Remote sensing and geoarchaeology: How do remotely sensed images help us to understand past cultures?

Module Overview

This module explores ways geographers and geoarchaeologists use remote sensing to uncover previously undiscovered sites of human occupation. Photographs have long been used by geoarchaeologists to document sites before, during, and after excavation. In the early 1980s, remote sensing became a tool used to detect human features on the contemporary landscape. These skills were applied to see ancient landscapes as well. Students apply remote sensing and map skills to study ancient and prehistoric sites.

Remote sensing is the use of sensors that detect electromagnetic radiation to record images of an environment. The sensors, attached to airplanes, satellites, and other Earth-orbiting objects, collect data to create images of human and physical features. Some wavelengths of electromagnetic radiation penetrate clouds, smoke, and vegetation, allowing detection of features and patterns that could otherwise not be seen.

***Investigation 1:* How does remote sensing help us understand the Anasazi?**

In the first investigation, students compare maps to remotely sensed images to master the skills of determining direction and scale. They consider different viewpoints about the endangered status of ancient sites in Chaco National Historic Site and recommend future actions.

***Investigation 2:* How do geoarchaeologists use remote sensing to interpret landscapes?**

In this investigation, students learn the seven elements geoarchaeologists and specialists in remote sensing use to detect significant human and physical features.

***Investigation 3:* How does remote sensing search for the geographies of the past?**

Students use the case of previously unknown ancient sites in Guatemala to explore the role of geography in understanding the physical and cultural features of a region through remotely sensed images and ground-level photographs of a site.

Geography Standards

The World in Spatial Terms

- **Standard 1:** How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective
- **Standard 3:** How to analyze the spatial organization of people, places, and environments on Earth's surface

Places and Regions

- **Standard 4:** The physical and human characteristics of places

Human Systems

- **Standard 12:** The processes, patterns, and functions of human systems

Environment and Society

- **Standard 16:** The changes that occur in the meaning, use, distribution, and importance of resources

Mathematics Standards

Numbers and Operations

- Compute fluently and make reasonable estimates

Geometry

- Analyze characteristics—properties of two- to three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- Use visualization, spatial reasoning, and geometric modeling to solve problems

Science Standards

Unifying Concepts and Processes

- Systems, order, and organization

Life Science

- Populations and ecosystems

Science in Personal and Social Perspectives

- Populations, resources, and environments

Technological Literacy Standards

Technology and Society

- **Standard 7:** The influence of technology on history

Connection to the Curriculum

This module supplements instruction in middle school science, mathematics, language arts, and social studies. Students use language arts skills as they draw conclusions, write summaries, and read and summarize brief expository passages. Physical science concepts related to physics are used to explain electromagnetic radiation. In mathematics, students calculate distance and scale as well as think proportionally. In social studies, students develop map skills and extend those skills to interpretation of remotely sensed images. The content fits well with the study of ancient Central American, American, and Old World cultures.

Time

Investigation 1: Three 45-minute sessions
Investigation 2: Two 45-minute sessions
Investigation 3: Three 45-minute sessions

Module Assessment

After completing the entire module, ask students how remote sensing aids geoarchaeologists in finding, analyzing, and maintaining sites. Review the ways remote sensing is used:

- to locate archaeological sites,
- to map Earth's features,
- to interpret spatial distribution of physical and cultural features,
- to analyze and interpret sites, and
- to maintain and preserve sites.

Discuss what impact remote sensing has on continuing geoarchaeological research, especially as resolution of images and technological applications improve.

How does remote sensing help us understand the Anasazi?

Investigation Overview

In this investigation students consider different viewpoints about the endangered status of archaeological sites in Chaco Canyon National Historic Site in New Mexico and recommend future actions. In the process, they compare maps to remotely sensed images to determine direction and scale.

Time required: Three 45-minute sessions

Materials/Resources

Copies of the following for each student:

- Briefing 1: Photographs—Chaco Canyon
- Briefing 2: Who were the Anasazi?
- Log 1: Comparing maps and remotely sensed images
- Log 2: Should Chaco Canyon be preserved?
- Map 1: Modern road map of Chaco Canyon region
- Map 2: Map of ancient Anasazi outlier settlements and roads
- Log 3: In conclusion

Colored pencils
U.S. map

Content Preview

Recent remotely sensed imagery reveals a series of previously unknown roads leading to and from Chaco Canyon. The Anasazi were one of several cultures who inhabited the southwestern region of the United States between 1100 and 1300. Thermal infrared multispectral scanner (TIMS) data are used to detect paths and buildings.

Classroom Procedures

Beginning the Investigation

1. Locate Chaco Canyon on a U.S. map (northwest New Mexico).

2. Distribute **Briefing 1** or display the photos for the class. Ask students to describe the physical environment. Ask them to identify both ancient and modern evidence of human occupation.

3. Discuss the Anasazi culture of the southwestern United States.

4. Inform students that in 1999, the National Park Service declared this region a "vanishing treasure." Have students offer ideas as to what this means and why this might be occurring. Organize students into groups to study Chaco Culture National Historical Site and determine

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

- Describe the essential characteristics and functions of maps and geographic representations, tools, and technologies.

Standard 16: Environment and Society

The changes that occur in the meaning, use, distribution, and importance of resources

- Evaluate different viewpoints regarding resource use.

Geography Skills

Skill Set 4: Analyze Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.
- Interpret and synthesize information obtained from a variety of sources—graphs, charts, tables, diagrams, texts, photographs, documents, and interviews.

Skill Set 5: Answer Geographic Questions

- Develop and present combinations of geographic information to answer geographic questions.

its future. Should Chaco Canyon be preserved by closing it to the public, opening it to the public with limited access, or opening it to the public with full access to the archaeological sites? Since the ruins are already exposed, maps and remotely sensed data are analyzed to determine the next course of action.

Developing the Investigation

5. Have students read and answer the questions in **Briefing 2**. Discuss the answers. What new insights about the Anasazi did students gain?

6. Distribute all pages of **Log 1**. Have students follow the directions for **Part I** of **Log 1**. Guide students through the instructions. Ask students to compare the similarities and differences between the two maps.

7. Continue **Log 1**. Have students read **Part II** and examine the TIMS images of the region. Help them to see that this is the same location shown in two different sets of data/images. Have students complete the questions comparing the TIMS imagery for Part II.

8. Ask students to explain how each of the aerial views of the region is helpful to a geoarchaeologist. Discuss why understanding the scale on each image is important. (*It gives a sense of space: size of region viewed, distances, size of features on the images.*)

Concluding the Investigation

9. Review with students why this site has been declared a vanishing treasure. Discuss recent findings about the roads and remotely sensed information verifying their locations. How valuable is this information in understanding Anasazi culture?

10. Have students complete **Log 2.** Students work in their groups to summarize what remotely sensed images indicate about the ancient Anasazi and its "vanishing treasure" status. Hold a class meeting to discuss group findings. You may have students make a presentation and conduct a survey of another class to gauge opinion on what should be done about preservation. As an alternative, have students prepare a one-page summary and poll to share with students from other classes. Results of the survey can be compiled and conclusions drawn as to what should be done to preserve Chaco Canyon. Discuss the results. Students complete **Log 2** and share their letters and recommendations about preserving the Chacoan ruins.

11. Have students complete **Log 3**.

Background

The Anasazi were one of several cultures who inhabited sites in New Mexico, Arizona, Utah, and Colorado between 1100 and 1300. Mesa Verde and Chaco Canyon are national historic sites. Through the discovery of many artifacts, geoarchaeologists have constructed an understanding of these people. They had a very complex society with specialized jobs. Irrigated agriculture was practiced in this dry region. Religion played an important role in social life. In fact, many of the clusters of towns, or *pueblos,* appear to have been religious centers connected to outlying settlements through a road system that traversed rugged terrain in straight lines. (Modern roads tend to follow the contour of the land.) The disappearance of the Anasazi culture is a mystery. Several theories exist, including a climate shift resulting in the Anasazi leaving the region or a war in which they were assimilated or annihilated. After 1300, there is no documented existence of this culture or of its lifestyle.

This investigation focuses on Chaco Canyon National Historic Site near the Chaco River and Canyon in northwest New Mexico. The canyon appears to be the site of a major religious center to which the Anasazi traveled. Many of the pueblos are endangered because of vandalism, the "wear and tear" of tourism, and erosion from freezing and thawing. Recent remotely sensed imagery revealed a series of previously unknown roads leading to and from Chaco Canyon. High school students worked with archaeologists to map the locations of the large amount of broken pottery along the roads detected in the remotely sensed images.

Evaluation

Briefing 2

Checks should be before Numbers 1, 2, 3, and 5.

Log 1

Part I

1. Salmon Ruins
2. Approximately 3.4 cm = 65 km
3. Approximately 3.4 cm; same as Map 2
4. The scale of kilometers on Map 1 should be the same size as on Map 2. A directional arrow should be added.

Part II

1. Roads
2. Most run N–S; connect cities/communities; routes of transportation; paved
3. Chacoan roads seem to have some purpose; all converge at one point. Chacoan roads weren't as wide as modern roads. Modern roads follow the terrain more, rather than going over it. They are wider. They connect areas of great distance (more than what is seen on the map). They may be for recreational travel as well as economic travel.
4. Chacoan roads run in straight lines while modern roads often follow the terrain by taking paths of least resistance.
5. Check arrow for accuracy; yes

Log 2

Answers will vary. Student responses should include a summary of what is seen in each of the TIMS images. Survey results should be stated. The response should make a recommendation for the future of Chaco Canyon. Reasons should be given for the recommendation.

Log 3

1. Photographs of site: Ground-level views show structures; vegetation indicates the aridity of the landscape leading to speculation about what might have grown; topography indicates rugged terrain and raises questions about why they built structures and roads as they did.
2. Map 1: Can be compared to historic maps to show areas that may not have been investigated due to remoteness from modern roads; shows current roads, Culture Center, and prehistoric sites.
3. Map 2: Indicates places where Anasazi lived and transportation links; leads to speculation of additional outlier settlements and roads; indicates patterns in terrain and patterns of settlement.
4. TIMS Image 1: Shows additional connections; road patterns; archaeologists look for evidence of the entire road system.
5. TIMS Image 2: Compares ancient roads to modern roads; shows that prehistoric roads are not disturbed.

   The photographs and maps show what has been excavated and what is known about the Anasazi settlements. The remotely sensed images give us a sense that there is more to find; speculations about lifestyle may be proven true or false by additional research. They indicate that preservation may be important so that the whole story is told.

6. Answers will vary but should be supported by reasons for preservation/type of preservation.

Resources

Baker Aerial Archaeology's Chaco Project
http://www.mia.com/~jaybird/AANewsletter?ChacoPage2.html

Chaco in the News, Conservation Group: Chaco Canyon endangered
http://members.aol.com/mjhinton/chaco/chaconews.htm

Map 1 http://members.aol.com/mjhinton/graphics/regionmaplg.jpg

Chaco Canyon in photographs
http://www.ncafe.com/4corners/roads.html
http://members.aol.com/mjhinton/chaco/
http://members.aol.com/mjhinton/chaco/9905/index.html

TIMS images of Chaco Canyon, New Mexico
http://www.ghcc.msfc.nasa.gov.archeology/chaco_compare.html

Module 4, Investigation 1: Briefing 1

Photographs—Chaco Canyon

Study the photographs to identify physical features of the region. What is the land like? What type of climate exists in this region? The photographs show some evidence of ancient and modern human occupation. What features are from the ancient Anasazi culture? What features show modern changes to the environment?

