Reprint of paper delivered at the International Conference *Man-Made Objects on the Seafloor,* Society for Underwater Technology, London, February 1st, 1995.

SEARCH FOR THE BULK CARRIER *DERBYSHIRE*: UNLOCKING THE MYSTERY OF BULK CARRIER SHIPPING DISASTERS

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ABSTRACT

The mysterious loss of the *Derbyshire* in September 1980, the biggest single shipping casualty in British maritime history, claimed the lives of 44 seafarers and ultimately became the focus of growing uncertainty about the structural design and safety of the world's bulk carrier tonnage. Despite seemingly compelling evidence of serious cracking in each of *Derbyshire's* five sister ships, as well as theoretical studies which identified dangerously large field stresses in the hulls, a 1987 UK formal inquiry into the casualty declared that the vessel "was probably overcome by the forces of nature in typhoon Orchid." In an effort to produce new and important evidence that could be used in a fresh inquiry into the cause of the sinking, an international trade union of seafaring workers hired Oceaneering Technologies (OTECH) to search for and locate the *Derbyshire* using their OCEAN EXPLORER 6000 deep ocean sidescan sonar system. Predicted by some experts to never be found, OTECH quickly located the wreck in the Philippine Sea some 40 miles away from her last known position at a depth of approximately 4,210 meters. Detailed sidescan sonar imagery, along with confirming video footage captured by OTECH's MAGELLAN 725 remotely operated vehicle (ROV), showed that the hull apparently fractured in a predicted area of weakness (frame 65) and ultimately shattered into thousands of pieces. This evidence, indicating an extremely violent break-up that must have initially occurred at the surface over a very short period of time, perhaps only seconds or minutes, refutes the conclusions of the 1987 formal inquiry and is being used in widespread calls to the UK Government for further investigation into the *Derbyshire's* loss.

INTRODUCTION

When the 169,000dwt combination carrier *Derbyshire* (originally the *Liverpool Bridge*) sank on September 10th 1980, some 230 miles off the coast of Okinawa (Figure 1), no one would have predicted beforehand that this great ship, the largest of her type in the world at the time, could have ever suffered the sudden and violently tragic ending that now appears to have befallen her. Despite that her loss came as she was being overtaken by a typhoon that may have subjected her to maximum winds of 85 knots and seas of sixty feet or more, *Derbyshire* was an immense vessel - 965 feet long and 145 feet wide (Figure 2) - being operated by an experienced Captain and crew and was capable of withstanding the most appalling weather. Moreover, the *Derbyshire*, which had been launched in 1976 as the last in the class of six sister OBO (Ore/Bulk/Oil) ships built by the well-regarded British shipbuilders Swan Hunter, had only been in service for less than 3 years of her very short 4 year life.

The earliest indication that *Derbyshire's* death was extremely sudden was the puzzling absence of a mayday call or any sort of distress signal. By September 13th, 4 days after their last radio communication, the owners - Bibby Bros and Co. - were sufficiently concerned by the absence of contact to request a search by the Japanese Maritime Safety Agency (MSA). MSA regulations on missing ships dictated that the search could not begin until September 15th, 24 hours after the *Derbyshire* was expected to arrive in Kawasaki.

On the 15th, with two patrol boats and two reconnaissance aircraft combing the seas, one of the aircraft spotted an oil slick that was about 1km wide by 2km long. The following day, a patrol boat directed to the slick confirmed that oil was bubbling up from the ocean in a location approximately 40 miles from *Derbyshire's* last reported position. Although the search was temporarily suspended for one day because another tropical storm was threatening the area, a third observation of "upwelling" fuel oil was made by an MSA aircraft on the 19th. No other sign of the ship or her crew was made, and on September 20th the search was terminated. Any remaining hope of saving the 42 British officers and crew and 2 wives on board the *Derbyshire* was extinguished.

Six weeks after the sinking one of *Derbyshire's* life boats was sighted by a Japanese tanker nearly 700 miles to the west-south-west of the search area. The empty life boat showed clear evidence of having been wrenched with great force from its davits on the ship, further suggesting that the sinking was rapid.

14 Years of Questions and Speculations

Reaction to *Derbyshire's* loss was immediate and intense. In the public and in the shipping industry the same questions were asked: how could such a large and seemingly invincible ship be lost almost without a trace? *Derbyshire* had been equipped with the latest electronic equipment capable of transmitting a mayday call at the push of a button. What possible catastrophe would leave the crew on the bridge with so little time to react in saving the ship and their own lives?

