DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MICHIGAN GEOLOGICAL SURVEY DIVISION
AND THE
CENTRAL GREAT LAKES GEOLOGIC MAPPING COALITION

OPEN–FILE REPORT 01-156

EXPLANATION OF MAP SYMBOLS

CONTACTóSolid where accurately located; dashed where gradational or approximately located; dotted where concealed

FLUVIAL TERRACE SCARPóCut by channel erosion; symbol drawn at base of scarp, hachures on upslope side

FLOOD PLAIN MORPHOLOGIC FEATURESóLines show local scarps of very low relief that bound old channels, point bar deposits, or areas of level to rolling topography on St. Joseph and Paw Paw River flood plains

CREST OF EOLIAN DUNEóLine symbol drawn on crest of dune ridge

EOLIAN SEDIMENT TRANSPORT DIRECTIONóDetermined from dune forms

SHORELINE BLUFFóCut by wave and slope erosion; line symbol drawn at base of scarp; hachures on upslope side

MELTWATER SEDIMENT TRANSPORT DIRECTIONóFlow direction of glacial meltwater stream or lake current, determined from crossbedding or ripple crosslaminations; observation at tip of arrow

FLOW DIRECTION OF GLACIAL STREAMóGeneralized flow direction of glacial meltwater stream inferred from slope of depositional surface of deposits

CONTOURS ON DEPOSITIONAL SURFACE OF GLACIOFLUVIAL DEPOSITSóContours show elevations of reconstructed surface of glaciofluvial deposits; contours drawn on downstream maximum extents of present topographic contours, extrapolated in areas of collapse deformation or erosion; contour interval 10 feet

DELTA FORESET SLOPE DIRECTIONóSediment transport direction of delta foreset strata, measured from dip direction of foreset strata; observation at tip of arrow

Qo 785' GLACIAL LAKE SPILLWAY CHANNELóChannel cut in meltwater deposits; letter symbol identifies glacial lake; flow direction of water shown by arrow; number is estimated altitude of channel floor, in feet

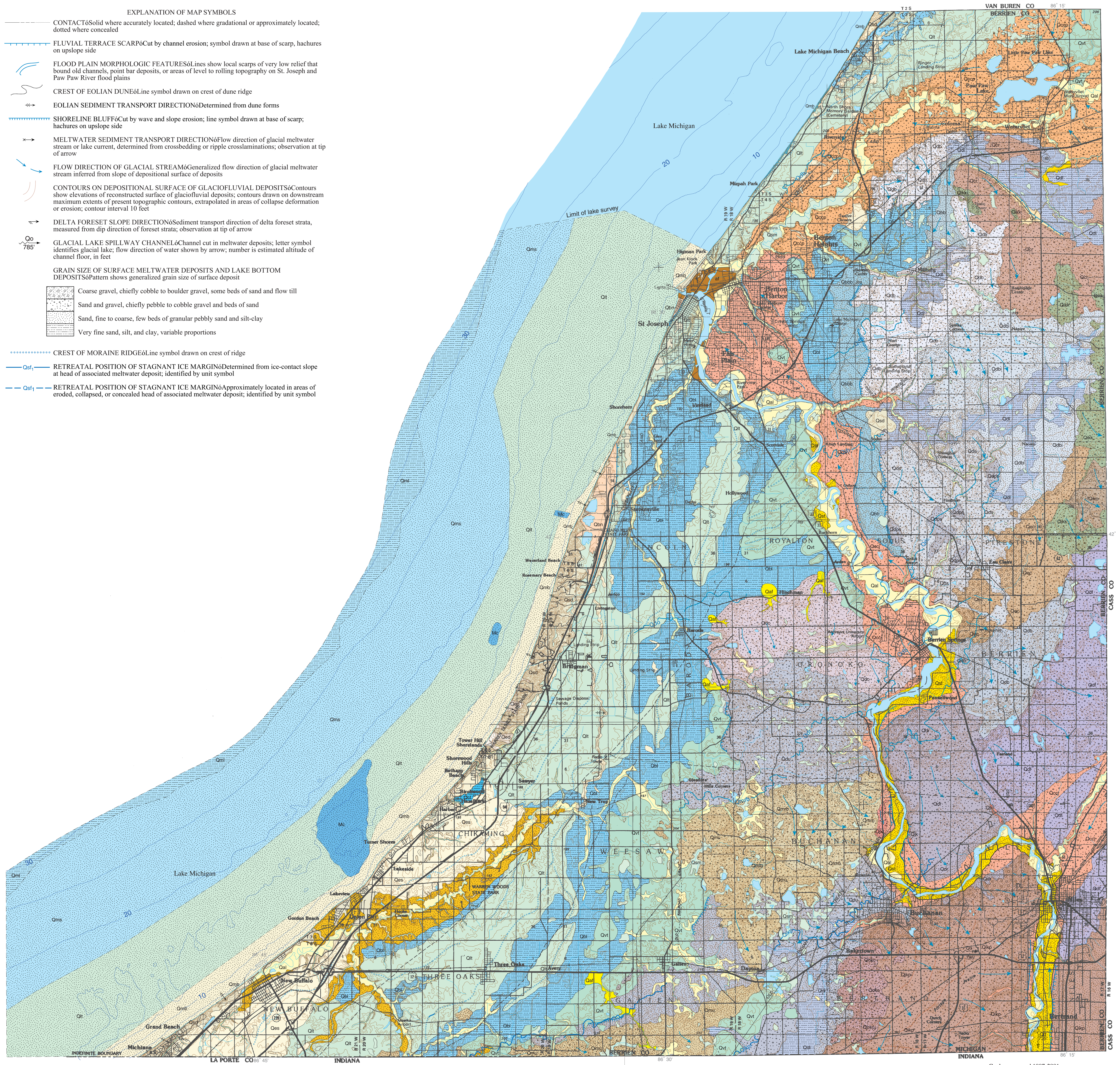
GRAIN SIZE OF SURFACE MELTWATER DEPOSITS AND LAKE BOTTOM DEPOSITSóPattern shows generalized grain size of surface deposit

