

# DYNAMIC PLANET

## Plate Tectonics

Students will demonstrate an understanding of the large scale processes affecting the structure of Earth's crust.

Divisions B & C

2016-2017

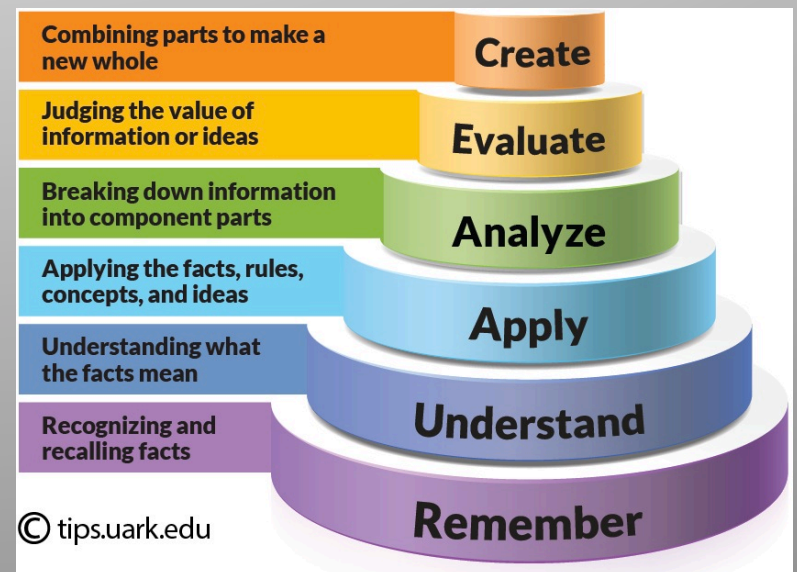
Beth Cahill

# Event Parameters

- One or two team members compete
- Non-graphing calculator (one per team member)
- Up to four 8.5" x 11" sheets of paper allowed
  - Info from any source
  - Make sure that it's 4 sheets and not 8 (Don't get DQ'ed)
  - Kids know to use tiny font. Also remind them to write in margins and use maps as backgrounds to other info.
  - As info is memorized, delete it from the cheat sheet to make room for other material

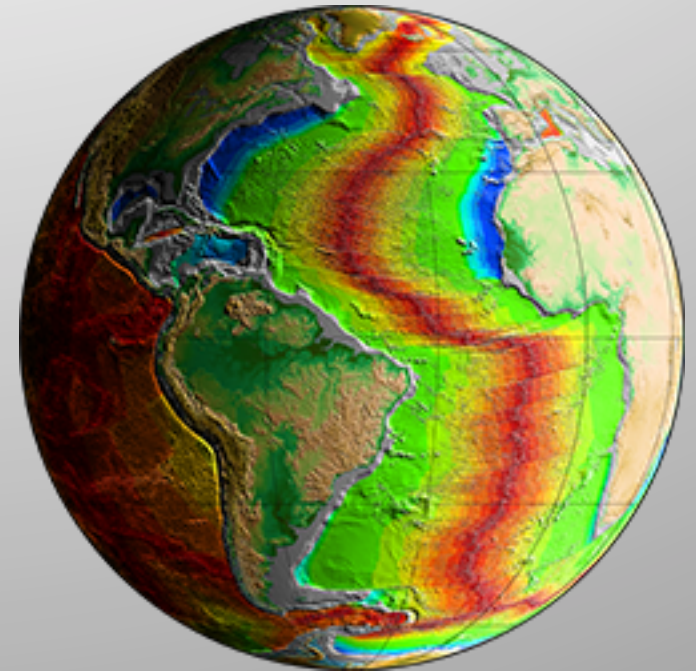
# Event Parameters

- Competition is geared toward analysis and performance rather than strictly knowledge-based questions
- May be a station-based format or a sit-down test with multiple tasks
- Don't neglect the knowledge and comprehension skills!
  - This is the base upon which the tasks are built
- Teams must understand how to work with the knowledge



# Content

- Teams need to understand how all parts of the lithosphere interact as well as the structure and characteristics of the Earth's interior.
- Often certain team members will be expert at their favorite topics
- All team members should have a basic understanding of all topics, and when teams are assembled, make sure their areas of expertise complement each other



# Competition hints

- Everyone should have a great “cheat sheet”, know to study, and work with their partners
- Practice with the partner before the competition
- If a test or station is able to be split into parts, partners may divide and conquer, then check each other
- Never skip tie breakers! This happens more than half the time. In every competition, many of the ties are broken because one team didn't bother to do the question at all.

