



To Find a Lost Fleet



Image captions/credits on Page 2.

lesson plan

Focus

Magnetometer surveys for shipwrecks

Grade Level

6-8 (Physics/Earth Science/Social Studies);
adaptations for grades 9-12

Focus Question

How can geo-magnetic principles be used to search for shipwrecks?

Learning Objectives

- Students will describe the cause and effect relationships of magnetic interactions that underlie magnetometer surveys for shipwrecks.

Materials

For simulated magnetometer surveys, Option 1:

- Magnetometer app for smartphones (see Learning Procedure, Step 3.1.a)
- Steel bolts (similar to 1/4" x 2" carriage bolts); four to six for each simulated survey area

For simulated magnetometer surveys, Option 2:

- Inexpensive orienteering compasses, one for each student group
- Bar or disk magnets; about 1/4" x 2" for bar magnets, about 1/2" diameter for disc magnets

For both options:

- Copies of *Magnetometry Survey Data Sheet* one copy for each student group
- Copies of Figure 2 on cardstock, one copy for each simulated survey area
- Cardboard approximately 2 inches larger than cardstock copies of Figure 1, one piece for each simulated survey area
- Duct tape or "cellophane" tape
- Hot glue gun and glue

Audio-Visual Materials

- (Optional) Interactive whiteboard

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words

Magnetometer

Magnetic

Whaling

Shipwreck

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.

In 1871, 33 American whaling ships were lost along Alaska's Chukchi Sea coast in a series of disasters that are widely believed to be a major cause for the decline of the U.S. whaling industry, which at the time was a major component of the nation's economy. What remains of these ships is unknown because the area's harsh climate has been a serious obstacle to exploration and mapping...until recently. Today, a warmer Arctic climate means that more systematic surveying is possible, but also increases the feasibility of other activities (commercial shipping; oil and gas exploration and production) that may threaten natural and cultural Arctic resources.

NOAA's Office of Marine Sanctuaries (ONMS) is responsible for the identification, establishment and management of national marine sanctuaries—maritime heritage resources are one of the things protected in these areas—as mandated by the National Marine Sanctuary Act. Working in collaboration with local researchers, NOAA is able to bring new, advanced technologies such as magnetometry and side scan sonar to assist with investigations of the lost whaling fleets. For more information about Office of National Marine Sanctuaries involvement with the lost whaling fleets, please see <http://sanctuaries.noaa.gov/whalingfleet/welcome.html>.

Images from Page 1 top to bottom:

Archaeologist deploying a magnetometer: The magnetic sensor is housed in the orange cylinder and sends data through the cable to a computer work station on the ship. The sensor is lowered carefully into the water as the vessel moves forward and is towed a set distance behind. Image courtesy NOAA/ONMS.

A base station magnetometer was set up on the beach near the village of Wainwright, Alaska and operated continuously throughout the entire project collecting the local background magnetic signature. The Earth's magnetic field varies each day as the Earth rotates on its axis and this magnetometer records these fluctuations. This data is used with the magnetic data collected on the water to filter out daily fluctuations to provide more accurate magnetic data. Image courtesy NOAA In Search for Lost Whaling Fleet Expedition - 2015.

Whalers Lost in the Western Arctic. Image courtesy ONMS.

<http://sanctuaries.noaa.gov/whalingfleet/involvement.html>

1871 Fleet Abandoned in the Ice (Harper's Weekly 1871). Image courtesy ONMS.

<http://sanctuaries.noaa.gov/whalingfleet/disaster1871.html>





Using the R/V UKPIK as the survey platform, the mission team will conduct a remote sensing survey using a gradiometer (two Marine Magnetism SeaSpy Magnetometers towed horizontally in parallel), a pole-mounted Multiphase Echo Sounder, and a towed side scan sonar system. Image Courtesy Southern Cross LLC. <https://sites.google.com/site/rvukpik/home>.

