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The Prospect for Fusion Power

Sonar Search for the Loch Ness Monster

Common Sense about Engineering

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Technology Review

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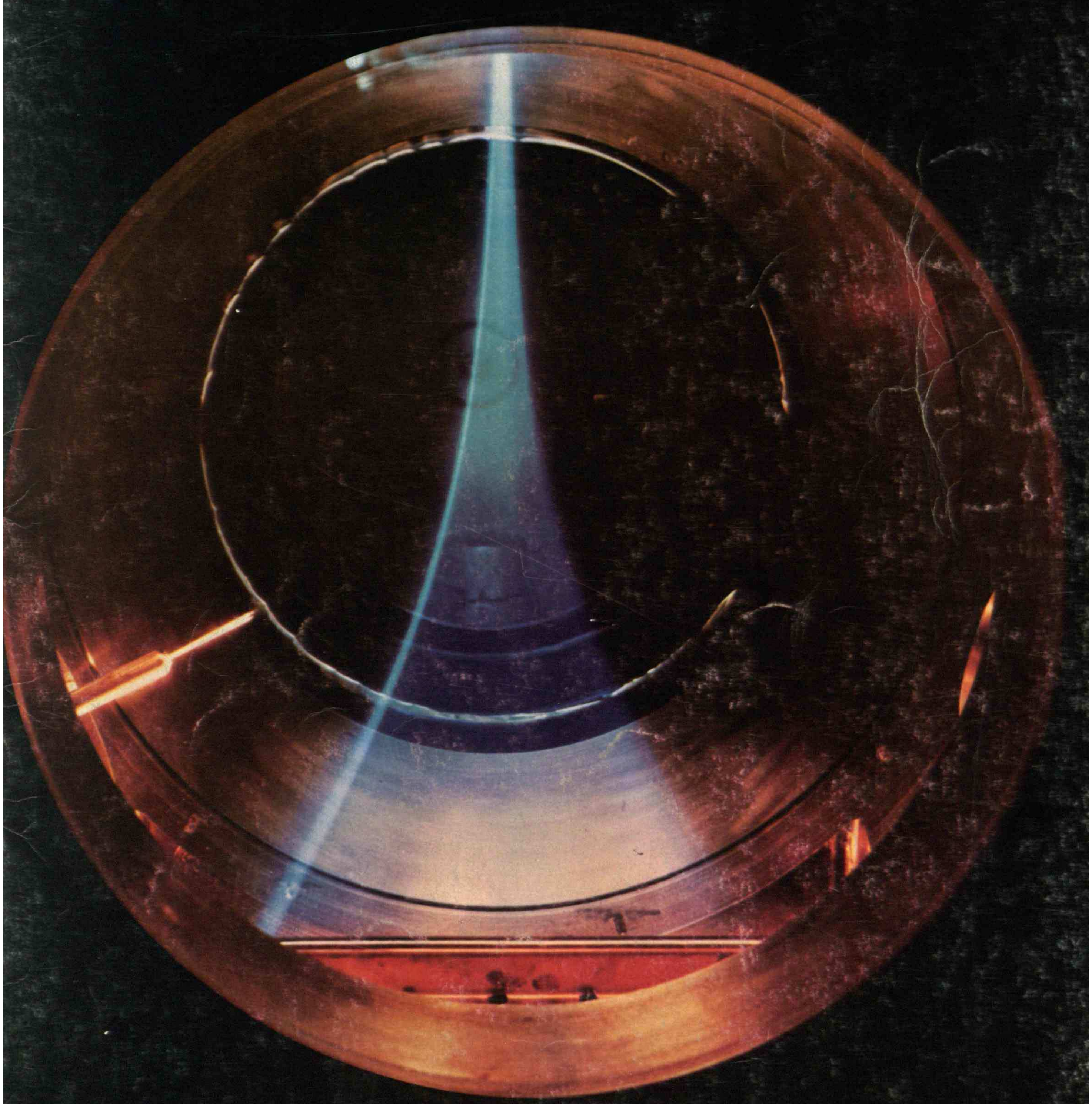


Martin Klein
Charles Finkelstein
Klein Associates, Inc.

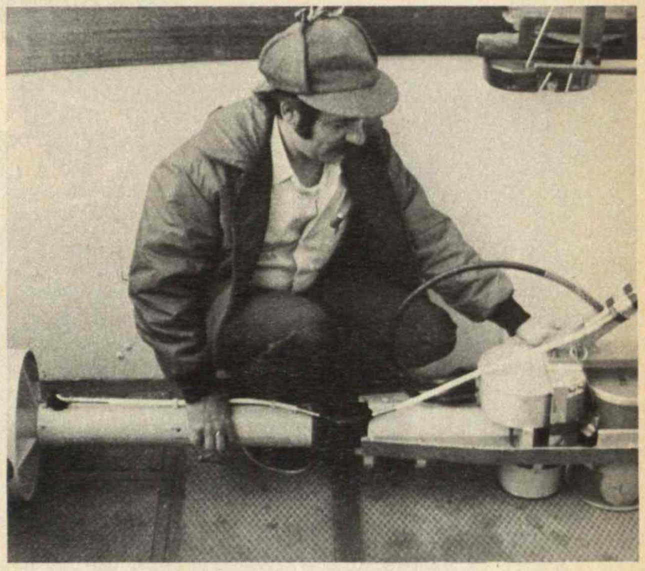
Sonar Serendipity in Loch Ness

During the summer of 1976 we at Klein Associates, Inc. had the privilege of participating with the Academy of Applied Science in a continuing investigation of the depths of Loch Ness. In our original work in the loch in 1970, we had made some important discoveries. We had proven to our own satisfaction that there are large, moving objects in the loch. We had observed on our sonar deep schools of fish which could, perhaps, give ample food supply for one or more large animals in the loch. We had also observed that the steep-sloping walls of the loch had very rugged terrain with sharp ridges and deep undercuts — possible "caves" or hiding places where a large creature could elude our photographic and sonar "eyes."

Other sonar researchers at the loch had shown, on many occasions, that there are large moving objects. The famous photographs made in 1975 by Robert Rines (*see "Search for the Loch Ness Monster,"* Technology Review, *March/April, 1976, p. 25)* renewed our enthusiasm, and we continued to ponder the challenge of how we could use our sonar this year to obtain more conclusive proof of the existence of the famous monster. In December, 1975, Klein was part of the Academy team which addressed the Preservation Committee of the House of Commons in London. We presented the evidence obtained to date, and we put forth the view that if there is a Loch Ness monster, it should be protected as an endangered species! At that meeting, Dr. Christopher McGowan, paleontologist with the Royal Ontario Museum in Toronto, expressed his enthusiasm for the controversial Rines photographs. However, he observed that only some actual samples of a carcass or bones of the animals would give positive proof. The idea occurred to us that our sonar might have enough resolution to detect whole carcasses or skeletons on the floor of Loch Ness.

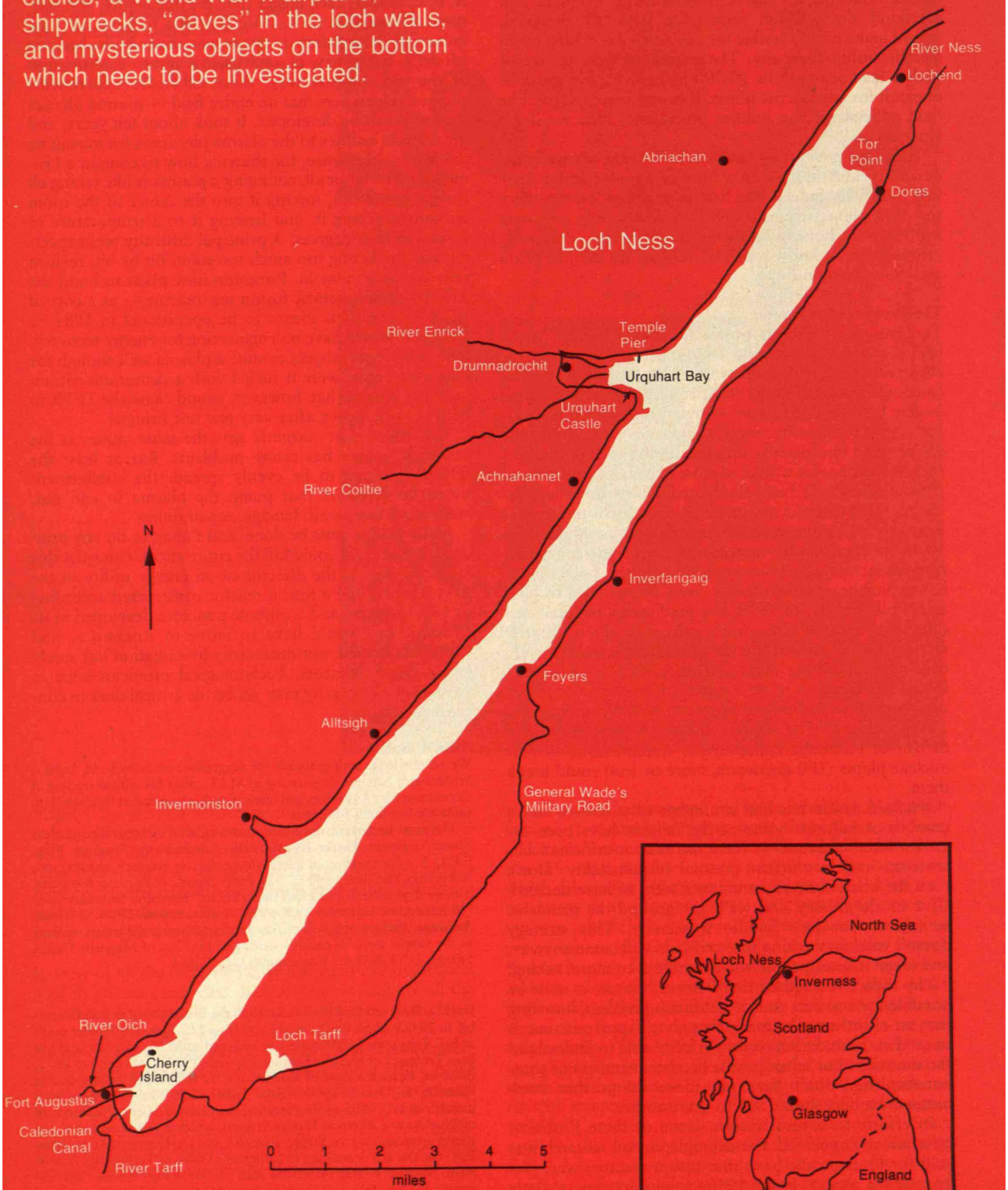
We suggested to McGowan that we should experiment to see if bones underwater would be an adequate acoustic target for our sonar. We offered to use our small research boat in a lake near our laboratory in Salem, New Hampshire. McGowan flew down from Toronto with a large suitcase full of mammoth bones. Finkelstein, an experienced diver, placed the bones in a pattern at the bottom of the lake. The sonar towfish was then towed over the area, and McGowan and Finkelstein were easily able to detect the bones. Encouraged by these experiments, we proceeded with plans for our expedition to Loch Ness. Our 1976 Academy expedition to Loch Ness was sponsored, in part, by the *New York Times.*

