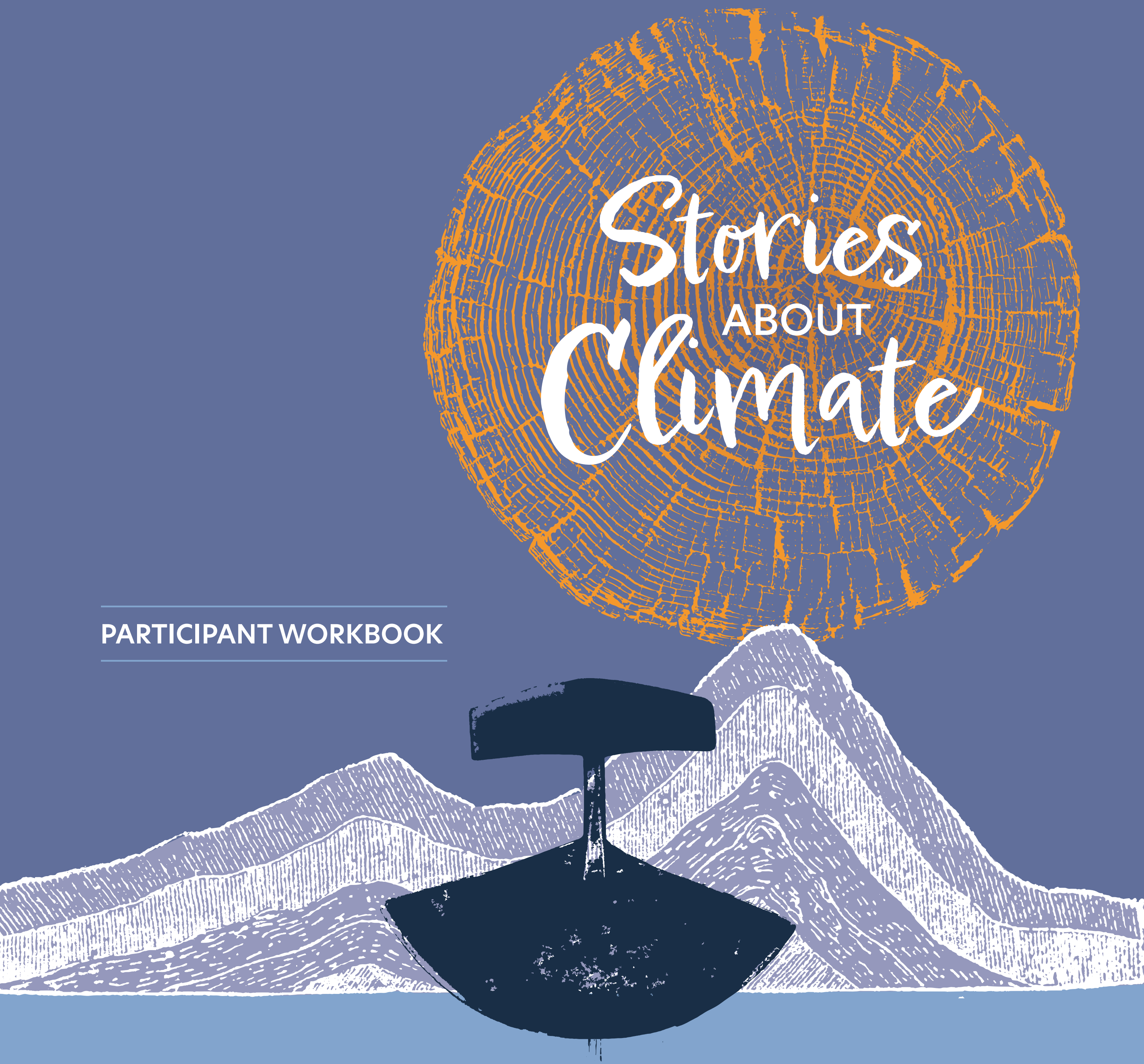
Stories ABOUT Climate

PARTICIPANT WORKBOOK



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WHAT IS THIS WORKSHOP ABOUT?

Gaining perspectives on past climates from natural archives to oral stories

AIM OF THIS WORKSHOP

We intend to build awareness about Arctic climate changes through a booklet with written questions and a comic book *The climate stories of Aklavik – a journey into the past*. More specifically, the workshop presents methods used to reconstruct past climate changes. These methods permit to highlight the importance of long time series or records for understanding climate dynamics and placing the ongoing climate change into perspective. Through this workshop, we hope to foster discussions on climate between people of different backgrounds and age.

CLIMATE OF THE PAST: why is it important?

We hear a lot about recent climate change and the impact of human activities on the environment. First, it is important to know that there is a difference between climate and weather. Weather describes the daily or hourly conditions outside, like cloudiness, temperature, precipitations, and so on. Climate is the mean atmospheric conditions of a region for a long period of time, usually 30 years. Researchers use computer models to explore future scenarios of the Earth's response to increased greenhouse gases, such as temperature rise and sea ice loss. Studying past climate conditions allows researchers to identify past climate extremes, trends, and environmental responses to external factors such as solar activity and greenhouse gases. Therefore, studying past climate helps improving climate predictions. The more accurate predictions are, the better we can prepare for the future and take care of our communities.

DIVING INTO THE PAST:
how can we do this?

To reconstruct the climate of the past, different approaches can be used: the study of tree rings (dendrochronology), the analysis of sediment cores that containt fossil in microorganisms, and historical archives including written stories, diaries, etc.

Another way to explore past climate and environments is through oral histories and local knowledge. Stories are unique because they can also unveil different perspectives on nature and its changes.

THE PAST:
how far back in time?

Through the study of tree rings, in Canada, researchers can go back in time as far as thousand of years[1]. Dendrochronologists, people studying tree rings, can reconstruct past climate from living and fossil trees. Sediment cores going back thousands to millions of years[2] have been recovered through gravity coring or drilling! Sediment cores retrieved from lakes can provide yearly information for hundreds of years[3].

Other types of material, including old rocks, allow researchers to investigate climate of the long-term geological past, going as far back as 550 million years[4]. However, the older the material is, the fewer details can be reconstructed. Finally, when we think of historical archives and oral histories, human memory is our only repository. Legends and stories can be very old, especially when transmitted from generation to generation!

