GEOLOGIC MAPPING OF THE UPPER IOWA RIVER WATERSHED
Phase 2: Freeport and Bluffton 7.5' Quadrangles

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INTRODUCTION

Two 1:24,000 quadrangle scale surficial geologic maps of the Freeport and Bluffton 7.5' topographic quadrangles were produced as the second phase of a multi-year project to map the geology of the Upper Iowa River (UIR) Watershed. The Freeport Quadrangle is bounded by 43° 15' to 43° 22.5' N latitude and 91° 45' to 91° 37.5' W longitude. The Bluffton Quadrangle is bounded by 43° 22.5' to 43° 30' N latitude and 91° 52.5' to 92° 00' W longitude. The mapping area is located in the Paleozoic Plateau region of northeast Iowa (Prior, 1991), an area characterized by shallow bedrock and karst topography and hydrology. The water quality impacts of non-point source contamination of shallow groundwaters in the karsted Ordovician carbonates of the Galena Group in northeast Iowa have long been the subject of continuing hydrogeologic investigations by the Iowa Geological Survey.

One of the goals of the multi-year mapping project in the UIR Watershed is to carry out a threefold subdivision of one of the earlier bedrock geologic mapping units (Ogp—the Galena Group and Platteville Formation) previously mapped by Witzke et al. (1998). Local interests have specifically requested mapping of the outcrop distribution of the Decorah Shale for the purpose of identifying sensitive areas where overlying fens may be naturally remediating contaminated near-surface groundwaters discharging from shallow karst aquifers. The role of the Decorah Shale in the bioremediation of discharging shallow groundwaters has received considerable attention in a somewhat analogous geomorphic situation around the City of Rochester in the Zumbro River Basin of southeastern Minnesota (Barret, Modjeski, and Lee, 2001; Lindgren, 2001). There, shallow groundwaters flowing through fens on the Decorah-Platteville-Glenwood outcrop belt are locally recharging the Cambro-Ordovician aquifer and the City of Rochester municipal well field. The proposed new mapping subdivision of the Galena Group in the UIR Watershed will help to determine the location of fens overlying the outcrop belt of the Decorah Shale in Iowa.

Previous surficial geologic mapping of Quaternary units in the map area consists of the Des Moines 4° x 6° Quadrangle at a scale of 1:1,000,000 (Hallberg et al., 1991). Previous bedrock mapping was completed at a 1:250,000 scale by Witzke et al. (1998). The prior STATEMAP project, Geologic mapping of the Upper Iowa River Watershed: Phase 1: Decorah 7.5" Quadrangle (Tassier-Surine et al., 2005), is adjacent to the current map area.

BRIEF GEOLOGIC HISTORY

Paleozoic History

Ordovician sedimentary strata exposed in the Freeport and Bluffton 7.5' Quadrangle areas are the deposits of shallow tropical seas that flooded the interior of the North America continent from about 470 to 445 million years ago. General summaries of the depositional history of these units can be found in Witzke and Bunker (1996) and Anderson (1998). Topical scientific investigations of the Decorah Formation, a major target for this mapping project, can be found in Ludvigson et al. (1996, 2004, 2005).

Quaternary History

Early researchers believed there were only two episodes of Pre-Illinoian glaciation in Iowa: Kansan and Nebraskan. Later regional studies determined that at least seven episodes of Pre-Illinoian glaciation occurred in this region from approximately 2.2 million to 500,000 years ago (Boellstorff, 1978a; Boellstorff 1978b; Hallberg, 1980a; Hallberg, 1986). Hallberg (1980a, 1980b, 1986) undertook a regional scale project that involved detailed outcrop and subsurface investigations including extensive laboratory work and synthesis of previous studies. These studies led to the abandonment of the classic glacial and interglacial terminology: Kansan, Aftonian and Nebraskan. Hallberg's study marked a shift from use of time-stratigraphic terms to lithostratigaphic classification. The result of Hallberg's study was 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.

Regionally extensive upland units were not deposited in the map area between 500,000 to 300,000 years ago. During this period several episodes of landscape development resulted in the formation of an integrated drainage network, slope evolution and soil development on stable landsurfaces (Bettis, 1989). Illinoian-age glacial ice did not advance as far west as the present map area (Hallberg, 1980b).

