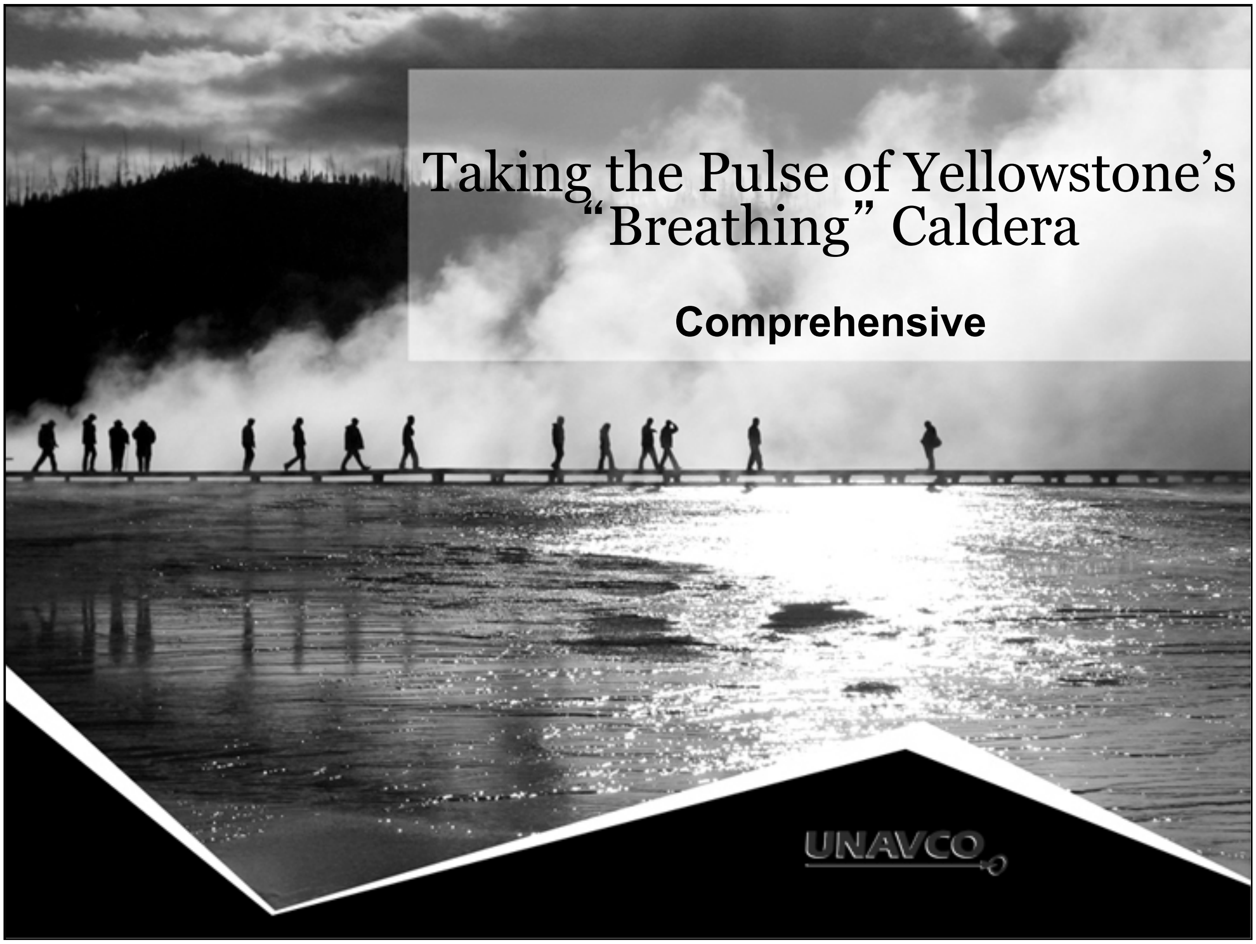
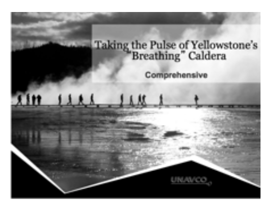


UNAVCO

Notes for slide 1

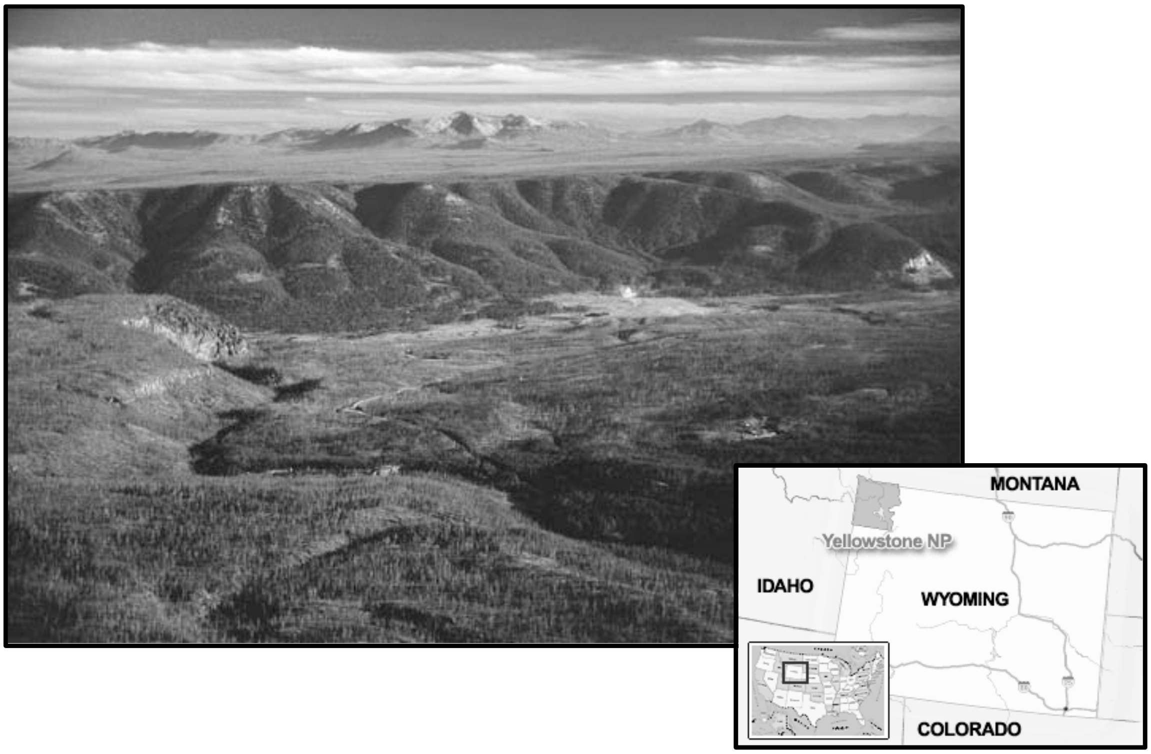


This presentation focuses on volcanoes and their side-effects in the Yellowstone region. First, you will view a seven minute video about volcanoes and hydrothermal features. To watch it, click anywhere on this slide. Then, you'll examine a few maps to see where Yellowstone National Park is and its significant features—geological as well as practical ones like roads and villages. Finally, you'll learn more about the history of eruptions in Yellowstone while your teammates learn more about earthquakes and hydrothermal systems.

The link to the video takes you to the American Museum of Natural History's Science Bulletin: "Monitoring the Fire Below." https://www.youtube.com/watch?v=rFe-VSf-TQ8 Retrieved 5 November 2014. (Search for "monitoring fire below youtube.")

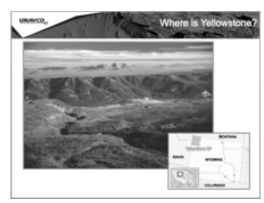
UNAVCO

Where is Yellowstone?



UNAVCO

Notes for slide 3



Yellowstone lies partially in three states -- Montana, Idaho and Wyoming.

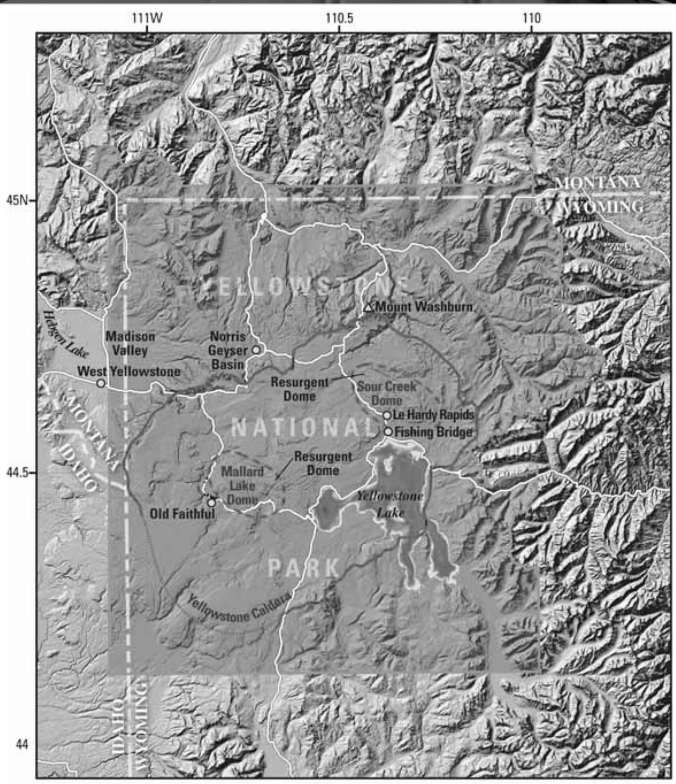
Much of Yellowstone is a large crater (a “caldera”) that is surrounded by cliffs. The cliffs are topped by lava flows. This picture was taken from the top of a lava flow. The green bluffs below the mountains are the rim of the caldera. In the foreground are two lava flows.

Photo by Bob Smith, University of Utah. Accessed from National Science Foundation: Discovery. “Yellowstone Rising.” http://www.nsf.gov/discoveries/disc_images.jsp?cntn_id=110651&org=NSF Retrieved 27 December 2011.

Map from National Park Service: “Yellowstone Location Map.” http://www.nps.gov/features/yell/interactivemap/yelllocationmap.htm Retrieved 27 December 2011.

UNAVCO

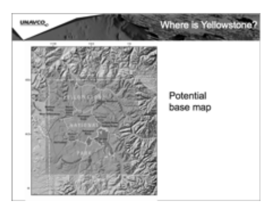
What is Yellowstone?



Exploring the landscape

UNAVCO

Notes for slide 5



This image shows that the region is mountainous, but there is more subdued topography within most of the national park. The Yellowstone caldera, 640,000 years old, appears as a red-orange line. Where the line is thinner, geologists can only infer the caldera boundary. Volcanic material has filled the caldera and smoothed out the topography. Two later episodes of volcanism pushed up domes within the caldera: the Mallard Lake Dome and Sour Creek Dome.

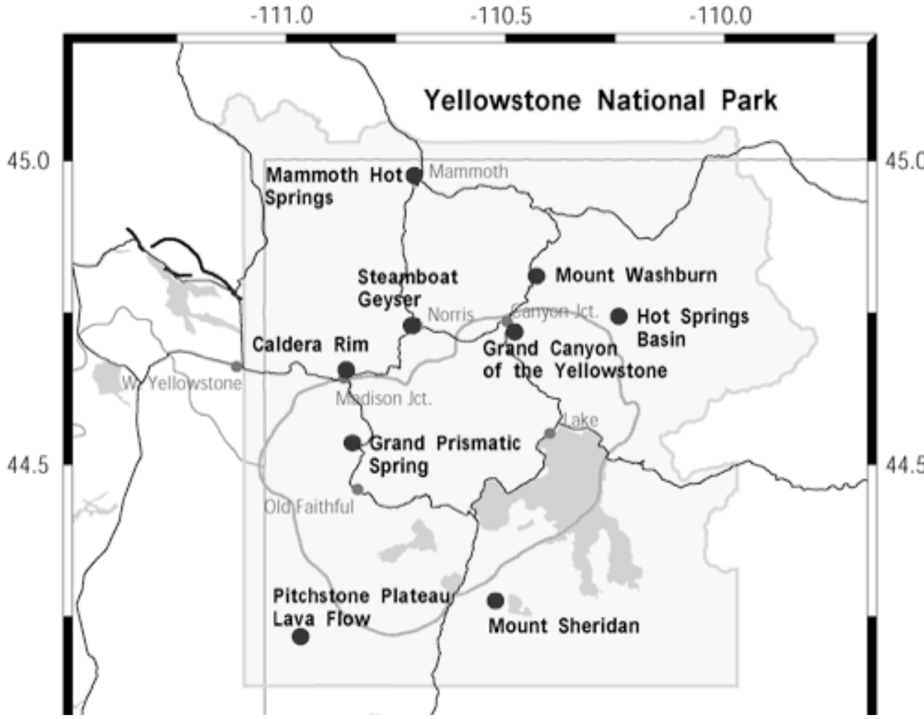
The squiggly white lines are paved roads.

