OCEAN EXPLORATION & RESEARCH

Exploring the Submerged New World 2011

Needles and Haystacks

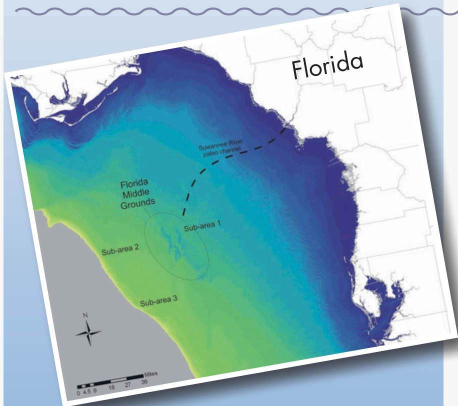

Image captions/credits on Page 2.

lesson plan

Focus

Underwater archaeology

Grade Level

7-8 (Life Science/Archaeology); adaptations for grades 5-6 and 9-12

Focus Question

How do archaeologists study paleoamerican settlements on drowned shorelines?

Learning Objectives

- Students will be able to explain some techniques that archaeologists use to look for paleoamerican settlements on drowned shorelines.
- Students will be able to infer and explain shoreline features that may be associated with paleoamerican settlements.
- Students will be able to describe how artifacts retrieved from sinkholes may be interpreted.

Materials

- ❑ 8 – Cardboard shipping boxes, approximately 15 cm x 15 cm x 30 cm
- ❑ Materials for objects to represent human-associated and non-human-associated artifacts (see Learning Procedure, Step 1b); *e.g.*, simulated human bones (see the Skeleton Store, http://www.skeletonstore.com/); oven-bake modeling clay; pieces of wood, bone, and shell; stones
- ❑ Awl or nail
- ❑ Ruler
- ❑ Hot glue gun and glue
- ❑ Masking tape
- ❑ Pencils, unsharpened; or wood dowels approximately 1/4-inch diameter x 8 inches; one for each student group
- ❑ Clear tape
- ❑ Copies of Sounding Rod Scale (Figure 1); see Learning Procedure, Step 1c
- ❑ Copies of *Diving into Paleo Florida*; see Learning Procedure Step 1c
- ❑ Copies of *Data Sheet*, six for each student group
- ❑ Copies of *Guidance Questions for "Diving into Paleo Florida"*, one for each student or student group
- ❑ Copies of *Archaeological Haystack Topography Worksheet*; one for each student group

Audio-Visual Materials

- ❑ None

Teaching Time

One or two 45-minute class periods, plus time for student research; more time may be required depending upon specific student assignments

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words

Paleoamerican
Pleistocene Epoch
Little Salt Spring
Underwater archaeology

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

Recent archaeological and molecular genetic evidence (Goebel, *et al.*, 2008) indicates that the first humans to inhabit North America migrated from Siberia around 15,000 years ago, near the end of the Pleistocene Epoch. These migrants are believed to have crossed a land bridge to the Pacific coast of North America, and continued southward, possibly using boats. Some of their descendants spread across what is today the United States, while others continued southward into South America. An important characteristic of these first Americans is that they used thrusting spears tipped with specialized stone points, and were very successful hunters. At this time, North America was inhabited by many large mammals that are now extinct, including mammoths, bison, short-faced bears, giant sloths, and sabre-toothed cats.

Some of the oldest archaeological sites discovered in North America are in the eastern United States, and there are numerous quarry-campsites in the southeastern states. Quarries are locations where raw rock material was mined and processed to make tools. If a reliable source of water is nearby (or was nearby during late Pleistocene times), residential sites are often found near the quarry. When the first humans arrived in Florida, sea level was much lower and there was more than twice as much dry land as exists today. The climate was considerably drier, and water was scarce. Not surprisingly, early American

Images from Page 1 top to bottom:
The eastern Gulf of Mexico showing the three sub-areas examined in 2008, the Florida Middle Grounds, and the Suwanee River paleo channel.
http://oceanexplorer.noaa.gov/explorations/09newworld/background/plan/media/fmg_surveyareas.html

During the Late Pleistocene Florida's shoreline extended much farther offshore than the present coast. The Florida Middle Grounds were part of the exposed coastal margin.
http://oceanexplorer.noaa.gov/explorations/09newworld/background/climatechange/media/pleistocene.html

Map of the Bering land bridge during the late Wisconsin glaciation, when global sea level dropped to about 120 meters or more below its present position.
http://oceanexplorer.noaa.gov/explorations/09newworld/background/occupation/media/beringia_late_wisconsin.html

This image portrays a more accurate reconstruction of Ice Age human behavior with a focus on small familial groups and the processing and use of plants as opposed to athletically fit young men attacking large, dangerous animals.
http://oceanexplorer.noaa.gov/explorations/09newworld/background/beliefs/media/correctpaleobehavior.html

All images courtesy NOAA.

settlements that have been discovered in the state are almost always associated with a reliable water supply such as rivers and springs. These areas would also have been attractive to animals, increasing the likelihood that human hunters would be able to find food.