[1] For example: Gennaretti et al., 2014; Naulier et al., 2015; Giguère-Croteau et al., 2019

[2] Zachos et al., 2001

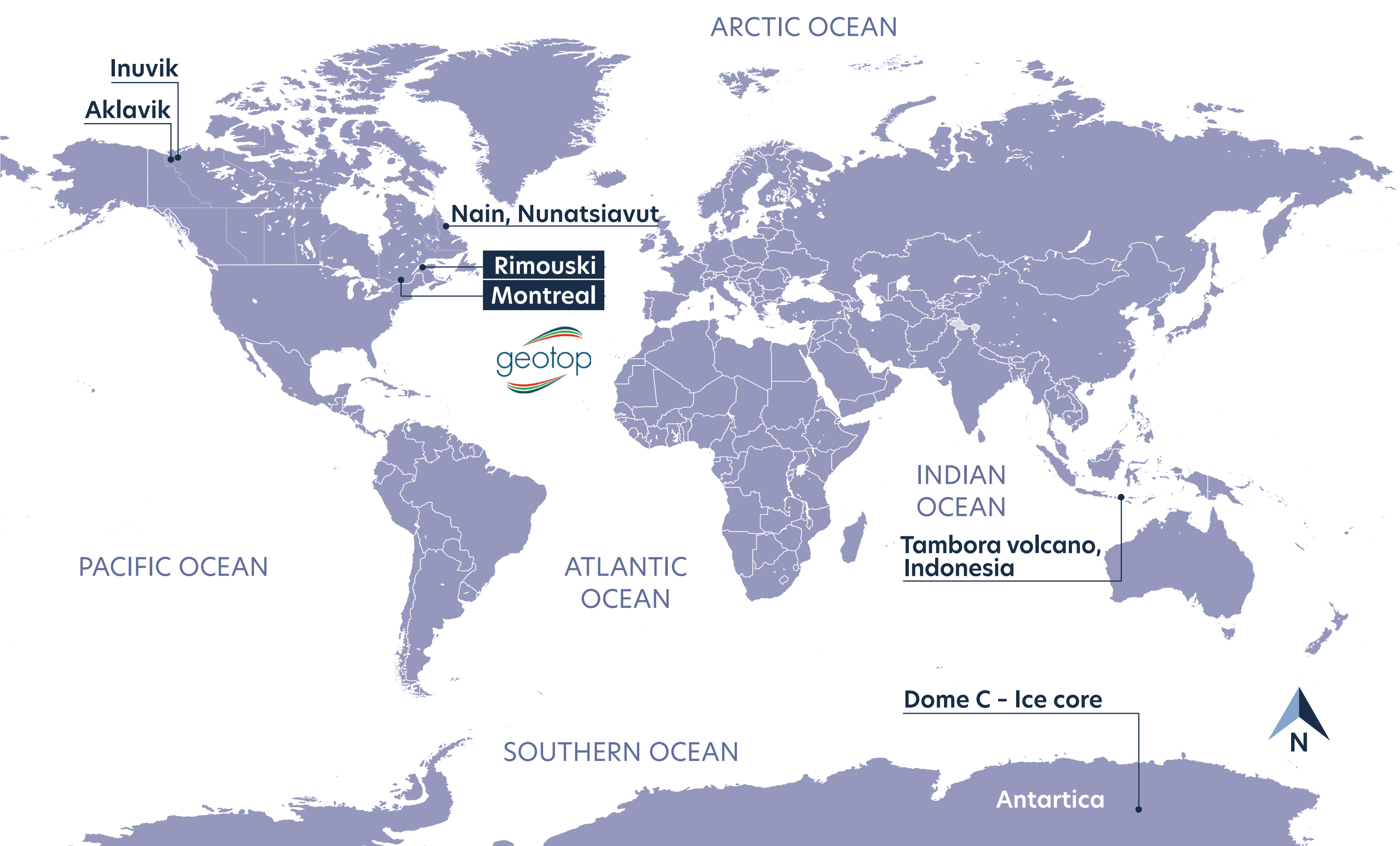
[3] Zolitschla et al., 2015

[4] Royer et al., 2004

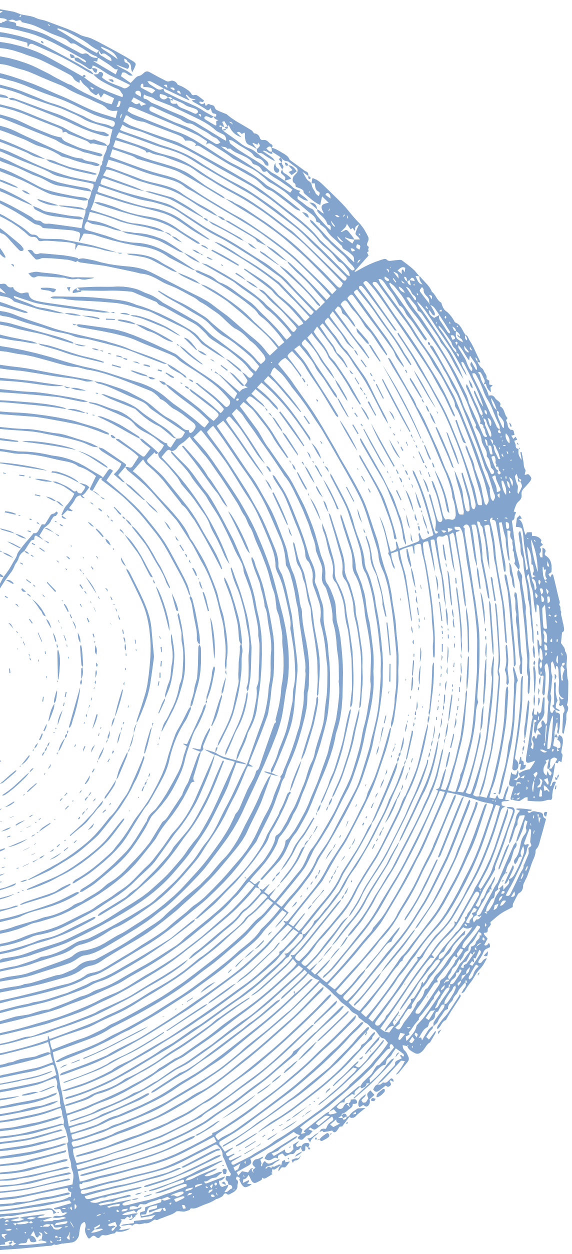
WHAT IS THE OLDEST STORY YOU KNOW?

Figure 1

Location of the main cities and communities mentioned in this booklet.
Geotop research centres are located in Rimouski (UQAR) and Montreal (UQAM and McGill).



HOW TO RECONSTRUCT PAST CLIMATE?



Tree rings

Dendrochronology is the study of tree rings. The name comes from the Greek words *Dendron* meaning tree, and *Kronos* meaning time. You probably have seen tree rings on a cut tree or shrub before. You can have a look at Figure 2 on the next page for an example. Every ring corresponds to one year of growth. By counting the rings of a tree, you can know its age! If you know the year it was cut, that means you can count back to the year the tree started growing. But that's only a start!