Although our time in Loch Ness was to be limited, we planned to run four sonar experiments. The first was to use our new sonar sub-bottom profiler to probe the sediments in the deep part of the loch. The second was to use our side scan sonar to further study the structures in the walls of the loch. Our third and possibly most important experiment was to search the bottom of the loch for carcasses or skeletons. We realized that such a search would have a very remote possibility of success, but we wanted to give it a try. Our sonar had been successful in many areas of the world finding difficult targets, and we had confidence in the technique. We also planned to continue our "fixed-mode" experiments by placing a sonar in the middle of Urquhart Bay looking out across the entire bay to make a "sonar curtain." We hoped that anything entering or leaving the bay would have to cross this path and be detected. We planned to set up our sonar in "fixed-mode" during the nights with the expedition cameras actually in the sonar beam. This way we might be able to detect when objects were near the camera, to improve our possibility of obtaining a photograph. Since we knew our time would be short, we planned to work long days with "mobile" experiments during the day and "fixed-mode" experiments at night.

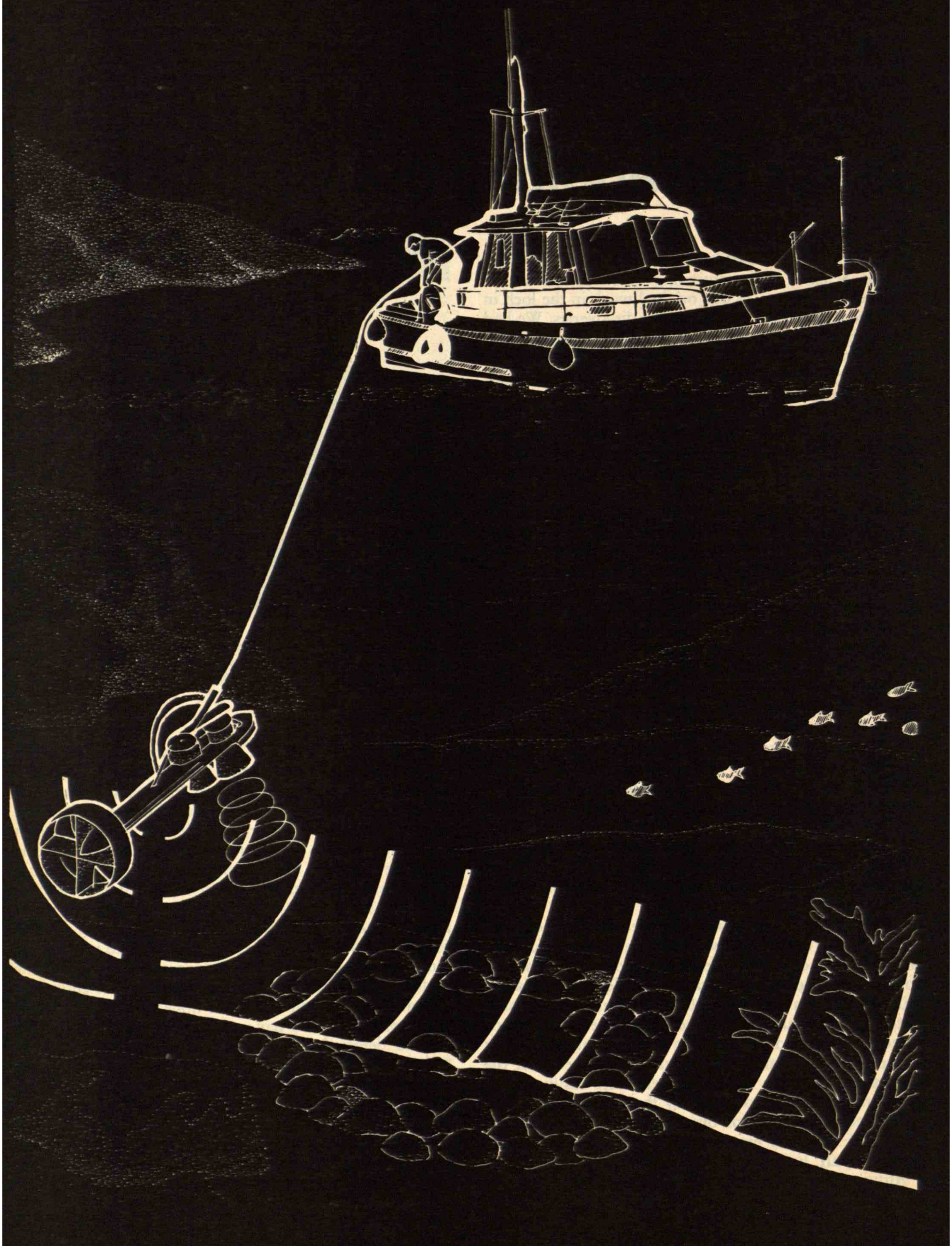


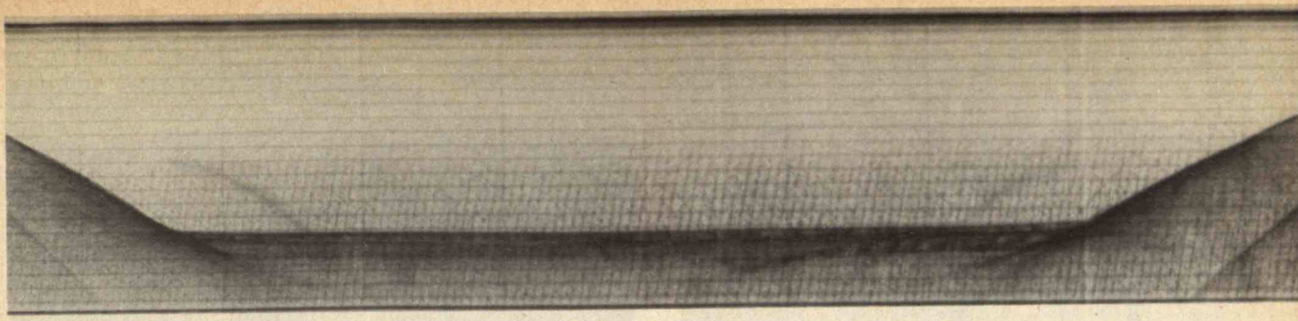
Author Martin Klein, president of Klein Associates, Inc., with the towfish for the HYDROSCAN Side Scan Sonar/Sub-Bottom Profiler, as used in Loch Ness. (Photo by Charles Finkelstein)

Sonar studies in Loch Ness have revealed some startling discoveries underwater — large, ancient stone circles, a World War II airplane, shipwrecks, "caves" in the loch walls, and mysterious objects on the bottom which need to be investigated.



The side scan sonar system consists of a towfish, which sends out powerful sound pulses and receives echoes from the bottom; an onboard recorder; and a tow cable. The Klein sonar used to search Loch Ness had, in addition to the left- and right-hand side sonar beams, a third beam aimed straight down to penetrate bottom sediments.





A sub-bottom profile of the cross-section of the bottom of Loch Ness, using a Klein Associates 3.5-kHz sonar. Each scale line represents 15 meters of depth. The "extensions" of the steep sides beneath the sediments appear to be false "side echoes." (Copyright Klein Associates, Inc. and the Academy of Applied Science.)

New Sonar Eyes

The equipment which we brought to Loch Ness in 1976 was our new combined side scan sonar/sub-bottom profiler system. Except for some local studies and some work with the U.S. Navy, this was the first major field expedition for this system. The system has three basic elements — a towfish, a tow cable and a graphic recorder. On page 46 is an artist's conception of our side scan sonar system.

