DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
OPEN–FILE REPORT 01-156
SURFICIAL GEOLOGIC MAP OF BERRIEN COUNTY, MICHIGAN
SCALE 1 to 100 000
By U.S. Geological Survey
Edited and integrated by Byron D. Stone
2001

Geology mapped 1997-2001
Digital cartographic compilation by S.C. Schindler, 1998, V.S. Williams and B.D. Stone, 000, B.D. Stone, 2001
Map compiled from field data registered to 1:24,000-scale topographic maps.
Geologic units and features on this map are registered to 1:100,000-scale base-map features.
PREPARED IN COOPERATION WITH THE MICHIGAN GEOLOGICAL SURVEY DIVISION AND THE CENTRAL GREAT LAKES GEOLOGIC MAPPING COALITION.

Base map from U.S.. Geological Survey digital line graph files of hypsography and hydrography from Benton Harbor and South Bend 1:100,000 scale topographic map series.

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CONTRIBUTING GEOLOGISTS
Byron D. Stone
Wayne L. Newell
Scott C. Lundstrom
Van S. Williams
Kevin A. Kincare, Michigan Geological Survey
Dennis W. O'Leary
Emily M. Taylor
William C. Burton
Thomas R. Armstrong
J. Stephen Schindler
Gregory J. Walsh
Robert P. Koeppen
Randall C. Orndorff
C. Scott Southworth
Benjamin A. Morgan
Paul E. Carrara
Ralph R. Shroba

Peter W. Barnes

SUPPORT FOR FIELD STUDIES AND
DIGITAL COMPILATION

Robert B. Fraser
Elizabeth Campbell, Virginia Geological Survey
Donald G. Queen
Mike Herder
James M. McNeal
James E. Quick

DESCRIPTION OF MAP UNITS

Map units include unconsolidated and locally cemented Quaternary surficial materials, >1 m (3.2 ft) thick. Sediment types and gravel-clast rock types, described below, are listed in decreasing order of abundance; color designations, in parentheses (Munsell, Inc., 2000), are based on naturally moist samples. A veneer of eolian silt, mixed with small amounts of fine sand, clay, and scattered gravel particles, ranging in thickness from a few centimeters to 3 m (10 ft) covers upland hills and plains; this veneer is not mapped. A discontinuous veneer of eolian fine sand, < 1 to 3 m (<3.2 to 10 ft) thick, is present locally, but is not mapped. Sandy colluvium, <1 m (3.2 ft) thick, covers most erosional slopes and is not mapped. Soil descriptions are modified from Larson (1980). Subdivision of Quaternary time is based on Richmond and Fullerton (1986).

HOLOCENE

ARTIFICIAL FILL (late Holocene)—Earth and manmade materials that have been artificially emplaced, including gravel, sand, silt, clay, compacted select earth materials, garbage, trash, and bulky waste. Thickness 1.8-15 m (6-50 ft). Fill is not shown where it is < 2.0 m (6 ft) thick in urban areas, and beneath most highway and railroad beds

LAKE MICHIGAN BEACH AND NEARSHORE DEPOSITS (late Holocene)—Very pale brown (10YR 7-8/4) to light gray (10YR 7/2) fine to very coarse sand with minor gravel, moderately sorted; local cobble gravel with fine to coarse sand matrix; deposited on modern beaches, and in offshore bars and shallow offshore areas; 1-6 m thick; thins and becomes patchy offshore

ACTIVE EOLIAN DUNE SAND (late Holocene)—Very pale brown (10YR 7-8/4) to light gray (10YR 7/2) fine to medium sand, massive or in planar or concave crossbeds in planar-tabular sets; in active coastal dunes

LAKE MICHIGAN LAKE-BOTTOM DEPOSITS (late Holocene)—Light gray to gray (10YR 7/2) to gray (10YR 6/1) silt and muddy sand (unit Qml), nonplastic or loose, containing variable trace amounts of organic materials; gray fine to very sand (unit Qms), loose; deposited in shallow offshore areas; thickens and becomes finer offshore