Limestone bedrock that underlies the Florida peninsula strongly influences the state's landscape. Limestone dissolves in acidic solutions, and over time has been sculpted by rainwater which is weakly acidic. This sculpting includes the formation of underground caves. When the roof of a cave becomes unstable, it collapses to form a hole in the ground called a sinkhole. Florida has hundreds of sinkholes, some of which became natural reservoirs for fresh water. Not surprisingly, some of the most artifact-rich paleoamerican sites are located near sinkholes.

Coastal areas inhabited by early Americans are difficult to explore because the coastlines of 15,000 years ago are now under more than 300 feet of water! As the last ice age drew to a close, melting ice sheets caused a rapid rise in sea level just as the first Americans were entering the New World. Drowned settlements may contain well-preserved artifacts that can provide important new information about how the first Americans lived and when they arrived at various locations in North and South America. The eastern Gulf of Mexico in the vicinity of the Ocala Uplift Zone (Florida) is particularly promising as a potential location for drowned coastal settlements because:

- There are numerous onshore archaeological sites along the same zone that are more than 13,000 years old;
- Clusters of similar sites have been identified along drowned shorelines in the northern Gulf of Mexico;
- Rivers that discharge into this part of the Gulf do not carry large quantities of sediment, so sites should not be deeply buried;
- The coastal shelf is gently sloped which would reduce the impact of waves and storms; and
- Rapid sea level rise would have reduced the impact of waves as coastal settlements were inundated.

The Northeastern Gulf of Mexico 2008 and Submerged New World 2009 Expeditions focused on ancient river channels in the vicinity of the Florida Middle Grounds, which are now several hundred feet below the Gulf's surface. Major accomplishments included:

- Locating and high resolution mapping of a large, essentially intact, and infilled ancient river channel several kilometers long, east of the Florida Middle Grounds;
- Identifying additional stream and river channels, some with clearly visible deposits along the banks;
- Locating and identifying more than 100 sinkhole features filled with material in stratified layers that may contain human artifacts as well as plant and animal material from early American times; and
- Mapping nearly 10 square kilometers of intact, shallow-water, near-

shore sand ripples/ridges adjacent to an area that would have been Florida's shoreline when sea level was at its lowest point during the last glacial period.

These expeditions found that Florida's late Pleistocene shoreline is extraordinarily well preserved in the area studied, and the numerous sinkholes are a potential treasure trove of new information about the late Pleistocene landscape and environment, as well as about the humans who lived there. Still, conclusively demonstrating the presence of humans along these drowned shorelines is a difficult task, and finding sites of ancient human settlements on submerged landscapes is very similar to searching for needles in a haystack. The 2008 and 2009 expeditions have located "haystacks" that may contain evidence of ancient human occupation; the Exploring the Submerged New World 2011 Expedition is focused on finding the anthropogenic "needles."

One of the primary challenges for this type of underwater archaeology is to narrow the list of possible target study sites to those that have the greatest probability of containing evidence of human presence. One technique for doing this is to consider what life might have been like for humans living on the ancient coast of Florida. The importance of a reliable source of water is mentioned above, and other investigations have found extensive paleoamerican settlements with hundreds of thousands of artifacts in locations where an ancient river channel formed a "T" intersection with another river channel. Side-scan sonar and sub-bottom profiler studies have helped identify one such site named Thor's Elbow, as well as areas that show stratified layers of sediment beneath a surface covering of silt and shell fragments (for more information about side-scan sonar and sub-bottom profiling, see the Exploring the Submerged New World Expedition Purpose, http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/purpose.html).

In 2011, archaeologists will use an induction dredge to remove the surface covering so that deep layers can be investigated. An induction dredge is analogous to an underwater vacuum cleaner. Typically, archaeologists will hand-fan sediments to suspend them in the water column, then suck the suspended material to the surface where sediments and small shell fragments are discharged onto a screen. Other archaeologists monitor the screen to search for small artifacts that may have been overlooked by the divers below. As archaeologists probe into deeper layers, they are constantly alert to any object that may have been associated with prehistoric human settlements.

In this lesson, students will model some of the techniques that marine archaeologists use to look for paleoamerican settlements on drowned shorelines, and describe some of the considerations involved with interpreting artifacts from such settlements.

Learning Procedure

[*NOTE: This lesson is targeted toward Grades 7-8; suggested adaptations for other grade levels are provided at the end of the Learning Procedure.*]

1. To prepare for this lesson:
   (a) Review introductory essays for the Exploring the Submerged New World 2011 Expedition at http://oceanexplorer.noaa.gov/explorations/11newworld/welcome.html.
   (b) Prepare Needles and Haystacks – In Step 5, students simulate the use of sonar to select archaeological sites for detailed investigation. For this simulation, eight boxes (Haystacks) will be prepared containing various objects (Needles). Some of these objects will represent artifacts that may be associated with human activity; others will be natural objects with non-human origins.

   Prepare about 15 "artifacts" that have human associations, such as human hand or foot bones (see Materials; don't use whole skulls); carved pieces of wood, bone or shell; arrowheads or spearpoints (make with oven-bake modeling clay); or animal remains with evidence of human association such as embedded spearpoints.

