Intro to Earth Sciences I
Lecture Topics and Brief Notes for Midterm Exam
Summer 2017

The major topic areas that we have covered are:
Origin of the Universe, the Elements, and the Earth and Solar System
Minerals; Igneous, Sedimentary, and Metamorphic Rocks; Environmental Health & Safety
Geologic Structures (especially faults)
Earthquakes Seismology and Earthquake Risks
The Earth's Interior
Continental Drift, Paleomagnetism, Marine Magnetic Anomalies and Seafloor Spreading

origins
- Big Bang theory for the formation of the universe
  evidence: the redshift, cosmic microwave background radiation
  what formed? only H & He according to theoretical considerations
- stellar evolution (birth, main stage, death)
  death of large stars (supernovas) and the formation of the elements beyond H & He
- Solar Nebula Theory of how Earth formed
  solar nebula included material formed in a supernova
- differences between terrestrial planets and gas giants and the apparent reason why
- the asteroid belt and meteorites found on Earth (what they tell us)
- origin of the Moon
- Earth layering: iron (mostly) core & rocky silicate mantle (and crust); how/why
- origin of the hydrosphere & atmosphere

atoms and minerals
calcite (calcium carbonate), quartz, feldspars, muscovite and biotite mica, amphiboles (hornblende), pyroxenes (augite), olivine
- the eight most abundant chemical elements in the crust (especially the two most abundant, O & Si)
- protons, neutrons, electrons and how they compose atoms
- the difference between atoms, elements, ions (cations), compounds, minerals, and rocks
- silicon (the element), silica (compound of silicon + oxygen), silicates (minerals containing silica)
- silicate minerals
  relative silica content vs. metal cation content (esp. Fe & Mg)
  felsic vs. mafic
- crystal forms can be hazardous, e.g., asbestos

igneous rocks
granite, rhyolite, diorite, andesite, gabbro, basalt
- melt: magma, lava
- melting/crystallization temperature of felsic (low) vs. mafic (hi) minerals
- solid-liquid-gas phases of matter and phase change melting/crystallization
    temperature = avg. kinetic energy
    physical (molecular) difference between solid and liquid (and gas) phases
- Igneous Texture: coarse-grained, fine-grained, porphyritic, glassy
    and mode of emplacement: plutonic (intrusive), vs. volcanic (extrusive)
- Color/Composition: felsic, intermediate, mafic, ultramafic
- classification of igneous rocks (texture and color/composition)

sedimentary rocks
conglomerate, sandstone, shale, limestone, coal
the 5 steps in the formation of sedimentary rocks
    1. weathering of pre-existing rocks produces sediments
    2. transport
    3. deposition
    4. compaction
    5. cementation
1. weathering
mechanical:
    stream abrasion, sand blasting, frost wedging
chemical:
    formation of carbonic acid:most natural surface waters slightly acidic
    hydrolysis: silicate minerals in acid solution alter to clays + soluble ions
    dissolution of some minerals (like calcite)
weathering products: gravel, sand, silt, clay, dissolved ions
2. transport: via streams, wind, glaciers, waves
    the faster the stream velocity, the larger the sedimentary particles that may be transported
    sorting and rounding
3. deposition (e.g., when stream velocity drops)
    sediments are deposited in horizontal layers (cross-bedding not withstanding)
    oldest layers are on the bottom, younger toward the top
4. compaction
5. cementation:
    crusts of minerals precipitated from ions dissolved in water into voids between sedimentary particles
    common cements: silica, calcite (fizzes), hematite (red)
classification of sedimentary rocks
    clastic: conglomerate, sandstone, shale
    biogenic (biochemical): limestone, coal
    chemical precipitates: halite

the importance of sedimentary rocks
fossil evidence for past life
record of past climate and environment: marine vs. terrestrial, stream deposits, desert deposits, glacial deposits
fossil fuels:
e.g., coal: high organic matter, oxygen-poor conditions (like saturated swamp soil),
organic matter preserved (not decayed)
also oil & natural gas: organic matter preserved in sed. strata; matures into oil & gas
oil and gas in petroleum traps
hydraulic fracturing (fracking) for exploitation of natural gas in impermeable shales

