Pingualuit Crater: A Meteorite Impact Feature in Northern Canada

Lesson Overview:

This lesson focuses on the Pingualuit Crater in Nunavik, northern Québec. Pingualuit is a very young lake, and is at the centre of an area designated as a Park by the government of Québec in 2004. This lesson is an exploration of how this crater was formed, its characteristics, and how it can be recognized, and the conflicting roles of tourism development and scientific research in understanding climate change.

Grade Level:
Grades 9-12. With simplified explanations and discussions, the lesson plan could be used for other levels.

Time Required:
One to two 60-minute classes

Curriculum Connection:
Any course in Geography / Environmental Science in Atlantic Canada.
Advanced Placement or International Baccalaureate Courses in Geography

Links to Canadian National Standards for Geography:

Essential Element #1: The World in Spatial Terms
- Map, globe and atlas use (e.g. observing and analyzing relationship)
- Expanding locational technology (including remote sensing, GPS and GIS)
- Map projections for specific applications
- Location/allocation situations (e.g. the best location for a fast food outlet and the extent of its market area; the best location for a hospital and the area it serves)
- Mental maps and spatial relationships

Essential Element #2: Places and Regions
- Physical and human processes shape places and regions
- The importance of places and regions to individual and social identity
- Changes in places and regions over time
- Interdependence of places and regions
- Political and historical characteristics of regions
- Critical issues and problems of places and regions
- Regional analysis of geographic issues and questions
Essential Element #3: Physical Systems
- Components of Earth’s physical system (atmosphere, lithosphere, biosphere and hydrosphere)
- Plate tectonics/continental drift
- World patterns of extreme events
- Global ocean and atmospheric systems
- World climate regions
- World patterns of biodiversity
- Inter-annual climate variation

Essential Element #4: Human Systems
- Population characteristics by world regions, country and regions within countries
- Demographic transition
- Impact of human migration
- Changes in human settlement patterns over time (from villages to megacities)
- Internal structures of cities in developed and developing countries
- Convergence and divergence of cultures
- Economic development by world regions, country and regions within countries
- Global economic interdependence (e.g. regional specialization, trade, transnationalism, multinationals)
- Patterns of global power and influence (e.g. NATO, United Nations, European Union)
- Cooperation and conflict in the division and control of Earth’s surface

Essential Element #5: Environment and Society
- Global effects of human modification of the physical environment
- Global effects on the human environment by changes in the physical environment
- Impacts of major natural hazards/disasters on humans
- World patterns of resource distribution and utilization
- Use and sustainability of resources
- Environmental issues (e.g. global warming, loss of biodiversity, deforestation, ozone depletion, air pollution, water pollution, acid precipitation, disposal of solid waste)

Essential Element #6: The Uses of Geography
- Influence of geographical features on the evolution of significant historic events and movements
- Local, regional and world policies and problems with spatial dimensions

Geographic Skill #1: Asking Geographic Questions
- Plan and organize a geographic research project (e.g. specify a problem, pose a research question or hypothesis and identify data sources)
Geographic Skill #2: Acquiring Geographic Information

- Systematically locate and gather geographic information from a variety of primary and secondary sources.
- Systematically assess the value and use of geographic information.

Geographic Skill #3: Organizing Geographic Information

- Select and design appropriate forms of maps to organize geographic information.
- Select and design appropriate forms of graphs, diagrams, tables and charts to organize geographic information.

Geographic Skill #4: Analyzing Geographic Information

- Use quantitative methods of analysis to interpret geographic information
- Make inferences and draw conclusions from maps and other geographic representations.
- Use the processes of analysis, synthesis, evaluation and explanation to interpret geographic information from a variety of sources.

Geographic Skill #5: Answering Geographic Questions

- Formulate valid generalizations from the results of various kinds of geographic inquiry.
- Evaluate the answers to geographic questions.
- Apply geographic models, generalizations and theories to the analysis, interpretation and presentation of geographic information.

