SUMMARY REPORT OF THE BEDROCK GEOLOGIC MAP OF THE WEST BURLINGTON 7.5' QUADRANGLE, DES MOINES COUNTY, IOWA

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INTRODUCTION

The Bedrock Geologic Map of the West Burlington (Iowa) 7.5’ Quadrangle is the result of the second phase of mapping aiming to refine bedrock mapping of portions of southeastern Iowa as part of the Iowa Geological Survey’s (IGS) ongoing participation in the STATEMAP mapping program. Due to increased demand for groundwater resources in the region, new research into the Lower Skunk River watershed, development of additional aggregate resources, and expanding urban areas lead to the selection of southeast Iowa as the next target for geologic mapping by the Iowa State Mapping Advisory Committee (SMAC). Key societal concerns that can be aided by this mapping project include watershed management, groundwater quantity and quality assessment, flood mitigation, aggregate resource protection, and land use planning and development.

GEOLOGIC SETTING

The West Burlington Quadrangle occupies approximately 56 square miles of primarily agricultural land situated within the Southern Iowan Drift Plain (SIDP) landform region (Prior, 1991). The map area is dominated by loess mantled till plains in the uplands, and fine to coarse grained alluvial deposits within Flint Creek and its tributaries. This area hosts glacial deposits of both Illinoian (130,000 to 190,000 years before present) and Pre-Illinoian age (ranging from 0.5 to 2.6 million years ago). The thickness of unconsolidated Quaternary deposits overlying the bedrock surface is variable across the quadrangle, ranging from 5 to 20 m (15-66 ft), reaching a maximum thickness of 125 m (410 ft) in the extreme northeastern part of the mapping area. Mississippian bedrock units dominate the bedrock surface with Devonian bedrock occupying a prominent bedrock valley in the northern part of the quadrangle. Bedrock exposures were identified along parts of Flint Creek in the northern part of the mapping area as well as along tributary creeks to the Skunk River in the southern part.

RESEARCH HISTORY

The conundrum that is the Mississippian in Iowa has been the subject of curiosity for many previous workers. Owen (1852) and Hall (1857) were the first to recognize that the abundance of bedrock exposures in southeastern Iowa likely correlated with those observed farther down the Mississippi River Valley, and then Van Tuyl (1923) took on the ambitious task of correlating all of the Mississippian units across Iowa. Many of their lithologic interpretations were valuable however the correlations were, and continue to be, subject to revision as later workers attempted to piece the Mississippian into the global stratigraphic framework. Harris and Parker (1964) provided inspirational insights into the structural context of southeastern Iowa by identifying a series of northwest-southeast trending anticlines that were later found to be superimposed on the larger northeast-southwest trending structural feature known as the Mississippi Arch (Witzke et al., 1990). Many questions remain regarding the stratigraphic correlations within the Mississippian such as whether the “St. Louis” Formation in Iowa truly belongs in the St. Louis Formation or should some of the upper members be reassigned to the Ste. Genevieve Formation; whether the Prospect Hill Formation is an offshoot of the Hannibal Formation of Missouri and Illinois; and whether the McCraney Formation is correlative to the McCraney in Illinois or if it should become a new stratigraphic interval (as proposed by Witzke et al., 2002). In an effort to address the question regarding the “St. Louis” Formation, detrital zircon analyses from sandstone samples collected near the mapping area were processed with the help of Emily Finzel (Assistant Professor of Geology at the University of Iowa (UI)). The geochronologic data provided by the detrital zircon analyses were not able to differentiate the sandstone units within the “St. Louis” Formation, however further study of the geochemistry and lithology of these sandstones may provide the evidence needed to identify whether these units belong in the St. Louis proper or in the Ste. Genevieve. Clarifying the issue regarding the Prospect Hill and McCraney formations is being done with the help of Brad Cramer (Assistant Professor of Geology at the UI), Brittany Stolfus (UI undergraduate student), and James “Jed” Day (Professor of Geology at Illinois State University). Samples collected from within the mapping area as well as at other locations in southeastern Iowa, eastern Illinois, and northeastern Missouri for conodonts and carbon isotopes have provided valuable bio- and chemostratigraphic information. Preliminary results suggest that the Prospect Hill and McCraney formations in Iowa may correlate with the Hannibal Formation. Further study will commence with additional sampling of surface exposures as well as core samples. Rectifying the questions posed by Witzke et al., 2002 may now become attainable.

The culmination of the diligent work of several key IGS geologists, and numerous other staff and student aides, resulted in a series of compilation geologic mapping projects, including Southeast Iowa (Witzke et al., 2004), that led to the creation of the first state-wide geologic map of Iowa using geographic information system (GIS) technology, published in 2010 (Witzke et al.). The 2010 map set the standard by which all subsequent geologic maps in Iowa are held.

