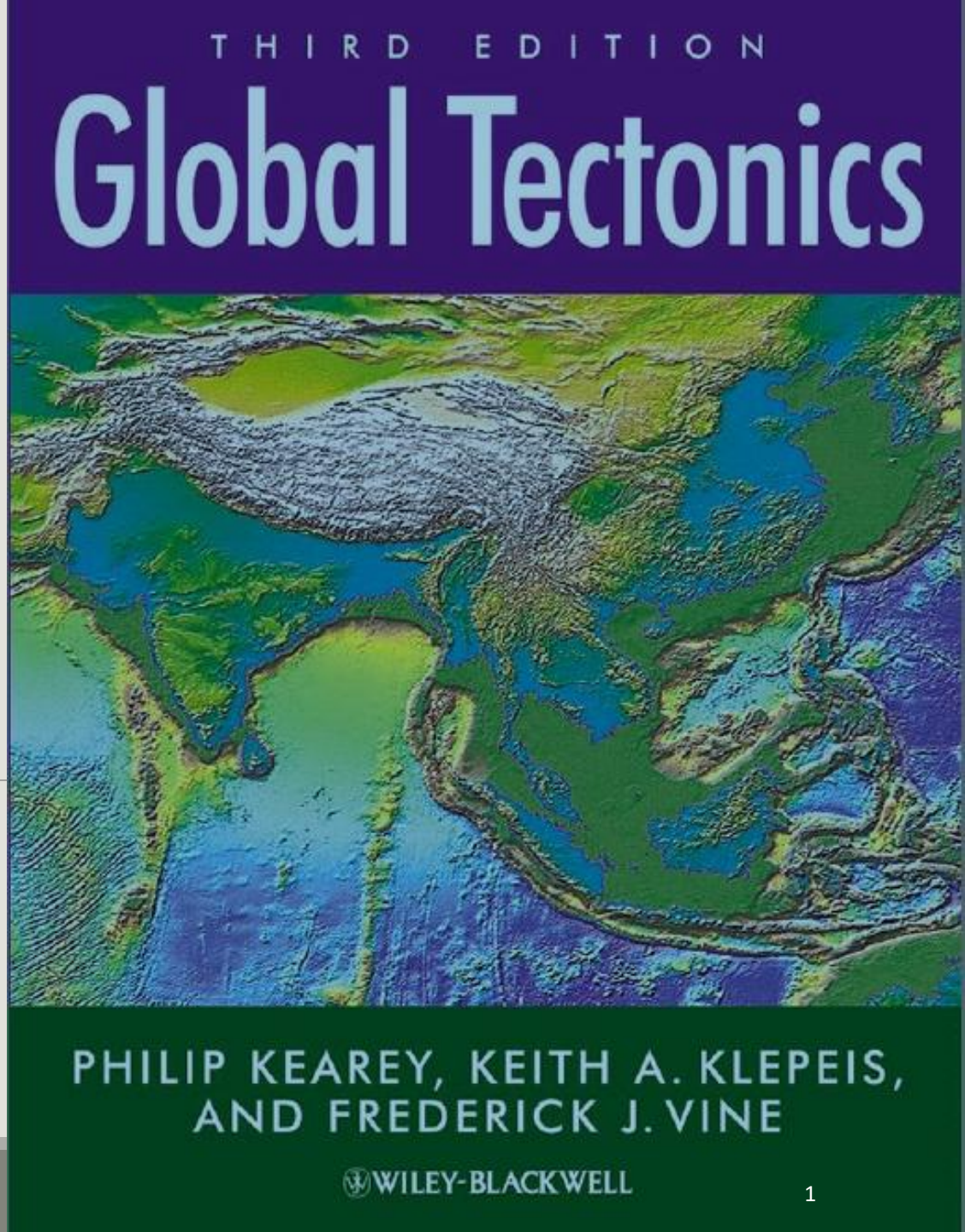
Global Tectonics
G404
Lecture-3

Instructor
Dr. Ali Z. Almayahi



Chapter 3: Continental drift

This chapter lays the foundation for plate tectonics by demonstrating how continents have moved and interacted throughout geologic history.

1. **Continental drift** was supported by geometric, geologic, climatic, fossil, and paleomagnetic evidence.

2. **Euler's theorem** explains continental motion as rotations about poles.

3. **Paleomagnetism** provided the first quantitative proof of drift.

4. **Gondwana and Laurasia** had distinct climates and biotas before fragmentation.

5. **APW paths** track continental movements over time.

Chapter 3: Continental drift

3.1 Introduction

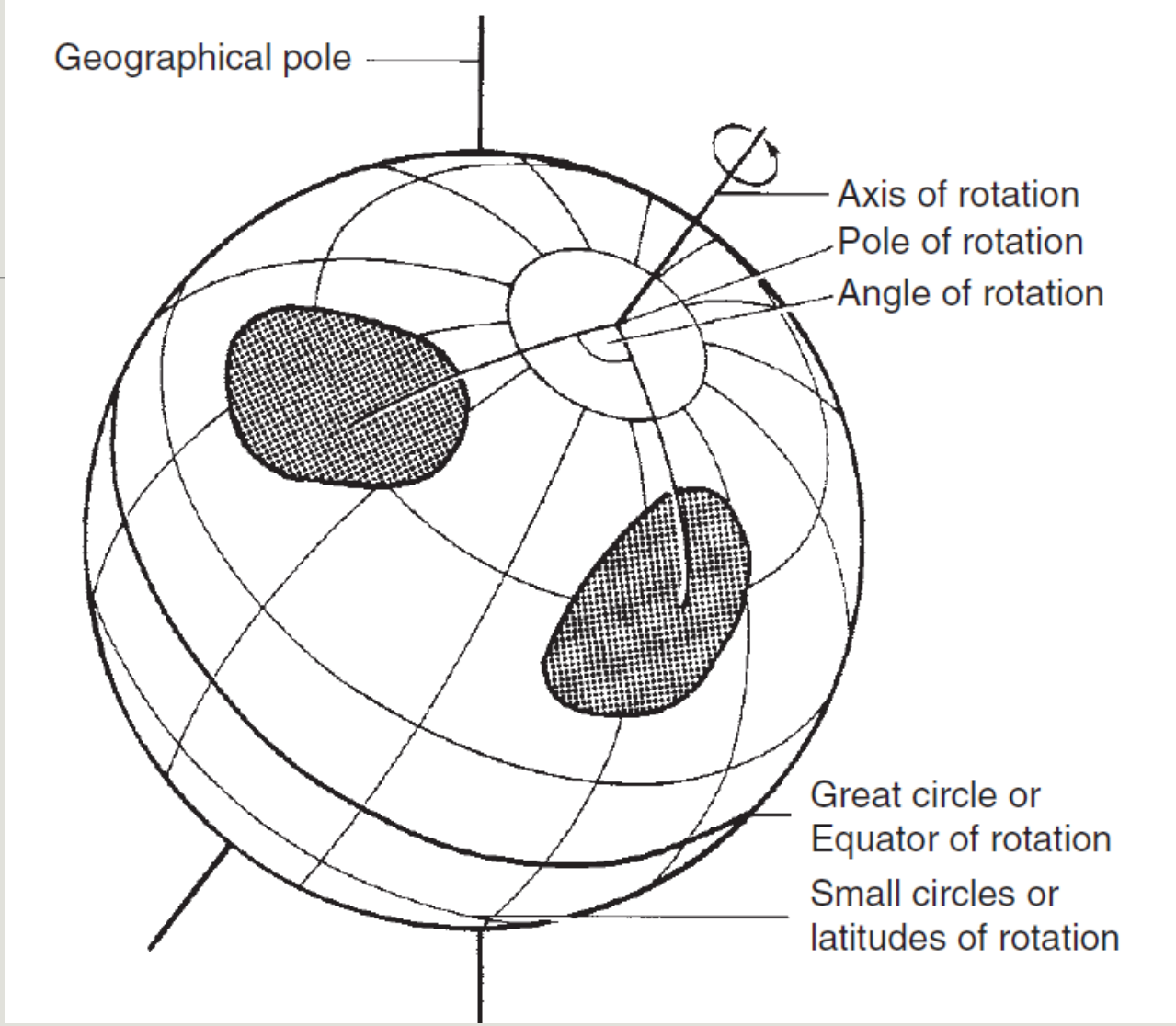
The chapter begins by noting that the fit of continents around the Atlantic Ocean was observed as early as the 16th century. However, the significance of this observation was not fully realized until the 19th century, when it became a key piece of evidence for the hypothesis of **continental drift**. Additional support came from:

- **Geologic correlations** across matching coastlines.
- **Paleomagnetic studies** (1950s–1960s), which provided the first quantitative evidence of continental movement, particularly in a north-south direction.

