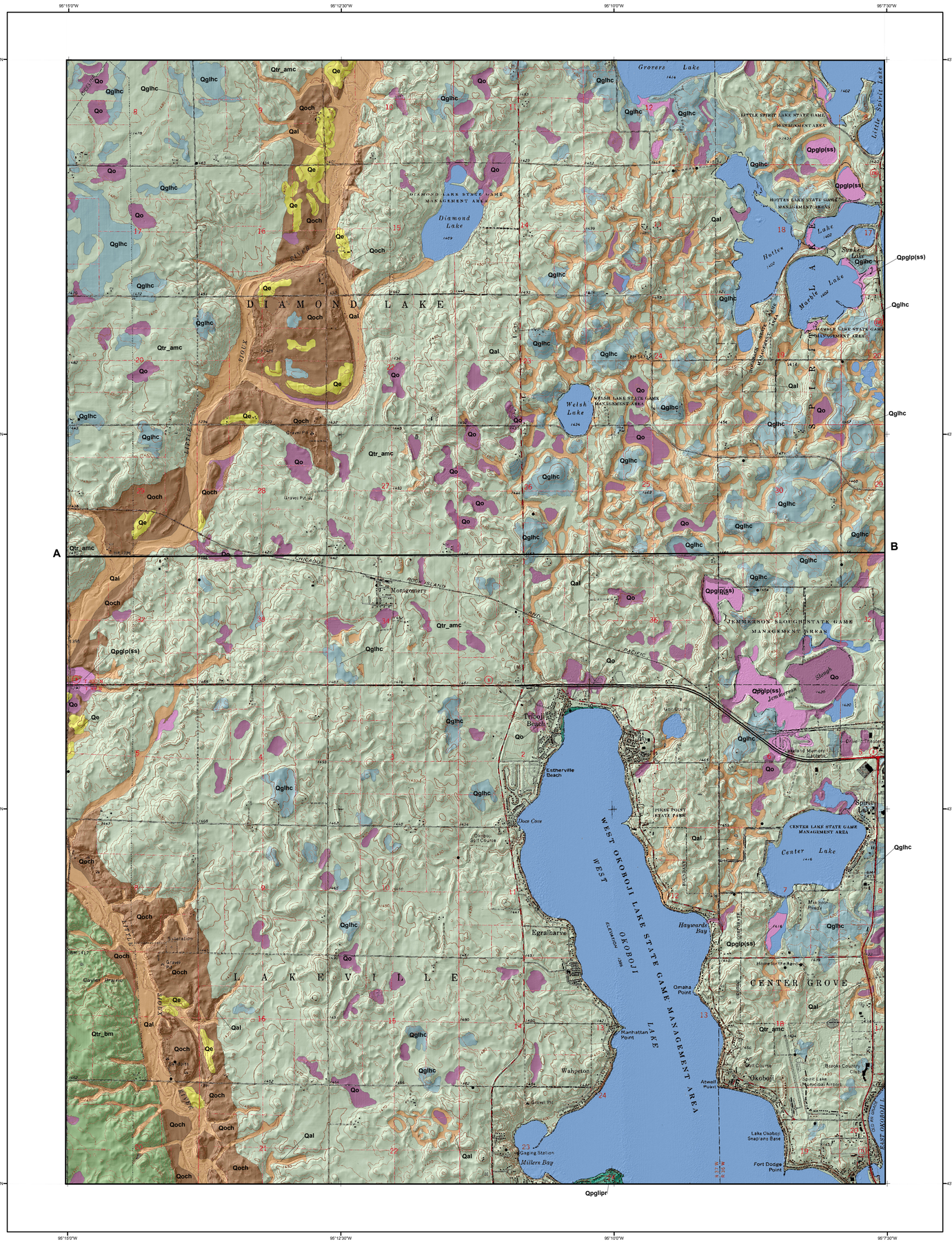
Surficial Geology of the Okoboji (Iowa) 7.5' Quadrangle



