UNDERWATER IMAGING ON THE GREAT LAKES TO LOCATE DEEP WRECKS

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ABSTRACT

Commercial Shipping on the Great Lakes began in 1679 with the arrival of the *Griffon*; the history of Great Lakes shipwrecks began with this same ship in the same year when she failed to reach port after setting sail out of Washington Island for Niagara. Since this first foundering, there have been an estimated 10,000 shipwrecks on the Great Lakes. The current method for locating these shipwrecks has been to do library research to determine a search area and then use side-scan sonar to locate the ship within that given area. Once the wreckage has been located, SCUBA divers descend on the site to identify the ship. Unfortunately, this method only works within the depths that a person can safely descend and ascend, roughly 400 feet, a relatively small portion of the Great Lakes. Recent technological advances in underwater imaging and sonar has made it possible to explore shipwrecks at depths beyond that which a person equipped with SCUBA gear can withstand, but this technology has not yet been utilized on the Great Lakes. This thesis will explore these new technologies and how they would be beneficial in the location, identification, and mapping of Great Lakes shipwrecks located in deep water.

INTRODUCTION

On November 17, 1958 the *Carl D. Bradley* departed for Rogers City, Michigan for what was supposed to be a thirty hour trip. By 5:15 PM the next day, winds had picked up to sixty-five mph with twenty to thirty foot waves. The *Bradley* only had water in her cargo holds as ballast and because of this was twisting and bending in the rough seas, shearing rivets off causing the hull to grow weaker. At 5:31PM there was a sudden thud heard in the wheelhouse by the Captain and First Mate, the two saw the stern section sag down as the ship began to break apart in the rough seas. A quick mayday was sent before the ship tore in two, severing the power lines; this transmission brought the *Sundew* out of Charlevoix, Michigan and the *Hollyhock* out of Sturgeon Bay, Wisconsin to her aid. Also heading for them was the German freighter *Christian Sartori*, four miles from the *Bradley*'s last known location. Two men survived the wreck and only eighteen of the thirty-three bodies were recovered (Hemming 1981). The wreckage lies in about 380 feet of water with about 120 feet separating the bow and stern section. This wreck remained untouched until 2001 when Mirek Standowic was the first to dive on the bow section. In July of 2004, John Scoles and John Janzen became the first to dive on the stern section (Janzen 2005).

This is a story that is becoming quite common on the Great Lakes, as diving technology improves allowing divers to go deeper and deeper; more wrecks are left to their mercy. No research has ever been conducted on the *Bradley*, as is the case with most of the shipwrecks on the Great Lakes, and now we have lost the opportunity to conduct research on a virgin wreck because we don't know what has been removed from the wreck as a souvenir.

What follows is an introduction into Great Lakes history including shipping, weather and shipwrecks as well as underwater imaging technologies. I argue that with the use of underwater imaging we can conduct research on the Great Lakes, specifically on the deep wrecks that still have their context intact.

BACKGROUND

Figure 1. Great Lakes Ports (Schenker et al. 1976)

Shipping

Figure 1 shows the ports located around the Great Lakes. The five Great Lakes combined are the largest navigable body of freshwater in the world (Schenker et al. 1976). In all, the Great Lakes have 3,385 miles of shoreline (Curwood 1909). The first Welland Canal was opened in 1832 (Havighurst 1975) and the last built in 1932, opening Lake Ontario to bulk carriers and linking the lake with the other Great Lakes by connecting Lake Ontario and Lake Erie. In 1970, the Poe Lock was opened at the Soo Locks located in Sault Ste. Marie. This allowed the shipyards to build 1000 foot vessels that could carry twice the cargo of the earlier vessels. When the St. Lawrence Seaway opened in 1959, it opened the Great Lakes to ocean-going vessels (Schenker et al. 1976). The locations of the Soo Locks and Welland canal are pictured in Figure 2 below.

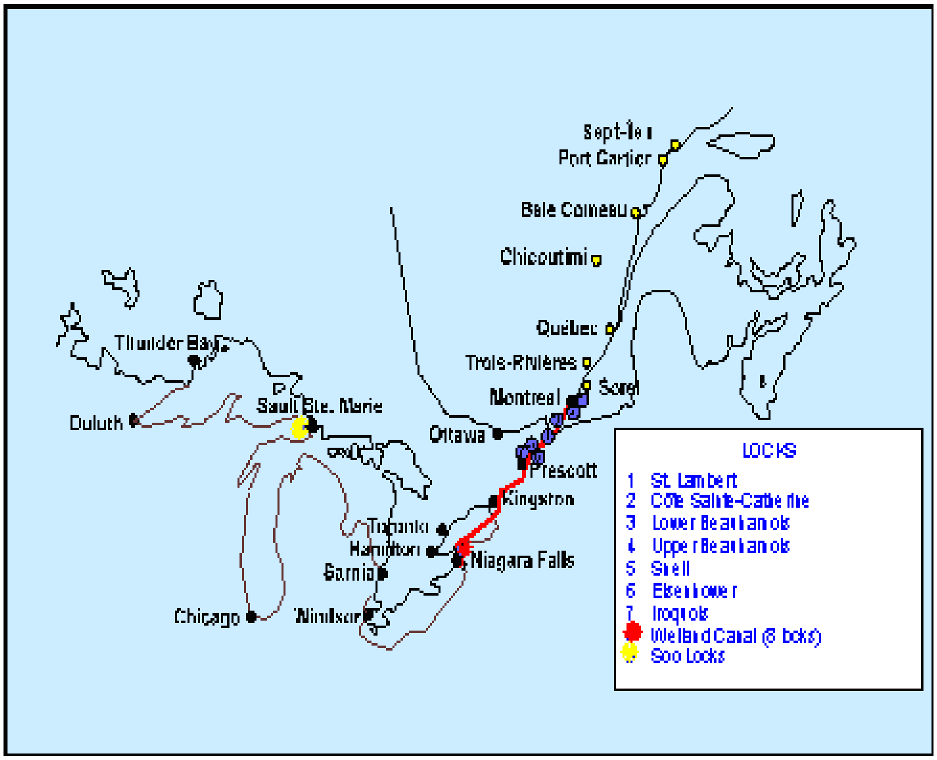

Figure 2. Locations of Welland Canal and Soo Locks
(Transport Canada et al. 2006)

Shipping first began in 1679 with the arrival of the *Griffon* in Niagara. On September 18, 1679 she departed Washington Island for Niagara and was never seen again (Ratigan 1960, Thompson 2000). Cargoes on the Great Lakes vary depending on the lake. In 1907 it cost ten cents to ship a bushel of grain from Chicago to New York by rail versus the six and a half cents by boat.   The lakes became a shipping highway linking the materials that produced steel during the age of steel in the United States because of the cost effectiveness of shipping by sea versus by rail (Havighurst 1975). It cost eighty cents to ship a ton of ore from Lake Superior to Lake Erie by ship whereas it cost seven times that to ship it by rail (Curwood 1909). Three-quarters of the iron ore that was mined came out of the area around Lake Superior and water transportation was required to bring the iron ore to the coal beds (Havighurst 1975). As more cargo was being shipped on the Great Lakes, the number of ships rose accordingly.

