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Department of Earth and Planetary Sciences
McGill University

EPSC-201
UNDERSTANDING PLANET EARTH

ESSENTIALS OF GEOLOGY [red on front] just came out in decemb

Winter term 2007
Monday, Wednesday and Friday; **13:35** to **14:25**, Room Otto Maass 112
Professors Robert Martin and Alfonso Mucci
Teaching assistants: Pénélope Burniaux and Cécile Noverraz
Tentative schedule and course outline

DO READINGS BEFORE CLASS (if possible)

WEEK	**TOPICS**
1	**Introduction** (AM) -organization (course description and schedule), books, evaluation
1/2	**Origin of the Universe/Solar System/Earth (Chapter 1 and appendix a)** (AM) -The Big Bang (the age of the Universe) -Nucleosynthesis (the atom, the elements, radioactive decay and radiometric dating) -Origin and age of our Solar System (radiometric ^{87}Rb/^{87}Sr dating) -Origin and composition of the Earth -Trivia and morphology of the Earth's surface -Hypsographic curve of the world's surface -Internal structure of the Earth
3/4	**Plate Tectonics (Chapter 2)** (AM) -Continental drift (observations on land, fitting of continental margins, apparent polar wandering) -Seafloor spreading or evolution or the oceanic basins (linear magnetic anomalies, rifting and plate motion on a spherical Earth) -Plate boundaries
5	* **Minerals (Chapter 3 + Interlude A)** (RM) -Structure -Properties -Classification of minerals
6	* **Heat Flow and Igneous Processes (Chapters 4 and 7)** (RM) -Magma -Volcanism -Classification of igneous rocks
7	* **Metamorphic rocks (Chapter 6)** (RM) -Metamorphism -Mineralogy and petrology

8/9 **Sediments, sedimentary rocks and the rock cycle (Chapter 5 + Interlude B) (AM)**
-Mechanical and chemical weathering
-Soil formation and classification
-Sources and classification of sediments
-Diagenesis and sedimentary rocks (compaction, organic matter degradation and lithification)

10 **Earthquakes and the Structure of the Earth's Interior (Chapter 8 + Interlude C) (AM)**
-Causes
-Seismic waves and their propagation
-Seeing inside the Earth

11 **Rock deformation and Orogeny (Chapter 9) (RM)**
-Rock deformation
-Faulting
-Mountain building and plate tectonics
-Origin and evolution of the continental crust

12/13 **Earth and Life History (Chapters 10 & 11 + Interlude D) (RM)**
-Geological time
-Stratigraphy
-Evolution of life on Earth

14 **Resources (Chapter 12) (RM)**
-Metals (source and concentration processes: massive sulphide deposits, epithermal deposits and porphyry copper deposits)
-Petroleum (source and concentration processes)
-Environmental impacts of exploitation (radiative gases, acid mine drainage, etc.)

Contact hours: Three one hour lectures (including: movies, hand specimen examination).

Evaluation:	Mid-term	30%
	Cumulative final exam	70%

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L'université McGill attache une haute importance à l'honnêteté académique. Il incombe par conséquent à tous les étudiants de comprendre ce que l'on entend par tricherie, plagiat et autres infractions académiques, ainsi que les conséquences que peuvent avoir de telles actions, selon le Code de conduite de l'étudiant et des procédures disciplinaires (pour de plus amples renseignements, veuillez consulter le site www.mcgill.ca/integrity).

Required textbook:

QE28.M3415 Marshak S. (2006) Essentials of Geology, Second Edition, W.W. Norton & Company Inc. New York, 545 pp.

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"PHYSICAL GEOLOGY" is what we're learning.

handout) ROCK CYCLE

rocks are brought up to the surface of the earth with volcanos (etc.).

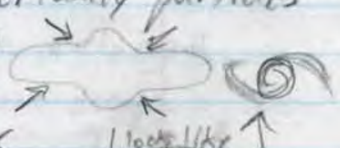
- plate techtonics is pretty recent and revolutionized the study of geology.
- components make up earth and interact [another realization recent]
  ↳ really complex interactions take place. With new technology its much easier. EARTH SYSTEM SCIENCE. integrated view how earth works. might officially come to mgill sept. 07.

THE BIG BANG [1927 first introduced by a priest].

- universe started from infinitely small "singularity" where entire mass of universe was contained.
- it expanded suddenly exponentially. ∴ we live in an expanding universe
  EVIDENCE: galaxies are "racing away from each other".
- heat was being dissapated and quarks started to stick together, forming atoms
  Hydrogen 75%, Helium 25%.
- as the heat kept dissapating,

protostars are 100x the size of sun

as universe cools, gasses made balls of cosmic dust & eventually clump together due to gravity (weak force). eventually particles stick together & form a NEBULAR DISK. → where "protostars" exist and then it makes a galaxy. star heats up as it accumulates more matter, so hot that H's get fused together [Hydrogen ignites] and make more helium (fusion) ∴ releases A LOT of energy! and light at particular wavelengths. (distance between wave peaks).



$f = \frac{1}{T}$

- light travels in waves. which have particular wavelengths & frequencies.
- doppler effect; wavelength shortens & frequency increases when its coming towards you since waves got compressed then it passes you and pitch decreases since waves are no longer compressed.

[handout w/ tram]

- Red shift: red is at a lower freq. than blue so as stars are moving away they look red.
  all galaxies show a red shift ∴ they're moving away.
  - magnitude of wavelength is a measure of the speed that they're moving.

- distance away is calculated in a trivial fashion.

- To measure distance away of galaxies can be found using size and brightness of the galaxies.

(handout) when the velocity vs. distance of galaxies is plotted, it appears to be linear. slope of the line is called the HUBBLE CONSTANT which gives the age of the universe. [10-15billion years] ↑(hubble telescope)

- We are assuming that the velocities of the galaxies haven't changed in the history of the universe.
- Big bang released heat which got bigger as universe expanded.
- Penzias & Wilson tried to fix backround noise in telecommunication and found that it was the residual energy from the big bang since this energy was constant anywhere they looked in the universe

Nobel Prize Winners

- Read Prelude of Book.
- Start Chapter 1.
- Nucleosynthesis (next class)

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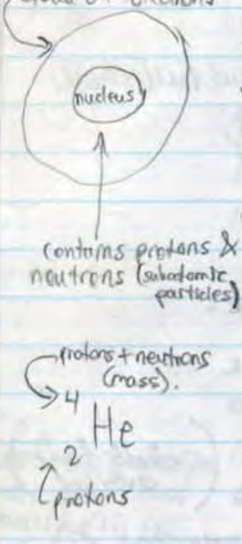
LECTURE 2.

- As the universe expanded neutrons converted to protons and electron. (sum of charges = 0). ½ life of this is 12 min ∴ 12 min after
- the big bang ½ particles were protons and half were neutrons.
- protons are H atoms. If you stick two protons together you get He atoms
- All matter is made of atoms. (which are 10^{-8}cm (1Å)
- nucleus is about 10^{-13}cm (much smaller). ∴ most of atoms volume comes from electron cloud.



- # of protons determines the (nature &) properties of the element/atom. $\boxed{{}_1H\ {}_2He\ {}_3Li}$
- ratio of protons to neutrons is close to 1:1 but as #protons increase, the ratio changes to 1.5. (needs more "neutron glue" in the nucleus to hold protons together)

protons + neutrons (mass). $^{4}_{2}He$ protons

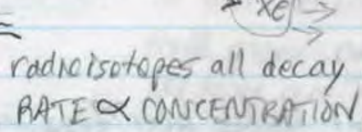
- neutrons and protons are about 1800 times heavier than electrons and have similar mass to each other.
- atomic mass = sum of proton & neutron mass. ^1_1H, ^4_2He, ^6_3Li, ..
- Isotopes: different proton-neutron combinations for certain elements. ^1_1H, ^2_1H, ^3_1H, (three isotopes of Hydrogen). (protium, deuterium, tritium).

★ **Radioactive decay**: isotopes are unstable and decay into something else.
tritium → ^3_2He [tritium is a RADIO-ISOTOPE].
heat is involved which was very important at origin of the earth.

3 ways a radioactive isotope goes through radioactive decay.

α decay $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$. [HELIUM].
β decay $^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e^-$ [ELECTRON] $(n^0 \Rightarrow p^+ + e^-)$
e.c. (electron capture) $(p^+ + e^- \rightarrow n^0)$ $^{40}_{19}K \boxed{+ ^{0}_{-1}e} \rightarrow ^{40}_{18}Ar$
} HEAT IS RELEASED

extra info [another type of decay is NUCLEAR FISSION.
large radioisotope breaks up into smaller radioisotopes.



CHAIN REACTION occurs when theres a CRITICAL MASS happens in nuclear reactors & bombs.

radioisotopes all decay according to their own rate.
RATE ∝ CONCENTRATION of the radioisotope. $R \propto k[A]$. (1st order).

Eg. ^{14}C has $t_{1/2}$ of 5730 years. using half life of ^{14}C you can determine the age of stuff.

Carbon dating is accurate to about 60 000 years ago.
other isotopes have half lives of billions of years. (^{235}U).
useful for determining age of solar system

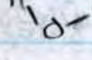
Noble gasses are "rare gasses" with full electron shells so they are neutral and not reactive. (some metals like Gold are similar eventhough they DONT have full shells.).

Na has 1 valence electron.

Cl has 7 valence electrons so it wants Na's electron. to make a full shell.

Na^+ Cl^- } IONS (they carry a charge). NaCl (table Salt).

cation. anion.
(usually smaller)



H_2O, WATER. uses chemical bonds.
↳ different from bonds in a nucleus.

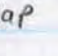
4 TYPES OF CHEMICAL BONDING

$Na^+ + Cl^- \rightarrow NaCl$ (table salt)

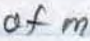
1) Ionic bonds (electrostatic) (NaCl) between ions of opposite charge (e⁻ shells don't overlap)

2) Covalent bonds (sharing of electrons from outer shells) eg: Carbon (overlapping e⁻ clouds)
(strongest)

LECTURE #3



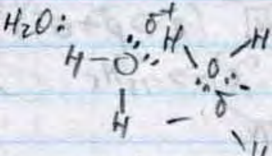
BONDS: Ionic (electrostatic attraction) NaCl (slightly weaker than covalent)
Covalent (sharing of electrons) C−C−C..., H_2O



← overlap

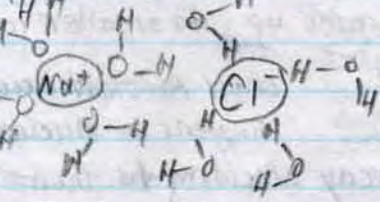
3) Bonds between molecules of different polarities.
electrostatic interaction between slightly positive or negative parts of molecules.

H_2O:



(POLAR) In water its called a HYDROGEN BOND.
responsible for all the famous properties of water,

Universal Solvent:



H_2O molecules shield each ion so that they do not recombine.