Fajada Butte in Chaco Canyon

Hungo Pavi Trailhead

Pueblo Del Arroyo from the South Gap

http://members.aol.com/mjhinton/chaco/9905/index.html

Module 4, Investigation 1: Briefing 2

Who were the Anasazi?

Use this briefing to study maps and remotely sensed images to learn about the culture of the Anasazi and the physical geography of the region inhabited by the Anasazi.

The Anasazi built their towns, or pueblos, between 1100 and 1300 A.D. near the Chaco River and Canyon in northwest New Mexico.

http://www.cr.nps.gov/worldheritage/chaco.htm

The dwellings were built out of sandstone blocks and mud to create small rooms. There were few doors on the ground level.

Pueblo villages had underground chambers called kivas. Kivas were used for council meetings and religious ceremonies. The pueblos appear to be the centers of communities.

In the past, it was believed that Chaco Canyon was a major city and ceremonial center. New interpretations indicate that there were few permanent residents and that it was a religious or ceremonial center to which the Anasazi traveled.

Geoarchaeologists have learned about the Anasazi lifestyle from artifacts found in and around the cliff dwellings. Items found include bows and arrows, clothing, and wooden implements. The Anasazi were farmers. They grew beans, squash, corn, cotton, and tobacco on the mesas above them or on the flat canyon bottoms. They hunted deer and mountain sheep. Dishes and bowls were made of clay pottery painted with red and black designs. Summer clothing was made from cotton, milkweed, and yucca fibers. In winter, fur robes and blankets made of turkey feathers kept them warm.

Evidence of an elaborate road system has emerged through the use of remotely sensed images. Many remnants of a road system have been found, some only after using the images to predict where they might be. Wide, paved roads were laid out in straight lines, despite the canyons, mesas, and hills. The Anasazi used no carts or work animals, so the size and condition of the roads is a mystery.

Figure 1

http://www.ghcc.msfc.nasa.gov/archeology/chaco_compare.html

Module 4, Investigation 1: Briefing 2

Who were the Anasazi?

Figure 1 is a remotely sensed image of the Chacoan region. Ancient Anasazi roads, detected using TIMS (thermal infrared multispectral scanner), are represented in red. The yellow lines are modern roads.

As you can see in Figure 2, the region is, for the most part, a plateau but is deeply cut by old rivers, creating a rough terrain and many mesas. Today the region has a dry climate with shrub and small tree growth on the top of the mesas.

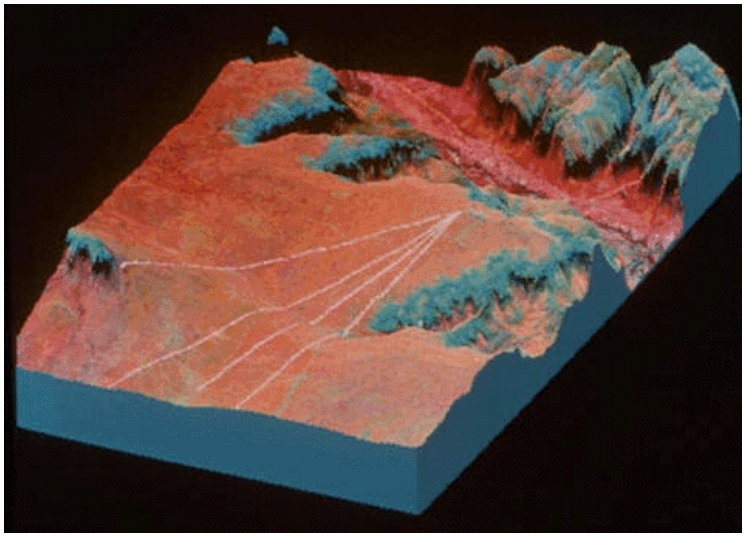


Figure 2: Chaco Canyon, looking from the southwest

http://www.ghcc.msfc.nasa.gov/archeology/chaco_canyon.html

Geoarchaeologists do not understand many parts of the Anasazi culture. For example, they do not know why the civilization disappeared around 1300. There are three commonly held theories. One is that the climate changed very drastically in a short time. This may have caused severe drought or loss of food supply. In order to survive, the Anasazi moved to where water was more dependable from year to year. Another theory is that the Anasazi, a seemingly peaceful group, were attacked by more warlike people. They perished (although there is no evidence of burials or bones) or they moved, giving up their homes and their land. A third theory is that the Anasazi population grew and exceeded the carrying capacity of this arid region. There may have been too many people and too few resources.

In 1999, the National Park Service declared this region a "vanishing treasure." Uncovering the ruins of this ancient civilization has exposed buildings and foundations to erosion from rain and freezing and thawing. There is also deterioration from tourists who walk through the dwellings.

The Park Service is unsure as to the next course to take: close the ruins altogether to public viewing, limit the number of visitors per year, or cover up the ruins so they are no longer exposed to erosion.

Resources

Chaco Culture National Historical Park http://www.nps.gov/chcu/home.htm

Chaco in the News—Conservation Group: Chaco Canyon endangered http://members.aol.com/mjhinton/chaco/chaconews.htm

"Cliff Dwellers." *World Book Encyclopedia*. 1999.

Seaver, Tom. Presentation: Global Hydrology and Climate Center. Huntsville, Alabama, March 2000.

TIMS Image http://www.ghcc.msfc.nasa.gov.archeology/chaco_compare.html

The Anasazi Culture

Put a check in front of the statements which correctly describe the Anasazi culture.

_____ 1. Built homes from sandstone

_____ 2. Constructed roads

_____ 3. Grew agricultural crops

_____ 4. Had horses

_____ 5. Had pottery

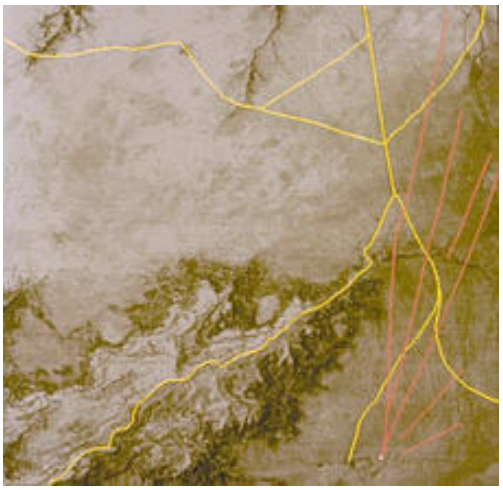
_____ 6. Roads followed the terrain

_____ 7. Square kivas provided dwelling accommodations

_____ 8. Warlike people

Module 4, Investigation 1: Log 1

Comparing maps and remotely sensed images



The image at the left shows the Anasazi roads in red and the modern roads, which follow the terrain, in yellow.

http://www.ghcc.msfc.nasa.gov.archeology/chaco_compare.html

Objective

In this investigation, you learn how to determine scale and direction on unmarked aerial images. You also explore new insights about the Anasazi by analyzing remotely sensed images.

Part I. Determining a Scale

You need

- colored pencils
- a ruler
- Map 1
- Map 2

Map 1 is a modern road map of the Chaco Canyon region in northwestern New Mexico. Map 2 is a map of ancient Anasazi settlements and roads in relation to present-day features.

To help you orient yourself to the maps, it is suggested that you color the maps as follows:

On Map 1

- Locate the following cities and highlight them in red: Shiprock, Farmington, Gallup, Cuba, Grants.
- Circle the Chaco Culture National Historical Park with a yellow pencil.
- Circle Aztec Ruins and Salmon Ruins in yellow.
- Trace over modern roads in red.
- Trace over prehistoric roads in yellow.
- Trace over rivers in blue.

On Map 2

- Circle the Chaco Core with a yellow pencil. Color in the outlier settlement symbols in yellow.
- Add and label Aztec Ruins and Salmon Ruins in yellow.
- Sketch in modern roads in red.
- Trace over prehistoric roads in yellow.
- Trace over rivers in blue.
- Use shades of tan and brown to shade in the mountains, plateaus, and mesas.

Use Maps 1 and 2 to complete the following statements.

1. Map 2 does not name the outlying settlements. The Anasazi roads on this map have been grouped and identified by direction. Find the group of roads marked A.

   Look at Map 1. Can you find the same Anasazi pattern of roads running northward from the Chaco Culture National Historical Park? Notice the angle in the road as it gets close to Salmon Ruins. Find this angle on both maps.

   On Map 2 the end of the Chacoan road is at the outlying settlement named:

   _____

Module 4, Investigation 1: Log 1

Comparing maps and remotely sensed images

2. Map 2 has a scale of kilometers and a directional arrow, but Map 1 does not.

   On Map 2, with your ruler measure the distance of the longest Chacoan road from the vertex of A to the farthest outlier point at Salmon Ruins. Compare the distance to the scale of kilometers.

   The road measures _____ cm and equals _____ km.

3. Now measure the same road on Map 1 with your ruler.

   The road measures _____ cm.

   Is this **more, the same**, or **less** than the measurement on Map 2? _____

4. Create a scale of kilometers and directional arrow on Map 1.

Part II. How Are Known Chacoan Roads Related to the TIMS Images?

The Anasazi developed extensive and elaborate road systems connecting communities and resources. In the Chacoan culture, more than 645 kilometers of prehistoric roadways have been identified. The roads connect 75 known communities.

Many of these roads are not visible from ground level. They were not detected from aerial photographs or color infrared photographs. Not until the use of TIMS did the ancient Anasazi road system become visible.

Chaco was at the center with roads radiating outward in many directions as seen on Maps 1 and 2. The longest identified road is one stretching from Bonito to the Salmon and Aztec communities. The north-south routes had settlements spaced apart at intervals of one day's travel time.

The roads were not simple trails. They were planned, constructed of stone, and maintained. They averaged about 9 meters wide. If the roadbed needed to be filled in to make it level, rocks were used to form a retaining wall so the soil would not wash out. In areas of bedrock, a masonry wall or line of boulders marked the edges of the roads.

Geoarchaeologists believed that the roads were used for transportation of goods and for communication between communities. Evidence suggests that Bonito was not the center of the population. It appears to have had only 25–30 permanent residents. The roads to Bonito may have been ceremonial. Although the maps show the roads reaching outliers, new interpretations suggest that the roads may have been used for ceremonial processions to sacred destinations. They often lead to topographic features, such as mountain crests. At these mountain crests, much broken pottery has been found. There may be a religious connection between the pottery and these significant ending points of the roads.

Figures 2 and 3, on the following page, show the same location. Different colors were assigned to the data. As you compare the two images, notice that features can be seen better by using different colors.

Module 4, Investigation 1: Log 1

Comparing maps and remotely sensed images

Figure 2

Figure 3

http://www.ghcc.msfc.nasa.gov/archeology/chaco_compare.html

Answer the following questions about the TIMS images. Refer to Maps 1 and 2 for reference points and additional information.

1. What does the mottled (darker, textured) area show?

   _____

2. The straight lines in Figure 2 are Chacoan roads. The brighter lines on Figure 3 are current roads. How are the Chacoan roads and current roads similar?

