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Report of Investigations No. 148

ARCHEOLOGICAL SEARCH FOR SHIPWRECKS IN THE VICINITY OF KELLEYS ISLAND, LAKE ERIE: A PILOT STUDY, AUGUST 2003

by

Dale L. Liebenthal, J. A. Fuller, and Constance J. Livchak

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Cover illustration: Side-scan sonar image of the *George Dunbar*.
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ABSTRACT

The Lake Erie Geology Group received a request in 2002 from the Ohio Department of Natural Resources Office of Coastal Management to conduct a pilot study to use side-scan sonar to locate, map, and assess shipwrecks in an area located near and around Kelleys Island. The Ohio Submerged Lands Act requires the State of Ohio to manage underwater shipwrecks by inventorying, evaluating, protecting, and designating underwater shipwreck locations, among other mandates. Another purpose of the study was to evaluate the use of side-scan sonar for the purpose of mapping possible shipwreck locations. This was accomplished by investigating some of the more well known shipwrecks within the study area, logging their position and condition as determined by side-scan sonar, and making a cursory search of some complex areas that may include additional wrecks. To conduct the study, the staff of the Lake Erie Geology Group outlined the field plan. In August 2003, fieldwork was performed over a two-week period, of which 5 days provided the calm-weather window needed to gain quality acoustic records to answer the proposed questions. The reconnaissance surveys that produced the best results used a range of 75-meters on each side of the vessel. These side-scan sonar records were merged and overlapped so they could be processed into area mosaics. More detailed surveys of each wreck were made with multiple passes over the wreck using a shorter range of 50-meters to show detail.

PURPOSE AND METHODS

This report documents the methodology, experience, and results of locating shipwrecks in a pilot area in the vicinity of Kelleys Island near the eastern edge of Lake Erie's Western Basin. It will provide guidance in the location and management of other sunken vessels within the Ohio portion of Lake Erie. In carrying out this investigation, the Lake Erie Geology Group requested the aid of Dr. Charles E. Herdendorf, an Underwater Archeologist, to assist in planning the work and the wreck sites to be visited. A general plan for evaluating regional side-scan sonar data collection of search areas was laid out. Possible data-collection methods at individual wreck sites were also discussed and evaluated.

Side-scan sonar uses high-frequency sound waves to acoustically image underwater objects producing a representation similar to an oblique aerial photograph. The sonar towfish emits a horizontally narrow pulse of sound at right angles to the track-line of the boat. Sound waves reflected off the lakebed are received by the towfish. The data are plotted on a thermal paper recorder and digitally recorded. Intensity of the reflected acoustic signal is a function of many variables, including the acoustic reflectivity of the substrate and objects resting on the bottom, relief of the bottom, and distance from the sound source. As intensity of the reflected signal varies in response to these factors, the resultant backscatter patterns are recorded. These backscatter patterns are then outlined and correlated to various substrates and bottom materials. Intensity of the reflected acoustic signal may also be affected by factors that produce acoustic interference. Sources of acoustic interference primarily include other electronics, boat motors, breaking waves, and thermoclines. Vessels fishing near wrecks on the bottom were sometimes sources of interference because they tend to have both their motors and acoustic fish-finders running.

Side-scan sonar surveys for this study were conducted with a dual frequency (100-kHz and 500- kHz) Klein Model 595® side-scan sonar deployed from the Ohio Geological Survey's *Research Vessel GS-3*. The *R/V GS-3* is a specially designed, custom-built, 25-foot long, trailerable vessel using a rigid bow mounting system for the side-scan towfish (Fig. 1). The rigid bow mounting allows the side-scan sonar to be deployed in very shallow water allowing little acoustic interference from the vessel itself. Raw data from the 100-kHz and 500-kHz channels of the Klein 595® were printed in real time on thermal paper and were also recorded in a Triton Elics ISIS Sonar® digital data acquisition system. The digital data from the side-scan sonar was continuously merged with navigation data obtained from a real-time, differentially corrected, sub-meter accuracy, Global Positioning System (GPS) receiver.

Side-scan sonar survey lines were run at a variety of ranges for area searches. The range setting on the side-scan sonar is the distance surveyed on each side of the boat and

FIGURE 1.—Research Vessel *GS-3*.

controls the ping rate or the amount of sound that envelops the target. Boat speed is also a critical controlling factor. The swath width is the total width in meters that the bottom is ensonified on each side of the boat or twice the range setting. To ensure complete coverage of study areas, survey lines were planned to provide at least 25% of overlap between adjacent survey lines. Once a target was located, specialized targeting software within the ISIS® system was used to record these targets for re-visit. Each target's location was accurately acquired and the research vessel was maneuvered so that successive passes would place the target in the center of either the port or starboard channel at smaller ranges. The target would then be "boxed" or passed at 90° angles to determine the orientation and detail of the object. A final pass was then made with the intent of placing the sound impulses at the best angle to the target to acquire the best image. An improved hydrographic survey software program was used that assisted in improving the efficiency in collecting total-area track-line miles and the detailed positioning required for target acquisition at the wreck sites.

In the office, the 500-kHz side-scan sonar data from area searches were post-processed to make corrected, georeferenced, side-scan sonar mosaics from the multiple survey lines. During post-survey processing, the side-scan sonar records were each corrected to remove distortion for slant range, beam angle, and grazing-angle returns. The navigation was extracted and smoothed; layback and offset corrections were applied, and then rejoined with the data to produce a corrected, georeferenced sonar record. Each side-scan sonar record was then merged with adjacent records into a geographically referenced map of sonar records called a side-scan sonar mosaic. The resulting mosaics of acoustic backscatter returns were then examined for other archeological objects not identified in the field. Side-scan sonar records of targets were also processed in this same manner but were generally not mosaicked.

DATA COLLECTION

This pilot study originally concentrated on the South Passage area, where a number of wrecks were thought to be located. Plate 1 shows the general location of the study area. Five days were allocated to the study for which very calm conditions were required to obtain quality data. The first task was to develop a plan for each day and scope of work. Referring to a map of the wreck sites within the study area (Herdendorf and Pansing, 2003), a series of sites were collectively selected to explore. Because it was a pilot study, the study focused on the most well known wrecks and the most time-effective route to use to collect the data. Seven documented shipwrecks, with proven coordinates, were chosen to test the area search capabilities of the side-scan sonar. These wrecks were within both the hard and the soft substrate environments of Lake Erie. Target search techniques were then used to evaluate the side-scan sonar as a source of detailed information about individual wreck sites. To search for other wreck sites, areas of known hard substrates with multiple unconfirmed wrecks were surveyed with overlapping side-scan sonar records to provide a continuous image of a large area of the lake bottom. These sites were: Gull Island Shoal, Kelleys Island Shoal, and the western side of Kelleys Island. Plate 2 shows daily track-line data with wreck sites superimposed over a standard navigational chart. Plate 3 shows the extent of side-scan sonar coverage with reference to wreck sites. Specific sites to be visited and mapped with side-scan sonar were:

Specific wrecks with good coordinates (Plate 2)

1. *F. H. Prince*
2. *W. R. Hanna*
3. *Adventure*
4. *St. Louis*
5. *Amaretta Mosher*
6. *Isabella J. Boyce*
7. *George Dunbar*

Selected areas (Plate 2)

1. Gull Island Shoal for a preliminary search for a string of 5 wrecks: *King Sisters, Q. A. Gilmore, Union Star, Sacramento, Grand Army of the Republic;*
2. Kelleys Island Shoal for a preliminary search for 3 wrecks: *St. Louis, Florence, Star of Hope;* and
3. Western side of Kelleys Island for preliminary search for 4 wrecks: *Oak Valley, L. B. Crocker, C. H. Plummer, Relief*.

Additional wrecks without good coordinates (Plate 2)

1. *Exchange*
2. *William Crosthwaite*
3. *Uncle Sam*
4. *Emory Fletcher*
5. *Ruby*
6. *Erie*
7. *Empire*

The Ohio Geological Survey's research vessel, *GS-3*, was launched each day at the Mazurik State Wildlife Area near Lakeside on the Marblehead Peninsula because of its central location to all wreck sites in the study area. Two weeks in August were selected to do the work because data acquisition requires near-calm lake conditions to collect quality data in very shallow water.

