POLAR TREC
Learning Resources

Details

Arctic / Antarctic
About 1 period
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Middle School and Up

Ground Penetrating Radar (GPR): Seeing Below the Surface While Keeping Scientists Safe

Overview

Ground Penetrating Radar (GPR) is a valuable technology that utilizes waves of low frequency electromagnetic radiation to help polar scientists understand what is beneath their feet! Using real field data from the Icelandic glacier Múlajökull, along with a small selection of short videos and web-based resources, this lesson allows students to explore the fundamental science of GPR technology, its value in developing a global understanding of the Polar Regions, and the ways that it helps to keep polar scientists safe while on the job in some of Earth's most treacherous and remote locations.

Learning Objectives

1. Students will be able to describe how GPR technology utilizes electromagnetic waves to help scientists and engineers visualize/identify subsurface materials and structures.
2. Students will be able to analyze the different uses of GPR in engineering and science.
3. Students will be able to observe and discuss the use of GPR to help advance Polar Science discoveries while simultaneously helping keep polar scientists safe in the field.
4. Students will be able to interpret GPR data from an Icelandic glacier system in order to predict the formation processes of particular glacial landforms (drumlins).

Lesson Preparation

This lesson is written for one 90-minute block or two standard length class periods. It is designed to be completed during or at the conclusion of a unit on electromagnetic waves and radiation (EMR). Once

Materials

- Computers, tablets, or other devices capable of accessing the Internet
- Student Handout
- Answer Key to Student Handout
- Introductory Slideshow for GPR Use in Iceland

students have developed a solid understanding of EMR structure, characteristics, and properties (i.e. wavelength, frequency, amplitude, period, crest, trough, etc.), this lab can be used to help students explore the important real world uses of EMR in simple GPR technologies in the Polar Regions. All in all, this lesson teaches students some very important real world applications of the basic scientific principles behind EMR and GPR while also allowing them to explore some of the exciting and interesting science being done in the Polar Regions.

This lesson follows the 5E Inquiry Model. This lesson model was chosen because it utilizes two instructional teaching methods that are well suited for science classrooms: advance organizers and inquiry. Advance organizers help to prepare and activate student's thinking at the start of the lesson, and inquiry allows students the opportunity to predict and design their own explanations for new scientific processes and discoveries. This particular lesson strives to teach students basic scientific knowledge as well as challenging them to evaluate, analyze, and synthesize this information into explanations and predications. In this regard, the 5E Inquiry Model is a great choice to help students navigate their way to the desired higher level thinking skills in the end of this lesson.

Key Terms

Electromagnetic Radiation and Waves
Spectrum
Frequency
Wavelength
Amplitude
Polar Regions
Glacier

Procedure

Engage (15 minutes)

1. Use the following videos of the GROVER Robot and the YETI Robot as advance organizers to hook the students:
   - GROVER: https://www.youtube.com/watch?v=i9bwwK2KQSw
   - YETI: (only play first 1 minute and 24 seconds) https://www.youtube.com/watch?v=qaq9m0ifSFQ
2. Once the videos are over, allow students to work with a partner near them to discuss and answer questions 1-3 on their student handout. Allow about 5 minutes. Walk around the room and listen to their discussions/look at what they are writing. Keep a few students in mind that you feel have appropriately answer them.
3. As a class, discuss their answers to questions 1-3 for another 5 minutes. Call on the students you noted in the previous step and ask them to share their answers. By the end of the discussion, students should have a basic understanding of how GPR is important for

conducting science in the Polar Regions and also how it is used to help keep scientists safe.
4. Explain to students that in the remaining part of this lesson, they will explore in greater detail how GPR technology works and how it is used to conduct science at Earth's Polar Regions.

Explore (30 minutes)

1. Allow students to access the Internet via classroom computers, tablets, or other devices. They may work together in pairs or alone. All of the necessary links and websites are provided on the student handout.
2. Use the provided Answer Key to monitor student progress by walking around and scaffolding answers, providing support, or asking additional probing questions.
3. When all students have finished, have them close their computers and bring their attention to the front of the room.