Weaker polarity bonds: Vander Walls. (salt makes beer fizz cause it takes up water so that CO_2 gets released).

4) Metallic Bonds: sea of electrons which travel throughout the compound. thats why they can carry electricity. (3rd strongest type of bond)

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Lecture #3 Continued. (after 4 types of bonds).

- Universe is expanding. Energy & mass is being diluted ∴ its hard to form new elements. New elements can only be created in high temperature, high density environments such as a STAR!
- Clouds of dust start to form and attract other particles because of gravity. As they get bigger their mass increases and density increases. Eventually they get so large, so dense, so hot that they ~~get~~ ignite. Hydrogen burns so that they stick to other Hydrogens. This makes He!
  H + H → He [fusion] → LARGE SOURCE OF ENERGY!
- Big Stars (Red Giants) 10-100x larger than our sun.
  As H turns to He, density increases since mass increases. Eventually Helium also ignites (needs 4x as much energy) 200 million degrees C.

our sun probably will never burn helium (its too small).

Carbon & oxygen can also be made at this point, and then Carbon burns and a new set of elements can be made.

The process is self maintained! (until it gets to Iron)

~~Wh produce~~ burning Iron doesnt give enough energy to continue.

How do we get atoms bigger than Iron?

Neutron Bombardment: As Red Giant burns and gets Really Hot, & dense, it eventually implodes, then explodes resulting in a SUPER NOVA detected once every 100 years (approx). Emits a "SHIT LOAD" of neutrons projected at the nuclei of other elements. Through β decay it sheds an electron and converts the new neutron into a proton. (sneaky way of getting bigger/heavier elements)

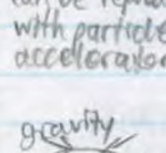
See Handout

- R(rapid) Process & S(slow process) - types of neutron bombardment.
- Slow Process: ~~neutron~~ atom loses an electron & neutron is converted to a proton Atoms grow one by one.

It goes through a cascade.

- Rapid Process: neutrons are coming too fast for decay to keep up so more than one neutron comes into the element, the more neutrons, the faster the decay. A lot of isotopes are made this way.

can be reproduced with particle accelerators.



OUR SUN also formed from a cloud of dust → nebular disc, proto sun. around the protosun discs of matter form around it which also stick together. These things get bigger, At 1km they are called Planetesimals. As time goes on small ones get bigger and others disappear 10-20 million yrs laters PROTOPLANETS around the sun. close to the sun planets have high melting points. farther planets are more voletile (saturn & jupiter)

heats up
M[illegible]t H&He

- Inner Planets TERRESTRIAL
- Outer Planets JOVIAN

Close to sun: terrestrial planets Farther: YUGE planets (jovian)

METEORITE: extraterestrial matter that may or may not hit the earth.

CHONDRITE (Chondrules: little spheres of silicate minerals)

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Lecture #4

T- URI Stage
the sun

- elements after Fe were made by bombarding existing elements with neutrons.
  ↳ SLOW & RAPID.
- we know the age of the solar system because of metiorites.

  METIORITES: CHONDRITES: rocky type w/ minerals.

  ↳ carbonaceous Chondrites (have never been melted since origin). believed to be non-volatile material from when all planets and the sun were formed.

  - Using radioactive elements & ½ life & decay we can determine the age of carbonaceous chondrites.

    Using $^{87}Rb \rightarrow {}^{87}Sr + e^-$ $t_{1/2} = 47$ billion years.

  - when plotting the data, the slope of ^{87}Rb to ^{87}Sr gives us the age of the solar system: 4.57 billion years
- It is believed that terrestrial planets were originally similar to carbonaceous chondrites.
- DIFFERENTIATION: heavier material on planet sank to core of planet, lighter stuff stayed near surface resulting in a layered planet.

  ↳ happens when planets heat up and are partially melted.

  ∴ STRATIFICATION of material on the basis of their density.
- Our moon is often thought of as a terrestrial planet. oldest rock on the moon that was brought back by the Apollo mission was 4.47 billion years old. Solar system is 4.57 billion years old.
- Apparently a violent collision w/ earth of another planetesimal caused debris to accumulate in orbit around the earth. (moon is earth's child).
- In space there are $10-10^8$ atoms/m^3 (not alot).
- On earth (⊕) there are 3×10^{25} atoms/m^3

• THE EARTH

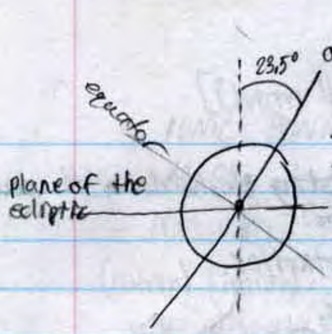
- earth has a magnetic field, (like a bar magnet), which gets distorted by SOLAR WINDS. (looks like a tear drop w/ tail pointing away from the sun).
- Magnetosphere: deflects solar winds (so we don't get fried).
- Van Allen Radiation Belts: (10500-300000 km from earth) stop most cosmic rays that would normally screw up our DNA.

NORTHEN LIGHTS { the stronger cosmic rays/particles follow earth's magnetic field. cosmic rays interact with gasses in the gasses in the atmosphere, (rays get deflected to the poles).

(1988-solar storm)

- Atmosphere: 80% Nitrogen (N_2), 20% Oxygen (O_2), traces of Ar, CO_2, CH_4...
  - as altitude increases, air pressure decreases. on earth P = 1atm. on everest (8.85km) P = 0.2-0.4 atm (can't survive without O_2 mask)

    atmosphere is in layers. temp decreases as you go up, then increases, decreases... in different layers. [36000 ft up it's -53°C].



$r_e = 6378km$

- gravity is always towards the centre.
- but the earth is turning so there's centrifugal force.

∴ the earth is a bit fatter at the equator than the poles.

equator radius = 6378km

pole radius = 6357km

∴ things weigh more at the poles since their closer to centre.

Surface of earth = $510 \times 10^6 km^2$

OCEANS: = $362 \times 10^6 km^2$ (71% of earth's surface).

Fig 1.18 from book & other handout — Pacific alone is larger than continents put together!

Most continents are in northern hemisphere (65%)

Continents absorb sunlight rather than reflect ∴ northern hemisphere is warmer.

Sea level determines amount of land exposed. Melting ice caps will flood some places.

handout! - When you swim out in the ocean, the continent goes out into the water until the continental shelf, continental slope, continental rise, abyssal plain.

- Underwater mountain: mid-ocean ridges are on the ocean floor.

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LECTURE #5

MIDTERM: Feb 16TH 2007

http://eps.mcgill.ca/~courses/C201_fall , sections 1,3,4 ⇐ good handouts online.

exogenic cycle - EARTH is dynamic. There's destruction by weathering, erosion (external forces) of topographic features on the surface of the earth (mountains).

endogenic cycle - there is also constructional processes: volcanoes, orogeny (internal forces (earth's heat))

- organic chem compounds: - carbon based.
  - involve two or more carbon atoms bond together.
  - oils, plastic, rubber.
- minerals: compounds where atoms are organized in an orderly pattern (NaCl, SiO_2, sand...)
- glasses: compounds in which the atoms are not organized in an orderly pattern. (formed through rapid freezing of liquids).

make up compounds on surface of the earth

- ROCKS: assemblage/mixture of minerals and/or glasses. (rocks are defined by the minerals that make it up).
  - → IGNEOUS ROCKS: form from cooling of molten rocks.
  - → SEDIMENTARY ROCKS: made up of pre-existing rocks which have been broken up or precipetated from water. If they are not cemented, then its called sediments.
  - → METAMORPHIC ROCKS: made of pre-existing rock whose texture and/or composition has been altered by high-temperature or pressure. (rock isn't melted, but changed)

MELTS: formed from solid materials that are melted. (lava, magma).
magma - molten rock under earth's surface.
lava - molten rock delivered on the earth's surface (volcano).

Volatiles: substances that transform into gasses at relatively low temperatures. (CO_2, CH_4, H_2O...).

Si, O ← silicate minerals. (most common minerals on earth's surface).

- silicate minerals are classified by their Si:(Mg+Fe) ratio,
  felsic (silicic) > intermediate > mafic > ultramafic (decreasing Si content)
  less dense ← → more dense
- earth went through differentiation so we know where to find these rocks.

- Earth's crust is thin, but still thick. atm + crust = 1% earths mass.
- deepest hole = 14km deep. how do we know what earth's made of?

Composition of the Earth

- we have to guess since we can only dig 14km deep.
- carbonaceous carbonites help since they're similar to composition of inner planets.

(handout) - comparing carbonaceous chondrites to the sun, they're very

Fe, Si, O, Mg. more ←→ less ← similar in composition (since they're from same nebular disk etc.).

- earth's crust is less dense than the carbonaceous chondrites. 2.50/cm³
- average density of the earth: 5.6 g/cm³ ∴ Fe is more in middle.
- moon is much less dense since its made of earth's surface material.
- **CRUST**: felsic, intermediate and mafic minerals (lighter minerals).
  - ↳ Continental Crust: 15-40km thick. (mostly felsic & intermediate silicate rocks).
  - → Oceanic Crust: 7-10km thick (mostly mafic rocks)
    - ↳ thinner but denser.

- Temperature increases by about 15-50°C per km. (geothermal gradient).
- eventually geothermal gradient decreases to about 10°c per km.

mantle has most of earth's mass & volume.

- **MANTLE**: (under crust) 2885km thick, ultramafic-peridotite rock. fairly hot, mostly solid, but some flows slowly. (15cm per year). it's being heated from below by earth's core. (like a lava lamp) SLOW CONVECTION!
- MOHO. (Andrija Mohorovičić): boundary between mantle & crust.
- **CORE**: (below the mantle), early '60's → 1st nuclear bombs were tested, helped us understand size of earth's core.
  - ↳ OUTER CORE: liquid Fe alloys (how do we know its liquid? "S-waves" can't go through liquid)
  - INNER CORE: Pressure: 3,600,000 atm!!! Temperature: 4700°C. } SOLID INNER CORE surrounded by liquid.

• movement in liquid outer core is responsible for earth's magnetic field!

- Interior structure of earth can ALSO be classified by how material flows (if its brittle or if it flows).
- LITHOSPHERE = CRUST + UPPER MANTLE. - continental lithosphere is thicker than oceanic lithosphere.
- AESTHENOSPHERE = LOWER MANTLE (the one that flows).

Plate techtonics: Monday's class (CH. 2 in book)

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MONDAY JAN 14, 2007.

LECTURE #6

- MIDTERM (FEB 16) or ~~23RD~~? 2007.
  ↳ short answer, ONE HOUR. (during class)
- PLATE TECHTONICS
- Alfred Wegener: Proposed the Idea of continental drift.
  - during history of earth, continents have drifted.
  - wasn't well recieved at first until more info was available.

helped us understand how earth works. TRULY REVOLUTIONARY.

