



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.

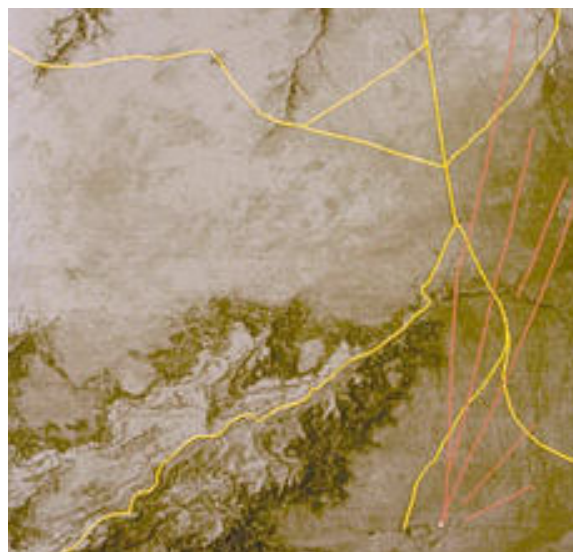
In the past, it was believed that Chaco Canyon was a major city and ceremonial center. New interpretations indicate that there were few permanent residents and that it was a religious or ceremonial center to which the Anasazi traveled.

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.

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.

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

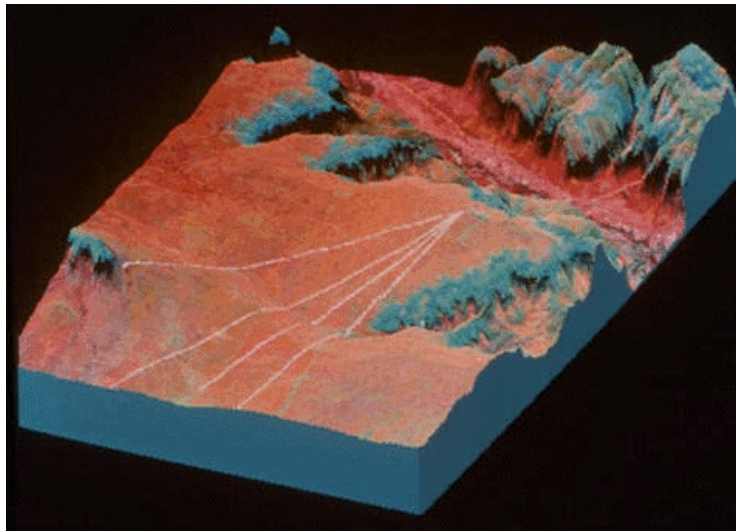


Figure 2: Chaco Canyon, looking from the southwest

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

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.

The Anasazi Culture

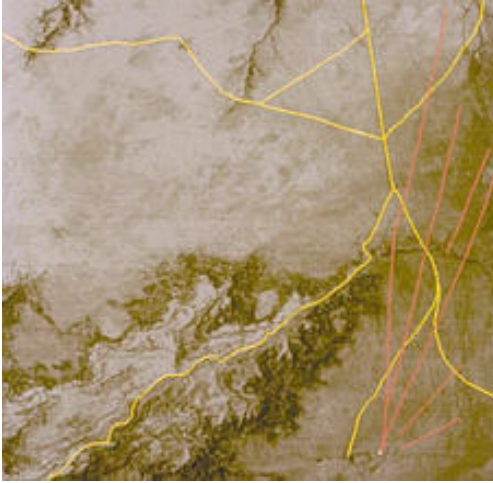
Put a check in front of the statements which correctly describe the Anasazi culture.

- _____ 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 road-bed 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.



An aerial photograph of a river system. A yellow line traces a path along the left bank and into the water, while a red line follows a path on the right bank. The river water is a murky brown color, and the surrounding land is green with some brown patches.

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.gfcc.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.

