SUMMARY REPORT
OF THE BEDROCK GEOLOGIC MAP OF THE GREENE 7.5' QUADRANGLE, BUTLER AND FLOYD COUNTIES, IOWA

Iowa Geological Survey
Open File Map OFM-17-1
June 2017

Huaibao Liu, Ryan Clark, Phil Kerr, and Stephanie Tassier-Surine

Iowa Geological Survey, IIHR-Hydroscience & Engineering, University of Iowa, Iowa City, Iowa

Iowa Geological Survey, Robert D. Libra, State Geologist

Supported in part by the U.S. Geological Survey
Cooperative Agreement Number G16AC00193
National Cooperative Geologic Mapping Program (STATEMAP)
Completed under contract with the Iowa Department of Natural Resources

INTRODUCTION

The Greene 7.5' Quadrangle is located on the border of Floyd and Butler counties, north-central Iowa. It covers an area from 42° 52' 30" to 43° 00' N latitude and 92° 52' 30" to 92° 45' W longitude. The bedrock geologic map of this quadrangle was completed as part of the Iowa Geological Survey's (IGS) ongoing participation in the National Cooperative Geologic Mapping Program (STATEMAP) in north-central Iowa, and was supported in part by the U.S. Geological Survey (USGS; grant number G16AC00193) and under contract with the Iowa Department of Natural Resources (IDNR).

The land surface of the Greene 7.5' Quadrangle is commonly covered by Quaternary sediments, but with abundant shallow bedrock exposures, especially along the Shell Rock River in the southwest and Flood Creek in northeast part of the quadrangle (Fig. 1). In terms of landforms, this quadrangle lies in the Iowan Surface landform region where the land surface has been modified by various episodes of erosion before and during the Wisconsin-age glacial events (Prior, 1991). Due to extensive glacial and erosional activities, the landscape of this area is characterized by relatively low topographic relief, slightly inclined to gently rolling with long slopes, and open horizons. This landform region also features common fieldstones of glacial origin known as glacial erratics.

The Quaternary sediments in the mapping area consist of loamy soils developed in loess, glacial till, and colluvium of variable thickness, and alluvial clay, silt, sand, and gravel. These deposits cover most of the land surface except in the valleys of the Shell Rock River and Flood Creek in the mapping area. The thickness of the Quaternary deposits usually varies between 9 and 24 m (30 and 80 ft) with a maximum thickness of up to 37 m (120 ft). These unconsolidated Quaternary sediments are undifferentiated and shown only on the cross-section of the bedrock geologic map. For the detailed Quaternary stratigraphy and distribution, see the surficial geologic map of this quadrangle (Kerr et al., 2017).

The bedrock surface of the Greene 7.5' Quadrangle is mainly comprised of Devonian strata, with some relatively thin patches of Cretaceous bedrock. The Devonian deposits in this region consist of carbonates, shale and minor other lithologies. These carbonate rocks, especially those of relatively pure limestones, are easily karstified (Moore, 1995). These Devonian carbonates form the important upper bedrock aquifer in the mapping area (Libra et al., 1984, 1994), and this aquifer is vulnerable to contamination when covered by thin surficial materials. Historic flooding in 2008 caused serious damages to north-central Iowa, and it created significant interest from local government and conservation groups that led to the formation of several watershed protection and management coalitions and initiatives in north-central Iowa. Key societal concerns that can be addressed with geologic mapping projects in this area include watershed management, water quality and quantity issues, flood management, and aggregate production and resource protection. Thus, as part of the geologic mapping program for north-central Iowa, producing a bedrock geologic map for Floyd County was strongly recommended by the Iowa State Mapping Advisory Committee (SMAC), and approved by the National Cooperative Geologic Mapping Program (STATEMAP). The bedrock geology of the Greene 7.5' Quadrangle is mapped as part of the second phase towards the completion of the bedrock geologic map of Floyd County.