   Prepare about ten other artifacts that do not have human associations, such as animal bones, shells, pieces of unworked wood, or stones. Holman and Clausen (1984) list the following animals that are associated with Paleo-Indian artifacts at Little Salt Spring, Florida:
   - giant land tortoise (*Geochelone crassiscutata*)
   - large mouth bass (*Micropterus salmoides*)
   - aquatic turtles (*Pseudemys floridana, P. nelsoni*)
   - gopher tortoise (*Gopherus polyphemus*)
   - wood stork
   - rabbit (*Sylvilagus* sp.)
   - mastodon (*Mammut americanum*)
   - ground sloth (*Megalonyx* sp.)

   To prepare the Haystacks, punch about 15 rows of holes 3 – 4 mm in diameter through one of the long sides of a cardboard shipping box with an awl or nail. Space the holes 2 cm apart over the surface of the side. For a 15 cm x 15 cm x 30 cm box you should end up with 75 – 100 holes (you punch the holes through one side rather than through the top or bottom so that you will be able to access the inside of the box to place artifacts inside). Label each row with a number, and each column with a letter. You may choose to have students perform this step as an exercise in measuring (or to save yourself some labor!). Give each Haystack a unique name, such as the name of a famous archaeologist or your favorite Pleistocene animal. If you don't have a favorite Pleistocene animal, see *The Pleistocene Zoo* lesson for some ideas (http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/zoo.pdf).

Five of the Haystacks should contain three or four human-associated artifacts. Fasten the artifacts with hot glue to the side of the box opposite from the side with the punched holes. Hold the flaps closed with masking tape. Place non-human-associated artifacts in the remaining three boxes, and tape the flaps closed.

(c) Prepare Sounding Rod Scales – Cut out enough Scales (Figure 1 - found on page 20) to make three Sounding Rods for each student group. If you are using the uncolored scales, color each interval with a colored pencil using the colored scales as a guide. Tape each scale onto a pencil or dowel to make three Sounding Rods for each student group. The bottom of the scale should be even with one end of the pencil or dowel.

(d) Review *Diving into Paleo Florida* (http://csfa.tamu.edu/mammoth/issues/Volume-23/vol23_num1.pdf) and decide how much of this article to assign as student reading. At a minimum, this should include all of pages 8 and 9. The remainder of the article includes more details about the Little Salt Spring site, as well as insights into some of the realities associated with archaeological research. You may provide copies of the selected pages, or provide the Web link for students to access on their own.

In August 2010, divers from the Florida Aquarium and the University of Miami conducted new investigations at Little Salt Spring. Numerous stories about these investigations appeared on the Internet, and you may want to include one or more of these as part of this lesson.

2. Lead a brief discussion about the arrival of the first humans in North America. Mention the approximate timing of the first migrations from Siberia (about 15,000 years ago), the fact that a land bridge existed between Siberia and North America at this time, and that some of the first Americans may have arrived by boat. Be sure students realize that some of the oldest Paleo-American archaeological sites have been found in the eastern United States. For more information, see the Exploring the Submerged New World Expedition Purpose, http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/purpose.html.

   Introduce the Exploring the Submerged New World 2011 Expedition, including the reasons that archaeologists believe remains of Paleo-American human settlements may be found along drowned shorelines. Discuss the "needle in haystack" aspect of searching for these settlements, and provide a general description of information collected by the 2008 and 2009 expeditions that helps identify sites for archaeological exploration in 2011.

If students are not familiar with sonar, provide a brief overview. Sonar is short for "sound navigation ranging," and uses sound waves to locate underwater objects by measuring the time it takes for a transmitted sound wave to be reflected back to its source. The sound wave is transmitted through a transducer, which is analogous to a speaker in a radio. Side-scan uses a transducer housed in a hollow container called a towfish that is towed through the water 10 to 20 feet above the bottom. The transducer emits sound waves to either side of the towfish, and measures the time it takes for the waves to be reflected back to the towfish. These measurements are processed into an image that resembles an aerial photograph, and can be viewed in real-time on a computer monitor aboard the towing vessel. A differentially corrected global positioning system (DGPS) is used to guide the towing vessel along predetermined search paths, as well as to identify points of interest on the side-scan image. This allows searchers to return to any point on the image for further investigation. Side-scan sonar does not depend upon light and can be used under conditions that would make searching by divers dangerous or impossible. Because it typically covers a swath of 60 to 120 feet at about 2 miles per hour, it is a very efficient way to search large areas. For these reasons, side-scan sonar has been used increasingly over the last few years to search for drowning victims.

3. Tell students that they are going to investigate some archaeological haystacks to find out whether they contain needles that may be associated with ancient human settlements. Because time is limited, they will not be able to examine all of the haystacks. Instead, they will make a preliminary study of five haystacks, and select three that they think are most likely to have evidence of human activity. Before beginning this investigation, though, it is important to have some ideas about how archaeologists interpret artifacts they find at a study site.