If you are doing this assignment with a paper map and transparent overlays instead of Google Earth, this map or the one on the next slide could serve as your base map. Your team of three experts will need to decide which map you will use. If you are using paper maps, you have a copy of the two maps in your instructions.

Image from USGS Fact Sheet 100-03. 2004. "Tracking Changes in Yellowstone's Restless Volcanic System." http://pubs.usgs.gov/fs/fs100-03/index.html#yellowstone_fig2 Retrieved 27 December 2011.

UNAVCO

What is Yellowstone?



Exploring the landscape

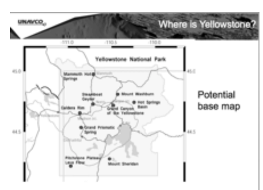
UNAVCO

Notes for slide 7

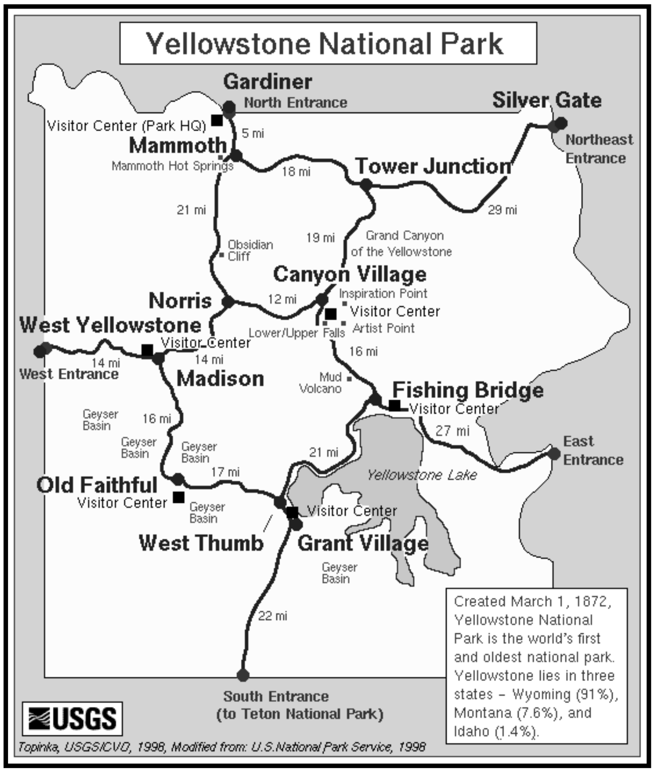
This map of Yellowstone shows roads as red lines and the location of the most recent caldera as a gold line. The park is the green area.

Red dots are links to photos and information about the park from the Yellowstone – Teton Epicenter's "Location Map." By clicking anywhere on the slide, you will open the webpage with live links on the red dots. http://www.yellowstonegis.utah.edu/maps/index.html. (Search for "yellowstone gis epicenter" and choose the maps link.

Image from Yellowstone – Teton Epicenter: "Location Map." http://www.yellowstonegis.utah.edu/maps/index.html Retrieved 28 December 2011.



What is Yellowstone?

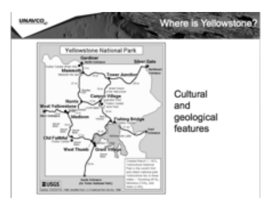


Cultural
and
geological
features

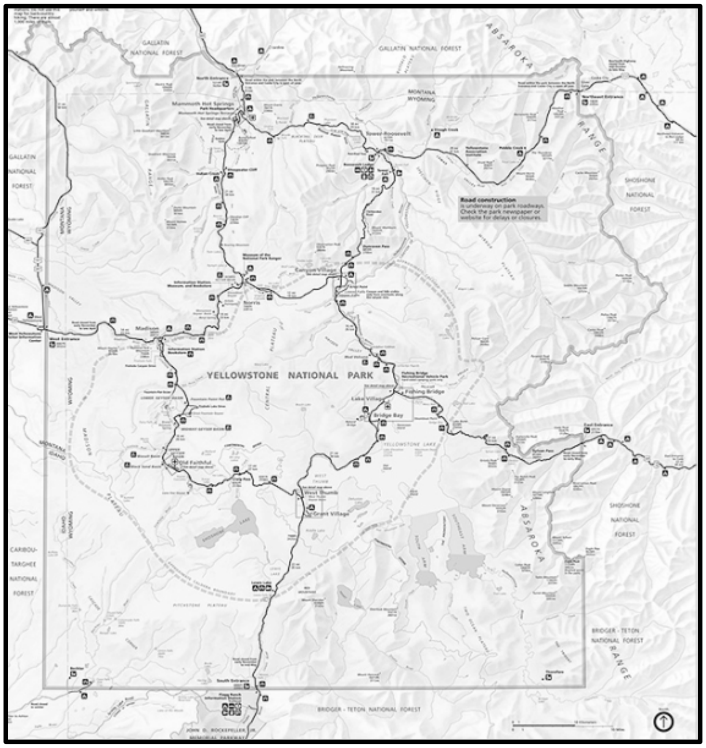
Notes for slide 9

This general map shows where some of the geological and cultural or tourist attractions are. These are where many visitors stop to look at sights, buy supplies, or stay the night. The next map shows more detail.

Map from USGS Cascade Volcano Observatory. http://vulcan.wr.usgs.gov/Imgs/Gif/Yellowstone/Maps/map_yellowstone.gif Retrieved 28 December 2011.



What is Yellowstone?



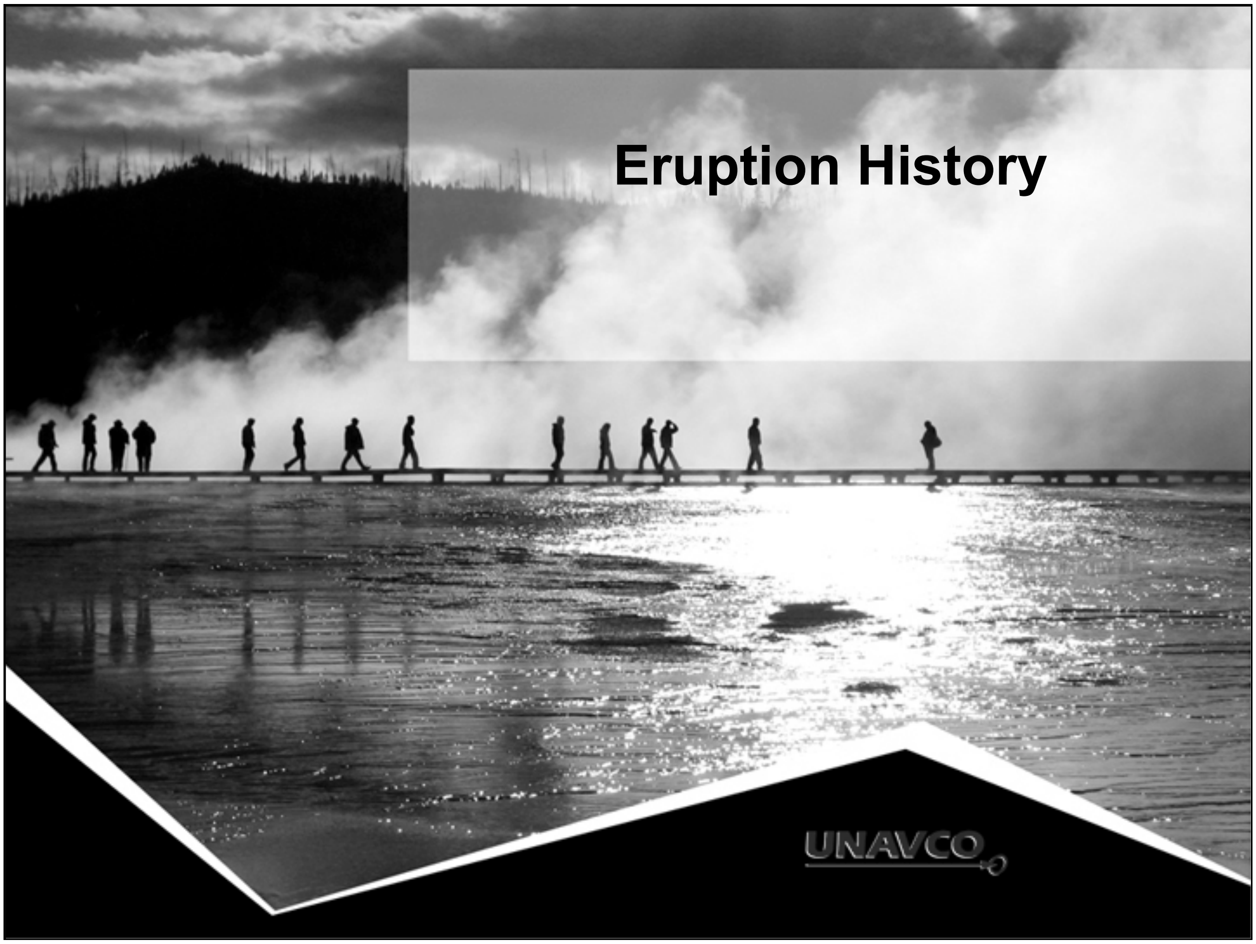
Cultural and geological features

Notes for slide 11

This map shows details that you might want to refer to when learning your part of the geology. It is part of the map/brochure that the National Park Service gives visitors as they enter the park. You can view this map better by clicking anywhere on the map and then being patient….there's a lot of data to open. http://www.nps.gov/hfc/carto/PDF/YELLmap1.pdf (Search for "Yellowstone detail yellmap1.")

The base map that you will draw on is a simplified version of this map.

Image from National Park Service: Park Map Viewer. http://www.nps.gov/pwr/customcf/apps/maps/showmap.cfm?alphacode=yell&parkname=yellowstone%20national%20park Retrieved 28 December 2011.



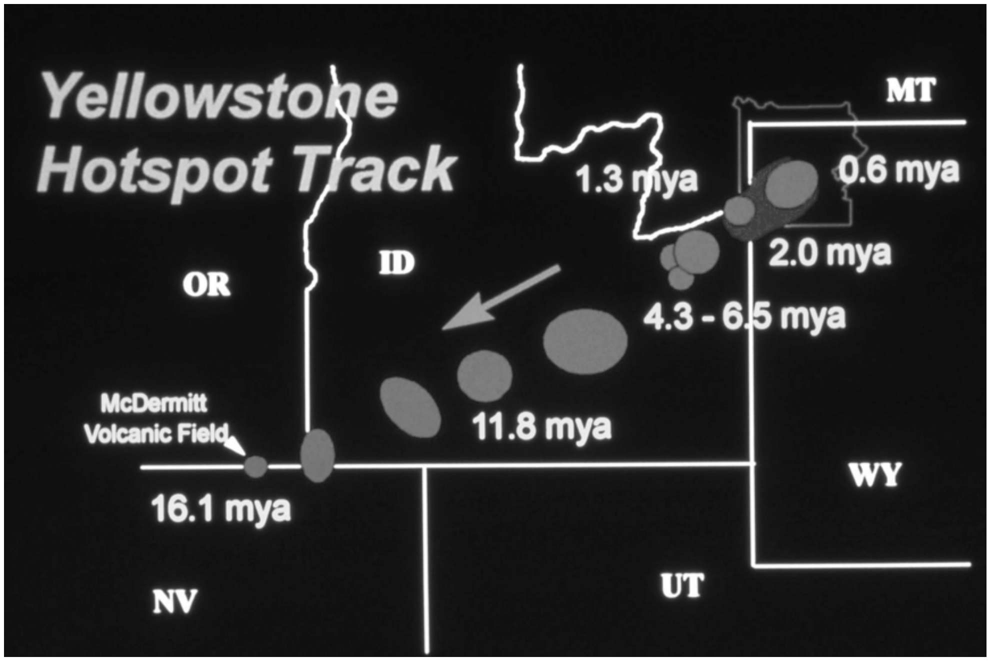
UNAVCO

Use the Yellowstone National Park Base Map to record your data.

