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to examine, and interpret the residues of past practices. While properly resituating religion, ritual, and ideology in interpretations of the past may require a considerable departure from our contemporary worldview, the results of such an endeavor, already begun, promise to considerably enhance the practice of archaeology.

See also: **Archaeoastronomy**; **Biblical Archaeology**; **Cognitive Archaeology**; **Image and Symbol**; **Interpretive Art and Archaeology**; **Marxist Archaeology**; **Modern Humans, Emergence of**; **Postprocessual Archaeology**; **Rock Art**; **Social Inequality, Development of**.

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ROBOTIC ARCHAEOLOGY ON THE DEEP OCEAN FLOOR

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Glossary

anomaly Anything that stands out from the background; anything different. In this case, something that side-scan sonar shows as different from the surrounding seafloor.
bathymetry Measuring ocean depths and using the results to map the seabottom.
GPS Global Positioning System; the system of satellites and transceivers that makes it possible to locate a GPS-equipped object, person, or vehicle with great precision on the face of the earth.
provenance (aka provenience) The original location and associations of an object.
ROV Remotely Operated Vehicle, in this case, a submersible vehicle adapted to perform archaeological survey, investigation and excavation controlled from the surface by an operator.
side-scan sonar Sound-location technology used to highlight and map anomalies on the ocean floor.
transducer A device which converts energy from one form to another. In side-scan sonar this is usually a piezoelectric crystal (a ceramic material which has the property of physically changing shape when a voltage is applied across it).
transponder An electronic device that when interrogated with a specific acoustic signal from a hydrophone responds with its own signature signal back to the hydrophone. Connected to a tracking system this signal is then computed as an x, y and z coordinate.

Introduction

When we think of an archaeologist working in the field, we usually think of someone with a bush knife, map, and compass hacking through the jungle looking for ruins, or down in a trench scraping away dirt with a trowel. In simple, vivid terms, those images do capture the essence of most archaeological fieldwork – survey on the one hand, excavation on the other, both performed by people with hand tools.

If we envision underwater archaeology, we tend to think of something similar: SCUBA divers swimming along under their clouds of bubbles, scanning the seafloor below for the remains of ships and their contents, or similarly equipped divers gathered over the barely recognizable hulk of a shipwreck, carefully dusting away the sediments that cover it. These images, too, are generally accurate ones.

But what if we need to find and excavate something on the floor of the really deep ocean – 500 m down, a

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thousand, even two thousand? How do we find a site, a shipwreck for example, down there? Even more challenging, how do we excavate it?

Until recently, the answer was a simple one: we don't. Oh, we could tow an array of electronic equipment and get some idea of what's down there, but the images we obtained would not tell us whether the steel wreck we had located was of welded or rivet construction, or allow us to reliably judge if a pile of long skinny things represented a wooden warship's cannons or a pile of discarded pipes. We might go down in a submarine or a diving bell and send a diver out, but the depth and conditions might not allow this. We could use deep-water grabs and dredging equipment to bring the remains of a shipwreck to surface, but we might destroy more than we get, and we would lose the contextual information that is basic to any archaeological study. Anything that had gone to the deep-sea bed was down there for good, beyond our ability to recover it using archaeological methods and principles.

In the twenty-first century things are different. The development of remotely operated vehicles (ROVs) and associated tooling, equipment, and technology allows the marine archaeologist to observe, closely and in great detail, shipwrecks that a few decades ago were beyond the range of human investigation. Now we can do archaeology on the deepest of seabeds, from the comfort of a control van where monitors, computers, fiberoptics, and other technology enable the ROV to serve as the archaeologist's hands and eyes. Just as we can send robots to investigate the surface of distant planets, we can now explore the great ocean depths.

The Origins of Deep Ocean Archaeology

Our ability to do deep-ocean archaeology is, of course, the product of modern technology. Although much of the needed technology was first developed by the military, and for commercial applications such as the placement of transoceanic telephone cables, its widespread availability is largely the product of the oil and natural gas industry. Everyone – at least on television – has seen oil and gas offshore installations – drilling and pumping platforms standing out in the ocean. Building such offshore platforms requires specialized equipment; servicing them and the drills and pumps that penetrate the seabed below them, requires technology. While many of the platforms do not stand in terribly deep water, most of the technology that works at 50 m can be made to work at 500. Some oil and gas platforms – many in the North Sea, for example, both fixed and floating, are in deep water – 200 m, 500 m deep. Whether they are floating or standing on the bottom, they need technology to manage their drills, pipes, and moorings.

