Northwestern Indiana Landscape Unit

What is the effect of climate on glacial landscape processes?

In this lesson, students will investigate the question, what is the effect of climate on glacial landscape processes? Students will be guided through understanding how climate factors, such as temperature and precipitation, affect the growth or depletion of glaciers using the online resource Climate Reanalyzer. Students will then investigate how glaciers influence topography by studying a variety of glacial landforms, and then connecting these landforms to the Indiana landscape through an ArcGIS storyboard.

After understanding how glaciers influenced Indiana directly, students will study the formation of Lake Michigan, and how the Last Glacial Maximum influenced the creation of the Grand Kankakee Marsh. Students will look at the distribution of sediment deposited by glaciers in Indiana with the online resource Soil Explorer to better understand the lasting glacial impact on the area, relating it to industry and human interaction. With knowledge of glacial influence and landscape features, students will apply the formations to the area they are living in by independently researching specific glacial history and creating a Google Earth tour of their area. At the end of this lesson, students will be asked to draw conclusions on how the future of glaciers and the global landscape will be affected by climate change.

Objectives

Students will:

- Interpret correlations between climate systems
- Describe how climate affects glaciers
- Determine the extent of the Last Glacial Maximum

- Discern glacial landscape features and their defining characteristics
- Explore Indiana's glacial history
- Explore causes for Glacials and Interglacials
- Explain how the Last Glacial Maximum lead to the creation of the northwestern Indiana landscape
- Evaluate resource distribution in Indiana
- Hypothesize how glaciers will be impacted by future changing climate
- Hypothesize how glaciers will impact future landscapes

All standards taken directly from Indiana DOE

Indiana Academic Standards for Science & Computer Science Standard Alignment
ES.4.6: Examine long term, natural climate change and periods of glaciation as influenced by Milankovitch Cycles due to the gravity of other solar system bodies (obliquity and precession of axis and eccentricity of orbit). **ES.5.5:** Explain how changing sea levels, climate, and glaciation have shaped Indiana geology **Env.1.3** Recognize and describe the difference between systems in equilibrium and systems in disequilibrium. Describe how steady state is achieved through negative and positive feedback loops. **Env.1.6** Describe the difference between weather and climate. Locate, identify, and describe the major Earth biomes. Explain how biomes are determined by climate (temperature and precipitation patterns) that support specific kinds of plants. **Env.1.8** Explain the factors that influence weather and climate, the action of gravitational forces, and the rotation of the Earth. **Env.1.9** Describe how weather can be influenced by global climatic patterns, such as El Niño and La Niña. **Env.2.11** Recognize and describe the role of natural resources in providing the raw materials for an industrial society.

All standards taken directly from Next Generation Science Standards

Next Generation Science Standards Standard Alignment
ESS1.B: **Earth and the Solar System** Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4) **ESS2.A**: **Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS ESS2-1),(HS-ESS2-2) The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4) **ESS2.C: The Roles of Water in Earth's Surface Processes** Water transport and deposition of materials is part of the glacial processes. (HS-ESS2-5) **ESS3.D: Global Climate Change** Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5) Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. (HS-ESS3-6) **PS1.C: Nuclear Processes** Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. *(secondary to HS-ESS1-5)*,*(secondary to HS-ESS1-6)*

Table of Contents

Glacial Features of Indiana Discussion Guide is meant to be utilized for in person instruction. In case of distance learning, *Glacial Features of Indiana* worksheet can be utilized. Answer Keys can be found in the zip file on the Science Education Resource Center website.

Introduction to Glaciers

Climate has been changing with a trend in a warmer direction. A repercussion of this trend is diminishing glaciers.

Watch the video *Climate 101: Glaciers*, linked below, to learn more about glacier dynamics and then answer the questions
https://www.youtube.com/watch?v=WJgpDyP9ewQ

Firn	Alpine Glaciers	Compression Melting	Glacier
Freshwater	Ice Sheets		

1. A _____ is a huge mass of ice that moves slowly over land.

2. _____ form on mountain sides and move downward through valleys, while _____ form broad domes and spread out from their centers in all directions.