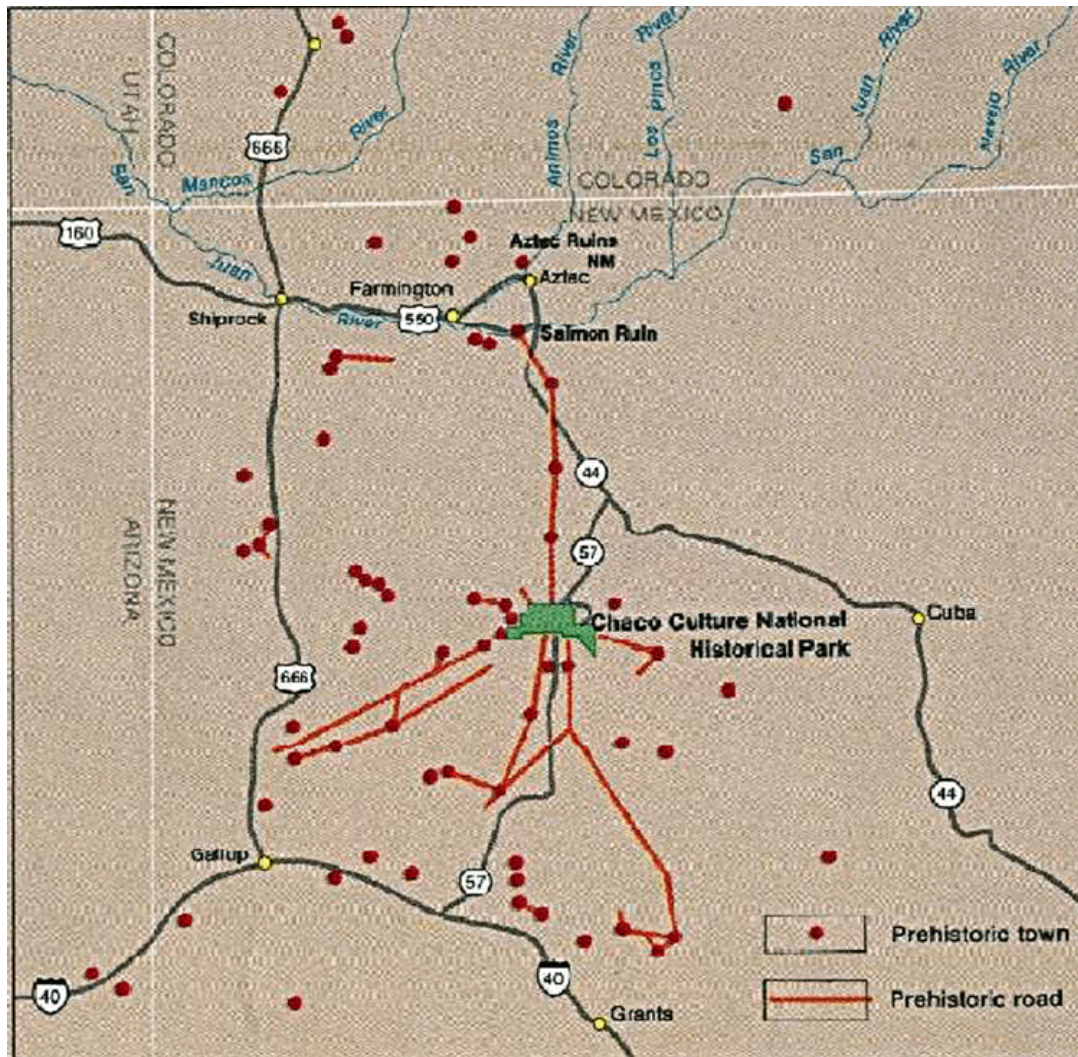
Compile the results of your survey and draw conclusions about public opinion. Write a recommendation concerning the preservation of the ruins to the chief ranger of the Chaco Culture National Historical Park.

- 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

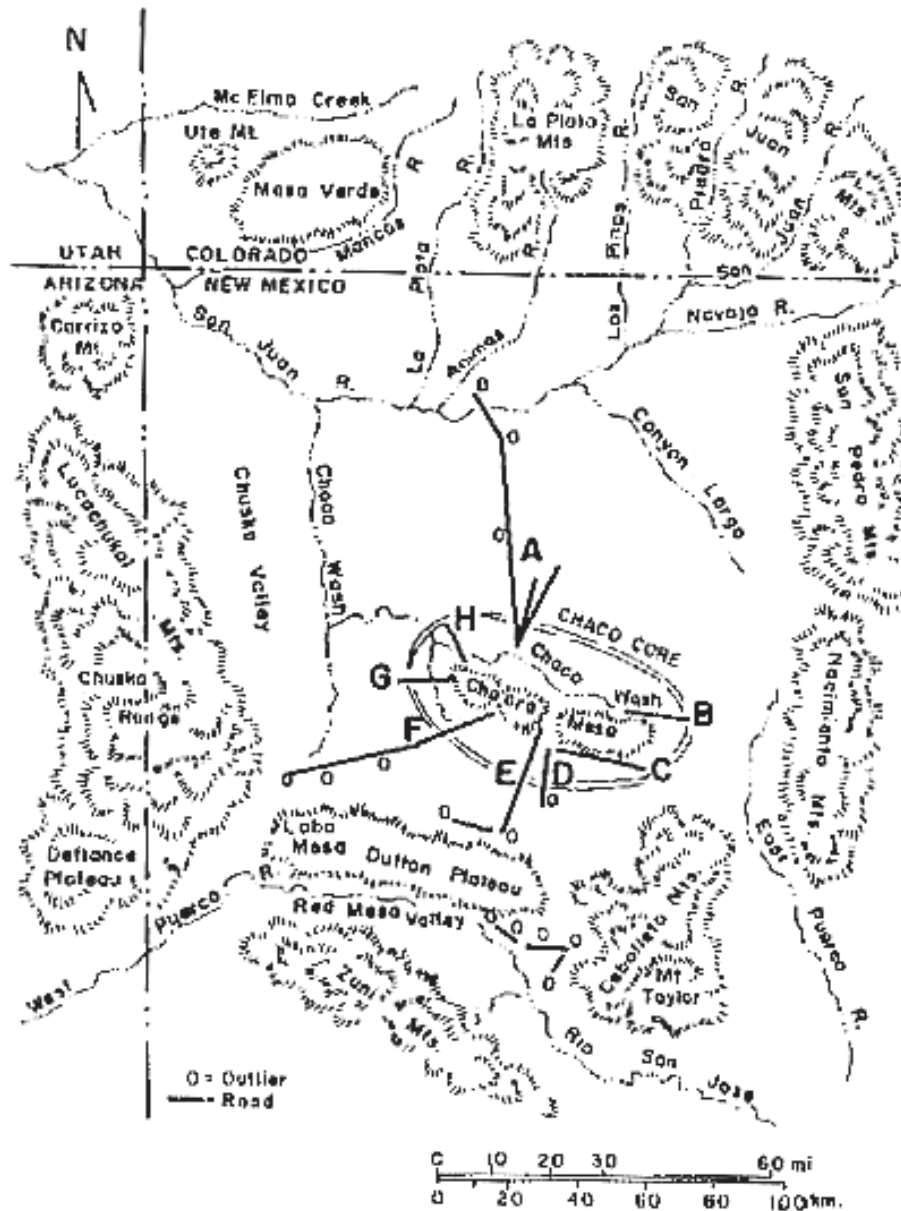
Modern road map of Chaco Canyon region



<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.
