SUMMARY REPORT OF THE SURFICIAL GEOLOGIC MAP OF MITCHELL COUNTY, IOWA

Iowa Geological Survey
Open File Map OFM-16-2
June 2016

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Supported in part by the U.S. Geological Survey
Cooperative Agreement Number G15AC00242
National Cooperative Geologic Mapping Program (STATEMAP)
Completed under contract with the Iowa Department of Natural Resources

INTRODUCTION

The 'Surficial Geologic Map of Mitchell County, Iowa' represents the final of three phases of surficial mapping in Mitchell County. A bedrock geologic map was also produced in conjunction with the surficial geologic map (Clark et al., 2016). The Mitchell County map covers an area from 43° 12' to 43° 30' N latitude and 93° 02' to 92° 31' W longitude. Mitchell County is located in north-central Iowa on the Wisconsin-age Iowan Surface (IS) landform region (Prior and Kohrt, 2006). The map area is dominated by unnamed loamy sediments (IS materials) of variable thickness overlying Wisconsin-age Sheldon Creek Formation glacial sediments, Pre-Illinoian age glacial sediments, or shallow rock. Significant areas of bedrock outcrop or areas with less than 5 m (16 ft) of loamy material over bedrock are present, especially along Rock Creek, the Cedar River and its tributaries, and portions of Burr Oak Creek and the Little Cedar River. The thickness of Quaternary deposits in Mitchell County is highly variable as they are typically less than 15 m (50 ft) in the western part of the county and reach a maximum thickness of 100 m (330 ft) in a bedrock valley on the eastern side of Mitchell County.

Calvin (1902) described and mapped the Quaternary and Paleozoic bedrock geology of Mitchell County. He noted the extreme variability of the till units, the presence of significant sand and gravel bodies, and also a relatively thick loess unit in the southern part of the county. Statewide bedrock geologic maps by Hershey (1969), and most recently by Witzke and others (2010), illustrate the improved understanding of the complex distribution of geologic units at the bedrock surface across north-central Iowa, including Mitchell County. Previous surficial geologic mapping completed as part of the STATEMAP program in Mitchell County includes Surficial Geology of the Osage Quadrangle (Tassier-Surine et al., 2014a), Surficial Geology of the St. Ansgar Quadrangle (Tassier-Surine et al., 2014b), and Surficial Geology of the New Haven Quadrangle (Kerr et al., 2015). Mapping adjacent to the project area includes Surficial Geology of Worth County, Iowa (Quade et al., 2012) and Surficial Geology of Cerro Gordo County, Iowa (Tassier-Surine et al., 2015).

PURPOSE

Detailed geologic mapping of Mitchell County was completed as part of the Iowa Geological Survey's (IGS) ongoing participation in the United States Geological Survey (USGS) STATEMAP Program. Mapping in Mitchell County was completed 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 Mitchell County provides much needed geologic maps in the Upper Cedar River watershed. The basin has been the subject of water quality projects in the past, but there was a renewed focus on the Cedar River following catastrophic flooding in 2008. 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 Iowa-Cedar Watershed Interagency Coordination Team (ICWICT) and 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 and in better identifying Cretaceous outliers. From a Quaternary perspective, characterizing and identifying the extent of the middle Wisconsin Sheldon Creek Formation is a fundamental question, as this unit extends much farther east than was previously mapped. 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. A more refined knowledge of both bedrock topography and bedrock geology provides an important bedrock perspective within this region that has significant shallow bedrock and karst terrain. The Quaternary IS 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, 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 to 500,000 years ago. 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, 1980, 1986). Hallberg (1980, 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 (1980) formally classified the units into two formations primarily 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. Following the Pre-Illinoian glaciations, several episodes of landscape development resulted in the formation of an integrated drainage network, slope evolution and soil development on stable land surfaces (Bettis, 1989).

In north-central Iowa, the highly eroded and dissected Pre-Illinoian upland is overlain by much younger Wisconsin-age glacial sediments. During the earlier and middle Wisconsin-age, ice advances dating from approximately 40,000 to 26,000 years before present were deposited throughout the map area. In Iowa, this glacial deposit is formally recognized as the Sheldon Creek Formation (Bettis et al., 1996; Bettis, 1997) and in earlier literature is referred to as the "Tazewell till" (Ruhe, 1950). These sediments are typically buried by loamy erosional sediments associated with the IS. The most recent glacial advance of the Des Moines Lobe did not extend into Mitchell County, but its influence is evident in the development of river valleys and periglacial alteration of the landforms.

