Saskatchewan's Mineral Resources
Lesson: Gold Exploration

Overview:
This activity provides the students a quick introduction to Mineral Resource Exploration or how to find a mineral deposit. Students will learn about the work of the exploration geologist as they receive 5 statements about a mineral property. Using these statements and the maps supplied, students will work their way through a mineral exploration program to determine where to drill in their search for gold.

Source: This lesson was developed by the Saskatchewan Mining Association for their **MAP (**Minerals and Products) event.

Duration: One class

Materials: (enough for 16 pairs)
- 8 envelopes
- SMA Dollar$
- Statement Cards
- Maps: Location map, Geology map, Geochemistry map, Geophysics map, Drill hole location map
- Information Cards: Rock types, Geochemistry, Geophysics
- Drilling Results Cards
- Container with gold beads. BB's work well (represents one troy ounce of gold)
- Paperclips
- Conductivity meters
    - 9V Battery Snap Connector
    - 9V Battery
    - Coated Wire
    - 2 alligator clips
    - Electrical tape
    - 1 Fairy light (aka Christmas lights)

Notes to Teachers: Students work in pairs or small groups.

Instructional Methods: Hands-on, Case Study

Learning Outcomes and Indicators
Grade 7 Earth's Crust and Resources
EC7.2 Identify 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., geophysical surveys, geochemical surveys 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
ES30-ER1 Identify the economic resources of Saskatchewan to recognize the impact these resources have on the province.

a. Investigate how the location of major mineral resources in Saskatchewan is influenced by their depositional setting and geologic history.
h. Use technology to identify and explain the economic mineral deposits of Saskatchewan (indirect)

ES30-TT1 Investigate the use of remote sensing tools to collect evidence relevant to understanding Earth's structure.

a. Provide examples of technologies that use different types of electromagnetic waves (e.g. x-rays, infrared, and radar) to extend human senses
k. Identify anomalies from actual geophysical surveys and geologic maps and relate them to structural features and resource deposits.

ES30-EP2 Analyse how the formation of the three main rock families are foundational to the economic mineral deposits of Saskatchewan.

e. Identify the geologic features associated with major mineral resources of Saskatchewan (e.g., gold, diamond, rare earth elements, copper, zinc, kaolin, coal, potash, uranium, salt, sodium sulphate).

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 ore (commercially viable concentrations of minerals) to mine.

Steps in exploration:

1) Prospecting
2) Staking a claim on the interesting property
3) Airborne Geophysical surveys –Instruments are used in geophysical surveys to check for variations in gravity, magnetism, electromagnetism (resistivity/conductivity of rocks) and a number of different other variables in a certain area. The most effective and widespread method of gathering geophysical data is via flying airborne geophysics.
4) Geological mapping to identify the rock types and structures
5) Geochemical sampling of rocks, soil, stream/lake sediments, water, and vegetation
6) Ground geophysical surveys to locate potential drill targets
7) Drilling of the targets

In this example the property has already been staked (has claims on it). It was brought to the company by a prospector who knew that the area north of La Ronge has some good gold "showings" – places where rock samples have been analysed and have gold in them. There are also old as well as current gold mines along the trend.

Although the location and geology is real, the geochemistry, geophysics and drilling results have been modified for the purpose of this activity.

Vocabulary

assay	Conductivity survey
fault	ppm
g/t	ore
Shear zone	

THE ACTIVITY

Teacher Preparation:

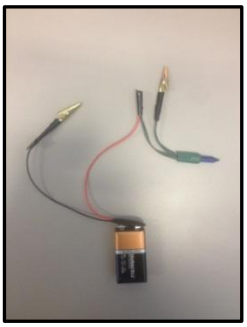
1. Fill each envelope (the bank) with $165,000.00 SMA Money (3x $5,000.00, 3x $10,000.00, 6 x $20,000.00).
2. Glue paperclips onto red EM conductors (on map) to be used with conductivity meters.

Assembly of Conductivity Meters

Materials:

- 9V Battery Snap Connector
- 9V Battery
- Coated wires
- Electrical tape
- 1 Fairy light (aka Christmas lights)

i) On the 9V snap battery connector, strip the ends of each wire.
ii) On the fairy light and strip the ends .
iii) Spin together one wire 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.
iii) Attach alligator clips to the remaining wires.
iv) Connect the snap connector to the battery and test it by touching the two alligator clips together.



Assembled conductivity meter

3. Print out statement and information cards for each group of students. Print out one set of cards if the activity is being teacher led.
4. Weigh out one troy ounce of an item to represent the weight of one troy ounce of gold. Copper BB's work well. One troy ounce of gold weighs **31.1034768 g.** The current value of gold is **$1,101.00** US per troy ounce (July 2015).

Each student pair should receive one envelope of money, one set of maps and one conductivity meter. Make sure the conductivity meters are working.

