



## Mining: The Lesson Pack



Canada is a country rich in minerals. Almost every significant mineral used in industrial societies is produced somewhere in this country. There are over 280 mines, producing thirty-four various metals and twenty-six non-metallic minerals in Canada. The mining industry impacts many realms of society; economic (\$), environmental (land use), human (direct \ indirect employment), regional (mining communities), political (trade) etc...

In the following lesson pack, we will relate ideal mining sites to the geology existing in the layers of the earth. Students will decide where to locate different types of mines according to the rock layers found below.

### Background Information

Teachers are encouraged to distribute this background information to their students.

- A) Basic glossary of terms
- B) General mineral relationships
- C) References

### Teacher's Guide

- A) Planning considerations
- B) Required Files

### The Student Side

- A) ArcView Fact Sheet
- B) ArcView Icons – Reference Guide
- C) Student Exercise Instructions
- D) Extension Exercise



## Additional Geologic Web Sites and Teaching Resources:

### Natural Resources Canada

This site has quite a complete glossary of mining terminology.

<http://www.nrcan.gc.ca/mms/school/glossary.htm>

### Online Journals

Here you'll find a list of academic journals, outlining comprehensive topics. These could be explored to examine real world applications, concerns, and present day issues involving geology and mining.

<http://www.geo.ntu.edu/volcanoes/journals.html>

### LINKS to Other Geological and Mining Sites

There are a lot of geologic links in here! Some of these include company sites, university sites, and government sites....

<http://pangea.stanford.edu/ODEX/EG/links.htm>



## Mining: Background Information

*We live in an age of metals! Almost every product we use in our daily lives is somehow related to mining. The cars we drive, the cans we open, the cement we walk on are only some obvious examples from our daily lives. There are also hidden items that come from mining, those items few of us notice on a daily basis, the steel beams in office buildings, the wires and cables beneath our city streets, the circuits inside our computers. The mining industry is certainly an integral part of our society.*

Ontario's diverse geology is host to a wide range of mineral resources. Between \$5 and \$7 billion worth of precious metals, base metals, aggregates, industrial minerals and other commodities are produced in Ontario each year.

### A) Basic Glossary of Terms

Let's review some terms that are essential in understanding geology in Ontario:

#### ***Geologic Cycle***

Earth's crust is in an ongoing state of change, being formed, deformed, moved and broken down by physical, chemical, and biological processes. The *endogenic* system (powered by heat energy from within the planet) is at work building landforms, while the *exogenic* system (powered by insolation and influenced by gravity) works to wear them down. This vast give-and-take at the Earth-atmosphere interface is called the geologic cycle.

#### ***Mineral***

Naturally occurring substances found in rocks, soils, or sediment. Some minerals contain metals or non-metals that society finds useful. Mineral deposits that are large enough to be mined profitably are called *ores*.

#### ***Rock***

An assemblage of minerals bound together. Literally thousands of rocks have been identified, all the result of three rock-forming processes: igneous, sedimentary and metamorphic.

#### ***Erosion***

Wearing away and transformation of the earth's crust caused by wind, water (rain, sea), ice and atmospheric agents.

Examples of erosion include the carving of canyons by rivers flowing through them (Grand Canyon), the creation of caves by water dripping through them and the formation of mountain landscapes by the advance and retreat of glaciers (Canadian Rockies).



### ***Igneous Rocks***

(*Igneous* means “fire formed” in Latin) Formed when molten rock, called magma, cools and turns solid. The magma may be ejected as lava from a volcano but there are also other processes that can bring it to the surface. Examples include granite and basalt.

### ***Pluton***

An intrusive igneous rock that cools slowly in the earth’s crust. A general term for any intrusive igneous rock body regardless of shape or size.

### ***Sedimentary Rocks***

Most are derived from preexisting rocks, or from organic materials (such as bone and shell) that form limestone. The processes of weathering and erosion generate the material sediments needed to form these rocks. Characteristically, sedimentary rocks are laid down by wind, water and ice in horizontally layered beds. Examples include limestone and coal.

### ***Metamorphic Rocks***

Any rock, either igneous or sedimentary, may be transformed into metamorphic rock, by going through profound physical and/or chemical changes under increased pressure and temperature. The name metamorphic comes from the Greek, meaning to “change form”. These rocks are generally more compact than the original rock and therefore are harder and more resistant to weathering. Examples include slate and marble.