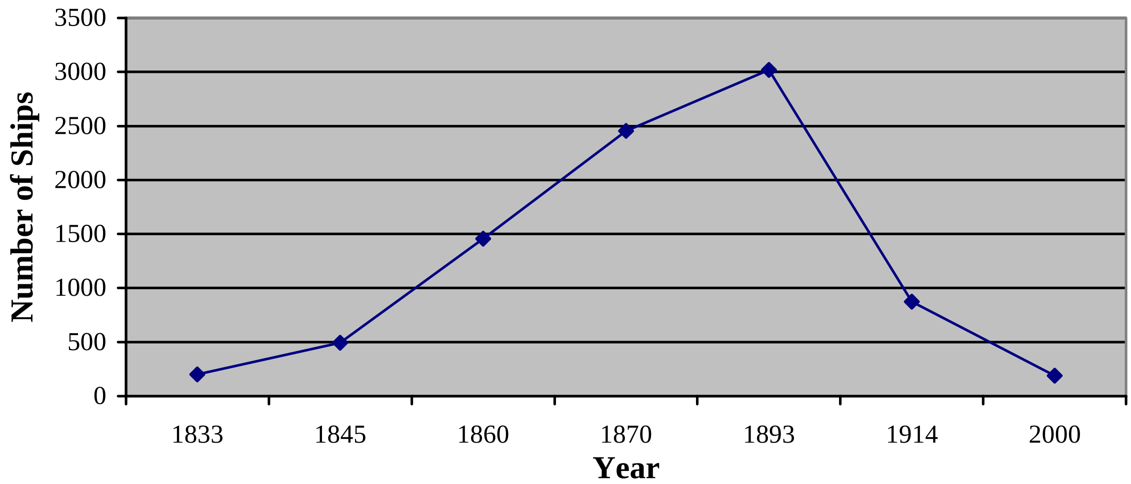

Figure 3. Number of Ships Operating on the Great Lakes (Thompson 2000)

Figure 3 shows the number of ships operating on the lakes in a given year. In the 1830s, the popular ship to be running on the Great Lakes was the schooner because it was maneuverable and required a small crew. In 1816, the first wooden steamboats are seen, though they were slow to gain popularity. In 1833, there were only eleven steamboats operating on the Great lakes. By 1872, more owners were building steamships bringing the number to 682 ships, though still small in comparison to the 1,654 sailing ships operating on the Great Lakes. It was during the 1880s that you first start to see steel and iron ships. In 1882, the first iron ship was built, the *Onoko*, followed by the first steel ship in 1886, the *Spokane*. In 1930, the last sailing ship foundered on the Great Lakes, ending the reign of sailing ships (Thompson 2000). The modern vessels that are still seen today are being built around 1913; they are constructed of steel and are steam operated. Most of these vessels are between 440 and 550 feet long (Barcus 1960).

Weather

A major reason there are so many shipwrecks on the Great Lakes is the weather, specifically the storms that hit during November. A third of all storm related shipwrecks occur during the month of November (Thompson 2000). These storms begin as a low pressure area over parts of North America, usually Northwest Canada, the Gulf Coast, and the Rocky Mountains (Barry 1981). The temperature differences caused by the low pressure areas are most extreme in the fall. The conflicting air masses trigger a counter clockwise swirling motion around a low pressure center that moves east where it comes into contact with the warm moist air over the Great Lakes. The low pressure system intensifies and the warm front in front of the low and cold front behind get closer forming an occulded front. Winds increase and waves form on the Great Lakes. At fifteen mph white caps will form and at twenty-thirty mph the wind will tear the spray off the crests. While wind shifts will knock the seas down, lowering the height of the waves, prolonged winds out of one direction will build higher and higher waves. Gales have waves around eight to twelve feet high. The highest waves recorded are between twenty and thirty feet high which is the same range as a hurricane (Thompson 2000). Since atmospheric circulation is greater during the month of November, these storms occur more frequently accounting for more storms of this intensity during this single month (Eichenlaub 1979).

There are two terms used to describe these phenomena on the Great Lakes: gales and storms. A gale will have winds between thirty-nine and fifty-four mph while a storm has winds over fifty-four mph. Table 1 below shows what an average year for storms and gales was on four of the Great Lakes.

LAKE	Number of Gales	Number of Storms
Superior	47	13
Michigan	42	10
Huron	25	6
Erie	27	5

Table 1. 1982 statistics on number of storms and gales on the Great Lakes (Thompson 2000)

A storm is the highest rating for anything with an attached low pressure system. Hurricanes do not have an attached low pressure system and there fore can not occur on the Great Lakes. By definition a hurricane occurs in tropical waters and has winds exceeding seventy-three mph. While Great Lakes storms have exceeded this limit, they are not considered hurricanes. The highest winds recorded on the Great Lakes were 103 mph. A study done back to 1835 found that at least twenty storms on the Great Lakes were of hurricane strength. One of these occurred in October and the rest were in November (Thompson 2000).

The worst storms on the Great Lakes can be broken down as follows: The *Alpena* Storm of October 1880, The Big Storm or *Mataafa* Storm of November 1905, the Great Storm of November 1913, the Black Friday Storm of October 1916, the Armistice Day Storm of November 1940, The *Bradley* Storm of November 1958, the *Morrell* Storm of November 1966, and the *Fitzgerald* Storm of November 1975. These eight storms took a toll of fifty-five wrecks on the Great Lakes, most of the storms listed above were named for the most famous shipwreck that occurred during that storm. From 1846 to 1930 at least one ship was lost as a result of gales and storms every year and at least forty-two seasons lost more than ten ships as a result of these storms. From 1679 to 1975 there have been an estimated 1,077 storm related shipwrecks on the Great Lakes. It's likely this figure is inaccurate as most early records are incomplete (Thompson 2000).

