KEY

1/e

The Cryosphere and Sea Ice

Activity 13.1

Name: ______________________ Course/Section: ______________ Date: __________

A The cryosphere is composed of all parts of Earth where water is frozen, whether on the surface (snow, ice, sea ice) or below the surface (permafrost).

1. Notice that Mexico is a beige- to yellow-colored region with no snow or ice near the bottom of **Fig. 13.1B**. What is the order in which you would encounter different parts of the cryosphere if you traveled overland from Mexico to the North Pole?

   1. Seasonal snow
   2. Permafrost discontinuous, some mountain glaciers
   3. Permafrost continuous, mountain glaciers + ice caps
   4. Sea ice (polar)

2. While continental glaciation occurs only in Greenland and Antarctica today, mountain glaciers and ice caps occur in many places, including Canada, Russia, Alaska, the Rocky Mountains, the Andes, the Alps, and the Himalayas. Some mountain glaciers exist very close to the equator. How do you think it is possible for glaciers to exist at the equator?

   Very high altitudes and a source of moisture

B Scientists at the National Snow and Ice Data Center (NSIDC) have measured the extent of Arctic and Antarctic sea ice every month since at least 1978 using satellite data. A table of data from NSIDC for September in the Arctic and February in the Antarctic is provided in Fig. A13.1.1.

Summer Extent of Sea Ice

Year	September in Arctic, in millions of square km	February in Antarctic, in millions of square km
2015	4.68	3.77
2014	5.29	3.90
2013	5.35	3.91
2012	3.63	3.61
2011	4.63	2.52
2010	4.93	3.20
2009	5.39	2.98
2008	4.73	3.95
2007	4.32	2.95
2006	5.95	2.69
2005	5.59	2.99
2004	6.08	3.66
2003	6.18	3.92
2002	5.98	2.98
2001	6.78	3.81

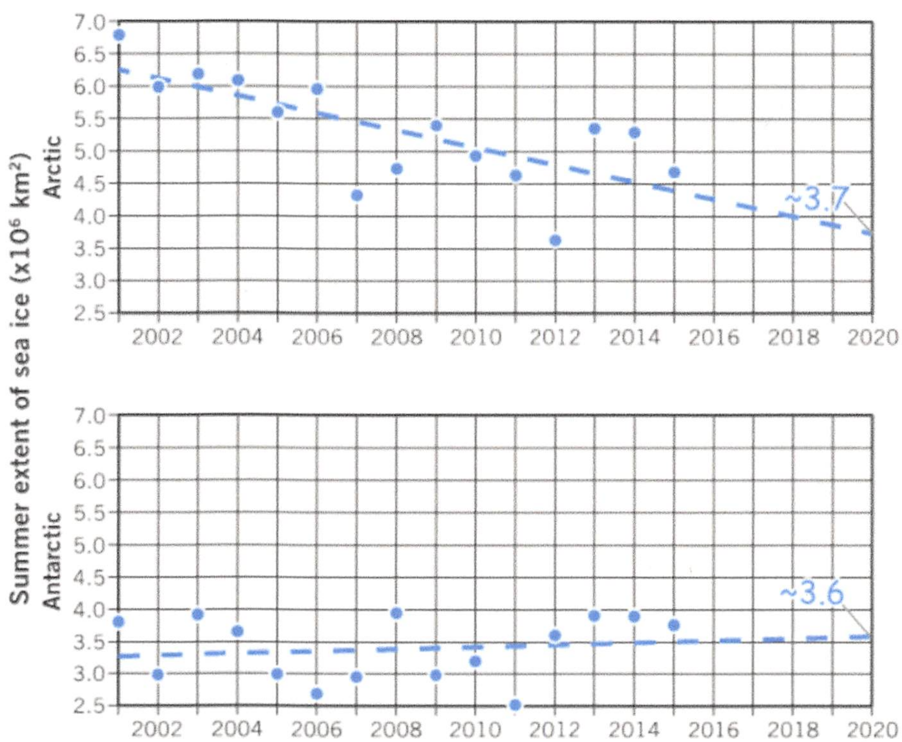


Figure A13.1.1

1. What was the average extent of Arctic sea ice in September from 2001 to 2015 in millions of km^2? Show your work.

   Sum of middle column ÷ 15 = 5.3 million km^2

2. Plot all of the data for the extent of Arctic sea ice from 2001 to 2015 on the graph labeled "Arctic" in **Fig. A13.1.1**, and then use a ruler to estimate a best-fit line through the points so that the number of points above the line is about the same as the number below the line.

