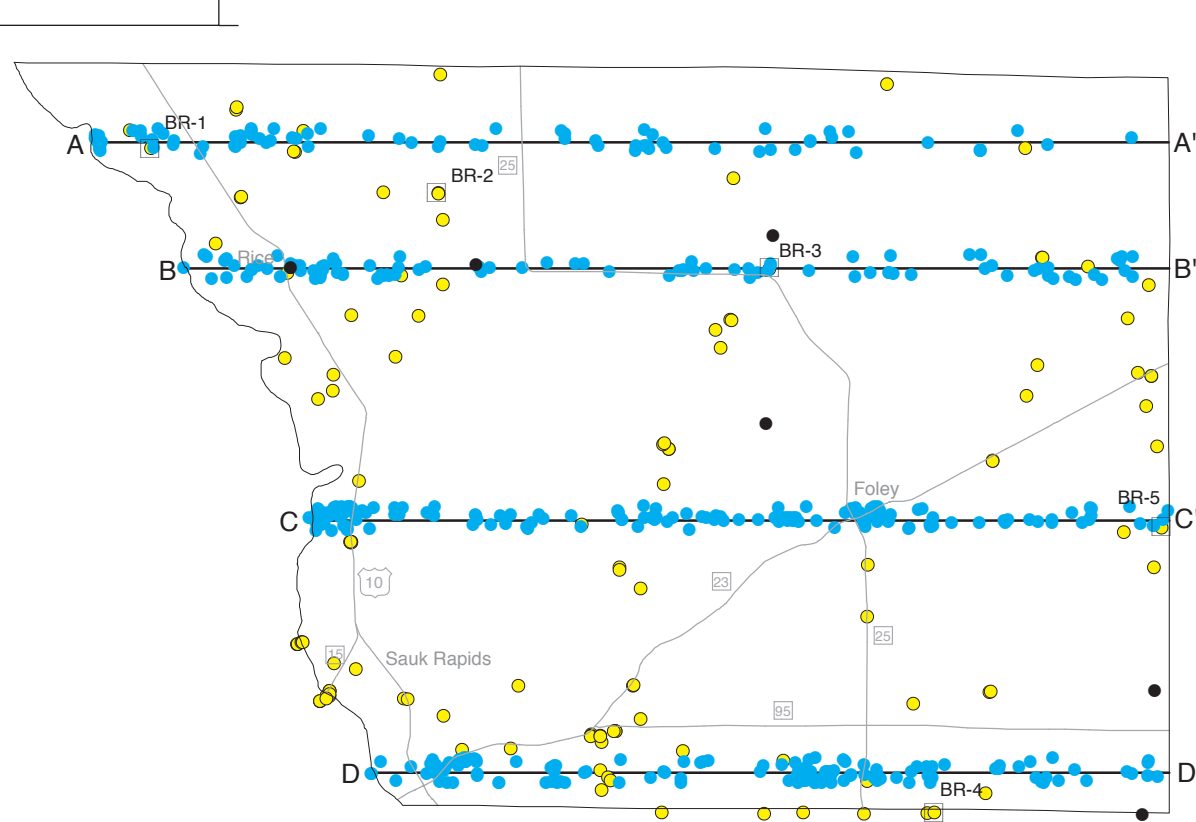
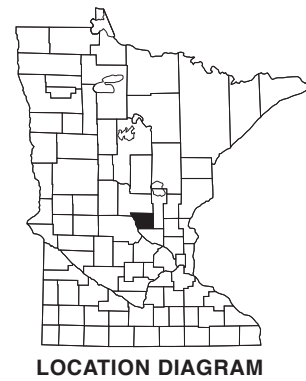