Link to the Canadian Atlas Online (CAOL)
www.canadiangeographic.ca/atlas/

Additional Resources, Materials, and Equipment Required:

- Computer and Internet access
- Atlases and maps of Canada
- Images of Pingualuit Crater:
  http://ottawa.rasc.ca/articles/odale_chuck/earth_craters/pingualuit/index.html
  http://www.satellitesightseer.com/id/2790/Canada/Quebec/Nunavik/Pingualuit_crat
ater
- Historical Maps of Canada:
  http://www.canadiangeographic.com/mapping/mappingcanada/
Additional websites:

http://www.earth.google.com
http://www.nunavik.ca
http://www.weatheroffice.gc.ca/city/pages/qc-128_metric_e.html
http://gsc.nrcan.gc.ca/meteor/index_e.php
http://miac.uqac.ca/MIAC/miac_frames_e.html
http://www.nunavik-tourism.com/
http://bivouac.com/MtnPg.asp?MtnId=4469
http://www.nunavik-tourism.com/parks.aspx

Main Objective:
The main objective is to understand how some landforms are not formed by the naturally occurring processes of glaciation, weather, and time. Landforms produced by meteorite impacts are unique. Pingualuit, because of its location and nature, is a crater with special attributes and of interest to many as a park and as a site of research that may allow us to understand climate change.

Learning Outcomes: By the end of the lesson, students will be able to:

- Understand how impact craters are formed
- Understand how researchers recognize an impact crater
- Understand Pingualuit in the context of Nunavik
- Understand why Pingualuit is of special interest to researchers of climate change
- Compare climate/weather conditions in their own community with that of Nunavik
- Recognize and appreciate that the role of economic development in a community and sustainable development and protection of special land/waterforms is a balance of interests
Pingualuit Crater, in Nunavik, northern Québec. Image from ottawa.rasc.ca
Pingualuit Crater. Image from National Air Photo Library of Canada

**Supplementary Material:**

**Article 1:**

Paper: *The Jefferson Bee* (Jefferson, Iowa)

Date: Tuesday, May 20, 1952

Chubb Crater

A geological team sponsored by the National Geographic Society and the Royal Ontario Museum of Toronto brought back proof that the giant Chubb Crater on the Ungava Peninsula of northern Quebec was gouged out by a meteor smashing onto the earth. The scar thus ranks as the largest of its kind known on the face of the globe.
Note: This newspaper article refers to the Pingualuit Meteorite Crater in Canada. This crater was originally known as Chubb Crater, renamed New Quebec Crater and now known as Pingualuit Crater.

Article 2:

Posted AT 5:23 AM EDT on 25/05/07

From Friday's Globe and Mail (Toronto, Ontario)

By Ingrid Peretz

Quebec Crater out of this World

MONTREAL — A massive crater in Northern Quebec has been luring the curious for over 50 years. Diamond prospectors, Second World War pilots and National Geographic all made pilgrimages to the distant natural wonder. Now, an international team led by Laval University in Quebec City has journeyed to the Pingualuit Crater near the Hudson Strait in hopes of unlocking 120,000 years worth of secrets about climate change.

Article 3:

Update Tuesday February 7, 2006 at 16:53 (Radio Canada Website)

New Quebec Direction!

Ten researchers at Laval University will undertake an expedition next May to the crater of New Quebec.

Over 1.3 million years ago, a meteorite struck what is called now New Quebec, causing an impact 8500 times more powerful than Hiroshima.

From the impact of this shock, there remained an open hole 2.7 kilometres in diameter which shelters a lake that is 267 meters deep, and frozen most of the time.

Twenty years after the first Québécois expedition to study the sediments of the lake, a team of the Laval University is going back there. This time, using better technology, the researchers hope to drill even more deeply.

"There are now more powerful techniques of coring which will allow us, one hopes, to take carrots of some tens of meters of depth and thus to go back very far in the past of the history of our planet", explains Reinhard Pienitz, professor in the Centre of Nordic Studies at Laval University.
The geological carrots constitute files on the old climates. They should make it possible not only to establish the succession of phases of warming and cooling of the Earth, but also to deduce how the continents were touched by climate change.

Difficult to access, the crater of New Quebec is in an area known to be among most hostile of the world. The Laval University team will have to work there about ten days.