# Recommended Texts

- Earth: An Introduction to Physical Geology
  - Tarbuck, Lutgens, and Tass ISBN: 9780321814067
- The Earth Through Time
  - Harold L. Levin ISBN: 9781118254677
- Earth Science Today, chapters 4-7
  - By Brendan Murphy and Damian Nance
- Essentials of Geology: 12th Edition
  - By Lutgens and Tarbuck ISBN: 9780321947734
- The Changing Earth: Exploring Geology and Evolution | Edition: 7
  - By James S. Monroe, Reed Wicander ISBN: 9781285733418

# Resources online

- MIT Open Courseware
  - <https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-001-introduction-to-geology-fall-2013/>
- Physical Geology, 15<sup>th</sup> ed.
  - By Charles C. Plummer, Diane H. Carlson, Lisa Hammersley
  - [https://archive.org/details/Physical\\_Geology\\_15th\\_Edition\\_by\\_Diane\\_H.\\_Carlson\\_Charles\\_C.\\_Plummer\\_Lisa\\_Hammer](https://archive.org/details/Physical_Geology_15th_Edition_by_Diane_H._Carlson_Charles_C._Plummer_Lisa_Hammer)
- Introduction to Physical Geology
  - By Thompson & Turk
  - <https://docs.google.com/file/d/0B7WuoflTzjJkSDZMTTdsZzVoMkU/> preview
- Agencies
  - GSA, <http://www.geosociety.org/index.htm>
  - NAGT, <http://nagt.org/index.html>
    - [nagt.org/nagt/teaching\\_resources/index.html](http://nagt.org/nagt/teaching_resources/index.html)
- University websites
- Look for exam questions and quizlets for practice



# Other Resources

- **Intro to Earth Science I**  
<http://www.columbia.edu/%7evjd1/notes.htm>
- **Earth 520 from Penn State** <https://www.e-education.psu.edu/earth520/>
- **Plate Tectonics: Geological Aspects** <http://www.le.ac.uk/gl/art/gl209/>
- **Cliffs notes**
- <https://www.cliffsnotes.com/study-guides/geology>
- **Radford Univ**
- <http://www.radford.edu/jtso/GeologyofVirginia/Tectonics/GeologyOfVATectonics6.html>
- **Geology 101** <http://jersey.uoregon.edu/~mstrick/>
- **Geol 3700 from U of Nebraska** <http://maps.unomaha.edu/maher/plate/syllabus.html>
- **Geoblox models** <http://www.geoblox.com/index.html>



# Basic topics you need but nobody tells you to study

- Geography!
  - Continents, oceans, mountain ranges, etc.
- Superlatives
  - Biggest, fastest, oldest, etc.
- Cartography
  - Longitude & latitude, topo maps
- Vocabulary
  - Prepare an awesome glossary. Don't forget acronyms.

## a. History

- Timeline
- Continental drift
- Evidence
  - Fit of continents
  - Fossils
  - Comparable rocks
  - Evidence of glaciation
  - Perplexing climate evidence
  - Matching mountain ranges
- Key Scientists
  - Nice list to start from under “The Giants!” at <https://www.e-education.psu.edu/earth520/content/l2.html>

## b. Earth Structure

- Composition, size, state, temperature, action
- How do we know?
  - Seismic waves
  - Shadow zone
- <http://crack.seismo.unr.edu/ftp/pub/louie/class/100/interior.html>

