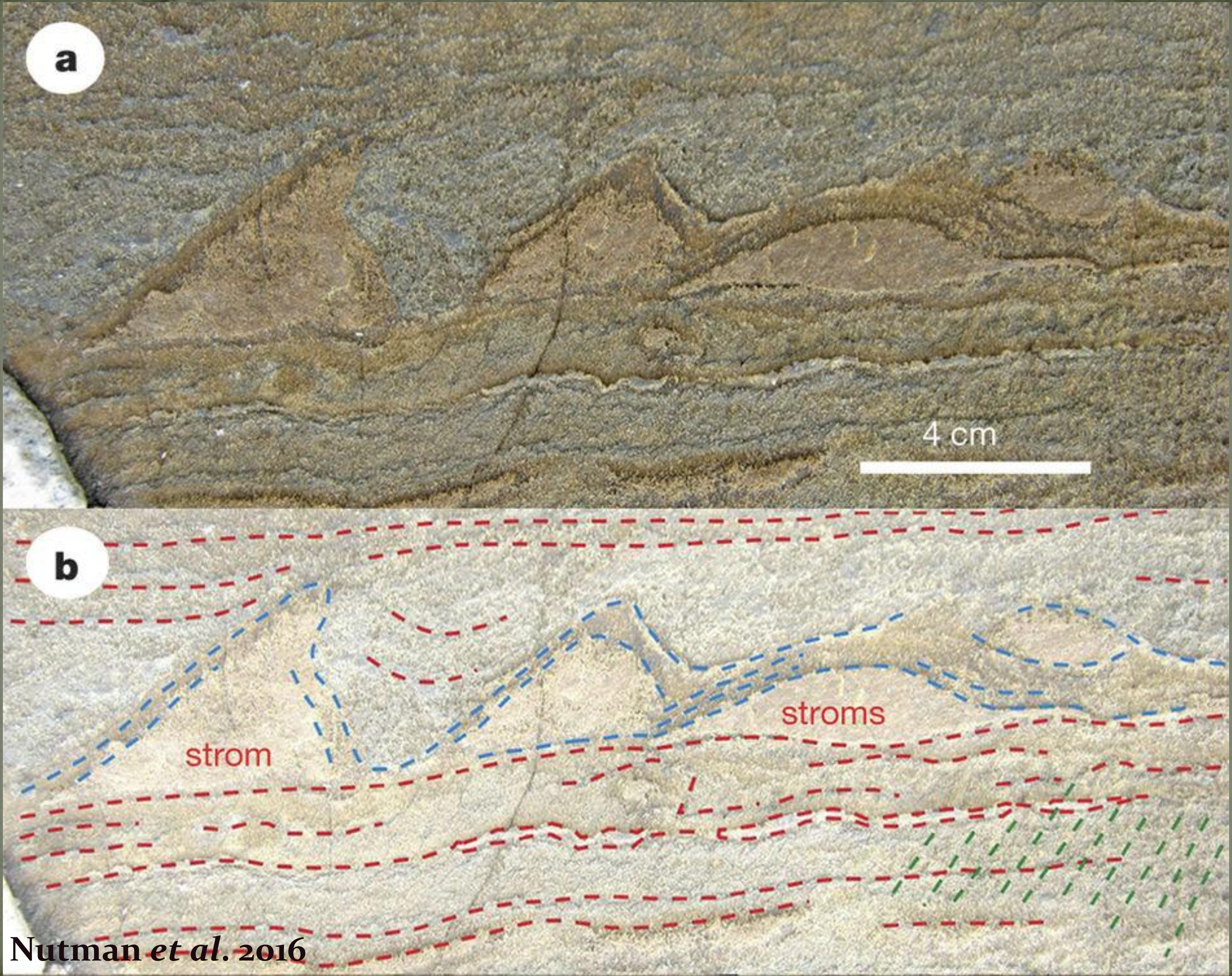
Palaeozoic Era

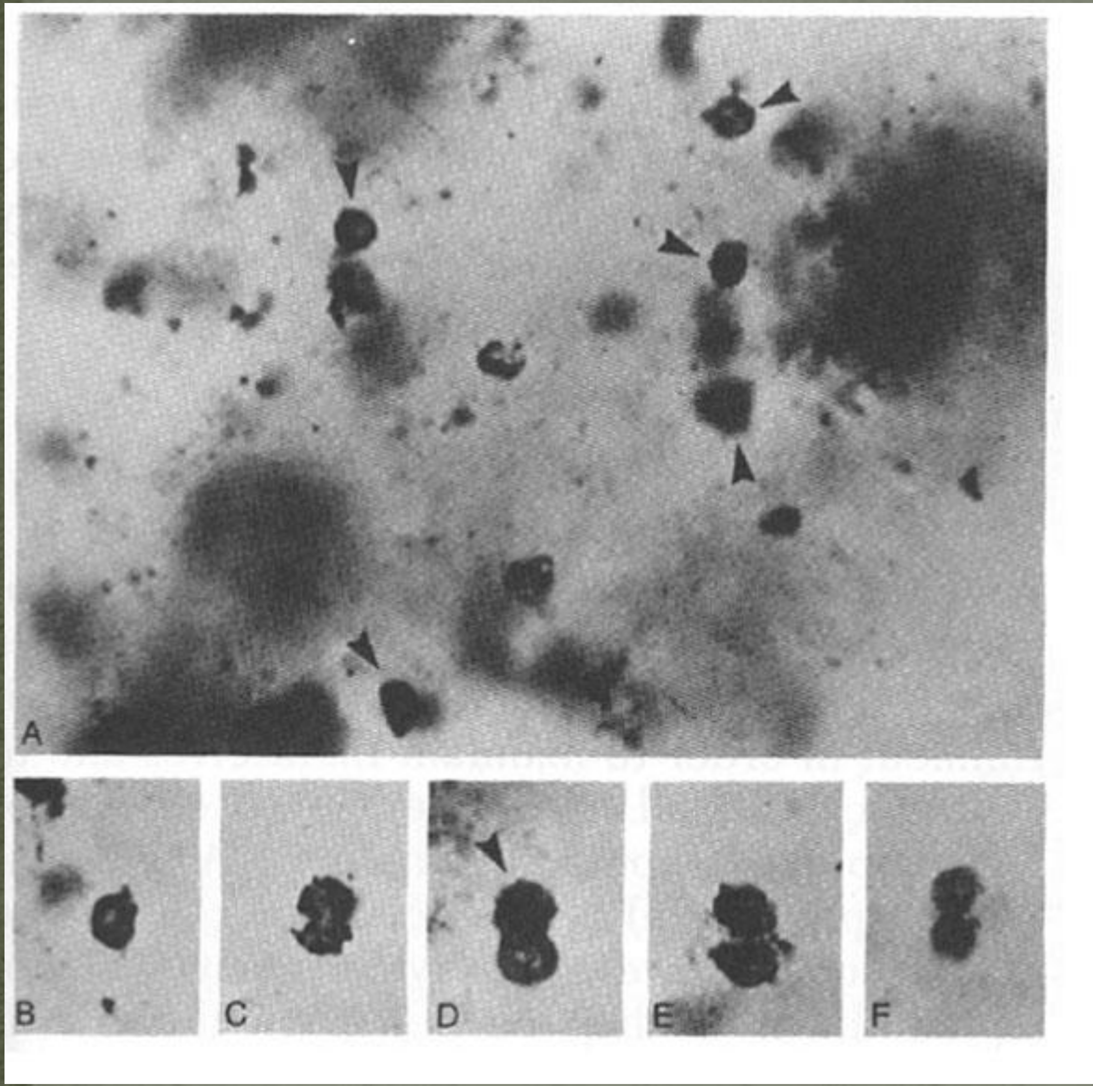
The oldest microfossils

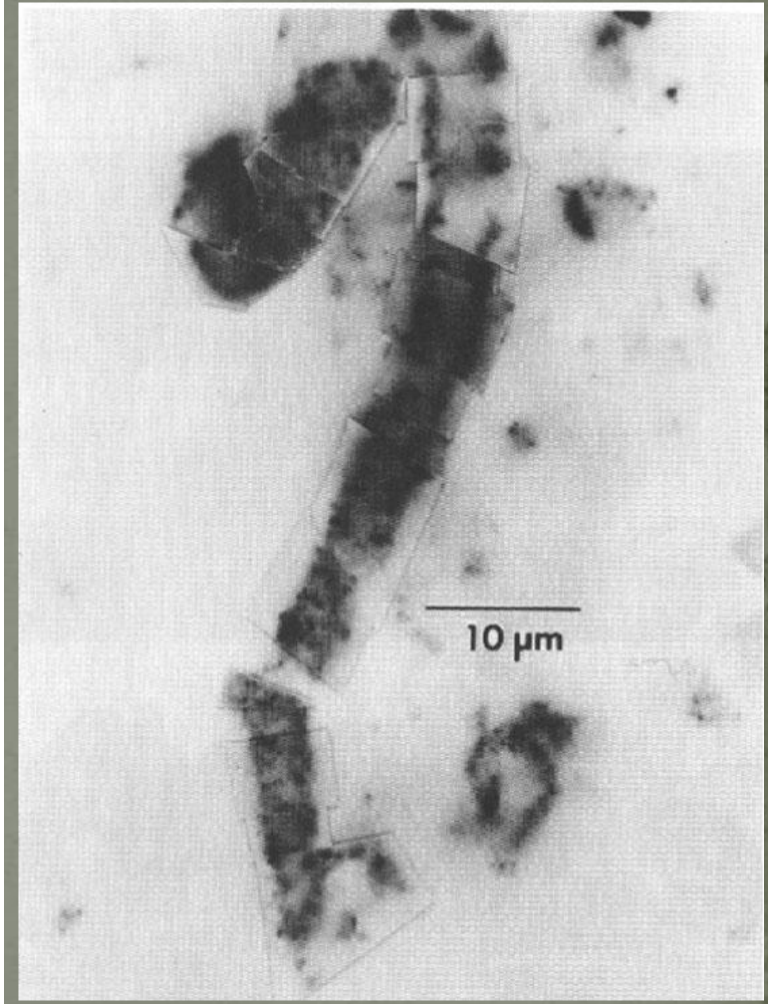
- 3700 my
- Isua supracrustal belt, Greenland, metacarbonate rocks
- Contain stromatolites 1–4-cm thick, laminar structures from microbial organisms (Cyanobacteria).
- They developed in shallow marine environments, as shown by rare earths and crossbedded layers and clastic breccia due to intense waves

Nutman *et al*. 2016



Nutman *et al.* 2016

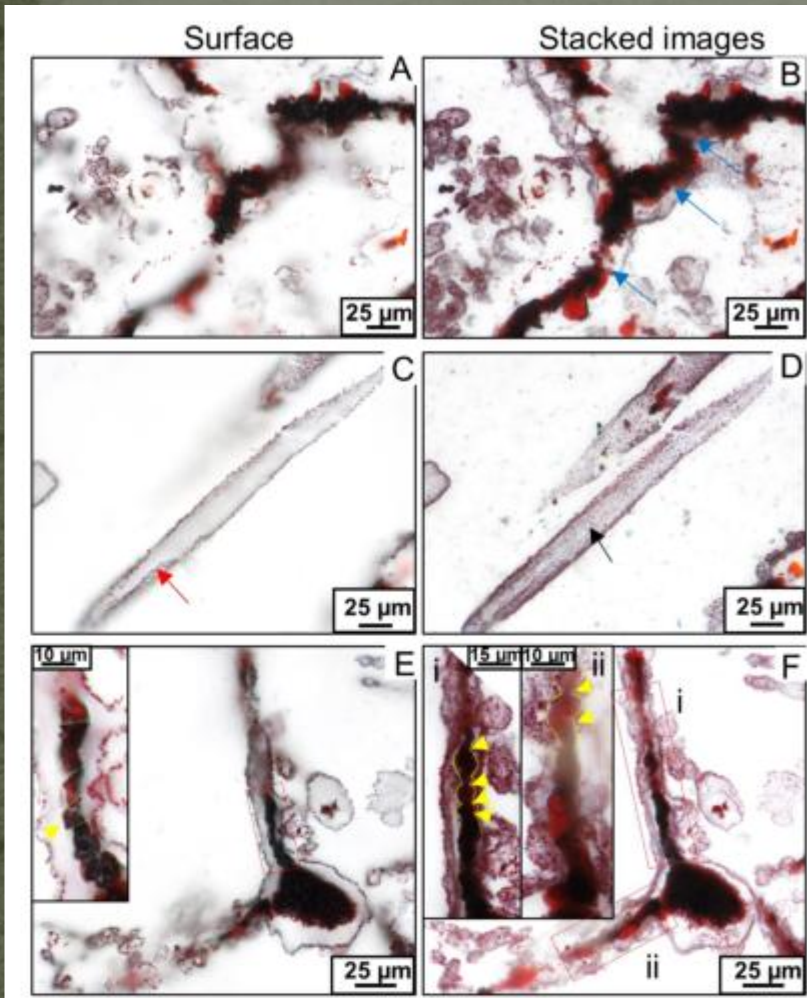

A
B
C
D
E
F

