The Geoarchaeological Context of Grand Island

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ABSTRACT Interpretations of the geoarchaeological context of Grand Island, Michigan have been a critical part of prehistoric archaeological investigations. Geoarchaeological investigations have generally focused on determining the age of various geomorphic surfaces, interpreting site settings, and paleoenvironmental reconstructions. Although no Paleoindian materials have yet been found, the island was available for human occupation following final deglaciation sometime after 13,000 cal b.p. High lake levels during the Nipissing Phase (ca. 5700–4450 cal B.P.) built a series of coastal landforms that where heavily used by Archaic Period people. Post-Nipissing fluctuations in lake levels presented a highly variable coastal setting for Terminal Archaic and Woodland Period people.

In the last 15 years, extensive archaeological investigations have been carried out on Grand Island. Archaeological surveys have identified many prehistoric and historic sites, several dozen of which have been tested; two have had large-scale excavation (Benchley et al. 1988; Skibo 2003, Skibo et al. this volume). The archaeological work has necessarily required an understanding of Grand Island's evolution for proper interpretations of past site settings, as well as an understanding of site stratigraphy and formation processes. Therefore geoarchaeology, the application of geoscience techniques to archaeological questions, has been a part of these investigations from the start of archaeological research on the island (Yuen 1988). In particular, the principal focus of geoarchaeological research on the island has been on paleoshoreline settings because of their importance for prehistoric settlement, resource utilization, and transportation (Anderton 1993, 1995, 1999; Dunham and Anderton 1999).

The purpose of this paper is to provide an overview of the current understanding of the geoarchaeology of Grand Island. All dates presented were converted to calendar years before present (A.D. 1950) using CalPal Online (2004), unless otherwise stated. All elevations are in meters above sea level based on USGS topographic maps (1985 metric provisional) as well as surveyed elevations at selected locations (Anderton 1993, 1995). A variety of methods, including digital elevation models, color infrared imagery, topographic maps, and field reconnaissance, were employed to reconstruct Late Quaternary conditions on Grand Island.

Geographical Setting

Grand Island (Figure 1) is the largest island on the south shore of Lake Superior. Separated from the mainland by a 600 m wide strait, Grand Island is

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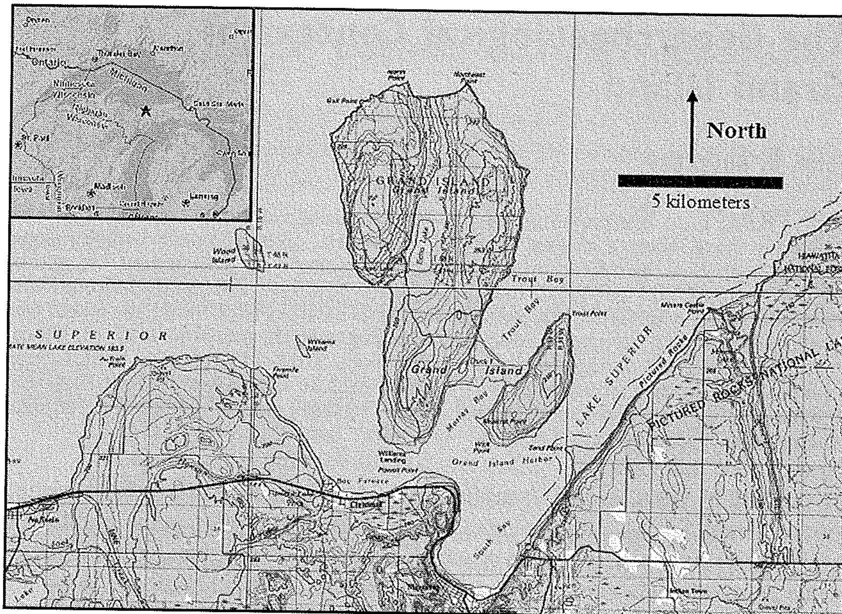

Figure 1. USGS topographic map of Grand Island and surroundings. Inset showing regional location.

located offshore from the town of Munising, Michigan. The island is roughly 8 km wide and 13 km long, with about 40 km of shoreline, and containing approximately 5,261 ha. Generally speaking, Grand Island consists of two parts: a larger, western portion, which is connected by a low, narrow isthmus to a smaller, eastern lobe, known locally as the "Thumb." Elevations range from 183 m at the Lake Superior shoreline, to over 300 m above sea level on the highest parts of the island. It is primarily wooded with a dense hardwood forest on the uplands and coniferous forest in the lowlands.

Bedrock Geology

An understanding of the bedrock geology of Grand Island is archaeologically important because certain rock units appear to have offered raw materials for stone tool production (Marcucci 1988). Also, the proper identification of potential archaeological site settings often hinges on the interpretation of the geomorphic processes that created the associated landform, including the erosion of bedrock units.

Grand Island lies at the northern edge of the Michigan Structural Basin, a series of various types of sedimentary rock units that gently dip to the south towards the center of the Lower Peninsula of Michigan (Dorr and Eschman 1970). Although there are some discrepancies in the naming and mapping of rock formations in Alger County (Michigan Department of Natural Resources

1987; Schwenner 2003), Hamblin's (1958) study of the Cambrian sandstones of northern Michigan presents the most detailed information on the island's bedrock geology (Table 1). His map of portions of Marquette and Alger Counties indicates that three rock formations are present on Grand Island (Hamblin 1958: Plate 2). These formations include a basal unit of Jacobsville Sandstone, overlain by Munising Formation Sandstone, and finally partially capped by Au Train Formation sandy dolomites and dolomitic sandstones (alternatively, the Trempeleau Formation [Michigan DNR 1987; Schwenner 2003]). The western part of the island is mapped with all three formations present, while the "Thumb" is shown with only the Munising and Au Train Formations (Hamblin 1958: Plate 2).