The towfish contains transmitting circuitry to energize transducers which project high-intensity, high-frequency bursts of acoustic energy in fan-shaped beams. These beams are narrow in the horizontal plane and wide in the vertical plane and project along the sea floor on both sides of the moving towfish. Objects or topographic features on the sea floor produce echoes which are received by the transducers. In the new system, a third transducer has been added to the towfish. This unit has a lower frequency to penetrate the bottom sediments. It has a conical beam which points vertically into the bottom. For our work in Loch Ness, the side scan had a frequency of 100 kiloHertz (kHz), a horizontal beam angle of one degree, and a pulse length of 0.1 millisecond. Our profiler used a frequency of 3.5 kHz, a conical beam of 50 degrees and a pulse length of 0.4 milliseconds.

The echoes received from the transducers are amplified in the towfish electronics and sent up the tow cable to the shipboard recorder. For our work in Loch Ness we used a 100-meter length of a special lightweight cable which has a strain member made of duPont Kevlar which has the strength of steel, but only a small fraction of its weight.

The Klein recorder processes the incoming echoes and prints them on a special three-channel writing mechanism. This creates a permanent, continuous graphic record of a wide path along the sea floor as well as the sub-bottom layers below the sea floor. The recorder places each echo side by side so that a coherent visual picture of bottom formations is built up from successive echoes. The side scan records frequently resemble large-scale aerial photographs. Normally, two of the recorder channels are used to display the left and right side scan echoes and one channel is used to display the results from the bottom profiler. However, at Loch Ness, we ran some interesting experiments by disconnecting the profiler and by feeding one of the side scan channels into two recorder channels. Klein Associates has been experimenting with a variety of signal processing techniques to better visualize the sonar "picture." We used some of these techniques to bring out the fine details of the sonar signals and to help interpret difficult signal areas.

Surveying the Bottom

Finkelstein arrived at the expedition site in Drumnadrochit, Scotland, on June 12, 1976, and Klein arrived on June 27. Unfortunately our equipment was held up in customs and nearly a week was lost.

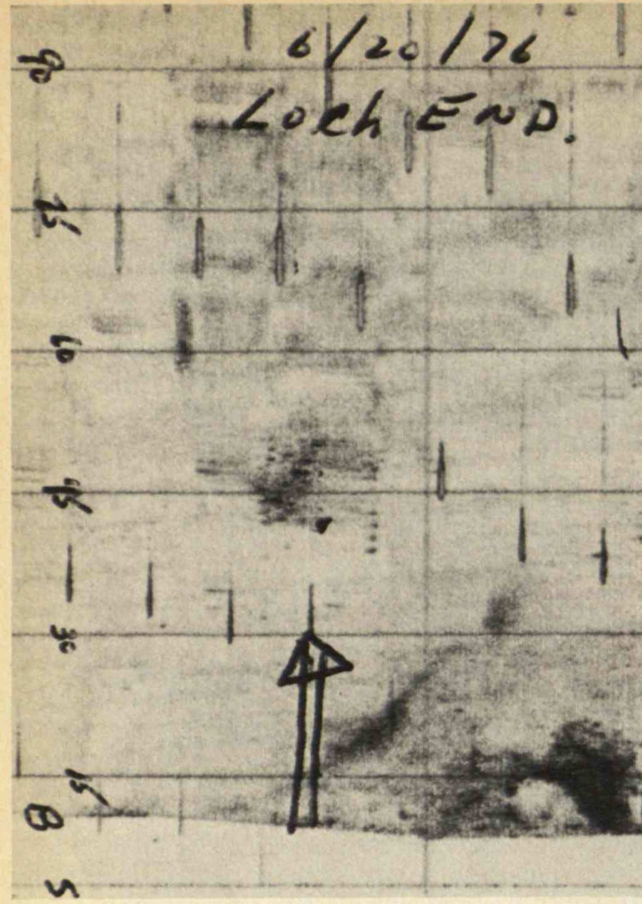
Upon arrival, we were delighted to find that Harold Edgerton of M.I.T. was already running "fixed-mode" sonar experiments at Temple Pier using another EG&G side scan sonar system *(see box p. 54)*. With this portion of the experiments in good hands, we were able to concentrate on our other experiments.

The sonar equipment was set up aboard the survey vessel *Malaran*. The ship, 33 feet long with power by twin diesels, proved to be perfect for our survey operations. We set up two automobile wheel rims in the stern over which we payed out the sonar cable. Our equipment was operated using two standard automobile batteries for power.

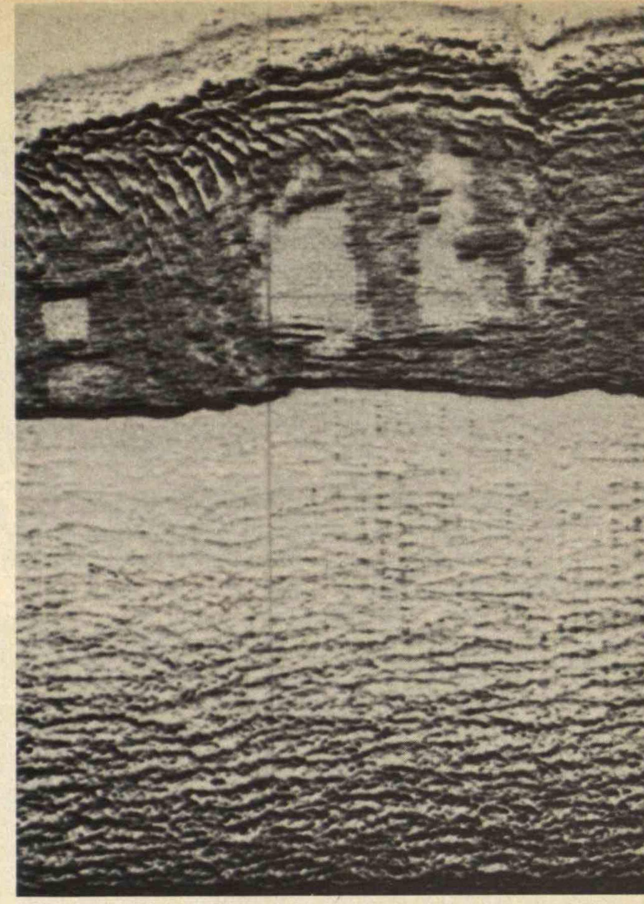
An important part of our survey operations was navigation. We wanted to run organized survey lines and then be able to return to these lines as necessary to further study what a survey had uncovered. Sophisticated radio navigation schemes are often used for such surveys, but budget considerations did not allow for one of these systems. Instead, we set up a simple system using sighting compasses with the able assistance of a local surveyor, George Reid. Two compasses were used on the boat to sight land bearings. Fixes were taken every few minutes. Two land bearings, the ship's heading, and the time were all recorded while an event mark line was simultaneously placed on the sonar recorder trace. Then George Reid plotted the lines so we could see what areas we had covered and reposition the ship as necessary. We were assisted during the survey by Chris McGowan and by Jeffrey Thomason, a zoologist now also with the Royal Ontario Museum. Robert Needleman of the Academy and Jean Mooney of M.I.T. helped with survey coordination and data recording.

Profiling the Sub Bottom

One of our first experiments was to profile the bottom-sediment layers by making runs from east to west across the narrow part of the loch. We hoped to settle one major controversy — whether the bedrock under the loch is V-shaped, or a flat-bottomed U-shape. Some argued that the bedrock had retained its V-shape over the millenia, and that the flat bottom had been formed by sediment settling into the "V." Others said that the gouging action of the glaciers which filled the loch during the



The first unknown target picked up on the 1976 sonar search was investigated by diver Finkelstein and turned out to be a line of rocks. The scale lines on the sonar trace are 15 meters apart. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)



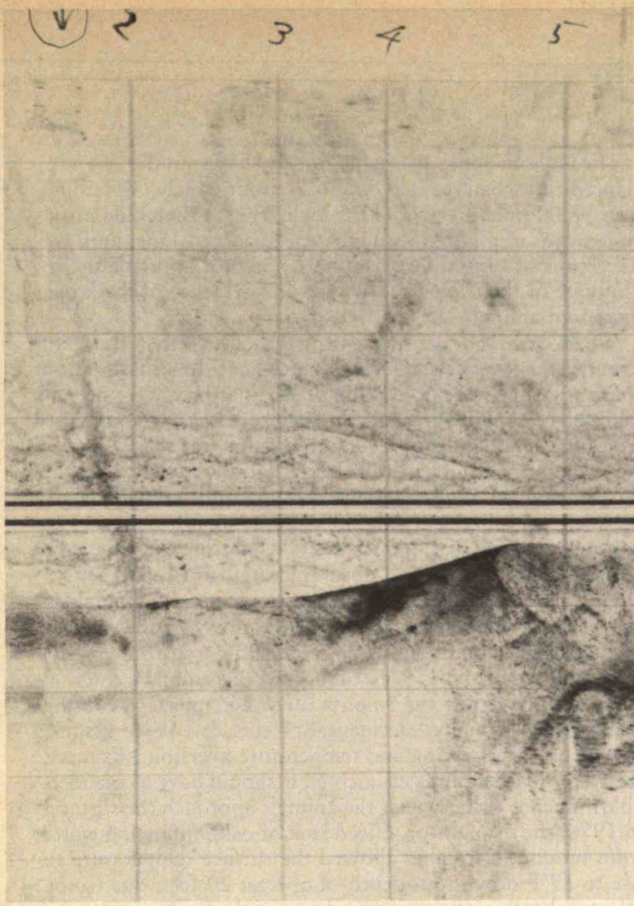
A side scan sonar trace of the steep walls of Loch Ness near Invermoriston. The dark stripes appear to be ridges or projections, and the light areas appear to be undercuts. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)

last ice age had formed the bedrock into a U-shape. Earlier echo soundings had indicated that the steep rock sides of the Loch continued straight down into the sediments, possibly meeting to form a "V." However, geophysicists advised us that the extensions indicated on such echo soundings could be a phenomenon known as "side echoes," which are produced when sound waves bounce off the interface where the steep slope meets the flat bottom. Our sub-bottom profiles revealed that these extensions were, after all, side echoes, because if earlier echo sounders had actually seen bedrock that far below the sediments, they should also have seen the many other sediment layers we picked up with our sonar. One of our profiles is shown on page 47. While our profile indicates that the bedrock is probably U-shaped, we still are not sure that we have penetrated all the sediments, and we recommend further studies with higher-power profiling devices.