### ***Mining***

Purpose is the extraction, concentration, smelting of economic minerals from a mineral deposit. Mining includes exploration, development of mineral deposits, construction of mines, mineral extraction and processing of ore or tailings.

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## **B) General Mineral Relationships**

Recognizing general relationships between mineral deposits and rock type is an important step in knowing where minerals are found in Canada.

***Metallic Minerals*** are most often associated with *intrusive igneous rocks*. At one time, these minerals were dispersed in large volumes of molten rock, or magma, deep in the earth’s interior.

***Fuel Minerals*** and ***Industrial Minerals*** are found mainly in *sedimentary rock*.



**Structural Minerals** (sand, gravel and clay) are the products of river, wind, and glacial deposition. They occur almost everywhere and are associated with *all kinds of rock*.

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### **Ontario Mining Facts!**

- The Creighton nickel and copper mine in Sudbury, is the deepest mine in Canada, reaching a depth of about 7200 feet (or 2.2 km)!
- Average weekly earnings in the Ontario mining industry (excluding oil wells) were \$1174 in 1996; one of the highest earning levels in the provincial economy.
- In 1996, Ontario yielded 46% of Canadian gold production and 81% of Canada's nickel production.
- The mining, quarries and oil wells industry employs about 21 000 people. Of the 13 900 employed in mining, about 12 500 are employed in mining metals, including nickel, copper and gold.

### **D) References:**

<http://nrcan.gc.ca/mms/efab/mmsd/facts/canada.html>

Natural Resources Canada: Minerals and Metals Sector. This site has extensive Canadian as well as provincial level information.

[http://www.gov.on.ca/MNDM/MINES/OIS/inme\\_601.html](http://www.gov.on.ca/MNDM/MINES/OIS/inme_601.html)

This site covers geology and mineral resources as well as exploration hotspots in Ontario.

Cartwright, Fraser et al. *Contact Canada (Second Edition)*. Oxford University Press Canada, 1996.

Christopherson, Robert W. *Geosystems: An Introduction to Physical Geography*. Macmillan Canada, Toronto 1992.



## Mining: Teacher's Guide

### A) Planning Considerations

#### Objectives:

1. Students will explore and manipulate various mapping tools using ArcView GIS.
2. Students will improve their cartographic skills and practice proper cartographic conventions.
3. Students will understand both physical and human considerations of mining in Canada.
4. Students will use their maps to describe, analyse, and interpret relationships between geologic phenomena and mine location.

#### Connection to Geographic Curriculum Themes:

Topics in this lesson can be applied to several themes in Geography and related courses.

They include:

1. Geology
2. Economics
3. Land Use Patterns
4. Environmental Issues
5. Cultural Perspectives

#### Who can use this exercise?

The exercise is designed to be accessible for all ability levels. Instructions have been written to accommodate both beginners and more advanced ArcView users. Teachers may wish to adapt sections of the exercise to meet specific needs.

#### Materials Required:

1. A copy of the **ArcCanada CD-ROM Version 2.0**.

#### Helpful Hints:

1. We strongly advise that teachers work through the exercise before distributing it to students.
2. We also recommend that if you plan to load the ArcCanada files onto a network directory, double-check to ensure they have copied properly. Remember to copy all three extensions (the .shp, .dbf., and shx.) for each file that you desire.



3. The student instructions explain the path from the ArcCanada CD-ROM to the files they will use. If the path you have created is different, make sure you inform the students of this change.
4. Timelines for completion of the exercise will vary. You may want to plan for several classroom periods to complete the exercise if you decide to use the exercise as a mini-project. However, the instructions are designed to ensure that a student can create the map in one classroom period (analysis may be limited).

## B) Required Files:

*All the files used in this exercise are from the ArcCanada CD-Rom, Disk 1 and Disk 2.*

### Disk 1

canada\prov99.shp	(Canadian Provincial Boundaries)
canada\cities.shp	(Canadian Cities)
on\rail.shp	(Rail lines in Ontario)
on\roads.shp	(Roads in Ontario)
on\lakes.shp	(Lakes in Ontario)

### Disk 2

na\rockunit.shp	(Geologic Data for North America)
na\faults.shp	(Faults Data for North America)

## Data Summary:

A description of all the files in ArcCanada can be found on the ESRI Canada K-12 web site at <http://www.esricanada.com/k-12/arccanada.html>. Included here is a summary of the data used in the Mining Lesson Pack. You may wish to go through this list with your students before they attempt the exercise. This will enable students to create meaningful maps.