3. The dense, grainy ice that has survived one year's melt cycle is called _____.

4. Process that allows for the movement of glaciers _____.

5. _____ is the most important resource provided by glaciers.

6. What conditions do you think allow for alpine glaciers to form? Hypothesize why alpine glaciers can be found on every continent except Australia.

7. Why do you think snow can accumulate and form ice sheets on Antarctica and Greenland?

8. Stop at 1:57, speculate why the velocity is highest and lowest where it is.

9. When was the latest retreat of glaciers? Make a conjecture about how scientists figured out this date.

10. How does the melting from glaciers affect the oceans? What happens when oceans are affected in this way? Is this a positive or negative feedback?

Climate Reanalyzer

From the video we learned that glaciers are one of the first signs of a changing climate. With the help of the Climate Reanalyzer we are going to take a deeper look into how climate factors interact with glaciers.

Part 1: Climate System Correlations

Before starting this activity search and define each of the terms listed below:

- Correlation -
- Snow Mass Balance -
- Melting Degrees (search for this under Degree Day Model Glaciation) -
- Sea Surface Temperature (SST) -
- Sea Ice Concentration -
- Cryosphere-
- Glacier Ablation Zone -
- Glacier Accumulation Zone -

Now go to https://climatereanalyzer.org/
Once there click on **Monthly Reanalysis Correlation**, this can be found under “Climate Models and Data”
When you get to the Monthly Reanalysis Correlation model make sure each drop down menu is aligned for **Input 1**:

- Dataset - ERA-Interim (1979-2018)
- Month - Annual

For **Input 2**:

- Dataset - Reanalysis

For **Output**:

- Projection - Map
- Region - World
- Significance Level - 0.95

Change the parameters for **Input 1** and **Input 2** based on the variables given below. After you change the parameters, hit the **Plot** button to generate a map. Describe what the map looks like and give a detailed interpretation of the map in the empty space.

Input 1 - Mean Temperature 2m **Input 2 -** Snow Mass Balance
Description/Interpretation:
Input 1 - Precipitation **Input 2 -** Snow Mass Balance
Description/Interpretation:
Input 1 - Melting Degrees **Input 2 -** Snow Mass Balance

Description/Interpretation:
Input 1 - SST **Input 2 -** Sea Ice Concentration
Description/Interpretation:

Choose two different sets of parameters you would like to see correlated and fill in the graphic organizer below.

Your Choice:
Description/Interpretation:
Your Choice:
Description/Interpretation:

Based on the graphs you created and interpreted answer the following questions

1. Do any of these maps indicate why ice sheets can form on Greenland and Antarctica? Why or why not.

2. Does the SST and Sea Ice Concentration map imply any potential loss of stability in the surrounding glaciers? Why or why not.

3. Hypothesize why the Snow Mass Balance off the east coast of Greenland is correlated with mean temperature and melting degrees in the way that it is.

4. Do the maps of your chosen parameters have any connections to glaciers? Why or why not.

5. What implications do your maps have with the health of current glaciers?

We know that Earth's climate has not always been stagnant, and only recently has the climate been relatively stable. Now that temperatures are increasing it is important to predict how glaciers will react to new temperatures, and to understand that we must understand how glaciers responded to changes in climate in the past.

Part 2: Environmental Change

Once you have completed the correlation part of this activity move to the upper left hand part of the screen to where it says **Climate**
Hover over the word **Climate** and scroll down and select **Environmental Change Model**
Once there select the drop down menus as follows:

- Region - World
- Parameter - Temperature
- Month - Annual

Fill in the table below and answer the following questions:

Global ΔT°C	4 (2100)	2 (2050)	0 (Modern Climate)	-3 (50% Modern, 50% LGM)	-6 (Last Glacial Maximum)
Observations					
Potential Locations for Glaciers					

