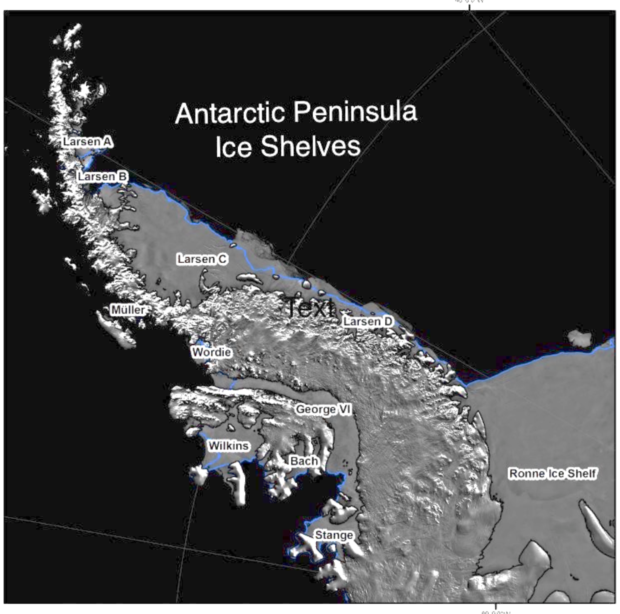
ACTIVITY II: THE FATE OF THE LARSEN'S, A FAMILY OF ANTARCTIC ICE SHELVES

Ice Shelves play a critical role in Antarctica, serving as a buffer between the ocean and the continental ice sheet covering the land.



In Activity II we will focus on the Antarctic Peninsula, the exposed handle shaped region of Antarctica that stretches up towards South America. The peninsula edges are currently lined with ice shelves. Historically there were even more!

An Important Point to Consider: Ice moves as gravity pulls on it. The deep stack of ice at the center of the Antarctic ice sheet is constantly flowing towards the edges of the continent. In the center of the ice sheet the movement is slow, a meter or so a year. But around the edges it can move much more quickly, in some areas up to 4000 meters a year! Let's think about this for a minute.

- 1 meter = 3.28 feet. A regulation football field is 120 yards long. Calculate how many football fields are in 4000 meters ___________
- Ice tends to accelerate in the summer months when it warms. However, if the ice moved at the same rate every day of the year how much would it move each day in meters__________ in feet___________.
This changes the meaning of the expression "Moving at glacial speed"!

Activity Goals:
In this activity you will:

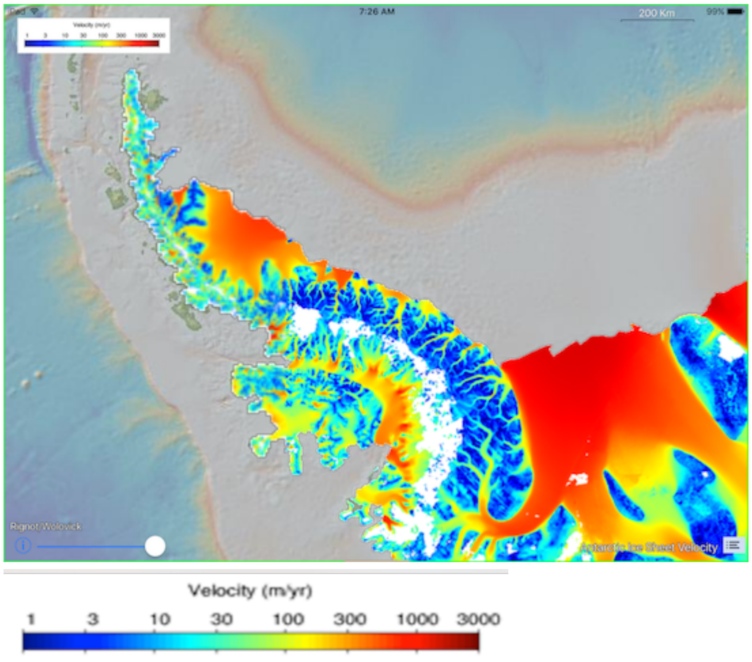
- Examine the role of ice shelves in Antarctic ice sheet stability.
- Consider the connections between the air (atmosphere), the ocean (hydrosphere) and the ice (cryosphere) in maintaining the current level of ice cover in Antarctica.
- Review the meaning of 'time' in the history of Antarctic ice.

Background items to consider about ice shelves:

1. Ice shelves form when ice flows off the land, bridging between the two types of ice, land based and floating ice.

2. The shelves remain attached to the continental ice sheet on at least one edge. At the front they are a thick floating section of ice up to ~100 meters thick. The satellite image at the top of the page is of the Antarctic Peninsula. There is a visual change in the surface where the ice is no longer attached to the land and starts to float as a shelf; it suddenly looks very flat and smooth. Use this method to identify a small ice shelf, then **use a yellow highlighter** to draw a line highlighting where it goes afloat from the land. Now locate the large Larsen and Ronne ice shelves, highlight where they transition and label the appropriate sections as ***land based*** or ***floating ice***.