ALLUVIUM (early to late Holocene)—Grayish brown (10YR 5/2) to pale brown (10YR 6/3) sand, gravel, silt, minor clay, and some organic material, deposited by modern streams; in flood plains of major rivers alluvium consists of poorly sorted gravel and sand at the base, overlain by laminated and thinly bedded sand, silt, and clay; thickness 1.8-9.1 m (6-30 ft); in lower St. Joseph River flood plain, unit is >24 m (>80 ft) thick; along smaller streams alluvium is composed of poorly sorted sand and gravel derived from adjacent glacial, meltwater, and colluvial materials; thickness generally <4 m (13 ft)

ALLUVIAL FAN DEPOSITS (early to middle Holocene)—Very pale brown (10 YR 7-8/4) sand, gravel, silt, minor clay, and some organic material, deposited at the mouths of modern streams on flood-plain alluvium

HOLOCENE AND LATE WISCONSIN

STREAM TERRACE DEPOSITS (late Wisconsin to middle Holocene)—Very pale brown (10 YR 7-8/4) to yellow (10 YR 7/6) sand, pebble gravel, minor silt; deposited by streams graded to fluvial base levels higher than modern levels or by streams with higher discharge regimes

BEACH DEPOSITS (late Wisconsin to middle Holocene)—Brown to very pale brown (10YR5/3-7/4) fine to very coarse sand with minor gravel, locally cobble gravel with fine to coarse sand matrix in beaches, spits, and bars related to glacial and postglacial lake stages in the Michigan basin; unit includes deposits of the Glenwood stage of glacial Lake Chicago (unit Qbcg); Calumet stage of glacial Lake Chicago (unit Qbcc); Lake Nipissing stage (unit Qbn)

EOLIAN DUNE SAND DEPOSITS (late Wisconsin to middle Holocene)—Very pale brown (10 YR 7-8/4) to yellow (10 YR 7/6) fine to medium sand, massive or in planar or concave crossbeds in planar-tabular sets; in inland dunes and in dunes related to glacial and postglacial lake stages in the Lake Michigan basin; unit includes deposits related to Glenwood and Calumet stages of glacial Lake Chicago; Tolston stage, Lake Algoma stage, Lake Nipissing stage

EOLIAN SAND SHEET DEPOSITS (late Wisconsin to middle Holocene)—Very pale brown (10 YR 7-8/4) to yellow (10 YR 7/6) fine to medium sand, massive, commonly 2-3 m thick

PAW PAW MELTWATER TERRACE DEPOSITS (late Wisconsin)—Grayish brown to dark yellowish brown, very pale brown to light yellowish brown pebble gravel and sand grading downstream to coarse sand; surface altitudes of terrace slope from 201 m to 190 m (660 ft to 625 ft); relict braid channels engrave the surface; 3.7-12.1 m (12-40 ft) thick; graded to the Calumet stage of glacial Lake Chicago

ST. JOSEPH MELTWATER TERRACE DEPOSITS (late Wisconsin)—Grayish brown to dark yellowish brown, very pale brown to light yellowish brown pebble-cobble gravel and sand grading downstream to coarse sand; surface altitudes of terrace slope from 204 m to 190 m (670 ft to 625 ft); relict braid channels locally engrave the surface; 3.7-12.1 m (12-40 ft) thick; graded to the Calumet stage of glacial Lake Chicago

ST. JOSEPH-KANKAKEE MELTWATER TERRACE DEPOSITS (late Wisconsin)—Grayish brown to dark yellowish brown, very pale brown to light yellowish brown pebble-cobble gravel and sand grading downstream to coarse sand; surface altitudes of terrace segments slope from 730 ft to 720 ft; locally collapsed; 3.7-9.1 m (12-30 ft) thick; graded to outwash alluvial surfaces in the Kankakee River valley

