Mesosaurus

Lystrosaurus

Cynognathus

U3A
Plate Tectonics 2
Continental Drift

Introduction

- Theory of continental drift, predates plate tectonics by several hundred years
- initially based entirely on observations of continent shapes
- until more recent times → only parts of Earth accessible to scientific study
- theory gained momentum as maps became more accurate along with scientific studies

Continental drift

- Idea of Continental drift is the separation and dispersal of continents on Earth that were once joined
- for a long period of time it was simply an observation proposed without explanation as to how it could occur
- we now know that continental drift → inevitable consequence of plate movement with continents passively carried by lithospheric plates
- evidence for continental drift originates from many different kinds of sources
- most obvious observation → accurate geometric fit of continents

Early ideas Abraham Ortelius

Abraham Ortelius (1527-1598)

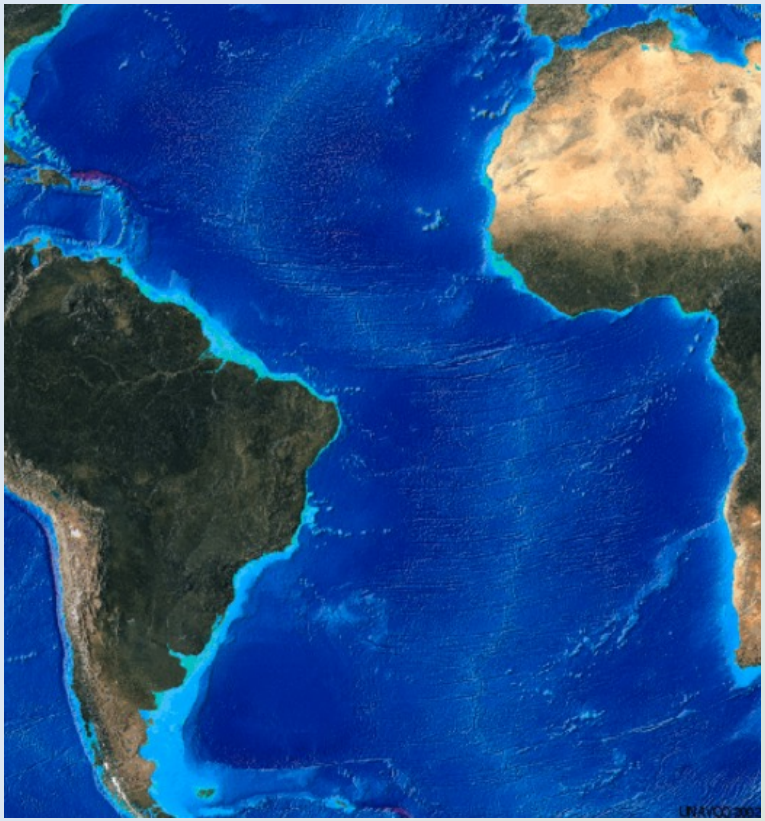
- First to recognise geometrical coincidence between coasts of the Americas Europe/Africa
- he suggested that "the Americas were torn away from Europe and Africa"

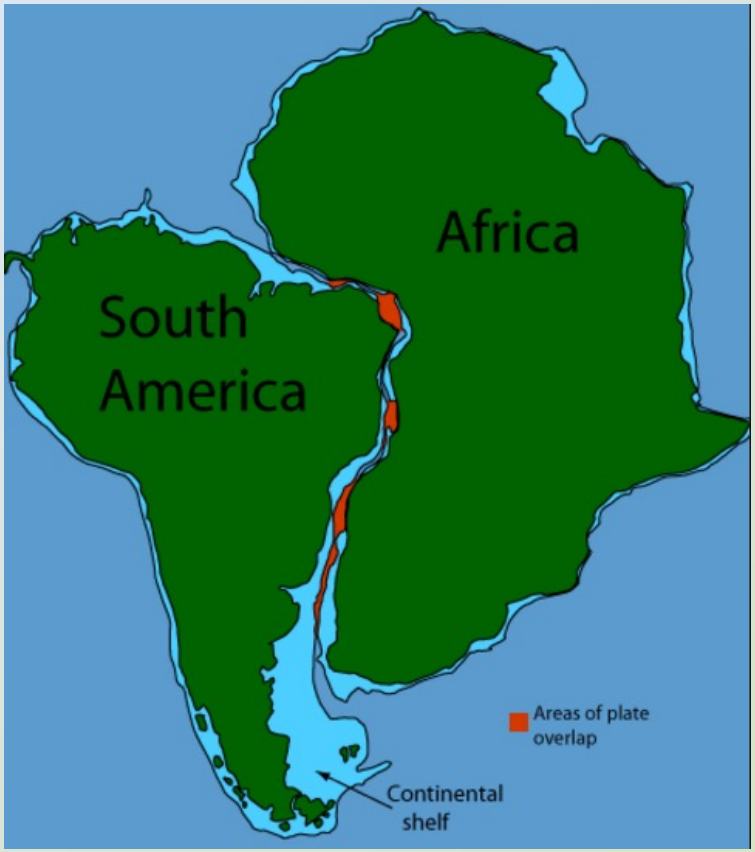
Map of the world, Ortelius, 1572

Coastline fit, Atlantic ocean

- As maps of coastlines became more reliable (18th century) → people were struck by similarity of shape of coastlines

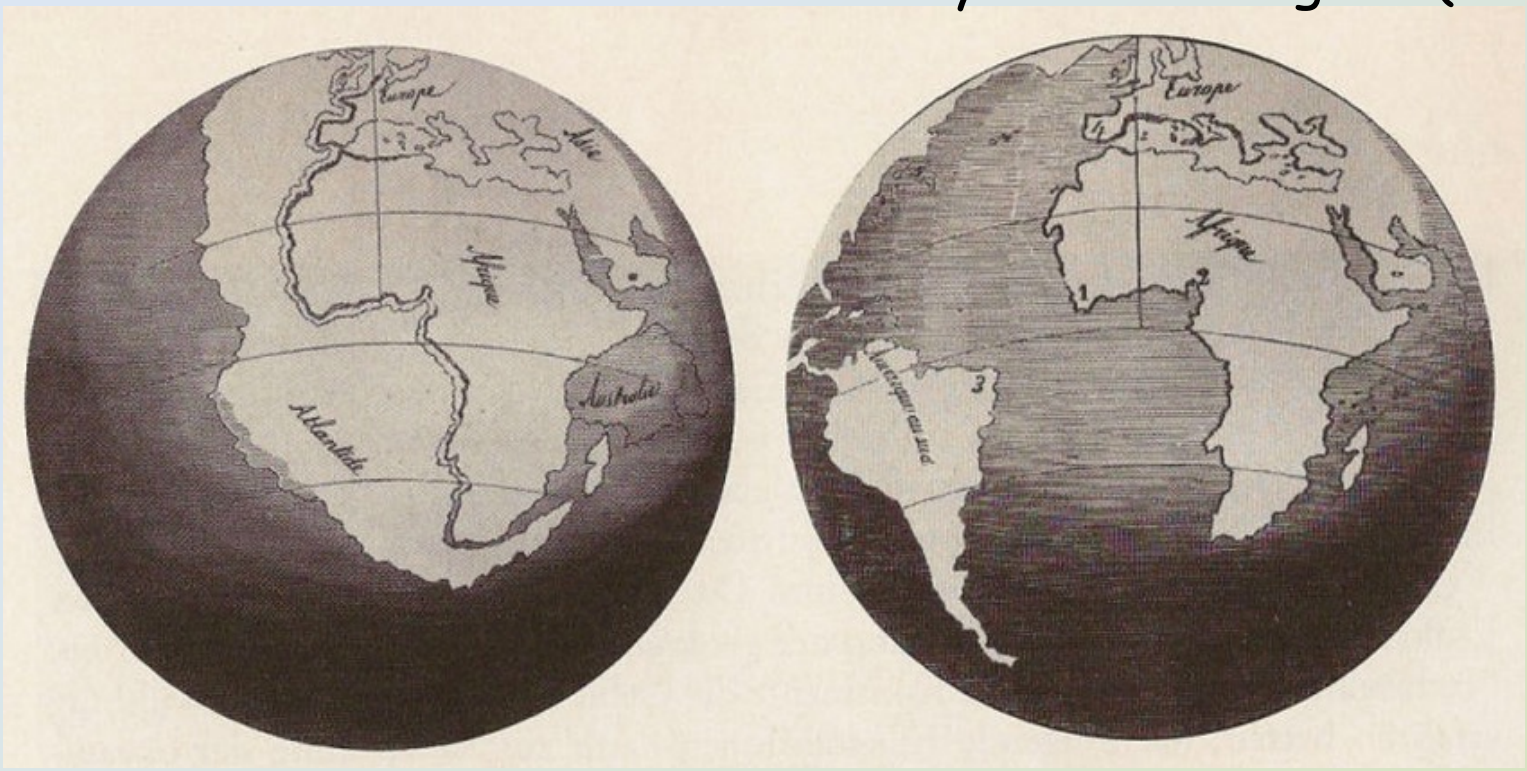
- margin of western Africa closely parallels that of South America