fossil fuel combustion and climate change
the greenhouse effect
CO_2 (produced by combustion of fossil fuels) is a greenhouse gas
the more of it in the atmosphere, the more heat the atmosphere can hold

metamorphic rocks
conditions for metamorphism
pressure and heat (not so much heat to melt the rocks)
fluids (including water and carbon dioxide stored in rocks)
regional metamorphism (our main interest)
elevated pressure and temperature caused by deep burial cause by tectonic collisions and mountain building
(other types include contact, hydrothermal, and cataclastic metamorphism)
protolith --> meta rx (characteristics of meta rocks compared to their protolith)
examples:
foliated (w/ slaty cleavage, schistosity, gneissic banding: know the characteristics of each)
shale --> slate
shale --> schist
mixed sediments, granite, etc. --> gneiss
non-foliated
sandstone --> quartzite
limestone --> marble

be able to draw simple sketches (magnified views) showing features of igneous, sedimentary, and metamorphic rocks

environmental health and safety:
durability of rocks and landslide hazard
mafic minerals and rocks are more susceptible to chemical weathering than felsic
porous rocks weather faster than non-porous rocks
tendency to split into sheets/layers
tilted sedimentary strata or metamorphic foliation are potential landslide hazards
structure: dangerous if layers are tilted downward toward a vulnerable location

bedrock mineralogy and human health

asbestos is a fibrous crystal form that occurs in certain minerals
    It has been used to produce fire-proof fabrics, insulation, brake-linings, etc.
    breathing asbestos fibers can cause lung disease
    but the primary danger appears to be mineral crocidolite, blue asbestos
        whereas white asbestos, chrysotile, may not be particularly dangerous
hard water, water high in dissolved solids (especially Ca, Fe, Mg, etc.) in drinking water are
    related to low incidence of cardiovascular disease
    limestone and certain volcanic bedrock yields groundwater rich in these ions
    limestone regions also produce strong bones:
        racehorse breeding (Kentucky, Florida)
natural arsenic in groundwater in southern Asia
    arsenic is mobile (soluble) under reducing (low oxygen) conditions
    organic-rich, oxygen-poor strata in southern Asia contain mobile arsenic
    millions of people in southern Asia delta regions are at risk of arsenic poisoning
radon risk from trace amounts of radioactive uranium or potassium in felsic igneous and
    metamorphic rock and sediment sediments derived from them
        contain radioactive uranium; decay produces radioactive radon
    radon gas seeps into basements
    breathing indoor air with elevated radon increases the risk of lung cancer
        especially among smokers

structural geology

folds, metamorphic foliation, joints, faults
- compression, tension, shearing stress
- initial elastic response to stress (non-permanent deformation)
- brittle vs. ductile response to stress (permament deformation)
- folds
    anticlines and synclines
    fold axis
    plunging folds
    erosion in tilted strata: valley and ridge topography
    (erosion in flat-lying strata: cliff and bench topography)
- foliation
    axial planar cleavage
- joint sets
    controls surface weathering and topography
- faults: hanging wall and footwall blocks
- the 3 categories (4 types) of faults and the stress environments in which they are found
    normal faults (extension) (example: basin and range province)
        crustal thinning and lengthening
        horst & graben (uplifted ranges and downdropped basins)
        half-grabens (Newark Basin & East African Rift)
    thrust & reverse faults (compression)
        crustal thickening and shortening
        mountain belts, collisions (e.g., modern Himalayas, ancient Appalachians)

strike-slip faults (shearing)
San Andreas Fault, offset streams
restraining and releasing bends
- orientation of faults, folds, and foliation relative to the applied (tectonic) forces
- topography related to underlying structure
basin and range topography
valley and ridge topography resulting from differential weathering of folded strata

be able to draw simple maps and profiles of faults and folds, etc.