   See above graphs

3. Based on your plot and calculations in part 2, would you say that the amount of Arctic sea ice as measured in September of each year is decreasing, increasing, or staying about the same? Explain.

Per the data, it is decreasing.

4. What do you predict the extent of Arctic sea ice will be in 2020?

approx 3.7 million km^2

5. What was the average annual extent of Antarctic sea ice from 2001 to 2015 in millions of km^2? Show your work.

sum right column ÷ 15 = 3.4 million km^2

6. Plot all of the data for the extent of Antarctic sea ice from 2001 to 2015 on the graph labeled Antarctic in **Fig. A13.1.1**, and then use a ruler to estimate a best-fit line through the points.

See completed fig A13.1.1

7. What do you predict the extent of Antarctic sea ice will be in 2020?

Approx 3.6 million km^2

8. Based on your work in response to parts B2 and B5–B7, would you say that the annual amount of Antarctic sea ice as measured in February of each year is decreasing, increasing, or staying about the same? Explain.

Slight increase

C REFLECT & DISCUSS How do the changes in Arctic sea ice extent over time compare with the Antarctic changes? If they are different, why do you think that might be? Consider as many possibilities as you can.

Answers can vary.
Arctic ocean differs from Antarctic in that the Arctic ocean is surrounded by seasonly bare land. the land adjacent to the Antarctic ocean is mostly covered with glaciers. this may be part of the reason for differing changes in sea ice.

Mountain Glaciers and Glacial Landforms

Activity 13.2

Name: ______________________ **Course/Section:** ______________________ **Date:** ____________

A **Figure 13.12** includes a topographic map of the area between El Capitan to the north (left) and the Cathedral Rocks and Bridalveil Valley to the south (right). This was once the stream-cut valley of the Merced River, but it has repeatedly been reshaped by glaciers during the past ~2.6 million years. The most recent glacier retreated from Yosemite Valley around 10,000 years ago.

1. Use the profile box in **Fig. A13.2.1** to construct a profile across Yosemite Valley from El Capitan to Middle Cathedral Rock (C and C′, respectively, in **Fig. 13.12**). The vertical lines in the profile box are where index contours (the thicker contours with labeled elevations) cross the line of section C–C′ in **Fig. 13.12**, and the profile is started for you on both sides of the profile box. Continue the profile down all the way to the two points connected by a dashed line between elevations 2800 and 3000 feet. This is the depth of the top of the granitic bedrock that was excavated by glaciers, and everything above that curve to the current ground surface is glacial or postglacial sediment.