The Jacobsville Sandstone Formation, a coarse red sandstone of late Precambrian or early Cambrian age, is the primary bedrock exposed in most of the wave-cut cliffs of the western part of Grand Island. The Jacobsville Sandstone Formation extends from just under lake level on the east side of the "Thumb," to over 36 m in thickness above Lake Superior on the northwest end of the island (Hamblin 1958:66, Figure 35).

The Cambrian age Munising Formation lies stratigraphically above the Jacobsville Formation. The Munising Formation consist of three distinct units including, in ascending order, a basal conglomerate, the Chapel Rock Member, and the Miner's Castle Member (Hamblin 1958:71). The basal conglomerate outcrops near water level on the east side of Grand Island, most notably along the water's edge on the "Thumb." Hamblin (1958:73) indicates that 90 percent of the types found in the basal conglomerate are vein quartz, quartzite, and chert, with small amounts of slate, iron formation, basalt, granite, and sandstone. Much of the basal conglomerate on Grand Island consists of pebbles and cobbles of quartzite. In terms of sources of raw materials for prehistoric people, the basal conglomerate of the Munising Formation likely served as a source of quartzite cobbles for stone tools production at the Trout Point I site on the north end of the "Thumb" (Marcucci 1988; Benchley et al. 1988).

Lying stratigraphically above the basal conglomerate, the Chapel Rock Member of the Munising Formation is a well-sorted, white sandstone, with relatively large cross-bedding. The third member of the Munising Formation,

Table 1. Grand Island Bedrock Geology in Stratigraphic Order (after Hamblin 1958).

Formation	*Age*	*Rock Type*	*Units*
Au Train	Ordovician	Dolomitic sandstone	None
Munising	Cambrian	Fine-textured, light grey sandstone	Miner's Castle Member Chapel Rock Member Basal Conglomerate
Jacobsville	Late Pre-Cambrian/ early Cambrian	Coarse red sandstone	None

Miner's Castle Member, is a poorly-sorted, white or light grey-colored sandstone, with smaller-sized cross-bedding. It is stratigraphically above the Chapel Rock Member. Collectively, the Chapel Rock and Miner's Castle Members often form the upper part of exposures seen in the lake cliffs of the western part of Grand Island. On the "Thumb," however, they outcrop much closer to lake level, immediately above exposures of the basal conglomerate.

Although the Michigan Department of Natural Resources geology map (1987) does not indicate any formations on Grand Island above the Munising Formation, Hamblin (1958) maps the Au Train Formation, an Ordovician age sequence of thin- to medium-bedded sandy dolomites and dolomitic sands, at the top of the rock section on the island. It occurs in three isolated patches on the highest elevations of the island where it forms a relatively resistant cap rock (Hamblin 1958: Plate 2). Although primarily interested in soils, Schwenner (2003:19) also indicates three outcrops of dolomitic sandstone in the same areas, which he indicates are Au Train Formation (alternatively, Trempeleau Formation). This same formation is also mapped at the top of the rock sequence on the mainland, where it forms a cap rock on the cliffs of the Pictured Rocks immediately east of Grand Island (Michigan DNR 1987; Schwenner 2003). Clearly, remnants of a dolomitic cap rock are present on the highest parts of the island.

The Late Pleistocene Environment: Are they High Scarps or Ancient Shorelines?

The bedrock of Grand Island was glaciated numerous times during the Quaternary Period; however, it is the last 13,000 years that is of particular interest in this study. Retreating ice probably first exposed Grand Island sometime between 13,000 and 12,700 cal B.P. (Drexler et al. 1983; Farrand and Drexler 1985). A complex series of high glacial lake stages likely occurred as ice retreated across the Upper Peninsula, however, any evidence of these stages, such as shorelines, that may have been created on Grand Island, was destroyed when glacial ice readvanced, completely covering Grand Island during the Marquette Advance (Drexler et al. 1983; Farrand and Drexler 1985; Hughes 1978).

Marquette Advance ice reached its maximum position at approximately 11,400 cal B.P., extending several miles inland or south of the present shoreline of Lake Superior and forming a series of moraines (Figure 2). The Grand Marais I moraine, located approximately 10 km inland from Grand Island, marks the southernmost extent of the Marquette Advance ice (Drexler 1981). Two recessional moraines, Grand Marais II and III, marking recessional positions of the Marquette Advance ice are also recognized immediately to the west of Grand Island, just inside the outermost or terminal moraine (Drexler 1981).

Also during the Marquette Advance, glacial meltwater was draining to the south through the Au Train–Whitefish channel, a large spillway that bisected the Upper Peninsula north to south between the current locations of the towns

Table 2. Lake Phases and Associated Geomorphic Evidence from Grand Island (from Anderton 1993, 1995; Farrand and Drexler 1985; Yuen 1988).

Lake Phase	*Cal BP*	*Geomorphic Evidence*
Post-Duluth	11,200–11,100	Unclear; high scarps ranging from 225 to 240 meters may reflect retreat of Au Train Formation capstone (mesa and scarp) rather than shorelines.
Minong	10,700	Unclear; may have been obscured by later Nipissing shoreline.
Houghton	8900	Submerged remains of forest at 60 meters depth on floor of East Channel. Gully system etched into uplands above 192 meters.
Nipissing I	5400	Prominent wave-cut shoreline at about 192 meters rimming much of island. Island separated into three lobes.
Nipissing II	4450	Extensive depositional coastal landforms between about 186 to 192 meters, including the Williams Landing Spit, Duck Lake Cuspate Barrier, Muskrat Point Cuspate Barrier, and others.
Post-Nipissing to Modern	Post-4450	Beach ridge complex/Tombolo between east and west lobes of island below 186 meters. Flooding of lowest beach ridges at head of Murray Bay due to post-1400–1200 cal B.P. transgression.

of Au Train and Rapid River (Drexler et al. 1983; Hughes 1990). Eventually, Marquette Advance ice began to retreat, possibly exposing Grand Island at about 11,200 cal B.P. as ice left the Grand Marais III moraine (Drexler 1981), leaving behind a blanket of loamy till on the uplands of Grand Island (Schwenner 2003). However, as ice retreated, drainage from Glacial Lake Duluth in the western Superior basin expanded to the east, initiating a short-lived series of nine named Post-Duluth Phase ice marginal lake stands (Drexler 1981; Farrand 1960; Farrand and Drexler 1985). These high lakes, thought to have been in existence for only about a century (11,200–11,100 ^{14}C B.P.), were created by dropping water levels as different outlets were opened or deepened by erosion.

