GEOLOGIC MAPPING OF THE UPPER IOWA RIVER WATERSHED
Phase 1: Decorah 7.5' Quadrangle

Iowa Geological Survey
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INTRODUCTION

A 1:24,000 quadrangle scale surficial geologic map of the Decorah 7.5' topographic quadrangle was produced to as the first phase of a multi-year project to map the geology of the Upper Iowa River (UIR) Watershed. The Decorah Quadrangle is bounded by 43° 15' to 43° 22.5' N latitude and 91° 45' to 91° 52.5' 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.

The issue of flood zoning, and its potential impact on commercial developments in the City of Decorah is also a topic of major local interest. New and proposed commercial developments along the Iowa Highway 9 corridor along the south edge of Decorah have intensified local concerns about the formulation of a floodplain zoning plan by city government. The delineation of alluvial mapping units in the Upper Iowa River Valley on this map can help to inform the process of future land use planning on the floodplain by the City of Decorah.

Previous surficial geologic mapping of Quaternary units in the map area consists of the Des Moines 4^{o} x 6^{o} 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).

BRIEF GEOLOGIC HISTORY

Paleozoic History

Ordovician sedimentary strata exposed in the Decorah 7.5' Quadrangle area 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).

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. This study 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 at 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. Three cores were collected within the Upper Iowa River valley to investigate the thickness and variability of the alluvium. The cores represent 136 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, 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

Peat and Muck (DeForest Formation-undifferentiated) Generally 2.5 to 6 meters of black to very dark gray, calcareous, muck, peat and silty clay loam colluvium and organic sediments in sideslope positions and thalwegs of higher order streams in upland positions. Overlies undifferentiated DeForest Formation, Peoria Formation loess, Pre-Illinoian tills, and the Maquoketa Formation in landscape positions where shallow groundwater discharges in seeps and springs. Supports wetland vegetation and can be permanently covered by water. High water table.

Alluvium (DeForest Formation-undifferentiated) One to four meters of massive to weakly stratified, grayish brown to brown loam, silt loam, clay loam, or loamy sand overlying less than three meters 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 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 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. Overlies Noah Creek Formation. Ox-bow lakes and meander scars are common features associated with this terrace level. Post settlement alluvium thickness varies from 0.5 m in higher areas to 2 m 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 Creek Member, and Gunder Member.). Variable thickness of less than 1 m to 5 m of very dark gray to

brown, noncalcareous, stratified silty clay loam to loam that overlies Noah Creek Formation. Occupies low terrace position. Seasonal high water table and frequent flooding potential

Upper Iowa River Valley - High Terrace (DeForest Formation-Gunder and Corrington members.) Variable thickness of less than 1 m to 7 m of very dark gray to brown, noncalcareous, silty clay loam, loam alluvium or colluvium. Overlies Noah Creek Formation. Occupies terrace and valley margin position 2-3 meters above the modern floodplain. Eolian silt and sand 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 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) 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).

Loess (Peoria Formation—silt facies) Generally 2 to 8 m of yellowish to grayish brown, massive, jointed noncalcareous grading downward to calcareous silt loam to silty clay loam. Overlies massive, fractured, loamy undifferentiated Pre-Illinoian glacial till with or without intervening clayey Farmdale/Sangamon Geosol. In most areas the Pre-Illinoian till is 1 to 5m thick, but may be up to 12m thick locally. This mapping unit encompasses upland divides, ridgetops and convex sideslopes. Well to somewhat poorly drained landscape. Precise boundary between Qps and Qpsr is uncertain.

Loess Over Bedrock (Peoria Formation—silt facies) Generally 2 to 8 m of yellowish to grayish brown, massive, jointed noncalcareous grading downward to calcareous silt loam to silty clay loam. Overlies Ordovician bedrock units or bedrock derived colluvium. This mapping unit encompasses upland divides, ridgetops and convex sideslopes. Well to somewhat poorly drained landscape.

Loamy and Sandy Sediment Shallow to Glacial Till (sediment associated with erosion surface) One to three meters 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 Silt (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 15m above the modern floodplain. Consists of undifferentiated alluvial and colluvial fill of unknown age and thickness. May be mantled by 1 to 3 m of Peoria Silt (loess).

