SUMMARY REPORT OF THE SURFICIAL GEOLOGIC MAP OF THE CENTER POINT NW 7.5' QUADRANGLE, BENTON COUNTY, IOWA

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

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

Iowa Geological Survey, Keith Schilling, State Geologist

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INTRODUCTION

The Center Point NW Quadrangle is located in central Iowa on the Iowan Surface landform region, commonly referred to as the Iowan Erosion Surface (IES) (Prior and Korht, 2006). The map area is dominated by dissected till plains with unnamed reworked sediments, sand sheets and dunes, and elongated loess-covered uplands called paha as well as larger 'erosional inliers' (Ruhe et al., 1968; Prior and Korht, 2006). The Cedar River has a significant role in shaping the surficial geology in this area as well. Stratigraphically, this area contains Pre-Illinoian age glacial deposits above Paleozoic carbonates. There are areas of shallow bedrock, where it is less than 2m (7 ft) from the surface. The thickness of Quaternary deposits in the Center Point NW Quadrangle is generally between 8 to 24 m (25-80 ft), but bedrock may be more than 45 m (150 ft) from the surface in the southeastern part of the mapping area.

Mapping the Center Point NW and Vinton quadrangles represents the first part of a multi-year program to map the surficial geology of Benton County. This county represents the last corridor along the Cedar River that has not been recently mapped. The counties to the north and east have been both completed under the STATEMAP program (Quade et al., 1998; Tassier-Surine et al., 2013). This area represents a unique geologic area, being on the southern edge of the IES. Studies conducted during the 1950s and 1960s showed that the often debated Iowan Glaciation did not occur, e.g. Ruhe et al. (1968). This work indicated that unique stratigraphy of the area was caused due to an erosional event due to fluvial downcutting. Modern periglacial ideas have challenged the older model of landscape development for the area, and detailed geologic mapping can be used as an important tool for investigating these processes. The majority of the older research's drill cores were collected in the same general vicinity, so a comparison can be made between the two different ideas on landscape development.

PURPOSE

Detailed geologic mapping of the Center Point NW quadrangle was completed as part of the Iowa Geological Survey's (IGS) ongoing participation in the United States Geological Survey (USGS) STATEMAP Program. Mapping in the area is produced as part of the IGS Impaired Watershed mapping initiative and provides comprehensive surficial and bedrock geologic information. These maps are the basis for further development of derivative datasets and map products for use by local, county and state decision-makers. In recent years, Iowa's State Mapping Advisory Committee (SMAC) has recommended mapping in areas with environmental concerns related to groundwater quality and land-use planning issues, and/or in rapidly developing areas. The IGS and SMAC recognize the need for maps of varying scales to address the complex environmental issues facing urban and rural Iowans. Mapping in Benton County provides much needed geologic maps in the Middle Cedar River watershed. Many new partners are concentrating efforts on water supply, water quantity and quality, land-use planning, and flood protection studies. Geologic mapping is crucial and foundational for many of these studies, and the project enjoys broad support from the Cedar River Watershed Coalition (CRWC).

Bedrock mapping efforts were successful in subdividing the Devonian mapping units used by Witzke and others (2010) into formations. From a Quaternary perspective, characterizing the materials deposited during the formation of the IES is a fundamental part of understand the recent geologic history of both Iowa and the glaciated parts of the Midwest. The mapping location also includes the Cedar River, which carried outwash from the Des Moines Lobe glacial advance, and has helped to further identify and characterize sand and gravel resources associated with glacial outwash plains and channels. The Quaternary IES materials are highly variable and poorly consolidated, and therefore do not provide good groundwater quality protection in shallow rock areas. It is necessary to identify areas of either better consolidated Quaternary materials or bedrock aquitards. Combining the bedrock and surficial map information is allowing stakeholders to address key questions related to shallow rock areas, potential karst issues, aggregate resource potential and protection, and groundwater vulnerability, while achieving the evolving goals of the watershed management plans.