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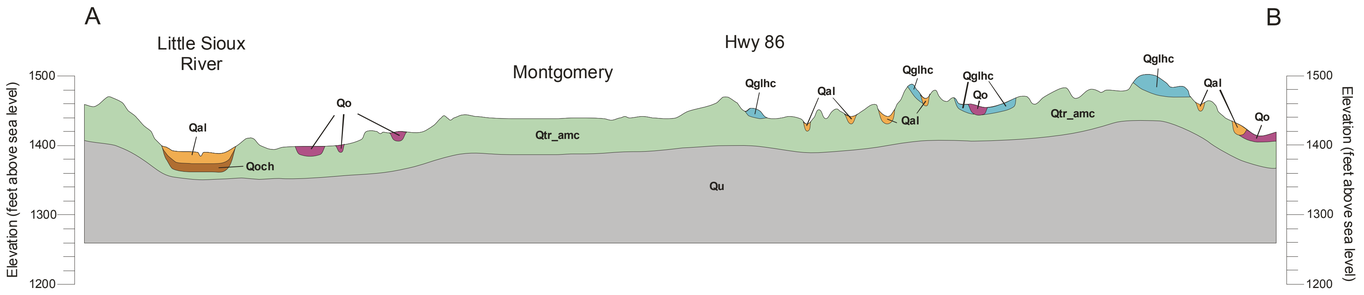
GEOLOGIC CROSS-SECTION A-B



SURFICIAL GEOLOGIC MAP OF THE 7.5' OKOBOJI QUADRANGLE

Iowa Geological and Water Survey
Open File Map OFM-12-10
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prepared by

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LEGEND

CENOZOIC

QUATERNARY SYSTEM

HUDSON EPISODE

Qo - Depressions (DeForest Formation-Woden Mbr.) 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 (Dows Fm.-Morgan/Alden Mbr.) or Noah Creek Fm. sand. 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 Dows Formation (Morgan or Alden Mbrs.) or Noah Creek Formation. 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.

Qpglp(ss) - Lake Sediment small-scale landform features (Dows Formation-Woden Mbr.) Generally less than 3 m (10 ft) of dark grayish brown, massive, calcareous, silty clay loam or silt loam overlying a thin (<1 m) basal increment of sand and gravel. Unit overlies yellowish to grayish brown calcareous, stratified loam to silt loam to sandy loam diamicton; textures can be quite variable (Dows Fm.-Morgan Mbr.) or it may overlie a gray, calcareous, massive, dense loam diamicton (Dows Fm.-Alden Mbr.). Small postglacial lake beds usually associated with very low relief till plains with reticulate-linked depression systems and occasionally on hummocky moderate relief terrain. High water table.

HUDSON and WISCONSIN EPISODE

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 Fm.), or it may overlie yellowish to grayish brown, usually calcareous, stratified loam to silt loam to sandy loam diamicton (Dows Fm.-Morgan Mbr.). Usually restricted to a narrow belt along major river valley bottoms or adjacent uplands on the Des Moines Lobe. Off the Des Moines Lobe this unit is not restricted to dunes along valley areas and may occur as sand stringers overlying unnamed erosion surface loamy sediments.

Qpglipr – Ice push ridge features (DeForest Formation-Triboji Mbr.) Generally 3 to 5 m (10-16 ft) of dark gray, dark grayish brown, dark brown to dark yellowish brown, medium to coarse sand, gravelly sand to pebbly gravel, with possible inclusions of fine-grained organic-rich silt. Unit overlies gray, calcareous, stratified loam to sandy loam diamicton; textures can be quite variable (Dows Fm.-Morgan Mbr.) or it may overlie a gray, calcareous, massive, dense loam diamicton (Dows Fm.-Alden Mbr.). Lake sediment associated with extant lakes of the Des Moines Lobe. High water table.

