SUMMARY REPORT OF THE BEDROCK GEOLOGIC MAP OF THE WEST POINT (IOWA) 7.5' QUADRANGLE, LEE COUNTY, IOWA

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INTRODUCTION

The Bedrock Geologic Map of the West Point (Iowa) 7.5' Quadrangle is part of the fourth 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 Point Quadrangle occupies approximately 57 square miles of primarily agricultural land with abundant forested areas situated within the Southern Iowan Drift Plain (SIDP) landform region (Prior, 1991) and a small portion of the Mississippi River Alluvial Plain in the extreme southeast corner of the quad. The SIDP hosts glacial deposits over 500,000 years old that contain a thick till package mantled by younger loess draped over upland hill slopes. Numerous rills, creeks, and rivers branch out across the landscape shaping the old glacial deposits into steeply rolling hills and valleys. The West Point Quadrangle also hosts the western extent of the Illinoisan ice advance with the terminal moraine transecting the quad from north to south. The thickness of unconsolidated Quaternary deposits is variable across the quadrangle. According to well data, the maximum thickness of Quaternary materials is over 97 m (320 ft) in the southeastern part of the mapping area. Mississippian bedrock units dominate the bedrock surface overlain by a few Pennsylvanian outliers. The majority of the bedrock exposures occur along Sugar Creek and its tributaries in the western part of the mapping area.

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 the abundance of bedrock exposures in southeastern Iowa and likely correlated them with those observed farther down the Mississippi River Valley. 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, p. 5). 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 from Missouri and Illinois; and whether the McCraney Formation is correlative to the type McCraney in Illinois or if it should become a new stratigraphic interval (as proposed by Witzke et al., 2002). Although the Mississippian bedrock in southeastern Iowa is no longer a widely used aquifer due to low yields and locally poor water quality, many of the bedrock units are highly desirable sources of aggregate, thus necessitating the continued effort to gain a better understanding of the local and regional stratigraphic characteristics and relationships of the Mississippian Subsystem in southeastern Iowa. 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 (Witzke et al., 2010). The 2010 map set the standard to 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). This left room for improvement. That is where the recent IGS mapping staff has picked up, with the support of the STATEMAP program. Refining the mapping units 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 Point (Iowa) 7.5' Quadrangle include: 1) differentiation of the Augusta Group into its three distinct formations, 2) better characterizing the extent and distribution of Pennsylvanian outliers, 3) refining the previous bedrock topography from 50' contour intervals to 25' contours, and 4) 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 Point (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 generated from drilling cutting samples, 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
- HVSR passive seismic survey data used for depth to bedrock calibration

GeoSam Data

Well records constitute the largest data set and were therefore diligently scrutinized for content, quality, and accuracy. More than 200 well records were studied during the data compilation phase. Driller's logs were valued primarily for depth to bedrock information. There were no core samples within the mapping area.

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 Lee County, Iowa (Lockridge, 1979), provided the basis for planning the field activities for this mapping project. Geologic reconnaissance of one abandoned quarry and seven bedrock exposures were conducted during field activities within the mapping area.

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 final map products are available as downloadable PDFs on the IGS publications website (https://www.iihr.uiowa.edu/igs/publications/search) and as shapefiles through the Iowa GEODATA Clearing House (https://geodata.iowa.gov).

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 Point Quadrangle was constructed using 25-foot contour intervals, 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. 1), which was used a base layer for the final map.

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. 2). These anticlines are thought to be superimposed on top of, and perpendicular to, the broader northeast-southwest trending Mississippi Arch (Witzke et al., 1990, p. 5). The well data in the mapping area does elude to possible folding, however, the areal extent of this map is too small to reflect these regional structural features on the map.

