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U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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SCIENTIFIC INVESTIGATIONS MAP 2930
SHEET 1 of 2

Visualizing the Geology of Lake Trout Spawning Sites: Northern Lake Michigan

By
Peter Dartnell,[1] Peter Barnes,[1] James V. Gardner,[2] and Kristen Lee[1]

2004

DISCUSSION

Geologists and biologists are working together to understand the links between lake floor geology (composition and shape) and the distribution of lake trout throughout their life cycle. Lake floor geology is one of the main factors determining where lake trout spawn, feed, and hide. In support of ongoing research to study Lake Michigan trout habitats, the U.S. Geological Survey in cooperation with the U.S. Army Corps of Engineers mapped the morphology of principle lake trout spawning sites (Dawson and others, 1997). Using the Army Corps of Engineer's SHOALS airborne lidar (Light Detection and Ranging) system we mapped six regions in Northern Lake Michigan (fig. 1) in order to identify ideal spawning regions composed of shallow, clean, gravel/cobble substrate, adjacent to deeper water (Barnes and others, 2003).

Lidar mapping systems, which use laser pulses to measure water depths from an airplane, are now available to map the nearshore lake morphology at meter-scale detail. Maps generated from the bathymetric data are used to define regions with smooth homogeneous substrate, regions with higher relief, and mixed regions with both smooth and rough relief. This morphologic information combined with sediment samples and direct bottom observations enable geologists to map areas with rougher relief composed of rock outcrop, boulders, and cobbles, as well as smooth regions covered with sand or mud. This information helps biologists, fishery managers, and ecologists visualize the lake floor in significant detail which promotes better fishery management, species protection, and habitat identification.

These posters present the maps and discuss the geology of the six lake trout spawning sites mapped by the lidar system. Where the mapping approached land, aerial photography of the land is combined with the bathymetric data to help visualize the scale of the offshore features. Map and perspective views of Boulder Reef, Hog Island Reef, and Little Traverse Bay are shown on sheet 1, whereas map and perspective views of Trout and High Island Shoal, Gull Island Reef, and Dahlia Shoal are shown on sheet 2. Additional information, bathymetric data, imagery, and metadata are available online at http://geopubs.wr.usgs.gov/open-file/of03-120/.

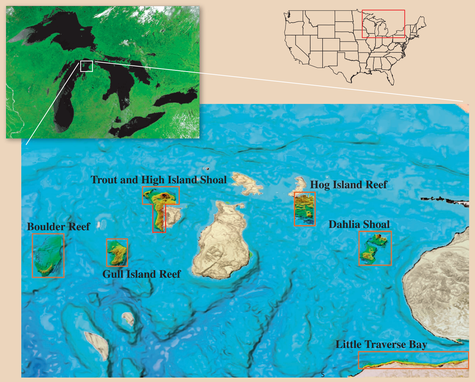

Figure 1. Location map of six sites mapped with the U.S. Army Corps of Engineer's SHOALS lidar system along with U.S. Geological Survey 30-m DEM topography and regional shaded bathymetry developed from Holcombe and others, 1996.

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Barnes, P., Fleisher, G., Gardner, J.V., and Lee. K., 2003, Bathymetry and selected perspective views of 6 reef and coastal areas in Northern Lake Michigan: U.S. Geological Survey Open-File Report OF03-120. [Available online at, http://geopubs.wr.usgs.gov/open-file/of03-120/.]

Dawson, K.A., Eshenroder, R.L., Holey, M.E., and Ward, C. 1997, Quantification of historic lake trout (Salvelinus namaycush) spawning aggregations in Lake Michigan: Canadian Journal of Fish Aquatic Science. vol. 54, no. 10, p. 2290-2302.

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Holcombe, T.L., Reid, D.F., Virden, W.T., Niemeyer, T.C., De la Sierra, R., and Divins, D.L., 1996, Bathymetry of Lake Michigan: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Boulder, Colorado. Report MGG-11 [A color poster with descriptive text and digital data available on CD-ROM].

Somers, L.H., 1968, Preliminary report on geological studies in northern Lake Michigan using underwater observation techniques: International Association for Great Lakes Research, Proceedings, 11th conference on Great Lakes Research, vol. 239-244.