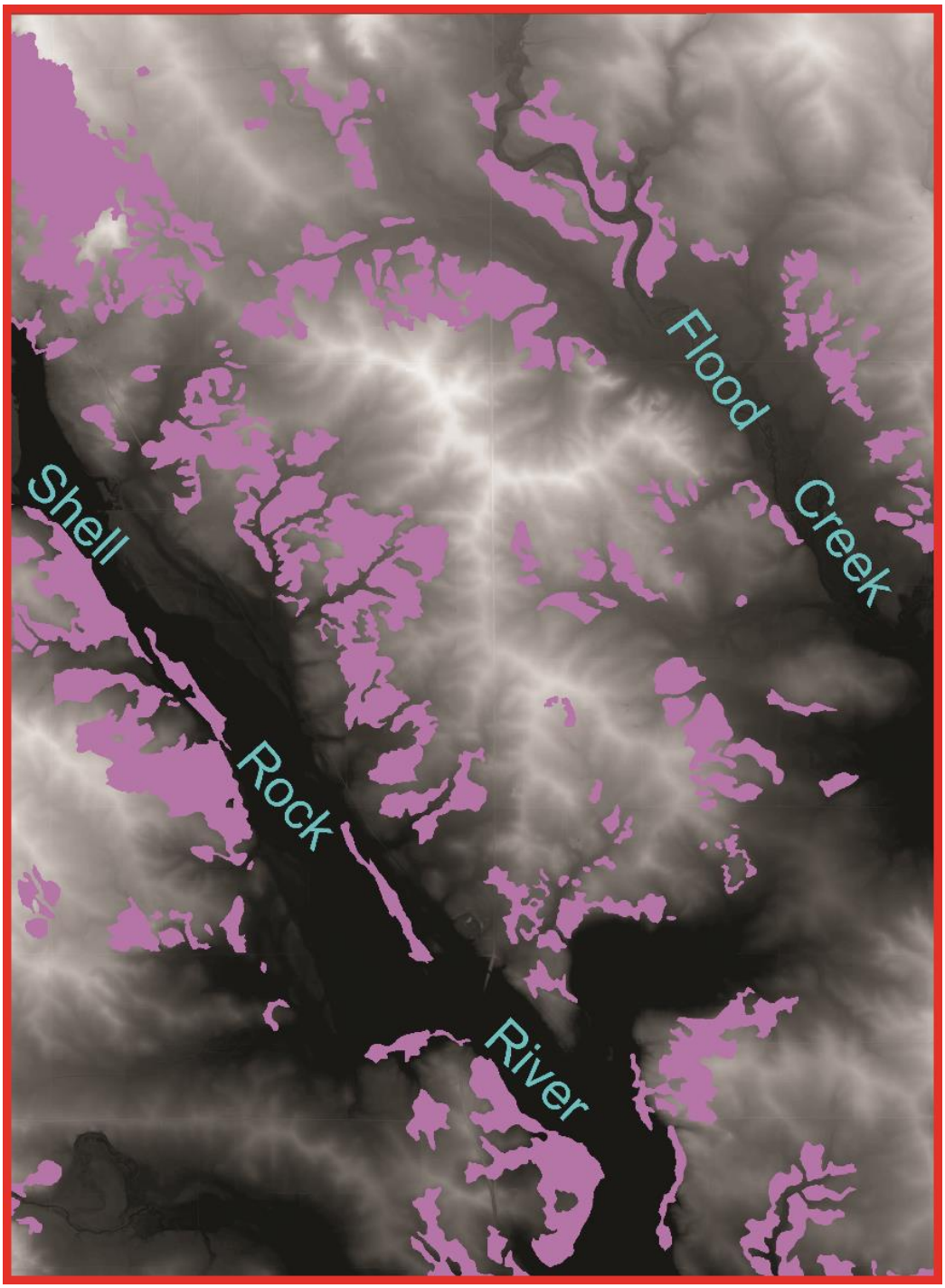

Fig. 1: The Greene Quadrangle shaded relief map (DEM-3M) and shallow bedrock distribution (in purple).

The previous bedrock geologic map of north-central Iowa was completed by Witzke and others in 2001. Since then, new geologic data from this area have been accumulated and become available for more detailed geologic mapping. To better understand the geology in the mapping area, the new bedrock geologic

map presented herein subdivides the widespread Devonian Cedar Valley Group into its distinct formations, which were undifferentiated on the bedrock geologic map of north-central Iowa (1:250,000; Witzke et al., 2001), as well as the bedrock geologic map of Iowa (1:500,000; Witzke et al., 2010). The underlying Devonian Wapsipinicon Group has also been subdivided into formations for applicable bedrock geologic maps in north-central Iowa. Within the Greene 7.5' Quadrangle, however, the Wapsipinicon Group does not occur on the bedrock surface, and only one well belonging to the city of Marble Rock penetrates into upper part of this group.

GEOLOGIC SETTING AND RESEARCH HISTORY

As described above, the bedrock surface of the Greene 7.5' Quadrangle is dominated by Devonian deposits, but some may be covered by thin Cretaceous sediments. Paleogeographically, the mapping area is within the northern portion of the Devonian Iowa Basin, a region with thickened carbonates, shale, and minor other lithologies deposited from the Eifelian through part of the Famennian age (Witzke et al., 1988; Witzke and Bunker, 2006; Day, 2006; Day et al., 2008). Lower Devonian strata have not been recognized in this part of the basin.

The Devonian Iowa Basin was the site of shallow marine to supratidal deposition during the Devonian. Sedimentation kept pace with subsidence, and did not develop as a bathymetric basin (Witzke et al., 1988). Many stratigraphic units in the Devonian Iowa Basin are fossiliferous. Based on the lithology and fossils, a stratigraphic sequence consisting of a series of formations was established in the northern part of the Iowa Basin, and it has been recognized that these deposits were controlled by seven corresponding major 3rd order relative sea level fluctuations which have been labeled as the Iowa Devonian transgressive-regressive (T-R) cycles (Witzke et al., 1988; Day et al., 2013a). Represented by typical sediments, several type sections of the Devonian stratigraphic sequence are located in north-central Iowa surrounding the mapping area. Three formations of the Devonian sequence have been recognized on the bedrock surface of the Greene 7.5' Quadrangle, representing the deposition of the later Givetian through Frasnian in the Devonian Iowa Basin.