   Provide each student or student group with a copy of *Diving into Paleo Florida* (or the Web link for this article) and *Guidance Questions for 'Diving into Paleo Florida'*; and tell them which pages they are assigned to read. You may want to tell students that RCYBP means radiocarbon years before present, and refers to age estimates based on the content of the carbon-14 isotope. CALYBP means calibrated radiocarbon years before present, and refers to age estimates that have been calibrated to account for variations in atmospheric concentrations of the carbon-14 isotope.

4. When students have completed their reading assignment, lead a discussion of the *Guidance Questions*, which should include:

- The Paleo Florida environment included about twice as much land as today's Florida environment, the climate was cool and dry, and freshwater was scarce.
- The prehistoric hunter described in the article lived more than 12,000 years ago.
- The ledge that is now under 90 feet of water was above sea level when the tortoise was killed, because sea level was about 300 feet lower at that time.
- "Direct contextual association" means that there is a relationship or connection between two or more objects or events other than the fact that they are found in the same place or happened at the same time.
- An atlatl is a spear-throwing device that uses leverage to provide greater velocity to a spear than can be achieved with the hand and arm alone.
- The underwater environment of Little Salt Spring is ideal for preserving Paleo-Indian artifacts because oxygen-depleted ground water produces an anoxic environment below a depth of about 3 m, which prevents the growth of bacteria necessary for decomposition.
- Bones found at Little Salt Spring and the Aucilla River suggest that the giant ground sloth and American mastodon may have been seen by the hunter who killed the tortoise.

5. Tell students that their assignment is to investigate three haystacks using procedures described on the *Archaeological Haystack Topography Worksheet*. Assign three Haystacks to each student group so that one or two of the assigned Haystacks include human-associated artifacts. Depending upon available time, you may want to limit the number of depth measurements that can be made on each Haystack. This limitation will require students to develop a sampling strategy to obtain the maximum amount of information from a limited number of samples.

   Be sure students understand that oceanographers usually record depth measurements as negative numbers, which means that they are usually plotted in Quadrant IV of the Cartesian plane. One advantage of this is that topographic features such as undersea mountains appear right side up; if depth measurements over these mountains were plotted as positive numbers, the mountains would appear to be upside down on the graph.

   Based on the results of their investigations, each group should select two Haystacks that they think are most likely to have evidence of human activity. When each group has made their selections, allow groups to open the selected Haystacks, one at a time. They should record their observations, decide whether there is evidence of human activity, and justify their conclusions. Caution students not to let other groups see inside the Haystacks while they are doing their examination, and not to share their observations and analysis with other groups. Making this activity into a contest between groups will provide additional incentive for students to keep results to themselves.

Students may say that the depth measurements don't give enough information to be sure which Haystacks contain artifacts that are human-associated. If this happens, congratulate them for their observation and say, "Welcome to marine archaeology!" Archaeologists often have to work with multiple pieces of information that provide clues to the location of significant artifacts; rarely does a single piece of information tell the whole story. Ask what may be significant about the pattern of depth measurements in different Haystacks: Do measurements suggest that objects are scattered or clustered? Do some objects seem larger than others? Experience often helps to recognize patterns that are associated with certain types of artifacts; but since students don't have much experience at this point, the best they can do is make a good guess and see what's in the chosen Haystack! Point out that in many cases, not finding what you are looking for can still provide useful information, if you can learn about clues that are NOT associated with the object of a search.

6. When students have completed their investigations, each group should present and discuss their observations and conclusions. Haystacks may be opened during these presentations so that the entire class can observe the contents.

   When all groups have made their presentations, ask students how their investigations could be improved. Students should realize that this activity does not simulate side-scan sonar, or even conventional sonar; it is more like the centuries-old method used by mariners who lowered a lead weight attached to a measured line until the weight touched the bottom (or some object resting on the bottom). A conventional sonar system would provide a continuous record of depth directly beneath a ship. This would improve resolution along the search path, but there would still be gaps between the paths that are much greater than the area actually imaged. Side-scan sonar would fill in these gaps, and give an almost continuous picture of the search area. Students should also realize that rough topography can obscure other topographic features, so better resolution is especially important when there are boulders, reefs, or other irregular objects in a search area. Even the most modern sonar technology cannot distinguish small, buried artifacts that are often the key to conclusively demonstrating the presence of human activity, so marine archaeologists still have to use the classic techniques of careful excavation and detailed documentation to find and interpret these artifacts.

Adaptations to Other Grade Levels

Grades 5 – 6: Graphing skills needed to complete this activity are consistent with Common Core Standards for Mathematics for these grades. If sufficient time is not available for students to complete the activity as described in Step 5, you may choose to have students investigate two Haystacks (one with and one without human-associated artifacts) and decide which one is most likely to have the human-associated artifacts. Student groups may then proceed to examine the contents of the selected haystack. This may be done as a class activity by having several groups involved in making the measurements and preparing the graphs, then having a whole-class discussion to interpret the contents of the selected haystack.

Depending upon reading skills, portions of *Diving into Paleo Florida* may be challenging for these grades. If this is the case, educators may choose to read portions of the article aloud, and discuss their meaning with the entire class.