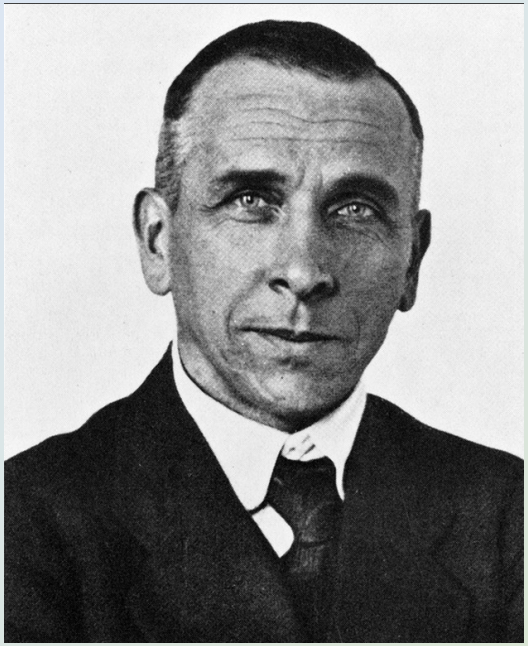
Early ideas

- Geographers noted similarities between coastlines of South America and Africa
- first illustration of continental drift was made by Antonio Snider-Pelligrini (1858)
- the idea was ridiculed and later revived by Alfred Wegner (1912)



Snider-Pelligrini's construction

Continental drift



Alfred Wegener

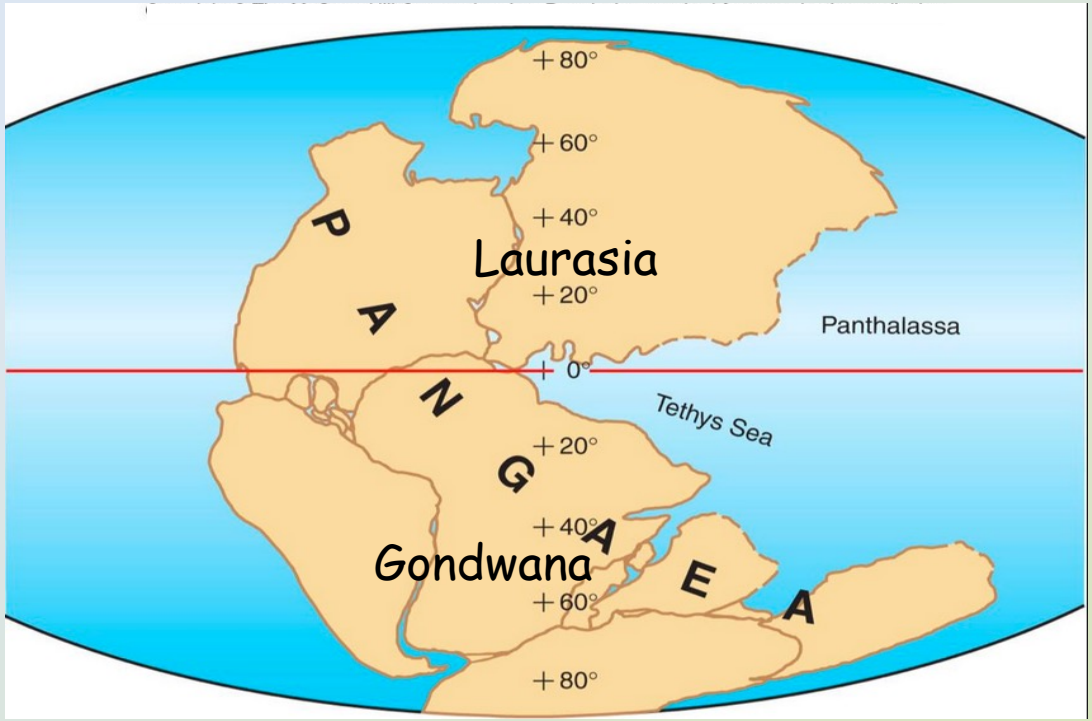
Alfred Wegener (1880-1930)

- German meteorologist, geologist and explorer
- strongly supported the theory that the continents were once joined (1912)
- he showed that by reconstructing continents the geology supported the fit
- first person to use the phrase "continental drift"
- he proposed that continents formed one landmass → super-continent he called Pangea

Pangea

- Pangea probably only existed for a short geological time
- Laurasia and Gondwana were northern and southern parts
- Laurasia → super continent composed of Europe, North America, Greenland and most of Asia

  Gondwana → South America, Africa, India, Antarctica, Madagascar and Australasia
- Panthalassa and Tethys were great oceans of the late Palaeozoic



Wegener's theory of continental drift

- Ideas based on fit of continents and continuity of geological features across juxtaposed continental boundaries
- noted similarities in fossils in Brazil and Africa → animals that could not swim or could only swim small distances
- his reconstructed landmass Pangea → matched other geological features (rock formations, mountain belts)
- his evidence implied → continents were once joined
- he was ridiculed → unable to provide mechanism as to how continents could move apart

Wegener's evidence for continental drift

- Striking geometric fit of continents (not just Africa, Sth America)
- similar sedimentary sequences of all the southern continents
  especially of Triassic and Permian age
- similarity of palaeoclimate indicators in previous adjacent
  continents e.g.
  - coal deposits
  - desert deposits
  - glacial deposits
- distribution of fossil flora and fauna
- many major geological features are truncated at modern coastlines
  e.g. Caledonian fold belt