Due to the unique depositional environments, complex sedimentary lithology, and many richly fossiliferous units, the geology, paleoenvironments, paleontology and stratigraphy of the Devonian Iowa Basin have been intensively studied. Early studies include the publications of Belanski (1927 and 1928) and Koch (1970). Recent studies of the Devonian Iowa Basin are represented by Witzke and Bunker (1984), Anderson (1984), Bunker and others (1986), Witzke and others (1988), Bunker (1995), Anderson and Bunker (1998), Groves and others (2008), McKay and Liu (2012), and Day and others (2006, 2008, 2013). Geologic mapping projects at 1:24,000 scale in north-central Iowa have been undertaken by the IGS since 2009. In addition to 7.5' quadrangle maps, 1:100,000 scale bedrock geologic maps have been recently completed for Bremer County (McKay et al., 2010), Worth County (Liu et al., 2012), Black Hawk County (Rowden et al., 2013), Cerro Gordo County (Liu et al., 2015), and Mitchell County (Clark et al., 2016) in the Devonian Iowa Basin. The bedrock geologic map of north-central Iowa (1:250,000) and the bedrock geologic map of Iowa (1:500,000) were completed by Witzke and others in 2001 and 2010, separately. Results from these geologic studies and bedrock geologic mapping projects provide significant regional geologic information and new data for the compilation of the present bedrock geologic map.

METHODS

The bedrock geologic mapping process includes data collection, subsurface geologic data analysis, descriptive logging when drilling materials are available, geologic field investigation and test drilling when needed, bedrock topographic map construction, and geologic map compilation.

All available sources of geologic information from the region were utilized in the production of this map, including subsurface geologic information, U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil survey data, aerial photography, satellite imagery, and LiDAR. Since much of the bedrock surface in the map area is buried by Quaternary sediments, subsurface bedrock information was mainly derived from the analysis of water well data which are stored in the IGS GeoSam database. Where available, engineering borings from public utilities, the Iowa Department of Transportation (IDOT), and monitoring well records of the U.S. Geological Survey (USGS) and IGS were also used. Information from Floyd and Butler county assessors helped to determine some of the well locations.

During the compilation of this bedrock geologic map, a total of 111 private and public wells located within the mapping area were studied, including five newly drilled holes especially for this mapping project. Among these wells, 45 have descriptive striplogs with cutting samples which are reposited at the IGS Oakdale Rock Library, and 33 of which were newly logged for this bedrock geologic mapping task. The rest of these wells usually have driller's logs containing basic geologic and locational information. These striplogs and most driller's logs provide important subsurface geologic information including bedrock depth, lithology, thickness, and distribution of mapping units. The locations of data points in the IGS GeoSam database were checked for accuracy and updated where needed. The topography of the bedrock surface of the quad has been updated based on all available well penetrations, as well as bedrock exposures. The previous bedrock topographic map (50' contour interval) was reconstructed with a 25' contour interval (Fig. 2). This formed an essential basis for the development and compilation of the new bedrock geologic map.

New geologic information was also obtained from field investigations of outcrops and quarry exposures. During the field investigations, shallow bedrock information from the digital soil surveys in Floyd County (Voy, 1995) and Butler County (Buckner, 1974) was used for delineating potential bedrock outcrops. Within the mapping area, 18 bedrock outcrops including several rock quarries were accessed and studied, which provided important regional stratigraphic information for the bedrock geologic map. Bedrock information from surrounding area, including bedrock outcrops, quarries, and subsurface geologic information from wells, was also studied and utilized for this mapping project.

ArcGIS 10.3 software and on-screen digitizing techniques developed during previous STATEMAP projects have been used for this mapping project. The newly compiled bedrock geologic map is stored and available as a shapefile in the NRGIS library of the Iowa Department of Natural Resources (IDNR), and as a PDF file on the IGS Publications website http://www.iowageologicalsurvey.org.