Although the 2010 geologic map utilized more than a century of archived geologic data and was crafted by the hands of unquestionably the finest geologists to pass through the history of the IGS, its one defining limitation is that it was at such a large scale (1:500,000). Refining the components of the 2010 map at quadrangle (1:24,000) and county (1:100,000) scales has provided users with valuable detail and insight that lacks in the state-wide map. The major refinements in the Bedrock Geologic Map of the West Burlington (Iowa) 7.5’ Quadrangle include, 1) differentiation of the Augusta Group into its three distinct formations, 2) refining the previous bedrock topography from 50’ contour intervals to 25’ contours, and 3) identifying the locations of known and previously unknown bedrock exposures. These factors set this map apart from all previous mapping efforts in the region and will hopefully provide a more robust and useful product for the user.

DATA SOURCES AND COMPILATION

The Bedrock Geologic Map of the West Burlington (Iowa) 7.5’ Quadrangle was compiled using all available sources of information on the distribution and stratigraphy of bedrock units. Data were derived from a number of sources including, but not limited to the following:

- Applicable field trip guidebooks, technical reports, and publications
- Unpublished archived field notes of outcrops, road cuts, and quarry sections
- Well records from the IGS’s online well database (GeoSam) including driller’s logs, lithologic strip logs, and core descriptions
- Iowa Department of Transportation (IDOT) bridge boring records and core
- Engineering reports
- Stratigraphic sections compiled by quarry companies
- Natural Resources Conservation Service (NRCS) county-scale soils maps
- Field observations made of outcrops, road cuts, and quarry sections as part of this mapping project

GEOSAM Data

Well records constitute the largest data set and was therefore diligently scrutinized for content quality and accuracy. More than 230 well records were studied during the data compilation phase. Although about 200 wells already had strip logs, 17 new strip logs were created for this mapping project. Driller's logs were valued primarily for depth to bedrock information.

Locational accuracy of well points is of utmost importance, especially for those associated with lithologic strip logs. Historical plat books, county assessor records, internet resources, and personal communications with individual landowners were incorporated in refining the locations of wells in the mapping area. Once a well was accurately located, an elevation was assigned based on digital elevation models (DEM) derived from LiDAR imagery, within 2-feet accuracy.

Outcrop Data

Previous IGS geologists that conducted field studies in the mapping area cataloged their findings in archived records at the IGS. That, coupled with shallow and/or exposed bedrock areas identified in the Soil Survey of Des Moines County, Iowa (Brown, M.D., 1983) provided the basis for planning the field activities for this mapping project. Geologic reconnaissance of one inactive quarry within the quadrangle as well as 23 bedrock exposures within and adjacent to the quadrangle were conducted during field mapping activities.

METHODS AND APPROACHES TO MAPPING

ArcGIS 10.5 software and on-screen digitizing techniques developed during previous STATEMAP projects were employed for this mapping project. Drawing bedrock topographic lines and bedrock contact polygons using ArcGIS allows for rapid data processing while utilizing multiple layers of information that are all accurately projected using the Universal Transverse Mercater (UTM) North American Datum (NAD) 1983 Zone 15 coordinate system. The IGS works with the IDNR-GIS Section to generate and refine the data packages that are cataloged in the Iowa GEODATA website (https://geodata.iowa.gov/) and utilized for a variety of relational work products such as STATEMAP publications.

Bedrock Topography

Once the data set for all depth-to-bedrock information was compiled, a refined bedrock topographic map was generated. Drawing the bedrock topography of the mapping area incorporated well point and outcrop data, as well as using land surface topography in areas where shallow bedrock was identified. Bedrock topography for the entire state was generated as part of the Bedrock Geologic Map of Iowa (Witzke et al., 2010) using 50-foot contour intervals. The refined bedrock topography of the West Burlington Quadrangle was constructed using 25-foot contour intervals (Fig.1), which provided the basis for constructing this map. In addition to aiding in lithologic contact interpretation, the refined bedrock topographic map was also utilized to create the aesthetic effect of "hillshade" to the bedrock surface (Fig. 2), which was used a base layer for the final map.