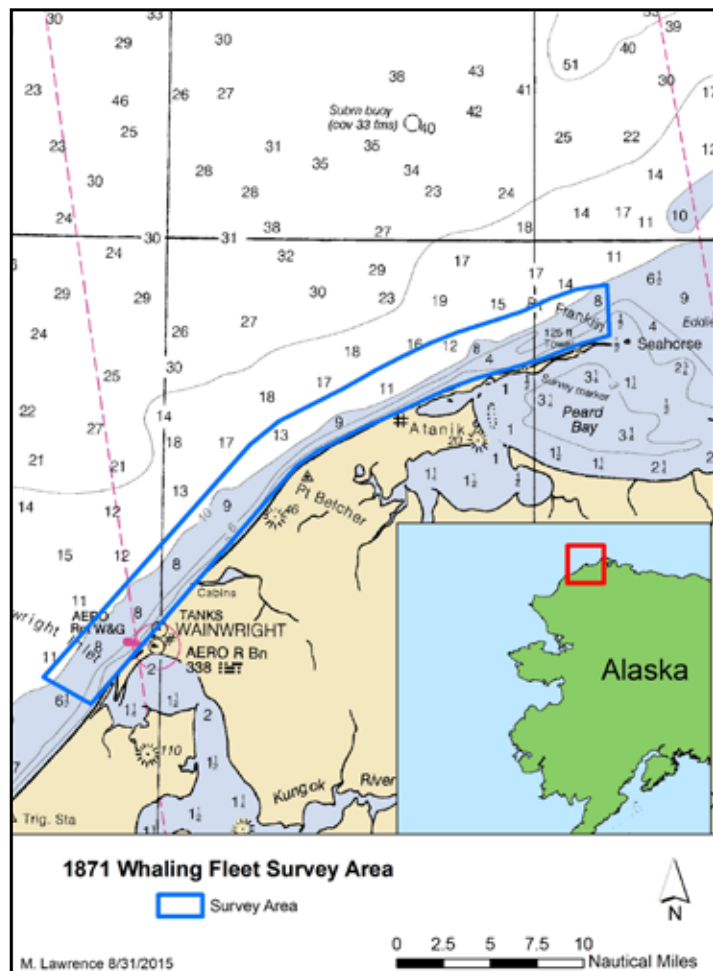
The goal of the In Search of the Lost Whaling Fleet Expedition 2015 is to search for remains of the whaling ships abandoned and lost in the area between Wainwright Inlet and the Seahorse Islands in the coastal waters of the Chukchi Sea. To achieve this goal, expedition scientists will use a combination of survey technologies, including:

- Swath bathymetry and side scan sonar to obtain detailed information on depth and other characteristics of the seafloor, including shipwreck debris and artifacts;
- Marine magnetometry to detect iron-containing material that may indicate the presence of shipwrecks; and
- Drop camera systems to obtain video imagery of shipwrecks and artifacts located by sonar and magnetometry.

Magnetometers are widely used for a variety of purposes, and all operate by measuring changes in Earth's magnetic field. These changes may be caused by astronomical forces (such as solar storms), as well as by the presence of iron or other magnetic material. Changes in Earth's magnetic field caused by magnetic substances can be used to locate archaeological materials.

