WHAT'S Hot IN YELLOWSTONE NATIONAL PARK

We are used to seeing the world around us in visible light. However, there are many other types of light, including x-rays, gamma rays, ultraviolet, infrared, microwaves and radio waves, which we cannot see with our eyes. Each of these types of light gives us a unique view of the world around us. In this lesson we will examine infrared images taken in Yellowstone National Park. All objects emit infrared. The amount of infrared emitted depends on the object's temperature. Hot objects emit more infrared than cold ones do. Infrared images give us special information that we cannot get from visible light pictures. In these lessons a special infrared camera was used to create infrared images which will be used to help students learn about infrared light. Infrared images of geothermal features and everyday objects will provide students with a unique and interesting view of the infrared world. In addition, the Infrared Yellowstone activities will give students a new perspective and new view of the interesting features of Yellowstone National Park.

In 1872 Yellowstone National Park was established as the world's first national park. It is located in northwest Wyoming and extends into Montana and Idaho. Covering 2,219,791 acres, it is about the size of Rhode Island and Delaware combined! Yellowstone National Park is in a huge volcanic basin which was the site of several massive volcanic eruptions, the last of which occurred about 600,000 years ago. Yellowstone National Park is a region of incredible beauty, abundant wildlife and amazing geothermal features. Among the geothermal features found in Yellowstone are numerous geysers, hot springs, bubbling mud pots, fumaroles and hot spring terraces. These features can be explored in a unique way through infrared imaging.

Infrared images show the relative distribution of heat as a false color map and can reveal information not found in visible light images. By comparing and contrasting visible light images and infrared images, learners will discover the importance of using different regions of the electromagnetic spectrum to study objects. Though not expressed in this particular lesson, this infrared exploration can be extended into exploring additional applications of infrared imaging on Earth and in space. Viewing objects using different types of light gives us a more complete understanding of these objects.

In this lesson:
Learners discover new perspectives on fascinating geothermal features like geysers, mudpots, hot springs, and hot spring terraces. Already familiar with the basic characteristics of these features, they explore the geology of Yellowstone National Park in a new light, infrared light! During this lesson, they will gain an understanding of infrared light and infrared imaging as well as deepen their content knowledge on geothermal features.

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I. GENERAL INFORMATION

Title: What's Hot in Yellowstone National Park

Brief Description: Learners are introduced to infrared imaging by first exploring Old Faithful geyser in infrared light. After a lesson in infrared imaging, they are ready to apply their new understandings to their current understandings of geothermal features. They are asked to create their own infrared images of geothermal features using visible light images as a guide.

Primary Goal: Use these activities to introduce learners to infrared imaging and the information that such images contain. Observation, compare and contrast, and reasoning skills are emphasized.

Activity Description: Your learners become curious about images of Old Faithful that are taken with an infrared camera. They are asked to express questions about the new type of picture and brainstorm what they think it might be. An activity in infrared imaging helps them figure out that the "new" pictures are taken with an infrared camera and can yield temperature information on an object/area in the images. Using their prior knowledge and brief worksheet descriptions of other Yellowstone National Park geothermal features (mudpots, hot springs, and hot spring terraces), they are tasked with creating their own infrared images of the geothermal features. They conclude the activity with a self-assessment as they compare and contrast their version of an infrared image with the real thing.

Learning Goals: Provided here are general learning goals for this entire lesson. You may have additional learning goals for your particular classroom and curriculum as these activities can be easily tailored to your own needs.

At the conclusion of this lesson set, your learners will be able to:

- Explain the differences between an infrared image and visible light image of the same object/scene.
- Explain that infrared light traces heat. Using infrared light, one can remotely study the temperature of an object.
- Correctly interpret an infrared image with false color map and temperature scale information.
- Create their own infrared image for a given known object to demonstrate understanding.