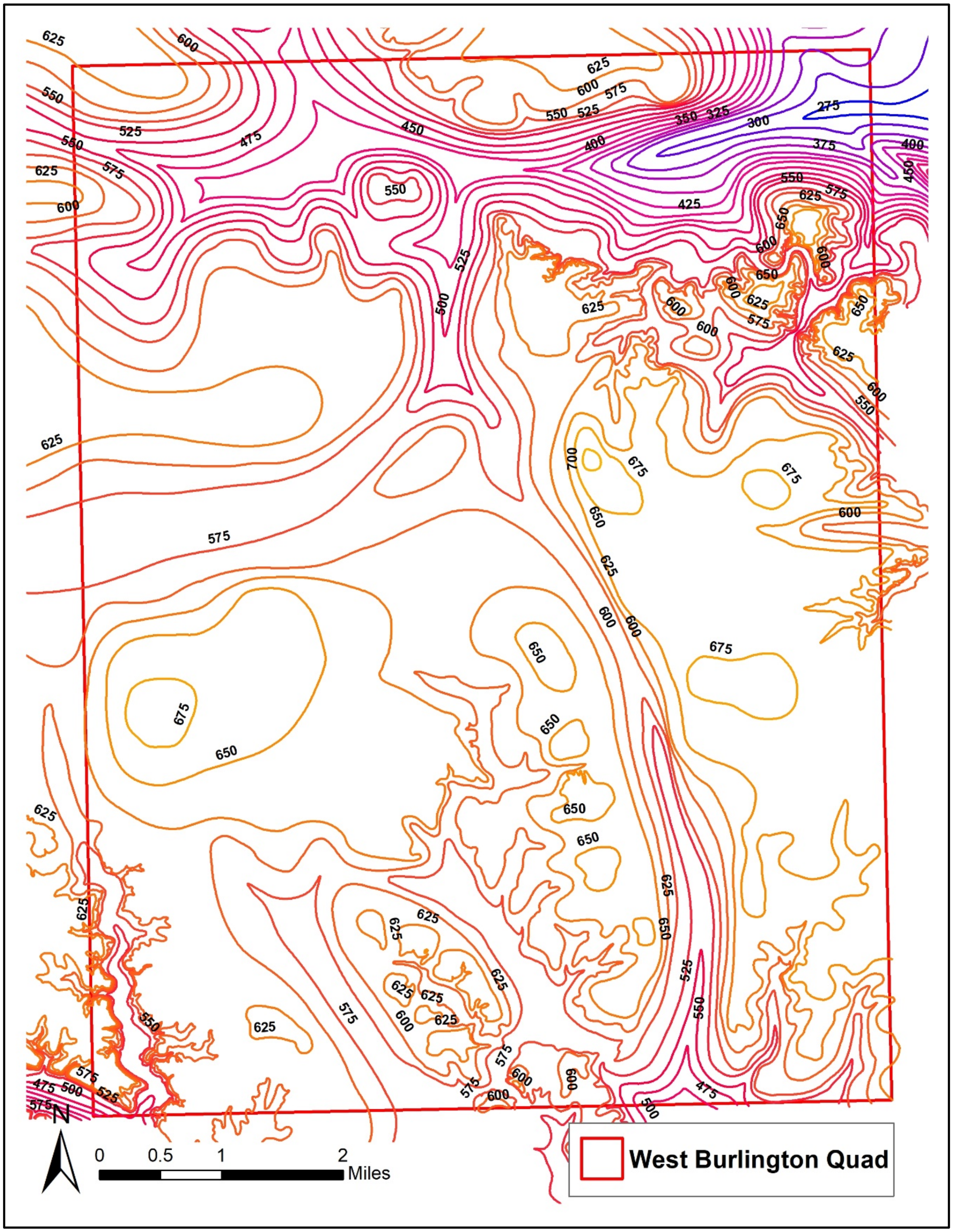

Figure 1: Bedrock topography of the West Burlington 7.5' Quadrangle drawn at 25-foot contour intervals.

