Tectonic applications

- Paleomagnetic poles
- Brief review of plate tectonics
- Apparent polar wander paths
- Paleomagnetism and plate reconstructions
Continental Drift?
An old idea (from 1596 even)

e.g., Antonio Snider-Pellegrini (1858): “before” and “after” maps

http://pubs.usgs.gov/gip/dynamic/historical.html  & UC Berkeley
Gondwana land

http://pubs.usgs.gov/gip/dynamic/historical.html
But most Northern hemisphere geologists/geophysicists didn’t buy it
Paleomagnetic poles

Assume the magnetic field is that of a GAD on average.

If we sample over sufficient time to average out PSV, the average of all the VGPs is a PALEOMAGNETIC POLE (Exactly what is “sufficient time” is not known but must be > 10,000 years).

Hospers (1955): paleomagnetic poles could be used to test the idea of continental drift (of e.g., Wegener, 1915) or polar wandering (Milankovitch, 1933).
Wandering continents or wandering poles?

Chapter 16
You need data from more than one continent AND older poles

Irving 1958

Data from 4 different continents support continental drift
meanwhile - mapping of the sea-floor

World encircling rift - Heezen and Tharp (1957)
At the time Heezen and Tharp thought the rift was from an expanding earth.
Paleomagnetists became “drifters” in the 50’s

No viable mechanism was proposed until the idea of sea-floor spreading (Hess, 1962)

Sea floor spreading (versus expanding earth) gained credibility with Morely-Vine-Matthews hypothesis (Vine and Matthews, 1963) which added in polarity reversals

Plate tectonics is “how it works”.

Tuesday, May 17, 2011
The major lithospheric plates
Get locations and present relative motions from earthquakes

http://www.pbs.org/wgbh/nova/teachers/activities/2515_vesuvius.html
last week we talked about relative motions over the last 200 Ma from magnetic anomalies.
Moving plates around on a sphere

- Move continuously using an angular velocity vector: Euler pole specified by latitude, longitude and rate of rotation.

- Can describe any rotation by a finite pole of rotation: latitude, longitude and total angle.

- Or by a sequence of “stage poles” which sum up to some total finite rotation pole.
Euler poles: pairs of plates separate by rotation around a pole \((\lambda_e, \phi_e)\) at a rate of \(\omega^\circ/\text{Myr}\)

\[ v = a\omega \sin \theta \]

\(a = \text{Earth radius}\)

Chapter 16
How to find Euler poles

- ridges point to them
- fracture zones make small circles around them
- magnetic anomalies give rates of spreading which via equation for velocity versus colatitude equation can give you rate of rotation
How to find finite rotation poles

- find the rotation that “puts things back together best” by trial and error
- can use a paleomagnetic pole to rotate a plate or plate fragment back to past orientation wrt north and latitude
- or find finite rotations that cluster poles the best
- see Table A.4 for set of finite rotations that put Gondwana continents back together.
but be ware of ambiguity!

which polarity? (a versus b)

longitude unconstrained (b versus c)

Chapter 16
Making the paleomagnetic poles fit
Back to apparent polar wander

There have been over 10,000 paleomagnetic poles published since 1925.

Range in age from Archean to recent

Range in quality from abysmal to excellent

Most are available in the pole database (GPMDB) available online: http://www.ngu.no/geodynamics/gpmdb/

More and more available with all the supporting site level data through earthref.org/MagIC
All the poles from Australia in the GPMDB
But how to select?
(see book for details)

- e.g., criteria of Van der Voo (1990) or Besse and Courtillot (2002)
- Gotta know the age!
- Must be geomagnetic field and average out PSV
- Tectonic tilt (and rotation!) must be accounted for
Australian pole set (<200 Ma) after selection (using BC02)
Creating “master” APWP paths

- Say we have a bunch of poles from different continents whose ages are well known.

- Finite poles of rotation connecting the different continents are known (from sea floor spreading data, e.g.) - can rotate all poles to common reference frame

- Average everything together to create a master APWP

- Then export the poles back to each continent.
Exported master APWP for Gondwana continents

Chapter 16
Watch out for “discordant” poles in the database!

circles: “stable” North America

triangles: “displaced terrains” from western US (e.g., Mojave desert)

Chapter 16
Take home message

- Plate Tectonics was one of the major discoveries of the 20th century

- Motions of the plates can be reconstructed using earthquake locations, deep sea mapping and paleomagnetic data (including anomalies)