- Coarse gravel, chiefly cobble to boulder gravel, some beds of sand and flow till
- Sand and gravel, chiefly pebble to cobble gravel and beds of sand
- Sand, fine to coarse, few beds of granular pebbly sand and silt-clay
- Very fine sand, silt, and clay, variable proportions

CREST OF MORAINE RIDGEóLine symbol drawn on crest of ridge

Qsf_1 RETREATAL POSITION OF STAGNANT ICE MARGINóDetermined from ice-contact slope at head of associated meltwater deposit; identified by unit symbol

Qsf_1 RETREATAL POSITION OF STAGNANT ICE MARGINóApproximately located in areas of eroded, collapsed, or concealed head of associated meltwater deposit; identified by unit symbol



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

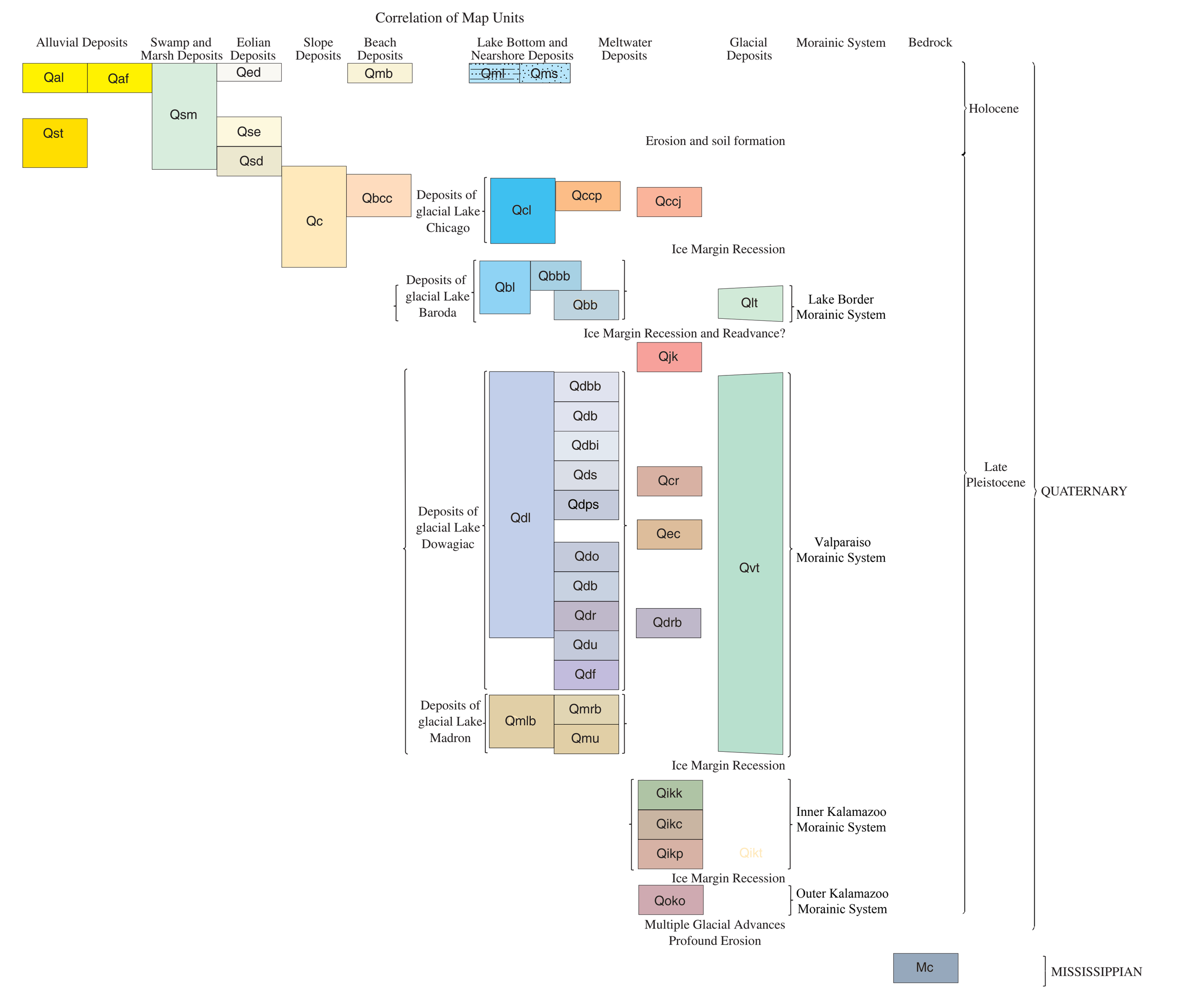
APPROXIMATE MEAN DECLINATION, 1998

SCALE 1:100 000

Topographic and bathymetric contour interval 5 m

Geology mapped 1997-2001
Digital cartographic compilation by
S.C. Schindler, 1998, V.S. Williams and
B.D. Stone, 2000, 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