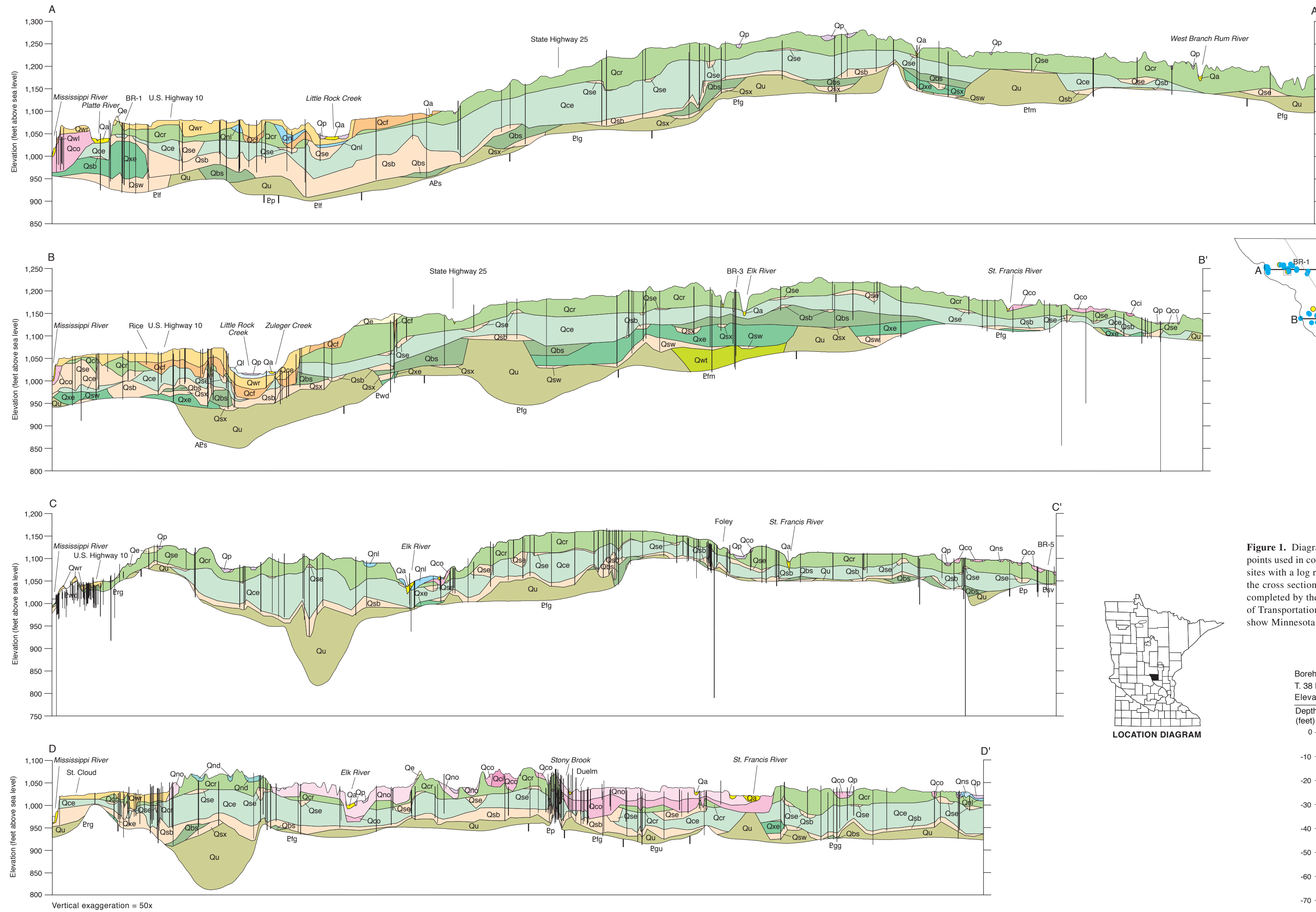


