

## WISCONSIN'S DOOR PENINSULA AND ITS GEOMORPHOLOGY

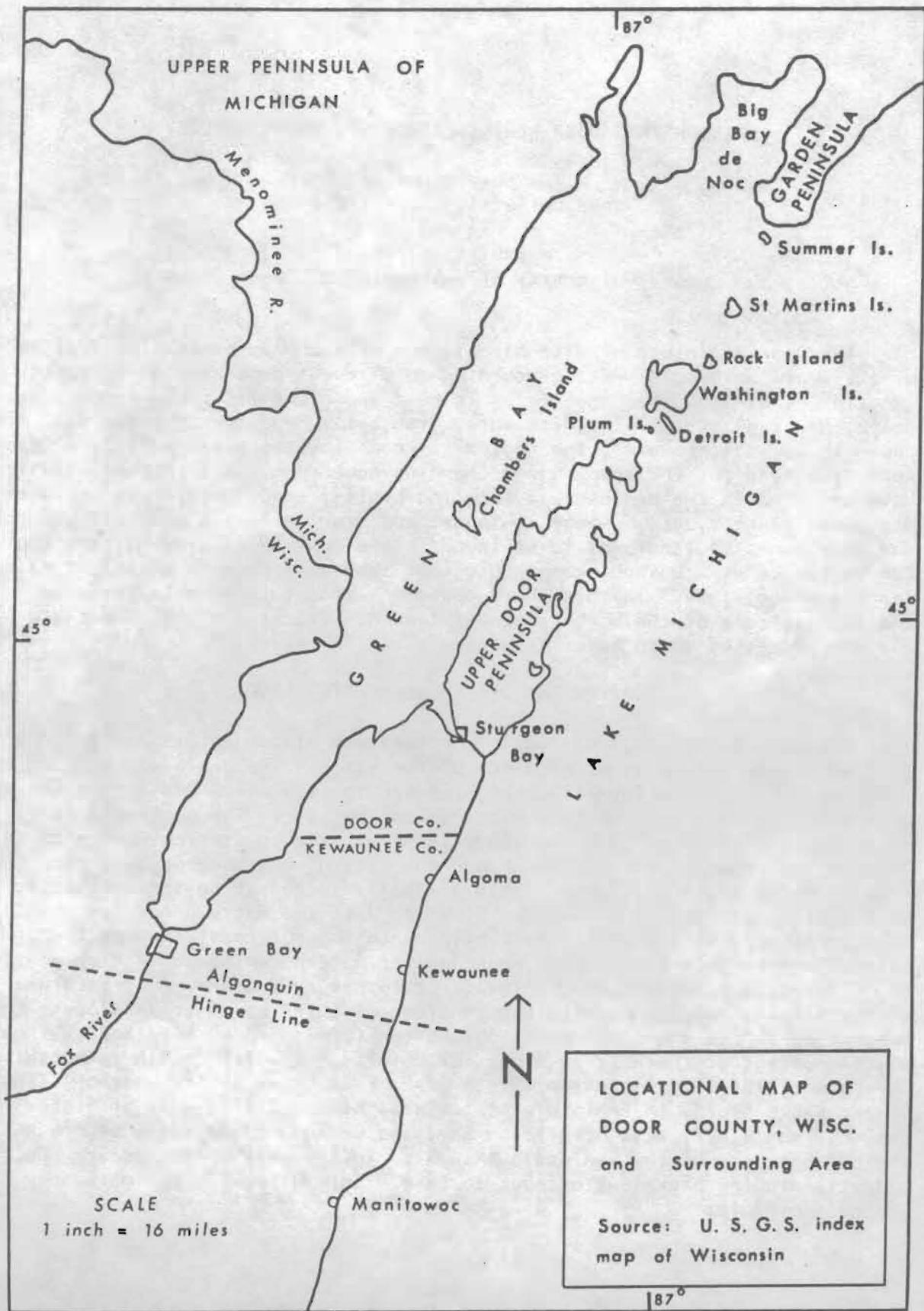
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The Door Peninsula of Wisconsin is one of the premier tourist regions of the American Middle West. According to a recent geography of Wisconsin (Vogeler et al 1986, 8), the region is best known for its picturesque sea-scape, New England-style architecture, fish boils, and cherry orchards. Among geomorphologists, however, the region is known for the great variety of land-form types and for the complex and changing geomorphological processes which have operated in the peninsula. Towering bluffs, sand dunes, lake terraces, abandoned beach ridges, swampy lowlands, and drumlin fields are only some of the many types of landforms to be found in the peninsula. Indeed, the region can be viewed as a unique geomorphological laboratory and an excellent example for classroom study. In this short paper an attempt is made to describe and analyze some of the more prominent landform features of the peninsula and the processes which have influenced their formation.