In eastern Iowa, the highly eroded and dissected pre-Illinoian upland and older terraces are mantled by Wisconsin loesses of variable thickness (Ruhe, 1969; Prior, 1991). These sediments are the youngest regionally extensive Quaternary deposits and were deposited between 30,000 and 12,000 years ago. Loess is thickest in the region near the Iowan Erosion Surface (IES) boundary and near local sources. Two loess units were deposited across eastern Iowa, the older Pisgah Formation and the younger Peoria Loess. 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 accmulated on stable landsurfaces in eastern Iowa from 25,000 to 21,000 years ago and was followed by a period of intense cold during the Wisconsin full glacial episode from 21,000 to 16,500 years ago (Bettis, 1989). Outside the Iowa Erosion Surface Peoria Loess continued to accumulate until 13,000 B.P; and in some parts of the IES a thin increment of loess accumulated as the climate ameliorated approximately 14,000 to 12,000 years ago. This period of intense cold and ensuing upland erosion led to the development of the distinctive landform recognized as the Iowan Erosion Surface (Prior, 1991). During this period surface soils were removed from the Iowan Erosion surface and the Pre-Illinoian till surface was significantly eroded; resulting in the development of a lag deposit referred to as a "stone line". The depositional history of the Iowan Surface was under great debate for an extended period of time. Early researchers believed the Iowan Surface was a separate glaciation occurring sometime between the Illinois and the Wisconsin episodes. Later work disproved this idea and determined that erosional processes controlled the landscape development (Ruhe et al., 1968). Hallberg et al. (1978) revisited the "Iowan Erosion Surface" to further research studies into the mechanisms behind the formation of the erosion surface and to reiterate Ruhe's classic work and to illustrate the need for continued research in the area.

DESCRIPTION OF LANDFORM SEDIMENT ASSEMBLAGE MAPPING OF QUATERNARY UNITS

Recent studies and Quaternary 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 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 LSA mapping concepts were extremely useful in overcoming the difficulties of mapping in large valleys and noted LSA's provided a unique opportunity to associate landforms with their underlying sediment packages.

Ten landform sediment assemblage units were identified in the map area utilizing orthophotos, topographic expression, digitized soil maps and existing and new subsurface boring information. Six cores were collected within the map area to investigate the thickness and variability of the loess and the extent of the till distribution. The cores represent 139 feet of new subsurface information. The ten LSA units are: Hudson Episode: Undifferentiated Alluvium, Upper Iowa River Valley- Low Terrace/Modern Channel Belt, Intermediate Terrace, and High Terrace; Wisconsin Episode: High Terrace-undifferentiated, Sand Sheet and Sand Dunes, Loess, Loess over Bedrock, Loamy and Sandy Sediment Shallow to Glacial Till; Pleistocene Undifferendiated: Rock Core Meanders/Structural Benches. The following is a description of each landform sediment assemblage listed in order of episode.

HUDSON EPISODE

Landform Sediment Assemblages

Alluvium (De Forest Formation-Undifferentiated) One to four meters (3 – 13 ft) of massive to weakly stratified, grayish brown to brown loam, silt loam, clay loam, or loamy sand overlying less than three meters (10 ft) of poorly to moderately well sorted, massive to moderately well stratified, coarse to fine feldspathic quartz sand, pebbly sand, and gravel and more than three meters (10 ft) of pre-Wisconsin or late Wisconsin Noah Creek Formation sand and gravel. Also includes colluvium derived from adjacent map units in stream valleys, on hillslopes, and in closed depressions. Seasonal high water table occurs in this map unit.

Upper Iowa River Valley- Low Terrace/Modern Channel Belt (DeForest Formation-Camp Creek Member and Roberts Creek Member) Variable thickness of less than 1 m 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 Upper Iowa River valley. Ox-bow lakes and meander scars are common features associated with this terrace level. Post-settlement alluvium thickness varies from 0.5 m (1.5 ft) in higher areas to 2 m (6.5 ft) along the river course and in lower lying areas. Seasonal high water table and frequent flooding potential.

Upper Iowa River Valley - Intermediate Terrace (DeForest Formation-Camp Creek Member, Roberts Member and Gunder Member) Variable thickness of less than 1 m to 5 m (3 – 16 ft) of very dark gray to brown, noncalcareous, stratified silty clay loam to loam that overlies calcareous, medium- to coarse-grained sand and gravel of Wisconsinan (Noah Creek Formation) and/or pre-Wisconsinan age. Occupies low terrace position. Seasonal high water table and frequent flooding potential

Upper Iowa River Valley - High Terrace (DeForest Formation-Gunder and Corrington Members) Thickness of less than 0.5 m to 1.5 m (1.5 – 5 ft) of very dark gray to brown, noncalcareous, silty clay loam, loam alluvium or colluvium. Overlies 3 m to 18 m (10 – 60 ft) of calcareous, medium- to coarse-grained sand and gravel of Wisconsinan (Noah Creek Formation) and/or pre-Wisconsinan age. Occupies terrace and valley margin position 3 to 4 m (10 – 13 ft) above the modern floodplain. Eolian materials composed of silt and sand facies may be present on the terrace surface. Seasonal high water table and rare flooding potential.