You will need to make a key for your map like those you see on several of the slides.

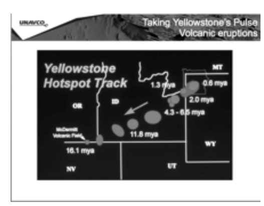
UNAVCO

Taking Yellowstone's Pulse
Volcanic eruptions



UNAVCO

Notes for slide 15



Yellowstone is one of the largest and most active calderas in the world. Eruptions in Yellowstone started about 2.3 million years ago. But, they follow a string of eruptions in the region that has left a path of calderas. Click on this slide and then on "Interactive: A Hotspot Trail" on the webpage to explore an animation of volcanism moving across the region over time.

The center of volcanism has moved because the North American plate is moving over a "hotspot" in the mantle that produces magma by melting rocks in the crust. The light blue arrow shows the direction that the North American plate is moving compared to the (almost) stationary hot spot.

"Mya" stand for "million years ago." That is when the hotspot was active there. For instance, the McDermitt Volcanic Field had volcanoes erupting 16.1 million years ago.

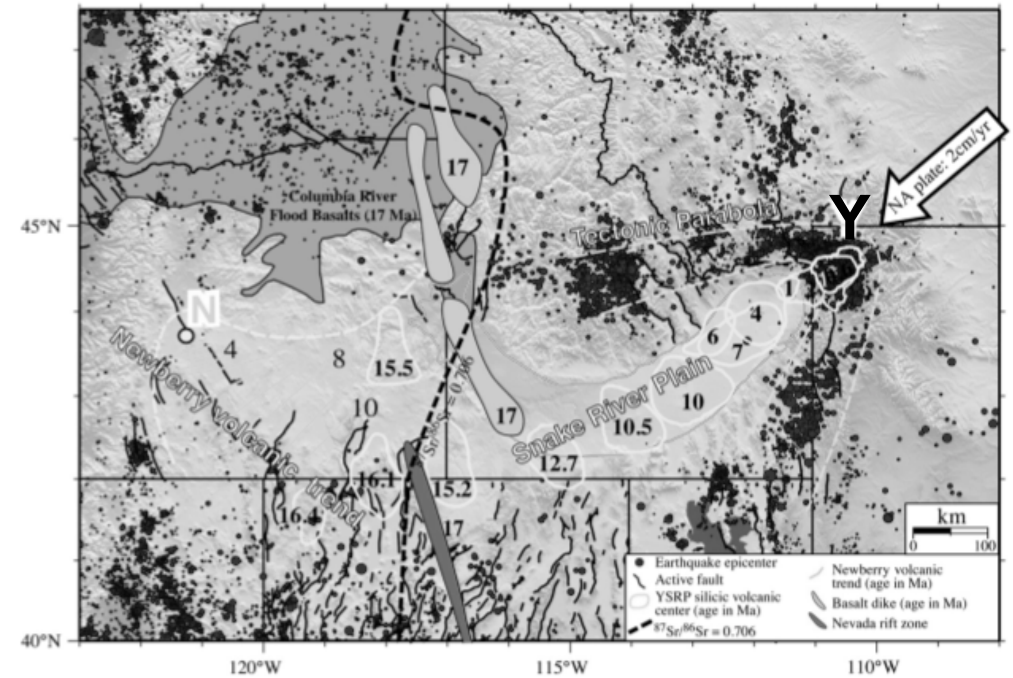
Between the caldera-forming events (three in Yellowstone), other lava eruptions and hydrothermal eruptions occurred. The topography of the older craters is quite flat because of millions of years of erosion and burial by other volcanic events such as the Snake River Plain flood basalts.

http://www.amnh.org/explore/science-bulletins/earth/documentaries/yellowstone-monitoring-the-fire-below/interactive-a-hotspot-trail (Search for "amnh hotspot trail.")

Image from Yellowstone's Photo Collection. "Yellowstone Hot Spot Track." http://www.nps.gov/features/yell/slidefile/graphics/diagrams/Images/15899.jpg Retrieved 12 November 2014.

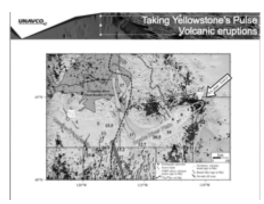
UNAVCO

Taking Yellowstone's Pulse
Volcanic eruptions



UNAVCO

Notes for slide 17



Look for the large yellow and white Y by the big white and black arrow. That is where the Yellowstone hot spot currently lies deep under the surface.

The rest of the map *is* certainly complicated but it shows the science behind the animation you explored in the previous slide. The black numbers show the ages of volcanic rocks west of Yellowstone in millions of years. 15.5, for instance, stands for rocks that are 15.5 million years old.

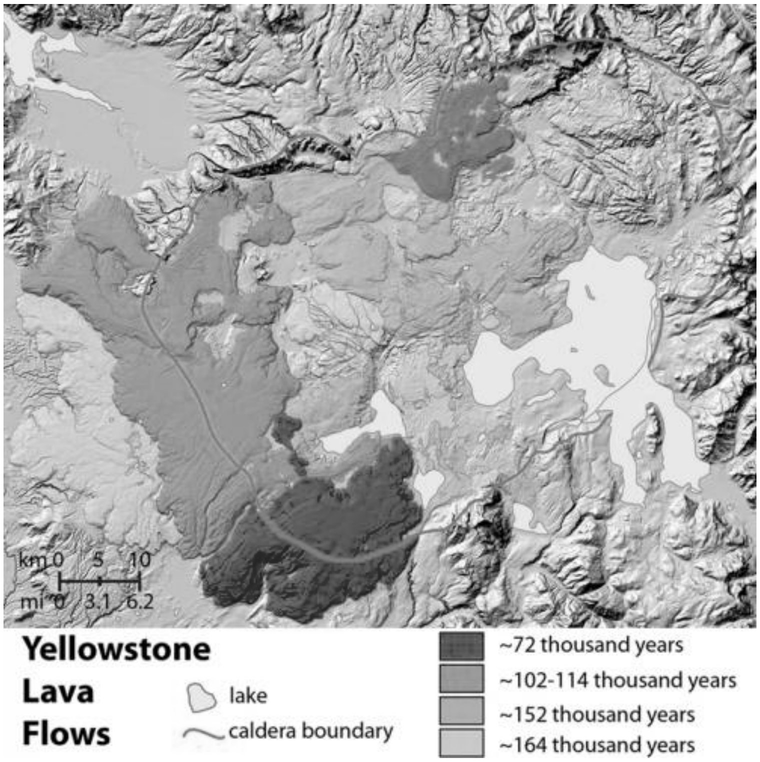
The red dots show where earthquakes were first felt on Earth's surface (the "epicenters.") Look at the legend to see what the other symbols represent.

This figure compiles the work of many geologists and is published in a scientific research journal. It's this kind of article, and the research that goes into it, that allowed the American Museum of Natural History to build the animation you explored on the previous slide.

Figure from Smith, R.B.; Jordan, M.; Steinberger, B.; Puskas, C.M.; Farrell, J.; Waite, G.P.; Husen. S.; Chan, W-L; and O'Connell, R.. 2009. "Geodynamics of the Yellowstone hotspot and mantle plume: Seismic and GPS imaging, kinematics, and mantle flow." Journal of Volcanology and Geothermal Research. v. 188. pp 26–56. Retrieved 29 December 2011.

UNAVCO

Taking Yellowstone's Pulse
Lava flows



Volcanic rocks erupted after caldera collapsed

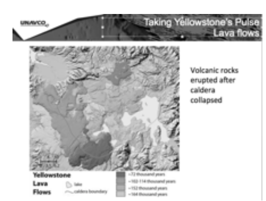
UNAVCO

Notes for slide 19

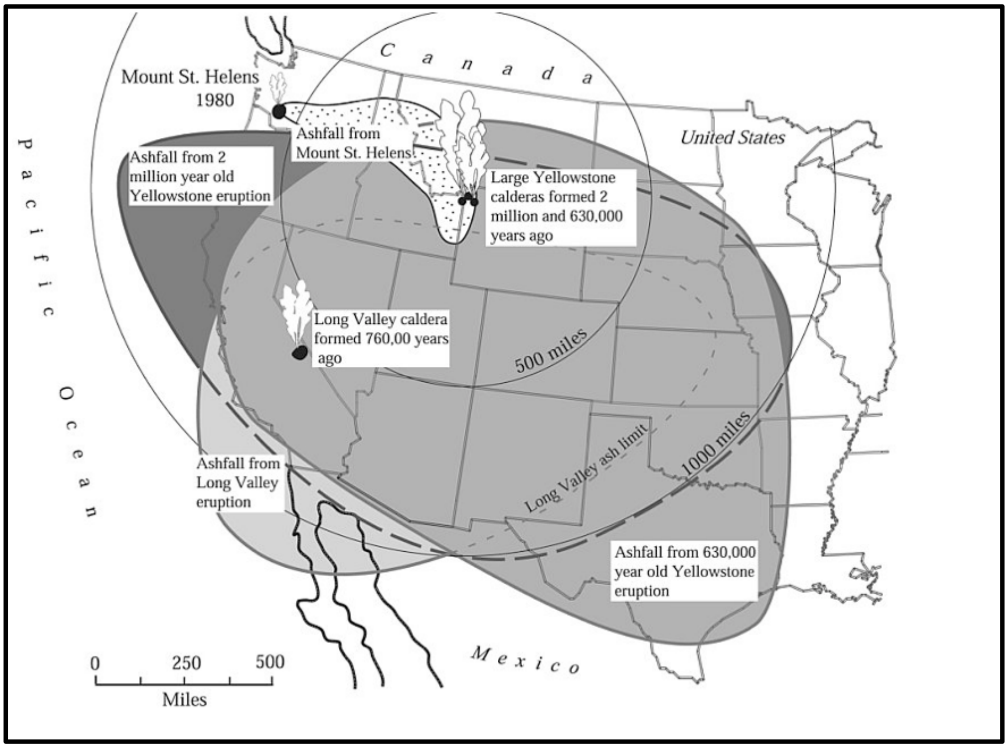
There have been about 80 lava flows since the most recent caldera formed 640,000 years ago. This map uses color to show different ages of the rocks, both inside and outside the caldera.

Clicking on the map links to The American Museum of Natural History's Science Bulletin. Select the "Different magmas - Different volcano" interactive link on this page to investigate the relationship between the different kinds of lava and volcanoes. http://www.amnh.org/explore/science-bulletins/earth/documentaries/yellowstone-monitoring-the-fire-below/interactive-different-magmas-different-volcanoes (Search for "amnh different magmas.")

Image from USGS Volcano Hazards Program: Yellowstone Volcano Observatory. Yellowstone maps. http://volcanoes.usgs.gov/volcanoes/yellowstone/yellowstone_gallery_14.html Retrieved 6 November 2014.