- Finally the theory of plate techtonics. (study of large scale movements & deformation of the earth's crust).
- popularized in mid '70s. early 80s it was accepted. (lagged a bit in europe).
- LITHOSPHERE. is made up of plates that move around on the surface of the earth.
- there are large plates and several smaller ones
- earthquakes show where plate boundaries are.
  ↳ happen when plates rub on each other.

EVIDENCE OF CONTINENTAL DRIFT.

- boundaries of continents will fit together if shifted
  If sea level is lowered, continental shelf (true boundaries of continents) shows an even better fit.
- 270 mya.: ONE SUPER CONTINENT: PANGEA.
  (one big ocean).
- 220 mya: continent broke up opening up the atlantic ocean.
- Glaciations occur at regular intervals during earth's existance. but vary in intensity.
  as they move, the pebbles & boulders they carry will carve striations on the rock below (bedrock).
- When the glacier melts you can see the direction it was moving. pebbles leave a layer of sediment on the ground called a glacial Till.
- Random rocks are dumped when glacier melts are called erratic? rocks.
- It was found that in the carboniferous period there were glaciers on earth (200 mya). on antarctica, S.A, Indi, australia...

(handout)

- by looking at striations, Wegener found that they were once joined (in a supercontinent PANGEA).
- distribution of other geological deposits such as coal, many of them are found in the northern hemisphere. (which used to be near the equator) which are ideal conditions for making coal.

- moving away from the equator of pangea, there are deserts and other dry areas.
- coral also shows a pattern providing evidence of continental drift.
- As early as 1912, palentologists looked at fossils which showed striking similarities which only make sense if the continents were joined.
- Plants: Glossopteris fossils show major patterns.
- Land Reptiles also also show patterns.
- At first paleontologists thought that there were "land bridges" but Wegener opposed this since he knew the composition of the ocean floor is different than that on land. So oceans could not re-absorb land materials. ∴ NO LAND BRIDGES.
- paleontological evidence helped support idea of continental drift.
- Africa had some surprising features (truncated near the coast).
- 1927 Alexander Du Toit South African geologist sailed over to Brazil to map geological formations in south america.
- He found that they were exactly the same (fit together perfectly together).
- Thats where the rest of the missing land ended up.

Geological Structures & rock formations.

- Also sediments (layers) were exactly the same on both continents.
- other things that fit perfectly: Appllation mountain rocks are found in NW Africa, scandinavia, & that area.

- EARTH'S MAGNETIC FIELD. (paleomagnetic measurements).

compasses read to TRUE NORTH. depending if you're left or right of the middle, compass will be off by a "declination" angle.

- there's a relationship between the angle of inclination & the latitude (using a dip needle). [Inclination = i angle of latitude, $\theta = \frac{1}{2} \tan i$] (dont need to know)
- GAUSS = Oerstedt are units of strength of magnetic field. ordinare horshoe magnet ~ 10 gauss.
- Earth's magnetic field ≅ 0.5 gauss.
- by looking at the strength of inclinations, it can be determined where the pole used to be.

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LECTURE # 7

EVIDENCE OF CONTINENTAL DRIFT { Glaciation & Climate Belts, Fossils, Mountain belts & archaen crust, earth's magnetic proportiles, looking at how continents are like puzzle pieces.

Heat destroys magnetism. most magnetic materials as they cool back down through the "curie point" will aquire a magnetization in the direction of the prevailing magnetic field.
Lava comes out of volcanoes and as it cools below the curie point, grains of stuff in it orient themselves according to the earth's magnetic field. It shows angles of declination.
THERMOREMINANT MAGNETIZATION: record of magnetic field from lava cools below curie point.
- rocks can be dated with radioisotopes.
- scientists took layers of earth and analyzed the inclination in the rock to find the latitude.
- They found that the earth's magnetic pole moves over time. APPARENT POLAR WONDERING CURVES.

- HOW? either the poles moved or the continents moved...
- but the polar wondering curves changed depending on where the data was taken from.
- this proves that the continents had actually moved (& not the poles) If the atlantic ocean was closed up, North American & European polar curves line up (at least 200-400mya).
- It was found that before 400mya, there was a deviation in the pattern of polar curves. It is thought that pangea-like continents had probably been in existance before (recurring pattern).

What Drives Continental Drift?

[handout] • During WWII, SONAR mapped ocean floors for sub marines. They showed mid-ocean ridges (mountains), trenches, sediments (which were only a couple km thick) thickness of sediments decreases as you come closer to mid-ocean ridges less sediments mean younger ocean floor. 1950 - HARRY HESS (Princeton).
SEAFLOOR SPREADING: hot lava makes new ocean floors and other oceanic floor makes trenches and get gobbled up.

[handout]

• During WWII, AIRBORNE MAGNETOMETERS to detect submarines. geophysicists took them and found magnetic anomalies. (difference between expected magnetic field of the earth at a given location & measured field)

They found both positive and negative magnetic anomalies.
as lava is extruded, as it cools below curie point (~500°) they show the orientation of earth's magnetic field at the time.
BERNARD·BEUNHES (1906) in AUVERGNE, FRANCE (mountains).
some rocks there showed opposite magnetic properties.
PAUL·MERCANTON, (1926) saw this too, he thought maybe these rocks show reversals in magnetic field. (as if field changed) which was laughed at.

- MOTONORI MATUYAMA (~1920s) noticed some rocks show same as todays and some show opposite, supporting Paul Mercanton.
- ~1950s – they said under certain conditions rocks will show opposite to todays m, field,
- ~1960s – now they know about convection in earth's core and agree that there could have been reversals.
- they made a history of reversals with periods of mostly normal fields and mostly abnormal fields

(overhead) - MAGNETIC EPOCH or CHRON. & sub epochs/chrons.
- anomalies are due to these epochs & chrons.
- still don't know what triggers the reversals.
- can be used for dating (relatively).

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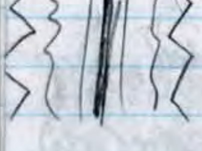
LECTURE #8

- POLARITY, INCLINATION (latitude), location of poles can be found in rocks
- 1960S - 3 scientists recorded magnetic bands extruded at the mid ocean ridges. where there's a magnetic record of the earth's magnetic field.

(vine, matthews, morley.)

Anomalies are the current earth's magnetic field plus or minus the rock's encrypted magnetic properties.

- using magnetic stratigraphy the sea floor spreading rate can be dated.
- there's a symmetrical distribution of anomalies since when lava comes out, half flows one way and half goes other way.

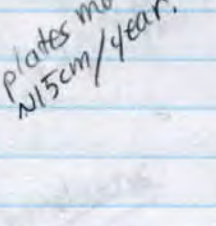


- ISOCHRON: periods of equivalent time on each side of where lava came out. over last 160-200 mya. width of these are the spreading rate.
- tells us the history of the breakup of pangea.
- using present ~~the~~ spreading rates, we can guess where continents will be in the far future.
- mountain building occurs when continents collide (africa & europe will probably collide & make a mountain).

plates move ~15cm/year.

Plate interactions/boundaries (3 TYPES)

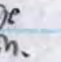
- DIVERGENT BOUNDARIES - plates move away from each other.
  - spreading occurrs along the mid-ocean ridge
  - surface depression along the ridge is called the spreading centre. (edge)
- CONVERGENT BOUNDARIES - plates move towards each other.
  - sea floor is being destroyed (at convergent margins).
- TRANSFORM BOUNDARIES/FAULTS - when plates scrape past each other without production/destruction of the lithosphere.



DIVERGENT BOUNDARIES

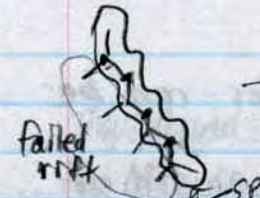
- magma pushes up onto continental lithosphere which buldges as high as 2.5km where eventually the continental crust will break forming "normal faults".

GRABEN: hole in buldge
HORST: Rocks falling in.

TRIPLE JUNCTION:  ← breaks in that pattern (at least 3 lines).
- can be found on ocean floor.

- mid-ocean ridges occur when a suite of triple junctions coaless ↗

LAURASIA
GONDWANA LAND



- failed rifts which made grabens, are now many rivers including the St Lawrence River.

SPREADING EDGE. (made from when atlantic first opened).

- Grabens that fill up w/ fresh water are called lakes.
- eventually they get to a point where sea water intrudes & fresh water gets replaced by sea water and marine sediments occur.
- red sea has sea salt in bottom that precepitated when sea was made and its dissolving back into the water.

- Passive Margins: only sedimentation at edges of ocean.
- plate movement varies w/ latitude & plates with more continental crust tend to move slower [Pacific Plate ~18cm/year].
- spreading rates increase as you get away from the spreading centre (pole),
- TRANSFORM FAULTS: ofsets that make up for the differences in spreading rate due to the geometry of a sphere.

4

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LECTURE #9

- Vine, Matthews, Morley(canadian) found the anomalies in the rocks which were injected at the mid ocean ridges.
- In Iceland there is divergent plate boundaries. Mid ocean ridges go through it. that's why there is so much volcanic activity there.

hearth's Istory.

- rift valleys are when diverging plates make valleys which are block-like. GRABENS, HORSTS are made.
- fracture zone: ~~separate~~ offsets between two mid ocean ridges. Where most earthquakes occur.
- san andreas fault: trans-form fault that is on land.

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7890

  * trans form faults join divergent & convergent margins.
- CONVERGENT MARGINS/BOUNDARIES: (oceanic-oceanic, oceanic-continental, continental-continental)

- oceanic-oceanic: oceanic plate subducts under another plate. oceanic lithosphere that is really old becomes denser than the asthenosphere under it. so it goes under. called the SUBDUCTION ZONE.

(JAPAN is like this)

(-oceanic-continental) as it subducts, it melts which comes up to the surface where it makes VOLCANIC ISLAND ARCS. on the continental plate.

Accretionary prism: where plate subducts it scrapes off layers of sediment which accumulates at the boundary.

himolaens
(40,50 mya)

- continental-continental: causes major uplift which makes major mountain belts.
- MOUNTAIN BUILDING: OROGENY
- oceanic crust can get incorporated into the uplifted land called: OPHIOLITES. which give geoscientist an idea of what the oceanic lithosphere's made of.
- Appalation mtn belts; 3 different collisions. Appalations were there on pangea, then when it broke up they were made up again, still a mystery why it re-opened up at the same place.

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$2.50 PAUL

PAUL HUSSMAN -

#1

LECTURE #10

$ BLING BLING

- older plate goes under younger plate since it's denser
- spreading rates vary in the different mid ocean ridges. they're moving relative to each other
- using satelites with lazers & stuff (within fractions of cm) you can tell how fast plates are moving. (all relative motion)
- need a fixed point on earth.