Explain (20 minutes)

1. Display the "Introductory Slideshow" on the projector where all students can see it.
2. Run through the slides and embedded videos on the slideshow to introduce students to the "Drumlin Formation in Iceland" PolarTREC Expedition from the summer of 2013.
3. Help students answer the corresponding questions on their student handout during the slideshow.

Elaborate (25 minutes)

1. Instruct students to observe the graph of GPR data on the second to last slide in the slideshow.
2. Have them work with the same partner as before while they complete the corresponding tasks using the GPR data file.
3. Use the provided Answer Key to monitor student progress by walking around and scaffolding answers, providing support, or asking additional probing questions.

Evaluate

1. Collect handout from students and use the provided Answer Key to:
   a. Assess the completion of learning objectives:
   - Learning Objective 1: Explore questions 1-4, 7,8
   - Learning Objective 2: Explore questions 3, 10-12 and all Explain tasks.
   - Learning Objective 3: All Engage questions and all Explain tasks.
   - Learning Objective 4: All Elaborate tasks.

   b. Assess the Evaluation results.
   - The Concept Map will visually represent the student's comprehension of the entire lesson.
   - The diagram/drawing will represent a student's technological understanding of the

basics of GPR technology.
• The last task will represent how well a student can apply this new knowledge of GPR to new contexts and situations.

Possible Lesson Extensions

1. Students who demonstrate exceptional interest or excitement about this topic can make a model GPR unit from cardboard or other arts/crafts supplies. This could ultimately produce a diorama of a Polar Scientists at work in the Arctic or Antarctic using GPR in any number of ways.
2. If a local engineering or construction firm or local university had a GPR unit available for use in the classroom, this could provide students with a wonderful hands-on experience collect simple GPR data. Students could choose a site on school grounds to use the unit and try to identify pipes or other underground structures along a given transect.

Accommodations

1. Provide printed slides of the slideshow in large, dark print on a light background for students needing visual accommodations. The graph of the GPR data can be translated into Braille ahead of time if need be, and text from the websites in the Explore component of the lesson can be recorded orally ahead of time for the student to listen to on tape if need be.
2. For students needing accommodations for fine/gross motor skills, be sure to pair this student with an appropriate partner/teacher's aid so that this partner/aid can control the keyboard and mouse on the computer or device.
3. For students needing accommodations for auditory disabilities, provide written transcripts for the necessary YouTube videos that are shown during the lesson.
4. For students needing social/emotional accommodations, provide them with a partner/ teachers aid than can assist the student to a more quite environment for completing the lesson (like the library or study hall).
5. For students needing cognitive/processing accommodations, allow additional time for each step of the lesson plan.

Assessment

The handout can be collected by the teacher to assess student completion of the learning objectives as outlined above in the Evaluation portion of the 5 E model. Each learning objective corresponds to particular components of the handout.

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2013 PolarTREC Teacher: "Drumlin Formation in Iceland"

File Attachments

Introductory GPR Lesson Slideshow
Student Handout
Answer Key to Student Handout

National Science Content Standards

Grades 5-8
Content Standard B: Physical Science
a. Transfer of energy

Content Standard E: Science and Technology
a. Abilities of technological design
b. Understandings about science and technology

Content Standard F: Science In Personal and Social Perspectives
a. Natural hazards
b. Risks and benefits
c. Science and technology in society

Content Standard G: History and Nature of Science
a. Science as a human endeavor

Grades 9-12
Content Standard B: Physical Science
a. Interactions of energy and matter

Content Standard E: Science and Technology
a. Abilities of technological design
b. Understandings about science and technology

Content Standard F: Science In Personal and Social Perspectives
a. Natural and human-induced hazards
b. Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
a. Science as a human endeavor

Idaho State Science Content Standards, Grades 8-10

Goal 1.2: Understand Concepts and Processes of Evidence, Models, and Explanations
- 9-10.B.1.2.1 Use observations and data as evidence on which to base scientific explanations.