Five full days of fieldwork were completed within the two-week period. The following section summarizes the science log that describes the field activities.

Day 1; August 11, 2003

On the first field day Dale Liebenthal, J.A. Fuller, Constance Livchak and Dr. Herdendorf were aboard the *R/V GS-3* to conduct an evaluation of side-scan sonar as a tool for a search for archeological artifacts in a mixed substrate area. Part of the day was spent investigating the best range scale to use for area searches and on minimum depth of water to allow positive wreck identification.

The first site used the steamer *F. H. Prince* on the east side of Kelleys Island (Fig. 2). The 150- and 100-meter ranges were both used and found to be too broad of a scale for this type of reconnaissance survey even with a known wreck location. The 75-meter range seemed to be best suited for area

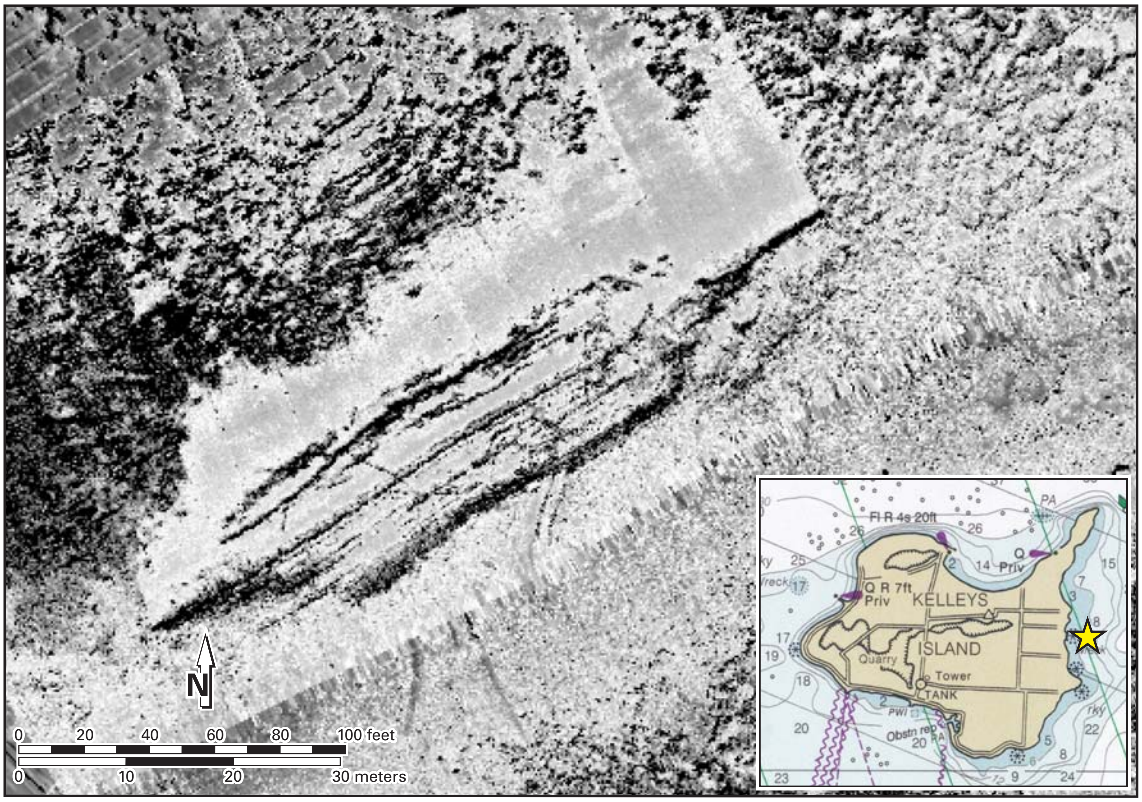

FIGURE 2.—*F. H. Prince*.

searching for the water depth in the study area. Excellent side-scan sonar records were collected at this wreck and a possible new wreck site was identified off the southeast end of the *F. H. Prince*. Subsequent investigations (on day 4) from different angles showed the unknown wreck was most likely a geologic feature.

The *R/V GS-3* proceeded to the North Bay area of Kelleys Island to investigate the wrecks, *W. R. Hanna* and the *Adventure*. The *W. R. Hanna* and the *Adventure* were archeologically studied (Labadie, Herdendorf, 2004a, b) but were in too shallow of water (3-4 meters, Labadie, Herdendorf, 2004a, b) and too spread out to be documented with the side-scan sonar.

A preliminary search with the 75-meter range for the *St. Louis* was conducted off Kelleys Island Shoal with only questionable possibilities of artifacts found. No definite large-scale wreck site was found, so a more detailed resurveying would be required. A preliminary assessment of the south and north sides of Gull Island Shoal (See Plates 1 and 3) was made with the 75-meter range, but no clear shipwrecks were located.

From Gull Island Shoal the *R/V GS-3* proceeded to the east point of Middle Bass Island to look for the *Isabella J. Boyce* with the 75-meter range. Reports from local SCUBA divers indicated the engine flywheel was still on the wreck site. The flywheel seemed to show on one side-scan sonar pass but, during post-processing, we felt we could not positively identify it. Approximately 21 miles of track-line were recorded for day 1 (Plate 2).

Day 2; August 13, 2003

We began the day by searching for the schooner *Exchange*, which lies close along the south shore of Kelleys Island with its keel lying nearly north and south. The 75-meter range was used to locate the wreck and a couple of passes were made to verify its location. Multiple passes were made over the *Exchange* using various range scales. As expected, the 50-meter range provided better detail of the wreck than the 75-meter range. The 37.5-meter range was attempted here but did not provide better resolution even though the shorter range provides more acoustic energy on the target. The 37.5-meter range simply required such precise navigation to put the wreck in the central third of a channel that it was not worth the time expended. It simply was too easy to have part of the wreck under the towfish or beyond the sonar range.

The next task was to survey the west side of Kelleys Island (Plate 2) as a detailed, continuous side-scan sonar search of an area for 4 possible wrecks. Of these, the probable locations of the *Oak Valley* (Fig. 3), and either the *L. B. Crocker* or tug *Relief* (Fig. 4) were identified. Continuing around the southwest corner of Kelleys Island, another wreck was found that could be the *Relief* or the *C. H. Plummer* (Fig. 5). Due to the abbreviated nature of this pilot survey, these wrecks will have to be positively identified in a subsequent study. Again, the 50- and 37.5-meter range scales were tried with the outcome being the same as at the *Exchange* where the 50-meter range was best.

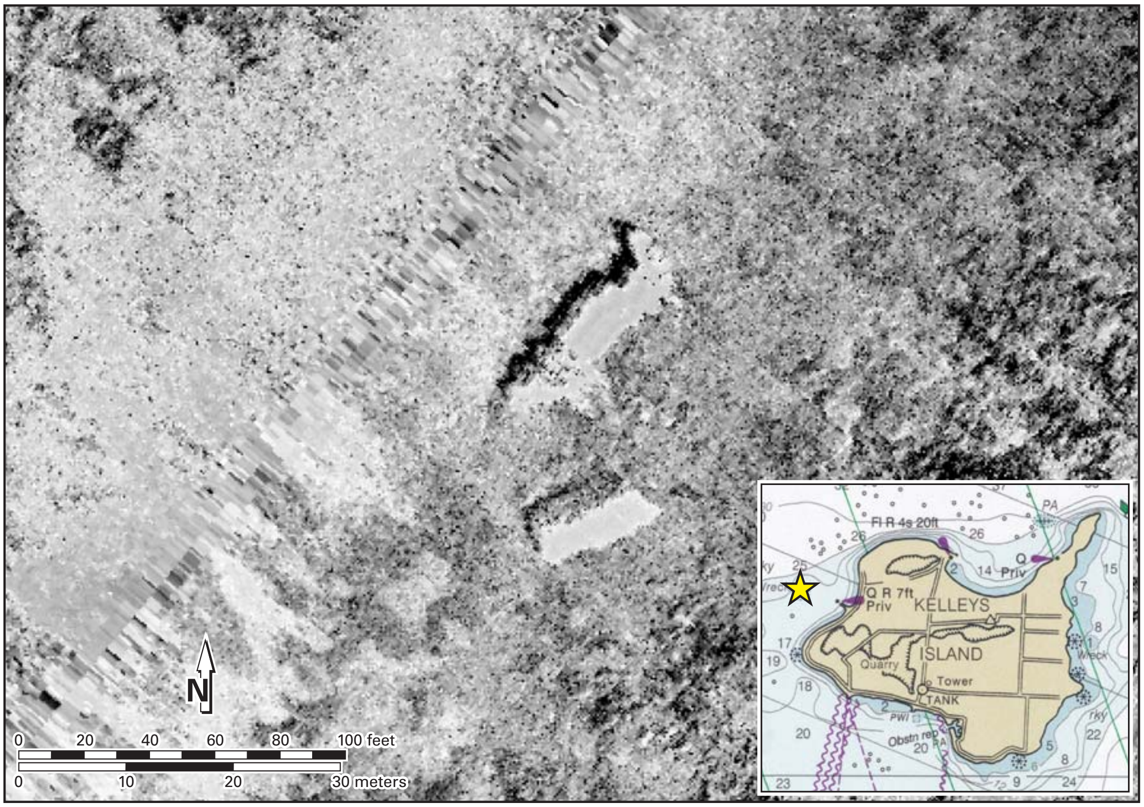

FIGURE 3.—*Oak Valley* or *L. B. Crocker*.