Eighteen months after the loss, one of *Derbyshire's* sisters, the *Tyne Bridge*, was forced to return to port because of cracking of the deck plate in an area just forward of the superstructure known as frame 65. In port, the severity of the cracks were alarmingly apparent. On the starboard side there was a 19-foot crack, on the port side an 11-foot crack (Ramwell and Madge, 1992).

Prompted by Lloyds Register, two sister ships, the *Cast Kittiwake* and *Sir Alexander Glen*, were inspected in the summer of 1982 and were both found to have identical problems with the design and workmanship of critical structural members around frame 65. The common defect in all three ships involved a pair of longitudinal bulkheads (girders) that nearly run the length of the ship and serve as main strength members. Contrary to the originally intended design, the two longitudinals were terminated at frame 65 and butt welded to the transverse bulkhead that marks the end of the line of cargo holds. Furthermore, the longitudinal bulkheads forward and aft of frame 65 which should be precisely aligned to preserve continuity and maximum hull strength, were misaligned by 25 to 45 mm (Figure 3).

A research study commissioned by the U.K. Department of Transport (Bishop, *et al.,* 1991) concluded that overall "field stresses" along *Derbyshire's* hull would be at a peak near frame 65, such that the combination of field stresses and high local stresses resulting from probable termination and misalignment of longitudinal members is likely to have resulted in rapid crack propagation and catastrophic structural failure of *Derbyshire's* hull.

A Formal Investigation (FI) into *Derbyshire's* loss was finally conducted in 1987. Unfortunately, the Bishop *et al.* study was excluded from consideration by the Wreck Commissioner, and the authors were never called to testify. Even more surprising, evidence from the *Kowloon Bridge*, another sister ship whose sinking and subsequent fracture all around frame 65 was the incident that initiated the inquiry, was essentially ignored. Ironically citing the lack of factual evidence, the FI report published in 1989 concluded that the *Derbyshire* was probably overcome by the forces of nature in typhoon Orchid (Anon, 1989).

The impact of *Derbyshire's* mysterious sinking on the shipping industry was great, but no where was it more personal than in Liverpool, where the ship made her home port and where 17 members of *Derbyshire's* crew lived. For many of the surviving wives, children and parents, their grief has been prolonged by the lack of a body to bury and their distrust in the 1987 Formal Investigation. Ultimately, the common loss shared by the family members led them to form the *Derbyshire* Families Association (DFA) and to persistently campaign for a true accounting of *Derbyshire's* loss.

Bulk Carrier Losses Continue

Against this backdrop of increasing controversy over the structural design of the Bridge-class of OBO ships, the world's bulk carrier fleet was experiencing casualties at an abnormally high rate throughout the 1980's and early 1990's. In the years 1990 and 1991 the pace of losses increased dramatically, as 25 bulk carriers ($\geq$ 15,000dwt) were lost under circumstances where structural failure may have been a factor, as reported by Lloyds Register. At least 273 crew died in these sinkings. Including the 123 crew that have perished in the worst four of this year's bulk carrier losses, it is estimated that more than 750 seafarers have lost their lives since 1988.

In response to proposals by the DFA and two U.K. transport unions, the RMT and NUMAST, the International Transport Workers' Federation (ITF) ambitiously decided to fund a search for the *Derbyshire* and to produce the first factual evidence of her sinking. Among their objectives, the ITF wanted to focus attention on maritime safety and the plight of seafarers, and to expose the practice of attributing mysterious sinkings to *force majeure*. There was also the hope that this investigation could begin to provide clues relevant to not only *Derbyshire's* loss, but to the many other unexplained bulk carrier casualties with the further hope that lessons could be learned to help prevent future losses of these ships and their crews.

SEARCH EQUIPMENT AND PLANNING

The ITF's selection of OTECH to perform the search was based largely upon OTECH's unique experience and capabilities in the conduct of deep ocean searches and marine accident investigations. In addition to OTECH's well known track record in major aircrash inquiries (*Air India 747, Space Shuttle Challenger, SAS 747, United Cargo Door, Itavia DC9)*, the company was developing a further specialty in the location and photo/video investigation of sunken ships. In 1990, OTECH made a major investment in this specialty by fielding the first state-of-the-art "teamed system" that combined a dual-frequency sidescan sonar with a work-class ROV system for the deep ocean ($\geq$ 6,000 m). The system was first used in solving the mystery of the freighter *Lucona* for an Austrian Court that was hearing a famous insurance fraud and murder case. Since this introduction, OTECH has used the teamed systems frequently on a variety of shipwreck insurance investigations and special salvage projects.