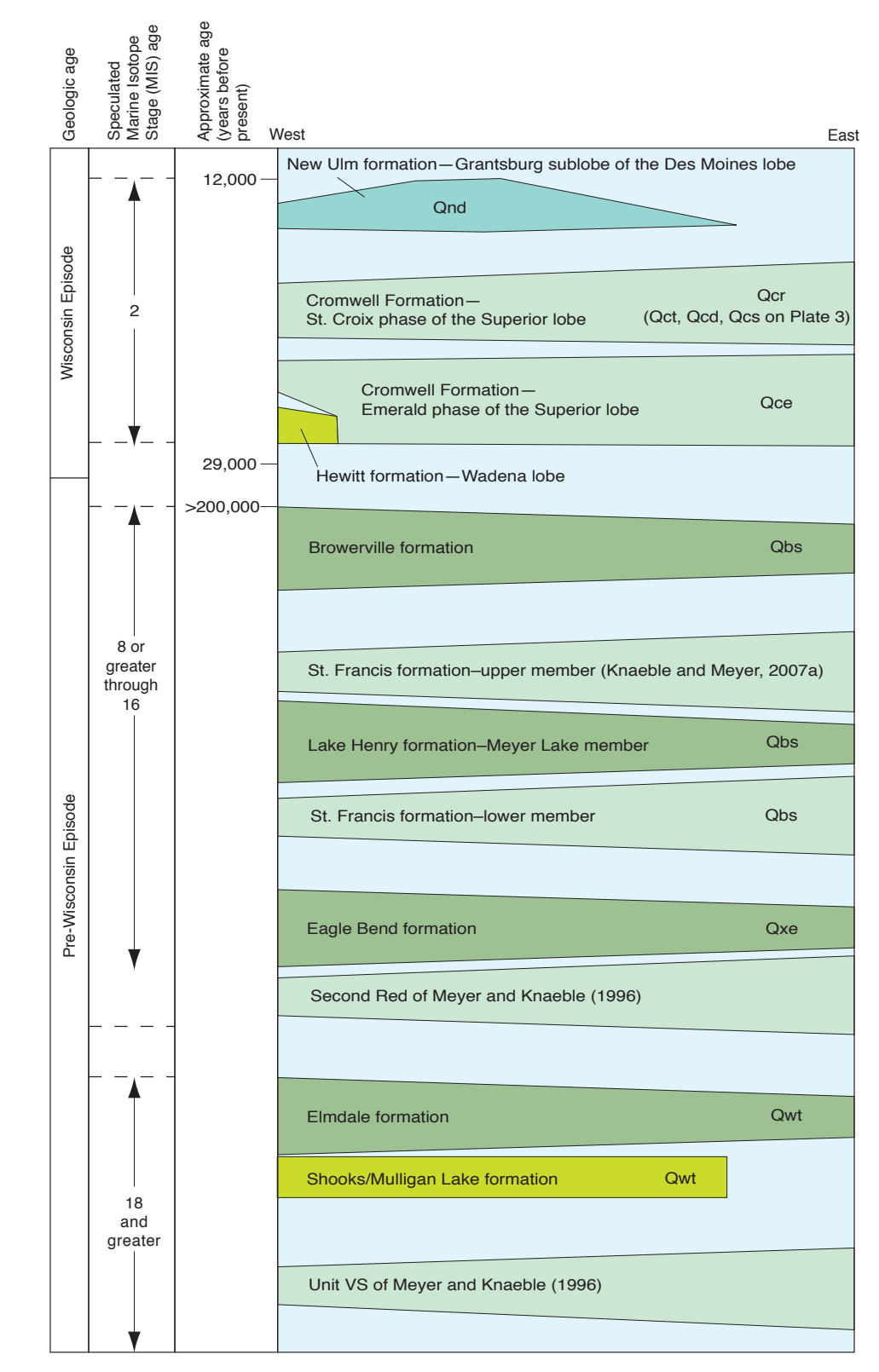
QUATERNARY STRATIGRAPHY

By  
Gary N. Meyer and Angela S. Gowan

2010



**Figure 1.** Diagram showing locations of cross sections A-A' through D-D', and the locations of the data points used in compiling stratigraphy for these four cross sections. Blue dots represent water-well drillers' sites with a log recorded in the County Well Index (only shown where within 0.5 mile [0.5 kilometer] of the cross section). Yellow dots include outcrops described during this study, and sites of auger borings completed by the Minnesota Geological Survey, the U.S. Geological Survey, the Minnesota Department of Transportation, and the Benton County Highway Department (not shown on cross sections). Squares show Minnesota Geological Survey rotary-sonic core sites, and black dots depict drill cutting sites.