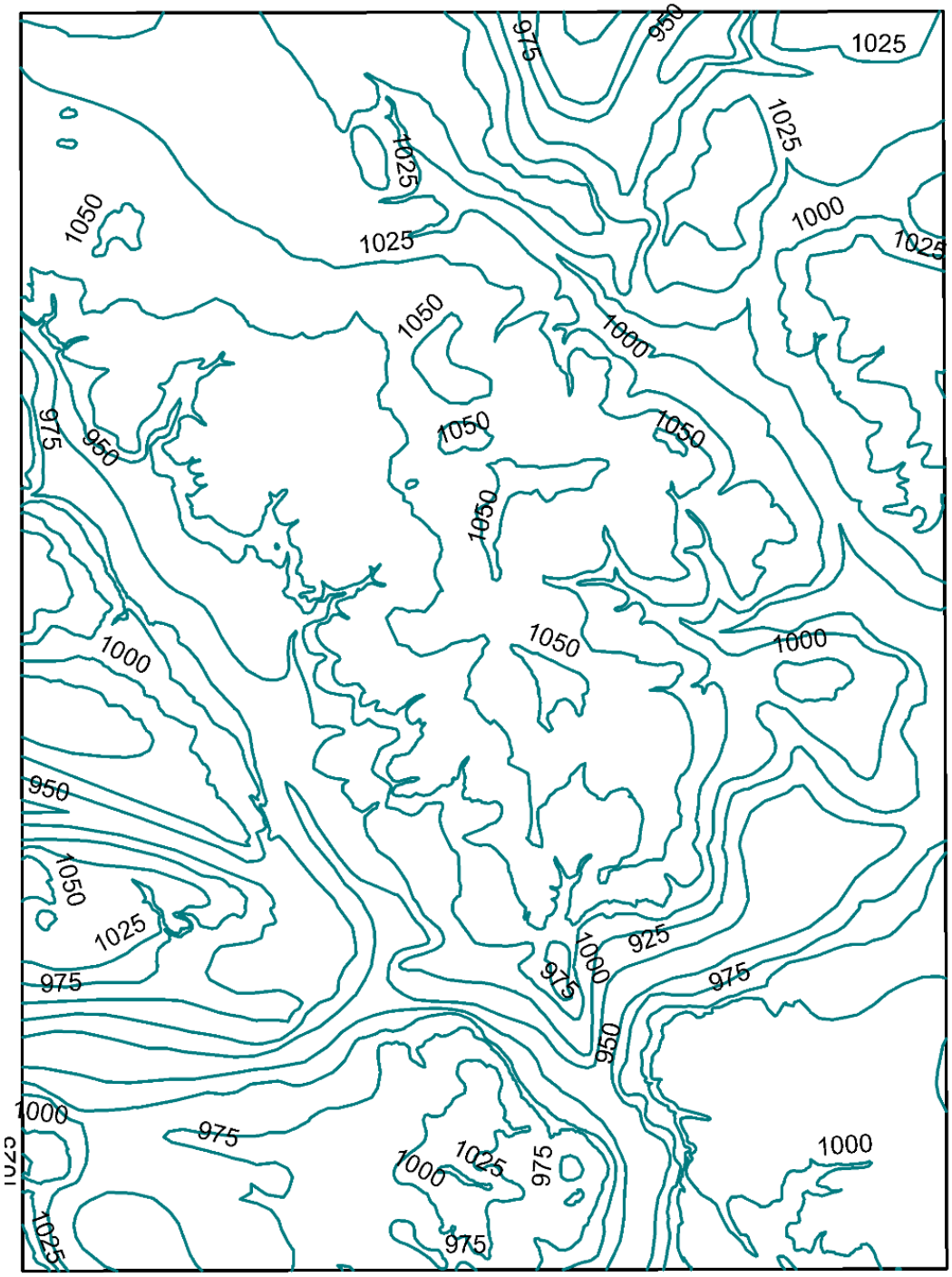

Fig. 2: The bedrock topographic map of the Greene 7.5’ Quadrangle with a 25’ contour interval.

BEDROCK STRATIGRAPHY AND MAPPING UNITS

The bedrock strata occurring in the Greene 7.5' Quadrangle include Cretaceous and Devonian deposits. Stratigraphic units mapped on the new bedrock geologic map are outlined on the map Legend and the Stratigraphic Column. The boundaries separating the various map units were selected to reflect 1) prominent lithologic changes, 2) fossils when available, and 3) major regional unconformities and/or disconformities. The bedrock stratigraphic nomenclature and correlation of the Devonian for this map follow the stratigraphic framework proposed by Witzke and others (1988). The thickness of each map unit was derived from well penetrations within the map area. However, variations in thickness occur for each unit across the map area.

Four bedrock formations, in descending order, the Cretaceous Dakota or Windrow Formation, the Devonian Lime Creek, Shell Rock, and Lithograph City formations comprise the bedrock surface of the map area. Two other formations, the Devonian Coralville and Little Cedar formations shown in the cross-section, are found in wells only and do not occur at the bedrock surface. The general lithologic features and thickness of each bedrock mapping unit are described as follows:

Mesozoic

Cretaceous System

Kd - Sandstone, Mudstone, and Siderite Pellets (Dakota/Windrow Formation) "Mid"-Cretaceous. This formation comprises a non-marine fluvial and pedogenic facies succession characterized by a variety of lithologies, commonly dominated by quartzose sandstones with secondary chert/quartz conglomerates, in part cemented by iron oxides. The thickness of this unit is variable, but is usually less than 6 m (20 ft) when presenting in the mapping area.

Paleozoic

Devonian System

Dl – Shale, Limestone, and Dolomite (Lime Creek Formation) Upper Devonian. This map unit occurs on the bedrock surface near the central part of the mapping area. Thickness of this unit is usually less than 8 m (25 ft) when it is present in the quadrangle. This formation consists of calcareous shales in the lower portion and limestone, dolomitic limestone, and dolomite in the upper part. Some layers are fossiliferous and pyrite-rich.

Dsr - Limestone, Dolomite, and Shale (Shell Rock Formation) Upper Devonian. This map unit occurs on the bedrock surface mainly in the northern part of the quadrangle. It usually has a thickness of 9 to 20 m (30-65 ft), but an outcrop of this unit just beyond the northern border of the quadrangle shows a total thickness less than 3 m (10 ft). This formation is characterized by limestone, dolomitic limestone and dolomite, with minor gray to light green shale and/or argillaceous carbonates. Fossiliferous layers, especially characterized by abundant bryozoans, brachiopods and stromatoporoids, commonly occur in the lower part of the unit.