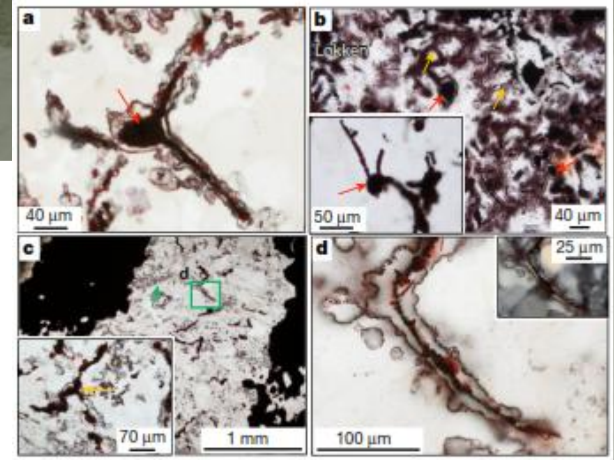

10 µm

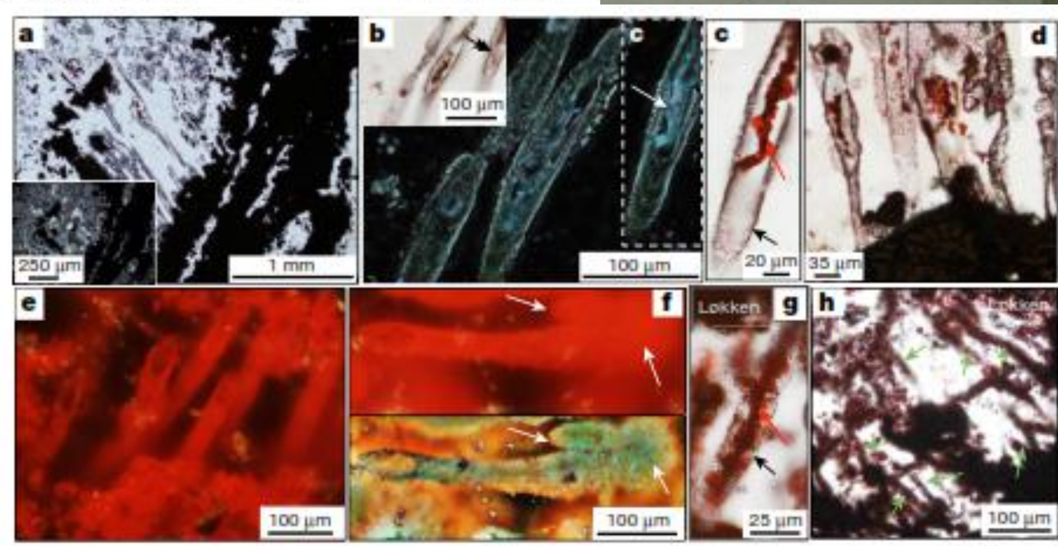
The oldest microfossils

- At least 3770 my (possibly 4040!!!)
- Nuvvuagittuq belt, Quebec, ferrous sedimentary rocks
- Tube like and laminae structures of a few micrometers made of hematite.
- Morphologies and mineral concentrations similar to lamellar microorganisms currently living in smokers (hydrothermal vents) and are similar with microfossils from younger rocks. They were interpreted as deposits formed on ocean bottoms around smokers. Oxidized remains of organisms