Goal 2.3: Understand the Total Energy in the Universe is Constant

- 8-9. PS.2.3.2* Classify energy as potential and/or kinetic and as energy contained in a field.
- CL: C: Students will be able to identify different forms of potential and kinetic energy and energy contained in electric, magnetic, or gravitational fields and can identify the organization of the electromagnetic spectrum.

Goal 5.2: Understand the Relationship between Science and Technology

- 9-10.B.5.2.1 Explain how science advances technology.
- 9-10.B.5.2.2 Explain how technology advances science.
- 9-10.B.5.2.3 Explain how science and technology are pursued for different purposes.

Name:_____ **Date:**_____ **Block:**_____

Ground Penetrating Radar (GPR) and Polar Science

ENGAGE: *Watch the opening video as a class, and then work with a partner for a few minutes to answer the following three questions. Be prepared to discuss your answers with the rest of the class.*

1.) Describe how the GROVER and YETI robots are helping scientists in the Arctic and Antarctic. How are they similar? How are they different?

2.) In what ways can you observe that the two robots both contribute to our scientific understanding of Earth's Polar Regions?

3.) Predict: how does Ground Penetrating Radar actually work on these robots? (Hint: think back to what we have been recently learning about with electromagnetic waves and radiation.)

EXPLORE: *Now it's your turn to doing some exploration about the basics of GPR technology and how it is used to help Polar Scientists. Please use the following websites to help you complete the corresponding questions. You may work with one other partner at your computer station if you would like.*

http://www.global-gpr.com/gpr-technology/how-gpr-works.html

1.) What are the basic principles of Ground Penetrating Radar? Draw a simple diagram to help your answer if need be.

2.) How is data collected for below ground objects/materials using a GPR?

3.) Please give a description of how GPR can be used not only by scientists, but also by construction contractors or concrete workers

4.) Once the GPR data has been collected, how is it analyzed?

5.) What materials can GPR waves go the deepest? What materials can GPR waves not go very deep into?

6.) Check out this YouTube video on GPR: https://www.youtube.com/watch?v=oQaRfA7yJ0g

Use it to go back and check your answers to questions 1-5, then state one new thing you learned about GRR from the video:

Now use this website to answer Questions 7-12: http://www.geophysical.com/whatisgpr.htm

7.) What are the three main components of a GPR system? What does each component do?

8.) Analyze the provided data table on the website: How is the frequency of the pulse from a GPR unit related to the depth that it can go?

9.) Describe when a GPR would receive a strong signal versus a weak signal. What causes these differences in signal strength?

10.) Choose the "Ice and Snow" tab from the menu on the left side of the screen. Summarize what you learn from the text and images on each tab of this page:

OVERVIEW:

ICE ROAD PROFILING:

GLACIOLOGY STUDIES

CREVASSE DETECTION

11.) Choose another Application of GPR from the menu on the left side of the screen and use 2-3 sentences to summarize how GPR is used in that branch of science or engineering.

12.) Check out this YouTube video to learn about how the British Geologic Survey uses GPR to study glaciers: https://www.youtube.com/watch?v=oJ0vMruQHik

State two ways that GPR is used to study glaciers by the scientist in the video.

EXPLAIN: *GPR was used by a group of scientists from the United States, Sweden, Denmark, and Iceland in a remote Arctic landscape of Central Iceland in the summer of 2013 on the glacier Múlajökull. Answer the following questions about their research and their use of GPR while watching the slideshow.*

1.) What is the goal of this research team?

2.) Where are they studying in the Arctic?

3.) Who are the lead scientists on the team? Where are they from?

4.) Give a description of how GPR is used by the team to accomplish the research goals you identified in question 1 above.