Results from this mapping project and others in Worth and Cerro Gordo counties represent significant changes to the understanding of the middle Wisconsin glacial advances in north-central Iowa (Quade et al., 2012; Tassier-Surine et al., 2015). The maximum extent of these deposits is still not fully understood, but recent mapping projects indicate that the Sheldon Creek glacial materials extend much farther east than were previously mapped. The Little Cedar River in Mitchell County is thought to generally represent an ice marginal position related to middle Wisconsin or earlier glaciation. The geometry of the river, differences in drainage pattern and density on the east and west sides of the Little Cedar River, and significant differences in geologic materials have led to this conclusion. West of the Little Cedar River, the predominant till unit is the Sheldon Creek Formation and to the east Pre-Illinoian till is exposed at the surface. Extensive sand and gravel deposits within the upper till package in the central and southeastern part of the county may represent either outwash deposits associated with the advance of the Sheldon Creek or colluvial deposits related to downcutting of the IS. Erosional remnants and outliers associated with the formation of the IS, as well as the presence of sand bodies overlain by weathered till, make it difficult to absolutely differentiate stratigraphic units and complicate establishing an exact ice-marginal (moraine) position. When compared with Pre-Illinoian tills exposed elsewhere on the IS landform region, the Sheldon Creek till is generally less dense and contains less clay in the matrix.

Mitchell County can loosely be divided into three regions west to east: the area west of the Cedar River, the area between the Cedar and Little Cedar rivers, and east of the Little Cedar River. The Sheldon Creek Formation is almost always present west of the Cedar River, with the exception of a few isolated areas in low lying landscape positions where it has been eroded. It often contains a paleosol at depth with a complete or truncated Yarmouth-Sangamon paleosol formed in the Pre-Illinoian till below it. The Minnesota Geological Survey uses the Cedar River as the eastern boundary for the Sheldon Creek glacial advance in Mower County, Minnesota (Meyer and Knaeble, 1998).

In Iowa, it is believed that Sheldon Creek deposits are also present between the Cedar and Little Cedar rivers. The topography is much less pronounced than areas to the east, and the presence of a thin loess mantle (less than 1 m, 2-3 ft) is common. Due to the presence of shallow rock along the Cedar River and extensive sand and gravel bodies in areas surrounding the Little Cedar River, obtaining core with good recovery and a complete stratigraphic section is rare. However, several core holes do have a loamy glacial deposit overlying a paleosol that appears to be Farmdale in age, indicating that the surface till is correlative with the Sheldon Creek Formation. Intermittent loess is present as described in IGS borings as well as mapped by the USDA Natural Resource Conservation Service (NRCS) soils map of Mitchell County (Voy and Highland, 1975). Presumably, when the Sheldon Creek glacial margin was farther north in Minnesota, outwash in the Cedar River provided a source for the eolian materials. A topographic high in eastern Mitchell County may have provided a barrier for loess transport, limiting loess deposition in the easternmost portion of the county. This high may have also been a topographic barrier for the advancing middle Wisconsin glacier.

East of the Little Cedar River, the Sheldon Creek till appears to be absent, except in isolated areas and near the major bend in the river near the Minnesota border. An area east of the Little Cedar River four to five miles east of Stacyville exhibits characteristics similar to the area between the Cedar and Little Cedar rivers, and therefore is thought to have Sheldon Creek materials at the surface. Two core holes have loamy sediments over a younger looking paleosol/peat unit and underlain by an older till unit, believed to be of Pre-Illinoian age, providing further support for the Sheldon Creek and Pre-Illinoian boundary position. Two cores drilled on the eastern margin of the county do not appear to have Sheldon Creek tills, but rather a colluvial lag deposit and soliflucted material over very dense till. This lag is believed to be related to the formation of the IS, and may be the equivalent of a stone line.

Extensive sand and gravel deposits within the upper till package in the central and southeastern part of Mitchell County may represent either outwash deposits associated with the advance of the middle Wisconsin glacier or represent lag deposits related to downcutting of the IS. These sand bodies and the presence of overlying weathered till make it difficult to absolutely differentiate stratigraphic units. The Cedar River likely carried significant outwash associated with the Sheldon Creek glacial advance at a time when the glacier front was farther north in Minnesota. The outwash thickness in the Cedar River is generally less than 10 m (33 ft). The sand and gravel thickness in the Little Cedar River is highly variable, ranging from 2 to 15 m (7-49 ft).