By interpreting geomorphic evidence and attempting to correlate it with known elevations of former shorelines reported from other parts of the region, Yuen (1988) identified three possible Post-Duluth Phase shorelines on Grand Island. A "wave cut bluff, gully system developed below 270 m on western Grand Island" and a "former wave cut bluff" at 255 m were correlated with the Shelter Bay Phase (Yuen 1988:36, Table 1). Likewise, a "former wave-cut bluff, gully system developed between 192 and 240 m on eastern Grand Island" was correlated with the Huron Mountain Phase (Yuen 1988:36, Table 1). This feature is located on the higher elevations of the "Thumb." And, thirdly, "beach

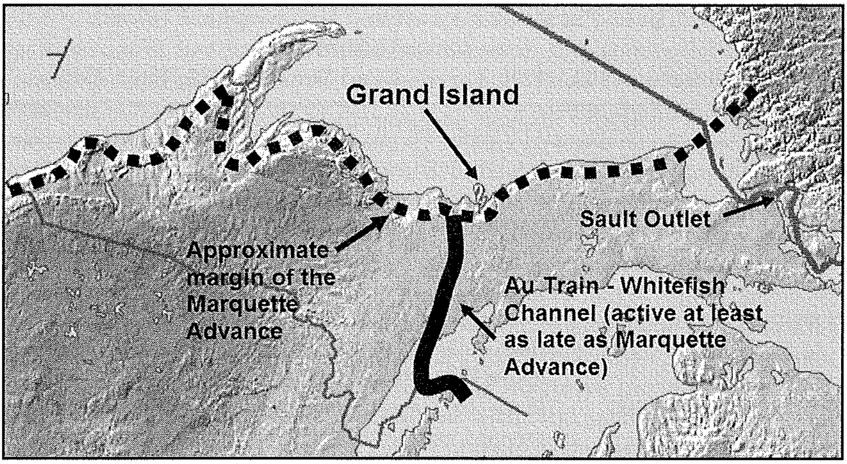

Figure 2. Grand Island in relation to the Marquette Advance Margin and the Au Train-Whitefish Channel, 11,200 calendar years B.P. (DEM, MSU-Geography Department).

shingles" on the western lobe of Grand Island between 225 and 210 m were attributed to an unnamed lake phase.

Yuen (1988) identified three prominent high scarps located in the interior of Grand Island as evidence of two named Post-Duluth Lake Phases (Figure 3). These high scarps present important questions for archaeologists working on Grand Island. Are they old glacial lake shorelines that might have been used by prehistoric people? Should archaeological survey efforts target these landforms? Obviously, Yuen (1988) interpreted them as shorelines. However, a careful examination of the scarps suggests that they are probably not coastal features. The first of these high scarps is located on the northwest side of the island (Sections 21, 28, 19, and 32, T48N, R19W) where it forms a distinct break in the topography between 240 and 285 m. This particular scarp was identified in a photograph of the western side of Grand Island by Dorr and Eschman (1970: 218, Figure ix–33) as a "wave-cut cliff and gently sloping wave terrace below, along uplifted glacial lake shore" in their seminal work on Michigan geology. The second scarp is located on the southwest end of the island (Sections 10, 15, 16, and 22, T47N, R19W), where it also forms a distinctive break in the topography, but at slightly lower elevations between 225 and 260 m. A third high scarp, which was also noted by Yuen (1988), is present on the island's "Thumb" between 225 and 240 m in Sections 12 and 13, T47N, R19W.

The high scarps of Grand Island present a number of characteristics that imply they may not be shorelines as suggested by Yuen (1988) and Dorr and Eschman (1970). Actual shorelines are usually traceable for much greater distances. If the scarps were shorelines they would have likely encircled the high surfaces of Grand Island, creating three small islands. Rather, all three scarps are only traceable along the west sides of the high ground and are not traceable for more than 3 to 4 km. It is possible that the scarps were created by higher wave energy due to their western aspects, which would have exposed them to prevailing winds. However, no shorelines at comparable elevations have been found on the mainland. Therefore, rather than shorelines attributed to some short-lived glacial lake phase that in all probability didn't last long enough to cut such prominent topographic breaks, the high scarps of Grand Island are thought to be something more akin to mesa-and-scarp landforms.

Mesa-and-scarp landforms occur when a relatively resistant layer of rock, or cap rock, is underlain by relatively less-resistant rock. Headward erosion by streams progressively strips away the weaker underlying rock, which undermines the overlying capstone, causing a cliff or scarp to form. Although mesa-and-scarp landforms are most commonly found in arid environments, the bedrock geology on Grand Island, with its overlying resistant dolomitic sandstone and underlying weaker sandstones, could contribute to the formation of this type of landform. It is important to note that the Au Train Formation acts as a capstone on the top of the rock section in the Pictured Rocks, immediately east of Grand Island (Hamblin 1958). Indeed, careful inspection of the high scarps shows a near perfect correlation to the Au Train Formation outcrops on Grand Island as mapped by Hamblin (1958).