The single worst storm to hit the Great Lakes was the Great Storm of 1913. This storm had low pressure systems develop in all three major areas of North America and then these three systems collided over the Great Lakes (Barry 1981). The storm was easily hurricane force, with winds over seventy-five mph and a blizzard in full swing during the course of the storm (Ratigan 1960). The storm itself lasted for four days and at least twelve ships disappeared without a trace. The death toll was set between 250-355 people (Hemming 1992), 255 of those lives coming from Lake Huron alone. The death toll on Lake Huron was so high because there was a false lull on Lake Superior causing the ships in port and in shelter to move down into Lake Huron where the storm was still at full strength. There was also a false lull on Lake Erie and along the Detriot and St. Clair Rivers, causing those ships to move up into Lake Huron. There were forty wrecks documented on Lake Huron, eight of which were never located (Ratigan 1960). Not only did this storm wreak a good deal of damage on the lakes, but it also dealt a great deal of damage on shore. The south breakwater of the Milwaukee harbor was completely swept away during the storm, doing $100,000 of damage to the harbor. In Chicago docks were wrecked, boulevards were washed out, trees were uprooted, plate-glass windows were smashed, and telegraph and telephone lines were wrecked. In all, the storm did one million dollars in damage to Chicago. Cleveland was hit the worst with five million dollars worth of damage (Barcus 1960).

Shipwrecks

As shipping on the Great Lakes has increased, so has the number of shipwrecks. The first documented shipwreck was the *Griffon* in 1679. She set sail out of Washington Island in September bound for Niagara and was not seen again after (Ratigan 1960). Since this first shipwreck, there have been at least 10,000 more on the Great Lakes many of which we don't know the location of. This is primarily explained by ships on the open water only having light and flag signals and megaphones to communicate with other boats and with those on shore (Hemming 1992). Radio telephones were not even considered for placement on ships until 1937, even though government agencies were urging shipping companies to equip their ships with radios starting in 1903 (Ratigan 1960). Information on these early wrecks is also scarce because it wasn't until 1936 that a panel was set up to investigate shipping casualties and to issue reports on the results of their findings. A ship was deemed a wreck when the ship didn't arrive in port or when debris from the ship washed up on shore. The *Bannockburn* left Port Arthur, Ontario with a load of wheat on November 21, 1902 and was sighted by two separate passing ships before she disappeared with all hands. The *Rouse Simmons* left Manistique, Michigan bound for Chicago with a load of Christmas trees in November of 1912. She was spotted off Kewaunee, Wisconsin flying a distress signal and then she vanished with all hands (Thompson 2000).

Ships still disappeared without a trace once they were equipped with radios. The *Daniel J. Morrell* disappeared in November 1966. The company reported the ship missing after they hadn't been heard from in thirty-six hours. The search turned up one survivor: Dennis Hale. It was determined that when the ship broke in half it severed the electrical lines that supplied power to the radio and so the crew was unable to broadcast a distress call. The Coast Guard changed is regulations as a result of the wreck; every shipboard radio had to be equipped with an emergency power supply in case the main power supply failed. This still did not prevent shipwrecks from occurring without a mayday being sent. The *Edmund Fitzgerald* was in communication with the *Arthur M. Anderson* and the first the *Anderson* knew of the ship's demise was when the *Fitzgerald* disappeared from her radar and Captain Cooper was unable to raise the *Fitzgerald* on radio (Thompson 2000; Great Lakes Maritime Institute 2007; Department of Transportation 1977; National Transportation Safety Board 1978).

Some have claimed that the Great Lakes are more dangerous to sail on than the ocean because on the ocean you have room to maneuver (Eichenlaub 1979). There is limited room to maneuver on all the Great Lakes and natural harbors are scarce, meaning there are few places for ships to take refuge during a storm. The man-made harbors are also difficult to enter during these storms (Barry 1981).

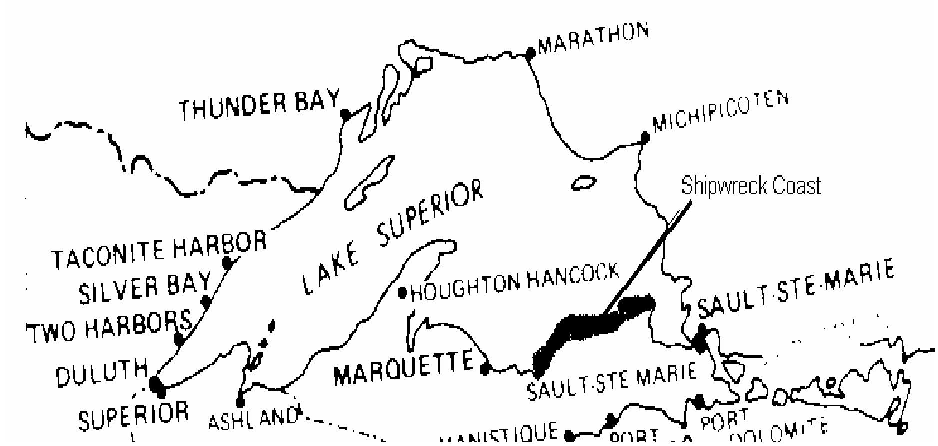

Figure 4. Shipwreck Coast on Lake Superior (Thompson 2000)

Scattered around the Great Lakes are 'graveyards' where ships have a tendency to wreck because of the terrain in the area or currents. Each lake has its graveyards that ship captains try and avoid. Lake Michigan has Manitou Passage in which the number of wrecks that occurred there is sketchy. The lake is also home to Death's Door passage in which eight schooners wrecked within seven days of each other in 1872. Lake Huron has Saginaw Bay, Bruce Peninsula, and the Straits of Mackinaw to name a few. Lake Superior has the infamous Shipwreck Coast shown in Figure 4. These graveyards only account for a small percentage of the wrecks on the Great Lakes, despite their infamous reputations (Thompson 2000).