DESCRIPTION OF MAPPING APPROACHES

FOR PALEOZOIC BEDROCK UNITS

The Iowa Geological Survey 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 195 wells in the area of the Decorah 7.5' Quadrangle. In order to take full advantage of this subsurface data, previously unstudied well sample sets in the quadrangle area were logged for interpretation of subsurface geology. During the course of this mapping project, 28 water wells with a cumulative length of 7,304 feet were logged by University of Iowa students, 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 Decorah 7.5' Quadrangle and immediately adjoining quadrangles, with additional measurements of bedrock unit contact elevations using a cross-referencing combination of GPS and barometric altimetry. These observations totaled to 166 site records.

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 Decorah 7.5' topographic quadrangle (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 45 m of green-gray to brown-gray shales with interbedded argillaceous limestone and dolostone. Fragmentary trilobite fossils are common in the basal Elgin Limestone Member. Forms a regional confining unit that bounds a karst system in underlying bedrock units. Forms unstable slopes with discharging groundwater seeps and springs.

Limestone (Dubuque, Wise Lake, and Dunleith formations.) A prominent cliff-forming unit of up to 70-75 m of limestone with minor thin interbedded shales. This is the major karst-forming bedrock unit in the area. The Dubuque Formation consists of 10 m of interbedded limestones and thin shales. The Wise Lake Formation consists of 21 m of massive limestone. The Dunleith Formation consists of 42 m of limestone and argillaceous limestone with chert nodules.

Shale, Limestone, and Dolostone (Decorah, Platteville, and Glenwood formations.) A nonresistant slope-forming unit of up to 20-25 m of green-gray shales, argillaceous limestones and dolostones, and minor green-gray sandstone. Forms a regional confining unit that bounds a karst system in overlying bedrock units. The Decorah Formation consists of 11 m of green-gray shales with minor interbedded limestones. The Platteville Formation consists of 7.6 m of limestone, argillaceous limestone, and dolostone. The Glenwood Formation consists of 3 m of green-gray shale and minor sandstone. Forms

unstable slopes with discharging seeps and springs; slopes commonly are colluviated, locally with mechanical karst.

Dominantly Sandstone with variable Shale (St. Peter Formation.) A resistant cliff-forming unit ranging from 15 up to 190 m in thickness, overlying a high-relief surface of unconformity with underlying units. Reddish to white sandstones range from hard cemented at top to very friable. Forms a local bedrock aquifer where confined by overlying bedrock.

REFERENCES

Anderson, W.I., 1998, Chapter 4, Ordovician: Warm, Shallow Seas: *in* **Iowa's Geological Past: Three Billion Years of Change**, University of Iowa Press, p. 65-105.

Barrett, D., Modjeski, T., and Lee, T., 2001, The use of multispectral images for locating wetland and high water table conditions, City of Rochester, Minnesota: Minnesota Ground Water Association Newsletter, v. 20, no. 1, p. 1-5.

Bettis, E.A., III, 1989, Late Quaternary history of the Iowa River Valley in the Coralville Lake area *in* Plocher, O.W., Geologic Reconnaissance of the Coralville Lake area: Geological Society of Iowa Guidebook 51, p.93-100.

Bettis, E.A. III, Hajic, E.R., and Quade, D.J., 1999, Geologic mapping of large valleys in glaciated regions: The use of landform and landscape sediment assemblages for multi-use maps: Geologic Society of America Abstracts with Programs, 33rd Annual Meeting North-Central Section April 1999, Champaign, Illinois, vol. 31 no. 5, abstract no. 04164.

Boellstorff, J., 1978a, North American Pleistocene Stages reconsidered in light of probable Pliocene-Pleistocene continental glaciation: Science, v. 202 p.305-307.

Boellstorff, J., 1978b, Chronology of some late Cenozoic deposits from the central United States and the ice ages: Transactions of the Nebraska Academy of Science, v. 6, p. 35-49.

Eyles, N. and Menzies, J., 1983, The subglacial landsystem, in *Eyles*, N. ed., Glacial geology-An introduction for engineers and earth scientists: Oxford, Pergamon, p. 19-70.