By looking at the width of the tree ring, you can determine if summer conditions were favorable or not. Indeed, wider rings mean a faster growth while narrower rings mean a slower growth. Each species of tree is different and has its own temperature and humidity requirements. If a ring is wide for a given year, we can assume that it reflects a warm summer with a suitable amount of precipitation (Figure 2; Activity 1). The ring width pattern on a single tree tends to be similar to the patterns found in neighboring trees of the same species, because all individuals grew under the same climate conditions. Therefore, tree ring patterns may be regarded as "barcodes": all trees growing in the same climate conditions share this "barcode". Dead trees that grew in a different climate also have barcodes, but depending of their age those barcodes only partially overlap with barcodes of living trees. This barcode matching, called cross-dating, is a powerful feature of trees that enables scientists to reconstruct past climates over the last hundreds or thousands of years before present (Figure 3).

Activity 1

TREE RINGS

This is a piece of a cut tree.
Each ring represents a year.

Observe and answer the questions.

Which year was the tree cut?

____

What is the age of the tree?

____

What years were the most favorable for growth?

____

Figure 2
Picture of a cut tree.
The species is a Norway Maple from the Montreal area.

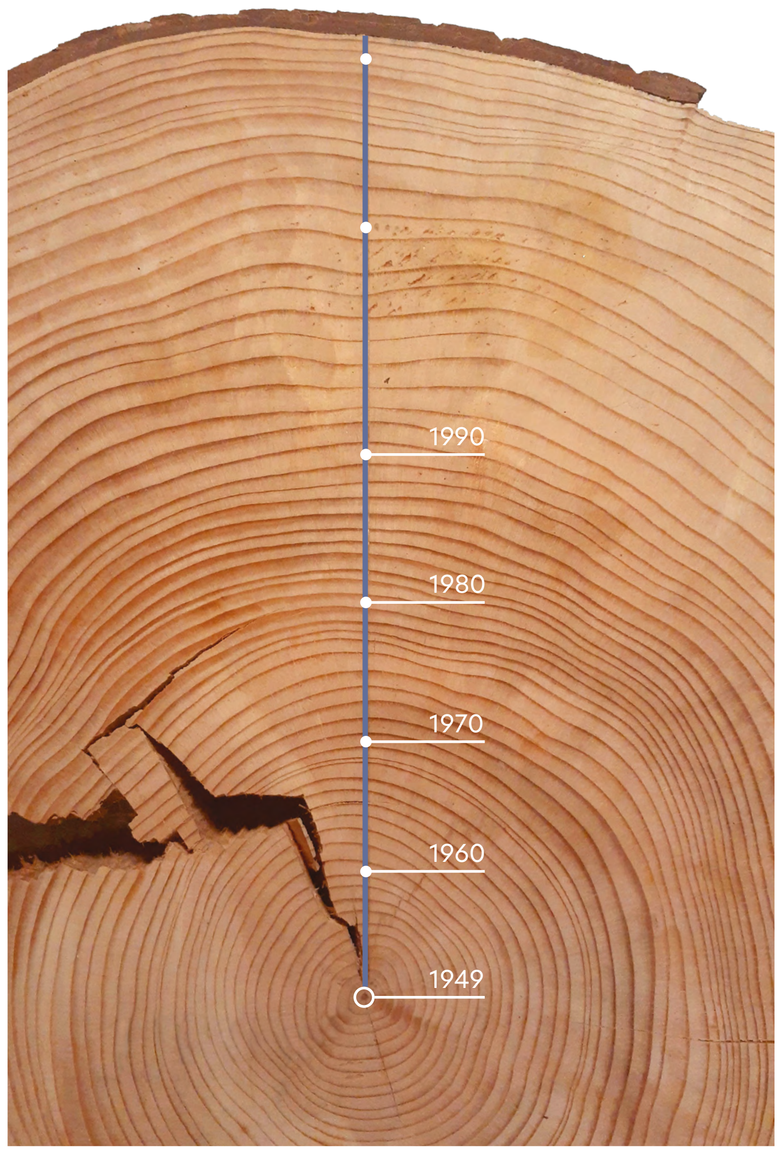
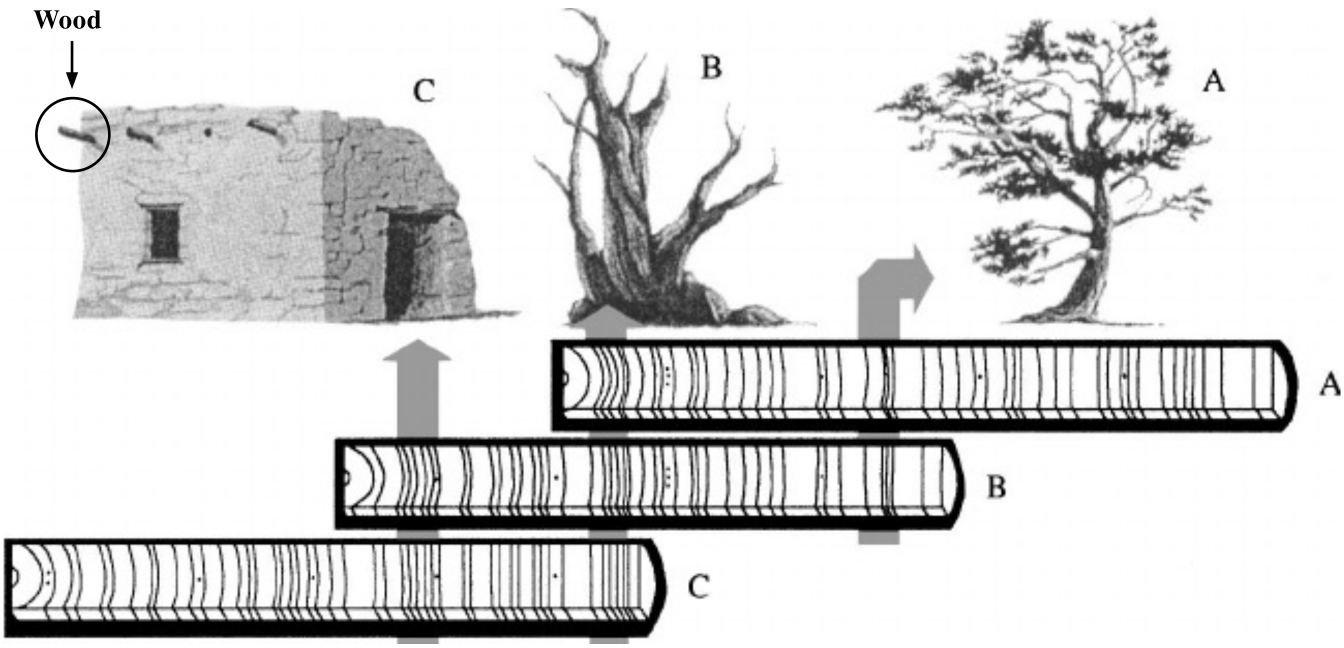


Figure 3

In this classic example from the Laboratory of Tree-Ring Research, University of Arizona, Tucson, there are three samples from the youngest to the oldest: A = a living tree, B = a dead tree and C = an ancient house framework.

