

Name _____

Section _____

Partner(s) _____

Date _____

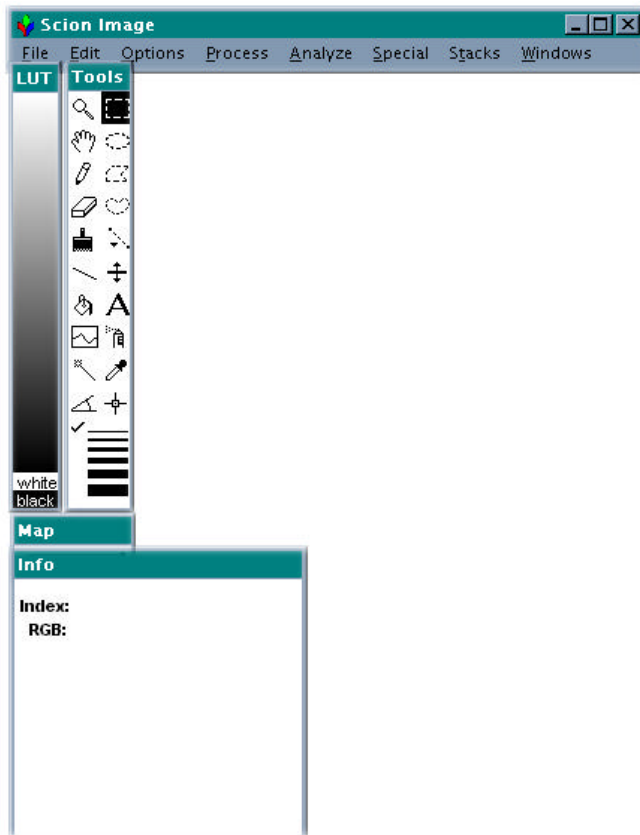
EXPLORING THE GEOLOGY OF OTHER WORLDS

In classrooms and through your personal experience over the years, you have had the opportunity to study some of the features of our home planet, Earth. You are familiar with oceans, rivers, mountains and hills, deserts with dunes, volcanoes and lava flows, rift valleys and trenches. But, are these features unique to our planet?

Our understanding of these features and the forces that form them help us discover the geologic history of other bodies in our solar system. In this series of activities, you will be able to investigate the nature of some of our planetary neighbors.

Before you begin this laboratory investigation:

To complete the individual activities in this investigation, you will be using a variety of materials from maps to computer image processing software. Let's start by getting the computer software running.



1. Turn on the computer and allow it to process until the icons have been displayed.
2. Double-click the **Scion Image** icon to start the image processing software. When it has loaded you should see a screen that has the display shown to the left.

The bar across the top that has the words “Scion Image” contains menus of functions for the software. You will also see an **LUT** (Look-Up Table) box and a **Tools** menu. There are also boxes titled **Map** and **Info**. Any of these boxes may be moved by left clicking and holding on its title bar while dragging the box with the mouse.

To open an image you go to **File** and “Open”. When you click on “Open” an **Open File** box will appear. All of the images you will use today will be found on the CD provided by your instructor. Locate

the CD drive and navigate to the folder “Activity 1”. When you click on this folder the image files it contains will be listed. Double-clicking on any file will open and display the image on the screen. You can reposition any image by left clicking and holding its title bar while dragging.

Activity 1: A First Look from Space

1. In Scion Image go to **File** and “Open”. Navigate to the CD and the folder “Activity 1” and click on it. Inside the folder, select the file “Earth.tif” and click open. Repeat the procedure with the files “Mercury.tif”, “Moon.tif”, “Venus1.tif”, and “Mars.tif”. Reposition the images on the screen so you can see most of each image. Some of the images will show only part of the surface but the view is representative.
2. Examine each image. You can see more detail by selecting the magnifying glass tool on the **Tools** bar. When you click on the image it will zoom in on the spot where you clicked. If you double click on the magnifying glass in the **Tools** bar the image will return to its original view.
3. On which images can you see:
 - a. sharp details of the available surface
 - b. no details or less clarity of the surface details

Why is there a difference in the surface detail you can see?

How might the difference affect our ability to study the planet surface from space?