Grades 9 – 12: Students may be assigned the task of preparing human-associated and non-human-associated artifacts based on independent research. Data obtained in Step 5 may be graphed as three-dimensional surface plots as described in the *Mapping the Deep-Ocean Floor* lesson, http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/hdwe_78_oceanfloor.pdf. Be sure students record their soundings as negative numbers (more negative = increasing depth) so that they will plot correctly in the graphing software.

The BRIDGE Connection

www.vims.edu/bridge/archeology.html

The "Me" Connection

Have students write a brief essay about how knowledge of paleoamerican settlements might be of personal importance or benefit.

Connections to Other Subjects

English/Language Arts, Geography

Evaluation

Students' research reports and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/11newworld/welcome.html for more about the Submerged New World 2011 Expedition.
2. Visit http://www.pbs.org/wgbh/nova/first/ for information and resources about the discovery and controversy surrounding a well-preserved, 9,000-year-old human skeleton called Kennewick Man.

3. Have students investigate techniques for producing atlatls and flint tools, and use these to create examples of tools that might have been used by paleoamericans. Be careful with flint knapping—wear gloves, because these tools really are very sharp!

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Grades 5-6

What's a Karst?
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/karst.pdf

Focus: Limestone landforms and aquifers (Physical Science/Earth Science)

Students will compare and contrast igneous, sedimentary and metamorphic rocks, and name examples of each. Students will define karst landforms; describe typical features of these landforms; explain processes that shape them, and discuss their relevance to aquifers.

The Pleistocene Zoo
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/zoo.pdf

Focus: Pleistocene mammals (Life Science)

Students will describe at least three now-extinct Pleistocene mammals, and explain three theories for why extinction occurred.

Shipwreck Explorers
(from the *Lophelia* II 2008 Expedition)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/shipwreck.pdf

Focus: Marine archaeology (Physical Science)

Students use data about the location and types of artifacts recovered from a shipwreck site to draw inferences about the sunken ship and the people who were aboard.

Call to Arms
(from the *Lophelia* II 2008 Expedition)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/calltoarms.pdf

Focus: Robotic analogues for human structures

Students will describe the types of motion found in the human arm, and describe four common robotic arm designs that mimic some or all of these functions.

Ship of the Line
(from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/shipline.pdf

Focus: Marine archaeology (Earth Science/Physical Science/Social Science

Students will describe general characteristics and technologies used in 18th century naval ships; draw inferences about daily life aboard these ships; and explain at least three ways in which simple machines were used on these vessels.

Looking for Clues
(from the RMS *Titanic* Expedition 2004)
http://oceanexplorer.noaa.gov/explorations/04titanic/edu/media/Titanic04.Clues.pdf

Focus: Marine archaeology of the *Titanic* (Physical Science)

Students will draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck; and will list three processes that contribute to the *Titanic's* deterioration.

Wreck Detectives
(from the 2003 Steamship Portland Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandwreckdetec.pdf

Focus: Marine archaeology (physical science)

Students use a grid system to document the location of artifacts recovered from a model shipwreck site; use data about the location and types of artifacts recovered from a model shipwreck site to draw inferences about the sunken ship and the people who were aboard; and identify and explain types of evidence and expertise that can help verify the nature and historical context of artifacts recovered from shipwrecks.

Grades 7-8

Paleo-Diving
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/paleodiving.pdf

Focus: Underwater archaeology of sinkholes (Physical Science/Archaeology)

Students will explain how sinkholes are formed; why they may be associated with paleoamerican settlements; and how artifacts retrieved from sinkholes may be interpreted.

We Arrived 10,000 Years Ago...
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/10000yrs.pdf

Focus: Lifeways of Paleoamericans (Archaeology/Anthropology)

Students will explain at least two ways that humans migrating from eastern Asia may have settled North and South America; and will make inferences about lifeways of paleoamericans based on an extant 10,000 year-old human culture in southern California.

Shipwreck Mystery
(from AUVfest 2008)
http://oceanexplorer.noaa.gov/explorations/08auvfest/background/edu/media/shipwreck.pdf

Focus: Marine Archaeology (Earth Science/Physical Science/Social Science)

In this activity, students will be able to draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck; use a grid system to document the location of artifacts recovered from a model shipwreck site; and identify and explain types of evidence and expertise that can help verify the nature and historical content of artifacts recovered from shipwrecks.

I, Robot, Can Do That!
(from the 2005 Lost City Expedition)
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf

Focus: Underwater robotic vehicles for scientific exploration (Physical Science/Life Science)

Students will describe and contrast at least three types of underwater robots used for scientific explorations; discuss the advantages and disadvantages of using underwater robots in scientific explorations; and identify robotic vehicles best suited to carry out certain tasks.