In the early days of deep ocean oil drilling, in the 1970s, oil companies found ways to send hard-hat divers to considerable depths, but the costs were very high and the risks were great. Technology – much of it developed originally for military use – came to the rescue. Robotic submersibles – that is, ROVs – were equipped with video cameras and a variety of manipulators and suction devices so they could swim down to the bottom under remote supervision and perform functions ranging from opening and closing valves to moving multi-ton pieces of equipment. As these ROVs became more common their cost declined, and they began to be within the economic reach of people other than oil companies. They became the basic tools of deep ocean archaeology (**Figure 1**).

Of course, before one can excavate a shipwreck one has to find it, and the technology to do this in the deep oceans is also largely the product of the oil and gas industry, together with the defense establishment and the telecommunications industry. Oil and gas companies have to run pipelines across the ocean floor, telecommunications companies lay fiber-optic cables, and the military has to know a great deal about the seabed to allow its submarines to navigate safely and stealthily through the depths. These practical requirements have resulted in the development of remote-sensing technology. Remote sensing in the ocean involves electronic equipment that can be towed behind a ship or fitted to the hull and is able to map the contours and features of the ocean floor using sound waves. With high degrees of accuracy, such technology can pinpoint anomalies like shipwrecks that can foul cables and trip up pipeline laying equipment. Coupled with Global Positioning System (GPS) technology – the satellites that give you interactive street maps in your car – these remote sensing systems have made it possible to locate and accurately measure the position of shipwrecks on the seabed.

Who Does Deep-ocean Archaeology?

All of this technology costs money, as do the ships from which it is deployed, and the skilled crews to operate them. It is a very rare museum, university, or other research institution that has long-term access to such equipment, and those that have it usually have to share it among departments investigating deep ocean geology, biology, hydrology, and other sciences as well as archaeology.

As a result, with very few exceptions, virtually all deep-ocean archaeology today is being carried out

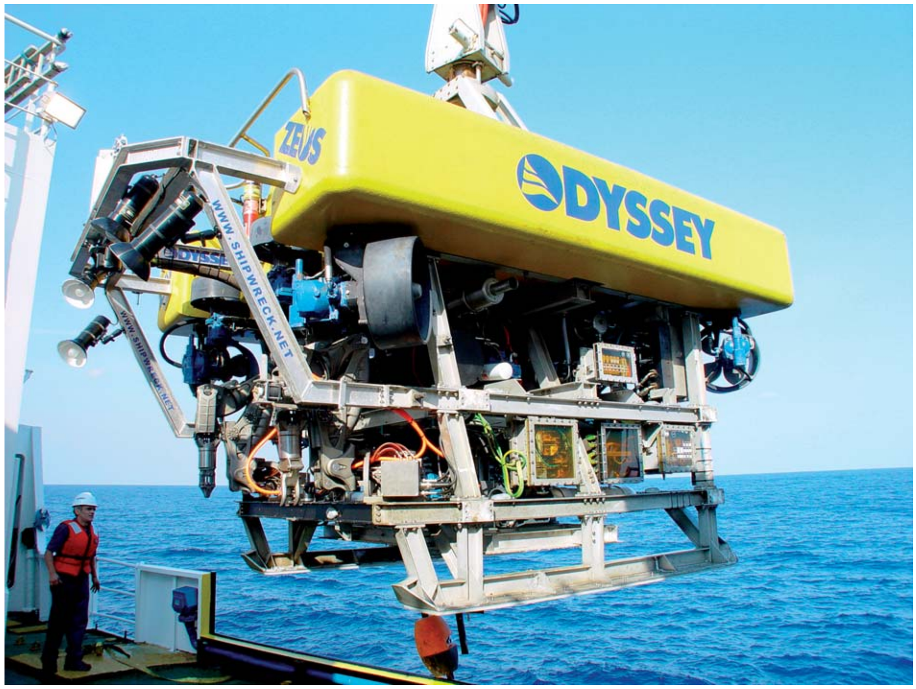

Figure 1 An ROV named *ZEUS*, the eight-ton, 205 horsepower remotely operated vehicle (ROV) used by Odyssey Marine Exploration, is raised from the Atlantic after a trip 1700 feet deep to the shipwreck of the SS *Republic*. (Photo credit: Odyssey Marine Exploration).

by commercial marine salvage companies. This fact outrages many traditional archaeologists, who believe that there is no room for accommodation between the interests of archaeology and those of treasure salvage (*see* **Ethical Issues and Responsibilities**). Some archaeologists, however, have reached working relationships with shipwreck exploration and salvage companies (Figure 2).