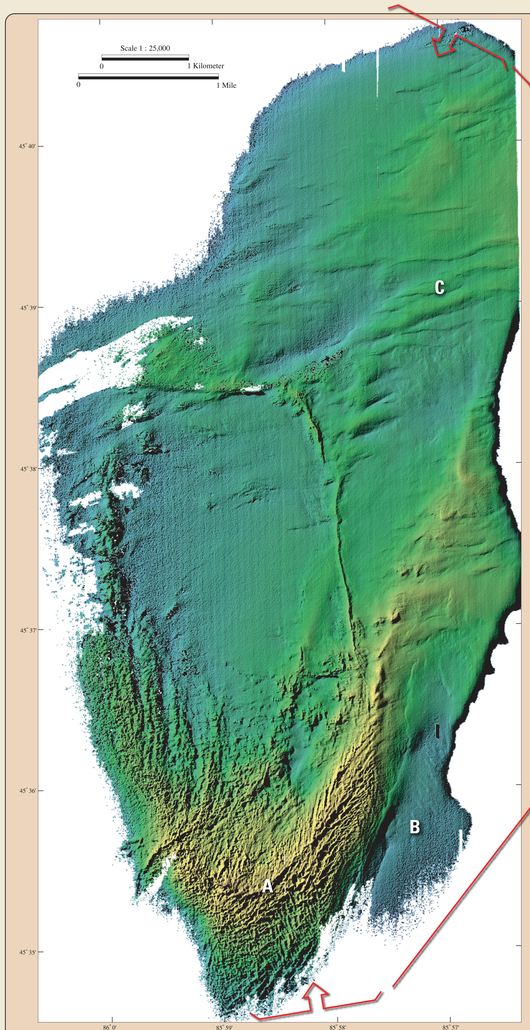


Figure 2.1. Color-coded shaded relief bathymetry of Boulder Reef. The rough relief in the southern and shallowest portion of the reef (6 to 22 m water depth) is covered with gravel, cobbles, and boulders, with rare patches of sand (Somers, 1968; Edsall and others, 1989; and video data). This coarse bottom material is roughly organized into highs and lows less than a meter high. The arcuate ridge at the south end of the reef (A) is likely a remnant depositional glacial feature from a small lobe of ice originating from the north. The coarse-texture material extends beyond the depths of the survey to the west and south, but transitions to a sand substrate to the east (B) and north (video observations by Greg Kennedy, U.S.Geological Survey, Ann Arbor, Michigan, personal commun., 2002). The strong east-west lineations at depths of 15-20 m in the north half of the image (C) could be related to glacial movement but this is transverse to movement suggested by the ridge to the south or to older glacial events. Sediment samples show that these lineations are drapped with clean sand. Note: The faint N-S lineations seen in the central part of the image are artifacts of the data gathering flight lines.

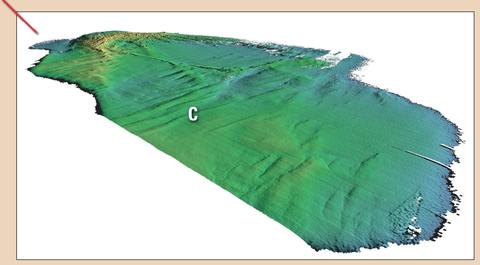


Figure 2.2. Oblique view of the Boulder Reef area looking southwest. This view emphasizes the east-west lineations (C) and smooth morphology of the sand draped surface north of Boulder Reef. The vertical exaggeration is 4x and the distance across the bottom of the image is about 4.0 km.

BOULDER REEF

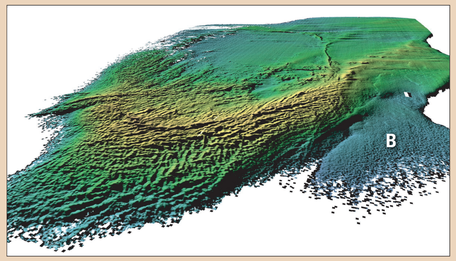
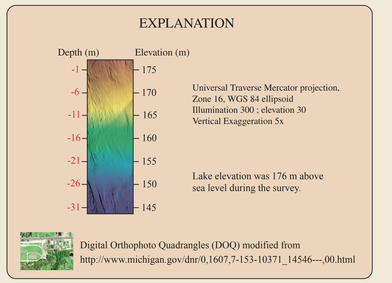


Figure 2.3. Oblique view of Boulder Reef looking northwest. The relatively steep slopes of the southern end of the ridge and the different rough morphologic character of the cobble and gravel substrate fill the foreground. A small depositional apron of sand (B) seen in underwater video collected at this site is forming off the southeast part of the reef. The vertical exaggeration is 4x and the distance across the bottom of the image is about 3.5 km.