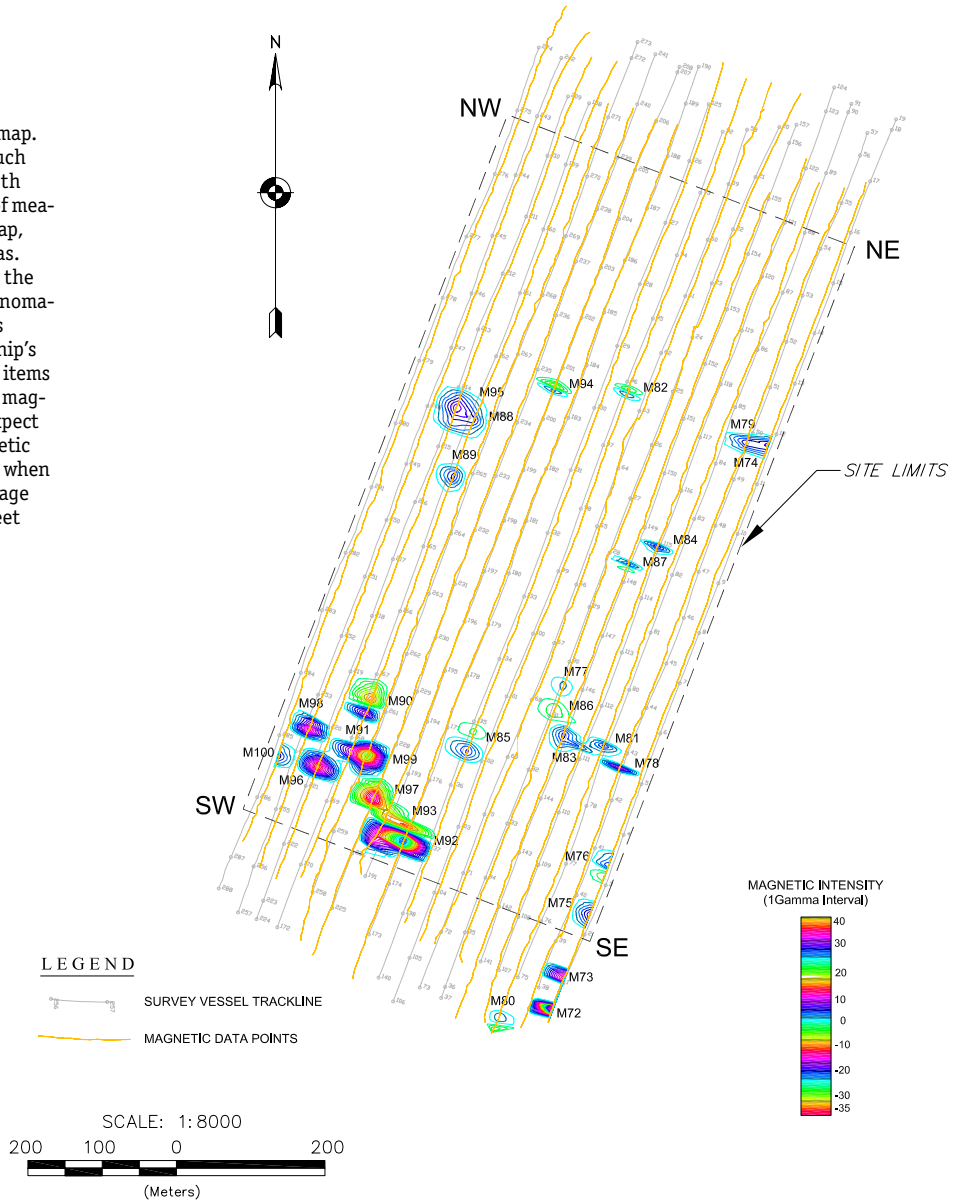


Archaeologist James P. Delgado is monitoring incoming magnetic data on one computer while another computer provides navigation information. The captain on the boat's bridge steers the vessel using the same navigation screen. Image Courtesy NOAA/Matthew Lawrence.



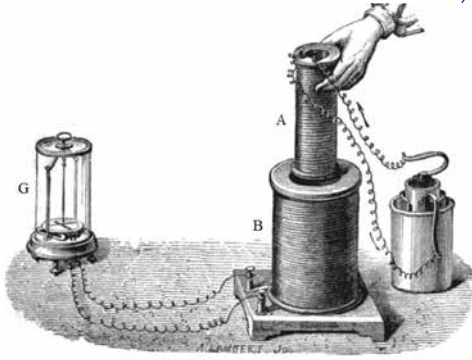
1871 Whaling Fleet Survey Area for In Search of the Lost Whaling Fleet 2015 Expedition. Map courtesy NOAA/Matthew Lawrence.

This is an example of a magnetic contour map. The magnetic data has been contoured much like a topographic map to show the strength and size of magnetic anomalies. Instead of measuring elevation in feet as on a contour map, magnetic data is scaled in teslas or gammas. The color scale chart on the side indicates the strength of magnetism. While magnetic anomalies can be caused by many things, ferrous iron artifacts, such as anchors, try pots, ship's rigging, and whaling gear are the types of items found on a whaling ship that would cause magnetic anomalies. Archaeologists would expect to see clusters of anomalies in their magnetic data, much like those shown on this map, when discovering a 19th century shipwreck. Image Courtesy In Search of the Lost Whaling Fleet Expedition 2015.