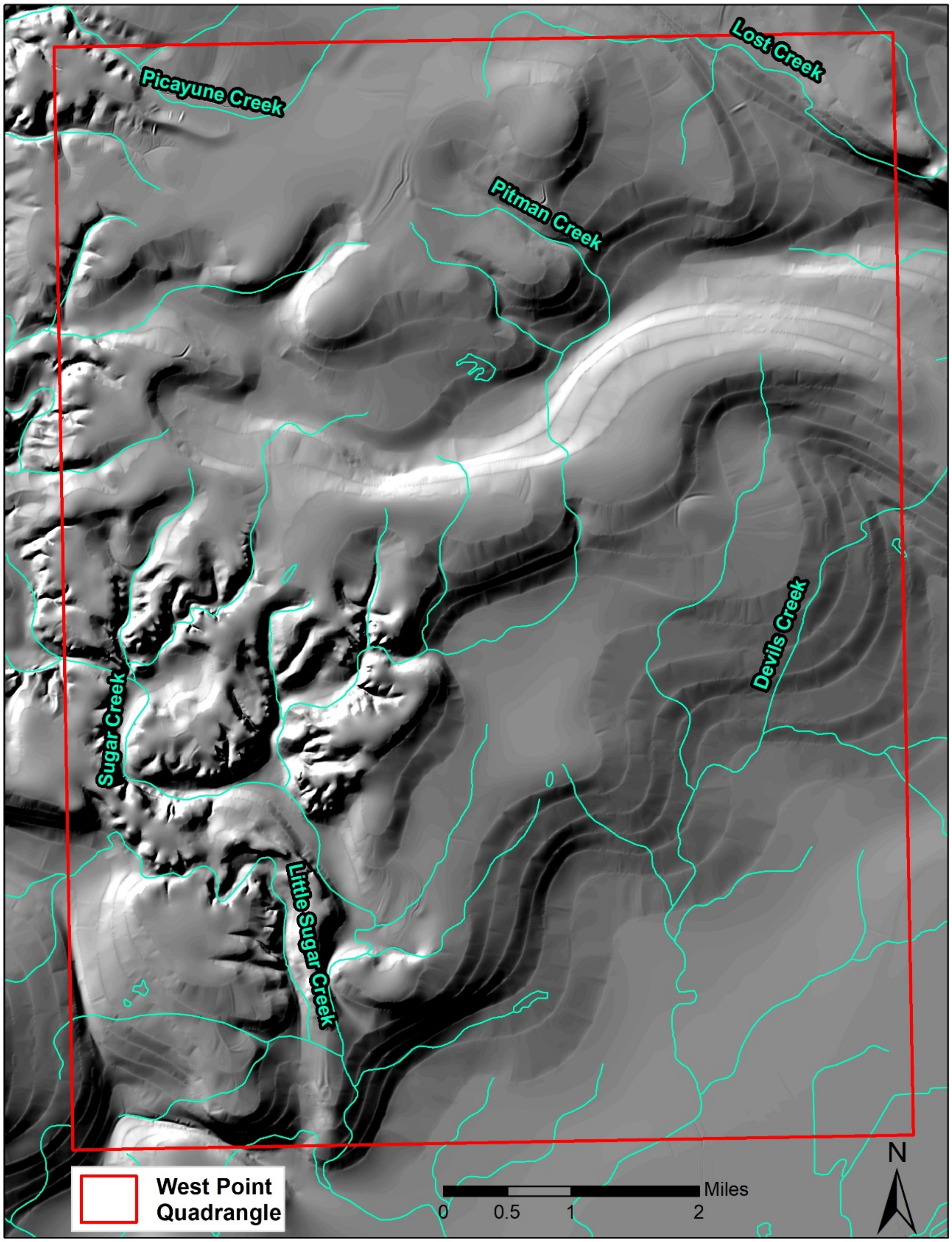

Figure 1: Raster image of the bedrock surface of the West Point 7.5' Quadrangle using a "hillshade" effect. Image generated from the bedrock topography lines drawn at 25-foot contour intervals.