See completed profile

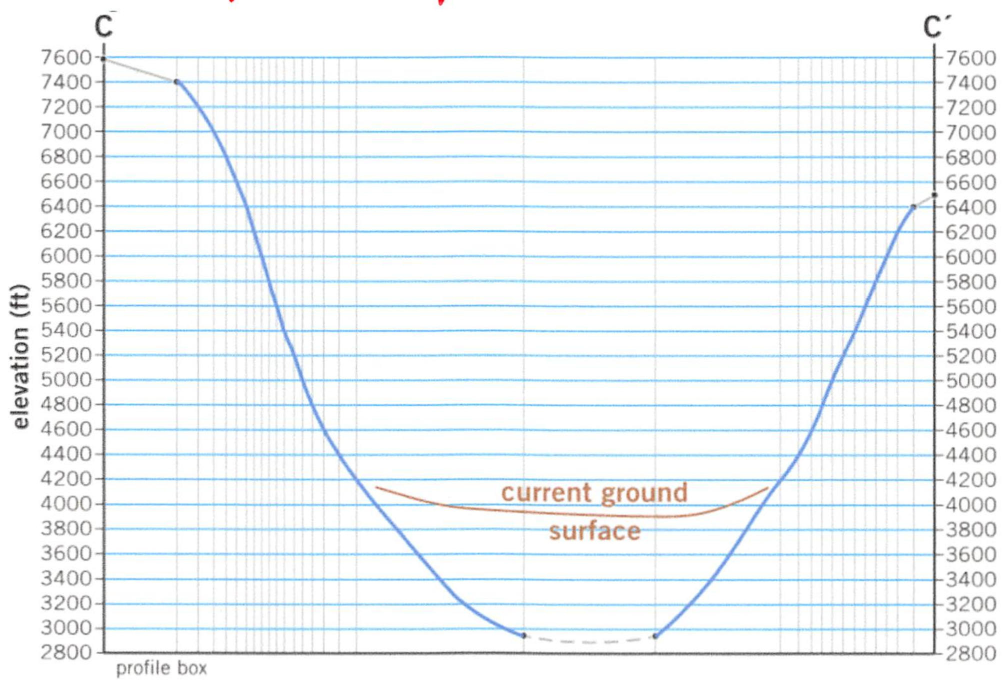


Figure A13.2.1

2. Use the profile box in **Fig. A13.2.2** to construct a profile across Bridalveil Valley from D to D′ in **Fig. 13.12**. The points at D and D′ are provided for you, as is the point along Bridalveil Creek at the bottom middle of the profile box. The vertical lines are where the index contours cross the line of section D–D′ in **Fig. 13.12**.

See completed profile

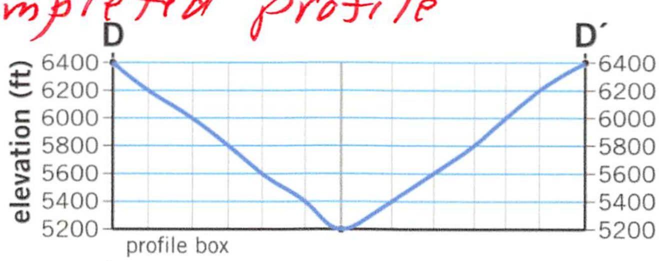


Figure A13.2.2

3. **Figure A13.2.3** includes a topographic map and profile box across the Merced River downstream from Yosemite Valley. Carefully construct the profile of section E–E′ in the profile box. There aren't any vertical lines this time to help you, so learn from your previous experience in parts **A1** and **A2** of this activity, or ask your teacher for help.