Delivery:

1. Hand out the money, the maps, and the statement and information cards to each team. Do not hand out the answer cards or reveal the answers until the students have completed the activity.
2. Each time a survey or activity costs money have teams place the correct amount of dollars into the envelope (The bank).
3. If this is a teacher led activity the Statement cards are for you to read to the students. If this is a student activity, provide students with both Statement and Information cards.
4. Work through the Statement cards encouraging students to use the information cards to explain the information on the maps and help them make their decisions.

Activity

1. **Read Statement #1** to students and have the students look at the Site map (#1). Have them take their money out of the bag and count out $30,000.00 (their salary for the 3 months) and put it aside.
2. Have students work through the statement cards to identify drill targets. One student per group controls the budget, paying the "bills" for work done as the program proceeds.
3. Have students select a drill hole.
4. Go through the Drilling Results with the students: Start with Drill Hole D, C, A and finally Drill Hole B.

At the end of activity announce: Because of your success, Golden Goose Resources Inc. gives you $500,000 to continue drilling. Your discovery is announced and the price of Golden Goose Resources Inc.'s stock triples in value.

Safety: If using BB's to represent the weight of one troy ounce of gold, secure the lid. BB's rolling on the floor are a slip/fall hazard.

Assessment Method and Evidence

✓ **Hands on Activity**

- Students will be able to explain that an EM survey (using a conductivity meter) represents some of the technology used in a geophysical survey to find ore deposits associated with conductive minerals.
- Students will be able to provide, soil/stream/rock geochemical sampling, mapping, EM geophysical surveys and diamond drilling as examples of technologies used to extend the human senses and further scientific research related to extracting geological resources.
- Students will have the opportunity to evaluate different approaches taken (mapping, geochemical/ geophysical surveys and diamond drilling) to make decisions when searching for a gold deposit in Northern Saskatchewan.
- Students will be able to list several careers associated with the Mining Industry (Helicopter Pilot, Exploration Geologist, Line cutter, Chemist, Geochemist, Geophysicist, Driller, Driller's helper).
- Students will investigate how the rock type, geological setting and geologic history are important to understand when looking for gold deposits in northern Saskatchewan.
- Students will identify anomalies from actual geophysical surveys and geologic maps and relate them to structural features and resource deposits.
- Students will associate the deposition of gold deposits in northern Saskatchewan with quartz veins along fault structures/shear zones along the margins of metavolcanic rocks.

Resources

What is Core Drilling? Available at: www.youtube.com/watch?v=3VQeqw2wWWY

Stock market value of gold:
Infomine at: http://www.infomine.com/

Saskatchewan Northern Geological Survey. **Resource Map of Saskatchewan** Available at: http://www.economy.gov.sk.ca/resourcemap

SMART: Saskatchewan Mining Association Resources for Teachers Available at: www.saskmininged.com

USGS Geologic Glossary Available at: http://geomaps.wr.usgs.gov/parks/misc/glossarya.html

Geology.com Dictionary Available at: http://geology.com/geology-dictionary.shtml

Vocabulary

Assay: Analysis (as of an ore or drug) to determine the presence, absence, or quantity of one or more components

Electromagnetic Conductivity Survey: EM conductivity surveys measure ground conductivity. Used to identify bedrock discontinuities and mineralization.

Fault: A fracture in the Earth along which one side has

moved in relative to the other. http://geomaps.wr.usgs.gov/parks/deform/gfaults.html

g/t: Grams per tonne

ppm: Parts per million

Ore: Ore is rock that contains important minerals including metals. The ore is extracted through mining and processed to extract the valuable element(s). Ore contains minerals that can be mined at a profit.

Shear Zone: A shear zone is a zone of strong deformation where the rock has been crushed and brecciated by many parallel fractures due to shear strain The shearing is caused by the rock moving in opposite directions.

STATEMENT CARDS

Statement #1:

You have been hired by a small mineral exploration company for the summer. The company has just staked a property in a known gold producing area north of La Ronge. Your job as a geologist is to find a gold deposit on the property.

This vial (have students hold the vials of "gold' weighs one troy ounce (or 31. 104 grams). One ounce of gold costs $1,100.00 per ounce or $35.36 per gram (July 2015).

The property you will be exploring has lots of trees, lakes, and rocky hills. It lies roughly 250 kilometers north of Prince Albert, 40 kilometres north of La Ronge. To get there you fly in by helicopter and set up your camp. The helicopter pilot drops you off and says he will be back in two weeks with the groceries. (Look at Map 1)- Site Map).

Your total budget is $165,000, but $30,000 is for your salary, $15,000.00 each leaving you $135,000 to run your exploration program. Take the $30,000 out of your working budget. You wouldn't want to see that spent on the summer project!

Looking for mineral deposits is a lot like solving a mystery. There are a lot of clues that you have to put together to solve the mystery.

Statement #2 Geological Mapping

The mining company has hired a crew (Line Cutters) to cut line through the bush in a grid pattern to make it easier for you to locate yourself. For the next month you map the rocks and boulders on the property. You send rock samples to the Chemists and Geochemists at the Saskatchewan Research Council labs for chemical analysis.