   _____

   _____

3. Why are there differences between the routes of current roads and ancient Chacoan roads?

   _____

   _____

4. Compare the current roads marked on TIMS Figure 3 with the terrain of Map 2. Complete the following sentence (select the phrases which complete the statement correctly):

Chacoan roads	run in straight lines	follow the terrain
	whereas	
current roads	run in straight lines	follow the terrain

5. Using the directional arrow on Map 2, match Chacoan roads and put a directional arrow on the TIMS Figures 2 and 3.

Are these images oriented in the same direction as the maps? _____

References

Baker Aerial Archaeology's Chaco Project
http://www.mia.com/~jaybird/AANewsletter/ChacoPage2.html

Chaco Culture National Historical Park
http://www.cr.nps.gov/worldheritage/chaco.htm
http://www.nps.gov/chcu/roads.htm

Chaco in the News—Conservation Group: Chaco Canyon endangered http://members.aol.com/mjhinton/chaco/chaconews.htm

Seaver, Tom. Presentation: Global Hydrology and Climate Center. Huntsville, Alabama, March 2000.

TIMS images of Chaco Canyon, New Mexico
http://www.ghcc.msfc.nasa.gov.archeology/chaco_compare.html

Module 4, Investigation 1: Log 2

Should Chaco Canyon be preserved?

The photograph at the left shows the ruins of a village.

Source: http://members.aol.com/mjhinton/chaco/9905/index.html

Objective

In this part of the investigation you review the conditions at Chaco Canyon that make it an endangered site. After taking a survey of public opinion, you recommend what action should be taken to preserve the site.

Close the Park?

Closing the park to tourists is an option to preserve the ruins. Prohibiting tourists would protect the ruins from wear and tear and vandalism. Also, the ruins could be protected from weather damage by covering them.

The chief ranger at Chaco Canyon National Historic Site has received many letters from tourists who think that the entire site should continue to be open to visitors. He has also received information from preservation groups, indicating that the Chaco ruins are in danger of disappearing.

Find out how others think about preservation of a national historic site. Here are two ways to do this:

1) Select a class or group in your school to survey. Arrange a time with the teacher when you might speak to the class or distribute information regarding Chaco Canyon. Be sure to discuss the alternatives to preservation.

Survey the class about what they think should be done:

- Should Chaco Canyon be closed to visitors?
- Should only selected archaeological sites of Chaco Canyon be open to the public, while others are closed to public viewing ?
- Should all archaeological sites in Chaco Canyon be open to the public?

Remember to ask the survey group to state reasons for their selection.

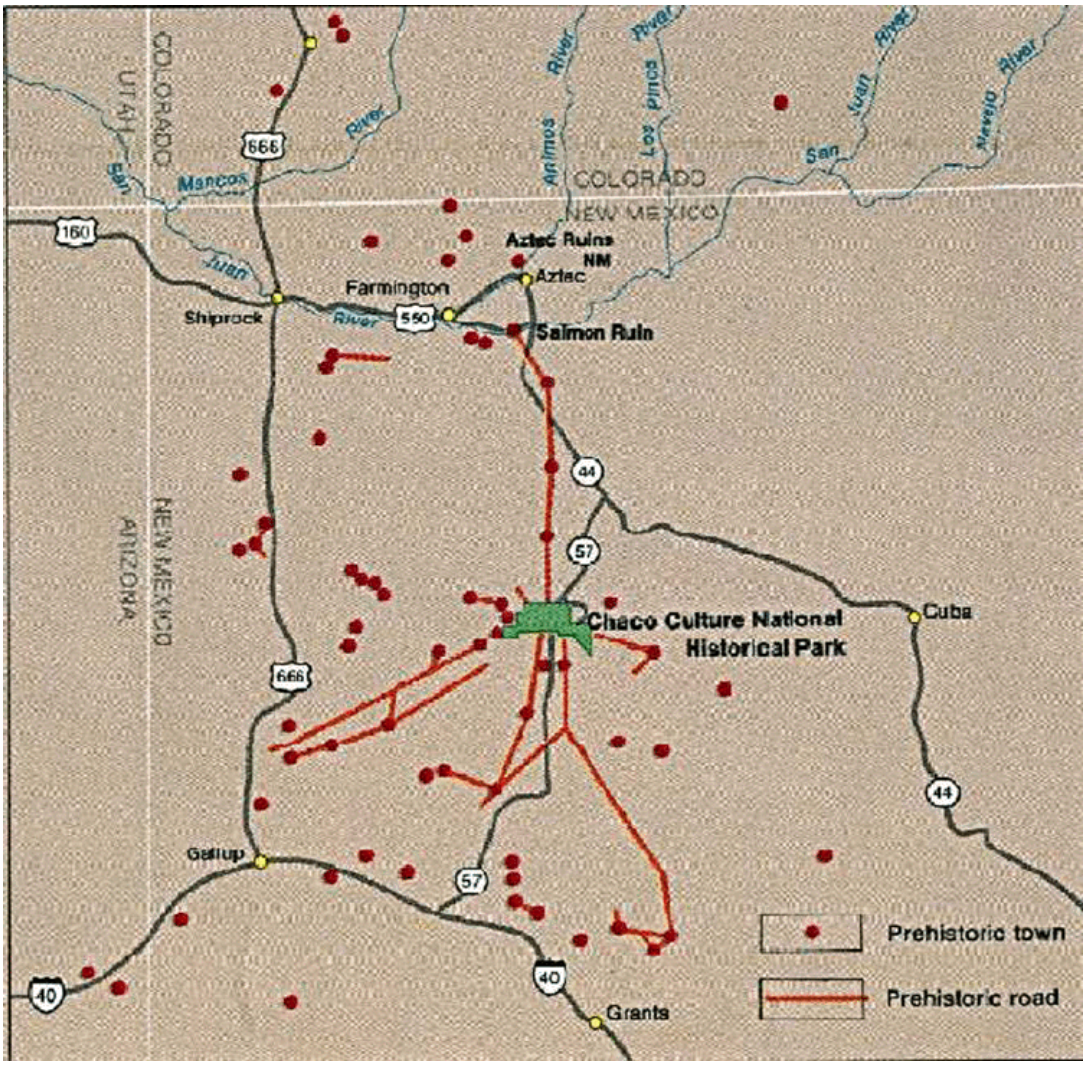
2) Prepare a one-page flyer and survey to distribute in school. The flyer should summarize key issues related to preserving Chaco Canyon and the survey questions. Hand it out to students at a time and place to ensure a high rate of return.

Compile the results of your survey and draw conclusions about public opinion. Write a recommendation concerning the preservation of the ruins to the chief ranger of the Chaco Culture National Historical Park.

- Include a summary of what you learned while studying Chaco Canyon.
- Include a summary of the survey results and conclusions.
- Make a recommendation concerning future action.

Module 4, Investigation 1: Map 1

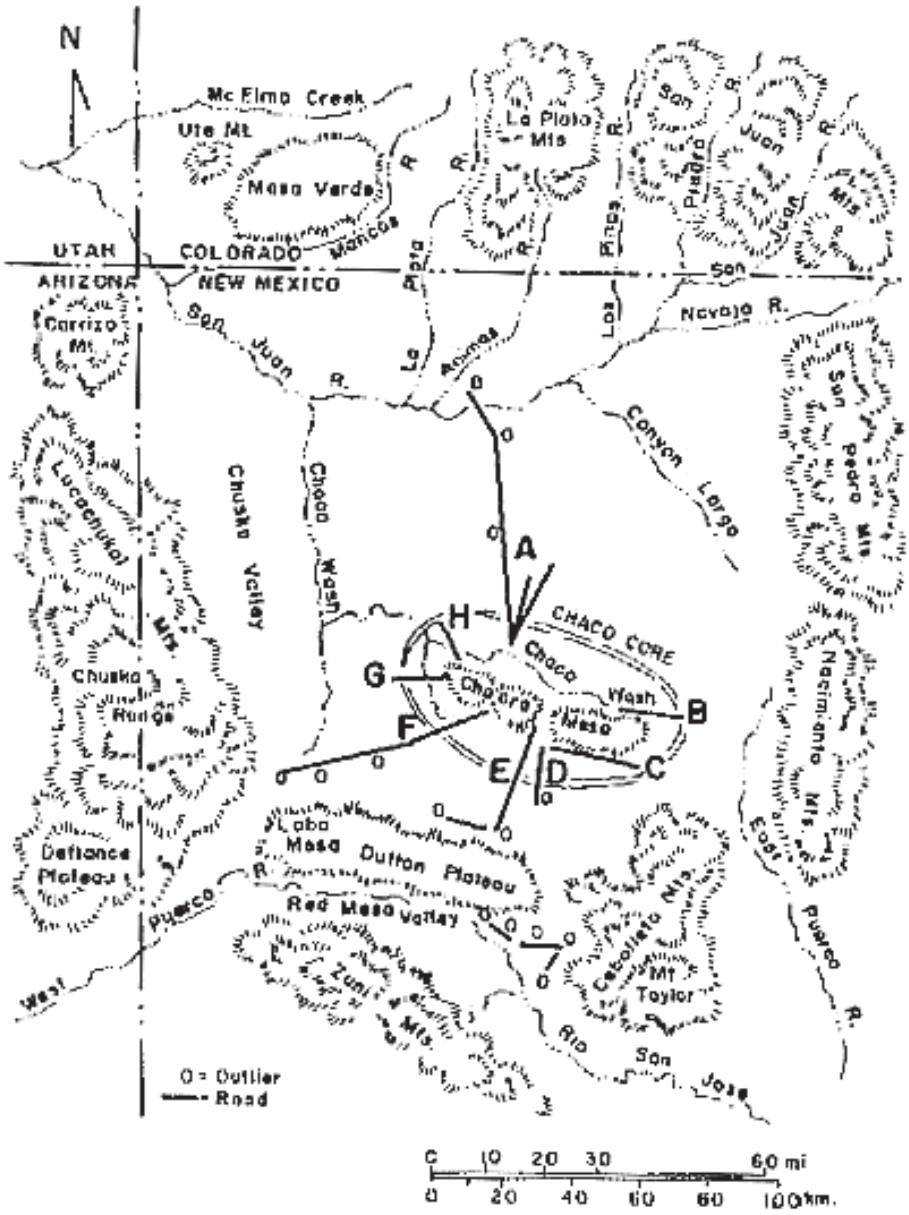
Modern road map of Chaco Canyon region



http://members.aol.com/mjhinton/chaco/maps.htm

Module 4, Investigation 1: Map 2

Map of ancient Anasazi outlier settlements and roads



http://www.nps.gov/chcu.roads.htm

Module 4, Investigation 1: Log 3
In conclusion

Briefly describe how each of the following graphics in Investigation 1 are helpful to a geoarchaeologist.

1. Photographs of Site

_____

_____

2. Map 1

_____

_____

3. Map 2

_____

_____

4. TIMS Image 1 (Figure 2)

_____

_____

5. TIMS Image 2 (Figure 3)

_____

_____

6. What do you think should be done regarding preservation of Chaco Canyon Historic Site? Support your answer.

_____

_____

_____

_____

_____

_____

How do geoarchaeologists use remote sensing to interpret landscapes?

Investigation Overview

In this investigation students learn the seven elements geoarchaeologists and specialists in remote sensing use to detect significant human and physical features. They apply these elements to analyze an image to learn more about ancient Egypt.