See completed profile

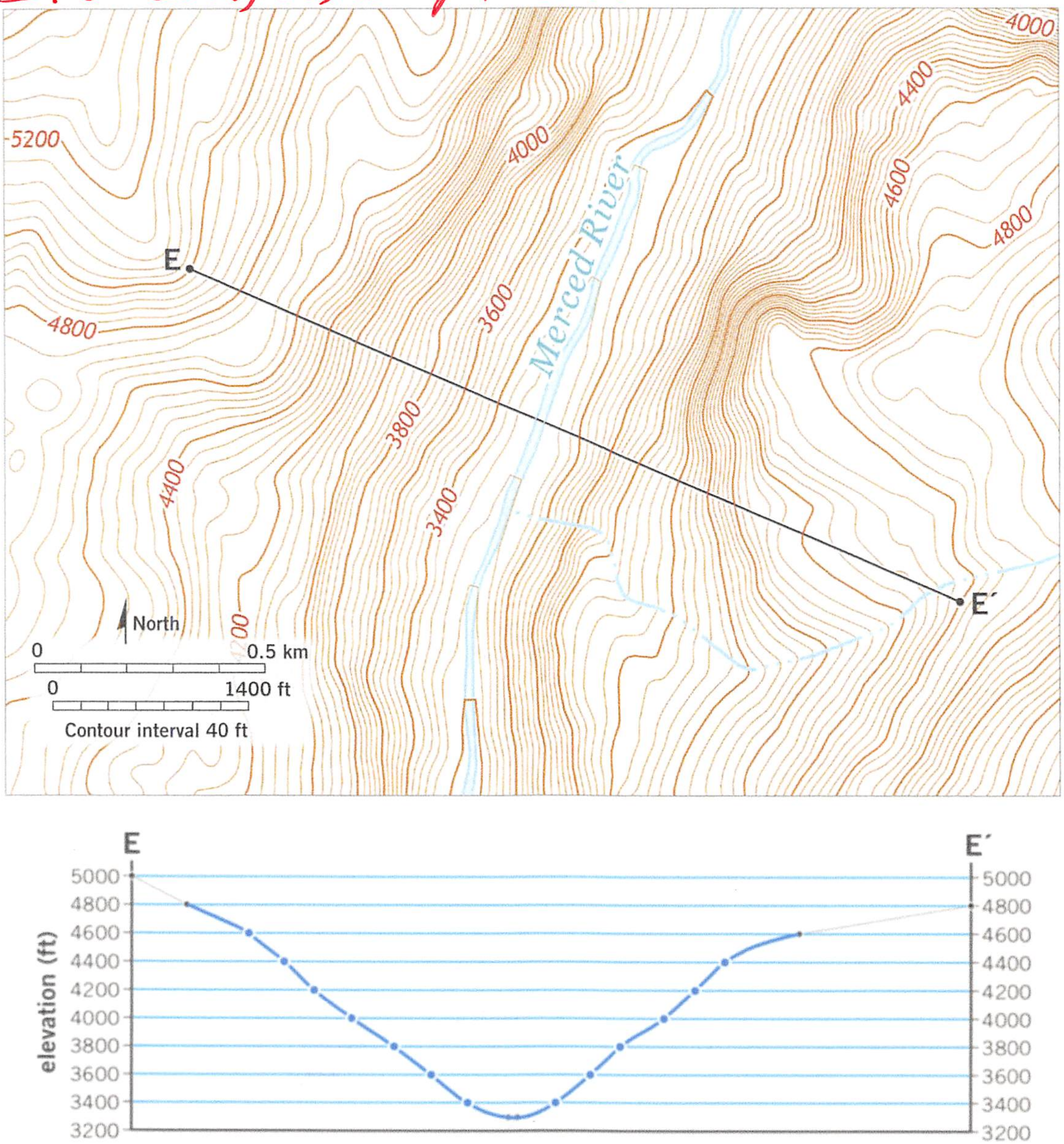


Figure A13.2.3

4. Geoscientists think that the upper part of this valley was modified by a very large glacier early in the Pleistocene Ice Age, but that the lower part of the valley was primarily or exclusively cut by the Merced River. Of course, the water and sediment from every glacial episode in Yosemite Valley was carried away by the Merced River, so it had a significant amount of erosive power at those times. Examine your finished profile E–E′. What part of the valley might you interpret as having been carved by the Merced River, and what part might have been modified by a glacier? That is, below what elevation along profile E–E′ is the part of the valley that might have been cut only by the river? Below 4500 ft approx.

B Generalize your observations into an initial hypothesis by completing the following two problems.

1. Based on your work, complete the following sentence using either a "U" or "V." Valleys eroded by rivers tend to have a V -shaped profile, whereas valleys modified by glaciers tend to have a U -shaped profile.

2. Interpret whether Bridalveil Valley (section D–D′) is more likely to have been shaped by a river or modified by a glacier or some contribution from both. Explain your reasoning.

more likely by a river.

Nisqually Glacier Response to Climate Change

Activity 13.3

Name: ______________________ **Course/Section:** ______________ **Date:** __________

Nisqually Glacier is a mountain glacier located on the south side of Mt. Rainier, Washington. Mt. Rainier is considered by the USGS to be one of the most threatening volcanoes in the Cascade Mountains. It has not erupted for more than a century, perhaps not for the past ~500 years.