Glacial-Lake Deposits—Sand, sand and gravel, and silty sand in deltaic, ice-channel, and glaciolacustrine fan deposits, and fine sand, silt, and clay in lake-bottom deposits. Deltaic deposits have glacial-stream topset beds, 0.6-18.3 m (2-60 ft) thick, composed of coarse gravel, sand and gravel (overprint patterns), and pebbly sand facies, which overlie deltaic foreset and bottomset facies. Foreset facies include: 1) sand and gravel foreset facies, consisting of gravel, pebbly sand, and coarse sand, poorly to moderately sorted, in 2-10 m (6.5-33 ft) thick sets of thin foreset beds which dip 25-35o; 2) sandy foreset facies, consisting of fine to medium sand, moderately sorted, in interbedded parallel-laminated and ripple cross-laminated sets of beds that are 2-5.2 m (6.5-16 ft) thick and that dip less than 25o; draped laminations of silt and clay are common in lower beds. Delta bottomset facies are: 1) sand and gravel bottomset facies, consisting of coarse pebbly sand in planar/tabular crossbeds and parallel-bedded fine sand, silt and clay, in sets of beds that dip less than 5o; 2) sandy bottomset facies, consisting of fine sand, silt, and minor clay, in ripple cross-laminated and parallel-laminated beds that dip less than 5o. Total thickness of deltaic sediments is 6-45.2 m (20-150 ft). Ice-marginal deltas in Berrien County contain sand and gravel and sandy foresets, including beds of silty flowtill, and thick sandy bottomset facies. Glaciolacustrine fans contain sand and gravel and sandy foreset and bottomset facies, and minor till, flowtill, and fine-grained lake-bottom sediments; fans underlie some deltaic deposits. Lake-bottom deposits (overprint pattern) contain two facies: 1) sandy facies, consisting of fine sand to silt in parallel laminated and minor ripple cross-laminated sets of beds; 2) silt-clay facies, consisting of silt-to-very fine sand, and clay in parallel laminations, microlaminations, and minor ripple cross-laminations; deposits with laminations of variable thickness have clay laminae <2 mm thick; varve deposits of this facies consist of couplets of microlaminated silt-to-very fine sand, and massive or graded clay; couplets are 0.4-10 cm (0.1-4.0 in) thick; vertical sequences of varves show little variation in couplet thickness.

LAKE-BOTTOM DEPOSITS, GLACIAL LAKE CHICAGO, GLENWOOD STAGE (late Wisconsin)—Pale brown fine sand at the surface locally, moderately sorted, laminated, and gray silt and clay, laminated; surface of lake-bottom plain 189 m (620 ft) altitude; 1-9.1 m (3-30 ft) thick; deposited in shallow water, nearshore lake environments

DEPOSITS OF GLACIAL LAKE BARODA (late Wisconsin)—Lake-bottom deposits consisting of fine sand, silt, and clay; littoral deposits composed of pebble gravel and

sand, and ice-marginal glaciodeltaic deposits consisting of sand and gravel topset beds overlying gravel and sandy foreset beds; reportedly totaling as much as 21.3 m (70 ft) thick. The dam for this large ice-marginal lake was older deltaic deposits of glacial Lake Dowagiac and other deposits of the Valparaiso morainic system in northern Indiana. The lake extended northward and westward as the ice margin retreated. Units include deposits related to lowering stages of the lake, which were controlled by lake spillway channels cut in older deposits in Indiana and Illinois at altitudes descending from about 225 m to 201 m (720 ft to 660 ft). Lake Baroda lowered to the Glenwood stage of glacial Lake Chicago following retreat of the ice margin from northern Indiana. Deposits of glacial Lake Baroda are correlated with the Lake Border morainic system (Leverett, 1908, Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985).