QUATERNARY HISTORY AND REGIONAL SETTING

The map area has a rich and complex Quaternary geologic history punctuated by at least seven periods of glaciation between 2.6 million and 500,000 years ago (Boellstorff, 1978a, b; Hallberg, 1980, 1986). Episodic erosion over the last 500,000 years has led to the destruction of pre-existing glacial landforms associated with Pre-Illinoian glaciations. While this area was not glaciated during the last glacial episode, the Wisconsin, the effects of the paleoclimate can be seen in deposits throughout the area. This period had an intensely cold and windy environment from 21,000 to 16,500 years ago (Walter, 1994; Bettis and Autin, 1997; Mason, 2015). Due to this climate, a periglacial environment prevailed with intensive freeze-thaw action, solifluction, strong winds, thin plant cover, and a host of other periglacial processes (Baker et al., 1986; Walter, 1994; Mason, 2015; Kerr et al., 2019).

During the formation of the IES, soils that had developed on the upland landscape were removed and the underlying Pre-Illinoian till weathering zone was significantly eroded in this area; this resulted in the development of a region-wide colluvial lag deposit referred to as a “stone line.” During this same interval, the Cedar River valley was filled with glacially derived deposits of sand and gravel from the Des Moines Lobe. This outwash provided a local source for wind-derived sediment. The distinctive features of this region are paha and the larger ‘erosional inliers.’ These are isolated landforms and may represent uneroded topographic highs of loess-mantled Pre-Illinoian till. They have a northwest to southeast alignment (McGee, 1891; Ruhe et al., 1968). This orientation seems to coincide with the regional paleo-prevailing winds (Muhs et al., 2013; Mason 2015; Kerr et al., 2019). Paha and ‘inliers’ usually have a thick package of wind-blown material, with some locations in the mapping area having over 12 m (40 ft) of loess and fine sand. Where paha are not present, packages of stratified loamy and sandy sediment cover the upland and hill slope positions on the landscape. This material is thought to be the remnants of solifluction lobes associated with the formation of the IES. The toeslopes and smaller valleys have thick packages of coarse sand and gravel interspersed with loamy and silty layers. Some valleys, like Hinkle Creek, have over 7 m (24 ft) of this coarse material beneath a thin mantle of reworked loess. These valley deposits were developed in response to the shifting climate and base levels during the formation of the IES (Bettis and Autin, 1997).

In eastern Iowa, the highly eroded and dissected Illinoian and Pre-Illinoian upland and older terraces are mantled by two Wisconsin loesses. The older Pisgah Formation is thin and includes loess and related slope sediments that have been altered by colluvial hillslope processes. The unit is characterized by the presence of a weakly developed soil recognized as the Farmdale Geosol. It is not uncommon to see the Farmdale developed throughout the Pisgah Formation and into the underlying older Sangamon Paleosol. The Pisgah loess was most likely deposited on the eastern Iowa landscape from 30,000 to 24,000 years ago (Bettis, 1989) and is typically buried by Peoria Formation loess. The Peoria Formation loess accumulated on stable landsurfaces in eastern Iowa from 25,000 to 21,000 years ago. Peoria Formation eolian materials mantle the upland till units and are present on the Wisconsin outwash terraces. On the uplands, the Peoria Formation is a uniform silt loam; in the valleys the silt commonly grades downward to fine sand. The loess deposits in the mapping area are relatively thin, generally less than 4 meters (12 ft).

Hudson age deposits are associated with fine-grained alluvial, organic, and colluvial sediments and include the DeForest Formation which is subdivided into the Camp Creek, Roberts Creek, and Gunder members. These deposits are present in valleys and upland drainages throughout the map area. The Holocene low terrace deposits occupy the active channel belt of the Cedar River. Both an intermediate and high Holocene terrace are present along the Cedar River and may be several meters above the modern floodplain. Due to the difficulty of differentiating these terraces where only one was present, they were combined into one mapping unit.

METHODS

Numerous existing sources of geologic information were utilized in the production of the surficial and bedrock geologic maps of the Center Point NW Quadrangle including subsurface information, USDA NRCS soil survey data, aerial photography, DEM's, satellite imagery, landform characteristics, and LiDAR. Where available, engineering borings from public utilities, the Iowa Department of Transportation, and monitoring well records of the USGS were used. Subsurface lithologic and stratigraphic information was mostly derived from analysis of water well cutting samples reposited at the IGS and stored in the IGS online GeoSam database. Over 250 public and private wells in GeoSam, including strip logs, were reviewed for lithology, stratigraphy and locational accuracy, and updated where needed. NRCS digitized soils data (Brown and Highland, 1980) provided information regarding shallow rock areas, helped to guide valley mapping units, and defined slope areas where glacial till is exposed. Bedrock mappers also used the digital soil surveys to help delineate areas of shallow rock outcrop prior to field reconnaissance. New geologic information was obtained from logging of well cutting samples for 3 unstudied wells. Quaternary geologists utilized the IGS truck mounted Giddings probe to drill a mix of solid stem and continuous core holes. Seventeen new drill holes totaling 441 feet were completed in or near the quadrangle to characterize the Quaternary sediments and establish unit thickness. Samples are being processed for grain-size with all results expected by July, 2019. Laboratory data will be incorporated into the online IGS GeoLab database.