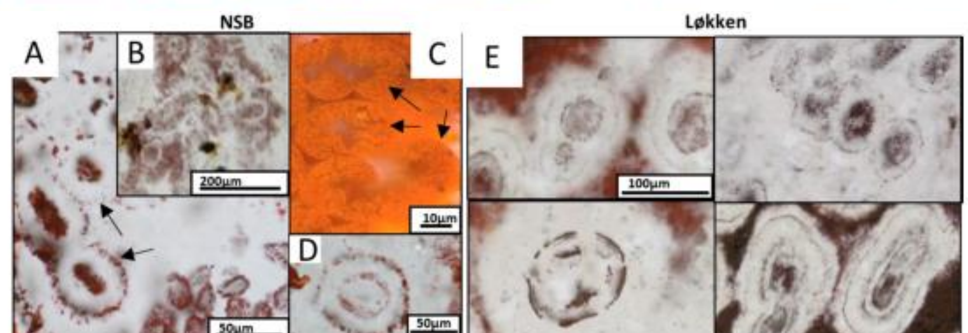
Dodd et al. 2017







Dodd et al. 2017



Extended Data Figure 7 | Transmitted light and reflected light images of haematite rosettes. a–d, From NSB; **e,** from Løkken jaspers. **a,** Large (60 µm) haematite rosettes (arrows) with cores. **b,** Haematite rosettes in dense haematite. **c,** Deformed, thicker-walled (25 µm) haematite rosettes (arrows). **d,** Concentric haematite rosette. **e,** Haematite rosettes from Løkken jaspers, same scale bar for all.

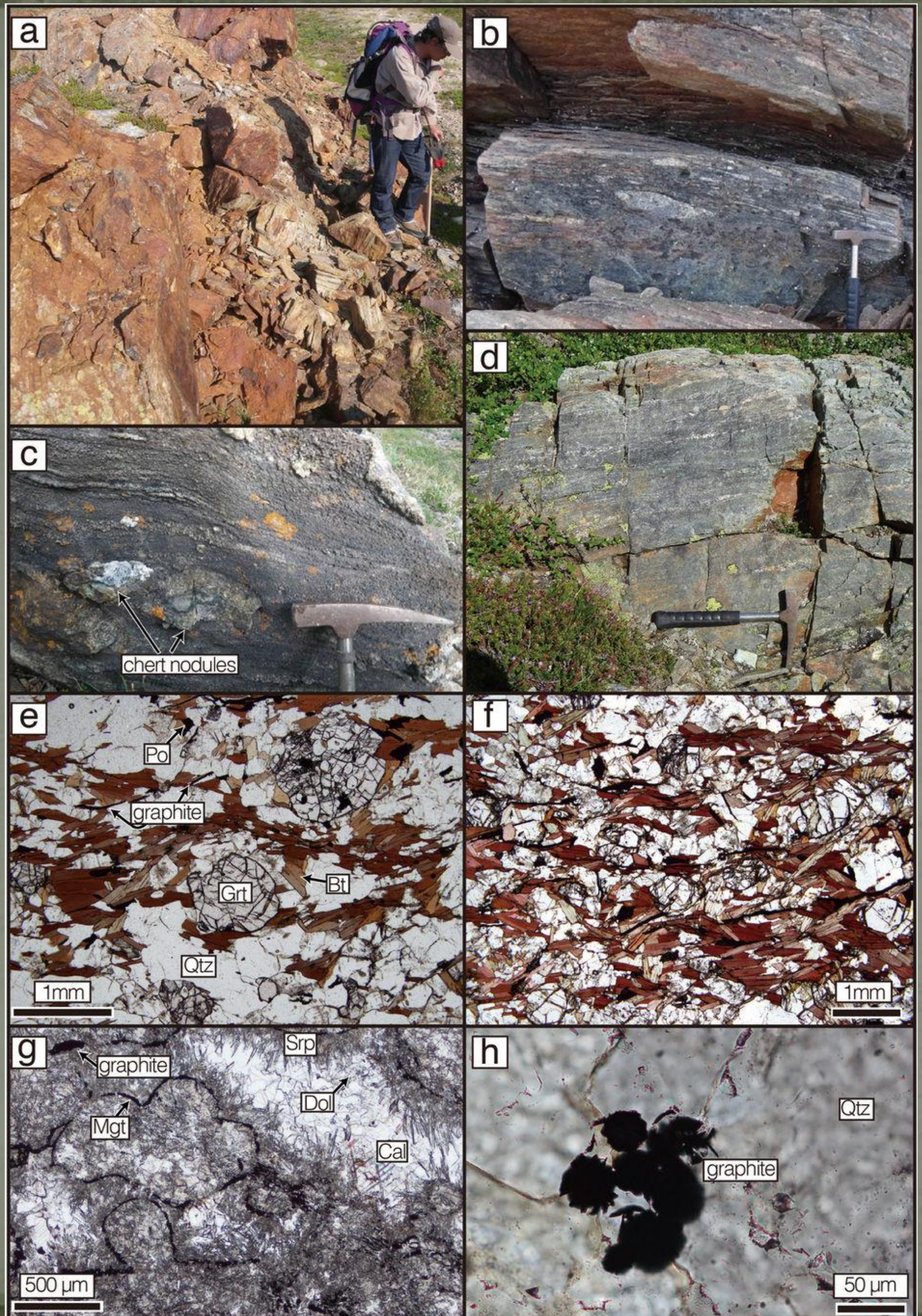
Oldest chemical fossils

- 3860 my
- Isua supracrustal belt, Greenland, metacarbonate rocks
- Two carvon isotopes ^{12}C and ^{13}C
- ^{12}C content relatively higher than ^{13}C in these rocks
- This enrichment is observed during photosynthesis
- So not only life but also photosynthesis

Oldest chemical fossils

- 3950 my
- Uivak Gneiss in Saglek Block, B. Labrantor Canada, metasedimentary rocks
- ^{12}C content relatively higher than ^{13}C in these rocks, comparable to younger rocks
- Discovery of authigenic biogenic graphite
- With the new evidence the first life on earth with certainty before 4 billion years