# Rock Type

Geologic Data Summary for North America:

Rock_type	Description
Mainly Sedimentary Rocks	None.
Mainly Volcanic Rocks	May include hypabyssal intrusions.
Mixed Volcanic, Volcaniclastic and Sedimentary Rocks	This designation includes Precambrian iron-formation-bearing sedimentary and volcanic sequences, as well as mixed sedimentary and volcanic or volcaniclastics sequences.
Plutons	Deep-seated to high-level intrusions are included. Many charnockites, anorthosites, and large ophiolites, classified as plutons, are distinguished in the database using the SIGNIF item. Ophiolites were classified as plutons, even where remnants may be extrusive and/or sedimentary.
Intrusive and Metamorphic Terranes	Mixtures of metamorphic and intrusive or plutonic rocks, tracts known as crystalline, migmatitic terranes, moderately to highly metamorphosed rocks of unknown origin with or without intrusions.
Tectonic Assemblages, Schist Belts, Melanges	Rocks distinguished in compilation sources primarily as part of a tectonic assemblage, belts of schist and mylonite of mixed parentage, and tectonic melanges.
Unclassified	Used rarely
Ice Cap of Major Significance	Used only for Greenland Ice Cap.




## The Student Side

### A) ArcView Fact Sheet


Here's a list and explanation of important features in ArcView:

**Project:** In ArcView, a file for organizing your work. Projects use five types of documents to organize information: views, tables, charts, layouts, and scripts.

**View** : A component of an ArcView project used for displaying, querying, and analyzing geographic themes.


**Table of Contents:** All themes in a View are listed to the left of the map. The Table of Contents shows the symbols used to draw features in each theme. The check box next to each theme indicates whether or not it is turned on or off in the map (whether it is currently drawn on the map).

**Theme:** A set of related geographic features, such as streets, parcels, or rivers, and the characteristics (attributes) of those features.

**Table** : Information formatted in rows and columns. A component of an ArcView project used for displaying Tabular data.

**Join:** In ArcView, an operation used to attach Tabular data to a theme. The fields of one table are appended to another table (usually the theme table) using a common field.

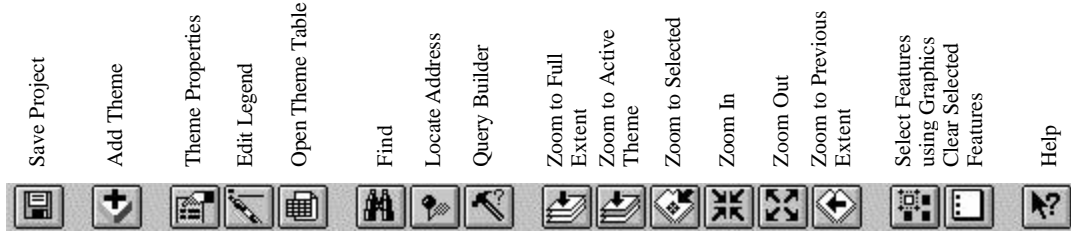
**Query:** A question or request used for selecting features or records. A query often appears in the form of a statement or logical expression. In ArcView, a query contains a field, an operator, and a value.

**Layout** : The design or arrangement of elements in a digital map display or printed map. A component of an ArcView project used for creating presentation-quality maps.