It works like this: the salvage company that wants to recover treasure from a shipwreck enters into a contract with archaeologists, and where law requires it, with government regulatory bodies, under which it is agreed that fieldwork will be performed according to high archaeological standards. Research designs are formulated and approved, and the work is carried out accordingly. What is recovered is divided into two big classes (often with various subdivisions) – one made up of material that must remain together and be cared for as a research collection, the other made up of material that can be sold. The research collection includes the remains of the ship itself, the personal gear of the crew and passengers, elements of the cargo – essentially, everything from which much can be learned about the ship, its people, and the times in which it operated. The marketable collection includes coinage, bullion, sometimes other manufactured material like bottles and other goods recovered from the shipwreck in large quantity. Sometimes things like coal from a ship's engine room are offered for sale. Little more can be learned from such material once basic information has been recorded – the dates and types of coins, the weight, shape, purity and surface markings of each gold bar, the type and date of each bottle and what it probably contained – so nothing is lost if it goes into the stream of commerce after

Figure 2 Coins on seabed. (Photo credit: Odyssey Marine Exploration).

archaeological documentation. The more valuable material – coins, for example – is also usually very carefully conserved and graded by companies with expertise in this area, and these companies keep elaborate records, simply because the material is so valuable. If someone someday wants to study all the coins from Shipwreck X, they may find the coins better preserved and more accessible in private hands than they would be in academic study collections.

Arrangements like this make it possible for an ethical archaeologist to cooperate with treasure recovery operations, because the information for which the archaeologist is responsible is collected, conserved, recorded, analyzed, and reported appropriately. The salvage company is able to justify the archaeology to its stockholders – that is, explain why they're spending money on very careful excavation rather than just grappling the stuff to the surface – because the archaeological work actually increases the commercial value of the material. A well-documented artifact is worth more than one whose provenance is poorly recorded.

But few such collaborations between treasure salvage firms and archaeologists have actually been undertaken, and those that have gone forward have happened largely in shallow waters. In fact, at this writing, Odyssey Marine Exploration Inc. of Tampa, Florida, may be the only company doing deep-ocean archaeology. Most salvage firms still have trouble finding qualified archaeologists who will work with them – so strong are the professional biases against such collaboration. However, it can be predicted that treasure salvage-supported archaeology will increase in the years to come; the treasures are on the seabed, and they are recoverable using technology that with few exceptions only commercial salvage companies can afford.

Deep-ocean Survey

Finding an archaeological site on the floor of the deep ocean, like finding one anywhere else, requires background research and patient, systematic, sometimes very boring fieldwork.

Although prehistoric and early historic once-terrestrial sites are found on the seabed – swamped prehistoric villages, sunken towns like Port Royal, the Jamaican pirate haven that sank into the ocean during an earthquake in 1692 ACE – most deep-ocean sites represent ships that floated and aircraft that flew over the ocean surface. Background historical research is a vital first step in locating such sites, and for that matter in even discovering that they exist. Commercial records, military records, the logs of ships, ship losses reported in newspapers and the diaries of passengers and their relatives, all can help identify wrecks worth searching for, and then narrow the search to something smaller than an entire ocean.

As an example of shipwreck research, consider the *Sussex,* a seventeenth-century British warship that is currently being studied by Odyssey Marine Exploration. In the mid-1990s an independent researcher discovered papers in a Paris archive describing the loss of a British ship in the Strait of Gibraltar in 1694. The ship, named the *Sussex,* was recorded as carrying a large cargo of coinage meant for the Duke of Savoy, a duchy in what are now northern Italy and southeastern France. The researcher offered the information to Odyssey, which purchased it and launched a major archival study to reconstruct the circumstances and location of the wreck. This involved research in the United Kingdom, France, and Spain, which eventually verified that the *Sussex* had indeed gone down in the Strait, provided a detailed description of the ship and its sinking, and gave a rough fix on where its loss might have occurred. Although the area of highest probability was fairly concentrated, the research indicated that the wreck might lie anywhere in an area some 400 square miles in extent.