Geometric fit of continents

Evidence from matching geology

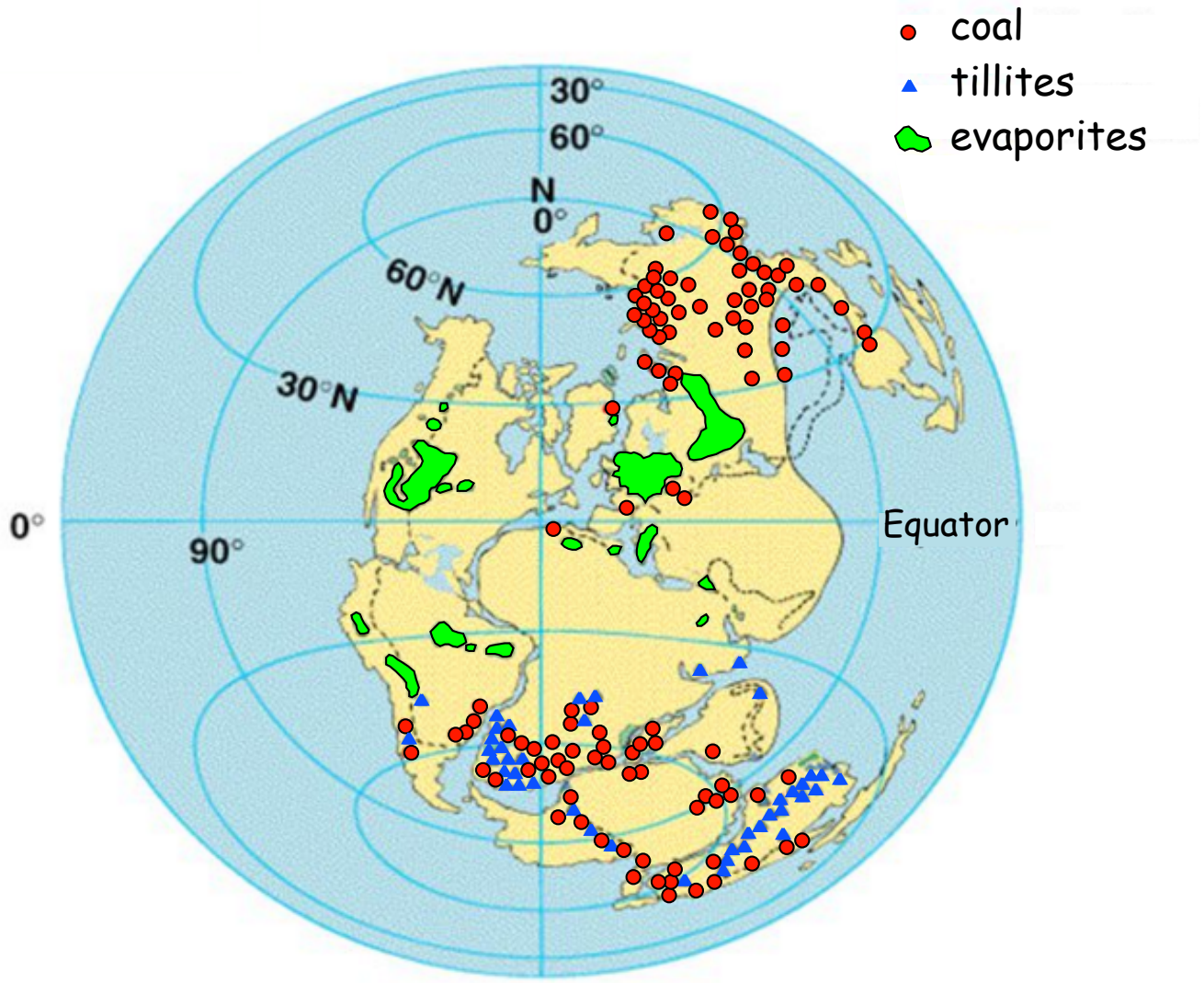
Ancient climate zones

- Distribution of sedimentary rocks that are sensitive palaeoclimate indicators make sense on a reconstructed globe
- coal deposits form where there is abundant plant growth mainly in tropical regions (cool temperature regions in the Permian)
- large dry deserts are confined to dry tropical regions
- widespread glacial deposits are formed by ice caps in polar regions
- glacial deposits only form in localised areas in the tropics where there are high mountains

Palaeoclimate evidence

- Distribution of climatic regions is complex → controlled by several parameters e.g. solar flux, wind direction, ocean currents elevation, topography
- latitude → major factor controlling climate
- study of past climates indicates → continents have drifted in a north-south sense
- during the Permian and Carboniferous, Gondwanan continents experienced extensive glaciation → situated near south pole
- at the same time in Europe and eastern USA → coal and extensive reef deposits were forming → tropical climates in equatorial latitudes

Permian climate indicators



Geological evidence for continental drift

Many geological features can be correlated across juxtaposed continental margins

- Fold belts – e.g. continuity of Appalachian Mtns with the Caledonian fold belt of northern Europe and Mauritanides of NW Africa → texture, composition and ages of rocks similar
- Age provinces – matching ages of rocks across the Atlantic Ocean
- Stratigraphic sections – distinctive stratigraphic sections can be correlated between adjacent continents
- Igneous provinces - e.g. Jurassic dolerite province that exists through southern Africa, Antarctica, South America and Tasmania
- Metallogenic provinces – regions containing manganese, gold, iron ore and tin can be matched on juxtaposed continents

Evidence from matching mountain belts

- Many mountain belts are truncated on modern continents
- Appalachian-Caledonian mountain belt → remnant of a major mountain chain → folded, intruded by granites, metamorphosed

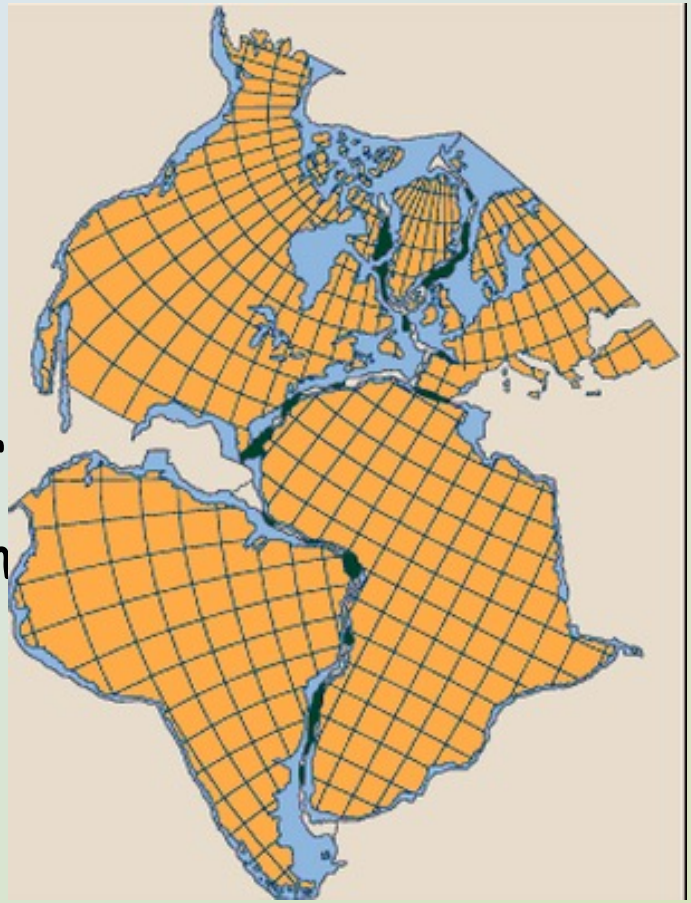
Precambrian geology of South America and Africa

- Good match between Precambrian rock types and structures in South America and Africa on either side of the Atlantic

Precambrian rocks

Modern continental reconstruction

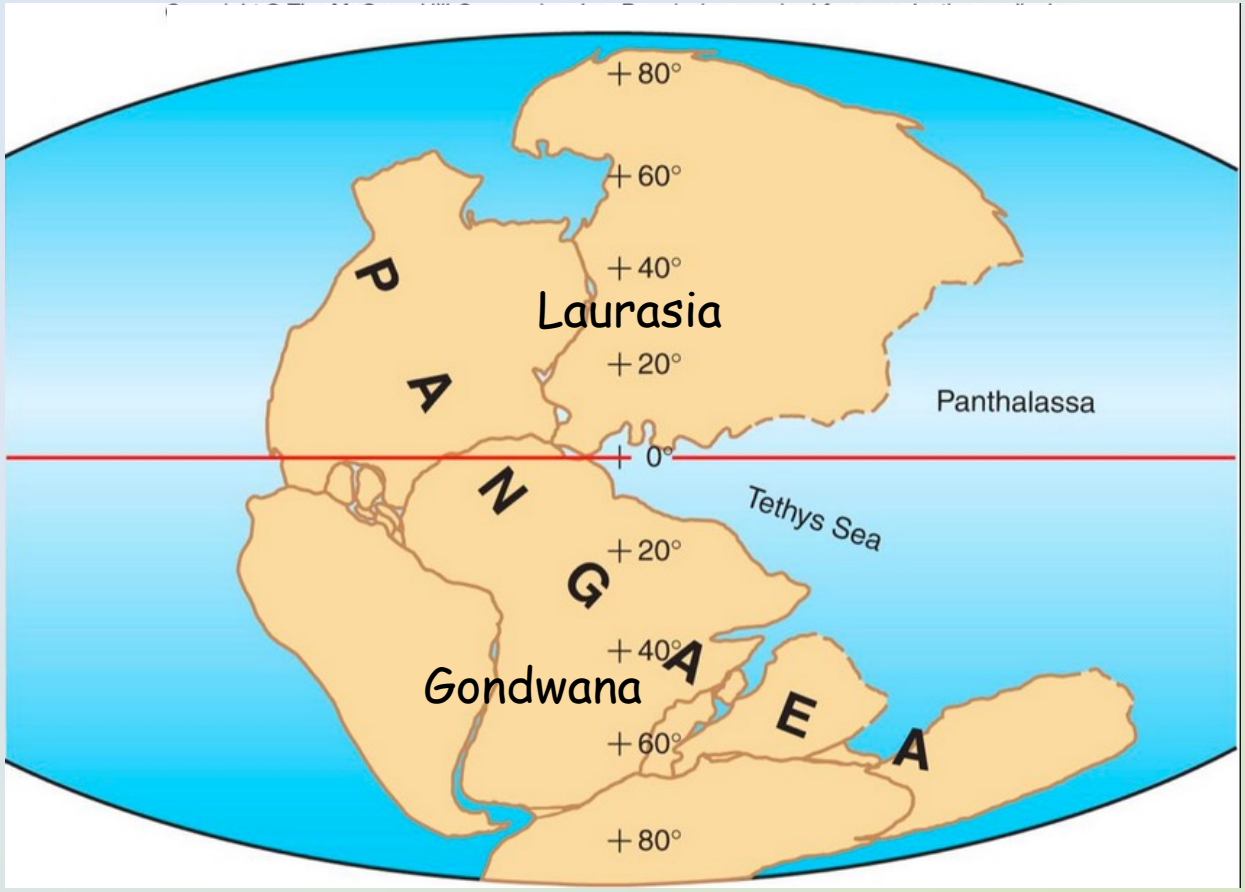
- Edward Bullard first used computer matching for Atlantic margins
- used 2000m depth contour to denote true edge of the continents, not the coastlines
- geometric fit of the Indian Ocean continental margin can be examined in the same way
- some overlaps and gaps occur between fitted continents but these are very minor
- overlaps are commonly due to accumulation of sediment since the break up e.g. Niger delta