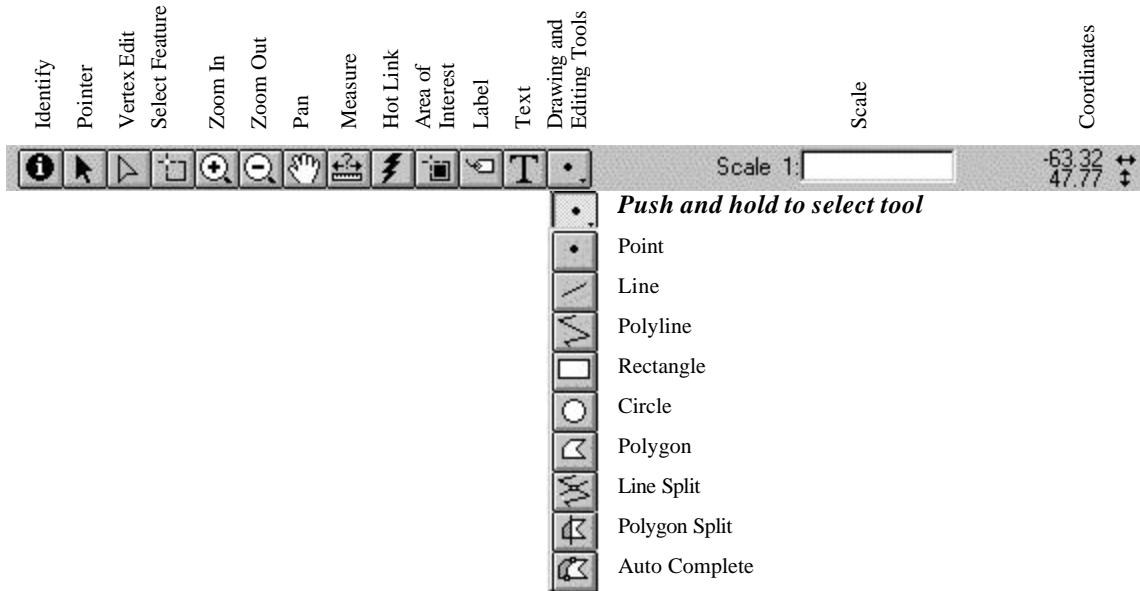


## B) ArcView Icons – Reference Guide

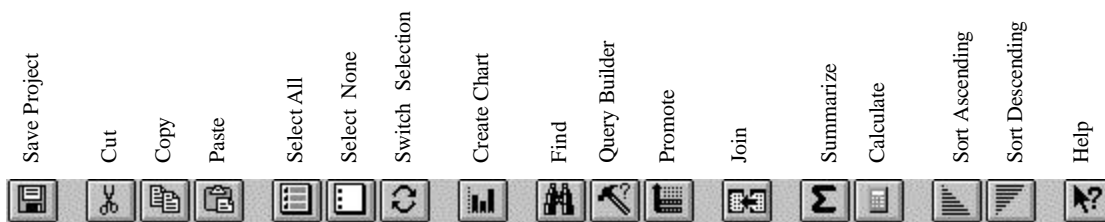
### View GUI - Buttons



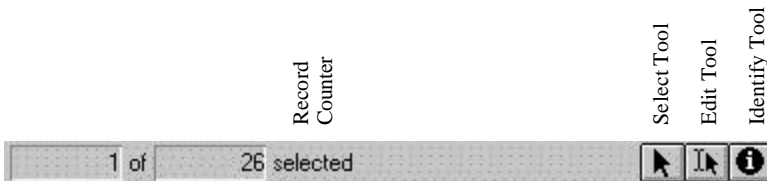
### View GUI – Tools



### Table GUI - Buttons

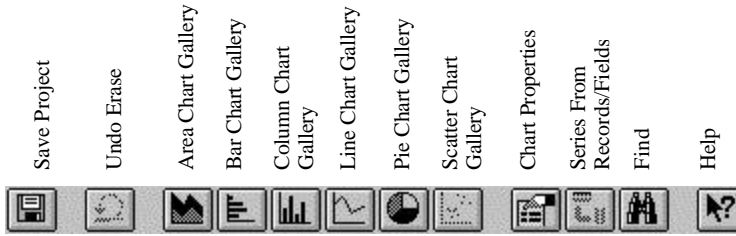


### Table GUI - Tools

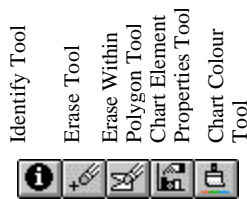




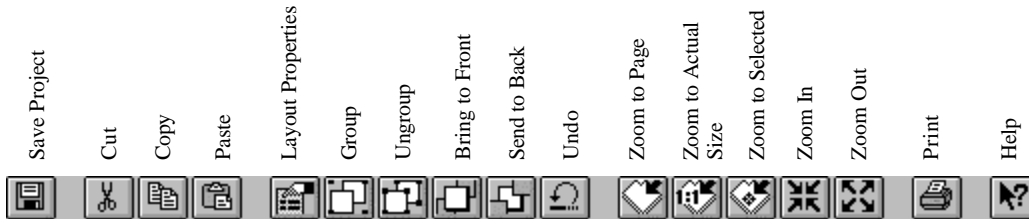
**Chart GUI - Buttons**



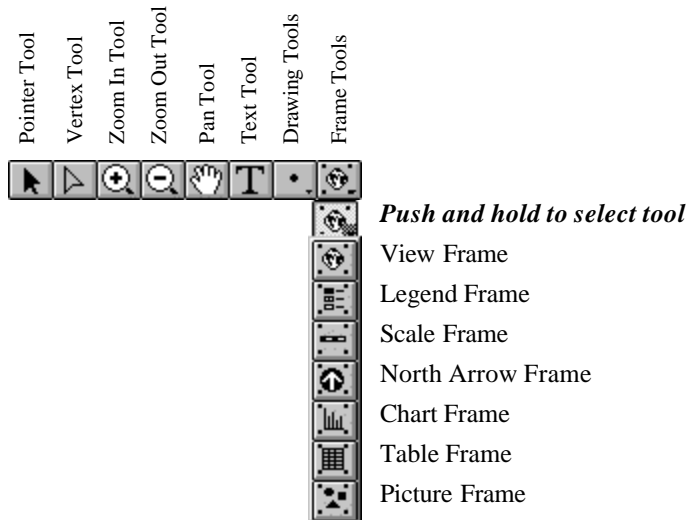
**Chart GUI - Tools**



**Layout GUI - Buttons**



**Layout GUI - Tools**



**Push and hold to select tool**



## Mining: Student Exercise

### “Where Should We Mine?”

You are a consultant for mining companies throughout Ontario. Your job is to propose ideal sites across Ontario to mine for specific types of minerals. There are 4 main types of mineral deposits: Metallic, Fuel, Industrial and Structural (see the Background Information Sheet for more information on these). By examining geologic areas, you are to propose ideal sites in Ontario in which to locate the following mines:

**Fuel Minerals:** coal mine  
natural gas mine

**Metallic Minerals:** nickel mine  
gold mine  
copper mine