In our solar system, the terrestrial planets Venus, Earth, and Mars have atmospheres. The atmosphere of Mars is relatively thin and does not significantly obscure our visibility of the planet. Earth and Venus have denser atmospheres. It is impossible to see the surface of Venus through the carbon dioxide blanket that surrounds the planet. To “see” the surface of Venus we have to rely on radar. In radar, a signal is beamed to the surface and we measure the time and angle of the return beam. From this information we can determine height and slope of the

surface features.

4. Close all of the images except Venus1.tif. This image shows the cloud cover that reflects sunlight (high albedo) and makes Venus such a bright object in the night sky. Open the image “Venus2.tif”. This image was generated from a radar instrument on the Magellan spacecraft. Compare the two images.

Which image is more valuable for studying surface features?

Which image is better for investigating atmospheric dynamics?

All of the Venus images and some of the Earth images you will use in the following activities are radar generated so that surface features are detailed.

5. What possible conditions can exist on a planet that has an atmosphere compared to one that does not?

How might the presence of an atmosphere affect surface features or surface change processes?

Close all images before proceeding.

Activity 2: Investigating the Most Common Extraterrestrial Landform

Put the computer aside for the moment and obtain a copy of the map of Moon. **DO NOT MAKE ANY MARKS ON THE MAP!** There is an index on the back of the map for convenience in locating named features.

1. Compare the nearside and farside of the Moon. Can you find any differences? List them.

2. What is the most common geological feature on the Moon? What do you notice about the shape of these features? How do you think this feature is formed?

The craters are formed by the explosive release of energy when an object (asteroid, meteorite or comet) collides with or impacts the surface. The impacting object is vaporized during the impact. Almost all craters are circular due to the explosive nature of impact. Some craters on the Moon show ejecta rays, rock thrown from the crater during impact.

3. Locate a crater with ejecta rays. Name of crater:
Draw a sketch of the crater showing the rays.
4. Can you find any non-circular craters? Give name and location. These are formed by very low angle impact (less than 15°).

Find the pair of Messier craters. They are both elliptical in shape. Notice the ejecta rays. Can you tell from what direction the impactor came?

Activity 3: Making Craters

Let's make some craters by performing a simple simulation of the impact process. To set up the cratering surface:

1. Place about 3-4 cm sand in the pan. Surface of the sand should be flat (smooth with ruler).
2. Using the stainer, spread a uniform, thin layer of colored chalk onto the sand.
3. After each cratering experiment, smooth the sand and chalk again.

Will the mass of the impacting object affect the size of the crater? Explain why or why not.

4. Drop each of the three different mass balls from a height of 2 meters. Measure the diameter and describe (including any relative changes in depth) the craters. Does any ejecta form (blanket or rays)?

Mass	Diameter	Description
LOW		
MEDIUM		
HIGH		

Sketch an aerial view and a cross-section (side-view) of the general shape of a crater produced from the high mass ball. Show how the diameter was measured on the cross-section.

5. Smooth and rechalk the surface. Set up the track provided so that it makes a 15-20° angle with the surface of the sand. Roll the lightest ball down the track into the sand.

Is the shape of the crater the same? Explain.

Low angle impacts form elliptical rather than circular craters. You have already seen an example of these in the Messier craters.

Activity 4: Cratering on Other Solar System Bodies

1. What might have caused the cratering on the Moon?

If the moon is covered with craters, are craters likely to appear on other solid bodies in our Solar System?

2. Open and arrange the following files from the folder "Activity 4":
 Mercury_crater.tif surface of Mercury

Mars_crat.tif
Callisto_crat.tif

surface of Mars
surface of Jupiter's moon Callisto

3. Each of the images shows cratering on the surface of the body. Look at the image of Callisto. What is different about these craters compared to the Moon, Mars, and Mercury? Why might these craters be different?

Callisto is thought to be covered with ice. Over time the surface ice has become "dirty". When a fresh impact occurs it exposes cleaner subsurface ice which is white.

4. Look at the Mars and Mercury images.

On which image is there a crater with ejecta rays?

Can you tell which planet was subjected to more impacts? Explain?

5. Now let's go back and review the nearside and farside of the Moon. Refer to the map if necessary.
Which side would you say had more impacts and why?

Is it reasonable for one side of a rotating body to have more impacts than another?

What is a possible explanation for the difference in crater density on the two sides of the Moon and on Mars compared to Mercury?

