Saskatchewan's Mineral Resources
Lesson: Mineral Exploration and Core Sampling

Overview
Students will explore three of the methods of mineral exploration; the airborne magnetometer survey, ground penetrating geophysics (conductivity) and core drilling. Students will identify a primary target through the airborne survey and follow-up that target with ground penetrating geophysics. After they have decided which the most suitable area for exploration is, they will commence a drill program. Each core sample will be checked for mineralization, and a successful program will be the one that intersects 'ore'. The intent is to match up a magnetic 'anomaly' and a conductive 'anomaly' to find 'ore'**.**

Source: This lesson was develop by D. Klassen and M. Batty (Exploration Geologists, Cameco) for the Saskatchewan Mining Association's **Minerals and Products (MAP)** event.

Duration: one class

Materials:
- Conductive and non-conductive play-dough (see **Preparation 1.**)
  - Two or three colours of non-conductive play-dough (one or two will be waste rock and one will be ore) and one colour of conductive play-dough (which will be host rock)
  - Ingredients: flour, salt, cream of tartar, vegetable oil, food colouring, lemon juice (optional)
- Package of 'Bubble Tea' drinking straws or large diameter straws.
- Wooden dowels or skewers that will fit inside the straw
- Two small magnets (preferably Neodymium magnets)
- One magnet on a light string (preferably a Neodymium magnet)
- Basic circuit for conductivity meter (see **Preparation 2.**)
  - Option 1:
    - 9V battery
    - 9V battery connector with wire
    - A small fairy light (attached small wire preferred)
    - Two nails or metal clamps
    - Electrical tape
  - Option 2:
    - Two 9V batteries
    - One 12V light bulb
    - Three wires with alligator clips at either end
- Pencil
- Thumbtacks
- A small, opaque container
- Place mat
- Saran wrap

Notes to Teachers: This activity could be a follow up to the activity Core Sampling.

Prior Knowledge:
- Students should understand that minerals have different and diagnostic properties. That these properties not only help in their identification but also help in the search for mineral deposits.

Instructional Methods: Modelling, Simulation

Figure 1: Helicopter performing an airborne electromagnetic survey.
Source:http://www.ngi.no/en/News-archive/News/NGI-into-

airborne-EM-surveys-/

Learning Outcomes and Indicators

Grade 7 Earth's Crust and Resources

EC7.2Identify locations and processes used to extract Earth's geological resources and examine the impacts of those locations and processes on society and the environment.

f. Provide examples of technologies used to further scientific research related to extracting geological resources (e.g., satellite imaging, magnetometer, and core sample drilling).

g. Evaluate different approaches taken to answer questions, solve problems, and make decisions when searching for geological resources within Earth (e.g., trial-and-error prospecting versus core sampling).

k. Research Saskatchewan careers directly and indirectly related to resource exploration

Earth Science 30: Lithosphere

ES30-LS3 Investigate the processes and technologies used to locate and extract mineral resources and fossil fuels locally, provincially and globally.

h. Recognize the importance of obtaining core samples to examine the physical characteristics and geochemistry of potential ore bodies and natural resource deposits.

Source: Saskatchewan Evergreen Curriculum

Big Picture Questions

1. **How do they find mineral deposits in Saskatchewan?**

Background Information

Mineral exploration is the process of finding mineral deposits, typically located underground, to mine by studying the geophysical, geochemical and geological conditions of the potential host rocks and its surrounding geological setting. At the earliest stages of exploration, an area must be selected that has the highest potential to host economically viable concentrations of the mineral that is being searched for. This is usually completed by selecting areas that have shown past successes or have significant evidence to host a deposit. After an area has been selected, a more local target for later drilling/core sampling must be generated. To accomplish this, one or a combination of several methods could be used; such as using aerial photography, sampling soil and lakes, airborne magnetometers, studying outcropping rock, electromagnetic (conductive) surveys, etc. After a favourable target has been selected in the underlying rock, a diamond drill will start coring the rock down to, through, and past the 'target'. After viewing the core, it is determined if that target has encouraging results and if the core displays reassuring results, further drilling may be required which may lead to the possible discovery of an ore deposit.

Figure 1. Helicopter performing an airborne electromagnetic survey.
Source: www.ngi.no/en/News-archive/News/NGI-into-airborne-EM-surveys-/

Figure 2. Drill rig at Fort a la Corne.
Source: Saskatchewan Mining Association

Figure 3. Drill core from northern Saskatchewan.
Source: Saskatchewan Mining Association.