3.2 Continental Reconstructions

3.2.1 Euler's Theorem

- Describes the movement of continents mathematically using **rotation about a pole** on the Earth's surface.
- Only the **rotation pole** and its antipodal point remain fixed during movement.



Euler's theorem. Diagram illustrating how the motion of a continent on the Earth can be described by an angle of rotation about a pole of rotation.

3.2.2 Geometric Reconstructions

•Early reconstructions were done manually (e.g., Carey, 1958), but modern methods use **computer modeling** to minimize misfits.

•**Key steps**:

- Assume rotation poles in a grid.
- Determine the **angle of rotation** that best fits continental margins (using the **continental slope**, e.g., the 1000 m isobath, rather than coastlines).
- Quantify fit using an **objective function** (degree of mismatch).

3.2.3 Reconstruction of the Atlantic Continents

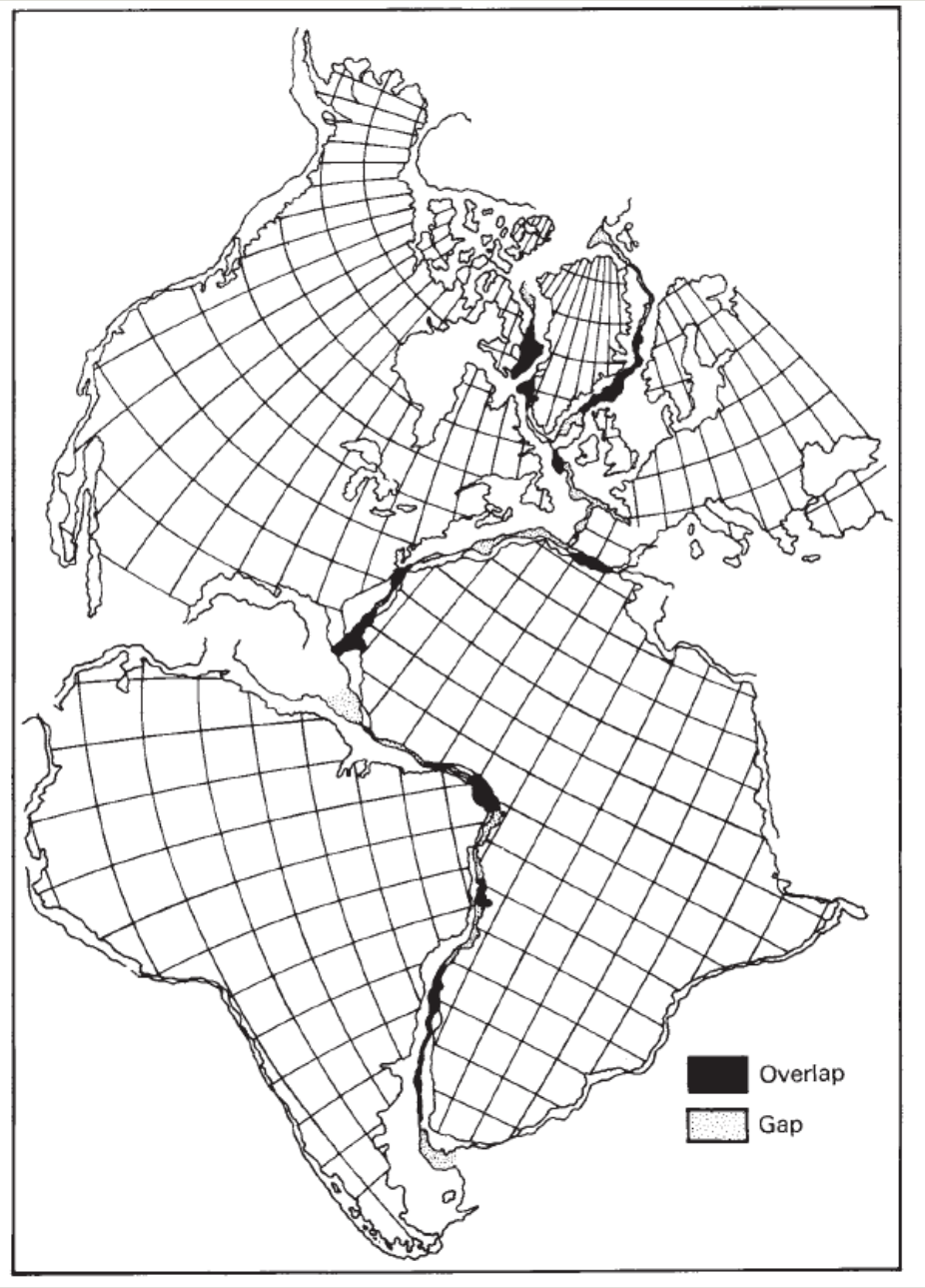
•**Bullard et al. (1965)** mathematically reconstructed the Atlantic continents.

•**Notable overlaps/issues**:

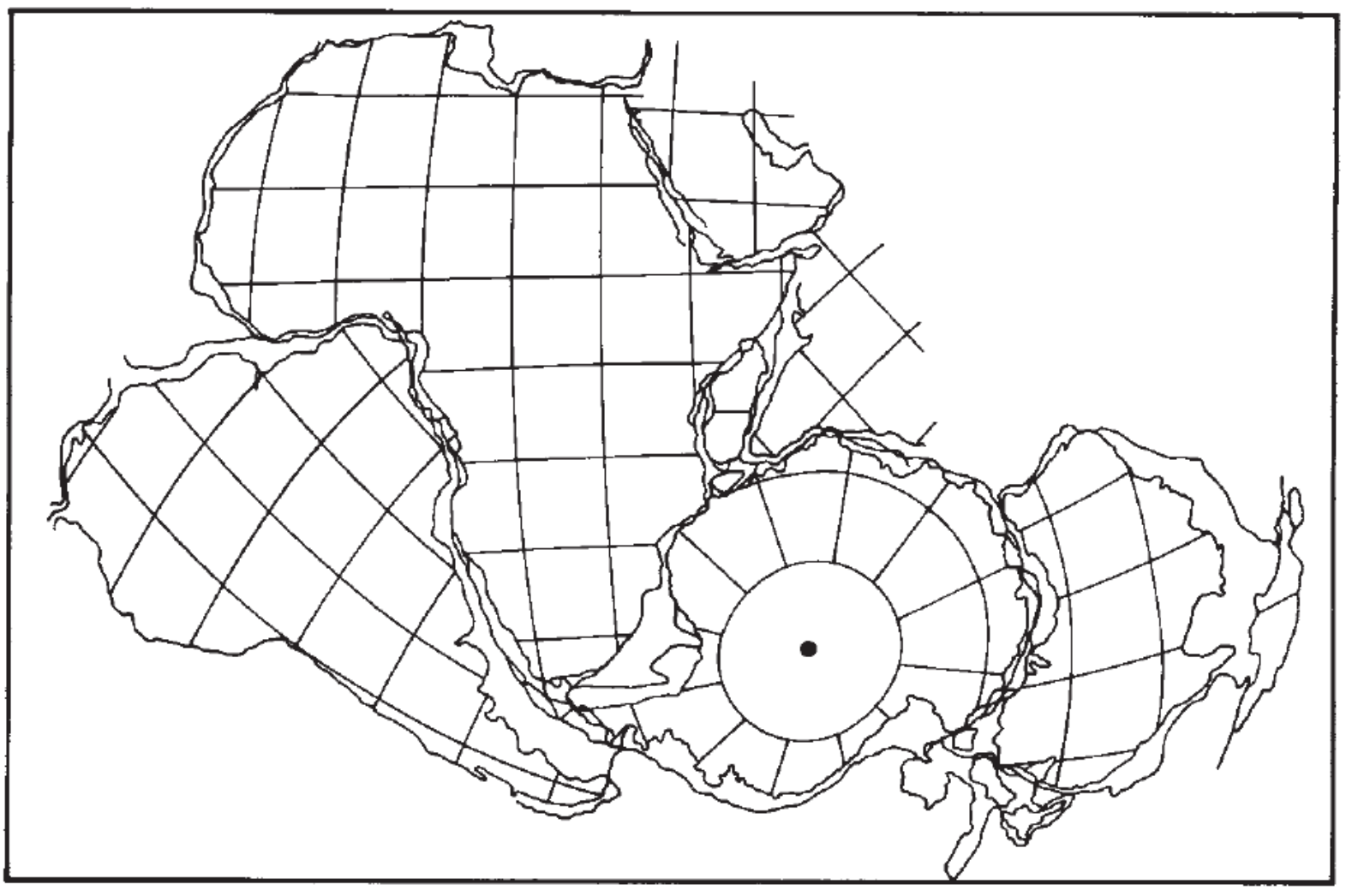
- **Iceland**: Absent (formed later).
- **Bahama Platform and Niger Delta**: Overlaps due to post-rift sediment accumulation.
- **Central America and Caribbean**: Overlap explained by later rotation of crustal blocks from the Gulf of México.