It is believed that early in the history of the solar system (approximately 4 billion years ago) rocky/icy debris from the formation of planetary bodies was bombarding the newly formed planets and moons causing extensive cratering similar to what is seen on the Mercury or the farside of the Moon.

Several of the bodies in the solar system have been geologically active and subjected to lava flows in the past (and present in the case of Earth and Jupiter's moon Io). These lava flows cover over or fill in cratered terrain generating regions of smooth plains or shallow craters. On the near side of the Moon these lava flows have formed the "maria" or seas of darker smooth surface. Mars and Venus also has evidence of extensive volcanic activity. On these planets, evidence of the early bombardment of all bodies in the solar system has been partially erased.

Bombardment is still occurring today and fresh craters can be seen on most terrestrial planetary bodies.

6. The craters you have looked at so far have been made on very solid surfaces.

What might happen when an impact strikes a surface that is softer or contains water in liquid or frozen form? Think about making a crater in a container of thick mud rather than sand. Remember that impacts generate a tremendous amount of energy (heat).

Close all previous images. Open the following images in the "Activity 4" folder:

Venus_crater.tif	craters on surface of Venus
Europa_crater.tif	crater on surface of Jupiter's moon Europa

Look at the Venusian crater image. What is different about the crater pattern on this image compared to the Moon or Mercury? What feature might tell you that the ground where the impact occurred may have contained water?

Look at the image of Europa. What is distinctive about this crater compared to others you have observed?

Scientists believe that Europa is ice covered. Explain what may have happened when the impact struck the icy surface to generate the resulting crater and why.

Activity 5: Earth Craters

1. If the solar system was subjected to severe bombardment, shouldn't there be evidence on the Earth's surface? Explain why or why not.

2. Open the following files from the folder "Activity 5":
 meteor_crater1.tif Meteor Crater from Space Shuttle
 meteor_crater2.tif Meteor Crater aerial shot

These two images show the Meteor Crater, also known as Barringer Crater, in Arizona. The first image was taken from the Space Shuttle. Locate the crater on this image.

Does the crater look recent (less than a million years) or ancient (over a billion years old)? Explain.

The 1200 meter diameter crater was probably formed about 50,000 years ago. It has a sharp, well-defined shape which indicates it is geologically recent.

3. Close the two images of Meteor crater and open the following files in "Activity 5" folder:
 Aorounga.tif Aorounga Crater in northern Chad, Africa
 Manic_crater.tif Manicouagan Reservoir, Quebec Province, Canada

What would lead you to believe that these features were formed by an impact?

How many crater features can you detect in the image of the northern Chad?

Scientists believe that there are at least two impacts close together at this site. They are located right and center on this image.

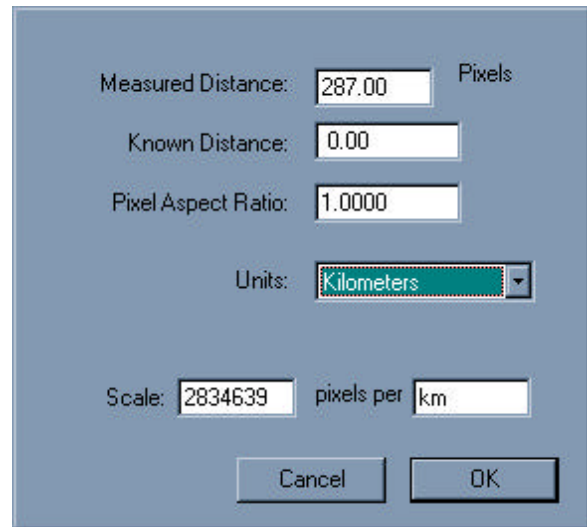
Try to determine the outermost extent of each of these craters (edge of any circular feature). Take a guess at how large the left crater is.

The left crater measure about 17 kilometers (10.5 miles) each. How well did you guess? This image was taken imaging radar that allowed penetration through thin layers of sand in this region of the Sahara Desert.

4. The second image shows the remnants of a crater on the Canadian Shield. It has been modified by advances and retreats of glacier since it was formed about 212 millions years ago.

The software you are using will allow you to measure the diameter of the crater as long as you know scale of the image. This square image covers a distance of 225 kilometers.