1. How much does a 2℃ increase in temperature affect the potential locations for glaciers? What about 4℃?

2. Would you expect glaciers in the United States at -3℃?

After you have completed the table and answered the questions change the **Region** you are looking at to **North America** and the **Parameter** you are using to **Potential Biomes**

Make observations in the table below in relation to the Cryosphere biomes:

Global ΔT℃	**Observations of Cryosphere Biomes**
4 (2100)	
3 (2075)	
2 (2050)	
1 (2025)	
0 (Modern Climate)	

-0.5 (Little Ice Age, ca. 1850)	
-1 (83% Modern, 17% LGM)	
-2 (66% Modern, 34% LGM)	
-3 (50% Modern, 50% LGM)	
-4 (33% Modern, 67% LGM)	
-5 (16% Modern, 84% LGM)	
-6 (Last Glacial Maximum)	

1. Was your prediction about whether there would be glaciers in the United States a -3℃ correct?

2. What cryosphere biome starts to appear first when the temperature decreases?

3. Think back to the video *Climate 101: Glaciers*. How long ago did the Last Glacial Maximum occur?

4. What states would we expect to find evidence of the Last Glacial Maximum?

5. How do you think an ablation zone, such as one seen in Indiana, would influence a landscape differently than a glacier accumulation zone, such as one seen in Maine?

Glacial Landform Identification

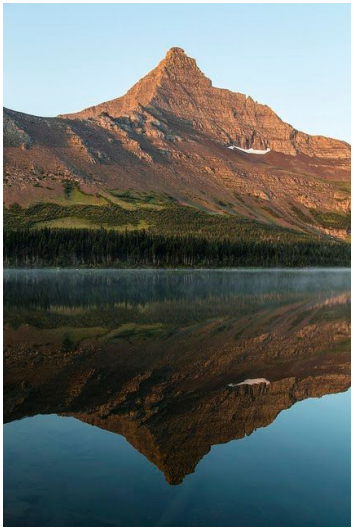
During the Last Glacial Maximum over 20,000 years ago, parts of the northern United States were covered with the Laurentide Ice Sheet. We visualized this massive ice sheet with the help of the Environmental Change Model, found on https://climatereanalyzer.org/. Before scientists were using online models to determine the extent of Laurentide Ice Sheet, or knew that there was even an ice sheet, they were out in the field discovering landforms. These landforms were hard to explain without pointing to a glaciated past, which led scientists to discover the change in climate our planet has gone through. Here you are going to try to distinguish glacial landforms.

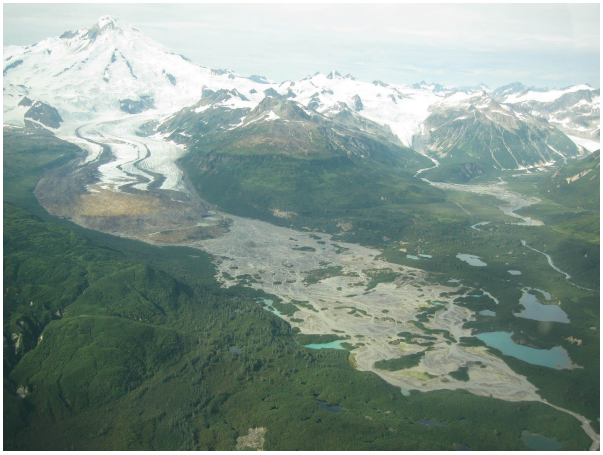
Using the following website, https://pubs.usgs.gov/of/2004/1216/text.html, determine which glacial landform term found in the box matches with each picture below. Give the defining characteristics in each box and determine if the landform is either depositional or erosional.