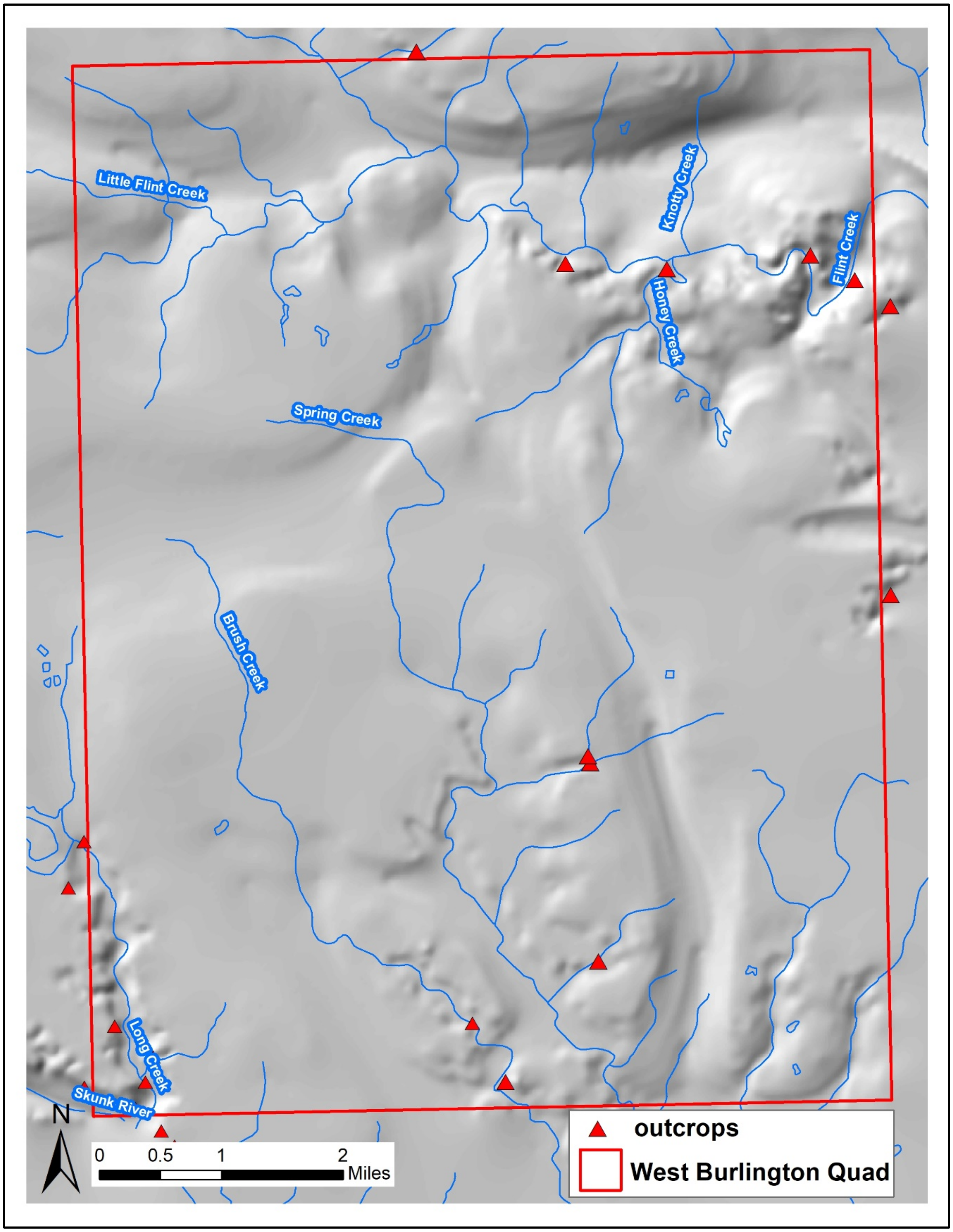

Figure 2: Raster image of the bedrock surface of the West Burlington 7.5' Quadrangle using "hillshade" effect. Image generated from the bedrock topography lines drawn at 25-foot contour intervals.

Bedrock Structures

In general, the bedrock strata in Iowa exhibit a subtle dip to the southwest, typically less than 5°. The stratigraphic data from the well points in the mapping area reflect the regional dip, however, dip orientations varied widely within the mapping area. Harris and Parker (1964) noted that multiple large scale northwest-southeast trending anticlines were observed within the Mississippian bedrock package of southeastern Iowa (Fig. 3). These anticlines are thought to be superimposed on top of, and perpendicular to, the broader northeast-southwest trending Mississippi Arch (Witzke et al., 1990). The well data in the mapping area does suggest possible folding, however, the scale of this map is too small to reflect these structural features on the map.