•**Timing**:

- North Atlantic opened ~180 Ma, South Atlantic ~130 Ma.
- By ~80 Ma, both Atlantic segments opened as a single unit.



Fit of the continents around the Atlantic Ocean, obtained by matching the 500 fathom (920 m) isobath (redrawn from Bullard et al., 1965, with permission from the Royal Society of London).



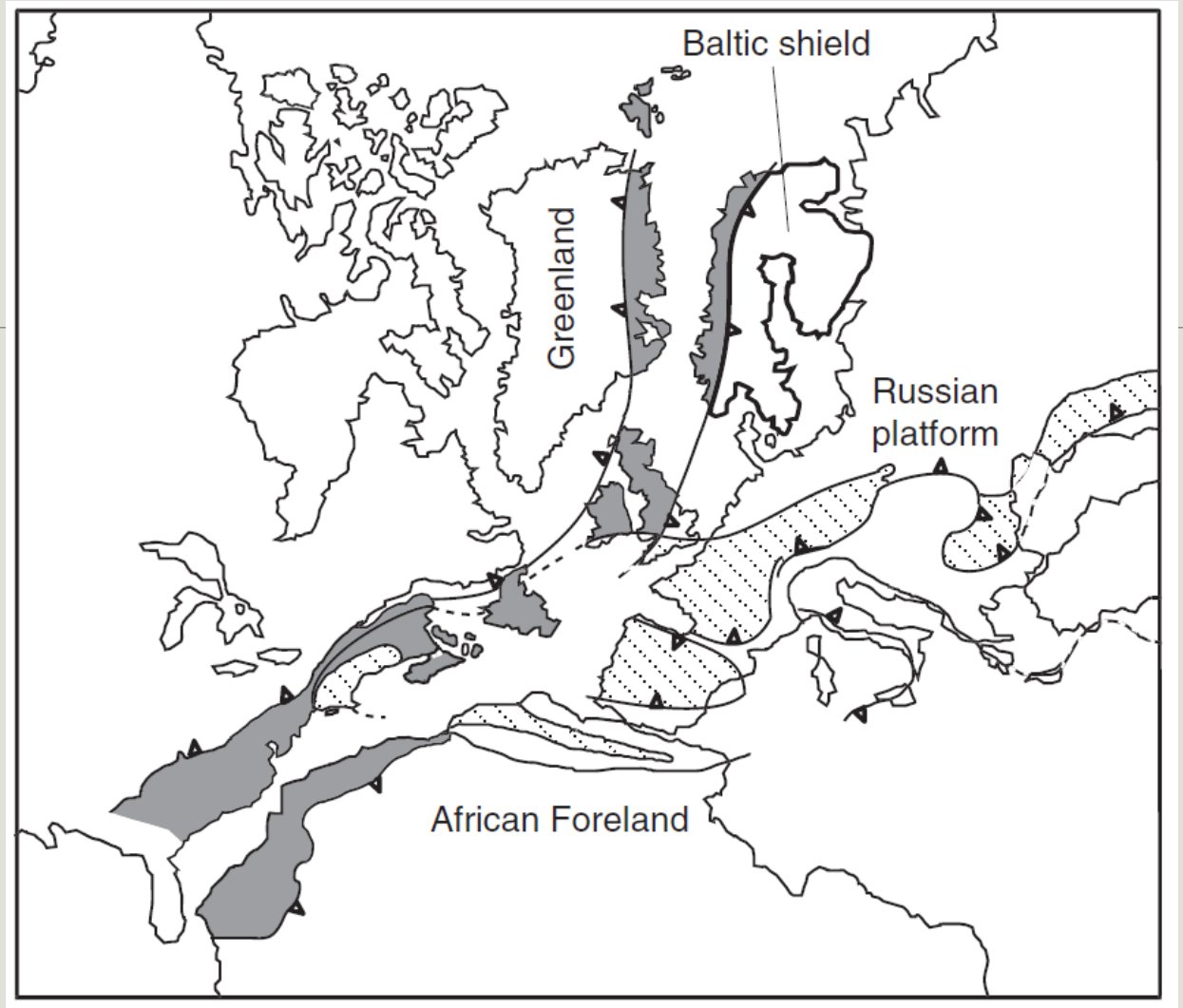
3.2.4 Reconstruction of Gondwana

•**Smith & Hallam (1970)** reconstructed Gondwana. Confirmed by **magnetic lineations** in the Indian Ocean.