Following the deposition of Sheldon Creek materials, a period of intense cold occurred during the Wisconsin full glacial episode from 21,000 to 16,500 years ago (Bettis, 1989). This cold episode and ensuing upland erosion led to the development of the distinctive landform recognized as the IS (Prior, 1976). The depositional history of the IS was under great debate for an extended period of time. Early researchers believed the IS was a separate glaciation occurring sometime between the Illinois and Wisconsin episodes. Later work disproved this idea and determined that erosional processes controlled the landscape development (Ruhe et al., 1968). Hallberg and others (1978) revisited the "Iowan Erosion Surface" to further research the mechanisms behind the formation of the erosion surface, to reiterate Ruhe's classic work on stepped erosion surfaces, and to illustrate the need for continued study of this landform region. The IS boundary was further refined by Prior and Kohrt (2006) utilizing higher resolution topographic information and slope classification.

A periglacial environment prevailed during this period with intensive freeze-thaw action, solifluction, strong winds, and a host of other periglacial processes (Walters, 1996). As a result, surface soils were removed from the IS and the Sheldon Creek and Pre-Illinois till surfaces were significantly eroded. A regional colluvial lag deposit referred to as a "stone line" developed. Thick packages of stratified loamy and sandy sediments located low in the upland landscape and adjacent to streams are remnants of solifluction lobes associated with the formation of the IS. These materials can be found along the Little Cedar River and its tributaries, the Wapsipinicon River near McIntire, and portions of Otter, Goose, Rock, and Spring creeks in southwest Mitchell County. Another common feature of the IS landform region is isolated and uneroded topographic highs of loess mantled Pre-Illinoian till. These elongated or elliptical shaped ridges, termed paha, have a directional orientation from northwest to southeast and exist as erosional outliers of the once higher and older landscape. No paha are identified in Mitchell County, but some may be found to the south in Franklin and Butler counties. Ice-wedge casts also commonly developed in the colluvial sediments as remnants of ice-wedge polygons that formed in frozen sediments (permafrost) during this period of intense cold. Where bedrock is shallow, IS materials do not provide an effective barrier (confining unit) to protect local groundwater resources.

Younger sediments may include Peoria Formation eolian deposits and Hudson Episode alluvial sediments. Two loess units were deposited across eastern Iowa between 30,000 and 12,000 years ago (Bettis, 1989), the older Pisgah Formation and the younger Peoria Formation. The Pisgah is thin and includes loess and related slope sediments that have been altered by colluvial hillslope processes, pedogenic and periglacial 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 and incorporated into the underlying older Sangamon Geosol. Most likely, the Pisgah loess was deposited on the eastern Iowa landscape from 30,000 to 24,000 years ago (Bettis, 1989). The Pisgah Formation 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. Up to 3 m (10 ft) of Peoria Formation silt facies (loess) is present southeast of Osage. Between Osage and Mitchell, this unit is typically thinner (less than 2 m, 7 ft) and may lie directly on bedrock. Additional eolian materials are limited to a thin (1 m, 3 ft) discontinuous mantle of loess between the Cedar and Little Cedar Rivers as well as isolated eolian sand stringers on the uplands.

Sediment continued to accumulate in stream valleys throughout the Hudson Episode between 14,000 to 11,000 radiocarbon years before present (Bettis et al., 1996). These deposits are part of the Deforest Formation which is subdivided into the Camp Creek, Roberts Creek, Gunder, Corrington, Flack and Woden members. These materials consist of fine grained alluvium, colluvium and pond sediments in steam valleys, on hillslopes, and in closed and semi-closed depressions.