Every evening you draft up your maps putting on the location of the rocks, samples and any other information you think might be useful. At the end of the month you have produced a fairly detailed geological map of the area (Look at Map 2- Geology)

During mapping you have identified potential gold bearing rocks. The best target rocks are the **Diorite/Gabbro** an igneous rock**. Look at the legend and the Geology Information Cards.** Gold in this area commonly occurs in quartz veins associated with other minerals such as pyrite (py), chalcopyrite (cpy), and arsenopyrite (aspy)in fault zones (fractures in the earth).

Also important to know is which way the glaciers flowed during the last glacial event. The glaciers grind up the rocks and carry them along with them. In northern Saskatchewan the glaciers flowed from the north east to the south west. Locate the arrow on the map.

Time to start thinking about where you would drill to find the gold deposit.
Clue #1: Gold in other areas has been found in Diorite/Gabbro rocks, along the edges of the rock unit.
Clue #2: Gold in quartz veins occur in areas of faulting
Clue #3: Glaciers have moved boulders in the direction the glaciers are moving.

Budget: Cutting the grid cost $25,000 and has left you with $110,000.00 to continue. (Pay the bank)

Statement #3 Geochemical Survey

The next step is to sample mud, sand, and silt from the bottom of the streams and lakes on your property and send them off to the Chemists and Geochemists at the Saskatchewan Research Council to be analyzed for gold.

The gold results are measured in ppb – parts per billion. One ppb would be like adding a pinch of salt to a 10 tonne bag of potato chips! If there is a lot of gold in the sample then they are plotted as grams per tonne (g/t). A paper clip weighs one gram. An average bull weighs one tonne.

Each place where you took a stream or lake sediment sample is marked with an X. Quartz boulders are marked with a triangle. (Map 3 – Geochemistry)

Clue #4: Values over 6ppb are anomalous. Values listed as grams per tonne are very anomalous and a good indicator that gold is nearby.

Budget: Geochemical analysis of the sediments costs you $20,000 leaving you with $90,000 to continue your summers work. (Pay the bank)

Statement #4 Geophysical Survey

To narrow down the search for the source of the gold anomalies we need to identify good targets to drill. We can do this by calling in the Geophysicists to carry out a geophysical survey over the grid.

A crew is hired to carry out an Electromagnetic (EM) survey. The crew walks along the grid carrying an instrument that measures how well the rocks conduct/resist electricity. Gold and many minerals associated with gold are good electrical conductors. Use the conductivity meters to test the area. Place one of the clips on one end of the fault and the other at the other end. Read the information about Geophysical Surveys.

The EM survey has turned up some interesting conductors. Not all conductors however are related to gold deposits, they may also indicate the change between rock types. (Map 4 – Geophysics)

Clue #5: An EM anomaly might be a good target for diamond drilling if the geology and geochemistry of an area also looks favourable.

Budget: The EM survey costs $30,000.00, leaving you with $60,000.00 (Pay the bank)

Statement #5 Diamond Drilling

This is the last stage of your exploration program. It is time to choose where you are going to drill. Based on your summer's work you have narrowed it down to 4 locations (ABCD) (Map 5- Drill Hole Location). You plan to drill one hole 200 metres deep at a cost of $300.00 per metre.

As a good geologist you will consider all the clues from the geological mapping, and the geochemical and geophysical surveys.

Choose your drill site carefully. **You can only afford to drill one hole, which will cost you $60,000.00 (Pay the bank). You will have $0 left in your budget to continue if you are wrong.**

Information: Rock Types

Granodiorite:
Only a small outcrop of granodiorite occurs in the northwest corner of your property. If a gold ore body is located within the granodiorite, you would probably see lots of quartz veins and signs that the rock has been broken. **Note**: The Contact Lake Mine, in the La Ronge gold belt, does have gold bearing quartz veins in a granodiorite host!

Meta sedimentary Rocks (greywacke):
The metasedimentary rocks are not good exploration targets because they show no evidence that they have been altered by warm mineralized fluids since they formed.

Greywacke is a dark grey sedimentary rock composed of mud and sand, probably laid down in an ancient ocean. Over time, these sediments were buried under more layers, much of the water was squeezed out and the particles became cemented together to form a rock.

Information: Rock Types

Diorite/Gabbro: These rocks have been intruded into the metasedimentary and metavolcanic rocks. In the western part of the property these rocks are more mafic. They commonly contain quartz veins in shear zones, but the quartz is barren (it does not contain gold). Gold mineralization is, however, associated with sulphide minerals such as pyrite (iron sulphide), chalcopyrite (copper-iron sulphide), and arsenopyrite (arsenic-iron sulphide) in quartz veins of shear zones along the margins of these intrusions.

Metavolcanic Rocks: The volcanic rocks that cover over half of your property were formed when chains of volcanoes along the edge of the basin where the greywacke were deposited erupted and expelled volcanic ash and lava. Today, such volcanic chain can be seen in the Caribbean, southwest Pacific and Indonesia. Many of the large gold deposits in the Canadian Shield are found in “greenstone belts”, where rocks from ancient volcanic island chains are preserved along with associated sedimentary and intrusive rocks.

