The Nature of Science: Making Sense of What is Not Seen

The Case of the "Lost Gorge"

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Note to teachers

The purpose of this activity is to facilitate learning about a key aspect of the "nature of science" (NOS), through a historic case study of an early map-making endeavor. Recent national science education reform documents (NRC, 1996; AAAS, 1990) emphasize the importance of student understanding of NOS as a critical component for science literacy. The approach taken in this activity is to first illustrate an example of a scientific process, then highlight the significance of a specific aspect of NOS in the context of the example. The NOS aspect we have chosen is *the role of, and distinction between, observation and inference in the development of scientific knowledge* (Lederman, 1998). Through illustrating this NOS concept using a real-world example, we hope to build students' general understanding of science as a unique way of knowing the world. This understanding is an ideal starting point for inviting the learner to engage in open-ended inquiry learning because it presents a specific theme for reflecting on during and after the inquiry. Suggestions for facilitating further inquiry learning beyond this activity are given at the end. This activity is appropriate for students in secondary science classrooms.

Nature of Science: The use of observation and inference

One of the fundamental applications of science is to describe the natural world. To do this, scientists make many observations about natural objects and phenomena and attempt to explain what they observe. This may seem like a straightforward and simple task; however, not all objects and phenomena in nature can be observed directly. For example, many scientists study the biology and ecology extinct organisms, like dinosaurs, but are not able to walk outside and look at one. How then are the scientists able to make claims about these animals without being able to observe them in their natural state? The answer is that by collecting evidence, or data, scientists can piece together observable facts in ways that can be used to *logically* explain things that cannot be otherwise observed. It is quite similar to the way that a detective uses evidence to solve a crime that was not witnessed.

When scientists use this approach to solving a problem, they are making an **inference**. The process of making inferences based on observable evidence is one aspect of science that gives us the ability to apply our knowledge and intelligence to describing and explaining the mysteries of the universe. However powerful they may be in establishing scientific knowledge, inferences cannot be considered absolute truth because they are an interpretation, not a description of evidence. Often times, inferences are later validated as being correct after technology is developed that makes direct observation of a specific object or event possible. Sometimes, a new technology or the discovery of contradictory evidence will reveal that a prior inference was incorrect. This does not mean that the science is flawed; it just means that science is an on-going process, and established knowledge will always be put to the test as new knowledge is developed. This is considered a strength of the way in which scientific knowledge develops, because it allows for the acceptance of new knowledge as it becomes accessible, even if it is contrary to what was previously accepted.

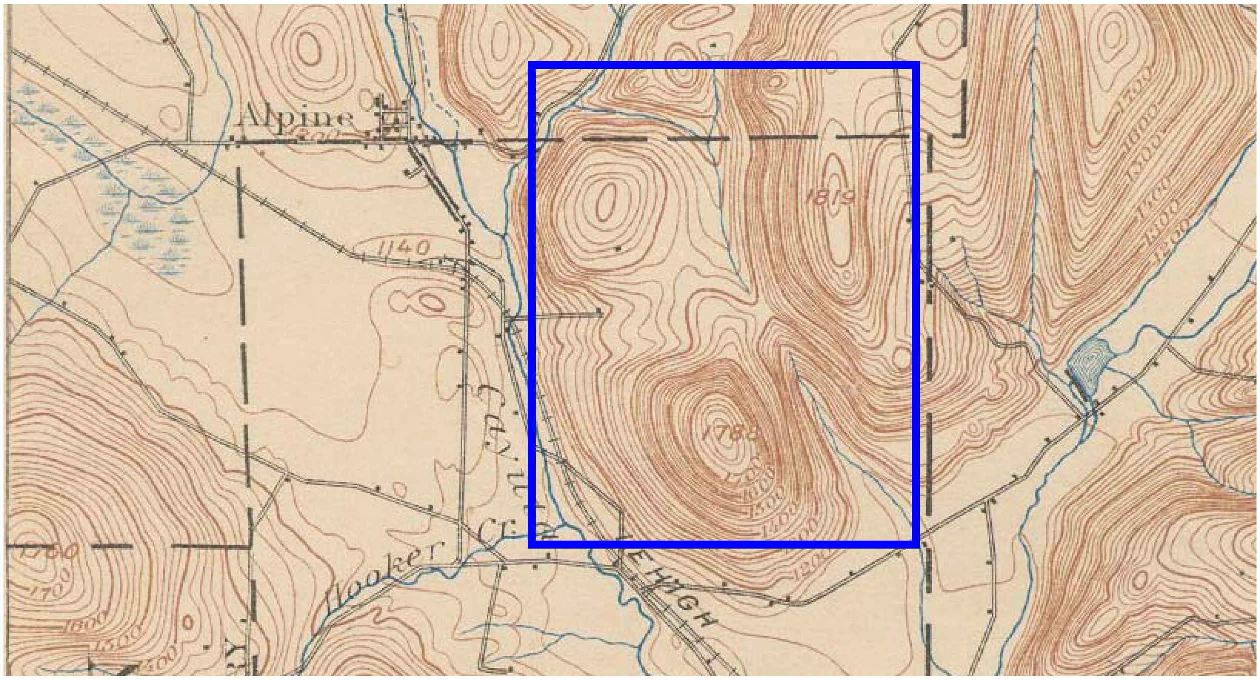
Mapping the hidden landscape: the case of the lost gorge