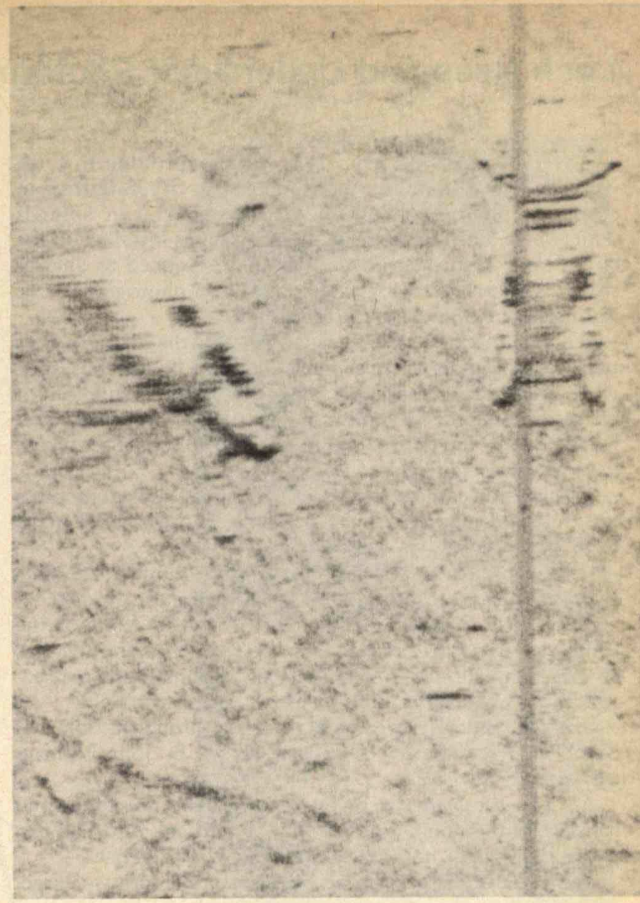
Search for the Carcasses

Our search for bones was to be in the shallow parts of the loch which could easily be investigated by divers. This proved more difficult than we planned, because there are hardly any shallow areas in the loch. In some areas, the sides of the loch slope so steeply that the bow of the boat can be in shallow water while the stern is in deep water! The normal hydrographic charts of the loch are not very detailed, so we set out to find out if a more detailed map existed. Fortunately, we were aided by Dick Raynor and Bill Owen at the Great Glen Exhibition in Fort Augustus, at the southern end of the loch. On the wall of their museum is a lovely map published by Bartholemew of a bathymetric survey of Loch Ness made in 1903 by Sir John Murray using lead lines. The map, made to a scale of 1:21,120 (3 inches to a mile) did not give great detail in shallow areas, but it gave us a lot of ideas. We wound up searching several relatively shallow areas in Urquhart Bay, Dores Bay, Lochend, Borlum Bay and near Cherry Island. Much to our amazement, every area we searched revealed targets of interest.

The first targets appeared on our sonar in Dores Bay, which is in the northern end of the loch (*above left*). Finkelstein observed patterns of objects on the sonar similar to the ones which showed up in the original tests with mammoth bones back in Salem. He dove on one of the formations, and swam around it. It turned out to be rocks which seemed to be in a straight line. While searching the area, Finkelstein was also startled to discover a hump-like formation on the bottom, amidst an area of smooth sand. The formation had a series of regular rib-like ridges on it. The formation turned out to be clay; however, it was later pointed out that the clay could have overlain another more solid structure beneath the silt. Finkelstein took a sample of the structure and gave it to Dr. McGo-



This side scan sonar trace near Cherry Island, at the south end of the loch, revealed an interesting open-sided square structure resting on the bottom (upper left of photo). The lower right-hand side shows echoes of the island structure. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)



One of the most intriguing sonar traces was obtained in Urquhart Bay. The object to the right is almost certainly a wooden sailing barge used to haul freight. The object to the left remains unknown, and should be investigated, say the authors. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)

wan for analysis. Unfortunately, he was unable to return to investigate this intriguing structure.

Next we went on to search Lochend, running a series of survey lines parallel to the northern shore, and some other cross lines. In our lines near the shore, we observed an odd circular formation. George Reid noted that somewhere near here a large steam engine had been in the water. We promptly labeled the odd target "the steam engine" and went along in our survey.

The Mysterious Circles — First Look

As we scanned along the edge of Lochend, we found one target that appeared to be a broken shipwreck. Then we discovered what appeared to be numerous circles and odd circular formations. We were running long days, and we came in each night with piles of records, so it was difficult to put together everything we had found until later. We heard various stories of dredging in Lochend and there were even accounts of explosive mine practice in the area. Our first thought was that the circular patterns were simply texture differences on the bottom created by one of these activities. We went on to survey other parts of the loch, hoping to return to these intriguing circles.

We surveyed the walls of the loch, and we found that the complex geology of ridges and undercuts which we had observed in 1970 ran for miles and miles all along both sides of the loch. The trace on page 48 shows a distinct pattern in the wall which looks like a square "cave" opening with a ridge over it.

Interpreting these records involves a complex geometry since we are looking at a sloping wall rather than the sea floor. We experimented with tipping the transducers to make the normally down-ward looking beam parallel to the slope. This made a different kind of pattern just as difficult to interpret. Unfortunately, we simply need a different kind of sonar system with a very narrow steerable conical beam to investigate these rugged walls in a quantitative fashion.

One of the unusual aspects of working with sonar at Loch Ness is that our sonar seemed to get unusually long ranges in this water. We discovered the phenomenon in 1970, and found the same thing in our 1976 experiments. Our 100 kHz side scan normally obtains average ranges of 200 to 300 meters on either side. In the loch, we were able to obtain ranges of up to 855 meters in some places. In fact, at times we were able to sail down the center and pick up both sides at once. It is known that Loch Ness has a low content of magnesium sulphate, a large molecule which is said to be a main factor in the attenuation of underwater sound.

We also found that this year in the loch we did not pick up the deep schools of fish which we had found years earlier. We speculated that the lack of rain (which is most unusual for the British Isles) may have been a cause.

Loch Ness and Underwater Photography

The photographic segment of the 1976 expedition to Loch Ness included a number of techniques never before tried in efforts to photograph the loch's large, unknown animals underwater. Each of the new camera systems installed on the large frame suspended in the loch was designed to answer specific deficiencies recognized in the 1975 photographs (*see* Technology Review, *March/April, p. 25*):

— To give more precise measurements of the animal's size, two 35-mm. underwater cameras, donated by Benthos, Inc., were arranged stereoscopically to allow triangulation of measurements on any photographs. These cameras used Kodak 2485 Film (ASA 2000) and had 16-mm. lenses which gave a wide-angle field of view.

— A television camera allowed a human operator to monitor the area in front of the cameras and trigger the other cameras at the proper time via a control box on shore.

— A videotape recorder, donated by Blonder Tongue Laboratories, attached to the television monitor produced a moving picture record of whatever swam in front of the cameras. The recorder could be set to record either at regular speed, or at a slower, time-lapse speed of one frame per second to allow longer taping times between rewinding.

— Instant pictures were made possible through a Polaroid SX-70 camera, adapted to underwater use by John Lothrop of Polaroid Corp.

Also on the frame were two strobe lights for the stereo cameras (150 and 50 watt-second) and a bank of flashbulbs in an underwater housing for the Polaroid camera.

Because the Loch Ness animals are apparently so large, and the range of photography in the murky loch so short, a major problem is how to obtain on a single frame an image of the animal's entire body. In 1972 and 1975 we had obtained "pieces" of an animal in our underwater photographs, but some sort of overall concept of the animal was needed in which to fit these pieces. We decided to capitalize on the fact that it was possible to photograph large areas in silhouette by placing a camera in the loch aimed upward, and using the sun as a light source. Vernon E. (Bill) MacRoberts of Professor Edgerton's laboratory and John Lothrop built for us a "silhouette" camera, which was a 35-mm. elapsed-time camera in a cylindrical waterproof housing. This camera would hang in the loch separate from the other systems taking a picture about every five seconds. It would be deployed only during sunlight hours and only if there was enough "activity" around the research area to warrant the effort.

Our third camera system consisted of the 16-mm. elapsed-time camera which had obtained the 1972 "flipper" photograph and 1975 pictures of what we believe to be a large animal. This year the strobe light was powered by a line to shore, rather than by batteries, so the unit could be more powerful and easier to service. The camera was loaded with high-speed Ektachrome film (ASA 160). We decided to aim the TV/stereo/Polaroid camera frame at the 16-mm. camera, because in 1975 the animal seemed to be attracted to it, for we had evidence that before or after several pictures of unknown surfaces or objects, the camera was knocked upward, photographing the bottom of the boat from which it was hung. Thus, we arrived at the arrangement of cameras shown in the drawing to the right.

During the 1976 expedition John Lothrop assembled a portable camera system consisting of a 35-mm. camera and 50 watt-second strobe, all battery powered. This portable unit allowed us to investigate other areas in the loch, either by making the unit sonar-activated or allowing it to operate in an elapsed-time mode, taking pictures every 15 seconds.