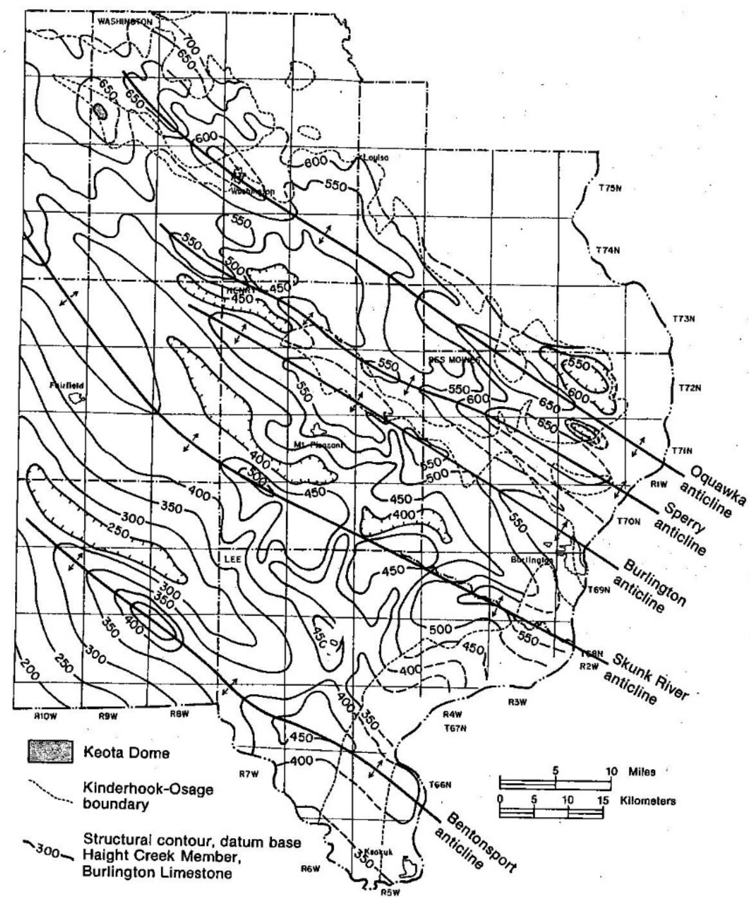

Figure 3: Structural contour map of southeast Iowa. Contours are drawn on the base of the Haight Creek Member of the Burlington Formation (Osagean Series). A number of anticlines are shown and are flanked by synclines (unlabeled). (From Harris and Parker, 1964, plate 2)

BEDROCK STRATIGRAPHY AND MAPPING UNITS

The units occurring at the bedrock surface in the West Burlington Quadrangle primarily include Mississippian deposits with Devonian units in the bedrock valley in the northern part of the mapping area. Stratigraphic units mapped on the new bedrock geologic map are summarized on the map Legend and the Stratigraphic Column and are described in further detail in the following sections. The boundaries separating the various map units were selected based on 1) prominent lithologic changes, 2) characteristic fossils, when available, and 3) major regional unconformities and/or disconformities. The bedrock stratigraphic nomenclature and correlation of the mapping units for this project follow that of Witzke et al. (2010), although the Augusta Group has been differentiated into its three distinct formations, in ascending order, the Burlington, Keokuk, and Warsaw. The thickness of each map unit was derived chiefly from well penetrations within and adjacent to the map area. Photos of lithologic features and exposures identified during field activities are included in Appendix A of this report.

Lithostratigraphic Setting

The mapping area consists of bedrock of the Mississippian Subsystem from late Kinderhookian to upper Osagean (about 355 – 330 million years ago) and Devonian strata of Famennian age (about 370 – 360 million years ago) (Ogg et al., 2008). Famennian strata are represented by brown, organic rich shales of the Grassy Creek Formation followed by gray-green silty shales of the Saverton Shale Formation and capped by the English River Formation siltstone. The thick shale packages represent major transgressive-regressive cycles of deposition in a stratified seaway (Witzke, 1987). Kinderhookian strata represent a sequence of interbedded carbonates and siltstones that unconformably underlie the Burlington Formation (early Osagean). The Burlington, Keokuk, and Warsaw formations (collectively the Augusta Group of Witzke et al., 2010) represent a relatively conformable package of marine rocks deposited during the Osagean transgressive-regressive (T-R) cycle. Interpreted as part of the central middle shelf of the Osagean sea that transgressed toward the northwest and the Transcontinental Arch, the Burlington Formation rocks were deposited across a vast subtidal epicontinental shelf that stretched from Illinois and Iowa into central Kansas and Oklahoma (Lane, 1978; Witzke et al., 1990). The Keokuk and Warsaw formations represent the regressive phase of the Osagean T-R cycle punctuated by a stark unconformity below the overlying Pella and "St. Louis" formations, regionally displaying up to 40 m (130 ft) of erosional relief (Witzke et al., 2002).

Multiple hardground surfaces, regional thinning or complete removal of units, and drastic facies changes makes correlation of Mississippian units in Iowa and surrounding states difficult. Although much research has been done in an attempt to unravel these complex relationships, more lithologic, geochemical, and biostratigraphic study will be needed to fully understand the Mississippian bedrock sequence.