A simple magnetometer can be constructed with a bar magnet suspended from a string. Changes in Earth's magnetic field will cause the bar magnet to point in a slightly different direction (see, for example, <http://image.gsfc.nasa.gov/poetry/workbook/page9.html>). Magnetometers used to locate magnetic substances are based on electronic principles that involve interactions between magnetic forces and electronic forces. One of the most basic principles (Faraday's Law) is that moving a coil of wire through a magnetic field will cause an electric current to flow through the wire.

There are many other approaches for detecting and measuring magnetic fields, and magnetometer technologies are found in settings that range from hospitals (MRI machines) to ... smartphones! Apps that can sense changes in direction typically use three magnetometers to calculate the direction of magnetic north, and three accelerometers



Faraday's experiment showing induction between coils of wire: The liquid battery (right) provides a current which flows through the small coil (A), creating a magnetic field. When the coils are stationary, no current is induced. But when the small coil is moved in or out of the large coil (B), the magnetic flux through the large coil changes, inducing a current which is detected by the galvanometer (G). Source: Wikipedia. Credit: Poyser, Arthur William (1892), *Magnetism and electricity: A manual for students in advanced classes*. London and New York; Longmans, Green, & Co., p. 285, fig. 248. Retrieved 2009-08-06.

(which sense gravity) to calculate the orientation of the phone in three dimensions. There are also apps that can display information from these sensors, and allow smartphones to be used as hand-held magnetometers.

In this lesson, students will simulate a magnetometer survey using a smartphone magnetometer app or, alternatively, a magnetic compass.

Learning Procedure

1. To prepare for this lesson:

- a. Review background information about the 2015 Lost Whaling Fleet Expedition [<http://oceanexplorer.noaa.gov/explorations/15lostwhalingfleets/welcome.html>], the mission log on magnetometry [<http://oceanexplorer.noaa.gov/explorations/15lostwhalingfleets/logs/logs.html>], and the Office of National Marine Sanctuaries "In Search of the Lost Whaling Fleets" Web page [<http://sanctuaries.noaa.gov/whalingfleet/welcome.html>]
- b. Review options for magnetometer survey simulation (Step 3), and prepare "survey areas" for the option you wish to use.

2. Briefly introduce the In Search of the Lost Whaling Fleet Expedition 2015, and lead a discussion about reasons for studying and preserving maritime heritage artifacts. Ask students how they would organize a search for underwater shipwrecks near the coast, but buried beneath enough sediment to make them invisible to visual surveys. Students should fairly quickly mention "metal detector" or "magnetometer," since treasure-hunting beachwalkers often appear in various forms of advertising and entertainment. Be sure students understand that the basis for these devices is the concept of detecting changes in Earth's magnetic field caused by iron or magnetic materials. Ask how many students own a magnetometer; many may not realize that these devices are now built into most smartphones as part of their orientation capabilities.

3. Magnetometry Survey Simulation

Two options are offered: Simulated survey using smartphone magnetometer apps, or simulated survey using conventional magnetic compasses.

Option 1. Simulated survey using smartphone magnetometer apps

- a. Install magnetometer apps for the type of smartphone students will be using. Free apps are available for both iPhone and Android devices, and any functional app should work. Move a steel bolt (see b.(3), below) around the device to determine which part of the device is most sensitive to magnetic interference (it is usually near the top of the device).

Lined writing area with a wavy vertical border on the right side.

- b. Prepare one or more mock survey areas:
 - (1) Copy Figure 2 onto one piece of cardstock for each survey area you want to construct.
 - (2) Construct a shallow (1-inch deep) cardboard tray that is slightly smaller than the cardstock grid.
 - (3) Using a hot glue gun, fasten four to six steel bolts (1/4" x 2" carriage bolts, for example) onto the bottom of the tray, so that each bolt is separated by at least two inches from the neighboring bolts.
 - (4) Tape the cardstock grid onto the cardboard tray so that the bolts cannot be seen.