Use your map and the bar scale to determine the scale ratio.

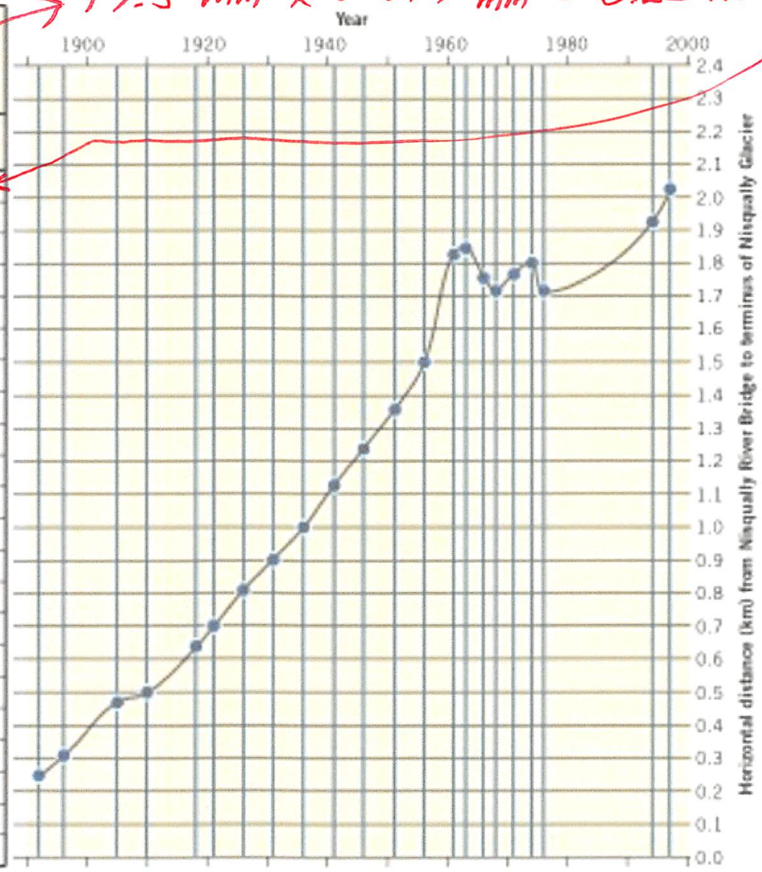
A Complete the following tasks to compile a data table showing the location of the end of Nisqually Glacier relative to the Nisqually River Bridge at different times.

$\frac{1\,km}{X\,mm} = x\,\frac{km}{mm} = 0.014\,\frac{km}{mm}$

1. Measure the horizontal distance from Nisqually River Bridge to each of the small yellow dots on **Fig. 13.13** that show where the end (terminus) of Nisqually Glacier was in the past. Record your map measurements (in mm) on the data table in **Fig. A13.3.1**.

→ $17.5\,mm \times 0.014\,\frac{km}{mm} = 0.25\,km$

Year	Horizontal distance from Nisqually River Bridge to terminus (lower end) of Nisqually Glacier: mm on map	Horizontal distance from Nisqually River Bridge to terminus (lower end) of Nisqually Glacier: km on ground
1892	17.5	0.25
1896	21.5	0.31
1905	33	0.47
1910	35	0.50
1918	44.5	0.64
1921	48.5	0.70
1926	56.5	0.81
1931	63	0.90
1936	69.5	1.00
1941	79	1.13
1946	86.5	1.24
1951	95	1.36
1956	100.5	1.44
1961	127.5	1.83
1963	129	1.85
1966	122.5	1.76
1968	120	1.72
1971	123.5	1.77
1974	125.5	1.80
1976	120	1.72
1994	134.5	1.93
1997	141.5	2.03



