Proglacial Lakes and Marine Environments

Work to do on this page:

1. Hyperlink phrases with other pages in the textbook
2. Add to Influences
3. Add to Facies

Welcome to Proglacial Lakes and Associated Marine Environments!

Outline of this page:

1. Introduction (why you should care), fig 1, 2
2. Sediment Transport Processes, fig 3, 4
3. Vertical Sequence, fig 5
4. Summery

Note: Subheadings will be in italics, keywords will be in bold when they are introduced, and a scavenger hunt for the remainder of the article (mostly for esthetic). Words (besides headings) outlined in blue are hyperlinks to pages where you can learn more about the keyword or phrase.

Topics will be introduced, and the figures will be below them, so if you are stuck, look ahead! If you are still stuck, look to the related material and links for more information. Additionally, don't hesitate to contact your professor, they like the
Keywords: Proglacial Lake, glacier, Ice, Moraine, Debris Flow, Turbidities, Outburst Flood (Jokulhaups)

Introduction:

Why study Proglacial Lakes and associated Marine Environments?

Proglacial lakes are formed as melt water from a glacier pools. Depending on the type of dam that holds the melt water, proglacial lakes can either be stable long after the glacier melts, or can fail catastrophically to produce jokulhaups, outburst floods. Given their nature, these lakes have important hazard implications in the past and present. In the past, the Younger Dryas, a major shifts in global climate, has been attributed to the outburst flood of a large proglacial lake. At present, with a warming planet, proglacial lakes are increasing in volume and abundance, as seen in figure 1. This increase puts communities at risk of outburst floods that may have not been at risk before.

From a scientific standpoint, proglacial lakes are important in studying climate because they preserve data with high temporal resolution. They are on par with speleothems in preservation, which allows us as scientists to make interesting observations into the past.

Again, studying proglacial lakes are important because:

- They preserves pristine records of paleoenvironments
- Have caused important changes in paleoclimates, such as the Younger Dryas
- becoming increasingly more common with the disappearance of glaciers

Fig1: The enlargement of Proglacial lakes off of the Llewellyn Glacier (British Colombia) in the Juneau Ice Field, Alaska (courtesy of Mauri Pelto, Professor of Environmental studies and head of the North Cascades Glacier Climate Project). The left image depicts lake levels in 1984, and the right shows the expansion of these lakes in 2016. Markings A-D in both satellite images represent approximate end of proglacial lakes (red denotes 1984 and yellow denotes 2016).

What makes up a proglacial lake?

Proglacial lakes come in several varieties. We will discuss ice, moraine, debris flow, and bedrock dammed proglacial lakes.

Ice dammed lakes are associated with the ice margin of a glacier. The rate of lake formation is heavily linked to glacier movement and ice accumulation. Ice accumulation is slow, and linked to glacier mass balance and the surrounding climate. Because of their ice dependence, ice dammed lakes only exist as long as the ice exists.
Moraine dammed lakes are associated with glacial retreat, often when the front of a glacier detaches from the remainder of the glacier. Moraine dominated lakes will fill places of low topography that was previously occupied by ice or melt water, and can continue to evolve. Consequently, these lakes can live longer than the glacier.

Debris flow dammed lakes are associated with slope failure of the surrounding bedrock from removal of bedrock material by the glacier. These lakes are short lived, and often either fail or are filled in by new debris flows.

Bedrock dammed lakes are associated with depressions in regions a glacier sat before. They are initially filled with melt water below the glacier, and can last long after the glacier.

Summery of the three common types of proglacial lakes and what they mean for structural integrity of the lake

- Ice dammed -> can be short lived, only as ice maintains integrity
- Moraine dammed -> long lived, can outlast glacier
- Debris flow dammed -> short lived, only as loose debris maintains integrity
- Bedrock dammed -> long lived

Fig2: Schematic on different types of proglacier lakes. (Tweed, Fiona S., and Jonathan L. Carrivick. "Deglaciation and proglacial lakes." Geology Today 31.3 (2015): 96-102.) Ice dammed lakes are bordered by ice, bedrock dammed lakes fill in a bowl in the bedrock created by the glacier, "landslide" or debris lakes are bordered by debris flows, and moraine dammed lakes are bordered by moraine at the toe of the glacier.

**What influences a proglacial lake? (To be continued)**

Proglacial lakes are heavily influenced by glacier dynamics and the surrounding environment.

