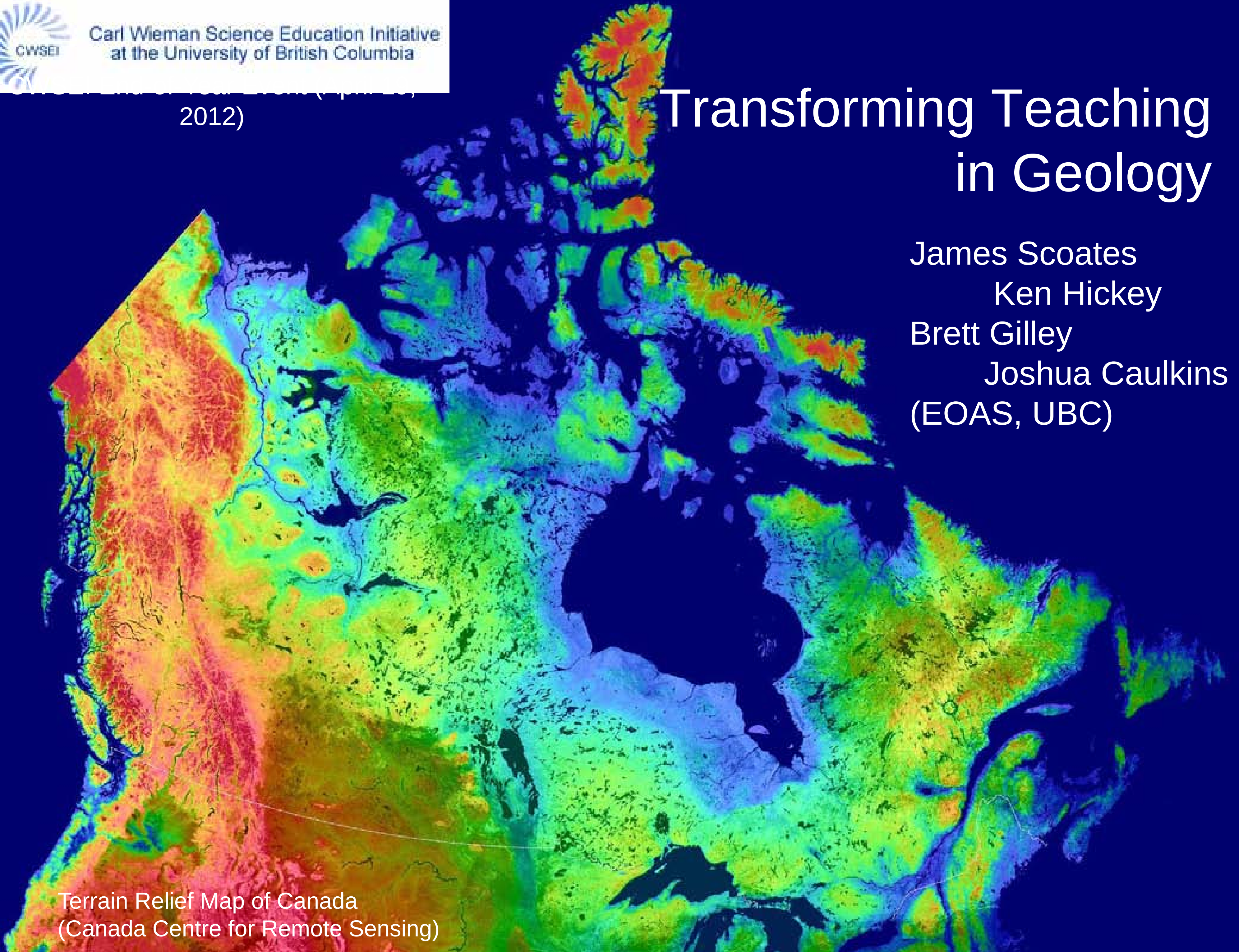
Carl Wieman Science Education Initiative
at the University of British Columbia

2012)

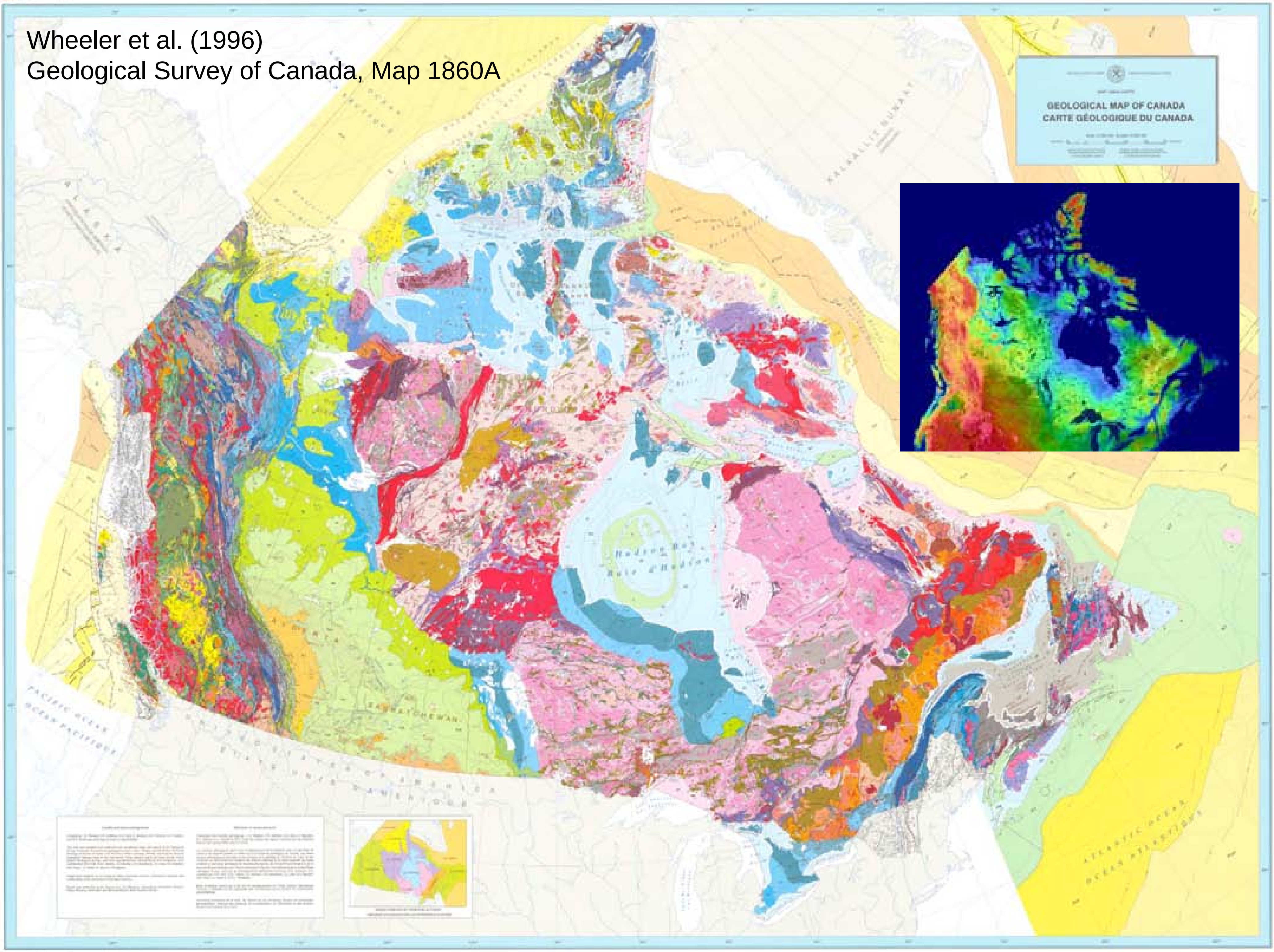
Transforming Teaching in Geology

James Scoates
Ken Hickey
Brett Gilley
Joshua Caulkins
(EOAS, UBC)