- a. Be sure the Manic_crat.tif image is selected.
- b. Go to **Analyze** and “Reset”. If you get a message that says measurements will be lost click “OK”.
- c. Select the dotted line tool from the **Tools** bar. Place the cursor at one side of the image and while holding down the left mouse button, drag the cursor to the other side of the image in a straight line. A dashed animated line should appear. If you do not like the line or it is not straight just move the cursor to another point and repeat the procedure until you have a line that is straight across the image.
- d. Under **Analyze** select “Set Scale”. You should see a screen that looks like the one shown here. Your measured distance may vary. Select kilometers in the unit box. In the box next to known distance type in 225. You have now indicated how many kilometers are represented by the pixels (picture elements) you measured. Now any measurements you make on this image will be recorded in kilometers.
- e. Go to **Analyze** and “Options”. Be sure the “Perimeter/Length” box is checked.
- f. Go to **Analyze** and select “show Results”. A new box titled “results” will appear.
- g. With the dotted line tool still selected move the cursor to one side of the crater and draw a straight line like a diameter across the crater. Go to **Analyze** and select “Measure”. The length of the diameter you drew will appear in the Results box in kilometers. Repeat the measuring procedure four or five time across



different parts of the crater. What is the average diameter of the crater based on your measurements? Check with your instructor to see how close you came to the actual diameter.

average diameter _____

Activity 6: Non-Impact Craters

Not all circular features on a planetary surface are caused by impacts. From your experience can you think of another process that can generate semi-spherical indentations?

1. Open the file named "Crater_lake.tif" from the "Activity 6" folder.

This lake is in the volcanic caldera of remnants of Mount Mazama in Cascade region of Oregon. The circular feature is a result of subsided lava dome that existed in this currently inactive volcanic peak. Close the image when finished.

2. Open and arrange the following files from folder "Activity 6":

MtStHelen.tif	Mount St. Helens volcano, September 1992
Galapagos.tif	Galapagos Islands, Pacific Ocean
Russianvolc.tif	Mount Kronotskaya, Kamchatka Peninsula, eastern Russia

This set of images shows Earth volcanoes photographed from the Space Shuttle. Observe the images and look for the volcanic craters. You should be able to locate more than one on each image except for Mount St. Helens.

Why might you expect more than one volcanic peak in a region?

When you have finished close all images except "Galapagos.tif".

3. Open and "Tharsis_Plain.tif" from folder "Activity 6"

This image shows the Tharsis Plain on Mars. Compare this image to the Galapagos image. What types of features are prominent on the Tharsis Plain? Explain your reasoning.

1.	1.
2.	2.
3.	3.

The darker, less cratered or smooth areas are called the **maria** (singular **mare**). The maria are composed of a rock known as basalt. The lighter, highly cratered or rugged areas are the **highlands**. The highlands, made of rock called anorthosite, are geologically older than the maria.

- Describe the shape of Mare Imbrium and Mare Crisium. What common feature do these seem to resemble?

Look at the edge of Mare Imbrium. What feature do you find?

- Mountain ranges on Earth tend to be linear (straight). What shape do lunar mountain ranges tend to have based on the edge of Mare Imbrium? Why? How do you think they formed?

The maria are formed inside very large impact craters, hence their circular shape. After the craters were formed, the crater floors were flooded with basalt. The arc-shaped lunar mountain ranges are formed from the surviving rims of the large craters. Mountain ranges on Earth are the result of the collision of two plates, a plate tectonic process. The Mare Orientale is a good example of a very large crater that was only partially flooded with basalt after formation.

Activity 8: What About Water?

What characteristics would you look for from space if you were searching for evidence of

water?

Would you look for the same features if there was no longer water on the surface? Explain.

1. Open the following file in folder "Activity 8": StLouis_river.tif

This false color radar image shows the region of Missouri near St. Louis. The Missouri River runs from west to east and meets the Mississippi River which flows from top to bottom in this image.

Do the rivers run straight over long distances? Why or why not?

Water finds paths of least resistance and tend to flow in "sinuous" pattern when viewed from a distance. The rivers meander with time as they deposit material and carve new land paths.

2. Open the following file in the "Activity 8" folder:
Mars_sinuous.tif Nanedi Vallis canyon, Xanthe Terra region, Mars

How does this image compare to the one of the US rivers? Look closely at the upper left corner of this image. What are you seeing here?

What does this imply about the existence of water on Mars?