**Structural Minerals:** sand mine  
gravel mine

**Industrial Minerals:** rock salt  
potash

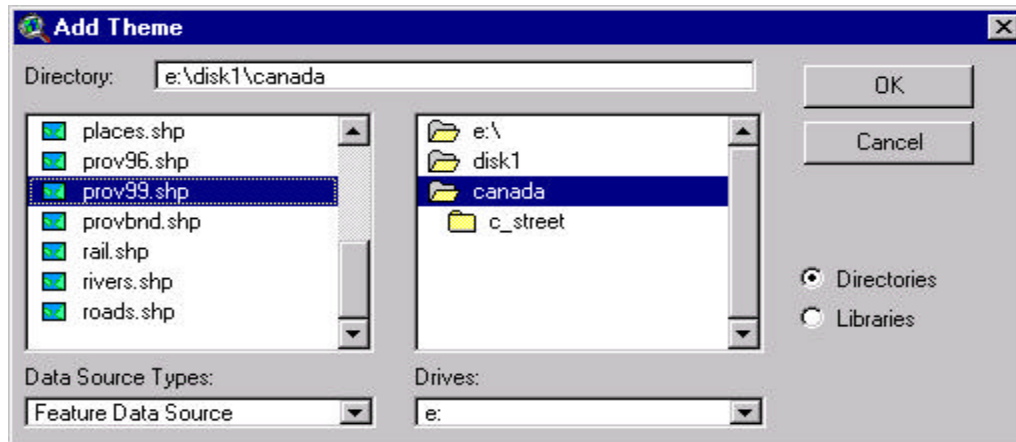
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### A) Getting Started:

1. Load **ArcView** if it's not already running.
2. From the Welcome to ArcView GIS window that appears, select “with a new View” and click on OK.
3. When asked “Would you like to add data to the View now?” click on OK. This will allow us to add the themes we wish to work with.
4. Navigate to the appropriate directory to retrieve the files for this exercise (check with your teacher if you're not sure where this is located).



- Double click on **canada (Disk 1)** and select the following two files from the list on the left: **prov99.shp** and **cities.shp** (in order to select both of these at once, hold down the Shift key).



- Click **OK**. You will notice that two themes have been added to your table of contents in your **View 1**.
- Let's add one more important theme to our table of contents. Click on the **Add Theme** button. Navigate to the **na** directory (**Disk 2**). From the files that appear, double click on **rockunit.shp**.
- Click **OK**.