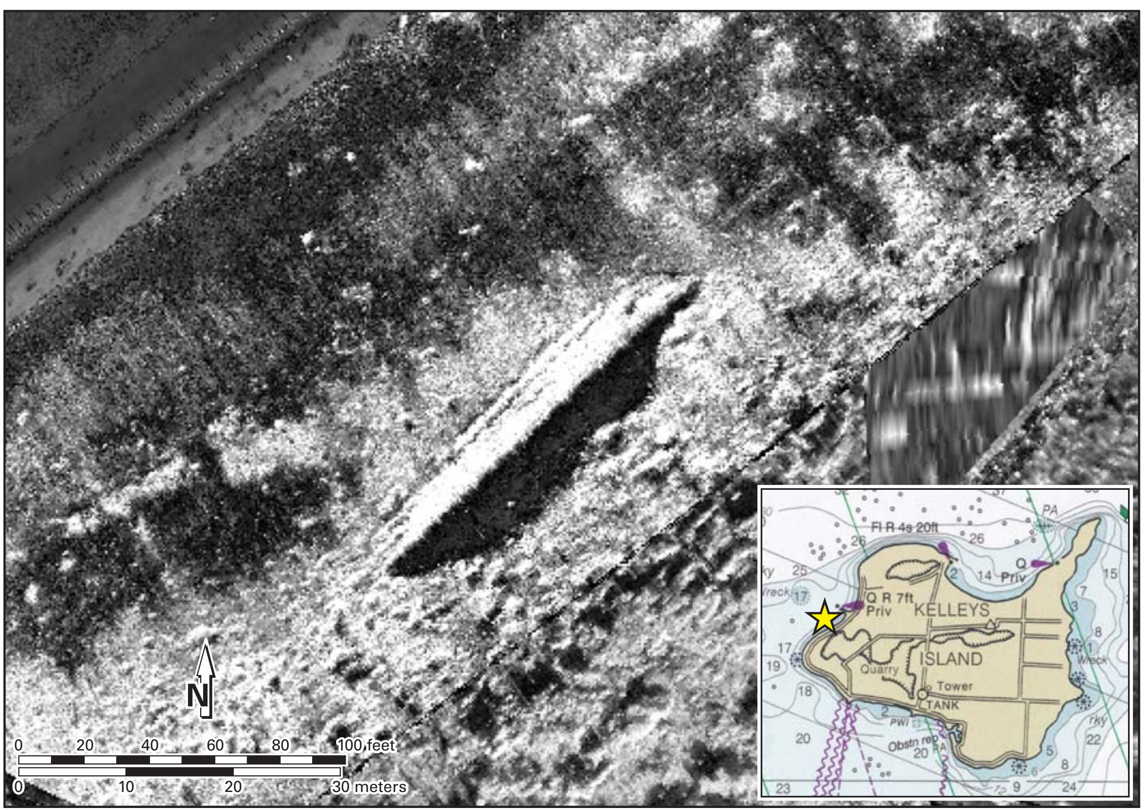

FIGURE 4.—*L. B. Crocker* or *Relief*.

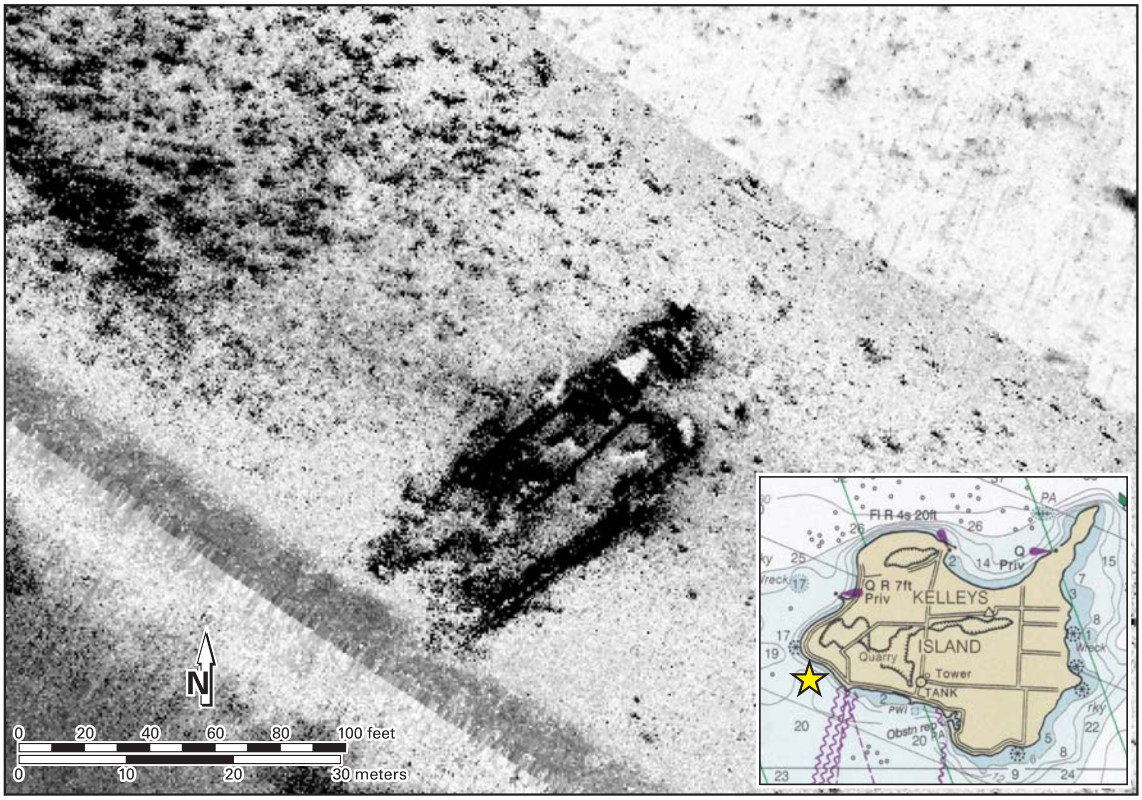

FIGURE 5.—*Relief* or *C. H. Plummer*.

From the west side of Kelleys Island we proceeded southwest to the approximate reported location of the *William Crosthwaite* in South Passage (Herdendorf and Pansing, 2003). An areal search with the 75-meter range provided nothing that looked promising as a target. Approximately 40 miles of track-line were recorded for day 2 (Plate 2).

Day 3; August 14, 2003

This day's survey began at Starve Island Reef at the wreck of the *Amaretta Mosher* with an areal search using the 75-meter range. The wreck lies on the southwest side of the reef and at the base of a large bedrock structure in deeper water (Fig. 6). The hull lies "unzipped" with the keel, rib timbers and side planking visible on some views. The wreck is badly damaged and scattered. A number of side-scan sonar passes with the 50-meter range were required to effectively highlight the wreck details. Much of the problem was that the wreck is sitting in a small low between two bedrock highs. This position made it difficult to "see" but probably has helped preserve the wreck.