- c. Provide each student or student group with a copy of the *Magnetometry Survey Data Sheet*, and direct each group to the mock survey area that they are to survey. Tell students to begin their survey in grid cell A,1 and to move the most sensitive part of their magnetometer slowly along each row, recording the magnetometer reading for each cell when the magnetometer is in the middle of the cell. When students have obtained readings for each cell, they should draw the approximate outline of any objects detected on their data sheet. When all groups have completed their surveys, have students remove the cardstock grids from the trays and compare their results to the actual location of the bolts.

Option 2. Simulated survey using conventional magnetic compasses

- a. Obtain inexpensive magnetic compasses for each student group. Any functional compass will work.

- b. Prepare one or more mock survey areas:
 - (1) Copy Figure 2 onto one piece of cardstock for each survey area you want to construct.
 - (2) Construct a shallow (1-inch deep) cardboard tray that is slightly smaller than the cardstock grid.
 - (3) Using a hot glue gun, fasten four to six bar or disk magnets (about 1/4" x 2" for bar magnets, about 1/2" diameter for disc magnets) onto the bottom of the tray, so that each magnet is separated by at least two inches from the neighboring magnets.
 - (4) Tape the cardstock grid onto the cardboard tray so that the bolts cannot be seen.

- c. Provide each student or student group with a copy of the *Magnetometry Survey Data Sheet*, and direct each group to the mock survey area that they are to survey. Tell students to begin their survey in grid cell A,1 and to move the compass slowly along each row, marking any deflections of the compass needle in the grid cell over which the deflection was observed (some deflections

may span more than one grid cell; in this case mark each cell). When students have surveyed the entire area, they should draw the approximate outline of any objects detected on their data sheet. When all groups have completed their surveys, have students remove the cardstock grids from the trays and compare their results to the actual location of the magnets.

4. Lead a discussion of students' results, and how their methods compare to techniques that might actually be used to search for submerged shipwrecks. Option 1 is a better simulation of magnetometer surveys, since it uses a real magnetometer and is detecting changes in Earth's magnetic field caused by iron-containing objects, while Option 2 is detecting magnetic fields produced by permanent magnets, which is not the same principle used in magnetometry. The grid-based survey, however, is reasonably analogous to actual survey methods.

Ask students to identify questions that they would ask to clarify the factors that affect the strength of magnetic interactions that are involved with their detection technique. Questions could include, for example, how distance between the detector and objects being detected affects the strength of interactions; how the size of detected objects might influence their results; or whether external influences such as solar storms would be likely to affect the strength of magnetic interactions involved with their detection technique.

Adaptations for Grades 9-12

Have students construct a model of a magnetometer interacting with a shipwreck through magnetic fields to illustrate the forces between objects and changes in energy of the objects due to the interaction. Models may include drawings, diagrams, and texts.

The BRIDGE Connection

www.vims.edu/bridge/ – In the menu on the left, scroll over “Ocean Science Topics,” then “Human Activities,” then “Heritage,” then click “Archaeology,” for links to information and activities about marine archaeology and shipwrecks.

The “Me” Connection

Have students write a brief essay discussing how preserving maritime heritage artifacts might be of personal importance.

Connections to Other Subjects

English/Language Arts, Social Studies

Assessment

Participation in class discussions provides opportunity for assessment.

Extensions

Visit [<http://oceanexplorer.noaa.gov/explorations/15lostwhalingfleets/welcome.html>] for daily logs and updates about discoveries being made by the In Search of the Lost Whaling Fleet 2015 Expedition.

Other Relevant Lessons from NOAA's Ocean Exploration Program

Looking for Clues (grades 5-6)

from the RMS Titanic 2004 Expedition

[<http://oceanexplorer.noaa.gov/explorations/04titanic/edu/media/Titanic04.Clues.pdf>]

Focus: Marine archaeology of the Titanic (Earth Science)

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

Wreck Detectives (grades 5-6)

from the Steamship Portland 2003 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.

Ping! (grades 7-8)

from the Steamship Portland 2003 expedition

[<http://oceanexplorer.noaa.gov/explorations/03portland/background/edu/media/portlandping.pdf>]

Focus: Sidescan sonar (Earth Science/Physical Science)

Students describe sidescan sonar, compare and contrast sidescan 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.