Time required: Two 45-minute sessions

Materials/Resources

Logs (one of each per student)
- Log 1: What features do geoarchaeologists look for on an image?
- Log 2: How do interpretive elements help us determine what the image is showing?
- Log 3: In conclusion

World map
White paper
Colored pencils

Content Preview

Traditional techniques of finding archaeological evidence include: locating and studying surface structures, studying aerial photographs, researching documents, and digging. Geoarchaeologists now use remote sensing techniques to look for information not yet detected using traditional techniques. They analyze images to discern where cultural evidence has been covered by sand, by vegetation, or by subsequent human occupation.

Classroom Procedures

Beginning the Investigation

1. Explain to students that remote sensing is the science of identifying, observing, and measuring an object without coming into direct contact with it. The process involves the detection and measurement of radiation of different wavelengths reflected or emitted by distant objects or materials. This data helps a remote sensor to identify substances and to categorize them by class, type, and spatial distribution. A primary use of remote-sensing data is to classify the variety of features in a scene, usually presented as an image. The image can then be used to create a thematic map, such as a land use map, a vegetation

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

- Describe the essential characteristics and functions of maps and geographic representations, tools, and technologies.

Geography Skills

Skill Set 4: Analyze Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.

map, or a rainfall map. A farmer might use thematic maps to monitor the health of his crops without going into his fields. A biologist might want to study the variety of plants in a large area. And a geoarchaeologist may use remotely sensed images to discover evidence of past human occupance in a region.

2. Identify and discuss how geoarchaeologists find locations of ancient cultures. Discuss new techniques.

3. Introduce the following terms: ground (eye) level view, oblique view, aerial view, tone, shape, size, pattern, texture, shadow, and association. Explain that these terms are used by geoarchaeologists as they examine remotely sensed images to discover information about the past.

Developing the Investigation

4. Distribute **Log 1**. Lead the class through the Log. As you look at the remotely sensed images for the interpretive elements, display the first image (Tone) in color. Have students discuss the questions before writing answers. Continue with each interpretive element in a similar manner.

5. Have students form into groups of three to four to work on **Log 2: Part I**. Display (or distribute) the image for Part I. Assign each group one of the interpretive elements. Have students study the image and complete the chart

6. Have students discuss the information they put on the chart and add additional details and information to help them better understand the image.

7. Have students continue working to complete the statements in **Log 2: Part II**. Review map-reading and map-making skills before students draw a sketch map of the remotely sensed image. Discuss responses to the questions and share the different ways students interpreted the image into a sketch map.

Concluding the Investigation

8. Have students individually complete **Log 3: In conclusion.**

Background

Geoarchaeologists look for information about the past by searching for and researching historic sites. They research the landforms, climate, and aspects of the ecosystem. Finally, they try to determine why environments change. Other geoarchaeologists specialize in human history by focusing on ancient cultures, colonial history, or the industrial era. They look for evidence that helps them put together a story of what life was like. Earth is too big to look randomly for sites. Geoarchaeologists use clues from writings or oral histories to select regions for further investigation.

Traditional techniques of finding archaeological evidence include:

- locating and studying surface structures, such as the pyramids, Anasazi ruins, Stonehenge;
- studying remotely sensed images and aerial photographs for traces which indicate human occupation, such as plow scars or old drainage or irrigation systems;
- researching documents for information that tells about the culture, such as a ship's logs and diaries; and
- digging to uncover artifacts left behind, such as in dry wells or garbage pits.

Geoarchaeologists now use sophisticated remote sensing techniques to discern where cultural evidence has been covered by sand, by vegetation, or by subsequent human occupation. Log 1 provides background on the seven interpretive elements used to analyze images. In addition, global positioning systems (GPS) pinpoint the locations of buildings and other cultural evidence. Geographic information systems (GIS) are used to map the data.

Evaluation

Log 1

Tone: tans, some blue and red, yellow
Brightest: yellow
Showing: roads
Shape: rectangle, square
Showing: buildings, reservoirs
Size: two-lane unpaved road
Connecting line: driveway
Pattern: water/rivers
Rectangular pattern: fields
Texture: trees (rain forest)
Vegetation: crops
Shadow: pyramids
Shape: square
Sides: 4
Shape: triangular
Tallest: Great Pyramid of Khufu
Association: water (a reservoir)
Other: water (canals)
Features: human made
Use: transportation; to store water

Log 2

Chart: Answers will vary. Some suggested answers are:
Tone: magenta and green dominate the image; a white streak runs across the image, and thin red streaks are visible
Shape: round, bumpy-looking features in magenta area; white streak has a fan-shape at one end
Size: red streaks are much smaller than the white streak; the bumpy features are all about the same size
Pattern: red lines converge into middle of image; white streak travels across the image; distinctive break between the magenta and green colors
Texture: magenta—bumpy; green—uneven, disrupted
Shadow: little to none; some shading in the green and on one side of the bumpy features in the magenta may be shadows
Association: red and white streaks are not the same feature, but may be related as red leads to center of the white streak

Questions

1. Tone: a
2. Shape: a
3. Size: c
4. Pattern: a
5. Texture: a
6. Shadow: c
7. Association: b
8. c

Log 3

1. Different interpretive elements on the images help geoarchaeologists determine features. Color is not always a good indicator of what a feature is because water may not be blue and plants may not be green. The interpretive elements are: **Tone**, which shows colors; **Shadows**, caused by the angle of the Sun and helps determine size of features; **Association**, what is around the specific features of interest; **Texture**, how the tone appears, for example, blotchy or smooth; **Shape**, which might help to determine whether the feature is natural or human made; **Size**, objects in relation to each other, using shadows to determine; **Pattern**, regularity of a texture or feature

2. Reading an image is similar to reading a map because you use similar skills and apply the same processes. You need to orient the remotely sensed image (know where the direction of north is) and have a sense of scale (for size of the region shown, as well as measuring distances). You might use a reference system to locate the image, and it is important to understand what the colors represent.

Additional Resources

Aerial photographs and satellite images (booklet) USGS. 1997 September.
Archeological remote sensing http://www.ghcc.msfc.nasa.gov/archeology/remote_sensing.html
Archeological remote sensing electromagnetic spectrum http://www.ghcc.msfc.nasa.gov
Putting NASA's earth science to work: Remote sensing applications (booklet) Upper Marlboro, Maryland: Raytheon Systems Company. n.d.
The technical page: Nuts & bolts of aerial archaeology http://www.nmia.com/~jaybird
Tom Sever: Off-planet archeology http://www.omninag.com/archives/interviews/sever.html
Understanding the biosphere from the top down http://geo.arc.nasa.gov/sge/jskiles/top-down/intro_product/Investigations-by-module.html

Module 4, Investigation 2: Log 1

What features do archaeologists look for on an image?

What are the seven elements used by geoarchaeologists to analyze and interpret remotely sensed images?

Geoarchaeologists face several issues when using remotely sensed images. They must determine the location on Earth, the height of objects, the scale of the image (based on the distance and the angle from which the image was sensed), and what the images show from the size and resolution of the image. These skills are similar to those used in reading a map. Perhaps the most important skill is analyzing the colors and patterns on a remotely sensed image.

Identifying Detail on Remotely Sensed Images

Seven interpretive elements help geoarchaeologists analyze an image:

- tone
- shape
- size
- pattern
- texture
- shadow
- association

Below are descriptions and examples of each element, followed by several questions to help you focus on what you see.

TONE

is the brightness or the color of objects in an image. It is a very important element in distinguishing target objects.* Different types of imaging (radar, infrared, photographic) record different types of energy reflected or emitted by the target. Whether true color, as on a photograph, or false color imaging, a target stands out.

*A target object is the geographic feature the geoarchaeologist is looking for, like a road or a building.

Chaco Canyon
http://www.ghcc.msfc.nasa.gov/archeology/chaco_compare.html

List the tones (colors) on this image. _____

Which tone is the brightest? _____

What do you think this bright color is showing? _____

Module 4, Investigation 2: Log 1

What features do archaeologists look for on an image?

SHAPE

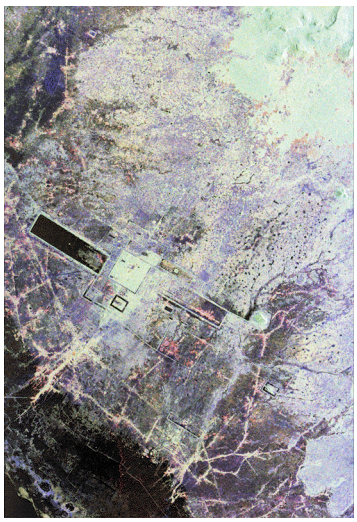
is the general form or outline of an object in an image. Shape helps distinguish an object. Most human-made objects have regular geometric shapes and edges, such as roads, buildings, and agricultural fields. Natural features typically have an irregular shape, such as a forest or a natural lake, although some natural features such as glacially formed lakes have fairly regular shore-lines.

List geometric shapes in this image:

_____

_____

_____



Ankgor, Cambodia
http://www.jpl.nasa.gov/radar/sirsxsar/angkor.html

What do you think is being shown by the shapes?

_____

_____

SIZE

of a target object relates to scale. Object size can be compared and measured using shadow length of known features. Size of objects is related to the distance from which the image is sensed and the type of sensor used.

Aureole of Chacoan Culture
http://www.nmia.com/~jaybird/AANewsletter/ChacoPage2.html Used with permission T. Baker

The lines crossing the aureole (circle) are automobile tracks.

Using this information, determine the width of the road that crosses the photo from left to right. Circle which size tracks that you think that they are:

- automobile tracks
- two-lane unpaved road
- four-lane highway

What is the line connecting the homestead (in the upper right corner) with the road?

_____

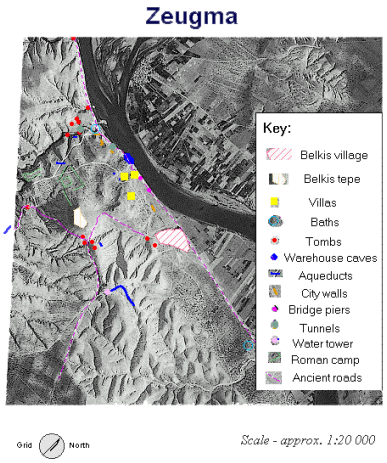
_____

Module 4, Investigation 2: Log 1

What features do archaeologists look for on an image?

PATTERN

is the spatial arrangement of objects in an image. An arrangement of lines or objects regularly spaced, such as streets in a city, is a pattern.



Euphrates River and Zeugma, Turkey
http://www.ist.lu/ele/html/department/zeugma/html/maps/gis1.html

The Euphrates River is the dark thick line which flows through the center of this photograph. On the left side of the river, the drainage branches form a pattern known as dendritic. Look carefully to notice that the "little branches" all flow into another branch which eventually flows into the Euphrates River.

This pattern is associated with what type of physical geographic feature?

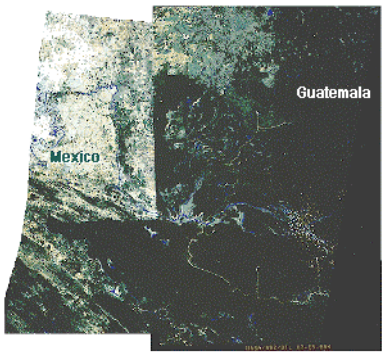
_____

On the right side of the Euphrates River is a more rectangular pattern. What do you think this pattern shows?