## B) Let's Explore Our Data!

- Maximize** your screen.
- Turn On** each theme by clicking in the small box beside each title.
- Click, hold and drag the **rockunit.shp** theme to the bottom of your table of contents. Release the mouse button. Click, hold and drag the **cities.shp** theme to the top. When you let go, all themes should become visible to you on screen.

*What does this tell you about the order in which ArcView draws the themes in your table of contents?*

- One of your three themes is your **Active** theme (it appears raised compared to the other two). ArcView can perform tasks on a theme only when it's **Active**. Which

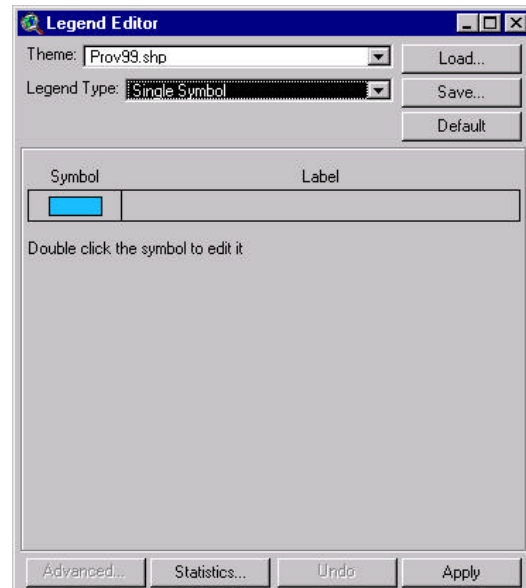
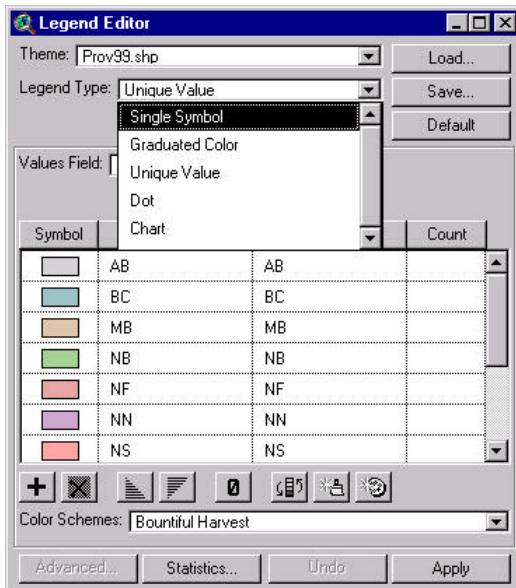


one of your themes is **Active** now? Click beside the other theme titles to see how easily you can make a new theme **Active**.

5. We need to make our map geographic by setting map units. In order to set measurement units for our map, go to the main menu under **View** and click on **Properties**.
6. Beside **Map Units**, click on *decimal degrees*.
7. Beside **Distance Units**, let's use *kilometers*.
8. Click **OK**.

### C) Changing Colour...

1. Let's get rid of the colour in our **prov99.shp** theme so that we can see only the provincial boundaries.
2. Double click on the colour box under the **prov99.shp** theme. This brings up the **Legend Editor** box.
3. Change the **Legend Type** to **Single Symbol**.
4. Double click on the symbol again to bring up the **Fill Palette** box.





5. Select the empty box in the upper left-hand corner.
6. Next, in the drop down menu beside **Outline**, scroll down and select **2**. This will make our provincial boundaries stand out more clearly.
7. Close the **Fill Palette** box.
8. In the **Legend Editor**, click on **Apply**. Close the **Legend Editor**.

### D) Where's My Data?

1. You can find data all over your map. For example, make your **cities.shp** theme your **Active** theme.
2. Click on the **Identify tool**. Use this tool to click on cities across Canada and examine their attributes.
3. Click on the **Open Theme Table** button to make the cities data table visible to you.