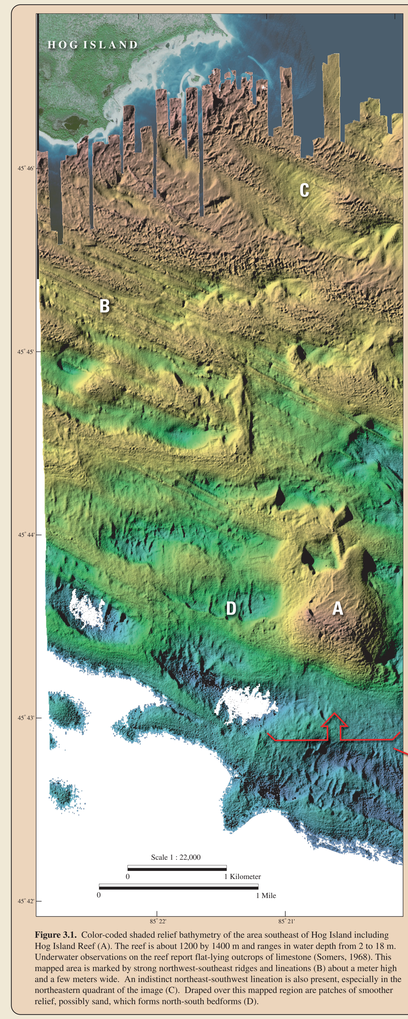


Figure 3.1. Color-coded shaded relief bathymetry of the area southeast of Hog Island including Hog Island Reef (A). The reef is about 1200 by 1400 m and ranges in water depth from 2 to 18 m. Underwater observations on the reef report flat-lying outcrops of limestone (Somers, 1968). This mapped area is marked by strong northwest-southeast ridges and lineations (B) about a meter high and a few meters wide. An indistinct northeast-southwest lineation is also present, especially in the northeastern quadrant of the image (C). Draped over this mapped region are patches of smoother relief, possibly sand, which forms north-south bedforms (D).

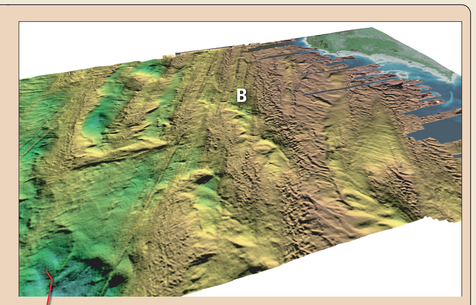


Figure 3.2. Oblique view looking west toward Hog Island. The pronounced northwest-southeast trending lineations in the center of the mapped area (B) die out to the north and appear buried by a coarse morphology that looks similar to the boulder and cobble areas seen at Boulder Reef (sheet 1, fig. 2.1) and Gull Island Reef (sheet 2, fig. 6.1). The vertical exaggeration is 4x and the distance across the bottom of the image is about 3.5 km.

HOG ISLAND REEF

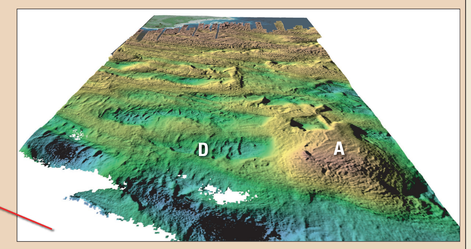


Figure 3.3. Oblique view looking north at Hog Island Reef (A). North-south trending bedforms (D) are associated with patches of modern lake sediment composed of sand alligned east-west. The fine and linearly continous morphology of glacial or bedrock outcrop underlie both the bedform and sand patches. The vertical exaggeration is 4x and the distance across the bottom of the image is about 3.5 km.