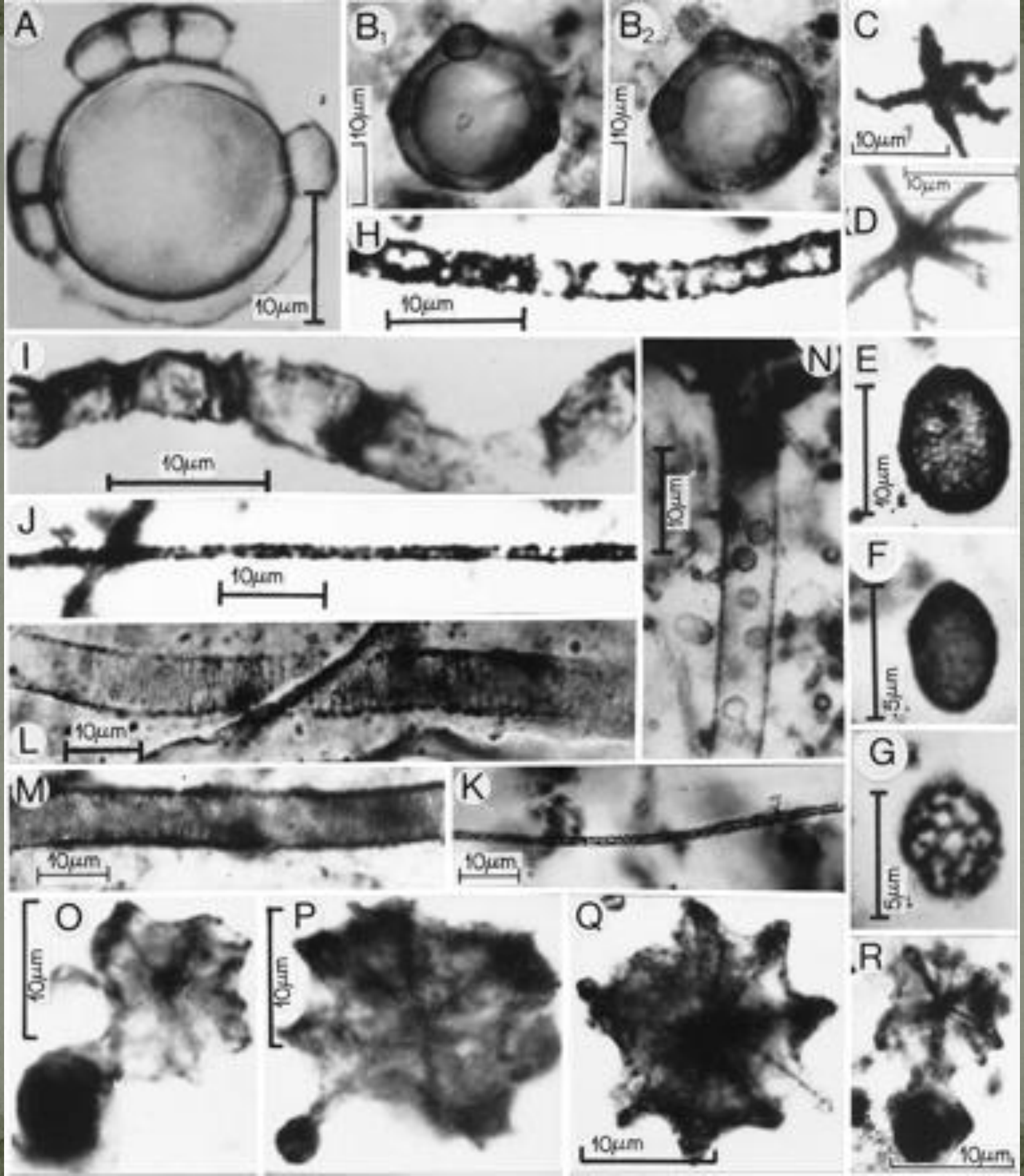
Tashiro et al., 28/9/2017



Tashiro et al., 28/9/2017

The first eukaryotic organisms

- Some of the first eukaryotic organisms were unicellular phytoplanktonics (acritarchs), protists and algae.
- The fossil record suggests that the photosynthetic line formed the main Proterozoic Eukaryotic organisms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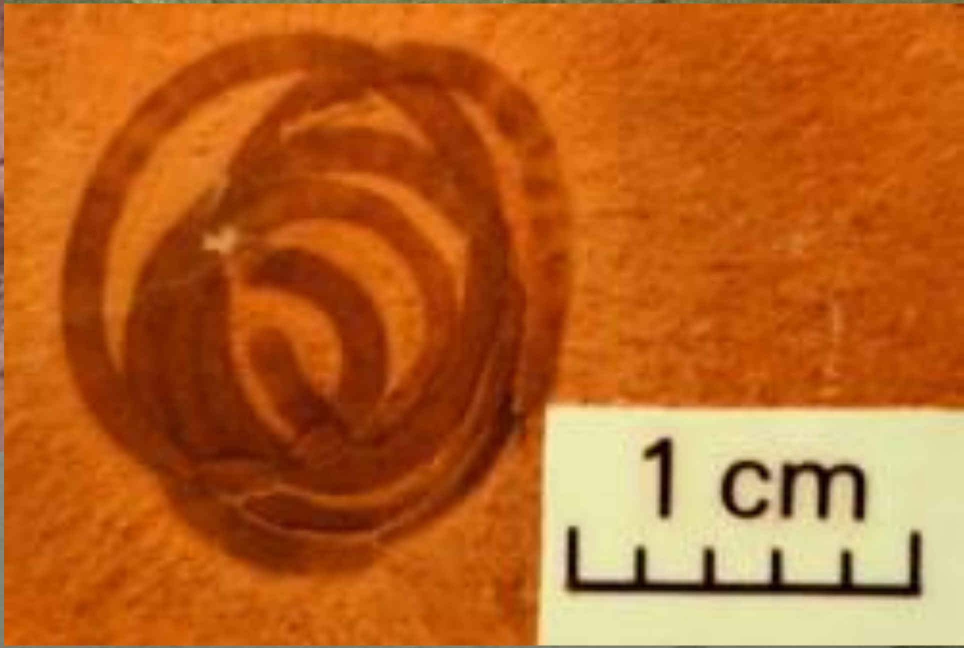
F
15µm
G
5µm
M
10µm
K
10µm
O
10µm
P
10µm
Q
10µm
R
10µm