Kettle Medial Moraine Striations Erratic Hanging Valley Cirque Horn Drumlin U-Valley Outwash Plain Roche Moutonnée

 Good, J. (1967). *Yellowstone National Park* [Photograph].	Landform: Depositional or Erosional? Defining Characteristic -

 Petrtyl, B. (n.d.). *Wrangell-St. Elias National Park* [Photograph].	Landform: Depositional or Erosional? Defining Characteristic -
 *Glacier National Park* [Photograph]. (n.d.). NPS Photo.	Landform: Depositional or Erosional? Defining Characteristic -

 Frank, J. (n.d.). *Flinsch Peak* [Photograph].	Landform: Depositional or Erosional? Defining Characteristic -
 Schmidt, J. (1977). *Yellowstone National Park* [Photograph].	Landform: Depositional or Erosional? Defining Characteristic -
 James St. John, *Acadia National Park, Maine* September 12, 2006 via Flickr, Creative Commons Attribute	Landform: Depositional or Erosional? Defining Characteristic -

 *Red Glacier* [Photograph]. (n.d.). NPS Photo.	Landform: Depositional or Erosional? Defining Characteristic -
 Hernandez, M. (n.d.). *Bridalveil Falls* [Photograph].	Landform: Depositional or Erosional? Defining Characteristic -
 Frank, J. (n.d.). *Wrangell-St. Elias National Park* [Photograph].	Landform: Depositional or Erosional? Defining Characteristic -

 LenP17, *Calgary, Canada* July 5, 2012 via Flickr, Creative Commons Attribute	Landform: Depositional or Erosional? Defining Characteristic -
 Dunmire, W. (1969). *Lamar Valley* [Photograph].	Landform: Depositional or Erosional? Defining Characteristic -

1. Think back to the last question for the Environmental Change Model. What landforms do you think would form in an ablation zone versus an accumulation zone?

Glacial Features of Indiana Discussion Guide

Now that we have modeled the extent of the Last Glacial Maximum and know that there were once glaciers covering parts of Indiana, and we have investigated some landscape features left by glaciers, let's look at how glaciers influenced Indiana's landscape.

Go to *Glacial Features of Indiana* ArcGIS storyboard linked below:
https://www.arcgis.com/apps/MapJournal/index.html?appid=1d675fcaddeb404690ed1b517b2f5a66#:~:text=Indiana%20has%20experienced%20several%20glaciations,pressure%20of%20their%20own%20weight.

Discuss the following questions:

Indiana Glaciers

1. How does the landscape change between before and after glaciation in the animation?

2. Why is it important to study current day ice sheets, such as the one in Greenland, to understand how glaciers moved in the past?

Climate in the Pleistocene Epoch

3. What is an epoch?

4. How does a change in the tilt of the Earth, and a change in the Earth's orbit around the sun, modify climate? How can we measure changes in the tilt and orbit?

5. What other ways do you think scientists can get paleoclimate records?

Extent of Glaciation in Indiana

6. Are we currently in a glacial or interglacial period?

7. Why do you think the Illinoian glacial lasted longer than the Wisconsin glacial?

8. How do you think they determined the extent of the Illinonian glacial period?

Unconsolidated Glacial Sediment

9. What landscape features are deposited directly from glaciers? What landscape features are deposited as a result of melt water?

3D Map Tour

10. Zoom out on the Brownstone Dunes. Are the Brownstone Dunes the only dunes found in Indiana? Why do you think so much sand was deposited in Indiana?

11. Why do you think some kettles, like the one shown, form in moraines?

12. Why would sediment move from east to west along the Chicago shoreline?

13. What is the significance of supraglacial lakes? Why do you think knowing the position of supraglacial lakes is important?

14. What landscape features have we investigated that are not found in Indiana? Why is that?

Investigating Glacial Deposits

15. What is meant by radiometric dating? How is it used to determine the age of deposits?

Glacial Features of Indiana

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Investigating Glacial Deposits

15. What is meant by radiometric dating? How is it used to determine the age of deposits? Does this method give a relative or absolute age of deposits?