Some Important Interactions Between Proglacial Lakes and Glaciers:

- Water Depth
- Bathymetry
Sediment Transport Processes:

**What Sedimentary structures are common in proglacial lakes and Marine Environments (Fig3)**

Sedimentation in proglacial lakes is tied to glacial dynamics, and often dependent on the distance between the glacier and the deposition area. Close to the glacier, channels that run underneath the glacier deposit sediments in subaqueous fans and submerged ramps. These slopes are occasionally altered by **turbidity currents**. Additionally, the type of sediment and distance it travels is dependent on the speed of the water from the glacial channel. Ultimately, most sediment in proglacial lakes settles due to suspension settling. These fine grained sediment layers can be disturbed by ice rafted debris, larger clasts that were carried by ice that had chipped off the glacier and transported across the lake. Organic material in proglacial lakes provide high temporal geochronology resolution, and are useful in reconstructing climate.

**Summery of Sediment Structures**

- fine sediment, with layers of **turbidity currents**
- drop stones/ ice rafted debris (IRD)
- subaqueous fans/ submerged ramps

![Fig3: Sediment types from Proglacial Lakes. 1: drop stones from icebergs, 2: Sediment deposited from Turbidity currents, 3:](attachment:image_url)

Outburst floods:

Another dispositional feature of proglacial lakes are outburst floods. These floods occur when the proglacial lake's dam is broken, or if the flow overtops the lake's dam. Material deposited in these features are a mix of sediment sizes, from silt to boulder size (fig_).

*More information about outburst floods can be seen here:*

Animation of outburst flood: https://www.youtube.com/watch?v=awLGx15JmjY

Buton outburst flood 1994: https://www.youtube.com/watch?v=3hMM5NiLIRw

Buton outburst flood 1994: https://www.youtube.com/watch?v=jpmtflUnwc4: Little corny, but good information!

Outburst floods have historically altered climate systems. The Younger Dryas was a period of intense cold on our planet caused by the failure of Lake Agazzi, a proglacial lake that had held melt water from the Laurentide Ice Sheet. As water rushed to the Northern Atlantic, the increase in cool freshwater shut down the gulf stream. By doing so, heated water from the equator did not reach as far north, causing further cooling.

*More information on the Younger Dryas:*


Younger Dryas Animation: https://www.youtube.com/watch?v=kqWIwp1beIw (no sound)

Younger Dryas Information: https://www.youtube.com/watch?v=8RpG49hSkjw (watch the first video first to see the animation, this one is just talking)

Summery of Outburst Floods:

- A dam may fail from overfill or breaking of ice and cause an outburst flood
- Outburst floods in the sedimentary record display clasts of mixed sizes
- Historical significance:
  - Lake Agazzi and the Younger Dryas cold event
- Implications in mountain communities in a changing world
**Typical Vertical Sequence of Facies Representing the environment:**

- **rhythmites**: layers of sediment lain down periodically
- **turbidity currents**: density currents that rapidly move a large amount of material down slope
- **suspension settling**: resultant of a calm environment, suspension settling describes the process of depositing finer material out of the medium (water here) by way of gravity.

5. Diagrammatic longitudinal cross-section through the glacial ...

Fig 5: This figure represents the type of facies that can be seen within a proglacial lake facies. In such a dynamic environment, there are many processes to observe like turbidites, rhythamlets in the shallow segment, and braided river deposits leading up to the lake. Kehew, Alan & Lord, M.L. & Kozlowski, Andrew & Fisher, Timothy. (2009). Proglacial megaflooding along the margins of the laurentide ice sheet. Megaflooding on Earth and Mars. 104-127. 10.1017/CBO9780511635632.007.

**Summery:**

Proglacial lakes are important features of glacial environments and can aid in reconstructing paleoclimates. The longevity of these lakes is dictated by the type of dam that holds in the water. Sedimentation in these lakes is heavily dictated by the current glaciation, and ranges from deposition by suspension to turbidity currents on the lakes sides. Ice rafted debris can carry glacial sediments far across the lake, and potentially across the ocean. Proglacial lakes have the potential to create outburst floods when dams break or the lakes are overfilled. These outburst floods have the potential to cause a catastrophic hazard in mountainous regions like Nepal. Further, extreme outburst floods can alter climate by interfering with ocean currents, as was the case in the Younger Dyas. Proglacial lakes are relevent in the geosciences because of their fine scale temporal resolution of material useful in chronostratigraphy.

**For more information on this exciting topic, visit these resources!**

**References/More Material**
**Proglacial lakes:**

1. *Proglacial Lakes: character, behavior, and geological importance* by Jonathan L. Carrivick and Fiona S. Tweed

**Failure of proglacial lakes associated with the Laurentide Ice Sheet:**

1. *Catastrophic glacial-lake outburst spillways: form and process relationships* by Alan E. Kehe, Western Michigan University and Mark L. Lord, Western Carolina University

**Anything else remotely glacier related:**

1. *Antarctica Glaciers*: look around the site! They have great information on many glacier related topics
2. *Glacial Types-Retreat*