3. Open the following images from the "Activity 8" folder:
Venus_sinuous.tif 200 km segment of sinuous channel on Venus
Moon_Hadley.tif Hadley Rille, Mare Imbrium, Earth's Moon

How do these images compare to the sinuous channels you viewed on Earth and Mars?

These channels were not formed by water but by lava flows underneath the surface which

collapsed on cooling. From what you know about the Earth's Moon and Venus, why is water not a likely cause of these features?

Close all images when finished

4. Now open the following images from the folder "Activity 8":
- | | |
|----------------|-----------------------------------|
| Larsen_ice.tif | Larsen Ice Shelf, Antarctica |
| Europa_ice.tif | surface of Jupiter's moon, Europa |

The Larsen image shows a portion of the Larson Ice Shelf on Antarctica. Make a note of the terrain to the lower right on the image. Compare that to the close-up of the surface of Jupiter's moon, Europa, in the second image.

What can you conclude about the surface components of Europa?

Based on information in an earlier part of this lab exercise, what other moon of Jupiter has a similar composition?

5. Close those two images and open the following ones in the folder "Activity 8":
- | | |
|--------------------|---|
| Antarctica_ice.tif | view of eastern Antarctica ice floe, 1995 |
| Europa_rafts.tif | ice rafts on Europa |

Although these images were not taken from the same distance away from the surface you can see a similarity in ice features. What causes the chunks or rafts of ice?

What does this imply about the dynamic nature of the Antarctic ice shelves and Europa's surface?

Close all images when finished.

Activity 9: Elevated or Depressed?

When you look at aerial photographs it is often hard to distinguish which features are elevated and which are depressed.

1. Open the image "Moon_hadley.tif" from the folder "Activity 8". Is this sinuous feature elevated or depressed? What clues might tell you? Come back to the image after you complete the rest of Activity 8 and decide if you were correct.
2. Look at the diagrams below and show where the shadows would be cast for the elevated feature A and depressed feature B. The Sun is to the left.

SIDE VIEW-

SUN



Now look at the same features from the top. Where are the shadows? Sketch them below.

AERIAL VIEW-



3. Look at the photographs of common lunar features provided by the instructor. Using the shadows, decide which are elevated (above ground) and which are depressed (below ground) features.



Feature	Elevated or depressed?	Feature	Elevated or depressed?
A		F	
B		G	
C		H	
D		I	
E		J	

Activity 10: What am I? - Identifying Planetary Features

Now you have had some experience interpreting images of planetary surface taken from space and understand how to tell if a feature is elevated or depressed. Keeping in mind what other surface features might exist on a surface, see if you can identify the type of feature in each of the following images found in folder "Activity 10". Open them one at a time and close each one when you are satisfied that you have interpreted each as well as you can. If you cannot think of the geological term for a feature, supply a brief description. If there is more than one prominent feature, describe each. Place the information in the table below.

Image File Name	Location of Image	Feature Identity or Description
Image1.tif	Earth	
Image2.tif	Mercury	
Image3.tif	Europa	
Image4.tif	Mars	
Image5.tif (sunlight from left)	Mars	
Image6.tif	Earth	
Image7.tif	Venus	

Image8.tif	Mars	
Image9.tif (sunlight from top left)	Mars	

Activity 11: Which Came First?

Knowing the order of events is very important for unraveling the geological history of an area. How can you determine the relative age of features on a planetary surface without being on the actual surface? Think about how you can tell in what order a series of large books were placed on a small surface area.

- Using the Moon map, for the following pairs of features, decide which feature is older or came first. Explain how you determined your choice.

Crater Plato or Mare Imbrium

Craters: Tycho or Walter

Crater Tycho or Mare Nubium

Crater Hyginus or Rima Hyginus (rille or collapsed lava tube)

- Rank the following craters in order of age (1-oldest). Explain your reasoning.

Huggins _____

Nasireddin _____

Orontius _____

Crater density can be related to the age of the lunar surface. The higher the crater density, the older the surface. This can be used on other planetary surfaces as well.

Which lunar area is older, the maria or highlands?

Where is most of the maria on the lunar surface?

Activity 12: Measuring Features

The National Geographic Society Earth's Moon map has a scale of 1 cm equals 105 km. Let's use the following formula to determine the actual size of features on the Moon:

$$\frac{105 \text{ km}}{1 \text{ cm}} = \frac{\text{actual size in km}}{\text{measured distance on map in cm}}$$

- Using the index on the back of the map, find the following craters. Measure their diameter (distance across crater) and complete the following table.