Field survey began with marking out grid lines in search blocks. At the same time, a bathymetric survey mapped the contours of the floor which in the Strait is around 800 m deep. Some mapping information was already archived and available; other data had to be collected anew using echo-sounding equipment. Then Odyssey launched the detailed survey, using side-scan sonar. This involves towing a sensor behind a ship along each grid line, just above the seabed. The sensor emits sonar signals and receives them as they bounce back, measuring the distance to objects around and below it. Modern side-scan sonar produces an accurate and detailed picture of the sea bottom, but it is very time consuming; Odyssey's research ship steamed back and forth like a tractor plowing a field, eventually covering the entire 400-square-mile block and plotting 419 anomalies on the sea bed.

From a vessel on the ocean surface equipped with an inspection ROV carrying video cameras, each of the anomalies that looked worthy of further investigation was visually inspected to determine what it was. Some anomalies turned out to be geological features; some were big coils of wire, others 55-gallon drums. Some were aerial bombs. Others really were shipwrecks, including what appear to be Roman and Phoenician wrecks, which were carefully recorded for future reference. One site – at a depth of 811 m

(2660 ft) was a long mound on the seafloor dotted with heavily concreted cannon, consistent with those aboard the *Sussex*.

ROV: The Deep-ocean Trowel

As of June 2006, the site thought to be the *Sussex* has not yet been excavated, though a thorough predisturbance survey including core sampling has been completed. Additional test trenching and further work is planned. Because (if it is the *Sussex*) it is a warship, and therefore the property of the British Crown, Odyssey has entered into a contract with the British Ministry of Defense governing how the excavation will be carried out and how anything recovered will be cared for. Odyssey is also working cooperatively with the governments of Spain and Andalusia, the Spanish autonomous region on the nearby shore.

Another Odyssey project, the SS *Republic* – a sidewheel steamer that went down in a hurricane shortly after the American Civil War with a rich cargo of coinage meant for economic redevelopment in the defeated South – illustrates how deep ocean excavations are carried out.

Odyssey located the Republic using the same methods employed in the Sussex case – detailed background research followed by painstaking bathymetric and side-scan sonar sweeps. The ship finally was revealed, sitting upright on the ocean bottom at a depth of approximately 500 m (1700 ft); her walking beam engine and two side-wheels plainly visible (Figure 3). After initial photography and mapping, Odyssey prepared for archaeological investigation and excavation.

An important part of archaeology is recording enough data to recreate the site as it was before the archaeologist disturbs it and removes anything, and then at each step in the excavation process. As in all types of archaeology, it is vital on the seabed to keep track of precisely where each recovered object and structural feature is located. This includes recording the context of each object, that is, its relationship to other objects and its location in the seabed layers. On land and in shallow-water sites, we do this by establishing firmly located datum points from which all measurements are taken, and then imposing a grid of some kind over the site – marked with stakes and strings on land, often with PVC pipe underwater. We label all the grid squares, and dig within them, drawing and noting the locations of everything we find. We cannot do quite the same thing hundreds of meters down, but with a well-equipped ROV we can do something that serves the same purpose (Figure 4).

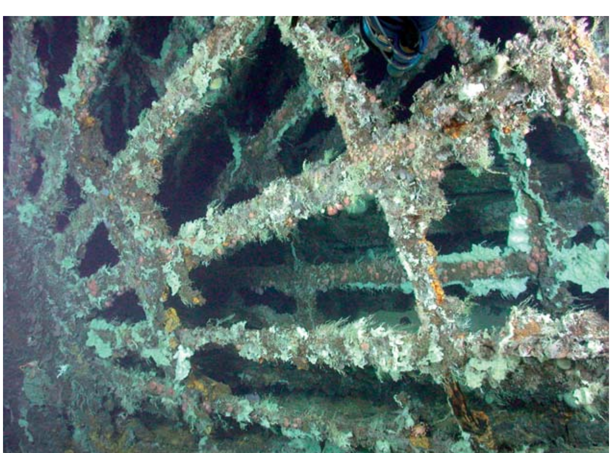

Figure 3 The *Republic's* starboard paddle wheel. (Photo credit: Odyssey Marine Exploration).