Similar patterns are observed in each of the samples, which permitted matching them with each other. This offers the opportunity to provide long records that go far back in time.



Trees are not the only organisms to capture climatic signals in their rings. So do shells! A thick band means good growth conditions and a thin band means harsh growth conditions. The study of shell growth bands is called sclerochronology. Other animals can even record information about their health in their horns or teeth (Figure 4)!

Figure 4
Growth bands on a seashell and a Dall's sheep horns.

HOW TO RECONSTRUCT CLIMATE?

Sediment cores

Water bodies such as estuaries, oceans and lakes can be considered as sinks. Every year, particles transported by the rivers, winds, and floating ice eventually sink to the bottom; this is called sedimentation. In the meantime, some organisms living at diverse depths in the water die, sink, and also accumulate at the bottom. Some small organisms (microorganisms) build shells to protect themselves. These shells can be made of various material: calcium carbonate like seashells, silica like glass, or organic matter, which can be preserved for a long time and studied later. Because the sediment accumulates gradually layer after layer on top of each other, the deeper sediment is older and the surface sediment is younger.

This is how sediment cores allow us to investigate the past (Figure 5; Activity 2). Sediment cores are collected from a boat using a large plastic cylinder that is pushed vertically into the sea floor to retrieve the accumulated material (Figure 10). Various methods are used to date the sediment, you can find descriptions in the **Supplementary material 1**. Each gram of marine sediment may contain several hundreds to thousands of microorganism shells (microfossils), which we observe and identify using microscopes. We use changes in microfossils abundance and species variety to assess the environmental conditions that existed when they were alive (Figure 6; Activity 3). Some species prefer warm waters, some are adapted to living near sea ice, some prefer saline waters, etc. Additionally, we can use the chemistry of their shell, mostly the ones made of calcium carbonate, to give information about the chemical properties of the water in which they grew. For example, this can help us determine the salinity and the temperature of the water, and whether there was lots of ice on land. You can see the **Supplementary material 2** for more details. Peatlands are also suitable environments to collect cores. Through the years, the peat grows and captures particles, vegetation debris, dead insects, pollen grains, etc. All this material is then preserved and fossilized.

Activity 2

SEDIMENT CORES

This is a marine sediment core taken close to the coast of the Arctic Ocean. Can you identify the surface and the bottom of this sediment core?

Check the right boxes and answer the question.

Figure 5
A sediment core

☐ Surface **OR** ☐ Bottom

Observe the difference between coarser grains (sandy sediment) and pale/beige fine-grained sediment.

When was the first time the pale beige sediment sank to the bottom of the seafloor?

____

☐ Surface **OR** ☐ Bottom

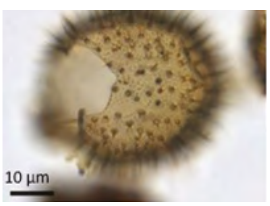
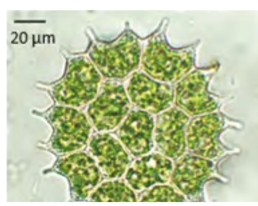
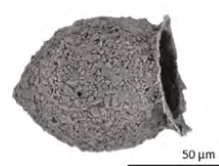
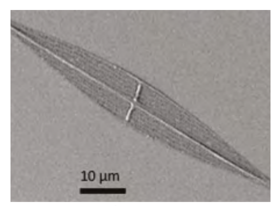
Activity 3

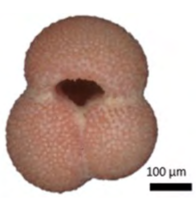
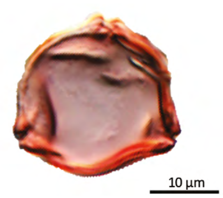
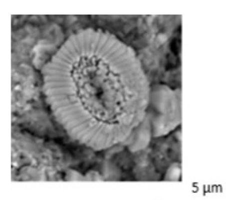
MICROPALEONTOLOGY

Microfossils can be observed from sediment.
The different types of microfossils that we find in the sediment are representative of the environmental conditions in which the organism lived in.

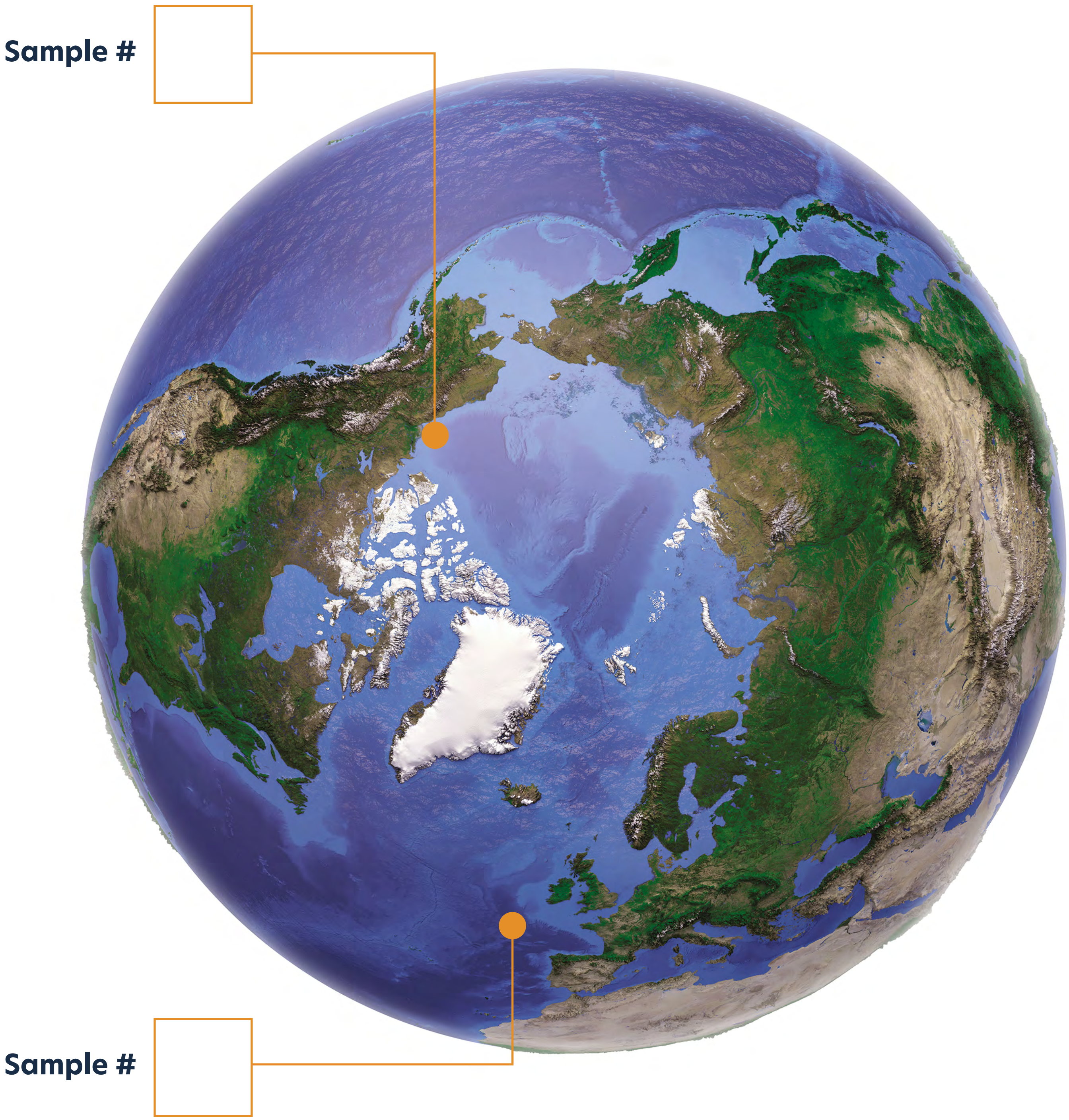
The two samples below contain very different microfossil types.