Intra-plate valcanism: linear volcanic mountain chains.

- hawian islands: sit in middle of pacific plate. (HOT SPOTS).
- suite of volcanic islands. dated using K-Ar isotopes. moving away from hawai'i, the mountains get older & older.
- could be used to determine actual motion of plates.

#

- magma rises from these spots like a volcano. As it goes through the lithosplere, it creates new volcanoes. As the plate moves, a new volcano comes up which tracks the absolute movement of the pacific plate over this PERMINENT hotspot.
- **LOIHI**: next volcanic island in hawiian islands., popping out as pacific plate moves over this hotspot.

New Islands come every ~1000 000 years.

(we're assuming the hot spot doesn't move but we don't know why).

- over 100 hotspots are identified on earth. ~40 are still active today.

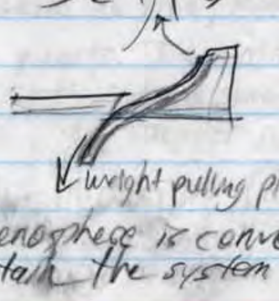
by following the trace of the hot spots we can reconstruct the velocity of the plates.

NHL'09

What causes plates to move? [ridge push, slab pull.]

RIDGE-PUSH:

??☆



pushing up, falling outwards
gravity pulls one down since mid ocean ridges are higher
ridge pushes on lithosphere of plate & it pulls it down

SLAB PULL:

weight pulling plate down & through.

also asthenosphere is convecting causing heat to come up and sustain the system

Prof: Robert Martin

PAUL HUSMAN.

LECTURE #11 (After Video)

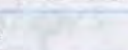
PPT:
EPSC201 29 Jan,
www.eps.mcgill.ca → department → course website.
→ 201 WINTER

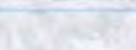
MINERALS

Definition → Homogeneous (cant be broken down into components).
→ Naturally Occuring: NOT MAN MADE.
→ Solid Substance (except for Hg (mercury))
→ DEFINABLE Chemical composition
→ Orderly arrangment of atoms
→ inorganic (generally) → do not arize from organic processes.

Bonanville Salt Flats. (bottom of alkali rich lake which dried up & formed layers of salt at the bottom).

- Halite, NaCl (Table Salt), is a Cubic mineral
- Order vs Disorder





Glass = solid with no order to structure
↳ super cooled silicate melt, rolled & quenched.
VOLCANIC GLASS IS NOT A MINER since it doesnt have a definate structure.

(bathroom break)

Snowflakes: perfectly hexagonal crystals less than 1mm across,
another formation at each verticy happens
the cooler it is, the more extreme the protrusion is.
no two snowflakes are alike.
volcanic rocks are made similarly.
popsicles are the ice with sugary stuff between the pointy parts.
Ice is held together with H-Bonds (not very strong so it melts).
ICE IS A MINERAL (Fits the 6 parts of the definition).

Footprints

Quartz: SiO_2 most impt crystal in earth's crust. (got to know it)
- used in electronics (watches), ceramics, glass,
- it has 6 sides and pyramids on top
- bubbles trap fluids inside which tell us what stuff it grew in.

Smoky Quarts: Little Three Mine, california: black Quartz.
Rose Quartz: Lavra da Ilha, minas Gerais, Brazil: pink Quartz
↳ due to Ti, F, Mn...
Typical massive quartz: Tanco Mine, Manitoba
grew somewhere with little space
irregular surfaces (as seen in rocks).

Potassium-feldspar - MICROCLINE (a polymorph of K-feldspar)
- Aracuai district, Minas Gerais, Brazil
- beige in colour

Amazonitic Microcline - green thing

~~HUSSMAN~~ ~~THUSS~~ ~~PAUL~~

ARTISTE

Biotite(dark mica) - used as an insulator
- sheet silicate

Beryl, variety aquamarine, Pakistan (birthstone for March).

faceted emerald; new discovery in the yukon (CANADIAN DISCOVERY)

cut by a person according to certain guidelines

canada is #3 producer of diamond as of 4,5 years.

emeralds from columbia - more valuble than diamond on a gram per gram basis.

Beryl: $Be_3Al_2Si_6O_{18}$ need a tiny bit of chromium instead of Al.

Zircon, Lawton, Oklahoma $ZrSiO_4$ key mineral for dating rocks.

(don't need to know formulas)

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LECTURE #12

$CaSO_4 \cdot 2H_2O$ - GYPSUM, Soft mineral, Worlds largest crystals.

Roughly 4200 minerals. 50 are added each year.

named after locality, discoverer, important property, important person, important institution.

- McGill connections: Adams, Dawson
- minerals are recognized by their physical properties, symmetry, shape, hardness, luster... etc.
- The structure of minerals is the field of crystallography
- crystallographers look at xray diffraction patterns to see arrangement of atoms.

- GALENA (PbS) has a structure like NaCl.
- shapes: cube, diamond, quartz, garnet, stibnite, ______
- FeS_2: FOOLSGOLD. cubes with striations.
- HARDNESS.

MOHS HARDNESS SCALE.

- Talc Gypsum, Fingernail, Calcite, penny, fluorite, apatite, glass, steel knife orthoclase, steel file, quartz, topaz, corundum(ruby), diamond.
- NOT LINEAR, diamond is much higher.

tongue piercings damage teeth.

TORONTO GIRLS CAN FLIRT ← acronym for hardness scale

- Talc: used in cars, layered structure., $Mg_3Si_4O_{10}(OH)_2$ magnesium silicate hydrous. used on babys bums.
- Calcite, $CaCO_3$: with heat turns to $CaO + CO_2$

$CaO + H_2O$ make $Ca(OH)_2$ (lime).

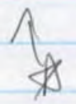
lime mixed w/ quartz & feldspar makes <u>cement</u>.

AND MANY QUEER THINGS CAN DO (the rest of the acronym),

bones, teeth are made of apatite. $Ca_5(PO_4)_3(F,OH,Cl)$.

polymorph!

TORONTO	GIRLS	CAN	FLIRT	AND	MANY	QUEER	THINGS	CAN	DO.
TALC	GYPSUM	CALCITE	FLUORITE	APATITE		QUARTZ	TOPAZ	CORUNDUM	DIAMOND



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GRAPHITE } WRITTEN W/ GRAPHITE STONE.

LECTURE #13

ATOMIC STRUCTURE OF DIAMOND.

C-C covalent bonds in crystal lattice structure

magical # of 8 electrons is satisfied

shaped by computer until you can see maximum colours

diamond is in NorthWest Territories, south Africa, somewhere else.

it is under ~~the~~ lakes from glaciers in NWT. in south africa it's just on the ground (no glacier).

diamond is found below lithosphere (in the asthenosphere) (~150km deep) above that its graphite.

diamond needs to come up to earth twice speed of sound to survive otherwise it will convert to graphite.

heating diamond rings will cause graphite to form.

rocks w/ graphite in them used to be diamond.

CLASSES OF MINERALS

- Silicates, Sulfates, (gypsum)
- Halides (halite, fluorite)
- Carbonates - (CO_3^{2-}) - like calcite $CaCO_3$
- Sulfides - (S^{2-}) like galena (PbS)
- native metals (Cu, Ag)
- Native elements: like diamond & graphite (C)

Importance of silicates

silicate - Oxygen tetrahedron

Olivine Peroxene Amphibole, Mica, Quarts, Feldspar

Polymerization: degree of sharing oxygens.

Olivine; Mg or Fe silicate

chain silicates

DIKE / SILL (vertical, lateral cracks in land.

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LECTURE 14

- In the future maybe robots will be able to mine deeper & get more diamonds & stuff.
- Mining is very dangerous for the time being.
- diamonds have to come up from way down there really fast. by magma or something.
- If it doesn't come up fast enough, it will just turn back to graphite.
- Metastability diamonds dont look like they're changing but they slowly are. They prefer to be at much higher pressures. They are metastable.

★ → - how is it possible to find animal deposits from way down deep?
subduction due to seafloor spreading can bring them down.

ROCKS

234567

- Aggregation of minerals. which are held together by cohesive forces
- Special case: many grains of a particular mineral make a rock.

Volcanic Glass (another special case)

IGNEOUS ROCKS: have been through a molten stage.
(recent melts) of material that used to be earth.

METAMORPHIC ROCK: squeezed, heated, recrystallized sediments

SEDIMENTARY ROCKS: layers of sediments that get compressed into rocks

BASALT (50% silica) type of magma Hawaii

Lava flows in Hawaii
ropy lava means it flowed slowly. far from source.
blocky lava cooled close to source & fast.

1200 °C at point of exit.

Shield volcano (like Hawaii).
magma 50% silica is very runny.
Andeside 62%
75%

OCEAN

gradational display of explosiveness depending on the order of the tetrahedral structure

Rhyolite = very dangerous. (next class).

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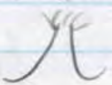
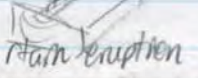
Shield Volcano (Hawaii)

Stratovolcano



smaller, sharper (mount vesuvious)

Paul Hussman



curtain eruption

Dike / Sill (vertical, lateral cracks in land.

volcanoes happen at plate margins a lot.
andesite comes from subduction - Stratovolcanos. (andes)
Hawaii = hotspot in middle of plate.
Mid-Ocean Ridge: have rifts which are curtains of lava.
doesnt explode, just flows very slowly made of basalt.
remelted continental crust.

Volcanoes Stratovolcano: different methods of eruption
dangers of viscous lava:
stuff in clouds falls down & sediments on top.
mud-flows can engulf entire towns.

STRATO ⇒ POMPEII (VESUVIUS) →

SHEILD ⇒ HAWAII →

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LECTURE #15

Patrology (STUDY OF ROCKS)

50% Basaltic Magma, low viscosity

65% high viscosity (kraft penut butter). Stratovolcanoes high, steep, narrow at base

Granite: polished w/ curundum paste, contains 4 minerals, high silica conten
quartz, sodium Rich Feldspar, K-feldspar, Mica.
① ② ③ ④

Island Arcs; why are they in arcs?
Andisidic Rocks form subduction zones. 2 mil yrs?

- Mt, Fuji, Japan
- Pinchincha, Ecuador
- Anak, Krakatau (Indonesia)

→ Andisidic / Stratovolcano: Pyroclastic flow.
eruption cloud (fine particles, ash, makes a cloud can be carried by wind very far) ← stratospheric haze
lahar (mud flow) → read about it, (follows a river system).
- the more silica content, the more dangerous it is. since the structure of the rock is strong & bubbles build up a shit load of pressure & it explodes.

- glass particles made of alkalis & phosphous & stuff rains down & is very very good for fertilization, so its good for agriculture. (glass breaks down w/ water & feeds crops).