In the case of the *Republic* (and the *Sussex* will be excavated the same way) the Odyssey team first placed electronic transponders around the wreck. These transponders, located with high precision using survey software and GPS, communicate with the navigation electronics aboard the ROV, and a continual record is maintained of precisely where the ROV is at every moment, in both horizontal and vertical space.

Having set the transponders, the team imposed a grid on the site of the *Republic*, but it was not marked with stakes and string or with PVC pipe; it was a virtual grid, stored in the ship's and ROV's computers. Whenever an archaeologist, pilot, or surveyor wanted to refer to it, it could be brought up on the screen and superimposed on the real-time images of the site coming up from the ROV.

These images came up to three of four control areas aboard the research ship: the ROV Control Van (from where the ROV is piloted), the Online Room (for survey and data-logging), and the Offline Room – equipped with large screen monitors and a computer where the archaeologist can oversee operations on the seabed through a communication system with the ROV operator. The fourth critical control area, of course, is the ship's bridge, responsible for ship navigation and holding a stable position over the wreck site.

Photography is a vital component of deep-ocean archaeological investigation. The ROV used on the *Republic* – named ZEUS – was configured with seven cameras. The ROV pilot had four cameras to monitor the vehicle; three other cameras were dedicated to archaeological recording. The high-resolution cameras, combined with Halide Mercury Incandescent (HMI) lighting, supplied the archaeologist and ROV operator with high-quality images. Every second of the expedition was video recorded on DVDs, and all images flowing into the ship's onboard computers were logged and retained, so there is a complete and permanent record of the excavation (Figure 5).

