Intro to Earth Sciences I
Lecture Topics for Final Exam
with Brief Notes
Summer 2017
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The major topic areas the we have covered since the midterm are:
Plate Tectonics
Volcanoes
Groundwater Geology
Soils
Stream Processes, Landforms, and Flooding
Coastal Processes

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plate tectonics
primary earthquake belts on the Earth and zones where igneous (volcanic) activity is concentrated are near plate boundaries
divergent plate boundaries
- midocean ridges
  - plates spread apart
  - new crust forms
  - earthquakes on normal faults (tension)
  - source of magma: decompression (partial) melting of upwelling mantle rock...
    - magma is all mafic (basalt & gabbro)
  - ridge stands high b/c hot (expanded); lithosphere cools & contracts as it spreads away
- continental rifts (e.g., East African Rift)
  - earthquakes on normal faults (tension)
  - volcanic activity in later stages of rifting
  - may continue to form new midocean ridge (Gulf of Aden)
  - or become a failed rift

convergent plate boundaries
- ocean-ocean subduction zone (e.g., Aleutians, Mariannas, Philipines, Japan)
- continent-ocean subduction zone (e.g., Andes, Pacific Northwest)
  - deep ocean trench
  - volcanic arc (continental or island arc) parallel to trench
  - magma produced by metamorphic dewatering of subducting crust
    - which causes flux (partial) melting of mantle above subducting crust...
    - erupting magma is mostly intermediate (andesite/diorite)
    - subduction zone volcanoes are typically stratovolcanoes
  - earthquakes on thrust & reverse faults (compression)
- continent-continent collision (e.g., Himalayas, Appalachians)
  - orogenic belt: thrust faulting and thickening of continental crust

volcanic activity ceases after all intervening ocean crust has finished subducting
earthquakes on thrust & reverse faults (compression)

transform plate boundaries
- generally no igneous activity
- earthquakes on strike-slip faults (shearing)
- oceanic transforms: ridge offsets
  - transform faults (plate boundaries) & fracture zones (not)
- continental transforms: (e.g., San Andreas, North Anatolian Fault in Turkey)

hotspot tracks (like the Hawaiian/Emperor chain of islands and seamounts)
- volcanically active at one end
- volcanoes get progressively older down the chain
- fed by mantle plumes: rising conduit of hot, solid mantle rock
  - perhaps from the core-mantle boundary
- the rising mantle rocks begin to partially melt near the base of the lithosphere
  - as a result of the reduced pressure (decompression melting)

evidence for plate tectonics
- satellite measurement (VLBI) show the plates are moving as expected
- normal fault earthquakes (stretching) at midocean ridges
- deep sea submersible observations of normal faults and new lava flows at midocean ridges
- age pattern of ocean crust from radiometric dating of drill cores
- Wadati-Benioff zones: plane of EQs descending from trench, down as deep as ~670 km
  - shows the location of top of subducting plate
  - Benioff EQs go as deep as ~660 km (well beyond region of melt formation for volcanic arc)

know the primary kind of faulting (earthquakes) that generally occurs at each type of boundary
- divergent (normal faults), convergent (thrust faults), transform (strike-slip faults)

Note: earthquakes occur at all plate boundaries!

be able to draw profiles and maps of midocean ridges, subduction zones, transform and fracture zones, and hotspots/mantle plumes

what drives plate motions?

original hypothesis: mantle convection drags the plates - WRONG (for the most part)

best bet: gravity
- slab pull:
  - the weight of the cold, dense plate as it sinks into the mantle pulls the plate
- ridge "push":
  - at midocean ridges the lithosphere lies on an inclined plane of elevated asthenosphere
  - the lithosphere slides down the slippery slope of the asthenosphere

Tectonic Events in Eastern North America

Grenville Orogeny: ~1 b.y. ago
- formation of Rodinia
- ca. 1 b.y. old gneissic bedrock underlies eastern North America

passive margin sequence: beginning ~700 m.y. ago through Cambrian and Ordovician Periods
- rifting from Rodinia and subsidence of continental margin
- deposition of limestone followed by muds-shale on drowned continental margin