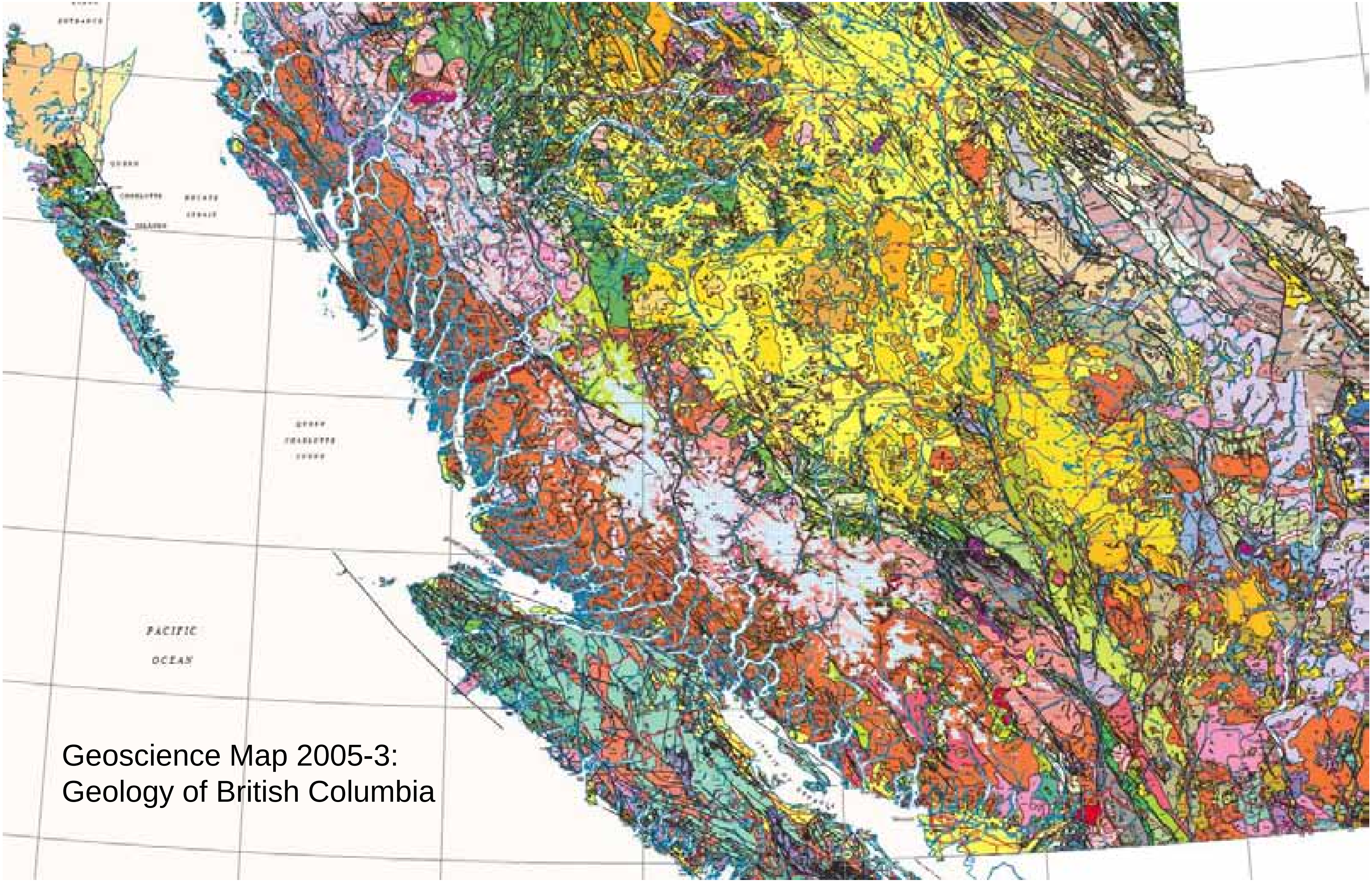


Terrain Relief Map of Canada
(Canada Centre for Remote Sensing)

Wheeler et al. (1996)
Geological Survey of Canada, Map 1860A

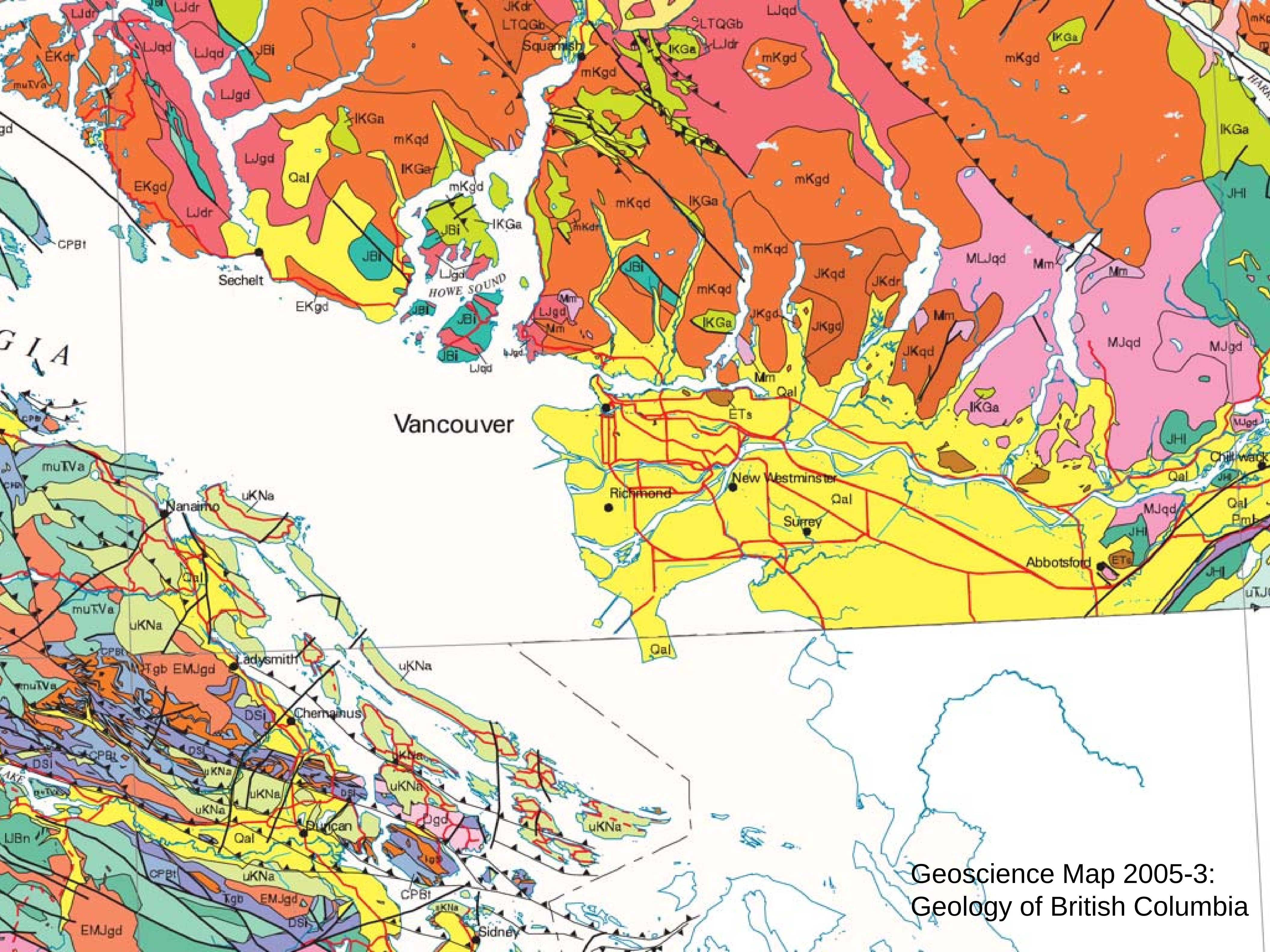


Maps"R"Us



Geoscience Map 2005-3:
Geology of British Columbia

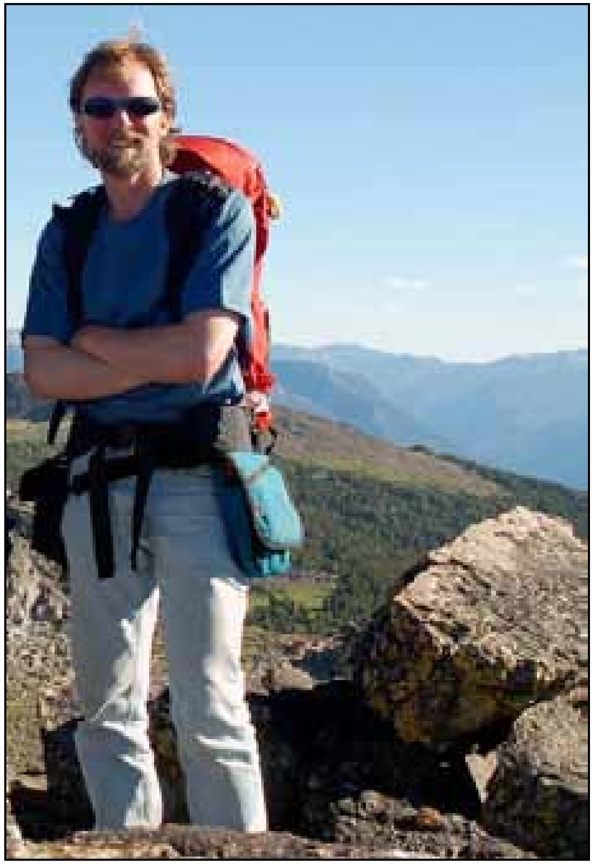
Available as pdf files at: http://www.em.gov.bc.ca/mining/GeolSurv/Publications/GeoMaps/GM2005-3/toc.htm