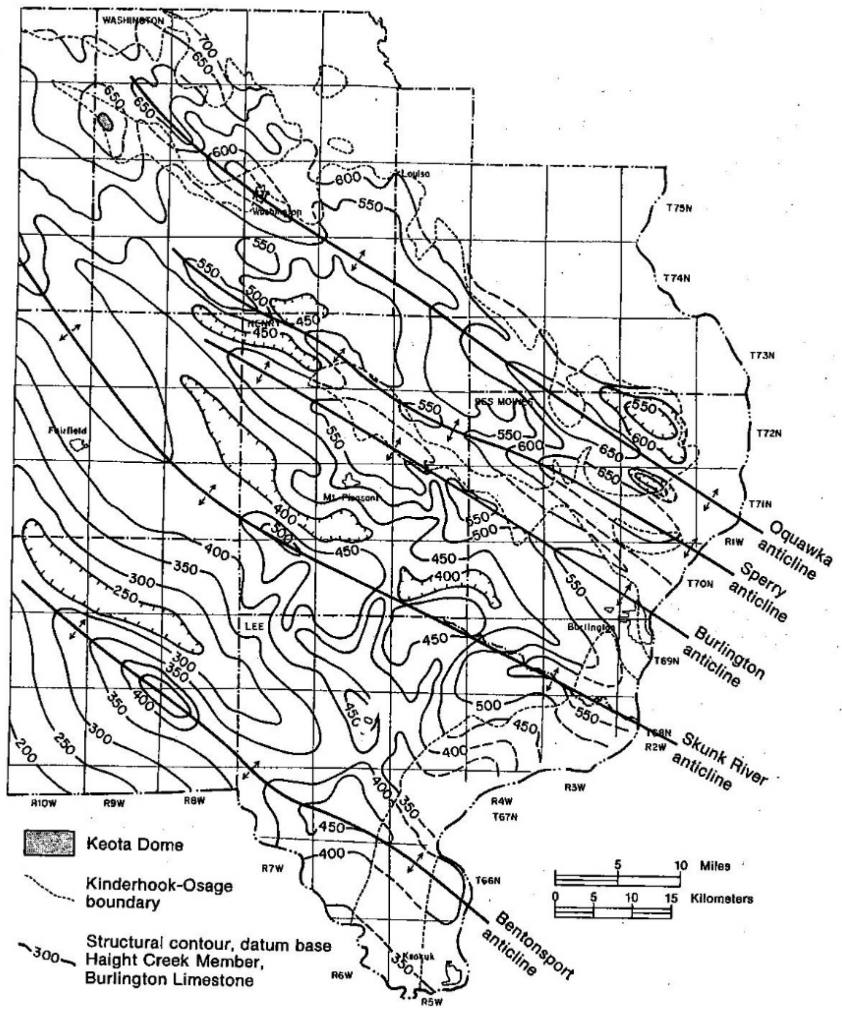

Figure 2: Structural contour map of southeast Iowa. Contours are drawn on the base of the Haight Creek Member of the Burlington Formation (Osagean Series). A number of anticlines are shown and are flanked by synclines (unlabeled). (From Harris and Parker, 1964, plate 2)

Karst Geology

In several of the areas where bedrock is known to be shallow, evidence of karst geology was observed in the LiDAR (Fig. 3). The example shown in Figure 3 is located in the northwestern part of the West Point Quadrangle where sinkholes identified in the Soil Survey of Lee County (Lockridge, 1979) are evident in the LiDAR. Unfortunately field reconnaissance of the area was not possible during the mapping process. Karst geology is more widespread in northeastern Iowa, however recent mapping efforts in southeastern Iowa has further expanded the realm of karst in Iowa. Thin soil/glacial cover over carbonate bedrock is the typical environment for generating karst and this area of the state is no exception.