Taconic Orogeny: ~450 m.y. ago, Ordovician Period

collision of island arc
burial and metamorphism of limestone forming Inwood Marble & shales into Manhattan Schist
Acadian Orogeny: ~380 m.y. ago, Devonian Period
collision with Baltica (NW Europe) and another terrane *(forming "Laurussia")*
sediments shed from the Acadian mountains found today as the Catskill redbeds
Appalachian Orogeny: ~280 m.y. ago during the Pennsylvanian and Permian Periods
collision of Laurussia with Gondwana (Africa, S.Amer., India, Australia, Antarctica)
and also collision of Siberia to east of Baltica
forming Pangea and building the Appalachians and several other late Paleozoic mountain ranges
Newark and other rift basins began ~ 225 m.y. ago in the Triassic Period
followed by separation of North Amer. from Africa by ~170-165 m.y. ago
this rifting of Pangea and opened the central Atlantic Ocean

geologic units of Manhattan/Central Park
Fordham Gneiss: 1 b.y. Grenville Orogeny, continental collision (earlier supercontinent), later breakup
latest Proterozoic-Cambrian-Ordovician passive margin sedimentation: sands-sandstone, reefs-limestone, muds-shale
late Ordovician Taconic Orogeny metamorphoses
sandstone to Lowere Quartzite,
limestone to Inwood Marble
shale (& basalt) to Manhattan Schist (& amphibolite)
- Manhattan Schist features
foliation & orientation of compression
amphibolite
pegmatites, fine-grained granite dikes, veins
- glacial features
striations, roches moutonées, erratic boulders
evidence for glacial flow direction

volcanoes
- viscosity and volcano shape (steepness of slope)
basalt is low-viscosity, flows easily because it is hot and because low in silica
intermediate & felsic lavas are high viscosity because cooler and because high in silica
- dissolved volatiles (gases), lava viscosity, and explosiveness of eruptions
- shield volcanoes – broad, gently sloping volcanoes
low-viscosity mafic/basaltic lava
pahoehoe lava, aa lava
- cinder cones – small steep volcanoes, "cinders" build up at the angle of repose
pyroclastics (bombs, lapilli, ash)
- stratovolcanoes (composite cones) – large, steep, prototypical volcanoes
alternating pyroclastic flows and intermediate/andesitic lava flows
- the greatest dangers from volcanoes are
pyroclastic flows
lahars (volcanic mudflows)
fluid lava flows too slow to be a serious hazard to people, though it will destroy property

groundwater

the hydrologic cycle: precipitation = runoff + infiltration + evapo-transpiration
porosity (void spaces between grains and in fractures)
  and permeability (ability of water to pass through voids)
typical permeable materials that make good aquifers: sand, gravel, sandstone, limestone
impermeable aquiclude materials: clay, shale, joint-free igneous and metamorphic rocks
zone of aeration, zone of saturation, water table, aquitards and aquicludes
unconfined aquifers and water table
confined aquifers and pressure surface (potentiometric surface)
  because water in confined aquifers is typically under pressure
groundwater flows (seeps) from where water table or pressure surface is high to where it is low
water wells, how they work
  cone of depression, drawdown
town water supplies and water towers
landfills (garbage dumps) and our groundwater supply
  requirements of a properly built sanitary landfill that protects the groundwater
land subsidence from over-pumping
saltwater intrusion from cone of depression in coastal aquifer
agricultural and lawn chemicals and groundwater
be able to draw and describe profiles of the groundwater system
  (including wells, cones of depression, groundwater flow, etc.)

weathering and soil

mechanical weathering breaks bedrock into smaller pieces via frost wedging, etc.
chemical weathering of minerals by slightly acidic rainwater changes minerals into
  clay minerals and leftover dissolved ions
weathering: mechanical & chemical transform bedrock into gravel, sand, silt, clay, and soluble ions

soils:

soil-forming processes:
  mechanical & chemical weathering of bedrock
  incorporation of organic matter
  downward washing of the finest particles (clays) and leaching of soluble ions
soil profile:
  O, A, B, and C horizons overlying bedrock or other parent material
  understand the characteristics of each soil horizon and how the soil-forming processes produce those characteristics
time: rich topsoil (O & A horizons) takes thousands of years to develop
negative effects of modern agriculture
  mechanical plowing bares the soil making it vulnerable to water and wind soil erosion
    and loss of soil organic matter
  contour farming and wind rows slow the erosion, but not enough for long-term sustainability
  no-till farming is a must for the long-term
  plowing plus chemical fertilizers and pesticides kill soil organisms (fungi & bacteria) that
    naturally supply nutrients and support resistance to disease and insects