Vocabulary

geophysics
magnetic survey
conductivity

THE ACTIVITY

Teacher Preparation:
Preparation of Conductive Play Dough:
Materials:
- 1 cup Water
- 1½ cups Flour
- 1/4 cup Salt
- 3 Tbsp. Cream of Tartar*
- 1 Tbsp. Vegetable Oil
- Food Coloring
- *9Tbsp. of Lemon Juice may be Substituted

1. Mix water, 1 ½cup of flour, salt, cream of tartar, vegetable oil, and food coloring in a medium sized pot.
2. Cook over low to medium heat and stir continuously.
3. The mixture will begin to boil and start to get chunky.
4. Keep stirring the mixture until it forms a ball in the center of the pot.
5. Once a ball forms, place the ball on a lightly floured surface.

   WARNING: The ball will be very hot. We suggest flattening it out and letting it cool for a couple minutes before handling.

6. Slowly knead the additional flour into the ball until you've reached a desired consistency.
7. Store in an airtight container or plastic bag. While in the bag, water from the dough will create condensation. This is normal. Just knead the dough after removing it from the bag, and it will be as good as new. If stored properly, the dough should keep for several weeks.

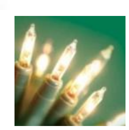
NOTE: PORTIONS OF MATERIALS MAY NEED TO CHANGE DEPENDING ON SIZE OF EXPERIMENT

Preparation of Non- Conductive Play Dough:
Materials:
- 1 cup Water
- 1 ½ cups Flour
- ½ Cup Sugar
- 3 Tbsp. Vegetable Oil
- Food Coloring

Procedure similar to conductive play-dough*
1. Mix water, 1 ½ cups of flour, sugar, vegetable oil, and food coloring in a medium sized pot.
2. Cook over medium heat and stir continuously.
3. The mixture will begin to boil and start to get chunky.
4. Keep stirring the mixture until it forms a ball in the center of the pot.
5. Once a ball forms, place the ball on a lightly floured surface.
   WARNING: The ball will be very hot. We suggest flattening it out and letting it cool for a couple minutes before handling.

6. Slowly knead the remaining flour into the ball until you've reached a desired consistency.
7. Store in an airtight container or plastic bag. While in the bag, water from the dough will create condensation. This is normal. Just knead the dough after removing it from the bag, and it will be as good as new. If stored properly, the dough should keep for several weeks.

Assembly of Conductivity Meters Option 1.
Materials:
- 9V Battery Snap Connector
- 9V Battery
- 2 non-coated finishing nails/clamps
- Electrical tape
- 1 Fairy light (aka Christmas lights)



1. On the 9V snap battery connector, cut the positive wire and strip the ends on each side of the cut.
2. Cut the wires on the fairy light and strip the ends on each side of the cut.
3. Spin together the wires of the Fairy light and the battery connector. Place electrical tape over

them.

a. Solder the wires together before hand if you have the materials.
b. Make sure to orient the positive and negative parts of the light's wire correctly.

4. Connect the snap connector to the battery and test it on the conductive play-dough.

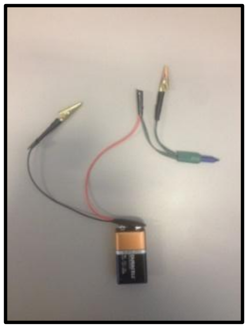


Figure 4. Assembled conductivity meter (option 1).

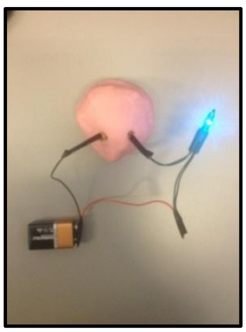


Figure 5. Conductivity meter on conductive play-dough.

Assembly of Conductivity Meters Option 2.

- Materials
- Two 9V Batteries
- One 12V light bulb
- Three wires with alligator clips at either end

1. Connect the two 9V batteries in serie e an 18V battery assembly.
2. From the three wires with alligator clips on either end, use one to connect to the positive terminal of the battery assembly and to the 12V light bulb. Use another wire to connect to the other half of the 12V battery (do not connect the other side) and use the final wire to connect to the negative terminal of the battery assembly (again, do not connect the other side).

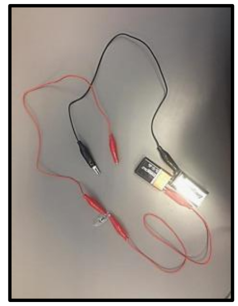


Figure 6: Assembled conductivity meter (option 2)

Figure 7. Two 9 V batteries connected in series.