In addition to the significant meltwater drainage to the west in the Au Train–Whitefish Channel at this time (roughly 11, 200 cal B.P.), meltwater eventually began flowing to the east between the uplands to the south of Grand Island and the ice margin to the north, following newly exposed lower

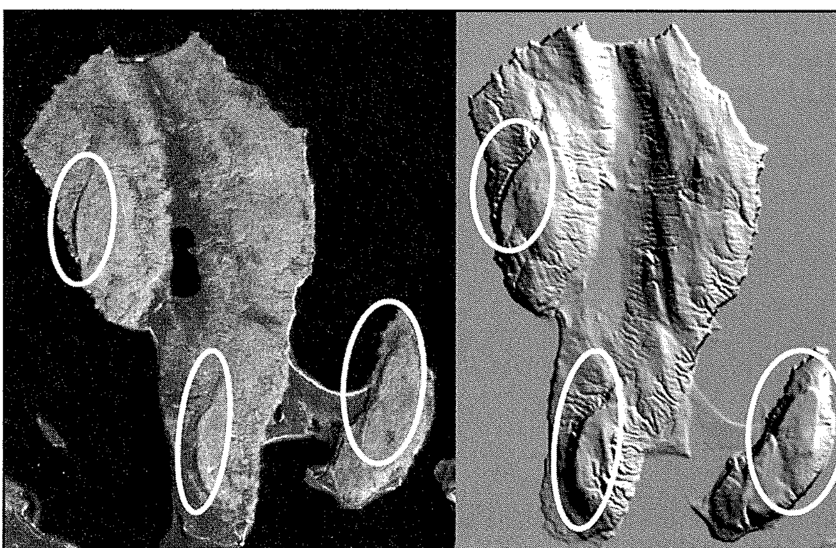

Figure 3. Aerial photograph (Michigan DNR) and digital elevation model (NMU-Geography Department) of Grand Island showing prominent high elevation scarps circled in white.

elevation outlets. The easterly flowing glacial outwash carved a series of east-west trending terraces that have been traced and mapped to the east in the Pictured Rocks National Lakeshore (Blewett 1994). It is likely that this same period of eastward flowing meltwater drainage carved a deep valley between Grand Island and the mainland, which is currently occupied by the waters of Grand Island Harbor.

Grand Island was permanently ice-free at least as early as 11,200 cal B.P. Indeed, Drexler (1981:231) reports a radiocarbon date of 10,221 ± 335 cal B.P. (9090 ± 240 ^{14}C B.P.) from a core taken from the base of Echo Lake on Grand Island. This radiocarbon date is the oldest available for Grand Island and represents a minimum estimate for the earliest possible time the island could have been available for human occupation. As ice continued to retreat to the north, Lake Minong (Main) was formed between about 11,200 and 10,700 cal B.P. (Drexler et al. 1983; Farrand and Drexler 1985) between the glacial margin and the uplands to the south. Yuen (1988) suggests that the Minong Shoreline is present on Grand Island between 202 and 199 m elevation, based on a possible wave-cut scarp he identified near Trout Point on the northern end of the "Thumb." However, no comparable scarps are identifiable anywhere else on Grand Island or the mainland at this elevation. Furthermore, Farrand and Drexler (1985:25) indicate that on the west side of Lake Superior the Minong shoreline, although uplifted by isostatic rebound, can only be traced as far south as Grand Portage, Minnesota, where it is intersected by the younger Nipissing shoreline. On the east side of the Superior basin, Farrand and Drexler (1985:29) indicate that a "good candidate" for the (Early) Minong shoreline is found between 213 and 219 m in the vicinity of Pendills Bay, to the west of Nadoway Point. However, this possible Minong shoreline has not been traced any farther west than Pendills Bay. The reason the Minong shoreline has not been traced any further is that later high lake phases, namely the Nipissing Phase, likely submerged the Minong shoreline in these areas of the south and west shores of the Lake Superior basin where there has been less isostatic uplift. Consequently, the Minong shoreline is probably not present on Grand Island, or, if it is present, it is at or very near the elevation of the Nipissing shoreline.

Sometime after 10,700 cal B.P., Lake Minong began to fall as down-cutting progressively lowered the Nadoway Point sill, west of the Sault (Farrand and Drexler 1985). The down-cutting was caused by a series of catastrophic floods related to the release of water from Lake Agassiz, as retreating ice opened the Nipigon channels on the northwest side of Lake Superior (Farrand and Drexler 1985). Yuen (1988:37) believed that the decline of Lake Minong was "recorded in numerous concave scarps on the sandstone bluffs around the island." This is not possible as the Minong shoreline is likely not preserved on Grand Island. The scarp at 202–199 m near Trout Point, mentioned by Yuen (1988) as possible evidence for Lake Minong, is more likely the result of localized geomorphic processes, such as groundwater seepage and/or frost-freeze action.

Early Holocene Environment and the Middle Archaic Hiatus

Following the Minong Phase, lake levels in the Superior basin began to drop as the sill at Nadoway Point near the Sault was down-cut (Farrand and Drexler 1985), reaching levels significantly lower than modern elevations of Lake Superior. Indeed, during the Houghton Low Phase (8900 cal B.P.), water in Superior basin dropped at least 60 m based on submerged stumps found at that depth on the bottom of the East Channel off the east side of Grand Island by local divers (Peter Lindquist, personal communication, 1992). A sample from one of these stumps was dated at 8777 ± 157 cal B.P. (7910 ± 100 ^{14}C B.P., Curtis Larsen, personal communication, 1992) indicating that they likely represent the remains of a forest that colonized the base of a steep-sided river valley or narrow strait that separated Grand Island from the mainland during the Houghton Low Phase.