Dlgc - Limestone, Dolomite, and Shale (Lithograph City Formation) Middle to Upper Devonian. This map unit forms most of the bedrock surface of the quadrangle. The thickness of this unit is usually 21 to 30 m (70-100 ft) in the mapping area. It consists of limestone, dolomitic limestone, dolomite, and minor shale. This unit is usually characterized by interbeds of laminated lithographic and sub-lithographic limestone and dolomitic limestone, in part argillaceous. "Birdseye" structures, vugs and calcite vug-fills are common. Some intervals are fossiliferous and stromatoporoid-rich.

Dcv - Limestone and Dolomite (Coralville Formation) Middle Devonian. This map unit consists of limestone, dolomitic limestone, and dolomite, in part argillaceous or shaly. The thickness of this unit varies between 12 and 21 m (40-70 ft) in the mapping area. Brachiopods, echinoderm debris and corals usually occur in the limestone facies. This unit does not occur at the bedrock surface of the map, and is only shown on the cross-section.

Dlc - Dolomite, Limestone, and Shale (Little Cedar Formation) Middle Devonian. This map unit is dominated by slightly argillaceous to argillaceous dolomite and dolomitic limestone, usually vuggy and partially laminated and/or cherty. Some minor shale may occur in the upper part of this formation. The thickness of this unit ranges from 27 to 40 m (90-130 ft) in the mapping area. This formation is commonly fossiliferous, and brachiopods are especially abundant in the lower portion. This unit does not occur at the bedrock surface of the map, and is only shown on the cross-section.

HIGHLIGHTS OF THIS MAPPING PROJECT

- **The new bedrock topographic top**

As mentioned above and illustrated in Fig. 2, the bedrock topographic map of this quadrangle was based on multiple geologic sources, and completed using a 25' contour interval. The new bedrock topographic map provides the basis for accurate compilation of the bedrock geologic map herein.

- **The Cretaceous deposits**

The Cretaceous sediments commonly occur as scattered erosional outliers in the northwestern part of this quadrangle. Although they were mostly identified by the soil surveys, some *in situ* exposures have been found in the field investigation. They occur as both sandstones (Fig. 3), which are high in quartz and can be referred to the Dakota Formation, and iron-rich residual deposits and nodules (Fig. 4), which are the features of the Windrow Formation. Although the relationship of the two lithologies is undeterminable based on the evidence in hand, this area may have the potential to resolve the questions about the Cretaceous depositional environments in the Midwest.

Fig. 3: Cretaceous outcrop found in the mapping area. The upper-right picture is the close-up image of the sandstone which is high in quartz.

Fig. 4: Cretaceous sandstone outcrop with abundant iron-rich nodules (upper-left image) found in the mapping area.

- **The contact between the Lithograph City and Shell Rock formations**

A section showing the contact of the Devonian Lithograph City and Shell Rock formations has been recognized in the Maxson Quarry near the City of Marble Rock. This section was first measured and described by Bunker et al. (1986), and the contact is represented by a pre-Shell Rock weathered zone between the thin-beds of dolomitic limestone of the Lithograph City Formation and the fossil-rich limestone of the Shell Rock Formation (Bunker et al., 1986, Stop 3). In addition to other features described before, the section at the quarry's south wall, which is found by this mapping project, shows that the bottom of the Shell Rock Formation is characterized by a massive skeletal biostrome layer dominated by stromatoporoids, bryozoans, and many others (Fig. 5). This distinctive layer has been recognized in many locations in north-central Iowa, therefore representing a stable depositional facies which has been successfully used as an indicator of the contact between the Lithograph City and Shell Rock formations.