Correlation of Map Units



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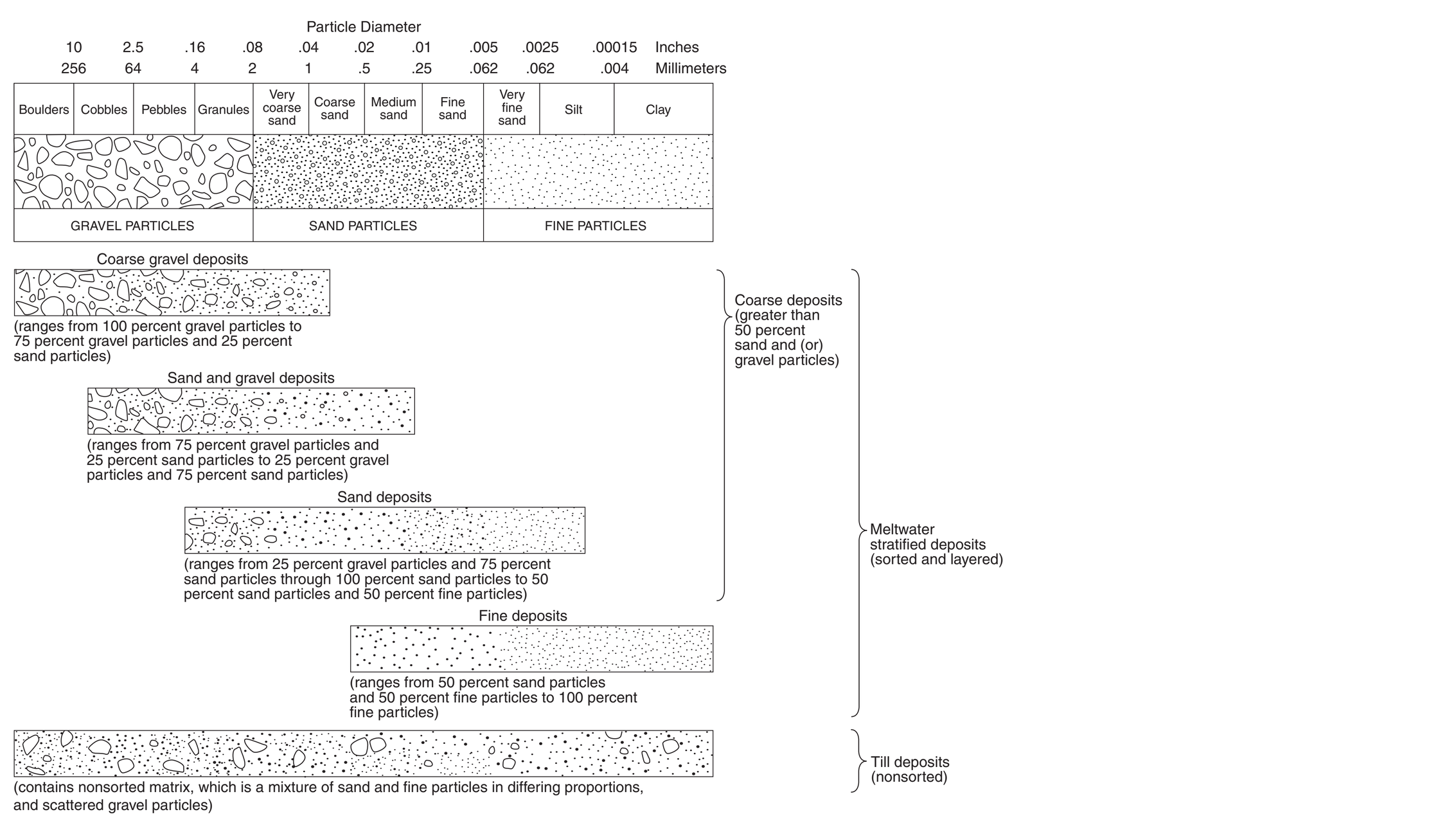

Figure 1.—Grain-size classification of meltwater stratified deposits and till deposits