Target Audience: Grades 9-12

Teacher Preparation Time: 1-2 hours the first time, 15 minutes each subsequent use

Estimated Activity Time:

Day 1:
- Engage Your Learners: 20-30 minutes
- Explore Infrared Imaging: 25-45 minutes

Day 2:
- Infrared Old Faithful: 20-30 minutes
- Exploring Geothermal Features in the Infrared: 45-60 minutes

Materials Needed:

- Ability to download large files off the internet
- Ability to open, view, and print PDF files
- Ability to print in color (Resolution is at 72 dpi. PDF files are print-ready for any professional printing establishment (e.g., Kinko's or OfficeMax)
- Ability to laminate or otherwise protect printed images
- Ability to project images, either via computer or color overhead transparency
- Large learning space for groups of students to work comfortably and not disturb each other

- Colored pencils or crayons, 1 full set (white, hot pink, red, orange, yellow, green, blue, purple, black) for each learning group (3 students)
- Optional: Internet ready classroom with projection unit
- Optional: PowerPoint presentation capabilities and projection unit

Authors and Idea Makers:

The ideas presented in this lesson are the collaborative effort of the teachers in the Invisible Universe Online course during the spring 2003 semester. This particular lesson has been organized and written by Adrienne Gauthier (Instructional Technology Specialist, University of Arizona) with the help of Linda Hermans-Killam (Spitzer Science Center/Caltech) and Doris Daou (Spitzer Science Center/Caltech). This lesson has been evaluated by the Origins Education Forum at the Space Telescope Science Institute.

National Science Education Standards (NSES):

Changing Emphases (…More Emphasis On…)

The NSES envision change through out the system. Below are descriptions of how this lesson supports the changing emphases:

- Understanding scientific concepts and developing abilities of inquiry.
- Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science.
- Implementing inquiry as instructional strategies, abilities, and ideas to be learned.

Changing emphases to promote inquiry:

- Investigations over extended periods of time.
- Communicating science explanations.
- Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content.
- Public communication of student ideas and work to classmates.

II. GETTING READY

Pre-requisite Skills for Learners:

Your learners should have the following skills in order to participate efficiently and smoothly in this lesson:

- Ability to work in small collaborative groups of 3-4 students each
- Ability to work independent of direct instructor facilitation as the instructor will be wandering the classroom and helping all groups
- Ability to communicate findings, reasoning, and work to others
- Cognitive ability to recognize patterns that have not been introduced/explained before hand

Pre-requisite Content Knowledge for Learners:

Prior to this lesson, learners should be familiar with the following concepts:

- Temperature is a measure of the average heat or thermal energy of the particles in a substance.
- Heat can move from place to place.

Prior to this lesson, learners should have a firm understanding of the following concepts:

- There are different categories of light on the electromagnetic spectrum (radio waves, microwaves, infrared radiation, visible light, ultraviolet light, x-rays, and gamma rays).
- Each wavelength category on the electromagnetic spectrum has general properties associated with it. In particular, each wavelength category could be summarized in order of energy (lower to higher) which relates to temperature (lower to higher). In ascending order from lower to higher energy: radio waves, microwaves, infrared radiation, visible light, ultraviolet light, x-rays, and gamma rays.
- Geysers are located in geological hotspots, such as a volcanic caldera, and are associated with hot springs.
- Geysers shoot superheated boiling water into the air. This is due to an underground constriction in the plumbing of a hot spring.
- The general area around a geyser and hot spring is usually heated and warm, if not hot.

Common Misconceptions:

Misconception: The spectrum of electromagnetic radiation consists of only visible light.
Reality: The electromagnetic spectrum consists of: radio, microwaves, infrared, visible, ultraviolet, x-rays and gamma rays, listed from lowest energy to highest energy (also longest wavelength to shortest wavelength). The visible spectrum is a very tiny slice of the whole electromagnetic spectrum.

Misconception: All radiation is harmful.
Reality: All components of the electromagnetic spectrum are considered radiation but only the most energetic, ionizing radiation is harmful (x-rays and gamma rays). Radiation with wavelength equal to or longer than visible light is considered harmless (radio, infrared, and visible light). Ultraviolet light can cause damage to a person's skin but it is not considered ionizing.