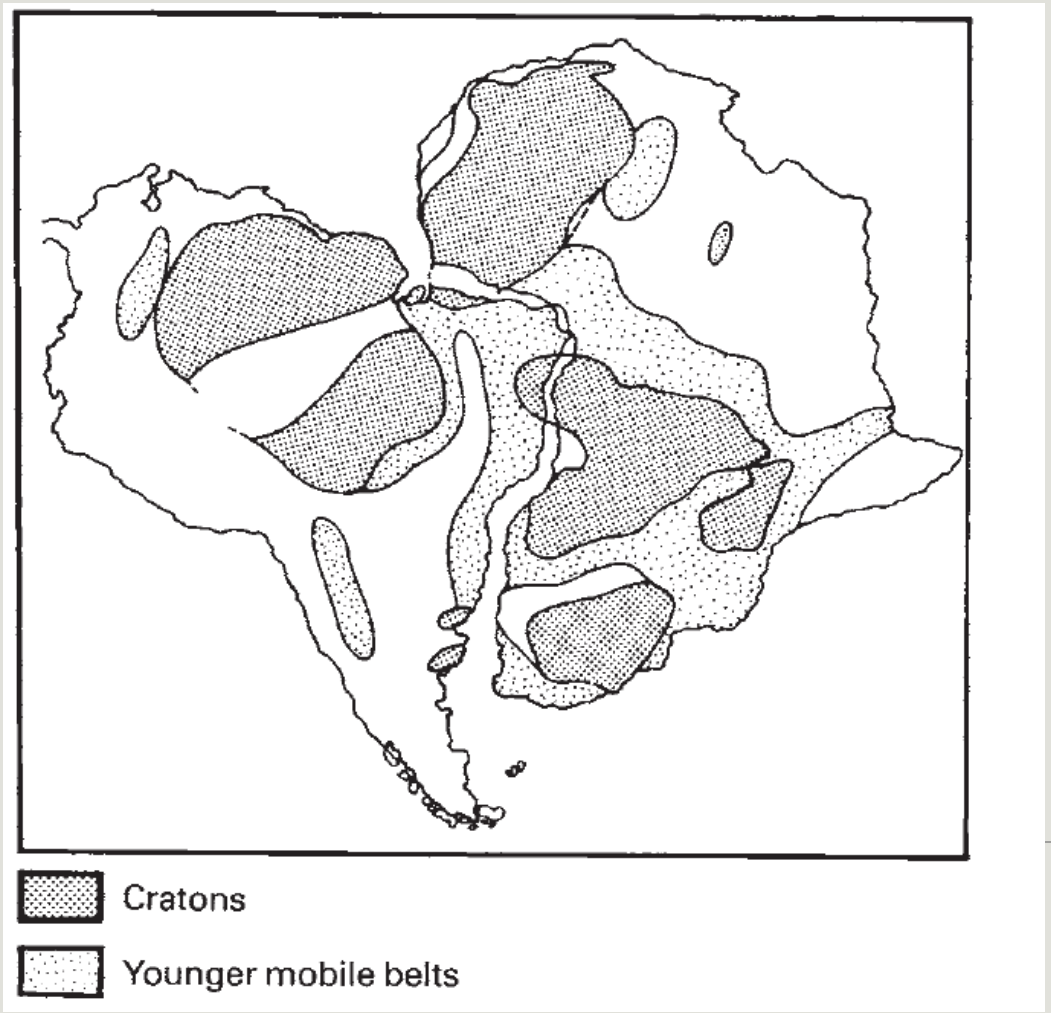
3.3 Geologic Evidence for Continental Drift

If reconstructions are accurate, geologic features should align across joined margins. Examples include:

1. **Fold belts** (e.g., Appalachian-Caledonian belts).
2. **Age provinces** (matching cratons and mobile belts).
3. **Igneous provinces** (e.g., Mesozoic dolerites across Africa, Antarctica, Tasmania).
4. **Stratigraphic sections** (e.g., Gondwana tillites and coal beds).
5. **Metallogenic provinces** (matching ore deposits).

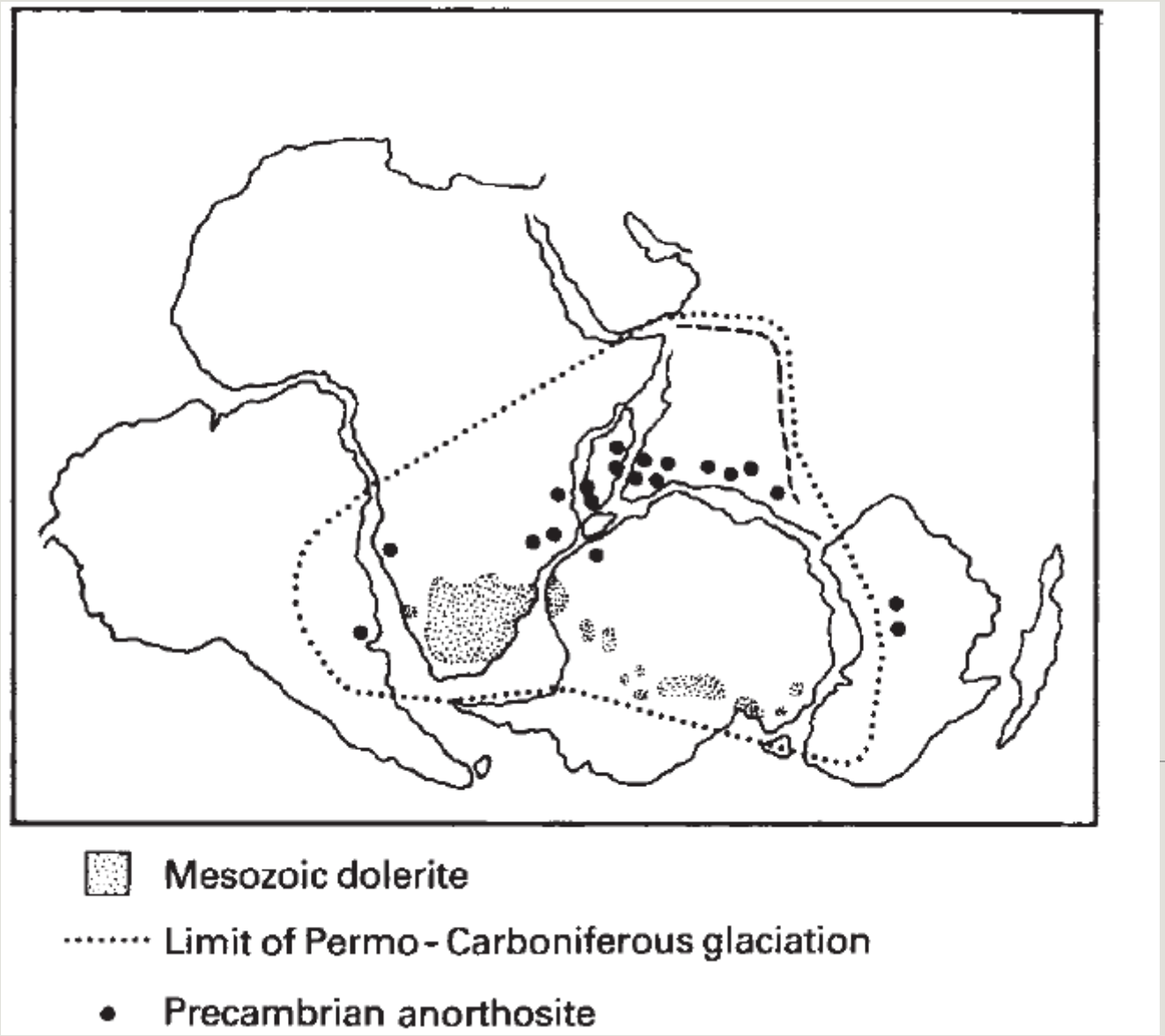


The fit of the continents around the North Atlantic, after Bullard et al. (1965), and the trends of the Appalachian-Caledonian and Variscan (early and late Paleozoic) fold belts (dark and light shading respectively). The two phases of mountain building are superimposed in eastern North America (redraw from Hurley, 1968; the Confirmation of Continental Drift. Copyright © 1968 by Scientific American, Inc. All rights reserved.)