_____

TEXTURE

refers to the pattern and tones in an image. Rough textures reflect energy and produce irregular, uneven images. This might be the top of a rain forest where trees are not the same height, a mountainous region, or soil with different amounts of water content. Smooth textures have surfaces with similar objects evenly mixed, such as a field of wheat, a parking lot, or grasslands. Texture is one of the most important elements in analyzing radar imagery.



Deforestation in the Petén

Deforestation in the Petén, Guatemala
http://www.ghcc.msfc.nasa.gov/archeology/peten.html

This image of the Petén has a very straight edge on it. In Guatemala, the Petén is a protected rain forest. In Mexico, land has been cleared of rain forest.

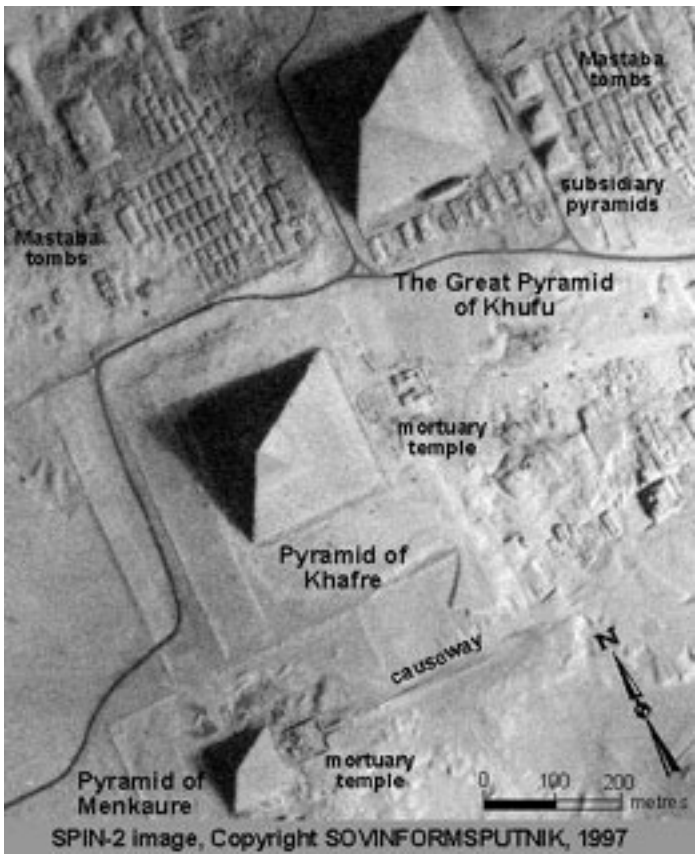
What vegetation does the darker texture show: rain forest or cleared land? _____

What vegetation does the lighter texture show? _____

Module 4, Investigation 2: Log 1

What features do archaeologists look for on an image?

SHADOW
is produced by the angle of the Sun and the angle of the equipment recording the image. A slightly oblique (side) view of a site often produces a shadow. Shadows are used to determine heights of objects.



Pyramids at Giza, Egypt
http://ourworld.compuserve.com/homepages/mjff/giza_kvr.htm

This photograph was taken at an oblique angle. The shadows on the target objects clearly show that they are _____ .

If you looked at the pyramids from directly above they would appear as what shape?_____

Because this photograph is taken at a slightly oblique view, you clearly see that these three main pyramids have _____ sides, each with a _____ shape.

Using the shadow as a guide, which pyramid is the tallest?

_____

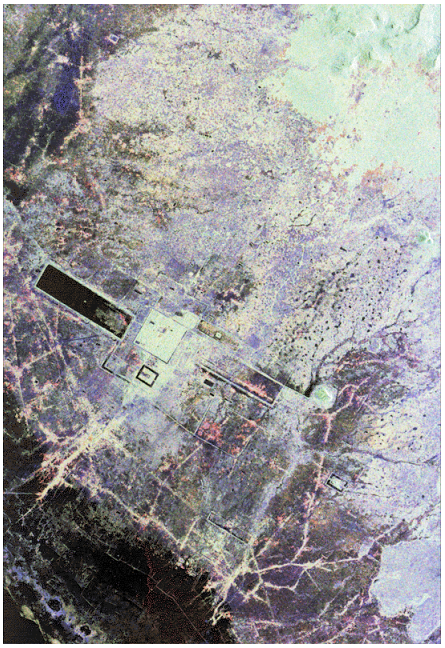
Module 4, Investigation 2: Log 1

What features do archaeologists look for on an image?

ASSOCIATION

is the relationship between recognizable objects and unrecognizable objects. Making an association allows the identification of objects which, by themselves, would not be recognized in an image. For example, many schools have playgrounds or ball fields. If the school building is recognizable, then the patch of ground near it can be identified. The reverse is also true—ball fields and parking lots may be used to identify a school building.

The dark area in the southwest corner is Tonle Sap, a lake in Cambodia. If we know that this smooth textured dark color is water, we may identify other water bodies on this image. Look carefully at the left center of the image. There is a large dark rectangle. We now associate this texture and tone with the lake.



Angkor, Cambodia
http://jpl.nasa.gov/radar/sircxsar/angkor.html

The large dark rectangle is _____
Near this rectangle are two more similar thick lines of similar tone and texture. One looks like an L; the other is a dark line around a light-colored square.

These are also _____

Are these three features natural or human made? _____
(Remember that natural features are usually irregular and that human-made features often have a regular geometric shape.)

What might these features have been used for? _____

_____

References

Angkor, Cambodia
http://jpl.nasa.gov/radar/sircxsar/angkor.html
Chaco Canyon
http://www.nmia.com/~jaybird/AANewsletter/ChacoPage2.html
http://www.ghcc.msfc.nasa.gov/archeology/chaco_compare.html
Giza, the Great Pyramids, Egypt
http://ourworld.compuserve.com/homepages/mjff/giza_kvr.htm
The Petén
http://www.ghcc.msfc.nasa.gov/archeology/peten.html
Project Zeugma
http://www.ist.lu/ele/html/department/zeugma/html/maps/gis1.html

Module 4, Investigation 2: Log 2

How do interpretive elements help us determine what the image is showing?

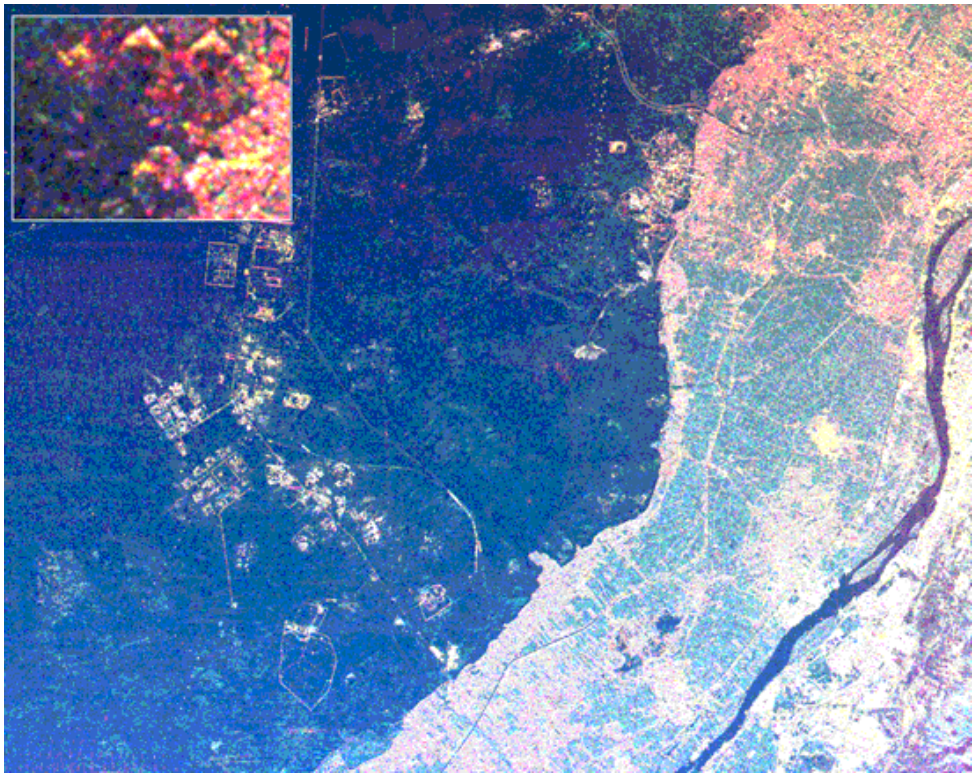
Objective

In this lesson you use interpretive elements to analyze a remotely sensed image.

Part I

In groups, study the image carefully.

This is an image of a very famous archaeological site of an ancient river valley culture. In this image it is easy to recognize the river (dark line in lower right of image). It is located in a very dry region of the world.



Module 4, Investigation 2: Log 2

How do interpretive elements help us determine what the image is showing?

Use the interpretive elements to identify what you are seeing. Record your observations for each category. Refer to the definitions and examples in Log 1 if you need help.

Tone	
Shape	
Size	
Pattern	
Texture	
Shadow	
Association	

Module 4, Investigation 2: Log 2

How do interpretive elements help us determine what the image is showing?

Part II

Make decisions based on your analysis of the image. Circle the answer that completes the statement.

1. Tone: Don't be fooled by what's light and what's dark on this image. Very light Earth colors look very dark in this image. Because this is a dry region, the river would have been used for many purposes.
   The lighter region along the river is
   a. agricultural land.
   b. desert.
   c. urban development.

2. Shape: Along the top edge of the image just to the left of the light region are three shapes. There is an inset image in the upper left-hand corner which shows an enlarged image of these three objects.
   The shape of these objects indicates they
   a. were used for a similar purpose.
   b. all had different uses.
   c. have no connection to each other.

3. Size: The light area to the left of the river is approximately 10 times as wide as the river. The dark area is much greater than this.
   The light area represents
   a. open space.
   b. desert.
   c. the river valley.

4. Pattern: Within the light tones and the dark tones, there are visible lines.
   These lines
   a. connect places and are roads.
   b. are tributaries to the river.
   c. connect places and are canals for transportation.

5. Texture: Whether light or dark, the texture is not smooth. It has a rough appearance.
   The differences between the shades of gray on any part of the image might be
   a. vegetation.
   b. water in the soil.
   c. houses.

6. Shadow: Concentrate on the enlarged inset image. If you look carefully at the three shapes, there is a shadow on each one. The shadows help us determine that the bases of these objects are
   a. rectangular.
   b. triangular.
   c. square.
   d. circular.

7. Association: Your ground-truthing team reports that these three objects are actually tombs. You can conclude that these objects are
   a. Hammurabi's Hanging Gardens.
   b. the Great Pyramids.
   c. Roman ruins.
   d. ziggurats in Mesopotamia.

8. You identify this image of an ancient river valley as part of the
   a. Indus River Valley.
   b. Euphrates and Tigris River Valley of Mesopotamia.
   c. Egyptian Nile River Valley.
   d. Huang He River Valley.

9. Can you determine what the image shows?

   _____

   _____

   _____

   _____

   _____

Module 4, Investigation 2: Log 3

In conclusion

1. How does remote sensing help geoarchaeologists read the landscape? Be sure to include information about the interpretive elements.