*How many records exist in this file? (Check the top left of your screen)*

*Answer:* \_\_\_\_\_

*What type of information can you find in this table?*

4. **Close** your table.
5. Extensive data also exists in our geologic theme called **rockunit.shp**. To make this more obvious, let's reclassify our data to show individual geologic areas.
6. Double click on the colour box under **rockunit.shp**. In the **Legend Editor** box, beside **Legend Type**, choose **Unique Value**.
7. Under the **Values Fields**, choose **Rock Type**. This classifies our data by type of rock.
8. Change your colour scheme to something other than **Bountiful Harvest**.
9. Click on **Apply**. Close the **Legend Editor**. If you find it difficult reading the names of your rock types, extend the border of your table of contents by clicking on the partition and dragging it towards your map (you are ready to drag once your pointer turns into a double headed arrow).



10. Let's change the title of **rockunit.shp** to something more meaningful, perhaps "Canadian Geology". Under **Theme** in the main menu, click on **Properties**.
11. Beside **Theme Name**, type in the title you've chosen. Click **OK**.
12. Use your **Zoom In** and **Zoom Out** tools to explore different areas of Canada.

(You may wish to **Turn Off** your cities.shp theme to answer the following questions)

*What kind of patterns do you notice in Canada with regards to the location of certain rock types?*

*In what areas do you find mainly "Intrusive and Metamorphic Terraines"?*

*According to our data, what province appears to be made up "Mainly Sedimentary Rock"?*

***Zoom In** on the Maritime Provinces. What geologic trends do you notice?*

*Where is the Canadian Shield located? Can you tell?*

*Where in Canada do we find concentrations of Plutons? (To see these more clearly, change the colour of plutons by double clicking on the symbol in the Legend Editor. Make it stand OUT!)*

## E) A New Theme...

1. Let's add a faults theme to our View to see how they relate to Canadian Geologic Patterns. Click the **Add Theme** button.
2. Navigate to the path **na\faults.shp** to find it and click **OK** once you've selected it.
3. Turn **On** your Faults theme. You may have to turn off other themes to properly see the faults.

*Where do you notice concentrations of fault lines in Canada?*

*What type of geology (rock type) appears to follow fault lines? Is there any consistency? Give some specific examples. **Zoom In** if required.*

4. Turn **Off** your faults theme once you've examined all the features.



## F) Ontario - Yours To Discover!

1. **Zoom In** on the province of Ontario.
2. With your **cities.shp** theme **Active**, use your **Identify tool** to locate cities across the province.
3. Many mining communities exist in Ontario. Use your **Find tool** to locate the following prominent mining communities:

Sudbury: nickel, copper, platinum metals, cobalt, silver, selenium, gold

Timmins: gold, zinc, copper, silver, lead, cadmium

Kirkland Lake: gold

Thunder Bay: palladium, copper, platinum, nickel, copper

4. Use your **"call-out" label tool** to name Sudbury, Timmins, and Kirkland Lake. Click on the label tool button and hold down the mouse button. This will give you a variety of label tools. Select the "call-out" label tool (second from the top).
5. Click on the point that represents Sudbury with the mouse button. Hold down the mouse button and drag the cursor outwards from the city. Let go of the mouse button and the name of the city now has a "call-out" label. Repeat these steps for Timmins, and Kirkland Lake.

*If you need to delete any labels, select the pointer tool and click on the label you want to delete (black handles should appear around it). Now press the Delete key on your keyboard. The label should then disappear.*

7. Now repeat the labeling instructions in step #4&5 to label the city of Thunder Bay. The label will be bigger and have a different font than the other labels.
8. Does the geology support the types of minerals that are mined by each community? Examine all four cities and explain your answer (remember, we have mapped the location of *mining communities*, not the *actual* mines).

## G) Now It's Your Turn...

Your job is to propose ideal sites across Ontario for mining. As stated before, there are 4 main types of mineral deposits: Metallic, Fuel, Industrial and Structural. Not only will you base your decision on geologic areas, you are also to consider road networks and railway lines (these factor heavily in terms of transport costs)



Road networks and railway lines are very important to consider given that in 1995, Ontario exported \$18.7 billion of non-fuel and mineral products making it the largest provincial exporter, followed by Quebec (\$10.5 billion) and British Columbia (\$3.2 billion).

## Time To Consult

Before we perform our consulting work, it is vital that we add three new themes to our **View 1**, road networks, rail lines and lakes.

1. Click on the **Add Theme** button. Navigate to the appropriate directory and double click on the file name called **on** (this stands for Ontario). Select three files to add to your table of contents: **rail.shp**, **roads.shp** and **lakes.shp**.
2. **Turn On** your new themes.