Project geologists combined information from the sources listed above to delineate surficial geologic mapping units at 1:24,000 scale for the Center Point NW Quadrangle. IGS mappers used ArcGIS and on-screen digitizing techniques developed during previous STATEMAP projects. The final map entitled 'Surficial Geologic Map of the Center Point NW 7.5' Quadrangle, Benton County, Iowa' will be available as a shapefile in the Iowa GEODATA Clearing House (https://geodata.iowa.gov), as a PDF file on the IGS Publications website, and will be submitted to the USGS National Geologic Map Database. This Summary Report is also available as a PDF file on the IGS Publications website.

STRATIGRAPHIC FRAMEWORK FOR EASTERN IOWA

The stratigraphic framework for eastern and central Iowa was established nearly 40 years ago (Hallberg, 1980, 1986). Surficial deposits in the map area are composed of six formations: the DeForest, Noah Creek, Peoria, Pisgah, Wolf Creek, and Alburnett formations, as well as unnamed erosion surface sediments. Hudson age deposits associated with fine-grained alluvial, organic, and colluvial sediments include the DeForest Formation which is subdivided into the Camp Creek, Roberts Creek, Gunder, Corrington, and Woden members (Bettis, 1990a; Bettis et al., 1992). The Noah Creek Formation includes coarse sand and gravel associated with outwash from the Des Moines Lobe, as well as coarse to fine-grained fluvial and colluvial deposits associated with local stream and river valleys (Bettis et al., 1996). Unnamed erosion surface sediments consist of reworked till, slopewash, and solifluccted deposits associated with periglacial activity during the late Wisconsin Episode. The Peoria Formation is found across the mapping area and has a silt and sand facies deposited during the Late Wisconsinan Stage (McKay, 1979; Bettis et al., 2003). Generally, the sand facies is found downwind (southeast) of the Cedar River, while the silt facies is found on the upland, especially in paha. Thin deposits of Peoria Formation, less than 1 m (3 ft), are found across most of the mapping area. The Pisgah Formation is comprised of loess and colluvium deposited during the Middle Wisconsinan (Bettis, 1990b). Beneath these materials are Pre-Illinoian glacial deposits, which, in Iowa, consist of two formations: the younger Wolf Creek Formation and the Alburnett Formation (Hallberg, 1980). The Wolf Creek Formation is divided into the Winthrop, Aurora, and Hickory Hills members (oldest to youngest). The Alburnett Formation consists of several "undifferentiated" members. This project had 17 new drill holes to assist with the geologic characterization.

Four bedrock mapping units (Pennsylvanian lower Cherokee Group; and the Mississippian Pella or "St. Louis", Warsaw, and Keokuk formations) are exposed at the bedrock surface in the Center Point NW Quadrangle. The Mississippian Pella or "St. Louis" formations and the Pennsylvanian lower Cherokee Group comprise the bedrock surface in most of the map area, especially in the upland areas. The other

Mississippian units occur within the bedrock valleys and tributaries. Bedrock exposures or rock present within one to two meters (7 ft) of the land surface are designated as 'Qbr' on the map. Specific bedrock units are shown on the cross-section and defined in the legend. For detailed bedrock information see The Bedrock Geologic Map of the Center Point NW 7.5' Quadrangle (Liu et al., 2019).