LAKE-BOTTOM DEPOSITS, GLACIAL LAKE BARODA (late Wisconsin)—Pale brown fine sand at the surface locally, moderately sorted, laminated, and gray silt and clay, laminated; surface of lake bottom plains 207 m to 201 m (680 ft to 660 ft) altitude; 1-9.1 m (3-30 ft) thick; deposited in shallow water, nearshore lake environments

LITTORAL DEPOSITS, GLACIAL LAKE BARODA (late Wisconsin)—Pale brown fine to very coarse sand, pebble gravel, and minor silt and clay; coarse-grained deposits are moderately sorted, planar bedded and cross-bedded; fine-grained deposits are laminated; surface of beach berms 216 m to 201 m (710 ft to 660 ft) altitude; 1-6 m (3-20 ft) thick; deposited in beaches, locally below shoreline cliffs, and in offshore bars and deltas in shoreline lake environments

LA BOYER ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Sand and gravel grading to pebble gravel and coarse sand, overlying sand, silt, and clay in subsurface; deposits include glaciotectonic thrust faults and recumbent folds in transverse ridge that is as high as 232 m (760 ft) at head of deposit; surface altitudes of glaciofluvial plain slope from 222 m to 213 m (730 ft to 700 ft)

DEPOSITS OF GLACIAL LAKE DOWAGIAC (late Wisconsin)—Ice-marginal and near-ice-marginal glaciodeltaic deposits consisting of sand and gravel topset beds overlying dipping gravel and sandy foreset beds and thick sandy and silty bottomset and lake-bottom beds. The dam for this large ice-marginal lake was older deposits of the inner Kalamazoo moraine on the southeast side of the basin, including Portage Prairie deposits (unit Qikp). The lake expanded northward and westward as the ice margin retreated; the open water of the lake extended through successively collapsed deposits to the lake spillway, which was a channel cut in deposits (unit Qikp) at about 225 m (740 ft) altitude. Lake Dowagiac lowered to the high level of glacial Lake Baroda following retreat of the ice margin from the western limit of the lake. Units include surface sandy lake-bottom deposits of glacial Lake Dowagiac of Leverett (1908). Deposits of glacial Lake Dowagiac are correlated with the Valparaiso morainic system (Leverett, 1908, Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985).

BAINBRIDGE ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include nine small ice-marginal deltas; surface altitudes of

glaciofluvial plains slope from 244 m to 224 m (800 ft to 735 ft); deltaic deposits overlie silty lake-bottom deposits (unit Qdl). The local depositional basin extended along the ice margin from Pipestone Creek area to 2 km southwest of Coloma

BIASTOCK ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include two large ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 244 m to 232 m (800 ft to 760 ft); deltaic deposits overlie sandy lake-bottom deposits in the subsurface, and grade down delta frontal slopes to lake-bottom plains (unit Qdl). The local depositional basin extended along the ice margin from Pipestone Creek area to Bainbridge Center

SHANGHAI ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include one large and one small ice-marginal delta; surface altitudes of glaciofluvial plains slope from 232 m to 224 m (760 ft to 735 ft); deltaic deposits overlie sandy lake-bottom deposits in the subsurface. The local depositional basin extended along the ice margin from 2 km north of Berrien Springs to west of Shanghai Corners

ORONOKO ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include four large ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 238 m or 232 m to 224 m (780 or 760 ft to 735 ft); deltaic deposits overlie sandy lake-bottom deposits in the subsurface. The local depositional basin extended along the ice margin from 3 km southwest of Berrien Springs to 1 km north of Hess Lake

PIPESTONE ICE-CHANNEL AND ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)— Multiple deposits undifferentiated but include deposits of five ice channels or ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 232 m to 225 m (760 ft to 740 ft). The local depositional basins developed in large melted holes along the edge of the the ice margin in Sodus and Pipestone Townships; collapsed margins of deposits are overlain by more distal deposits of unit Qds

BERRIEN ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—One large ice-marginal delta; surface altitudes of glaciofluvial plain slope from 247 m to 235 m (810 to 770 ft); deltaic deposits overlie sand, silt, and clay lake-bottom deposits in the subsurface. The local depositional basin extended from Little Indian Lake to Berrien Springs.