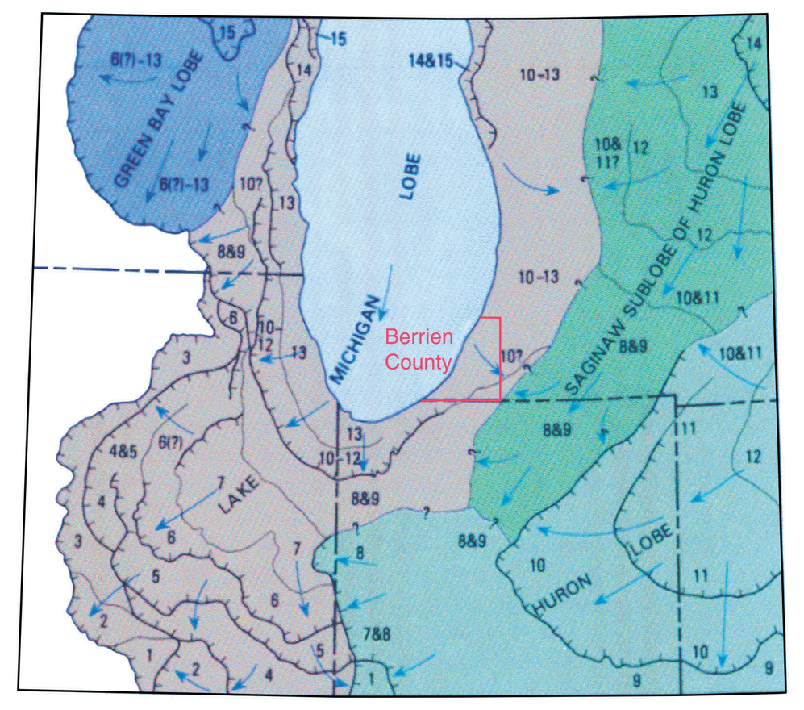

Figure 2. Relationships of late Wisconsin glacial lobes, sublobes, and advances within lobes and sublobes. Numbers indicate relative ages of surface tills in respective sublobes (oldest to youngest) in this region. Hachues indicate limits of ice-margin readvances; arrows indicate generalized ice-flow directions within lobes and sublobes (Lineback and others, 1983).

SURFICIAL GEOLOGIC MAP OF BERRIEN COUNTY, MICHIGAN

By
U.S. Geological Survey
Edited and integrated by
Byron D. Stone
2001

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

af — 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

Qmb — 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

Qed — 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

Qms, Qml — 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

Qal — 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)

Qaf — 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

Qst — 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

Qbn, Qbcc, Qbcg — 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)

Qsd — 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

Qss — 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

Qsm — SWAMP AND MARSH DEPOSITS (late Wisconsin to late Holocene)—Black to dark reddish brown (5 YR 2.5/1 to 3/3) to gray (10 YR 5-6/1) peat and muck interbedded with and overlying laminated silt, clay, and minor sand and gravel; peat is decomposed, fibrous or granular, woody or herbaceous; muck is organic, clayey or sandy silt; thickness, including basal silt and clay, generally less than 5.5 m (l8 ft) thick

Qc — COLLUVIUM DEPOSITS (late Wisconsin to middle Holocene)—Very pale brown (10 YR 7-8/4) to yellow (10 YR 7/6) silty sand or sandy silt deposits, consisting of a poorly sorted matrix of sand and silt containing 5-20 percent (by volume) pebbles; commonly massive to indistinctly layered; locally stratified

LATE WISCONSIN

Glacial Meltwater Deposits

Grayish brown to brown (10 YR 5/2-3) to dark yellowish brown (10 YR 4/4) sand and gravel, and light brownish gray (10 YR 6/2) to very pale brown to light yellowish brown (10 YR 7-6/4) gravelly sand, fine sand, and silty sand (fig. 1), stratified, poorly to moderately sorted, generally calcareous, and light brownish gray (10 YR 6/2) silt and gray (5 Y 5/1) clay, stratified, moderately sorted. Gravel composition is polymict, composed of granitic gneiss, sandstone, quartzite, conglomerate, carbonate, shale; gravel clasts are subrounded to well rounded, generally nonweathered, some coarse gravel clasts are striated. Sand composition is highly variable from lithic coarse sand to sublithic fine sand; grains generally are nonweathered. The stratified deposits were deposited by glacial meltwater, and are divided into two groups of map units based on their sedimentary facies. Deposits of glacial-stream units contain three sedimentary facies, consisting of coarse to fine gravel, and sand. Deposits of glacial-lake units contain ice-channel, deltaic, and lake-bottom deposits. Ice Channel deposits contain coarse gravel, commonly interbedded flowtill deposits, and interbedded sand and gravel in the subsurface. Deltaic deposits consist of sand and gravel facies in delta topset sediments, sand and gravel to fine sand delta foreset facies, and fine sand to silty sand delta bottomset facies in the subsurface. Sand and gravel glaciolacustrine fan facies locally underlies some deltaic deposits. Fine sand and silt-clay lake-bottom facies underlies distal delta deposits and lake-bottom plains.