Mt Vesuvius 79 A.D. ★ Nuée ardente (Pompeii): near the base of the volcano theres a cloud w/ chunks of magma & gas. (FLUIDIZATION): a lubricated solid, incandecant, liberates gasses on which this stuff spreads very rapidly. Engulfs cities, towns, people & everything.

1991 - Phillipines - Mt Pinatubo: Ash fall (like snow but denser).
causes damage to rooves.

(Santorini) 1883 - Krakatau Eruption, 10000 times heroshima explosion. 36000 killed.
18 km^3 material was ejected, island disappeared.
caused a tsunami, boat was found many metres above sealevel.

Volcanic Gas sampling → direct samping
→ remote samping (spectrophotometer).

deeprock; plutonic
volcanic rock (higher up).

Mount Royal: intrusive body — magma lifting sedimentary rock to make a bump. magma bubble underneath stays down there.

Dike, Sill (vertical, lateral cracks in land.

Batholiths: highlands because of uplifts & erosion
Dikes: vertical structures where magma comes up in a crack.
Sills: magma spreads laterally, lifts rock above.

☆ GRANITE:
- quartz
- mica
- Na-Spar
- K-spar

} minerals.

LOGITECH

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LECTURE 16.

RHYOLITIC VOLCANISM.

even higher SiO_2 contents! (even greater than andesitic magma).
also more H_2O content (melting the crust),
H_2O builds up pressure & explodes a lot.
Yellowstone park, Wyoming. : Yellowstone caldera
Island Park Caldera in Idaho
Yellowstone / HOTSPOT like hawaii islands. (mantle heats, melts crust).
Geysers, fumaroles
water heats up & boils & erupts & it repeats.
↳ water is near surface origin
sometimes earthquakes arise from this too.

WAYS OF ROCKS MELTING.

- decompression melting how most of sea floor is made (mid ocean ridge).
- cross section of sea floor: scarps, sediment basalt, dikes, gabbro, mantle/asthenosphere
  crystal mush, magma chamber.
- hydration melting: subduction:
  basalt reacts w/ seawater, becomes hydrated basalt.
  old sea floor heats up releasing water. (at partial melting zone).
  wet rock melts easier by a lot (by a couple hundred degrees),
  H_2O gives product more silica which makes andesitic volcanoes.
  silica content increases as it rises.

Know types of rocks discussed

fenocryst: new crystal
sp?

gabbro: equivalent to basalt   crystals. calcium rich plagiplase, pyroxene

rhyolite has flow texture, crystal fragments.. made of fragments of stuff. phenocryst
Pumice (frothy & light), Granite

Properties of certain types of rocks.

this Lecture ~~will~~ will not be on midterm
but it will be in the final.

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LECTURE #17

(Biotite ?)
Granite: Quarts, K-feldspar, Na rich plagodase, dark mineral like Mica.
its easy to bypass crystalization: cooling rate can be controlled in a furnace.

Sequence of crystalization;
as snowflakes are made they fall since they're more dense than air,
same deal w/ rocks.
the crystals form in magma & settle
material left over in liquid is different (w/ a little bit of H_2O)
H_2O doesn't go into crystals.
∴ H_2O proportion increases in magma

(See powerpoint).
crystallization happens in a specific pattern
BOWEN'S REACTION SERIES.
mafic, intermediate, silicic (what minerals do they contain?)

mineral Resources (end of course).
chromite ; dense mineral, small particles settle quickly
bottom of ~~metal~~ magma = layer of chromite
chromium comes from this.
This is mostly in SOUTH AFRICA.

abcdefghijklmnopqrstuvw

Midterm FRIDAY FEB 16, 2007
in class, short questions, short answers
NO Multiple choice, ch. 1-4, Int. A, 7.

ROCK CYCLE

ABCDEF
GHIJKLMNOPQRSTUV

- Igneous changes to metamorphic rocks by temperature & pressure

Recrystallization
snow accumulates & recrystallizes to ice which is what we ski on
ice is more crystalized if its older/deeper.

is glacier ice a rock? YES: it is an assemblage of one or more minerals.

limestone → marble VENUS DE MILO
~~marble is a favourable~~ for sulptures. (slightly larger than real life statue)
arms are no longer there.
marble (calcite) hardness = 3 fingernails = 2.5
∴ can't be damaged but easy to carve.

PAUL
HUSSMAN

Paul Hussman

Hussman

HUSS

ABCDEFGHIJKLMNOPQRST
ABCDEFG
HIJKLMN
OPQRST
UVWXY

PAULZ
HUSS

a

DUE

rocks get squished resulting in elongation of the crystals
damaged rocks that are ~~more~~ squished are more soluble.
Sheering; rocks (deck of cards) shift along a plane. SLATE shingles.
slaty cleavage: product of metamorphic differential stress.

Paul Hussman

FEB 14, 2007.

Paul Hussman Hello My Name is Paul

LECTURE #18

midterm! short Answer, (don't repeat the question) Paul
8 of 12 questions must be answered.

Recrystalization: (marble) (calcite) (limestone) are softer

movement during recrystalization
differential stress & folding. (deck of cards: slaty cleavage).
mica nucleates causing slatey cleavage.
PHYLLITE: a bit higher grade than slate.
SCHIST: a bit higher grade than phyllite, defined by muscovite.
METAMORPHISM & FORMATION OF NEW MINERALS.

FOLIATION
SCHISTOCISITY
Biotite garnet schist: will break along line due to orientation of crystals.
GNEISS: highest metamorphic grade
muscovite converted to feldspar.
alternating light & dark layers.
presence of garnet tells us that
ANATEXIS (PARTIAL MELTING) formation of migmatites.
melting causes lines to go horizontally instead of vertically.

[Review Rock cycle Slide]

Mount Royal is a laccolith from 125 million years ago.
but its very small. Its a bulging in the crust due to a batch of lava pushing up on it from underneath.
Hornfels: re-cooking of slate looses foliation

Sheet Silicates
Metamorphic Minerals. tell you what grade
aluminosilicate minerals & metamorphic grade
andalusite, sillimanite, kyanite (polymorphs).
contact metamorphism

PAUL
HUSSMAN.

Monday, Feb 2$\boxed{6}$, 2007
6?

LECTURE # 19

Metamorphic Index Minerals.
look for indicator minerals!

Al_2SiO_5 Aluminosilicate has 3 polymorphs. like diamond/graphite
↳ Andalusite, Kyanite, Sillimanite. (according to metamorphic grade).

Metamorphic Facies →
↳ Zeolite
green schist
amphibolite
granulite
P-P
blueschist
eclogite

Prograde Metamorphism (upcycle)

-Retrograde Metamorphism (downcycle)
- decompressing & cooling as its coming up
- add H_2O & CO_2

Appalachians show prograde metamorphism

PAUL HUSSMAN.
FEB, 28, 2007

(1st after Indonesia)

LECTURE #20

☆ FINAL EXAM APR. 19, 2007, 9AM (TENTATIVE).

Mountainbelts disappear due to $\boxed{\text{weathering}}$ erosion & mass-wasting.
like a rusting car – fairly slow process, but happens always, everywhere.

Intimately related processes!

WEATHERING: chemical decay & physical fragmentation of rock under earth surface conditions.

EROSION: Transport of rock fragments and mineral by a mobile agent. (typically water & wind).

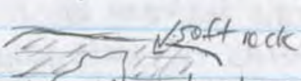
MASS-WASTING: transfer of rock material down slope under the influence of gravity.

[We are going to discuss weathering more than erosion & mass wasting.]

- why do rocks weather?

weathering is the rock's response to a changing environment.

example mont royal:



(now hard rock has to adjust to new environment since its no longer in eq'm with its surroundings.)

- Weathering results in SEDIMENTS (which are UNCONSOLIDATED)

Sediments can be converted to $\boxed{\text{sedimentary rock}}$ through digenesis & specifically through a process called lithification.

Surface Area is increased ↗ - PHYSICAL (mechanical) WEATHERING: fragmentation of rock (into smaller pieces) while keeping composition/minerology in tact).

∴ more material available for chemical weathering (rxn rate is proportional to SA)

- CHEMICAL WEATHERING: Chemical composition of minerals is degraded in the rock constituents. (can result in new minerals that are more stable under earth's conditions).
(rate depends on surface area exposed).

WAYS FOR ROCKS TO FRACTURE (4 ways)

- usually fracture on weak spots. (called joints)

1. UNLOADING: release of pressure, removing stuff above, rocks expand under, crack ☆

very efficient → 2. FROST WEDGING: result of alternate freezing & thawing of water (ice expands 9%)

3. THERMAL EXPANSION: forest fires can cause the outside of rocks to explode (mechanical weathering)

4. ORGANIC ACTIVITY: (plants & other organisms) seeds, roots in cracks, bacteria makes acids (CO_2 etc.) which accelerates chemical weathering.

☆ cracks let water in which starts weathering even before exposed to the surface.

COLUMNAR JOINTS: hexagonal prisms 10s of metres high (result of contraction of cooling rock).

EXFOLIATIONS: peeling like onion skin: creates an accumulation of rock debris w/ physical weathering

SPHEROIDAL WEATHERING: the more SA exposed, the faster the weathering.
- the more a square rock erodes, it turns round.
- round rocks can roll easier away from the site.

Weathering Rate depends on a few things... ∴ it varies. $\Rightarrow O_2, CO_2$, inorganic/organic } acids

- Properties of rock (its constituents)
- Climate < rainfall: water is a very good solvent ∴ holds minerals & chemicals in solution which help w/ weathering.
  temperature.
- Presence of soil & vegetation
- slope
- time.
- Stability
- Solubility.

olivine is a very easily weathered mineral (follows bowens rxn series).

- Water can hold in chemicals that are useful for accelerating weathering
  oxidation of sulfide minerals can make sulfuric acid which degrades rocks.
- Temperature: higher temp, faster weathering rate.

(2nd after Indonesia)

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Mar. 2, 2007

LECTURE #21

Weathering, Mass Wasting, Erosion

Bedding: plane of weakness in the rock due to weathering.

Fractures occur when igneous rock cools since it contracts which make columnar joints [hexagonal columns] [can be seen if you walk up PEEL st.]

Exfoliation: as a result of UNLOADING rock cracks since less pressure is on top of it.
Chemical weathering occurs better since water can get in cracks
physical weathering occurs since water can freeze in cracks & expands, pushing blocks apart. [FROST WEDGING]

Talus slope: when frost wedging occurs on a slope and sediments accumulate at the bottom of the slope.

Thermal weathering: Forest fires cause exterior of rocks to explode.

weathering occurs on surfaces ∴ surface area matters. cubes erode on corners since that's where the most surface area per unit volume exists.

Factors that affect weathering rates

- solubility, structure, composition, surface area
- climate; rainfall & temperature: rain brings eroding stuff to erode rocks, ↑temp, ↑ rate.
- presence of soil & vegetation: trees grow, roots push rocks apart
- slope steepness: soil will not accumulate, gravity helps,
- length of exposure: time

★ CHEMICAL WEATHERING breakdown of rock to its minerals, which makes new minerals.