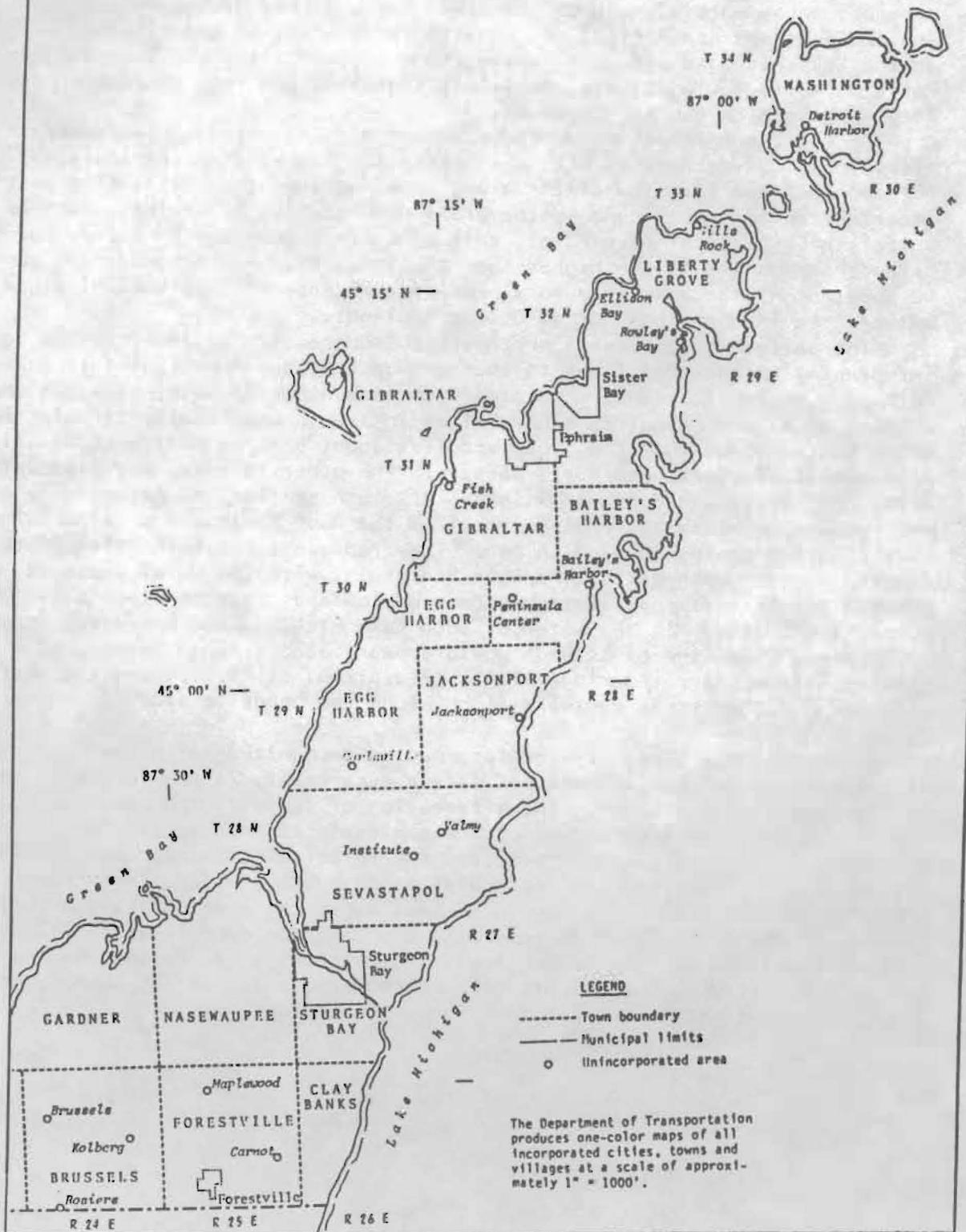
### LOCATION AND GENERAL CHARACTERISTICS

The Door Peninsula, located in northeastern Wisconsin, is part of the Eastern Ridges and Lowlands province of the state. The peninsula extends in a northeasterly direction into Lake Michigan to separate Green Bay on the west from the main body of Lake Michigan on the east. The peninsula is approximately 64 miles long and about 26 miles wide on its southern end, between the mouth of the Fox River and the city of Kewaunee on Lake Michigan (Map 1). The width of the peninsula gradually decreases to the northeast, to a minimum of about 3 miles near Gills Rock in the extreme north. The upland which forms the peninsula continues to the northeast in a string of islands and ends in the similar, but smaller Garden Peninsula of Michigan.

The western edge of the peninsula is formed by the irregular escarpment of the Niagara dolomite cuesta and consists of a series of steep slopes descending to the shores of Green Bay, often forming rocky headlands. The most important of these steep slopes or "bluffs," are from south to north: Government Bluff, in Potawatomi State Park; Fish Creek Bluff, west of Fish Creek; Eagle Bluff, in Peninsula State Park; Sister Bluff, west of Sister Bay; Ellison Bluff, west of Ellison Bay; and Deathdoor and Table Bluffs at the northern end of the peninsula (Map 2). To the east of the escarpment, a gently dipping backslope extends to Lake Michigan forming the main body of the peninsula.