Misconception: Heat and Temperature are the same thing.
Reality: Heat and temperature are related to each other, but are different concepts. Heat is the energy an object has because of the motion of its atoms and molecules. Temperature is a measure of the average heat or thermal energy of the particles in a substance. Temperature is not energy, but a measure of it. Heat is energy.

Preparation Work for the Instructor:

1. Create a PowerPoint presentation of the images in Image Appendix, **Image Set 1**, Geysers (Section VI, A)

Image Appendix, Image Set 1, Geysers (Section VI, A) - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet1.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet1.pdf

You can obtain digital images (JPEGS) of these images here:
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone
If you do not have the means to create or present a PowerPoint presentation, you can make overhead color transparencies.

2. Print out and make laminated copies of the image sets listed below. Depending on how you want to run the activity you will need to make enough sets for each small learning group or for each learner.

Image Appendix, Image Set 2, Old Faithful (Section VI, B) - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet2.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet2.pdf
Image Appendix, **Image Set 3, Mudpots (Section VI, C)** - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet3.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet3.pdf
Image Appendix, **Image Set 4, Hot Springs (Section VI, D)** - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet4.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet4.pdf
Image Appendix, Image Set 5, Hot Spring Terraces (Section VI, E) - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet5.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet5.pdf

3. Print out and make copies of the worksheets listed below from **Section V Worksheets** of this lesson guide. Depending on how you want to run the activity you will need to make enough sets for each small learning group or for each learner.

A. Worksheet 1 - make enough copies for each small learning group
B. Worksheet 2
C. Worksheet 3
D. Worksheet 4
E. Worksheet 5

4. Prepare the Exploring Infrared Imaging lesson. This lesson is located online here:
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/

5. Review the lesson and brainstorm modifications for your particular set of learners. Have ready some discussion questions and points that you want to cover for the lesson to fit into your existing curriculum and state science standards.

6. Design an evaluation rubric for this lesson based upon your learners, how you have tailored this lesson, and where this lesson falls into your curriculum. We do not provide an “evaluation” activity/rubric in this lesson, but we do provide sample learning goals generic to this lesson “as is” in the General Information section for this lesson.

7. Arrange the classroom for group work. Learners will need to have a desk, table, or floor space to spread pictures out without being cramped or too near other groups.

Background Knowledge and Resources for the Instructor:

Provided below are some internet resources to help you get a better grasp on infrared light and imaging. Please note that we have compiled a Cool Cosmos Teacher’s Guide to the Infrared that can be found here:

- Cool Cosmos Teacher’s Guide to the Infrared
  http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/background.html

Other Resources:

- Infrared Tutorial
  http://coolcosmos.ipac.caltech.edu/cosmic_classroom/ir_tutorial/

- Video- Infrared: More Than Your Eyes Can See
  http://coolcosmos.ipac.caltech.edu/videos/more_than_your/

- Heat and Temperature
  http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/

Geology Resources:

- Infrared Yellowstone at Cool Cosmos from Spitzer
  http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/gallery.html

- Yellowstone National Park: Mammoth Hot Spring Terraces and How They Work
  http://www.nps.gov/yell/nature/geothermal/mamterrc.htm

- Yellowstone National Park: Geysers and How They Work
  http://www.nps.gov/yell/nature/geothermal/geysers.htm

- Yellowstone National Park: Mudpots and How They Work
  http://www.nps.gov/yell/nature/geothermal/mudpots.htm

III. DAY 1: LEARN ABOUT INFRARED LIGHT AND INFRARED IMAGING

A. Engage Your Learners

Activity Time: 20-30 minutes

In this section you will introduce your learners to infrared imaging by showing them an image of a familiar geothermal feature, Old Faithful. They will certainly recognize the visible light image of the famous geyser, but will they be able to figure out what the infrared image is showing them? The goal of this verbal exploration and discussion is to reach the following topic ideas:

- The normal (visible light) picture is of a geyser that shoots hot water upward from underground.
- The "new" picture (infrared light) is unknown, but seems to be taken at the same time as the visible picture.
- The "new" picture (infrared light) seems to be color-coded and we think that the different colors represent different temperatures.
- The "new" picture (infrared light) is maybe a recording of non-visible wavelengths of light: radio waves, microwaves, infrared light, ultraviolet light, x-rays, or gamma rays.