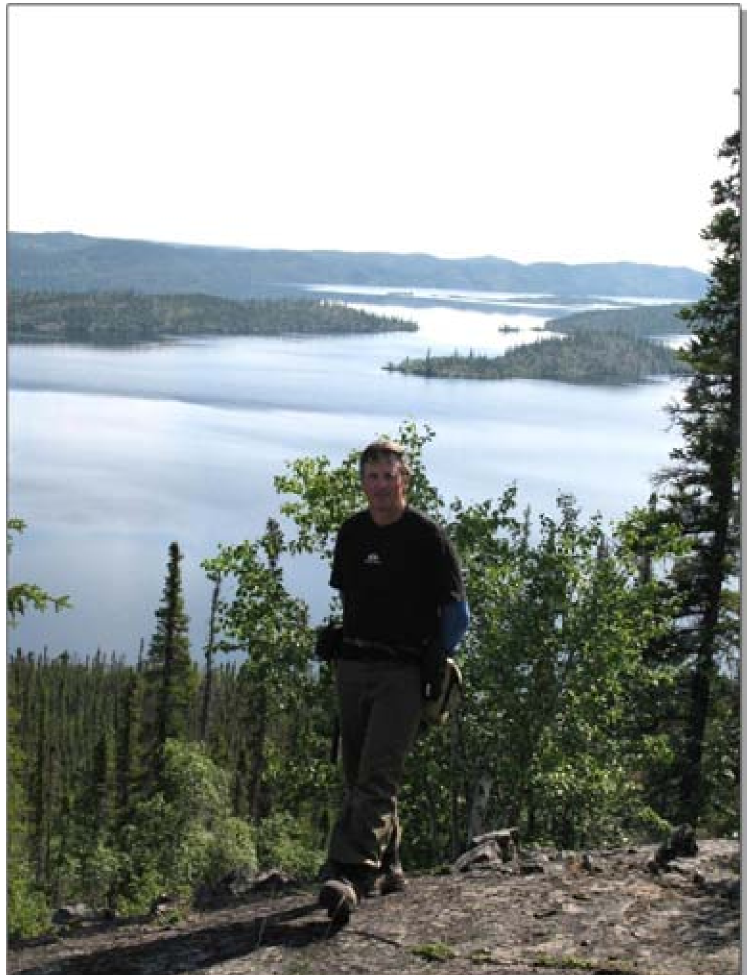
Geoscience Map 2005-3:
Geology of British Columbia

Transformation Team

+ Joshua Caulkins
CWSEI Teaching & Learning Fellow
(Field School)



James Scoates
Professor



Ken Hickey
Assistant Professor

Brett Gilley
CWSEI Teaching & Learning Fellow


STLF
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GEOLOGY OF THE SOLAR SYSTEM

Campuses + | UBC Directories + | UBC QuickLinks +

UBC a place of mind

FACULTY OF SCIENCE

Department of Earth and Ocean Sciences

HOME | ABOUT | PEOPLE | ACADEMIC | COURSES | RESEARCH UNITS | RESOURCES | MYEOS

Course Information

- Non-specialist courses
- Distance Education
- EOSC 100 level
- EOSC 200 level
- EOSC 300 level
- EOSC 400 level
- EOSC 500 & 600
- Alternate Year courses
- All ATSC courses
- All ENVR courses
- ECAC Assistance Centre
- B.A.Sc. Thesis Manual
- Professional Devel. Series
- new Registration Issues

Related Links

- Undergrads in EOS
- EOS Undergrad Program
- Undergrad Brochure

Courses > eosc331

EOSC 331 - Introduction to Mineral Deposits

Course Description

Introduction to economic geology and models related to mineral exploration. Study includes typical deposit types and their plate tectonic setting.

40-50 students/yr
2 hr lecture + 3 hr lab/wk
2 lab sections

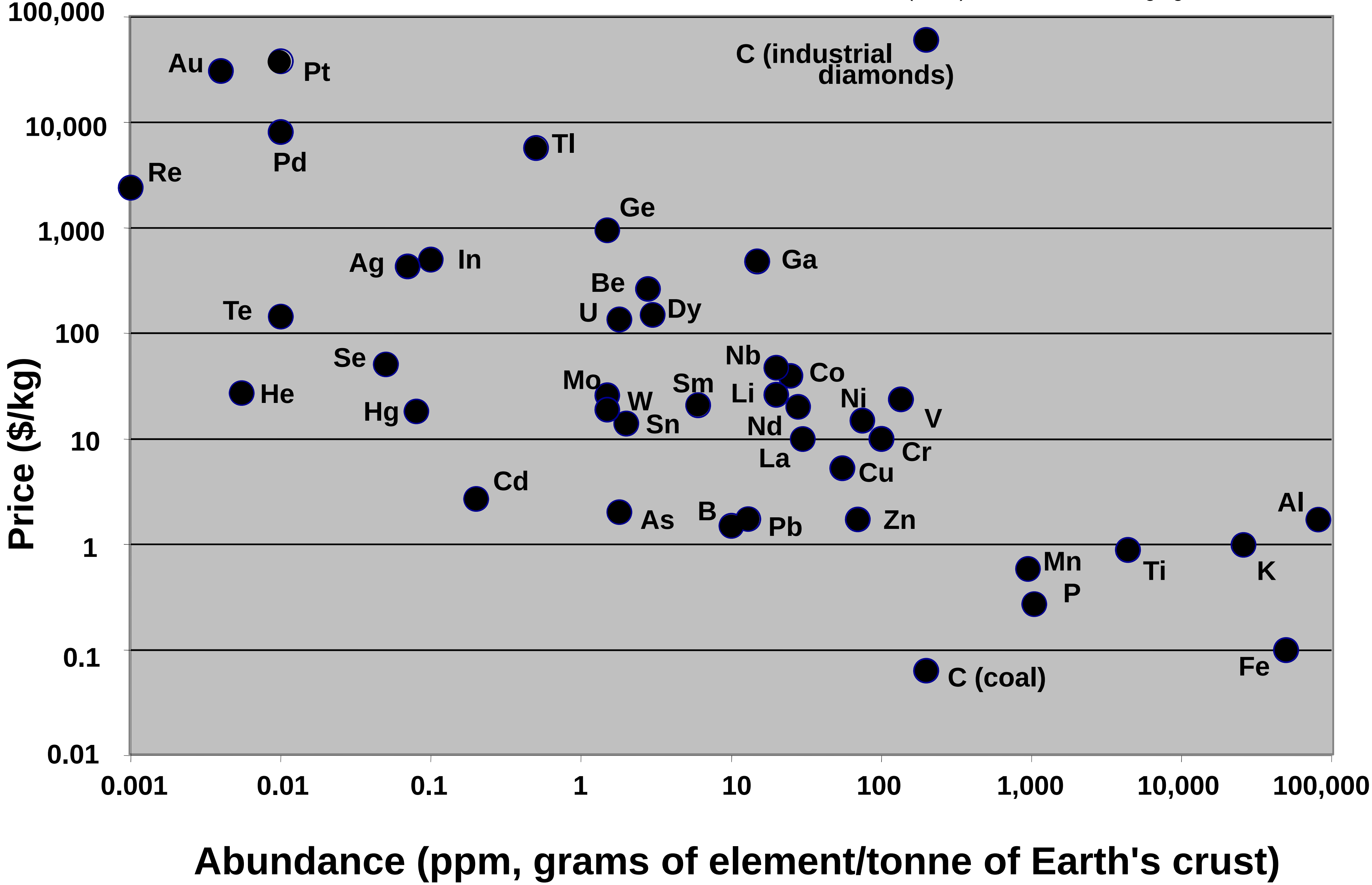
UBC Calendar

For a full listing of course offerings please see the UBC calendar description

Activity: Element Abundance vs. Price

In groups of 4, carefully examine and discuss the graph below – what general relationships do you observe between price and crustal abundance (draw trends) and what are the exceptions (circle commodities)?

Price JG (2010) The World is Changing. SEG Newsletter 82, 12-14.



