POLAR TREC Learning Resources

Details

Completion Time: About one period
Permission: Download, Share, and Remix

Arctic Impacts

Overview
Lake El'gygytgyn (67.5° N, 172° E) is one of the best preserved large asteroid impact craters on earth. In the winter of 2009, I joined an international science team and traveled to the frozen arctic lake to drill and extract lake sediments to study climate change as well as sample the rocks that were changed when the crater was formed 3.6 million years ago.

While standing on one wall of the crater looking across to the far crater wall, I was impressed by the immense size and scale of the crater. This lesson will help students gain a perspective on cratering processes and the size of El'gygytgyn and other impact craters.

Objectives
The primary goal of this activity will be to learn about the nature of the asteroid impact that formed El'gygytgyn crater. This activity will re-enforce the importance of changing a single variable for valid scientific comparisons while documenting variables in an orderly way (with or without the use of provided data sheets). Students will review basic graphing procedures (by hand or electronic graphing using Microsoft Excel). Students will use satellite imagery on Google maps to explore terrestrial asteroid/meteor impact sites.

Lesson Preparation
This lesson will best be used in a planetary astronomy unit for Earth Science classes that are studying processes at work in our solar system.

Background:
Asteroid and meteorite craters are a dominant process in shaping solid bodies in the solar system. A quick survey of the objects with solid surfaces (Mercury, Venus, Mars and the moons of many planets) show that impact cratering may be the most dominant geologic process

Materials

- Computer lab or adequate classroom computer access
- Data Sheets 1, 2 and 3 (download with lesson)
- Graph paper or access to computers with spreadsheet/graphing software such as Microsoft Excel

Extension materials:
- Strong magnets
- Plastic sheeting
- Microscope

at work in the solar system. On earth this process is largely concealed because 70% of the earth's surface is covered by oceans and the land surfaces are altered by tectonics and weathering. In spite of these erosive forces, in the last number of years many impact craters have been identified on our home planet.

Since cratering is such a dominant geologic force at work in our solar system, planetary scientists are very interested in studying these features. Well studied craters include Meteor crater AZ, Chicuxlub, the crater at the edge of the Yucatan peninsula, (this impact was likely responsible for the Cretaceous-Tertiary extinction event that killed the dinosaurs), Chesapeake Bay Crater, and Bosumtwi in Ghana.

Lake El'gygytgyn located in the Chukotka province of NE Russia is one of the largest, well preserved, young impact craters on earth. It is the only well preserved crater in silica rich igneous rocks. Because of the underlying geology, many scientists believe that El'gygytgyn may be the best earth analog for craters on the moon and Mars.

If you have access to Google Earth, below is a good web site to introduce students to the significant number of craters that have been identified. You may download .kml files that show impact sites around our planet.
http://www.thinklemon.com/pages/ge/

Alternatively students can explore impact sites here:
http://geology.com/meteor-impact-craters.shtml

Also you will want to watch this short web video of the El'gygytgyn Drilling Project lead scientist discussing the geology of Lake El'gygytgyn: http://polartrec.com/node/9734

Procedure

I have prepared data recording sheets however this lesson could easily be adapted to complete much of the work in a science journal or in an electronic format using Microsoft Excel.

Students should each have access to an Internet-connected computer. Much of the lesson will use the Impact Calculator web site: http://simulator.down2earth.eu/# (Note: site has multiple language options)

Part A

- Divide students into working groups of three. Each student should receive data sheet 1, 2, or 3.
- Review or remind students of the importance of only changing one variable during any experiment.
- Using the Impact Calculator, students should test the effect that four primary variables have on the formation of impact craters in igneous (volcanic) rocks. Note: As of the 2009 expedition, scientists are still looking for evidence of the impactor. The origin, composition

and other characteristics remain a topic for new discovery.