RANGE LINE ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—One large ice-marginal delta; surface altitudes of glaciofluvial plain slope from 238 m or 232 m to 224 m (795 ft to 750 ft); flowtill deposits exposed in northwestern part of ice-contact head; deltaic deposits overlie sand, silt, and clay lake-bottom deposits, and probable collapsed coarse ice-channel deposits in the subsurface. The local depositional basin extended from 3 km east of Buchanan to 1 km south of Pennellwood

LAKE-BOTTOM DEPOSITS, GLACIAL LAKE DOWAGIAC (late Wisconsin)—Pale brown fine sand at the surface locally, moderately sorted, laminated, and gray silt and

clay, laminated; surface of lake bottom plains 219 m to 210 m (720 ft to 690 ft) altitude; 1->15.2 m (3->50 ft) thick; deposited in deep to shallow ice-marginal lake environments

ICE-MARGINAL DELTAIC DEPOSITS, GLACIAL LAKE DOWAGIAC, UNDIFFERENTIATED (late Wisconsin)—Multiple deposits undifferentiated but include deposits of at least eight small ice-marginal deltas and two large near-ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 250 m to 229 m (820 ft to 750 ft). Deltaic deposits are highly collapsed, and overlie sandy lake-bottom deposits in the subsurface. Two local depositional basins developed along the edge of the the ice margin: one basin extended from southwest to northeast of Galien, the other expanded from Clarks Lake northward 6 km. A third depositional basin formed as ice melted away from the ice-contact heads of units Qikp and Qoko; two large near-ice-marginal deltas prograded into this arm of Lake Dowagiac, which spilled over the regional drainage divide along the Indiana Toll Highway at altitude of about 226 m (742 ft)

FAIRLAND ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include at least two large ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 244 m to 229 m (800 ft to 750 ft); deltaic deposits overlie sand, silt, and clay lake-bottom deposits in the subsurface. The local depositional basin extended from Niles to the the ice margin from Little Indian Lake to 1 km north of Smith Lake

CARMODY ICE MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include at least two large ice-marginal deltas and ice-channel deposits; surface altitudes of glaciofluvial plains slope from 247 m to 232 m (810 ft to 760 ft); deltaic deposits overlie sandy lake-bottom deposits in the subsurface. The dam for this local ice-marginal lake was older deposits of the inner Kalamazoo moraine on the southeast side of the basin. The local depositional basin developed within a large melted reentrant in the ice margin that extended from 2 km south of Coloma to Bainbridge Center and eastward to the lake dam in Cass County. This local lake lowered to the level of Lake Dowagiac following ice margin recession from western Cass County.

EAU CLAIRE ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include at least one large and three small ice-marginal deltas and ice-channel deposits; surface altitudes of glaciofluvial plains slope from 244 m or 238 m to 232 m (800 ft or 780 ft to 760 ft); deltaic deposits overlie sandy lake-bottom deposits in the subsurface. The dam for this local ice-marginal lake was older deltaic deposits of units Qdb, Qf, and Qikk on the southeast side of the basin. The local depositional basin developed along the ice margin from Berrien Springs and Eau Claire to 3 km east of Naomi. This local lake lowered to the level of Lake Dowagiac following ice margin recession from the ice-contact head of the deposit

DEPOSITS OF GLACIAL LAKE MADRON (late Wisconsin)—Ice-marginal glaciodeltaic deposits consisting of sand and gravel topset beds overlying dipping gravel and sandy foreset beds and thick sandy and silty bottomset and lake-bottom beds. The dam for this ice-marginal lake was older deltaic deposits of units Qikp and other deposits

in northern Indiana and Cass County. The spillways for this lake was a channel cut in Qikp deposits 2.5 km southeast of Buchanan, and channels cut in older deposits in norther Indiana. The lake expanded northward and westward as the ice margin retreated; the open water of the lake extended through successively collapsed deposits to the lake spillways. Lake Madron lowered to the level of glacial Lake Dowagiac following retreat of the ice margin from the western limit of the lake. Deposits of glacial Lake Madron are correlated with the Valparaiso morainic system (Leverett, 1908, Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985).