**DOOR COUNTY POLITICAL SUBDIVISIONS  
DEPARTMENT OF TRANSPORTATION**

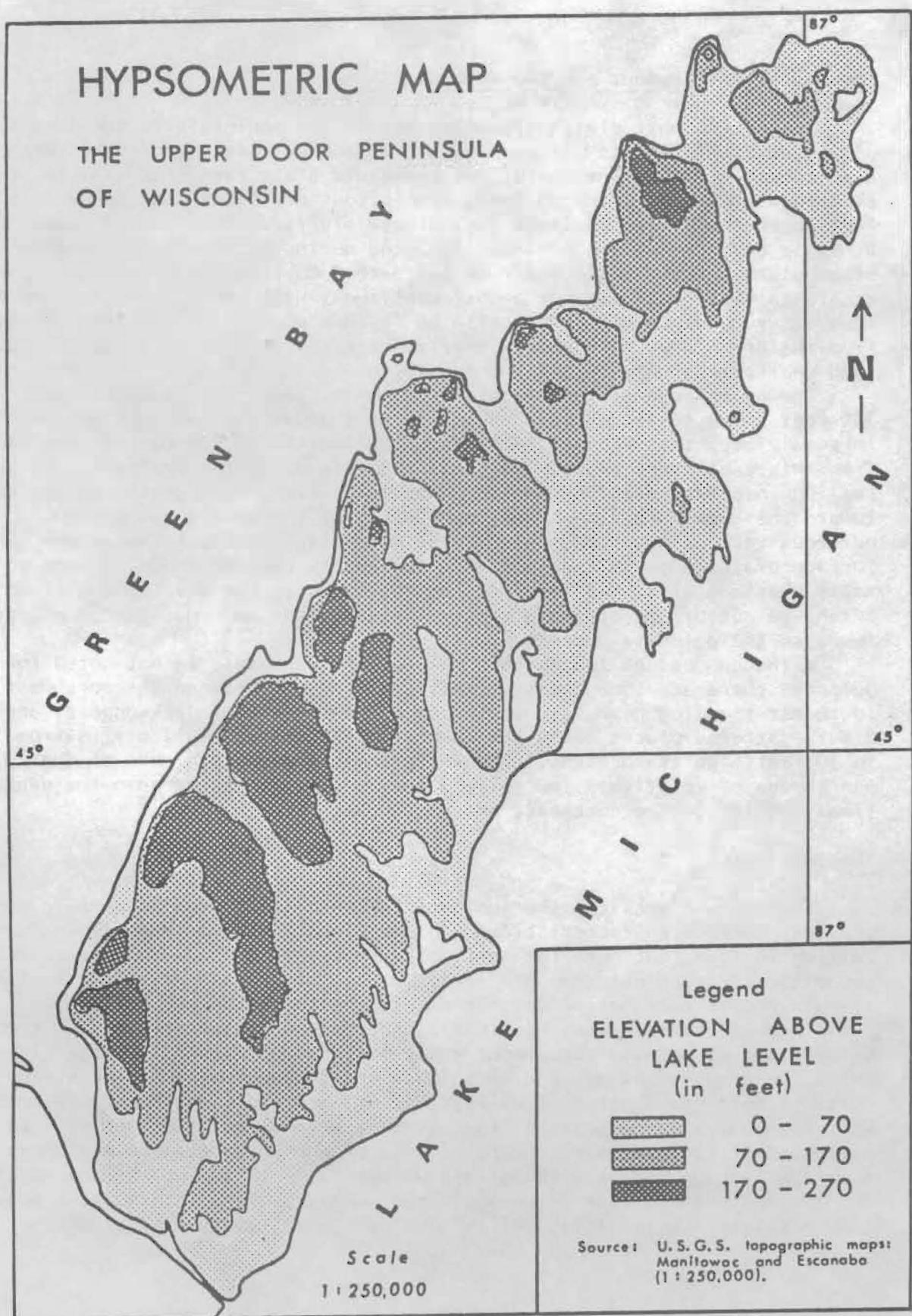


The crest of the Niagara escarpment does not follow an even line throughout its length down the western edge of the peninsula. It is broken by a series of lowlands running diagonally across the land in a generally northwest to southeast direction that have resulted in the formation of numerous embayments along both the Green Bay and Lake Michigan coasts. The lowlands are nearly flat and contain large areas of swampy land, especially on the Lake Michigan side. Moreover, some of them, like the Sturgeon Bay and Porte de Morts lowlands, are completely inundated and form navigable passages between Lake Michigan and Green Bay.