WISCONSIN EPISODE

Qglhc - Collapsed lake sediments-hummocky isolated ice-walled lake plains (flat-topped hummocks) (Dows Formation-Lake Mills Mbr./Morgan Mbr.) Generally less than 3 m (10 ft) of dark grayish brown, massive, calcareous, silty clay loam to silt loam; often overlying a thin basal increment of sand and gravel (<1 m). It overlies yellowish to grayish brown, usually calcareous, stratified loam to silt loam to sandy loam diamicton; textures can be quite variable (Dows Fm.-Morgan Mbr.). Isolated ice-walled lake plains comprise a portion of this landform area. Other hummocks consist of less than 15 m (49 ft) of yellowish to grayish brown, usually calcareous, stratified loam to silt loam to sandy loam diamicton (Dows Fm.-Morgan Mbr.). Overlies gray, calcareous, massive, dense loam diamicton (Dows Fm.-Alden Mbr.). Moderate to high relief hummocky landform area with 3 to 10 m of local relief.

Qoch - Valley train outwash (Noah Creek Formation) Generally 3 m (10 ft) to less than 8 m (26 ft) of dark gray, dark grayish brown, dark brown to dark yellowish brown, medium to coarse sand, gravelly sand to pebbly gravel. Overlies gray, calcareous, massive, dense, loam diamicton (Dows Fm.-Alden Mbr.). In valley positions, it is at the land surface of older terraces. On the modern floodplain, it is buried by DeForest Fm. alluvium. Low-relief landforms expressed as broad terraces; long, narrow longitudinal terraces; or cuspate-shaped point terraces. Terraces associated with the major valleys are benched on a gray, calcareous, massive, dense loam diamicton (Dows Fm.-Alden Mbr.).

Qtr_amc - Till ridge (Dows Formation-Morgan, Pilot Knob, or Lake Mills Mbrs.) Generally 9 to 15 m (27-49 ft) of yellowish to grayish brown, usually calcareous and fractured, stratified loam to silt loam; stratified sands and gravels to sandy loam diamicton; textures can be quite variable. Overlies gray, calcareous, massive, dense loam diamicton (Dows Fm.-Alden Mbr.). The Alden Mbr. in this mapping unit can extend to depths in excess of 25 m (85 ft). This sediment package overlies the Sheldon Creek Formation diamicton or Pre-Illinois age undifferniated diamicton. Moderate to high relief hummocky landform features exceed 3 to 10 m (10-33 ft) of local relief. This landform is associated with the Altamont Moraine Complex and is characterized by moderate to high relief hummocks, esker and kame features, and ice-walled lakes. Seasonal high water table.

Qtr_bm - Till ridge (Dows Formation-Morgan Mbr.) Generally 3 to 15 m (10-49 ft) of yellowish to grayish brown, usually calcareous and fractured, stratified loam to silt loam; stratified sands and gravels to sandy loam diamicton; textures can be quite variable. Overlies gray, calcareous, massive, dense loam diamicton (Dows Fm.-Alden Mbr.). The Alden Mbr. in this mapping unit rarely extends to depths greater than 15 meters (49 ft) and overlies the Sheldon Creek Formation diamicton. At the DML margin, this landform may be mantled with a thin layer of Peoria Formation silt. Low to moderate relief hummocky landform features exceed 3 to 5 m (10-16 ft) of local relief. This landform is associated with the Bemis Moraine. Seasonal high water table.

WISCONSIN AND PRE-ILLINOIS EPISODE

Qu – Glacial Till (Dows Formation and Sheldon Creek Formation-undiff.) Generally 3 to 50 m (10-170 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. It is not uncommon to see few Pierre Shale clasts in core samples. This unit overlies the much older Pre-Illinois age diamicton. Pre Illinois sediments are generally not more than 9 to 50 m (27-170 ft) of very dense, massive, fractured, loamy glacial till of the Wolf Creek or Alburnett formations. These formations are undifferentiated and shown only in the cross-section.

Other Mapping Units

Water Features Rivers, lakes and small ponds formed by blockage of drainageways and river channels. Extent mapped as shown in county soil surveys and as identified on aerial imagery.