Anyone who has been to the Finger Lakes region of New York Sate has witnessed the dramatic landscape of rolling hills and secluded valleys. To the early settlers, it was a frontier wilderness of deep forest and rugged terrain that required skill to navigate. To early mapmakers, or cartographers, the terrain posed these same challenges, as well as the additional challenge of trying to make sense of the land surface that was difficult, if not impossible to view through the thick forest.

However, the cartographers were persistent in their work, and in the late 1800's, the United States government formed a survey team to produce topographic maps of the entire country. This survey became known as the US Geologic Survey (USGS). Topographic maps display the three-dimensional characteristics of the land by lines (contours) that indicate a specific elevation, as opposed to road maps, which do not allow us to see changes in elevation.

Since the surveyors who collected the information for making topographic maps had to cover a lot of territory on foot or horseback, using time-consuming survey methods with very limited technology, it was impossible to *directly* measure all of the topographic features of the vast landscape. Instead, once they were familiar with the overall landscape patterns of an area, they began to make inferences about what the unseen landscape features, such as remote valleys, looked like. They based their inferences on previous observations of features such as the drainage patterns of creeks. For example, by looking at the size of a stream, estimates can be made to as how much land surface collects the rainwater that flows into the stream. Using the process of *inference*, the surveyors were able to complete extensive mapping projects in a reasonable amount of time. This process represents how observation and inference were used together to achieve scientific goals. It also explains how a landscape as complex and vast as the Finger Lakes region could efficiently be described in detail.

Take a few minutes to study the topography of this section of a map that was created in the late 1800's. A tutorial in map interpretation can be found at: http://www.gardenmosaics.cornell.edu/pgs/science/topomap.htm. Further information about aerial photo and map interpretation, along with learning activities, can be found in Barnaba et al. (2000).



After you have looked at this map, compare it to the actual photograph of the landscape taken from an airplane many years later (blue box covers same area).

Pay close attention to the landscape feature that appears as a curved line that cuts diagonally across the landscape. What do you think that feature is? Do you notice any inconsistencies between the photo and the topographic map?

Hopefully you will have noticed that the large gorge depicted in the photograph does not appear the same as in the original map—a major difference!