METHODS

Numerous existing sources of geologic information were utilized in the production of the Mitchell County surficial and bedrock geologic maps 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 900 public and private wells in GEOSAM, including 322 strip logs, were reviewed for lithology, stratigraphy and locational accuracy, and updated where needed. Quaternary mappers used NRCS digitized soils data to assist with delineating areas with loess cover, thin or no loess cover, shallow bedrock, extent of alluvium, and to attempt to differentiate till units. 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 field investigations of more than 100 outcrops (including quarry exposures) and logging of well cutting samples for 115 unstudied wells totaling 24,318 feet. Quaternary geologists worked with a contract driller and utilized the IGS Giddings probe to drill a mix of solid stem and continuous core holes. Fifty-two drill holes totaling 1,398 feet were completed throughout the duration of mapping in Mitchell County. Samples have been submitted to the Quaternary Materials Lab at the University of Iowa's Earth and Environmental Sciences Department for grain-size analysis. All results are expected by August, 2016. Three short geophysics lines for electrical resistivity were completed by IGS to confirm bedrock depth.

Project geologists combined information from the sources listed above to delineate surficial geologic mapping units at 1:100,000 scale for Mitchell County. IGS mappers used ArcGIS and on-screen digitizing techniques developed during previous STATEMAP projects. The final map entitled 'Surficial Geologic Map of Mitchell County, Iowa' will be available as a shapefile in the Iowa Department of Natural Resources NRGIS library, 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.

STRATIGRAPHIC FRAMEWORK FOR NORTH-CENTRAL IOWA

An important aspect of surficial geologic mapping on the IS is the development of map units that utilize previously established lithostratigraphic frameworks for the Hudson, Wisconsin and Pre-Illinoian deposits in Iowa (Johnson et al., 1997). A stratigraphic framework allows us to better understand the surficial materials of north-central Iowa. Surficial deposits in the map area are composed of six formations: DeForest, Noah Creek, Peoria, Sheldon Creek, 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, Flack, and Woden members. The Noah Creek Formation includes coarse sand and gravel associated with outwash from the Des Moines Lobe, as well as coarse to finer grained fluvial deposits associated with local stream and river valleys. Unnamed erosion surface sediments consist of reworked till and slopewash deposits associated with periglacial activity during the Wisconsin ice advance. Areas of Peoria Formation eolian materials are present southeast of Osage and intermittently mantle most other mapping units. Sheldon Creek Formation glacial deposits are undifferentiated and occur in northwest and north-central Iowa. The maximum extent of these deposits is still not fully understood, but generally coincides with the position of the Little Cedar River in Mitchell County. West of the Little Cedar River the predominant till unit is the Sheldon Creek Formation and to the east Pre-Illinoian till is exposed at the surface. Pre-Illinoian glacial deposits in Iowa consist of two formations: the younger Wolf Creek Formation and the Alburnett Formation. 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.

Four bedrock mapping units (Cretaceous Dakota/Windrow Formation; Devonian Shell Rock, Lithograph City, and Coralville formations) are exposed at the surface in Mitchell County, with the Lithograph City and Coralville formations comprising most of the outcrop in the map area. Bedrock outcrops occur along most rivers and creeks in the western half of the county and occasionally along the Little Cedar River. More than 100 rock outcrops, including quarries, are located in the map area and were investigated in the field. The Devonian rocks are dominated by carbonates varying between limestone and dolomite, accompanied with minor shale. The Cretaceous Dakota/Windrow Formation is characterized as a reddish shaly sandstone with siderite pellets.

DESCRIPTION OF LANDFORM SEDIMENT ASSEMBLAGE MAP UNITS

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 1:100,000 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.

Sixteen landform sediment assemblage units were identified in the map area utilizing aerial imagery, topographic expression, digitized soils, and existing and new subsurface geologic boring information. Fifty-two borings were collected representing 1,398 feet of new subsurface information obtained as part of this mapping project. The following is a description of each landform sediment assemblage listed in order of episode:

Hudson Episode

Qo - Depressions (DeForest Formation- Woden Member) - Generally 2.5 to 6 m (8-20 ft) of black to very dark gray, calcareous, muck, peat and silty clay loam colluvium and organic sediments in drained and undrained closed and semi-closed depressions. Overlies gray, calcareous, loam diamicton (Sheldon Creek, Wolf Creek, or Alburnett formations) or Noah Creek Formation sand and gravel. Associated with low relief features that occupy depressions and low sags on the landscape. Supports wetland vegetation and can be permanently covered by water. High water table.

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, 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, Sheldon Creek, Wolf Creek, or Alburnett formations; fractured Devonian carbonate bedrock or Cretaceous sandstone or mudstone. 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.