Figure 6
Photos of microfossils retrieved at two different sites in the northern hemisphere.

SAMPLE # 1				
				
© Photo	Van Nieuwenhove et al. (2020)	microscopeandmonsters.com	Jade Falardeau	Harđardòttir/Concarneau MNHN
Name	***Islandinium minutum***	***Pediastrum* sp.**	***Tintinnopsis fimbriata***	***Haslea spicula***
Type	Dinocyst	Green algae	Tintinnid	Diatom
Ecological preference	Sea-ice environment	Fresh water	Marine environment, near river months	Sea ice environment

SAMPLE # 2				
				
© Photo	Tiffany Audet	Van Nieuwenhove et al. (2020)	Joan Vallerand	Nicole Snyder
Name	***Globigerinoides ruber***	***Spiniferites mirabilis***	***Betula* sp.**	***Emiliania huxleyi***
Type	Planktic foraminifer	Dinocyst	Pollen grain (birch tree)	Coccolith
Ecological preference	Warm and saline waters	Warm waters	Mixed forest - temperate climate	Warm and saline waters

Guess where the samples #1 and #2 were collected. Two potential sampling sites are shown by the orange dots.



HOW TO RECONSTRUCT CLIMATE?

Historical archives and oral histories

Historical archives include any kind of written documents: books, journals, poems, or oral histories. Writers or story tellers can communicate perceptions and experiences related to climate, and transmit knowledge that has been passed across generations and communities of people. Perceptions of climate can also be expressed in art, photography or paintings. Historical archives and oral histories show the relationship between nature and the human experience.

Written archives – life stories, novels and journals – and oral histories often present exceptional events, such as a notorious snowstorm, a very hot summer, or a late snow season. These exceptional events are generally of short duration and might not be detected by the methods described previously. Historical archives and oral histories can also provide information on any time of the year, whereas scientific approaches often measure a seasonal phenomenon.

Activity 4

HISTORICAL ARCHIVES AND ORAL HISTORIES

How would you describe today's weather conditions if you were writing a book or telling a story to a friend or a relative?

Think about it and answer the questions.

In winter, how is the climate where you live?

____

____

In summer, how is the climate where you live?

____

____

Have you observed changes in climate or in nature since you were young?
Check the box(es) below that correspond to your observations or add your own observations.

- ☐ Warmer temperature
- ☐ Colder temperature
- ☐ Longer warm season
- ☐ Shorter warm season
- ☐ More snow
- ☐ Less snow
- ☐ More rain in summer
- ☐ More rain in winter
- ☐ Less rain in summer
- ☐ Less rain in winter
- ☐ More wind
- ☐ Less wind
- ☐ More freezing snow
- ☐ Less freezing snow
- ☐ Very hot summers
- ☐ Flood
- ☐ High water level in rivers
- ☐ Low water level in rivers
- ☐ Different birds
- ☐ Different fishes
- ☐ Different animals
- ☐ More bugs
- ☐ Less bugs
- ☐ Less days with safe ice for travelling
- ☐ More days with safe ice for travelling

CLIMATE
in texts and stories

Example 1

The text is called *Qiviuq, the Boy with the Spirit of two birds*. It is a story told by the Inuvialuit living in north-western Canada. This selected exerpt is about ice (siku) and how the ice forming is important for them. It also says that sea ice is about to form in late fall.

Glossary Inuvialuktun-English

Siku: ice or any water in a solid form

Ulu: the woman's half-moon-shaped knife

Sikuliaq: young ice or a very thin layer of first-year ice

"The *siku* had frozen over quite a ways out but was thin because it was late fall and just forming. When he threw the *ulu*, it hit the *sikuliaq* and split it in half, therefore opening a pathway for him to travel out through"

Qiviuq, the Boy with the Spirit of two birds, Inuvialuit Cultural Center Digital Library

Figure 7
An example of an *ulu*

Example 2

This example comes from the Inupiaq of Alaska. The story *The time summer time did not come*. This was at the end of the month of June. It is about a very cold summer, with snow during all months and frozen bodies of water. It shows how exceptional that year was.

"After the birds of all kinds came to Alaska the weather turned cloudy and overcast. The wind turned into a northly wind. The ground was all exposed. There was no snow. The rivers and creeks began to flow and the lakes had water.

Suddenly, it turned into cold weather. Soon the water stopped running. It froze over. Snow began to fly. Big storms came. [...] The north wind was a very strong wind. [...] There were eighteen months of cold, hard, winter weather"

