CEEES/SC 10110-20110 Drifting Continents and Spreading Seas





Chapter 3

Alfred Wegener: Challenged the concept that continents were fixed.

He suggested that all the continents were once joined in one large landmass = **Pangea**. Subsequently, this had split apart and the the continents drifted apart = **Continental Drift**.





The hypothesis of Continental Drift formed the basis of **Plate Tectonics** - the Earth's surface is comprised of *lithospheric plates*. Plate Tectonics includes **Seafloor Spreading** and **Subduction**.

Evidence for Continental Drift

Location of Past Glaciations

Paleozoic (> 250 m.y old) glacial deposits present on different continents that are now far apart and not at the poles. End of glacial advance is marked by a "terminal moraine". These line up as if continents were together.



Evidence for Continental Drift



Fit of Continents

Continental jig-saw puzzle – they fit together to form the supercontinent, **PANGEA**

Evidence for Continental Drift Paleoclimatic Belts: climate information can be obtained from the rocks.

Past climates differ dramatically from present day (e.g., coal in the Arctic). Either: Continents moved; or

Rotational poles moved.



Present pole position (geographic North Pole)



Ancient pole position and present pole position the same



Evidence for Continental Drift



Continents were once joined Migration of organisms over waterways Parallel evolution

Evidence for Continental Drift



Matching Rock Units: (both type & age) on continents.

Early speculation: continents "plowing" through the oceans.



Wegener could satisfactorily not explain how the continents moved.

Study of Earth's magnetic field in the past.



Paleomagnetism



Difference between direction a compass needle points and true North = Magnetic Declination.



Paleomagnetism

Igneous rocks crystallize and "**magnetite**" aligns with magnetic field at the time of crystallization - locks in magnetic field when temperature drops below "**Curie Point**".



Sedimentary rocks can also be used in paleomagnetic studies, as long as iron is involved.



Paleomagnetism

Sample by taking mini-cores and measuring the orientation of the magnetic field at the time the rock formed – shows the place on the globe where it formed magnetic inclination.

Magnetic inclination dependent upon the location on the Earth – can give original location.



Paleomagnetism can show the position of the magnetic poles at time of rock formation.

South America

Many measurements from different continents – show that poles have moved with time = **APPARENT POLAR WANDERING**.

Initial interpretation - magnetic poles were moving.



Paleomagnetism

Different continents give different polar wander paths.



Indicates the continents have been moving independently through time, although N. America and Europe coincide 280-180 Ma when they were both part of Pangea.

Evidence from the Oceans



Three major provinces of oceans:Continental margins (shelves)Ocean basin floor (abyssal plains)Mid-ocean ridges and rises

Continental Margins



Eastern USA

Western USA

Continental Margins

Passive Margins (e.g., Atlantic coast): geologically quiet, no major earthquakes, no volcanoes.

Sediments accumulate on the wide *Continental Shelf*. Can be moved down the continental slope by turbidity currents.

Sediments on the continental shelf are derived from the continents = *Terrigenous* sediment.

The *Continental Slope* is the transition between the shelf and the *Abyssal Plains*. It descends from 100-200 meters to 4,000 - 6,000 meters at an average angle of $4-5^{\circ}$.



Ocean Basin Floor

Abyssal Plains: flat seafloor in deep water beyond the continental slope.

Depth: 4,000 – 6,000 meters.

Flattest place on earth – topology of the oceanic crust is fairly irregular, but sediments fill in the irregularities, resulting in "mud-flats".

Sediments = fine *pelagic* deposits.

Pelagic sediment – settles slowly through the ocean water and is made up of fine-grained clay and the skeletons of microscopic organisms.

Includes muds – clay, silt from the continents, accumulated *oozes* (from skeletal remains of the microscopic organisms), shale, and chert.



Figure 18.24

Photograph (taken through a scanning-electron microscope) of pelagic sediment from the floor of the Pacific Ocean. The sediment is made up of microscopic skeletons of single-celled marine organisms (large objects are foraminifera; smaller, sievelike ones are radiolaria about 0.05 mm in diameter).

Pelagic Sediments: Bedded cherts.



"Relief" in the Ocean Basins

Mid-Ocean Ridges: Submarine mountain ranges. The crest = "ridge axis". Rise ~2-2.5 km above the Abyssal Plains.

Deep-Ocean Trenches: Lie at the margins of oceans bordering volcanic arcs - 8-12 km deep. [Subduction Zones]

Seamount Chains: Isolated submarine mountains that form chains (e.g., Hawaii). Once they were subaerial volcanoes, but activity ceased and they sank below the ocean - erosion produces a flat top or "guyot". Usually an active volcano is at the end of the chain.





Rift Valley: Area of many shallow focus earthquakes, high heat flow, and positive gravity anomalies (mantle upwelling).