3. Ice accelerates as it moves towards the edges of the land but ice shelves help to slow the flow of ice moving from the land into the ocean where it contributes to global sea level rise. Working a bit like a dam, ice shelves act like a brace holding back the ice sheet on the land behind them. Below is a velocity map showing the speed the ice is moving on the Peninsula. Consider the role of the ice shelves in protecting the ice sheet. Using your experience outlining the ice shelves, pick two ice shelves and record below how much faster the ice is moving at the unprotected front of the ice shelf and at the attached back of the ice shelf. Label the shelves #1 and #2 on the image.



Velocities:

#1 Front___________ **#1 Front**___________

#2 Back ___________ **#2 Back**____________

4. Ice shelves have long history covering many thousands of years. The Antarctic ice sheet has a much longer history covering a few million years. Our own life history is very short in comparison.

5. Ice shelves rest in the ocean, which is a degree or more warmer than the ice.

6. Average air temperatures in the Antarctic Peninsula have risen by 2.5°C (3.8°F) over the last 50 years. In the center of the ice sheet the elevation is high and the air is colder. Ice shelves are at sea level where the air is warmer.

Lets examine the story of a set of Ice Shelves…the Larsen's

The Larsen ice shelves are well known in Antarctic science because of how they have changed in human history. How does human history relate to ice history?

Let's start with the history of the Antarctic ice sheet. Ice has covered some portion of Antarctica for at least 34 million years. It is hard to even imagine that far back. The ice shelves are much younger than the ice sheet. Larsen A formed, broke apart, reformed about 4,000 years ago, and ultimately broke apart again. Larsen B had a life of 10,000-12,000 years before it broke apart. Thousands of years is a long time, but compared to millions it is young. To help us think about this let's create a timeline of these events.

Using the line below place markers and dates to create a timeline showing the temporal (time) relationship between the four following events in Earth's history:

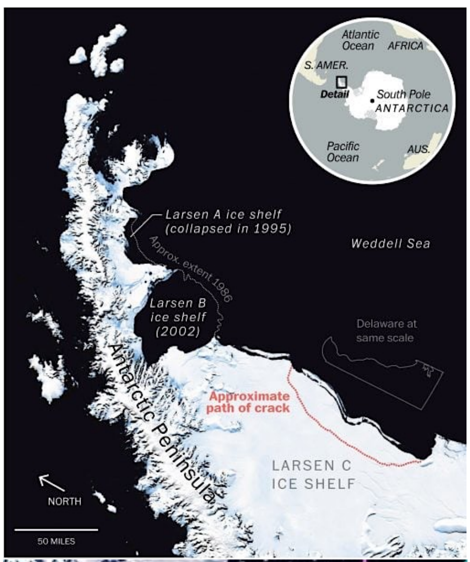
1) Origin of the Antarctic Ice Sheet
2) Formation of Larsen A ice sheet
3) Formation of Larsen B ice sheet
4) Your own origin on planet Earth

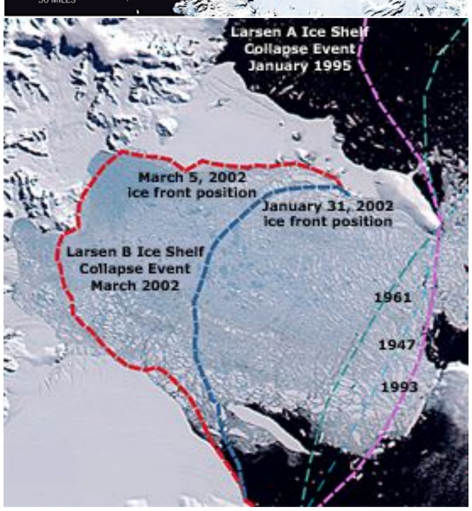
You will need to plan your spacing carefully. Think about the time relationship between each event before you place them on the timeline. Mark and label each of the four events.

TIMELINE ARROW

How would you describe the relationship between human history and geologic history?

