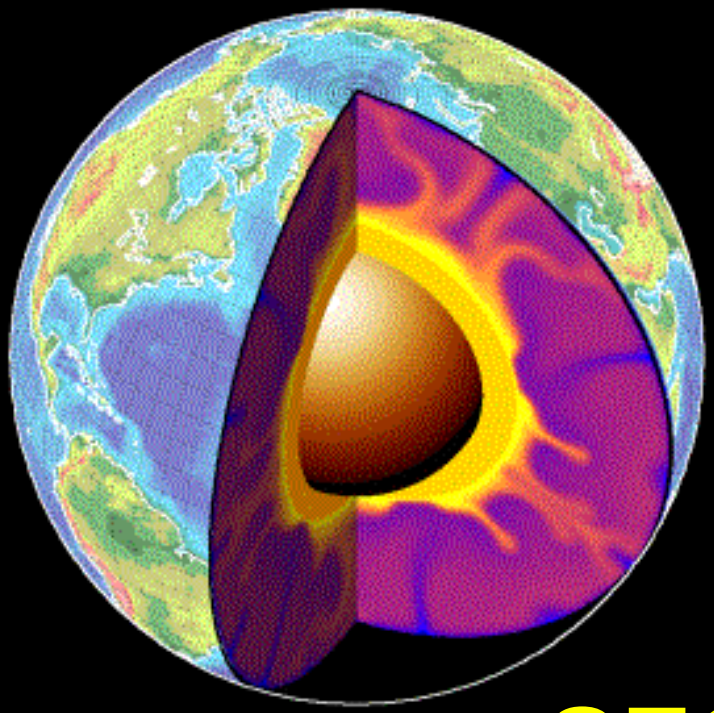


Special thanks to the local expert, Dr. Vadim Kravchinsky, a previous instructor who helped shaping this course.

GEOPH 210

Structure, Dynamics and Evolution of the Earth and Planetary Interiors

Me Me Me…

To me, my research is worth…
1 Million Dollars!!

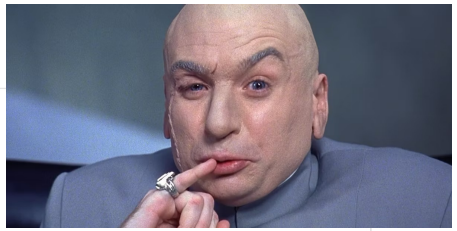
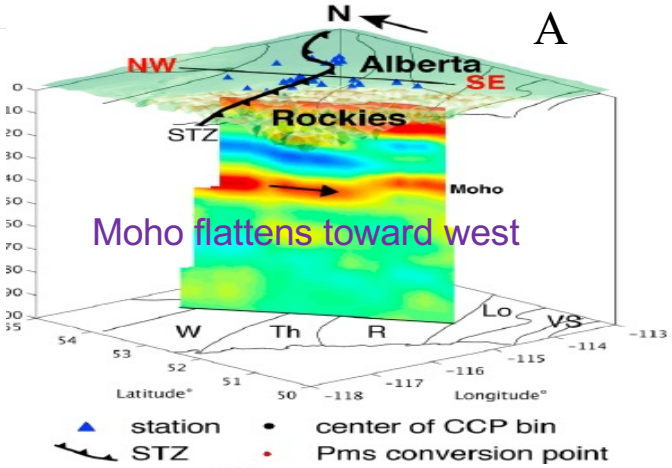