Throughout June, 1976, and into July, we ran the 16-mm., elapsed-time bait camera almost continuously, obtaining over 98,000 pictures under the loch. The TV/stereo/Polaroid system was monitored through a large part of June, until we were convinced that large animals were not approaching it. On none of the frames did we see any evidence of the large, unknown animals.

We theorize that the severe drought in the British Isles had lowered the level of the loch so much that the usual salmon spawning runs were not taking place, and there were no salmon in the shallow areas of the loch to bring the animal up from its usual depths to feed. Support for this theory comes from the poor fishing season being had by anglers, and the fact that out of almost 100,000 photographs taken beneath the loch, we obtained only 33 pictures of fish and eels. In contrast, one roll of 2,000 frames taken during the same time of year in 1975 showed a dozen pictures of fish and eels.

One interesting theory holds that the unknown animals in Loch Ness dislike higher temperatures and avoid the warmer surface of the water. (According to this theory, surfacing occurs only when the loch is calm, and the animal's internal sonar cannot detect the smooth air-water interface causing them to occasionally "accidentally" surface.) If we assume this theory of surfacing and temperature aversion is correct, the water temperatures at Loch Ness should have a considerable influence on how near the animals approach the surface. In 1976, the drought-produced lack of cold, inflowing water from mountain streams allowed the surface temperature to rise to 57°F down to a depth of at least 20 feet, due to the effective heating of the surface layer of the brown waters by the sun. This was far above the usual temperature of 42°F. Such warm surface layers may have driven the animals down into the cooler depths of the loch.

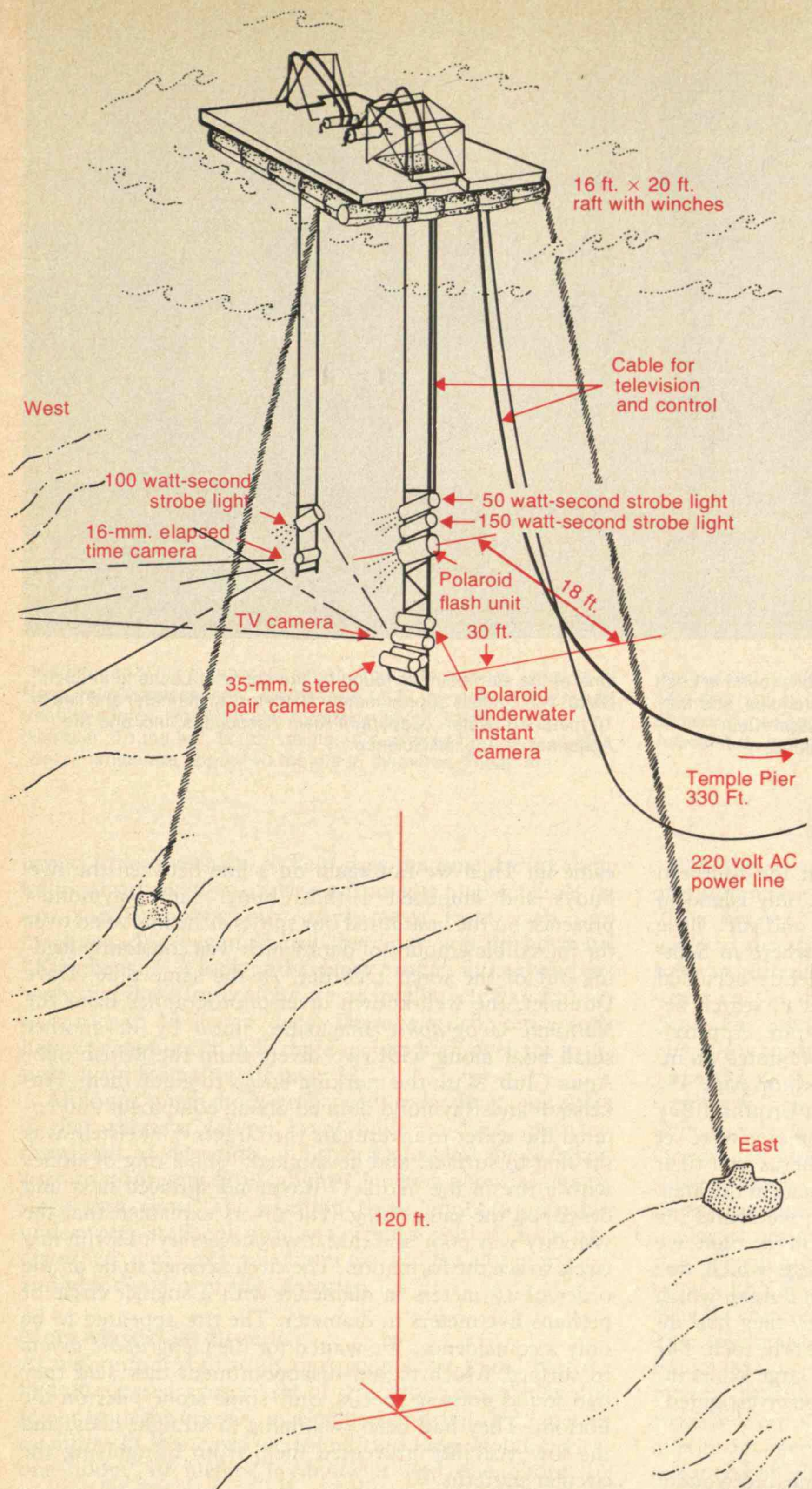
Although we did not obtain any photographic evidence in 1976, we did have a chance to investigate further the possibilities for underwater photography in the loch, and we remain convinced that underwater photography is the only logical way to aim future expeditions.

In fact, the loch is not as forbidding a place photographically as we had believed. Calibration tests showed that the television camera could detect certain objects as far as 25 feet away, and we are convinced that it is quite possible to obtain still photographs as far as 40 feet away.

For future expeditions the Academy plans to increase the photographic range and improve lighting by installing more strobe lights on the research raft we are now using. These "slave" strobes will have photoelectric cells attached which will be triggered by the light from the main strobe light, attached to the cameras.

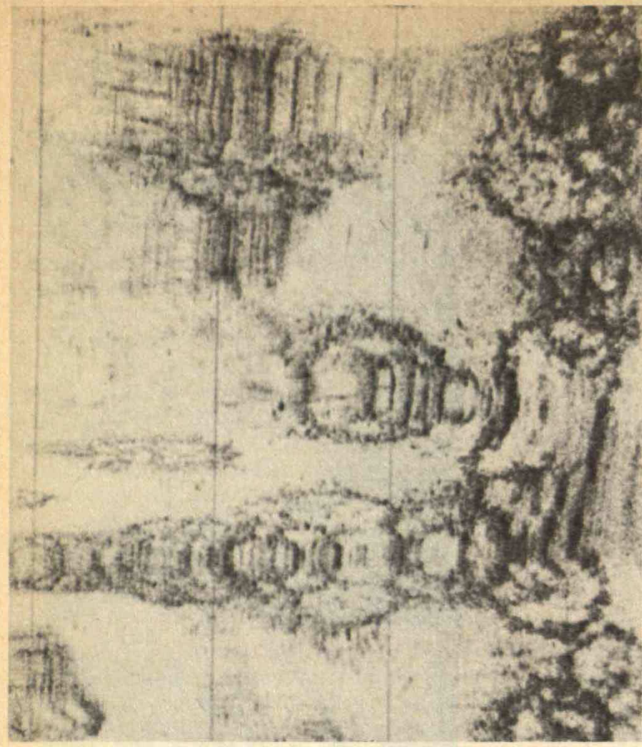
Rather than rely solely on human operators manning a monitoring station, we plan to resort to sonar-activated cameras, in which a sonar transducer attached to the camera will monitor the area in front of the camera. A computer attached to the sonar device is "gated" so that only objects over a certain size moving into the beam will trigger the camera to begin taking an elapsed-time picture once every five seconds as long as the object remains in the field of view. If it turns out in future expeditions that the sonar-activated cameras are seeing considerable action, we will revert to the TV/stereo/Polaroid type camera systems monitored by human operators.

We also plan to continue other experiments to obtain further sonar records of the animals' movements and perhaps sound recordings. — *Charles W. Wyckoff, Applied Photo Sciences, Inc.*

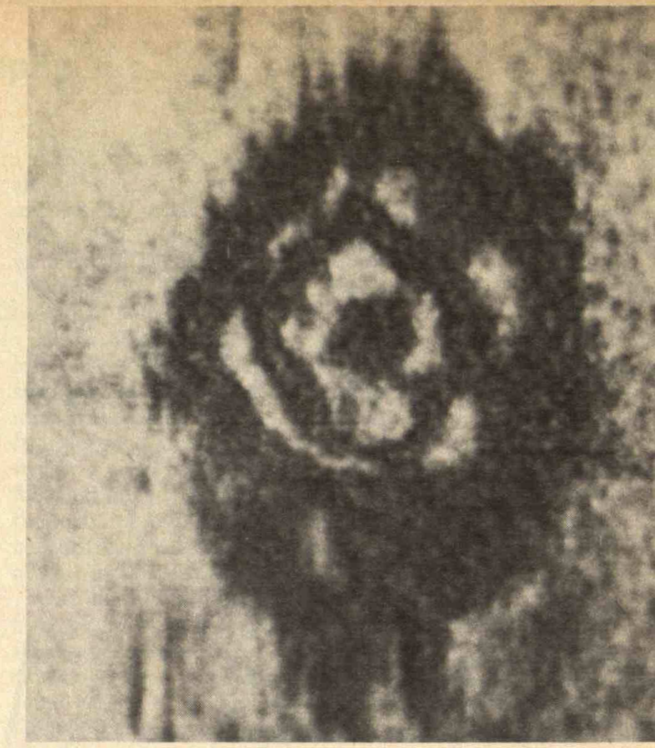


The underwater photographic apparatus used in the 1976 expedition to Loch Ness.

