SUMMARY REPORT OF THE SURFICIAL GEOLOGIC MAP OF THE DONNELLSON 7.5' QUADRANGLE, LEE COUNTY, IOWA

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Stephanie Tassier-Surine, Ryan Clark, and Phil Kerr

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 Donnellson Quadrangle is located in southeastern Iowa on the Southern Iowa Drift Plain landform region (Prior and Kohrt, 2006). The map area is dominated by loess mantled till plains in the uplands, and coarse to fine grained alluvial deposits within Sugar Creek and its tributaries. Glacial till is only exposed in drainages and steep sideslopes. The Quaternary stratigraphy of the region consists of 2 to 5 m (7-15 ft) of Peoria Formation loess over a well-developed Yarmouth-Sangamon paleosol formed in Pre-Illinoian till. The Illinoian moraine lies less than three miles to the east of the Donnellson Quadrangle. The thickness of Quaternary materials varies widely across the quadrangle generally ranging from 0 to 18 m (0-60 ft). Based on well data, the maximum thickness is 55 m (180 ft) in the southern part of the mapping area. Bedrock exposures are found along Sugar Creek and its tributaries. Mississippian and Pennsylvanian units dominate the bedrock surface. An accompanying map of the bedrock geology of the Donnellson Quadrangle has been published concurrently with this map.

Mapping the Donnellson and West Point quadrangles is the fourth phase of a multi-year program to map the surficial and bedrock geology of southeast Iowa. It has been nearly 40 years since Hallberg (1980a,b) established the stratigraphy for the Illinoian and Pre-Illinoian glacial advances in eastern and southeastern Iowa. The majority of the drill cores and outcrops for those studies were to the north and east of the Donnellson Quadrangle and provide the stratigraphic framework for the mapping area. Additional data available since that time (LiDAR, DEMs, and digital soil surveys) has allowed for the refinement of the Illinoian boundary and greater detail in mapping the valleys. Previous mapping under the STATEMAP program included the Lowell and Danville quadrangles in FY16 (Clark et al., 2017a,b; Tassier-Surine et al., 2017a,b), the Sperry and West Burlington quadrangles in FY17 (Clark et al., 2018a,b; Tassier-Surine, 2018a,b), and the Mount Pleasant and Salem quadrangles in FY18 (Clark et al., 2019a,b; Tassier-Surine et al., 2019a,b). The only other surficial map of the area consists of the Des Moines 4˚ x 6˚ Quadrangle at a scale of 1:1,000,000 (Hallberg et al., 1991). Several Iowa Geological Survey (IGS) field trip guidebooks outline the Pleistocene, Devonian, and Mississippian stratigraphy (Witzke et al., 2002; Witzke and Tassier-Surine, 2001), but their focus is on the area near Burlington (to the east).

PURPOSE

Detailed geologic mapping in southeast Iowa was completed as part of the Iowa Geological Survey's (IGS) ongoing participation in the United States Geological Survey (USGS) STATEMAP Program. Mapping was completed as part of the IGS Developing Areas and Impaired Watershed mapping initiatives 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. An 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 led to the selection of southeast Iowa as a 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.

Bedrock mapping efforts were successful in subdividing the Mississippian Augusta Group used by Witzke and others (2010) into the Warsaw, Keokuk, and Burlington formations and in better identifying Pennsylvanian outliers. Quaternary mapping efforts focused on better delineation and characterization of

the glacial deposits, gaining an understanding of the nature of the alluvial system and terrace deposits, confirming loess thickness in the region, and delineating areas of shallow bedrock. The map area includes Sugar Creek, which joins the Mississippi River a few miles south of the quadrangle. Prior to the recent mapping, little information was available regarding the nature and thickness of sand and gravel deposits in Sugar Creek. Mapping has helped to further delineate alluvial terraces of both Holocene and Wisconsin age. Combining the bedrock and surficial map information is allowing stakeholders to address key questions related to shallow rock areas, groundwater protection, water supply concerns, and aggregate resource potential and protection.