Lake floor images generated from SHOALS lidar data below 178.80 m (ref. IGLD 85).
Data aquired on a four-meter grid in August 2001 were collected and processed by J.E. Chance & Associates under contract to the Army Corps of Engineers and the U.S. Geological Survey.

Land imagery created from Digital Orthophoto Quadrangles (DOQ) modified from, http://www.michigan.gov/dnr/0,1607,7-153-10371_14546---,00.html

Data, imagery, and metadata available online at, http://geopubs.wr.usgs.gov/open-file/of03-120/.
Data collection field activity metadata URL: http://walrus.wr.usgs.gov/infobank/t/t101lm/html/t-1-01-lm.meta.html.
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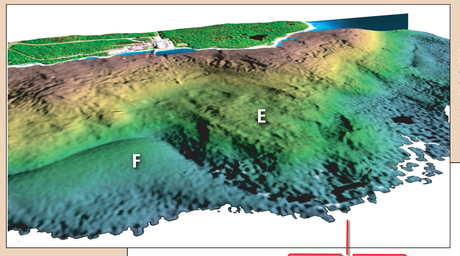

Figure 4.2. Oblique view looking south towards Big Rock Point. Rough irregular morphology (E) composed of bedrock outcrop extends from the coast offshore to the edge of the survey, except in the left foreground (F), which appears depositional. The vertical exaggeration is 4x and the distance across the bottom of the image is about 1.3 km.

LITTLE TRAVERSE BAY

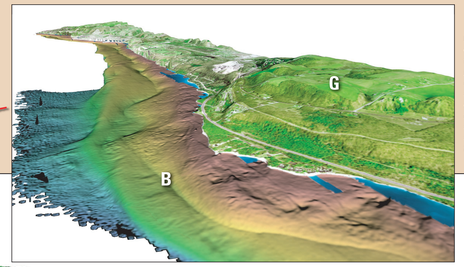

Figure 4.3. Oblique view looking toward the east over Nine Mile Point. This view illustrates the onshore (G) and offshore expression of a glacially created drumlin trending northwest-southeast. The view also shows the sharp trough-like boundary (B) between the offshore sediment covered region and the nearshore, irregular relief of coarser material and outcrop. The vertical exaggeration is 4x and the distance across the bottom of the image is about 1.0 km.

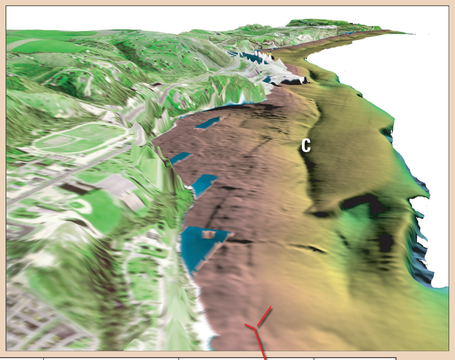

Figure 4.4. Oblique view of the eastern portion of the Little Traverse Bay data set looking west along the coast. This view illustrates the nearshore, rough relief of outcrops and coarser substrate and the offshore, sediment covered substrate, separated by the shore-parallel trench (C). The blue rectangular areas close to shore are bathymetry data gaps and show the water column from the aerial photographs. The vertical exaggeration is 4x and the distance across the bottom of the image is about 800 meters.