On the Lake Michigan side the eastward-dipping uplands have lower elevations. Nevertheless, they are noticeably higher than the lowlands between them and form low cliffs along some parts of the coast. The most important uplands are found in the areas of Whitefish Bay Point, south of Whitefish Bay, and at Cave Point, east of Clark Lake. North of Cave Point the uplands are only a little higher than the lowlands, and in some areas can be located only because they form prominent extensions into Lake Michigan between the indentations formed by the lowlands.

The pattern of alternate northwest to southeast trending lowlands and intervening uplands continues to the northeast of the Door Peninsula in the form of a chain of islands separated from each other by water passages (Map 1). Washington Island, about 25 square miles in area and generally circular in shape is the largest of the group and lies about 5 miles northeast of Gills Rock across the Porte des Morts Passage. The other islands, known as Detroit, Rock, St. Martins, and Summer Islands, are much smaller and extend in a definite southwest to northeast trending line from the Door Peninsula of Wisconsin to the Garden Peninsula of Michigan. They represent a continuation of the Niagara cuesta northeast of the Door Peninsula, with the water passages between the islands representing submerged lowlands cutting diagonally across the cuesta. If the water of both Lake Michigan and Green Bay were to be lowered, this line of islands would appear, according to Shrock, as a "rather narrow, serrated ridge with a precipitous cliff....along the west side and a rather steep eastward slope along the opposite side" (Shrock 1940, 101-102).

Three overall types of land form may be recognized in the peninsula: 1) the uplands and the associated western escarpment; 2) the lowlands; and 3) the coastland and shore. The alternation of lowlands and uplands, though one of the main characteristics of the peninsula, is not as easily noticed as one might expect. This arises from the relatively low overall relief of the region (Map 3). Whereas the peninsula has an average width of seven miles, the highest points are only about 250 feet above the level of Lake Michigan. The horizontal dimensions, therefore, are on average approximately 147 times the maximum vertical dimensions. Nevertheless, the uplands and lowlands can be identified on topographic maps of the area and, for the purpose of this study, the distinction between them is very important.



### The Western Escarpment and the Uplands

One of the most distinctive features of the peninsula is the long line of rugged bluffs on its western shore. In some places these bluffs descend almost vertically to the shore. At Peninsula State Park, for example, the escarpment takes the form of bold, precipitous cliffs, rising to over 150 feet above the waters of Green Bay. These bluffs also form bold headlands at Eagle Bay, Sister Bay, Ellison Bay, and northwest Washington Island. In other places, for example south of Egg Harbor to almost Sturgeon Bay, the escarpment forms a lower but almost continuous wall paralleling the shoreline of Green Bay. Bluffs may also be found a considerable distance inland from the Green Bay shore, particularly where the uplands parallel the lowland depressions which break the escarpment.

The upper edge of the Niagara escarpment stands out at approximately 700 feet above sea level, and about 120 feet above the level of Lake Michigan. In some places the land gradually rises an additional 100 to 150 feet back from this escarpment edge. Typically the uplands of the peninsula are gently rolling in character. The entire surface, however, dips gently to the east toward the Lake Michigan shoreline. On top of the upland can be found numerous bedrock outcrops, thin gravel deposits, and small swamps and marshes. Surface drainage on this upland is often poorly developed due in part to the small overland distances involved, but also due to the development of an extensive subsurface drainage system formed by the numerous joints and cracks found in the dolomite bedrock.

Although most of the eastern half of the peninsula is not noted for its uplands, there are some areas of noticeable relief between the northwest to southeast trending depressions. At Cave Point south of Jacksonport, and in other scattered places along the Lake Michigan shore, small cliffs from 15 to 30 feet high are present. These represent the eastern ends of the uplands and though of relatively low relief, they are still higher than the depressions located to the northeast and southwest.

### The Lowlands

The lowland areas of the peninsula are similar to the uplands in some of their surface characteristics. In many locations the land is gently rolling in form, but here the surface is developed on much thicker gravel deposits. Bedrock outcrops are rare. Overall the drainage of the lowlands is much poorer than on the uplands due to the fact that much of the land is closer to base level (Lake Michigan). Swamps and marshes typical of the uplands are also found throughout these lowlands but are much larger in size. Extensive areas of swamps and marshlands are found along the Mink River, north of North Bay, north of Baileys Harbor, and along the coast south of Whitefish Bay. Ephraim Swamp, for example, which lies about one mile to the southeast of Eagle Harbor, covers an area of approximately one and one-half square miles and merges with Baileys Harbor Swamp in the southern part of the lowland. The divide between the two swamps is less than 40 feet above Lake Michigan (Deller 1971, 24). This lowland is fairly typical of the

other lowlands of the peninsula and may be regarded as representative of them. The size of these swamps has proved a barrier to transportation across the peninsula. One often finds the few roads traversing the swamps following abandoned beach ridges that encircle many of the bays.