**Figure 2.** Diagram showing relative age, locations (across Benton County from west to east), provenance (Plate 3, Fig. 3 and Table 1), and related unit labels from the cross sections for Wisconsin Episode and pre-Wisconsin Episode glacial deposits (Table 1). The age column and deposit drawings are not to scale. Marine Isotope Stage correlations were estimated using figures in Jennings and others (2006). Approximate age shown for deglaciation of the Grantsburg sublobe was based on two radiocarbon dates, which averaged 11,600 years before present, from wood at the base of Hudson Episode deposits burying the New Ulm formation, collected about 30 miles (48 kilometers) west of Benton County near Melrose, Minnesota (Knaeble and Meyer, 2007a). Similar radiocarbon dates have been found from wood in similar depositional settings in the Twin Cities area (Meyer, 1998). The approximate age (29,000 years before present) for the onset of the Emerald phase of the Superior lobe is based on a radiocarbon date from wood in a core drilled in Chisago County (Meyer, 2010). Two calcite samples from marl deposits above Brownville formation till in Todd County had an uranium/thorium disequilibrium minimum date of 200,000 years before present (Knaeble and Meyer, 2007a). Placing the Elmdale formation at MIS 18 or greater is based on equivalent evidence from detrital remanent magnetization analysis that may indicate it was deposited prior to or near the Brunhes reversed-Matuyama normal polarity boundary, dated at 780,000 years B.P. (Meyer, 1986, 2000). The presence of the upper member of the St. Francis formation (Knaeble and Meyer, 2007a), the Second Red unit, and unit VS (Meyer and Knaeble, 1996) is speculated from their occurrence to the west. Ice that deposited these units presumably crossed Benton County.

Borehole name: BR-1 Unique number: 270105  
T. 38 N., R. 32 W., sec. 11: DDDDBD  
Elevation in feet above mean sea level: 1,073

Depth (feet)	Lithology	Description
0	Fine-grained sand; brown silt (West Campus Formation)	Quartz and sand; brown
5	Brown sandy till; Superior provenance (Cromwell Formation)	
10	Yellow-brown silty sand and gravel	
15	Yellow-brown sandy till; 27-28.5 feet sand	
20	Brown sandy till	
25	Yellow-brown sand and gravel	
30	Dark gray silty clayey till; 40-41 feet yellow-brown; abundant carbonate (Eagle Bend formation)	
35	Dark gray clayey till, as above; silt and wood inclusions with depth	
40	Dark gray silty till, as above	
45	Dark gray silty till, as above; silt to fine-grained sand inclusions; organics; 109-110 feet sand to silt	
50	Dark gray laminated silt and clay	
55	Gray fine- to medium-grained sand, well sorted; 127-128.5 feet shell fragments; 141.5-142 feet medium- to coarse-grained sand; 142-143.5 feet sandy silt to silt with wood	
60	Gray-olive coarse-grained sand to fine-grained gravelly sand; rounded and polished pebbles; Rainy provenance sandy diamictic layer at 150 feet	
65	Saprolite in schist (Little Falls Formation)	

**Figure 3.** Descriptive log of rotary-sonic core BR-1 drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 1 and Plate 1. Samples from all Pre-Wisconsin Episode units exhibited normal polarity remanent magnetism.

Borehole name: BR-3 Unique number: 270097  
T. 38 N., R. 29 W., sec. 29: DADDDD  
Elevation in feet above mean sea level: 1,204