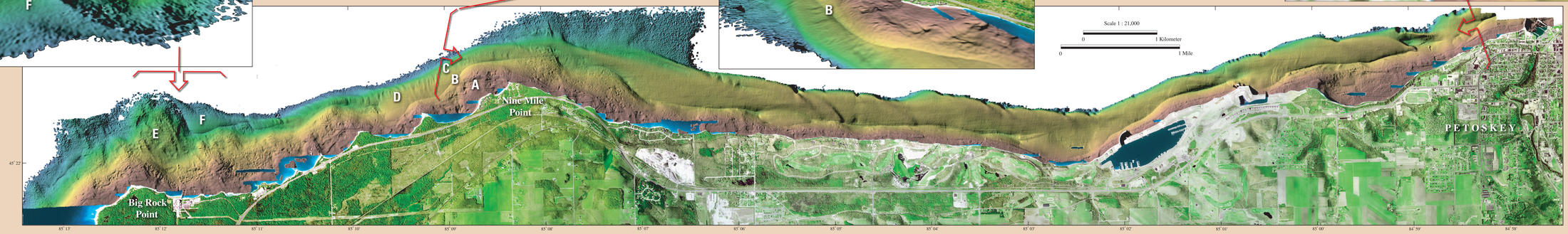

Figure 4.1. Color-coded shaded relief bathymetry of the nearshore region along the south coast of Little Traverse Bay (fig. 1). Onshore aerial photography and Digital Elevation Models (DEMs) show that the surface morphology of this region is marked by glacial drumlins aligned northwest-southeast. Nearshore, mainly in water depths from 0 to 10 m (A), the morphology is irregular and blocky, suggesting outcrops and coarse substrate. Offshore of the outcrops, a shore-parallel trench (B), 1-3 m deep, separates the outcrops from the deeper sediment covered region (C). Superimposed on the sediment are a series of shore-normal (north-south) bedforms, less than 0.5 m high at (D), west of Nine Mile Point, suggesting sediment transport parallel to the shoreline.

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SCIENTIFIC INVESTIGATIONS MAP 2930
SHEET 2 of 2

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2004

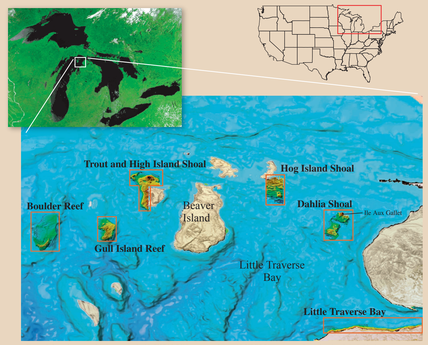

Figure 1- Location map of 6 sites mapped with SHOALS lidar system along with USGS 30-m topography and regional shaded bathymetry developed from Holcombe et. al., 1996. See sheet 1 for an introduction.

Lake floor images generated from SHOALS lidar data below 178.80m (ref. IGLD 85).
Data aquired on a four meter grid in August 2001 were collected and processed by J. E. Chance & Associates under contract to the Army Corps of Engineers and the U.S. Geological Survey.

Land imagery created from Digital Orthophoto Quadrangles (DOQ) modified from, http://www.michigan.gov/dnr/0,1607,7-153-10371_14546---,00.html

Data, imagery, and metadata available online at, http://geopubs.wr.usgs.gov/open-file/of03-120/.
Data collection field activity metadata URL: http://walrus.wr.usgs.gov/infobank/t/t101lm/html/t-1-01-1m.meta.html.
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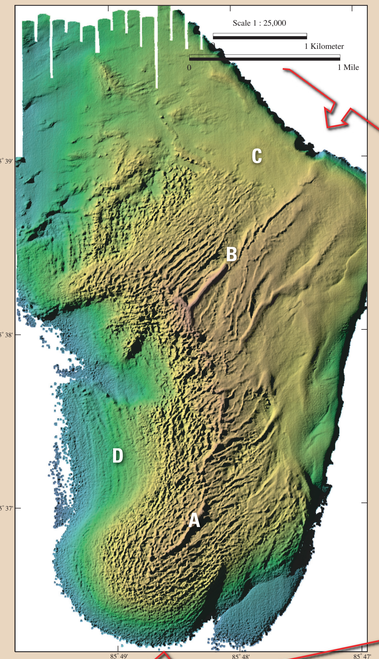


Figure 6.1. Color-coded shaded relief bathymetry of Gull Island Reef. The morphology is similar to that of Boulder Reef (sheet 1, fig. 2.1). Underwater video shows the rough relief is composed of cobble and boulder substrate with less than a meter of local variation (Greg Kennedy, U.S. Geological Survey, Ann Arbor, Michigan, personal commun., 2002). The arcuate shape of the shallow ridge, 3 m depth at (A), suggests derivation from a small lobe of ice moving eastward. This contrasts with the southward ice motion suggested by the morphology at Boulder Reef. Erosional and (or) depositional ridges radiate outward to the northeast from the reef, including a straight, 1-km-long ridge (B). Along the north and east edges of the reef, bottom samples suggest that a smooth, modern sand sheet drapes the rougher substrate (C).