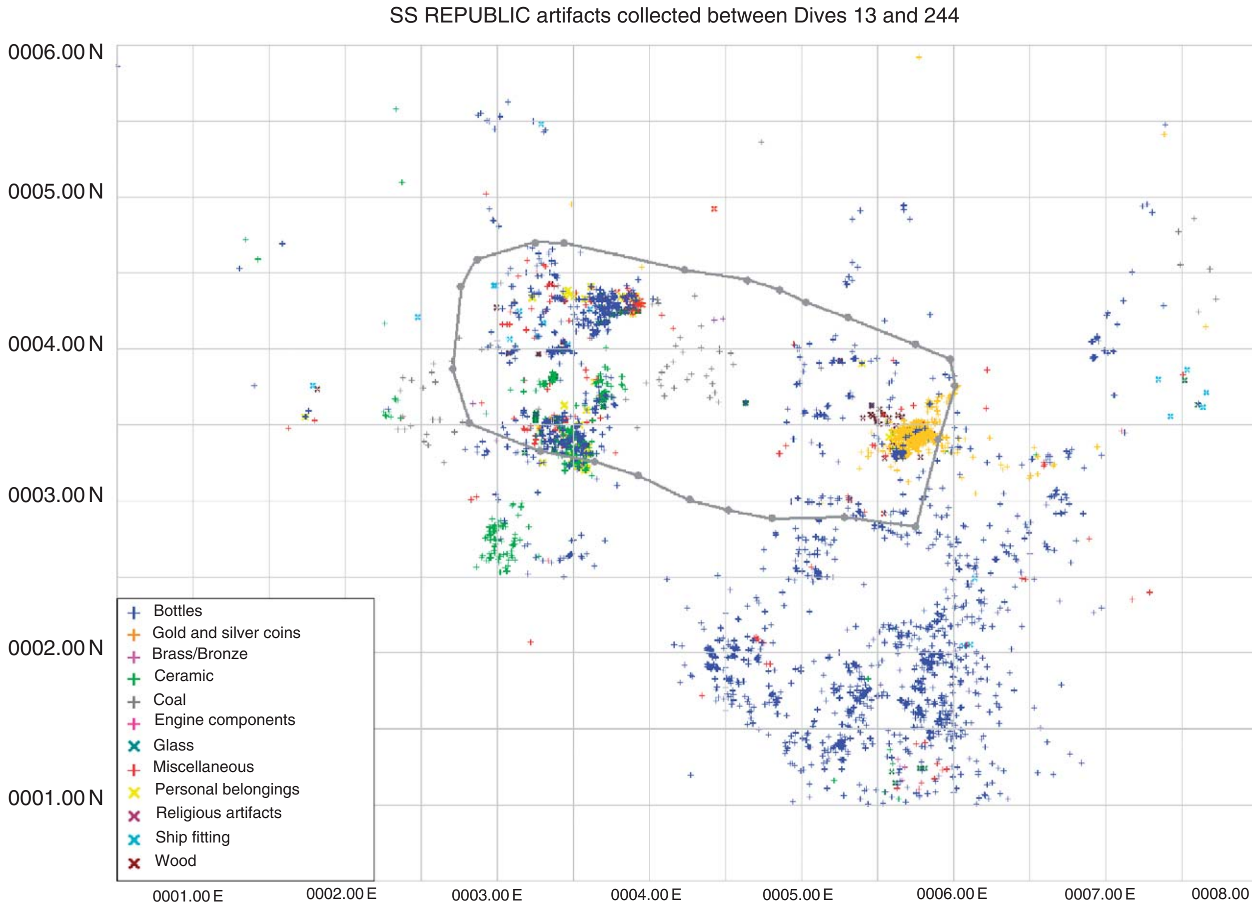

Figure 4 SS *Republic* artifact distribution map. (Photo credit: Odyssey Marine Exploration).

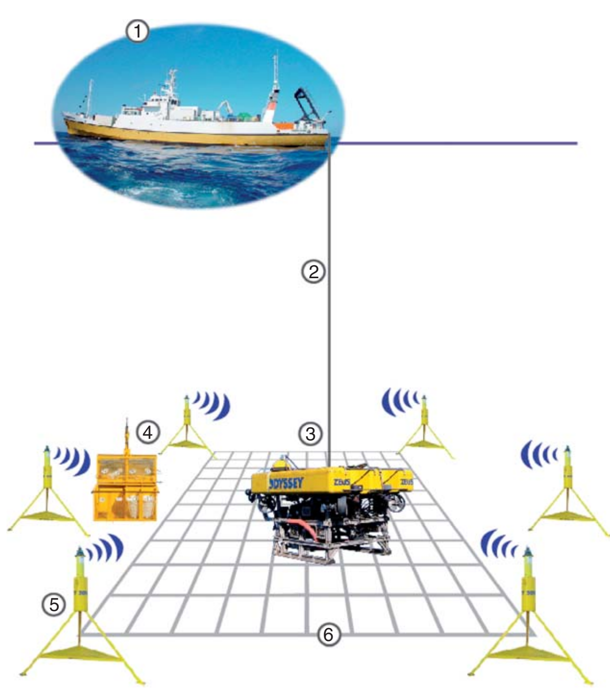

Figure 5 Components of deep-ocean excavation. (Photo credit: Odyssey Marine Exploration).

Having chosen a grid square within which to dig, the operator positions the ROV over it. Though ZEUS is about the size of a large sport utility vehicle – roughly a 10 foot square cube that weighs about 8 tons – it can hover over the site with a high degree of stability, or rest lightly on the bottom, maintaining position with small thrusters. The ROV is neutrally buoyant and before a dive can be made heavier or lighter by the addition or removal of lead weights. Once the ROV is in place, excavation can begin, all under the watchful eye of the archaeologist several hundred meters above (Figure 6).

The ROV has several kinds of excavation and recovery tools. Odyssey's ZEUS typically carries two seven-function master/slave manipulator arms fitted at either side of the front of the vehicle, a dredge pump, a specialized sediment sifting and collection device, and a limpet suction device. The pump – called a venturi – creates suction with no moving parts. This allows any small artifacts that are sucked up to fall out and be collected undamaged. The pump then blows the silt out high enough in the water column to be distributed without obscuring visibility on the