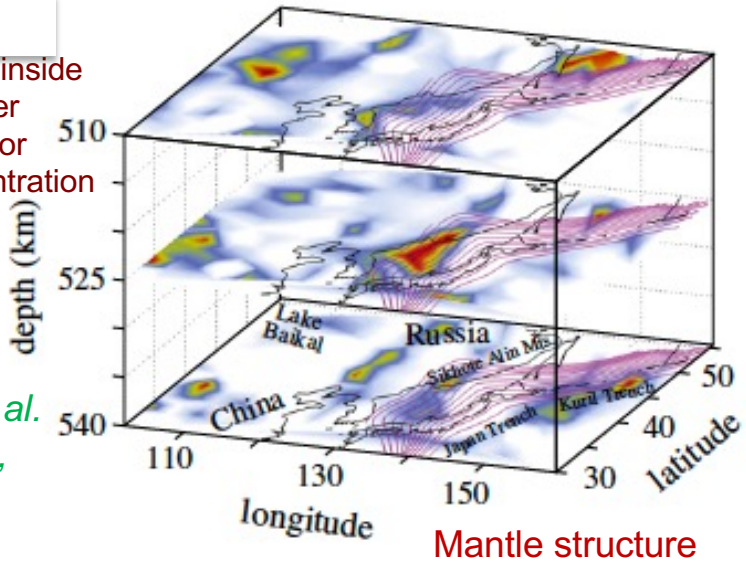
Photo From Wikipedia

Crustal Structure



Gu et al., Tectonics, 2018

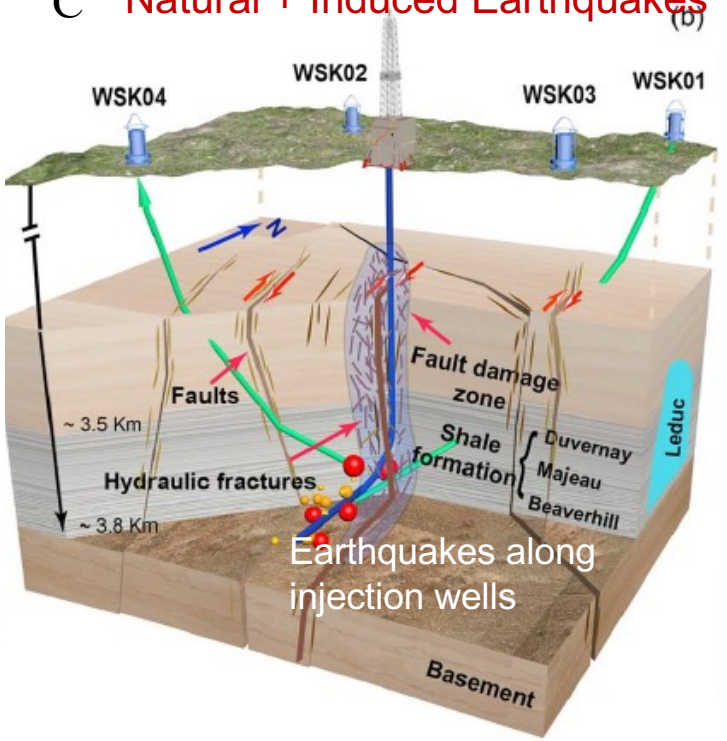
"Bright spot" inside mantle, higher temperature or water concentration



Gu et al. EPSL, 2012

Mantle structure

C Natural + Induced Earthquakes



Li, Gu et al.,GRL, 2019

*Regional & global crustal seismology
*Natural and induced earthquakes
*Computations, ultrasound imaging

Has taught:

Physics 144, 234
Geoph 224, 421, 426, 499, 624
210, 326

Fieldwork

Yours Truly trying to butcher a solar panel installation for a broadband seismic station in southern Alberta (2005). Student to the right: Yunjie Huang (undergraduate summer student).

Right: Two vaults (buried drums) that house a seismometer and a recording unit. These instruments are powered by solar panel and stay in the field for months/years, quietly recording earthquake signals from as far as Japan.

Logistics

Course web-page:
https://www.ualberta.ca/~ygu/courses/geophys210

Containing:
- logistics (my info and TA email)
- lecture notes online (usually available before class, under the link "Notes" from this page)
- assignment-related material (will be distributed via email)
- announcements (emails)

Class room: BS M-149
Class time: M, W, F 12:00 PM - 12:50 PM
Office hours:
- Wednesday 10:00-11:30 AM
- or make an appointment (*email*) or simply show up in my office when I am available

Course outline

1. Introduction (today)
2. Gravity (3-4 weeks)
3. Seismics (~6 weeks)
4. Magnetic exploration (~2 weeks)
5. Plate tectonics, thermal structure, margins (1-2 weeks)

Recommended Textbook

Fundamentals of Geophysics: W. Lowrie, Cambridge University Press, 1997. ISBN: 978-0521461641 (get online version from 'knovel', see class homepage for link, need your CCID to login)