1. Start this activity by projecting (via computer presentation or color overhead transparency) the visible light and infrared light images of Old Faithful. **Image Set 1** of the Image Appendix contains a variety of visible, infrared, and combined (side by side) views of Old Faithful for you to choose from.

Image Appendix, Image Set 1, Geysers (Section VI, A) - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet1.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet1.pdf

Note that these images have had the temperature legend stripped. Additionally, refrain from referring to them as "visible light" and "infrared light" views as it may give too much away at the beginning of the activity.

2. After reviewing your choice of the images, project one of the side by side (visible light and infrared light) images from **Image Set 1** of the Image Appendix (Section VI, A).

3. Ask a few probing questions to get their curiosity flowing.

Sample Probing Questions:

- What is this picture (visible light) of? [a geyser]
- What do we know about geysers? [they shoot hot water into the air]
- What is *this* picture of (infrared light)? [looks like the same geyser, but is different colors/not what our eyes see]

4. Encourage your learners to express their curiosities about the infrared view of the geyser. Example: What do you want to know about this (infrared) image?

Suggested Key Curiosities to encourage:

- What do the different colors represent?
- How was the picture taken?

5. Once keyed into the suggested curiosities from above, dive into a brainstorm class discussion that will cover the following points:

- The normal (visible light) picture is of a geyser that shoots hot water upward from underground.
- The “new” picture (infrared light) is unknown, but seems to be taken at the same time as the visible picture.
- The “new” picture (infrared light) seems to be color-coded and we think that the different colors represent different temperatures.
- The “new” picture (infrared light) is maybe a recording of non-visible wavelengths of light: radio waves, microwaves, infrared light, ultraviolet light, x-rays, or gamma rays.

6. Once the last two points above are expressed by your learners, you are ready to move forward into an activity focusing on infrared imaging.

B. Exploring Infrared Imaging

Activity Time: 25-45 minutes

This lesson is a mini-exploration and serves as an introduction to infrared imaging. At the conclusion of this exploration, your learners should understand the following:

- Infrared images (like the ones here) show how much infrared light was detected by the camera. Infrared light is used to measure the heat emitted by these objects. This measurement is transferred to color codes and is equivalent to degrees Fahrenheit.
- The infrared image has been scaled to show the temperature of the various areas of the object using a false-color map.
- False-color maps, like the infrared images here, come with a legend that tells the observer which temperatures are associated with which colors. This is how someone can accurately interpret the image.
- By looking at or observing the images, one can determine warmer or cooler areas. One is unable to do this with visible light images.

This activity is common to many of our lesson guides. Please go back to the website (http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/) and choose Exploring Infrared Imaging to access the lesson guide

IV. DAY 2: HOW HOT IS IT?

A. Infrared Old Faithful

Activity Time: 20-30 minutes

The goal of this brief activity is to get your learners thinking about how to apply their newfound understanding of infrared images of everyday objects to a well-known geothermal feature, Old Faithful. In this activity they will discover that they can determine a relative temperature of the water from the geyser and also get a sense of the temperatures of the nearby landscape as compared to the geyser water. Please note that the infrared images of the geothermal features in Yellowstone National Park were taken from quite a distance away and the temperatures described by the false color mapping do not represent actual temperatures since the heat reaching the infrared camera drops off with distance from the source. However, the infrared images are very useful for describing objects in the scene relative to each other, as in warmer or cooler, hotter or colder, etc. using the false color map as a guide.