2. How is reading a remotely sensed image like reading a map? Be sure to include all of the map-reading skills.

How does remote sensing search for the geographies of the past?

Investigation Overview

Students explore how a radar sensor detects previously unknown ancient sites in Guatemala. They find relationships between remotely sensed images and ground-level photographs of a site and recognize the role of geography in understanding the physical and cultural features of a region. Students discover the differences among aerial, oblique, and ground-level images. This investigation includes a culminating activity that requires access to computers and the Internet.

Time required: Three 45-minute sessions

Materials/Resources

Copies of the following for each student:

- Log 1: Gaining different perspectives
- Briefing 1: Background on the Petén and ground truthing
- Log 2: Ground truthing in the Petén
- Briefing 2: Ground truthing and the geography of sites
- Log 3: Checking it out on the ground
- Log 4: Ground truthing
- Log 5: Writing your own ground-truthing log
- Log 6: In conclusion

Student world atlas (one per student)
Colored pencils
Lined paper (or graph paper) for each student
One ruler for each student
One three-dimensional object (blocks or doll house furniture works well) for each group of students

Content Preview

Remotely sensed images and photographs have different perspectives: aerial, oblique, and ground level. An aerial view is referred to as "bird's eye." An oblique view is an angled view. Ground truthing, also called referencing, is the exercise of field work to verify the interpretation of imagery.

Classroom Procedures

Beginning the Investigation

1. Display a three-dimensional object in front of the class. Ask how it appears from different angles. Introduce the terms aerial view, oblique view, and ground-level view using the object to demonstrate the three perspectives. Have students follow the procedure outlined in **Log 1**.

Geography Standards

Standard 1: The World in Spatial Terms

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

- Describe the essential characteristics and functions of maps and geographic representations, tools, and technologies.

Standard 4: Places and Regions

The physical and human characteristics of places

- Analyze the physical characteristics of places.
- Analyze the human characteristics of places.

Geography Skills

Skill Set 2: Obtain Geographic Information

- Systematically observe the physical and human characteristics of places on the basis of fieldwork.

Skill Set 4: Analyze Geographic Information

- Interpret information obtained from maps, aerial photographs, satellite-produced images, and geographic information systems.

Skill Set 5: Answer Geographic Questions

- Make generalizations and assess their validity.

2. Introduce the term "ground truthing." After using maps, documents, and remotely sensed images, geoarchaeologists need to verify features observed on an image. They search on the ground for features seen from above.

3. Distribute **Log 2** and **Briefing 1** and **2**. Ask students to read **Briefing 1** and answer the comprehension questions as an opening for discussion about ground truthing. Discuss the following points with students.
   - High resolution images are more accurate than low resolution images because they can detect and measure smaller features.
   - On the ground, research teams rely on local maps and people to help them locate features on images.
   - Global positioning systems (GPS) are used to pinpoint exact latitudes and longitudes of sites.
   - Ground truthing is tedious and even dangerous. Many ancient sites in Central America are covered with dense forest with no access to them. In some areas, geoarchaeologists have met hostile populations.

Developing the Investigation

4. In preparation for the next activity, ask students to read **Briefing 2**. Read and discuss the various perspectives of viewing an object featured in **Briefing 2**.

5. Distribute **Log 3** and atlases. Organize students into groups to complete the chart. When students have completed the chart, distribute **Log 4**. Students will match the photographs and remotely sensed images to the locations in the chart. When they have completed the last column by noting ground-truth evidence from the photos, discuss the importance and value of ground truthing and remote sensing to geoarchaeological research.

6. If you wish to have students complete an Internet-based research project, continue with this final portion of the investigation. Review some guidelines and suggestions for writing a field research log in **Log 5**. Refer to the readings about the Petén and review the ground-truthing expedition. Select an archaeological site for each research team, other than the Petén. (Suggestions: Chaco Canyon in New Mexico, Arenal Region in Costa Rica, Ubar in Oman, Angkor in Cambodia, Mirador in Guatemala, Zeugma Project in Turkey—See Additional Resources.) Using Internet resources, students should imagine they are a team of geoarchaeologists sent to ground truth the images. The groups should create a log about their ground-truthing experience, including remotely sensed images, maps, descriptions, photos, sketches, and personal experiences during the field experience.

Concluding the Investigation

7. Students present their ground-truth logs to the class.

8. Students complete **Log 6**.

Background

Aerial View

A bird's eye view, looking straight down on an object, is an aerial view. This is similar to flying in an airplane and looking out to see rooftops. Maps and remotely sensed images from space are often aerial views.

Ground-Level View

When looking at the side of an object or a building from eye level, you get a ground-level view.

Oblique View

When looking at objects or buildings at an angle, usually from above, where you see a side and the top, you have an oblique perspective.

Global Positioning System (GPS)

A global positioning system is a device that pinpoints the location of the unit by latitude and longitude. The location is reported in decimal units. The GPS unit receives signals from satellites. Reception from satellites, however, is dependent on whether the satellites are in appropriate positions.

Geoarchaeologists use GPS to accurately locate larger features. Locating features is difficult when field maps are inaccurate or outdated.

Evaluation

Log 2

1. b
2. d
3. c
4. a
5. b
6. T
7. T
8. F
9. F
10. T

Log 3

Preparing to visit a site: Use the chart below as a key.

Log 4

Photo identification:

Arenal Region, Costa Rica—Photo B
The Petén, Guatemala—Photo A
Ubar, Oman—Photo D
Angkor, Cambodia—Photo E
Zeugma, Turkey—Photo C

1. What do these sites have in common?
   Answers vary. Suggested responses: Transportation (footpaths, canals, rivers/bridges) seem to be important to all cultures for trade and communication. All are ancient cultures which have disappeared. People are able to adapt to hostile environments. All had large buildings without the aid of today's technology.
2. How does remote sensing help geoarchaeologists find features common to all ancient sites?
   Answers vary. Suggested responses: Unusual variations in the texture or color of a remotely sensed image may indicate human disturbance beneath tree cover or deserts.

	Climate/ Precipitation	Climate/ Temperature	Vegetation	Elevation/ Terrain	Ground-Truth Evidence
Cambodia	Tropical rainy Seasonal rainfall 150+ cm/yr	Always hot 21-32 °C (70-90 °F)	Broadleaf evergreen	Coastal plain, low relief 0-305 m	Much vegetation; water
Costa Rica	Tropical rainy over 200 cm/yr	Always hot 21-32 °C (70-90 °F)	Broadleaf evergreen	Mountainous, narrow coastal plain 0-610 m	Vegetation
Guatemala	Tropical rainy Seasonal rainfall 100-200 cm/yr	Hot summer, mild winter 21-32 °C (70-90 °F)	Broadleaf evergreen	Mountainous, narrow coastal plain 0-3050 m	Many trees, tree areas
Oman	Dry–desert under 25 cm/yr	Always hot 21-32 °C (70-90 °F)	Broadleaf deciduous, shrubform in groups or patches, other areas lacking vegetation	Coastal plain, low relief, some hills 0-610 m	Dry, sandy soil, no vegetation
Turkey	Dry steppe to Mediterranean Seasonal rainfall Great variability 25-150 cm/yr	Hot summer, cool winter 10-32 °C (50-90 °F)	Grass (in steppe); mixed deciduous and needle leaf	Mountainous 610-1525 m	Dry with sparse trees

Log 5

This activity is meant to be creative. Students are encouraged to research sites and read archaeology logs.

Check for

- accuracy of information;
- inclusion of remotely sensed information;
- information about the ancient culture; and
- use of current technology, like GPS and GIS, radar, etc.

Log 6

Answers vary. Here is a suggested answer:

1. Archaeological truth means using evidence of the past to reconstruct culture. Written documents, if available, provide data for reconstructing the past. However, in cultures which have disappeared, often evidence is lacking to prove the existence of the culture or to reconstruct ways of life.

   Until recently, geoarchaeologists relied on aerial photographs, sketches and maps, and written and oral stories to locate past cultures.

   Remote sensing is changing how geoarchaeologists search for evidence. By using false color images, they can highlight specific features and detect things never before seen. For example, dense vegetation prevented geoarchaeologists from being able to locate Mayan ruins in Central America. Through use of remote sensing, geoarchaeologists locate ruins never before seen. Microwave radar helps geoarchaeologists "see" into porous soils, leading to discovery of old caravan routes and settlements.

   Remote sensing helps geoarchaeologists decide where to send out ground-truthing expeditions to verify features seen in the images. Then "digging" begins. Remote sensing adds greater flexibility and accuracy to how geoarchaeologists search for the past.

2. Geography helps to understand the terrain, vegetation, and climate of regions. Also, climate factors indicate how well a site may be preserved. Dry sites are usually better preserved than wet sites. Landforms may also be important. Some sites are buried in volcanic ash. Other aspects of geography, like map skills, help geoarchaeologists interpret remotely sensed images.

Additional Resources

Angkor, Cambodia
http://www.jpl.nasa.gov/radar/sircxsar/angkor.html
Photos: http://www.csulb.edu/~kkeo/angkor/P024.html

Arenal Region, Costa Rica
http://www.ghcc.msfc.nasa.gov/archeology/arenal.html
Photo: http://www.ghcc.msfc.nasa.gov/archeology/arenal.html

Chaco Canyon, New Mexico
http://www.ghcc.msfc.nasa.gov/archeology/chaco_compare.html
Baker Aerial Archaeology's Chaco Project
http://www.mia.com/~jaybirdAANewsletter?ChacoPage2.html
Chaco in the News, Conservation Group: Chaco Canyon endangered
http://members.aol.com/mjhinton/chaco/chaconews.htm
Chaco Culture National Historical Park
http://www.cr.nps.gov/worldheritage/chaco.htm
http://www.nps.gov/chcu/roads.htm

The Petén, Guatemala
http://www.ghcc.msfc.nasa.gov/archeology/peten.html
http://www.ghcc.msfc.nasa.gov/archeology/peten_deforest.html
Photos: http://www.ghcc.msfc.nasa.gov/archeology/peten_groundtruth.html

Ubar, Oman
http://www.jpl.nasa.gov/radar/sircxsar/ubar1.html
Photos: http://observe.ivv.nasa.gov/nasa/exhibits/ubar/ubar_4.html

Zeugma, Turkey
http://www.ist.lu/ele/html/department/zeugma/home.html
http://www.ist.lu/ele/html/department/zeugma/remote.html
Photos: http://www.ist.lu/ele/html/department/zeugma/remote.html
http://www.ist.lu/ele/html/department/zeugma/html/photos/z04.htm

Module 4, Investigation 3: Log 1

Gaining different perspectives

You will need

- colored pencils,
- lined paper (or graph paper), and
- a three-dimensional object (supplied by your teacher).

1. Place an object on the floor. Look at it from directly overhead. Sketch it.

   This is an aerial view. Airplanes, satellites, the Space Shuttle, and the International Space Station can take aerial views of objects on Earth.

2. Place an object on a flat desk or table top. Stand to the side of the object. You should see both the top and one or two sides of the object. Sketch it. Add perspective to capture the shape more correctly.

   This is an oblique view. Airplanes, satellites, the Space Shuttle, and the International Space Station can also take oblique views of objects on Earth.

3. Kneel or sit down so you are looking directly at the side of the object. You should not see the top of the object. Sketch it.