Ocean Explorer 6000/Magellan 725 ROV Teamed Systems

The OCEAN EXPLORER 6000 sidescan sonar was originally designed for the rapid location of sunken ships and man-made objects in the deep ocean (6,000 meter rated). In a single towfish the system uniquely combines a wide swath (to 4.8 kilometers) sidescan capability via a 33/36 kHz sonar array with a high-resolution sidescan capability via a 120 kHz array (Figure 4). Single frequency or simultaneous dual frequency operations are selected on the fly from topside controls with essentially no interruption in data collection. The production of superior acoustic imagery is ensured through the use of low Q transducers, wide bandwidth receivers, short transmit pulse lengths, and a 2-body towing configuration (depressor and neutrally buoyant towfish decoupled from ship's heave) that permits continued operations up to sea state 6.

OCEAN EXPLORER's data acquisition and processing is based around a Q-MIPS image processing computer that provides high-resolution color display of acoustic imagery and permanent storage on high-capacity optical disks. Roll, pitch, heading, depth, altitude and navigation sensors on board the towfish are integrated with Q-MIPS to yield real-time sonar imagery that is corrected for speed distortions. Although water column removal and slant range corrections are also possible in Q-MIPS, these processes are generally not used during searches as they can reduce the sensitivity of detection for objects in the water column and just beneath the towfish. To enhance the detection and classification of sonar contacts, advanced image processing and analysis techniques such as thresholding, spatial filtering, zooming, and object measuring are routinely used.

The concept of teaming OCEAN EXPLORER with a work-class ROV system derived from the competitive pressure to compress the schedule and reduce the overall costs of deep ocean search and ROV investigation/recovery projects. Prior to this teaming, a typical two-phased approach (the initial search phase followed by the ROV investigation/recovery phase) would require two separate mobilizations and often two different support vessels. If the client decided to use different contractors for each phase, this additional complication could easily result in a loss of continuity that would jeopardize the project's success (i.e., how many times has the story been told about an ROV crew complaining that the search crew gave incorrect positions or that their high probability targets were nothing but a pile of rocks).

To truly reduce schedules and costs, however, the OCEAN EXPLORER search and MAGELLAN ROV systems would require their combination in a manner that 1) resulted in a reasonable overall footprint that was within the deck space limits (300 square meters) of typical offshore supply/tug/salvage vessels, 2) allowed a single, unified crew of cross-trained search and ROV technicians to operate both systems on a 24-hour/day basis, 3) allowed transition from the search phase to the ROV phase to be made at sea in a minimum of time without returning to port, and 4) still allowed fairly sophisticated recovery operations to be performed.

Of the numerous innovations that were made to facilitate this successful teaming, the most significant were the design of a cable handling system and deployment/recovery crane that would accommodate both the OCEAN EXPLORER towfish and MAGELLAN vehicle, and the design of the MAGELLAN 725 ROV system itself. The MAGELLAN 725 is a deep ocean (7,000 meter rated) advanced ROV system designed for high-quality inspection, work and recovery operations. The 4,500-pound MAGELLAN vehicle operates in a highly maneuverable free-swimming mode from an instrumented depressor (Figure 5). The use of a fiber optic umbilical ensures high speed video, sonar and data communications with virtually no loss in signal quality. For detailed photo/video documentation work, MAGELLAN is typically outfitted with a 35 mm still camera (stereo and 750 frame options) and strobe lights, a wide-angle b/w SIT camera, a color camera with zoom capabilities, and a bank of variably controlled flood lights. Video options include a three-chip camera for the highest broadcast quality and an extremely small (2.5 cm diameter), boom-deployed camera for internal penetrations. This range of high-quality photo/video configurations is available to ensure that MAGELLAN's visual evidence is clear to lay people and is defendable in a court of law.

For heavy work and complex recovery tasks, MAGELLAN is outfitted with a pair of rugged five-, and seven-function manipulators that are complemented by an assortment of proprietary tools. An optional heavy lift recovery system that employs unique spooling machines for recovery line deployment can be provided for lifts of up to 12.5 tons from 6,000 meters.