Other useful references:

Introduction to applied geophysics: Exploring the shallow subsurface. H.R. Burger, A.F. Sheehan, and C.H. Jones, Prentice Hall, 2006. ISBN: 0-393-92637-0 *(also used in GEOPH 223)*

The Solid Earth (2nd edition) – Fowler (2004) *(used in GEOPH 210)*

An introduction to geophysical exploration (3rd edition) – Keary et al. (2002)

Introduction to Seismology ---- Peter M. Shearer (1997)

Grade Assessment

Assignments: 25% (4-5, preliminary)
- late assignments will be penalized at 15% per 24 hours AFTER due time, barring special circumstances (instructor permission). Assignments will receive a 0 after 3 days barring instructor permission.

Midterm exam: 30% (mainly shape + gravity + seismic)

Final exam: 45% (all inclusive)

- *Exams are closed book, but formula sheet will be provided*
- Exams are in-person

Grade evaluation

• final grades will follow the UofA 4-point system. The mean grade is expected to be approximately 2.83 (university 'recommendation').

What is GEOPH 210 about?

•• It is an overview of planets and the Earth. We will study three key geophysical techniques for determining the structure and evolution of the Earth (they work for *other planets too*) **down to the core**

- **Gravity, Global seismology and plate tectonics, Reflection and refraction, magnetics**

•• we will focus more on *global and* ***passive*** studies, less on active source techniques:

Some environmental / geotechnical applications *(GEOPH 223 for more, some exploration methods for GEOPH224)*

•• for each technique, the emphasis will be on:

- • **the physical basis**

- what is being measured and why

- • **the practical application**

- data collection → data processing → geological interpretation

- What is the big picture? What advantages and limitations of each technique?

Planet Earth

Aristotle (384 B.C. to 322 B.C.) was an Ancient Greek philosopher who is still considered one of the greatest thinkers in politics, psychology and ethics+scientific reasoning. *He gave reasons and logic to everything in life and explained them in a simple and convincing way (e.g., conservation of momentum and energy).* He was also the ultimate theoretician whose concepts are often impractical, i.e., *a credible scientist he was often not!*

Earth+Stars+planets: unfortunately, the history of scientific progress regarding the Earth often involved debunking some of Aristotle's big claims.

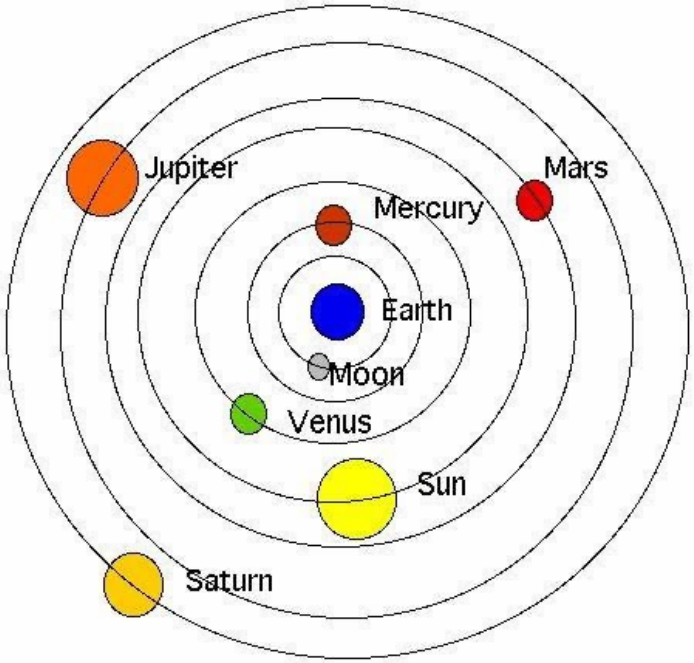
A few wrong ideas that delayed the modern understanding by hundreds to thousands of years:

1. The eternity of the world/rivers, fossils don't exist or are ignorable
2. Weight of object is proportional to its speed.
3. Geocentric system

Geocentric system

Aristotle (384 B.C. to 322 B.C., universe is finite in space but infinite in time)