WISCONSIN EPISODE

Landform Sediment Assemblages

High Terrace- either Late Phase or Early Phase (Peoria Formation – silt and/or sand facies) Two to seven meters (6.5-23 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, pebbly sand, loam, or silt loam alluvium (Late Phase) or may overlie a Farmdale Geosol developed in Roxanna 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).

Sand Sheet and Sand Dunes (Peoria Formation - sand facies) Variable thickness of 2 m to 8 m (6 – 27 ft) of yellowish brown, massive , calcareous loamy sand to fine sand deposited by eolian processes. It may overlie Upper Iowa River – High Terrace or bedrock along lower elevation portions of Upper Iowa River valley walls. Seasonal high water table and rare flooding potential.

Loess (Peoria Formation—silt facies) Generally 2 m to 8 m (6 – 27 ft) of yellowish to grayish brown, massive, jointed noncalcareous grading downward to calcareous silt loam to silty clay loam. Overlies massive, fractured, loamy glacial till of the Pre-Illinaoian Wolf Creek or Alburnett formations with or without intervening clayey Farmdale/Sangamon Geosol. In most areas the Pre-Illinoian till is 1 m to 5 m (3 – 16 ft) thick, but may be up to 10 m (33 ft) thick locally. This mapping unit encompasses upland divides, ridge-tops and convex-side slopes. Well to somewhat poorly drained landscape.

Loess over bedrock (Peoria Formation—silt facies) Generally 2 to 8 m (6 – 27 ft) of yellowish to grayish brown, massive, jointed noncalcareous grading downward to calcareous silt loam to silty clay loam. Overlies Ordovician bedrock units or colluvium. This mapping unit encompasses upland divides, ridge-tops and convex side-slopes. Well to somewhat poorly drained landscape.

Loamy and Sandy Sediment Shallow to Glacial Till (sediment associated with erosion surface) One to three meters (3 – 10 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 (6.5 ft) of Peoria Formation- silt facies (loess). Overlies massive, fractured, firm glacial till of the Wolf Creek and/or Alburnett formations. Seasonally high water table may occur in this map unit.

PLEISTOCENE UNDIFFERENTIATED

Rock Core Meanders/Structural Benches – Includes rock core meanders associated with Pre-Wisconsin river development and terrace deposits overlying bedrock benches. Some areas occupy positions as much as 10m (33 ft) above the modern floodplain. Consists of undifferentiated alluvial and colluvial fill of unknown age and thickness. May be mantled by 1 to 3 m (3-10 ft) of Peoria Formation-silt facies (loess).

DESCRIPTION OF MAPPING APPROACHES FOR PALEOZOIC BEDROCK UNITS

The Iowa Geological Survey (IGS) maintains the GEOSAM comprehensive digital database of geologic site records for the State of Iowa (http://gsbdata.igsb.uiowa.edu/geosam/), and most of these are water well records from the voluntary submission of samples and driller's logs from commercial water well drillers. The GEOSAM database contains records of 192 wells in the area of the Freeport 7.5' Quadrangle and 68 wells in the area of the Bluffton 7.5' Quadrangle. In order to take full advantage of this subsurface data, selected unstudied well sample sets in the quadrangle areas were logged for interpretation of subsurface geology. During the course of this mapping project, 19 water wells and drill holes with a cumulative length of 5,710 feet were logged by University of Iowa students and IGS staff, and their stratigraphic correlations were interpreted by Iowa Geological Survey staff geologists.

Active field mapping studies by the staff of the Iowa Geological Survey were aided by a subcontract with Luther College in Decorah, Iowa. These works included detailed location and elevation measurements of water well sites using GPS technology, and a systematic inventory of bedrock exposures in the Freeport and Bluffton 7.5' quadrangles, with additional measurements of bedrock unit contact elevations using a cross-referencing combination of GPS and barometric altimetry. These observations totaled to 141 site records on the Freeport 7.5' Quadrangle, and 111 on the Bluffton 7.5' Quadrangle.

Bedrock exposure polygons were modified from polygons extracted from GIS coverages of NRCS Soil Survey Map of Winneshiek County (Kittleson and Didericksen, 1968) that were filtered by parent materials, and were visually rectified to the 1:24,000-scale land surface topography of the topographic quadrangles (20 foot contour intervals). Additional areas of bedrock exposure were identified during active field mapping. The bedrock exposure polygons were subdivided into constituent bedrock mapping units using a combination of subsurface structure contour mapping of bedrock unit contacts and the field observations compiled during the course of the mapping project.