Hallberg, G.R., 1980a, Pleistocene stratigraphy in east-central Iowa: Iowa Geological Survey Technical Information Series 10, 168p.

Hallberg, G.R., 1980b, Illinoian and Pre-Illinoian stratigraphy of southeast Iowa and adjacent Illinois: Iowa Geological Survey Technical Information Series 11, 206p.

Hallberg, G.R., 1986, Pre-Wisconsin glacial stratigraphy of the central plains region in Iowa, Nebraska, Kansas, and Missouri: *in* Richmond, G.M. and Fullerton, D.S., eds., Quaternary Glaciations in the United States of America, Report of the International Correlation Programme-Project 24: in Sibrava, V., Bowen, D.Q., and Richmond, G.M., eds., Quaternary Science Reviews, Quaternary Glaciations in the Northern Hemisphere, v. 5, p. 11-15.

Hallberg, G.R., Fenton, T.C., Miller, G.A., and Lutenegger, A.J., 1978, The Iowan erosion surface: an old story, an important lesson, and some new wrinkles: *in* Anderson, R., ed., 42nd Annual Tri-State Geological Field Conference Guidebook, p. 2-1 to 2-94.

Hallberg, G.R., Lineback, J.A., Mickelson, D.M., Knox, J.C., Goebel, J.E., Hobbs, H.C., Whitfield, J.W., Ward, R.A., Boellstorf, J.D., and Swinehart, J.B., 1991, Quaternary geologic map of the Des Moines 4° x 6° quadrangle, United States: U.S. Geological Survey, Miscellaneous Investigations Series, Map I-1420, 1:100,000 scale map sheet.

Kittleson, K.K., and Dideriksen, R.I., 1968, **Soil Survey of Winneshiek County, Iowa**: U.S. Department of Agriculture, Soil Conservation Service, 225 p.

Lindgren, R.J., 2001, Ground-water recharge and flowpaths near the edge of the Decorah-Platteville-Glenwood confining unit, Rochester, Minnesota: U.S. Geological Survey, Water-Resources Investigations Report 00-4215, 41 p.

Ludvigson, G.A., Jacobson, S.R., Witzke, B.J., and González, L.A., 1996, Carbonate component chemostratigraphy and depositional history of the Ordovician Decorah Formation, Upper Mississippi Valley: *in* Geological Society of America, Special Paper 306, p. 67-86.

Ludvigson, G.A., Witzke, B.J., González, L.A., Carpenter, S.J., Schneider, C.L., and Hasiuk, F., 2004, Late Ordovician (Turinian-Chatfieldian) carbon isotope excursions and their stratigraphic and paleoceanographic significance: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 210, p. 187-214.

Prior, J.C., 1991, **Landforms of Iowa**: University of Iowa Press, 154 p.

Ruhe, R.V., 1969, Quaternary Landscapes in Iowa: Ames, Iowa State University Press, 255p.

Ruhe, R.V., Dietz, W.P., Fenton, T.E., and Hall, G.F., 1968, Iowan drift problem, northeastern Iowa: Iowa Geological Survey Report of Investigations 7, 10p.

Sugden, D.E., and John, B.S., 1976, Glaciers and Landscape: New York, John Wiley & Sons, 376 p.

Witzke, B.J., and Bunker, B.J., 1996, Relative sea-level changes during Middle Ordovician through Mississippian deposition in the Iowa area, North American craton: *in* Geological Society of America, Special Paper 306, p. 307-330.

Witzke, B.J., Ludvigson, G.A., McKay, R.M., Anderson, R.R., Bunker, B.J., Giglierano, J.D., Pope, J.P., Goettemoeller, A.E., and Slaughter, M.K., 1998, Bedrock Geology of Northeast Iowa (1:100,000 scale): Iowa Department of Natural Resources, Geological Survey Bureau, Open File Map; contract completion report to U.S. Geological Survey for Assistance Award No. 1434-HQ-97-AG-01719, August 1998 (a PDF can be downloaded from http://gsbdata.igsb.uiowa.edu/gsbpubs/).