In addition to the swamps and marshes, there are three large lakes on the eastern side of the peninsula. These are, from north to south, Europe Lake, Kangaroo Lake, and Clark Lake (Map 2). These lakes average about two to two and one-half miles in length and one mile in width, and they lie at the eastern ends of three of the northwest to southeast trending depressions. They are generally oval in shape and are oriented parallel to the lowlands that form them. All are separated from the water of Lake Michigan by areas of sand dunes, one-half to one-fourth of a mile wide.

#### The Coastlands and the Shore Zone

The shoreline of the peninsula is very irregular throughout much of its length. Most of the irregularity is due to the alternation between uplands and lowlands resulting in numerous indentations and projections. The Green Bay side of the peninsula representing the cliff face of the Niagara dolomite cuesta is characterized by prominent headlands and towering bluffs broken by seven indentations or bays. These indentations are, from south to north, Sturgeon Bay, Egg Harbor, Fish Creek Harbor, Eagle Harbor, Sister Bay, Ellison Bay, and Hedgehog Harbor (Map 2). All of the bays have sand and cobble beaches at their heads and open to the northwest. Most of them average between one and two miles across at their mouths and provide excellent deep water anchorages for boats. At an early date all of these harbors became important centers for trade, leading to the development of small villages. The villagers often had to build on the sides of the neighboring upland tracts bordering the bays, for the lowlands in back of the bays were generally very low-lying, poorly drained, and extended a good distance inland. This tendency for many villages on the Green Bay coast to cling to the neighboring uplands has greatly enhanced their picturesque character and has made villages such as Sister Bay, Ephraim, and Fish Creek the favorite tourist stops of the peninsula.

The Lake Michigan shore also has numerous bays, one for each of the corresponding bays on the Green Bay shore. Long stretches of sandy beach, dune fields, and coastal marshes dominate much of the shoreline along these bays. Bedrock outcrops are rare. The gentle slope of the Niagara cuesta off the east side of the peninsula has aided the filling of many of these bays with sediment, making most very shallow. The deposition of sand and gravel by glaciers, the movement of sand by longshore currents, and the dumping of silt and clay brought by rivers draining much of the interior have all helped to fill in these bays. As a result, most east coast embayments are poor anchorages for ships, and few have developed villages typical of the west shore, the exceptions being Jacksonport and Baileys Harbor.

#### LANDFORM PROCESSES WHICH HAVE SHAPED THE PENINSULA

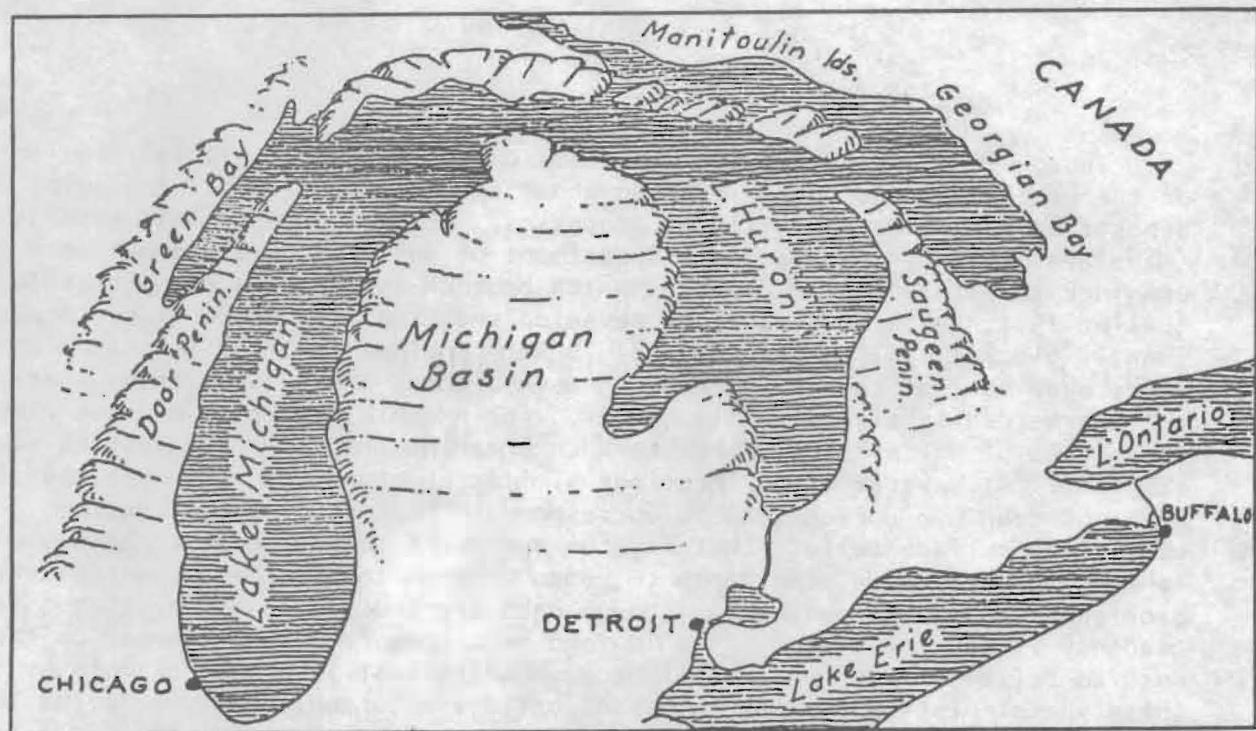
The different types of landforms present within the study area are a result of various geomorphic processes working upon a relatively simple