Claudius Ptolemy (100-170 AD, more developed geocentric system with Earth in the middle followed by moon, Mercury, Venus, Sun)



Heliocentric system

Nichlas Copernicus (1743-1543, died of natural causes)

Giordano Bruno (1548-1600, Burned by Church for his views)

Gallileo Galilei (1564-1642, ***master of observations, father of modern physics/science***, gagged and recanted)

Johannes Kepler (1571-1630, 3 laws of planetary motion, dynamic system, assistant to Tycho Brahe)

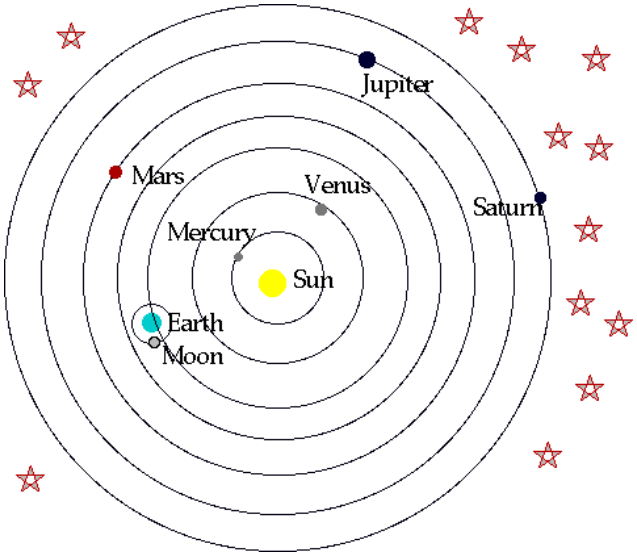
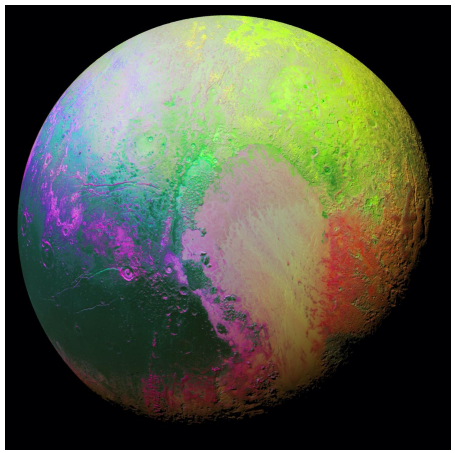


Image from https://people.highline.edu/iglozman/classes/astronotes/history.htm

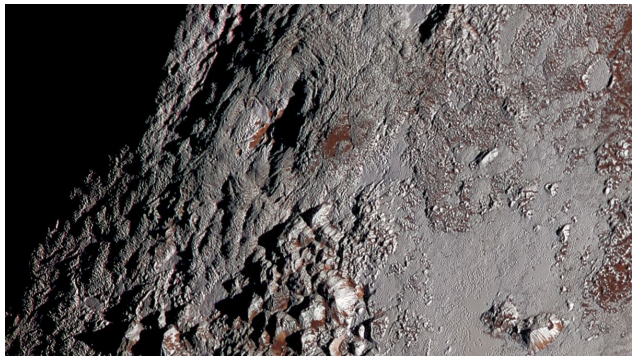
Pluto: a planet or not?

- Discovered in 1930s
- Stripped off the 'planet' status (2012), categorized as a 'dwarf planet'
- Icy mountains, craters, moon half the size (Big thumb up: New Horizon space ship, 2015)