## b. Earth structure - Crust

OSiAlFeCaNaKMg

- Oceanic
  - Thinner
  - More dense
  - Basaltic
  - Younger
- Continental
  - Thicker
  - Less dense
  - Granitic
  - Older

## b. Earth structure - Mantle

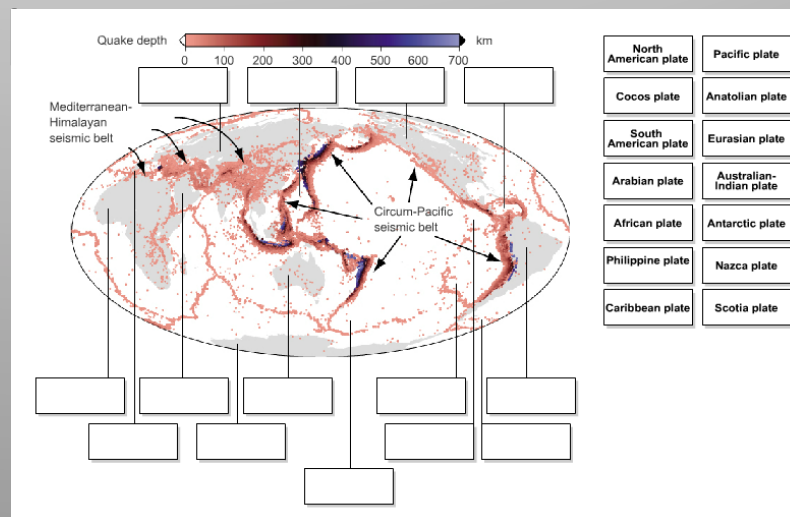
- Composition, size, state, temperature, action
- Lithosphere
  - Includes crust and uppermost mantle
  - Contains the Mohorovičić Discontinuity
  - Divided into plates
- Asthenosphere
  - Asthenis = weak, this layer flows due to convection
  - Source of magma
- Transition Zone of the mantle
  - Contains more water than Earth's oceans
- Lower mantle
  - Unpredictable D double-prime layer (D'') at base
  - Core-mantle boundary (CMB) is called the Gutenberg Discontinuity
- Other Mantle features
  - <http://nationalgeographic.org/encyclopedia/mantle/>
  - Hot spots at mantle plumes
  - Two superplumes, or large low shear velocity provinces (LLSVP)
    - One in southern Pacific, one under southern and western Africa

## b. Earth structure - Cores

- Composition, size, state, temperature, action
  - <http://www.bbc.com/earth/story/20150814-what-is-at-the-centre-of-earth>
  - <http://nationalgeographic.org/encyclopedia/core/>
- Heat sources
- Iron catastrophe
- Planetary differentiation
- Outer core
  - Magnetic field
    - Cause
    - Reversals
- Inner core
  - Bullen discontinuity (Lehmann discontinuity)
  - Hemispheres
  - “Inner inner” core

## c. Characteristics of plates

- Types of plates
  - Major & minor plates, microplates
  - [https://en.wikipedia.org/wiki/List\\_of\\_tectonic\\_plates](https://en.wikipedia.org/wiki/List_of_tectonic_plates)
  - Cratons (shields & platforms)
- [http://www.wiley.com/college/trefil/0470118547/animations/ch17/earthquakes\\_margins/fig\\_10\\_15\\_fixed\\_size](http://www.wiley.com/college/trefil/0470118547/animations/ch17/earthquakes_margins/fig_10_15_fixed_size).





## c. Characteristics of plates - boundaries

- <https://www.geolsoc.org.uk/Plate-Tectonics/Chap3-Plate-Margins>
- Types of plate boundaries (oceanic and continental locations)
  - Convergent
    - Subduction and/or mountain building
    - Ocean->Ocean, Ocean->Continent, Continent ->Continent
  - Divergent
    - Rifts and ridges
  - Transform
    - relative motion along faults
- Features that occur at each type of boundary
  - Volcanoes, trenches, hydrothermal vents, earthquakes, Benioff zone
- Paleomagnetism
- Margins
  - Ophiolites, terranes
    - <http://maps.unomaha.edu/maher/plate/week6/terranes.html>
- Identification of boundaries from paleogeographic reconstructions