Bullard's reconstruction of Atlantic margins

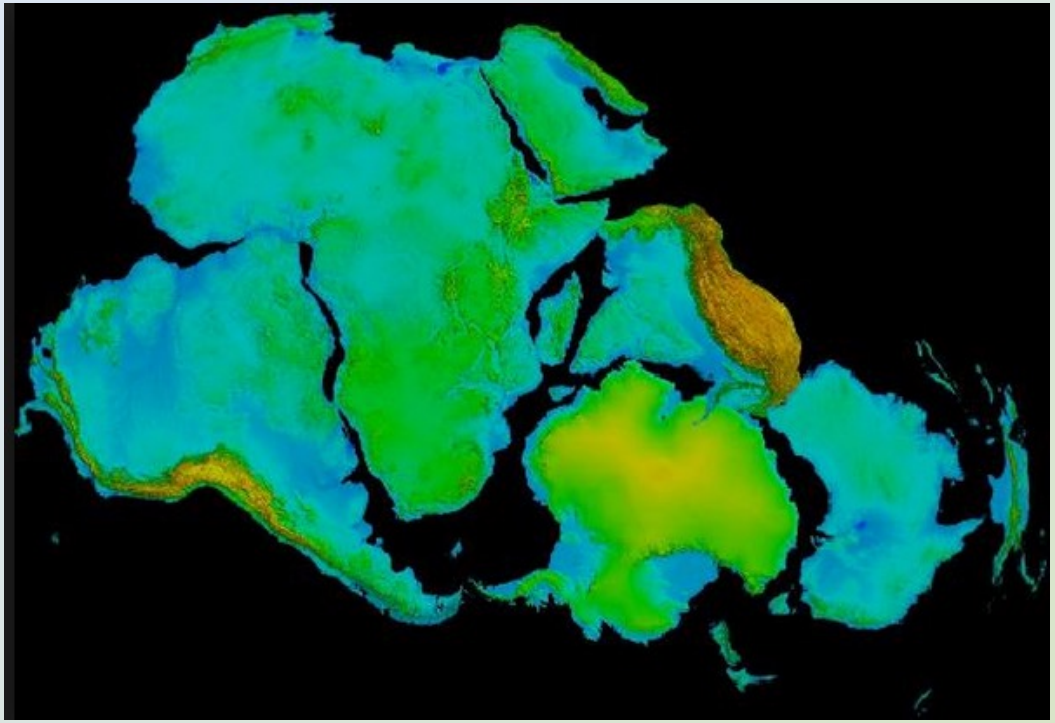
Continents and oceans of the Late Palaeozoic

- Separated continents combined (?) to form Pangea in Late Palaeozoic
- Laurasia and Gondwana are northern and southern parts
- Laurasia → supercontinent composed of Asia, Europe and North America
- Panthalassa and Tethys were the great oceans of the Late Palaeozoic



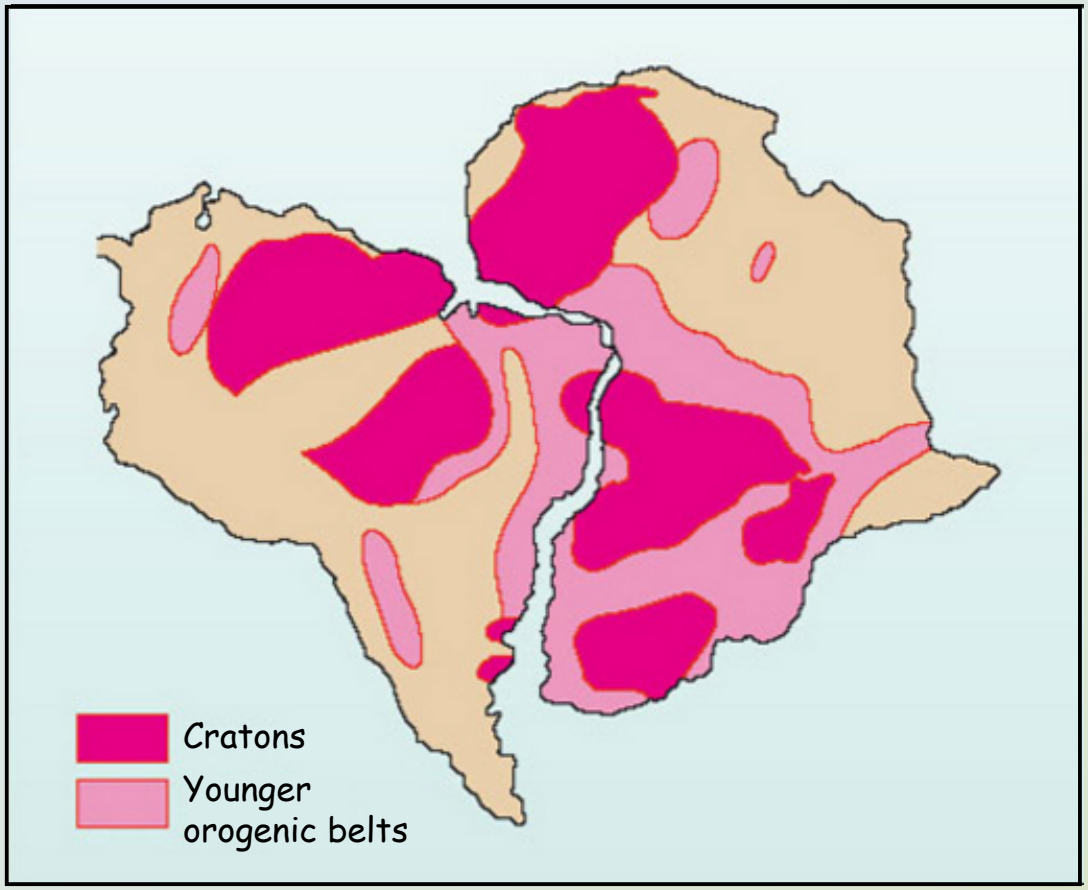
Gondwana

- Gondwana comprised South America, Africa, Antarctica, Australia and India
- numerous small segments were present on northern boundary and New Zealand on east
- Gondwana started to break up in the Jurassic Period