Loss Data and Search Probability Analysis

Like all searches, the *Derbyshire* search began with a very thorough collection and analysis of the known loss data. Of six reported sightings of oil slicks and debris, only three were felt to be reliable and accurate. These sightings, #'s 3, 4 and 5 in Figure 6, were made by the Japanese MSA and were confirmed during a visit to their headquarters in Okinawa just prior to mobilization. The major uncertainty in these positions was the lateral displacement the oil bubbles would have experienced during their 2.6 mile rise to the surface in response to the prevailing surface and subsurface currents at that time. Although some studies suggested that displacement could be greater than 10 nm away from the wreckage, our analysis indicated a worst-case displacement of 5 nm. Another vital clue came from the Japanese Hydrographic Office, whom provided doppler current data that showed a prevailing southerly current in the area. This information was important because it indicated a more complex regime with prevailing currents opposite to the conventional wisdom of a northwesterly flowing Kuroshio current.

Using the principals of modern probability analysis (Discenza and Greer, 1994), an overall search area of 172 square nautical miles (590 square kilometers) was established with a high probability zone of roughly 90 sqnm (Figure 6). The search plan to cover this area relied on seven 14 nm long lines running 100°/280° where the ocean floor slopes off the Daito Ridge at 7° towards a basin over 5,200 meters deep (Davies, 1994). Given OCEAN EXPLORER's demonstrated ability to search at rates of 60-70 sqnm per day, the original wide-swath search for *Derbyshire* was expected to take less than three days.

Provisions in the search schedule were also made to deploy the OCEAN EXPLORER at a location 21.5 nm southwest of the primary search area where another upwelling of oil was reportedly sighted. Speculation about the separation between this single reported upwelling and the three oil slicks observed by the MSA led some to believe that this was proof *Derbyshire's* hull had indeed fractured and that oil was escaping from bunker tanks in the stern and bow sections lying on the seabed 21.5 nm from each other. Serious questions about this theory arose when the source of the single upwelling oil sighting could not be identified, and a suitable explanation could not be offered as to how the bow section (sans propulsion) would be able to travel 21.5 nm northeast directly into the Force 11 winds and 30-ft. seas of typhoon Orchid.

THE SEARCH OPERATIONS

Following mobilization of the OCEAN EXPLORER and MAGELLAN systems on board the Japanese survey vessel *Shin Kai Maru* in the port of Yokohama, the 680 nautical mile transit to the search area began, albeit in Force 7 conditions and under threat of an approaching tropical depression. Despite the early poor weather, the transit was uneventful and completed well ahead of schedule.

The OCEAN EXPLORER sonar was launched at 1405 on 29th May to begin the search. By 2152, the towfish was on line and its wide swath sonar (33/36 kHz) was sweeping a 4.8 km swath of ocean floor in search of *Derbyshire's* wreckage. This first line was directly in the middle of the high probability zone in close proximity to all three of the reported oil slick sightings. A little more than halfway along this line, the sonar detected a grouping of contacts at the extreme edge of the starboard channel which were logged for further review. The second search line along the southern margin of the high probability zone did not result in any contacts.

On the third line, less than 23 hours from the start of the search pattern, the sonar detected a large and dense area of high backscatter that also showed a scattering of individual contacts. On first inspection, this pattern seemed more likely to be caused by an outcropping of rocks than by the remains of a sunken ship. While there was an expectation that *Derbyshire* would be found fractured, there was no reason to believe that this would have resulted in breakup of the hull into more than a few intact sections. Thus, the decision was made to proceed with the search plan and afterwards to make a high-resolution pass over this area.

As the search progressed over the next two lines, only one other promising sonar contact was found. Plotting of the contact's position showed that it was associated with the contacts previously found on the first and third lines. This contact area was now completely localized within the high probability zone approximately 2 nm north of the oil slick positions, generating new confidence in this contact area. Moreover, a northerly position of the wreck was being predicted as the surface currents were observed to be southerly and would account for drift of the oil upwellings to the south. A decision was made to abort the search plan and to accelerate the intended return to the contact with a high-resolution pass (simultaneous 33/36 kHz and 120 kHz) of 1.2 km.

At 0123 on 3rd June, with the OCEAN EXPLORER flying at an altitude of 60 meters off the hilly seabed, the sonar's color display monitor began revealing a scene of immense destruction. The track of the sonar was designed to squarely hit the center of the contact area and it did so perfectly. As the incoming images advanced one sonar ping at a time, hundreds of individual sonar contacts, all very hard and unquestionably man-made, filled the full 1.2 km expanse of seabed being imaged (Figure 7). Although much confirming work remained to be done, there was no doubt that the remains of the bulk carrier *Derbyshire* had been discovered and that she had been obliterated beyond all reasonable expectations.