Drill Holes

Introduction to the Surficial Geology of the Okoboji 7.5' Quadrangle

The Okoboji Quadrangle is located in Dickinson County in northwestern Iowa. The mapping area encompasses the western margin of the Late Wisconsin-age Des Moines Lobe (DML) landform region, the most recently glaciated region of the state (Prior and Kohrt, 2006). The DML is the product of a Late Wisconsin lobate extension of the Laurentide Ice Sheet that flowed down a regional topographic low into Iowa approximately 15,000 years before present and reached the terminal position at Des Moines about 13,800 RCYBP. The DML landform is bounded by pre-Wisconsin topographic highs on the east (Mississippian bedrock) and west (pre-Wisconsin glacial deposits comprising the Prairie Coteau). In the map area, the DML consists of a complex suite of depositional landforms and sediment sequences related to supraglacial, subglacial, and proglacial sedimentation. The DML is characterized by hummocky terrain that forms arcuate belts of moraine complexes and undulating plains with thick increments of supraglacial sediment (>3 m). In the map area, the Bemis Moraine (terminal end moraine) occupies a narrow sliver of the map area in the extreme southwest portion of the map (west of the Little Sioux River valley). The rest of the map is dominated by the younger Altamont Moraine Complex (AMC) which is mapped as a complex this far north on the DML. The landscape is characterized by a complex sediment package and a host of geomorphic features ranging from kames, eskers, closed and semi-linked depressions, and ice-walled lakes on the moraine surface; and kame-type terraces on the eastern wall of the Little Sioux River Valley in the southern part of the map area. A dominant feature on the map is West Okoboji Lake. The lake bottom sediments associated with this and area lakes are categorized into post glacial age deposits known as the West Okoboji Member of the DeForest Formation (Bettis et al., 1996). The West Okoboji Member represents the organic-rich silt deposits associated with lake sedimentation but do interfinger with colluvial and organic sediments associated with slough and backwater areas as well as interfingering with unnamed sandy and gravelly sediments (Triboji Member, Quade and Vogelgesang, 2011) associated with ice-push ridges (ridges resulting from the pushing action of a lake's ice sheet against the shoreline). The mapping reveals that younger advances of ice re-advanced over previous positions; the Altamont I and II moraines recognized in central Iowa are not discernable in this area. The Bemis and Altamont ice advances are well dated with an approximate 1,000 year time span between the two advances (Bettis et al., 1996).

McBride (1899) described and mapped the Quaternary geology of the county and noted "Dickinson County is pre-eminently the county of lakes and well isolated kames" in his county report. The only regional 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). Recent mapping includes the Surficial Geologic Map of Dickinson and Emmet Counties (Quade et al., 2004). Statewide bedrock geologic maps by Hershey (1969), and most recently by Witzke, Anderson, and Pope (2010), depict the increased understanding of the complex distribution of geologic units at the bedrock surface across this region, including Dickinson County.