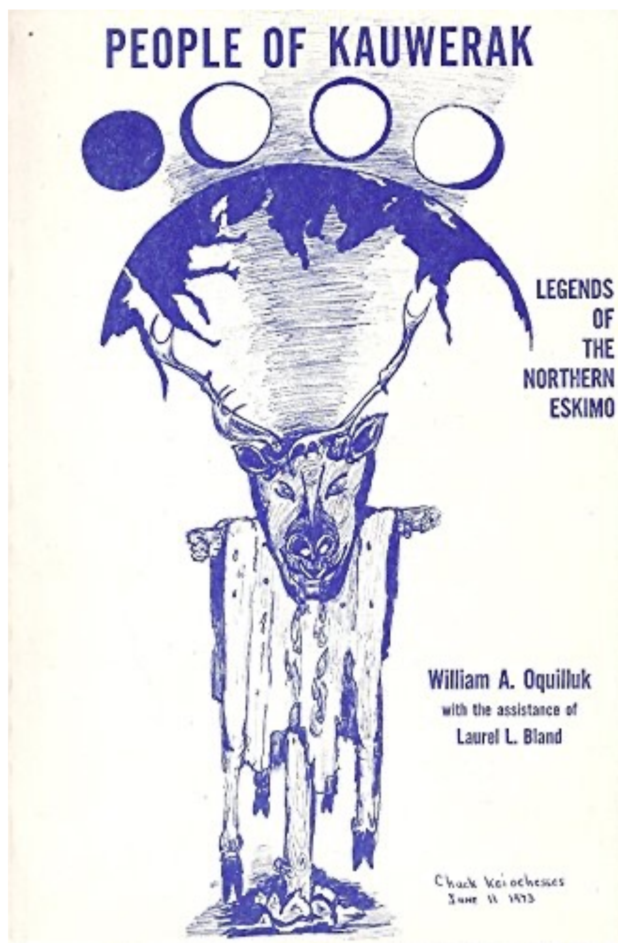


Figure 8
"The time summer time did not come"
from William A. Oquilluk, *People of Kauwerak*, 1973.

Example 3

In Europe and in North America, the year 1816 was known for its very cold and wet summer caused by the eruption of the Tambora volcano, in Indonesia (Figure 1), that led to large quantities of ashes being released to the global atmosphere acting as a filter for the solar radiation. At that time, people did not know the cause of this sudden cooling. It is precisely during this summer that Mary Shelley wrote her famous novel Frankenstein in the heart of the Swiss Alps, experiencing cold and foggy weather.

Along the coast of Nunatsiavut, the navigation in the Labrador Sea became perilous because of the extreme presence of sea ice. The Captain of the Moravian Missionary[5] ship named "Jemima" commented:

"October 28th, 1816. The "Jemima" arrived in the river from Labrador, after one of the most dangerous and fatiguing passages ever known. As in almost every part of Europe, so in Labrador, the elements seem to have undergone some revolution during the course of last summer"[6]

[5] Moravian Missionaries are originally from Southern Czech Republic, and they exiled in Germany in 1722.

[6] Periodical accounts, vol.6, p. 270.

Figure 9
Mount Tambora eruption in the distance.
Rob Wood – wrh-illustration.com

HOW TO RECONSTRUCT CLIMATE?

Local knowledge

Local knowledge refers to practices, skills and philosophies that arise from people's experience and understanding of the land.

Local knowledge can be seen in historical archives, but it is mostly shared in oral form. For this project on stories about climate, local knowledge was collected in Aklavik, a community in the Northwest Territories, Canada (Figure 1).

Activity 5

LOCAL KNOWLEDGE

People are telling us stories about the climate of the past.

Listen to the audio clips or read the transcripts and add a check mark in each of the climate-related categories: nature, weather, seasons and people.

Transcript 1

We've been noticing some different birds are coming up, some of them are coming earlier, or later, staying later, the one that migrate. The ice like right now it's taking a while to really freeze, you know like today, it's the first cold we had and we're in the middle of November.

Transcript 2

I guess our People as we, as time goes by, we just learned to adapt to it and have to go with it and lucky our people we've been on around here long enough we know there is other places we gotta go like for instance when we got a go whaling in the summertime. There are all these places that are shallow now, but then they find their ways you know. They know their land.

Table 1
Talking about climate/weather.

Clip 1	Clip 2	CLIMATE-RELATED CATEGORIES
☐	☐	**Nature** Changes in migration, blooming, animal or insect behavior. Changes in seasonal growth, leaf falling or freezing of the ground.
☐	☐	**Season** Changes in season's start or end.
☐	☐	**Weather** Changes in temperature, rain, snow, fog or humidity.
☐	☐	**People** Changes in activities on land. Changes in places where people go hunting or fishing, and where they travel.

TAKE HOME

Activity 6

ASK QUESTIONS AROUND YOU!

These stories might have inspired you and you might want to ask around to family and friends for more stories!

Legends and stories are keeping memories alive.

Ask an elder to tell you a story about a climate extreme (like a flood, a snowstorm, freezing rain, etc.), write it down.

Question ideas for your interviews:

- In your lifetime, what has changed the most in the climate or in nature?
  - During summer?
  - During winter?
- Name 3 words to describe the climate in your childhood? Would you choose the same 3 words today?
- What do you think of climate change? Is it important to talk about it with younger generations?
- Can you tell me the oldest story or legend you know, or heard from someone? If possible associated with climate or nature.

CONCLUSION

What have nature and people told us about the climate of the past?

In Canada, people have measured weather conditions for almost two hundred years using various instruments like thermometers, rain gauges or most recently satellite imagery. This allows monitoring the variations in the environmental conditions through time, especially representative of the recent climate changes. However, the measurements rarely cover all the regions of the planet, especially when it is far from densely populated areas. Moreover, two hundreds of years are very short compared to the history of the Earth! Thus, there are still many things to learn about the climate dynamics. Thankfully, nature and the people knowledge can teach us about past environmental conditions and bring to light hidden mysteries of our planet's climate.

In this booklet, you have been introduced to four approaches to reconstruct the climate of the past:

Tree rings

Each year a new ring tells us about the weather and environmental conditions.

Historical archives and oral histories

Written documents and oral stories show how people experience their environment and what was their relationship to climate.

Sediment cores

Pollen grains, microfossils, and other remains help us understand regional climatic conditions far back in the past.

Local knowledge

People remember the climate of their childhood and their younger years, or they even pass down information about events that happened long ago. Chatting with elders and knowledge holders is rich, it shows us how the climate and the land have changed, and how it is different now.