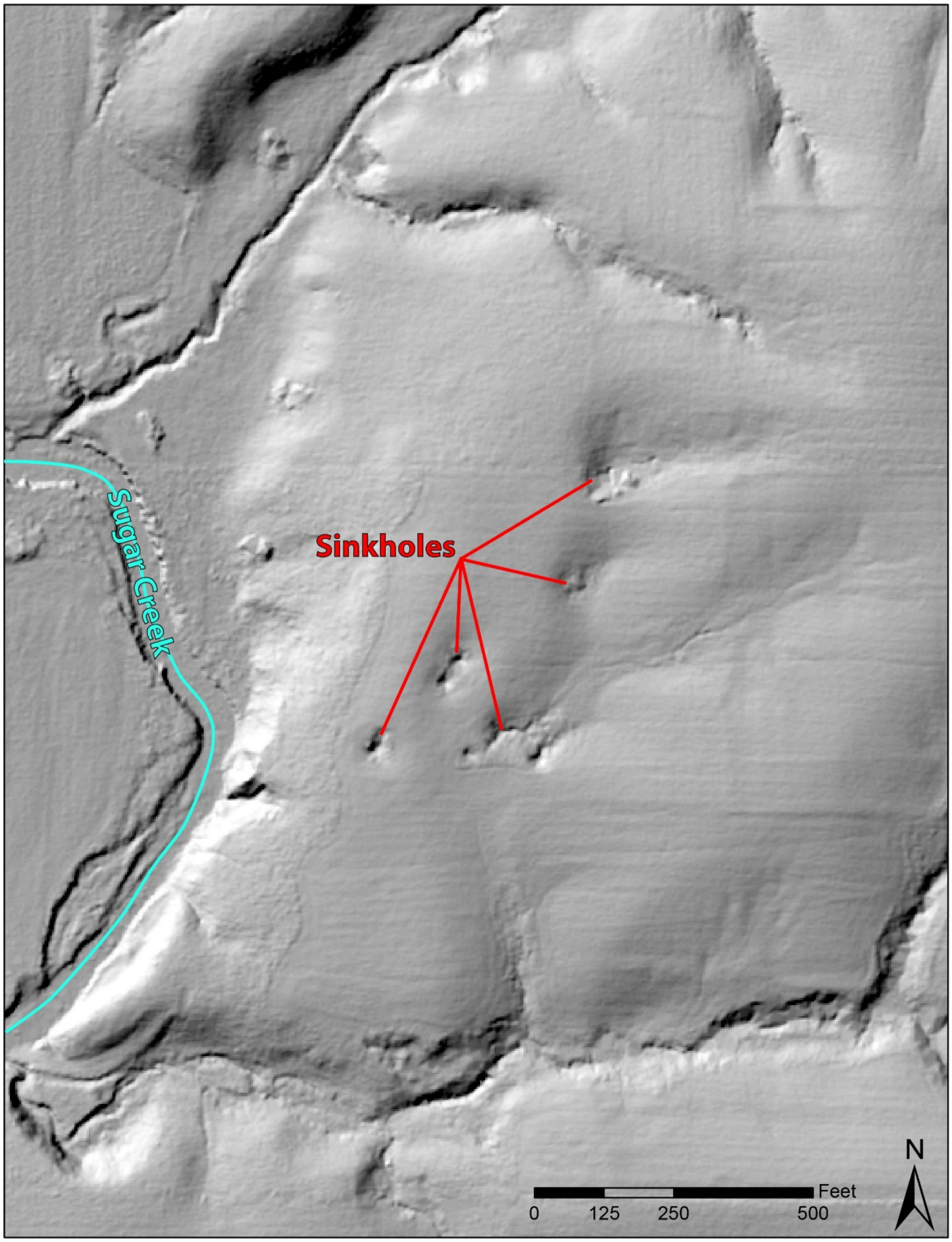

Figure 3: LiDAR image with "hillshade" effect to illustrate karst geology in the northwestern part of the West Point Quadrangle. Multiple sinkholes were identified in the Soil Survey of Lee County (Lockridge, 1979), however these were not able to be verified during field reconnaissance.

BEDROCK STRATIGRAPHY AND MAPPING UNITS

The units occurring at the bedrock surface in the West Point Quadrangle primarily include Mississippian deposits with a few Pennsylvanian outliers. Stratigraphic units mapped on the new bedrock geologic map are summarized in 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 is dominated by bedrock of the Mississippian System that was deposited in a variety of marine environments from the late Kinderhookian to early Chesterian, approximately 355 – 330 million years ago (Ogg et al., 2008). Kinderhookian strata represent a sequence of interbedded carbonates and siltstones that unconformably underlie the Burlington Formation (early Osagean) and are not exposed at the bedrock surface within the mapping area. 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, p. 55). 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). The Pella and “St. Louis” formations are mapped as one unit due to their stratigraphic complexity and questionable correlation to the type sections in Missouri and Illinois (Witzke et al., 1990, p. 23). The Pella and “St. Louis” formations were deposited in a near-shore environment as evidenced by mudflat facies rocks, evaporites and associated collapse breccias (Fig. 4), and increased terrigenous sandstone deposits, with periods of brackish and/or lacustrine deposition interpreted from coal deposits and root casts (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. Mississippian strata unconformably overlie an eroded surface of Devonian shales and siltstones in the mapping area.

Figure 4: Cross-bedded sandy limestone of the Pella/"St. Louis" formations observed in the abandoned Franklin Quarry along Sugar Creek in the southwestern portion of the West Point Quadrangle.

Mapping Units

<u>Pennsylvanian Sub-System</u>

Lower Cherokee Group – Pennsylvanian units occur as erosional outliers reaching a thickness of approximately 18 m (60 ft) within the mapping area. This unit consists of shale/mudstone, light to medium gray, part silty to sandy and fine to medium quartz sandstone, rarely conglomeratic, and coal. Some shales are carbonaceous to phosphatic. No outcrops of this unit were identified in the mapping area.

<u>Mississippian Sub-System</u>

Pella & "St. Louis" formations – This map unit ranges between 9 and 18 m (30 – 60 ft) thick and reaches a maximum thickness of 24 m (80 ft) in the mapping area. It is dominated by limestone, sandstone, dolomitic limestone, and dolomite with minor shale and chert. Limestones of the Pella Formation are typically sub-lithographic with scattered to abundant fossils, primarily brachiopods, echinoderms, ostracods, and solitary corals. The "St. Louis" Formation is dominated by limestone, sandy limestone, sandstone, and dolomite, variably cherty. The limestone facies of this unit can be fossiliferous with brachiopods, echinoderms, and several varieties of coral while the dolomitic facies typically exhibit fossil molds. Some fossils are silicified. Sandstones of the "St. Louis" Formations are typically very fine to medium quartz sandstones that are poorly to moderately cemented with calcite or quartz. The lower portion of the "St. Louis" Formation is commonly gray to dark brown dolomite, locally brecciated and sandy, with rare fossils. This mapping unit dominates the bedrock surface in the mapping area and is overlain by Quaternary sediments or Pennsylvanian outliers. Seven outcrops and one abandoned quarry exposing this mapping unit were identified in the mapping area.