ICE-MARGINAL DELTAIC DEPOSITS, GLACIAL LAKE MADRON,UNDIFFERENTIATED (late Wisconsin)—Multiple deposits undifferentiated but include at least seven small ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 244 m to 241 m (800 ft to 790 ft) in the northern basin, and from 238 m to 232 m (780 ft to 760 ft) in the southern basin; deltaic deposits overlie sandy lake-bottom deposits in the subsurface. Two local depositional basins developed along the edge of the the ice margin: one basin extended from southern Three Oaks Township to Pine lake, the other expanded from Clear Lake to Boyle Lake

RED BUD ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include three small ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 244 m to 241 m (800 ft to 790 ft); deltaic deposits overlie sand, silt, and clay lake-bottom deposits in the subsurface. The local depositional basin extended along the ice margin from Weaver Lake to 1 km north of Madron Lake

LAKE-BOTTOM DEPOSITS, GLACIAL LAKE MADRON (late Wisconsin)—Pale brown fine sand at the surface locally, moderately sorted, laminated, and gray silt and clay, laminated; surface of lake bottom plains 219 m to 210 m (720 ft to 690 ft) altitude; 1->15.2 m (3->50 ft) thick; deposited in deep to shallow ice-marginal lake environments

KEELER ICE CHANNEL AND ICE MARGINAL DELTAIC DEPOSITS (late Wisconsin)— Multiple deposits undifferentiated but include three small ice-marginal deltas and ice-channel deposits; surface altitudes of glaciofluvial plains slope from 271 m or 265 m to 256 m (890 ft or 870 ft to 840 ft); includes ice-channel deposits as high as 259-256 m (850-840 ft) altitude inferred to be ongrade to delta glaciofluvial plains that slope to 241 m (790 ft) in Keeler Township in Cass County; deltaic deposits overlie sandy lake-bottom deposits in the subsurface. The dam for this local ice-marginal lake was older deltaic deposits of the inner Kalamazoo morainic system in Cass County. The local depositional basin extended from 2 km northwest of Brush Lake to melt channels in the ice margin north and northwest of Pipestone Lake. Keeler deposits are correlated with the inner Kalamazoo morainic system (Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985).

CUSHING ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Two small ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 271 m or 265 m to 256 m (890 ft or 870 ft to 840 ft). The dam for this local ice-marginal lake probably was stagnant glacial ice; the local depositional basin probably was a small melt hole near the

edge of the ice margin. Cushing deposits are correlated with the inner Kalamazoo morainic system (Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985).

PORTAGE PRAIRIE ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—One large and two small ice-marginal deltas; surface altitudes of glaciofluvial plains slope from 262 m to 241 m (860 ft to 790 ft); deltaic deposits overlie sand, silt, and clay lake-bottom deposits in the subsurface. The dam for this local ice-marginal lake was older deltaic deposits of the inner Kalamazoo morainic system in northern Indiana. The local depositional basin extended from Cass County, Michigan, and northern St. Joseph County, Indiana, to Buchanan. This local lake drained following ice margin recession from the Kalamazoo morainic system and headward erosion of meltwater streams in the Kankakee River valley in northern Indiana. Portage Prairie deposits are correlated with the inner Kalamazoo morainic system (Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985).