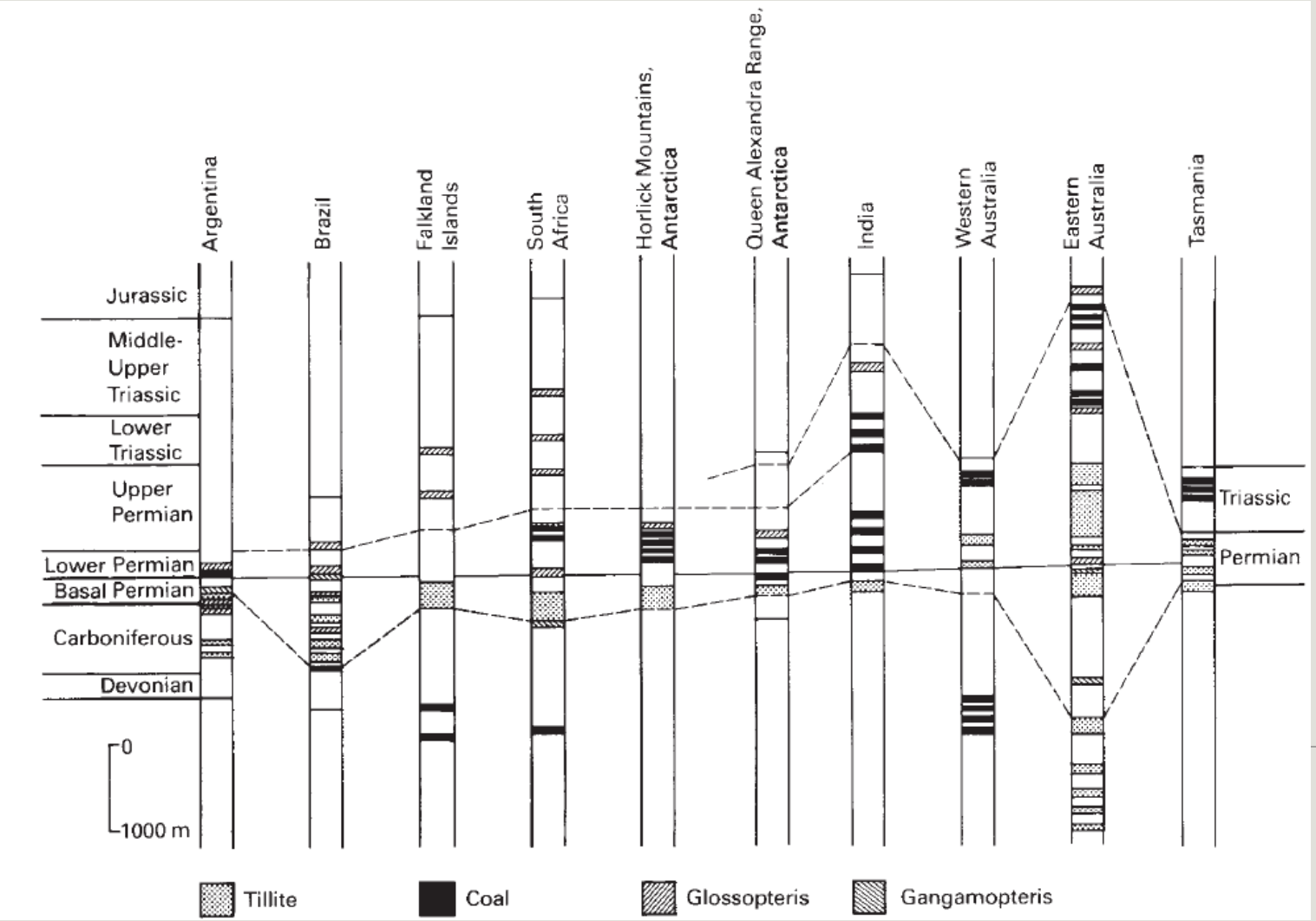


Cratons are ancient, stable, and relatively undeformed regions within continents. They are the oldest and most stable parts of Earth's continental crust, having survived multiple cycles of continent formation and breakup. Essentially, they are the heart of continents, often containing the oldest rocks on Earth.

Correlation of cratons and younger mobile belts across the closed southern Atlantic Ocean (redrawn from Hurley, 1968, the Confirmation of Continental Drift. Copyright © 1968 by Scientific American, Inc. All rights reserved.)



Correlation of Permo-Carboniferous glacial deposits, Mesozoic dolerites, and Precambrian anorthosites between the reconstructed continents of Gondwana (after Smith & Hallam, 1970, with permission from Nature 225, 139–44. Copyright 1970 Macmillan Publishers Ltd).



Correlation of stratigraphy between Gondwana continents (redrawn from Hurley, 1968, the Confirmation of Continental Drift. Copyright © 1968 by Scientific American, Inc. All rights reserved.)

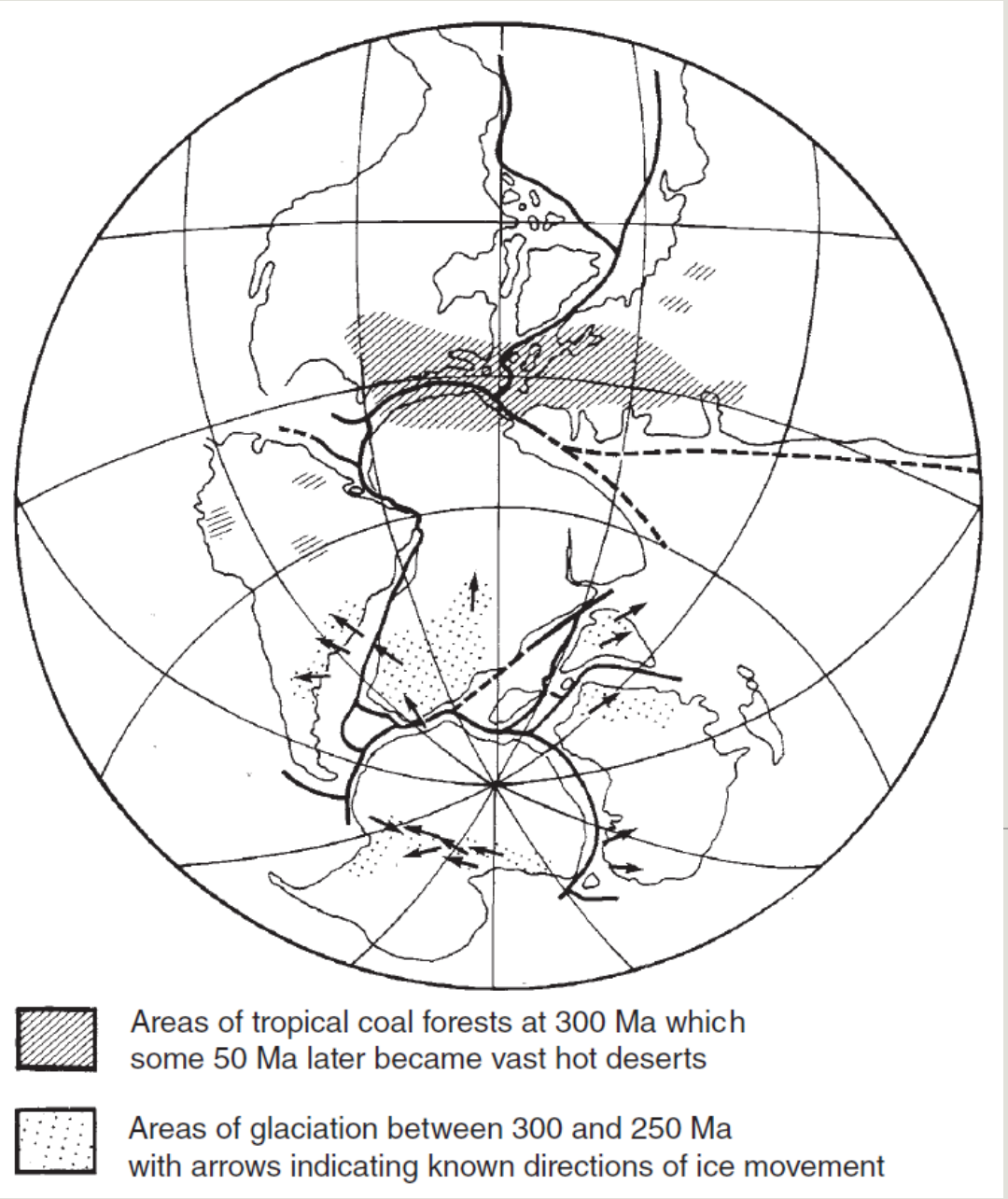
3.4 Paleoclimatology

Past climate indicators (linked to latitude) support continental drift:

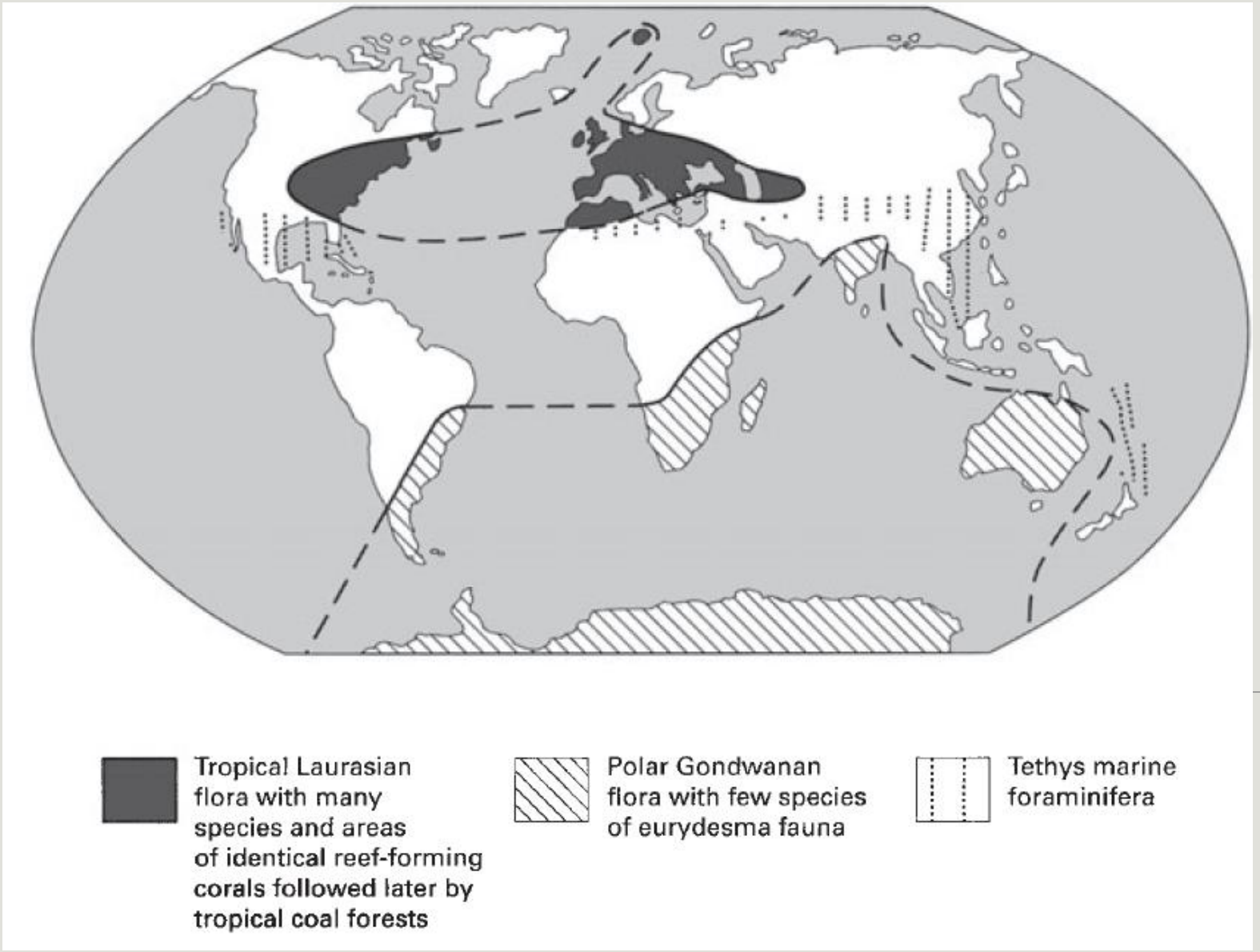
- **Low-latitude indicators**:
  - Carbonates, reefs (warm waters near the equator).
  - Evaporites (arid subtropical zones).
  - Red-beds (hot, oxidizing conditions).
  - Bauxite/laterite (tropical weathering).
- **High-latitude indicators**:
  - Glacial deposits (Permo-Carboniferous glaciation in Gondwana).
  - Coal (temperate/tropical forests).

3.5 Palaeontologic Evidence

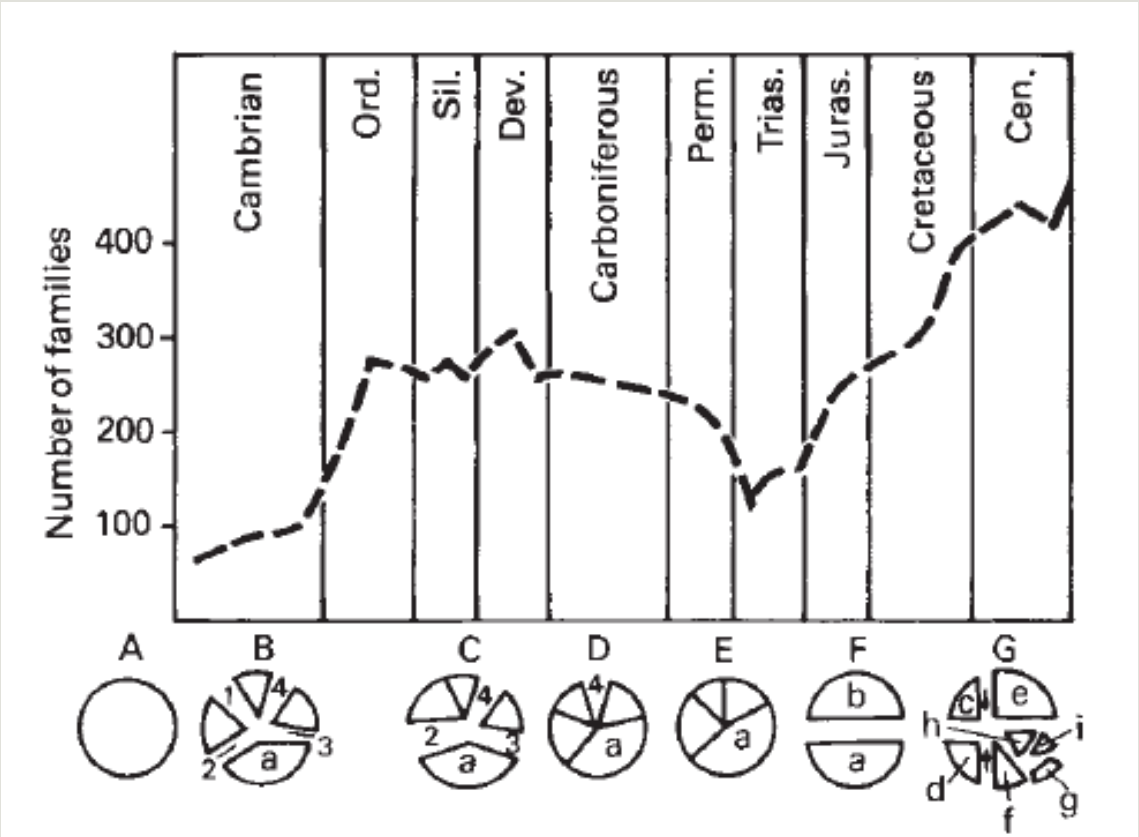
- **Barriers to dispersal**: Oceans separate species (e.g., *Mesosaurus* in Brazil and Africa).
- **Faunal provinces**: Cambrian trilobites suggest ancient separated continents.
- **Floral evidence**:
  - Gondwana's *Glossopteris* flora (cold climate).
  - Laurasia's tropical flora.
- **Diversity**: Increases with continental fragmentation.



Use of paleoclimatic data to control and confi rm continental reconstructions (redrawn from Tarling & Tarling, 1971).



Present distributions of Pangean flora and fauna (redrawn from Tarling & Tarling, 1971).



Correlation of invertebrate diversity with time and continental distribution. A, earlier Pangea; B, fragmentation of earlier Pangea producing oceans preceding Caledonian (1), Appalachian (2), Variscan (3), and Uralian (4) orogenies; C, suturing during Caledonian and Acadian orogenies; D, suturing during Appalachian and Variscan orogenies; E, suturing of Urals and reassembly of Pangea; F, opening of Tethys Ocean; G, fragmentation of Pangea. a,Gondwana; b, Laurasia; c, North America; d, South America; e, Eurasia; f, Africa; g, Antarctica; h, India; i, Australia (after Valentine & Moores, 1970, with permission from Nature ***228***, *657–9. Copyright 1970 Macmillan Publishers Ltd).*

3.6 Paleomagnetism

Rock Magnetism

•**Ferromagnetic minerals** retain ancient magnetic fields (remanent magnetization).