Lake Michigan Geomorphology

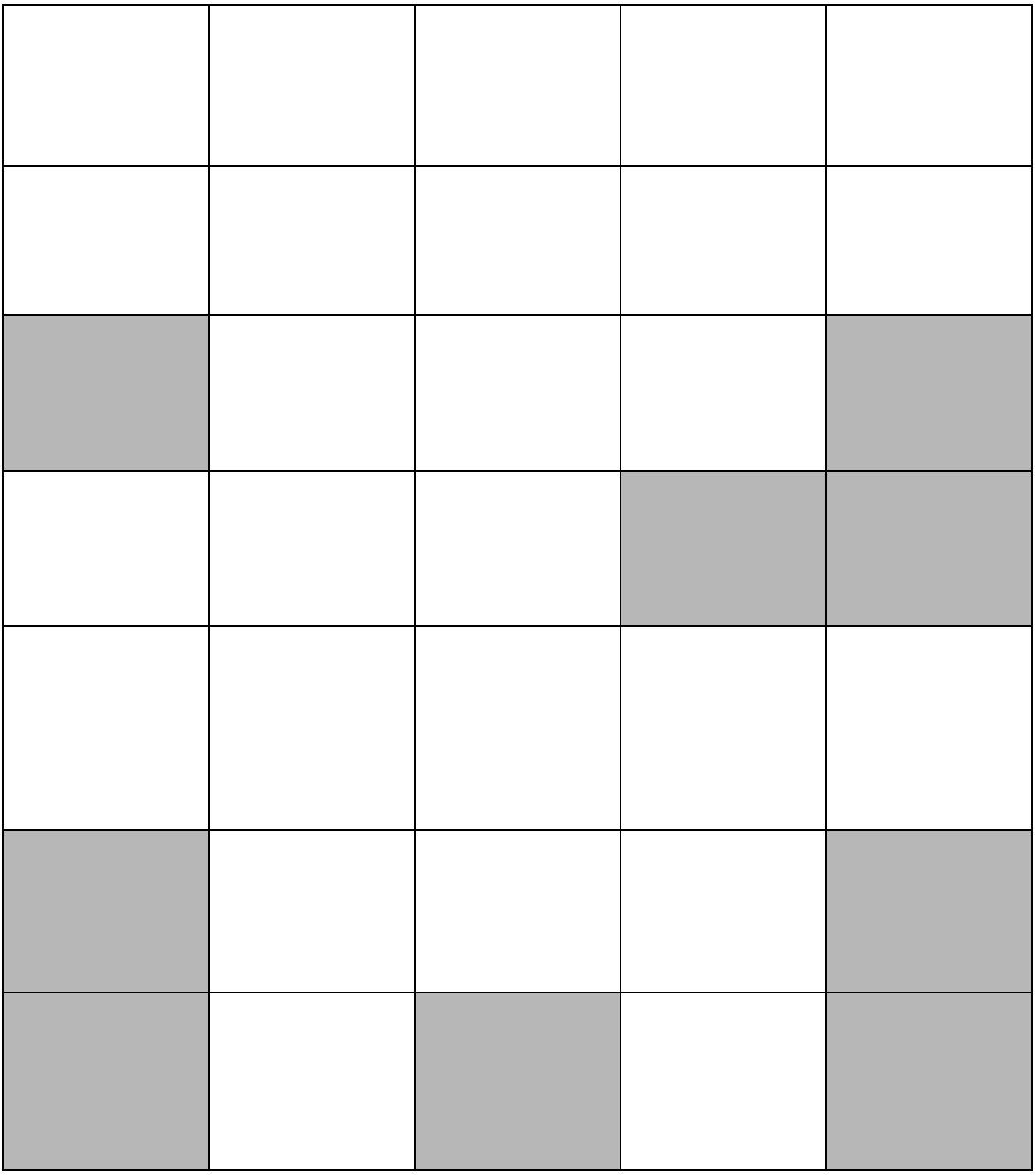
From the Glacial Landforms activity, we saw there are a number of ways that glaciers shape the landscape with erosion and deposition. We saw that Indiana's landscape is full of depositional and erosional marks left by the last glaciation from the ArcGIS storyboard, *Glacial Features of Indiana,* you previously examined. However, these landforms are not the only influences glaciers have on the landscape. Some landscape features are the result of glacial activity, but were not in contact with the ice sheet directly. An example of this would be the Presumpscot Formation in Maine, a deposit of blue marine clay that indicates that the sea level was once higher in the area than it is currently. The change in sea level can be attributed to isostasy and water levels from the melting Laurentide.