Crater	Located on maria or highland	Diameter (km)	Any rays? Yes or No
Plato			
Tycho			
Lansberg			
Alphonsus			
Copernicus			

Craters with ejecta rays are young craters (less than 1 billion years old) since the rays will not survive longer.

Which craters above in the table are young craters?

Find and measure the longest ejecta ray of the Crater Tycho. In what direction from the crater is it located?

2. How long are the Montes Apenninus (mountains)?

How long is Vallis Alpes?

Now get a copy of the Mars map. The diameter of Mars is 6794 km at the equator. Set up an equation similar to the one used on the lunar map to scale a distance measured on the Martian map.

$$\underline{\hspace{2cm}} = \underline{\hspace{2cm}}$$

3. Now use this relationship to determine the size of the following geological features on Mars:

Valles Marineris _____

diameter of the base of Olympus Mons _____

When you look at photographs of the Earth or other planetary surfaces taken from space it is often hard to judge the size of features such as craters and valleys. If you can compare the features to objects or areas you are familiar with it can help you get a feel for the dimensions of geological features.

4. Below are five geological features from the terrestrial planets along with their descriptions and dimensions. You need to determine what size they would be if placed on the attached map of the contiguous United States. The map scale is 1 cm equals 210 kilometers (km).

Feature	Description	Actual Size	Map Size
Olympus Mons	largest volcano on the surface of Mars (diameter)	650 km	

Valles Marineris	largest canyon on Mars	5000 km x 240 km	
Mare Orientale	basalt filled multi-ringed crater (diameter)	1000 km	
Caloris Basin	largest crater feature on Mercury; largest impact feature on any planet (diameter)	1300 km	
Chicxulub Crater	largest terrestrial crater (diameter)	300 km	

5. Sketch the features on the United States map in the appropriate size. Try to see if you can match a feature to a particular state or group of states. Keep our location in mind.

U.S.Map Graphic

PLANETARY IMAGE SOURCES

All of the images used in these laboratory activities were located through the Internet. Below are a series of sites that are particularly rich in images and information on our solar system. If you have the time and interest we encourage you to explore some of the web sites listed here. If you find some sites that have good planetary images and they are not listed here, please pass them on to one of the authors and we will check them out.

<http://photojournal.jpl.nasa.gov/>

NASA's Planetary Photojournal

This site has a multitude of images from the planets and moons in our solar system from a variety of planetary missions. The site allows you to modify the size of the image you download and the format (ex. TIF or JPG or GIF) of the image. The captions for each image are detailed and informative.

http://nssdc.gsfc.nasa.gov/photo_gallery/

National Space Science Data Center

In addition to images on solar system this site has deep space objects.

<http://earth.jsc.nasa.gov/>

Earth from Space: An Astronaut's Views of the Home Planet

This NASA site is an archive of Space Shuttle Earth Observations Photography. It has a database of over 250,000 images referenced by geographic area, or feature, or climatic condition (and many more). The captions for each image are excellent.

<http://pds.jpl.nasa.gov/planets/>

Welcome to the Planets

This is a collection of many of the best images from NASA's planetary exploration program. The collection has been extracted from the interactive program "Welcome to the Planets" which was distributed on the Planetary Data System Educational CD.

<http://lunar.arc.nasa.gov/archives/index.html>

The Lunar Prospector Archives

The Lunar Prospector Archives is the largest collection of lunar media in the world. If a photograph has been snapped, a movie filmed, or a sound recorded, it's probably stored in this archives (or soon will be). It contains literally millions of images, wave files, feature length films brought to you in streaming video, artwork, and many, many relevant documents.

<http://images.jsc.nasa.gov/>

NASA Johnson Space Center Digital Image Collection

Each Shuttle mission produces 2000 to 5000 photographic images. Over 250,000 images have been captured, digitized, and stored. This site has a prime selection of these images.

<http://www.nasa.gov/gallery/photo/index.html>

Photo Gallery

This Web page is an attempt to bring as many of NASA's still images as possible in one location. This is not a unified searchable data base, though some of these collections have search capability. Most of the sites listed above can be accessed from this site.