Initial on-site computer analysis of the high-resolution sonar imagery concentrated on the largest individual contacts within the debris field to quickly confirm that the wreckage was consistent with the known size of *Derbyshire*. Meanwhile, OTECH crews were reconfiguring the deck of the *Shin Kai Maru* and preparing the MAGELLAN ROV for a positive confirming dive to the wreck. In addition to an attempt to locate her name on the bow, other objectives of the dive included 1) documentation and identification of the largest sonar contacts, 2) making a small recovery of the iron ore cargo, 3) placing a memorial plaque on the wreckage site, and 4) searching for further clues of the cause of the sinking.

Due to time limitations, MAGELLAN was deployed in the wreckage field for just six hours. The initial scene which greeted her was one of thousands of bright sparkling reflections from the tons of iron ore particles that had escaped the cargo holds and settled on the seabed. It wasn't long before the first piece of fractured shell plating was found. Thereafter, large pieces of wreckage were videotaped in unusual contorted angles lying next to lengths of bent piping and other small debris. Until finally, a very large section of the ship sitting upright, but deeply buried within an impact crater, was recognized as the bow. Maneuvering high above to visualize the widest view of wreckage possible, the bow appeared to be fractured straight across at frame 339. Moving past the large spare anchor that was still lashed to the deck, MAGELLAN closed in to observe the last five letters of the name on the port side: *SHIRE* - which had not been seen in nearly 14 years.

Before leaving the wreck, MAGELLAN performed one final act, gently placing a bronze plaque, bearing words of remembrance from the *Derbyshire* families, on the forecastle as a final memorial to the 44 who died.

POST CRUISE DEVELOPMENTS

Further detailed analysis of the sonar imagery following the search mission has yielded another significant finding - the identification of a sonar contact believed to be *Derbyshire's* stern section fractured just forward of the superstructure in the suspected weak section around frame 65 (Figure 8). This conclusion is based upon four characteristics of the contact, which taken independently and as a whole, are strongly indicative of *Derbyshire's* stern and superstructure. The four characteristics are: 1) the shape of the contact, 2) the dimensions of the contact, which closely match the stern fractured near frame 65, 3) the relative strength and pattern of the sonar signals returning from the contact, and 4) the very large acoustic shadow given off by the contact. Careful and independent analysis by the University of Wales College of Cardiff has reached a similar conclusion (Davies, 1994).

This location of the stern, in addition to the confirmed fracture of the bow and the presence of hundreds of relatively small pieces of wreckage, indicates an extremely violent break-up that must have occurred over a very short period of time, perhaps only seconds or minutes. The extensive shattering of the hull clearly visible in the high-resolution sonar image has raised new questions about what forces came to bear on the *Derbyshire* in the moments just before, and after her sinking. One possible explanation being offered for the extensive shattering is implosion of the air voids in the hull, particularly in the hold section, where there was double shell plating, gas-tight hatch covers and empty wing ballast tanks (Davies, 1994).

In the view of the ITF and many other supporters, this spectacular scene of destruction is new and important evidence that invalidates the conclusion of the 1987 Formal Inquiry that the *Derbyshire* "was probably overcome by the forces of nature in typhoon Orchid." As calls for a fresh public inquiry and a new expedition to gather more evidence from the wreckage field mounts, the UK Marine Accident Investigation Branch has been tasked by the Secretary of State for Transport to study this new evidence and report back their recommendations.

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Illustration Captions

Figure 1: Location map showing the approximate last known position of *Derbyshire* (courtesy of John Prescott/Lloyd's List).

Figure 2: The last of the Bridge Class of OBO ships: the *Liverpool Bridge* (later renamed *Derbyshire*).

Figure 3: Diagram illustrating the misalignment of longitudinal bulkheads at frame 65 just forward of the superstructure (courtesy of Independent Television News).

Figure 4: Launch of the OCEAN EXPLORER sonar from survey vessel *Shin Kai Maru* (courtesy of Dr. Chris Davies/University of Wales).

Figure 5: Launch of the MAGELLAN 725 ROV from survey vessel *Shin Kai Maru* (courtesy of Dr. Chris Davies/University of Wales).

Figure 6: Search plan covering 172 sqnm based upon Japanese MSA oil slick sightings 3, 4, and 5.

Figure 7: OCEAN EXPLORER sidescan sonar image (1.2 km swath) of the *Derbyshire* wreckage field at a depth of 4,210 meters.

Figure 8: Enhanced sonar image of contact #9, believed to be *Derbyshire's* stern fractured around frame 65.