PALEOZOIC UNITS

ORDOVICIAN SYSTEM

Shale, Limestone, and Dolostone (Maquoketa Formation.) A nonresistant slope-forming unit of up to 20 m (65 ft) of interbedded argillaceous limestone, dolostone and grey and brown shale. Fragmentary trilobite fossils are common in the basal Elgin Limestone Member. Forms a confining unit that bounds a karst system in underlying Wise Lake and Dunleith formations, and may host sinkholes in its lower portion.

Limestone and minor Shale (Wise Lake and overlying Dubuque formation) A prominent ledge and cliff-forming unit of up to 31 m (102 ft) of limestone with notable thin interbedded shale in the upper 6 m. This map unit is the upper of two successive major cavern and karst-forming bedrock units in the area. The Wise Lake Formation consists of 21 m (67 ft) of massive limestone portions of which exhibit a distinctive bioturbated fabric. The Dubuque Formation consists of 10 m (34 ft) of crinoidal limestones and thin interbedded shale. Sinkholes are common to abundant within this map unit. Often mantled by 0 m to 2 m (0 –6 ft) of loess-derived and weathered bedrock-derived colluvium.

Limestone (Dunleith Formation) A prominent ledge and cliff-forming unit of up to 42 m (137 ft) of limestone with minor thin interbedded shale. This is the lower of two successive major cavern and karst-forming bedrock units in the area. The formation consists of fossiliferous limestone and argillaceous limestone with common chert nodules. Major springs occur near the base and sinkholes and karst features are common. Frequently mantled by 0 m to 2 m (0 – 6 ft)of loess-derived and weathered bedrock-derived colluvium.

Shale, Limestone, and Dolomite (Decorah, and underlying Platteville, and Glenwood formations) A nonresistant slope-forming unit of green-grey shales, dense limestones, argillaceous limestones, and dolostone with average thickness of 26 m to 27 m (85 –90 ft). Large detached slump-blocks of overlying Dunleith Formation limestone often rest on the upper surface of this unit. Forms a regional confining unit that serves as the basal boundary of the karst system in the overlying Dunleith, Wise Lake and Dubuque formations. The upper division, the Decorah Formation, consists of 12 m to 14 m (39 – 46 ft) of green-grey fossiliferous shales with minor interbedded limestones. The middle division, the Platteville Formation, consists of 7.5 m (25 ft) of limestone, argillaceous limestone, and dolostone. The lower division, the Glenwood Formation, consists of 2 m to 3 m (7 – 9 ft) of green-grey shale with minor siltstone to fine sandstone. This map unit, especially the Decorah and Glenwood subdivisions , is rarely exposed and almost everywhere is mantled by 0 m to 2 m (0 – 6 ft) of loess-derived and weathered bedrock-derived colluvium.

Sandstone (St. Peter Formation) A moderately resistant unit forming distinctive elongate ridges in upland landscape positions, especially where capped by Platteville Formation limestone. It generally ranges from 15 m to 45 m (50 – 150 ft) in thickness, but may attain a thickness of several hundred feet where it overlies paleotopographic low areas on the high-relief surface of unconformity with underlying units. A white to tan, and occasionally red to orange stained, quartz-rich sandstone ranges from hard cemented at top to friable. Grey shale and conglomerate occurs locally in the lower part, particularly in thicker sections. Forms a local bedrock aquifer where confined by overlying bedrock. Commonly mantled by 0 m to 2 m (0 – 6 ft) of loess-derived and weathered bedrock-derived colluvium.

Dolomite and Sandstone (Shakopee Formation) A variably resistant slope to ledge-forming unit ranging in thickness from 0 m – 30 m (0 – 100 ft). Composed of interbedded dolomite, sandy dolomite and sandstone with a prominent 8 m – 10 m sandstone (New Richmond Sandstone Member) occupying its lower part. Contains some chert nodules, and has distinctive oolitic and stromatolitic facies. May locally be thin or absent where truncated beneath the unconformity at the base of the overlying St. Peter Formation. Small springs locally occur near its base and it may host karst caverns. Mostly mantled by 0 m to 2 m (0 – 6 ft) of loess-derived and weathered bedrock-derived colluvium.

Dolomite (Oneota Formation) A highly resistant ledge and cliff-forming unit of up to 60 m of dolomite that has chert nodules, small calcite crystal filled cavities, and stromatolite facies. May host limited karstic cavities, caverns, and springs. Forms a bedrock aquifer throughout much of the map area. May be mantled by 0 m to 2 m (0 – 6 ft) of loess-derived and weathered bedrock-derived colluvium

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