From Starve Island Reef, we proceeded in the *R/V GS-3* back to the east point of Middle Bass Island to search again for the *Isabella J. Boyce*, which had burned to the waterline after grounding. Local divers located the wreck, but reported that only scattered timbers, pipes and an engine flywheel remained on site. Much of the engine machinery had been previously salvaged. Another attempt was made to locate the flywheel and any other material but it was not successful. The reported shape of the wreck, the very shallow water, and thermocline on the side-scan sonar records all limited our ability to identify the wreck site.

We proceeded to the North Bay area of Kelleys Island to make area searches for any signs of the wrecks of the sloop *Ruby* and the schooner *Emory Fletcher*. Nothing was visible on the side-scan sonar records at the reported locations. Approximately 31 miles of track-line were shot for day 3 (Plate 2).

Day 4; August 19, 2003

The wreck of the *George Dunbar* was searched for and found (using the 75-meter range) approximately 10.7 kilometers (6.7 miles) northeast of Kelleys Island (Herdendorf and Pansing, 2003) and lies just beyond the International Boundary in Canadian waters. Due to deeper water than at other wreck sites, the 50- and 37.5-meter-range scales were used to provide more detailed records of the wreck, and again the results were the same as reported from the *Exchange*; the 50-meter range provided better records more effectively. The wreck is surrounded by a soft bottom, which allows it to stand out on the records. Presumably the soft sediments are not very thick because the wreck has not settled into the bottom enough to be unrecognizable. This wreck sits upright and intact on the bottom very close to the reported position with her deck machinery and cabins visible on the side-scan sonar record. Her stack lies approximately 12.7 meters (40 feet) off her port stern (Fig. 7). Other

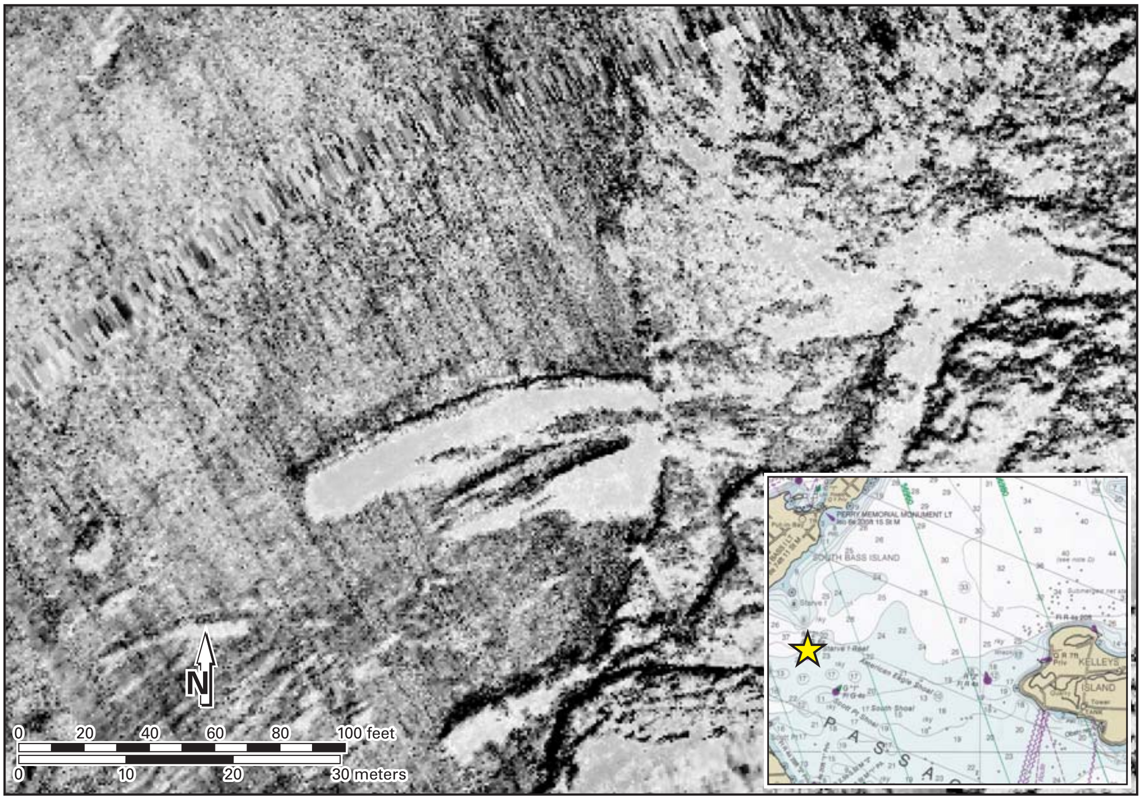

FIGURE 6.—*Amaretta Mosher*.

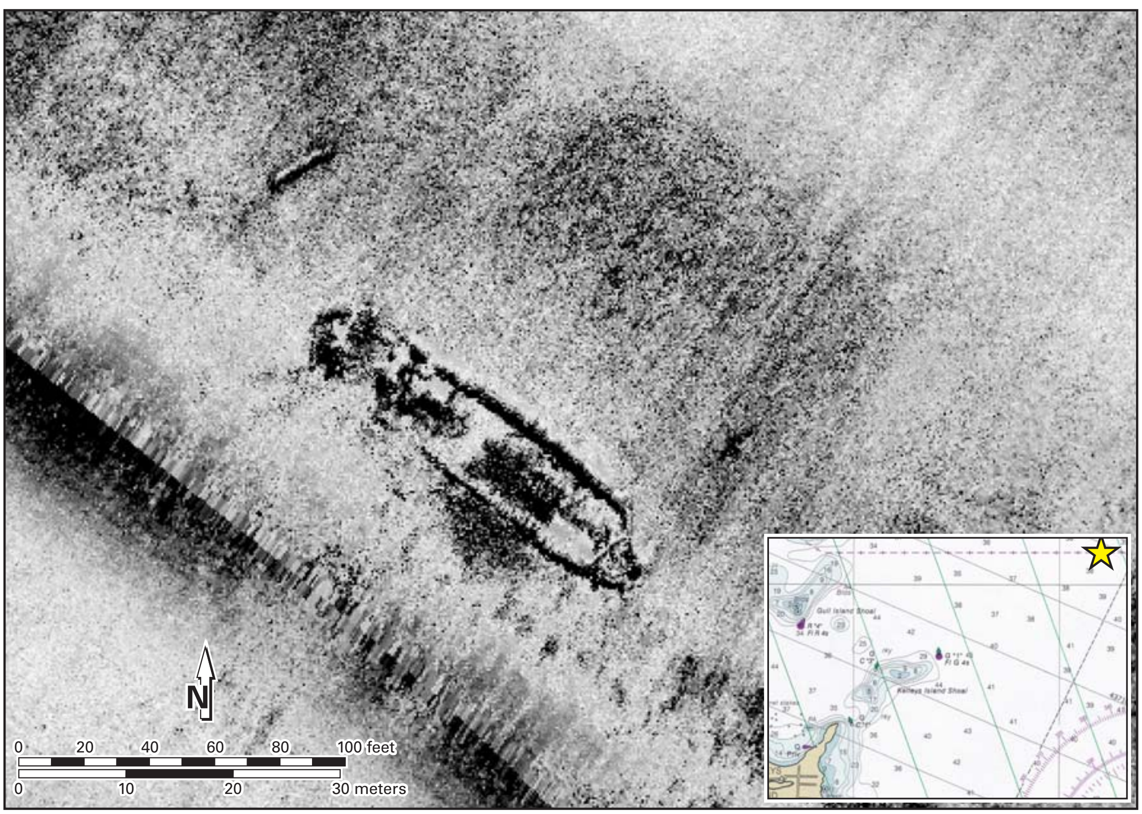

FIGURE 7.—*George Dunbar*.

pieces of wreckage appear to be lying off her port bow.

Kelleys Island Shoal was surveyed using the 75-meter range with overlapping lines to provide a more thorough search for the wreck *St. Louis*. This wreck was reportedly found by local divers, but good location coordinates were not available. A mosaic was constructed of the whole northern side of Kelleys Island Shoal, but no probable targets were found.

We then proceeded to the east side of Kelleys Island to return to the wreck of the *F. H. Prince*. During the previous visit, a possible new target to the southeast of the wreck site was located. A 75-meter range mosaic of this area was constructed and this feature is interpreted to be a geologic structure. The wreck was scanned at 50-meter range to provide good detail. This ship caught fire and burned for a period of time sufficient to destroy much of the deck detail (Herdendorf and Pansing, 2003), but individual planks and an outline "shadow" of the remaining structure can be still be seen in the sonar image (Fig. 2).