5.) How does their use of GPR compare to the uses of GPR that you explored earlier in this activity? Does their chosen frequency of the radar waves match with your answer to question 8 in the Explore component of this activity?

6.) Why is their research important and valuable?

ELABORATE: *Now it's your turn to use and analyze a small amount of the team's GPR data from Múlajökull. This data helped the team determine just how the drumlin landforms are being created. Observe the GPR data on the slideshow while completing the following tasks.*

1.) Observe the depth of the waves on the y-axis of the graph. How deep into the glacial drumlin was the GPR capable of collecting data? Does this support your answer to Explore Question #8?

2.) Observe the wave amplitude on the x-axis of the graph. Describe the trends in amplitude that can be observed while going deeper into the drumlin. At what depths are amplitudes high? At what depths are they low?

3.) Observe the amplitude of the waves from 5.5 – 7.0 meters of depth. What do you notice about the wave amplitudes as you move from the left side of the drumlin to the right side of the drumlin? Do you see straight-line patterns from left to right or curved line patterns from left to right?

4.) Predict: what do you think that this means about how drumlins actually form? Does this data indicate erosional formation or depositional formation? Why? (Hint: curved line patterns indicate depositional formation, straight-line patterns indicate erosional formation.)

EVALUATE

1.) Draw a picture or Concept Map that visually represents what you have learned about GPR and its uses in polar science.

2.) Draw a simple diagram/picture illustrating how GPR works in a given situation to either advance science or protect scientists.

3.) Think about your daily life both in and out of school: what is one way that GPR could be useful FOR YOU!? Get creative!

Name:_____ **Date:**_____ **Block:**_____

TEACHER ANSWER KEY: Ground Penetrating Radar (GPR) and Polar Science

ENGAGE: *Watch the opening video as a class, and then work with a partner for a few minutes to answer the following three questions. Be prepared to discuss your answers with the rest of the class.*

1.) Describe how the GROVER and YETI robots are helping scientists in the Arctic and Antarctic. How are they similar? How are they different?

Answers will vary: identify a student or student(s) with answers that are exceptionally creative and intriguing.

2.) In what ways can you observe that the two robots both contribute to our scientific understanding of Earth's Polar Regions?

YETI indirectly contributes to scientific research by providing the safe working conditions for science to be done. GROVER on the other hand directly contributes to scientific research on glacial mass balance, etc.

3.) Predict: how does Ground Penetrating Radar actually work on these robots? (Hint: think back to what we have been recently learning about with electromagnetic waves and radiation.)

Answers will vary: identify a student or student(s) with answers that come as close to the correct answer as possible. Look for these key words: electromagnetic waves, radar waves, reflection, antennae, frequency, etc.

EXPLORE: *Now it's your turn to doing some exploration about the basics of GPR technology and how it is used to help Polar Scientists. Please use the following websites to help you complete the corresponding questions. You may work with one other partner at your computer station if you would like.*

http://www.global-gpr.com/gpr-technology/how-gpr-works.html

1.) What are the basic principles of Ground Penetrating Radar? Draw a simple diagram to help your answer.

Ground Penetrating Radar (GPR) uses a high frequency radio signal that is transmitted into the ground and reflected signals are returned to the receiver and stored on digital media. The computer measures the time taken for a pulse to travel to and from the target, which indicates its depth and location. The reflected signals are interpreted by the system and displayed on the unit's LCD panel.

2.) How is data collected for below ground objects/materials using a GPR?

In order to find the location and depth of an object, buried subsurface, various types of GPR equipment are used to collect the data. The type of GPR equipment required is dependent on the depth and size of the target to be located. The radar unit emits and receives reflected signals up to a thousand times per second. These signals are viewed by the field operator on location immediate analysis and are also stored in the system and downloaded to a computer for further data analysis if required.