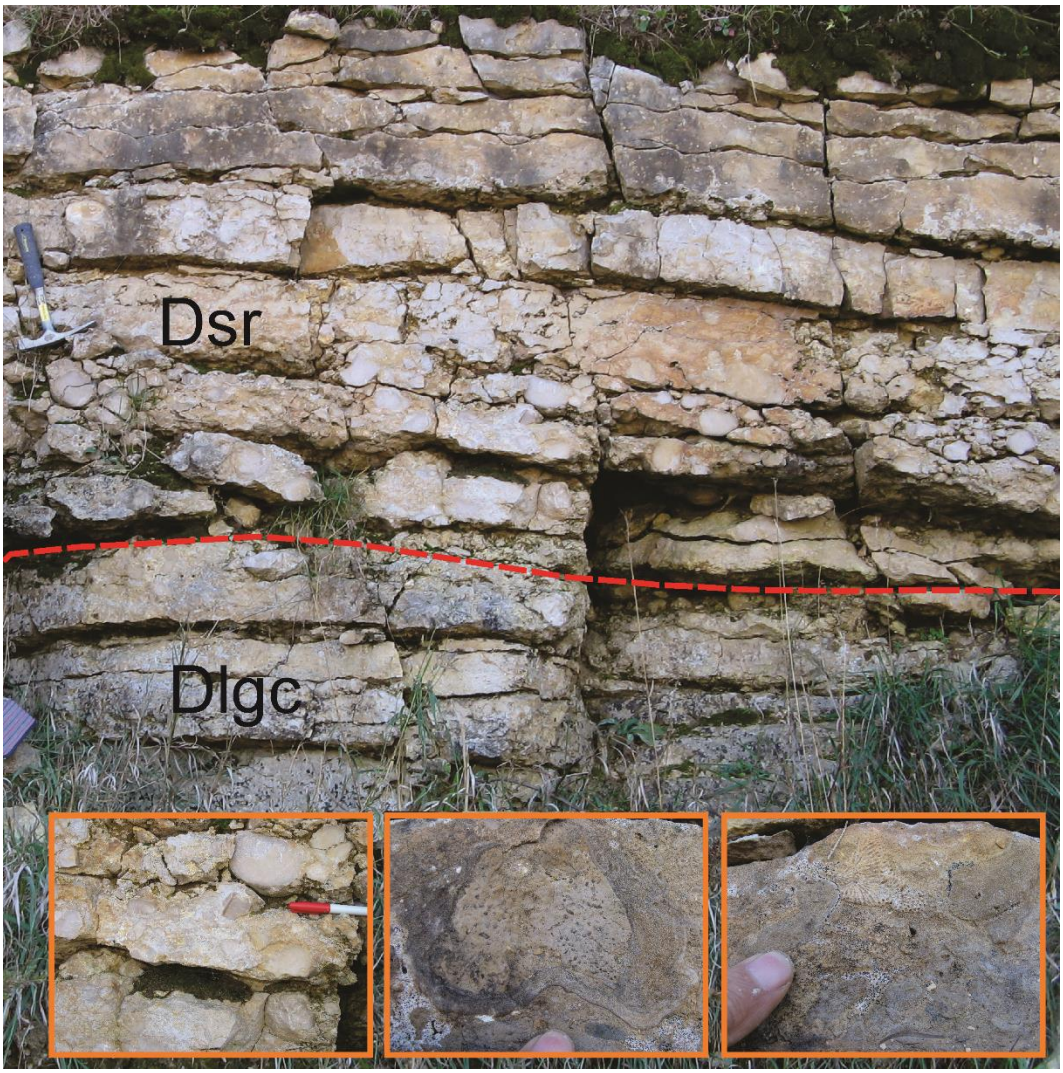

Fig. 5: This section of the Masxon Quarry south wall shows the contact between the Devonian Lithograph City (Dlgc) and Shell Rock (Dsr) formations. The lower images show some typical fossils from the bottom fossiliferous layer (biostrome) of the Shell Rock Formation.

- **The occurrence and thickness of the Shell Rock Formation**

As shown in this bedrock geologic map, the Devonian Shell Rock Formation is one of the dominant units on the bedrock surface of the Greene 7.5' Quadrangle. When it is naturally exposed, however, this unit is often less than its typical thickness (~60 ft). For example, in an exposure by Beaver Creek just beyond the northern border of this quadrangle, the Lime Creek Formation disconformably overlies the lower part of the Shell Rock Formation, which is characterized by the massive skeletal biostrome layer (Fig. 6), and indicates that the Shell Rock Formation is less than 10 feet thick at this location. This likely resulted from extensive pre-Lime Creek erosion that occurred in the Devonian Iowa Basin (Witzke et al., 1988).