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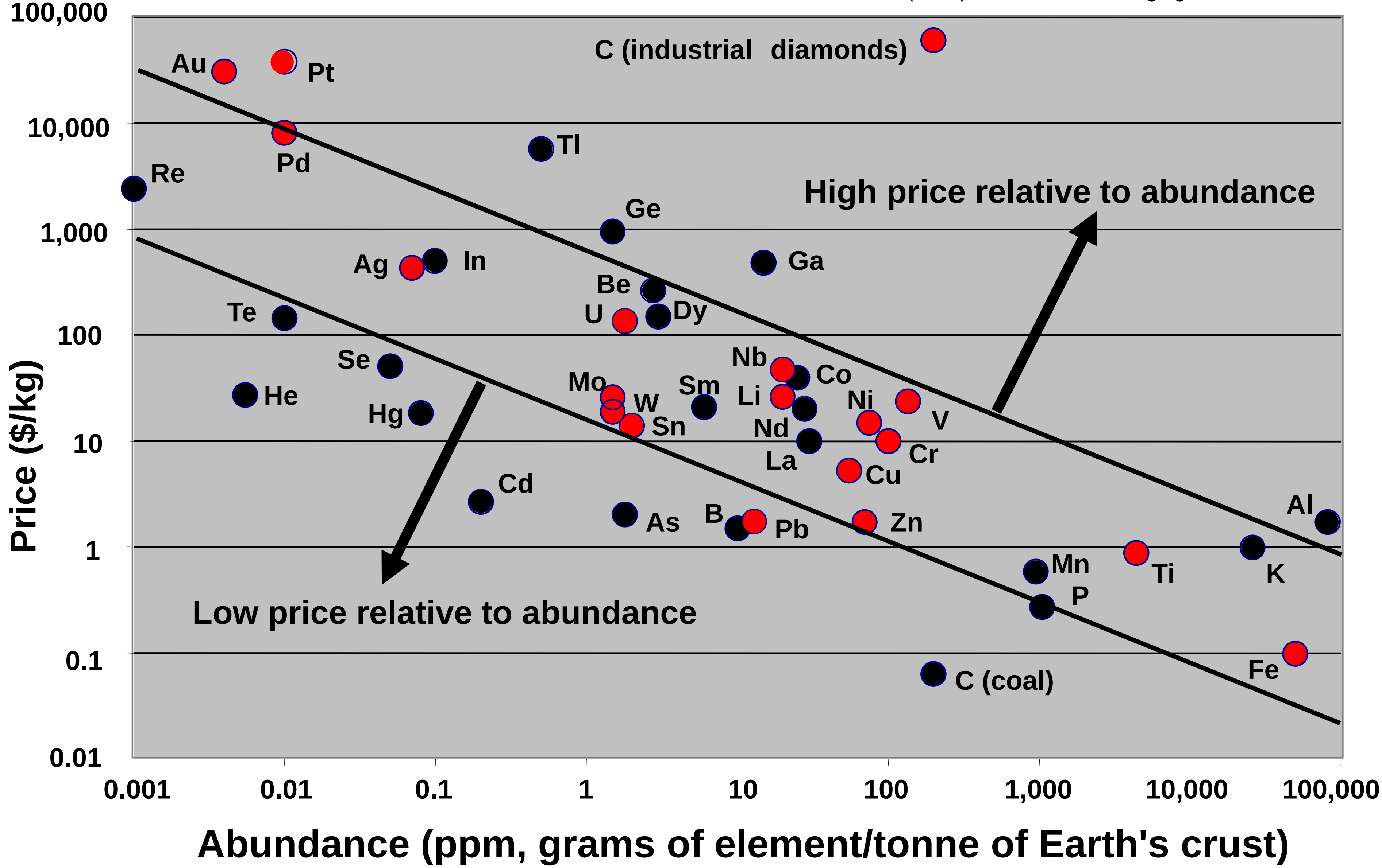

Commodities that are explicitly dealt with in the course

A "rare" find at Thor Lake could save future iPhones

Syenite pegmatite-hosted rare earth element, Zr, Ta and Nb deposit

Claire Orlov and Sara Edith Hoffritz (Group 13, Course EOSC 331)

ABSTRACT

The Thor Lake Rare Metal Deposit is located 100 km south-east of Yellowknife in the Northwest Territories in Canada (figure 1). The deposit contains economic mineralizations of Rare Earth Elements (REEs), as well as other rare metals including zirconium (Zr), tantalum (Ta) and niobium (Nb). Thor Lake is considered particularly important because of its size and enrichment in the rarer and more valuable Heavy REEs (HREEs), and once in production it has the potential to be the second largest REE deposit in the world. The metals sit within pegmatite phases in the nepheline-sodalite syenite of the Nechalacho deposit, which is emplaced in the Thor Lake Syenite. The rare metals were sourced from the crust and transported in solution by magma from the mantle. Fluorine content allowed the metals to be dissolved and transported, but it is unclear whether the fluorine was present in the melt or hydrothermal fluids, or perhaps both. The metals were trapped within the syenite pegmatites as cooling of the melt prompted mineralization, concentrating them in zircon and edialyte. The edialyte was later altered to secondary mineral assemblages when hydrothermal fluids infiltrated the intrusion. The deposit is characterized as a syenite pegmatite-hosted rare earth element, Zr, Ta and Nb deposit.

Figure 1: Location of Thor Lake (source: Avalon Rare Metals)

The Rare Earth Elements:
HREEs: Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu,
LREEs: La, Ce, Pr, Nd, Pm, Sm
Other Rare Metals: Zr, Nb, Ta, Li, Rb ,Cs, Hf, Ga, Ge, In, Sn

Figure 2: Area geology and location of zones (source: Avalon Rare Metals)

Figure 3: Core The Nechalacho Deposit (source: Avalon Rare Metals)

BACKGROUND GEOLOGY

Local and Regional Geology:

The Thor Lake rare metal deposit is hosted in the peralkaline granite-syenite pluton of the 2.15 Ga Blatchford Lake Intrusive Complex, which intruded the Archean metasedimentary rocks of the southern Slave Province. The Thor Lake syenite (figure 2) is emplaced within the peralkaline Grace Lake granite, with a body of nepheline-sodalite syenite located within and below. The Thor Lake deposit contains a variety of rock types including syenites, gabbros, granites, and cross-cutting pegmatite phases in which the rare metal mineralization occurs (figure 3).

Mineral	Chemical formular	Type	Zone	Ore
Zircon	$ZrSiO_4$	Both	Both	Zr, HREE
Fergusonite	$(Ce,La,Nd,Y)NbO_4$	Hydrothermal	Both	HREE, Nb, Ta
Fe-columbite	$FeNb_2O_6$	Hydrothermal	Both	Nb, Ta
Bastnaesite	$(Ce,La,Y)F(CO_3)$	Hydrothermal	Both	LREE
Synchysite	$Ca[Y,Ce,La,Nd,Gd][F(CO_3)_2]$	Hydrothermal	Both	LREE
Allanite	$(Ce,Ca,Y)_2(Al,Fe)_3(SiO_4)_3(OH)$	Hydrothermal	Both	LREE
Monazite	$(Ce,La,Th)PO_4$	Hydrothermal	Upper	LREE
Columbite	$(Fe,Mn)(Nb,Ta)_2O_6$	Magmatic	Basal	Nb, Ta
Eudialyte	$Na_{15}Ca_6(Fe,Mn)_3Zr_3(Si_{25}O_{73})(O,OH,H_2O)_3(OH,Cl)_2$	Magmatic	Basal	REE
Albite	$Na(AlSi_3O_8)$	Alteration	Upper	
Orthoklas	$K(AlSi_3O_8)$	Alteration	Upper	
Quartz	SiO_2	Alteration	Upper	
Biotite	$K_2(Mg,Fe)_{6-4}(Fe,Al,Ti)_{0-2}[Si_{6-5}Al_{2-3}O_{20}](OH,F)_4$	Alteration	Upper	
Magnetite	$Fe^{2+}Fe_2^{3+}O_4$	Alteration	Upper	
Fluorite	CaF_2	Alteration	Upper	
Calcite	$CaCO_3$	Alteration	Upper	

Table 1: Ore and alteration minerals in the Nechalacho Deposit

Ore Mineralogy:

The deposit contains economic mineralizations of REEs, zirconium (Zr), tantalum (Ta) and niobium (Nb). HREEs are present in zircon and fergusonite, LREEs are found in bastnaesite, synchysite, allanite and monazite (table 1). Major amounts of Zr are found in zircon, while Nb and Ta are hosted in ferrocolumbite and fergusonite (figure 4).

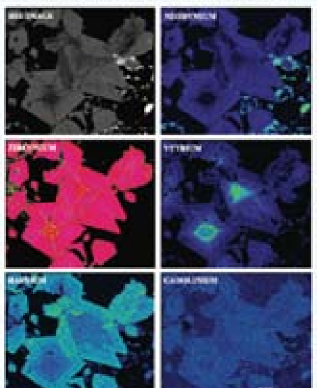

Figure 4: Electron microprobe element maps of a zircon crystal showing distribution of Nd, Zr, Y, Hf and Gd (Source: Sheard, 2010)

Alteration and Mineralization:

The region has been subjected to hydrothermal alteration. Late-stage volatile and incompatibl element enrichment promoted processes of albitization, silicification, microclinization and carbonation (figure 7.4). It is divided into five distinct zones (figure 2) of mineralization separated by vertical faults: the Nechalacho deposit (Lake Zone), North T, South T, S and R Zones, although only the Nechalacho and North and South T Zones are of economic interest.

The Nechalacho deposit, hosted in the nepheline-sodalite syenite, is the largest mineralization zone, and is particularly important because of its enrichment in HREEs. It contains two main sub-horizontal layers of REE mineralization, forming the Upper and Basal Zones. Ratios of HREE to LREE oxides increase with depth, with proportions in the Upper Zone typically 7-10%, while the Basal Zone has an average over 20% and can reach as high as 50%.

CONTROVERSIES

In the early 1990s China increased mining of rare metals, and other countries soon reduced or stopped production as they could not compete with China's low prices. As a result, China currently has a monopoly on REEs as it controls production of 95% of the world's supply. World demand for rare metals has increased significantly within the last few years, and is predicted to continue the increasing trend, rising to 200,000 tonnes by 2015 (figure 5).