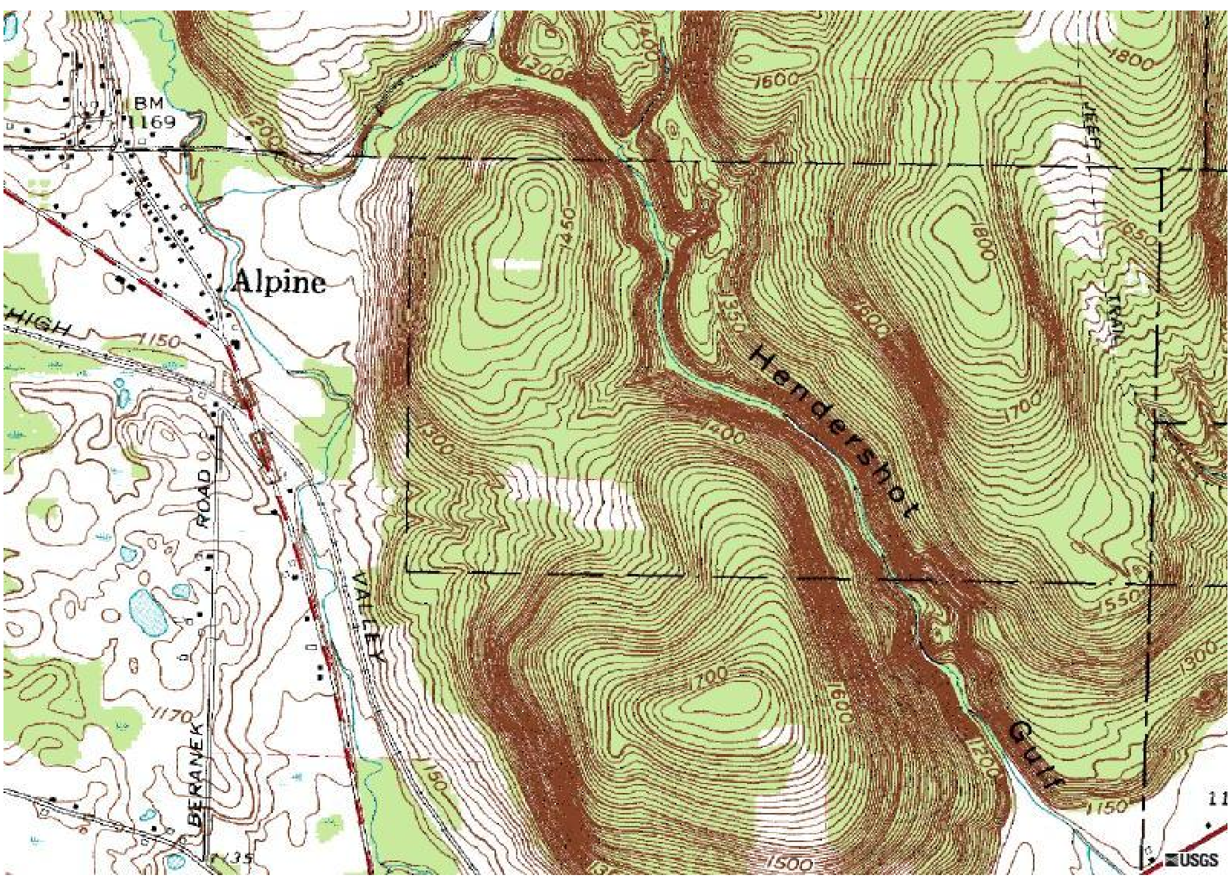
Whoops….mistakes happen!

The fact that the surveyors relied on inference in completing this map section explains how they made a major mistake. As one geologist explained what happened:

"Back in 1893, when the first topographic survey of the Cayuta Lake area was made, the men who did the work with transit and rod made an assumption to save themselves work. It was a reasonable enough inference in a general sense, but the surveyors were not sufficiently versed in geomorphic science to read the field evidence correctly... What the surveyors failed to recognize or appreciate was the wide-flat bottomed channel leading out from the rock gap was a wholly inappropriate discharge from a gully stream coursing down a hillside."