Warsaw Formation – The Warsaw Formation varies in thickness due to a disconformity at the upper contact, reaching a maximum thickness of approximately 15 m (50 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 these fossils are more common in the carbonate lithologies. Outcrops of this unit were not observed in the mapping area.

Keokuk Formation – The Keokuk Formation can be up to 26 m (85 ft) thick in the mapping area. This unit is dominated by tan to gray interbedded skeletal limestones displaying packstone/grainstone fabrics. Nodular to bedded chert, in part fossiliferous, is common in the lower half of the sequence. 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 locally abundant geodes are also commonly associated with this unit. Outcrops of this unit were not observed in the mapping area.

Burlington Formation – The Burlington Formation can be up to 24 m (80 ft) thick in the mapping area. This unit is subdivided into three members (in ascending order: the Dolbee Creek, Haight Creek, and Cedar Fork), characterized by distinct lithologic groupings. The Dolbee Creek Member is dominated by white to tan skeletal limestone displaying packstone/grainstone fabrics and nodular to bedded chert. 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. 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 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. Outcrops of the Burlington Formation were not found in the mapping area.

Kinderhookian formations – The Kinderhookian sequence ranges in thickness from 5 to 15 m (20 – 50 ft) with a maximum thickness of 27 m (90 ft) in the mapping area. This unit comprises three formations (in ascending order: the McCraney, Prospect Hill, and Wassonville), characterized by distinct lithologic groupings described below. Kinderhookian rocks make up the bedrock surface in a deep bedrock channel in the southeastern corner of the mapping area.

The Wassonville Formation, including the basal Starr's Cave Member, consists of massive dolomite that is variably cherty grading into dolomitic limestone lower in the section. The basal Starr's Cave Member is a fossiliferous limestone with packstone/grainstone fabrics and is commonly oolitic. Crinoids (partly articulated) are the dominant fossil type of the Starr's Cave Member. A diverse assemblage of brachiopods are present with lesser amounts of blastoids, starfish, corals, bryozoans, and trilobites reported.

The Prospect Hill Formation is a light to medium gray, dolomitic siltstone that grades to shale in some locations. 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 is composed of alternating beds of sparsely fossiliferous, sub-lithographic limestone and dark brown, unfossiliferous dolomite, generating a unique "zebra striped" appearance in outcrop. A basal oolite is locally present.

Devonian System

English River Formation – The English River Formation is up to 8 m (25 ft) thick within the mapping area. This unit is dominated by gray to olive-green siltstone with apparent bioturbated fabrics. Bivalves and brachiopods are common, especially in the upper beds, with scattered to abundant fossil molds as well. This unit only appears in the cross-section, not on the map.

Saverton Shale Formation – The Saverton Shale Formation can be up to 41 m (135 ft) thick within the mapping area. This unit is dominated by green-gray shale, commonly burrowed with sparse to absent macrofossils. This unit only appears in the cross-section, not on the map.

Grassy Creek Formation – The Grassy Creek Formation can be up to 40 m (130 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. Differentiation between the Grassy Creek and overlying Saverton Shale was primarily based on color and relative abundance of spore scarps identified in well cuttings. This unit only appears in the cross-section, not on the map.

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Photo 1: Cross-bedded sandy limestone of the "St. Louis" Formation seen in the Franklin Quarry located near the eastern quad boundary along Sugar Creek.

Photo 2: Desiccation cracks in sandy limestone of the "St. Louis" Formation at the Franklin Quarry.

Photo 3: Thinly bedded and shaly dolomite of the "St. Louis" Formation near the Franklin Quarry.

Photo 4: Exposure of the "St. Louis" Formation along Pitman Creek near the center of the West Point Quadrangle.

Photo 5: Brecciated limestone of the “St. Louis” Formation seen at the same location as Photo 4.

Photo 6: Specimen of “Lithostrotion” coral, indicative of the lower “St. Louis” Formation, found in the same location as Photos 4 and 5.

Photo 7: Exposure of intensely brecciated carbonate of the "St. Louis" Formation along Pitman Creek, downstream of the previous photos.

Photo 8: Chert nodules in dolomite of the "St. Louis" Formation near the location of Photo 7.

Photo 9: Geode found along Sugar Creek in the southwestern part of the West Point Quadrangle. Geodes are indicative of the Warsaw Formation.