The Lesson:

<table>
<thead>
<tr>
<th>Teacher Activity</th>
<th>Student Activity</th>
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<tbody>
<tr>
<td>Read aloud or distribute the above newsclips</td>
<td>Respond to why Pingualuit is of such interest and why scientists are trying to unlock secrets about climate change.</td>
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<tr>
<td>Display given images of Pingualuit or have students explore suggested websites. <em>(Note that previously, the crater was called Chubb and Nouveau-Québec Crater, before Pingualuit was formally declared the name in 1999.)</em></td>
<td>Observe image of Pingualuit.</td>
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<td>Speculate on how this lake might have formed.</td>
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<td>Lesson Development</td>
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<tr>
<td><strong>PART 1: NUNAVIK</strong></td>
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<tr>
<td>Guide students in finding the <em>absolute</em> location of Pingualuit Crater at 61°17’N latitude, 73°40’W longitude.</td>
<td>Locate Pingualuit on a map; or by using GoogleEarth: <a href="http://www.earth.google.com">www.earth.google.com</a></td>
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<td>Direct students to find Nunavik on a print map.</td>
<td>Locate Nunavik on a map.</td>
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<tr>
<td>Give population and area figures for Nunavik: <strong>Area:</strong> 443,685 km² of land north of 55° N latitude (about one-third of Québec). <strong>Population:</strong> approximately 12,000</td>
<td>Calculate the population density for Nunavik as persons per square kilometre.</td>
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<tr>
<td>Direct students to briefly explore the history of Nunavik by accessing historical maps of Canada found at <a href="http://www.canadiangeographic.ca">http://www.canadiangeographic.ca</a></td>
<td>Study maps indicating the historical expansion of Canadian territory in this region at <a href="http://www.canadiangeographic.ca/mapping/mappingcanada/">http://www.canadiangeographic.ca/mapping/mappingcanada/</a></td>
</tr>
<tr>
<td>Explain that more information can be found by visiting Nunavik’s web site.</td>
<td>Visit Nunavik’s web site, <a href="http://www.nunavik.ca">http://www.nunavik.ca</a></td>
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<tr>
<td>Direct students to <a href="http://www.weatheroffice.gc.ca/city/pages/qc-128_metric_e.html">Environment Canada’s Weather Office</a> page for Salluit, develop an understanding that the northern part of Nunavik, including Pingualuit Crater, is north of the tree line and has an Arctic climate. Outflow of cold water along Hudson Strait helps to keep the climate relatively cold. <em>(Kangiqsujuaq is the nearest community to Pingualuit Crater. The nearest weather station is at Salluit.)</em></td>
<td>Visit the Weather Office (Environment Canada) web page for Salluit, <a href="http://www.weatheroffice.gc.ca/city/pages/qc-128_metric_e.html">http://www.weatheroffice.gc.ca/city/pages/qc-128_metric_e.html</a></td>
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<tr>
<td><strong>Calculate the population density for Nunavik as persons per square kilometre.</strong></td>
<td>Compare the climate conditions listed here to those of your own community</td>
</tr>
</tbody>
</table>
PART 2: PINGUALUIT CRATER

Provide the following information to students:

*Pingualuit Crater is 3.4 kilometres in diameter and 400 metres deep.*

The lake in the centre is approximately 250 metres deep.

*Pingualuit is almost perfectly circular and has steep vertical sides. Overall, the crater has a bowl-like shape.*

The renewal time of water in the lake (the average time required to replace all the water molecules in the lake basin) is approximately 330 years. This is very slow compared to other lakes, which typically have renewal times of 10 to 20 years.

The estimated volume of water in the lake would fill more than 2 billion bathtubs.

A raised rim of rock surrounds Pingualuit. This is the origin of the Inuit name Pingualuit, where the land rises.

The surrounding rock is predominantly granite of Archaean age (2.5 billion years old).

Glaciers covered the area several times in the past 1 million years. The linear ridges visible on the photographs were formed as glacial ice scoured the bedrock. These features were formed after the crater was developed.

Instruct students to calculate the surface area of the lake.

Ask the following questions to raise awareness of the fragility of the lake.