Taking Yellowstone's Pulse
Ash falls

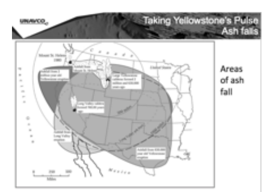


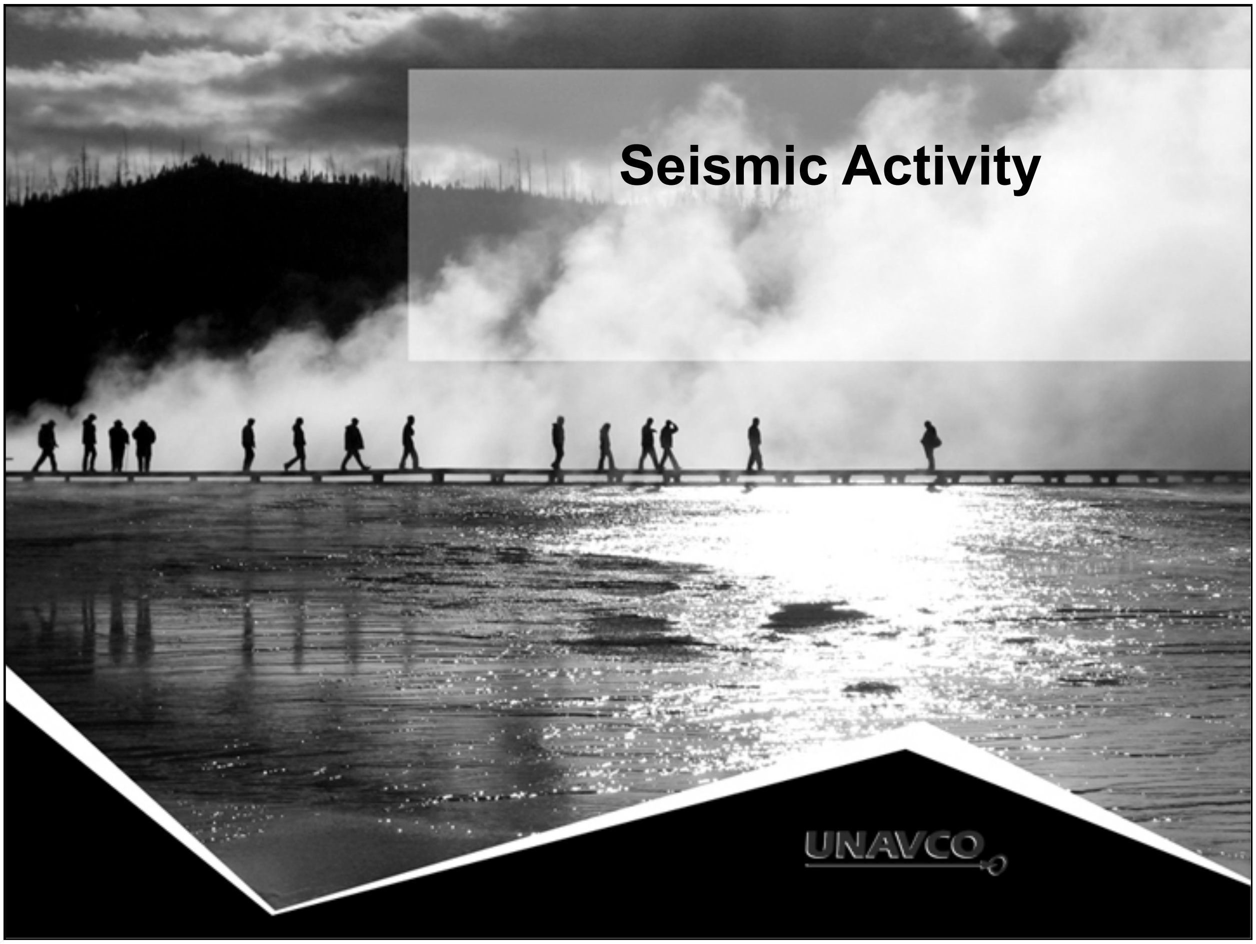
Areas of ash fall

Notes for slide 21

The collapse of calderas is cataclysmic. Rocks and lava explode upward and outward as the caldera collapses, and the debris covers huge regions. This map shows how far volcanic ash went during the 2,100,000 and 630,000 year-old eruptions that led to calderas in Yellowstone.

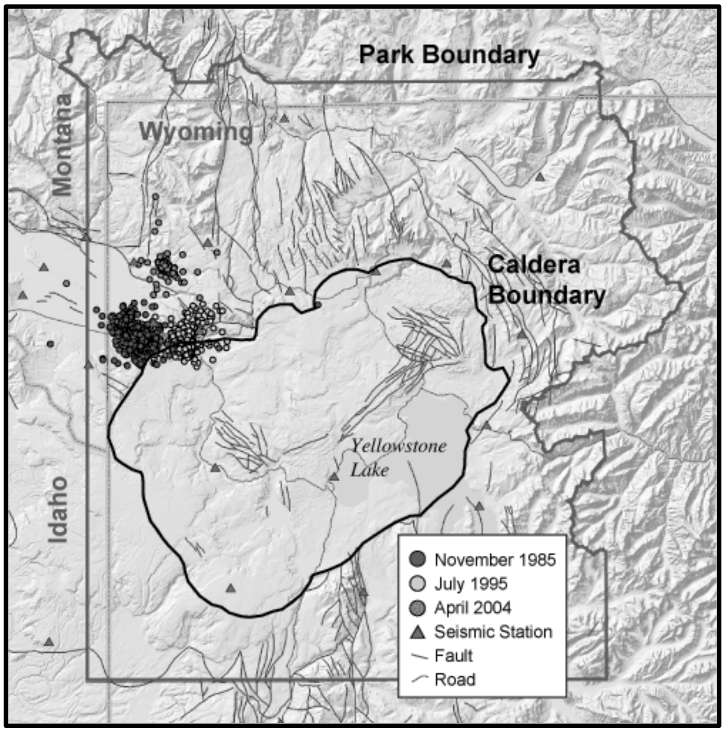
Figure from Smith, R.B. and Seigel, L.J. 2000. Windows into the Earth, The Geologic Story of Yellowstone and Grand Teton National Park. Oxford University Press. Accessed from the Yellowstone Volcano Observatory. http://volcanoes.usgs.gov/yvo/images/2000-rbs-3.2volcanicashcover_large.jpg Retrieved 30 December 2011.





Use the Yellowstone National Park Base Map to record your data.

You will need to make a key for your map like those you see on several of the slides.

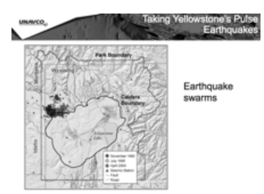


Earthquake
swarms

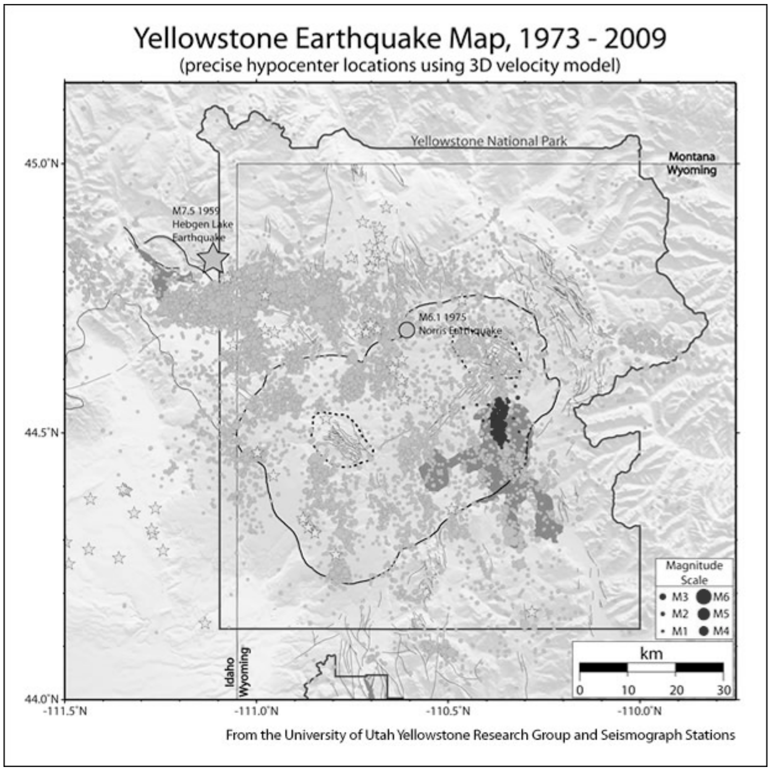
Earthquake swarms from 1985 to 2004 are shown on this map. Colored dots stand for different periods of time, as shown in the key. The black line marks the caldera boundary.

Map from Yellowstone Volcano Observatory: Yellowstone Earthquake Swarms.

http://volcanoes.usgs.gov/yvo/publications/2004/apr04swarm.php
Retrieved 30 December 2011.



Taking Yellowstone's Pulse Earthquakes



36 years of earthquakes

Notes for slide 27

This map shows the locations of earthquake epicenters. In the 36 years of records shown here, there have been only 2 major earthquakes:

1959 7.5 Hebgen Lake earthquake, marked with a grey star; and
1975 6.5 Norris Geyser Basin, marked with a large grey circle.

Red circles mark earthquakes that occurred in a swarm in 2008. Small grey circles mark other earthquakes. Yellow stars are volcanic vents.

Map from Yellowstone Volcano Observatory: More Yellowstone Lake Earthquake Swarm Images.
http://volcanoes.usgs.gov/yvo/publications/2009/moreswarm.php
Retrieved 30 December 2011.

UNAVCO

Taking Yellowstone's Pulse
Student resources

Other resources:

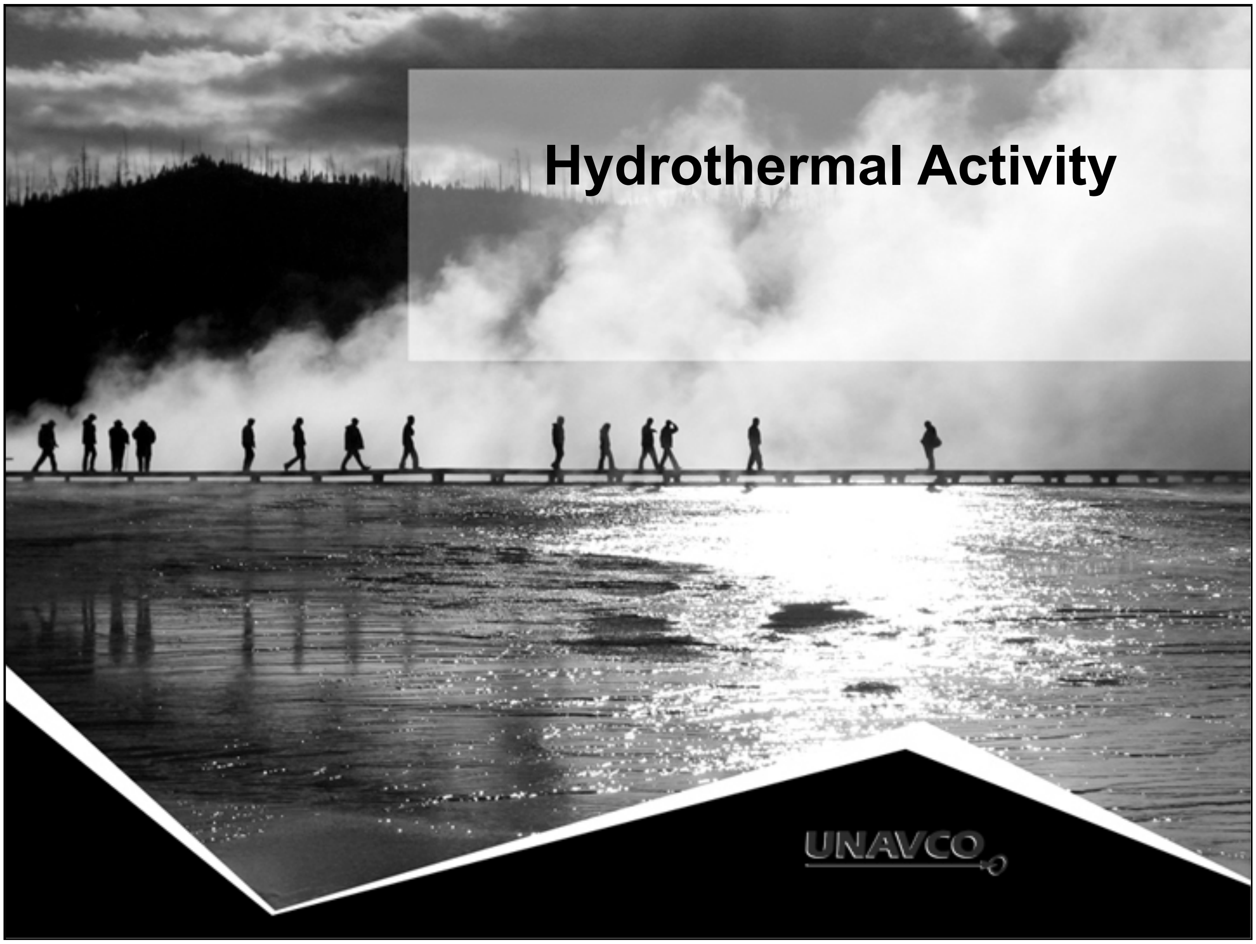
Data

- Recent earthquake activity (7 day)
  http://www.seis.utah.edu/req2webdir/recenteqs/Maps/Yellowstone.html (Search for "recent earthquakes yellowstone.")
- Live seismograms
  http://quake.utah.edu/helicorder/yell_webi.htm (Search for "earthquake helicorder yellowstone.")

