Introduction

Door County is located in northeastern Wisconsin and occupies the majority of the Door Peninsula that separates Green Bay from Lake Michigan (fig. 1). The county has been entirely glaciated numerous times during the Pleistocene Epoch, including during the Wisconsin Glaciation (fig. 2).

Unconsolidated sediments provide only a thin cover over bedrock, and are less than 5 ft (1.5 m) thick in many parts of the county. Generally, the thickness of unconsolidated sediment cover increases toward the southern parts of the county. The topography throughout the county is largely controlled by the underlying bedrock topography.

The resistant Silurian Niagara Dolomite forms prominent escarpments and bluffs along the western (Green Bay) shore of the Door Peninsula, and the locations of several bays and inlets along the coast are dictated by bedrock valleys that cut across the peninsula.

**Figure 1.** Location of Door County, Wisconsin, in relation to: (A) the lobes of the Laurentide Ice Sheet during the height of the Wisconsin glaciation, and (B) the larger Laurentide Ice Sheet. Arrows indicate ice flow directions; hachures indicate the margin of the ice sheet.

**Figure 2.** Time-distance diagram showing the extent of the Green Bay Lobe of the Laurentide Ice Sheet during the late Wisconsin Glaciation. The horizontal axis represents the approximate distance from southern to northern Wisconsin. Modified from Attig, Bricknell, and others (2011).
Elevations in the county range from approximately 579 ft (176 m) at the Lake Michigan water level to roughly 860 ft (262 m) at the highest points. Local relief is typically no more than 30 to 60 ft (10 to 20 m) throughout the county except in the vicinity of the bedrock escarpment along the western shore, where relief is as much as 150 ft (45 m).

Regional glacial history
The glacial history of eastern Wisconsin consists of repeated advances of the Green Bay and Lake Michigan Lobes of the Laurentide Ice Sheet that are represented by a sequence of tills (fig. 3).

Pre-Wisconsin deposits (older than about 100,000 years) are largely absent in Wisconsin, except in the south-central part of the state and just north of the Driftless Area of western Wisconsin (Baker and others, 1983; Miller, 2000). Some pre-Wisconsin till may be present at depth in east-central Wisconsin, in Sheboygan County, but can only be found in borings (Chapel, 2000). The majority of the surficial glacial material in Wisconsin is from the late Wisconsin Glaciation, beginning with the Holy Hill Formation, which was deposited about 26,000 to 18,000 calendar years ago (Syverson and others, 2011).

Preliminary data from the Baraboo Hills in south-central Wisconsin suggests that the Green Bay Lobe began to retreat about 18,500 calendar years ago (Attig, Hanson, and others, 2011), although it is debated whether the retreat was rapid or slow (Colgan and others, 1998; Colgan, 1999). At some time during the retreat, ice melted back far enough to allow water from the Lake Superior basin to enter Green Bay and Lake Michigan through the Whitefish–Au Train channel. Red sediment from the Lake Superior basin was carried along the glacier front, or possibly beneath the glacier, into the Green Bay and Lake Michigan basins (Alden, 1918). Subsequent re-advances of the Green Bay and Lake Michigan Lobes, each terminating farther north than the previous advance, reworked this red lake clay and deposited the reddish-brown members of the Kewaunee Formation. Chamberlin (1877) originally described these deposits as lake clay, but Alden (1918) recognized them as till of a single advance, based on their position on the landscape and the disturbance of underlying sediment. In the 1970s, extensive field work in Manitowoc County revealed that the Valders red till mapped by Alden (1918) consists of several different units, with only the latest advance being post–Two Creekan in age (Everson 1973a, 1973b; Evenson and Mickelson, 1974; Mickelson and Evenson, 1975; Evenson and others, 1976; Schneider, 1990a).