Elements	Application	Demand/Users
RARE EARTH ELEMENTS		
Nd, Pr, Sm, Tb, Dy	Permanent Magnets	Computer hard drives, consumer electronics, hybrid vehicle electric motors, wind turbines, cordless power tools, Magnetic Resonance Imaging, headphones, microphones
La, Ce, Pr, Nd	Batteries	Hybrid vehicle batteries, hydrogen absorption alloys for re-chargeable batteries
Eu, Y, Tb, La, Ce	Phosphors	LCDs, LEDs, energy efficient fluorescent lamps, computer monitors, lighting, radar, televisions, x-ray intensifying screens, electronic thermometers, pigments, superconductors, smartphones(iPhones), tablets (iPads)
La, Ce, Pr, Nd	Fluid Cracking Catalysts	Petroleum refining and production
Ce, La, Nd	Polishing powders	Televisions, computer monitors, mirrors, silicon chips (in nano-particulate form)
Ce, La, Nd	Automotive catalytic converters	Meeting tighter NO_x and SO_2 standards
Ce, La, Nd	Glass additive	Cutting down transmission of UV light, increasing glass refractive index for digital camera lenses, solar panels
Er, Y, Tb, Eu	Fibre optics	Signal amplification
OTHER RARE METALS		
Zr	Ceramics, foundry application, opacifiers, refractories, abrasives, chemicals, metal alloys and welding rod coatings	nuclear energy and chemical process industries, dentistry, jewellery, deodorants
Ta	Alloys, compounds, fabricated forms, ingot, metal powder, electronic capacitors, glass additive	Camera lenses, cutting tools, Miniaturization of electronics for: aviation and automotive electronics, pagers, blackberries, personal computers, mobile phones, radios
Nb	Ferroniobium, metal and alloys, superconducting magnets, glass additive	Steel industry, aerospace industry, magnetic resonance imaging, corrective glasses, pacemakers

Table 2: Uses of Rare Earth Elements and other Rare Metals (modified from Cox et al. 2010)

At the end of 2010, China dramatically reduced its exports by over 40%, causing the price of REEs to skyrocket and creating renewed efforts to develop resources outside of China. The sudden reduction in supply has created fears that developments in technology, particularly in green energy, will be held back (table 2).

In light of this current controversy, the Thor Lake deposit is particularly important because of its size and its enrichment in the rarer and more valuable HREEs. Once in production it will likely by the second largest REE deposit in the world and the third largest contained Nb deposit.

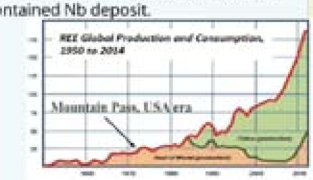

Figure 5: Relationship between global demand and production of rare earth elements showing China's dominance of production (source: Avalon Rare Metals)

MINING

Due to the potential for extensive surface disturbance, as well as the relatively low ore grades close to the surface, open pit mining has been rejected in favour of underground mining methods. The Project's Life of Mine Plan indicates the resource will be mined over 18 years, starting in 2014, with expected production of 151,257t of TREO, 305,938t of ZrO_2, 27,374t of Nb_2O_5 and 1,549t of Ta_2O_5, based on an initial rate of 1,000 tonnes/day increasing to 2,000 tonnes/day with 4 years.

The Indicated Mineral Resources for the Nechalacho deposit indicate 21.37 million tonnes total rare element oxides (TREO), at 1.82% in the Basal Zones and 1.45% in the Upper Zone, while Inferred Mineral Resources indicate 175.93 million tonnes with an average TREO grade of 1.43% (figure 6). Using predicted commodity prices (US\$21.94/kg TREO, US\$3.77/kg ZrO_2, US\$45/kg Nb_2O_5 and US\$130/kg Ta_2O_5), the Thor Lake project is expected to generate an estimated C\$536 per tonne of ore mined, or US\$11.91 per kg of product, in net revenue.

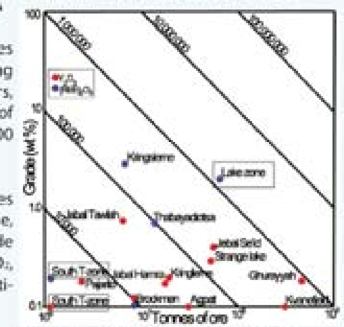

Figure 6: Grade Tonnage diagramme (source: Richardson and Birkett, 1996)

SOURCE-TRANSPORT-TRAP

Source

Magma: melting of undepleted, metasomatically enriched mantle
Fluids: F and CO_2 rich hydrothermal fluids from magmatic source
Metals: continental crust partially melted by magma

Transport

The metals were predominantly transported in solution by the magma body as it moved through the crust. Fluorine in the magma made the metals soluble, providing a mechanism for transportation. As the magma travelled upwards it underwent severe fractionation, preferentially concentrating the incompatible non-volatile elements (the metals) in the residual melt. The layered zones in the deposit reflect several phases of magma injection. After the metals were emplaced by the magma, they were remobilized and concentrated by hydrothermal fluids. The LREE are more stable at elevated temperatures which is why they were remobilized in preference to the HREE. Metals were also potentially transported to the site through scavenging by postmagmatic metasomatic fluids that later infiltrated the intrusion (figure 7).

Trap

A buildup As the magma cooled fluorite mineralization occurred, stripping fluorine from the melt, causing the metals to lose their solubility. The metals were initially trapped in-situ in disseminated grains of edialyte and zircon. Hydrothermal fluids then remobilized the metals into new mineral assemblages, including biotite, magnetite, and albite, both enriching and depleting REEs locally.

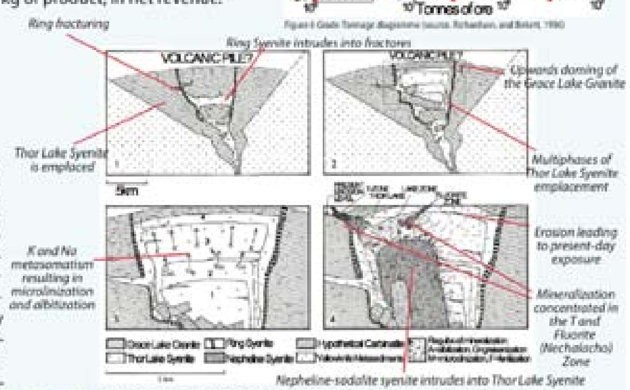

Figure 7: Schematic diagram showing stages in the development of the Thor Lake Deposit (source: Pinckston and Smith, 1995)

References

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Cox, J.J., Moreton, C., Goode, J.R. and Hains, D.H. 2010. Technical Report on the Thor Lake Project, Northwest Territories, Canada. NI 43-101 Report. Scott Wilson Mining. 313 pages

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Pinckston, D.R. and Smith, D.G.W. 1995. Mineralogy of the Lake Zone, Thor Lake Rare-Metals Deposit, NWT, Canada. Canadian Journal of Earth Science, vol (32), p519-532

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Smith, D.G.W., de St. Jorre, L., Reed, S.J.B. and Long, J.V.P. 1991. Zonally metamictized and other zircons from Thor Lake, Northwest Territories. Canadian Mineralogist, vol (29), p. 301-309

Stratfor Global Intelligence, October 12th 2010. Special Report: China and the Future of Rare Earth Elements. [Online] Downloaded at: http://www.stratfor.com/memberships/173275/analysis/20101008_china_and_future_rare_earth_elements [Accessed on: 14/11/2011]

USGS, 2011. Niobium, Rare Earths, Tantalum, Zirconium and Hafnium. U.S. Geological Survey, Mineral Commodity Summaries, January 2011, p. 110-11, 128-29, 162-63, 180-81. [Online] Downloaded at: http://minerals.usgs.gov/minerals/pubs/commodity/ [Accessed on: 13/11/2011]

Marks: 5 pts. for the Question+Answer worksheet, 5 pts. for Self-Assessment Rubric

POSTER #:

TECHNICAL QUESTION (Source-Transport-Trap):

ANSWER:

Marks: 5 pts. for the Question+Answer worksheet, 5 pts. for Self-Assessment Rubric

POSTER #:

TECHNICAL QUESTION (Source-Transport-Trap):

ANSWER:

Marks: 5 pts. for the Question+Answer worksheet, 5 pts. for Self-Assessment Rubric

POSTER #:

TECHNICAL QUESTION (Source-Transport-Trap):

ANSWER:

POSTER #:

Mineral Deposit Poster Forum


#67
Pb-Zn Ores at Navan: A Classic "Irish-type" SEDEX Deposit
Goldfield Epithermal Au-Ag

Course Information

- Non-specialist courses
- Distance Education
- EOSC 100 level
- EOSC 200 level
- EOSC 300 level
- EOSC 400 level
- EOSC 500 & 600
- Alternate Year courses
- All ATSC courses
- All ENVR courses
- ECAC Assistance Centre
- B.A.Sc. Thesis Manual
- Professional Devel. Series
- new Registration Issues

Related Links

- Undergrads in EOS
- EOS Undergrad Program
- Undergrad Brochure

Courses > eosc424

EOSC 424 - Advanced Mineral Deposits

Course Description

Advanced concepts in the processes that lead to the formation of mineral deposits. Introduction to the study of ore minerals using reflected light microscopy.