OAK FOREST ICE-MARGINAL DELTAIC DEPOSITS (late Wisconsin)—Multiple deposits undifferentiated but include small ice-marginal deltas; maximum surface altitude of glaciofluvial deposits 283 m (930 ft); highly collapsed. The dam for this local ice-marginal lake probably was stagnant glacial ice; the local depositional basin probably was a large melt hole near the edge of the ice margin. Oak Forest deposits are correlated with the outer Kalamazoo morainic system (Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985).

Till and Moraine Ridge Deposits

Gray clayey silt sediment, consisting of a very poorly sorted matrix of silt, clay, and sand (fig. 1) containing commonly 1-10 percent (by volume) pebbles and few small cobbles, and very few scattered boulders; generally nonstratified, homogeneous, compact. Gravel clasts are subangular to subrounded; some have been glacially faceted and striated; most gravel clasts and sand grains are nonweathered; many gravel clasts have thin silt caps that adhere to their upper surfaces. Gravel composed of local shale bedrock constitutes 40-60 percent of clasts. Fine to coarse sand fraction contains conspicuous black, platy shale fragments. Till forms a compact, nonlayered sediment having subhorizontal fissility and subvertical joints, few thin lenses of sorted silt and fine sand, and gravel clasts with long-axis fabrics generally oriented in the direction of glacier flow. This till facies is subglacial till of lodgement or meltout origin.

The compact till is present in a smooth till-sheet deposit in wide lowland areas and in moraine ridges in the western part of Berrien County; thickness is 2->24 m (6->80 ft). Till generally overlies bedrock, known from offshore subcrops on the bottom of Lake Michigan, and is inferred to underlie stratified meltwater deposits in the eastern part of the County. Locally the gray silty till overlies or is interbedded with stratified sediments at the ice-contact heads of some meltwater deposits.

Soils associated with till deposits generally are alfisols developed in silty sand that overlies compact till deposits in the soil C horizon, or in the compact till. The alfisols have well developed argillic B horizons 0.2-0.6 m (9-27 in) thick overlying C horizons in lightly oxidized, calcareous till deposits.

CLAYEY SILT TILL DEPOSITS OF THE LAKE BORDER MORAINE (late Wisconsin)— Gray (5YR 5/1) to grayish brown (10YR 5/2) compact clayey silt till at the surface overlying stratified sand and silt, and minor gravel and clay. Till consists of clayey silt matrix with little sand, containing 5-10 percent pebbles and few small cobbles. Gravel clasts include shale, sandstone, limestone, dolomite, granite, gneiss, quartzite, and tillite. Gray till, 6 m (20 ft) thick, overlies glaciolacustrine fan deposits exposed in lake bluffs north of Benton Harbor; gray till > 26 m (85 ft) thick underlies moraine ridges in the southwestern part of the County. Moraine ridges are 6-13 m (20-40 ft) high, with symmetric cross sections and curved but locally irregular crest traces; ridge crests commonly attain 207 m (680 ft) altitude, rising to 213 m (700 ft) in the northern part of the county; moraine ridges include the Covert Ridge of the Lake Border moraine of Leverett (1908). Offshore, the till is overlain by a gray medium to coarse sand and gravel, which is interpreted to be a surficial lag deposit derived from eroded till; the till is also overlain by thin, patchy, very fine to fine sand lake-bottom deposits and near shore sand deposits. Till was deposited subglacially, generally subaqueously in glacial Lake Baroda; deposits are correlated with the Saugatuck till of Larson and Monaghan (1982).

CLAYEY SILT TILL DEPOSITS OF THE VALPARAISO MORAINE (late Wisconsin)—Gray (5YR 5/1) to grayish brown (10YR 5/2) compact clayey silt till, consisting of clayey silt matrix with little sand, containing 5-15 percent pebbles and small cobbles. Gravel clasts include shale, sandstone, limestone, dolomite, granite, gneiss, quartzite, and tillite. Gray till, >14 m (45 ft) thick, is interbedded within stratified sediments of unit Qdo. Gray till, > 2 m (6 ft) thick, underlies sandy sediments of unit Qdr. Till was deposited subglacially, generally subaqueously in glacial Lake Dowagiac; deposits are correlated with the Saugatuck till of Larson and Monaghan (1982).