We moved to the reported wreck site locations of the *Erie* and *Empire* off the tip of Marblehead Peninsula. Neither of these locations was reported as exact (Herdendorf and Pansing, 2003). Only one target was observed on the 75-meter-range record that required further investigation the next day. According to Herdendorf and Pansing (2003), both of these ships foundered in a storm and washed ashore; therefore the locations appeared suspect from the outset. Approximately 40 miles of track-line were recorded for day 4 (Plate 2).

Day 5; August 20, 2003

Gull Island Shoal (Plate 3) was reported by Herdendorf and Pansing (2003) to have as many as 5 wrecks located in the immediate vicinity. The last day of field activities was used to produce an area mosaic (75-meter range) of the hard substrate area near the reef. This reef, known to be the most treacherous reef in Lake Erie by mariners, would likely produce archeological remains. If any wreckage were still present and recognizable, it would appear on the hard substrate rather than partially sunk into the softer sediments, which often surround the reefs in deeper water. The majority of the day was used in the detailed mapping of this reef. Three blocks were observed off the west end of the high point of the reef that were later re-examined with the 50-meter range, in the post-processing phase (Plate 4). These could be large geologic features with possible glacial grooving which can, at first, appear man-made. Two other targets were ensonified with the 50-meter range but no definitive identifications were made. On the southeast side in the deeper portion adjacent to the reef, the side-scan sonar mosaic revealed an influx of softer sediment trending from east to west which may indicate that energy forces in the form of wind-driven waves, currents and/or ice keels are present and could have destroyed or carried off any archeological remains at this site.

A return was made to the previous day's target in the area of the *Empire* and *Erie*. These 50-meter-range records provided little more help in identifying the features. The donut-shaped areas appear to be dumped or spilled piles of harder material. Approximately 37 miles of track-line were recorded for day 5 (Plate 2).

CONCLUSIONS AND DISCUSSION

The ability of side-scan sonar technology to rapidly image the bottom surface makes it an excellent tool to use for area and target searching. In addition to side-scan sonar there are other electronic tools that can be employed concurrently or as a separate survey that could enhance the data collected. A towable magnetometer would sense magnetic fields associated with those wrecks that still have machinery in place. It must be considered that many of the wrecks surveyed had the machinery removed for use on other ships or to be recycled for use during the two world wars (Herdendorf and Pansing, 2003), and divers have also removed many artifacts from wreck locations. Another possible search tool is single or multi-beam sonar. This device uses a wide-angle sound impulse that maps the vertical detail of the lake bottom in high resolution. Such data allows digital 3-D imagery that can assist the observer by finding shapes of shipwrecks that are not obvious with side-scan sonar alone.

During the study, some time was taken to determine the best range scale to obtain the optimal results of a regional search. By repeatedly passing known wrecks, it was found that the 150-meter range would not be sufficient to conduct wide-area searches due to the very shallow water in which most wrecks are located in the Western Basin of Lake Erie, and the small size of the wrecks on the record. The 100-meter range is the maximum range to use and then only in special instances; most of the time, the 75-meter range is best for regional searches. For detailed mapping, the 50-meter range seems to provide the best detail of known wrecks. In addition, many other targets were located that may be anthropogenic. Some examples are shown in Plate 4 that are representative of the unidentified targets found in this pilot project, which would require further investigation. Our system can scan a range of 37.5 meters to examine targets in detail, but this range did not provide enough improvement in resolution to warrant its use over the 50-meter range for objects as large as these wrecks. Side-scan sonar can technically resolve approximately 3-cm targets with the appropriate range and contrast, but in practice it is difficult to achieve. Turbidity, ambient noise, shallow-water problems and tuning are all difficulties that the side-scan sonar operator must overcome.

This pilot project concentrated on known areas of hard substrate consisting primarily of glacial deposits or bedrock. The locations of these areas were known by past experience and from both in-house data and published documents such as Hartley (1961a, b) and Fuller and Foster (1998). Areas of soft sediment substrates were generally avoided in the pilot study because pieces of wreckage could be concealed in areas of softer sediments by sinking below the lake bottom surface. In addition, gas is an underwater acoustic isolator; therefore the targets may be undetectable due to gases generated and trapped in the more-recent soft sediments.

On the other hand, there are also challenges with archeological remains of ships on the hard substrates. Storms producing wind-driven waves would damage many artifacts by abrasion against the rock reefs. Also, the wrecks would almost assuredly be susceptible to damage from ice. The Western Basin of Lake Erie is defined as the area west of a line from Pt. Pelee, Ontario, Canada to Vermilion, Ohio (Assel, 2003). The Western Basin is the first to form ice and attains maximum coverage and concentration more frequently than the Eastern or Central Basins of Lake Erie (Assel, 2003, 2004; Assel and others, 2003). This is because ice formation requires shorter periods of low air temperatures in the Western Basin due to its shallower depth and lower heat-storage capacity. The annual maximum ice cover for Lake Erie for the last four decades has averaged over 87%. Wind-driven ice, shifting back and forth can develop rafting, ridging, and windrowing ice with keels reaching completely to the bottom of the shallow Western Basin. These keels develop over 20 meters (65.6 feet) in depth in the deeper Central and Eastern Basins (Canadian Ice Service, 2004; Grass, 1984). These keels could destroy and carry off any remains, increasing in force around reef and shoal areas. Wrecks on reefs could have been destroyed unless protected by the rock reef itself, such as in the case of the *Amaretta Mosher* on Starve Island Reef. Her keel seems to be nestled in a small valley of rock that may have saved what remains of the wreck from ice damage.

An additional problem with some of the wreck sites is that with the advent of recreational underwater sport diving, many of the wreck sites were plundered and artifacts were stolen. Some of these artifacts are the objects that would show up best on side-scan sonar records.

RECOMMENDATIONS

A survey of this or a similar-sized area of like hydrographical features should include these major phases:

1. A continuous side-scan sonar georeferenced image of the entire navigable underwater area at 75-meter range. The track-lines would be laid out in the office prior to field work and oriented to the direction that would provide the least amount of maneuvering over the longest distances. At this stage, each of these lines of side-scan sonar records would be processed individually as opposed to mosaicking to avoid hiding possible targets by overlapping records.
2. Each record would be manually scanned in the office for targets after geo-processing. Targets would be identified using a targeting software integral to the Triton Elics ISIS® Sonar software and logged on a hydrographic survey software such as Coastal Oceanographics Hypack Max® software.
3. Once targets are identified, each will be re-surveyed in the field by making repeated passes at 90° angles to the keel or centerline of the wreck. The operator would make any adjustments necessary to obtain quality images. The target would then be examined using a low-light, drop-video camera in an effort to verify and identify the wreck. Those that cannot be identified would need further archeological investigation.
4. Each of the individual records would be processed into mosaics of nominal file size. The final target survey side-scan sonar records would be processed onto mosaics.
5. The mosaic would be imported into ESRI Arc GIS software where a detailed, georeferenced, final report could be produced.

Based on these tasks, an estimate of field time to complete a detailed survey of a hypothetical 40- square-mile area would be as follows:

1. Since actual survey areas are rarely rectangular this hypothetical area is being separated into sub-areas. Track-lines would be planned to run parallel to the longest side that allowed coverage of the most area with the least maneuvering. Orientation of the track-lines would often need to be changed to optimize the track-line length and number while avoiding obstacles. If using the 75-meter range, track-line spacing is approximately 125 meters.

2. Generally, a 40-square-mile area may have 500 total track-line miles. We estimate we can survey approximately 35 miles per day, in a 10-12 hour day. At this rate, it would take about 15 days in the field to finish the hypothetical area search on average, assuming appropriate calm lake conditions are present. Experience has shown that only 40 to 50% of the summer days are good for lake fieldwork and that the percentage is even less when working in shallow water. This means that the window of fieldwork needs to be a large portion of one field season.