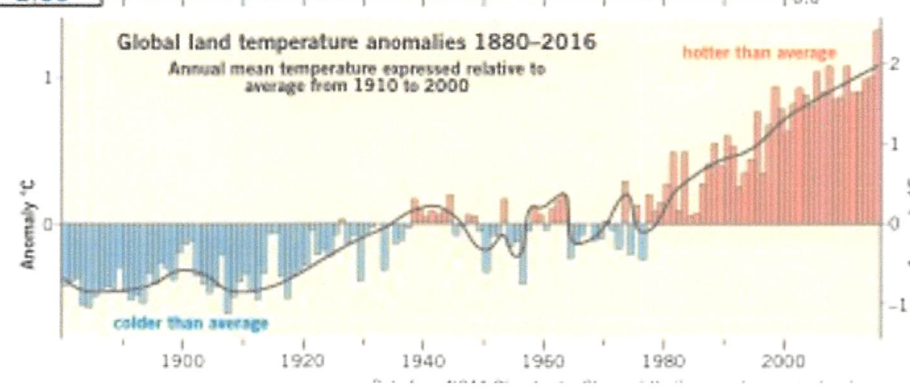


Figure A13.3.1

2. Use the bar scale on **Fig. 13.13** and your knowledge of proportions to convert your map measurements (in mm) to distance measurements at full scale (in km). Record your calculated distances, rounded to the hundredth of a km, on the data table in **Fig. A13.3.1**. See completed table

B Plot your data.

1. The vertical lines on the graph in **Fig. A13.3.1** represent the years for which data have been compiled. The horizontal lines correspond to horizontal distances between the bridge and the glacier terminus in tenths of km. Carefully plot the data you have compiled on the graph as a set of points. See graph
2. Lightly draw a smooth pencil line through each of the data points in the correct sequence. See graph
3. Notice that the glacier terminus retreated up the valley at some times but advanced back down the valley at other times. Summarize these changes in a brief written description that includes the specific time intervals when the glacier retreated or advanced.

* Retreated 1840-1963
* Advanced 1963-1968
* Retreated 1968-1974
* Advanced 1974-1976
* Retreated 1976-1997

C There is a bar chart below the graph you just completed, and the horizontal time axis in the bar chart is identical to the horizontal axis in the Nisqually Glacier graph. Notice the blue and salmon pink graph of climatic data at the bottom of your graph (part **B**) provided by the NOAA National Climatic Data Center (NCDC). NCDC's global mean temperatures are mean temperatures for Earth calculated by processing data from thousands of observation sites throughout the world (from 1880 to 2009). The temperature data were corrected for factors such as increases in temperature around urban centers and decreases in temperature with elevation. Although NCDC collects and processes data on land and sea, this graph shows the variation in annually averaged global land surface temperature only since 1880.

1. Describe the long-term trend in this graph—how averaged global land surface temperature changed from 1880 to 2015.

the Long-term trend is warming of about 1.5-1.75°C

2. Lightly in pencil, trace any shorter-term pattern of cyclic climate change that you can identify in the graph. Describe this cyclic shorter-term trend.

See graph.
Short intervals of cooling occur in the 1950's and in the 1970's (approx).

D Describe how the changes in position of the terminus of Nisqually Glacier compare to variations in annually averaged global land surface temperature. Be as specific as you can.

Advances and retreats of the glacier approximatly match global variations in temperature.

E **REFLECT & DISCUSS** Based on all of your work above, do you think Nisqually Glacier can be used as an indicator of climate change? Explain.

Yes. there seems to be a correlation between global temperature changes and glacier advances and retreats.

Glacier National Park Investigation

Activity 13.4

Name: ______________________ Course/Section: ______________ Date: __________

Refer to the map of Glacier National Park in **Fig. 13.14**.

A List the features of glaciation from **Figs. 13.3–13.10** that you can observe in **Fig. 13.14**.

* Cirques * Finger Lakes
* Cirque glaciers * U-shaped valleys
* Aretes * horns

B Locate Quartz Lake and Middle Quartz Lake in the southwest part of the map. Notice the patrol cabin located between these lakes. Infer the chain of geologic/glacial events (steps) that led to formation of Quartz Lake, the valley of Quartz Lake, the small piece of land on which the patrol cabin is located, and the cirque in which Rainbow Glacier is located today.