Recent studies and mapping indicate that the map area encompasses a complex suite of depositional landforms and sediment sequences related to glaciations, alluviation, subaerial erosion, and wind-blown transport. To map diverse landscapes at 1:24,000 scale, we have selected the most comprehensive mapping strategy- a landform sediment assemblage (LSA) approach. Various landforms are the result of specific processes at work in the geologic system. Landforms typically have similar relief, stratigraphic and sedimentologic characteristics. Recognition of the genetic relationship among landforms and their underlying sediment sequences allows one to generalize and map complex glacial terrains over areas of large extent (Sugden and John, 1976; Eyles and Menzies, 1983). Bettis and others (1999) found that LSA mapping concepts were extremely useful in overcoming the difficulties of mapping in large valleys and noted that LSA's provided a unique opportunity to associate landforms with their underlying sediment packages. Eight landform sediment assemblage units were identified in the map area utilizing aerial imagery, topographic expression, digitized soils, LiDar, and existing and new subsurface geologic boring information. The following is a description of each landform sediment assemblage listed in order of episode:

HUDSON EPISODE

Qal - Alluvium (DeForest Formation - Undifferentiated) Variable thickness of less than 1 to 5 m (3-16 ft) of very dark gray to brown, noncalcareous or calcareous, stratified silty clay loam, clay loam, loam to sandy loam alluvium and colluvium in stream valleys, on hill slopes, and in closed depressions. May overlie Wolf Creek or Alburnett formation glacial tills, Peoria Formation loess or eolian sand, or Wisconsinan sand and gravel. Associated with low-relief modern floodplains, closed depressions, modern drainageways, or toeslope positions on the landscape. Seasonal high water table and potential for frequent flooding.

Qalb - Alluvium Shallow to Bedrock (DeForest Formation - Undifferentiated) - Variable thickness of less than 1 to 5 m (3-16 ft) of very dark gray to brown, noncalcareous or calcareous, massive to stratified silty clay loam, clay loam, loam to sandy loam alluvium and colluvium in stream valleys, on hillslopes, and in closed depressions. May overlie the Noah Creek, Wolf Creek/Alburnett formations, or fractured Devonian bedrock. Bedrock surface is within 5 m (16 ft) of the land surface. Associated with low-relief modern floodplains, closed depressions, modern drainageways, or toeslope positions on the landscape. Seasonal high water table and potential for frequent flooding.

Qallt - Low Terrace (DeForest Formation - Camp Creek and Roberts Creek members) Variable thickness of less than 1 to 5 m (3-16 ft) of very dark gray to brown, noncalcareous, stratified silty clay loam, loam, or clay loam, associated with the modern channel belt of the Cedar River and its tributaries. Overlies Wisconsinan sand and gravel of the Noah Creek Formation. Occupies the lowest position on the floodplains, i.e., the modern channel belts. Seasonal high water table and frequent flooding potential.

Qali-ht - Intermediate-High Terrace (DeForest Formation - Roberts Creek and Gunder members) Variable thickness of less than 1 to 5 m (3-16 ft) of very dark gray to brown, noncalcareous, silty clay loam to loam alluvium or colluvium. Overlies Wisconsinan sand and gravel of the Noah Creek Formation or Devonian aged bedrock. Occupies terrace and valley margin positions 1 to 2 m (3-7 ft) above the modern floodplain of the Cedar River and its tributaries. Seasonal high water table and low to moderate flooding potential.

HUDSON and WISCONSIN EPISODE

Qnw2 - Sand and Gravel (Noah Creek Formation) Generally 2 to 10 m (6-33 ft) of yellowish brown to gray, poorly to well-sorted, massive to well-stratified, coarse to fine feldspathic quartz sand, pebbly sand and gravel with few intervening layers of silty clay. A thin mantle of loess, reworked loess, or fine-grained alluvium may be present. This unit includes silty colluvial deposits derived from the adjacent map units. Seasonal high water table and some potential for flooding.

Qnw3 - Sand and Gravel Shallow to Bedrock (Noah Creek Formation) 1 to 6 m (3-20 ft) of yellowish brown to gray, poorly to well-sorted, massive to well-stratified, coarse to fine feldspathic quartz sand, pebbly sand and gravel. May be overlain by up to 3 m (10 ft) of silty alluvial material. In places, this unit can be mantled with fine to medium, well-sorted feldspathic quartz sand derived from wind reworking of the alluvium. Fractured carbonate bedrock is less than 6 m (20 ft) below the land surface. The unit encompasses deposits that accumulated in river and stream valleys during the late Wisconsin as well as exhumed Pre-Illinois Episode deposits of the Wolf Creek and Alburnett formations.

