Dynamic Earth

GG 101

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- Textbook webpage: http://www.mygeoscienceplace.com
- Class ID = cm284806
Dynamic Earth

Text:

Overview of the geology of Hawaii and local environmental issues

Dynamic Earth Course Objectives

- Learn about the Earth, its origin and evolution, and how human activities affect it
- Overview of the geology of Hawaii and local environmental issues
Dynamic Earth Goals

- To present knowledge that will be useful for life, whether forming opinions on environmental issues, selecting a home site or other property, evaluating a business, or appreciating and understanding your surroundings.

Dynamic Earth Goals

- To prepare you to consider many environmental issues facing society, such as resource utilization, water use and conservation, and land-use planning.
Dynamic Earth
Course Structure

- Lecture, Reading, Videos, Discussion
  - Read the text *before* class
    - Complete on-line chapter test before class
      - Late tests will not be accepted
    - [www.mygeoscienceplace.com](http://www.mygeoscienceplace.com) click on chapter test and submit answers before class
  - Lecture notes available before class on web site
  - Time for questions at the beginning of class

Field Trips

- Big Island trip
- O`ahu field trips
- Field trips are optional
  - I strongly encourage participation
  - Extra credit will be given for field trip participation
Field Trips

- Big Island Field Trip
  - Leave Friday afternoon
  - Return Sunday afternoon
  - Cost ~$175 plus airfare
    - $175 covers lodging, transportation and some food on Big Island
    - You will need to purchase your own airline ticket and dinners
    - Will need non-refundable deposit soon

Field Trips

- Big Island Field Trip
  - Plan to visit Kilauea
  - Watch lava flow into the ocean
  - Hike Mauna Ulu
Field Trips

- O`ahu Field Trips -- No Cost
  - Option of three trips
  - Roughly early October, late October and early December
  - Exact dates unknown
  - Saturday 9:00 am – 4:00 pm

Dynamic Earth Grading

- On-line chapter tests – 25%
- 2 Mid-term Exams – 25% each
- Final Exam – 25%
Dynamic Earth Grading
- Let me know ASAP if you are going to miss an exam
- No make-up exams – will use average of other 2 exams

What is Geology?
Geology is the study of the Earth
Geology is a science...
...just like chemistry and physics!
What is different about Geology?

Geologists face the special challenge of not being able to do experiments in the sense that chemists and physicists do. The problem of experiments

Geologists are interested systems that are:

(1) Very Big (hundreds of km) and

(2) Have evolved over long periods of time (millions of years)
The problem of experiments

So, geologists cannot conduct controlled experiments.

They must observe the results of Nature’s experiments that are already complete.

TIME

- The big difference between geology and other sciences (Not much happens geologically in a human lifetime!)

- Rates of geologic processes: \(~\text{cm/year}\)

- Big earthquakes may displace the ground several meters in a few seconds, but they occur only every 500 years or so (in a given location).
The rates of geologic processes are almost always slower than the rates of human effects on the environment.

Geologists use millions of years as the standard unit of time:
- Ma = million years ago
- m.y. = an interval of time (million years)

Some geologic features take millions of years to form.
Geology In The News

Manoa Flood
UH salvages what's left after Halloween Eve flood

- Flooding leaves lots of work
- Photo Gallery

By James Conner and Dan Nakano
Advertiser Staff Writers

Manoa residents shookered mud and debris out of their homes yesterday, while University of Hawaii officials canceled today's classes and estimated damage in the millions after deluge revealed the full extent of damage caused by the Halloween Eve flood of 2004.

Three cars remained tossed like toys within a stand of trees. The floodwaters knocked man down and mowed down house, a scene of devastation.

Manoa Stream flooded, washing away belongings in what the Red Cross estimated was an eight-block stretch along East Manoa Road and Woodlawn Drive.

The UH-Manoa campus was hit hard after the flood triggered the banks of Manoa Stream and created a new river that raced through the heart of campus. The Library and the Biomedical Sciences building sustained the most serious damage, officials said.

About three dozen campus buildings did not have electricity yesterday, and workers were striving to get to them.