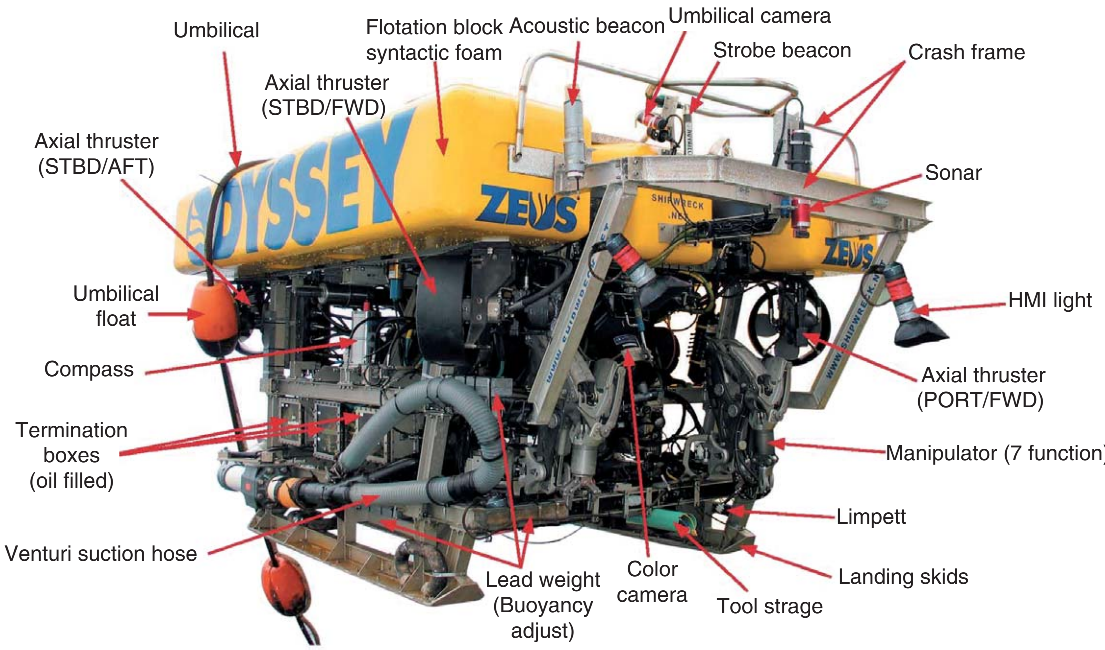

Figure 6 Parts of an ROV. (Photo credit: Odyssey Marine Exploration).

Figure 7 Gold coin on limpet. (Photo credit: Odyssey Marine Exploration).

Figure 8 Drakes Plantation bitters bottle recovered from seabed. (Photo credit: Odyssey Marine Exploration).

bottom. The operator uses the dredge tip like a trowel and brush, gently removing sediment and exposing whatever lies within the grid square. The dredge can be operated with a high degree of precision, maintaining close control over depth and horizontal location.

When it is time to collect an artifact from within the square, its precise location is recorded by the data loggers in the online control room, and of course imaged by the video and still cameras. Then the ROV can either grasp it with its manipulator arm, or lift it with the suction limpet device – the latter device is especially good for very delicate items (Figures 7 and 8). Either way, the item is picked up and placed in a collection basket, which the ROV then places in a labeled section of a larger divided lifting container for retrieval to the surface. The same is done with whatever small items have been collected by the dredge – just as in a land excavation, where small finds caught in sieves are collected and recorded. At intervals, the lifting container is hoisted up to the ship, and the material recovered goes straight to the on-board conservation laboratory, where it is recorded, logged, photographed and given first-aid conservation treatment to stabilize it until it reaches the main conservation facility on land.

The ROV also performs many other functions – for example, flying over the site at controlled depths taking thousands of photographs from which photomosaics can be constructed, performing detailed mapping, collecting sediment, water and biological samples, and recording environmental features (Figure 9).

Figure 9 SS *Republic* photomosaic. (Photo credit: Odyssey Marine Exploration).

After the Fieldwork

As in any archaeological excavation, the fieldwork on a deep-ocean site is only part of the operation. Conservation of whatever is recovered is an important next step, particularly because the artifacts have been resting on the seabed, in the complex chemistry of seawater and bottom sediments, and have usually experienced a variety of physical and chemical changes. Sometimes, after years in a saltwater environment, they can react violently when exposed to oxygen, cracking, crumbling, and falling apart. They usually have to be kept immersed in seawater at first, gradually replacing the salt water with filtered fresh water so the salts in the artifacts leach out. Depending on what the artifacts are made of, different kinds of chemical preservatives may need to be applied, together with such techniques as electrolysis and freeze-drying, Meanwhile, further recording, analysis, cataloging and research continue.

In the end, as in every other kind of archaeological research, reports and technical papers are prepared, together with popular publications and exhibits. In the case of Odyssey, the company has built a conservation facility in Tampa, Florida, where its shipwreck artifacts are conserved and stored. The collections that have value for ongoing research and public interpretation are made available for study and presented to the public through scheduled lab visits and educational programs offered to the local schools.