Yuen (1988) reported a series of gully systems on the higher elevations of Grand Island, which he associated with Post-Duluth lake levels. However, these gully systems are clearly related to fluvial erosion, rather than coastal lacustrine processes. Due to the extreme drop in local base level during the Houghton Low Phase, streams and rivers were able to deeply erode the uplands creating "arroyo-like" systems of gullies throughout much of the Lake Superior basin. On Grand Island, these Houghton Low Phase-related gully systems are generally found between 250 and 192 m, with some heads of gullies reaching as high as 285 m on the west side of the island. The down-cutting dissected glacial sediments on the uplands and in most cases cut well down into the bedrock (see Figure 4). Consequently, most of the gullies are bedrock floored. Also, with some exceptions, most of the gullies no longer

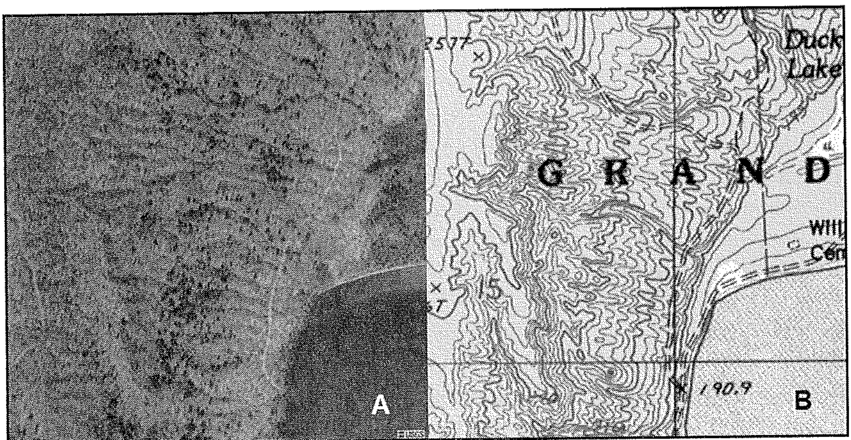

Figure 4. Aerial photograph (A) and topographic map (B) excerpts showing Houghton Low Phase-related gully system on the uplands along the east side of Murray Bay (both USGS).

contain flowing water, are underlain by relatively well-developed soils, and are covered by forest vegetation.

The environment for human occupation at this time would have presented an actively eroding landscape with streams and rivers deeply eroding their valleys. The dissection of the landscape probably started at least as early as 10,200 cal B.P. as lake levels began dropping from the Minong Phase. However, by at least 8900 cal B.P., falling water levels had stabilized at the Houghton Low Phase, and then began a rising trend, which is known as the Rising Nipissing Phase (Farrand and Drexler 1985; Larsen 1985). On the mainland shore opposite the west side of Grand Island just north of the town of Christmas, two recently reported radiocarbon dates, found during the monitoring of an archaeological site (FS 09-10-03-692) in the Hiawatha National Forest, seem to verify this rising trend (Franzen 1998). A peat layer buried under 1.5 m of sand, found outcropping in an eroding shoreline bluff, was radiocarbon dated at 7378 ± 67 cal B.P. (6470 ± 80 ^{14}C B.P.; Franzen 1998). In addition, a white pine (*Pinus strobus*) log found in a matrix of peat in the modern nearshore zone of Lake Superior just offshore from the site was radiocarbon dated at 7129 ± 88 cal B.P. (6230 ± 60 ^{14}C B.P.; Franzen 1998). These dates probably reflect the burial of a forested wetland by lacustrine sand, which was likely deposited as rising lake levels inundated low coastal areas in the Grand Island area.

Obviously, prehistoric people living on the island at this time (between 8900 and 5700 cal B.P.) would have had to contend with a continually rising shoreline. Consequently, any evidence from coastal settlements of this period is undoubtedly submerged. Not surprising, archaeological evidence from the Early and Middle Archaic Periods has not been found on Grand Island.

Middle Holocene Environment and the Late Archaic Use of the Nipissing Shoreline

Almost without exception, the Houghton Low Phase gullies on Grand Island are truncated by the Nipissing I shoreline, which forms a distinctive break in topography where the dissected upland landscape ends abruptly. At this time, and until the Sault became the controlling outlet for the Lake Superior basin, all three of the major upper lake basins (Superior, Michigan, and Huron) were contiguous. The Nipissing I shoreline represents the maximum water level attained following the rising trend (Rising Nipissing) after the Houghton Low Phase. With the exception of recently eroded areas, most landscape surfaces on Grand Island above the Nipissing I shoreline predate the Nipissing transgression, and therefore are much older surfaces, while all surfaces below the Nipissing I shoreline are Nipissing age or younger.

On Grand Island, the Nipissing Phase is firmly dated by two radiocarbon dates of 5510 ± 104 and 5257 ± 188 cal B.P. (4810 ± 80 ^{14}C B.P. and 4590 ± 120 ^{14}C B.P.), taken from organic material in a 10 m thick exposure of beach sand on the north end of the island (Yuen 1988). The Nipissing I shoreline is at approximately 192 m on Grand Island (Anderton 1993, 1995), where it is often expressed as prominent wave-cut bluffs formed in bedrock. Following Nipissing I, lake levels dropped to the Nipissing II level, which is thought to be at about 186 m on Grand Island (Anderton 1993, 1995). Collectively, both Nipissing I and II shorelines are traceable around much of Grand Island (Anderton 1993, 1995) and are characterized by the presence of extensive depositional landforms such as spits and barriers (Figure 5).

In general, during the Nipissing Phase, high water levels resulted in the separation of Grand Island into three distinct lobes. Water flooded into much of the Echo Lake Lowlands between Echo Lake and the mouth of North Light Creek, creating a nearly continuous shallow strait. Lake water also separated the "Thumb" from the western side of the island at this time. Most notably, however, was the development of several large spits and barriers that formed in the more protected reaches of the Nipissing shoreline, including the Williams Landing Spit, Duck Lake Cuspate Barrier, Muskrat Point Cuspate Barrier, and others (see Anderton 1993, 1995 for a detailed discussion of mid- to late-Holocene-age shorelines in each quadrangle covering Grand Island).