30-40 students/yr
2 hr lecture + 3 hr lab/wk
2 lab sections

UBC Calendar

For a full listing of course offerings please see the UBC calendar description

Learning Goals

To provide a framework for examining processes in the concentration of metals in the Earth's crust and for assessing mineral potential in a given region based on available geologic information and constraints.

In this course, we will work through 3 different modules to establish the frameworks noted above:

Q1: What part of this system was relatively straightforward to draw and label?

Q2: What part of this system was challenging to draw and label?

Q1: What part of this system was relatively straightforward to draw and label?

Q2: What part of this system was challenging to draw and label?

Q1: What part of this system was relatively straightforward to draw and label?

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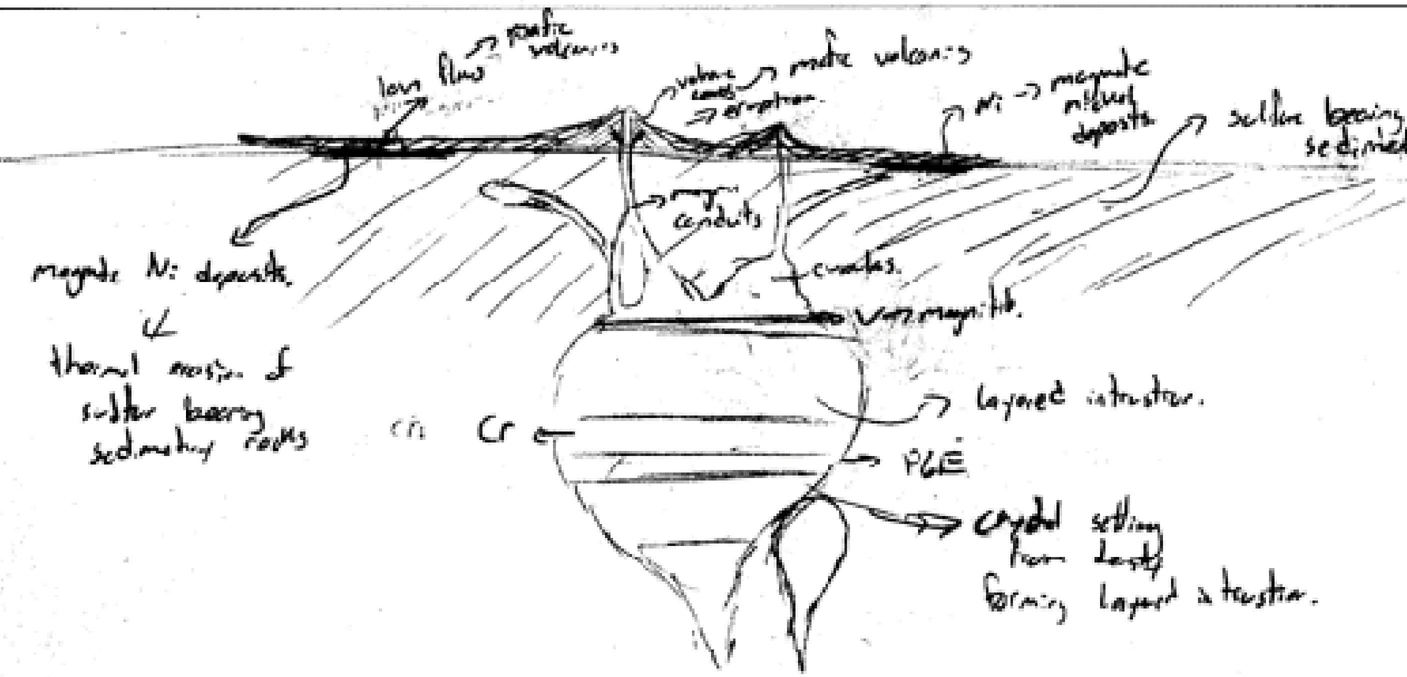
Q1: What part of this system was relatively straightforward to draw and label?

Q2: What part of this system was challenging to draw and label?

EOSC424: Advanced Mineral Deposits **Student Name:**

Lecture 01 – Pre-course Assessment Activity: Magmatic & Hydrothermal Ore-forming Systems and Processes

PART 1: Magmatic Ore-forming System (time ~10-15 minutes): in the box below, sketch a schematic magmatic ore-forming system involving magma conduits, a layered intrusion, and mafic volcanic rocks. Pay attention to approximate **scale**, but don't worry about tectonic setting. Carefully label where different deposit types could be found and highlight specific processes involved in helping to make these deposits. Do NOT use any additional resources, except your pen and your acquired knowledge of mineral deposit formation!



Jan. 4, 2012
First Day of Class

Q1: What part of this system was relatively straightforward to draw and label?

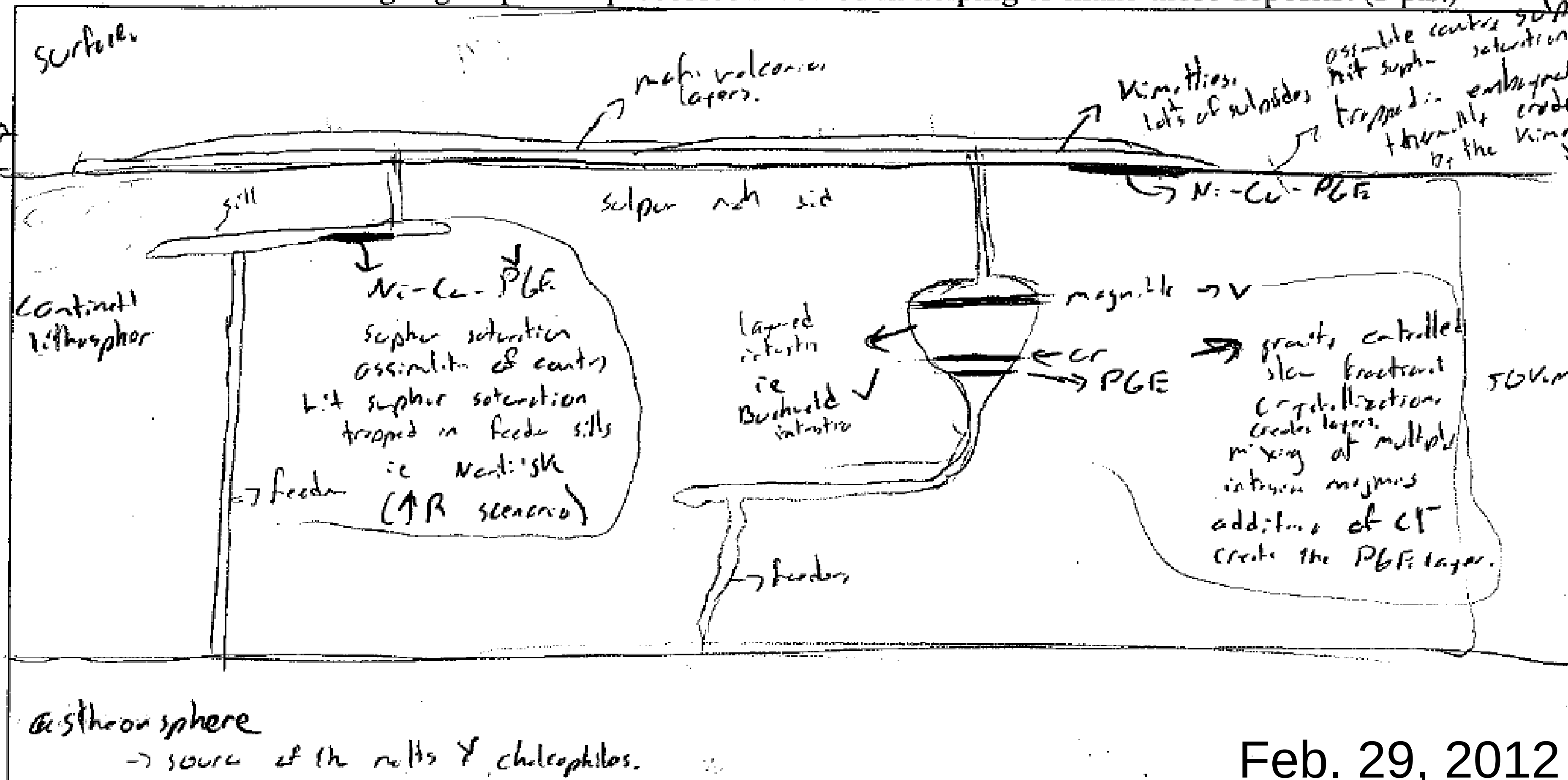
magmatic Ni deposits

Q2: What part of this system was challenging to draw and label?

Scale

Name: Student #: 62594088

2. In the box below, sketch a schematic magmatic ore-forming system involving magma conduits, a layered intrusion, and mafic volcanic rocks. Pay attention to scale. Carefully label where different deposit types could be found and highlight specific processes involved in helping to make these deposits. (5 pts.)