Conclusions

The discipline of deep-water archaeology is in its infancy and is often questioned by traditional academics because of its association with the commercial sector. It is hard to imagine, however, how deep-water archaeology could be carried out at all without such a relationship. During the last 15 years deep-water archaeological investigations have successfully been conducted at various sites around the world. The techniques for mapping sites, controlling the ROV, and recording data have evolved and been refined. A close working relationship has developed among the ROV operators, technical crew, and the archaeologists. The system is complex and challenging, but it works.

However, deep-water projects are expensive, and require detailed planning and working partnerships. Ongoing assessment and auditing are required to keep focused on the archaeology. Every deep-water project faces unique challenges that require innovation, so each project has to provide for expensive trials of equipment and techniques.

Recent deep-water archaeology has been groundbreaking in the development and testing of new tools, systems, methods, and techniques. It has set high standards for archaeologists and salvage firms alike who are willing to carry out joint archaeology/commercial ventures in the deep ocean. It remains to be seen whether the mainstream archaeological community will embrace such ventures, and how both they and the technology they employ will evolve.

Acknowledgements

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See also: **Conservation, Archaeological**; **Conservation and Stabilization of Materials**; **Ethical Issues and Responsibilities**; **Maritime Archaeology**; **Sites**: Conservation and Stabilization; **Underwater Archaeology**.

Further Reading

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ROCK ART

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Glossary

cave art Rock art occurring in caves.

petroglyph A rock art motif that involved a reductive process in its production, such as percussion or abrasion.

pictogram A rock art motif that involved an additive process in its production, such as the application of paint, dry pigment, beeswax.

Pleistocene The geologic timescale from 1 808 000 to 11 550 years BP.

rock art A somewhat arbitrary term describing nonutilitarian humanly made markings on natural rock surfaces.

'Rock art' is a somewhat arbitrary term describing nonutilitarian human-made markings on natural rock surfaces, made either by an additive (the application of material) or by a reductive process (the removal of rock material). The former result is called a pictogram or rock painting and this form includes also pigment drawings, stencils, and beeswax figures; the latter is a petroglyph or engraving, sometimes called carving. The term rock art is usually not applied to human markings on prepared or dressed stone surfaces, such as may be found on buildings or rock-hewn structures. Nor does it include human-made but unintentional rock markings (such as those occasioned by bulldozers), utilitarian rock markings (e.g., drainage channels on ax grinding panels) or markings made by nonhuman animal species, even if made 'deliberately' (e.g., certain forms of cave bear claw marks in European caves). Broadly speaking, the term rock art refers to anthropic (humanly made) markings on natural rock surfaces; they may be prehistoric or historic, and they may occur in caves or out of caves.

Rock art is a very widespread phenomenon on our planet, occurring in nearly all countries. Its uneven distribution across all continents except Antarctica is, however, not so much attributable to differences in cultural conventions, as primarily a taphonomic attribute, that is, a result of preservation bias. For instance, the high-pH and low precipitation regimes of arid and semi-arid regions have greatly facilitated the preservation of rock art in various parts of the world, such as the Sahara, Arabia, Central Asia, the American Southwest, Peru, and Australia. Another major determinant of rock art distribution is geology. Some of the largest surviving concentrations are those found in the sandstone facies of the former Gondwana plate, that is, in southern Africa, India, Australia, and northwestern Brazil. These sandstone deposits have facilitated the formation of rock shelters that provide excellent preservation conditions, especially for rock paintings. Similarly, the practice of Upper Palaeolithic rock artists to place some of their productions in deep limestone caves has significantly helped the survival of some of that period's rock art.

Prehistoric rock art represents by far the largest body of evidence we possess of humanity's cultural, cognitive, and artistic beginnings. Through its relative permanence, it has profoundly influenced the beliefs and cultural conventions of subsequent societies up to the present. It is therefore an integral part of humanity's collective memory, and the greatest surviving witness of our cultural evolution.

Cave Art

When rock art occurs in caves it is called 'cave art'. Although found in several regions, the most famous traditions of cave art are those of the Upper Palaeolithic period in southwestern Europe. Occurring primarily in northern Spain and across France, this has become one of the world's best-known forms of rock art. Officially, it was discovered by Don Marcelino Santiago Tomás Sanz de Sautuola