QUATERNARY HISTORY AND REGIONAL SETTING

The glacial history of Iowa began more than two million years ago, as at least seven episodes of Pre-Illinoian glaciation occurred between approximately 2.6 and 0.5 million years ago (Boellstorff, 1978a,b; Hallberg, 1980a). Early researchers believed there were only two episodes of Pre-Illinoian glaciation in Iowa. Later regional studies determined that at least seven episodes of Pre-Illinoian glaciation had occurred and led to the abandonment of the classic glacial and interglacial terminology: Kansan, Aftonian and Nebraskan (Boellstorff, 1978a,b; Hallberg, 1980a, 1986). Hallberg (1980a,b, 1986) undertook a regional scale project in east-central Iowa that involved detailed outcrop and subsurface investigations, including extensive laboratory work and synthesis of previous studies. Hallberg's study marked a shift from the use of time-stratigraphic terms and resulted in the development of a lithostratigraphic framework for Pre-Illinoian till. In east-central Iowa, Hallberg formally classified the units into two formations on the basis of differences in clay mineralogy: the Alburnett Formation (several undifferentiated members) and the younger Wolf Creek Formation (including the Winthrop, Aurora and Hickory Hills members). Both formations are composed predominantly of till deposits, but other materials are present. Paleosols are formed in the upper part of these till units.

A limited area of southeastern Iowa was glaciated during the Illinois Episode, around 190,000 to 130,000 years ago (Hallberg, 1980b; Curry et al., 2011). These deposits are to the east of the mapping area, but the valley configuration and alluvial deposits may have been influenced by the Illinoian glacial advance. Following the Illinoian glaciation, this area underwent landscape development and erosion until deposition of the Wisconsin Episode loess began. The Pre-Illinoian till is only exposed in drainages and relatively steep sideslopes.

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 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).

Sugar Creek and Little Sugar Creek deposited coarse sand and gravel associated with erosion and development of the Mississippi River Valley during the Wisconsin Episode. Based on the alluvial framework established by Esling (1984), three terrace assemblages can be identified: the Early and Late

Phase high terraces, and Low Terrace deposits. The high terraces are characterized by the presence of Peoria and Pisgah formation sediments overlying alluvium, with or without the intervening Sangamon Paleosol. Low Terrace deposits are younger and not overlain by the Peoria loess. These terraces are found along Sugar Creek and in many cases may be benched on bedrock.

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 Sugar Creek and Little Sugar Creek. Both an intermediate and high Holocene terrace are present in some areas 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 Donnellson 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 280 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 (Lockridge, 1979) 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 59 unstudied wells totaling 10,975 feet. Quaternary geologists utilized the IGS truck mounted Giddings probe to drill a mix of solid stem and continuous core holes. Three new drill holes were completed in the quadrangle to characterize the Quaternary sediments and establish unit thickness. Samples are being processed for grain-size with all results expected by December, 2020. Laboratory data will be incorporated into the online IGS GeoLab database. Six outcrops as well as two active and three abandoned quarries were investigated during the mapping project. Fourteen passive seismic data points were collected to help determine the depth to bedrock in select areas and assist with production of the bedrock topography map.

Project geologists combined information from the sources listed above to delineate surficial geologic mapping units at 1:24,000 scale for the Donnellson Quadrangle. IGS mappers used ArcGIS and on-screen digitizing techniques developed during previous STATEMAP projects. The final map entitled 'Surficial Geologic Map of the Donnellson 7.5' Quadrangle, Lee 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 SOUTHEAST IOWA

The stratigraphic framework for southeast Iowa was established by Hallberg (1980a,b) nearly 40 years ago. Surficial deposits in the map area are composed of six formations (youngest to oldest): Hudson

DeForest; Wisconsin Peoria, Pisgah, and Noah Creek; and Pre-Illinoian Wolf Creek and Alburnett. 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, and Corrington members. The Noah Creek Formation includes coarse sand and gravel associated with outwash from the Des Moines Lobe and colluvial deposits in smaller streams. Loess deposits include both Peoria and Pisgah formation silt that are present mantling the upland till units and high terraces. On the high terraces, the Peoria Formation grades downward to eolian sand. Eolian deposits are found intermittently on Holocene terraces. Pre-Illinoian glacial deposits are found throughout the mapping area and consist of two formations: the younger Wolf Creek and Alburnett formations. 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. Pre-Illinoian tills are only exposed in drainages and relatively steep slopes.