old-fashioned incorporation of organic matter (manure, mulch, compost)
is a must for long term sustainability
organic (no synthetic chemicals) agriculture needs to become the conventional agriculture again
and this time it needs to be no-till
if we are to maintain soil fertility and crop yields
the current “conventional” (chemical/mechanical) agriculture will continue to deplete global
soils resulting in drastically decreasing crop yields
despite increasing inputs of synthetic fertilizers, pesticides,
and ever more expensive oil and gas for fertilizer & pesticide production and tractor fuel

streams

relationship of groundwater and surface water
(surface streams, lakes and ponds, welands)
gaining and losing streams
perennial vs. intermittent and ephemeral streams
stream discharge (Q = width x depth x velocity = VA)
stream velocity profile (slowest along stream bed and banks - friction)
cross-sectional shape of stream channel and ease of flow *(hydraulic radius)*
stream transport - bed load, suspended load, dissolved load
deposition vs transport vs erosion depending on stream velocity (Hjulstrom’s curve)
small changes in stream velocity mean big changes in ability to erode/transport sediments
stream networks, stream orders
discharge increases down a stream network into higher and higher order streams
meandering streams:
velocities across a bend
shallow inner bank, low velocity, deposition of point bars
deep channel near outer bank, high velocity, erosion of cut bank
development of oxbow bend, cutoff, and oxbow lake
floodplains, valley walls
youthful and mature streams (profiles and map views)
stream velocity at flood stage (fast) vs. slow water (slow)
stream hydrographs: why does stream discharge slowly increase and peak hours or days after major
rains? (b/c of water supplied by upstream network of tributaries)
why does stream continue to flow long after rain discharge has flowed downstream?
(b/c perennial streams are fed by groundwater baseflow)
the meaning of 10, 20, 50, 100 year floods and how they are calculated (using historic data)
flooding and effect of artificial levees
deltas
be able to draw profile and map views of streams and stream valleys
(esp. youthful & mature; flood plains & oxbows, etc.)

coastal processes

shorelines are modified by waves, tides, storms, and changing sea level rise
size of waves determined by wind speed, duration, and fetch
waves: crest, trough, wavelength (L), wave height, period
- wave velocity depends on wavelength

orbital motion of water as wave passes, decreases to zero at depth of L/2
wave velocity depends on wavelength (in deep water) and water depth (in shallow water, < L/2)
what happens to a wave as it approaches shore (when water depth < L/2)
- waves slow, wavelength gets shorter, waves get steeper and higher, and then break

breakers, swash, backwash
beach profile: shoreface, berm, dune
littoral (longshore) drift and longshore currents
- due to waves approaching shore at an angle
- growth of sand spits

winter vs. summer beach profiles and cause of differences
coastal sedimentation: coarse along the shoreline, progressively finer going offshore: why?
tides:
- moon exerts ~2 times tide force as sun
- why 2 high tides per day rather than 1
- phases of the moon and spring and neap tides
  - spring tides when sun-Earth-moon aligned at full and new moon
  - neap tides around first and third quarter moons (sun-Earth-moon form right angle)

coastal storms and beach erosion:
- storm surge
  - inverted barometer effect from low pressure in eye of a hurricane
  - wind setup from constant wind blowing toward shore
- beach erosion due to the combination of wind setup, strong waves, and return flow
- worst erosion & flooding in storms at high tide of a spring tide

sea level rise from thermal expansion of the oceans and melting of glaciers as Earth warms
- the greenhouse effect
- CO_2, water vapor, methane and others as greenhouse gases

combined effects of slowly rising sea level and stronger coastal storms with warmer ocean
- (especially at high tide of the spring tides)

trying to protect our receding shorelines
- groins capture sand on updrift side, but cause excessive erosion on downdrift side
- seawalls cause excessive erosion by reflecting storm waves; destroys beach
- beach nourishment replaces beach with offshore (maybe finer) sand
- none is a permanent solution
  - all require continuing large financial investment to maintain coastal properties

be able to draw profile and map views of the coast showing features and processes
- (wave-stirring with depth, beach profile, wind setup & return flow, Earth-Moon-Sun & tides)