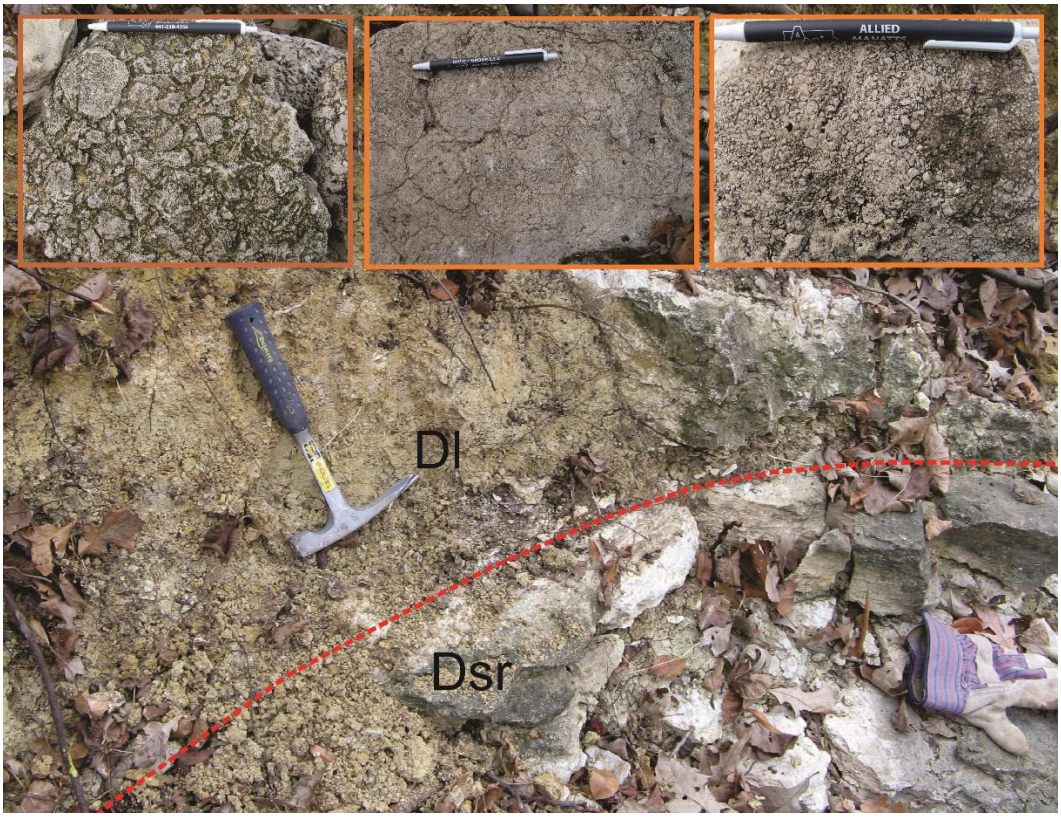

Fig. 6: An exposure showing the Lime Creek Formation (Dl) directly overlying the lower portion of the Shell Rock Formation (Dsr) which is characterized by the massive biostrome layer. The small images on the top show the fossils occurring in the fossiliferous layer.

ACKNOWLEDGMENTS

We thank Croell Co., Greene Limestone Co. and L. R. Falk Construction Co. for allowing us to work in their quarries in and around the mapping area. Special thanks to Nate & Traci Bartels, Ron & Sandra Lebeck, Doug Marsh, Ella Severs, and Brett & Lisa Steere for allowing and/or helping us to access bedrock outcrops in their properties. Zachary Demanett of the Iowa Geological Survey (IGS) and University of Iowa (UI) students Samantha Moser, Ryan McKeon, and Gia DeBartolo prepared well cutting samples for stratigraphic logging. New subsurface geologic data was generated by Tanner Hartsock and Diar Ibrahim, UI Department of Earth and Environmental Sciences students, by producing descriptive logs of water well drilling samples. Thanks also to Rick Langel (IGS) for managing the Iowa geologic sampling database (GeoSam). Adriana Schnoebelen of the Iowa Department of Transportation (DOT) provided important geologic information of some quarries in the mapping area. Jed Day of Illinois State University, Bill Bunker, Brian Witzke, Robert McKay, and Ray Anderson of the Iowa Department of Natural Resources (IDNR) provided valuable discussions regarding the geology of north-central Iowa. Bedrock topography is updated from Ray Anderson's (IDNR) previous work. Casey Kohrt and Chris Kahle of IDNR and Andrew Roers of IIHR Hydroscience & Engineering provided GIS technical help. Administrative support was provided by Megan Delaney, Rosemary Tiwari, Teresa Gaffey, Angi Roemerman, and Carmen Langel.

REFERENCES

Anderson, W.I. (ed.), 1984: General Geology of north-central Iowa. Guidebook for the 48th Annual Tri-State Geol. Field Conf., 150 p.

Anderson, R.R., and Bunker, B.J., (eds.), 1998: Fossil shells, glacial swells, piggy smells, and drainage wells: the geology of the Mason City, Iowa, area. Geol. Soc. of Iowa Guidebook No. 65, 71 p.

Belanski, C.H., 1927: The Shellrock Stage of the Devonian. American Midland Naturalist, v. 10, p. 316-370.

Belanski, C.H., 1928: The Shellrock Stage of the Devonian; Description of some typical fossils of the Shellrock Stage. American Midland Naturalist, v. 11, p. 165-212.

Buckner, R.L., 1974: Soil Survey of Butler County, Iowa. U .S. Dept. of Agriculture, Soil Conservation Service, 209 p. with 70 map sheets.

Bunker, B.J., Witzke, B.J., and Day, J.E., 1986: Upper Cedar Valley Stratigraphy, North-Central Iowa, Lithograph City Formation. Geol. Soc. of Iowa Guidebook No. 44, 41 p.

Bunker, B.J., (ed.), 1995: Geology and hydrogeology of Floyd-Mitchell counties, north-central Iowa. Geol. Soc. of Iowa Guidebook No. 62, 169 p.

Clark, R., Liu, H., Kerr, P., Tassier-Surine, S., Rowden, R., and Streeter, M., 2016: Bedrock geologic Map of Mitchell County, Iowa. Iowa Geological Survey Open File Map OFM-16-1.

Day, J., 2006: Overview of the Middle-Upper Devonian sea level history of the Wapsipinicon and Cedar Valley Groups, with discussion of new conodont data from the subsurface Cedar Valley Group of southeastern Iowa. *in* Day, J., Luczaj, J., and Anderson, R., (eds.), New Perspectives and Advances in the Understanding of Lower and Middle Paleozoic Epeiric Carbonate Depositional Systems of the Iowa and Illinois Basins. Iowa Geological Survey Guidebook Series No. 25, p. 3-21.