Sonar Simulation
(from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/sonarsim.pdf

Focus: Side-scan sonar (Earth Science/Physical Science)

Students will describe side-scan sonar; compare and contrast side-scan sonar with other methods used to search for underwater objects; and make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

Ping!
(from the 2003 Steamship Portland Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandping.pdf

Focus: Side-scan sonar (earth science/physical science)

Students will describe side-scan sonar; compare and contrast side-scan sonar with other methods used to search for underwater objects; and make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

This Old Ship
(from the 2006 Phaedra Expedition)
http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/old_ship.pdf

Focus: Ancient and prehistoric shipwrecks (Earth Science/Social Studies)

In this activity, students will be able to describe at least three types of artifacts that are typically recovered from ancient shipwrecks; explain the types of information that may be obtained from at least three types of artifacts that are typically recovered from ancient shipwrecks; and compare and contrast, in general terms, technological features of Neolithic, Bronze Age, Hellenistic, and Byzantine period ships.

Mapping the Aegean Seafloor
(from the 2006 Phaedra Expedition)
http://oceanexplorer.noaa.gov/explorations/06greece/background/edu/media/seafloor_mapping.pdf

Focus: Bathymetric mapping of deep-sea habitats (Earth Science)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data; create a three-dimensional model of landforms from a two-dimensional topographic map; and interpret two- and three-dimensional topographic maps.

Grades 9-12

Now Take a Deep Breath
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/breath.pdf

Focus: Physics and physiology of SCUBA diving (Physical Science/Life Science)

Students will define Henry's Law, Boyle's Law, and Dalton's Law of Partial Pressures, and explain their relevance to SCUBA diving; discuss the causes of air embolism, decompression sickness, nitrogen narcosis, and oxygen toxicity in SCUBA divers; and explain the advantages of gas mixtures such as Nitrox and Trimix and closed-circuit rebreather systems.

The Puzzle of the Ice Age Americans
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/puzzle.pdf

Focus: Origin of the first humans in the Americas (Anthropology, Earth Science)

Students will describe alternative theories for how the first humans came to the Americas and explain the evidence that supports or contradicts these theories; explain how exploration of a submerged portion of the North American west coast may provide additional insights about the origin of the first Americans; and describe the role of skepticism in scientific inquiry.

The Robot Archaeologist
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/robot.pdf

Focus: Marine archaeology and marine navigation (Earth Science/Mathematics)

Students design an archaeological survey strategy for an autonomous underwater vehicle (AUV); calculate expected position of the AUV based on speed and direction of travel; and calculate course correction required to compensate for the set and drift of currents.

By Land or By Sea or Both?
(from the Exploring the Submerged New World 2009 Expedition)
http://oceanexplorer.noaa.gov/explorations/09newworld/background/edu/media/landsea.pdf

Focus: Watercraft in Paleoamerican Migrations

Students will describe evidence that supports the idea that the initial settlement of North and South America involved watercraft; discuss types of watercraft that might have been involved in new world settlement; and explain at least three advantages and three disadvantages of coastal settlements compared to inland settlements.

My Wet Robot
(from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wetrobot.pdf

Focus: Underwater Robotic Vehicles

Students will discuss the advantages and disadvantages of using underwater robots in scientific explorations; identify key design requirements for a robotic vehicle that is capable of carrying out specific exploration tasks; describe practical approaches to meet identified design requirements, and (optionally) construct a robotic vehicle capable of carrying out an assigned task.

Do You Have a Sinking Feeling?
(from the 2003 Steamship Portland Expedition)
http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandsinking.pdf

Focus: Marine archaeology (Earth Science/Mathematics)

Students plot the position of a vessel given two bearings on appropriate landmarks; draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck; and explain how the debris field associated with a shipwreck gives clues about the circumstances of the sinking ship.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/explorations/11newworld/welcome.html – Web site for the Submerged New World 2011 Expedition http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.kumeyaay.com – Web site dedicated to the promotion and preservation of the Kumeyaay culture, with extensive information presented from the Kumeyaay perspective

http://centerfirstamericans.org/index.php – Web site for the Center for the Study of the First Americans

http://www.jqjacobs.net/anthro/paleoamericans.html – Online article on issues and evidence relating to peopling of the New World

http://www.pbs.org/wgbh/nova/first/ – Web site to accompany the NOVA presentation, "Mystery of the First Americans" (originally broadcast on February 15, 2000) documenting the discovery and controversy surrounding a well-preserved, 9,000-year-old human skeleton called Kennewick Man; includes "Does Race Exist?," "Meet Kennewick Man," "Claims for the Remains," "The Dating Game" (about carbon-14 analysis), and links to resources

Goebel, T., M. R. Waters, and D. H. O'Rourke. 2008. The Late Pleistocene Dispersal of Modern Humans in the Americas. *Science* 319:1497-1502.

Clausen, C. J., A. D. Cohen , C. Emiliani, J. A. Holman, and J. J. Stipp. Little Salt Spring, Florida: A Unique Underwater Site. *Science* 203(4381):609 - 614.

Holman, J. A. and C. J. Clausen. 1984. Fossil Vertebrates Associate with Paleo-Indian Artifact at Little Salt Spring, Florida. *J. Vertebrate Paleontology* 4(1):146-154.