UNAVCO

Notes for slide 29

Use these links to update your maps with the most recent earthquake information.



UNAVCO

Use the Yellowstone National Park Base Map to record your data.

You will need to make a key for your map like those you see on several of the slides.

Taking Yellowstone's Pulse
Hydrothermal explosions

Notes for slide 33

The left-hand image is an old postcard of a hydrothermal explosion at Excelsior geyser in 1888. In the 1880's to 1890's Excelsior Geyser, in Midway Geyser Basin, had a series of explosions. (Note that the date on the postcard is wrong.) Unlike volcanic eruptions, hydrothermal explosions are from pressurized water exploding out of the ground—not lava.

The right-hand picture is of Indian Pond, which is a crater made by a hydrothermal explosion in Yellowstone. The crater has since filled with water.

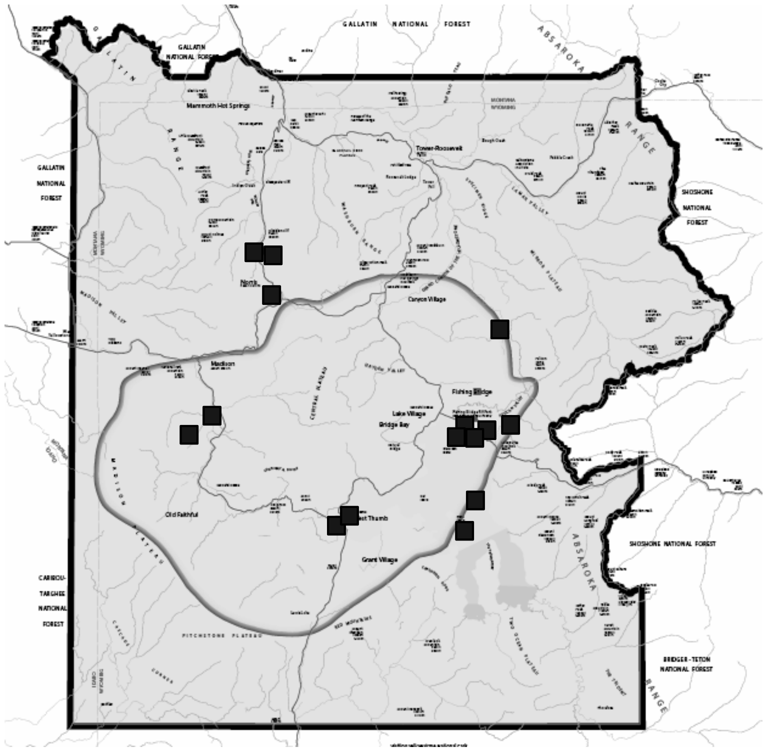
The largest hydrothermal-explosion crater in the world is located on the northern edge of Yellowstone Lake. There are more than a dozen large hydrothermal-explosion craters between Norris Geyser Basin and Mammoth Hot Springs. And, as recently as 1989, Porkchop Geyser exploded. You can learn much more by clicking on the postcard. http://yellowstone.net/geology/steam-explosion/ Retrieved 17 November 2014. (Search for "porkchop steam explosion.")

Postcard from Haynes, KF.J. 1888. Accessed from U.S. Geological Survey Fact Sheet 2005-3024. 2005. "Steam Explosions, Earthquakes, and Volcanic Eruptions—What's in Yellowstone's Future?" http://pubs.usgs.gov/fs/2005/3024/ Retrieved 31 December 2011.

Photo from Peaco, J. 2001. National Park Service: Yellowstone Digital Slide File: Thermal Explosions: 17244. http://www.nps.gov/features/yell/slidefile/thermalfeatures/thermalexplosions/Page.htm Retrieved 30 December 2011.

UNAVCO

Taking Yellowstone's Pulse
Hydrothermal explosions



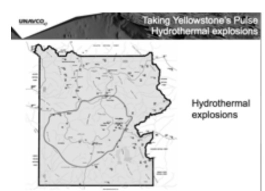
Hydrothermal explosions

UNAVCO

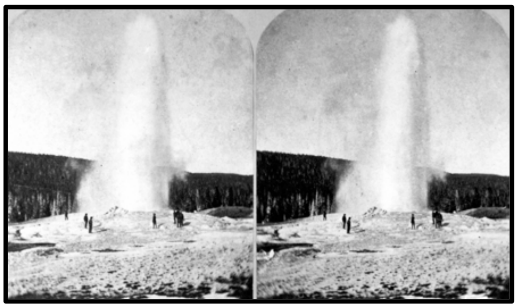
Notes for slide 35

Look for the dark blue squares that mark where scientists find evidence for hydrothermal explosions. (Red lines are roads; the grey oval is the caldera.)

Data from USGS Fact Sheet 2005-3024. 2005. “Steam Explosions, Earthquakes, and Volcanic Eruptions—What’s in Yellowstone’s Future?” http://pubs.usgs.gov/fs/2005/3024/ Retrieved 30 December 2011.



Old Faithful



Notes for slide 37

Old Faithful is probably the most famous geyser in the world, gathering an international audience even in winter to watch it erupt next to the Old Faithful Inn. The photos on the left were taken in 1872 by the famous photographer William Henry Jackson. He worked for the "Hayden Survey," the first official survey of Yellowstone, led by Ferdinand V. Hayden. Jackson and the painter Thomas Moran produced images that were essential for bringing the marvels of Yellowstone into the public eye—and into Congress's eye. The pair of images are slightly offset from each other so that viewers could see Old Faithful in 3D using a stereopticon.

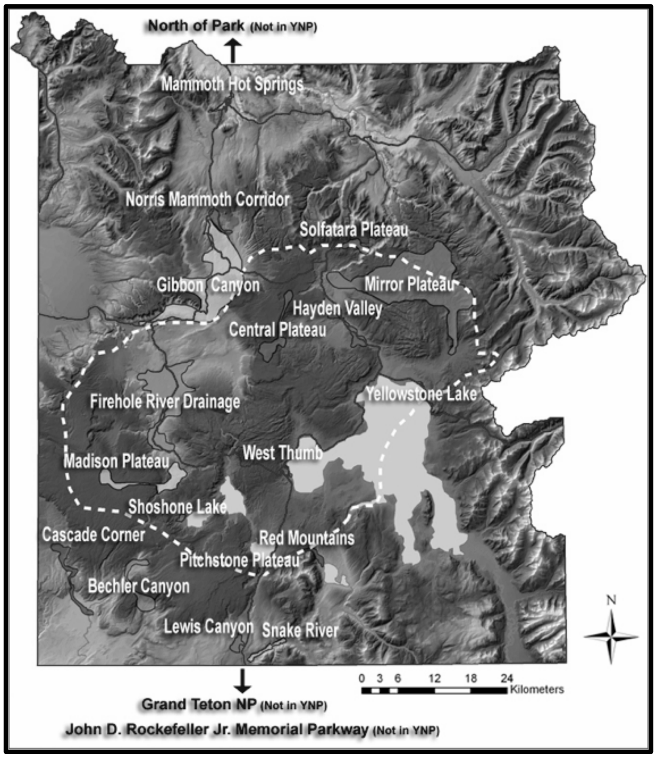
When you click on the 1872 photos, you will be taken to a streaming webcam of Old Faithful. This can take a minute or more to load. http://www.nps.gov/features/yell/webcam/oldFaithfulStreaming.html Retrieved 16 November 2014. (Search for "old faithful geyser webcam.")

When you click on the modern color photograph, you will be taken to a webcam at Old Faithful and several other sites in Yellowstone. (Be patient) http://volcanoes.usgs.gov/volcanoes/yellowstone/yellowstone_multimedia_10.html Retrieved 7 November 2014. (Search for "YVO webcam.")

Left-hand image from Jackson, W.H. 1872. US Geological Society Photographic Library. ID. Jackson, W.H. 1572. http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20Jackson,%20W.H.%201572 Retrieved 31 December 2011.

Right-hand image from National Park Service: Yellowstone Digital Slide File. Upper Geyser Basin: 05205. 1964. http://www.nps.gov/features/yell/slidefile/thermalfeatures/geysers/upper/Page-6.htm Retrieved 31 December 2011.

Taking Yellowstone's Pulse
Hydrothermal activity



Regions of geysers, volcanic vents, and mudpots

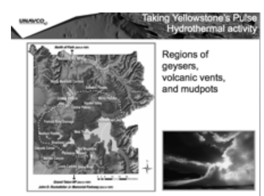
Notes for slide 39

Yellowstone has over 10,000 water and hydrothermal features. Hydrothermal regions are labeled on this map in white letters. Clicking on the map links to a website that details the geysers and fumaroles and mudpots known to researchers at Montana State University and the National Park Service. Click on a balloon to zoom into a thermal region. By continuing to zoom, you can learn about individual features. http://www.rcn.montana.edu/Default.aspx Retrieved 7 November 2014. (Search for "rcn montana yellowstone.")

The photo is of Great Fountain Geyser, in the Lower Geyser Basin.

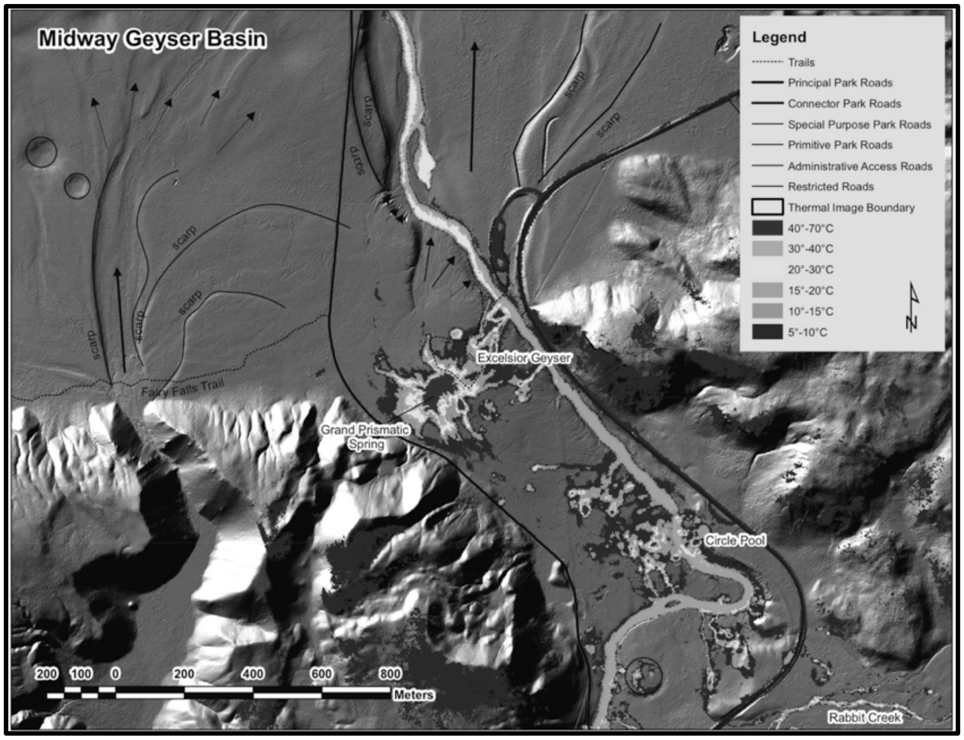
Left-hand image from the Research Coordination Network: YNP Thermal Features. http://www.rcn.montana.edu/resources/features/features.aspx?nav=11&map=81 Retrieved 31 December 2011.

Right-hand image from Schmidt, H. 1977. Yellowstone Digital Slide file: Midway & Lower Geyser Basins: 06675. http://www.nps.gov/features/yell/slidefile/thermalfeatures/geysers/midwaylower/Page-3.htm Retrieved 31 December 2011.