Charles Wyckoff loads film into one of the stereo 35-mm. cameras, in preparation for its first "splashdown" in Loch Ness. The stereo cameras would allow more precise measurements of any object photographed underwater, for sizes could be calculated using triangulation. (Photo: Dennis Meredith)



"Kleinhenge I" — a series of stone circle formations found in Loch Ness. One of the formations consists of multiple circles, and the total formation is at least 75 meters long. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)



One of the stone circles found by the sonar at Lochend in Loch Ness. The circle is approximately 10 meters in diameter and lies in 10 meters of water. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)

We continued on to Cherry Island near the southern end of the loch. This tiny structure is the only island in Loch Ness. It is known to be man-made, and such little islands, called crannogs, are known elsewhere in Scotland. At one time, the islands were apparently occupied by small forts. The area was very difficult to search because of the very rapidly changing bottom. Approximately 100 meters away from the island we noted an interesting open-sided square structure as seen on page 49.

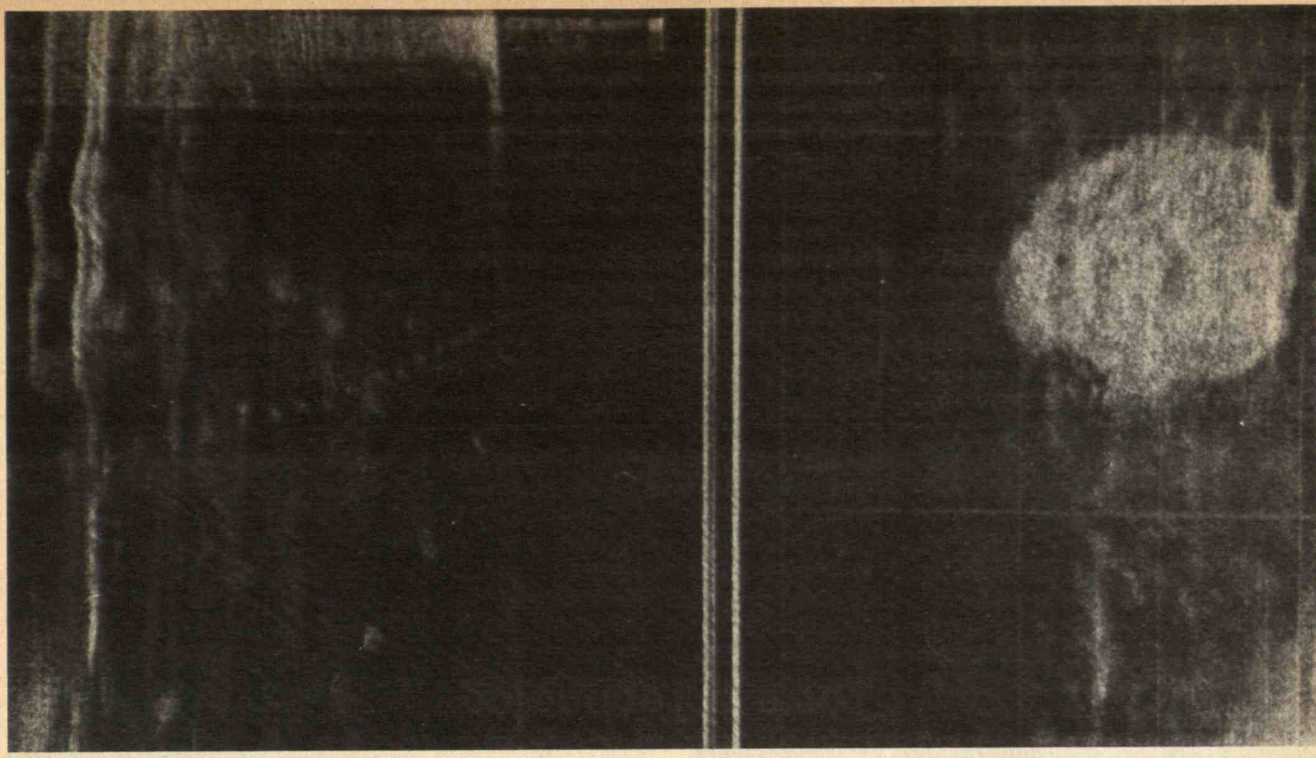
Next, we decided to take a quick run in Urquhart Bay near Temple Pier where the underwater cameras were set up. We were able to see the pier, the cameras and their rigging, and the moorings of the various boats in the area. Approximately 100 meters from the pier, we found the two targets shown on page 49. The target on the right, we feel certain, is an old wooden sailing barge which was well known to the Loch Ness Investigation Bureau which studied the loch in previous years. In fact, they had inspected it several years ago while we were at the loch. The target next to it . . . another shipwreck? A large skeleton? We don't know, but it certainly needs to be investigated.

The Circles Discovered!

As we proceeded with the work, we continued to wonder about the circle formations at Lochend. Finally we decided to take time to find out. Sam Raymond, President of Benthos, Inc. of Falmouth, Mass., joined us on the *Malaran*. Since our navigation plots had not yet been completed, we brought along the sonar and several buoys and began to run in the area. When the sonar picked up a clear circle we launched a buoy. We turned in the opposite direction and launched another buoy when the target came in. Then we ran again on a line between the two buoys and launched a third buoy. Sam Raymond's presence on the boat lifted our spirits as he marveled over the incredible amount of data which was constantly feeding out of the sonar recorder. At the same time, Dave Doubilet, the well-known diver-photographer from the *National Geographic* magazine, stood by in another small boat along with two divers from the British Sub-Aqua Club. With the marking buoys to guide them, Finkelstein and Raymond donned diving equipment and entered the water to investigate the targets. Finkelstein was the first to surface, and he shouted, "It's a ring of stones with a tire in the middle!" Raymond surfaced next and described the same thing. The divers explained that the visibility was poor and that it was necessary to swim in a circle to see the formation. The circle seemed to be on the order of 10 meters in diameter, with a smaller circle of perhaps five meters in diameter. The tire appeared to be only a coincidence. We waited for the *Geographic* divers to surface. Much to our disappointment they said they had found nothing special, only some stone piles on the bottom. They had been swimming in straight lines, and the low visibility prevented them from recognizing the circular patterns.

Suddenly, things began to fall into place. We began asking a lot of questions and studying the records in more detail. We learned that stone circles are well known in the British Isles, and that some are known near Loch Ness. We observed that the record showed not only concentric circles such as the one at the top right but also odd multiple circle formations such as the ones at top left.

One of the traditions of our sonar survey business is to



"Kleinhenge II" is a separate set of circular formations in Loch Ness, much deeper than "Kleinhenge I." At the right of the sonar trace is a large, solid circular formation about 30 meters in diameter. To the left, faintly visible, is a straight formation of 20 "dots," which are about two meters in diameter. These are surrounded by a larger 50-meter circle of similar "dots." The image was reversed to give better resolution, so that the sonar contacts showed up as light areas on a dark background. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)

invent little diversions to help pass the time during long hours of survey. One of these pastimes is to give names to our sonar targets, our survey areas and even our machines. We began to call the circle area in Lochend "Kleinhenge." A look at the depth profiles in Lochend reveals that these formations are on a relatively flat area on the order of 10 meters deep. There is a definite mound, however, approximately three meters high over the multiple circle formation of page 52.

Although much more study needs to be done, our guess is that these structures were built on land, perhaps thousands of years ago, and that the level of the loch has risen to its present level (about 17 meters above sea level) since that time. The exciting thing about a possible underwater archaeological site is that it is likely to be undisturbed, whereas similar sites on land have been moved and plundered over the centuries.

More Mysterious Patterns

As we continued to study our records, we found that we had discovered *another* set of structures, completely different from the first set, in even deeper water of 25 meters or more. In this case, we found two large, solid circles, one about 30 meters in diameter and one about 16 meters. The circles are connected by a row of "dots" on the sonar. The trace above shows the 30-meter solid circle. Right next to this circle is a long row of around 20 "dots" each about two meters in diameter. Surrounding this straight row is a large circle of similar dots. This circle is approximately 50 meters in diameter. A giant underwater clock? A calendar? Or perhaps only a strange coincidence. Only time and detailed investigation will tell.

We appear to have discovered two relatively flat areas at different levels underwater, which we now refer to as "Kleinhenge I" and "Kleinhenge II." A look at their levels leads to the speculation that the two sets of rings were built in different eras, and both were perhaps built on what was, at their respective times, the "beach" at Loch Ness. The discovery could, of course, have dramatic implications regarding the possible water levels in the loch since the glacial period about 12,000 years ago during which the loch was buried under thousands of feet of ice. Our discoveries may give evidence that the loch and the Great Glen were more intimately connected to the sea, a subject which often comes up when the famous monster (a sea creature?) is discussed.

One of our most intriguing discoveries on the loch bottom was an airplane! The plane (*see page 55*) turned out to be a PBY Flying Boat which went down during World War II. The crew of four escaped when the plane ditched. The American-built plane was operated by the Royal Air Force. It had a wingspan of 35 meters and a length of 32 meters. Two large 1,050 horsepower Pratt and Whitney engines were mounted on the wings. The plane had a maximum speed of 179 miles per hour. Judging by the sonar record, the plane appears to be reasonably intact in about 30 meters of water.