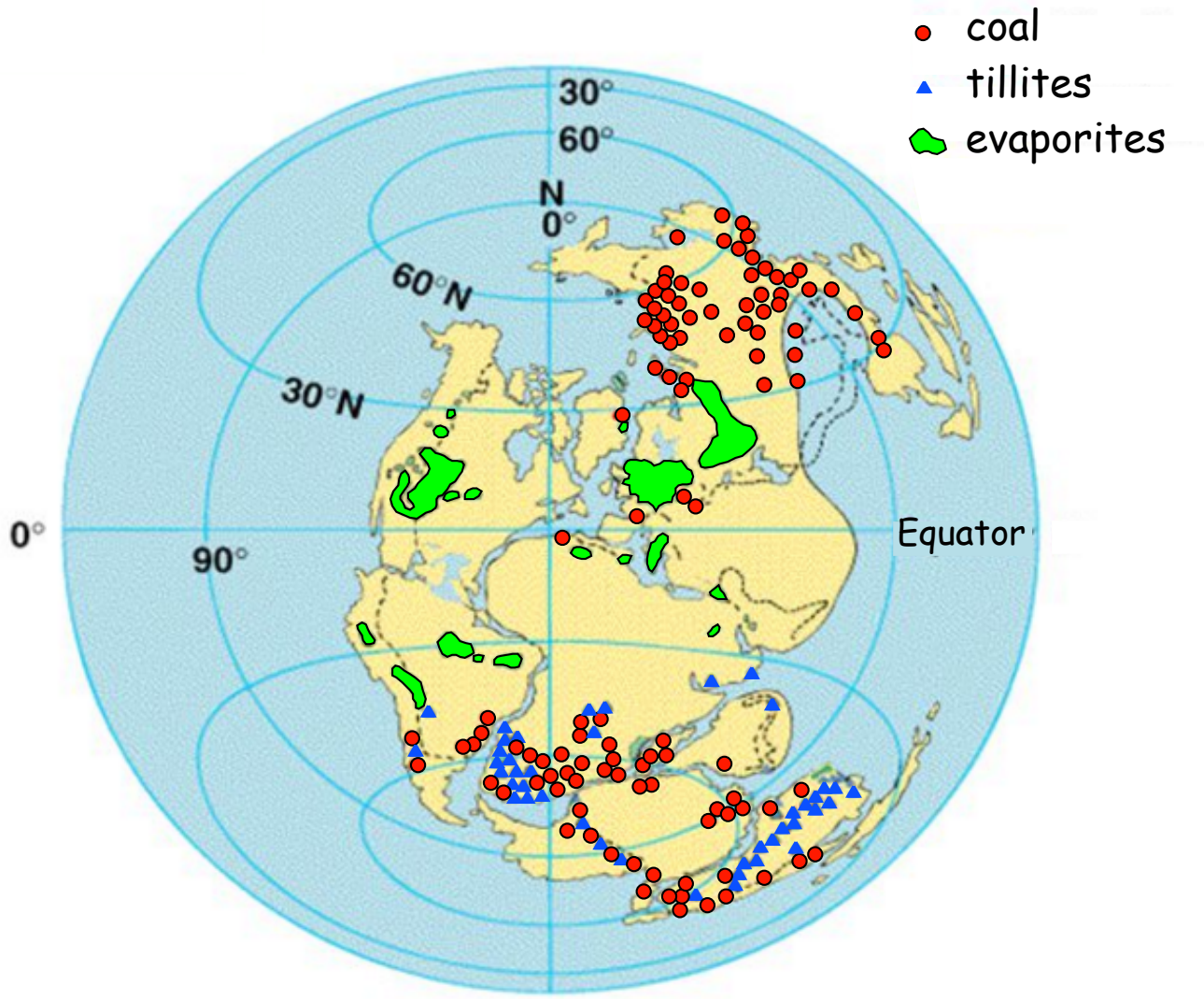
Precambrian geology of South America and Africa

- Good match between Precambrian rock types and structures in South America and Africa on either side of the Atlantic