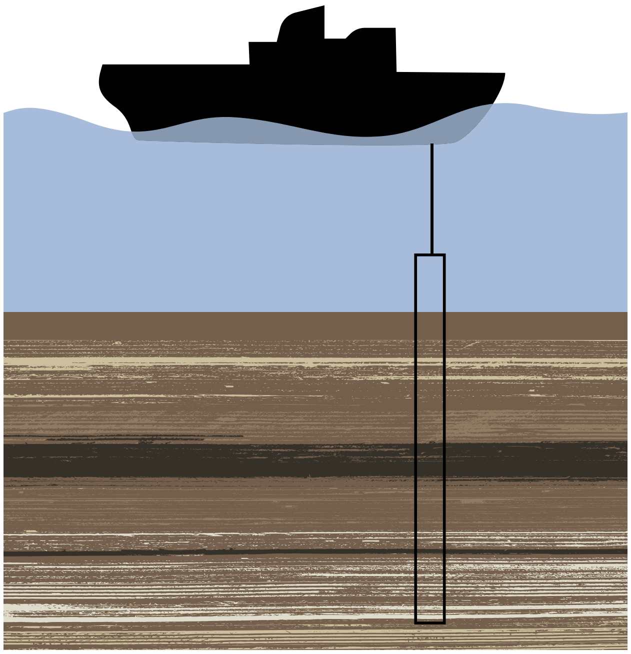
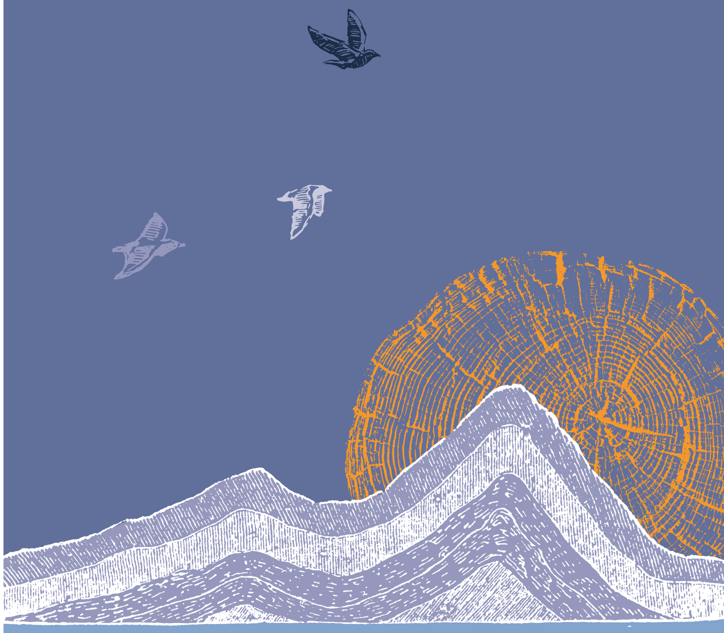


Figure 10
Sediment coring from a research vessel

More methods to reconstruct the climate of the past exist. As an example, the composition of the ice drilled in Antarctica can provide information about atmospheric gases and temperature as far back as 800 000 years ago (Figure 1).

By investigating past climatic conditions based on natural and societal archives, scientists validate and improve the quality of climatic predictions for the future.

This is of highest importance in the context of on-going rapid climate change. Climatic reconstructions contribute to the understanding of the dynamics of the oceans, land, sea ice, glaciers, atmosphere and biosphere.



We hope you enjoyed this activity, now you can keep exploring and go on a journey into the climate of the past!

Follow me into my adventure!

SUPPLEMENTARY MATERIAL

SUPPLEMENTARY MATERIAL

Isotopes

Every chemical element in the nature, like hydrogen (H), carbon (C) or oxygen (O), has an atomic number, which corresponds to the number of protons (+) in its nucleus. For example: $_1H$, $_6C$ and $_8O$.

But, in the nucleus, there are also neutrons, which are particles with a neutral electric charge. The mass number indicates how many neutrons there are in the nucleus. For example, if the mass number of one atom of oxygen is 16, it is noted ^{16}O. As there are 8 protons in the nucleus of this element, you know that there are 8 neutrons in ^{16}O (Figure 11).

Isotopes: Atoms of one chemical element can have different numbers of neutrons in their nuclei; they are called isotopes.

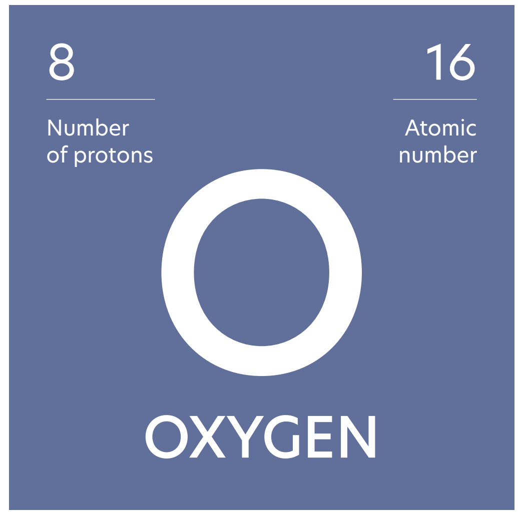
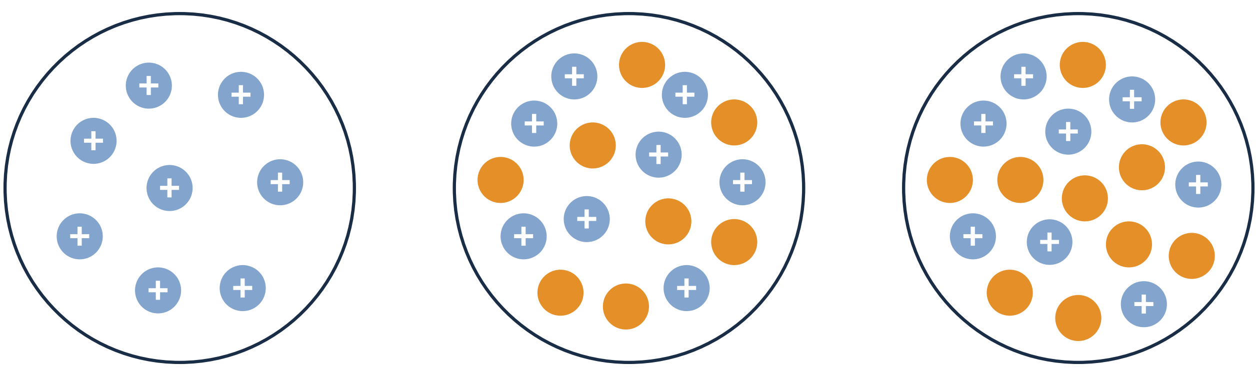


Figure 11

What is an isotope? Example from Oxygen-16 Oxygen-18



An oxygen atom contains 8 protons

99.757 % of oxygen contains 8 neutrons (^{16}O). Its mass is lighter.

0.205 % of oxygen contains 10 neutrons (^{18}O). Its mass is heavier.

1. DATING MATERIAL with radioisotopes

Sometimes, the isotope of one element is unstable, which means that it will gradually lose (emit) its neutrons to become stable again. Such isotopes are called radioisotopes, and the emission of neutrons is called disintegration. The rate of disintegration is determined by the half-life, which is specific to every radioisotope. It is just like radioactivity, but for most of the elements, it is unharmful!

At the radiochronology laboratory of Geotop[7] in Montreal (Figure 1), we use mainly two radioisotopes to date recent sediments: lead-210 (^{210}Pb) and cesium-137 (^{137}Cs).