Continuing with the hypothetical area, we used an area with reefs near an island to estimate the percent of hard and soft substrates in a typical area in the Islands region of the Lake (Hartley, 1961a, b). About 60% of the area is expected to be soft substrate (mud) and the remaining 40% is expected to be a hard bottom of mixed boulders with sandy/rocky areas. Using this pilot study as a guide, we estimated that an average of 3 questionable targets per field day would be seen when surveying over the soft substrate and 9 targets per day could be expected while surveying over the hard substrate areas (28 in 60 % of the area and 56 in 40 % of the area) that would need further investigation. A projected total of approximately 84 targets would need to be surveyed in detail**.** The detailed survey of each target would include boxing each target with at least the 50-meter-range side-scan sonar along with bottom grab sampling, underwater camera work, and possibly SCUBA diving. Probably at least 1.5 hours would be needed for ground-truthing each target. Using this time estimate, the time needed to ground-truth targets in the field totals 126 hours or about 16 days at an 8-hour day on site or a 10-hour day with transport to and from the field site. These totals are reflected in Table 1.

There usually is a considerable amount of effort in post-processing side-scan sonar data for use in GIS. An estimate of 4 times the field time to process the results is used, but because of detailed review of the records for targets, the processing and analysis time is estimated to be somewhat higher. Also, there can be setbacks to this estimate because

TABLE 1.—*Estimate of field time to survey the entire water area of a hypothetical 40 square mile area in the Islands region of Lake Erie*

Total track-line miles	543	
Miles of track-line expected per day	35	
Days running track-lines	15.5	15.5, 10 to 12 hour days
Track-line field days soft substrate	9.3	
Track-line field days hard substrate	6.2	
Expected targets on soft substrate per day	3	
Expected targets on hard substrate per day	9	
Total targets soft substrate (60% time)	28	
Total targets hard substrate (40% time)	56	
Total targets expected to need further investigation	84	
Hours needed for each target	1.5	
Total hours needed for target investigation	126	16, 8-hour days on targets

some data may need electronic repair or enhancement. The result is that at least 30 perfect field days are needed and at least 120 days of data processing would be needed for the hypothetical area prior to any report preparation.

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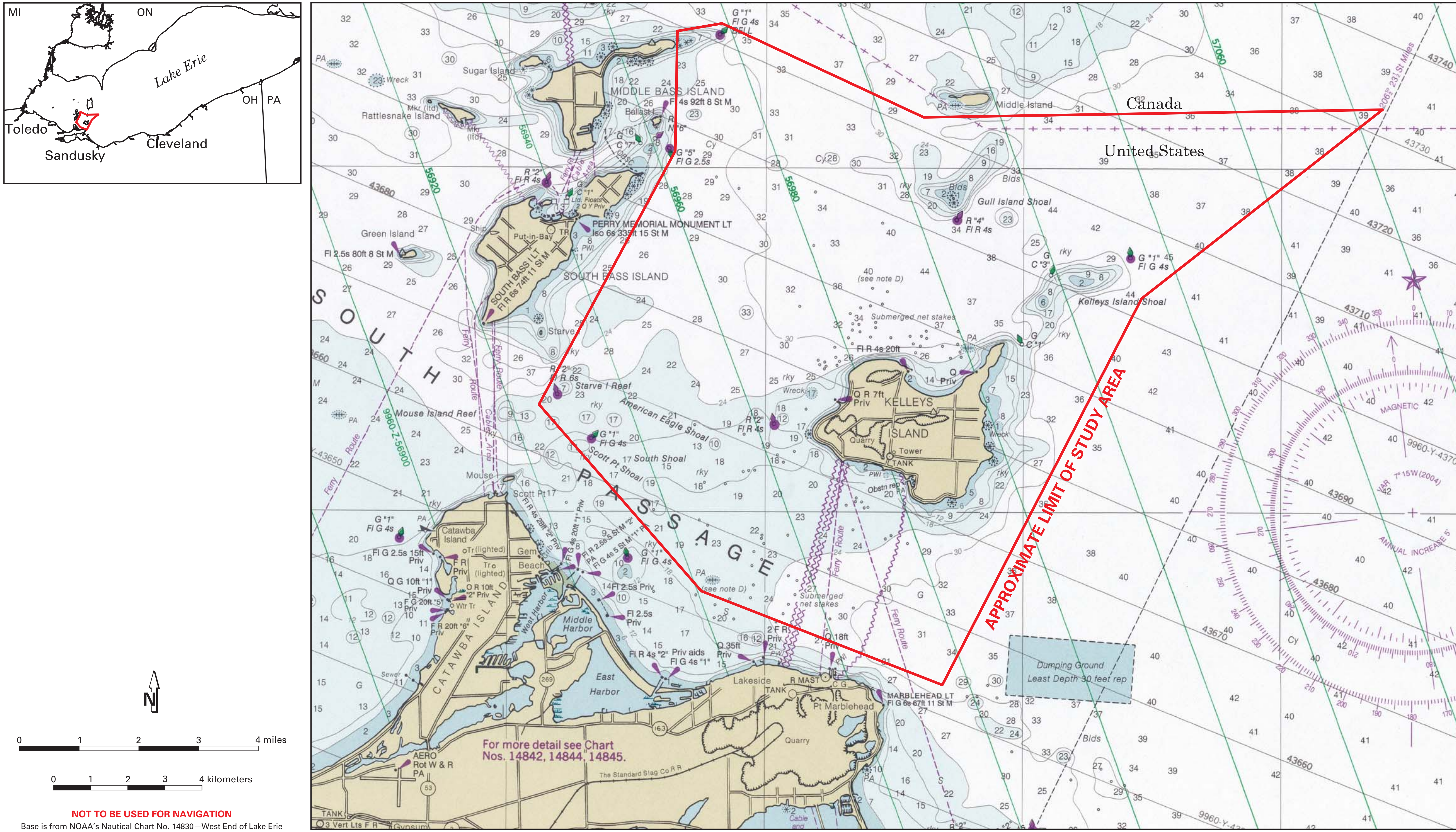


PLATE 1.—Study area around Kelleys Island.