Stratified meltwater deposits are subdivided into map units on the basis of the distribution, stratigraphic relationships, and altitudes of sedimentary facies in different depositional basins that were present at the melting margin of the ice sheet. Map units show the extent of sediments in each glacial-stream deposit or sediments deposited in or graded to each glacial lake. Each map unit contains one or more ice-marginal or near-ice-marginal meltwater deposits, known as morphosequences (Koteff and Pessl, 1981). Each morphosequence typically consists of a progression of landforms and sedimentary facies, grading from ice-contact landforms underlain by coarse-grained facies at the head of the deposit to depositional, noncollapsed landforms underlain by finer grained facies in distal parts of the deposit. The heads of ice-marginal deposits are coarse grained, locally containing boulders and lenses of poorly sorted flowtill sediments, and they characteristically have a zone of collapsed and deformed bedding along ice-contact slopes. Glaciofluvial deposits at the surface of each morphosequence are graded to a specific base level, which was controlled by the altitudes of various glacial lakes that covered parts of Berrien County.

Soils associated with upland glacial meltwater deposits generally are alfisols developed either entirely in overlying eolian sandy silt deposits, or in sandy silt that overlies sand and gravel deposits in the soil C horizon. On slopes and meltwater terrace deposits the alfisols are in sandy silt overlying sand and gravel. The alfisols have well developed argillic B horizons, 0.2->1.5 m (25->60 in) thick, overlying C horizons in lightly oxidized, calcareous sand and gravel sediments. Soils associated with lake bottom-deposits are mollisols commonly developed in eolian silty sand deposits that overlie fine sand, silt and clay deposits in the soil C horizon. Mollisols have gleyed argillic B horizons, 0.2-0.6 m (10-26 in) thick, overlying nonoxidized sand, silt, or clay sediments.

Glacial-Stream Deposits—Interbedded sand and gravel, moderately to poorly sorted, horizontally stratified. Deposits grade downstream from 1) coarse gravel facies in ice-proximal heads of units, to 2) sand and gravel facies, to 3) pebbly coarse sand facies in distal parts of some units. The coarse gravel facies consists of massive cobble gravel beds that have a poorly sorted sand matrix; beds of small boulders are common. Coarse gravel beds generally are less than 1 m (3.2 ft) thick; beds composed of finer grained sediment are rare. The sand and gravel facies is most prevalent; it consists of pebble and cobble gravel beds interbedded with beds of medium-to-coarse sand. Cobble gravel beds are massive or planar bedded, poorly to moderately sorted, and have local imbrication of clasts; pebble or cobble gravel beds also contain planar/tabular and trough crossbeds. Gravel beds are 0.2-1.2 m (0.7-5 ft) thick. Sand beds are chiefly coarse sand with pebbles and granules, poorly sorted, in trough and planar/tabular crossbeds. Medium- and fine-sand ripple cross-laminated beds are minor constituents. The pebbly coarse sand facies consists chiefly of coarse sand with pebbles in trough and planar/tabular cross-beds, and in planar beds. Thin beds of pebble gravel are minor constituents.

Map units containing only glacial-stream deposits in Berrien County originated as valley-train outwash deposits, which are preserved in valleys as eroded terrace deposits that extend to ice-marginal heads of outwash east of the County. The valley-train terrace deposits have smooth downstream surface profiles, and the deposits overlie older glacial-lake deposits.

Qccp — 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

Qccj — 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

Qjk — 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 25-35°; 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 25°; 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 5°; 2) sandy bottomset facies, consisting of fine sand, silt, and minor clay, in ripple cross-laminated and parallel-laminated beds that dip less than 5°. 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.

Qcl — 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).

Qbl — 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

Qbbb — 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

Qbb — 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).

Qdb — 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

Qdbi — 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

Qds — 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

Qdo — 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

Qdps — 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

Qdb — 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.

Qdr — 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

Qdl — 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

Qdu — 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)

Qdf — 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

Qcr — 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.

Qec — 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).

Qmu — 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

Qmrb — 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

Qmlb — 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

Qikk — 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).

Qikc — 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).

Qikp — 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).

Qoko — 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.

Qlt — 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).

Qivt — 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

Mc — COLDWATER SHALE (Lower to middle Mississippian)

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.