

Plate Tectonics and Climate

Plate Tectonics and Continental Reconstructions

Alfred Wegener & Continental Drift

Alfred Wegener recognized a century ago that late Paleozoic sedimentary rock strata contained glacial deposits located at present-day low latitudes and tropical (equatorial) coal in present-day temperate North America and Europe. Based on this and other evidence he developed his theory of continental drift which posed that the continents were once part of a supercontinent called Pangea that lay farther south in the late Paleozoic.

How could this theory be confirmed, and if true, how can we determine the positions of the continents through time? Without this we could not hope to model past climates nor use records of climate history to understand potential future changes to modern climate.

Paleomagnetism and Confirmation of Continental Drift

Earth's dipolar magnetic field is like a bar magnet

- lines of force point from south to north

- lines of force vertical upward at south pole, vertical down at north pole

- lines of force progressively less steep moving from pole to equator

- lines of force horizontal at equator

- magnetic inclination is proportional to latitude

most rocks contain small quantities of magnetic minerals, like iron oxides

- magnetism in rock parallels the Earth's magnetic field when rock forms

- from measuring inclination and direction of magnetism in ancient rocks

- we can determine direction to pole and latitude when rock formed

paleomagnetists in the 1950s and 60s (and continuing through to the present)

- determined the apparent position of the north pole using the direction and inclination

- of magnetism in rocks of various ages through the past 500 million years. The re-

- sults formed a smooth Apparent Polar Wander path. They recognized that each

- continent had its own APW path indicating that the continents had drifted independ-

- ent of one another rather than the geographic pole of the Earth changing position.

paleomagnetic measurement of ancient rocks allows us to reconstruct the past position

- of continents, at least their latitude and any rotation

Reversals of Earth's Magnetic Field

paleomagnetists also discovered that the Earth's magnetic field reverses polarity spo-

- radically and has done so many times in the past

the first magnetic polarity timescale was published in 1963 showing reversals of the field during the past 4 m.y.

Marine Magnetic Anomalies and Seafloor Spreading

marine geophysicists discovered in the 1960s that the ocean crust was magnetized in strips of normal and reversed magnetization that paralleled the midocean ridges. The magnetic pattern was a mirror-image on opposite sides of the ridges. They concluded that ocean crust/lithosphere was separating at the ridges and new crust was forming in the gap thus formed; the new crust was magnetized with the polarity of the magnetic field at the time of formation. Seafloor spreading is the mechanism for the motion of plates.

Plate Reconstructions

We can return continents to former positions by "rewinding" seafloor spreading. This only works for the past ~200 m.y. because all older ocean crust has subducted. Paleomagnetic study of continental rocks must be used for older reconstructions. Paleoclimate indicators in sedimentary rocks are also used to aid reconstructions.

Continental Flooding and Seafloor Spreading Rate

Cycles of Continental Flooding

The continents have been flooded several times in the past 500 million years in broad ~100 m.y. cycles as evidenced by sequences of marine carbonates; the marine sediment sequences are separated by major unconformities indicating periods of low sea level and continental erosion or non-deposition. One process that may account, at least in part, for these very long-term changes in sea level is long-term variation in the rate of seafloor spreading and formation of new ocean crust. The deep ocean basins are shallowest at the midocean ridges because as new lithosphere forms it is hot/expanded/buoyant; as it spreads away from the ridge it cools and contracts. If seafloor spreading rate increased, there would be more young/hot/buoyant/shallow seafloor in the ocean basins; the average depth of the ocean basin would decrease; sea level would rise.

Plate Tectonic Settings and Climate

midocean ridges

2 lithospheric plates are pulled apart
magma is produced by decompression of upwelling hot mantle rock
(partial melting - only the lowest melting temp minerals melt)
magma fills in cracks formed by spreading forming new crust
CO₂ from mantle rises with magma and outgasses at ridge

hostpots & mantle plumes

magma is produced by decompression of upwelling hot mantle rock
(partial melting - only the lowest melting temp minerals melt)
CO₂ from mantle rises with magma and outgasses at hotspot volcanoes

subduction zones

magma is produced by
metamorphism of subducting ocean crust which releases water
which decreases the melting point of the overlying mantle rocks
(partial melting - only the lowest melting temp minerals melt)
CO₂ from the mantle and from metamorphosed oceanic carbonates
rises with the magma and outgasses at arc volcanoes

continent-continent collisions

metamorphism of carbonate rocks can release CO₂ back to atmosphere

BUT...

weathering is greatly increased due to the exposure of fresh rock

- steep slopes (mass wasting) and
- glaciation of high peaks (grinding rock into smaller bits)

aids rapid chemical weathering and removal of CO₂ from atmosphere