Mapping Units

Mississippian Subsystem

Pella & "St. Louis" formations – The Pella and "St. Louis" formations were mapped as one unit in Witzke et al. (2010) and that methodology was adopted for this mapping area as well. Although the two formations display distinct lithologic characteristics, their nature and occurrences lend them to be grouped in mapping exercises until further information becomes available to allow their differentiation. This map unit can be up to 12 m (40 ft) thick within the mapping area. It is dominated by limestone and dolomite, partly sandy, with minor shale and chert. Limestones of the Pella Formation are typically sub-lithographic with scattered to abundant fossils, primarily brachiopods, echinoderms, and ostracods. The limestone facies of the "St. Louis" Formation can be fossiliferous with brachiopods, echinoderms, and several varieties of coral while the dolomitic facies typically exhibit fossil molds. Some fossils are silicified. The lower portion of this unit (historically referred to as the Spergen) is commonly gray to dark brown dolomite, locally brecciated and sandy, with rare fossils. This mapping unit is isolated to an upland bedrock high in the western portion of the mapping area. Outcrops of this mapping unit were not found within the mapping area.

Warsaw Formation – The Warsaw Formation varies in thickness thickness from 3 to 12 m (10 - 40 ft). This unit can generally be divided into two major lithologic groupings, a lower argillaceous dolomite sequence and an upper shale-dominated sequence. The upper shale is typically light to medium gray, silty, and variably dolomitic with minor chert, sand, and sparse quartz geodes. The lower dolomite, sometimes referred to as the "geode beds", is argillaceous to shaly, with scattered to abundant quartz geodes. Minor limestone units occur locally as thin, lensatic beds with crinoidal packstone/grainstone fabrics. Brachiopods, echinoderm debris, and bryozoans are found throughout this mapping unit, although are more common in the carbonate lithologies. This unit exhibits wide variability leaving only the upper shale or lower dolomite in place. Outcrops of this unit were not found within the mapping area.

Keokuk Formation – The Keokuk Formation can be up to 21 m (70 ft) in thickness in the mapping area. This unit is dominated by tan to gray interbedded skeletal limestones displaying packstone/grainstone fabrics (Photo 1). Nodular to bedded chert, in part fossiliferous, is common in the lower half of the sequence (Photo 2). Dolomite, variably argillaceous, and thin shales also occur throughout the unit. The unit displays multiple hardground surfaces and bone beds with scattered to abundant fish debris, the most prominent of these serves as a marker bed at the base of the formation (sometimes referred to as the Burlington-Keokuk or B-K bone bed). Brachiopods, crinoids, bryozoans, solitary corals, and fish bones and teeth occur throughout this unit as both abraded debris and partly articulated specimens. Molds of sponge spicules are noted in the dolomite facies. Traces of glauconite and minor geodes are also found in this formation. A handful of outcrops were found along Long Creek in the southwestern corner as well as on a tributary of Spring Creek (Photo 3) in the south-central part of the mapping area.

Burlington Formation – The Burlington Formation typically ranges between 12 to 18 m (40 – 60 ft) in thickness, reaching a maximum thickness of 23 m (75 ft) within the mapping area. This unit is subdivided into three members (in descending order: the Cedar Fork, Haight Creek, and Dolbee Creek), characterized by distinct lithologic groupings. The Cedar Fork Member is a pure white crinoidal packstone limestone unit which is usually differentiated from the packstones of the overlying Keokuk Formation by its white appearance. Occasional fish debris and glauconite are also observed in this member. The Haight Creek Member is characterized by dolomite with an intermittent unit of skeletal limestone (sometimes referred to as the "middle grainstone") and thick beds of chert (Photos 4 – 6). A glauconite-rich zone marks the lower contact between the Dolbee Creek and can be used as a regional marker bed. Fossil molds are also present in the dolomite facies. The Dolbee Creek Member is dominated by white to tan skeletal limestone displaying packstone/grainstone fabrics and nodular to bedded chert. Outcrops of this mapping unit can be found throughout the Burlington/West Burlington metro area in the northeastern portion of the quadrangle as well as a few locations in the southeastern portion.

The Burlington Formation hosts the most abundant crinoid fauna of any Mississippian, and possibly any Paleozoic Era, stratigraphic unit. In Witzke et al. (2002), Forest Gahn wrote "Over 600 species of crinoids and blastoids have been described from the Burlington Limestone. Nevertheless, only about 400 species of crinoids and 30 species of blastoids are currently recognized as valid, and many of these are synonymous." The variety of lithologies and fossil fauna of the Burlington Formation make it an absolute pleasure to work on as a field geologist.

Kinderhookian formations – The Kinderhookian sequence ranges in thickness from 6 to 11 m (20 – 36 ft) reaching a maximum thickness of 20 m (65 ft) within the mapping area. This unit comprises three formations (in ascending order: the McCraney, Prospect Hill, and Wassonville), characterized by distinct lithologic groupings (Photo 7). These formations are separated by minor unconformities noted by the occasional thinning or absence of one or more units observed within the mapping area. Outcrops of Kinderhookian strata occur along Flint Creek, specifically at Starr's Cave State Preserve in the northeastern part of the mapping area (Fig. 4), as well as near the mouth of Long Creek in the southwestern corner of the mapping area. The old Prospect Hill quarry near the southern boundary of the mapping area also has Wassonville and Prospect Hill formations exposed. Excellent Kinderhookian exposures can be found east of the mapping area along the bluff line of the Mississippi River, especially at Crapo Park.