The worst year for marine accidents on record was 1914. There were 702 vessels involved in accidents of some sort out of the 875 that were operating on the Great Lakes. The *Edmund Fitzgerald* holds the title of being the last ship to go down in a storm and be declared a total loss (Thompson 2000). This might change as a final ruling on the tugboat *Seneca* hasn't been made. The tugboat was lost on the eastern end of Lake Superior on December 3, 2006 after she broke off from her tow during a storm. She was found grounded eighteen miles east of Grand Marais, Michigan. According to the captain of the vessel, the waves went from four feet high to fourteen feet high in an hour. This wasn't so dangerous until you paired the waves up and in some cases had triple sixteen foot waves hitting the vessels. There was no time for them to turn around so the crew had to plow on (Olivo 2006). The last total loss of a ship was the tanker *Jupiter* in 1990. She exploded and burned at the docks in Bay City, Michigan with 50,000 gallons of gasoline in her tanks. The flames were over 100 feet in the air. Surprisingly only one man was killed, he drowned when the crew abandoned ship. It took three days to put out the blaze and cost the company $6.1 million (Thompson 2000).

Underwater Imaging Technologies

A free-swimming remotely operated vehicle or ROV is controlled from a remote location through a tether that delivers power and allows for communication between a surface ship and the ROV. They can be equipped with sonar, video, still photography camera, etc. There are several issues that can affect their performance including: depth, current, sea state, level of complexity, and the environment (DeRoos et al. 1993).

An autonomous undersea vehicle or AUV is self powered and can operate without a physical connection to the vehicle operator. The data the vehicle collects is stored onboard. It can operate according to a preprogrammed schedule or can receive course and depth change commands from the surface via an acoustic link(DeRoos et al. 1993).

ROVs, AUVs, and towed vehicles can be equipped with two general purpose underwater search sensors: sonar and optical, both of which produce images. Sonar images can be hundreds to thousands of feet across and tend to be much faster. Optical sensors are usually a few tens of feet across. The problems associated with sonar tend to be that the images are low resolution, which unless it's a fully intact ship or submarine can make it hard to distinguish hits from false targets. These vehicles tend to be used in two phases. The first is a broad area search with sonar. Once a target has been found, they will use optical contact evaluation to verify the target. The first phase can be done with either a towed, manned, or autonomous vehicle and the second phase can be done with a manned or towed vehicle. There are problems associated with using this technology. When using a towed vehicle or tow fish, slight course corrections in the surface ship's course can take hours to affect the tow fish, while abrupt changes in course can cause slack in the tow cable causing the tow fish to crash into the bottom. A speed increase can yank the tow fish upwards. Common problems with deep water searches include: poor maneuverability, the inability to stop or hover, delayed contact evaluation, slow target closure process, limited target inspection capability, and extremely inflexible tactics (Uhrich and Watson 1992).

Another option is to use an unmanned, untethered, semi-autonomous search vehicle or AUSS. These vehicles have been used in depths of 2,000 to 20,000 feet down. Some benefits of this AUSS are that it can hover for twenty-four hours and it can search an area for ten hours with a maximum speed of five kt. It can be equipped with a still camera for individual pictures, picture series, photo mosaics, and retransmission of prior images. Since it can hover, it allows for better target inspection (Uhrich and Watson 1992).

A towed vehicle is pulled by a ship or other surface vehicle by a cable. It can be mid-water or bottom based. A mid-water towed vehicle is powered by the surface ship by the cable and can be equipped with television cameras, either real-time or slow-scan, as well as photography cameras for photomosaicing. A bottom search or survey can have problems when the surface vessel heaves in rough seas (DeRoos et al. 1993).

There are three different types of sonar that ROVs, AUVs, tow fish, and AUSSs can be outfitted with. The first and most common is side-scan sonar. It transmits sonar beams to each side of the tow 'fish' or vehicle and is able to cover a large territory with a relatively high resolution (Black Laser Learning 2004). Low resolution systems are generally used for a broad area search survey while a high resolution system can be used to get a detailed image of the site or debris field (Singh et al. 2000). Multi-beam sonar is mounted to the side of survey vessels and looks down onto the bottom and transmits multiple beams at the same time. It's bigger and generally costs more but will cover large distances with a high resolution for the images. Sector scan sonar is mounted on a tripod or ROV and works like a radar giving a circular image. In each case the system uses acoustic pulses that bounce back to the sonar creating a line of data that is compresses into an image. Each creates shadows that can give the viewer an idea of details such as if the object is upright. Some problems associated with sonar systems can be that when the weather moves the vessel it moves the tow fish as well, creating a bad image. Wakes from other vessels will show up in the sonar image, and the viewer can't see what's under it. If there is a thermocline, you will have to get the tow fish below it to get a usable image (Black Laser Learning 2004).

Photomosaicing is a good way to get a full picture of the entire vessel and/or debris field. A vehicle conducts a survey over a grid giving complete and redundant coverage. The images are combined into strips that are then merged to form larger mosaics that show the entire site. The problem with using any imaging system underwater is the low contrast nature of images. Also, all lighting has to be supplied by the imaging platform when you are operating in deep water (Singh et al. 2000)

Magnetometer remote sensing can produce multi-point source and dipolar anomalies that will reflect the amount of steel and ferrous material in the target area. This is important because nineteenth and twentieth century ships were built with more and more steel and ferrous materials. Even wooden vessels would have some components that would show up on a magnetometer survey such as: metal fittings and fasteners, ballast rock, nautical implements, marine hardware, and some personal items of the crew (Anuskiewicz 1998).

METHODOLOGY

Library research was conducted on the subjects of: Great Lakes commercial shipping history, Great Lakes shipwrecks, the location methods of those shipwrecks currently being used, the problems associated with those techniques, and the recent developments in underwater imaging. This research was then evaluated to determine if it would be practical and beneficial to employ underwater imaging technologies such as side scan sonar, multi-beam survey, Magnetometry, and photo mosaicking to locate, identify, and map shipwrecks in deep water.

RESULTS

Underwater archaeology surveys begin with the identification and location of potential archaeological sites. These sites are located through documentary sources that include historical and photographic records, interviews with local divers, collectors, fishermen, local historians and the like that are familiar with the location. The State Historical Society of Wisconsin has documented 680 shipwrecks using this method and only fifty of those have been documented through archaeological fieldwork (Cooper and Jensen 1995). From July 5, 1989 to August 3, 1989 the State Historical Society of Wisconsin conducted a marine archaeological survey of Northern Door county’s Death’s Door Passage in Lake Michigan to locate, identify, and evaluate the submerged cultural resources there. The surveys were conducted in two phases. The first phase was the reconnaissance and identification of the archaeological resources within a given search area through surface survey and remote sensing in the form of side-scan sonar and magnetometers. The second phase was the evaluation of the site for archaeological significance. Death's Door Passage is a graveyard on the Great Lakes that in a single week in 1872 claimed 100 large vessels. The historical society was able to use a proton precession magnetometer, which can only be used in water about 100 feet deep. The ferrous metals of the ships create a large magnetic anomaly that is easily detected using this equipment. The downside of using a magnetometer is that you don't produce a picture of the bottom contours or of the vessel. These field surveys help the historical society and the state of Wisconsin manage and protect the sites and to enhance their usage through recreation and tourism. The Abandoned Shipwreck Act of 1987 places the responsibility for protecting these historic shipwrecks in the hands of each individual state. Unfortunately, many states haven't risen to this responsibility leading to the looting of many underwater sites on the Great Lakes (Cooper and Rodgers 1990).