geologic base of Niagara Dolomite. The Door Peninsula is one of a number of peninsular and insular features arranged in a strikingly concentric pattern around the structural Michigan Basin. Lake Michigan on the western side of the basin corresponds to Lake Huron on the eastern side. Similarly, the Door Peninsula corresponds to the Saugeen Peninsula of Ontario; Green Bay to Georgian Bay; and the islands between the Door and Garden Peninsulas to the Manitoulin Islands (Map 4).

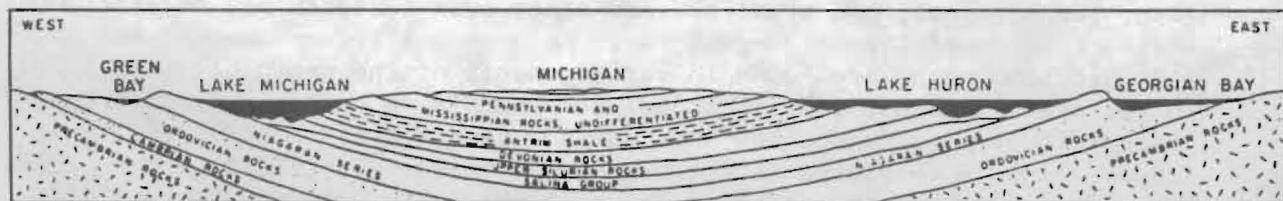
This very pronounced symmetrical pattern of land and water is the result of the synclinal structure of the Michigan Basin (see geological cross section). The Niagara Dolomite is a cuesta-former because of its relatively high resistance to erosion. This formation is the cap rock of the Niagara cuesta escarpment which surrounds, in a discontinuous line of peninsulas and islands, the Michigan Basin and the associated water bodies of Lake Michigan and Lake Huron. In the Door Peninsula, the cliffs along the western shore represent the escarpment of the cuesta, while the main body of the peninsula is the cuesta's dip slope. Bordering the cuesta on the west is the Green Bay-Lake Winnebago lowland, and on the east, the Lake Michigan basin. Below the base of the Niagara formation lies the more easily erodible Richmond shale. It forms the main part of the Green Bay-Lake Winnebago lowland and is exposed in many areas along the base of the escarpment south of Sturgeon Bay. North of Sturgeon Bay, however, surface exposures of the shale are entirely absent.

It is upon this base of dolomitic limestones of Silurian age, that the main landform features of the peninsula have evolved. The general cuesta shape of the peninsula, and its division into the northwest to southeast trending uplands and lowlands are thought to be the result of pre-glacial stream erosion of the tilted bedrock surface. It has been suggested that the lowlands which cross the peninsula were cut by pre-glacial tributaries of either a former river which occupied the basin of Lake Michigan, or one which occupied the Green Bay and Lake Winnebago lowland (Martin 1932, 230). It may have been that at various times in the geologic past both events occurred, but there is little evidence to support either one. The gap in the escarpment at Sturgeon Bay and the Sturgeon Bay lowland itself, are believed to have been cut by the pre-glacial predecessor of the Menominee River, a tributary of a river which occupied the pre-glacial valley located in the present area of Lake Michigan.

It is also possible that glacial erosion may have played a role in the formation of many of the lowlands crossing the peninsula. The existence of straight cliffs along much of the Green Bay shore of the peninsula (for example, southwest of Egg Harbor and west of the city of Sturgeon Bay), the absence of small outliers of Niagara dolomite, and the relative rarity of caverns in the dolomite, have all been used as evidence of the effects of glacial erosion in the Door Peninsula (Thwaites and Bertrand 1957, 843). The interpretation of such evidence, however, has resulted in a long standing controversy among those familiar with the land form of the peninsula. According to Martin, the only major features of the peninsula which can be more or less attributed to the effects of glacial erosion, and more specifically to the effects of glacial plucking controlled by joints, are the straight clifffed portions of the escarpment, such as the section along the



Map 4 (from: Lobeck, p. 15)