- Student #1 will test impactor size (suggested size 1000, 2000, 3000, 4000 and 5000 meter asteroids) and record the resulting crater diameter for each size. This student will repeat the process for each of the four primary impactor types: ice, porous rock, dense rock and iron. With each simulation student #1 is suggested to set the trajectory angle to 45° (statistical average) and the object velocity at 30 km/s (average impact speed).
- Student #2 will test trajectory angle (suggested test angles 90°, 65°, 45°, 25°, and 1°.). These trials should be completed with a 1000 m asteroid and average object velocity of 30 km/s. This process will be repeated for each impactor type.
- Student # 3 will test impactor speed (suggested speeds: 10, 20, 30, 40, 50 km/sec). These trials should be completed with a 1000 m asteroid and average trajectory angle of 45°. This process will be repeated for each impactor type.
- After data is collected each student should plot the data points and construct a graph comparing each of the four impactor types.
- Students will then share their results with others in the group. Students should compare/contrast results and discuss how each variable (Size, Angle, or Velocity) has an effect on crater size.
- Depending on their math background, students may be assigned to determine more of the mathematical nature of the relationship.

Part B

- Students will be asked to use the embedded google map to determine a theoretical impactor that could have potentially created El'gygytgyn crater.
- First, find El'gygytgyn on the map. The "map-view" google map may be changed to a satellite image view by selecting any of the city or crater sites from the drop down menu. Using the zoom tool, zoom out to a full earth view on the map. Center the map on the Chukchi Peninsula in the Chukotka Province of Russia (The Chukchi peninsula is the eastern most tip of Asia). As you zoom in, you will notice Wrangle Island to the north in the Arctic Ocean and Chaun Bay, the largest bay on the Arctic ocean in Eastern Russia. El'gygytgyn will be identifiable by the 5th click on the zoom scale. It is located south and slightly east of Chaun bay and southwest of Wrangle Island. It is best viewed at the 10th click.
- Notice details about the crater. The lake does not fill the crater, it is off-set to the southeast.
- Once the crater has been identified, click the "go-back" button and using the graphs that they just completed, students should experiment with the different variables to determine a theoretical impactor (Size, angle, velocity, and composition) that would have had the right properties to form a crater the size of El'gygytgyn. Students should record the parameters for the impactor.
- Once students have determined a potential size, speed and composition of an asteroid that could have created a crater the size of El'gygytgyn, they should move the map to find their home location. "Place" the simulated crater on their home town, neighborhood or school. This will help students gain a perspective as to the immense size of El'gygytgyn

crater.

Extension
Complete the same type of investigation with any other earth impact structures.
http://geology.com/meteor-impact-craters.shtml

Catch your own (micro)meteorites.

On any clear night, it is possible to see a meteor or "shooting-star". Every day hundreds of tons of material falls to the earth from space. Most of these meteorites are microscopic. As a meteor "burns-up" or vaporizes in the Earth's atmosphere, the remaining microscopic fragments will gradually fall or become the nuclei on which rain or snow flakes form.

Although these fragments will not form large craters and are not as impressive as the asteroid that collided with the earth to form Lake El'gygytgyn 3.58 million years ago, students may begin a collection of micro-meteorites at home or school.

I have successfully collected iron micrometeorites. The process I used was to place a large piece of plastic sheeting outside for several days, after which I carefully folded the sheet until the collected debris fell to the center. Using a powerful magnet enclosed in a plastic bag, I slid the magnet over the debris that collected on the plastic sheet. Iron rich micrometeorite particles clung to the magnet and could then be viewed under a microscope.

This idea has been documented numerous times on the web. For more info visit one of the links below:

Activity associated with the Antarctic Ice Cube Neutrino telescope (also a PolarTREC project) http://icecube.wisc.edu/outreach/activities/micrometeorites.php

NASA / JPL Lesson Plan idea
http://education.jpl.nasa.gov/educators/micromet.html

Resources
Dr. Julie Brigham-Grette, University of Massachuttes, Project PI
Dr. Pavel Minyuk, Far Eastern Branch Russian Academy of Science, Project PI
Dr. Christian Koeberl, University of Vienna, Project PI

Gurov, Koeberl, and Yamnichenko, El'gygytgyn Impact Crater Russia, Structure, Tectonics and Morphology. Meteorics and Planetary Science 42 No. 3 p 307-319 (2007)