Lingle declares flood disaster

UH-Manoa cancels classes today as massive cleanup work begins
Geology In The News

Manoa Flood
Rockfalls and landslides
CASTLE JUNCTION

After 11 months, the state has finished work on a $7.8 million project at Castle Junction in Windward O'ahu.

An eroding, nearly vertical cliff was scaled into a gently sloped, landscaped hillside.

By the numbers

250,000 - number of cubic yards of dirt removed.

18,000 - number of truckloads required to remove the dirt.

141,000 - estimated number of motorists who pass through Castle Junction every day.

JOHN T. VALLES | The Honolulu Advertiser
Geology In The News

Earthquake/tsunami in Asia
Rockfalls and landslides
Coastal erosion
What Issues Does Geology Address?

- Natural hazards
  - Volcanoes
  - Landslides
  - Earthquakes
  - Tsunamis
  - Floods
What Issues Does Geology Address?

- Land use issues
  - Where to locate land fills
  - Where to locate new subdivisions, highways, etc.

What Issues Does Geology Address?

- Human impacts on the environment
  - Groundwater
  - Waste disposal
  - Extractive industries (mining, petroleum production, etc.)
What Issues Does Geology Address?

- Global environmental issues
  - Climate change — how badly are human activities causing global warming?

What is Geology?

Geology is the study of the Earth.
Geology is a science...
...just like chemistry and physics!
Scientific principles

The universe is sensible and governed by unchangeable rules.

The scientific method

1) Make an observation about the sensible world.

2) Develop an explanation (hypothesis) that predicts the outcome of other observations or experiments.
The scientific method (cont.)

3a) Make new experiments.
3b) Make new observations.

4) Do the results match the predictions of the hypothesis?
   - yes → return to step 3
   - no → reject the hypothesis

return to step 2

return to step 3
Hypothesis - Theory - Law

- A *hypothesis* is an explanation initially offered for a set of observations.

- When a hypothesis withstands many tests it may be called a *theory*.

- A theory for which there seem to be no sensible reasons to challenge is called a *law*.

Uniformitarianism

The present is the key to the past

— *James Hutton*

Natural laws do not change — however, rates and intensity of processes may.
An Example:

Geologic Time
and
the Age of the Earth

Relative vs Absolute Age

- Relative: Rock “A” is older (or younger) than rock “B”
- Absolute = The exact age of a rock (in years)
- Usually geologists first establish relative ages then try to get absolute age dates
How can we figure out the absolute age of the Earth?

Let’s start with an easier problem: How old are the Hawaiian Islands?

OK, a simpler problem: How old is Kilauea volcano?
The Age of Kilauea

- We know Kilauea is growing.
- We know how big it is.
- If we can work out how fast it grows we can just divide the volume by the growth rate to get the age.
Flows from last 20 years covered ~20% of Kilauea and are ~ 1-2 m thick

Kilauea is at least 5000 m above the adjacent sea floor
The Age of Kilauea

(1 m / 5000 m)/20 yrs = 1/100,000 years
(2 m / 5000 m)/20 yrs = 1/50,000 years
So, it took 50,000-100,000 years to build 20% of Kilauea

Thus, it took 250,000-500,000 years to build all of Kilauea

The Age of Kilauea

- There are big uncertainties:
  - How constant was the rate of eruption?
  - Since Kilauea is perched on the side of Mauna Loa, how much of the edifice is Kilauea and how much is Mauna Loa?
Now look at Oahu:

How long did it take to build the Ko`olau volcano?
Ko`olau was about twice as big as the current Kilauea, so ~500,000 – 1 my

Now look at Oahu:

How long did it take to erode Ko`olau volcano?
Are we able to tell how fast the island is eroding?
We are in a big valley – how long did it take to cut this valley?

Ko`olau volcano stopped erupting more than 1 million years ago

Now look at Kauai:

Volcanism on Kauai stopped ~2 million years ago

Waimea Valley is larger than Manoa Valley
What assumptions have we made?

- Things happened the same way in the past as they do now (uniformity of process).
- Things happened at the same speed in the past as they do now (uniformity of rate).

Origin of solar system

Pick a theory, any theory, but it must be consistent with these facts:

1) Planets all revolve around the Sun in the same direction in nearly circular orbits.

2) The angle between the axis of rotation and the plane of orbit is small (except Uranus).