UNAVCO

Taking Yellowstone's Pulse
Hydrothermal activity

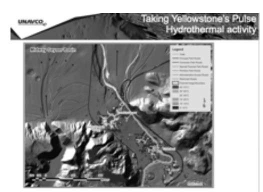


UNAVCO

Notes for slide 41

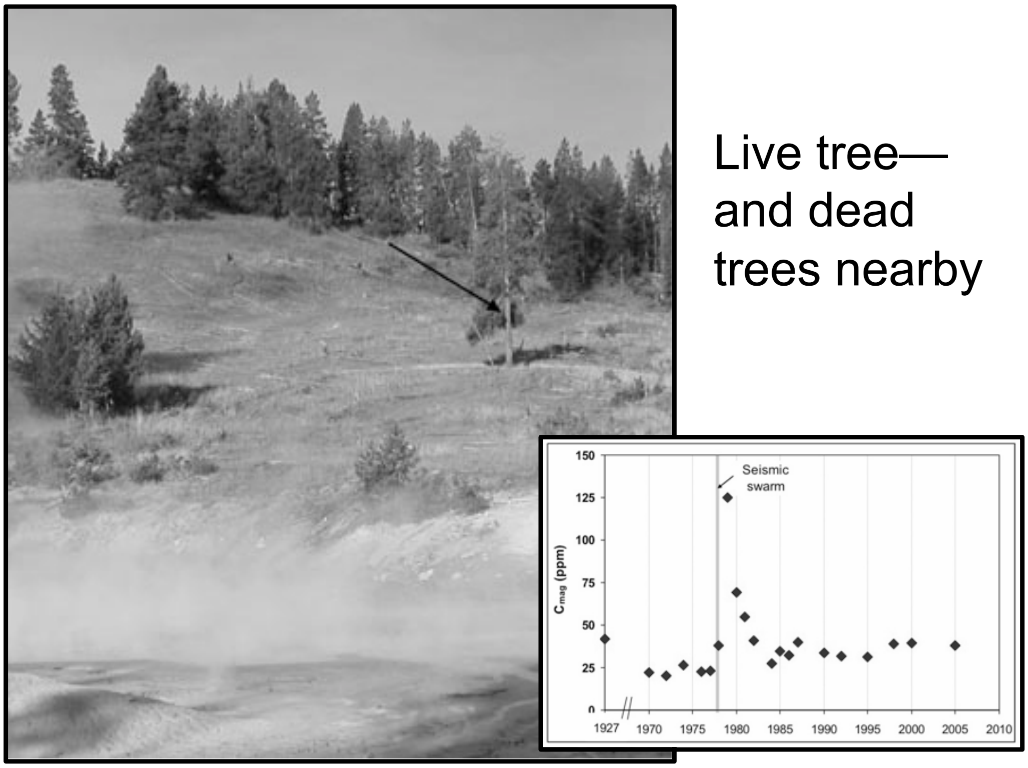
We can also now view hydrothermal features with infrared cameras on airplanes. The technology is called Forward Looking InfraRed (FLIR) and is suited perfectly for Yellowstone and other volcanic areas.

Image from Jaworowski, C.; Heasler, H.P.; Neale, C.M.U.; and Sivarajan, S. 2010. "Using Thermal Infrared Imagery and LiDAR in Yellowstone Geyser Basins," Yellowstone Science, v. 18, no. 1, pp. 8-19. Accessed from from Yellowstone Volcano Observatory: "New technologies help characterize hydrothermal activity at Yellowstone." http://volcanoes.usgs.gov/yvo/publications/2010/jaworowski.php Retrieved 31 December 2011.



UNAVCO

Taking Yellowstone's Pulse
Volcanic gas emissions

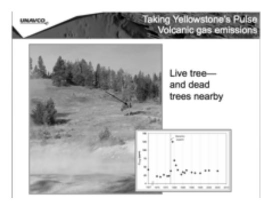


Live tree—
and dead
trees nearby

UNAVCO

Notes for slide 43

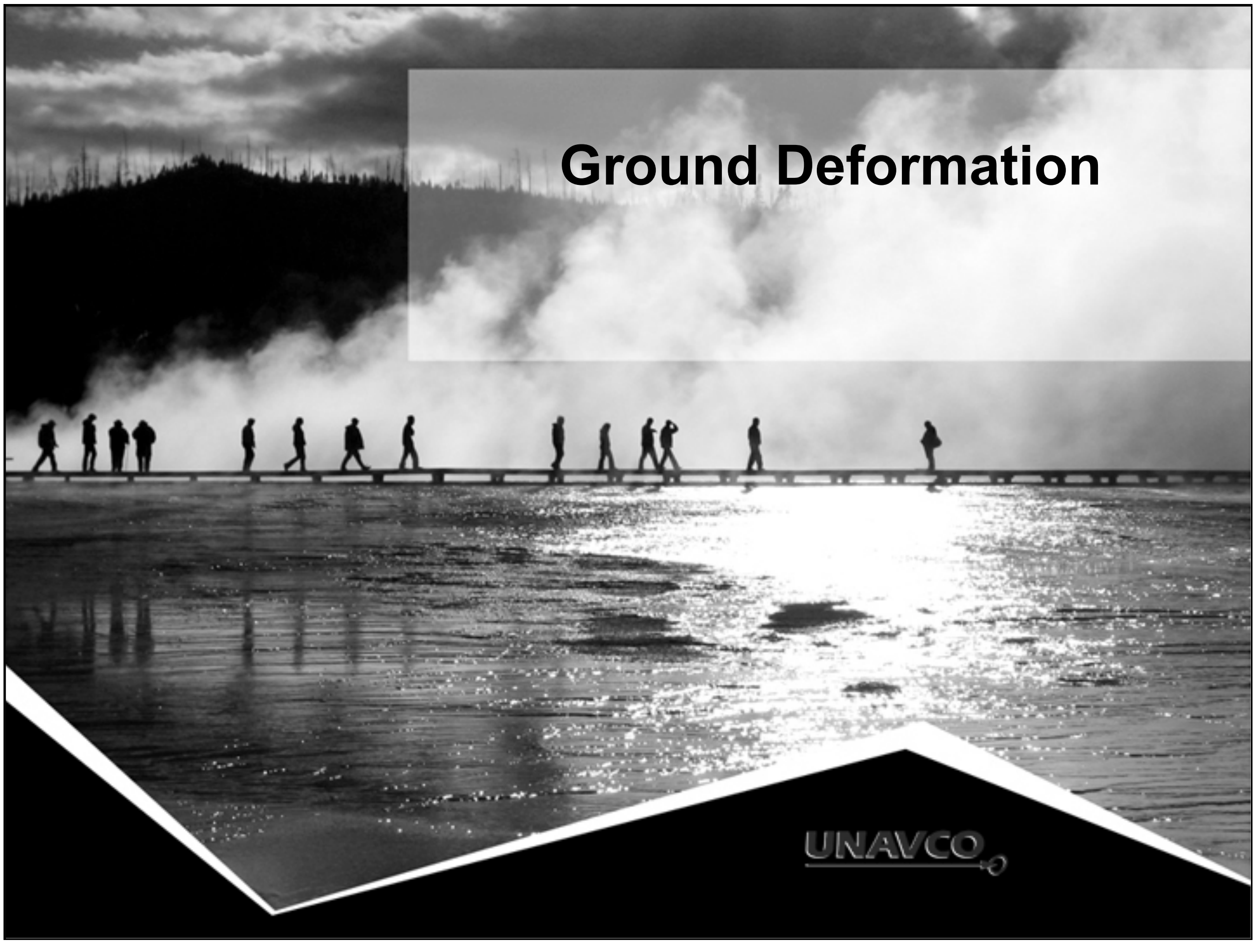
Volcanic gases can be unsafe to sample. However scientists can use other sign that the ground has emitted volcanic gas. The arrow in the photo points to a tree at Cooking Hillside, just north of Yellowstone Lake. Scientists sampled a core of its wood to measure its carbon content. The graph shows the results of the measurements. The spike in 1978 is associated with a swarm of earthquakes. Click on the graph to learn more. http://volcanoes.usgs.gov/volcanoes/yellowstone/yellowstone_monitoring_85.html (Search for "yvo gassy link.")



The dead trees around the live one were killed by heat. Other tidbits are that:

- 1897. Eight bears were found dead near "Death Gulch" (southeast of the park boundary) from carbon dioxide (CO_2) or hydrogen sulfide (H_2S) poisoning. These gases are heavier than air and tend to stay near the ground especially on windless cold nights.
- 2003. Several new vents that release volcanic gases were found in Norris Geyser Basin. These are called "fumaroles."
- 2004. Five bison were found dead in the Norris Geyser Basin, probably from CO_2 or H_2S poisoning.
- Only one human has died due to gases in Yellowstone.
- CO_2 is released in small amounts from virtually all of Yellowstone's hydrothermal features.

Images from Evans, W.C.; Bergfeld, D; McGeehin, J.P.; King, J.C.; and Heasler, H. 2010. "Tree-ring ^{14}C links seismic swarm to CO_2 spike at Yellowstone, USA," Geology v.38, p. 1075-1078. Accessed from Yellowstone Volcano Observatory: "New Study Reveals Gassy Link to Past Earthquake Swarm." http://volcanoes.usgs.gov/yvo/publications/2011/11cookinghillside.php Retrieved 31 December 2011.



UNAVCO

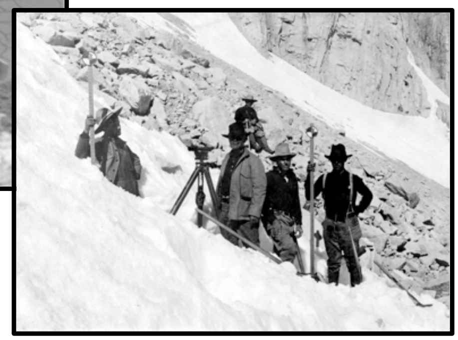
Use the Yellowstone National Park Base Map to record your data.

You will need to make a key for your map like those you see on several of the slides.

UNAVCO

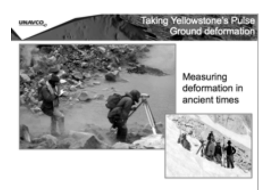
Taking Yellowstone's Pulse
Ground deformation

Measuring deformation in ancient times



UNAVCO

Notes for slide 47



At Yellowstone, scientists began monitoring changes in ground level in 1923 using old-fashioned surveying equipment like that seen in the photos. This was decades before GPS was invented. They continued surveying this way until 1996. They had to survey every year, a time consuming task, but in gorgeous surroundings.

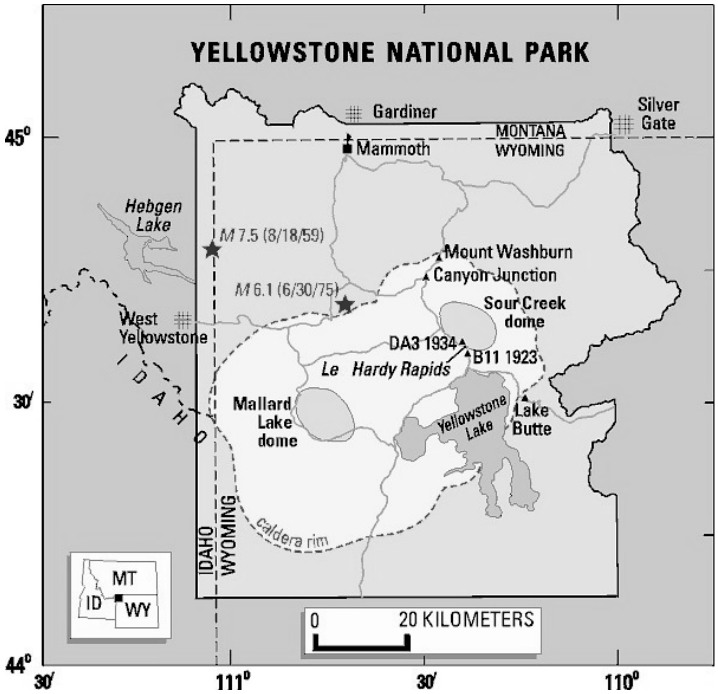
Scientists measured distance and elevation between points on "leveling lines." The photos show scientists surveying leveling lines in 1905 and 1981. The black and white photo is of scientists on Mount Whitney, California, at 14,500 feet elevation. The color one is of geologists working in the crater of Mount St. Helens on 6 November 1981.