- What are the implications of the long renewal time?
- What could happen if park facilities were developed next to the lake, including toilets?
- What other problems could result if tourism to this area increases?
- What might happen to Pingualuit as a result of climate change?

Record physical characteristics of Pingualuit.

View images of Pingualuit from the website list.

Calculate the surface area of the lake.

Discuss the questions and deduce the implications of long-term effects of increased tourism.
PART 3: FORMATION OF PINGUALUIT

Present information on the formation of Pingualuit and have students deduce why it is a crater formed by a meteorite.

Pingualuit has the characteristic form of a crater formed by the impact of a meteorite. However, other circular lakes are formed by other means – for example, by the melting of permafrost, or from dissolution of soluble bedrock such as limestone or rock salts. Why could Pingualuit not be formed in one of these ways?

(No fragments of any meteorites have been found at Pingualuit: they are likely at the bottom of the lake and could be covered by younger sediment.)

To determine if this is a meteorite crater, researchers look for signs of high-pressure and high-temperature impacts. The key features are tektites, fragments of glass that formed as the granite was shocked and melted when the meteorite struck. These are found along the surrounding raised rim of the crater. The presence of tektites indicates that Pingualuit is a meteorite impact crater.

The local gravitational field is another indication that Pingualuit is a meteorite crater. Careful measurements of the gravity field indicate a zone of lower gravitational attraction, symmetrical with the crater.

The gravitational anomaly is the result of the presence of fractured rock in the centre of the crater, and expanded crystal rocks forming the rim. This type of gravitational anomaly has been detected at many meteorite craters.

Geological dating indicates that Pingualuit Crater was formed by the impact of a meteorite about 1.4 million years ago.

The energy of the impact was equivalent to 8500 times that of the atomic bomb dropped on Hiroshima, Japan in 1945.

But, unlike the impact 65 million years ago that contributed to dinosaur extinction, no extinctions resulted from this impact. This meteorite was relatively small, but it did succeed in creating this conspicuous landform.

Discussion of the information and formulation of answers e.g.:

- The surrounding bedrock is granite which does not dissolve rapidly (is not soluble).
- Melting of permafrost (thermokarst) only forms lakes in thick accumulations of sediment (silt and clay).
- The lake formed before glacial activity so it could not have been gouged out by glacial ice.
Ask the following questions to raise awareness of the importance of the lake.

1. Why would Nunavik want to create a park around this unique waterform?

2. How is this lake in particular valuable to university researchers?

3. Should visitors be allowed unlimited access to Pingualuit or should they require permits?

4. What environmental guidelines should be considered in this park to preserve it?

Respond to questions in a general discussion and offer conclusions and solutions.

Lesson Extension:

Scientists can learn much about the past by analyzing the water/ice in Pingualuit Lake. Currently research teams from Laval University and the University of Helsinki in Finland are carrying out studies. Their databases can be searched to find out more about Pingualuit Lake and its pristine water and what it can tell scientists.

http://www.cen.ulaval.ca/paleo/projets/Pingualuit/index.html

Further investigation of meteorites and impact craters
Further thoughts about the problems of park development in northern or isolated regions

Assessment of Student Learning:

- Recognition of landforms and formative processes
- Heightened awareness of Nunavik
- Competency in examining environmental issues from different perspectives

Assessment forms are best left to teacher discretion dependent upon knowledge, skills, and attitudes outcomes chosen.
Teacher Information

Pingualuit

Nunavik, means a “place to live” in the Inuit language of the region.

Residents of the area are Inuit, although there is a single Cree village of Whapmagoostui.

Area: 443,685 km² of land north of 55 N latitude (about one-third of Québec). Population: approximately 12,000

This area became part of Québec in 1912. Prior to that, it was known as the District of Ungava, part of NWT. It has also been referred to as Nouveau-Québec in the past, but only the name Nunavik is used today.

Kangiqsujuaq is the nearest community to Pingualuit Crater. The nearest weather station is at Salluit.

Pingualuit is ice-covered from early November to mid-July.

Pingualuit is surrounded by a raised rim of rock. This is the origin of the Inuit name Pingualuit, “where the land rises”.

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