The Final Surprise

We made some of our last runs with the side scan in Borlum Bay near the Abbey in Fort Augustus. As is often the situation in our type of work, we made one of our most intriguing finds just as we were about to wind up our survey. In approximately 100 meters of water, we picked up

A Sonar Watch Pays Off

Although the photographic portion of the 1976 Academy of Applied Science/*New York Times* expedition to Loch Ness failed to capture photographs of large animals under the loch, a number of intriguing sonar contacts were obtained of large, moving, underwater objects. These contacts confirmed that there were subjects to be photographed in the loch, but not within photographic range.

The sonar apparatus was set up underwater off Temple Pier and aimed out into the loch so that it "watched" the underwater camera rig. At first we used a side-scan sonar fish, with one of its two fan-shaped vertical beams aimed outward to illuminate the cameras. However, on June 30, we developed a more sophisticated system. We mounted the sonar towfish on a metal stand which would hold it about 2½ feet off the bottom, and placed the fish about 10 meters off Temple Pier. We also mounted on this stand the sonar transducer from the other side of the sonar fish, so that the beam would be a horizontal fan. This combination of beams gave an indication of both the vertical and the lateral location of objects moving in the beam.

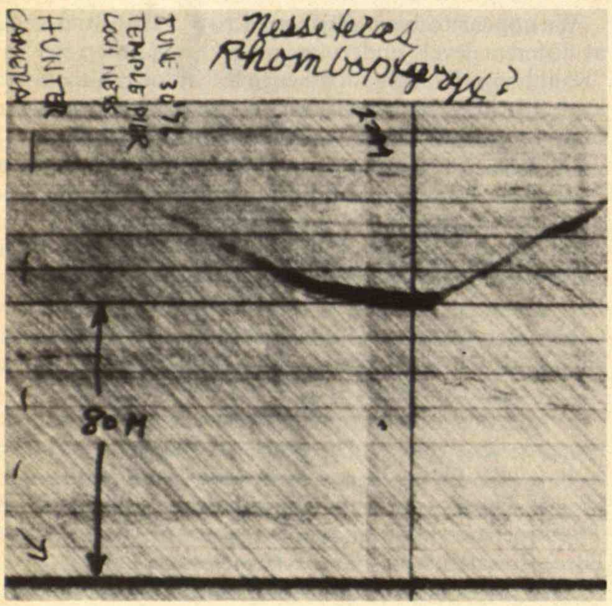
The vertical and horizontal sound beams were then centered on the underwater camera rigs. The sonar beams were 55 meters from the cameras, and the sonar rig had a range of 200 meters. We monitored the system as much as was feasible during the period of June 23 to July 5, and we obtained numerous fairly large targets. Unfortunately all of the targets were at considerable distance from the underwater cameras.

The two most important sonar traces came on June 30 and July 1, 1976. The June 30 contact, obtained while Helen Wyckoff was on watch, occurred at 22:44 hours. The sonar trace (*see below left*) shows an object coming in at a distance of 180 meters from the sonar (120 meters from the camera). After about a minute of movement inward, the object slowed and stopped, presenting a target width of three meters. After about one minute of rest, 80 meters from the cameras, the object departed with about the same velocity, but with a slight hesitation after about one minute of movement. Also on this record can be seen two small signals, which could be reflections from disturbed fish.

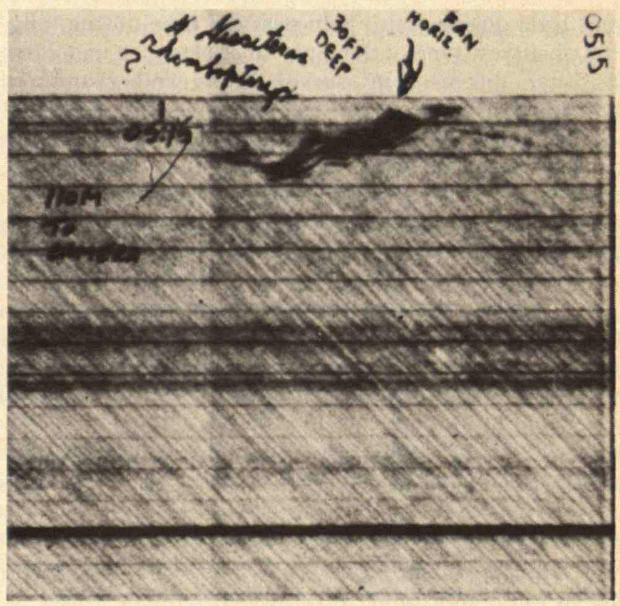
The second important sonar contact occurred on July 1, 1976, about 05:00 hours while Charles Wyckoff was on watch. This sonar contact (*see below right*) had a target width of about ten meters. This contact was interesting because of the filamentous nature of the traces, which indicated a number of reflecting surfaces. Also, note the small trace that could be caused by a fish that had been alarmed.

On July 5, a large research barge was installed to support the cameras, and although monitoring continued, no further contacts were observed. It is not certain whether the barge had anything to do with the scarcity of targets. These 1976 contacts were only the latest of many past sonar contacts with large moving objects under the loch, including contacts by Martin Klein in 1970 and Robert Rines in 1972. Our contacts confirm that there are large, presumably animate, objects under the loch that should be further investigated. The 1976 results also show that sonar is an excellent tool to provide camera operators with warning of approaching photographic subjects and to study the movements of underwater creatures to decide camera placement — *Harold E. Edgerton, M.I.T.*

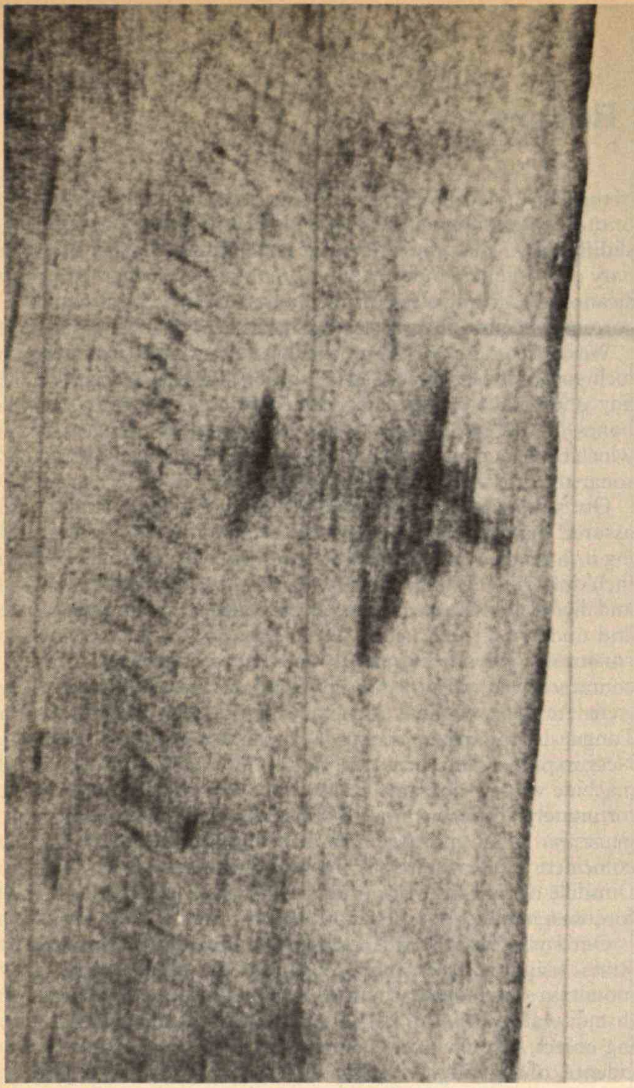
(The side scan sonar used in the stationary mode sonar watch was an EG&G Model 259.)



On June 30, 1976, a large underwater object moved into the expedition's sonar beam, approached within 80 meters of the underwater cameras, paused for a few minutes, and then departed. The time scale on the sonar trace reads from left to right, and each horizontal line represents ten meters of distance from the sonar. Note the small traces which could represent fish in the beam. The horizontal line at the bottom represents the trace of the permanently anchored cameras.



On July 1, 1976, a large object again intruded on the sonar beam, giving a target width of ten meters. This object gave a parallel-trace type of contact. The thick, horizontal line at the bottom represents the trace from the underwater cameras. Each horizontal distance mark represents ten meters. Note the small trace to the right of the larger one which could represent a fish moving in the beam. (Both photos copyright Academy of Applied Science.)



Sonar record of a PBY aircraft discovered on the 1976 survey lying in 34 meters of water in Loch Ness. This plane was an American-made "flying boat" operated by the R.A.F. It went down during World War II, and its crew of four escaped. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)

The object in this sonar trace was nicknamed "The Average Plesiosaur," after the prehistoric reptile that has been one candidate for the identity of the Loch Ness monster. The object, about 10 meters long, was detected in about 100 meters of water off Fort Augustus. (Copyright Klein Associates, Inc. and the Academy of Applied Science.)

the target shown above right. The target has a carcass-like shape with a long neck-like projection, and the whole thing appears to be about 10 meters long. It does not look like any of the other targets which we picked up in the loch. Of course, it would be wild speculation to make any assumptions about this target without further investigation. An underwater television or a small submersible would probably be needed for identification at this depth. We named this target "The Average Plesiosaur" to tease our paleontologist friends. It will be interesting to find if the target is still there when we next go to look for it.