Day, J., Witzke B., and Bunker, B.J., 2008: Overview of Middle and Upper Devonian Cedar Valley Group and Lime Creek Formation carbonate platform facies, faunas, and event stratigraphy of northern Iowa. *in* Groves, J.R., Walters, J.C., and Day, J., (eds.), Carbonate platform facies and faunas of the Middle and Upper Devonian Cedar Valley Group and Lime Creek Formation, northern Iowa. Iowa Geological Survey Guidebook No. 28, p. 15-39.

Day, J., Witzke B., and Lundy, S., 2013: Aspects of the Paleozoic history of epeiric seas of the Iowa basin. Iowa Geological and Water Survey Guidebook No. 29, 118 p.

Groves, J.R., Walters, J.C., and Day, J., (eds.), 2008: Carbonate platform facies and faunas of the Middle and Upper Devonian Cedar Valley Group and Lime Creek Formation, northern Iowa. Iowa Geological Survey Guidebook No. 28, 96 p.

Kerr, P., Tassier-Surine, S., Liu, H., and Clark, R., 2017: Surficial geologic map of the Greene 7.5' Quadrangle, Butler and Floyd counties, Iowa. Iowa Geological Survey Open File Map OFM-17-2.

Koch, D.L., 1970: Stratigraphy of the Upper Devonian Shell Rock Formation of north-central Iowa. Iowa Geological Survey Report of Investigations 10, 123 p.

Libra, R.D., Hallberg, G.R., Ressmeyer, G.G., and Hoyer, B.E., 1984: Groundwater quality and hydrogeology of Devonian-Carbonate aquifers in Floyd and Mitchell counties, Iowa. Iowa Geological Survey Open File Report 84-2, p. 1-106.

Libra, R.D., Quade, D.J., Hallberg, G.R., and Littke, J.P., 1994: Groundwater quality, hydrogeology, and agricultural drainage wells, Floyd and Mitchell counties, Iowa. Iowa Geological Survey Technical Information Series 29, 64 p.

Liu, H., McKay, R., Rowden, R., Quade, D., Tassier-Surine, S., and Giglierano, J., 2012: Bedrock Geology of Worth County, Iowa. Iowa Geological and Water Survey Open File Map OFM-12-1.

Liu, H., Clark, R., Fields, C., McKay, R., Rowden, R., Tassier-Surine, S., Kerr, P., and Streeter, M., 2015: Bedrock Geology of Cerro Gordo County, Iowa. Iowa Geological Survey Open File Map OFM-15-1.

McKay, R.M., Liu, H., and Giglierano, J.D., 2010: Bedrock Geology of Bremer County, Iowa. Iowa Geological and Water Survey Open File Map OFM-10-10.

McKay, R.M. & Liu, H., 2012: Cedar Valley Group: the Lithograph City – Shellrock Formation contact at Mason City, Iowa. Geol. Soc. of Iowa Guidebook No. 90, 12 p.

Moore, F., 1995: Floyd County groundwater protection project and sinkhole cleanout. *in* Bunker, B.J., (ed.), Geology and hydrogeology of Floyd-Mitchell counties, north-central Iowa. Geol. Soc. of Iowa Guidebook No. 62, p. 75.

Prior, J.C., 1991: Landforms of Iowa. University of Iowa Press, Iowa City, 154 p.

Rowden, R., McKay, R., Liu, H., Quade, D., Tassier-Surine, S., and Giglierano, J., 2012: Bedrock Geology of Black Hawk County, Iowa. Iowa Geological and Water Survey Open File Map OFM-13-3.

Voy, K.D., 1995: Soil Survey of Floyd County, Iowa. U.S. Dept. of Agriculture, Soil Conservation Service, 260 p. with 63 map sheets.

Witzke, B.J. and Bunker, B.J., 1984: Devonian stratigraphy of north-central Iowa. Iowa Geological Survey Open File Report 84-2, p. 107-149.

Witzke, B.J., Bunker, B.J., and Rogers, F.S., 1988: Eifelian through lower Frasnian stratigraphy and deposition in the Iowa area, central midcontinent, U.S.A. in McMillan, N.J., Embry, A.F, and Glass, D.J. (eds.): Devonian of the World. Canadian Soc. of Petroleum Geologists, Memoir 14, vol. I, p. 221-250.

Witzke, B.J., Anderson, R.R., Bunker, B.J., Ludvigson, G.A., and Greeney, S., 2001: Digital geologic map of Iowa, Phase 3: North-Central Iowa (1:250,000). Iowa Geological Survey Open File Map OFM-01-3.

Witzke, B.J. and Bunker, B.J., 2006: Middle shelf facies of the Cedar Valley Group (Devonian) and their stratigraphic relationships in eastern Iowa. *in* Day, J. E., Luczaj, J., and Anderson, R., (eds.), New Perspectives and Advances in the Understanding of Lower and Middle Paleozoic Epeiric Carbonate Depositional Systems of the Iowa and Illinois Basins. Iowa Geological Survey Guidebook Series No. 25, p. 23-46.

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-10-1.