The most famous shipwreck of the Great Lakes is undisputedly the *S.S. Edmund Fitzgerald*; she is also the largest vessel to sink on the Great Lakes. This wreck is an excellent example of how shipwreck location should be conducted on the Great Lakes with wrecks located in deep water. The *S.S. Edmund* Fitzgerald was launched on June 7, 1958. The vessel was owned by Northwestern Mutual Life Insurance Company and was named after its Chairman of the Board (NOAA's National Weather Service 2005). Once she entered service in 1958, the *Fitzgerald* began to amass ore-carrying transport records for the Great Lakes, being the largest ship on the lakes at the time at 729 feet long (Ramsay 2006).

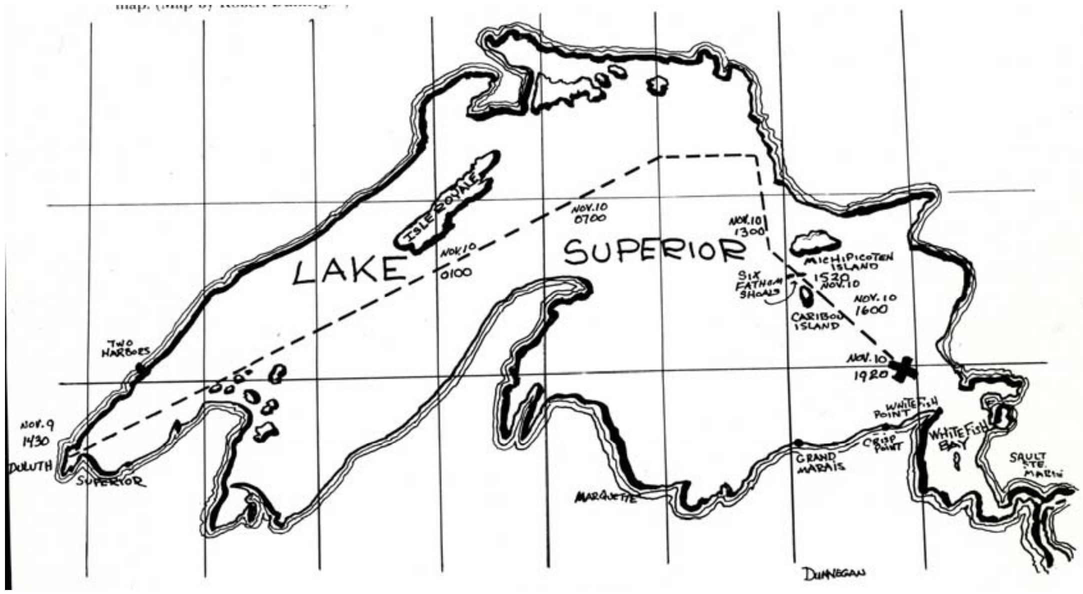

Figure 5. Route of the *S.S. Edmund Fitzgerald* (Hemming 1981)

The *Fitzgerald* set out from Superior, WI on November 9, 1975 with a load of 26,116 long tons of taconite bound for Detroit. Figure 5 above shows the route she would take until eventually sinking. The *Arthur M. Anderson* departed Two Harbors, Minnesota the same day at 4:30 PM. The *Fitzgerald* was the faster ship and soon overcame and passed the *Anderson*. At 7 PM on the 9th, the National Weather Service posted Gale Warnings on the Great Lakes. The next day at 2 AM they were upgraded to Storm Warnings. The *Anderson* and *Fitzgerald* turned southeast toward Whitefish Point at 4 AM, hoping to seek shelter in Whitefish Bay until the storm blew over. The winds were coming out of the southeast, right at the two ships. The two ships passed Michipicoten Island around 2 PM and the winds were only five mph. By 2:45 PM the winds were at forty-eight mph and it was snowing. It was at this time that the *Fitzgerald* passed northeast of Caribou Island (McCall 2006; Thompson 2000; U.S. Department of Transportation 1977). Caribou Island had a shoal north of it with only thirty-six feet of water covering it. With winds at forty-nine mph the waves would have been about twelve to sixteen feet high, making it shallower for passing ships (Thompson 2000).

Topside damage was reported by Captain Ernest McSorley of the *Fitzgerald* to Captain Bernie Cooper of the *Anderson* at 3:30 PM, the *Fitzgerald* had also developed a list. Cooper reported at 4:20 PM that the winds were up to sixty-seven mph and the waves were twelve to eighteen feet high. Ships fully loaded only have about ten feet of freeboard, so waves would be rolling over the decks of both vessels. The *Fitzgerald* radioed that they had lost both of their radars at 4:30 PM. At 6:30 PM thirty foot high waves hit the *Anderson* and some the crew reported that waves were so high they were going over the bridge deck located thirty-five feet above the water line. Cooper estimated the waves would hit the *Fitzgerald* at around 7:15 PM. At 7:10 PM the *Fitzgerald* was seen on the *Anderson*'s radar and the last radio transmission was recorded; by 7:20 PM the ship was gone (Hemming 1981; U.S. Department of Transportation 1977; McCall 2006; Thompson 2000). The crew aboard the *Anderson* could see no lights from the *Fitzgerald.* They tried to hail the *Fitzgerald* on radio, but to no avail. The *Anderson* then radioed the *William Clay Ford* to make sure their radio was working. At 8:35 PM Captain Bernie Cooper of the *Anderson* contacted the Coast Guard that they couldn't see the *Fitzgerald* on radar or hail her on the radio. After the Coast Guard made several failed attempts to raise the *Fitzgerald*, the rescue center was alerted and a helicopter dispatched to the *Fitzgerald*'s last known location at 9:15 PM (McCall 2006; Thompson 2000; U.S. Department of Transportation 1977; Great Lakes Maritime Institute 2007). The cutter *Naugatuck* was dispatched from Sault Ste. Marie and the *Woodrush* was sent from Duluth to join in the search effort. At 10 PM the *Anderson* joined the search followed by the *William Clay Ford* and the *Hilda Marjanne* out of Whitefish Bay. The *Marjanne* had to turn back due to the rough seas. At 8 AM on the 11th the *Anderson* spotted the forward two-thirds of lifeboat No. 1 from the *Fitzgerald*, at 9 AM lifeboat no. 2 was found intact, both were empty. Neither lifeboats were launched; instead they were ripped loose when the *Fitzgerald* sank. The two twenty-five man life rafts were found later on the Canadian shore. The search for survivors was officially ended on November 13, 1975 (McCall 2006; Thompson 2000; U.S. Department of Transportation 1977).