We have obviously made many interesting discoveries with our side scan sonar and sub-bottom profiler in Loch Ness. Our work was only a beginning, but we feel that a detailed full-scale exploration survey would be fully justified. Our records and maps are, of course, available for further study by archaeologists or any others interested in further investigation of our finds. *(The sonar system used in Loch Ness was a Klein Model 430 HYDROSCAN Side Scan Sonar — Sub-Bottom Profiler System with a Model 431 Three-Channel Klein Recorder. The system features Hands-Off Tuning® with Texture Enhancement.™)*

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The 1976 Expedition: Links With Past Results

When we obtained the June 30 and July 1, 1976, sonar traces of large objects moving underwater in Loch Ness, it was a personal thrill to see that Charles Wyckoff had pencilled in beside the targets the words *Nessiteras rhombopteryx*. This was the scientific name for the Loch Ness animals, which we introduced with Sir Peter Scott (*Nature*, Vol. 258, December 11, 1975, p. 466) to secure conservation protection for them.

What Charlie Wyckoff had noted about the trace, as had we all, was that there was a definite similarity between the multiple parallel traces of 1976 and the parallel sonar traces obtained with an entirely different machine on August 9, 1972. (The 1972 traces, showing two large objects under the loch, were obtained with the sonar operated in the same stationary mode. They appeared at the same time our underwater elapsed-time camera obtained the two 1972 flipper photographs and a third photograph suggestive of two large bodies in the frame.)

Especially fascinating was that in both the 1972 and the July 1, 1976, targets we found substantially the same number of parallel traces, with substantially the same spacing and extending over approximately the same 10 meters of target width.

In the 1972 sonar trace (*see below*) the parallel traces maintained the same spacing throughout the period of the record, until the traces changed into a single, thick trace. One might speculate that these changes into a single, thick trace represented another aspect of the same object as it turned. (We think "side view.")

Another interesting coincidence is that the thick, single trace of the second object in the 1972 trace had the same approximately three-meter target width as the June 30, 1976, target. All this, despite the large differences between the 1972 sonar apparatus — a modified Raytheon DE 725C depth-type sonar — which had a frequency about twice that of the EG&G side scan sonar used in the 1976 traces.

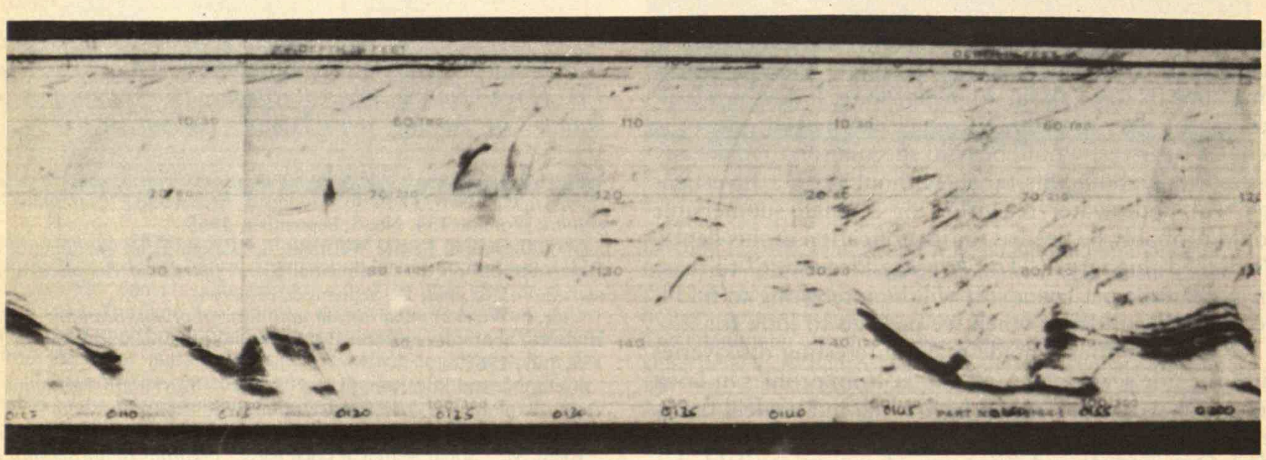
Just as our photographic techniques at Loch Ness have continued to improve, so has our use of sonar become more sophisticated — we hope with benefit to other areas of underwater exploration. For instance, in the 1976 expedition, working with Christopher McGowan of the Royal Ontario Museum, we evolved a technique to enable very accurate dredging along the interface between the steep side-walls of the loch and its flat bottom. We theorize that animal bones or other interesting objects might lodge at this interface, after sliding down the precipitous sides. We found that an ordinary depth-finder could readily be monitored for the first indication of a rising slope from the bottom. The pilot could correct his course to keep the dredge in the area of interest.

We carried out preliminary dredging along a portion of the loch south of Urquhart Castle, without having to resort to any above-the-surface navigation. Although we found no bones in this sampling, we recovered extensive lengths of winch cable and other debris, and perhaps developed a useful sonar tool for further dredging operations.

Our studies at Loch Ness will resume as soon as we can be assured that spawning salmon and sea trout will be migrating into the loch in considerable numbers. These studies will include mobile forays into other bays of the loch with sonar and hydrophone monitoring of suspended strobe cameras and underwater television. We undertook several such excursions in July, 1976, and in one, had a fascinating sonar contact. It was early one morning, and on board the *Malaran* were Academy board chairman Ike Blonder of Blonder Tongue Laboratories, his son Greg, and well-known Loch Ness explorer Tim Dinsdale. While monitoring the sonar machine we saw a sizable object move into the beam — unfortunately above the level of our underwater camera rig — pause for a few minutes, and then disappear. The contact coincided with a startling hydrophone detection by Tim Dinsdale of chirp-like or rattle-like sounds, which ceased before we could begin tape-recording.

Our surface-watch was carried out principally by Carol Rines using a Questar-telescope-camera system from a mountain overlooking the loch. She noted only two large, distant wake disturbances, as from a large, submerged moving object, throughout the summer, which is a very low incidence of sightings for this station, compared with past years.

Another research project, by Professor George Newton of M.I.T., aimed at determining whether infrared scanning of the loch surface might be able to detect tiny temperature differences between surfacing animals and the surrounding waters. Dr. Newton used a sensitive infrared scanner loaned by Magnavox Government and Industrial Electronics, and found he could detect fractional-degree variations at ranges



of up to two miles. Such a system could monitor surfacings of large creatures more effectively than visible-light-based schemes, since it can function under adverse weather conditions and at night.

As usual, the expedition to Loch Ness was a volunteer effort, and many individuals and companies gave of their time, effort and products. From *Technology Review* came Dennis Meredith, who acted as press officer and aided with the operations. From the *New York Times* came chief science writer John Noble Wilford and London correspondent Robert Semple, and from N.B.C. came film unit manager Nick O'Gorman and his colleagues. Academy staff members Howard Curtis and Robert Needleman gave logistic support for the complex undertaking, and we were fortunate in having the local aid of Gordon MacKintosh, who acted as a liason with Scottish authorities. And, of course, the business of ferrying 2,000 pounds of equipment was handled with dispatch by British Airways.

For the present, we are continuing automatic photographic surveillance in Urquhart Bay, using our sonar-triggered underwater camera system, set to activate upon the approach of a large underwater object. These systems are being maintained by two Scottish associates, Alex Menzies and Tony Gerlings.

We hope to resume surveys this spring with television, camera, and divers to investigate the interesting sonar targets obtained in the Klein/McGowan/Finkelstein scans of the loch. We will receive aid in these surveys from John D. Mills of Underwater Instrumentation Co., Weybridge, England, and Aberdeen, Scotland, and from Robert Helmreich, University of Texas. Dr. Helmreich is a psychologist who visited the expedition to study the human interactions of the expedition members, as part of a study for N.A.S.A. on choosing crews for the Space Shuttle. We discovered that Dr. Helmreich was an experienced diver and persuaded him to use his expertise to help us photograph "Kleinhenge" and other underwater targets.

It was a minor miracle, keeping a host of scientists, each normally accustomed to leading his own project, working harmoniously, but, although we didn't contact the animals in the loch as closely as we would have liked, we have certainly proven our equipment. — *Robert H. Rines, Academy of Applied Science*

The August 9, 1972, sonar contacts with large, moving, underwater objects closely resembled the 1976 contacts (*see page 54*). The July 1, 1976, contact consisted of a number of parallel traces, resembling the parallel-trace objects in the 1972 contact. The other 1976 contact consisted of a smaller, thick, solid trace, also like one of the 1972 contacts. The trace at left shows two separate encounters with the objects, one beginning around 1:00 a.m., and one around 1:45 a.m. During the second contact, the "flipper" pictures were obtained by the elapsed-time underwater camera. The small traces on the record are almost certainly fish. (Copyright Academy of Applied Science)

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Martin Klein received his S.B. in electrical engineering from M.I.T. in 1962 and has done graduate work in physical oceanography at Northeastern University. He is currently president and founder of Klein Associates, Inc. of Salem, New Hampshire. Before forming Klein Associates he was Program Manager for Sonar Systems at EG&G International, Inc., where he was responsible for the design, development and field operation of the EG&G Mark 1 Side Scan Sonar System. He was also responsible for the design and installation of the first side scan sonar system on the bathyscape *Trieste,* and has worked with numerous other deep-diving research submersibles. He also has extensive ocean survey and exploration experience in the waters of North America, Europe and Asia. **Charles Finkelstein** is a design and development engineer with Klein Associates, Inc. He is working toward his S.B. in electrical engineering at M.I.T. He has participated in several projects in developing undersea research instruments, and is an expert scuba diver.