## d. Tectonic Basins

- <http://www.csus.edu/indiv/k/kusnickj/geology12/tectonicbasins.html>
- Types
  - Rift (East African Rift Valley, Red Sea)
  - Passive margin (Atlantic Ocean, Indian Ocean)
  - Back arc (behind volcanic islands) & Fore arc (above trench) at subduction zones
  - Foreland basins at large mountain ranges – with river deposits or continental sea (foredeep) marine deposits
  - Intermontane – basin & range
  - Intracratonic (North Sea & Baltic Sea)
- Formation processes
- Sedimentary records
  - Ophiolites, accretionary wedges, melanges
- Examples

## e. Driving forces

- [http://www.columbia.edu/~vjd1/driving\\_forces\\_basic.htm](http://www.columbia.edu/~vjd1/driving_forces_basic.htm)
- <http://www.geosci.usyd.edu.au/users/prey/ACSGT/EReports/eR.2003/GroupD/Report1/web%20pages/Convection.html>  
(summary done as an assignment, but with references and great diagrams)
- Mantle convection
  - <https://www.khanacademy.org/partner-content/amnh/earthquakes-and-volcanoes/plate-tectonics/a/mantle-convection-and-plate-tectonics>
  - <https://www.khanacademy.org/partner-content/amnh/earthquakes-and-volcanoes/plate-tectonics/v/computer-model-of-mantle-convection>
- Mantle plumes
  - Someone is *really* into this topic. <http://www.mantleplumes.org/>
- Subduction
- Slab pull
- Ridge push
  - Not actually a push, but sliding down the asthenosphere “high” elevation

## f. Plate movements and their impacts

- Wilson cycle
  - <http://csmres.jmu.edu/geollab/Fichter/Wilson/Wilson.html>
  - <http://www.radford.edu/jtso/GeologyofVirginia/Tectonics/GeologyOfVATectonics6-2c.html>
- Terranes
- Orogenic belts
- Past supercontinents
  - [https://en.wikipedia.org/wiki/List\\_of\\_supercontinents](https://en.wikipedia.org/wiki/List_of_supercontinents)
- Convergence
- Divergence
- Transform motion
- Associated faults
- Opening and closing of ocean gateways and land bridges (with impacts on biota)

## g. Aulocogens

- Aulocogens are failed arms of triple junctions
- <http://www.geologyin.com/2015/02/what-is-aulacogen.html>
  - They occur mid-plate
  - Become a filled graben
  - May reactivate
  - From aulax (furrow)
    - Ottawa-Bonnechere Graben (Pangaea)
    - New Madrid Seismic Zone (Rodinia)
    - Southern Oklahoma Aulacogen (Pannotia, Laurentia)
    - Rio Grande Rift
    - Lusitanian Basin
    - Dniepr-Donets aulacogen

## g. Hot Spots

- Zones of volcanism above a thermal mantle plume
  - <http://pubs.usgs.gov/gip/dynamic/hotspots.html>
  - <http://geology.com/usgs/hawaiian-hot-spot/>
- Hawai'i/Emperor Island chains
- Yellowstone
- Galapagos
- Azores
- Iceland
- [http://pubs.usgs.gov/gip/dynamic/world\\_map.html](http://pubs.usgs.gov/gip/dynamic/world_map.html)

## h. Isostatic Adjustments

- Plate thickness
  - <https://www.cliffsnotes.com/study-guides/geology/inside-the-earth/isostatic-equilibrium>
- Impact of mass wasting
- Impact of glaciation
  - <http://academic.emporia.edu/aberjame/ice/lec09/lec9.htm>
- Hypsometry and elevation/depth of crust
  - <http://serc.carleton.edu/mathyouneed/hypsometric/index.html> (with sample problems!)
  - Continental
  - Oceanic