earthquakes

- elastic strain buildup -> rupture (slippage) on faults -> seismic waves propagate outward through Earth
- body waves: P waves, S waves
- surface waves: Love waves, Rayleigh waves
- epicenter and focus (hypocenter)
- basic principal of seismometers (inertial mass that remains stationary as the crust moves)
- determining distance from earthquake by S-P interval
- earthquake location via triangulation (S-P interval from three seismic stations)
- information needed to determine an earthquake's magnitude
peak amplitude of ground motion at recording station
S-P interval (to determine distance)
- the Richter magnitude scale of earthquake strength: logarithmic scale (powers of 10)
- what the moment magnitude scale measures as compared to the Richter scale
- Modified Mercalli scale of earthquake intensity
- first motion studies to determine type of fault in an earthquake
- type of plate boundary where worst (greatest magnitude) earthquakes tend to occur
convergent plate boundaries where an oceanic plate subducts (sinks) beneath another
- local bedrock geology and earthquake damage risk (esp. solid bedrock vs. unconsolidated sediments and saturated muds)
- construction practices and damage in earthquakes
unreinforced stone and concrete is weak in tension: doesn’t flex, it breaks
soft first stories (buildings held up on columns) fall off the columns
wood frame construction can flex (up to a point) without breaking
- earthquake "prediction"
probabilities of EQs of given magnitude in certain number of years
EQ sequence (e.g., Parkfield, Istanbul)
seismic gaps (e.g., Alaska)
but earthquake prediction?
- how tsunamis are caused by earthquakes
- earthquake early warning systems

be able to draw simple sketches to illustrate methods in seismology (triangulation, first motion studies, magnitude determination)

earth's interior
- wavefronts and ray paths
- Moho: what it is (crust-mantle boundary) and how it was discovered
- characteristics of continental crust, oceanic crust, and mantle rock
- the average thickness and the predominant igneous rock types (felsic, mafic, etc.) found in ocean crust and in continental crust
-the core-mantle boundary (Gutenberg seismic discont.) - P and S wave shadow zones
- the mantle: low velocity zone (LVZ) - the asthenosphere (evidence for it; its characteristics)
- the lithosphere: all the crust and mantle above the asthenosphere
- major subdivisions of the earth from core to surface and the materials that make them up: inner core, outer core, mantle, crust
- evidence for interior composition:
  crust: we walk on it;
  core: must be high density material common in the solar system,
    and account for seismic velocity and fluctuating magnetic field
- magnetic field produced by convection of molten iron in the outer core
- mechanisms for cooling the earth:
  conduction? No, b/c rock is a good insulator, poor conductor
  convection? Yes, b/c rock in the mantle is ductile

be able to draw profiles of the Earth's interior and describe the major layers and boundaries
be able to draw simple sketches to show how the Moho and Core-Mantle Boundary were discovered

isostasy
- the crust 'floats' on the more dense (solid but ductile) mantle
- mountains (thick continental crust) have deep sub-crustal roots
  (just as 9/10 of an iceberg lies beneath the ocean surface)
- as orogenic belts erode, the crust rises

historical developments leading to plate tectonics
- continental drift: Alfred Wegener
  jigsaw puzzle fit of the continents
  truncated geologic features:
    matching geologic formations on opposite sides of the Atlantic
  far-flung fossils: same species in presently geographically isolated locations
  paleoclimate indicators: glacial deposits on the southern continents, same time as tropical coals in the northern continents
- paleomagnetism: paleomagnetic evidence for continental motions
  magnetism recorded in rocks can tell ***direction*** and ***distance*** to the pole at time rock formed
  magnetic inclination indicates ancient latitude;
  magnetic direction indicates direction to the pole ancient
  "apparent poles" recorded in ancient rocks do not coincide with the actual pole as recorded by recently formed rocks
  each continent has its own apparent polar wander path
  therefore these distinct pole paths indicate the movement of the continents

- seafloor spreading
  - evidence: marine magnetic anomalies
  - contributions of Harry Hess, Vine & Matthews (1963), Pitman & Heirtzler (1966)
  - magnetization of the ocean crust in alternately normal and reverse polarity strips parallel to midocean ridges
  - anomalies are symmetric about the ridge - supporting the view that new crust formed and spread away from ridges
  - seismic evidence (first motion studies):
    - normal fault earthquakes (stretching-divergence) along midocean ridges
    - thrust fault earthquakes (compression - convergence) at deep-ocean trenches