You will be using the Old Faithful visible and infrared light collages (Old Faithful 1, Old Faithful 2, Old Faithful 3) from **Image Set 2** of the Image Appendix (Section VI, B).

Image Appendix, Image Set 2, Old Faithful (Section VI, B) - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet2.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet2.pdf

1. Begin the activity by dividing your learners into small learning groups of 3-4 learners each. Be sure the groups have enough space to spread the images out and discuss without disturbing other groups.

2. Hand out a set of images to each group. You can make note that the three images are sequential: Old Faithful 1 is near the beginning of an eruption, Old Faithful 2 is near the middle of an eruption, and Old Faithful 3 is near the end of an eruption.

3. Refresh the understanding of infrared images by asking a simple question, “What is the image on the right showing you?” Be sure to get a clear answer of, “It’s showing us the relative temperature of the areas of the image using the temperature legend as a guide”, before moving forward.

4. To each group, hand out **Worksheet 1** (Section V, A). Assign a recorder to write answers for the group. Allow 10 minutes for completion of the worksheet.

5. When the groups are finished, go over the answers to **Worksheet 1** (Section V, A) by asking groups to report their answers. Encourage them to express additional questions they may have about the images.

B. Exploring Geothermal Features in the Infrared

Activity Time: 45-60 minutes

In this culminating activity learners will be creating their own infrared images of geothermal features and then self-assessing their work by using actual infrared images of the features taken at Yellowstone National Park. Learners should have a familiarity and understanding of the geothermal features presented in this activity before they begin. The worksheets have basic information on the geothermal feature which should be supplemented by their own textbook or another resource. Be aware, if you allow the students to research online they will most likely stumble across the Infrared Yellowstone Gallery and will see the infrared images we use in this lesson.

Provided for you are 3 separate worksheets that you can use for this activity. There is a worksheet for mudpots (**Worksheet 2**, Section V.B), hot springs (**Worksheet 3**, Section V.C), and hot spring terraces (**Worksheet 4**, Section V.D). The Hot spring terraces worksheet is the most challenging of the three.

You may choose to break your class into small learning groups for this activity or have individuals work independently.

1. Each learner or learning group will need a visible light image set for a feature (mudpots, hot springs, or hot springs terraces), a corresponding worksheet, and a set of crayons or colored pencils.

- Mudpots: **Image Set 3**: Mudpot 1a, Mudpot 2a, Mudpot 3a and **Worksheet 2**
- Hot Springs: **Image Set 4**: Hot Springs 1a, Hot Springs 2a, Hot Springs 3a and **Worksheet 3**
- Hot Springs Terraces: **Image Set 5**: Hot Springs Terraces 1a, Hot Springs Terraces 2a, Hot Spring Terraces 3a and **Worksheet 4**

Image Appendix, **Image Set 3, Mudpots (Section VI, C)** - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet3.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet3.pdf
Image Appendix, **Image Set 4, Hot Springs (Section VI, D)** - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet4.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet4.pdf
Image Appendix, Image Set 5, Hot Spring Terraces (Section VI, E) - a separate MS Word or pdf file
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet5.doc
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_yellowstone/lessons/WhatsHot_ImgSet5.pdf

2. As a first step, learners should review the information presented on the geothermal feature that we provide as well as use their textbook to research properties and behaviors of their feature.

3. To complete the worksheet(s), your learners will apply their understanding of infrared images and the geothermal feature to “false color map” a gray-scale version of the visible light image. They will also answer a few basic questions about their reasoning.

4. After completion of the worksheet(s), hand out to each learner/group the infrared image set of their geothermal feature and the **Worksheet 5** (Section V.E).