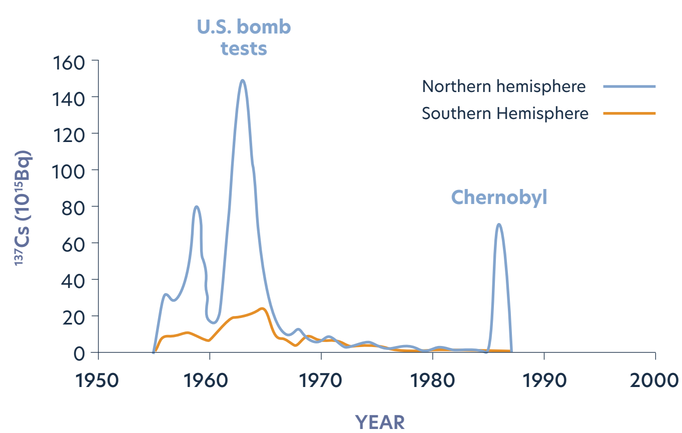
^{210}Pb

^{210}Pb in excess accumulates at the bottom of the oceans, lakes, or peatlands. It comes from the atmosphere, just like dust. The half-life of ^{210}Pb is 22.23 years. This means that half of the ^{210}Pb that accumulated 22.23 years ago will have disintegrated after this period. Thus, after about 120 years, all the ^{210}Pb in excess that accumulated at the seafloor is gone. This is how the sediment in a core can be dated. When sediments are recent, near the interface with the water or the atmosphere, they are rich in ^{210}Pb, but as you go deeper into the sediment, there is less and less of the excess ^{210}Pb, until it is undetectable. At this depth, you know that the sediment is at least about 120 years old.

^{137}Cs

^{137}Cs is a bit different. ^{137}Cs is only present on the planet since around 1945 because of nuclear tests or disasters that emitted cesium to the atmosphere[8]. You have probably heard of the Hiroshima and Nagasaki bombing in 1945. There are several years of abnormally high ^{137}Cs release to the atmosphere, as it was the case in 1963 in the United States (nuclear bomb tests) or in 1986 during the Chernobyl nuclear power plant reactor explosion in Ukraine. Depending on the study area, we can use these high ^{137}Cs increases in a sediment core as time indicators (Figure 12).

Figure 12
Cesium concentration in the atmosphere[9]



[7] geotop.ca/en/laboratoires/radiochronologie
[8] Aoyama et al., 2006
[9] Le Roux & Marshall, 2011

2. UNDERSTANDING WATER COMPOSITION **with stable isotopes**

Contrary to radioisotopes, stable isotopes are stable in the nature. There are many elements that have stable isotopes, and we can analyse a large variety of them at Geotop at the Radiogenic and non-traditional stable isotope geochemistry laboratory[10] or at the Light stable isotope geochemistry laboratory[11] in Montreal (Figure 1).

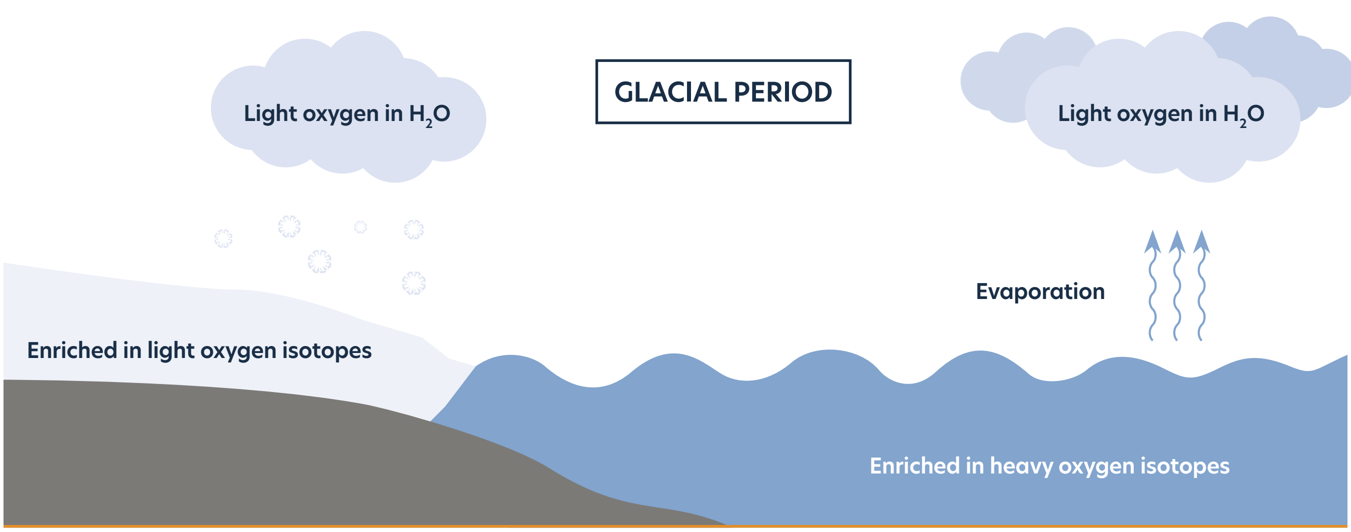
Here, we choose to focus on one stable isotope of oxygen: the oxygen 18 (^{18}O). The ^{18}O isotope composes around 0.205 % of the oxygen in the atmosphere, compared to the most common form, ^{16}O, which represents 99.757 %[12] (Figure 11). Oxygen is present in the molecule of water (H_2O). Oxygen can also be present in mollusc or microorganism shells, because the composition of a shell is often made of $CaCO^3$ (calcium carbonate). Thus, when an aquatic organism builds a carbonated shell, it captures the concentration of ^{18}O in the water at that moment.

Since ^{16}O is lighter (less neutrons) than the ^{18}O isotope, it is more easily transported from the water to the atmosphere by evaporation. Therefore, ^{16}O is more abundant than ^{18}O in the clouds, and later, it will return to the continent or to the ocean rain or snow (Figure 13). Consequently, waters that are poor in ^{18}O (light) are freshwaters from precipitations and running water on the land. Contrarily, the waters that are rich in ^{18}O (heavy) tend to be saltier. By analyzing the ratio between ^{18}O and ^{16}O that is recorded in the shells accumulated in the marine sediment cores, we can reconstruct the past properties of waters, especially salinity and temperature.

Figure 13

Light and heavy oxygen isotopes in the water cycle[13]

During glacial periods, light isotopes are captured in land ice, which means that the ocean has a higher composition in heavy ^{18}O.



[10] geotop.ca/en/laboratoires/radiogeniques-UQAM
[11] geotop.ca/en/laboratoires/isotopes-stables-UQAM
[12] Rosman and Taylor, 1999
[13] Ouellet-Bernier and de Vernal, 2018

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ANSWERS

Activity 1
63 years
2012
1995 or 1999 or 2001

Activity 2
The top is the surface
The bottom is the bottom
in 1914

Activity 3
Sample 1 : Northwestern Canada
Sample 2 : European Atlantic coast

Activity 4
Your answers!

Activity 5
Transcription 1 : nature, season
Transcription 2 : season, weather, people

Activity 6
Your answers!