   This is a ground-level view. Airplanes, satellites, the Space Shuttle, and the International Space Station do not take this type of view of Earth. It is what is typically seen by human eyes.

Module 4, Investigation 3: Briefing 1

Background on the Petén and ground truthing

The Petén, Guatemala

The Petén, northern Guatemala, was once inhabited by a population of several million Maya before the population collapsed in the 9th century A.D. The 7th and 8th centuries were the height of the Mayan civilization; by 930 A.D. only a few scattered houses remained. Scientists think that at the time the population collapsed, the Maya had deforested much of their region. Now after centuries of regrowth, the Petén is the largest tropical forest in Central America, but once again, it is experiencing rapid deforestation as new settlers invade the area. The old sustainable techniques used by the native population are being abandoned in favor of more destructive monoculture and cattle raising. These new methods also contribute to the destruction and looting of unrecorded archeological sites.

Today remote sensing and geographic information system (GIS) analysis are used to address issues in Maya archeology as well as to monitor the effects of deforestation. The ancient Maya successfully adapted their agricultural methods to their environment, but even so, they finally overused their resources. Current inhabitants are threatening to do the same thing in less time with a smaller population. Scientists are using remote sensing and GIS to learn from the past to protect the resources of the future, but they cannot rely only on remotely sensed data. By studying remote sensing images of the Petén, scientists can see

- different types of vegetation,
- the pattern of deforestation,
- Mayan roads that lead to unrecorded sites, and sometimes
- archeological sites themselves.

Sometimes it is necessary to go to the jungle to verify what they see in the remote sensing images. This is called ground truthing.

Maya Biosphere Reserve

Central American countries have established dozens of national parks, including the Petén. Change-detection analysis, using satellite data from 1986 to 1997, shows increasing deforestation, but the large size of the forest makes it hard to monitor and protect. Satellite imagery is proving to be a valuable monitoring tool. The Maya Biosphere Reserve was established in 1990 through an agreement between three neighboring countries, Mexico, Guatemala, and Belize. The reserve represents the largest continuous tract of tropical forest remaining in Central America. Besides forest, the reserve also contains extensive, environmentally important, seasonal, freshwater wetlands (bajos).

When settlers clear and burn the rain forests for agriculture, the thin soils quickly erode, and as a result, the flora and fauna are destroyed. Archeological sites are damaged by the fires' heat and by the erosion. The newly cleared landscape also makes undiscovered archeological sites more visible and accessible to looters. For the reasons mentioned previously, protecting the rain forest almost always protects the archeological sites too.

Ground Truthing in the Petén

Ground-truth information, often referred to as "reference data," involves the collection of measurements or observations about objects, areas, or phenomena that were remotely sensed. This ground-truth information can be used by social scientists in two ways: first, the data can aid in the interpretation, analysis, and validation of the remotely sensed data; second, it helps in understanding the socioeconomic forces behind human-produced, land-cover modifications.

Ground truthing is expensive and time consuming. In recent years, even though the cost of computer hardware and software for remote sensing has dropped, the costs of ground-truth activities have increased because airfare, lodging, vehicle rental, food, labor, and other costs have risen. Recent advances in GPS receivers and digital data field recorders have helped keep costs down because they make researchers much more efficient while they are in the field.

In order to create an accurate reference data set, scientists have to visit as many sites as possible in remote and rugged Petén. Typically, they change locations each day. They do not remain at a site or village to excavate archeological features—they simply map and verify their existence. Some of the challenges encountered by the field workers included logistical and communication problems,

equipment failure, poor map quality, physical stress, and unfriendly local inhabitants. Once a research team was captured and held at gunpoint for several hours before being released.

Logistics are probably the biggest fieldwork problem. Often team members are the first professionals to visit an archeological site. A logistics coordinator schedules, in advance, the jeeps, boats, aircraft, mules, horses, and workers that will help the team get to its destination. Since many areas of the Petén do not have telephones, a Guatemalan team member must make arrangements for the rentals with local people weeks or months in advance. The more inaccessible the location, the more difficult the arrangements. Once the logistics have been coordinated, the field missions last two to three weeks. As the mode of travel switches from jeeps to boats to horses and mules, it is critical that the dates, times, and locations be arranged in advance so that the vehicles, guides, and animals are there to help the team get to its destination. Sometimes the team encounters road and pathway hazards such as downed trees and extremely muddy conditions.

Occasionally, teams are met with suspicion regarding their true purpose. Teams have successfully combated this situation by showing the local residents a large number of satellite images, explaining how the imagery is used, and by leaving a copy with the local residents. Only through years of exposure and word of mouth do teams gain acceptance and support for their activities from the local inhabitants. Many local people have become so educated about satellite imagery and GPS units that they can help teams interpret some of the features and anomalies on the images. Having a Guatemalan on the research team is a real benefit.

GPS measurements are very helpful to the field researchers. In 1988, when there were fewer satellites in orbit, and the receivers were not as good, teams often found themselves climbing a temple at midnight to determine their position because the satellites were in position only between 1 and 4 a.m. In addition, the dense rain forest vegetation sometimes interfered with the satellites' signals. Today readings can be taken at any time. More satellites and better GPS receivers allow field workers to collect more data with greater accuracy, but even with all the latest technology, there are still hazards.

One problem is the inaccuracy of available maps. Often lakes, rivers, archeological sites, and cultural features are not located where the map indicates. If information from these inaccurate maps is incorporated into a GIS, it will lead to faulty predictions. This problem is solved by constantly comparing GPS measurements, imagery, and maps to eliminate any errors. But even this doesn't help when the names on the maps are not the same as those used by local inhabitants.

Protecting the Petén

As teams studied deforestation in the Petén, they tried to distinguish between new forest clearings and regrowth. They are now expanding their activities to include information about the decisions that lead to land-use change and land conversion. Teams are in the process of interviewing local farmers and ranchers to address the scientific issues of deforestation rates and trends in land-use conversion. Through the interviews, the scientists hope to learn how farmers decide the amount of land they convert to pasture or shifting to agriculture, how they decide the amount of land they cultivate and the amount they leave fallow, how forest fragmentation affects the environment, what are the spatial characteristics of cleared land, and what are the socioeconomic characteristics of the farmers. These data will be correlated to provide better analytical information for future land-management decisions—and to help save archaeological sites, known and unknown.

Module 4, Investigation 3: Log 2

Ground truthing in the Petén

Read Briefing 1. Check your understanding by answering these questions.

1. The Petén is a _____.
   a. city in Guatemala
   b. a tropical rain forest in Central America
   c. the name of a national park
   d. a temple

2. The Petén, today mostly uninhabited, was the home to _____ during 7th–9th centuries.
   a. Spanish conquistadors who conquered the native population
   b. many endangered animal species of the tropical rain forest
   c. the Aztec Indians
   d. several million Maya

3. Sites of this ancient culture are difficult to locate today because _____.
   a. the buildings were burned and left as rubble
   b. the buildings were made of wood and have long since decayed into the rain forest floor
   c. the tropical rain forest has grown over the buildings and paths and cannot be easily seen either on the ground (forest is too thick) nor from aerial photographs (vegetation covers it)
   d. new cities have been built over the old sites, and agricultural and industrial areas cover the ancient remains

4. Ground truthing means to _____.
   a. collect measurements, data, and objects in locations that were remotely sensed
   b. ask native populations in the region to tell the truth as they relate stories about the ancient culture
   c. look at maps and pictures of an area
   d. use many remotely sensed images of different types to gather information

5. Ground truthing is expensive and time consuming because _____.
   a. computers, used to record the data, are very expensive and difficult to carry
   b. costs of travel, lodging, guides, and food are expensive, and arrangements are not always easy to make
   c. geoarchaeologists must stop to excavate the site before continuing
   d. the remotely sensed images are expensive, and it takes years to learn how to interpret the image before you can ground truth it

Indicate whether the following statements are true or false.

_____ 6. Ground truthing aids in interpretation, analysis, and validation of the remotely sensed data.

_____ 7. Global positioning systems (GPS) provide flexibility and accuracy in pinpointing exact locations.

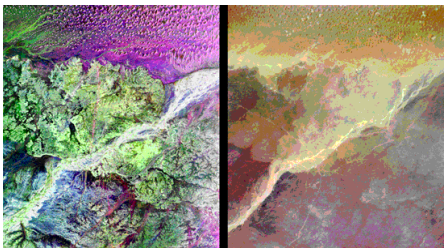
_____ 8. Following the ancient footpaths is an easy task since modern-day inhabitants have kept them clear for the tourists.

_____ 9. All native people welcome geoarchaeologists who ground truth because they bring new knowledge about the ancient inhabitants and their ancestors.

_____ 10. One problem with ground truthing is that local maps may be inaccurate.

Module 4, Investigation 3: Briefing 2

Ground truthing and the geography of sites



http://www.jpl.nasa.gov/radar/sircxsar/ubar1.html

http://observe.arc.nasa.gov/nasa/exhibits/ubar/ubar_4.html

Objectives

In this part of the investigation you learn how and why a geoarchaeologist ground truths features detected on remotely sensed images. You match geographical information to archaeological sites and photographs of archaeological sites to aerial views.

Part I

Ground Truthing

A geoarchaeologist's job is to discover and explain historical sites. After using remote sensing, the geoarchaeologist travels to the site to discover what is on the ground and to excavate (dig) for more information to assemble the pieces of history, geography, and culture. This process is called ground truthing. The geoarchaeologist matches remotely sensed data with exact features on the ground.

With global positioning systems, the objects and features can be accurately mapped. Photographs are taken to study geographical and cultural features.

By comparing locations and features on the ground with those in the image, geoarchaeologists are better able to interpret the remotely sensed images.

If an unknown feature appears on a remotely sensed image—say a rectangular red object—ground truthing may determine what it represents. If it is a temple, then other rectangular red objects on the same image are interpreted as temples.

The Geography of a Site

When traveling to a country to ground truth an image, geoarchaeologists need to know what conditions to expect. Climate influences how well sites may be preserved. A dry region preserves artifacts. A wet climate could encourage deterioration and vegetation that covers the features. On one ground-truthing expedition to Guatemala, geoarchaeologists reported accidentally finding ruins about three meters from the road. The vegetation was so thick they could not see the temple ruins from the road. Vegetation had also grown over the site so it was hidden from any airplane search. The temple was difficult to pinpoint on the remotely sensed image due to the scale and inaccuracy of the local maps. Researchers wondered how many other ruins they may have missed.

Knowing the terrain is also important when ground truthing. Geoarchaeologists need to know elevation and ruggedness to plan for special equipment or vegetation.

Module 4, Investigation 3: Briefing 2
Ground truthing and the geography of sites

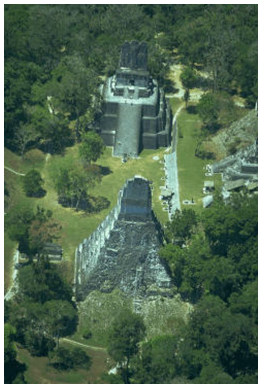
Part II
Types of Images
There are three types of images:

- **Ground-level views**—used to show how an object in an aerial view looks on the ground.
- **Oblique views**—may be taken from an angle (usually above), giving a partial side view of a site. The oblique view provides a sense of shape and features of buildings.
- **Aerial views**—taken from directly above allowing objects to be seen from the top down. The advantage of an aerial view is that you can see patterns not visible in a ground view.