•Types:

- **Thermoremanent (TRM)**: Igneous rocks.
- **Detrital (DRM)**: Sedimentary rocks.
- **Chemical (CRM)**: Secondary mineralization.

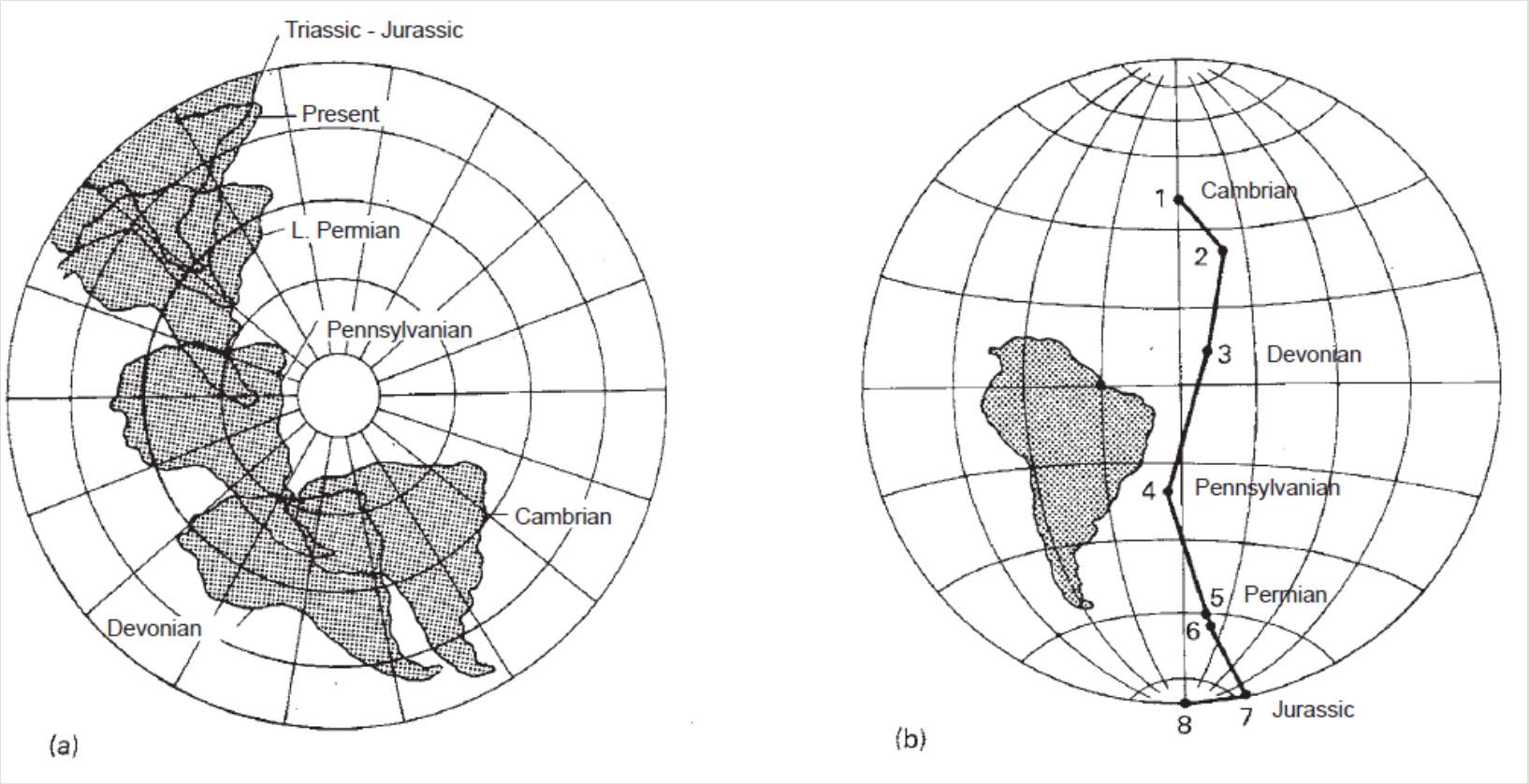
Geomagnetic Field and Polar Wander

Earth's field approximates an **axial dipole**. **Paleomagnetic data** reveal past latitudes but not longitudes. A**pparent Polar Wander (APW) paths** show continent movement.

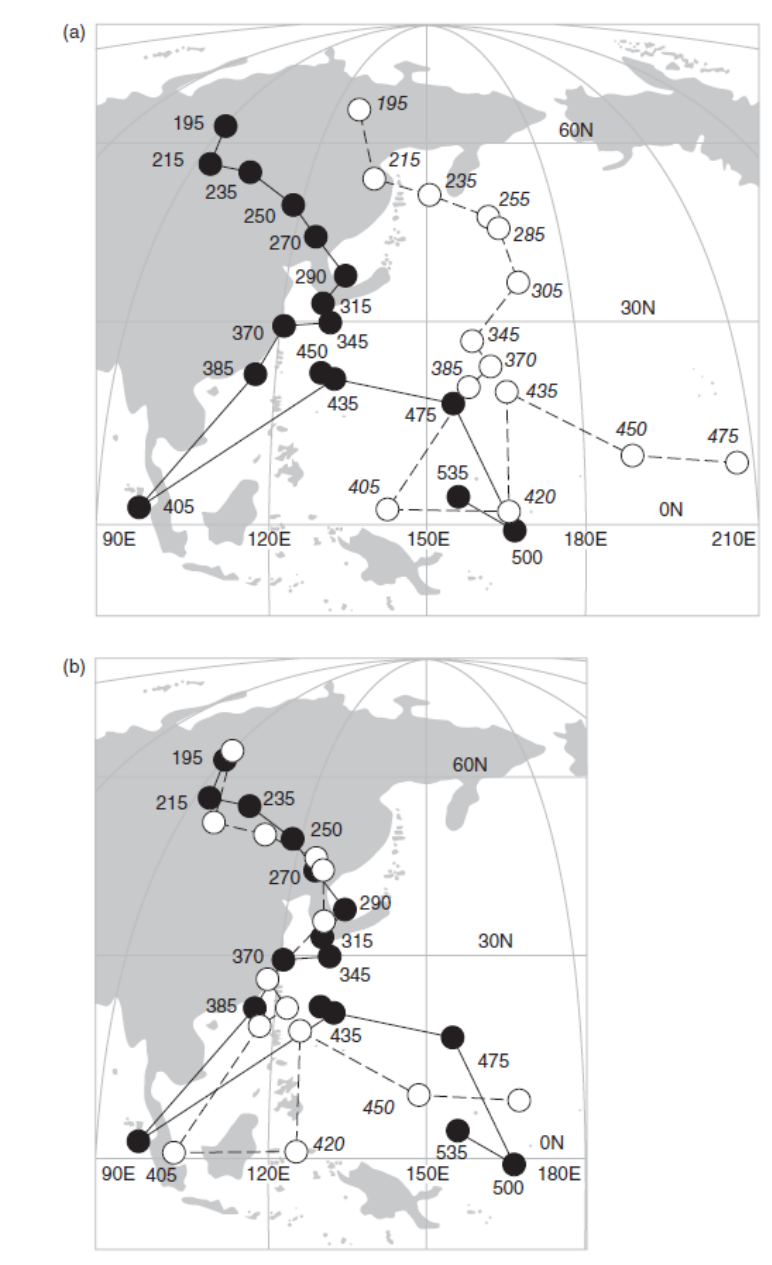
Reconstructions

- APW paths confirm drift (e.g., North America and Europe match when Atlantic is closed)