Before going through the slideshow *Lake Michigan Geomorphology* define the terms below:

- Isostatic Rebound-
- YBP-
- Glacial Lobe-
- Paleo-Shoreline-

After defining the terms, go through the slideshow *Glacial Influence on Lake Michigan* and fill out the table below. Grey boxes do not have to be filled in:

Name of Phase/Paleo-Shore	**Age of Event YBP**	**High or Low Lake Levels**	**Cause for Lake Level Change**	**Extent of Lake Level Change**



Once you have filled out the table, draw an outline of the changes in Lake Michigan levels on the map below. Include dates for all the changes.

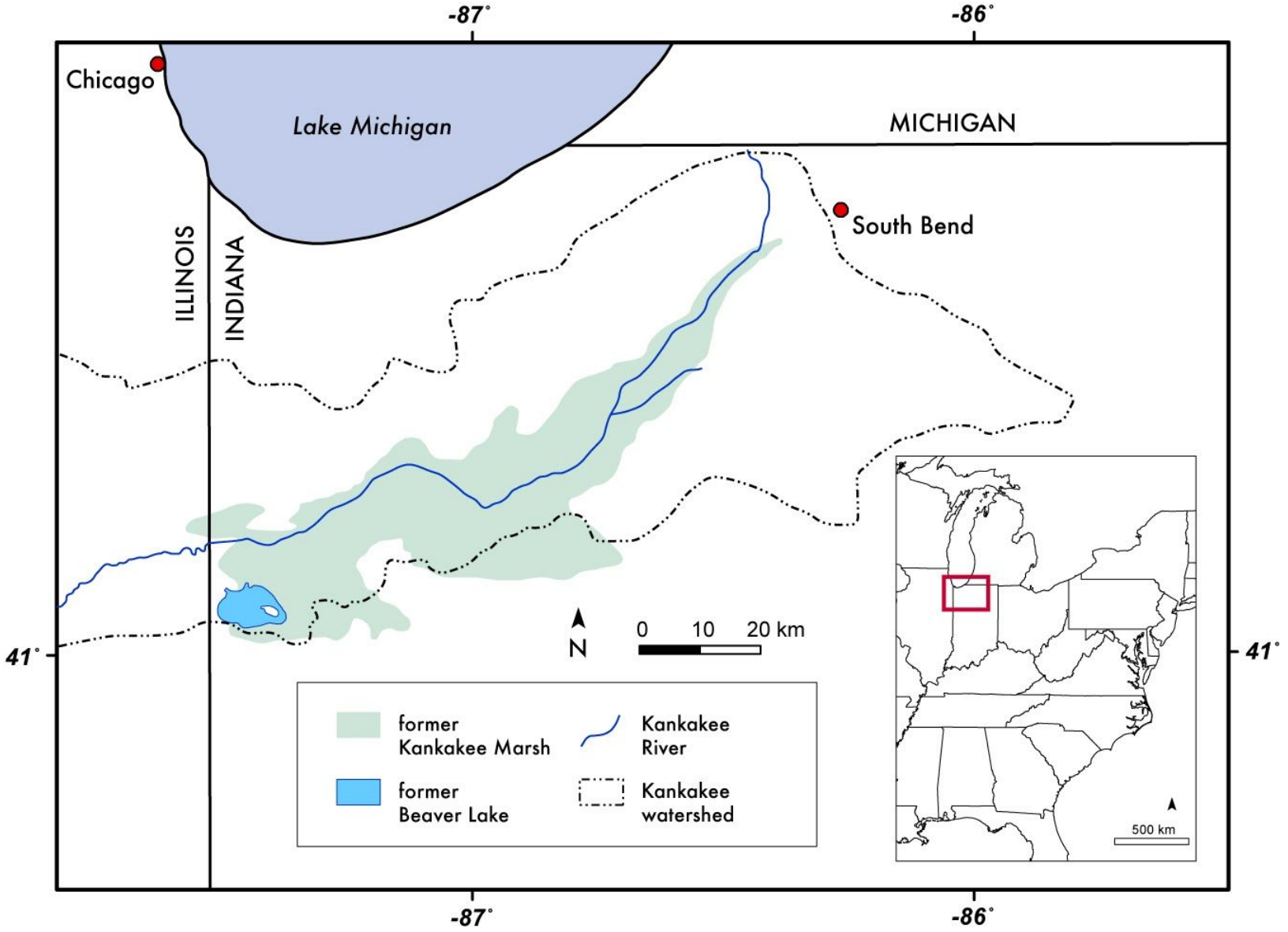


Image from: Glover, 2020. The Early PAGES blog.

How was the creation of the Grand Marsh and sand dunes an inadvertent effect of glaciation in the area?

Soil Explorer

From studying the *Glacial Features of Indiana* storyboard and Lake Michigan's formation, we learned the glaciers have deposited massive amounts of sediment in the area, even before the Last Glacial Maximum. These sediments are valuable resources for industries such as agriculture and construction. However, to be able to harvest these resources we must know how they are distributed across the landscape. Using the online resource, Soil Explorer, we will investigate their distribution.

Before starting this activity define the following terms:

- Alluvium-
- Loess-
- Lacustrine-
- Eolian-
- Loam-
- Till (glaciers)-

Directions:

1. Go to https://soilexplorer.net/ and hit accept to their terms of use.
2. Next, select Indiana from the regions dropdown menu.
3. Click on the **Dominant Soil Parent Materials** tab on the right side of the page.
    a. You can clear the map of **Boundaries Roads and Places** by unselecting it located above Dominant Soil Parent Materials.
4. There are five icons on the left, the bottom icon gives you a color key for the different soil parent materials. Click on the icon and compare the map to the color key.

Fill out the graphic organizer on the next page with your observations on how the noted Dominant Soil Parent Materials are distributed:

Dominant Soil Parent Materials	Observations on Distribution
Eolian Sands / Sandy Sediments	
Loamy Wisconsin Till	
Clayey Wisconsin Till	
Wisconsin Outwash	
Illinoian Till	
Organic Materials	

After you have completed the table, answer the following questions, cite evidence in your answers:

1. What is the largest dominant soil parent material in the area? Where is it located?

2. Why is the Wisconsin Outwash soil parent material found in and around river channels?

3. How do soil scientists know the difference between Illinoian Till and Wisconsin Till?

4. Is the distribution of eolian sands/sandy material consistent with the geomorphology of Lake Michigan?

5. What dominant soil parent materials can be found in the Grand Kankakee Marsh?

6. Where would you suggest someone dig for construction materials?

7. Where would you suggest someone start a farm?

Change from Dominant Soil Parent Material to **Natural Soil Drainage Classes**

1. Does the dominant soil parent material influence the drainage class? Why or why not.

2. What class or classes of drainage occur in the Grand Kankakee Marsh?

3. Is the class or classes of drainage that occur in the Grand Kankakee Marsh consistent with the formation of marshes? Why or why not.

4. Where would you expect to find ground water resources?

Change from Natural Soil Drainage Classes to **Hillshade**

1. What glacial landscape features can you discern? Add screenshots.

2. Notice that most of the state is relatively flat compared to the bottom southwest of the state. Why is there a difference in topography in that area?

3. In part of the flat eastern area of the state there are around 5 waves features. These were mentioned on the ArcGIS storyboard. What are they?

Glacial Landscapes Project

Now that you have spent time determining the defining characteristics of different types of glacial landforms, and have studied different ways glaciers influence the landscape, it is time to figure out what glacial landforms are in your backyard! Your task is to research prominent glacial landforms in Indiana and make a Google Earth tour exploring them.