The wreckage of the *Fitzgerald* was located using side-scan sonar on November 14 (Thompson 2000). A US Navy plane equipped with a magnetic anomaly detector located what it believed to be the wreckage of the *Fitzgerald* seventeen miles North-Northwest of Whitefish point. The *Woodrush* was dispatched equipped with side-scan sonar equipment and located two pieces of the wreckage. A third survey was conducted in May of 1976. The Navy also brought in the CURV III, an unmanned underwater recovery vehicle that took video and photographs of the wreckage including a picture of the name plate that positively identified the wreck as that of the *S.S. Edmund Fitzgerald*. As the wreck lies in 535 feet of water, it is impossible to dive on (Great Lakes Shipwreck Museum 2007; The Great Lakes Maritime Institute 2007; U.S. National Transportation Safety Board 1978). From the video and still images obtained from CURV III, images and a map of the site were generated shown in Figures 6 through Figure 8 below. Figure 9 is a side-scan sonar image of the wreck.

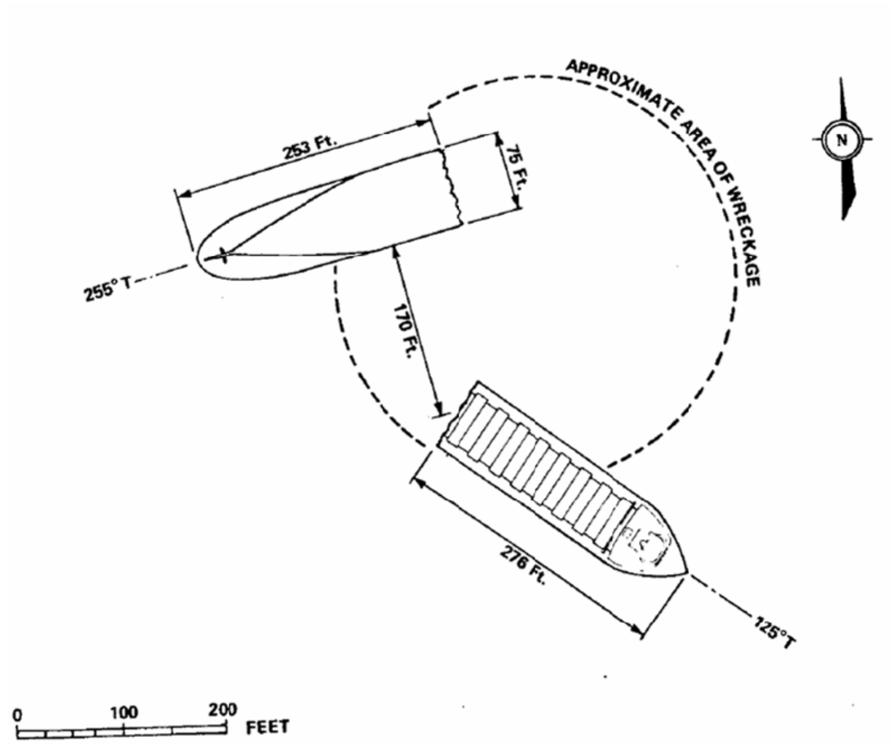

Figure 6. Position of *Edmund Fitzgerald* wreckage
(U.S. Department of Transportation 1977)

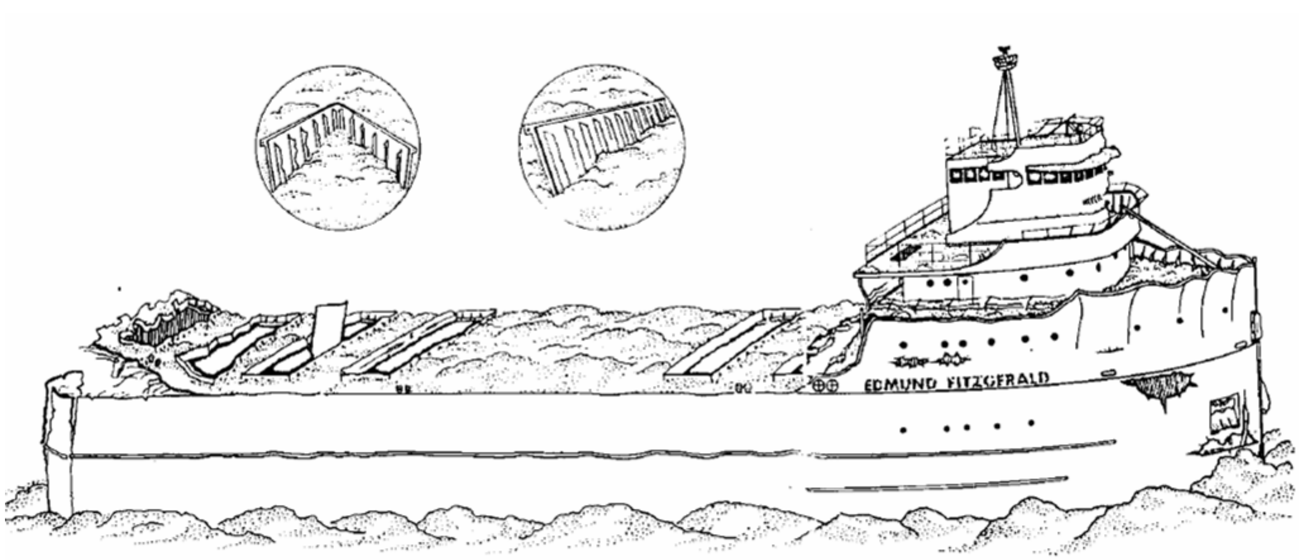

Figure 7. Bow Section of *Edmund Fitzgerald*
(U.S. Department of Transportation 1977)