Five bedrock mapping units (Pennsylvanian Lower Cherokee Group; and the Mississippian Pella or "St. Louis", Warsaw, Keokuk, and Burlington formations) are exposed at the bedrock surface in the Donnellson 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 uplands. The other Mississippian units occur within the bedrock valleys and tributaries. Bedrock exposures or rock present within two meters (7 ft) of the land surface are designated as 'Qbr' on the map. Specific bedrock units are shown on the cross-section. For detailed bedrock information see The Bedrock Geologic Map of the Donnellson 7.5' Quadrangle (Clark et al., 2020).

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. Nine 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 to 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 Pre-Illinoian formation glacial till, Peoria Formation loess or eolian sand, or Noah Creek Formation sand and gravel. Associated with low-relief modern floodplain, closed depressions, modern drainageways or toeslope positions on the landscape. Seasonal high water table and potential for frequent flooding. The depth to bedrock may be less than 8 m (26 ft) along portions of Sugar Creek and its tributaries.

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 to calcareous, 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 Formation, Mississippian or Pennsylvanian bedrock. Bedrock surface is within 5 m (16 ft) of the land surface. Associated with low-relief modern floodplain, 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 Sugar Creek and Little Sugar Creek. Overlies Noah Creek Formation sand and gravel. Occupies the lowest position on the floodplain ie. modern channel belts. Seasonal high water table and frequent flooding potential.

Qali-ht - Intermediate-High Terrace (DeForest Formation-Gunder Member) 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 Noah Creek Formation sand and gravel along Sugar Creek and Little Sugar Creek and their tributaries. Occupies terrace and valley margin positions 1 to 2 m (3-7 ft) above the modern floodplain. Two terrace levels are present in some areas. Seasonal high water table and low to moderate flooding potential.

WISCONSIN EPISODE

Qnw - Sand and Gravel (Noah Creek Formation) Generally 3 to 9 m (10-30 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. This unit is buried by Peoria Formation silt or younger Hudson-age alluvial deposits associated with Sugar Creek and Little Sugar Creek and encompasses deposits that accumulated in river valleys during the Wisconsin Episode. This unit is shown only on the cross-section.

Qpt - Loess Mantled Terrace (Peoria Formation-silt and/or sand facies) 2 to 7 m (7-23 ft) of yellowish brown to gray, massive, jointed, calcareous or noncalcareous, silt loam and intercalated fine to medium, well sorted, sand. May grade downward to poorly to moderately well sorted, moderately to well stratified, coarse to fine feldspathic quartz sand, loam, or silt loam alluvium (Late Phase High Terrace) or may overlie a Farmdale Geosol developed in Pisgah Silt which in turn overlies a well-expressed Sangamon Geosol developed in poorly to moderately well sorted, moderately to well stratified, coarse to fine sand, loam, or silt loam alluvium (Early Phase High Terrace). This unit may be benched on bedrock.

Qps - Loess (Peoria Formation-silt facies) Generally 2 to 5 m (7-15 ft) of yellowish to grayish brown, massive, jointed calcareous or noncalcareous silt loam to silty clay loam. May overlie a grayish brown to olive gray silty clay loam to silty clay (Pisgah Formation- eroded Farmdale Geosol) which is less than 1.5 m (5 ft) thick. The Pisgah Formation is in the same stratigraphic position as the Roxanna Silt which is mapped in Illinois. The Farmdale Geosol may be welded to an older Sangamon Geosol developed in loamy glacial till of the Wolf Creek or Alburnett formations. This mapping unit encompasses upland divides, ridgetops and convex sideslopes. Well to somewhat poorly drained landscape.

PRE-ILLINOIS EPISODE

Qwa3 - Till (Wolf Creek or Alburnett formations) Generally 10 to 18 m (33-60 ft) of very dense, massive, fractured, loamy glacial till of the Wolf Creek or Alburnett formations with or without a thin loess mantle (Peoria Formation- less than 2 m) and intervening clayey Farmdale/Sangamon Geosol. This mapping unit

encompasses narrowly dissected interfluves and side slopes, and side valley slopes. Drainage is variable from well drained to poorly drained.

OTHER MAPPING UNITS

Qbr - Loamy Sediments Shallow to Dolomite, Limestone, Shale and Sandstone (DeForest, Noah Creek, 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 Pennsylvanian or Mississippian bedrock surface. All areas of bedrock outcrop or shallow to bedrock soils are shown in red on the map, regardless of the bedrock mapping unit. Bedrock units are shown on the cross-section and may be identified on the bedrock map of the Donnellson Quadrangle.

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