- Mudpots: **Image Set 3**: Mudpot 1b, Mudpot 2b, Mudpot 3b (Section VI.C) and **Worksheet 5** (Section V.E)
- Hot Springs: **Image Set 4**: Hot Springs 1b, Hot Springs 2b, Hot Springs 3b (Section VI.D) and **Worksheet 5** (Section V.E)
- Hot Springs Terraces: **Image Set 5**: Hot Springs Terraces 1b, Hot Springs Terraces 2b, Hot Spring Terraces 3b (Section VI.E) and **Worksheet 5** (Section V.E)

5. On the **Worksheet 5** (Section V.E) they are asked to reflect on how they completed their geothermal feature worksheet(s) and how it compares to the real infrared image.

6. Hold a class discussion to conclude the activity. Groups or individuals can present their geothermal feature worksheet(s) and their **Worksheet 5** results.

V. WORKSHEETS

A. Worksheet 1
Make 1 copy for each small learning group

B. Worksheet 2
Make 1 copy for each small learning group or individual assigned to this feature

C. Worksheet 3
Make 1 copy for each small learning group or individual assigned to this feature

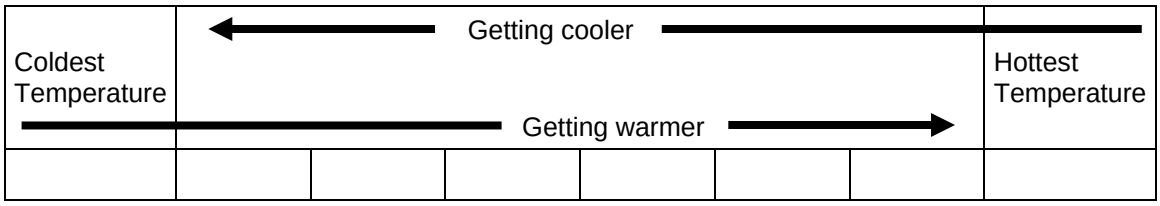
D. Worksheet 4
Make 1 copy for each small learning group or individual assigned to this feature

E. Worksheet 5
Make 1 copy for each small learning group or individual assigned to this feature

Name(s): _____ **Worksheet 1**

1. Write in the bottom boxes where each color belongs according to the false color mapping on the infrared image.

- Red/Hot Pink
- White
- Purple
- Blue
- Yellow
- Black
- Green
- Orange



Color

2. Make observations for the images by writing notes below. Compare and contrast the visible light image to the infrared image of each geyser. In what ways are they similar? In what ways are they different?

Similarities Between the Visible and Infrared Images	Differences Between the Visible and Infrared Images

3. Which area of Old Faithful 2 is the hottest? What do you know about geysers that supports your answer?

4. Which area of Old Faithful 2 is the coldest? Why do you think this is?

5. What is the blue area in Old Faithful 2 (infrared side)? Using what you know about geysers, explain why this area is cooler than the hottest area and warmer than the "black" regions.