Feb. 29, 2012

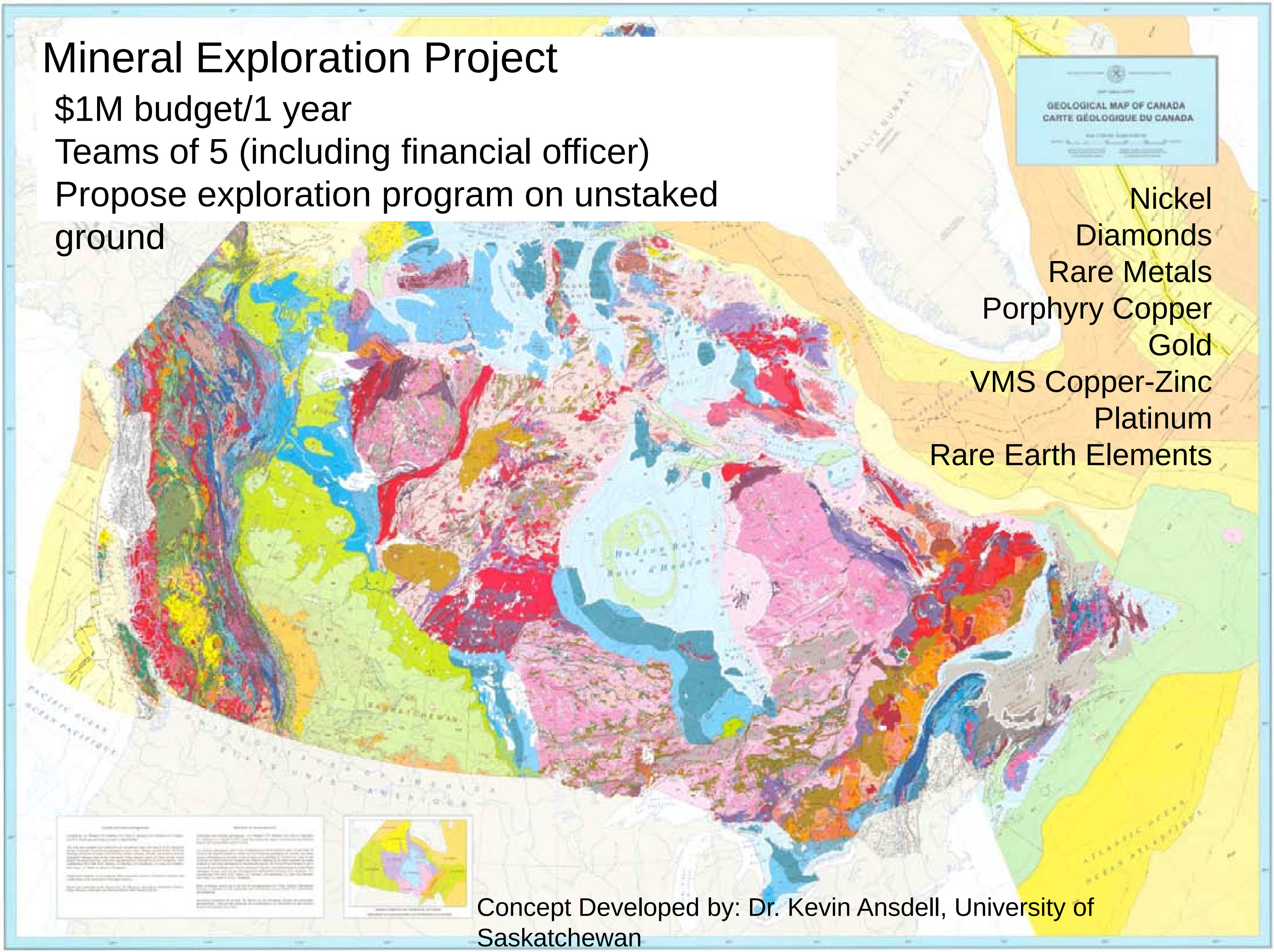
Midterm

Q: What part of this system was still challenging to draw?

the scale

Mineral Exploration Project

- $1M budget/1 year
- Teams of 5 (including financial officer)
- Propose exploration program on unstaked ground



Nickel
Diamonds
Rare Metals
Porphyry Copper
Gold
VMS Copper-Zinc
Platinum
Rare Earth Elements

Concept Developed by: Dr. Kevin Ansdell, University of Saskatchewan

Minex Project Introductory Activity

Minex Project Introductory Activity – The Movie

QuickTime™ and a
decompressor
are needed to see this picture.

Minex Project Presentations


BANK OF KEN&JAMES*
6339 STORES ROAD
VANCOUVER, B.C. V6T-1Z4
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DATE: APRIL 4, 2012
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THE ORDER OF: GROUP # 5
GOLD
$1,000,000
THE SUM OF One Million DOLLARS
AUTHORIZED SIGNATURE(S)
0100 111222333 444555
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EOSC 328 - Field Geology

Course Description

Recording and processing geological data in the field. Held within the three weeks following April examinations after third year. A special fee is to be paid by January 31.

~40 students/yr
2 day Bootcamp at UBC
18 days mapping, Oliver, BC

UBC Calendar

For a full listing of course offerings please see the UBC calendar description

Learning Goals

Course Information

- Non-specialist courses
- Distance Education
- EOSC 100 level
- EOSC 200 level
- EOSC 300 level
- EOSC 400 level
- EOSC 500 & 600
- Alternate Year courses
- All ATSC courses
- All ENVR courses
- ECAC Assistance Centre
- B.A.Sc. Thesis Manual
- Professional Devel. Series
- new Registration Issues

Related Links

- Undergrads in EOS
- EOS Undergrad Program
- Undergrad Brochure


EOSC 328 Field Geology
Welcome to BOOTCAMP!
"Where the Field Begins"
UBC
What: 2 Days of Intense Geo-Training!
When: Sat-Sun, April 30-May 1, 2011
Where: Outdoors + in EOS Main
First Meeting: EOS Main Room 121

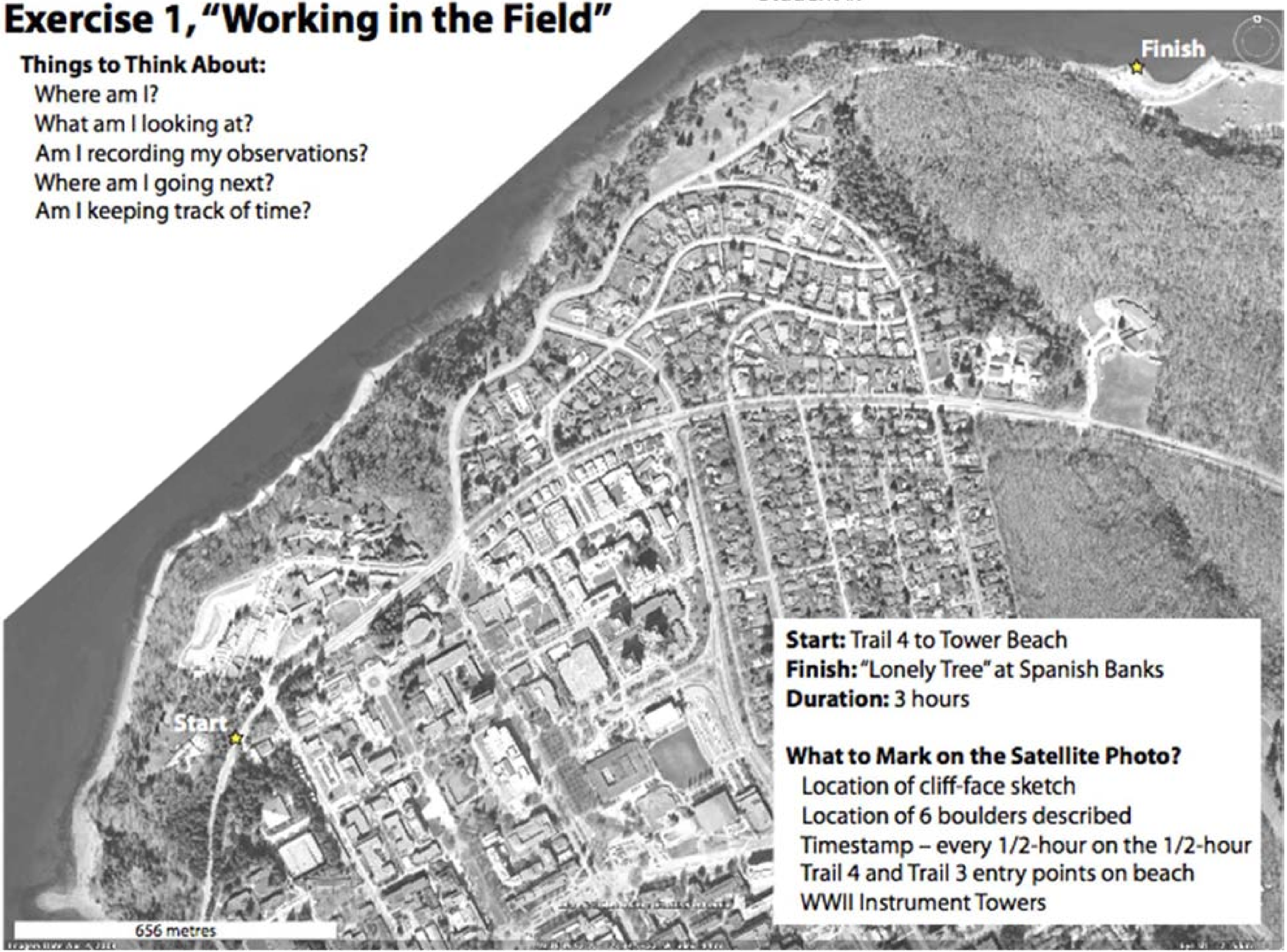
EOSC 328: Field Geology – Bootcamp
Exercise 1, "Working in the Field"

Name:
Student #:

Date:

Things to Think About:

Where am I?
What am I looking at?
Am I recording my observations?
Where am I going next?
Am I keeping track of time?