Infrared image of Pluto



Icy Mountains



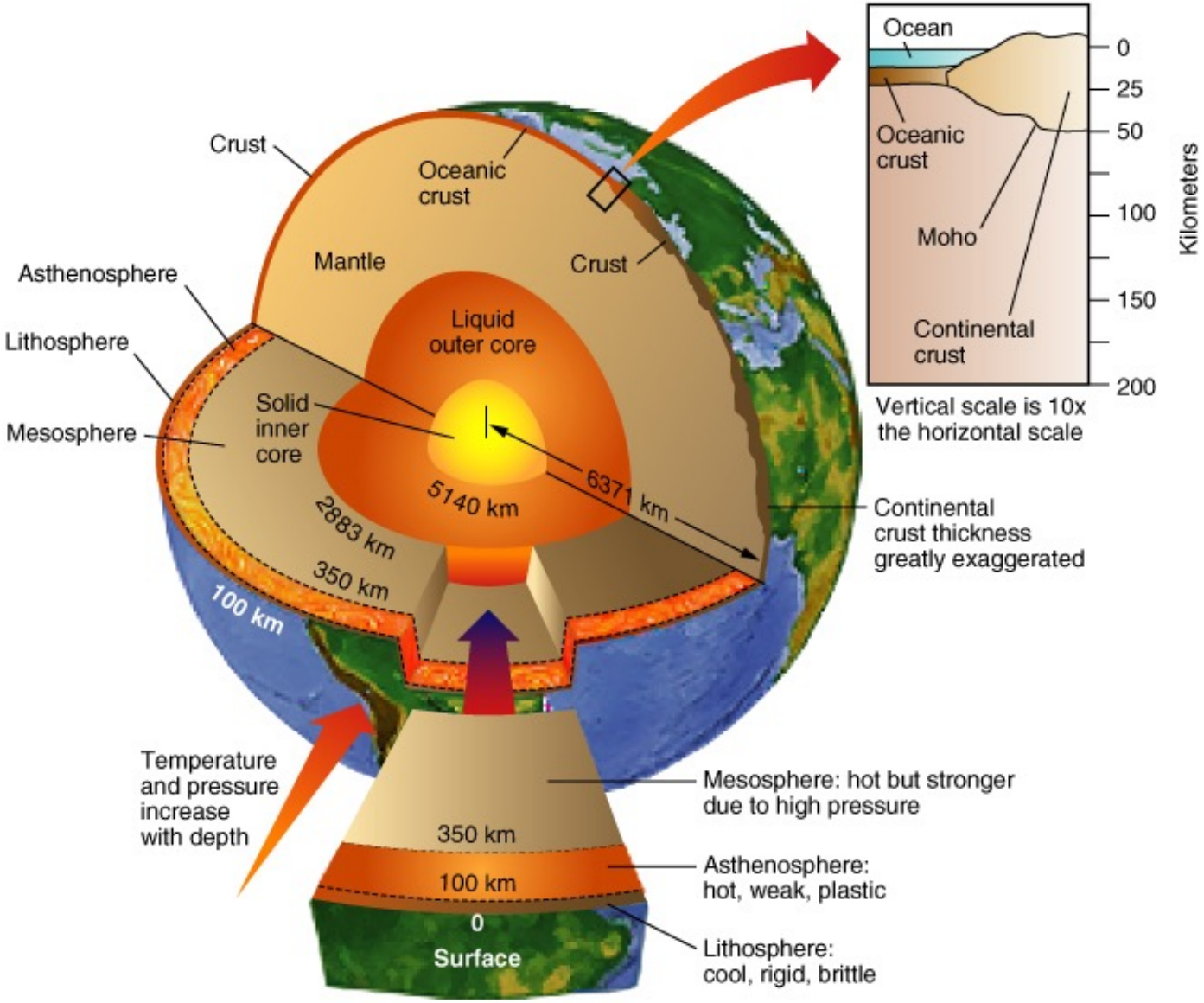
Pluto & its Moon Charon

Images from space.com

Notable names from 1930: Clyde Tombaugh, Venetia Burney

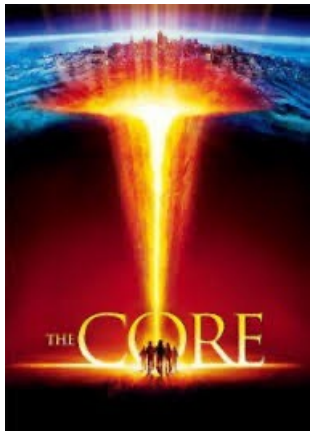
Now back to Earth, what is geophysics?