1. Glacier formed the valley
2. As it retreated, it slowed to form recessional moraine where cabin now is.
3. Glacier retreated up to the cirque
4. Rain and melt water filled the lakes

C Based on your answers above, what kind of glaciation (mountain versus continental) has shaped this landscape?

Mountain glaciation

D Locate the continental divide on **Fig. 13.14**, and recall that it divides surface water that flows west into the Pacific Ocean from water that flows east into the Atlantic Ocean or Gulf of Mexico. Think of ways that the continental divide may be related to weather and climate in the region. Recall that weather systems generally move across the United States from west to east.

1. Describe how modern glaciers of this region are distributed in relation to the Continental Divide.

   It is likely more glaciation has occured on the west side of the divide, where more precipitation falls.

2. Based on the distribution you observed, describe the weather/climate conditions that may exist on opposite sides of the Continental Divide in this region.

   Wetter (incl. snow) on west side, and drier on east side.

3. Look at the location of glaciers in this map area in relation to ridges and mountain peaks. Do the glaciers tend to occur on the north, south, east, or west sides of these landforms? If so, on what side do most tend to be located? Suggest at least one explanation for this observation.

   North side, due to less exposure to the sun.

E Using the data table in **Fig. 13.14**, describe how the area of Agassiz Glacier changed from 1850 to 2005. Agassiz Glacier is in the northwest part of the map.

It dramatically decreased in size, but has recently stabilized

F Describe how the area of Vulture Glacier changed from 1850 to 2005. Vulture Glacier is in the southeast part of the map.

It also has decreased significantly, but has recently stabilized.

G **REFLECT & DISCUSS** What do you expect the area (km^2) of Agassiz and Vulture Glaciers to be in 2020? Explain.

Not assigned

Activity 13.5 Some Effects of Continental Glaciation

Name: ______________________ **Course/Section:** ______________ **Date:** __________

A A topographic map of an area near Whitewater, Wisconsin, shows many landscape features that are characteristic of continental glaciation (**Fig. 13.19**). Many of those features are listed in **Figs. 13.4–13.6** and **13.15–13.18**.

1. Study the size and shape of the short, oblong rounded hills in the northwestern part of **Fig. 13.19**. Detail map A shows one of these hills. Fieldwork has revealed that they are made of till. What type of feature are they, and how did they form? It is a drumlin, formed out of remolded till under a flowing glacier.

2. Toward what direction did the glacial ice flow in this area, and how can you tell?
Probably flowed generally from north to south. the streamlined end of a drumlin points in flow direction.

3. Find the long, narrow, sinuous ridge that extends into a lake, shown in detail map B. What do you interpret this feature to be, and how do you think it formed?
It is an esker. It formed along a flowing stream that was under or on top of a glacier.

4. In the southeast part of **Fig. 13.19** are many enclosed depressions marked by hachures on topographic contours like the one shown in detail map C. What do you interpret the depression in detail map C to be?
Some are kettle lakes. they formed when chunks of ice became buried, then melting later.

5. The features we just looked at in part **4** are part of an area that is a bit higher than the land to the north and has many small hills and depressions within a topography that seems chaotic. That area starts parallel to a line from point D to D′, and extends to the southeast corner of the map. What glacial landform do you interpret this area to be?
It is likely a terminal or recessional moraine.

6. Note the marshy area running from the west-central edge of **Fig. 13.19** to the northeastern corner, separating the features shown in detail map A from those labeled B, C, and D–D′. Describe the probable origin of this flat marshy area. (More than one answer is possible.)
It is likely a poorly drained area between two ressional moraines.

7. List the features of glaciated regions that you can recognize in **Fig. 13.19**.
* Esker
* Drumlin
* Kettle, and kettle lake
* Marshes and swamps
* Recessional moraine

B **REFLECT & DISCUSS** How is the glaciated area of **Fig. 13.19** different from areas affected by mountain glaciation, and how are they the same?
Glacial features are distinctly different. But, both types leave behind a lot of loose debris (till).