acritarchs

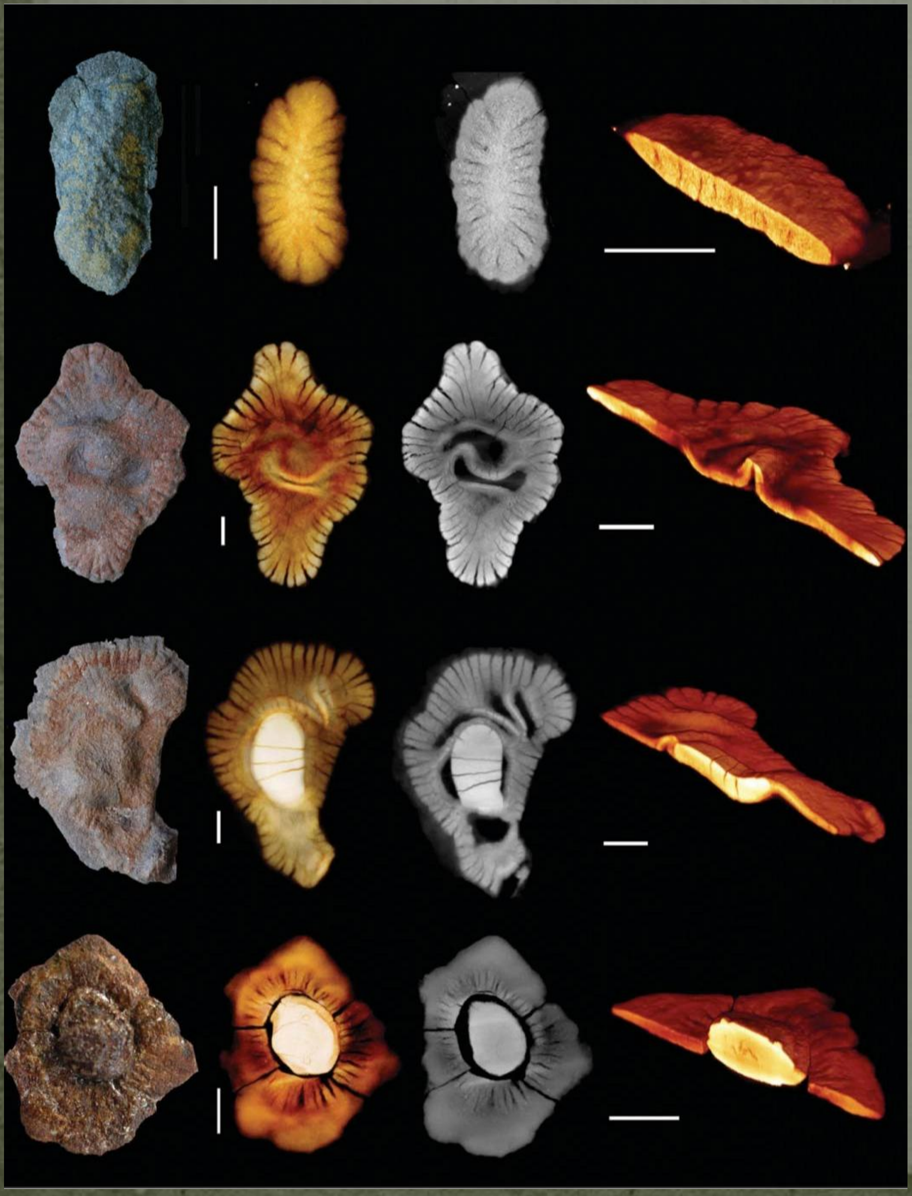
Grypania

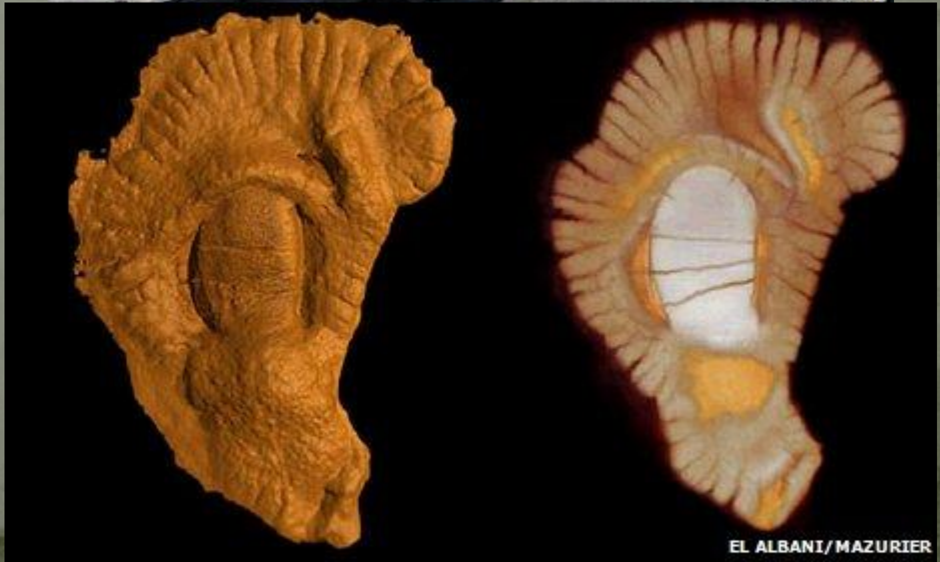
- There is little evidence for multicellular organisms
- Probably the first multicellular organism was Grypania that looked like a ribbon and was found in 2.1 billion year old carbonate rocks from Michigan
- Similar samples in China, India, Canada.
- The Grypania ribbons are 2 mm wide, 5-15 cm long, preserved in loose rotations with a diameter of 0.5 - 2.5 cm.
- Cellular structures were not retained.
- Due to size, shape, and preservation probably a multicellular eukaryotic alga.

Grypania



Multicellular organisms, 2,1by, Gabon





Endosymbiosis

- Bilion years ago, several prokaryotic cells were found living together symbiotically within a cell for protection and adaptation from an oxygenated environment.
- These prokaryotic cells became organelles.
- Evidence of this is also the fact that mitochondria have their own DNA.

- Eg. - a host cell (anaerobic fermenting bacterium) + aerobic organelle (mitochondrium) + plus organelle such as spirochaetis (a whip for locomotion).

Proterozoic macrofossils

- After Grypania the oldest macrofossils, carbonate imprints of the spherical Chuaria, the elongated Tawuia and the bell-shaped Longfengshania
- Global expansion in Proterozoic sediments
- Significant exposures in Canada and China
- From 1000-700 my ago
- Probably primitive pre-Ediacaran metazoa

Chuaria

Tawuia

The first Metazoa

- Multicellular animals with various types of cells organized into tissues and organs.
- The first of these metazoa first appeared in the Neoproterozoic, about 630 million years (at the end of Varangian glacial). They were preserved as imprints of organisms with soft parts in sandstone.

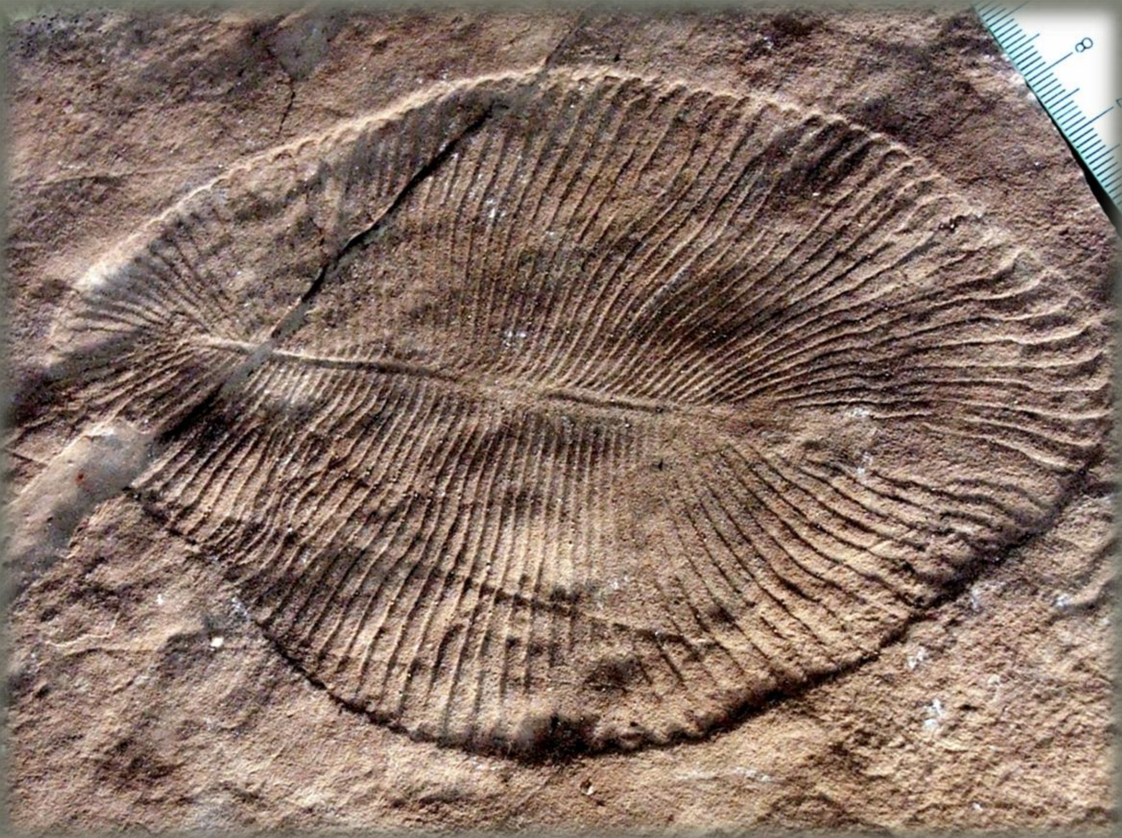
Typical Metazoan faunas of the Proterozoic

- **Ediacara Fauna** – The first imprints of animals with soft parts were found from Sprigg on the Ediacara Hills in South Australia in the 1940s.
- Eggs and Metazoan Embryos in Doushantuo Upper Neoproterozoic Formation in South China.
- Tracefossils of digging metazoa in rocks younger than the Varangian glacial period.
- Animal fauna with tiny shells

Ediacara Fauna

- The first with the characteristic Ediacaran body type and simple tracefossils appear at the end of the Proterozoic (590-550 million years).
- Today, such animals are known from more than 20 localities around the world (Russia, England, Namibia, Canada)
  Stratigraphically, they are located over rocks with traces of the Varangian glaciers and below the base of the Cabrian.
- The first evolutionary radiation of multicellular animals.
- Some were probably ancestral forms of Palaeozoic invertebrates.
- The oldest were found in China. Typical forms with high structural level Dickinsonia, Spriggina and Tribrachidium

Dickinsonia costata



Cyclomedusa

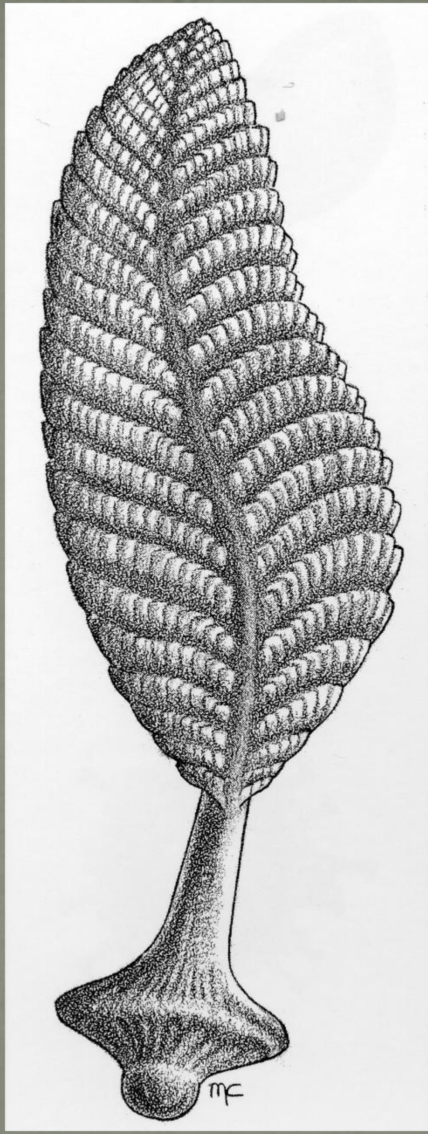
Spriggina flounensi

Ediacara Fauna

- The creatures of the fauna do not look like anything that lives today, so it was proposed to be placed in a separate taxonomic group or on a new Phyllum. The proposed name is Vendoza (from Ventian the uppermost Neoproterozoic).