Depth (feet)	Lithology	Description
0	Red-brown sandy till; leached to 10.5 feet; brown loamy sand and gravel 11.5-12.5 feet (Cromwell Formation)	
5	Black dolomite boulder	
10	Brown-gray sandy till; mixed with sand below 39 feet	
15	Gray-brown coarse-grained sand	
20	Brown gray sandy till; dense	
25	As above mixed with yellow and brown till, sand, and gravel	
30	Yellow-brown till (Meyer Lake member, Lake Henry formation)	
35	Brown loam to sandy clay loam till (St. Francis formation)	
40	Yellow-brown clayey till (Eagle Bend formation)	
45	Dark gray clayey till	
50	Olive-gray loam to silty clay loam-textured till; highly mottled; less carbonate than above; gray below 158 feet	
55	Green-gray clayey silt with organics; top few inches calcareous over black organic zone noncalcareous; varies to highly calcareous in places; pollen indicated warming upwards from a brackish-dominated forest to a prairie or pine savanna (Wright and Shellenow, unpub. data, 2009)	
60	Dark gray till; mottled; leached clayey silt beds at 127.5, 130 feet (Elmdale formation)	
65	Silt to silty clay diamict to 133.5 feet; clayey silt to clay below; moderately calcareous	
70	Dark gray till; calcareous; with silt and sand lenses; 143-144 feet clayey silt with silty diamict beds	
75	Gray silty sand and gravel; 145-145.5 feet till; 145.5-146 feet fine-grained sand	
80	Gray sand to gravelly sand	
85	Very dark gray till; dense	
90	Dark gray coarse-grained loamy till mixed with very dark gray silty to clayey till; dense	
95	Dark gray coarse-grained loamy till; saprolite(?) at base (Shooks/Mulligan Lake formation)	

**Figure 5.** Descriptive log of rotary-sonic core BR-3 drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 1 and Plate 1. Samples from all Pre-Wisconsin Episode units exhibited normal polarity remanent magnetism.

Borehole name: BR-4 Unique number: 270098  
T. 36 N., R. 28 W., sec. 31: CDDDDA  
Elevation in feet above mean sea level: 1,029

Depth (feet)	Lithology	Description
0	Yellow-brown silty fine-grained sand (New Ulm formation)	
5	Yellow-brown sand, few pebbles; 23-24 feet brown sandy till with shale clasts	
10	Brown sand and gravel (Cromwell Formation)	
15	Brown sandy till; 37.5-39 feet silty gravelly sand; 39-40 feet sandy till mixed with sand	
20	Gray-brown sandy till; 66-67 feet interbedded with sand; 72.5-73 feet sand and gravel; coarse loamy textured till at 71 feet	
25	Gray-brown gravelly sand to 78.5 feet; fine-grained sand with sandy silt to 78 feet; sandy till layers to 80 feet	
30	Gray-brown silty fine-grained gravelly sand	
35	Brown-gray sandy silt; sand and gravel below 99.5 feet	
40	Gray-brown sand and silt beds; noncalcareous	
45	Brown sand and silt beds; slightly calcareous; Superior provenance	
50	Gray silt with sand beds; slightly calcareous; 159.5-161 feet yellow-brown silt with fine-grained sand beds	
55	Gray to brown sandy diamict	
60	Brown to gray silty sand and gravel	
65	Gray sandy till	
70	Brown-gray silty sand and gravel; 175.5-177 feet gray laminated silt; sandy diamict layer at 176.5 feet	
75	Gray-yellow sand and gravel	
80	White saprolite formed in coarse-grained tonalite to granodiorite (Glenorator pluton)	

**Figure 6.** Descriptive log of rotary-sonic core BR-4 drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 1 and Plate 1. Samples from all Pre-Wisconsin Episode units exhibited normal polarity remanent magnetism.

INTRODUCTION

The Quaternary Stratigraphy plate shows the unconsolidated sediment expected to be encountered between the land surface and bedrock in Benton County. The geologic units shown on the cross sections were defined using data from previous studies completed in the area (see Plate 3, Introduction), and through the interpretation of new data collected for this study. Some units match those on Plate 3, *Surficial Geology*, some new units appear only on the cross sections, and others are a combination of multiple units from Plate 3. Outcrops, auger samples, drill core, drill cuttings, and water-well drillers' logs were used to interpret the stratigraphy. Their locations are shown on Figure 1. Vertical exaggeration is 50x for all cross sections.

ACKNOWLEDGEMENTS

Robert Koziel and Gerald Howde of the Benton County Highway Department arranged permission for drilling in county road right-of-ways and gave access to county bridge boring records. Thanks are extended to Gary Johnson-Cheeseman, Gordon Jurek, Ronald Larson, Michael Schneider, and Allan Wolak, landowners who allowed rotary-sonic drilling on their property, and to all gravel pit operators and landowners who gave permission to examine exposures on their property.