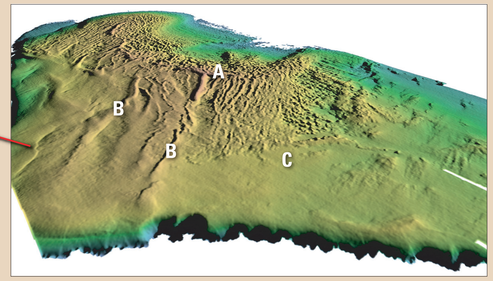


Figure 6.2. Oblique view looking southwest toward Gull Island Reef. The front of the arcuate ridge (A) and radiating parallel ridges (B) of gravel and boulders are emphasized in this view. Also seen is the sand sheet draping the rough substrate (C). The vertical exaggeration is 4x and the distance across the bottom of the image is about 2.5 km.

GULL ISLAND REEF

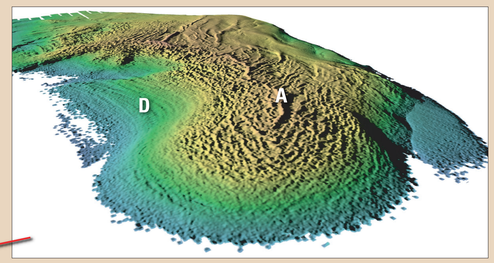


Figure 6.3. Oblique view of Gull Island Reef looking north. The arcuate pattern of the reef (A) is replicated in a step-like fashion into deep water (D). The ridge crest (A) is composed of boulders and cobbles as seen in video data (Guy Fleischer, NOAA, Seattle, Washington, personal commun., 2002). The vertical exaggeration is 4x and the distance across the bottom of the image is about 2.0 km.

TROUT AND HIGH ISLAND SHOAL

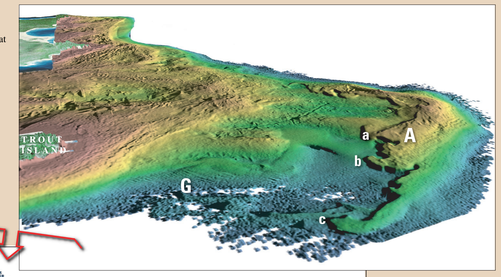
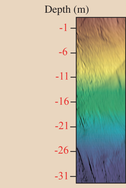


Figure 7.2. Oblique view looking southwest at Trout Island Shoal (A). Three generations of recurved spits (a,b,c), possibly composed of sand, are migrating eastward past the shoal. Northwest-southeast linear ridges at (G) are partly obscured by recent patches of smooth sand. The vertical exaggeration is 4x and the distance across the bottom of the image is about 2.5 km.

Figure 7.3. Oblique view looking north along the west coast of High Island. The rough morphology nearshore (B), possibly glacial material, is similar in texture and trend to Gull Island Reef (fig. 6.1). This relief abruptly changes to a smooth, possibly sandy bottom (C) along a 2- to 3-m high scarp (D) at about 10 m water depth. The bottom of this scarp may represent the location of a previous glacial shoreline. The vertical exaggeration is 4x and the distance across the bottom of the image is about 1.8 km.

Figure 7.1. Color-coded shaded relief bathymetry of Trout Island Shoal (A), Trout Island area, and west coast of High Island. Similar to the Little Traverse Bay region (sheet 1, fig. 4.1), the rough nearshore relief west of High Island (B) transitions abruptly offshore to a smooth depositional substrate (C) that is possibly composed of sand. The morphology of Trout Island Shoal suggests a large sand shoal migrating eastward over rough glacial deposits. Two or three gouges (D) of unknown origin, possibly ice or manmade, extend east of Trout Island Shoal for over 1 km. Aerial photography shows the nearshore region to a certain depth and shows sand spits extending offshore (E). Expressions of these sand spits can be seen in the lidar data directly offshore (F).

EXPLANATION



Universal Traverse Mercator projection,
Zone 16, WGS 84 ellipsoid
Illumination 300 ; elevation 30
Vertical Exaggeration 5x

Lake elevation was 176 m above sea level during the survey.