The map area has a rich and complex geologic history punctuated by at least seven periods of glaciation between 2.2 million to 500,000 years ago (Boellstorff, 1978a, b; Hallberg, 1980, 1986). In this area, Pre-Illinoian Episode glacial deposits and associated buried soils are overlain by much younger Wisconsin-age glacial deposits. During earlier and mid Wisconsin-age, glacial materials associated with ice advances dating from approximately 40,000 to 26,000 years before present were deposited throughout the map area. The diamicton has very similar properties to Dows Formation Alden Mbr. diamicton (same source area), so identification in the field is difficult. Identification is aided by the preservation of weathered Sheldon Creek surfaces (oxidized and noncalerous) and in some instances the presence of a proglacial sand and gravel unit. In Iowa, this glacial deposit is formally reorganized as the Sheldon Creek Formation (Bettis et al., 1996; Bettis, 1997), and in earlier literature is referred to as the "Tazewell till" (Ruhe, 1950). Approximately 15,000 years ago the southern edge of the Laurentide Ice Sheet split into several lobes that each flowed down regional topographic lows. The DML extended from central Canada through the Dakotas and Minnesota into Iowa, terminating at what is now the City of Des Moines. The DML was active in Iowa between about 15,000 and 12,000 RCYBP, about 5,000 to 8,000 years later than glacial lobes to the east made their southern most maximum advance (Johnson, 1986; Fullerton, 1986). The DML advance occurred during a period of regional warming and was thus climatically out of equilibrium (Kemmis et al., 1994). Ice thickness reconstructions indicate that the DML was probably thin and gently sloping (Mathews, 1974; Clark, 1992; Brevik, 2000; Hooyer and Iverson, 2002). Clark (1992) reconstructed the DML thickness near Ames, Iowa, at ~80 m. More recently, ice reconstructions by Hooyer and Iverson (2000) were based on a model assuming the Bemis Moraine was ice-cored, which yielded ice thickness estimates of ~250 m. Despite these variations, all agree that the DML ice sheet was extremely thin and gently sloping. This ice advance was rapid and episodic and was most likely fueled by basal lubrication; in other words, a warm-based, non-deforming bed glacier. These assumptions are backed up by evidence of numerous plants (Baker et al., 1986) and trees (Bettis et al., 1996) found near the base of the DML package. Furthermore, the complex landform sediment assemblages found on the DML in Iowa seem more indicative of regional stagnation, by a surging-type glacier, not rapid recession.

Surficial deposits of the map area are composed of four formations: DeForest, Dows, Noah Creek, and Peoria formations. 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 Dows Formation consists of upland glacial deposits and is subdivided into the Alden, Lake Mills, Morgan, and Pilot Knob members. The Noah Creek Formation includes coarse sand and gravel associated with outwash from the DML. Areas of Peoria Formation eolian materials are present along the Little Sioux River valley.

In the map area, bedrock consists of mid-Cretaceous age Dakota Formation, consisting primarily of the lower dominated sandstone Nishnabotna Member and an upper shale and mudstone dominated Woodbury Member (Witzke et al., 2010).

References

Baker, R.G., Rhodes, R.S. II, Schwert, D.P., Ashworth, A.C., Frest, T.J., Hallberg, G.R., and Janssens, J.A., 1986, A full-glacial biota from southwestern Iowa, USA: Journal of Quaternary Science, v.1, p. 91-107.

Bettis, E.A. III, Quade, D.J., and Kemmis, T.J., 1996, *in* Hogs, bogs, and logs: Quaternary deposits and environmental geology of the Des Moines lobe. Edited by: E.A. Bettis, III, D.J Quade, and T.J Kemmis. Iowa Department of Natural Resources-Geological Survey Bureau, Guidebook Series No. 18, 170p.

Bettis, E.A. III, 1997, Late-Middle and Early-Late Wisconsin Glaciation in North Central Iowa, Geological Society of America North-Central Section Meeting Abstracts with Programs 29 (4):5.

Brevik, E., 2000. Limits of ice thickness in Iowa during the Late Wisconsinan: Journal of the Iowa Academy of Science, v.107, p. 46-50.

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.

Clark, P.U., 1992, Surface form of the southern Laurentide ice sheet and its implications to ice-sheet dynamics. Geological Society of America Bulletin, v. 104, p. 595-605.

Fullerton, D.S, 1986, Stratigraphy and correlation of glacial deposits from Indiana to New York and New Jersey, *in* Richmond, G.M. and Fullerton, D.S., eds, Quaternary glaciations in the United States of America, *in* Sibrava, V., Bowen, D.Q., and Richmond, G.M., eds., Quaternary Glaciations in the Northern Hemisphere: Quaternary Science Reviews, v. 5, p.23-37.

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

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., 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, 1:1,000,000 scale map sheet.

Hershey, H. G., 1969, Geologic map of Iowa, Iowa Geological Survey, scale 1:500,000 (out of print).