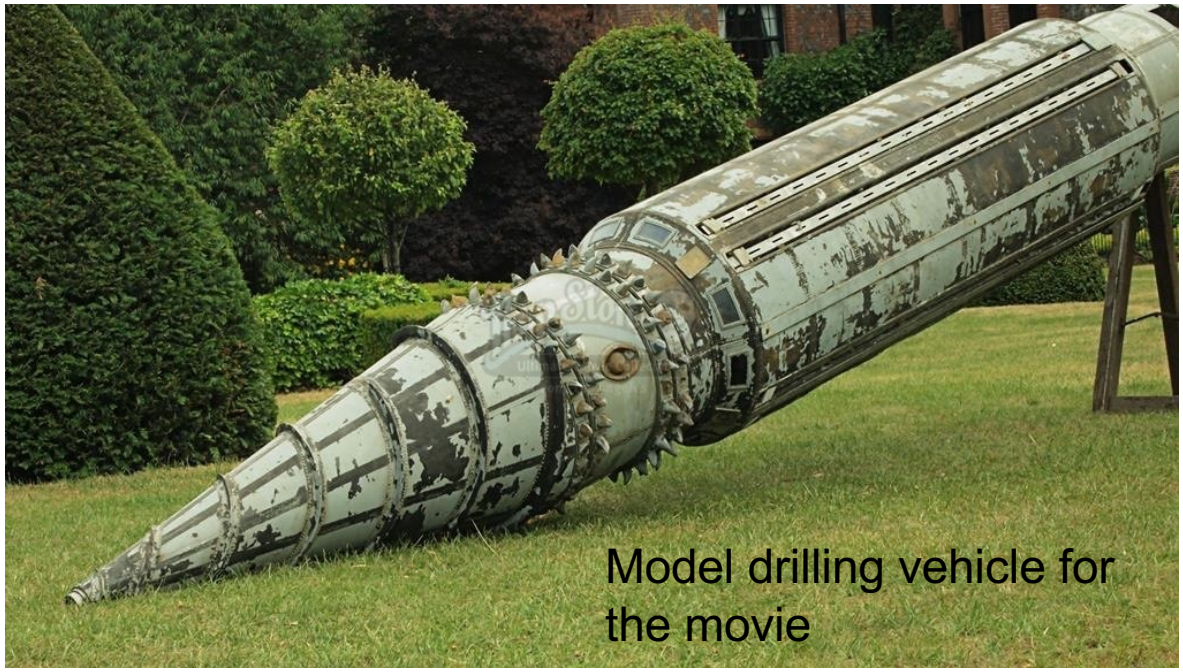
The science of geophysics applies the principles of physics to the study of the Earth and its surrounding atmosphere and hydrosphere.



The dream world

Movie: The Core





Model drilling vehicle for the movie

The wishful thinking is somehow, someday we could visit the core using these special drilling vehicles and discover '***Zion***')

Interior of the Earth with mushroom-like structures ***('World within World')***

The reality of Earth Imaging

1. Geological mapping

- detailed information about rocks exposed at surface

However: limited information about deeper structures
(in areas that have undergone uplift, erosion, faulting)

2. Borehole studies

- extensive information about one location (rock types, thicknesses, etc.)

However: point measurement, expensive, few km deep

Kola Superdeep Borehole (Russia)

- several boreholes drilled from 1970 to 1989
- deepest borehole (SG-3):
  - 12.262 km deep
  (0.2% of the way to the Earth's centre)
- temperatures were too high to drill deeper

The deepest Canadian well

Ensign Energy + Shell sponsored project: 8925 meters, near Fox Creek, Alberta!

https://www.dawsoncreekmirror.ca/regional-news/alberta-peace/fox-creek-canadas-deepest-land-based-well-3498051

3. Magma or xenolith studies

- material that is extruded to the Earth's surface in volcanic eruptions
- geological and geochemical analysis can provide detailed information (such as: composition, pressure and temperature in the source region)

However: - limited occurrence
- representative of regional structure? Alteration during transit?
- depth?