*Where are roads and rail lines concentrated in Ontario? Where are their limits?*

*Zoom In to an area to make sure your mine won't be placed on top of a lake.*

*Does your **Identify** tool provide you with any lake attributes?  
(You may like to turn certain themes on and off in order to view others themes more clearly)*

**REMINDER:** Based on geologic areas, roads and railways, your job is to propose ideal sites in Ontario in which to locate the following mines:

**Metallic Minerals:** Nickel mine  
Gold mine  
Copper mine

**Fuel Minerals:** Coal mine  
Natural gas mine

**Industrial Minerals:** Rock salt  
Potash

**Structural Minerals:** Sand mine  
Gravel mine



3. Decide where your mines will be located. **You should choose four locations, one for each main type of mineral deposit.** When you've decided on an appropriate location for each type of mine, use the **Draw Point tool** to mark your spot.
4. Click on the **Text tool**. Click next to the point representing your mine. In the Text Properties dialog box, type the name for the mine you've located on the map. Click on OK. Do this for all the mines.

*What is the reasoning behind your decision? Write a paragraph for each mine location describing the reasoning you used.*

## H) Map Layout: The Final Frontier

Before we create our layout for printing, turn off your lakes theme (this theme is very dense and won't help you see the information you've mapped). Make all of your other themes active.

1. Make sure to change all your theme names to meaningful titles (use terms that a beginner map reader would understand).
2. Return to the **Project** window (from the menu **Window**, choose **untitled**). From the **Project** window, click the **Layout** icon and hit the **New** button.
3. This brings up a blank **Layout Document**. On this **Layout** you will create your final map. Under the **Layout** select **Page Setup**. Change the orientation to **Landscape**. Resize the **Layout** window to make it as big as you can.
4. Using the **View** frame tool, draw a box inside your **Layout** page. A dialogue box will appear, asking you to choose the **View** you'd like to display. Choose the View that reflects the themes you are mapping, in our case, **View 1**. Click **OK**. Click on the black **Pointer** tool to resize your map.
5. Use the tools located **under the View frame** to add a **North Arrow**, a **Scale Bar** and a **Legend** (a series of tools scroll out from the bottom).
6. Add a title, name, and any other relevant information to your map using the **Text** tool.
7. Using the **Rectangle** tool, draw neat lines around your **Legend**.  
*(This may be unnecessary when using the **Legend Editor** tool)*
8. Make sure your map is balanced and that you've used proper mapping techniques.



9. You may wish to **Print** out your map to hand it in (ask your teacher to make sure). If you are using a black and white printer, remember to change your colours to a gray scale and/or use hatching patterns to represent different colour schemes.
10. Don't forget to **Save** your work.

## Extension Exercise

1. A gold mine has just been discovered! Geologists first map the area, then use diamond drills to sample and determine the size, shape, and depth of the mineral bearing rock hidden underground. If it is decided that a mineral deposit can be mined profitably, the company must then decide on a method of mining:
  - *Open-Pit Mining*
  - *Strip Mining*
  - *Underground Mining.*

Although you are a consultant, you are also an environmentalist. Conduct research regarding on the environmental impacts caused by all three types of mines. Rank the three mining methods from the least destructive to the environment to the most destructive. Give reasons for your ranking. Draw a sketch of each type.

### 2. Group Activity

Each member of your group must assume one of the following roles:  
***Mine Worker; Site Geologist; Environmental Assessment Agency; Urban Planner***

Your group is to plan a future mining community. Your team must come up with a plan that satisfies each of the following individuals. Each one of the following members has equal say in how the community will unfold. Sketch a plan for your community, outlining the various features you've discussed (where is the gold mine located? where is the community located? what types of services will be provided and why? will there be green space? is everyone satisfied?) Compare your results to those of other groups.

3. Add world geologic data to a **New View** by following this path:

**af\rockunit.shp**  
**an\rockunit.shp**



```
as\rockunit.shp
oc\rockunit.shp
eu\rockunit.shp
na\rockunit.shp
sa\rockunit.shp
```

1. Turn on your new themes and reclassify them using the **Legend Editor**.
2. What type of geologic relationship do you notice on a worldwide scale?
3. Bring up more themes and see how they relate to world geology. To find more world data, look in the **world** folder.

*Do you notice any trends between cities and geologic patterns? What about rivers? What other relevant themes could you include?*