Assembly of "Mineral Deposit"

1. Create the essential tools and materials for the project
   a. Bake all colours (three or four) of play-dough including the conductive play-dough.
   b. Assemble the 9V circuit that will be used for the conductivity meter
   c. Wrap the magnets with saran wrap

2. Place two saran wrapped magnets at the bottom of the container, and then place a thin 1-2cm layer of non-conductive play-dough (yellow) over them; make sure to note where you placed the magnets.

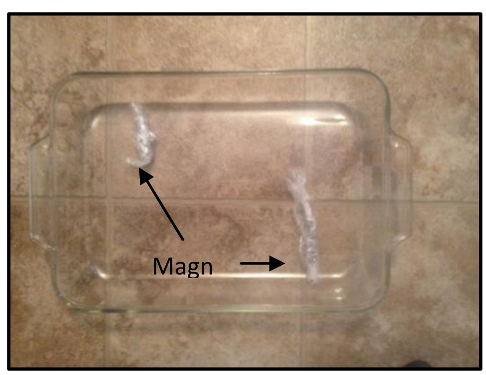


Figure 8: Saran wrapped magnets placed into

container.

Figure 9: Magnets covered with non-conductive play-dough.

3. Over one of the magnets, place 'ore' play-dough (white) and conductive play-dough (pink). In another spot away from both magnets, place some conductive play-dough. Fill the rest of the container with non-conductive 'waste rock' play-dough (green), making sure that conductive play-dough isn't thicker than the conductivity meter's nails or clamps.

Figure 10: 'Ore' is placed over one of the magnets. Conductive play-dough is placed in spots away from the magnets.

Figure 11. Conductive play-dough placed over the 'ore'.

Figure 12. Non-conductive 'waste rock' is added to fill the rest of the container.

4. The intent is to create a situation where there will be a:
   a. A conductive anomaly and magnetic anomaly with 'ore'
   b. A magnetic anomaly with no conductive response and no 'ore'
   c. A conductive anomaly with no magnetic response and no 'ore'

Motivational Set (5 minutes)

COOL FACT: Some geophysical exploration techniques (for example, magnetics) originated from military technology used to search for submarines underwater.

Explain: The Earth acts as a giant magnet and influences minerals that are magnetic or may be magnetised, particularly objects containing iron.

Magnetometers measure changes in the magnitude of a magnetic field.

Magnetic surveys may be undertaken from the air or on the ground. The data are presented as a magnetic map using computer technology.

Tell the students that they will be looking for a buried ore deposit.

Activity:

1. Following 3 or 4 lines that run parallel to the edge of the container, pass the string with the magnet end on it, noting where it showed a

response with a red thumbtack.

a. Be careful, because closely spaced magnets will create irregular responses. Slow, diligent swipes with the magnet will provide greater resolution.

Explain that the magnetometer locates rocks with magnetite and other magnetic minerals in them.

2. Following the same 3 or 4 lines, puncture through the top play-dough layer with the conductivity meter, noting where the set-up had a response with a green thumbtack.
   a. Try to keep the positive and negative end of the conductivity meter approximately two centimetres away from one another while puncturing the play-dough.
   b. Along the lines, create a puncture point (of both the positive and negative ends in unison) approximately every 5 to 6 centimetres. This may create lots of green thumb tacks, depending on how much conductive play-dough was used in the creation of the set up.

Explain that the conductivity survey locates rocks with conductive minerals in them. Minerals that will conduct an electrical current.

3. From the arrangement of thumb tacks, the students should be able to decide where to drill. Allow them three drill holes. They can rotate the bubble tea straws into the play-dough and remove a small 'core' of play-dough. If ore is hit, then it was a successful exploration program.

Safety:

When finished disconnect the batteries and cover terminals with tape to store.

Assessment Method and Evidence

✓ **Hands on Activity**

- Students will understand and be able to describe how deposits with magnetic and conductive minerals can be located using magnetic and conductivity surveys.
- Students will be able to provide information about magnetic and conductivity surveys as an example of a technology used to further scientific research related to extracting geological resources
- Students will be able to provide examples of technologies (magnetometer survey) that use different types of electromagnetic waves to extend human senses.
- Students will be able to identify magnetic and conductive anomalies and relate them to structural features and resource deposits.
- Students will use simplified equipment to simulate the technology used to identify and explain the location of economic mineral deposit.