Largent, F. B. 2004. Diving into Florida Prehistory. Mammoth Trumpet 19(4):18-20; http://csfa.tamu.edu/mammoth/issues/Volume-19/vol19_num4.pdf

Lovgren, S. 2007. First Americans Arrived Recently, Settled Pacific Coast, DNA Study Says. National Geographic News; http://news.nationalgeographic.com/news/2007/02/070202-human-migration.html

Wisner, G. 2008. Diving into Paleo Florida. Mammoth Trumpet 23(1):8-11; http://csfa.tamu.edu/mammoth/issues/Volume-23/vol23_num1.pdf

Correlations

Framework for K-12 Science Education

A. Scientific and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

B. Crosscutting Concepts

1. Patterns
4. Systems and system models

C. Disciplinary Core Ideas

Life Sciences

Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics

LS2.A: Interdependent Relationships in Ecosystems

LS2.D: Social Interactions and Group Behavior

Earth and Space Sciences

Core Idea ESS2: Earth's Systems

ESS2.B: Plate Tectonics and Large-Scale System Interactions

ESS2.C: The Roles of Water in Earth's Surface Processes

ESS2.D: Weather and Climate

Core Idea ESS3: Earth and Human Activity

ESS3.D: Global Climate Change

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

Essential Principle 2.

The ocean and life in the ocean shape the features of the Earth.

Fundamental Concept a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

Fundamental Concept b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

Fundamental Concept c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.

Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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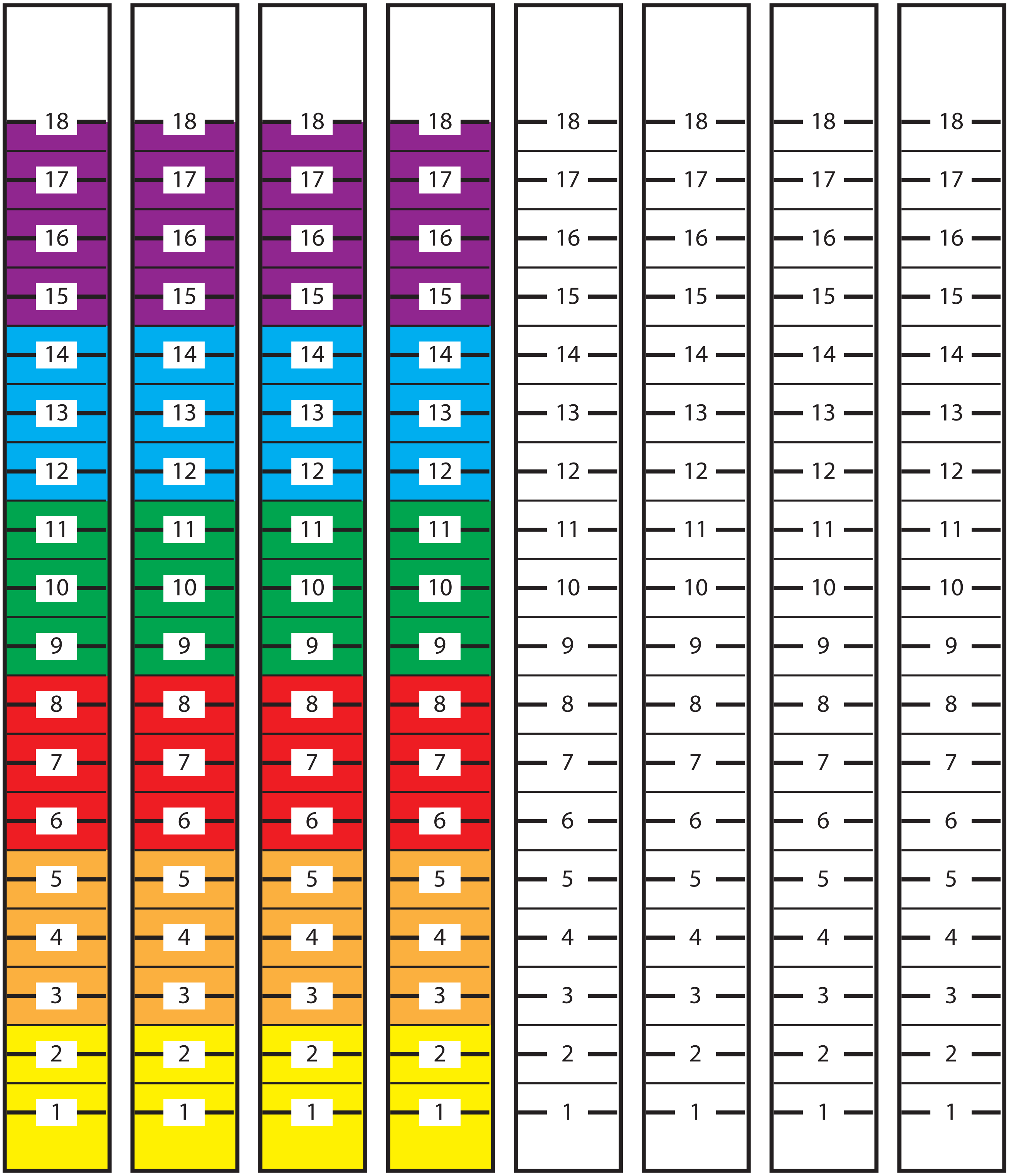
Credit

Figure 1. Sounding Rod Scales



Needles and Haystacks
Data Sheet

ROWS	COLUMNS: A	B	C	D	E	F	G
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

Needles and Haystacks
Guidance Questions for “Diving into Paleo Florida”

1. What are three ways in which the environment of Paleo Florida was different from the Florida environment that we know today?