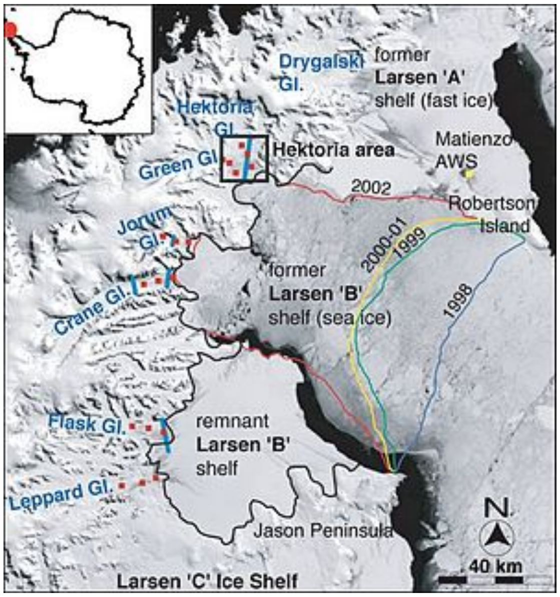
THE LARSEN STORY





Larsen A - It was January 1995, toward the end of the Antarctic summer, when Larsen A, broke apart rather suddenly and was gone. Located the furthest north of the Larsen 'family', this small shelf was located just north of the Larsen B and just outside of the area designated as the Antarctic Circle. Due to its size and location, the 1,500-square-kilometer block of ice was the most vulnerable of the series of Larsen shelves. Warming water that had been moving around the peninsula was the expected cause of its collapse.

Larsen B – Without Larsen A, Larsen B became more vulnerable. Although twice the size, at 3,250 square kilometers, the shelf was now un-protected from warming ocean waters to the north. This exposure combined with several warm summers causing Larsen B to weaken and destabilize. In 1998, satellites captured evidence of the front edge of Larsen B beginning to change. Large ponds of water showed on the surface of the shelf, but with ~220 meters of ice thickness, these ponds did not seem to pose a threat. However, between early February and early March 2002, the shelf suffered a massive collapse, with section after section all but evaporating as the world watched. There was disbelief among the science community that a shelf this size, that had been relatively stable for an estimated 10,000-12,000 years, could collapse so swiftly. Locate the light blue surface melt ponds



located on the top of the ice shelf from the in this image from the National Snow and Ice Data Center. It is believed that these weakened the thick shelf from the surface and the ocean weakened it from below.

Acceleration & Elevation Change

It had long been hypothesized that the loss of ice shelves led to a speed up of the glacial land ice behind. This results in more ice moving from the land into the ocean where it adds to global sea level, and the land ice thinning as it flow rate increases. Here we cite data from two studies using two techniques to measure ice velocity from a set of glaciers flowing into Larsen B both before and after the shelf collapse. The glaciers can be located in this Larsen image. Review the data to test this hypothesis, do the calculations and provide your conclusions.

Data Set #1 - Landsat 7 & IceSat Data

Glacier	**Speed m/yr 2000**	**Speed m/yr 2003**	**Calculate the rate of acceleration 2000-2003 (Δ velocity/Δ time)**
Crane	~550 m/yr	~1500 m/yr	
Green	~350 m/yr	~1500 m/yr	
Hektoria	~350 m/yr	>1800 m/yr	
Jorum	* increase noted but not as dramatic		

Data Set #2 INSAR data (Radar Interferometry)

Glacier	**Speed m/yr 2000**	**Speed m/yr 2003**	**Calculate the rate of acceleration 2000-2003 (Δ velocity/Δ time)**
Crane	>500 m/yr	> 1500 m/yr	
Green	~275 m/yr	~2200 m/yr	
Hektoria	~275 m/yr	>2200 m/yr	
Evans (next to Green Glacier)	~275 m/yr	>2200 m/yr	

Data Sets 1 (Scambos et al 2004) and 2 (Rignot et al 2004a) are reported in "Coastal Change & Glaciological Map of Larsen Ice Shelf Area, the Peninsula ***Antarctica: 1940-2005, Ferrigno et al. 2008 U.S.G.S. and B.A.S.***

Elevation: In addition to acceleration these glaciers also showed tens of meters a year of elevation loss demonstrating the thinning of the glacier due to its accelerated flow and movement of ice into the ocean.

Neighboring Glaciers: A small section of Larsen B remained in place after the collapse. Two glaciers, Flask & Leppard, lie behind what remains of the Larsen B ice shelf. Neither of these two glaciers showed a velocity change or any noticeable change in ice surface elevation after the collapse of Larsen B.

Conclusions:

- Consider the **velocity data** from Data Set #1 and Data Set #2.
- Consider the **elevation data**.
- Consider the data from the **neighboring glaciers blocked** by the remnants of the Larsen B shelf

Write your hypothesis of the role of ice shelves in ice velocity:

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Why did we include two different data sets from two different studies? Do you think this was necessary? Explain your answer.

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Take this to the next level
You have been asked to give a short presentation to the School Board explaining why students should be studying climate and the polar-regions in the science curriculum. There is concern on their part that this topic is not critical to the curriculum. The arguments they provided for dropping this topic are that there is already a significant amount of material to cover in science education, the polar-regions are very far away and have no apparent connection to us, and they have remained unchanged for all of human history and there is no credible data saying otherwise.

Outline your ideas below for your presentation.
What key ideas will you use to convince them?
Be sure to cite evidence in your presentation outline.

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