Hooyer, T.S. and Iverson, N.R., 2000, Clast-fabric development in a shearing granular material: Implications for subglacial till and fault gouge: Geological Society of America Bulletin, 112(5), 683-692.

Hooyer, T.S. and Iverson, N.R., 2002, Flow mechanism of the Des Moines lobe of the Laurentide ice sheet, Journal of Glaciology., 48(163), 575-586.

Johnson, W.H., 1986, Stratigraphy and correlation of the glacial deposits of the Lake Michigan lobe prior to 14 ka BP, *in* Richmond, G.M. and Fullerton, D.S., eds., Quaternary Glaciations in the United States of America, *in* Sibrava, V., Bowen, D.Q., and Richmond, G.M., eds., Quaternary Glaciations of the Northern Hemisphere: Quaternary Science Reviews, v. 5, p.17-22.

Kemmis, T.J., Bettis, E.A. III, and Quade, D.J., 1994, The Des Moines lobe in Iowa: a surging Wisconsinan glacier: American Quaternary Association, Program and Abstracts, 13th Biennial Meeting.

McBride, T. H., 1899, Geology of Osceola and Dickinson Counties: Iowa Geological Survey, Annual Report, v. 10, p. 185-239.

Mathews, W.H., 1974, Surface profile of the Laurentide ice sheet in its marginal areas: Journal of Glaciology, v. 13, p. 37-43. Minneapolis, Minnesota. p. 112.

Prior, J.C. and Kohrt, C.J., 2006, The Landform Regions of Iowa, Iowa Geological Survey, digital map, available on IDNR GIS Library- http://www.igsb.uiowa.edu/nrgislibx/

Quade, D.J., Giglierano, J.D., and Bettis, E.A., III, 2004, Surficial geologic materials of the Des Moines Lobe of Iowa, Phase 6: Dickinson and Emmet Counties: Iowa Geological Survey Open File Map OFM-04-2, 1:100,000 scale map sheet.

Quade, D.J. and Vogelgesang, J.A., 2011, East Okoboji Technical Assessment for IDNR Fisheries Bureau, Iowa Geological and Water Survey, 11 p.

Ruhe, R.V., 1950, Reclassification and correlation of the glacial drifts of northwestern Iowa and adjacent areas: University of Iowa Department of Geology, Iowa City, unpublished Ph.D. thesis, 124 p.

Witzke, B.J., Anderson, R.R. and Pope, J.P., 2010, Bedrock Geologic Map of Iowa, scale: 1:500,000, Iowa Geological and Water Survey, Open File Digital Map OFM-10-1.

Adjacent 7.5' Quadrangles

SIOUX_VALLEY	LAKEFIELD_SW	LAKEFIELD_SE
LAKE_PARK	OKOBOJI	SPIRIT_LAKE
LAKE_PARK_SE	MILFORD	SPIRIT_LAKE_SE

Correlation of Map Units

Alluvial and Outwash Deposits	Eolian Deposits	Glacial Deposits		
Qo				
Qal		Qpglp(ss)	Hudson	Holocene
Qoch	Qe	Qpglipr		
		Qglhc	Wisconsin	Pleistocene
		Qtr_amc		
		Qtr_bm		
		Qu	Pre-Illinois	

QUATERNARY

Location Map

Base map from USGS Okoboji 7.5' Digital Raster Graphic (IGS GIS file DRGB13.TIF) which was scanned from the Okoboji 7.5' Topographic Quadrangle map, published by US Geological Survey in 1970, photorevised 1980. Topographic contours and land features based on 1966 aerial photography, field checked in 1970. Land elevation contours (10' interval).Lidar shaded relief from 2010 data.

Iowa Geological and Water Survey digital cartographic file Okoboji_SurficialGeology.mxd, version 10/28/12 (ArcGIS 10.0)
Map projection and coordinate system based on Universal Transverse Mercator (UTM) Zone 15, datum NAD83.

The map and cross section are based on interpretations of the best available information at the time of mapping. Map interpretations are not a substitute for detailed site specific studies.