The fault/shear zones:
Some outcrops you mapped contain evidence for shearing and faulting. The rocks looked like they had been broken up, the original minerals had been altered to other minerals (e.g., quartz, calcite, chlorite, epidote, and sulphides) and there were lots of quartz veins.

These are good signs because the warm fluids that moved through the broken rock and altered the minerals can sometimes carry dissolved gold. This gold can be deposited in the surrounding rocks, along with quartz and other sulphide minerals such as pyrite (py), chalcopyrite (cpy), and arsenopyrite (aspy).

Not all quartz veins contain gold.

Glacial direction: The glaciers moved across this area from the northeast to the southwest. The moving ice can break up rocks and carry them up to hundreds of kilometers. It is important to keep this in mind when looking at boulders and geochemistry results.

Information: Geochemistry

2 – 6 ppb: The mud, sand and silt from these locations contain only a few parts per billion (ppb) of gold. This is considered "background", the amount you can expect in samples that have not been enriched in gold.

40+ppb: 40 parts per billion (ppb) gold may not sound like very much, but this is definitely more that the other samples. It is an **anomaly** that should spark your interest! The gold may have washed in from weathered rocks in the area.

g/t grams per tonne: When geologist see results in g/t they start to get excited**.**

Information: Geophysics - EM anomalies:

An EM anomaly can be caused when conductive minerals such as pyrite and arsenopyrite are concentrated in one place. Such sulphide minerals are commonly associated with gold deposits. **Therefore, an EM anomaly might be a good target for diamond drilling if the geology and geochemistry of an area also looks favourable**.

DRILL HOLE RESULT CARDS

Drill Hole A: Sorry, no gold in this drill hole.

You may have been targeting a possible fault, where there are some quartz boulders. However, the rock sample you sent to the SRC Labs doesn't contain anomalous gold and the stream sediment sample values are at background levels. There is no EM anomaly associated with this fault and the quartz boulder has probably been moved there during glaciation.

There are lots of things to think about when considering where to drill. Check those clues from the geophysics and geochemistry more carefully!

Drill Hole B: Congratulations! You find gold in drill hole B!

A location near the margin (edges) of the Diorite/gabbro intrusion, fault zones, good EM conductor, boulders containing gold with sulphides, and a nearby geochemistry anomaly make this the best target on the property.

You drill down 200 metres, and you see lots of good signs in the core. You even see a tiny speck of visible gold (very rare!!). You send core samples to the SRC Labs to be assayed. Some of the sections contain up to 17 grams of gold per tonne (0.5 ounces per ton), a promising sign.

It will take many more drill holes, perhaps hundreds, before the company will know if there will ever be a mine here. Lots of drill holes are needed to determine the amount of gold, and the size and shape of the ore body, if there is one.

Drill Hole C: Sorry, no gold in this drill hole.

You may have been targeting the EM anomaly but you drill down 200 metres and don't hit anything of great interest. The hole is located at the contact of the metasedimentary and metavolcanic rocks (at the change of rock types). The EM anomaly is probably caused by the difference in the electrical characteristics of the two rock types. Gold is found in the Diorite/Gabbro. The quartz boulder although anomalous has been moved by the glacier.

Check the clues from the geology and geochemistry again!

Drill Hole D: Sorry, no gold in this drill hole.

You may have chosen this site because it is near a strong gold anomaly, but the gold in the stream sediment and the quartz boulder have most likely been transported to this location by stream flow or by glaciers. Gold is found in the Diorite/gabbro rocks.

Check the clues from the geology and geophysics more carefully!

SASKATCHEWAN MINING DOLLARS (Print $165,000 for each group)