3) All planets (except Venus and Uranus) rotate in the same direction as their revolution; their moons do, too.
Origin of solar system

4) Each planet is roughly twice as far as the next inner planet from the Sun (the Titus-Bode rule).
5) 99.9% of mass is in the Sun; 99% of angular momentum is in the planets.
6) Planets in two groups:
   - Terrestrial (inner): Mercury, Venus, Earth, Mars. Mercury is mostly Fe ($\rho = 5.4$)
   - Jovian (outer): Jupiter, Saturn, Uranus, Neptune. Jupiter mostly gas and ice ($\rho = 0.7$) Pluto ????
7) Terrestrial planets are mostly O, Si, Fe, Mg. The Sun is almost entirely H & He (also important in Jovian planets).

Nebular hypothesis

Primeval slowly rotating gas cloud (nebula) condensed into several discrete blobs.

fits          doesn't fit
rotation     angular momentum
mass
**Collision hypothesis**

Portions of the Sun were torn off by a passing star: planetesimals then collided to form planets.

Problems: gases coming from Sun would be too hot to condense; stellar collision exceedingly rare.

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**Protoplanet hypothesis**

- Large gas cloud begins to condense.
- Most mass in the center, turbulence in outer parts.
- Turbulent eddies collect matter meters across; small chunks grow and collide, eventually becoming large aggregates of gas and solid chunks.
- Protoplanets, much bigger than present planets, eventually contracted due to their own gravity.
Why worry about the beginning?

- The evolutionary course is significantly influenced by the initial state.

- We know the state of the Earth today relatively well; knowing the beginning will help constrain the in between.
A Differentiating Planet

An Early Homogeneous Earth
Differentiation Begins

(b)

(c)

Solid iron inner core (5150–6370 km)
Liquid iron outer core (2891–5150 km)
Crust (0–40 km)
Mantle (40–2891 km)
Relative Abundance of Elements

- Lithosphere
- Hydrosphere
- Atmosphere
- Biosphere

**Whole Earth**
- Other (<1%)
- Aluminum (1.1%)
- Calcium (1.1%)
- Sulfur (1.9%)
- Nickel (2.4%)
- Magnesium (13%)
- Silicon (15%)
- Oxygen (30%)
- Iron (35%)

**Earth's Crust**
- Other (<1%)
- Sodium (2.1%)
- Potassium (2.3%)
- Calcium (2.4%)
- Magnesium (4%)
- Iron (6%)
- Aluminum (8%)
- Silicon (28%)
- Oxygen (46%)
Three types of rocks

Igneous

Sedimentary

Metamorphic

Igneous rocks make up most of the earth sediments while sedimentary rocks make up most of the surface.
Major Rock Groups

**IGNEOUS**
- Source of material: Melting of rocks in hot, deep crust and upper mantle
- Rock-forming process: Crystallization (solidification of magma)

**SEDIMENTARY**
- Source of material: Weathering and erosion of rocks exposed at surface
- Rock-forming process: Deposition, burial, and lithification

**METAMORPHIC**
- Source of material: Rocks under high temperatures and pressures in deep crust and upper mantle
- Rock-forming process: Recrystallization in solid state of new minerals

Igneous Rocks

Rocks formed from the cooling and consolidation of magma.
Intrusive Granite

EXTRUSIVES:
- quick cooling, tiny crystals or glassy
- Lava and ash

INTRUSIVES:
- slow cooling, large crystals

Magma chamber

Intrusive Granite
Extrusive Basalt

Rocks formed by the consolidation of fragments of previously existing rock or chemically precipitated from solution.

Sedimentary Rocks
From Weathering to Sedimentary Rock

Genesis of Sedimentary Rocks

- **Physical weathering**: reduction in size
- **Chemical weathering**: change in composition
- **Transportation**:
  - Solid particles ... clastics by water, wind, ice
  - Ions in solution ... chemical
How common are sedimentary rocks?

Rocks whose original form has changed in the solid state due to increased temperature and/or pressure.

Metamorphic rocks

Rocks whose original form has changed in the solid state due to increased temperature and/or pressure.
Where does Metamorphism occur?

Regional Metamorphism

Contact Metamorphism

Magma

Contact border
The Rock Cycle