3.) Please give a description of how GPR can be used not only by scientists, but also by construction contractors or concrete workers

To locate objects such as rebar, conduits and post-tension cables imbedded in concrete a high frequency GPR system is used. The data can be collected in simple line scans to determine the thickness of concrete or in a grid format which will

produce a map of any targets located in the concrete. Using this method we can look at virtual slices in the image to determine the depth of the objects and create a 3D map of the image.

4.) Once the GPR data has been collected, how is it analyzed?

GPR waves travel through many different materials. Different types of soil, concrete, fill material, debris, and varying amounts of water saturation all have different dielectric and conductive properties that affect the GPR waves, and thus GPR data interpretation. Although the data images are displayed on the screen they still require someone with field experience to interpret them in order to accurately determine the findings.

5.) What materials can GPR waves go the deepest? What materials can GPR waves not go very deep into?

Deepest: Ice and air

Shallowest: Seawater

6.) Check out this YouTube video on GPR: https://www.youtube.com/watch?v=oQaRfA7yJ0g
Use it to go back and check your answers to questions 1-5, then state one new thing you learned about GRR from the video.

Student answers will vary.

Now use this website to answer Questions 7-12: http://www.geophysical.com/whatisgpr.htm

7.) What are the three main components of a GPR system? What does each component do?

The Control Unit contains the electronics which triggers the pulse of radar energy that the antenna sends into the ground. It also has a built-in computer and hard disk/solid state memory to store data for examination after fieldwork. Some systems, such as the GSSI SIR 20, are controlled by an attached Windows laptop computer with pre-loaded control software. This system allows data processing and interpretation without having to download radar files into another computer.

The antenna receives the electrical pulse produced by the control unit, amplifies it and transmits it into the ground or other medium at a particular frequency. Antenna frequency is one major factor in depth penetration. The higher the frequency of the antenna, the shallower into the ground it will penetrate. A higher frequency antenna will also 'see' smaller targets. Antenna choice is one of the most important factors in survey design.

GSSI GPR equipment can be run with a variety of power supplies ranging from small rechargeable batteries to vehicle batteries and normal 110/220-volt. Connectors and adapters are available for each power source type. The unit in the photo above can run from a small internal rechargeable battery or external power.

8.) Analyze the provided data table on the website: How is the frequency of the pulse from a GPR unit related to the depth that it can go?

The lower the frequency the greater the depth

9.) Describe when a GPR would receive a strong signal versus a weak signal. What causes these differences in signal strength?

GPR works by sending a tiny pulse of energy into a material and recording the strength and the time required for the return of any reflected signal. A series of pulses over a single area make up what is called a scan. Reflections are produced whenever the energy pulse enters into a material with different electrical conduction properties or dielectric permittivity from the material it left. The strength, or amplitude, of the reflection is determined by the contrast in the dielectric constants and conductivities of the two materials. This means that a pulse which moves from dry sand (dielectric of 5) to wet sand (dielectric of 30) will produce a very strong reflection, while moving from dry sand (5) to limestone (7) will produce a relatively weak reflection.

10.) Choose the "Ice and Snow" tab from the menu on the left side of the screen. Summarize what you learn from the text and images on each tab of this page:

OVERVIEW: Student answers will vary; check website to verify that summaries match what is on the site.

ICE ROAD PROFILING: Student answers will vary; check website to verify that summaries match what is on the site.

GLACIOLOGY STUDIES: Student answers will vary; check website to verify that summaries match what is on the site.

CREVASSE DETECTION Student answers will vary; check website to verify that summaries match what is on the site.

11.) Choose another Application of GPR from the menu on the left side of the screen and use 2-3 sentences to summarize how GPR is used in that branch of science or engineering.

Student answers will vary.

12.) Check out this YouTube video to learn about how the British Geologic Survey uses GPR to study glaciers: https://www.youtube.com/watch?v=oJ0vMruQHik

State two ways that GPR is used to study glaciers by the scientist in the video.