In particular, on the extreme south end of the island, the Williams Landing Spit formed as a series of large sandy ridges were deposited during the Nipissing Phase (Anderton 1993, 1995; Dunham and Anderton 1999). From a

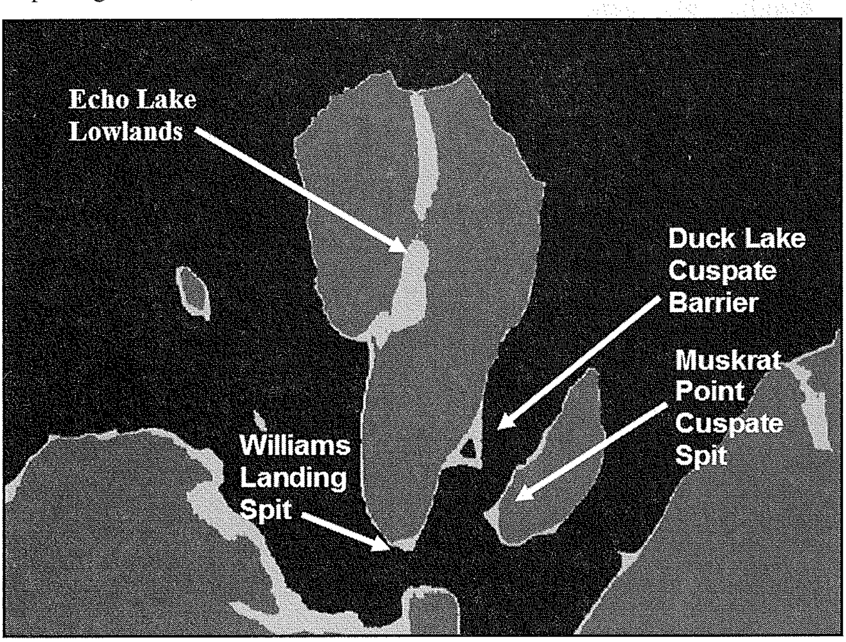

Figure 5. Digital elevation model showing reconstruction of Grand Island coastal setting during Nipissing Phase. Dark gray represents uplands above 192 m, which were unaffected by Lake Nipissing. Light gray represents elevations between 192 and 186 m, the range at which the Nipissing shoreline is found (DEM courtesy of Dr. Jeong-Chang Seong, NMU Geography Department).

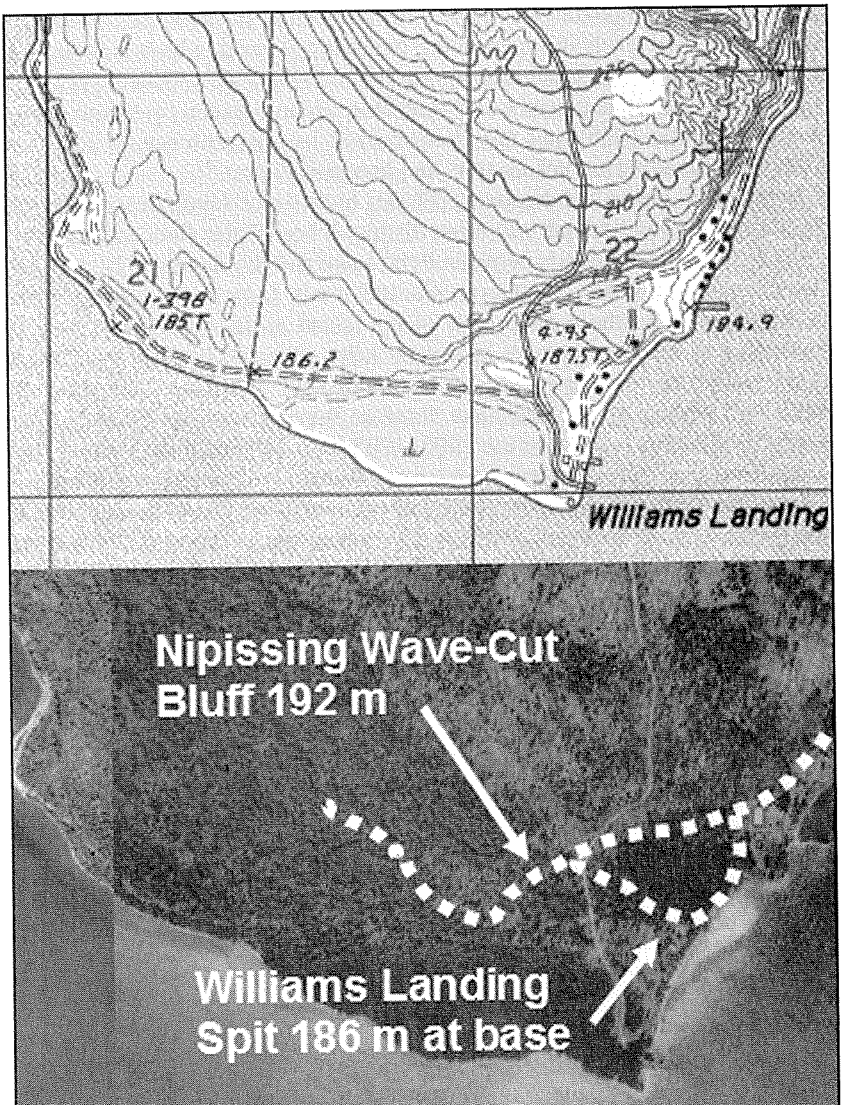

Figure 6. Williams Landing area Nipissing Phase shoreline mapping. Excerpts from USGS topographic map and black-and-white aerial photography coverage.

prominent wave-cut rock bluff, the spit extends to the southeast for a distance of approximately 200 m between 192 and 186 m in elevation (Figure 6). An extensive stand of red pine trees currently covers this surface. Modern wave erosion is presently cutting into the southeast end of the spit, exposing cultural materials in a wave-cut bluff. The Williams Landing Spit has been used by people beginning at least 4,600 years B.P. based on a well-dated palimpsest of hearths that was recently excavated at the Popper Site (FS 09-10-03-825/20AR350), which generated two radiocarbon dates of 4785 ± 75 and 4649 ± 123 cal B.P. (4260 ± 50 and 4100 ± 60 ^{14}C B.P.; Dunham and Anderton 1999). To date, these are the oldest radiocarbon dates associated with an archaeological context on Grand Island and are thus representative of the earliest human occupation of the island.