Rift valleys are offset by strike slip faults called *Transform faults* (differential movement) or *Fracture Zones* (movement in same direction). Earthquakes occur along these also.

Continuous mountain ranges stretching for 65,000 km and run through every ocean.



Observations

Oceanic crust = basalt (+ gabbro): different from continental crust.

Heat flow: much greater beneath MORs relative to elsewhere – thinner crust.





Earthquakes are concentrated at the margins of ocean basins and along the MORs.

This must be regions where differential movement takes place.

Sea Floor Spreading

Thin sediment layer on ocean crust suggests oceans are younger than continents. The fact the layer thickens away from MORs suggests the crust gets older away from the ridge crest.

Harry Hess suggested ocean crust was made at the ridges and destroyed at the trenches.

Hess also suggested it was the lithosphere, not just the crust, that moved - no need for Wegener's "continent plowing" hypothesis.



Distance between the trench and arc controlled by angle of subduction.

Sea-Floor Spreading & Paleomagnetism

<u>Magnetic Anomaly</u>: difference between the expected strength of the magnetic field at a given location and the measured field. Positive Anomaly = greater; Negative Anomaly = less.

Patterns of anomalies on the continents are chaotic, but are more regular in the oceans.





Sea-Floor Spreading & Paleomagnetism

Some rocks indicate magnetization in a magnetic field of reversed polarity relative to that present day (normal polarity). Evidence that occasionally the Earth's magnetic field reverses itself - quickly!



Sea-Floor Spreading & Paleomagnetism

What causes magnetic reversals? No-one really knows, but they may reflect changes in the configuration of flow in the outer core.



Sea-Floor Spreading & Paleomagnetism



Sea-Floor Spreading & Paleomagnetism



the present day field.



Vine & Matthews Hypothesis

Anomalies are due to N-S reversals of Earth's magnetic field.

Rocks record the orientation of the magnetic field at the time of formation.

Therefore, mid-ocean ridges are the locations where new sea floor is born and spreads outward

(upwelling of hot mantle - decompression melting).

Verified by comparison of anomalies to anomalies found in continental lava flows – correlation of vertical flows on land with oceanic floor (radiometric dating).

As magnetic reversals have been correlated on the continents & on the ocean floor, anomalies are age dated.



occurred 4.5 million years ago is found 45 km from the ridge rift valley. Rate = 10 km/Myr or 1 cm/yr. This is the spreading rate.

Age of Sea Floor

Mid-ocean ridges mark positions of divergent plate boundaries.

Age of crust 0-180/190 Myr.

Youngest oceanic crust is at the ridges.

Oldest oceanic crust at continental margins.

180-190 Myr crust is western Pacific – farthest from mid-ocean ridge.

Sediments thickest over oldest crust.



What is a Lithospheric Plate?





Junction between oceanic and continental crust = Continental Shelf.

Active Margin = Plate Boundary. Passive Margin ≠ Plate Boundary.



Plate Boundaries



Locations of earthquakes mark plate boundaries.

Three types of Plate Boundary:



Divergent Plate Boundary



High heat flow Active volcanism Shallow focus earthquakes

Oceanic crust is made at a mid-ocean ridge.

Slow spreading ridges: <10 km wide with steep cliffs.

Fast spreading ridges: less well defined.



Divergent Plate Boundary



Faults indicate tension. Dikes connect pillow basalts with the magma chamber.

Tension thins the lithosphere and partial melting occurs.

Increased heat from buoyant magma produces the elevation of MORs. As magma moves away from heat it becomes rock & part of the plate.

Pillow basalts.





Pillow Basalts "on land". "Obduction"

45 pBasalt.mov

Divergent Plate Boundary



Black smokers.mov



Black Smokers



SCsmoker2.mov

Why are Mid-Ocean Ridges Elevated?



Combination of heat beneath the MOR reducing density and the fact that as the crust moves away, it cools and becomes more dense. The older the crust, the more dense it is.



The crust furthest from the ridge is the oldest.



Dredging



Coring



Seafloor drilling has greatly enhanced our knowledge.



Deep Sea Drilling Project: Glommar Challenger



The Ocean Drilling Program

JOIDES Resolution





Summary

Continental Drift: "fit" of continents; paleoclimatic belts; similarity of rocks and fossils.

Paleomagnetism: declination; inclination; polar wander; curie point.

Oceans: Continental Margins (passive/active); Abyssal Plains (pelagic sediment); Mid-Ocean Ridges; Deep Ocean Trenches; Seamount Chains; Fracture Zones (Transform Faults).

Sea-Floor Spreading: Earthquake distribution; rock types; heat flow; plaeomagnetism; magnetic reversal chronology; spreading rate.

Age of the Sea Floor.

Ocean Floor Exploration.