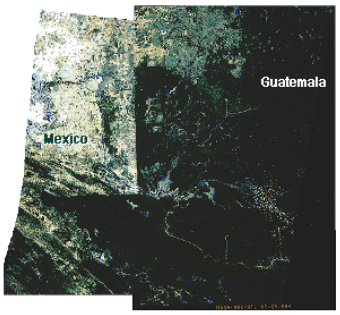
Examples of Images
Below are three images taken of the Petén, a rain forest in Guatemala. The ground-level view provides a sense of the shapes and heights of the trees. The oblique view reveals a larger space with buildings. You see some features of the buildings (like steps), their sizes, the distances between them, and their relationship to one another. The aerial view shows a much larger region. No small features are clear, but there is a pattern showing the edge of the rain forest (the straight line between the light area and the darker green area).

A Ground-Level View

An Oblique View



An Aerial View



Deforestation in the Petén

http://www.ghcc.msfc.nasa.gov/archeology/peten.html

Module 4, Investigation 3: Log 3

Checking it out on the ground

Preparing to Visit a Site

Archaeological sites are located in these countries:

Cambodia
Costa Rica
Guatemala
Oman
Turkey

Use an atlas to locate the five countries and complete the chart using information in the atlas to understand the physical geography of each country. For example, a climate map helps you identify the precipitation and temperature.

After completing the chart, analyze the photographs and remotely sensed images found in Log 4. Match each photo and image to a country below.

Using the information obtained from these data, complete the last column by listing supporting visual evidence. What information from the images did you use to ground truth?

	Climate/ Precipitation	Climate/ Temperature	Types and Quantity of Vegetation	Elevation/ Terrain	Ground-Truth Evidence
Cambodia					
Costa Rica					
Guatemala					
Oman					
Turkey					

Module 4, Investigation 3: Log 4

Ground truthing

Matching Ground Photos with Historic Sites

Below are site photos taken at ground level or oblique angles. These are followed by aerial images and descriptions of the sites. Under the site description write the letter of the photo(s) that shows what feature is found at this site. You may want to consult an atlas to identify climatic conditions and vegetation in different regions to help you interpret which photos match which sites.

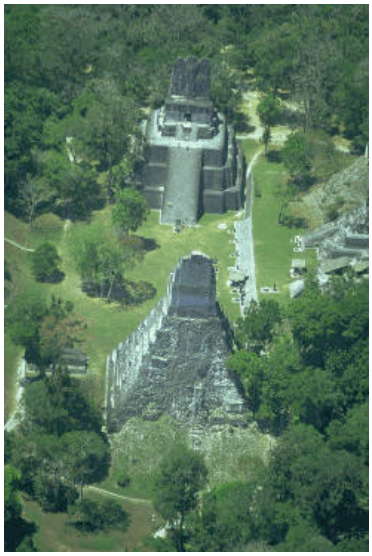


Photo A

Photo B

Photo C

Photo D

Photo E

Module 4, Investigation 3: Log 4

Ground truthing

Arenal Region, Costa Rica

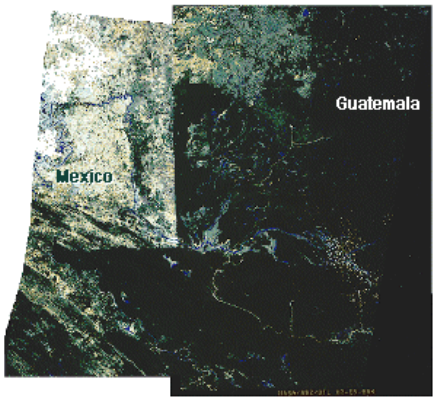
TIMS image of footpaths

http://www.ghcc.msfc.nasa.gov/archeology/arenal.html

The people in this area appeared to live in small groups that adjusted to shifting living locations because of frequent volcanic eruptions. Footpaths wound through the hilly terrain.

The description of the Arenal Region matches Photo_____.

The Petén, Guatemala



Deforestation in the Petén

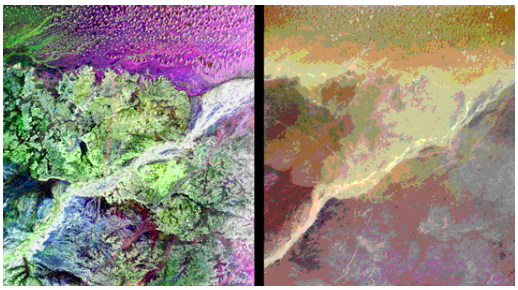
http://www.ghcc.msfc.nasa.gov/archeology/peten_groundtruth.html

This region is rich in Mayan history. Old buildings were found covered by dense rain forest. Several sites have been cleared and the structures rebuilt for tourists. Connected by footpaths, the cities have step pyramid temples with broad courts for games.

The description of the Petén matches Photo_____.

Ubar, Oman

SIR-C radar image



http://www.jpl.nasa.gov/radar/sircxsar/sc-ubar1.gif

Ubar was an ancient city along the frankincense trade route. Although this area is very dry today, more water was available in ancient times. Water was stored in deep caverns, indicating periods when water supplies fluctuated.

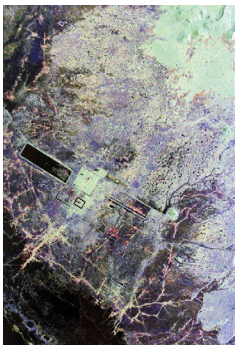
The description of the Ubar matches Photo_____.

Module 4, Investigation 3: Log 4

Ground truthing

Angkor, Cambodia

SIR-C/X-SAR radar image



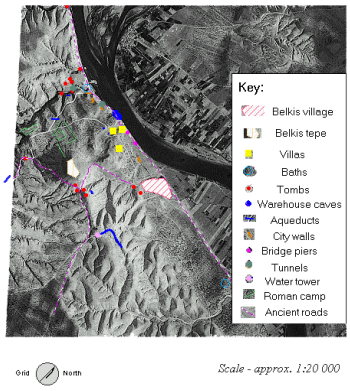
http://www.jpl.nasa.gov/radar/sircxsar/angkor.html

This region is covered today by thick rain forest. Only radar penetrates the tree cover to reveal evidence of human occupation. This was once a city and religious center for at least one million Khmer people. They built temples that reflected both Hindu and Buddhist influence. There is evidence of an extensive irrigation system.

The description of the Angkor matches Photo_____.

Zeugma, Turkey

KVR image



http://www.ist.lu/html/projects/de/Zeugma/gis1.html

This region was part of the ancient Greek and Roman Empires. At one time it was the best way to cross the Euphrates River. As transportation routes shifted farther south, this area lost its importance. The reservoir created behind the dam is expected to cover fields of pistachio trees and evidence of various empires.

The description of Zeugma matches Photo_____.

1. What do these sites have in common (besides being ancient)?

_____

_____

_____

2. How does remote sensing help archaeologists find features common to all ancient sites?

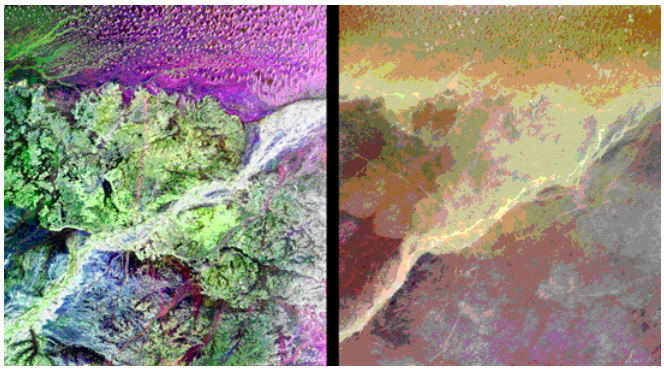
_____

_____

_____

Module 4, Investigation 3: Log 5

Writing your own ground-truthing log



http://www.jpl.nasa.gov/radar/sircxarsar/ubar1.html

Objective

In this part of the investigation you research an archaeological site and create a ground-truthing log to explain what is discovered at the site.

The regions listed below are well documented by remote sensing and ground-truthing photos. With a little research on Internet sites, your group will be able to create a ground-truthing trip and write a field log.

Imagine that your group has been sent on a one-week trip to ground truth the images of your selected site. Prepare a log, which includes the remotely sensed data, a map, and a description of your trip: where you went and what you found day by day. Describe the physical and human characteristics of the region and the evidence found of prior human occupation. Include photos, sketches, and descriptions of interviews and encounters with the local population. Be accurate.

Below is a sample field log model to get you started.

Sites to choose from:

- Chaco Canyon in New Mexico
- Arenal Region in Costa Rica
- Ubar in Oman
- Angkor in Cambodia
- Mirador in Guatemala
- Zeugma Project in Turkey

Our group was sent to _____.

It is located at _____. (latitude/longitude)

Some objects/colors in the remotely sensed images we studied are:

_____

_____

Module 4, Investigation 3: Log 5

Writing your own ground-truthing log

Things we need to know before our trip:

Climate during this time of the year: _____

_____

Expected terrain: _____

_____

Vegetation: _____

_____

Native population, language, special cultural features: _____

_____

_____

Our team member: _____
(include photos if you like)

Daily log (for one week from landing at the airport to leaving)
Include: what you did on each day
what you looked for
who you met
who you interviewed
what you discovered

Our trip was a success! We discovered _____

References

Angkor, Cambodia
http://www.jpl.nasa.gov/radar/sircxsar/angkor.html
Photos: http://www.csulb.edu/~kkeo/angkor/P024.html

Arenal Region, Costa Rica
http://www.ghcc.msfc.nasa.gov/archeology/arenal.html
Photo: http://www.ghcc.msfc.nasa.gov/archeology/arenal.html

Chaco Canyon, New Mexico
http://www.ghcc.msfc.nasa.gov/archeology/chaco_compare.html

Baker Aerial Archaeology's Chaco Project
http://www.mia.com/~jaybird/AANewsletter?ChacoPage2.html

Chaco Canyon endangered
http://members.aol.com/mjhinton/chaco/chaconews.htm

Chaco Culture National Historical Park
http://www.cr.nps.gov/worldheritage/chaco.htm
http://www.nps.gov/chcu/roads.htm

The Petén, Guatemala
http://www.ghcc.msfc.nasa.gov/archeology/peten.html
http://www.ghcc.msfc.nasa.gov/archeology/peten_deforest.html
Photos: http://www.ghcc.msfc.nasa.gov/archeology/peten_groundtruth.html

Ubar, Oman
http://www.jpl.nasa.gov/radar/sircxsar/ubar1.html
Photos: http://observe.ivv.nasa.gov/nasa/exhibits/ubar/ubar_4.html

Zeugma, Turkey
http://www.ist.lu/zeugma
http://www.bbc.co.uk/science/horizon/Zeugma_info.shtml

Module 4, Investigation 3: Log 6
In conclusion

Remote sensing is used to help geoarchaeologists locate sites of past human occupations. Scientists continue to improve ways of enhancing images to better detect human and physical features.

Write answers to the following questions in the spaces below. If you have completed one or more of the investigations, include information from them to help you answer the question.

1. How does remote sensing help the search for archaeological sites?

_____

_____

_____

_____

_____

_____

_____

2. How and why is geography important to understanding remotely sensed images and archaeological sites?

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____