Ediacara Fauna

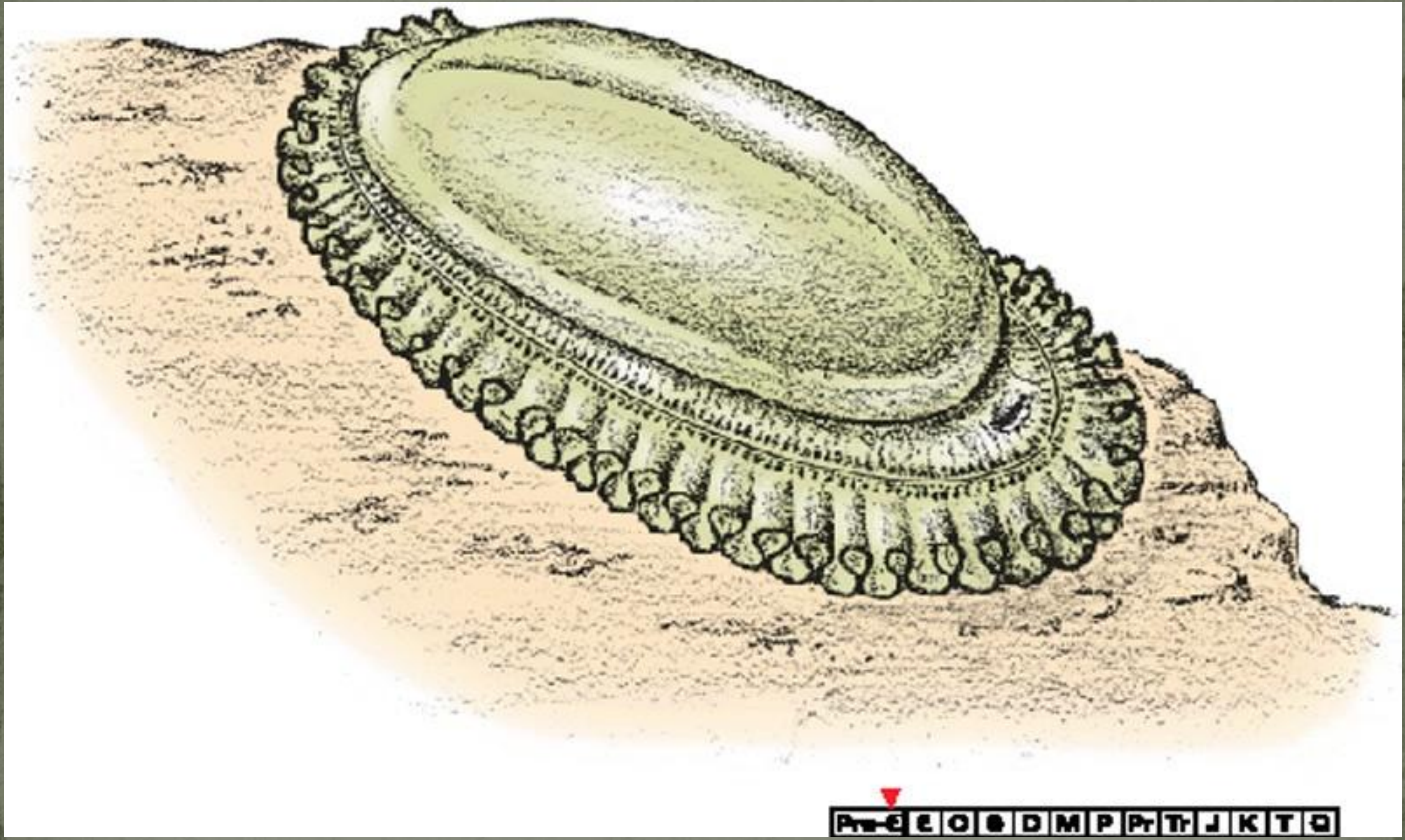
- Organism size from 1cm to 1m
- Good preservation of molds due to the absence of scavengers and lack of bioturbation.
- The majority of primitive Cnidarias(jellyfish, hydrozoa), worms, arthropods and other problematic.
- New forms different from any known animal.
- Many species are associated with modern Cnidaria such as the hydrozoa (Charnia, Charniodiscus), and other problematic (the enigmatic Tribrachidium)
- Recent findings show the existence of animals that resembled arthropods (Parvancorina).