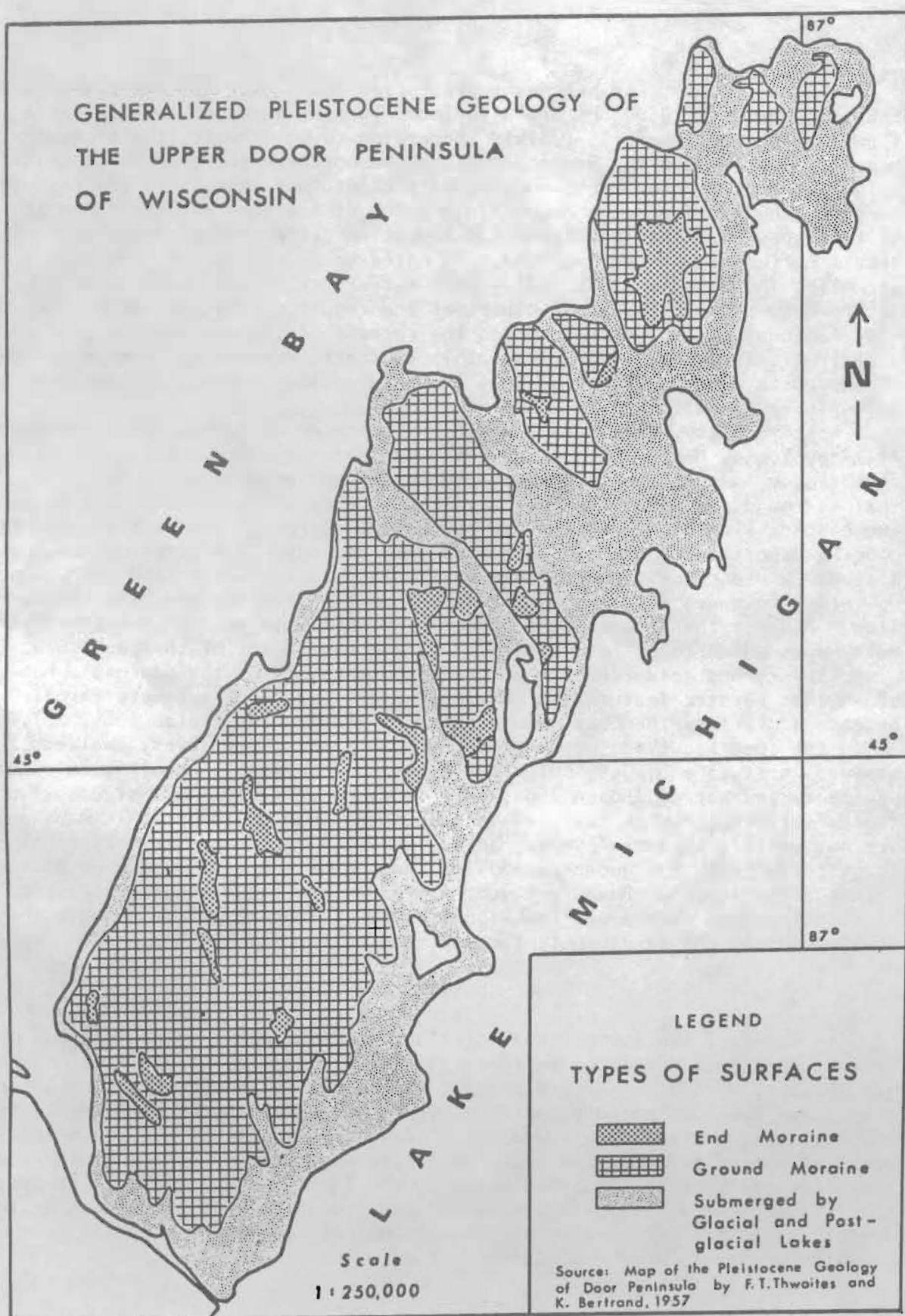
Geological Cross Section of the Michigan Basin (from: Pincus, p. 12)

Green Bay coast between Egg Harbor and Sturgeon Bay (Martin 1932, 244-250). Thwaites and Bertrand (1957) reviewed various glacial erosion arguments and came to the rather well-guarded conclusion that "despite the occurrence of highly weathered bedrock and of a few caverns, glacial erosion must certainly be regarded as one of the most potent forces in shaping the bedrock which controls the present landscape." Despite the numerous interpretations of the glacier's erosional effects on the peninsula, the data remain insufficient to permit formulation of any definite conclusions.