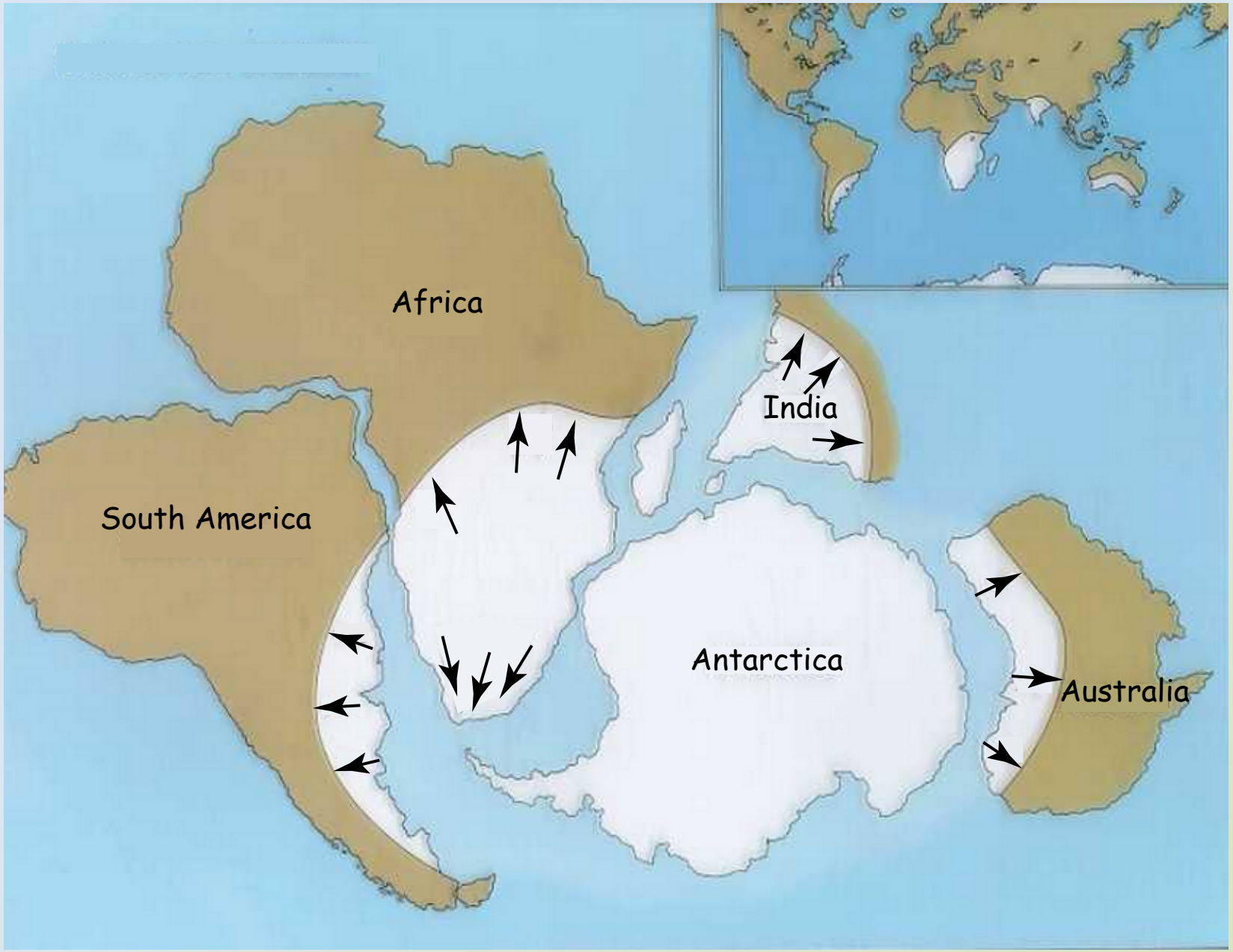


Permian climate indicators

Permian glacial deposits → widespread on southern continents

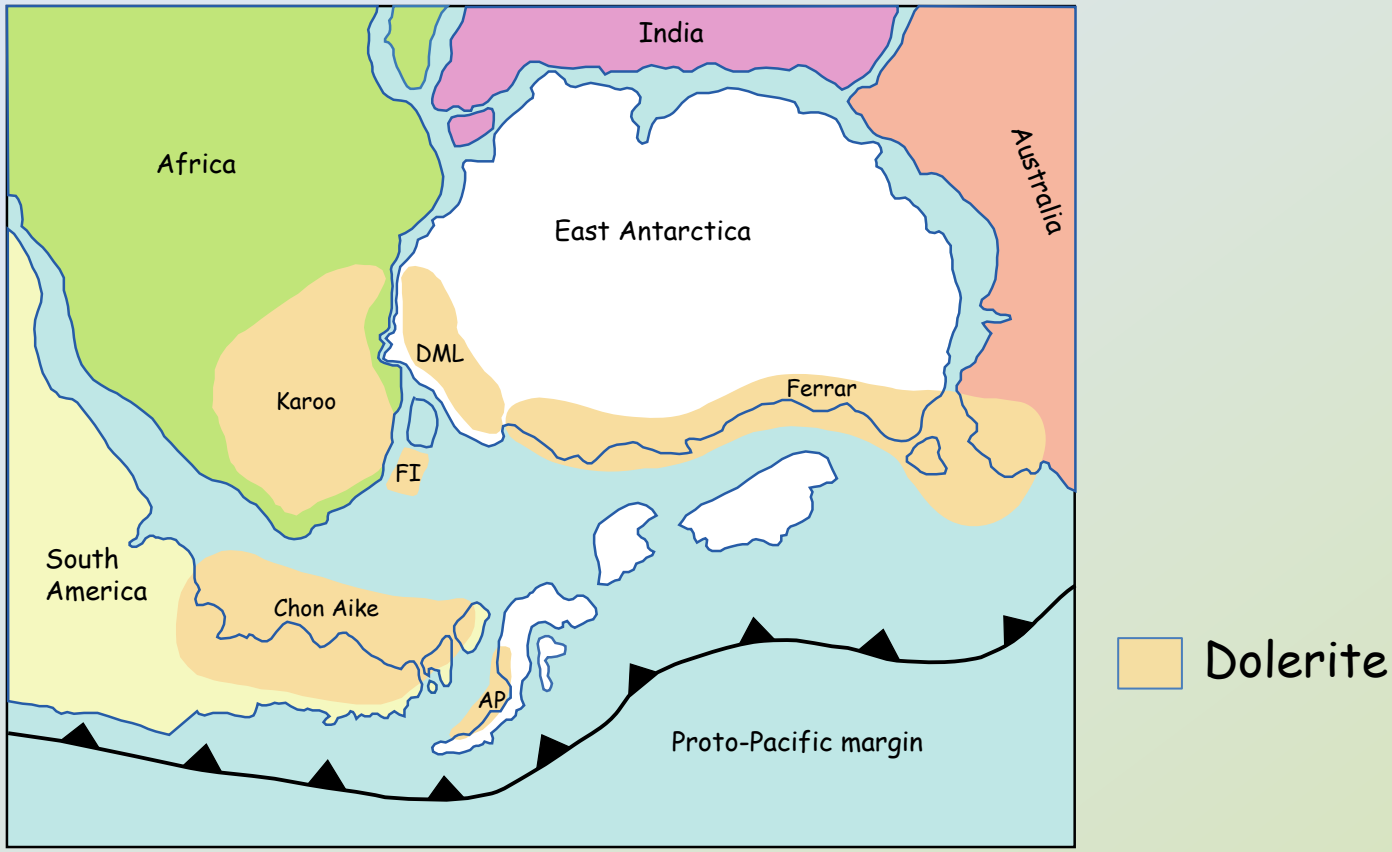


Distribution of Permian glacial deposits



Gondwana Jurassic dolerites

- Thick, massive, dolerite sills of Jurassic age found → large volumes occur in Tasmania, Antarctica, South America, Southern Africa
- dolerite → medium-grained igneous rock of basaltic composition
- dolerites → first evidence of igneous activity → precursor to the break up of Gondwana



Fossils of the Gondwana continents

- Widespread fossil assemblages are found in terrestrial sediments
- sediments of Permian and Triassic age found on Gondwanan continents are almost exclusively terrestrial → marine sediments are rare
- they contain important flora → the Permian tree ferns, *Glossopteris and Gangamopteris*
- also a number of early mammal-like reptiles e.g. *Lystrosaurus Cynognathus, Mesosaurus*

Evidence – plant fossils

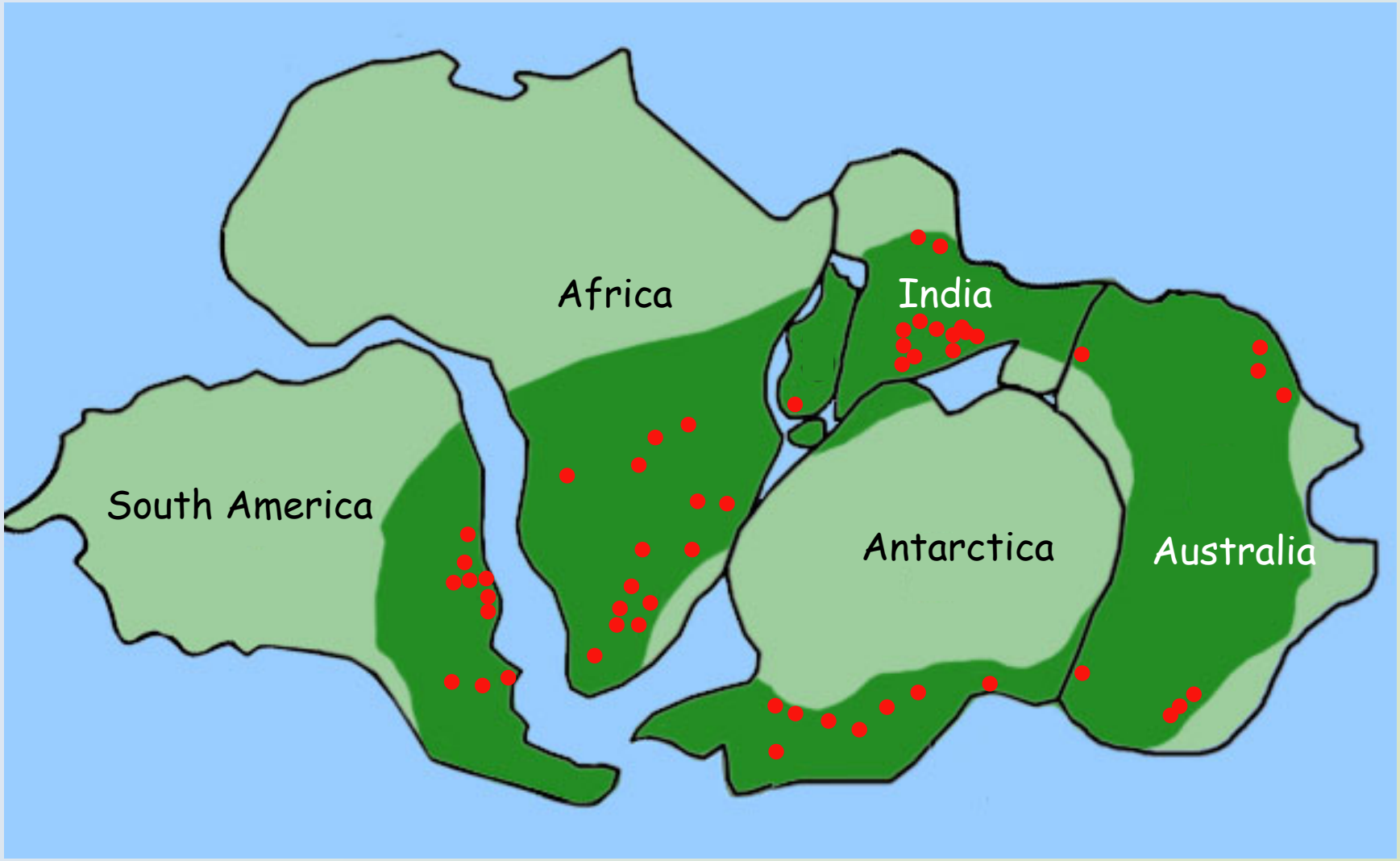
- Widespread fossil plant assemblages occur throughout southern continents

- very important are the Permian ferns *Glossopteris* and *Gangamopteris* → major contributors to Permian coal deposits