1) DISSOLUTION:

$$\underset{\text{(calcite)}}{CaCO_3} + \underbrace{H_2O + \underline{\underline{CO_2}}}_{\text{makes carbonic acid } (H_2CO_3).} \rightarrow \underbrace{\underset{\text{(calcium ion)}}{Ca^{2+}} + \underset{\text{(bicarbonate ion.)}}{2HCO_3^-}}_{\text{two most important ions in river; water}}$$

$$\underset{\text{(dolomite)}}{CaMg(CO_3)_2}$$

(how most silicates weather)

2) HYDROLYSIS: Substitution of H^+ or OH^- (constituents of water) in a mineral.
forms a secondary mineral.

(simplified reaction)

$$\underset{\text{K-feldspar}}{2KAlSi_3O_8} + H_2O \rightarrow \underbrace{\underset{\text{(clay mineral)}}{\underset{\text{Kaolinite}}{Al_2Si_2O_5(OH)_4}}}_{\text{secondary mineral.}} + \underbrace{4SiO_2 + 2K^+}_{\text{silicate + Potassium}}$$

gets carried on by H_2O and taken away. feeds plants.

↳ soluble & stable on earth

olivine, pyrite contain reduced iron (Fe^{2+})

$Fe^{2+} \rightarrow Fe^{3+}$
ferrous ferric

3) OXIDATION: Reaction of atmospheric oxygen with reduced mineral constituents.

Pyrite: FeS_2, Both Iron & Sulfer are Reduced.

$$\underset{\text{pyrite}}{2FeS_2} + 7.5O_2 + 5H_2O \rightarrow \underset{\text{Goethite}}{2FeO(OH)} + \underset{\text{sulfuric acid}}{4H_2SO_4}$$

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HYDRATION: Addition of water to minerals.

minerals that were originally anhydrous, get hydrated in presence of water.

$C_2SO_4 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O$

anhydrite Gypsum

(weaken the structure of rocks by expanding)

SOIL FORMATION

material gets leached out of surface which leads to separation of material in soil profile

(horizons)
- O
- A } topsoil, zone of leaching
- E ← transition
- B ← subsoil, zone of accumulation
- C ← inorganic soil made of broken up bedrock below.
- R

} SOLUM (active soil where roots are).

ELUVIATION: LEACHING OF MINERAL CONSTITUENTS.

N

O

P

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MAR 5, '07

(3rd after Indonesia)

LECTURE #22

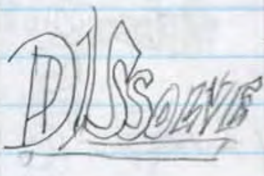
Factors that affect weathering rates:

Properties of rock (or its mineral constituents: reactivity, solubility, structure)
Climate
Presence of soil & vegetation
slope steepness
length of exposure (time).

silicate rocks are more resistant to weathering (tomb stones)

Chemical weathering
Dissolution; mineral constituent goes into solution immediately
Hydrolysis; water replaces some other part of the molecule
oxidation; reaction w/ oxygen (like Iron Oxide)
Hydration; minerals get hydrated, expand which changes the properties.

Dissolution
affects Carbonate molecules
weathering of marble
Hydrolysis
weathering of granite (K-spar → Kaolinite + quartz) silica
oxidation
- affects minerals like olivine $Fe^{2+} \Rightarrow Fe^{3+}$ and pyrite
- rusting



Soils
soils develop through the percilation of water through materials in the ground. results in layering.

Horizons
O
A
E
B
C
R
} Soil Profile.

higher latitudes have enough water for a good soil profile
too high = too cold ∴ no chemical weathering (no soil)
so physical weathering occurs.

we're not doing soil orders.

3 3 3 45
34

(Al) (Fe) (Ca) (Al)

3 types of soils Pedalfer, Padocal, Laterine

Pedalfer: fairamount of rainfall, soil well developed, leaching occurs ∴ carbonate poor, rich in Iron & Aluminum Oxide

Z

Pedocal:

Laterite: soluble minerals have been leached out
- infertile (almost no nutrients)
- hard (can make bricks or paint).
- africa
- very thick

Zho
haolyrod

Sediments
produced by weathering of bedrock.
fragments of rock & biproducts accumulated unsorted by gravitational deposition (stones roll down hill)
- Various types of sediments are defined by the way they accumulate and separate on land.

Wopsvu
- Compaction & cementation convert sediments into sedimentary rock.
- Most of earths surface is covered by sediments or sedimentary rock eventhough sedimentary rock is only a small volume of earths crust

jamp
- they are important because they ~~determine earth~~ have a record of the hearth's Istory, and

trampol
ine

Sources of Sediments

insoluble, stable

clays & quartz

clastic/detrital sediments: originate as solid fragments that are carried to the site of deposition.
chemical sediments: soluble material precipitated by inorganic processes
biochemical sediments: soluble material precipitated by organisms.
organic sediments: made of remnants of biological material. (carbon-rich)

clays: insoluble, stable, result of weathering of
quartz: stablest thing & fairly insoluble.

Clipzo

Rock flour: mixture of fine grain minerals as a result of glaciers
clastic sediments are classified in terms of their size
bolders: >25.6cm
cobbles:
pebbles:
sand:
silk:
clay: 1 or 2 microns in size.

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MAR. 7, 2007

LECTURE #23

Horizons: layering of soil profile
soil quality depends on many things
most importantly on climate (amount of rainfall & temperature)
but also steepness of slope, etc.
latitudes: too close to equator = too hot, less water ∴ immature soils.
temperate regions: substantial soils that can sustain vegetation
soil 7-10m thick.

Soil types

Pedalfer:

Pedocal:

Laterite:

Sediments

mud at bottom of lake, dust on windowsill = sediment.
usually taken away from its place of formation
final resting place usually oceans.
through processes such as ~~sedimentation~~ lithification ____ it is made into Sedimentary rock.
sediments are weathered ~~the~~ physically or chemically.
size of sediment depends on how its made or how it is moving.
as they go down hills they get smaller
Sand particles travel very far (sand particles from sahara go by wind to miami florida over the entire ocean. these particles are sorted since only a certain "class" can make it the whole way across (depends on size & weight).

Sources of sediment

- Clastic/detrital: originate and are transported as solids and deposited as solids

Chemical sediments: soluble material made by chem. weathering, precipitated by inorganic processes

Biochemical sediments: soluble material

Organic sediments

Clastic
- Flakes of clay = <2 microns across.
- clays are stable, soluble, fine grain, mak up most of clastic sediments.
- Quarts; mostly in clastic sediment, strong stucture

Clastic sediments; boulder, cobble, pebble, grannule, sand, silt, mud.

Chemical sediments
mineral constituents as a result of chemical weathering
most precipetated by organisms (biogenic).
Stalactites and Staligmites are chemical sediments
silica deposited from hot springs. (crystallization).
Corral Reefs; precipetated by organisms.
Microfossils; produce most limestone deposits through biochemical processes
(biochem) Coccolithophores, foraminifera, diatoms, radiolaria,
$\underbrace{\text{Coccolithophores, foraminifera,}}_{CaCO_3}$ $\underbrace{\text{diatoms, radiolaria,}}_{SiO_2}$

Evaporites; made from evaporating water.
when evaporation exceeds runoff & condensation rates, salts are deposited since salt content of air is high).
Halites, sylvite, Gypsum.

Organic sediments: carbon-rich (like coal).

Diagenesis (converting sediments into sedimentary rock).
Uses proceses (LITHIFICATION) converting unconsolidated (loose) particles are converted into solid rock.
happens through <u>compaction</u> & <u>cementation</u>.

Compaction: accumulation of sediments get compressed under their own weight.
the water gets squeezed out from between the sediment particles.
the POROSITY decreases
↳ volume of water in pores / volume of sediment.

Cementation; process by which minerals are precipetated between mineral grains. which "welds" them together
Calcite & silica & Iron Oxides
↖(hardest rocks)

Classification of S-rocks

Clast size: size
Composition: what its made of
Sphericity: how round it is. & angularity (how elongated it is). □, ○, ▭, ⬭,
Sorting: all same size or all different.
Character of cement: silica, calcite, Iron oxides.

MAR 7th, 2007 (CONT'D)
~~TAUL~~

GM

LECTURE #23 CONT'D

Conglomerates w/ sandstone lenses.
↳ rounded edges
sandstone; when most particles are sand grain size.
↳ if most are quarts then its quarts sandstone.
3 types of sandstone: Wacke: quarts, feldspar, clay
↘
↘

GLA

Siltstone (smaller than sand but larger than clay)
not a very well held together rock.

Shale silt & clay size particles held together by pressure
breaks concoidilly. (not in straight line).

blood

at 1/2 point $V_B = {}^{15.2}/_{2}$

$$= \frac{1/2\ 0.09775\,M \cdot 0.02\,L}{V_B}$$

$$= 1.2862 \times 10^{-4}\ M$$

MAR. 9, 2007

4073224811 LECTURE # 24

1132 AM

↱ ultimate product of chem weathering & stable on earth

Clastic Sediments (Clays & Quartz) ← most stable thing on earth

Classes of sediments (boulders & pebbles...).

$CaCO_3$ in ocean sediments comes from sediments of microorganisms

White cliffs of dover made mostly of forammeritera

evaporites: mineral precepetates from evaporating water
like table salt

Coal (carbon-rich relicts of plants).

DIAGENESIS → lithification → compaction → cementation } sediments ⇒ sedimentary rock
clays & silts (fine particles)
coarse grains (calcium carbonate, silica (hardest rock), iron oxides)

Clast size, composition, angularity & sphericity, sorting by size, character.

Conglomarates: round clast edges (material was transported far before cementation)

Breccia: sharp clasts (material was cemented before travelling anywhere far.

Quartz Sandstone: each grain is made up mostly of quartz
— - wacke

Siltstone: made of silt grains, made from compaction, crumble easily

shales: made from compaction of fine clay particles, doesn't crumble
↳ show lineation, breaks along beddings.
mudstone breaks concoidially.

Biochemical sed. Rocks

cherts
evaporites

Limestone: can be precipetated inorganically but mostly biogenically
- Coquinas: cemented mass of shell fragments
- White cliffs of Dover: mostly foraminifera make it up.
- $CaCO_3$ inorganically made from hotsprings due to supersaturating & precip. when its heated its less soluble which precipetates.
- Dolomite (another type of limestone) w/ magnesium, named after the dolomite mountains. (slow process, no new ones, all are very old.
Rock = dolomite Mineral = dolomite (same name)

Cherts: made of microcrystaline silica, hard rock, inorganically precipetated ultimately but most have a diagenic source (recrystalized)

FLINTS: arrowheads, concoidal fracture, very hard, contains organic matter

JASPER: red, chert w/ iron oxide ∴ red jewerly

petrified wood: silica reprecipetates in wood after its buried in sound as wood degrades, holds structure of the wood.