Right-hand image from Department of Agriculture, Experiment Stations, Berkeley. 1905. US Geological Society Photographic Library. "ID. Topography A 240." http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20Topography%20A%202402 Retrieved 2 January 2012.

Left-hand photo from Topinka, L. 1981. USGS. U.S. Geological Survey Earthquake Information Bulletin, v. 16, no.2, p. 77. March-April 1984. Accessed from US Geological Society Photographic Library. "ID. CVO-F. 87ct." http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20CVO-F.%20%2087ct Retrieved 2 January 2012.

UNAVCO

Taking Yellowstone's Pulse
Ground deformation



Reference map for leveling data

UNAVCO

Notes for slide 49

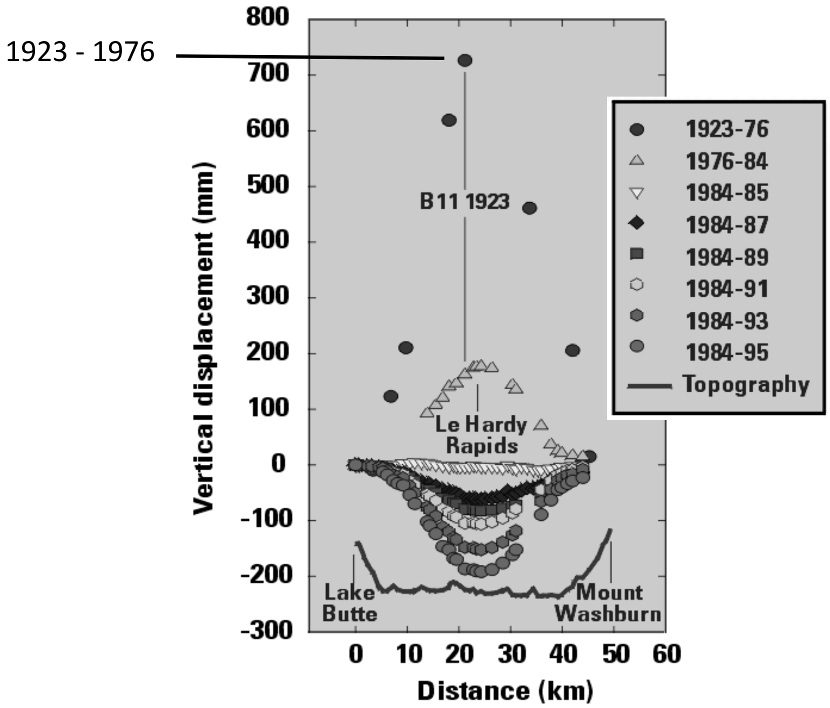
On your paper map, draw a line between Lake Butte and Mount Washburn. This will be like a leveling line. We have surveyed ("leveling") data from Lake Butte, Mount Washburn, and from many other stations in between, including at the Le Hardy Rapids and where B11 1923 is. located Mark those four points on your map.

Where is this line compared to the caldera? Discuss this as a group.

Map from Yellowstone Volcano Observatory: Map of Yellowstone Caldera and Leveling Benchmarks. http://volcanoes.usgs.gov/yvo/LvlMap.html Retrieved 30 December 2011.

UNAVCO

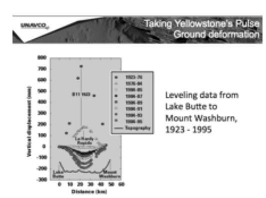
Taking Yellowstone's Pulse
Ground deformation



Leveling data from Lake Butte to Mount Washburn, 1923 - 1995

UNAVCO

Notes for slide 51



This graph shows how the elevation has changed along your leveling line from 1923 to 1995. Benchmark locations were measured repeatedly using surveying methods like those shown in the photos.

You might find it useful to look at one benchmark location, such as Le Hardy Rapids, closely. You could extend the short blue vertical line above the "H" to follow the symbols through time to see what happened to the ground at Le Hardy Rapids. The benchmarks can go either up or down through time.

The data on the graph are in the same order as the legend.

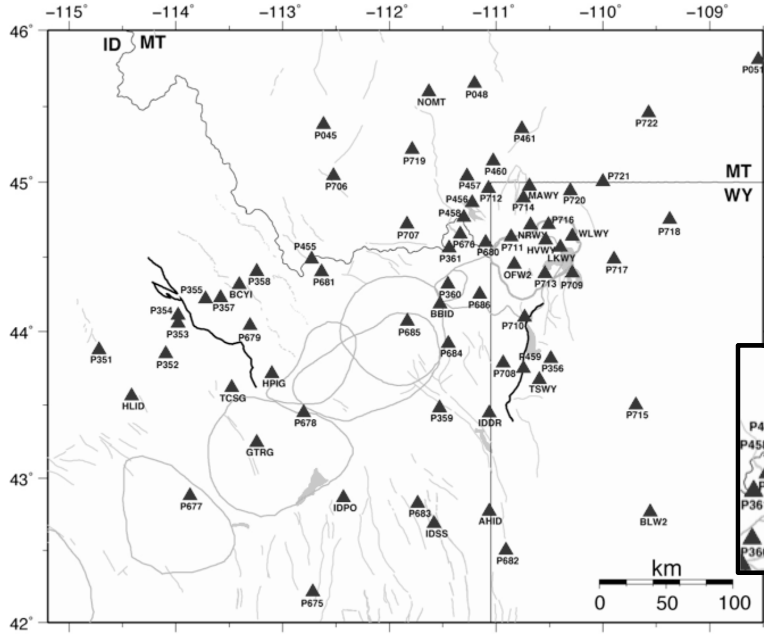
As a group, discuss these questions—and, if your teacher asks you to, write down your responses.

1. What does the horizontal axis show? The vertical axis?
2. What do positive numbers on the vertical axis mean? What about negative ones?
3. When was the area rising? When was it falling?
4. Which benchmarks moved the most – near the center or at the edges of the leveling line.

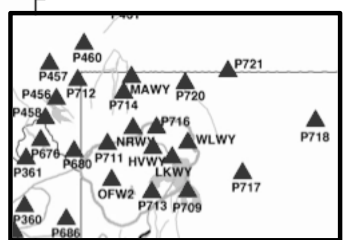
This data is for only the portion of Yellowstone along your leveling line from Lake Butte to Mount Washburn. That's about 50 km—30 miles. Other parts of the park might have behaved very differently from 1923 to 1995.

Image from Dzurisin, D., Savage, J.C., and Fournier, R.O., 1990, "Recent crustal subsidence at Yellowstone Caldera, Wyoming." Bulletin of Volcanology, v. 52, p. 247-270. Accessed from Yellowstone Volcano Observatory. http://volcanoes.usgs.gov/yvo/LvlData1923-1995.html Retrieved 2 January 2012.

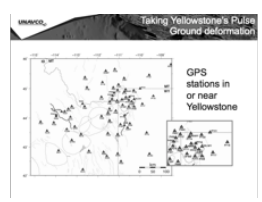
Taking Yellowstone's Pulse
Ground deformation



GPS stations in or near Yellowstone



Notes for slide 53



We also use ground stations that work in concert with satellites in a Global Positioning System, or GPS. Each of the stations on this map records data repeatedly every day. The stations are set into the ground ten meters, in concrete. They measure the position of the station very precisely. If the ground moves only a few millimeters in a year, the station can detect the change in position.

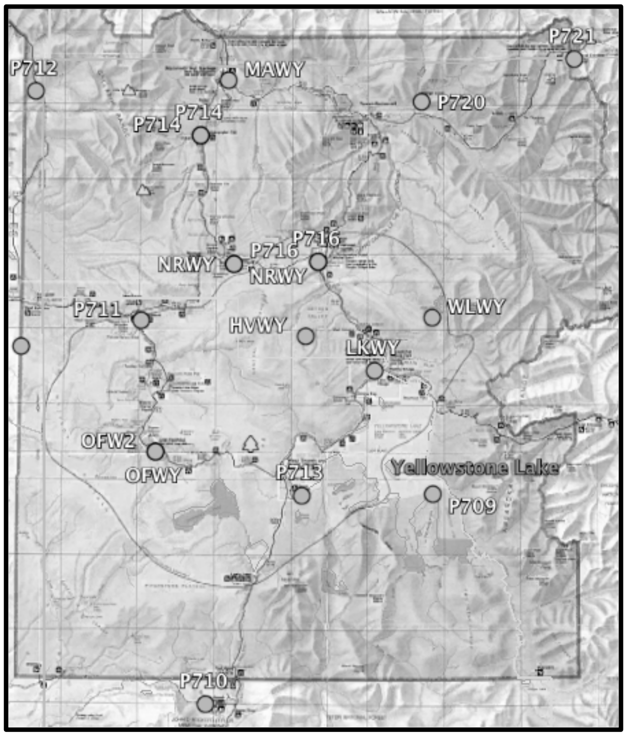
When you click on the large, regional, map, you will link to an interactive website that feeds you GPS data for the stations shown. The smaller map zooms in closer to Yellowstone. http://www.uusatrg.utah.edu/ts_ysrp.html (Search for "utah permanent gps network.")

The golden loops mark calderas.

Maps from Yellowstone-Snake-River-Plain GPS Network http://www.uusatrg.utah.edu/ts_ysrp.html Retrieved 2 January 2012.

UNAVCO

Taking Yellowstone's Pulse
Ground deformation



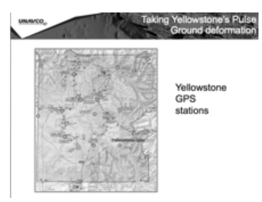
Yellowstone
GPS
stations

UNAVCO

Notes for slide 55

You will now work with GPS data near your leveling line. Four GPS stations lie near the line you drew on your paper map. They are P716, HVWY, LKWY, and P709. Draw their locations and ID labels on your map.

The data you need to graph is on the next slide.



Taking Yellowstone's Pulse
Ground deformation data

Change in Elevation of Four GPS Stations, Yellowstone N.P. (mm.)

Station	2004	2005	2006	2007	2008	2009	2010	2011	2012
P716		4.09	2.77	2.62	0.15	-0.65	-1.66	-6.74	-10.77
HVWY	-67.14	-47.14	-13.83	13.08	32.69	38.53	32.28	15.42	-2.87
LKWY	-116.5	-82.86	-21.31	14.14	41.41	60.85	55.00	36.18	19.10
P709		-12.14	-4.17	0.86	5.22	3.34	0.33	-2.42	-1.87

Notes for slide 57

Here is data that shows how much four GPS stations have moved up or down from 2004 to 2012. Positive numbers mean that that spot has risen. Negative values means that it has sunk. For instance, station P716 rose 4.09 millimeters in a year in 2005. These numbers are averaged from measurements taken daily for a year.

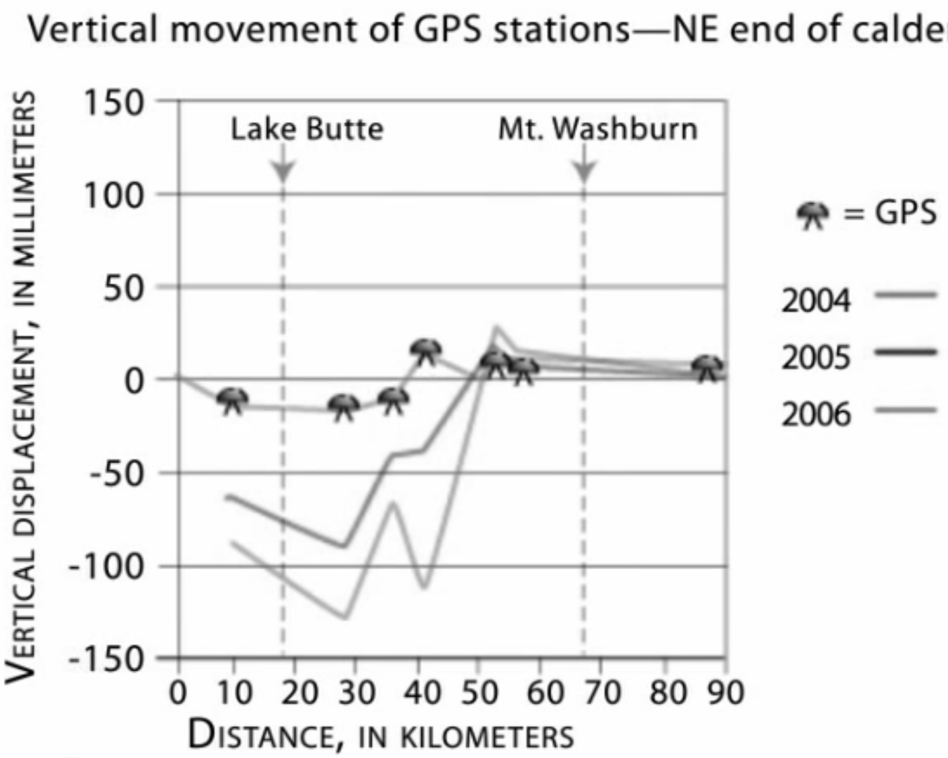
You will graph these stations' elevation over time, much like the leveling data was graphed in slide 9.
Make a line graph using the **station names on the X-axis** and the **change in elevation on the Y-axis**. You will want to find the range in the data for the four locations in order to set up the graph. *The X-axis will NOT be to scale like the leveling data was. If you would like to use the same scale, you can use a map of the park and measure the distance each station is from Lake Butte.*

Use a different color or symbol for each year's data or make a separate graph for each year. If you use different colors, make a key, and put the colors in a sequence like the rainbow or "ROY G. BIV."