Glossopteris

Gangamopteris

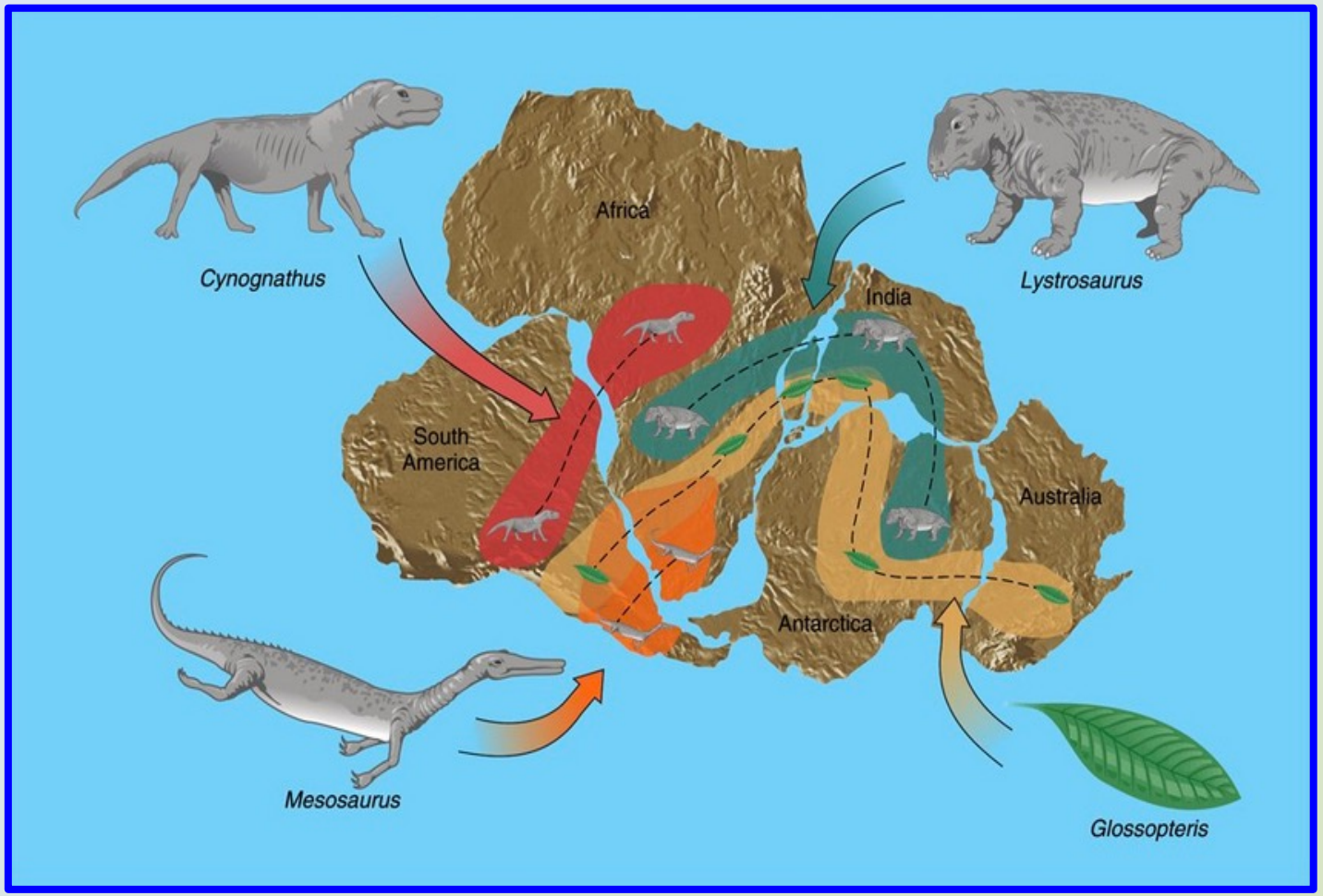
Glossopteris distribution in Gondwana



- Location of *Glossopteris* fossils

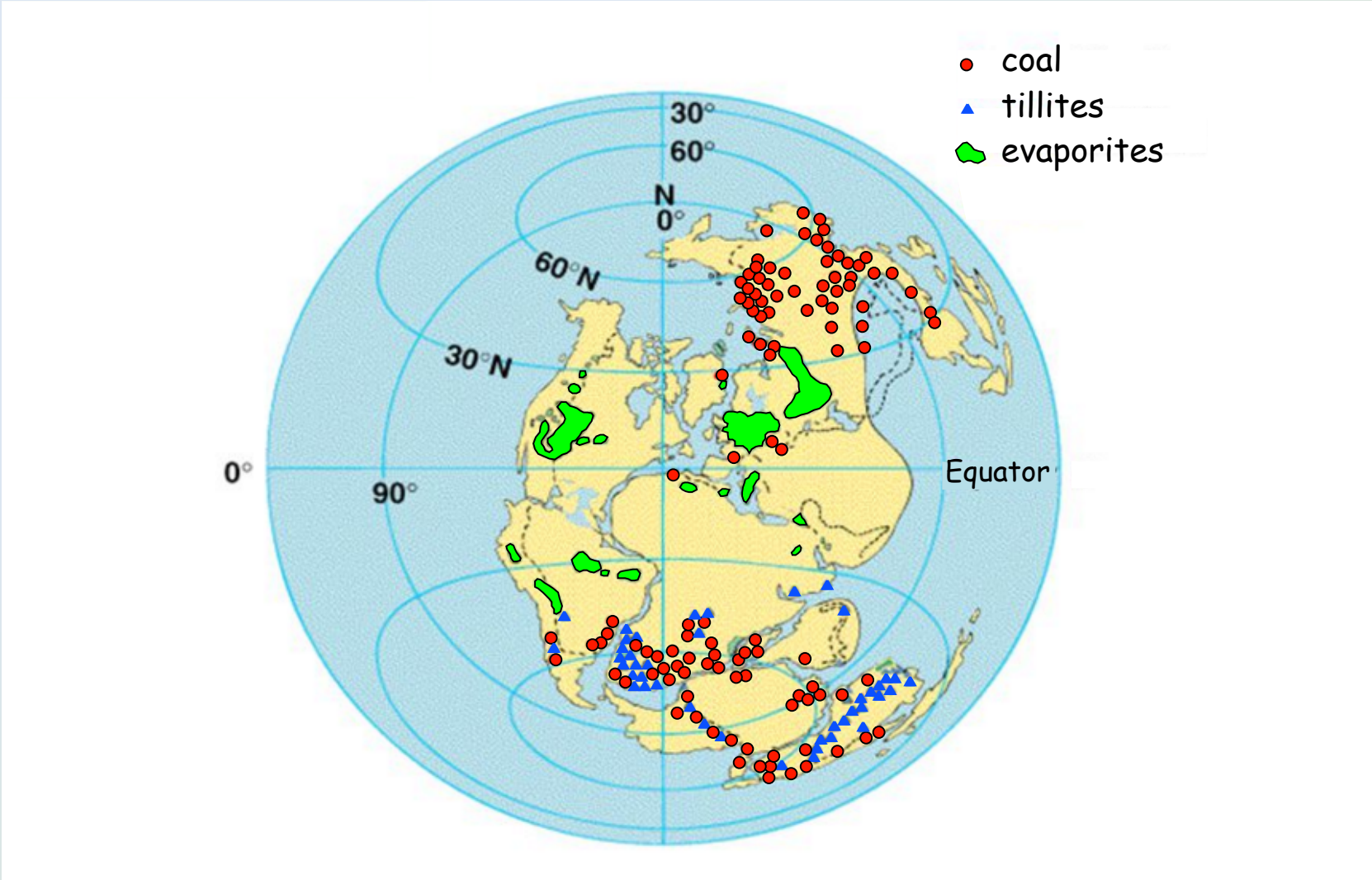
Gondwana fossil evidence

- Growth of oceans between continents → prevented migration between them by tetrapods



Permian coal deposits

By late Permian plant debris accumulated in coal swamps under cold humid conditions



Evidence from modern biogeography

- Distribution of modern plant and animal forms hard to explain
  → make sense if you consider → these continents once joined
- many plant groups represented only on Gondwana remnants
  e.g. *Nothofagus* (Antarctic beeches) found in Australia, New Zealand, Chile, New Guinea, New Caledonia, fossils in Antarctica

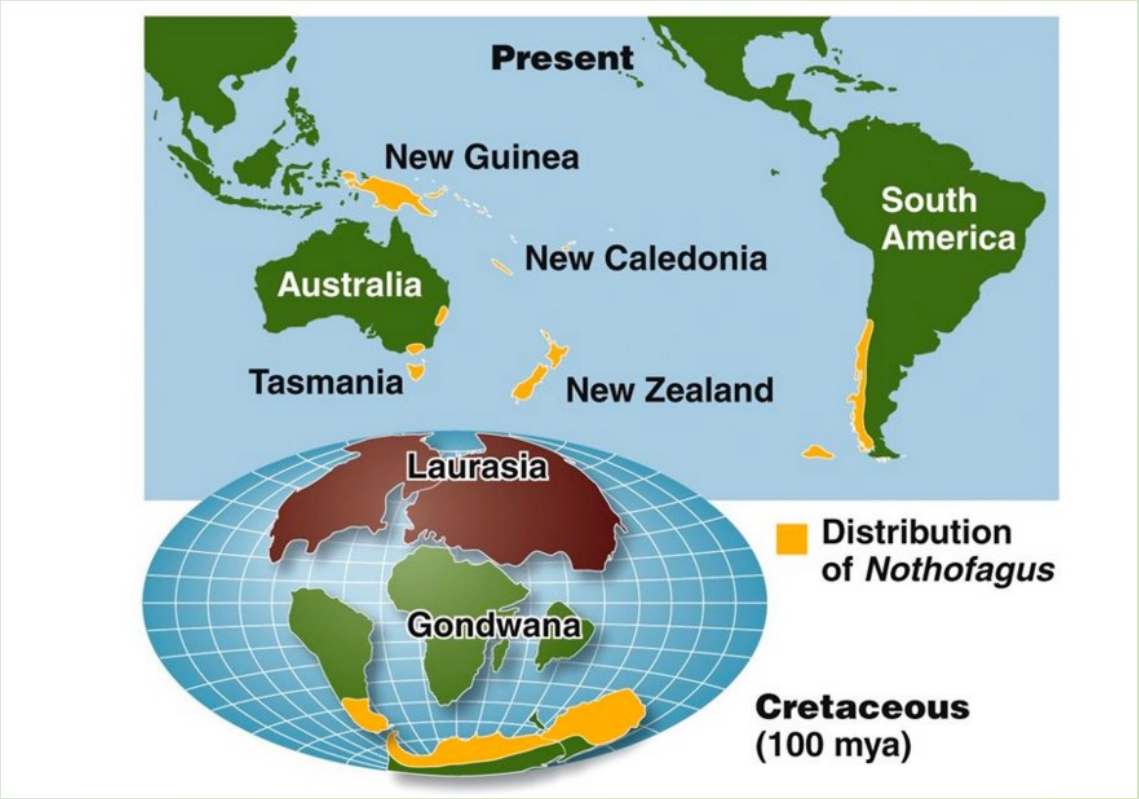
- distribution of certain bird groups e.g. Ratites [Ostrich, Emu, Rhea, Kiwi and Moa (extinct)]
  Parrots (South America, Australia, India, Africa)