Directions:

- Research glacial landforms in Indiana and find **5** you would like to study. Indiana's geologic survey is a good place to start finding out more information, along with scholarly articles.
- Synthesize the information you gathered into a Google Earth tour, here is a link to the website https://www.google.com/earth/
- Include citations for all information, including photographs

To create a Google Earth Tour:

1. Sign into your google account
2. Once on the Google Earth hit **Launch Earth**
3. On the left side of the page there will be icons, hover over the fifth icon down which should say **Projects**, click on it
4. Hit the **New Project** button and select **Create project in Google Drive**
5. Under **New Feature** you can search for landforms you have come across in your research and add them to your project that way
    a. If you can not find them in the search bar you will have to search the landscape for them by zooming in and looking at the terrain directly
    b. To move the camera double click the compass in the bottom right corner, double clicking should enlarge it
    c. Once the compass is enlarged you can drag the compass vertically to tilt the view of the camera and better see landforms, you can drag the compass horizontal to rotate the camera and get a 360° view of the landforms you are looking at
6. After you have found a landform you would like to include in your tour add a placemark found in the bottom left corner
    a. Name the landform what type of glacial feature it is, or if it has a specified name, such as the Valasparío Moraine, you may use that
    b. After you have added a placemark look under your project and edit the feature with the pencil icon to add a description of the landform and other details you have learned from your research, such as date of formation
    c. Add a picture of either your specific landform you researched, or a general picture of what the landform looks like

Click on Google Earth to see an example of some landforms on Google Earth, or use the link at the end of handout

Grading Rubric

	4	3	2	1
Research	Project shows thorough research into the glacial landforms in Indiana - At least 5 landforms are marked -All 5 landforms have accurate names and descriptions	Project shows some in depth research of the glacial landforms in Indiana - Less than 5 landforms are marked - Landforms have some accurate names and descriptions	Project shows little research of the glacial landforms in Indiana - Less than 3 landforms are marked -Landforms rarely have accurate names and descriptions	Project shows no research of the glacial landforms in Indiana - Less than 3 landforms are marked - Landforms do not have accurate names and descriptions
Presentation	Project has all components - At least 5 landforms - All landforms have pictures and descriptions	Project has some components - Less than 5 landforms - All landforms have pictures and descriptions	Project has little components - Less than 3 landforms are marked - Not all landforms have pictures - Not all landforms have descriptions	Project has close to no components - Less than 3 landforms are marked - Landforms have no pictures - No Landforms have descriptions
Mechanics	Project has little to no grammatical or spelling errors	Project has little grammatical or spelling errors	Project has recurrent grammatical or spelling errors	Project contains frequent grammatical or spelling errors
Sources	Project uses reliable sources - Cites them properly - Cites photos	Project uses some reliable sources - Cites some properly - Cites some photos	Project uses few reliable sources - Cites few properly - Cites few of the photos	Project uses no reliable sources - Doesn't cite properly -Cites no photos

https://earth.google.com/earth/rpc/cc/drive?state=%7B%22ids%22%3A%5B%221Ord2o-5O82onzVJZP9CLM7ngottz2dVl%22%5D%2C%22action%22%3A%22open%22%2C%22userId%22%3A%22102578540804965223525%22%7D&usp=sharing

Future Predictions

We have learned about glaciers of our past, and now it is important to think about the future. From the first video we watched we learned that melting from glaciers is an early warning sign of a warming climate. From the Climate Reanalyzer we saw the drastic difference a few degrees can mean for glaciers.

Watch *What Happens If All the World's Ice Melts?*, linked below, to see how our planet will be affected by the rapid melting of glaciers and then answer the questions:
https://www.youtube.com/watch?v=S0I4re0XUXU

1. Based on what you learned in the video and outside knowledge, how much glacial melt do you think will occur in the future?

2. How do you think the future global landscape is going to be impacted by what you predicted above?

3. How do you think Indiana will be affected?