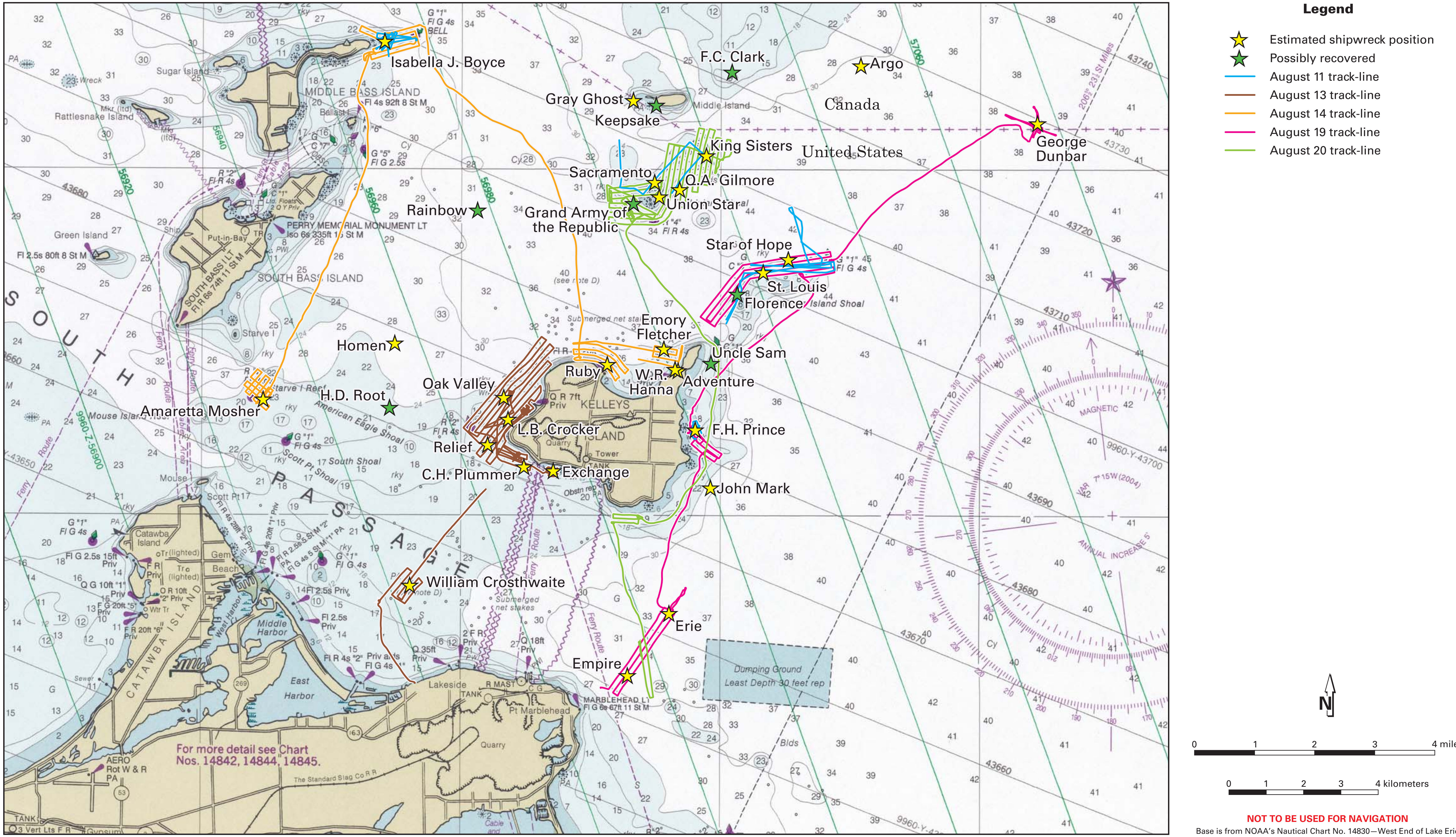


PLATE 2.—Study area track-lines.

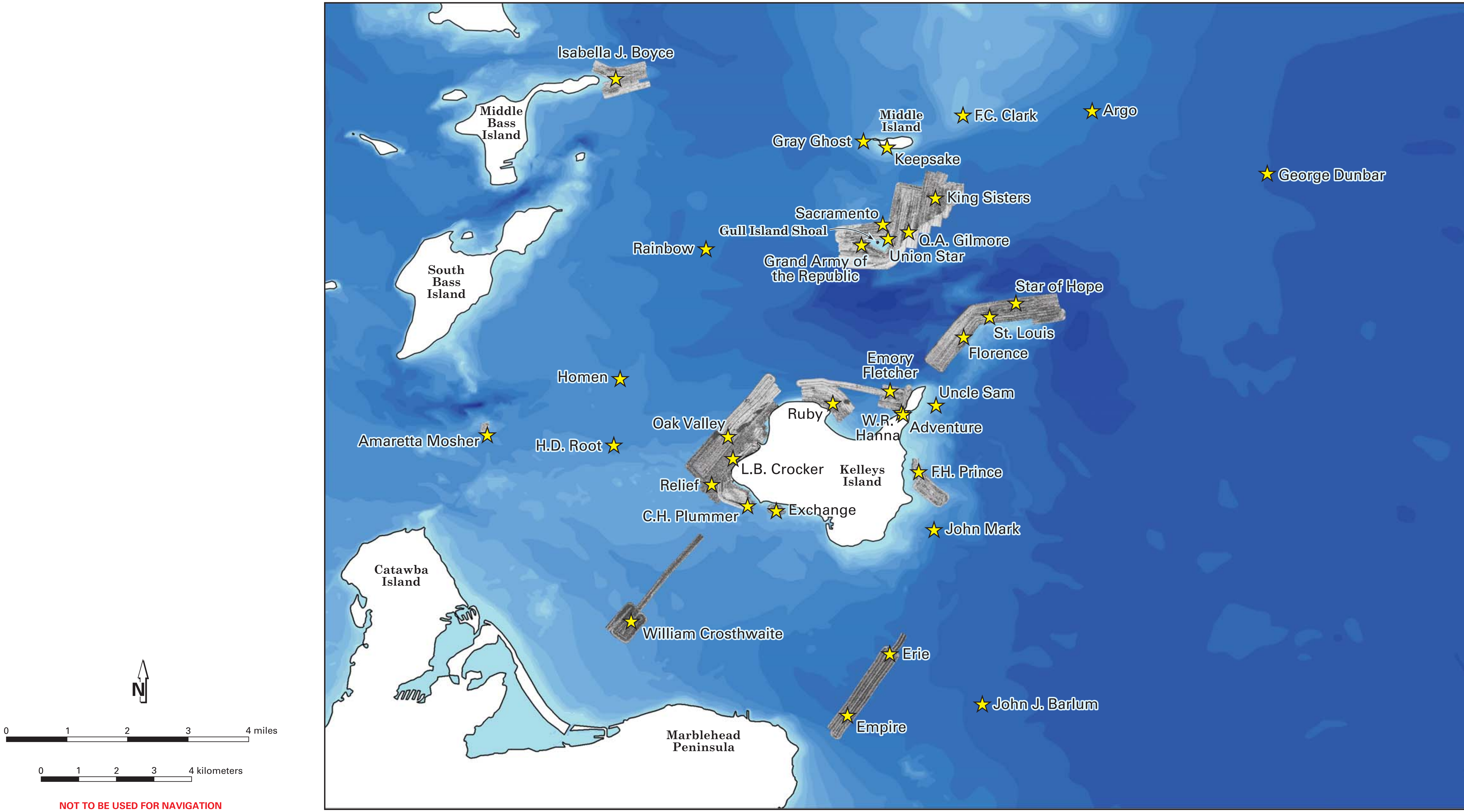
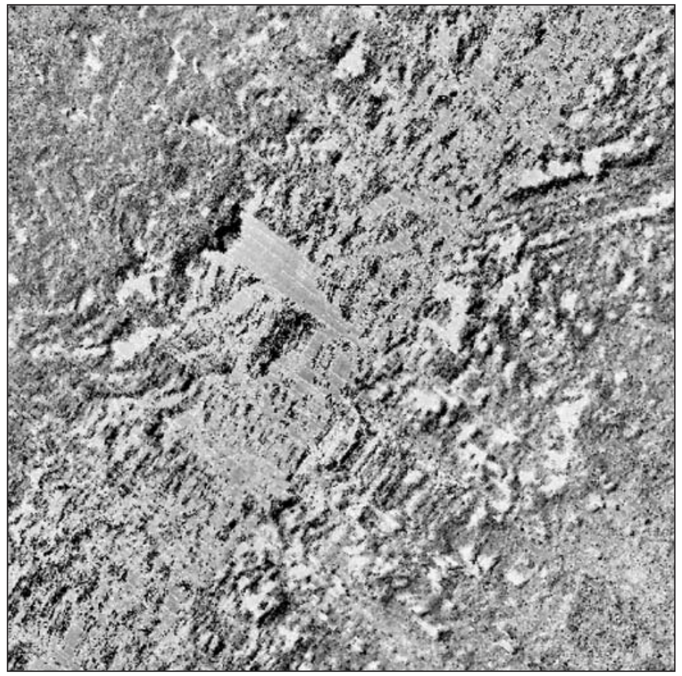
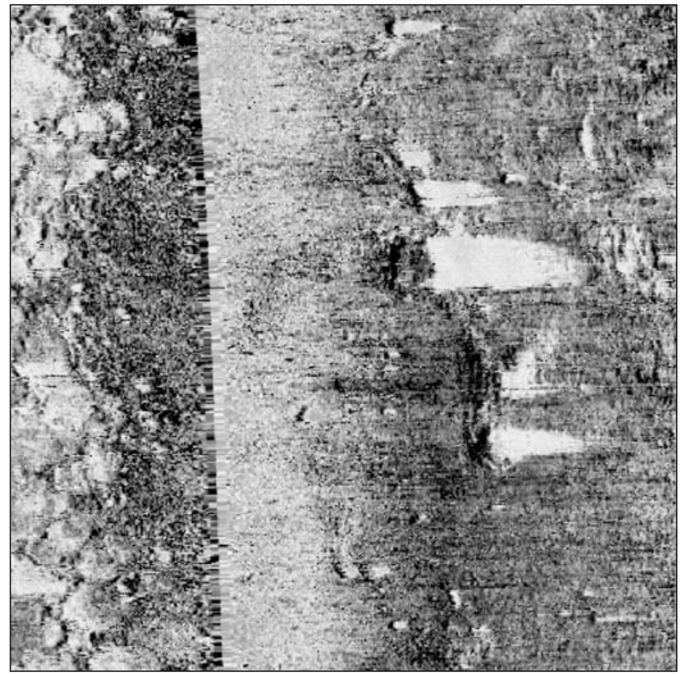