2. How long ago did the prehistoric hunter described in the article have his meal of roast tortoise?

3. The prehistoric hunter killed the tortoise on a ledge that is now under 90 feet of water. How was this possible?

4. What does “direct contextual association” mean?

5. What is an atlatl?

6. Why is the underwater environment of Little Salt Spring ideal for preserving Paleo-Indian artifacts?

7. Considering bones found at Little Salt Spring and the Aucilla River, what prehistoric megafauna may have been seen by the hunter who killed the tortoise?

Needles and Haystacks

Archaeological Haystack Topography Worksheet

1. Your group should have three Sounding Rods. You will use these Rods to measure the depth under each of the holes in the Haystack, then you will plot these depths to create a three-dimensional model of whatever is in the Haystack.

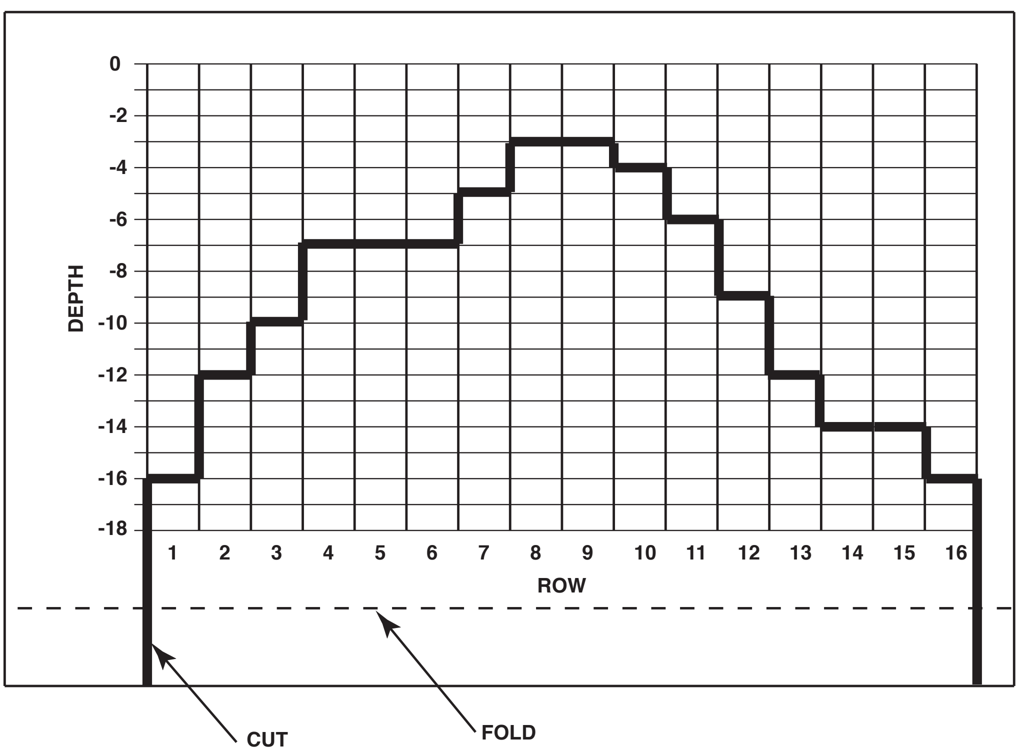
2. When your teacher tells you to begin, measure the depth in one of the holes using a Sounding Rod. Two or three group members can measure the depth in different holes, then take turns calling out the row number, column letter, and depth measurement while another group member records this information on the Data Sheet. Measure the depth under all of the holes in the Haystack unless your teacher tells you to measure a smaller number of holes. Oceanographers often record depth measurements as negative numbers, so you should too!

3. When you have measured all of the depths, and entered all the values, plot the results for each column on a bar graph. Figure A shows an example of a graph of one row of depth data. It will probably be quickest if each team member is responsible for plotting specific columns of data.

DATA

ROWS	COLUMNS A
1	-16
2	-12
3	-10
4	-7
5	-7
6	-7
7	-5
8	-3
9	-3
10	-4
11	-6
12	-9
13	-12
14	-14
15	-14
16	-16

Figure A.



4. When your graphs are completed, cut them out as shown in Figure A. Be sure to leave the border at the bottom of each graph! Fold as shown, and tape each graph onto a blank Data Sheet so that the folded edge of each graph lies on its corresponding column on the Data Sheet. Stand the graphs up so that they are perpendicular to the Data Sheet (additional tape may be needed to keep the graphs upright).

   Now you should have a three-dimensional model of the interior of the Haystack. Write the name of the Haystack somewhere on the model.

5. Repeat Steps 2 – 4 to create models for two more Haystacks. Now discuss your results, and decide which Haystacks are most likely to contain objects that are associated with humans.