The Face of the Earth

Agents for Development of Earth’s Surface

• Interactive Dynamic Processes at the Surface
  • Roles of the atmosphere (gases, winds, climate), ocean (rivers, waves, currents) and biology (cycles of growth and consumption)
• Internal Dynamic Processes
  • Driven by the Earth’s radioactive heat
  • Energy release to the surface
• Influences on Continental Configurations
  • What are the major processes that shape the surface of the Earth?

Continents and Oceans

Thematic Questions about Internal Forces

• Evidence of internal forces at Earth’s surface
  • What causes earthquakes?
  • How do volcanoes form?
• Locations of Earthquakes and Volcanoes
  • Where do earthquakes and volcanoes occur?
  • Are they uniformly distributed across Earth’s surface? Or not?
• Temporal Constraints on Activity
  • Are the processes continuous, or intermittent?
  • What triggers their occurrence?
Plate Tectonics: Unifying Concept

Observations, Hypotheses and Validation

- Earthquakes and Volcanoes
  - Locations and characteristics: non-uniform
  - Evidence for Earth’s surface as plates
- Plates and Plate Boundaries
  - Concept and justification of plate divisions
  - Types of plate boundaries and processes
- History of the Earth’s Surface
  - Reconstructing the ancient face of the Earth
  - Changes in continents through time
  - Evidence for cyclical tectonic processes

Earthquakes

Ground shaking produced by Seismic Waves

- Examples from California

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Seismic Waves

Clues to Earth’s Interior

• Primary (P) waves (pass through liquids)
• Secondary (S) waves (cannot travel in liquids)
• Refracted by differences in density; gives shadows in the occurrence of seismic waves
• Earthquake locations assessed by triangulation
• Seismic wave speed depends on rock temperature (hot: slow, cold: fast)

Earth’s Layered Structure

Lithosphere and Asthenosphere

• Asthenosphere: plastic part of upper mantle
• Lithosphere: rigid and solid
Catalog of Seismic Records

Earthquake Positions on Earth’s Surface

- Distinct linear belts; shallow and deep

Occurrence of Earthquakes

Belts Create Divisions of Earth’s Surface

- A series of distinct regions, or plates
Global Configuration of Plates

Mosaic Defined by Earthquake Activity

- Crustal plates with appropriate geographic titles
  - continent
  - oceanic
  - both
- Boundaries
  - locations of earthquakes & volcanoes

Global Configuration of Plates

Motion Occurs at Plate Boundaries
Plate Boundaries — 3 Types

**Divergent**
- extension, stretching
- spreading centers where new crust is formed
- Found at mid-ocean ridges (MOR)
- Mid-Atlantic Ridge, E. Pacific Rise
- Sites of volcanism
  - pillow basalts

**Convergent**
- compression, collision
- ocean crust is subducted, generating deep earthquakes, forming trenches, mountain belts

**Transform**
- sliding, shearing
- offset mid-ocean ridges, form fracture zones

Types of Plate Boundaries — I

**Divergent**
- Extensional, stretching, spreading motion
- Centers where new ocean crust is formed
- Found at mid-ocean ridges (MOR)
- Mid-Atlantic Ridge, E. Pacific Rise
- Sites of volcanism
  - pillow basalts

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Mid-Ocean Ridges

• Lava formed by extrusion onto seafloor
• Cooled rapidly by seawater
• Forms rounded pillow-like structures

Pillow Lavas

Lava Contact

• Contrast between new and old lava flows
**Pillow Lavas**

**Formation of Lava**

- Extrusion of lava along suture

Forms bulbous pillow-like structures

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**Evidence for Sea-Floor Spreading**

**Magnetic Reversals or Anomalies**

- Symmetrical patterns across MOR, alternation of positive and negative anomalies

zone of cooling where polarity is 'locked' in magma
Evidence for Divergence at MOR

Age of Oceanic Crust

- Youngest crust at mid-ocean ridges
- Oldest in W. Pacific
- Crust 'ages' away from MOR
- Rate: 1-17 cm/yr

Mid-Atlantic: slower 3 cm/yr
E. Pacific Rise: fast 6-17 cm/yr

Types of Plate Boundaries — II

Convergent

- Compression of crust, plate collision
- Ocean/ocean, ocean/continent, continent/continent
- Ocean crust subducts, causing deep earthquakes
- Forms ocean trenches and mountain belts
  - Aleutians, West coast of S. America, Tibet
Continental Collision

Mountain Building

- Eurasian/Indian plate collision
- Tethys ocean closed

Thrusting, buckling and thickening of crust with earthquakes wherever movement occurs

Transform Faults

- Sliding, shearing of plates
- Offset mid-ocean ridges, form fracture zones
  - Mendocino fracture zone
  - San Andreas Fault
Sites of Volcanism

Arches, Mid-Ocean Ridges and Hot Spots

- Arches produce violent ash eruptions from steep-sided volcanoes (strato-volcanoes) linked to subduction of ocean crust (convergence)
- MOR underwater activity forms pillow lavas
- Hot spots build gentle-sloped shield volcanoes

Volcanic Eruptions

Different Styles of Eruption

- Pillow lavas on ocean floor
- Flowing (pahoehoe) or blocky (aa) lava
- Ash, gases, pyroclastics
Types of Volcanic Eruptions

- **flowing lava (pahoehoe)**
- Pyroclastics
- Pyroclastics
- Pyroclastics

Hawaiian Islands

- Age increases SE to NW
- Eroded when eruptions end

Loihi: a future Hawaiian island

Hot spot has remained fixed; pacific plate has moved over it

Only the youngest island (Hawaii) is currently active
Process Driven by Mantle Heat, Density

- Divergence, Convergence, Transform Faults
**History of Ocean Basins — 200Ma**

**Triassic**
- Supercontinent Pangaea; superocean Panthalassia

**History of Ocean Basins — 70Ma**

**Cretaceous**
- Supercontinent Pangaea fragmented

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**Oligocene**

- Supercontinent Pangaea continues to fragment

- Atlantic widening
- Drake passage opening
- Himalayas building
- Australia and Antarctica separated

**Present Day**

- Pangaea fully fragmented

- N. and S. America joined
- Drake passage fully open
- Tethys closed
- Antarctica isolated
History of Ocean Basins

Sequence of Changes over past 150My

Wilson Cycle: Initial Stages

Sequential Events: A to D

- Stable Continental Craton
- Hot Spot and Rifting
  - disturbance from magma plume
- Creation of New Oceanic Crust: Early Divergent Margin
- Full Divergent Margin
Sequential Events: E and F

- Convergent Boundary: Volcanic Arc
- Collision of Island Arc and Continent:
  - mountain building

Sequential Events: G to H

- Cordilleran mountain building
- Continent/continent collision:
  - mountain building
- Stable continental craton
Wilson Cycle: Full Sequence

Series of Events

- Sequential processes that create and destroy oceans and build continents

A. stable craton
B. early rifting
C. ocean basin
D. subduction
E. ocean closure
F. collision
G. continent

Building of Continents

Terranes: Continent Fragments

- Added by subduction processes
  - island arcs, submarine deposits, ancient ocean floor
- Continents gradually constructed

old cratons: brown  young strata: green