✓ **Discussion Questions**

- Students will evaluate different approaches taken (magnetometer survey, conductivity survey and diamond drilling combined) and will be able to determine the most advantageous path to take when searching for geological resources using geophysical surveys as tools.
- Students will be able to provide examples of technologies that use different types of electromagnetic waves to extend human senses.

Resources

Canadian Society of Exploration Geophysicists. **Resources for Teachers Available at:** http://cseg.ca/students/k-12-teachers

Kearey, P., Brooks, M., Hill, I., (2002). **An Introduction to Geophysical Exploration**. Third Edition. 264 pages. Available at: http://www.lnu.edu.ua/faculty/geology/phis_geo/fourman/library-Earth/AN%20INTRODUCTION%20TO%20GEOPHYSICAL%20EXPLORATION.pdf

Squish Circuits Conductive Play Dough: Available at: http://courseweb.stthomas.edu/apthomas/SquishyCircuits/conductiveDough.htm

For more information about Magnetic surveys go to: www.youtube.com/watch?v=AZyNIGFHsE4

For more information on geophysical surveys used in mineral exploration go to:
http://www.geophysicalmethodsofexploration.com

Environmental Geophysics:
http://www.epa.gov/esd/cmb/GeophysicsWebsite/pages/reference/methods/index.htm

Vocabulary

Geophysics: A branch of physics dealing with the Earth, including its atmosphere and hydrosphere. It includes the use of seismic, gravitational, electrical, thermal, radiometric, and magnetic phenomena to interpret Earth data.

Magnetic Survey: The Earth acts as a giant magnet and influences minerals that are magnetic or may be magnetised, particularly objects containing iron. Magnetometers measure changes in the strength of a magnetic field. Magnetic surveys may be undertaken from the air or on the ground. The data are presented as a magnetic map using computer technology. This information can be used to help find mineral deposits associated with magnetite. Magnetic surveys can also help map geological units and faults.

Conductivity: The definition of conductivity is the ability to transmit heat, sound or electricity. An example of conductivity is heat transferring from hot pot of soup to a metal ladle sitting in the pot.

Name: ______________________________

Discussion Questions

1. What two properties of minerals were used during these exploration surveys?

2. What other properties of minerals can be used to locate mineral deposits?

3. What are some advantages and disadvantages of exploring for underground mineral deposits in this manner?

4. What are some other geophysical surveys used in mineral exploration?

For more information about Magnetic surveys go to: **www.youtube.com/watch?v=AZyNIGFHsE4**

For more information on geophysical surveys used in mineral exploration go to:
http://www.geophysicalmethodsofexploration.com/

http://www.epa.gov/esd/cmb/GeophysicsWebsite/pages/reference/methods/index.htm

FYI:
The cost of drilling a hole into the ground to look for the extent of the deposit is very expensive. It ranges from $ 100 to $200 per meter (Source: Infomine at: www.infomine.com/library/publications/docs/InternationalMining/Riles2012.pdf) and sometimes more depending upon the diameter of the drill hole and how hard the rock is. It can take mining companies many years and dollars to define the drill targets using surface geophysical surveys and geochemistry before committing to a drilling program.

Answers to Discussion Questions

1. What two properties of minerals were used during these exploration surveys?
   Magnetism, conductivity

   Identify minerals that are magnetic: magnetite (Fe_3O_4), pyrrhotite ($Fe_{1-x}S$) weak, franklinite ($(Zn, Fe, Mn)(Fe, Mn)_2O_4$) weak**,**

   Identify minerals that are conductive: gold, copper, silver, graphite, chalcopyrite, and galena

2. What other properties of minerals can be used to locate mineral deposits?
   Radioactivity, chemistry, density/gravity

3. What are some advantages and disadvantages of exploring for underground mineral deposits using magnetic and conductivity surveys?

   Advantages: a wide area can be covered using a plane or satellite in a magnetometer survey. Once an area has been located follow-up can be done on the ground.

   Disadvantages: not all deposits contain useful amounts of magnetic or conductive minerals; not all magnetic and conductive anomalies contain ore-bearing minerals; expensive; still need to drill to confirm ore is present.

4. What are some other geophysical surveys used in mineral exploration? Gravity, Radiometric, Resistivity (Conductivity), Seismic …
   (See http://www.epa.gov/esd/cmb/GeophysicsWebsite/pages/reference/methods/index.htm)

FYI:
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