– from *The Finger Lakes Region* by O.D von Engeln

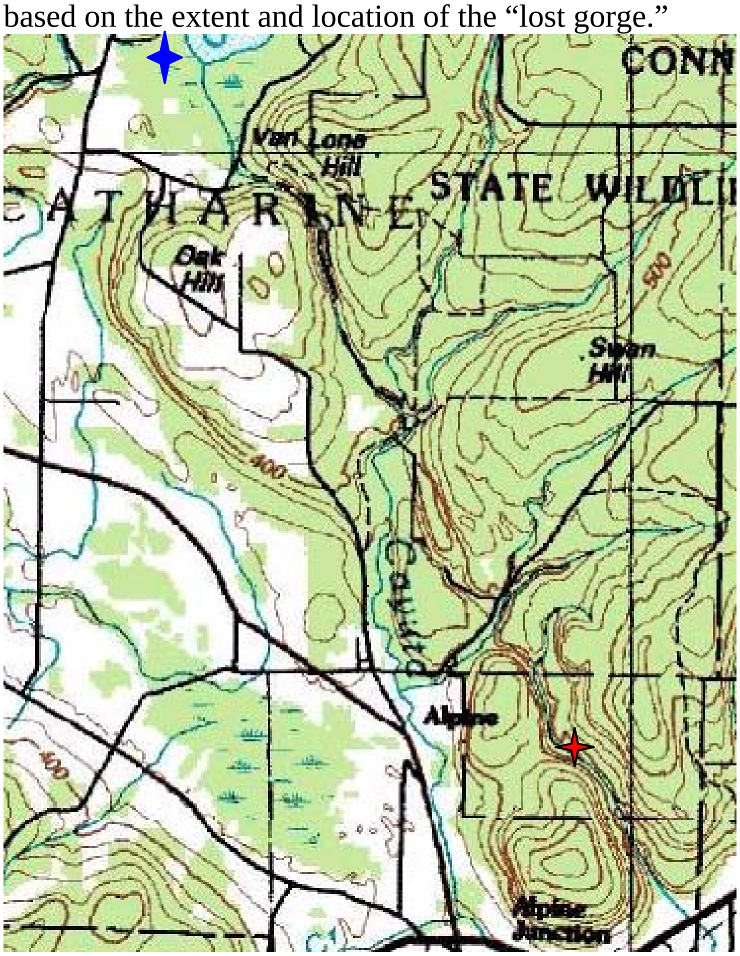
This is the current version of the topographic map that clearly includes the 'lost gorge" of Hendershot Gulf:



What other differences do you notice between the old map and the more recent photo and map? How would you explain these changes?

Better evidence leads to more inference…

Many years after the first map was made, airplanes were used for conducting survey work, exposing the entire landscape for observation. The result was that topographic mapping was done with greater accuracy in a much more efficient manner. With the emergence of more detailed topographic maps, geologists were able to study the landscapes from a new perspective, resulting in new knowledge. One way in which science advanced in light of new evidence was in understanding the formation of geologic landscape features that took place long before anyone was around to witness. Once again, since geologists cannot go back thousands of years and observe a natural phenomenon, they use inference based on current observations to make new discoveries. In fact, an interesting discovery was made about the geologic history of the region that is based on the extent and location of the "lost gorge."



The red star is the location of the "lost gorge.
The blue star is the location of Cayuta Lake.

When geologists looked at this map, they were puzzled about the long, interrupted gorge that connected the "lost gorge" to the southern shore of Cayuta Lake. They eventually inferred that the long gorge was formed by a sudden rush of water that spilled over the edge of a large lake that was located where the smaller Cayuta Lake remains today. They also inferred that the original lake formed from water that collected in a basin in front of the melting continental glacier during the last ice age. Since the margin of ice retreated northward as the glacier melted, it formed a dam that trapped the water, which continued to fill the basin. Eventually the water got so high that it spilled over at the lowest possible point in the basin rim. (Think about how a wash tub with a notch in the rim would overflow if it were filled to the top with a hose.) When this happened the rushing water eroded the gorge that remains there today.

Interestingly, geologists use this example pro-glacial lake overflow to make other inferences of phenomena that took place to form many of the landscape features in the Finger Lakes region. This "chain of inference" is all based on the only hard evidence observable to scientists: the actual appearance of the landscape today. Yet from this evidence, they are able to make many explanations about past phenomena by making a series of inferences in a logical manner.

Topographic Mapping Today

Until recently, many regions of the earth remained unmapped for the same reasons it was difficult to map the Finger Lakes region a century ago. The unmapped regions, such as dense rainforests and remote mountains, are very difficult to access. Just as new flight technology allowed more accurate mapping in the Finger Lakes region, current technology has opened up the once restricted regions to observation via remote sensing from space. Using specialized radar equipment mounted on a NASA space shuttle, scientists can now create accurate topo maps of the entire planet!

Go to the NASA mission website to learn about how the new maps are made and view some interesting images of the Earth. http://www.jpl.nasa.gov/srtm/mission.htm

While visiting the NASA website take time to learn about other kinds of mapping projects and try identify where the scientists are using inference and where they are using observation to construct the new maps.

As long as scientists continue to study the natural world they will have to rely on inference when the objects of their inquiry are hidden in space or time. Given that we are limited by our own human capacities, inferences based on our limited observations will be a driving force in the development of scientific knowledge. Sometimes this process can fail and result in an inaccurate interpretation of the natural world, as we saw in the case of the "missing gorge." But most of the time it allows us to make great discoveries about the mysteries of our unseen universe, as the geologists did once they had accurate observations to base their inferences on.

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