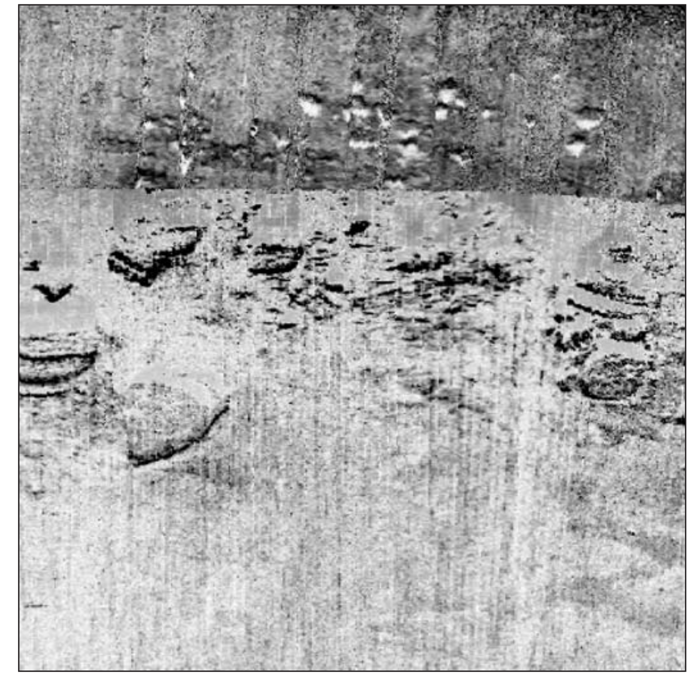
PLATE 3.—Reported wreck locations with side-scan sonar coverage.



Near the reported location of the tug *Relief*

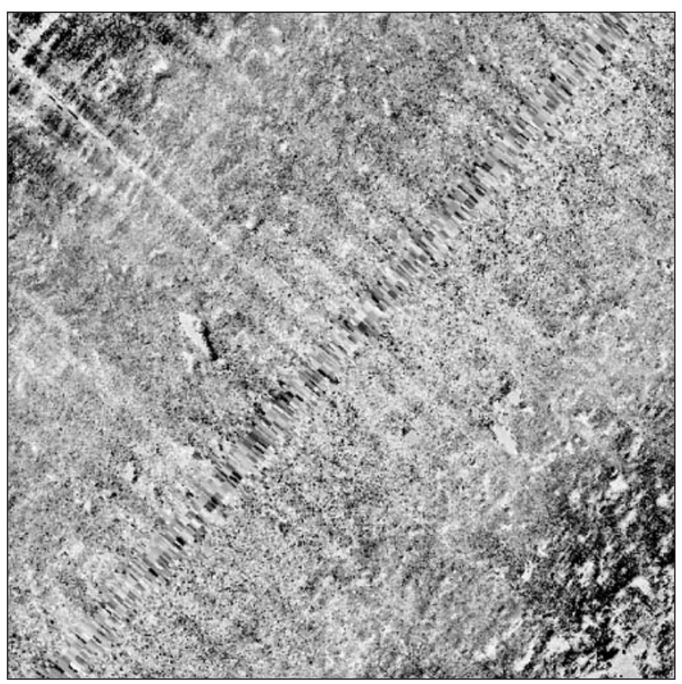


Northwest of Gull Island Shoal

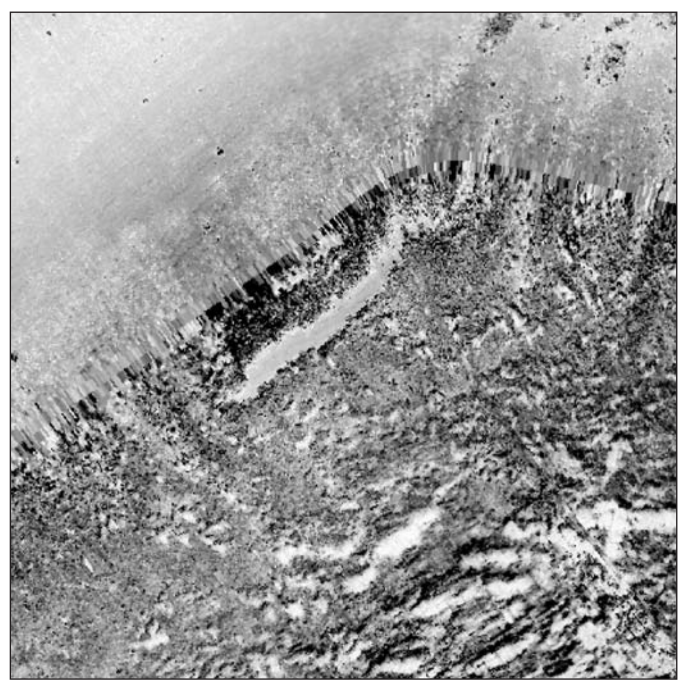


Southwest of Gull Island Shoal

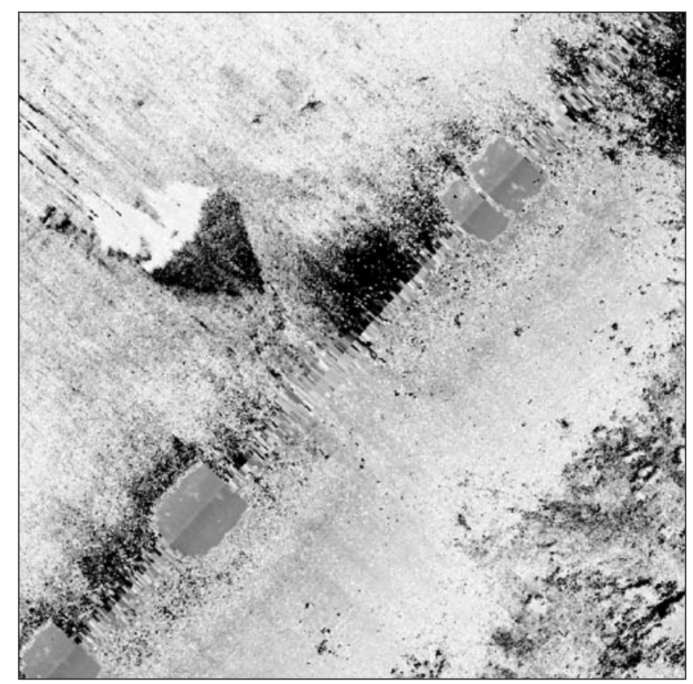
West of Gull Island Shoal



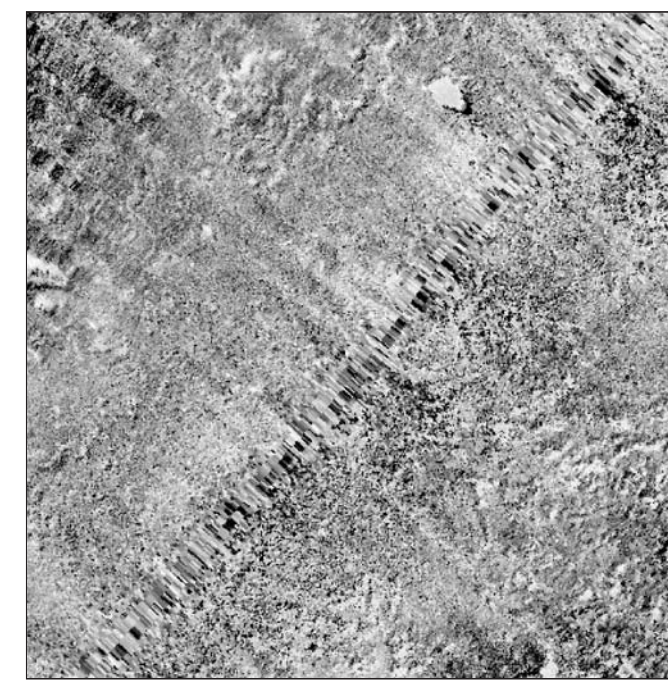
Kelleys Island near Carpenter Point



Kelleys Island near Lafarge dock



Kelleys Island near Lafarge dock



Kelleys Island near Lafarge dock

PLATE 4.—Typical contacts that need subsequent investigation.

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