MISSISSIPPIAN
COLDWATER SHALE (Lower to middle Mississippian)

DEVONIAN
TRAVERSE GROUP (Middle Devonian)

EXPLANATION OF THE SURFICIAL GEOLOGIC MAP, MAP UNITS, AND ACCOMPANYING FIGURES

The surficial geologic map shows the distribution of surficial materials at land surface and in the shallow subsurface in Berrien County, southwestern Michigan. These materials overlie local carbonate bedrock and shale bedrock, which crops out only on the bottom of Lake Michigan west of the county. The geologic map differentiates surficial materials of late Quaternary age on the basis of lithologic characteristics, stratigraphic relationships, and age, as shown in the correlation diagram and described in the description of map units. Constructional geomorphic features composed of thick surficial deposits, such as moraine ridges and eolian sand dunes, are distinguished as map units and by map symbols. Ancillary figures provide additional information about particle-size

classifications and materials classification and thickness (fig. 1), and the distribution of moraines and glacial ice lobes of the southern Lake Michigan region (fig. 2).

Surficial materials in Berrien County are mostly nonlithified deposits of glacial, meltwater, alluvial, colluvial, eolian, marsh and swamp, and lake estuarine origin. Carbonate-mineral cement has lithified the meltwater deposits locally. Surficial materials are known also as unconsolidated soils, which include coarse-grained soils, fine-grained soils, or organic fine-grained soils as described by engineering classifications. Surficial materials underlie and are the parent materials of modem pedogenic soils that have developed in them at the land surface. Materials in different map units are distinguished lithologically by grain size, mineralogy, and structure. Organic sediments in marsh and swamp, and lake estuarine deposits underlie modern wetland areas. Eolian deposits are shown as units where they are >l m thick. Eolian loess, a mixture of silt, clay, and fine sand, containing scatterd gravel clasts, overlies most glacial meltwater deposits in the upland areas. Loess varies in thickness from <1 m to >3 m locally; it is not shown on the map. Lake-bottom deposits underlie moderate to deep offshore areas in Lake Michigan. Alluvial deposits underlie modern flood plains and stream terraces, and are differentiated on the basis of weathering characteristics, stratigraphic relationships, and topographic position. Colluvial deposits are shown where they accumulated on hillslopes above erosional lake shoreline scarps.

Deposits of glacial origin are subdivided on the basis of grain-size and sedimentary characteristics, origin, and age. Glacial deposits are related to the late Wisconsinan glacial episode of the Michigan ice lobe (Leverett, 1902, Lineback and others, 1983, Hansell and others, 1999). Till deposits consist of nonsorted sediments deposited from ice. Moraine ridges are laterally continuous bodies of thick glacial and meltwater deposits that cross the county in a north-northeasterly direction (Leverett and Taylor, 1915, Lineback and others, 1983, Farrand, 1985). End moraines are distinguished as groups of map units and are of two kinds: 1) moraines composed of glacial meltwater deposits, and 2) moraines composed chiefly of till at the surface. Meltwater deposits, which are sorted and stratified, are divided into two groups: glacial-lake and glacial-stream deposits. These meltwater deposits are further subdivided into map units on the basis of their distribution in different depositional basins, and the relationships of sedimentary facies within the depositional basins. The correlation diagram shows the relative ages of numerous moraines and meltwater lake and stream deposits that accumulated at the glacier margin in local depositional basins during retreat of the Michigan ice lobe. In deposits of glacial lakes, map overprint patterns show the distribution of fine-grained lake-bottom sediments and sand and gravel deposits of delta topset beds. Map unit descriptions provide details about glacial-lake dams and spillways, and drainage of the lakes.