Bounty Deposit – Mouse Lake Area
Saskatchewan
73P – 07

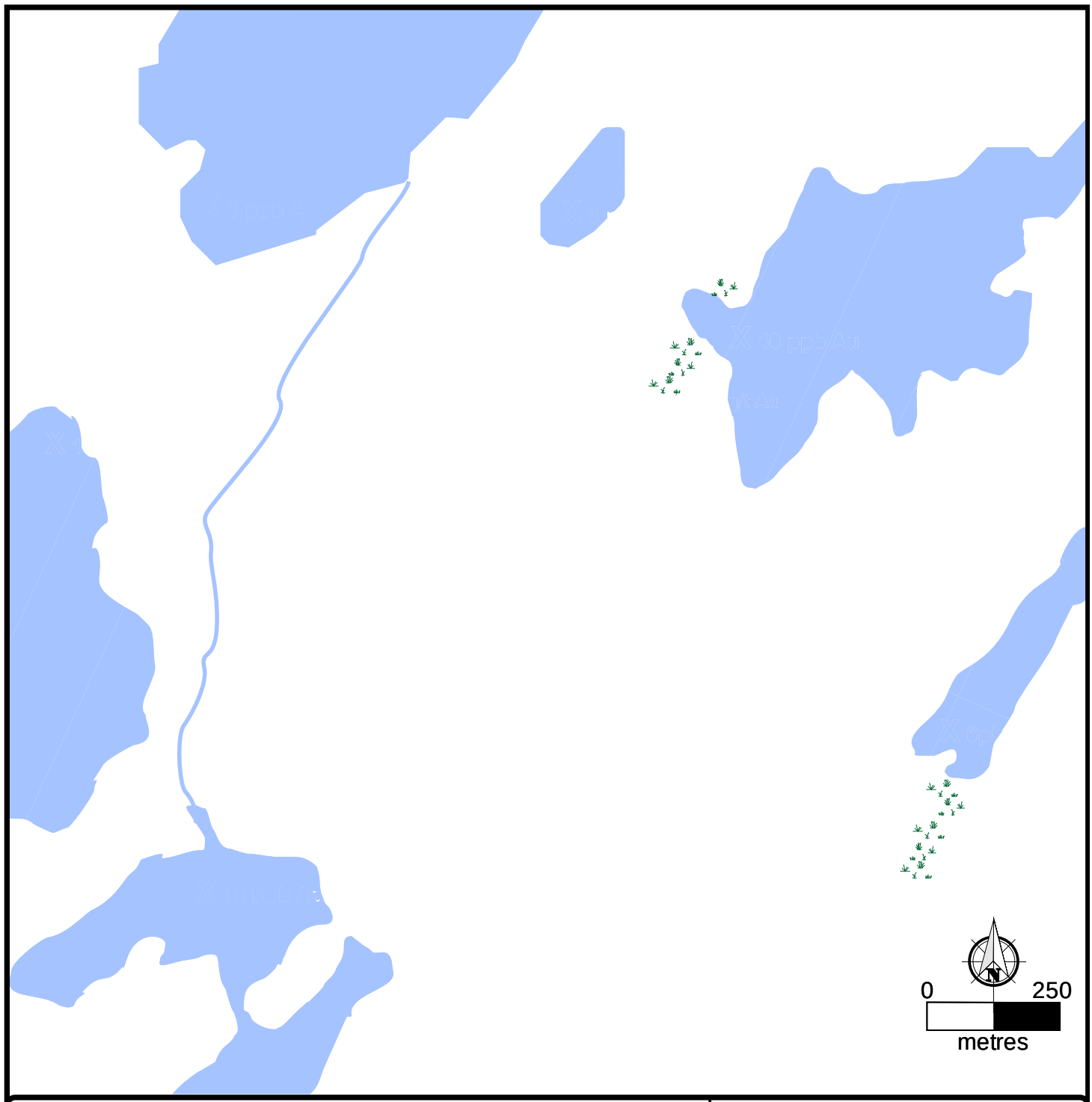
Summer Exploration Summary

Golden Goose Resources Inc.

Authors: R. U. Orr P. Geol (Professional Geologist)
G. F. Issacs G.I.T (Geologist in Training)