The Wassonville Formation is typically about 4.5 m (15 ft) thick in the mapping area and is subdivided into an unnamed upper member and the basal Starr's Cave Member (formerly Starr's Cave Formation). The upper member is dominated by medium bedded dolomite that is variably cherty, grading into dolomitic limestone near the base. Faint laminations, often irregular or disturbed, are locally present within the upper member. The Wassonville Formation is known to be almost entirely limestone locally displaying packstone fabrics with abundant crinoid fossils. The Starr's Cave Member, typically less than 1.5 m (5 ft) thick when present, is a fossiliferous limestone with packstone/grainstone fabrics and is locally oolitic (Photo 8). Crinoids (partly articulated) are the dominant fossil type of the Starr's Cave Member. The Wassonville Formation hosts a diverse assemblage of brachiopods (especially chonetids) with lesser amounts of blastoids, starfish, corals, bryozoans, and trilobites reported.

The Prospect Hill Formation, typically less than 3 m (10 ft) thick when present, is a light to medium gray, dolomitic siltstone that grades to shale in some locations (Photos 9 & 10). This unit is often laminated with vertical and horizontal burrow fabrics and faint cross stratified bedforms. Fossils are rare to absent, although fossil molds are locally abundant.

The McCraney Formation ranges from 3 to 6 m (10 – 20 ft) thick within the mapping area and is composed of alternating beds of sparsely fossiliferous, sub-lithographic limestone and dark brown, unfossiliferous dolomite, generating a unique "zebra striped" appearance in outcrop (Photo 11). A basal oolite is locally present.

Figure 4: Exposure along Flint Creek at Starr's Cave State Preserve located in the northeastern corner of the mapping area. (Photo by Ryan Clark)

<u>Devonian System</u>

English River Formation – The English River Formation ranges in thickness from 4 to 9 m (13 – 30 ft) within the mapping area. This unit is dominated by gray to olive green siltstone with apparent bioturbated fabrics (Photo 12). Bivalves and brachiopods are common, especially in the upper beds, with scattered to abundant fossil molds as well. An outcrop of the English River Formation exists in the base of the exposure at Starr's Cave State Preserve in the northeastern portion of the mapping area.

Saverton Shale Formation – The Saverton Shale Formation can be up to 46 m (150 ft) thick within the mapping area. This unit is dominated by green-gray shale (Photos 13 & 14), commonly burrowed with sparse to absent macro-fossils. Outcrops of the Saverton Shale Formation were not observed within the mapping area.

Grassy Creek Formation – The Grassy Creek Formation can be up to 50 m (165 ft) thick within the mapping area. This unit is dominated by organic-rich brown shale with minor green-gray shale in the upper part of the unit (Photos 15 & 16). Differentiation between the Grassy Creek and the overlying Saverton Shale was primarily based on color and relative abundance of spore scarps identified in well cuttings. Outcrops of the Grassy Creek Formation were not observed within the mapping area.

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Photo 1: Exposure of Keokuk Formation along Long Creek on the Iowa Army Ammunition Plant property.

Photo 2: Gray fossiliferous limestone with chert nodules in the Keokuk Formation at the same exposure seen in Photo 1. (Rock hammer for scale)

Photo 3: Exposure of Keokuk Formation along a tributary to Spring Creek in the south-central part of the mapping area.

Photo 4: Exposure along North Gear Avenue near Flint Creek in the northern part of the mapping area. Haight Creek Member of the Burlington Formation showing white crinoidal limestone (aka "middle grainstone") on top of brown, fossil moldic dolomite. (blue handle of rock hammer for scale)

Photo 5: Same location as Photo 4 showing large white chert nodules within brown crinoidal limestone of the Burlington Formation. (rock hammer for scale)

Photo 6: Possible old quarry face behind a home on Market Street in Burlington just east of the mapping area. Nodular and bedded chert within dolomite of the Haight Creek Member of the Burlington Formation. (rock hammer for scale)

Photo 7: Exposure along Flint Creek at Starr's Cave State Preserve in the northeast corner of the mapping area. This is the best exposure of strata from the English River Formation (base) through the Kinderhookian to the Dolbee Creek Member (top).

Photo 8: Oolitic limestone with solitary coral fossil and calcite-filled vug in the Starr's Cave Member at its type locality, Starr's Cave State Preserve.