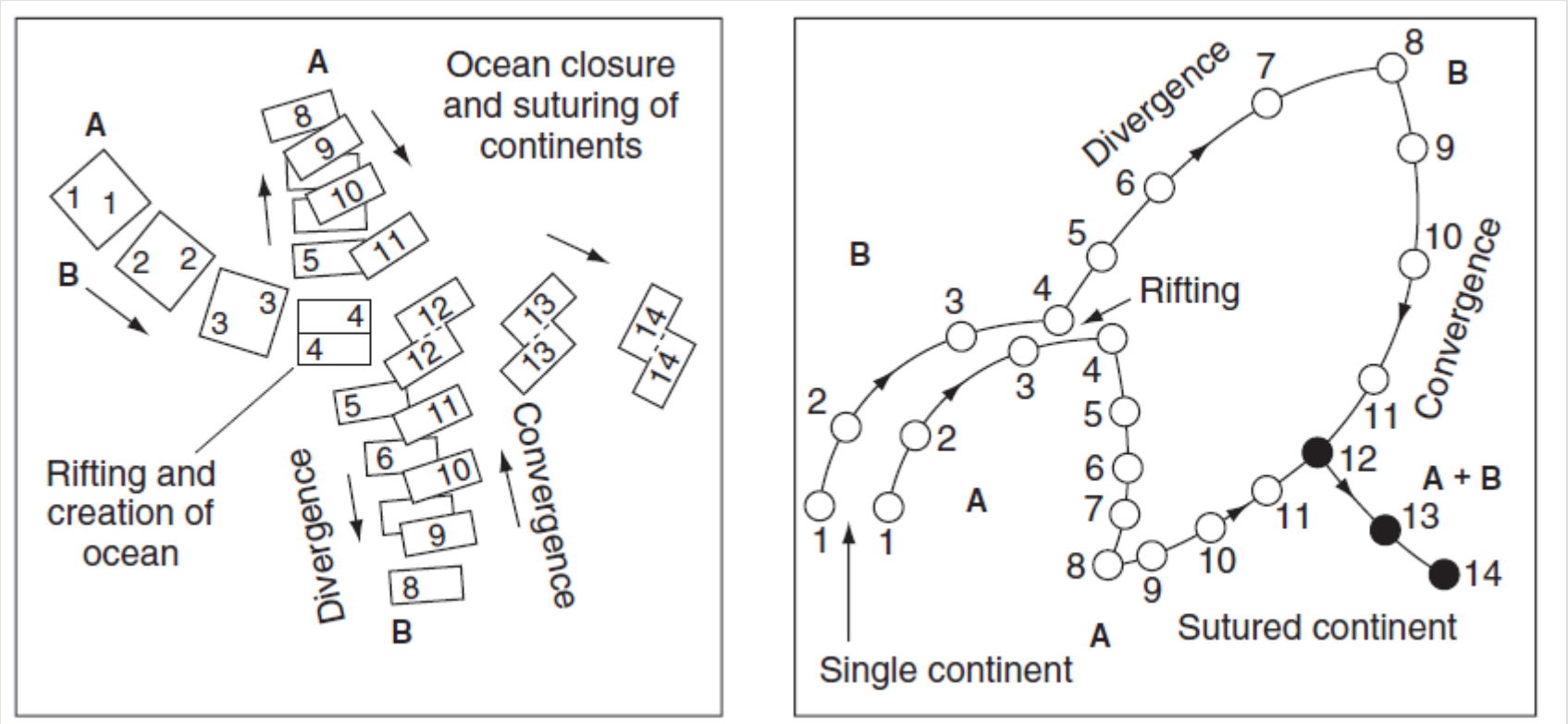
- Gondwana's APW path places the Carboniferous pole near Africa (supporting glaciation evidence).



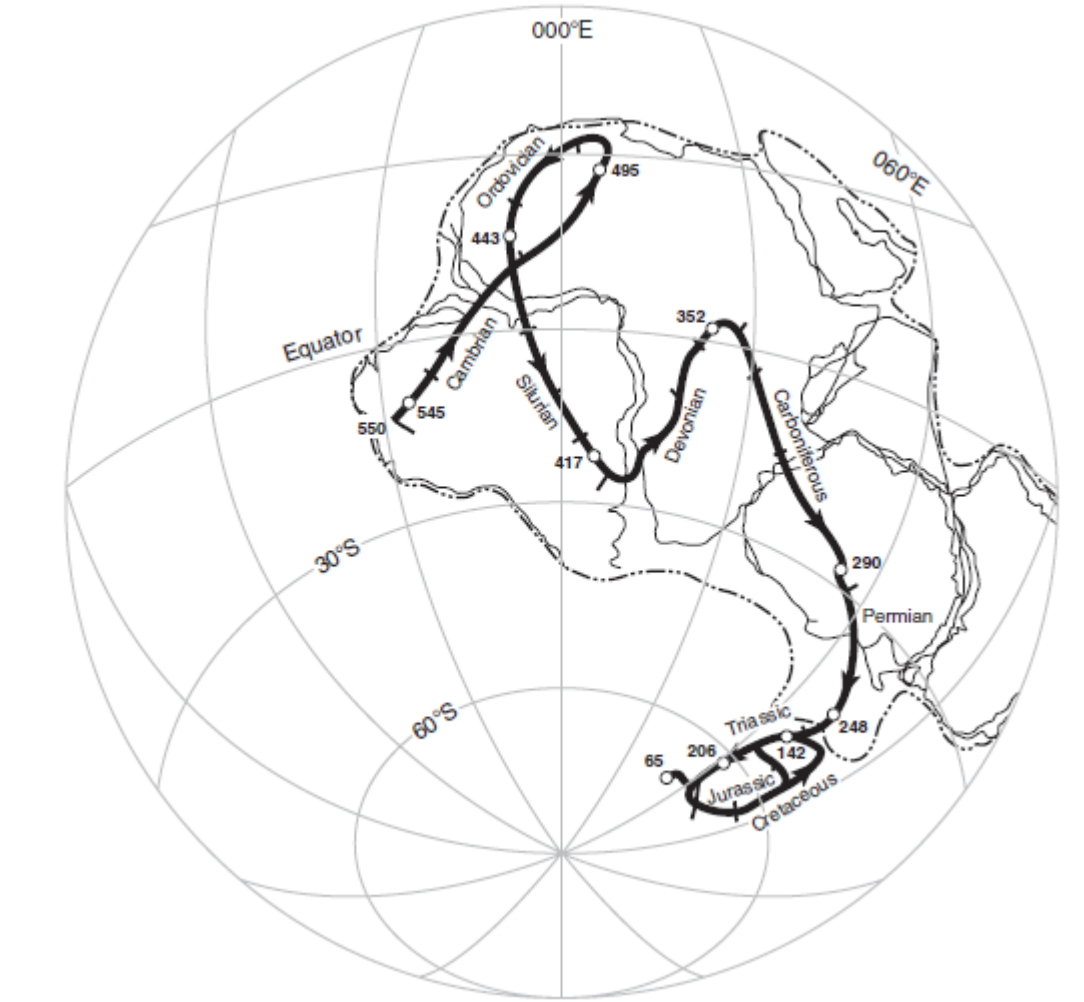
Two methods of displaying paleomagnetic data: (a) assuming fixed magnetic poles and applying latitudinal shifts to the continent; (b) assuming a fixed continent and plotting a polar wander path. Subsequent work has modified the detail of the movements shown. Note that the south pole has been plotted (redrawn from Creer, 1965, with permission from the Royal Society of London).



Apparent polar wander paths for North America (solid circles and solid line) and Europe (open circles and dashed line) (a) with North America and Europe in their present positions, and (b) after closing the Atlantic ocean. Ages for each mean pole position are given in Ma with those for Europe in italics (redrawn from McElhinny and McFadden, 2000, with permission from Academic Press. Copyright Elsevier 2000).



Paleomagnetic signature of plate divergence and convergence (redrawn from Irving et al., 1974, by permission of the American Geophysical Union. Copyright © 1974 American Geophysical Union).



APW path for Gondwana, based on the reconstruction of Lottes & Rowley (1990) (redrawn from Torsvik & Van der Voo, 2002, with permission from Blackwell Publishing).