September 30, 2014

2 km

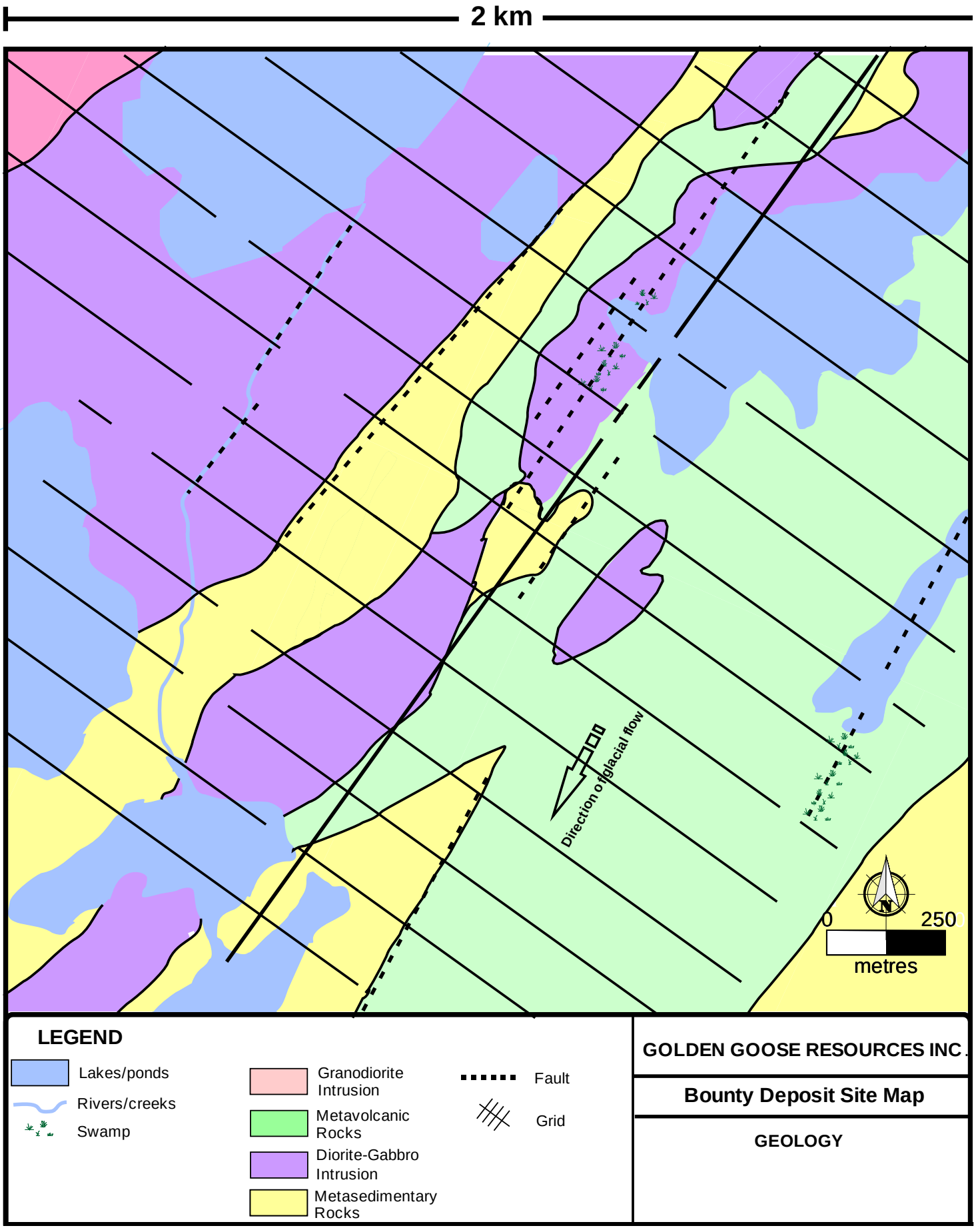


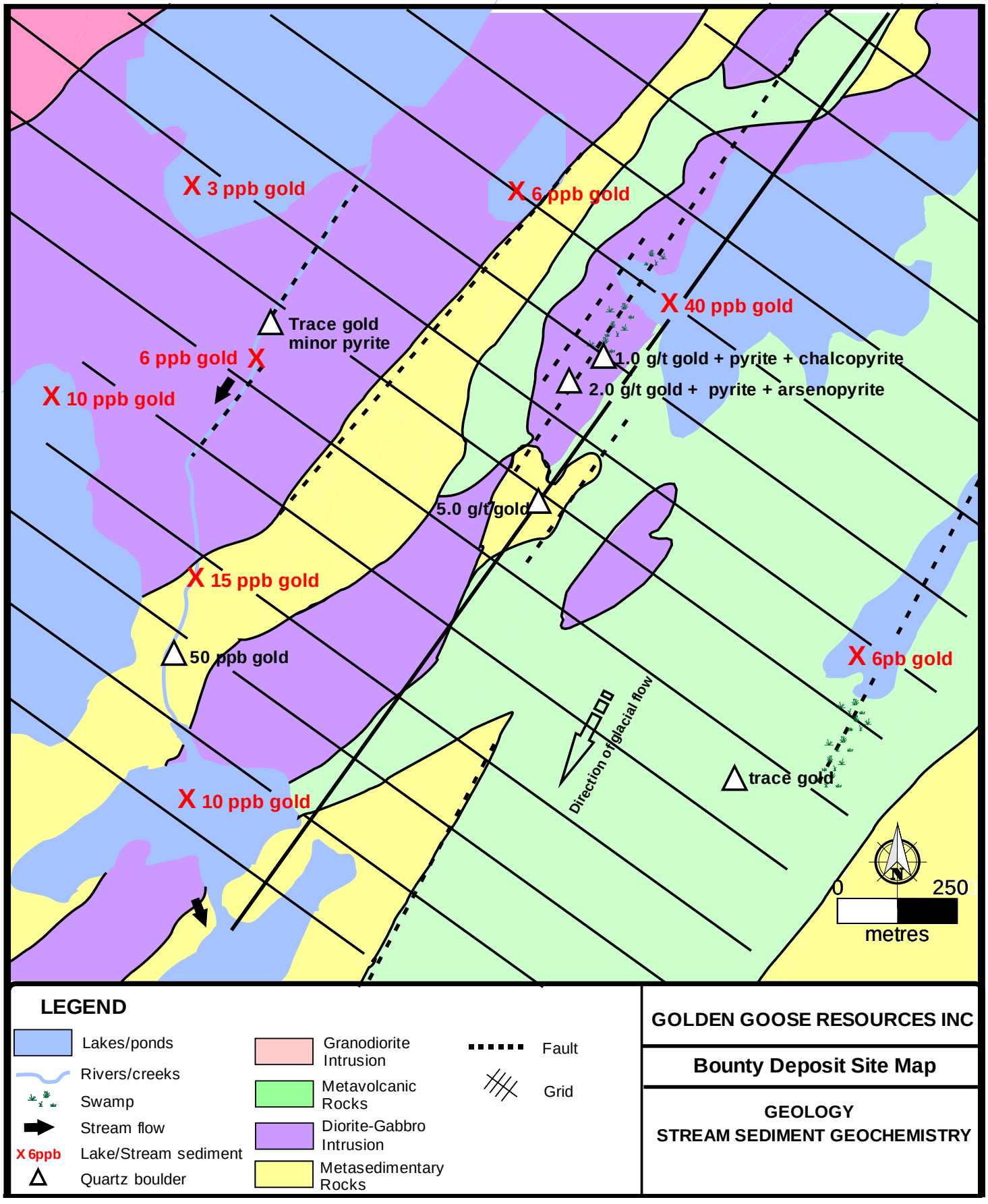
LEGEND

- Lakes/ponds
- Rivers/creeks
- Swamp

GOLDEN GOOSE RESOURCES INC.