Charnia

Soft corals and jellyfish

Parvancorina, arthropod

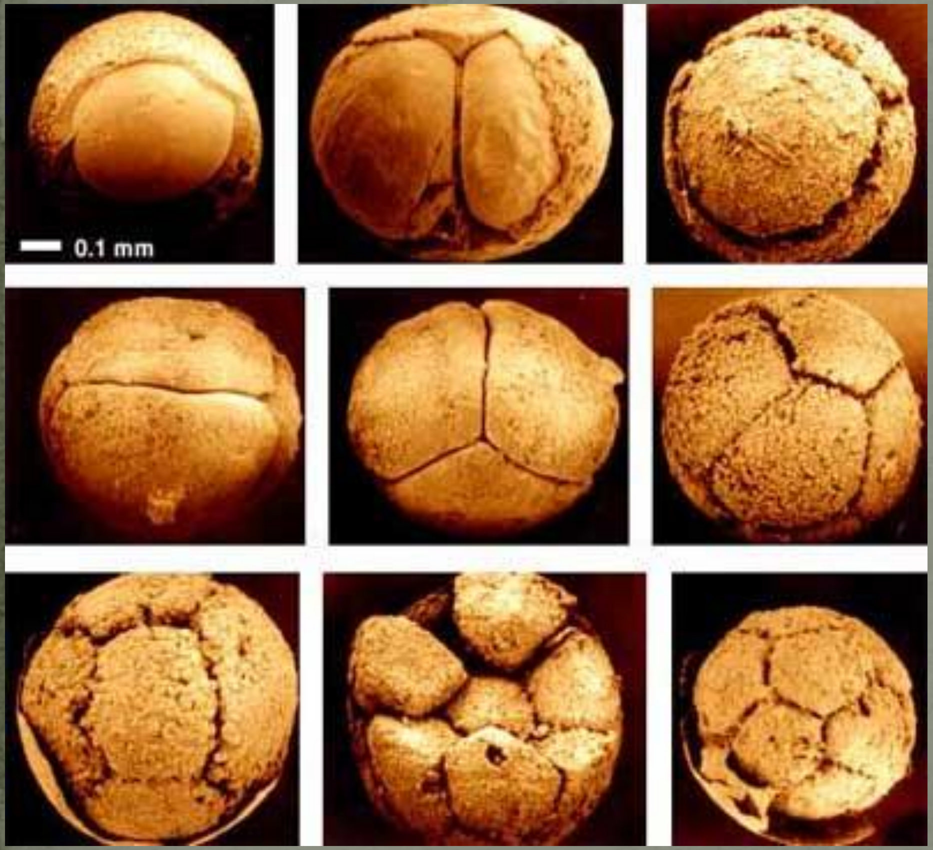


***Kimberella*,**

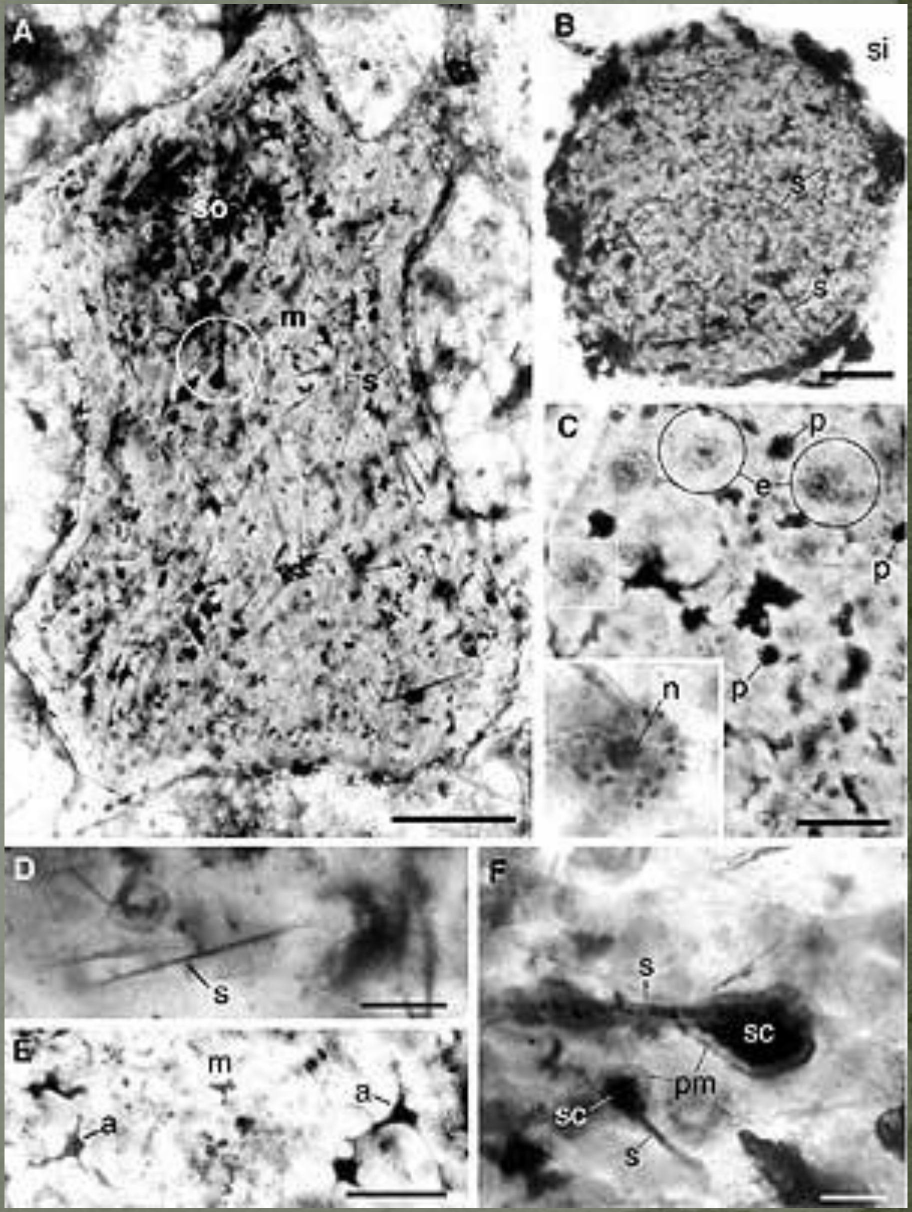
Cyclomedusa, gellyfish, Αυστραλία

Ediacara Fauna

Doushantuo in S. China



Metazoan embryos

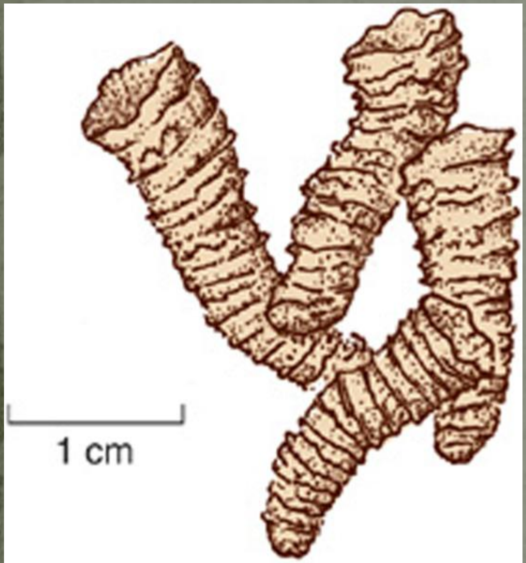


Σπόγγοι

Animal fauna with tiny shells: The first hard skeletal parts

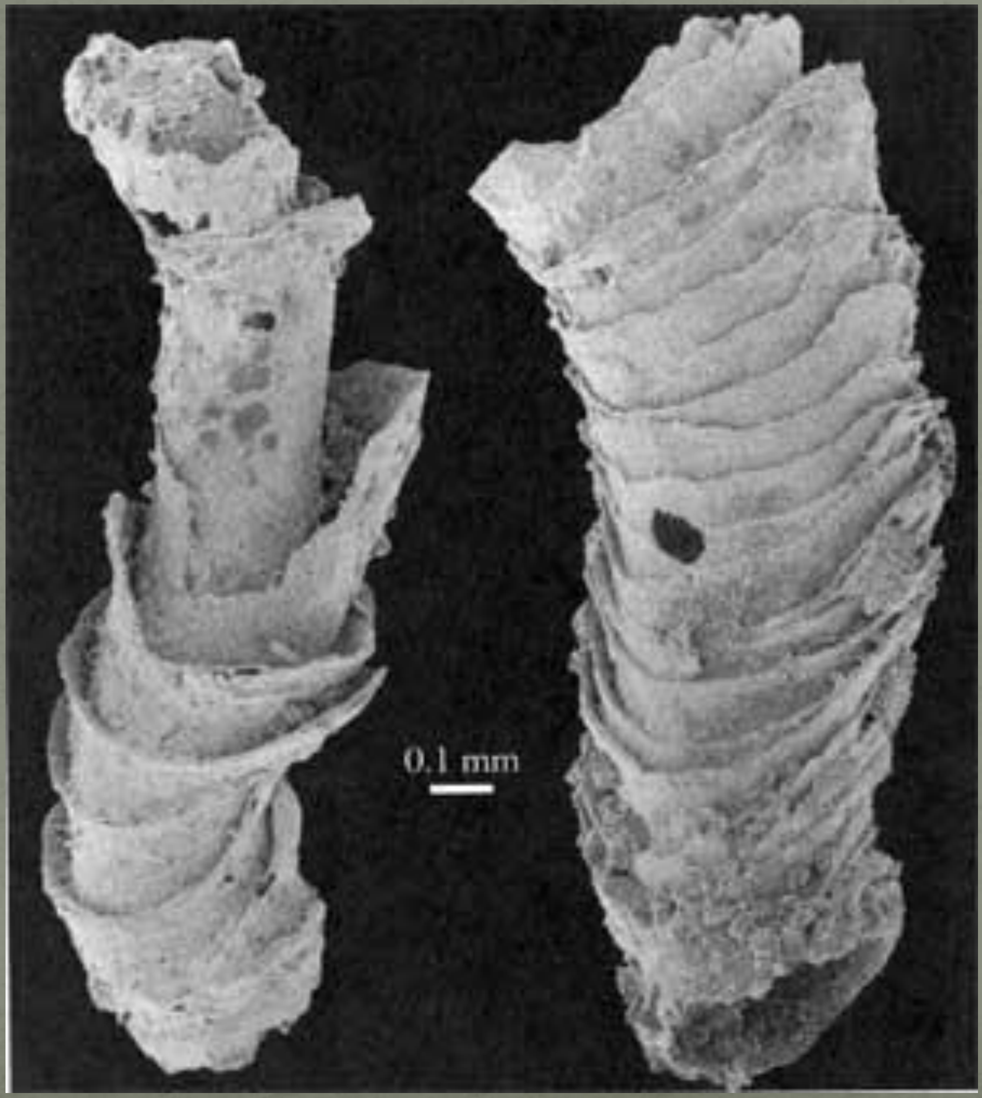
The first fossils with hard parts or shells appear in the Upper Neoproterozoic

Cloudina the first fossil with hard parts



Cloudina, an organism with a small tubular shell made of calcium carbonate ($CaCO_3$).
It resembles the structures made by the anelides living in tubes.
The first organism with a $CaCO_3$ shell.
Found in Namibia, Africa.