# i. Natural Hazards

- Earthquakes
  - Depths
  - Scales (Richter and Mercalli)
  - Types of movement
  - Types of seismic waves
  - Types of faults
  - Calculating epicenters
  - Prediction
- Volcanoes
  - <http://volcano.oregonstate.edu/>
  - Types
  - Magma composition
- Tsunamis
  - Causes
  - DART
  - Characteristics
- Landslides
  - Factors
  - Madison Canyon 1959
  - Vajont 1963

# j. Magma Formation

- <http://nationalgeographic.org/encyclopedia/magma/>
- <http://www.trinity.edu/gkroeger/GEOS1307/Notes/magmas.htm>
- [http://www.tulane.edu/~sanelson/Natural\\_Disasters/volcan&magma.htm](http://www.tulane.edu/~sanelson/Natural_Disasters/volcan&magma.htm)
- Geological settings
  - Plate boundaries
  - Hot spots
- Chemistry
  - <http://mtweb.mtsu.edu/cribb/100magma.html>
  - [http://www.indiana.edu/~geol105/images/gaia\\_chapter\\_5/origin\\_of\\_magmas.htm](http://www.indiana.edu/~geol105/images/gaia_chapter_5/origin_of_magmas.htm)
  - Composition of crust
  - Addition of water
- Properties
  - Composition
  - Viscosity

# k. Geologic History of North America

- Evolution of craton
  - <https://www.geol.umd.edu/~jmerck/geol100/lectures/25.html>
  - Timeline <http://www.cbc.ca/geologic/teachersguide/GeologicJourneyTRG%20figures.pdf>
  - Maps! <http://jan.ucc.nau.edu/rcb7/nam.html>
  - <http://jan.ucc.nau.edu/~rcb7/RCB.html>
- Rocky Mountains
  - Ancestral Rocky Mountains (Pennsylvanian)
  - Modern orogenies
    - Antler, Laramide
- Appalachian Mountains
  - Orogenies (compare to Variscan orogeny in Europe)
    - Taconic, Acadian, Alleghenian
- Yellowstone Hot Spot
- Other
  - Basin and Range
  - New Madrid earthquake zone
  - Rio Grande Rift
  - Ouachitas

# I. Data

- Brittle/ductile deformation
  - <http://www.tulane.edu/~sanelson/eens1110/deform.htm>
  - [http://www.soest.hawaii.edu/GG/FACULTY/POPP/Sept30\\_Ch\\_10.pdf](http://www.soest.hawaii.edu/GG/FACULTY/POPP/Sept30_Ch_10.pdf)
- Magnetic anomalies
  - <http://mrdata.usgs.gov/magnetic/>
  - State maps! <http://www.uwgb.edu/DUTCHS/StateGeophMaps.HTM>
- Gravity anomalies
  - <http://mrdata.usgs.gov/geophysics/gravity.html>
  - <http://earthobservatory.nasa.gov/Features/GRACE/page3.php>
  - [http://bgi.omp.obs-mip.fr/activities/Projects/world\\_gravity\\_map\\_wgm](http://bgi.omp.obs-mip.fr/activities/Projects/world_gravity_map_wgm)
- Stress
  - <http://serc.carleton.edu/quantskills/methods/quantlit/stressandstrain.html>
  - <http://www.geologyclass.org/Structures%20Concepts.htm>
- Seismicity
  - <http://earthquake.usgs.gov/contactus/golden/neic.php>
  - <http://earthquake.usgs.gov/earthquakes/map/>

# m. Hazard Mitigation

- <http://earthquake.usgs.gov/hazards/>
- Building codes
  - <https://www.fema.gov/earthquake-publications-building-codes-and-seismic-rehabilitation>
  - [http://mceer.buffalo.edu/1906\\_Earthquake/industry\\_impacts/impact-building-codes.asp](http://mceer.buffalo.edu/1906_Earthquake/industry_impacts/impact-building-codes.asp)
  - <http://earthquake.usgs.gov/learn/publications/saferstructures/>
- Preparation of population
  - <https://www.cdc.gov/disasters/earthquakes/>
  - <https://www.cdc.gov/disasters/volcanoes/index.html>
- Supplies
- Training
- Alerts, response