Bounty Deposit Site Map


2 km
Direction of glacial flow
N
0
250
metres
LEGEND
Lakes/ponds
Rivers/creeks
Swamp
Granodiorite Intrusion
Metavolcanic Rocks
Diorite-Gabbro Intrusion
Metasedimentary Rocks
Fault
Grid
GOLDEN GOOSE RESOURCES INC.
Bounty Deposit Site Map
GEOLOGY


2 km
X 3 ppb gold
X 6 ppb gold
X 40 ppb gold
Trace gold
minor pyrite
6 ppb gold X
X 10 ppb gold
1.0 g/t gold + pyrite + chalcopyrite
2.0 g/t gold + pyrite + arsenopyrite
5.0 g/t gold
X 15 ppb gold
50 ppb gold
X 6pb gold
Direction of glacial flow
trace gold
X 10 ppb gold
0
250
metres
LEGEND
Lakes/ponds
Rivers/creeks
Swamp
Stream flow
X 6ppb Lake/Stream sediment
Quartz boulder
Granodiorite Intrusion
Metavolcanic Rocks
Diorite-Gabbro Intrusion
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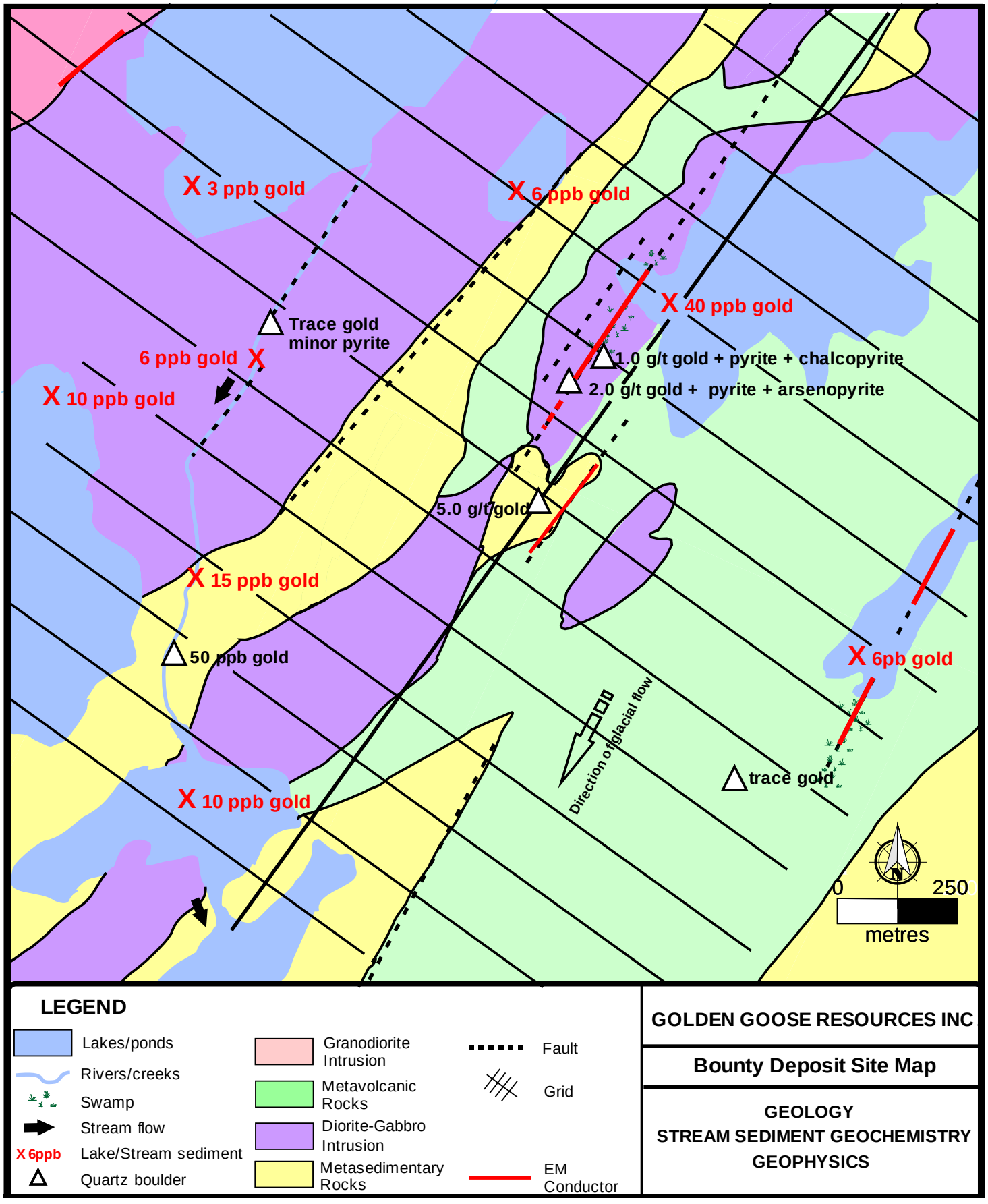
Grid
GOLDEN GOOSE RESOURCES INC
Bounty Deposit Site Map
GEOLOGY
STREAM SEDIMENT GEOCHEMISTRY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EM Conductor
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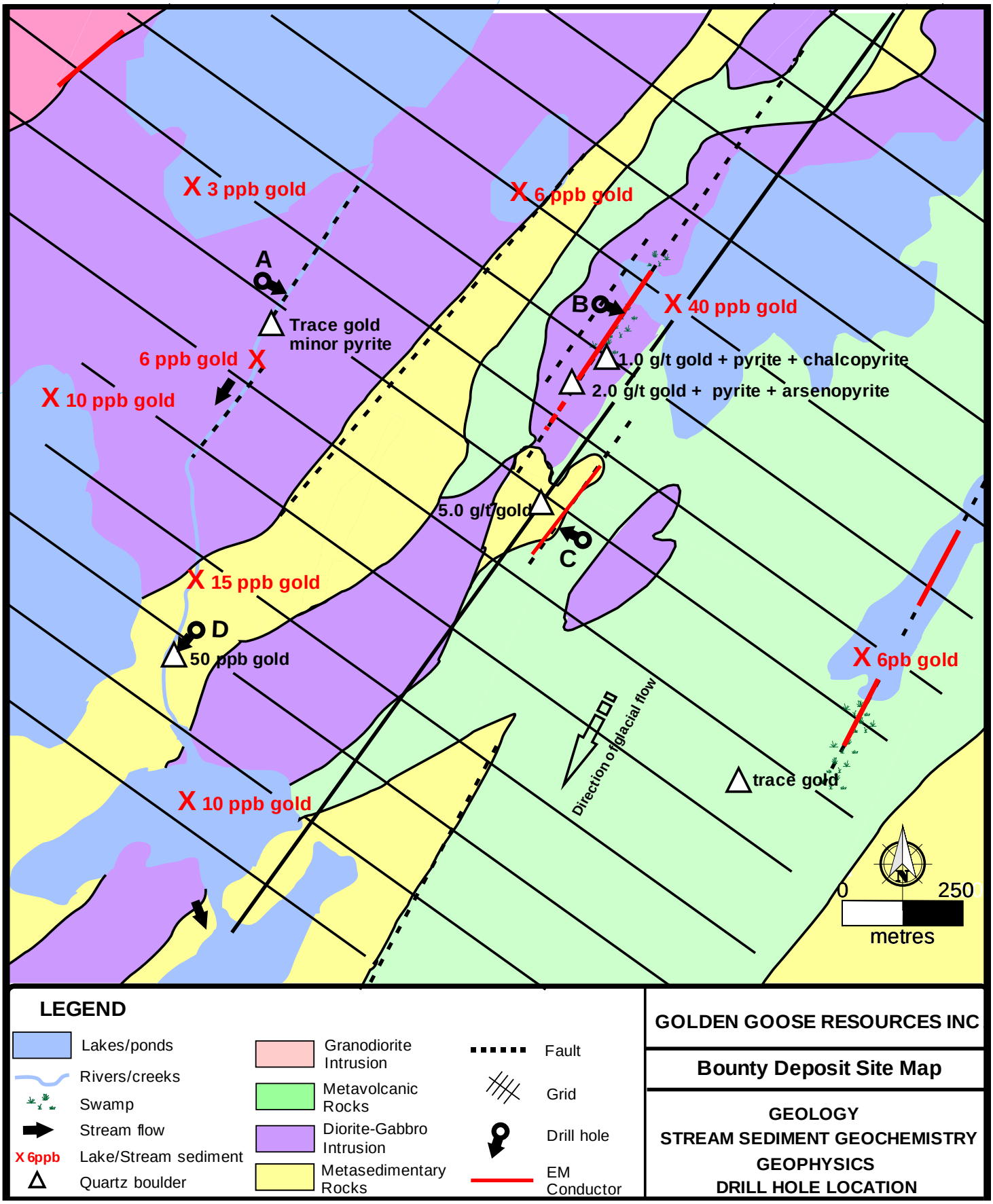
STREAM SEDIMENT GEOCHEMISTRY
GEOPHYSICS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X 40 ppb gold
Trace gold
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2.0 g/t gold + pyrite + arsenopyrite
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DRILL HOLE LOCATION