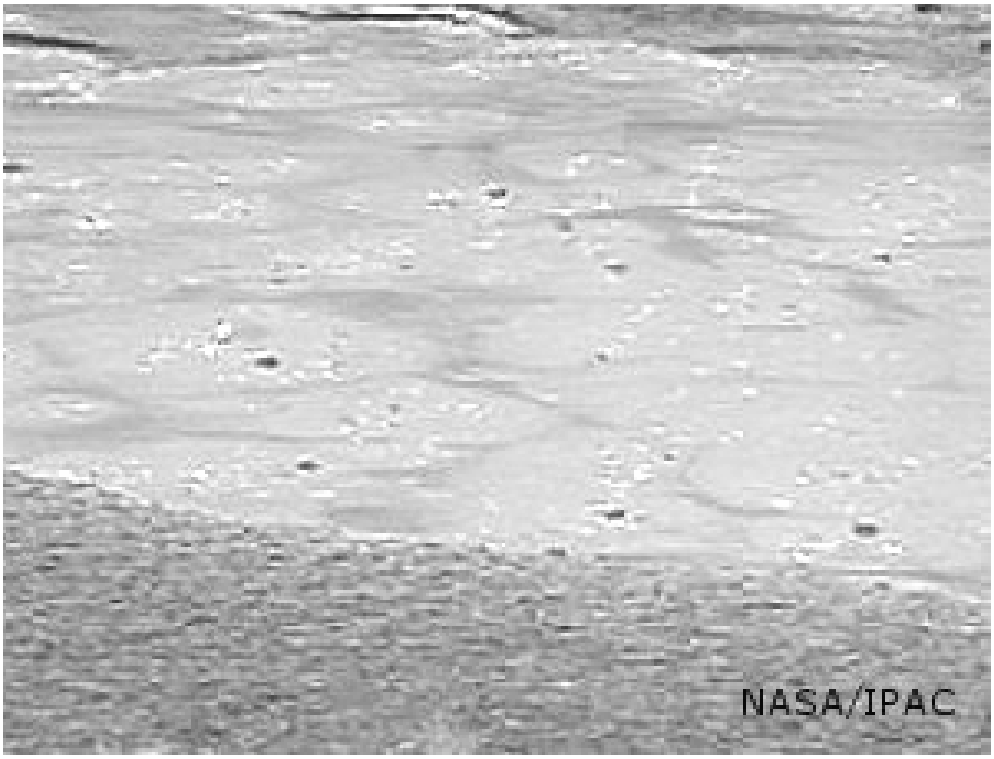
Name(s): _____ **Worksheet 2**

What is a Mudpot?

Mudpots are hot springs which do not have much water. The water in a mudpot is very acidic and it dissolves nearby rock into small pieces of clay. This clay then mixes with the hot water to create mud. Hot steam rising from below causes the mud to bubble and pop as the steam is released into the air.

Using the colored markers, crayons or pencils and the gray-scale image of mudpots below, create a false-color map of what you think the related infrared image would look like."

Create Your Legend:



Explain your reasoning for how you created your false-color map of the mudpot. What are the hottest areas? Why? What are the coolest areas? Why?

Name(s): _____ **Worksheet 3**

What is a Hot Spring?

Hot springs are pools of superheated hot water that have seeped to the Earth's surface to form small ponds. Much of Yellowstone is on a giant volcanic crater and hot magma (molten rock) is still close to the surface. This is the source of heat for Yellowstone's hot springs and other geothermal features.

Using the colored markers, crayons or pencils and the gray-scale image of hot spring below, create a false-color map of what you think the related infrared image would look like.

Create Your Legend:

Explain your reasoning for how you created your false-color map of the hot spring. What are the hottest areas? Why? What are the coolest areas? Why?

Name(s): _____ **Worksheet 4**

What are Hot Spring Terraces?

One of the most beautiful features found at Yellowstone National Park are the hot spring terraces found at a site called Mammoth Hot Springs. Heat, water and limestone combine to form these terraces. Water from rain or melting snow seeps deep into the earth where it is heated by magma. The heated water then rises through cracks and faults through ancient limestone deposits. The hot water dissolves some of this limestone and carries it along. When the water spills onto the surface it deposits the limestone which forms stair-like terraces. The terraces at Mammoth Hot Springs are continually sculpted by hot flowing water.

Using the colored markers, crayons or pencils and the gray-scale image of hot spring terraces below, create a false-color map of what you think the related infrared image would look like.

Create Your Legend:

Explain your reasoning for how you created your false-color map of the hot spring terraces. What are the hottest areas? Why? What are the coolest areas? Why?

Name(s): _____ **Worksheet 5**

After you have examined the infrared images answer the questions below.

1. How does your infrared geothermal drawing compare with the infrared image produced by the camera?

2. Are you surprised by the actual infrared image of your geothermal feature? How? If not, why aren't you surprised?

3. Describe in what ways your infrared false-color drawing is similar to the actual infrared image.

4. What are some reasons why your drawing is very similar to the infrared image? What information helped you have some accurate ideas?

5. Describe in what ways your infrared false-color drawing is different from the actual infrared image.

6. What are some reasons why your drawing is different than the infrared image? Can you think of additional information that could have helped you be more accurate?