4. Geophysical techniques

- surface measurement of natural or artificial signals that travel through the Earth (e.g., seismic waves from an earthquake)

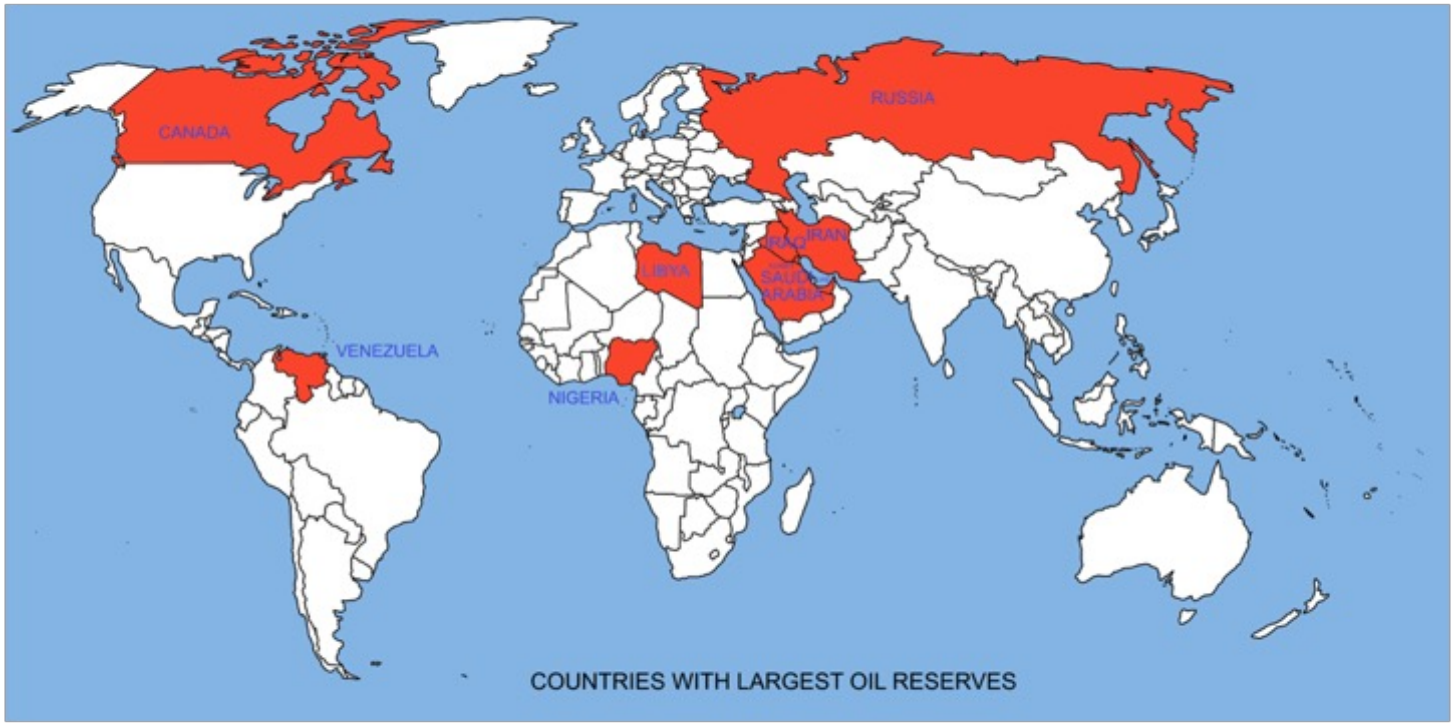
- **indirect** observations of the Earth's interior (subsurface imaging)

  - provide information about **material properties** (e.g., seismic velocity)

  - must then **interpret** the observations
    (e.g., relate the seismic velocity to a rock type and geometry)

    → **often non-unique**
    - more than one rock type or rock geometry yields the same observation