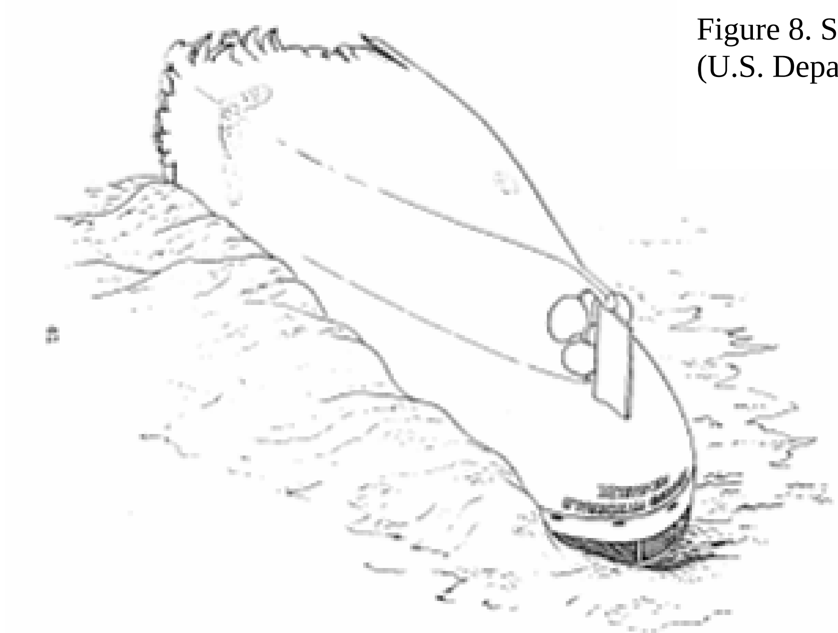

Figure 8. Stern section of *Edmund Fitzgerald* (U.S. Department of Transportation 1977)

Figure 9. Side-scan sonar image of the *Edmund Fitzgerald* (Ramsay 2006)

In September of 1980, Jean Michel Cousteau led an expedition in which a team took a two-man sub down to investigate the wreck. No new information was uncovered. In August of 1989, Michigan Sea Grant with help from the National Oceanographic and Atmospheric Administration (NOAA), the National Geographic Society, the Great Lakes Shipwreck Historical Society, the US Army Corps of Engineers, and the Michigan Department of Natural Resources, dispatched a ROV down on the wreck, once again no new information was uncovered (McCall 2006). The Coast Guard determined that the vessel sank due to sudden flooding of the cargo hold due either to collapsed hatch covers (U.S. National Transportation Safety Board 1978) or from ineffective hatch covers (U.S. Department of Transportation 1977). These two theories were not well received by the shipping community and other investigations were done with different conclusions.

The majority of the research done on shipwrecks of the Great Lakes has been confined to wrecks located in shallow water that SCUBA divers have access to. The Great Lakes Shipwreck Preservation Society or GLSPS uses side-scan sonar at low resolutions to locate shipwrecks. They then send down a drop camera to determine if the hit is in fact a ship, and if it is confirmed to be a shipwreck, the organization will send down divers to determine what vessel the wreckage is. (Merryman 2006, Beebe 2006, Eliason 2006, Fountain and Reynolds 2006).

CONCLUSIONS

With the number of shipwrecks that remain unfound on the Great Lakes, archaeologists need to start seriously looking into conducting research in deep water. Up to now the research has been confined to areas that SCUBA divers have access, giving nautical archaeology done on the Great Lakes an aura of wreck hunting. When the average depth of Lake Superior is 483 feet with a maximum depth of 1332 feet, that's leaving a lot of ground uncovered. The same could be said for Lake Michigan with a maximum depth of 925 feet (Manninen 2006). Even the average depth of Lake Superior is too deep for a SCUBA diver to go to the bottom. Figure 10 below, shows the depth of Lake Superior in meters. Basically, we can dive in all the purple areas and the dark blue areas are pushing the depth limits and have small bottom times. The only alternatives are remote-sensing, ROVs, AUVs, or mini-subs. The most cost effective of these is remote-sensing in conjunction with the use of an ROV for picture and video of the wrecks.

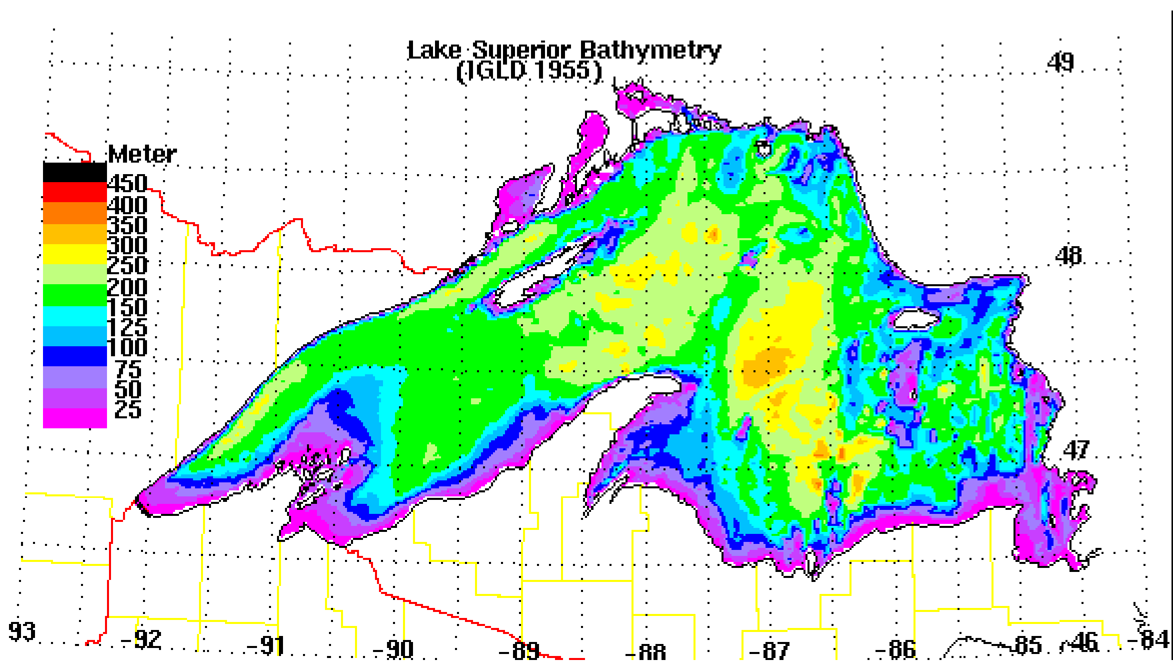

Figure 10. Bathymetric Map of Lake Superior (Environmental Protection Agency 2006)

Difficulties do arise in trying to locate shipwrecks in deep water. The first problem is where to look. Shipping lanes offer a starting point, but most ships veer off the shipping lanes during storms to take advantage of shelter from the winds and waves. Figure 10 below shows the *Fitzgerald*'s route as compared to the recommended shipping lanes of the time. The main way of locating shipwrecks in any depth of water is to find out where they departed and where they were heading to. Then from weather data from the era, you try and plot the mostly likely route based on winds and seas. This is your search area.