Evaporites: from lake/sea water precipetates.
where evaporation exceeds precipetation
GYPSUM $(CaSO_4 \cdot H_2O)$

Organic sedmentary Rocks (coal).

coal forms in swampy areas when organic matter accumulates under O_2 poor, waterlogged conditions.
320mya in carboniferous areas, coal was made from swampy lands
organic matter converts to peat then lignite COALIFICATION/
then lignite is converted to bitummeous coal (metamorphism) (most abundant on earth but dirtier to burn).
then converts to anthracite which is harder but cleaner (too hart to eastly mine).

BEDDING, STRATA & FORMATIONS (layers)

- layers are the most distinctive feature of sedimentary rocks which cover 70% of the earth's surface.
- BEDDING PLANE (where rocks normally break) - area between layers.
- FORMATIONS: sequence of layers that were precipetated under similar environmental conditions of deposition, usually sandwiched ~~fon~~ by very different types of layers

- RIPPLES: river or ocean currents cause ripples to be cemented in sedimentary rocks
- CROSSBEDDING: inclined layers like sand dunes caused by crests material to be  carried to the troughs. happens in different directions depending on wind, water.

MUDCRACKS:

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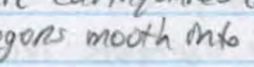
MARCH 12, 2007

LECTURE #25

EARTHQUAKE: vibrations due to fractures of rock
- when rocks break energy is released, S-waves are emitted and felt on the earth's surface.
- earthquakes happen all the time but they're too small to feel.
- quite a few are harmful though
- FAULTING: movement of lithospheric plates relative to each other.
- Earthquakes are mainly caused by FAULTING, usually at plate boundaries.
- Seismology (dates back ~2000yrs) study of earthquakes.

Seismoscope: first instrument to measure earthquakes (32 BC).
ball would fall from dragons mouth into frogs mouth

Seismographs: weight on spring attatched to pen & rotating drum
extremely sensative instruments that they can detect vibrations as small as atoms. can detect wind.

seismogram: record of a seismograph ()
shows location and energy of earth quake. (& the type).

Focus/hypocentre: point where waves are released from.

epicentre: position on the surface of the earth directly above the hypocentre.

Earth quakes are triggered when stress is applied on rocks.
Stress is released when it builds up to the point that rock breaks/fractures.
when rock breaks it causes an earthquake.

Tectonic Forces (responsible for rock fracture).

Compressive Forces: squeezing & shortening rocks (at convergent margins)
Tensional Forces: stretching of rock, pulling it apart (at divergent margins).
Shearing Forces: Push two sides of rock in opposite directions (transform faults).

FAULT: plane along a fracture.

Classification of faults.
Inclination of the surface:

Relative movement of rock on its 2 sides.
- Vertical displacements:
- Horizontal displacements:
- Horizontal & Vertical

Dip-slip fault: hanging wall slips below footwall
  Inclination is angle of Fault Scarp. (dip angle).
  strike line: where rock splits
Normal faulting at rift valleys
  plates move apart, make horsts & Grabens at the new rift.
Reverse faulting
  plates move together,
  hanging wall is pushed up above footwall
  Thrust Fault: when dip angle is small like 30°.
Strike-slip faults: result of shearing.
  left lateral: } sit on one and see what direction land on other side is
  right lateral: } moving
oblique slip faults: combination of tensional & compressional and shearing forces.

san andreas: energy is released bit by bit since stress is permanant.
  (STICK & SLIP behaviour).

- elastic rebound theory (1874)
  crust bends at san andreas fault until Apr. 1906 when strain was released & it was no longer bent (they had markers in the ground).
today there are markers in the ground monitored by lasers & satelites & GPS.
stress built up in land over time can be easily monitored which helps predict earth quakes.
faults can be thousands of kilometers long.
horizontal displacement can be 15 m
vertical displacement can be up to 50 m (alaska).
  Mar, 1964: vertical displacement of 11.5m (in anchorage, Alaska)
    "good friday earthquake".

Energy is transmitted through seismic waves.
on surface of earth we feel surface waves.
  Rayleigh waves } occur slowly on earths surface.
  Love waves }
Body waves travel through the earth (faster than surface waves)
fastest type → Primary - compressional waves. travel through solids, liquids & gasses
  Secondary - shear waves (like a rope fixed at one end. (∿∿∿).
    - only travel through solids.

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Lecture # 25 (cont'd).

Since Seismic waves occur at different speeds, it allows us to measure how far away earthquakes are.
using seismographs in different locations on earth and the measured wave speeds of each type, location of quake is found.
need 3 locations on earth to find spot w/ triangulation.
technology today allows us to determine magnitude & position of earth quakes in the matter of seconds

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MAR. 14, 2007

LECTURE # 26

Earthquakes: vibrations caused by released energy when rocks under stress break. happens at faults

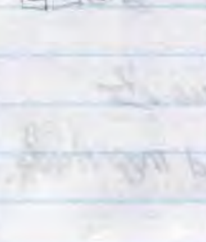
study of earthquakes: seismology.

measured by seismographs ← very sensitive instruments that measure vibrations in all 3 dimentions

seismogram: history of seismograph which shows location & intensity of quake

HYPOCENTRE: underground source of earthquake.

EPICENTRE: point on surface of earth above the hypocentre



Techtonic Forces cause stress in rocks

different types of techtonic forces cause different types of faults.

- Dip-slip fault, strike-slip fault, oblique-slip fault.
- stick & slip behaviour - stress is applied, builds up and is suddenly released when rocks break.

energy released is in the form of seismic waves.

surface waves (love waves & rayleigh waves) happen through the surface of the medium (solid, liquid, gas).

Body waves: Primary waves
Secondary waves (solids only).

Determining the magnitude of an Earthquake

by determining the stress stored before an earthquake, and displacement of land it could be estimated how strong the earthquake is but its not a reliable method.

Charles Richter: by measuring the amplitudes of the surface waves, the strength of earthquakes can be determined (scale is logarithmic) its measured from 100km away.

energy of an earthquake is determined by Amplitude AND frequency

$E = f^2 A^2$

vibrations result in damage, but fires caused most damage. (gas lines).

if land moves / vibrations happen in the ocean, it can generate a tsunami.

Tsunamis are HUGE tidal waves. unlike storm waves they have extremely large wavelengths but small amplitudes ∴ they have momentum built up when they strike land. they affect deep water too.

december 26 2004 tsunami affected indonesia, srilanka, africa...

tsunamis happen quite often in history. they are recurring events.

shallow earthquakes are more common since brittle rock is at surface deep ones happen at subduction zones since subducting plate maintains some brittleness as it goes down into the mantle. up to 700km deep earthquakes can happen.

Isostatic rebound.

when ice melts, pressure is relieved on earth, crust rebounds, generates earthquakes

Predicting Earthquakes: cant be done short term.
long term can be determined by stresses on land and how frequent they are, we only know 50years back.

- ancient evidence like fault scarps are still fairly recent since its not eroded away.
- dating layers of the ground, displacement can be detected and magnitude.
- probability of earthquake can be estimated.
- maps of seismic hazard have been put together.

MARCH 16, 2007
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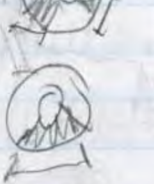
LECTURE #27

Ricter scale: logarithmic scale.
reports max amplitude of surface waves
100km away from epicentre.
Amplitude is only a fractional measure of the energy.
energy is a function of both frequency and amplitude
surface wave amplitude increases by a factor of 10
energy increases by a factor of 32.

destruction of buildings due to movement of crust
and fires cause a lot of damage & deaths.
earthquakes can induce landslides.
fine grain soils (sand & clay) if shaken up, liquify ∴ mud volcanoes
can erupt, stuff can sink, toilet drain exploded
TSUNAMI: [NOT A TIDAL WAVE!] generated by vertical displacements of the
sea. displacement is given to the water ~~front~~ column.
show small amplitude and long wavelength (VERY POWERFUL).
Mercalli Intensity Scale: how destructive earthquakes are.
most quakes happen around the pacific circle plate thing.
most of them are shallow earthquakes
but at convergent margens subducting crust cause deep earthquakes.
below 670 km its too hot so rock just melts instead of breaks.
isostatic rebound (as a result of melting ice pressure is relieved and
asthenosphere moves back in) results in local earthquakes
like in northern quebec.

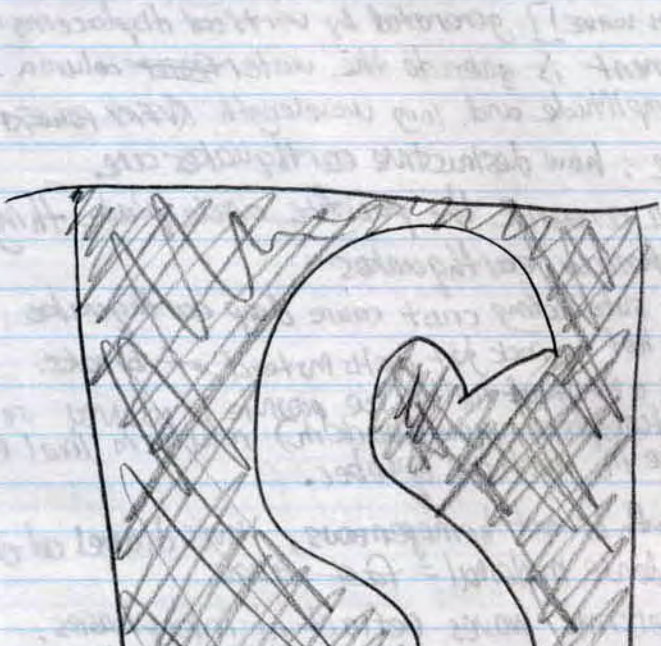
since interior of earth is not homogeneous, waves travel at diff speeds
at diff layers. dense material = fast waves.

like light waves, seismic waves refract at interphases.
← if density increases it bends up



1909 - Andrija Mohorivicic: waves take different paths depending on density
so waves arrive at seismographs at different times.
MOHO: interface between crust and mantle.
there is a shadow zone where primary waves dont make it to ~~since~~ because of diffrac
S waves arent even recorded past 103° since they dont travel through liquid core.
both wave types are reflected of the inner core boundary so we can
calculate the depth of the $^{\text{inner}}$ core surface (2900km).

seismic tomographic images
like a cat scan (thousands of images cross sections put together to make a 3D image
3D images of convection are made
velocity vs depth curve shows heterogenious mantle
velocity increases as you go deeper in the mantle. at techtonic plate boundarys it slows down
Transition zones (changes in structure of minerals) causes waves to change speed.
boomer trucks use air to generate seismic waves, reflections are recorded.
Seismic reflection profiles show structure of the sedimentary strata.
useful for mining and stuff.