Key Target: 1. Hydrocarbons

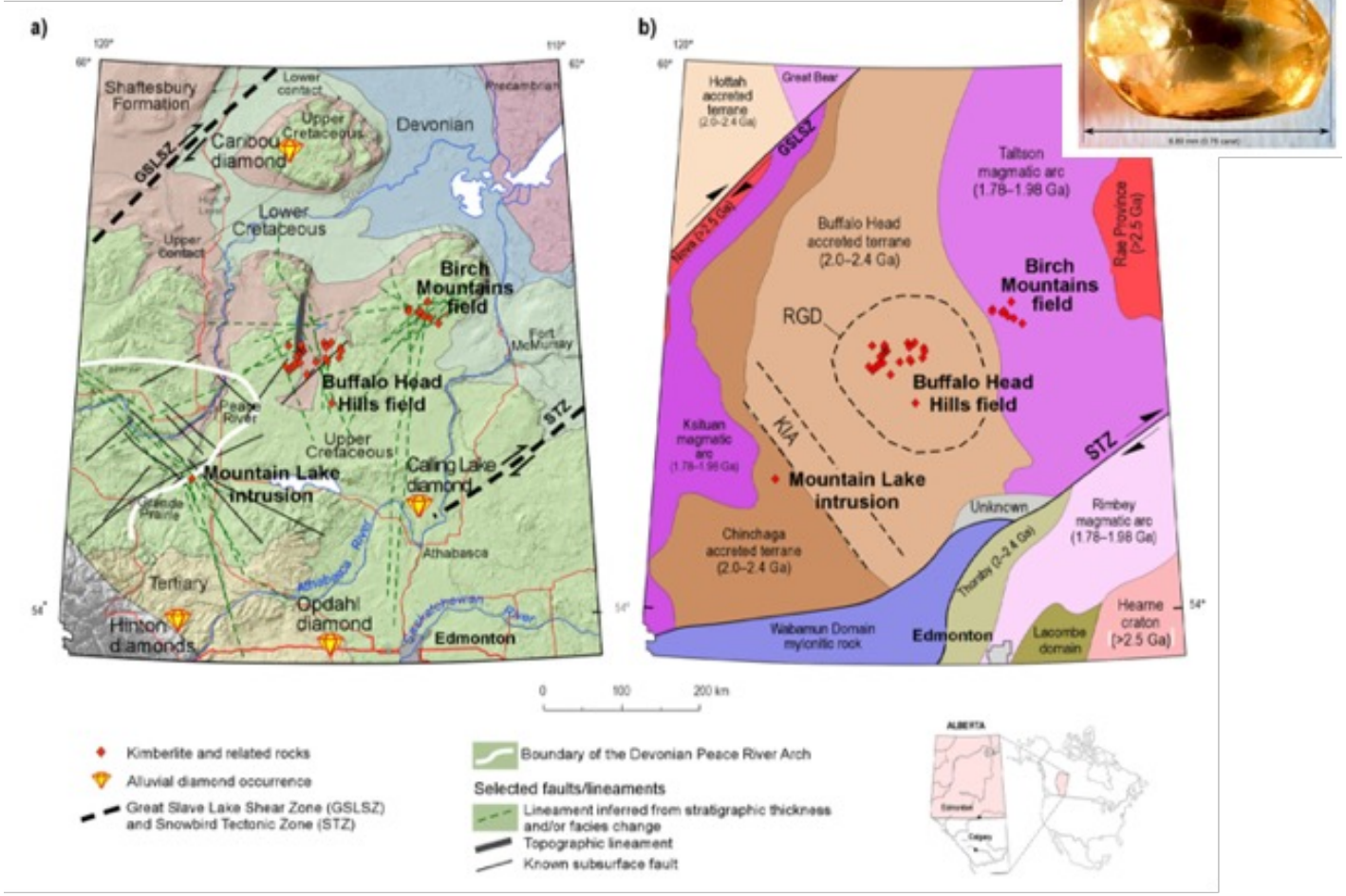


The red areas are countries/regions with large oil reserves.

1. Venezuela (300 Billion Barrels)
2. Saudi Arabia (~290 BB)
3. Iran (~200 BB, 800 BB in total, #1 total hydrocarbon reserve)
4. Canada (~160 BB)

from wikipedia based on CIA Factbook

Key Target: 2. minerals



from Eccles, AGS Open File Report 65, 2011 (not highly economical)

x

Buffalo Head region in Northern Alberta are known to produce diamonds. The rocks that contain them are called ‘mantle xenoliths’. The diamonds are formed under high pressures and temperatures at 150+ km depths. They are entrained through melted mantle rocks at certain conduits a long time ago. Unfortunately, these mines are not yet economical.

Key target: 3.Tectonics

Crustal Structure of Alberta

- Archean and Proterozoic basement covered by WCSB
- basement domains identified using geophysical data and rocks from oil wells

(Pilkington et al., 2000; Hope and Eaton, 2002)