Photo 9: Contact between the overlying Wassonville Formation dolomite and the underlying gray siltstone of the Prospect Hill Formation in the former Prospect Hill quarry, located near the southern boundary of the mapping area.

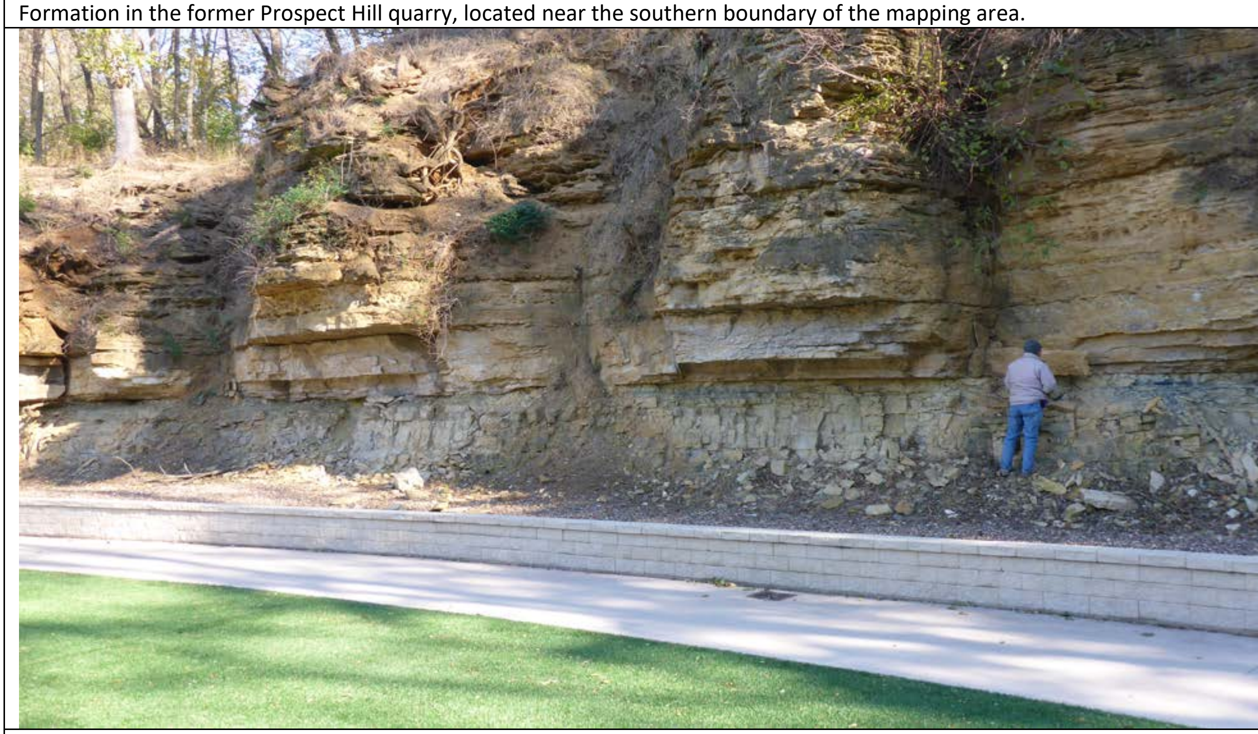

Photo 10: Exposure of Wassonville Formation over Prospect Hill Formation at Bracewell Stadium (football field) in Burlington, about one mile east of the mapping area.

Photo 11: Close up view of the McCraney Formation at Starr's Cave State Preserve.

Photo 12: Exposure of English River Formation siltstone/shale beneath McCraney Formation near Blackhawk Spring at Crapo Park in southern Burlington, about 1.5 miles east of the mapping area.

Photo 13: Photo of the upper Saverton Shale Formation in the Sullivan core, drilled just outside the southeastern part of the map area. Photo courtesy of the Iowa Geological Survey's GeoCore Database (https://www.iihr.uiowa.edu/igs/geocore/home)

Photo 14: Photo of the lower Saverton Shale Formation in the Sullivan core, drilled just outside the southeastern part of the map area. Photo courtesy of the Iowa Geological Survey's GeoCore Database (https://www.iihr.uiowa.edu/igs/geocore/home)

Photo 15: Photo of the upper Grassy Creek Formation in the Sullivan core, drilled just outside the southeastern part of the map area. Photo courtesy of the Iowa Geological Survey's GeoCore Database (https://www.iihr.uiowa.edu/igs/geocore/home)

Photo 16: Photo of the lower Grassy Creek Formation in the Sullivan core, drilled just outside the southeastern part of the map area. Photo courtesy of the Iowa Geological Survey's GeoCore Database (https://www.iihr.uiowa.edu/igs/geocore/home)