The Duck Lake Cuspate Barrier formed on the east side of the middle lobe of Grand Island (Figure 7). During the Nipissing Phase, wave action in the lee (east) side of the western upland lobes of the island, moved sediment to the north as well as to the south. These opposing sediment flows resulted in the development of a triangular-shaped or cuspate barrier, with a small lagoon trapped between them. Present-day Duck Lake is a remnant of this Nipissing-age lagoon. The south arm of the cuspate, which trends east–west, is found just inland of the northwest end of Murray Bay, while the east arm, which trends north–south, forms a prominent terrace adjacent to the poorly drained western side of the Tombolo. The Duck Lake Cuspate Barrier, which is the largest of the Nipissing depositional landforms found on Grand Island (70 ha), was used extensively by Late Archaic people (Anderton 1993, 1995; Franzen 1998). The island's historic cemetery also occupies this surface.

The Muskrat Point Cuspate Barrier, another large Nipissing-age coastal landform, formed on the southwest side of the "Thumb." Sediment movement

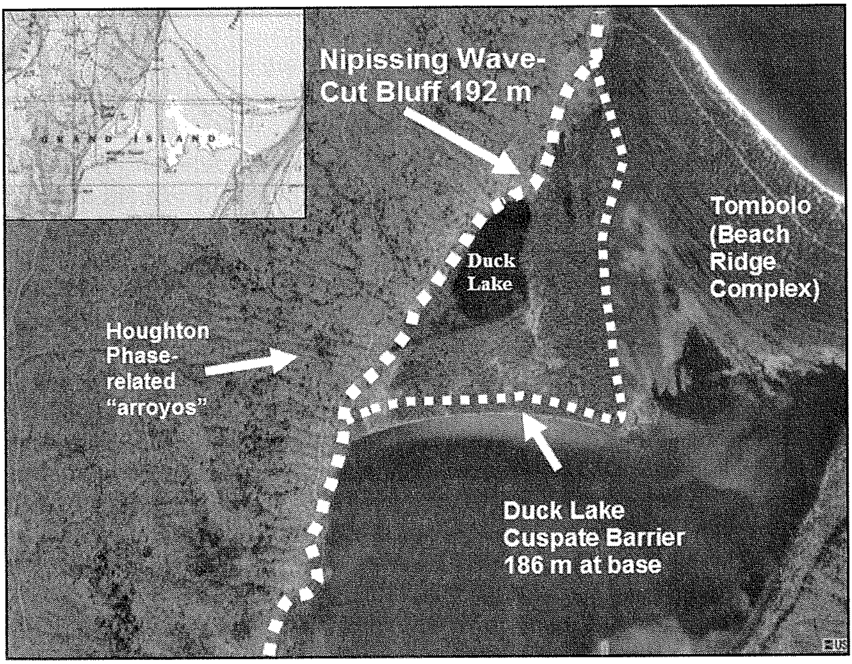

Figure 7. Duck Lake area Nipissing Phase shoreline mapping. Excerpts from USGS topographic map and black-and-white aerial photograph coverage.

at the time of formation appears to have been from the east as well as from the north, creating another triangular or cuspate barrier, with a small lagoon. A small, unnamed wetland (northeast quarter of Section 23) appears to be a remnant of this lagoon. Finally, the Echo Lake Barrier and the North Beach Barrier, both small bay-mouth barriers, formed on the south and north ends of the western lobe of Grand Island, respectively. Yuen's (1988) radiocarbon dates were taken from an exposure of the North Beach Barrier.

The Nipissing shoreline was clearly the focus of intense Late Archaic Period settlement, with major foci at Williams Landing Spit, Duck Lake Cuspate Barrier, and Muskrat Point Cuspate Spit (Anderton 1993, 1995, 1999; Dunham and Anderton 1999; Franzen 1998). The paleoenvironmental setting of these site locales may indicate an emphasis on spring fishing activities (Anderton 1995). However, what appears as an explosion of human use of the island in the Late Archaic must be carefully interpreted within the geomorphic context. During this time, the Nipissing shoreline was relatively high and was followed by a regressive or falling trend, which created a well-preserved shoreline that in turn resulted in well-preserved archaeological sites. Also, the length of time that the Nipissing shoreline features were available for occupation was extensive, likely offering attractive coastal settings from as early as 5400 until at least 4450 cal B.P. and likely later. Indeed, since they continued to offer well-drained terraces near coastal settings, Nipissing-age coastal landforms often continued to be used by people through modern times on Grand Island (Dunham and Anderton 1999).

Post-Nipissing Fluctuations (4450 Cal B.P. to Present)

Following the high levels of the Nipissing Phase, lake levels began a long-term falling trend, which was punctuated by a series of minor fluctuations over the next 4,000 years. The Algoma High and at least four other minor, unnamed high lake levels are recognized in the Lake Michigan/Huron basin for this time period (Baedke and Thompson 2000; Larson 1985, 1994; Thompson and Baedke 1995, 1997). Based on studies of buried soils within the Grand Sable Dune field, located about 70 km to the east of Grand Island, these same fluctuations, which probably ranged from 1–2 m in height, likely took place in the Lake Superior basin until it became separated from the lower basins (Anderton and Loope 1995). At this time on Grand Island, a beach ridge complex was constructed between the "Thumb" and the main (western) lobe of the island, forming what is commonly referred to as the Tombolo (Figure 7). This is a very accurate place name, since this narrow isthmus is an actual tombolo coastal landform, which connected a smaller island (i.e., the "Thumb") to the main part of Grand Island.