DESCRIPTION OF CROSS SECTION UNITS

Each unit description on the cross sections is placed in one of three categories, as indicated in parentheses after the description: 1. *Surficial Geology* unit—unit having an identical description, label, and color as on Plate 3, *Surficial Geology*; see Plate 3 for detailed descriptions. 2. Modified unit—multiple units from Plate 3 combined into one unit on the cross sections. 3. New unit—unit that appears only on the cross sections that has a unique label and color. Sand and gravel bodies were assumed to divide the deposits of the two phases of the Superior lobe that compose the Cromwell Formation. Other sand and gravel lenses are present in places within till of the Cromwell Formation, but are generally too small or thin to show. The surficial sand aquifer or water table aquifer, which includes sediment mapped in units Qc1, Qc2, Qc3, Qc4, Qc5, Qc6, Qc7, Qc8, Qc9, Qc10, Qc11, Qc12, Qc13, Qc14, Qc15, Qc16, Qc17, Qc18, Qc19, Qc20, Qc21, Qc22, Qc23, Qc24, Qc25, Qc26, Qc27, Qc28, Qc29, Qc30, Qc31, Qc32, Qc33, Qc34, Qc35, Qc36, Qc37, Qc38, Qc39, Qc40, Qc41, Qc42, Qc43, Qc44, Qc45, Qc46, Qc47, Qc48, Qc49, Qc50, Qc51, Qc52, Qc53, Qc54, Qc55, Qc56, Qc57, Qc58, Qc59, Qc60, Qc61, Qc62, Qc63, Qc64, Qc65, Qc66, Qc67, Qc68, Qc69, Qc70, Qc71, Qc72, Qc73, Qc74, Qc75, Qc76, Qc77, Qc78, Qc79, Qc80, Qc81, Qc82, Qc83, Qc84, Qc85, Qc86, Qc87, Qc88, Qc89, Qc90, Qc91, Qc92, Qc93, Qc94, Qc95, Qc96, Qc97, Qc98, Qc99, Qc100, Qc101, Qc102, Qc103, Qc104, Qc105, Qc106, Qc107, Qc108, Qc109, Qc110, Qc111, Qc112, Qc113, Qc114, Qc115, Qc116, Qc117, Qc118, Qc119, Qc120, Qc121, Qc122, Qc123, Qc124, Qc125, Qc126, Qc127, Qc128, Qc129, Qc130, Qc131, Qc132, Qc133, Qc134, Qc135, Qc136, Qc137, Qc138, Qc139, Qc140, Qc141, Qc142, Qc143, Qc144, Qc145, Qc146, Qc147, Qc148, Qc149, Qc150, Qc151, Qc152, Qc153, Qc154, Qc155, Qc156, Qc157, Qc158, Qc159, Qc160, Qc161, Qc162, Qc163, Qc164, Qc165, Qc166, Qc167, Qc168, Qc169, Qc170, Qc171, Qc172, Qc173, Qc174, Qc175, Qc176, Qc177, Qc178, Qc179, Qc180, Qc181, Qc182, Qc183, Qc184, Qc185, Qc186, Qc187, Qc188, Qc189, Qc190, Qc191, Qc192, Qc193, Qc194, Qc195, Qc196, Qc197, Qc198, Qc199, Qc200, Qc201, Qc202, Qc203, Qc204, Qc205, Qc206, Qc207, Qc208, Qc209, Qc210, Qc211, Qc212, Qc213, Qc214, Qc215, Qc216, Qc217, Qc218, Qc219, Qc220, Qc221, Qc222, Qc223, Qc224, Qc225, Qc226, Qc227, Qc228, Qc229, Qc230, Qc231, Qc232