Qe - Sand Dunes and Sand Sheets (Peoria Formation - sand facies) Generally less than 3 m (10 ft) of yellowish brown, massive, calcareous, loamy sand to fine sand. It occurs as sand stringers or dunes overlying Wisconsin aged outwash or bedrock.

WISCONSIN EPISODE

Qps6 - Eolian Dunes and Sand Sheets Shallow to Glacial Till (Peoria Formation - sand facies) Generally 2 to 4 m (7-14 ft) of yellowish brown, massive to well-stratified, noncalcareous, fine to medium, well-sorted feldspathic quartz sand. Overlies pebbly loam erosion surface sediment which, in turn, overlies eroded massive, jointed, firm, loamy glacial till of the Wolf Creek or Alburnett formations.

Qps2 - Eolian Sand and Intercalated Silt (Peoria Formation - sand facies) Generally 5 to 15 m (16-49 ft) of yellowish brown to gray, moderately to well-stratified noncalcareous or calcareous, fine to medium, well-sorted, eolian sand. May contain interbeds of yellowish brown to gray, massive, silt loam loess. This unit may form large dunes in river valleys or the upland landscape. Overlies eroded, massive, fractured, loamy glacial till of the Wolf Creek or Alburnett formations or fractured Devonian-age carbonate bedrock.

Qps1 - Loess and Intercalated Eolian Sand (Peoria Formation - silt and/or sand facies) Generally 2 to 5 m (7-16 ft) of yellowish brown to gray, massive, fractured, noncalcareous grading downward to calcareous, silt loam and intercalated fine to medium, well-sorted sand. Sand is most abundant in the lower part of the eolian package. Overlies massive, fractured, loamy glacial till of the Wolf Creek or Alburnett formations with or without the intervening clayey Farmdale/Sangamon Geosol.

Qps1b - Thick Loess and Intercalated Eolian Sand (Peoria Formation - silt and/or sand facies) Generally 5 to 15 m (16-49 ft) of yellowish brown to gray, massive, noncalcareous grading downward to calcareous silt loam and intercalated fine to medium, well-sorted sand. Minimum thickness of 5 m (16 ft) on uplands. Maximum thickness of 2 to 7 m (6-23 ft) of loess occurs on adjacent slopes. Overlies massive, fractured, loamy glacial till of the Wolf Creek or Alburnett formations with or without the intervening clayey Farmdale /Sangamon Geosol.

Qnw - Sand and Gravel (Noah Creek Formation) 3 m (10 ft) to more than 30 m (100 ft) of yellowish brown to gray, poorly to well-sorted, massive to well-stratified, coarse to fine feldspathic quartz sand, pebbly sand and gravel. In places, mantled with 1 to 3 m (3-10 ft) of fine to medium, well-sorted sand derived from wind reworking of the alluvium. This unit encompasses deposits that accumulated in the Cedar River Valley during the Wisconsin Episode.

Qwa2 - Loamy and Sandy Sediment Shallow to Glacial Till (Unnamed erosion surface sediment) Generally 2 to 8 m (6-26 ft) of yellowish brown to gray, massive to weakly-stratified, well to poorly-sorted loamy, sandy and silty Iowan Erosion Surface sediment. Map unit includes some areas mantled with less than 2 m (7 ft) of Peoria Formation materials (loess and eolian sand). Overlies massive, fractured, firm, glacial till of the Wolf Creek and Alburnett formations. Seasonal high water table may occur in this map unit.

PRE-ILLINOIS EPISODE

Qwa3 - Glacial Till (Wolf Creek or Alburnett formations) - Generally 3 to 15 m (10-50 ft) but can be more than 45 m thick (150 ft) within the bedrock valley in the eastern part of the mapping area. This mapping unit consists of very dense, massive, fractured, clay loam glacial till of the Wolf Creek or Alburnett formations. This mapping unit can be overlain by unnamed erosion surface sediments, colluvium, outwash, loess, eolian sand, or alluvium. This unit is shown only on the cross-section.

OTHER MAPPING UNITS

Qbr - Loamy Sediments Shallow to Dolomite, Limestone and Shale (DeForest, Peoria, Wolf Creek and Alburnett formations) 1 to 2 m (3-7 ft) of yellowish brown to gray, massive to weakly-stratified, well to poorly-sorted loamy, sandy and silty sediments that overlie the Devonian bedrock surface. All areas of bedrock outcrop or shallow to bedrock soils are shown in red on the map.

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