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, Devonian carbonate bedrock, or Cretaceous 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 the Little Cedar and Wapsipinicon river valleys and their tributaries. Overlies the Noah Creek Formation. Occupies the lowest position on the floodplain, i.e. modern channel belts. Seasonal high water table and frequent flooding potential. Along the Little Cedar River, the bedrock surface may be within 5 m (16 ft) of the surface south of Stacyville.

Qalit - Intermediate Terrace (DeForest Formation- Camp Creek, Roberts Creek, and Gunder members) - Variable thickness of less than 1 to 5 m (3-16 ft) of very dark gray to brown, noncalcareous, stratified silty clay loam to loam that overlies the Noah Creek Formation. Occupies low terrace position. Seasonal high water table and frequent flooding potential.

Hudson and Wisconsin Episodes

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 may overlie yellowish-brown, coarse-grained sand and gravel (Noah Creek Formation), or it may overlie yellowish to grayish brown, usually calcareous, stratified loam to silt loam to sandy loam diamicton (Sheldon Creek, Wolf Creek, or Alburnett formations). Usually restricted to a narrow belt along major river valley bottoms, adjacent uplands, or may occur as sand stringers or dunes overlying unnamed erosion surface loamy sediments.

Qnw2 - Sand and Gravel (Noah Creek Formation) - 2 to 15 m (7-49 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. Along many valleys a thin mantle of loess, reworked loess, or fine-grained alluvium (Qal) may be present. This unit includes silty colluvial deposits derived from the adjacent map units. In places this unit is mantled with 1 to 3 m (3-10 ft) of well sorted fine to medium sand derived from wind reworking of the alluvium. This unit encompasses deposits that accumulated in low-relief stream valleys during the Wisconsin and Hudson episodes. Seasonal high water table and some potential for flooding.

Wisconsin Episode

Qps1 - Loess and Intercalated Eolian Sand (Peoria Formation- silt 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. Overlies massive, fractured, loamy glacial till of the Sheldon Creek, Wolf Creek or Alburnett formations with or without the intervening clayey Farmdale/Sangamon Geosol. Near the towns of Osage and Mitchell, this unit may be significantly thinner (less than 2 m, 7 ft) and overlie fractured Devonian carbonate bedrock.

Qnw - Sand and Gravel (Noah Creek Formation) - Generally less than 10 m (33 ft), but there may be significantly thinner coarse-grained deposits in smaller stream valleys. Yellowish brown to gray, poorly to well sorted, massive to well stratified, coarse to fine feldspathic quartz sand, pebbly sand and gravel. Overlies middle Wisconsin-age Sheldon Creek Formation diamicton or Pre-Illinois Espisode diamicton of the Wolf Creek or Alburnett formations. This unit encompasses outwash deposits that accumulated in valley trains during the Wisconsin Episode.

Qnw3 - Sand and Gravel Shallow to Bedrock (Noah Creek Formation) - 1 to 3 m (3-10 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 2 m (7 ft) of silty alluvial material. In places mantled with fine to medium well sorted feldspathic quartz sand derived from wind reworking of the alluvium. Fractured Devonian carbonate bedrock or Cretaceous sandstone and mudstone is less than 5 m (16 ft) below the land surface. The unit encompasses deposits that accumulated in river and stream valleys during the late Wisconsin as well as exhumed middle Wisconsin Sheldon Creek Formation materials and/or Pre-Illinois Episode deposits of the Wolf Creek and Alburnett formations.

Qsc2 - Loamy Sediments Shallow to Glacial Till (Unnamed erosion surface sediment) - 1 to 6 m (3-20 ft) of yellowish brown to gray, massive to weakly stratified, well to poorly sorted loamy, sandy and silty erosion surface sediment. Map unit includes some areas mantled with less than 1 m (3 ft) of Peoria Formation (silt or sand facies); this is especially common between the Cedar and Little Cedar rivers. Formed in and often overlies massive, fractured, slightly firm glacial till of the Sheldon Creek Formation. This unit may be absent in isolated areas at lower elevation west of the Little Cedar River, is absent in the most eastern portion of Mitchell County, and may be intermittent east of the Little Cedar River.

Qsc3 - Loamy and Sandy Sediment Shallow to Rock (Unnamed erosion surface sediment) - Generally 1 to 6 m (3-20 ft) of yellowish brown to gray, massive to weakly stratified, well to poorly sorted loamy, sandy and silty erosion surface sediment. Map unit includes some areas mantled with less than 3 m (10 ft) of Peoria Formation sand facies (eolian sand). Formed in Sheldon Creek Formation materials and overlies fractured Devonian carbonate bedrock.