, Qc233, Qc234, Qc235, Qc236, Qc237, Qc238, Qc239, Qc240, Qc241, Qc242, Qc243, Qc244, Qc245, Qc246, Qc247, Qc248, Qc249, Qc250, Qc251, Qc252, Qc253, Qc254, Qc255, Qc256, Qc257, Qc258, Qc259, Qc260, Qc261, Qc262, Qc263, Qc264, Qc265, Qc266, Qc267, Qc268, Qc269, Qc270, Qc271, Qc272, Qc273, Qc274, Qc275, Qc276, Qc277, Qc278, Qc279, Qc280, Qc281, Qc282, Qc283, Qc284, Qc285, Qc286, Qc287, Qc288, Qc289, Qc290, Qc291, Qc292, Qc293, Qc294, Qc295, Qc296, Qc297, Qc298, Qc299, Qc300, Qc301, Qc302, Qc303, Qc304, Qc305, Qc306, Qc307, Qc308, Qc309, Qc310, Qc311, Qc312, Qc313, Qc314, Qc315, Qc316, Qc317, Qc318, Qc319, Qc320, Qc321, Qc322, Qc323, Qc324, Qc325, Qc326, Qc327, Qc328, Qc329, Qc330, Qc331, Qc332, Qc333, Qc334, Qc335, Qc336, Qc337, Qc338, Qc339, Qc340, Qc341, Qc342, Qc343, Qc344, Qc345, Qc346, Qc347, Qc348, Qc349, Qc350, Qc351, Qc352, Qc353, Qc354, Qc355, Qc356, Qc357, Qc358, Qc359, Qc360, Qc361, Qc362, Qc363, Qc364, Qc365, Qc366, Qc367, Qc368, Qc369, Qc370, Qc371, Qc372, Qc373, Qc374, Qc375, Qc376, Qc377, Qc378, Qc379, Qc380, Qc381, Qc382, Qc383, Qc384, Qc385, Qc386, Qc387, Qc388, Qc389, Qc390, Qc391, Qc392, Qc393, Qc394, Qc395, Qc396, Qc397, Qc398, Qc399, Qc400, Qc401, Qc402, Qc403, Qc404, Qc405, Qc406, Qc407, Qc408, Qc409, Qc410, Qc411, Qc412, Qc413, Qc414, Qc415, Qc416, Qc417, Qc418, Qc419, Qc420, Qc421, Qc422, Qc423, Qc424, Qc425, Qc426, Qc427, Qc428, Qc429, Qc430, Qc431, Qc432, Qc433, Qc434, Qc435, Qc436, Qc437, Qc438, Qc439, Qc440, Qc441, Qc442, Qc443, Qc444, Qc445, Qc446, Qc447, Qc448, Qc449, Qc450, Qc451, Qc452, Qc453, Qc454, Qc455, Qc456, Qc457, Qc458, Qc459, Qc460, Qc461, Qc462, Qc463, Qc464, Qc465, Qc466, Qc467, Qc468, Qc469, Qc470, Qc471, Qc472, Qc473, Qc474, Qc475, Qc476, Qc477, Qc478, Qc479, Qc480, Qc481, Qc482, Qc483, Qc484, Qc485, Qc486, Qc487, Qc488, Qc489, Qc490, Qc491, Qc492, Qc493, Qc494, Qc495, Qc496, Qc497, Qc498, Qc499, Qc500, Qc501, Qc502, Qc503, Qc504, Qc505, Qc506, Qc507, Qc508, Qc509, Qc510, Qc511, Qc512, Qc513, Qc514, Qc515, Qc516, Qc517, Qc518, Qc519, Qc520, Qc521, Qc522, Qc523, Qc524, Qc525, Qc526, Qc527, Qc528, Qc529, Qc530, Qc531, Qc532, Qc533, Qc534, Qc535, Qc536, Qc537, Qc538, Qc539, Qc540, Qc541, Qc542, Qc543, Qc544, Qc545, Qc546, Qc547, Qc548, Qc549, Qc550, Qc551, Qc552, Qc553, Qc554, Qc555, Qc556, Qc557, Qc558, Qc559, Qc560, Qc561, Qc562, Qc563, Qc564, Qc565, Qc566, Qc567, Qc568, Qc569, Qc570, Qc571, Qc572, Qc573