Impact simulator, Faulkes Telescope Project, National Museum of Wales
http://down2earth.eu

Impact location resources:
http://www.thinklemon.com/pages/ge/

http://geology.com/meteor-impact-craters.shtml

Micrometeorite Collection Activity
Activity associated with the Antarctic Ice Cube Neutrino telescope (also a Polar TREC project) http://icecube.wisc.edu/outreach/activities/micrometeorites.php

NASA / JPL Lesson Plan idea
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Assessment
Students may be asked to submit data sheets and graphs for assessment and or a brief reflective writing assignment that includes size, composition, trajectory angle and velocity of a potential impactor that could have formed El'gygytgyn Crater.

Credits
Tim Martin, 2009 PolarTREC teacher, tmartin@greensboroday.org
Thanks to Lake El'gygytgyn Drilling Project - Principle Investigator: Dr. Julie Brigham-Grette and Dr. Pavel Minyuk

National Science Education Standards (NSES)

Content Standards, Grades 5-8

Content Standard A: Science As Inquiry
a. Abilities necessary to do scientific inquiry

Content Standard B: Physical Science
a. Properties and changes of properties in matter
b. Motions and forces
c. Transfer of energy

Content Standard D: Earth and Space Science
b. Earth's history
c. Earth in the solar system

Content Standard F: Science In Personal and Social Perspectives
c. Natural hazards

Content Standards, Grades 9-12

Content Standard A: Science As Inquiry
a. Abilities necessary to do scientific inquiry

Content Standard B: Physical Science
b. Structure and properties of matter
d. Motions and forces
f. Interactions of energy and matter

Other Standards
North Carolina Earth Science Standards
(2) North Carolina Earth Science Standards
US-NC-ES
1.01,02,03; 3.01; 6.01
Use of simulations and satellite imagery to understand the origin and evolution of the earth system, and formation of the solar system.

Arctic Impact

Asteroid Impact Data Sheet #1

Table #1 Ice Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1	1000	45	30	
2	2000	↓	↓	
3	3000	↓	↓	
4	4000	↓	↓	
5	5000	↓	↓	

Table #2 Porous Rock Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1		45	30	
2		↓	↓	
3		↓	↓	
4		↓	↓	
5		↓	↓	

Table #3 Dense Rock Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1		45	30	
2		↓	↓	
3		↓	↓	
4		↓	↓	
5		↓	↓	

Table #4 Iron Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1		45	30	
2				
3				
4				
5				

Crater Diameter vs. Asteroid Size

Arctic Impact

Asteroid Impact Data Sheet #2

Table #1 Ice Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1	1000	1	30	
2		25		
3		45		
4		65		
5		90		

Table #2 Porous Rock Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1	1000		30	
2				
3				
4				
5				

Table #3 Dense Rock Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1	1000		30	
2				
3				
4				
5				

Table #4 Iron Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (^{o})	Object Velocity (km/s)	Crater Diameter (m)
1	1000		30	
2				
3				
4				
5				

Crater Diameter vs. Trajectory Angle

Arctic Impact

Asteroid Impact Data Sheet #3

Table #1 Ice Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (^{o})	Object Velocity (km/s)	Crater Diameter (m)
1	1000	45	10	
2	↓	↓	20	
3	↓	↓	30	
4	↓	↓	40	
5	↓	↓	50	

Table #2 Porous Rock Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (^{o})	Object Velocity (km/s)	Crater Diameter (m)
1	1000	45		
2	↓	↓		
3	↓	↓		
4	↓	↓		
5	↓	↓		

Table #3 Dense Rock Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (^{o})	Object Velocity (km/s)	Crater Diameter (m)
1	1000	45		
2	↓	↓		
3	↓	↓		
4	↓	↓		
5	↓	↓		

Table #4 Iron Asteroid

Trial #	Asteroid Diameter (m)	Trajectory Angle (°)	Object Velocity (km/s)	Crater Diameter (m)
1	1000	45		
2				
3				
4				
5				

Crater Diameter vs. Object Velocity