-filled vugs. Shale stringers and argillaceous laminae. Limestone is medium gray-brown, dense, mottled, with brachiopods and crinoids, calcite veins.

Geological Society of Iowa 300 Trowbridge Hall Iowa City, Iowa 52242-1319 www.iowageologicalsurvey.com

Directions from The University of Northern Iowa	Turn left onto Hudson Rd	2 † Continue straight to stay on Hudson Rd	3 A Use the right lane to take the ramp onto US-20 E	 Take exit 232A for US-218 S toward Laporte City 	5 r Slight right onto US-218 S/Washington St	6 r Turn right at the 1st cross street onto E Shaulis Rd	7 Turn left at the 1st cross street onto Dysart Rd/Hwy V37	0.4 ml	BMC Aggregates LC, 11305 Dysart Rd, Laporte City