Do You Have a Sinking Feeling? (grades 9-12)

[<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://sanctuaries.noaa.gov/whalingfleet/welcome.html> – Office of National Marine Sanctuaries web page about the lost whaling fleets

<http://makezine.com/projects/treasure-finder/> – Instructions for making another type of magnetometer

Next Generation Science Standards

While they are not intended to target specific Next Generation Science Standards, activities in this lesson may be used to support specific NGSS elements as described below.

MS-PS2 Motion and Stability: Forces and Interactions

Performance Expectation

MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

[Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.]

Science and Engineering Practices

Asking Questions and Defining Problems

- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when

Lined writing area for student notes.

appropriate, frame a hypothesis based on observations and scientific principles.

Disciplinary Core Ideas

PS2.B Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Common Core State Standards Connections:

ELA/Literacy –

- RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

Mathematics –

- MP.2 Reason abstractly and quantitatively

HS-PS3 Energy

Performance Expectation

HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]

Science and Engineering Practices

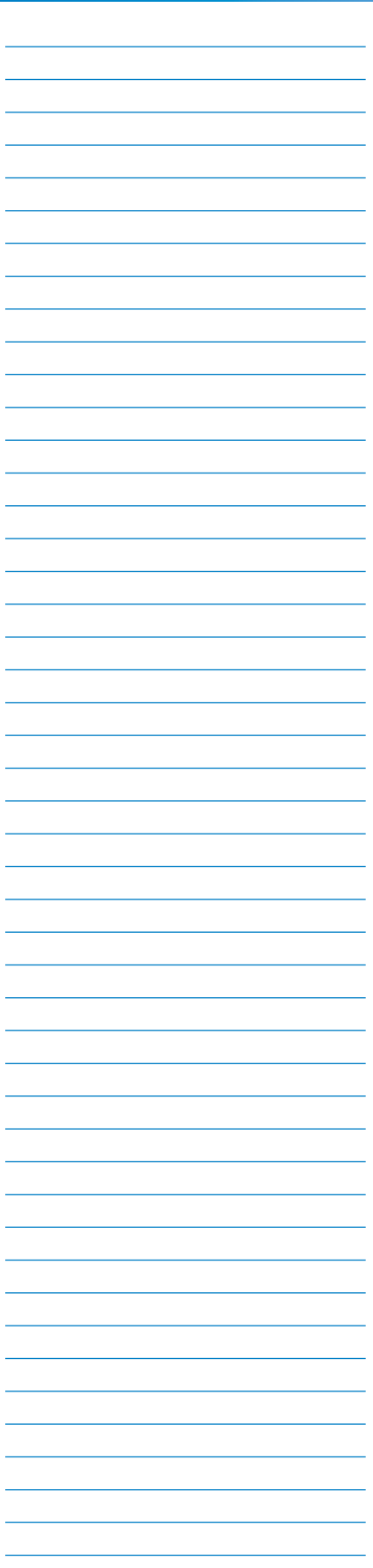
Developing and Using Models

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas

PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed



Crosscutting Concepts

Cause and Effect

- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Common Core State Standards Connections:

ELA/Literacy -

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Mathematics -

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 6.

The ocean and humans are inextricably interconnected.

Fundamental Concept b. The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.

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.

Essential Principle 7.

The ocean is largely unexplored.

Fundamental Concept a. The ocean is the largest unexplored place on Earth—less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.

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, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

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.