Though little direct evidence exists on the extent of glacial erosion on the peninsula, much more is known about the characteristics of glacial deposition and other depositional processes. Several hundred well records (made available by the Wisconsin Department of Resource Development) were examined to determine the depth at which bedrock is found in the peninsula (Deller 1971, 90). This analysis revealed that the overburden (i.e., predominantly glacial till and beach sand) is very shallow (usually less than 2 feet) over most of the study area. However, there are several areas where the overburden is significantly deeper. For example, depth to bedrock along the shores of Whitefish Bay and Clark Lake varies from approximately 60 to 125 feet. At several other locations similar observations have been made. Areas of deep overburden seem to correspond to regions of low elevation and little surface relief, that is, the northwest to southeast trending lowlands. In many cases, the depth to bedrock seems to be greater on the Lake Michigan side of the peninsula, though data are too scanty to say that this tendency is generally true. The lowland extending from Eagle Harbor on the west to Baileys Harbor and Moonlight Bay on the east is a good example of this type of distribution of the transported overburden. Maximum depths to bedrock from 50 to 70 feet were recorded on the Green Bay side of this lowland, while these depths ranged from 70 to 80 feet on the Lake Michigan side. This suggests a northwest to southeast gradient for the bedrock bottom of the lowland. Assuming that pre-glacial rivers did cut the lowlands, and that glaciation contributed little to their deepening, these figures would suggest that the pre-glacial streams flowed across the cuesta from northwest to southeast.

The deposition by glaciers also left many of the most obvious landform features of the peninsula. The deranged drainage, the large areas of marshland, the moraines, the drumlins, and other such features may be attributed to the effects of glacial deposition. Large areas of Woodfordian age morainic topography are found in various parts of the peninsula (Map 5). In the area northeast of Sister Bay, for example, a morainic type of topography with typical knobs and kettles is a very visible part of the landscape. Also in this area is the most prominent drumlin field of the peninsula. These drumlins have been studied in great detail by O.L. Kowalke and have been found to consist of unsorted boulders, sand, and clay (Kowalke 1952, 15-16). Exposures of the more recent red Valders till in the peninsula are relatively rare and occur only in very small isolated patches.

In addition to pre-glacial stream erosion, glacial erosion, and glacial deposition, wave erosion and other shore processes operating during glacial and recent times have had a major impact on the formation of the peninsula. Two abandoned shore lines representing former levels of the present Great Lakes are generally recognized in the region. At the 17 to 20 foot level are found shore zone remnants of glacial Lake Nipissing (Kowalke 1946, 293). Several former beach ridges and cliffs of Nipissing age (c. 3500 BP) are found on the dip slope of the cuesta and in various scattered locations near the base of the escarpment along the Green Bay shore (Thwaites and Bertrand 1957, 874). Probably the best developed and preserved Nipissing shore zone features are the ridges formed just north of Baileys Harbor.



Ridges, cliffs, and beaches representing the higher and older glacial Lake Algonquin (c. 8500 BP) are also found in many parts of the peninsula (Thwaites and Bertrand 1957, 874). According to Goldthwait, the highest beaches of Algonquin age are found along the northern shore of Washington Island at an elevation of 95 feet above present lake level. In contrast to this, the corresponding Algonquin beaches at Sturgeon Bay are found at 40 feet above present lake level (an elevation difference of about 55 feet over a horizontal distance of about 40 miles or an average of 1.38 feet per mile) (Goldthwait 1907, 102). This difference in altitude has been interpreted by Goldthwait and others as the result of the gradual post-glacial regional uplift which followed the retreat of the continental glaciers (Goldthwait 1907, 111-119). Since this isostatic rebounding is much greater in the north, the Algonquin beaches in those areas are found at considerably higher elevations.

Most recently, activity by waves and shore currents has led to additional filling of many Door County embayments with sand deposits. These can be found today in the form of numerous submerged and exposed beach deposits that surround the inside of most bays, but are best represented by bays on the eastern side of the peninsula. Longshore currents have carried sand from glacial deposits and eroding headlands into the bays of the region for deposition. Where deposition has been particularly active, the sand was whipped up into sand dunes which form a prominent part of the eastern coast shoreline. Many of these dune areas actually cut off what were once much larger embayments which today form the lakes of the east coast of the peninsula.

Very recent research on the karst geomorphology of the peninsula has shown that karstic features in the peninsula "....are of a greater areal extent and variety than has been documented previously" (Rosen 1984, 28). Among the specific types of karstic features present are caves, swallets, stepped karst assemblages, solutionally widened joints, sinkholes, dolomite pavement, and karren (Rosen 1984, 29). Because of their small size most of the karstic features in the peninsula do not appear on topographic maps and are not visible on aerial photographs. Nevertheless, they are very significant features in the geomorphology of the region and well-deserving of the recent attention they have received. In addition, the widespread presence of such features points out the significance of subsurface drainage to the development of the landform features of the peninsula.

#### CONCLUSION

In summary, the salient characteristics of the Door Peninsula's present land form appear to be the result of pre-glacial stream erosion, glacial action, and former and present wave work. Although processes other than these have undoubtedly operated, it is suggested that these three sets of processes, working upon a geological base of slightly tilted sedimentary rocks of varied hardness and resistance, are most responsible for the present characteristics of the Door Peninsula's land form. Add to these major processes the influence of differential isostatic rebound along with subsurface drainage processes and one obtains a geomorphological laboratory of great complexity, one truly worthy of further study.

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