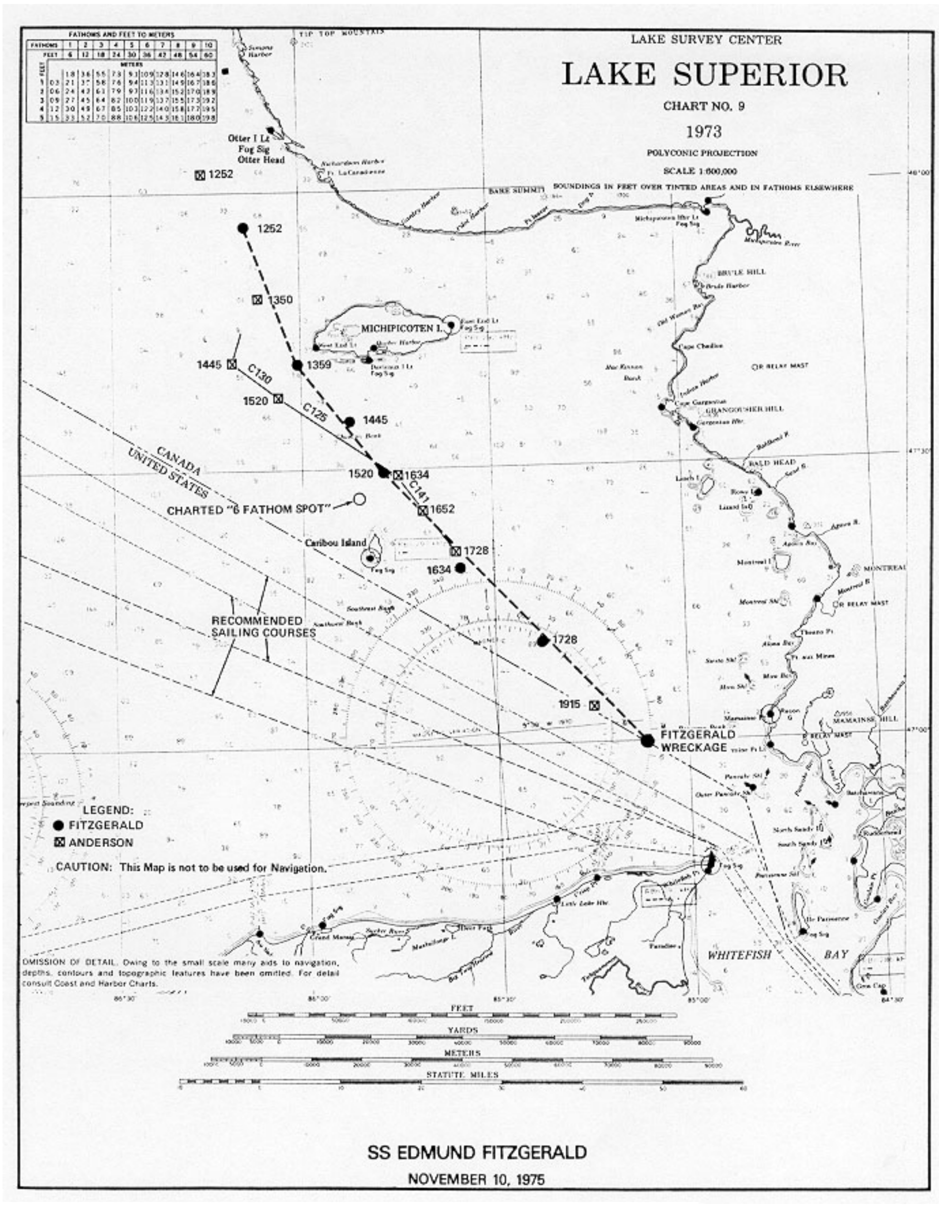

Figure 10. Route of the *Edmund Fitzgerald* in relation to recommended sailing courses (U.S.National Transportation Safety Board 1978)

SCUBA diving comes with its own risks. While the cold temperatures of 40˚ to 60˚F found on the Great Lakes make for good site preservation, it also makes it difficult to function. A diver will get cold in water that is 80˚F making hypothermia a big concern for Great Lakes SCUBA divers. You are also faced with the problem of breathing a fixed amount of air. The time a single tank can sustain a diver depends on each individual diver and the depth they are at(Wisconsin Historical Society 2007). A big danger of depth is the bends. This occurs when you breathe air under pressure, the pressure forces quantities of nitrogen into the blood stream and tissues of the body. When the pressure is released quickly, nitrogen returns to its gaseous state too rapidly to pass out of the body and nitrogen bubbles form in the blood. The bends has serious consequences if not properly treated, including paralysis and death (U.S. Navy 1998).

Deep water wrecks hold as much significance as wrecks located in shallow water, and in some cases could hold more because no divers have been down on the site to disturb it. By locating these wrecks, identifying them, and determining why they sank we can better understand how shipping evolved on the Great Lakes to what it is today. It would also help us to prevent future disasters on the Great Lakes. Raymond Ramsay recently came out with a publication stating that the reason the *S.S. Edmund Fitzgerald* sank was not due to leaking hatch covers or striking the bottom off Caribou Island (Thompson 2000) but was due to a design flaw that made her structurally weak and more susceptible to breaking in two (Ramsay 2006). He stated at Gales of November held in Duluth, Minnesota that had the *Arthur M. Anderson* and the *Fitzgerald* been in the other's position, we would be mourning the loss of the *Anderson* instead of that of the *Fitzgerald* (Ramsay 2006). The design of the *Fitzgerald* and the *Anderson* are the same as most of the ships running on the Great Lakes, most of which are still carrying cargo today. By investigating why many of the ships of this design sank, we can seek to stop any future occurrences of shipwrecks.

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