The water levels in Green Bay and Lake Michigan fluctuated drastically with the advance and retreat of glacier ice. As the lobes retreated into their respective basins, water ponded against the glacier fronts, forming proglacial lakes. As the glaciers retreated farther, successively lower outlets were uncovered, allowing the water level in the lakes to drop. The opposite occurred as the lobes advanced. Water levels also fluctuated with the amount of water flowing in and out of the basin, the downcutting of outlets, and the rate and pattern of isostatic uplift due to removal of the weight of the glaciers (Hansel and Mickelson, 1987; Larsen, 1987). This series of events created raised shorelines, marked by a variety of wave-cut and wave-deposited features (Goldthwait, 1907; Kowalke, 1946; Schneider, 1993a, 1993c).
Sources of information
U.S. Geological Survey 7.5-minute topographic maps were the primary base for fieldwork and mapping. Aerial photographs (scale 1:20,400) and the Soil Survey of Door County (Link and others, 1978) were used to produce a preliminary 1:24,000-scale surficial glacial geology map of Door County.
Field data were collected during the summers of 1999 and 2000 by examining road cuts, foundation exposures, gravel pits, quarries, and other excavations. We collected 153 sediment samples at various localities for laboratory analysis. Where bedrock was exposed, we measured the directions of striations. We also collected split spoon drill-core samples from 22 drill holes and retrieved core samples from an additional 37 holes using solid-stem auger sampling.
Till samples were analyzed for grain size, color, and carbonate content at the University of Wisconsin–Madison Department of Geoscience’s Quaternary Laboratory (Grant, 1978). Grain sizes were grouped into three fractions: sand (0.625 to 2.0 mm), silt (0.002 to 0.625 mm), and clay (<0.002 mm). The color of each sample was taken from suspended silt and clay fractions. Calcite/dolomite ratios of the coarse silt fraction were determined for selected samples by Chittick analysis (Dreimanis, 1962).

A preliminary map of the distribution of Door County’s Quaternary deposits was constructed using Link and others’ (1978) soil survey and a digitized ArcView soil map coverage. Soil series were grouped according to parent material, as suggested in the soil definitions, or inferred from profile and textural descriptions. All soil series from similar parent material were combined within ArcView to form a coverage to be used as a proxy for surficial sediment. Many of the soil series are partially defined by the presence of bedrock within 5 ft (1.5 m) of the ground surface and thus a map of thin sediment cover was also constructed.
Following the completion of mapping, lidar (Light Detection and Ranging) coverage for the entirety of Door County was produced. This became available in 2002, and has been used in figures and the glacial geology map (plate 1).

Previous work
Thwaites and Bertrand (1957) initially mapped the Pleistocene geology of the Door Peninsula at 1:500,000 following the stratigraphic classification scheme set up by Alden (1918). Because this classification scheme has since been modified, the Wisconsin Geological and Natural History Survey and the United States Geological Survey provided funding to map the Quaternary deposits of Wisconsin, using the modern stratigraphic framework, at a scale of 1:100,000. Brown and Kewaunee Counties, south of Door County, have been mapped by Need (1985) and Clayton (2013), respectively. Maps of counties farther south, such as Calumet and Manitowoc (Mickelson and Socha, in press), Sheboygan (Carlson and others, 2011), and Washington and Ozaukee (Mickelson and Syverson, 1997), have been completed or are in progress.
Since the map of Thwaites and Bertrand (1957) was published, there has been little formal mapping in Door County. Schneider (1981, 1982, 1988, 1989, and 1993a–c) has summarized various aspects of the glacial geology and geomorphology of the peninsula. A soil survey of the county was completed in 1978 (Link and others), replacing the survey by Whitson and others (1919). The karst geomorphology has been studied by Rosen (1984), Rosen and others (1987), Johnson (1987), and Johnson and Stiegllitz (1990). In 1993, Stiegllitz and Schuster prepared a summary of the Door Peninsula’s karst features.

Many detailed groundwater studies have been conducted in Door County, as the potential for groundwater contamination in the area is very high due to thin surficial sediment cover and pervasively jointed bedrock. Sherrill (1978) compiled the first detailed study of groundwater flow in the county, followed by Blanchard (1988). Bradbury and Muldoon (1992) and Underwood (1999) have studied fracture flow at several sites near Sturgeon Bay. Summaries and discussions of groundwater and associated contamination in Door County have been summarized by Stiegllitz and Schuster (1988) and by Bradbury (1990).

Figure 4. Major geographic features of Door County.