, Qc574, Qc575, Qc576, Qc577, Qc578, Qc579, Qc580, Qc581, Qc582, Qc583, Qc584, Qc585, Qc586, Qc587, Qc588, Qc589, Qc590, Qc591, Qc592, Qc593, Qc594, Qc595, Qc596, Qc597, Qc598, Qc599, Qc600, Qc601, Qc602, Qc603, Qc604, Qc605, Qc606, Qc607, Qc608, Qc609, Qc610, Qc611, Qc612, Qc613, Qc614, Qc615, Qc616, Qc617, Qc618, Qc619, Qc620, Qc621, Qc622, Qc623, Qc624, Qc625, Qc626, Qc627, Qc628, Qc629, Qc630, Qc631, Qc632, Qc633, Qc634, Qc635, Qc636, Qc637, Qc638, Qc639, Qc640, Qc641, Qc642, Qc643, Qc644, Qc645, Qc646, Qc647, Qc648, Qc649, Qc650, Qc651, Qc652, Qc653, Qc654, Qc655, Qc656, Qc657, Qc658, Qc659, Qc660, Qc661, Qc662, Qc663, Qc664, Qc665, Qc666, Qc667, Qc668, Qc669, Qc670, Qc671, Qc672, Qc673, Qc674, Qc675, Qc676, Qc677, Qc678, Qc679, Qc680, Qc681, Qc682, Qc683, Qc684, Qc685, Qc686, Qc687, Qc688, Qc689, Qc690, Qc691, Qc692, Qc693, Qc694, Qc695, Qc696, Qc697, Qc698, Qc699, Qc700, Qc701, Qc702, Qc703, Qc704, Qc705, Qc706, Qc707, Qc708, Qc709, Qc710, Qc711, Qc712, Qc713, Qc714, Qc715, Qc716, Qc717, Qc718, Qc719, Qc720, Qc721, Qc722, Qc723, Qc724, Qc725, Qc726, Qc727, Qc728, Qc729, Qc730, Qc731, Qc732, Qc733, Qc734, Qc735, Qc736, Qc737, Qc738, Qc739, Qc740, Qc741, Qc742, Qc743, Qc744, Qc745, Qc746, Qc747, Qc748, Qc749, Qc750, Qc751, Qc752, Qc753, Qc754, Qc755, Qc756, Qc757, Qc758, Qc759, Qc760, Qc761, Qc762, Qc763, Qc764, Qc765, Qc766, Qc767, Qc768, Qc769, Qc770, Qc771, Qc772, Qc773, Qc774, Qc775, Qc776, Qc777, Qc778, Qc779, Qc780, Qc781, Qc782, Qc783, Qc784, Qc785, Qc786, Qc787, Qc788, Qc789, Qc790, Qc791, Qc792, Qc793, Qc794, Qc795, Qc796, Qc797, Qc798, Qc799, Qc800, Qc801, Qc802, Qc803, Qc804, Qc805, Qc806, Qc807, Qc808, Qc809, Qc810, Qc811, Qc812, Qc813, Qc814, Qc815, Qc816, Qc817, Qc818, Qc819, Qc820, Qc821, Qc822, Qc823, Qc824, Qc825, Qc826, Qc827, Qc828, Qc829, Qc830, Qc831, Qc832, Qc833, Qc834, Qc835, Qc836, Qc837, Qc838, Qc839, Qc840, Qc841, Qc842, Qc843, Qc844, Qc845, Qc846, Qc847, Qc848, Qc849, Qc850, Qc851, Qc852, Qc853, Qc854, Qc855, Qc856, Qc857, Qc858, Qc859, Qc860, Qc861, Qc862, Qc863, Qc864, Qc865, Qc866, Qc867, Qc868, Qc869, Qc870, Qc871, Qc872, Qc873, Qc874, Qc875, Qc876, Qc877, Qc878, Qc879, Qc880, Qc881, Qc882, Qc883, Qc884, Qc885, Qc886, Qc887, Qc888, Qc889, Qc890, Qc891, Qc892, Qc893, Qc894, Qc895, Qc896, Qc897, Qc898, Qc899, Qc900, Qc901, Qc902, Qc903, Qc904, Qc905, Qc906, Qc907, Qc908, Qc909, Qc910, Qc911, Qc912, Qc913, Q