Discuss the following questions:

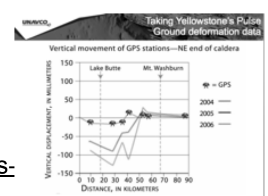
1. Do you see the same trend in the GPS data as was in the leveling data?
2. Can you assume this trend is true for all of Yellowstone?
3. Why might the GPS data be different from the leveling data?

Taking Yellowstone's Pulse
Ground deformation data



Notes for slide 59

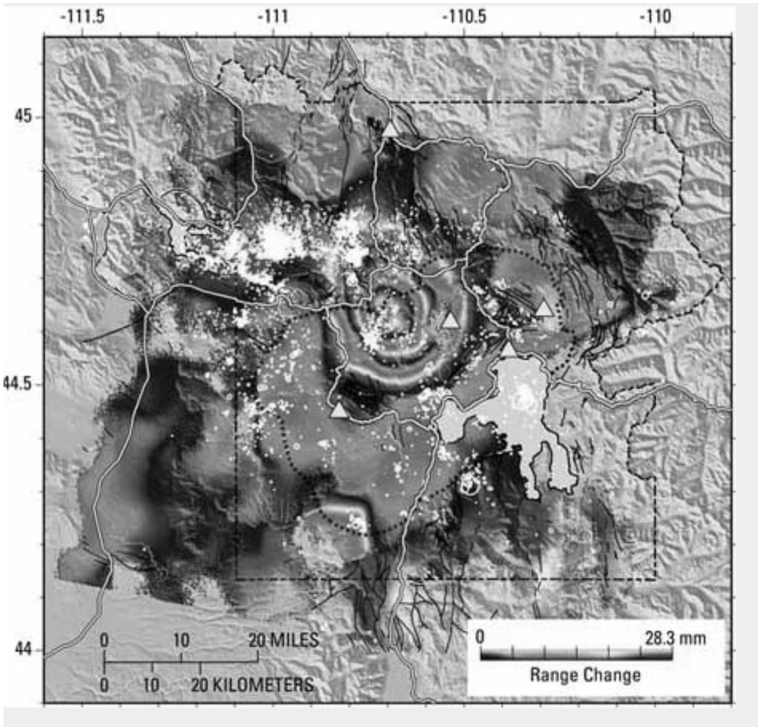
If you click on this graph, you can view an animation of the data that shows stations rising and falling.



Animation by Jenda Johnson for UNAVCO, 2013.

http://www.unavco.org//education/resources/educational-resources/lesson/gps-yellowstone/module-materials/yellowstone-gps-2004-2011.mov (Search on YouTube for "UNAVCO research P8.")

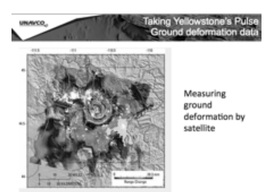
Taking Yellowstone's Pulse
Ground deformation data



Measuring ground deformation by satellite

Notes for slide 61

Scientists can also collect data about how the ground has deformed using a satellite-based instrument called Interferometric Synthetic Aperture Radar (InSAR). Computers compare two radar images of the area taken at different times and show changes in elevation with the colors you see. Each repetition of a color (say, from a yellow band to another yellow band) represents 28 mm of uplift. This image shows changes between 1996 and 2000. How much uplift was there?



Other features: white dots are earthquake epicenters. Yellow triangles are GPS stations. Yellow lines are roads.

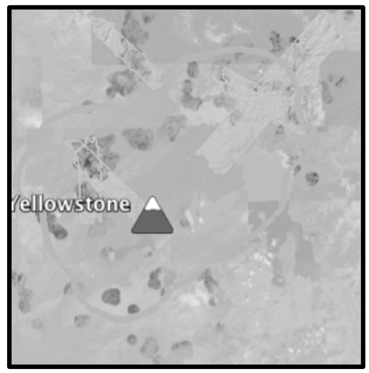
Click on the image to link to a brief article about ground deformation in Yellowstone. http://volcanoes.usgs.gov/yvo/publications/2007/upsanddowns.php (Search for "yvo ups downs.")

Compare and contrast leveling, InSAR, and GPS data for this area.

Use what you have learned about the changes in elevation at Yellowstone as you decide on a suitable site for a research station in Yellowstone.

Image from "Monitoring YNP's Heartbeat," Old Faithful Virtual Visitor Center, National Park Service. http://mms.nps.gov/yell/ofvec/exhibits/science/heartbeat/index.htm Retrieved 20 November 2014.

Geologic features in Google Earth



Notes for slide 63

If your team will be using Google Earth (GE) to compare where the interesting features in the park are, you might want to become familiar with your data on GE now. These two images were made with GE. The lefthand one shows all of the park, with an overlay of the National Park Service map, the caldera in gold, and turquoise outlined areas of high-tech satellite-based topography (LiDAR).

The righthand image is zoomed in closer. You can see where it's from by the northwest-southeast trending LiDAR region. This image does not have the official park map showing. It just has the base map, the caldera, LiDAR, and hot areas in orange shades. The heat was measured from NASA's Landsat satellites from 1985 to 2007. With GE, you can see the changes over time. You'll be able to add layers and remove them easily in GE.

There is a separate set of instructions which guide you through using Google Earth. Also, we have prepared some files that are ready for you to open in GE. (You can also make your own files from a spreadsheet by following our instructions.) The next slide has links to these files.

Taking Yellowstone's Pulse Data

Links to data files:

- The National Park Service map as an overlay
- Satellite images of the ground (LiDAR)
- Yellowstone's caldera
- Yellowstone's hot areas
- Yellowstone's 200 most recent earthquakes (as of January 2012)
- Yellowstone's 200 largest earthquakes
- Earthquakes from the last week

Taking Yellowstone's Pulse Google Earth Instructions

Links to instructions:

- Instructions for using Google Earth
- Instructions for converting an Excel spreadsheet into a file for Google Earth

Information

- EARTH: "Tracking Yellowstone's Activity"
  http://www.earthmagazine.org/article/tracking-yellowstones-activity
  (Search for "tracking yellowstone's activity.")

- "Steam Explosions, Earthquakes, and Volcanic Eruptions—What's in Yellowstone's Future?"
  http://pubs.usgs.gov/fs/2005/3024/fs2005-3024.pdf (Search for "pdf usgs explosion yellowstone.")

- "Tracking Changes in Yellowstone's Restless Volcanic System"
  http://pubs.usgs.gov/fs/fs100-03/ (Search for "tracking changes yellowstone.")

Other Resources

Data

- Map linking to data for individual hydrothermal features.
  http://www.rcn.montana.edu/Default.aspx (Search for "rcn montana yellowstone.")

Information

- Learn about hydrothermal systems and how they work.
  http://www.nps.gov/yell/naturescience/geothermal.htm (Search for "nps how hydrothermal systems work.")
- Learn about geysers and other hydrothermal features of Yellowstone.
  http://yellowstone.net/geysers/ (Search for "yellowstone net geysers.")
- Learn more about geysers from the Geyser Observation and Study Assoc.
  http://www.geyserstudy.org/ (Search for "geyser observation.")
- Learn more measuring volcanic gas emissions.
  http://volcanoes.usgs.gov/activity/methods/gas/index.php (Search for "usgs monitoring volcanic gases.")

Other Resources:

Information

- Learn about the 2008 earthquake swarm at Yellowstone lake
  http://volcanoes.usgs.gov/yvo/publications/2009/09swarm.php (Search for "usgs 2009 swarm.")
- Learn about the 2010 earthquake swarm at Madison Plateau
  http://volcanoes.usgs.gov/yvo/publications/2010/10swarm.php (Search for "2010 swarm madison.")
- Learn about Yellowstone's earthquakes and volcanoes (Geology chapter).
  http://www.nps.gov/yell/planyourvisit/resourceandissues.htm (Search for "nps yellowstone resources.")
- Learn from National Geographic about the Yellowstone supervolcano and earthquakes.
  http://ngm.nationalgeographic.com/2009/08/yellowstone/achenbach-text (Search for "achenbach yellowstone.")

- American Museum of Natural History (n.d.) Science Bulletins: "Yellowstone: Monitoring the Fire Below, "Signs of Restlessness." http://www.amnh.org/explore/science-bulletins/earth/documentaries/yellowstone-monitoring-the-fire-below/article-signs-of-restlessness (Search for "amnh signs restlessness.")
- Christensen, R. et. al.2007. USGS: Open-file Report 2007-1071. "Preliminary Assessment of Volcanic and Hydrothermal Hazards in Yellowstone National Park and Vicinity." http://pubs.usgs.gov/of/2007/1071/ (Search for "preliminary volcanic hydrothermal hazards yellowstone.")
- Dzurisin, D.; Savage, J.C.; and Fournier, R.O. 1990. "Recent crustal subsidence at Yellowstone Caldera, Wyoming." Bulletin of Volcanology, v. 52, p. 247-270. accessed from Yellowstone Volcano Observatory," Leveling Data Across Yellowstone Caldera." http://pubs.er.usgs.gov/publication/70016303 (Search for "recent subsidence at yellowstone.")
- Puckas, C.; Smith, R; Meertens, C.; and Chang, W-L. 2007. "Crustal deformation of the Yellowstone-Snake River Plain volcano-tectonic system: Campaign and continuous GPS observations, 1987-2004." Journal of Geophysical Research, v. 112. http://volcanoes.usgs.gov/yvo/2007/PuskasJGR.pdf (Search for "Puskas deformation yellowstone-snake river.")
- UNAVCO: Johnson, J. 2013. "Vertical Movement of GPS Stations—NE End of Caldera. http://www.unavco.org//education/resources/educational-resources/lesson/gps-yellowstone/module-materials/yellowstone-gps-2004-2011.mov Retrieved 20 November 2014. (Search on YouTube for "UNAVCO research P8.")
- USGS. 2007. Yellowstone Volcano Observatory. "Recent Ups and Downs of the Yellowstone Caldera—2007 article" http://volcanoes.usgs.gov/yvo/publications/2007/upsanddowns.php (Search for "yvo ups downs.")
- USGS. 2010. Yellowstone Volcano Observatory. "Volcano Monitoring at Yellowstone National Park" http://volcanoes.usgs.gov/yvo/activity/monitoring/index.php (Search for "YVO monitoring.")
- USGS. 2008. Yellowstone Volcano Observatory. "Recent ups and downs of Yellowstone Caldera." http://volcanoes.usgs.gov/yvo/publications/2007/upsanddowns.php (Search for "ups downs yellowstone.")
- USGS. 2005. U.S. Geological Survey Fact Sheet 2005-3024: "Steam Explosions, Earthquakes, and Volcanic Eruptions--What's in Yellowstone's Future?" http://pubs.usgs.gov/fs/2005/3024/ (Search for "usgs steam explosions yellowstone.")
- USGS. 2004. U.S. Geological Survey Fact Sheet 100-03: "Tracking Changes in Yellowstone's Restless Volcanic System." http://pubs.usgs.gov/fs/fs100-03/ (Search for "tracking changes yellowstone.")