ROBERT MARTIN

PAUL HUSSMAN
MAR. 19, 2007

LECTURE #28

Deformation and Mountainbuilding

Brittle: shatters (ceramic plate) } temperature & time are important.
Ductile: deforms (silly putty).

Stress = force (such as extension → stretching or compression → shortening)
Strain = result of stress

shear: deck of cards, θ = the angle

DIP & STRIKE: dip line, strike angle, bedding plane, strike line

Dip-slip faults: fault = crack where movement happens
joint =

dont need to know the difference — very similar { reverse = compression results in hanging wall
thrust = compression, hanging wall moves up
normal = due to extension, hanging wall moves down

Horst: uplift caused by compression.
Graben: stretching causes land to fall lower

Strike-Slip fault: horizontal movement.
sit on one side and if it moves right across the fault then its a right-lateral fault & vice versa.

Oblique-slip faults (combinations of different types).
eg. normal fault + right-lateral fault
or reverse + left lateral fault.

Thrust faults squish together to form rocky mountains
detachment fault (main fault below the sequence of new rocks being squished together up above).

San Andreas fault (Right-lateral fault).
transform fault (part of a HUGE fault).

Folding

FOLDING:

very common, horizontal plane of folding { Syncline: folded sedimentry sequence, striking & diping. new rock in centre
Anticline: folded up thing old rocks are in centre
Monocline: (not so important). stretching/opening where one side collapses
Plunging: axis of folding plane plunges

G G

HUSS

Paul Huss

HUSS

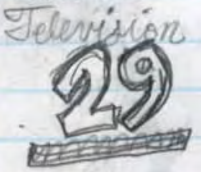
PAUL HUSSMAN.
MAR 21, 2007

29

LECTURE #29

strike & dip symbols: ⊥ ∔

The Brittle-Ductile Transition (p. 252) [WILL BE ON THE EXAM] ✩
Temperature, Pressure, deformation rate, composition, H_2O,
Folds & Map patterns
antidine, syncline, plonging



maps of cities are important for subway systems & nuclear reactors.
You must know where the faults are.

DOME & BASINS: interesting folds.
mountainbelts have a positive build up in mass so they have a crustal root to help it stay up (buoyancy like icebergs). This is called ISOSTASY.
(Isostatic equilibrium).

Mountainbelts
- subduction results in mountains. rock = bad conductor.
- himaleas: two continents hitting each other heat underneath
- everest: people start slowly, hard to walk & talk up high.
caused by continent-continent collision and mountain building.

~~R~~ Rift Mountains. continuous ridges.
basin & range topography
Cross section of a rift
bulging from below causes mountains.

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LECTURE # 30

Relative Age: the principle of uniformitarianism.
(the present is the key to the past) - James Hutton, 1726-1797
Comparing recent mudcracks with paleozoic mudcracks shows that the same processes are going on now that always have
mudcracks are made by mud drying in the sun
paleozoic mudcracks are already filled with other material.

Relative age: the principle of superposition
stuff deeper down is older (in layers)
the principle of HORIZONTALITY:
principle of original continuity:
cross-cutting relationships; dykes & sills, show relative timing
xenolith: pieces of stuff from interface material inside a sill.
FOSSIL RECORD (paleontology). help show relative age by assemblages & correlations.
certain fossils are present at certain depths
either conditions have changed or species became extinct.
Unconformities & gaps in time.
uplifted segment eroded then sediment on top. (angular uncomformity).
we don't know how much time her evolved between erosion & sediments.
Stratigraphic Correlation. L.A. vs grand canyon. LA is less compressed (and
↳ can be done on a global scale

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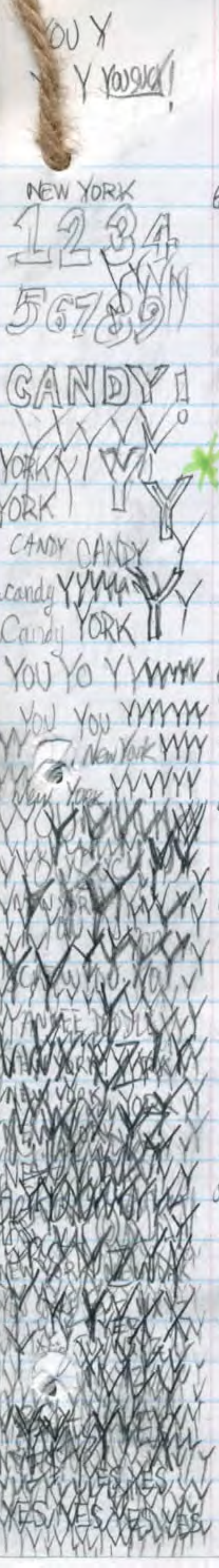

Lecture #31

Global Stratigraphic Correlation : time periods (read the chapters).
Know orders and small description of each.

ISOTOPES: vary w/ # of neutrons

Halflife: time until half amount exists.

$^{238}U \rightarrow {}^{206}Pb$ 4.47x109 yrs

$^{235}U \rightarrow {}^{207}Pb$ 704x10⁶ yrs

mass spectometry (counting masses)
method of dating rocks

crystallizing ZIRCON

ZIRCON ($ZrSiO_4$) valence 4+

very dense, can be separated by crushing rocks and hand picking them
crystals can be polished into little gem-like crystals.
slight departure of Zr for U or Th.
If this happens so much, AMORPHIZATION occurs (cracks in rocks, gets damaged and age can't be determined).

throughout the paleozoic there is evidence of glacial deposits
global warming might not be due to humans, its nothing new.
earth has been through this before.

humans are not that important. they come at the very end of a very long time period of the history of the earth

radiometric dating in rocks can be erased w/ heat (metamorphism)
so rocks like this show some major events.

lunar rocks show 4,6 bya crystals of zircon.
the moon has no H_2O to get into cracks to disturb the parent/daughter isotope relationship ∴ accurate dating.
shows the effects of H_2O on earth.
everything on earth before humans happened naturally.

History of North America

there's a core continent and things plastered around the edges.
% continental area exposed above oceans, increased greatly in the archaen period

canada contains the most archaen crust in the world.

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MAR 30 2007.

LECTURE #32

earth is 4.6 bya but by counting generations in the bible they thought it was only 6000 years old.

radiometric dating has allowed us to map out areas of rocks on the continent by age
North america has the most archaen rock on earth
craton → stable continent (like North America).
subduction zones on the edges create newer rocks on the edges.
granville; north of montreal: uplift of metamorphic 30-40km up.
similar to himalayas but VERY Eroded. (laurentians).
quebec has BIF which is magnetic ∴ Iron mines. redd's quartz is in it too.
Banded Iron Formation, folded.

Suspect terrains pieces of western N.A. that have joined to the continent

why is there no volcanism where africa hits asia? Nothing's subducting.

GLACIATION! Canada was covered with ice

GLACIERS!!!

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APR. 4, 2007

Missed Lecture # 33 (Non-Renewable Resources)

Lecture # 34

natural gas & oil fields are non-renewable resources.
deeper down = hotter ∴ oil/gas gets destroyed.
we depend on oil being shallow & risen to a trap.

Renewable Resources

Metals:

accumulations on the sea floor of metallic sulfide sediments.

EXAM ★★ how sediments form on the sea floor will be on the exam!!!
yearly we use the most Iron & steel compared to other metals.
we can recycle metals ∴ they're renewable
Canada has a lot of nickel ∴ we can export it & make money.
Canada is rich in metals & other resources due to its many
ABCD different types of land & stuff.
EFGHI geological history of a country determines how rich a country will be with resources.
the United States besides Alaska has been explored & discovered but Canada still has many potential discoveries to be found.
northern brazil has a lot of igneous rock w/ feldspar & stuff but most stuff gets taken out w/ water but Aluminum & $Al(OH)_3$s stay in the rocks which can be mined. hydro-electric dams are usually needed for the power to mine

EXAM: Diagram; Black smoker sulfide ore deposits,
memorize. at midocean ridges, heat from below the surface
of the ocean floor heats water
hotsprings; hot water going through comes out through cracks,
black smokers very fine grains
when black smoker forms on the sea floor why would an older crystal arise when recrystallization.
where's the closest place to montreal that this happens? Iceland,
off the coast of BC, a ridge is going under Vancouver Island.
3km deep water mining costs too much and is too hard.
Hydrothermal / Vein deposits
cinnabar (HgS) bearing quartz
gold dissolves mercury, boiling it off it goes into the atmosphere.
Brazil is one of the biggest Hg contribution to the atmosphere

Hg comes out of atmosphere, deposits in vegetation, stays in the food chain. Methyl Mercury gets in fish and we eat it and it gets to be poisonous.
fluid trapped in quartz

fluid inclusion; heat until bubble is gone

mountainous areas, pluton near

Longo – gold bearing conglomerate

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Lecture #35

Metallic Mineral Exploration

aluminum at low temperatures is not very mobile.
boxite (almost all aluminum oxide or Al hydroxide).
-every 36 hours alcan brings a shipload of boxide and they refine it. the boxide that comes in is rich in iron oxide. last week the spill, the iron rich residue left behind from refining was spilled which also contains arsenic which nobody discussed in the news.

- Pyrite reacts w/ water to make ______

E

Witwatersrand goldfields 35% of worlds gold is from there.

EXAM

Ore deposits from magma
just like snow nucleates and comes down in layers, SAME THING in magma happens.

$FeCrO_4$ Iron chromium oxide (chromite)
rocks have chromite bands in south africa and its easy to process
chromium plated stuff like car rims, bumpers
Why only in africa and not in Canada? (geologists don't really know but think that it has to do w/ the mantle in the earth
Sudbury has alot of nickel. nickel is used in stainless steel.

G'ZAM

Sudbury formed because they are the main supplier of nickel.
magma was saturated on its way up with sulfide
nickel sulfide was globulated inside the stuff like salad dressing.
sulfide is denser than the black liquid.

Alligator

sudbury is a bowl by medior impact then continentinental collision which scrunched the area making an ellipse ~100km long & ~50km across.
medior striked 1.8 billion yrs ago
in the future robots will mine deeper in sudbury.
ore is too deep except by the edge.

abcdefghijklmnopqrstuvwxyz

abcdefghijklmnopqrstuvwxyz

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Non metallic Resources

Quebec produces alot of granite

to get granite, no deformation could have taken place

also no other stuff rained into it. (homogeneous).

montreal has a lot of granite buildings.

polished w/ corundum makes it nice

when it gets blow torched it gets rough so you dont slip

exam format

similar to mid term but more depth required

answer 20 out of 30 questions

cumulative (putting everything together).

Ch 12, ~~13~~ (no mass movement)

everything up until ch 12 that we discussed in class

nevermind the interlude.

exam = 100%

or 30%/70%, mid/exam