Start: Trail 4 to Tower Beach
Finish: "Lonely Tree" at Spanish Banks
Duration: 3 hours

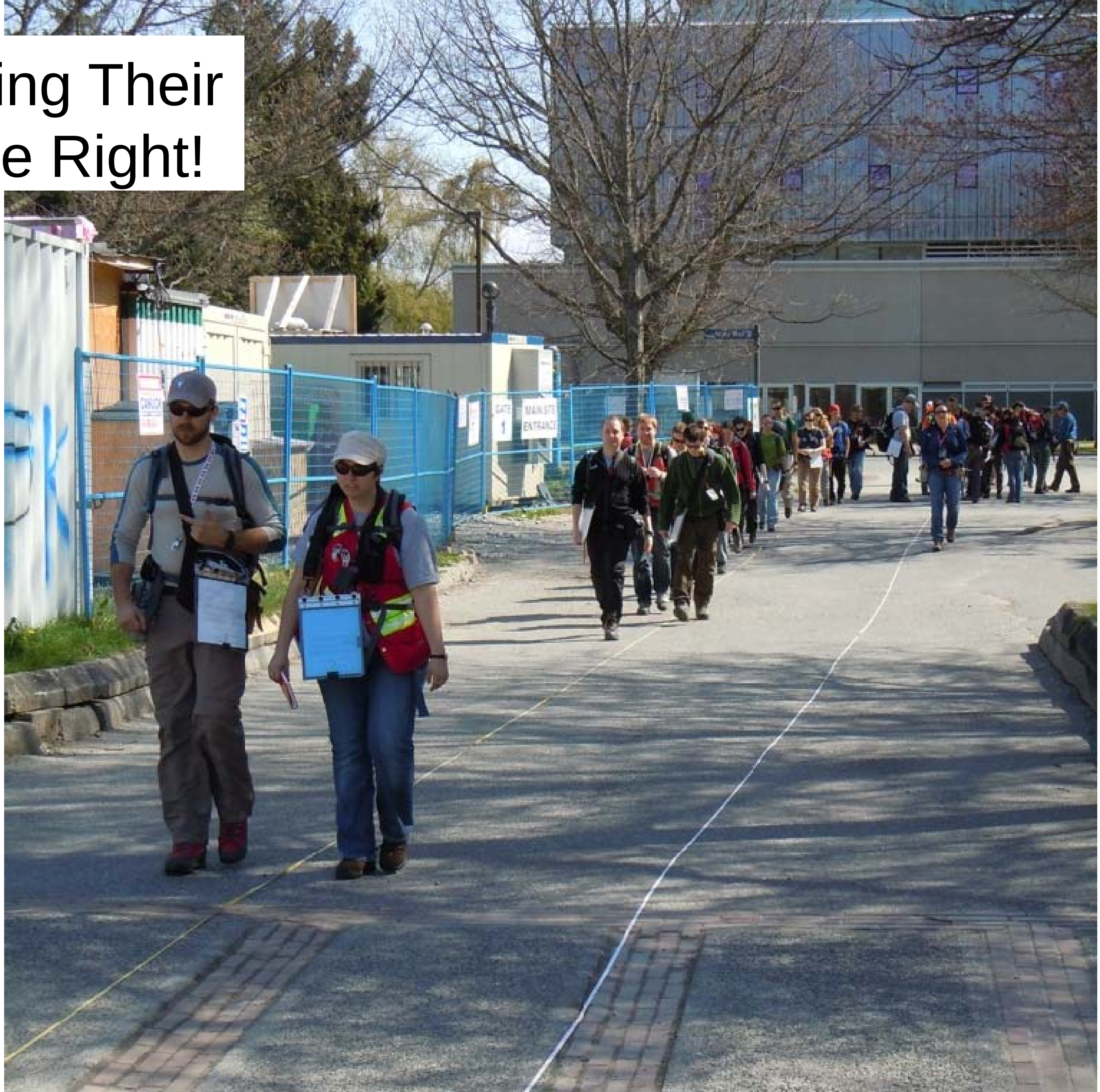
What to Mark on the Satellite Photo?

Location of cliff-face sketch
Location of 6 boulders described
Timestamp – every 1/2-hour on the 1/2-hour
Trail 4 and Trail 3 entry points on beach
WWII Instrument Towers

Wreck Beach
Field Exercise

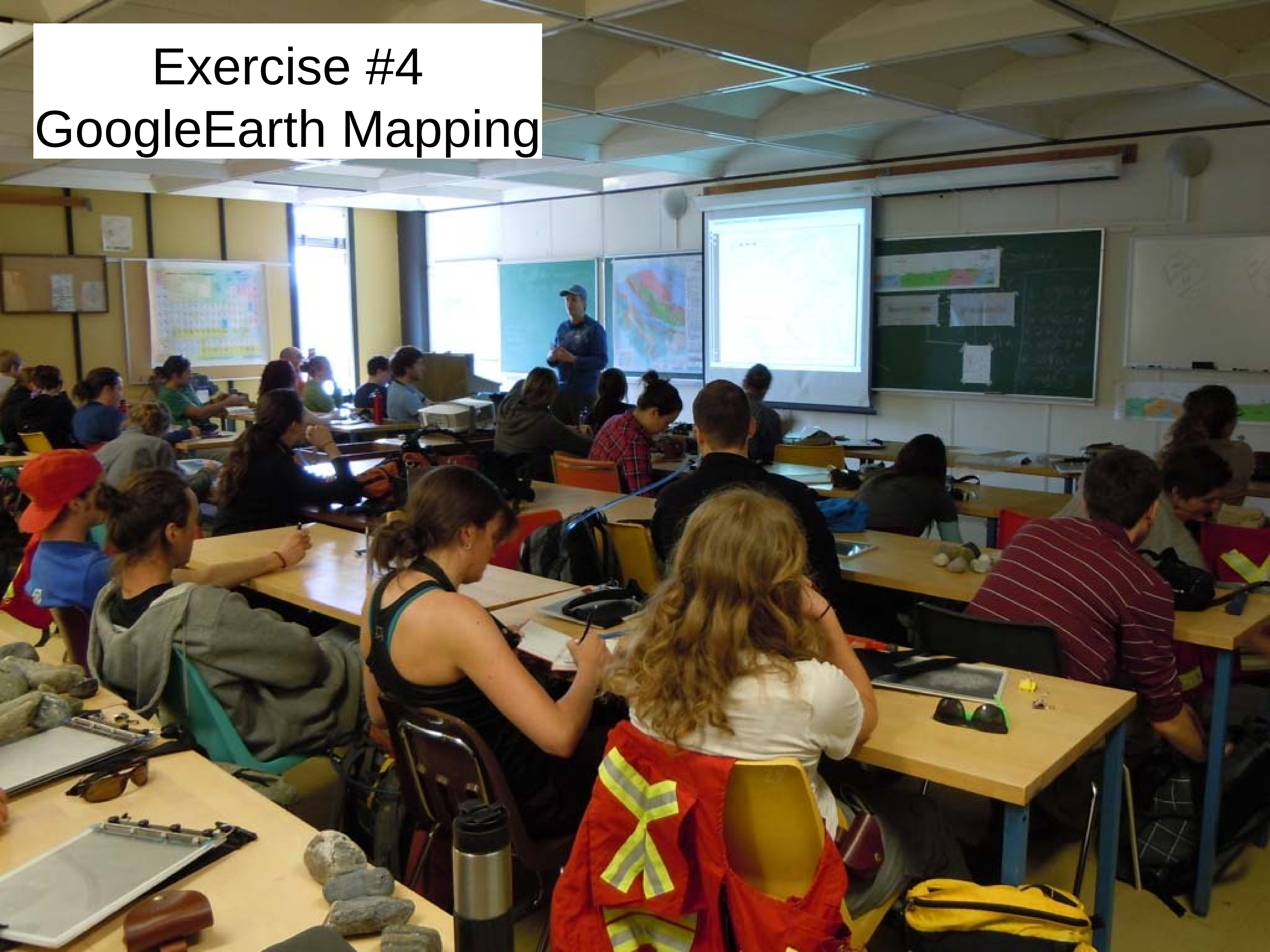
Exercise #2
Cross-Sections

Getting Their Pace Right!



Exercise #3
Compass Navigation

Exercise #4
GoogleEarth Mapping



Oliver Field School

Where We Start!

Successfully Completing a Geological Map

Where We Want to Finish!