Qsc - Glacial Till (Sheldon Creek Formation- Undifferentiated) - Generally 3 to 15 m (10-49 ft) of yellowish brown to gray, calcareous, fractured to massive clay loam; at depth this unit can be variably textured and contain significant sand and gravel bodies with a thickness generally ranging from 2 to 8 m (7-26 ft). The upper 3 to 6 m (10-20 ft) may be periglacially altered. This unit overlies Pre-Illinois diamicton, Devonian carbonate bedrock or Cretaceous sandstone. This unit may be absent in isolated areas at lower elevation west of the Little Cedar River, is absent in the most eastern portion of Mitchell County, and may be intermittent east of the Little Cedar River.

Qwa2 - Loamy and Sandy Sediment Shallow to Glacial Till (Unnamed erosion surface sediment) - Generally 1 to 6 m (3-20 ft) of yellowish brown to gray, massive to weakly stratified, well to poorly sorted loamy, sandy and silty erosion surface sediment. Map unit includes some areas mantled with less than two meters 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 12 m (10-39 ft), but can be as thick as 100 m (330 ft) within the prominent bedrock valley in the eastern part of the mapping area. Map unit consists of very dense, massive, fractured, loamy glacial till of the Wolf Creek or Alburnett formations. Significant sand and gravel bodies up to 14 m (45 ft) in thickness are present within this mapping unit and often occur in the base of the bedrock channel in the eastern portion of Mitchell County. This mapping unit can be buried by glacial sediments (Sheldon Creek Formation), unnamed erosion surface sediments, loess or alluvium.

Other Mapping Units

Qbr - Loamy Sediments Shallow to Dolomite, Limestone, Shale and Sandstone (DeForest, Noah Creek, Sheldon Creek, 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 alluvial sediments that overlie the Middle to Upper Devonian or "Mid" Cretaceous bedrock surface. A detailed description of the bedrock units may be found on the bedrock map of Mitchell County.

ACKNOWLEDGMENTS

Special thanks to the landowners who allowed access to their properties for drilling: Don Ahrens, Todd Bates, Marcella Brandt, Larry Bless, Betty Clark, Charles Feldt, Larry Feldt, Greg Fox, Curt Halvorson, Tony Helfter, Deb Igou, Robert and Darlene Jacot, Bill Johanns, Clem Johanns, Randy Kephart, Tom Knudsen, Jerald Kruse, Cleason Martin, Eugene Merten, Joe Merten, John Miller, Levi Miller, Dorothy Niess, Robert Niess, Isaac Nolt, Dana Norby, Dean Norby, Lisa Peterson, Richard Reding, Dar Ruehlow, Rick Sletter, Joe Smith, Paul Smith, Allen Suchy, Dan Schwark, John Schwark, Dave Tollefson (Mayor, City of St. Ansgar), Lynn Walk, Tyrel Williamson, and Dean Wright. The Mitchell County Conservation Board and Director Adam Shirley allowed access to numerous parks and wildlife areas. Drilling was provided under contract with Cahoy Well and Pump Service; special thanks to driller Kaes DeGroot.

Zachary Demanett of the Iowa Geological Survey (IGS) and Austin Pothoff, University of Iowa (UI), prepared well cutting samples for stratigraphic logging. Zachary Demanett also assisted with field work during drilling. New subsurface geologic data was generated by Tanner Hartsock, a UI Department of Earth and Environmental Sciences student, by producing descriptive logs of water well drilling samples. Thanks also to Rick Langel (IGS) for managing the Iowa geologic sampling database (GEOSAM). Jason Vogelgesang (IGS) provided valuable depth-to-bedrock information via geophysical surveys in select locations. Also, special thanks to Kathy Woida, Natural Resources Conservation Service, Deborah Quade, Iowa Department of Natural Resources (IDNR), and Art Bettis, UI Department of Earth and Environmental Sciences, for assistance with core description and for numerous valuable discussions regarding the geology of north-central Iowa. Casey Kohrt and Chris Kahle (IDNR) provided GIS technical help. Administrative support was provided by Megan Delaney, Teresa Gaffey, and Sara Conrad.

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