- marsupials are found in Australia and the Americas. Abundant fossils found in South America and Antarctica

Biogeographic evidence – plant distribution

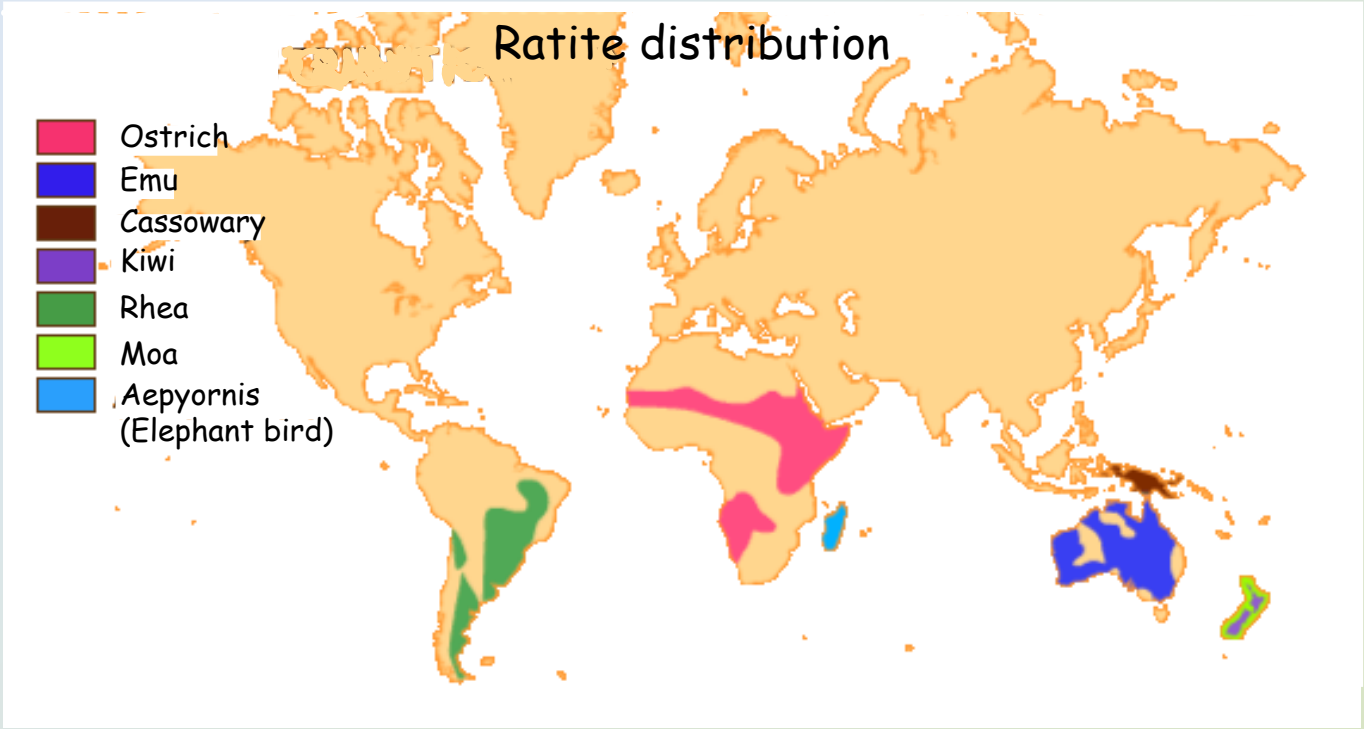
- *Nothofagus* flora (Antarctic beeches) occur in eastern Australia, Chile, New Zealand, New Guinea and New Caledonia

- fossil remains found in Antarctica



Biogeographic evidence bird groups

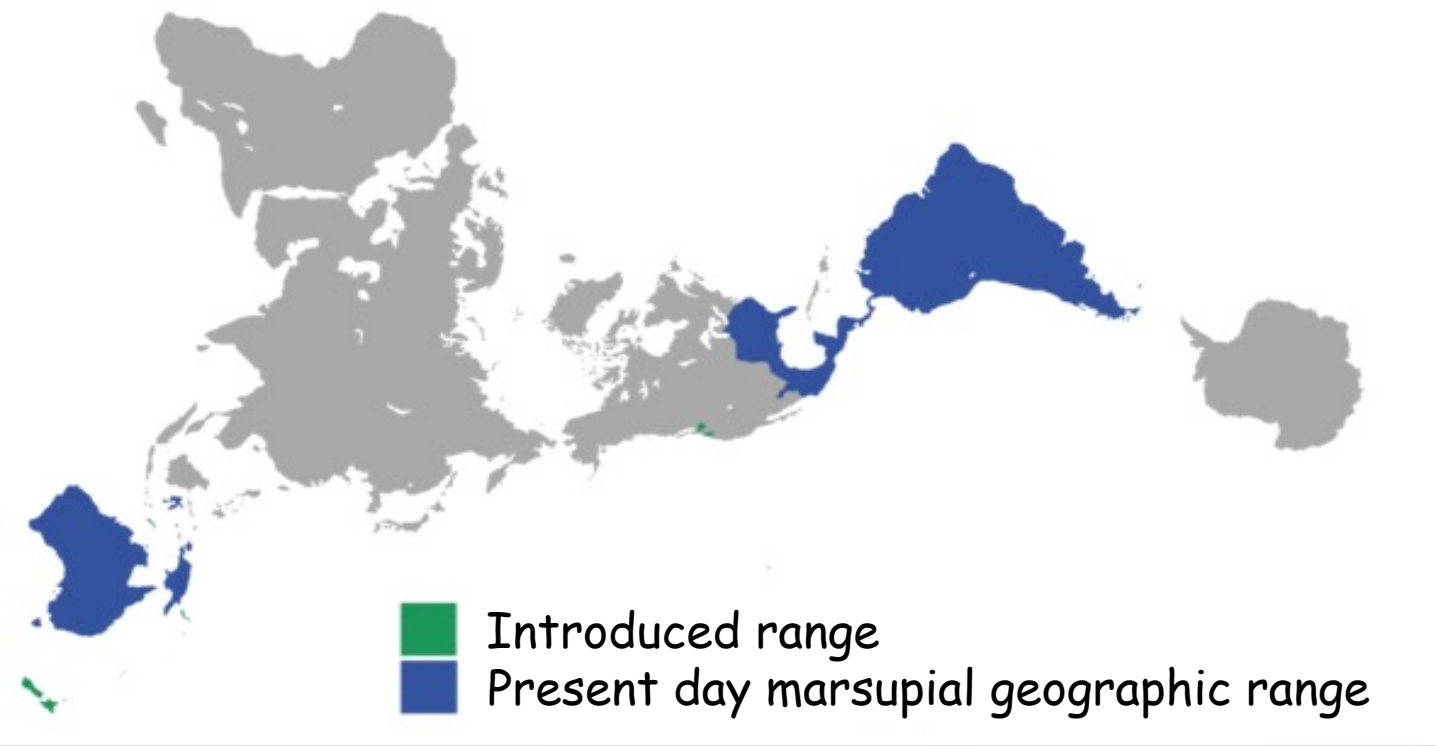
- Ratites → large flightless birds → no keel on sternum e.g. Emu, Ostrich, Cassowary, Kiwi, Rhea, extinct Moa and Elephant bird
- only found on Gonwanan continents
- parrots are found in Australia, South America, India, Africa



Distribution of marsupials

- Marsupials are endemic to Australia and South America
- one group (opossums) found in North America are recent

  → immigrants (Isthmus of Panama, American land bridge)
- marsupials characteristic of Australia → also characteristic of South America and Antarctica in fossil record



Summary of continental drift

- Distribution of Permo-Triassic geological features and modern day fauna and flora is consistent with the theory of continental drift
- evidence gives credence to Wegner's ideas
- consequences of breakup of continents → they will, eventually re-aggregate → continents cannot keep moving further and further apart on an Earth of finite size.
- certain parts of Gondwana have already embedded on a new super-continent (Asia)
- continental drift indicates movement of large blocks of the Earth

India collision with Asia

- Indian plate broke away from Gondwana 100million years ago
- began colliding with Eurasian plate ~50million years ago (Eocene)
- ocean basin between Asia and India was subducted below Eurasian plate
- collision resulted in orogenesis → formation of Himalayas