Digital Orthophoto Quadrangles (DOQ) modified from
http://www.michigan.gov/dnr/0,1607,7-153-10371_14546---,00.html

DAHLIA SHOAL

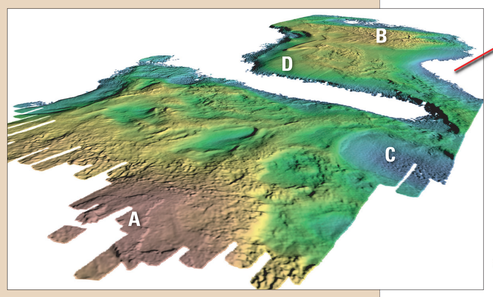
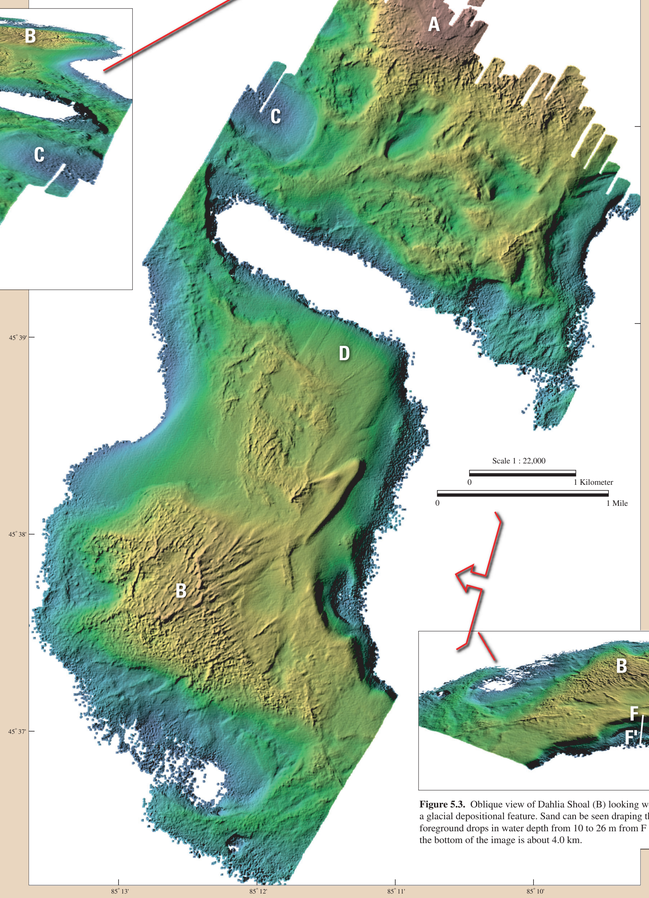


Figure 5.2. Oblique view looking south over Ile Aux Gallet (A) with Dahlia Shoal (B) in the background. The rough relief of cobbles, boulders, and (or) outcrop occurs in water depths less than 15 m. Limestone outcrops were identified close to Ile Aux Gallet from underwater observations (Somers, 1968). Deep regions with smooth morphology (D) as well as deep pits (C) are covered with sand substrate. The vertical exaggeration is 4x and the distance across the bottom of the image is about 2.5 km.



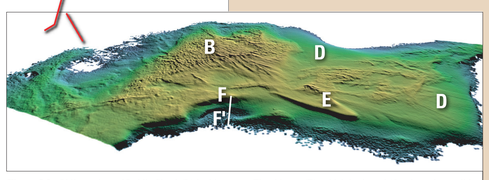


Figure 5.3. Oblique view of Dahlia Shoal (B) looking west. The ridge at (E), which is about 940 m long, is possibly a glacial depositional feature. Sand can be seen draping the rough relief (D) surrounding the shoal. The pit in the foreground drops in water depth from 10 to 26 m from F to F'. The vertical exaggeration is 4x and the distance across the bottom of the image is about 4.0 km.

Figure 5.1. Color-coded shaded relief bathymetry of Ile Aux Gallet (A) and Dahlia Shoal (B). Dahlia Shoal has rough relief, an arcuate ridge, and radiating ridges to the northeast similar to those seen at Gull Island Reef (fig. 6.1). Surrounding Ile Aux Gallet and Dahlia Shoal are numerous pits. The pit at (C) is about 650 m wide northeast to southwest and about 30 m deep at the edge of the survey. Origins of the pits are unknown, but at present the pits appear to be filling with sediment. The center of this region was unmapped because the water depths were too deep to be mapped with the lidar system.

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