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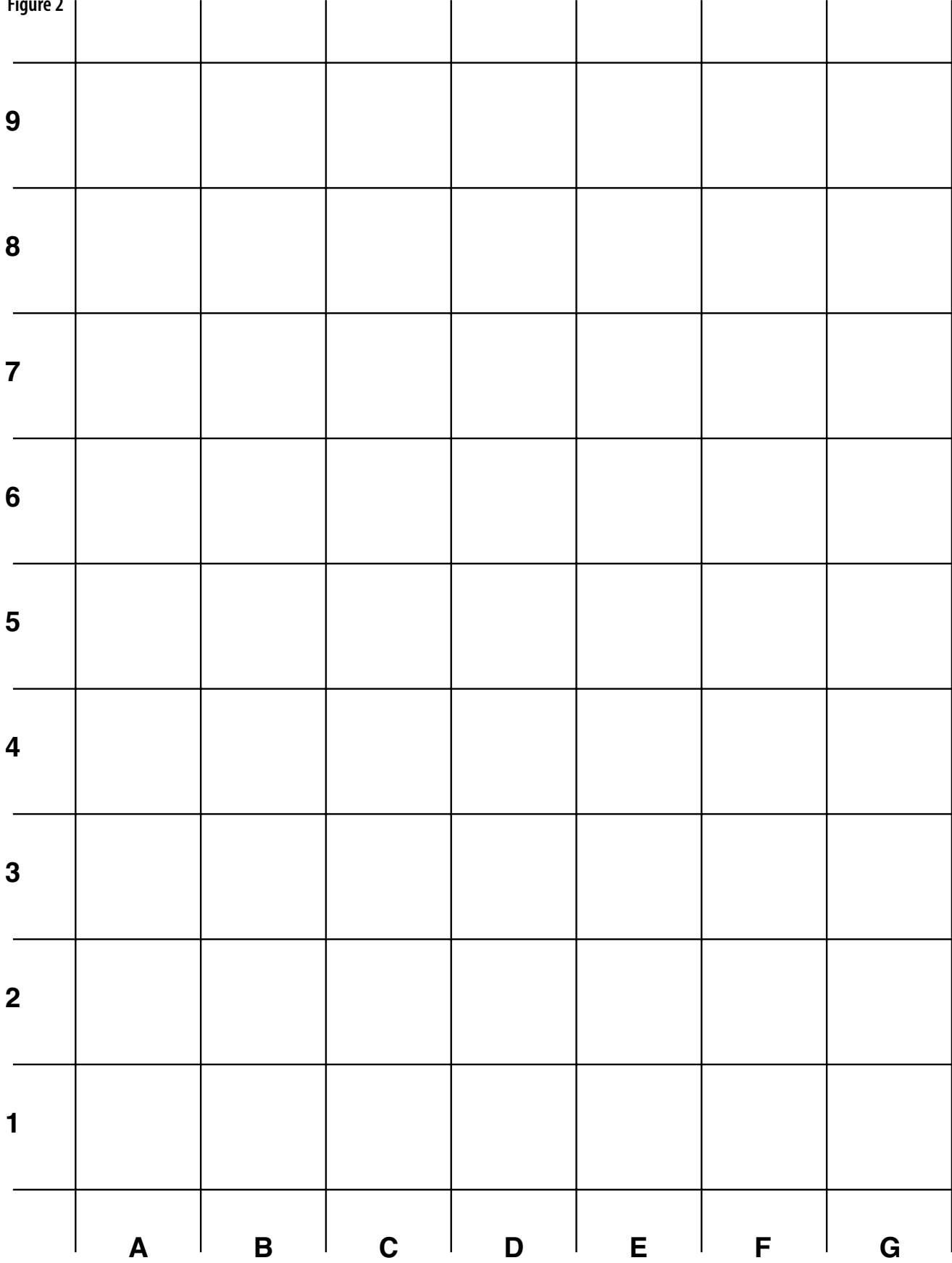
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Credit

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Figure 2



Magnetometry Survey Data Sheet

Grid Cell	Magnetometer Reading
A,1	
A,2	
A,3	
A,4	
A,5	
A,6	
A,7	
A,8	
A,9	
B,1	
B,2	
B,3	
B,4	
B,5	
B,6	
B,7	
B,8	
B,9	
C,1	
C,2	
C,3	

Grid Cell	Magnetometer Reading
C,4	
C,5	
C,6	
C,7	
C,8	
C,9	
D,1	
D,2	
D,3	
D,4	
D,5	
D,6	
D,7	
D,8	
D,9	
E,1	
E,2	
E,3	
E,4	
E,5	
E,6	

Grid Cell	Magnetometer Reading
E,7	
E,8	
E,9	
F,1	
F,2	
F,3	
F,4	
F,5	
F,6	
F,7	
F,8	
F,9	
G,1	
G,2	
G,3	
G,4	
G,5	
G,6	
G,7	
G,8	
G,9	