By as early as 2400 cal B.P. down-cutting of outlets had caused lake levels in the Michigan-Huron basins to fall below the elevation of the rebounding bedrock sill at the east end of the Superior basin, separating the waters of the Superior basin from those of the Michigan-Huron basins (Farrand and Drexler

1985). Recently, Johnson et al. (2003) suggested that the Sault Ste. Marie outlet became the controlling outlet of water in the Lake Superior basin between 1400 and 1200 cal B.P. After this time, the south shore of the lake began to experience a transgressive lake level trend as isostatic uplift caused the Sault outlet to rise. This rising lake level trend is clearly evident on Grand Island in the form of flooded beach ridges on the north side of Murray Bay along the southern end of the Tombolo. Although it is difficult to say just how much lake levels have risen in the last 1,200 to 1,400 or so years, the implication for the preservation of coastal archaeological sites is profound. Water-worn prehistoric artifacts have been found at and just below modern lake level at the head of Murray Bay (John Franzen, personal communication, 1992), undoubtedly the result of this more recent transgressive trend.

Definitive statements about the level of water in the Lake Superior basin during this time are difficult to make. Clearly, terminal Late Archaic and Woodland people were faced with a highly dynamic shoreline environment. At times, water levels may have been relative low, while at other times water levels would have been relatively high. Consequently, shoreline configurations and resulting nearshore environments would have been in a state of flux. While there are many prehistoric sites that date to this period on Grand Island (Drake and Dunham 1993, Drake and Dunham this volume), the Trout Point I site (Benchley et al. 1988) and the Gete Odena site (Skibo 1993, Skibo et al. this volume) deserve further discussion.

The Trout Point I site (20AR189) on the northern tip of the "Thumb" was excavated by the University of Wisconsin–Milwaukee in 1986 (Benchley et al. 1988). Although no formal tools were recovered, an extensive pavement of flaked and fire-cracked quartzite cobbles was found. The site is perched roughly 20 m above Lake Superior on the top of a rock cliff at an elevation between 201 and 203 m above sea level. While Yuen (1988) studied the post-glacial geology of Grand Island, he did not carry out stratigraphic investigations at the Trout Point I site. However, based on excavation descriptions (Benchley 1988), the site appears to have a well-developed forest soil (Spodosol) developed into sandy till or glacio-fluvial (outwash) sand. Yuen (1988) believed that the site was associated with Lake Minong based on its elevation. However, as noted earlier, the Minong shoreline is likely not present on Grand Island. Dating the Trout Point I site based on this correlation is therefore erroneous. This is not to say the surface on which the site is located is not old. The Trout Point I site is clearly located above the highest mid-Holocene shoreline (Nipissing I), thus it could have been used by people from after deglaciation until modern times. Perhaps the best indication of the site's age is from three thermoluminescence dates on fire-cracked rock. The dates ranged from 2150 to 2370 ± 200 years B.P., indicating a terminal Late Archaic affiliation for the site (Benchley et al. 1988).

The Gete Odena site (FS 09-10-03-803), a Late Woodland/Historic Period site near Williams Landing, has been the focus of several years of more recent excavation (Dunham and Branstner 1995; Robinson and Weir 1991; Skibo

2003, Skibo et al. this volume;). While definitive statements about the setting of Gete Odena and its relationship to lake levels are difficult to make since no formal geoarchaeological studies have been done at the site, some basic observations can be made. It is located on the upper surface of a sandy terrace at an elevation of about 187 m on the southernmost edge of the Williams Landing Spit. The base of the terrace is at an elevation of about 185 m, approximately 1.5 m above the current level of Lake Superior. Site stratigraphy appears to be primarily wave deposited, sand laminae capped by eolian sand deposits with a poorly developed soil A-horizon at the ground surface (Skibo 2003, Skibo et al. this volume). The site is located on a geomorphic surface that was likely formed after the end of the Nipissing II Phase, perhaps between 3000 and 2000 cal B.P. This interpretation fits well with recent excavation results indicating that the earliest occupation of the site was during the Late Archaic based on a radiocarbon date of 1060 B.C. to 860 B.C. (roughly 3000 to 2800 cal B.P.) from a single hearth feature (Skibo 2003, Skibo et al. this volume). However, the main occupation of the site is clearly Woodland/Historic in age. The location of Gete Odena tentatively suggests that Woodland and later groups may have adapted to fluctuating Late Holocene lake levels by placing villages on the relatively higher ground or older shoreline features, rather than immediately adjacent to the lake shore.

Conclusion

An understanding of the geoarchaeology of Grand Island has been a critical part of prehistoric archaeological investigations. Although no Paleoindian materials have yet been found, the island was available for human occupation following the retreat of Marquette Advance ice (11,200 cal B.P.). The high scarps of the interior of the island are probably not Post-Duluth shorelines as has been suggested by previous scholars, but are rather mesa-and-scarp landforms created by the retreat of the Au Train Formation cap rock. It also seems highly improbable that the Minong shoreline is present on Grand Island, having likely been submerged by Lake Nipissing.

During the Houghton Low Phase, lake levels dropped to at least 60 m below modern level based on the remains of a submerged forest on the bottom of the East Channel. Much of the uplands were deeply incised by stream channel erosion at this time, creating an extensive series of gullies above 192 m. Coastal landforms created by the high lake levels of the Nipissing Phase (5400–4450 cal B.P.), including the Williams Landing Spit, Duck Lake Cuspate Barrier, and the Muskrat Point Cuspate Barrier, were heavily used by Late Archaic Period people. Post-Nipissing fluctuations (4450 cal B.P. to present) in lake levels presented a highly variable coastal setting for terminal Late Archaic and Woodland Period people. The post-1400 to 1200 cal B.P. shoreline transgression has affected the preservation of archaeological material.

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