Look beneath the surface of the ice to observe its bed, thickness, layers, thrust planes, fracture planes. This helps them look at how water flows through the ice.

EXPLAIN: *GPR was used by a group of scientists from the United States, Sweden, Denmark, and Iceland in a remote Arctic landscape of Central Iceland in the summer of 2013 on the glacier Múlajökull. Answer the following questions about their research and their use of GPR while watching the slideshow.*

1.) What is the goal of this research team?

To determine the formation processes of the mysterious glacial landform called the drumlin.

2.) Where are they studying in the Arctic?

The glacier Múlajökull is home to the only known active drumlin field on planet Earth. Drumlins are being created there right now!

3.) Who are the lead scientists on the team? Where are they from?

Dr. Neal Iverson: Iowa State University

Dr. Thomas Hooyer: University of Wisconsin Milwaukee

4.) Give a description of how GPR is used by the team to accomplish the research goals you identified in question 1 above.

The GPR unit was used by the team to determine the structure of subsurface till layers composing the drumlins. The GPR was pulled across the drumlins while collecting data. It was also used on the glacier's ice margin to get information about how the drumlins emerge from underneath the glacier.

5.) How does their use of GPR compare to the uses of GPR that you explored earlier in this activity? Does their chosen frequency of the radar waves match with your answer to question 8 in the Explore component of this activity?

As explained by geophysicist post-doctorate researcher Luke Zoet, the team's GPR frequency is 200MHZ to a depth of 10-15 feet (3-5 meters). This matches perfect with the table analyzed in Question 8.

6.) Why is their research important and valuable?

The more that is known about how glaciers move and behave (drumlins being only one small aspect of this), the more accurately scientists can predict future movements of glaciers. This is significant for computer models predicting future climate change and associated sea level rise due to the observed recession of a majority of Earth's glaciers.

ELABORATE: *Now it's your turn to use and analyze a small amount of the team's GPR data from Múlajökull. This data helped the team determine just how the drumlin landforms are being created. Observe the GPR data on the slideshow while completing the following tasks.*

1.) Observe the depth of the waves on the y-axis of the graph. How deep into the glacial drumlin was the GPR capable of collecting data? Does this support your answer to Explore Question #8?

The GPR waves penetrated 0-10 feet. Yes, this supports question #8.

2.) Observe the wave amplitude on the x-axis of the graph. Describe the trends in amplitude that can be observed while going deeper into the drumlin. At what depths are amplitudes high? At what depths are they low?

Amplitudes are fairly high from 1-3 feet in depth. Then there is low amplitude until 5-7 feet in depth where it gets higher again. Amplitudes get lower again below 7 feet.

3.) Observe the amplitude of the waves from 5.5 – 7.0 feet of depth. What do you notice about the wave amplitudes as you move from the left side of the drumlin to the right side of the drumlin? Do you see straight-line patterns from left to right or curved line patterns from left to right?

Slight curved patterns are observed from left to right.

4.) Predict: what do you think that this means about how drumlins actually form? Does this data indicate erosional formation or depositional formation? Why? (Hint: curved line patterns indicate depositional formation, straight-line patterns indicate erosional formation.)

This trend in amplitudes indicates that drumlins could potentially be deposited in the shape that they are in. If they were erosional landforms, amplitude layers would be straight across and truncated at the left and right margin of the drumlin.

EVALUATE

1.) Draw a picture or Concept Map that visually represents what you have learned about GPR and its uses in polar science.

Student answers will vary. Refer back to the objectives of this lesson to confirm students' work.

2.) Draw a simple diagram/picture illustrating how GPR works in a given situation to either advance science or protect scientists.

Student answers will vary. Refer back to the website for this lesson to confirm students' work.

3.) Think about your daily life both in and out of school: what is one way that GPR could be useful FOR YOU!? Get creative!

Student answers will vary. Refer back to the objectives of this lesson to confirm students' work.