Cloudina the first fossil with hard parts



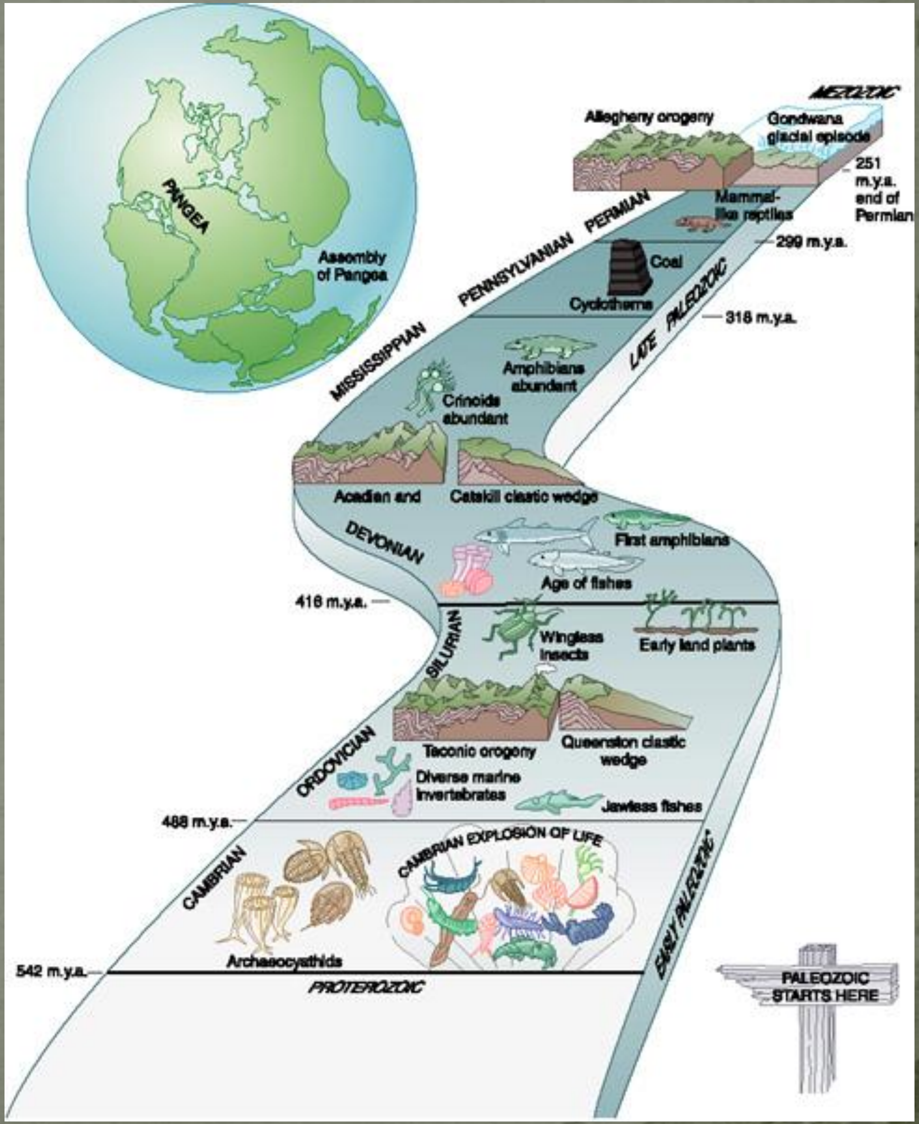
***Cloudina* από το Νεοπροτεροζωικό της Κίνας**

Palaeozoic Era

- The Palaeozoic Era is divided into:
  Lower Palaeozoic = Cambrian, Ordovician and Silurian
  Upper Palaeozoic = Devonian, Carboniferous, Permian

Palaeozoic Era

It is characterized by long periods of sedimentation interrupted by orogenetic events



- During the Palaeozoic era two orogenetic events occurred:
  Kalidonian (Europe), Takonian, Akadian

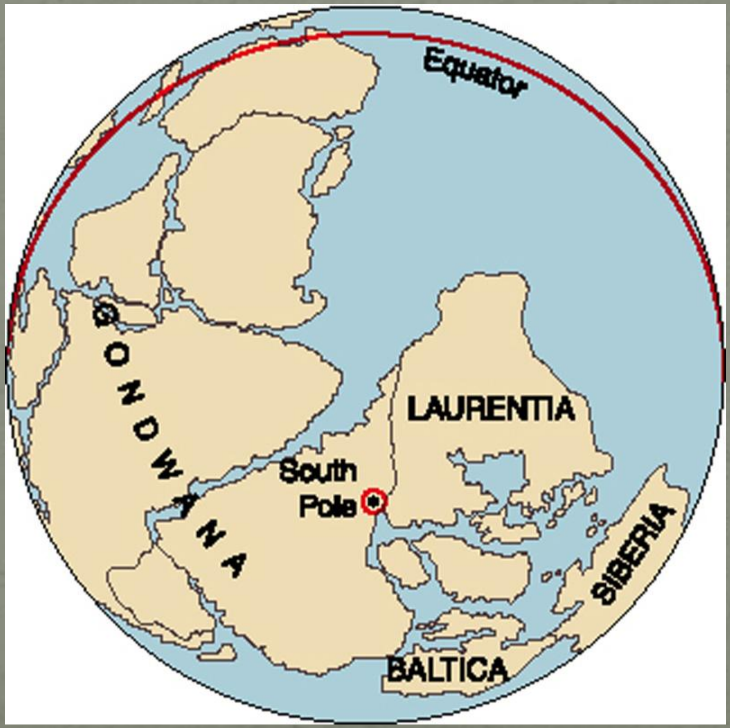
  Hercinian or Variscan (Europe), Alleganian

Palaeoclimate

- Palaeoclimatic elements are obtained from sedimentary environmentally sensitive rocks (glacial deposits, carbon deposits, carbonate deposits, evaporites).
  In the lower Palaeozoic the climate was influenced by many factors:
  The earth turned faster and had smaller days.
  Tidal effect was stronger because the moon was closer to the earth.
  There were no terrestrial plants

At the end of the Proterozoic

- Shortly before the Palaeozoic began, Rodinia was divided into six large and several smaller continents. Their location around the South Pole

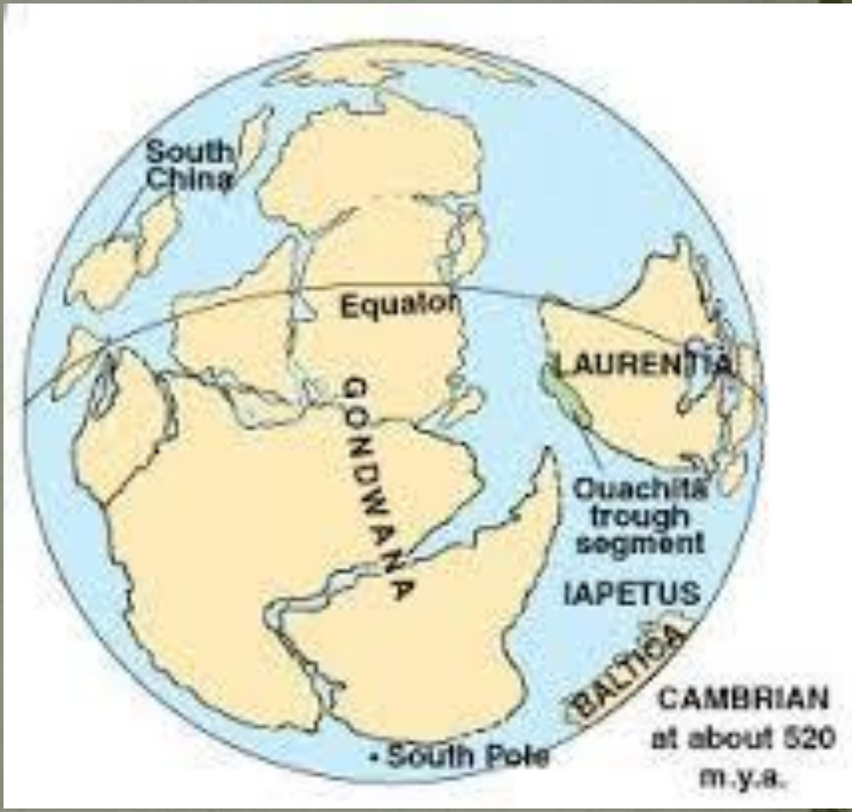


The continents

- Laurentia (North America, Greenland, Ireland and Scotland)
  Baltica (North Europe and Russia)
  Kazakhstania (between Caspian and China)
  Siberia (Russia and Mongolia)
  China (China and Indochina)
  Gondwana (Africa, South America, India, Australia, Antarctica)

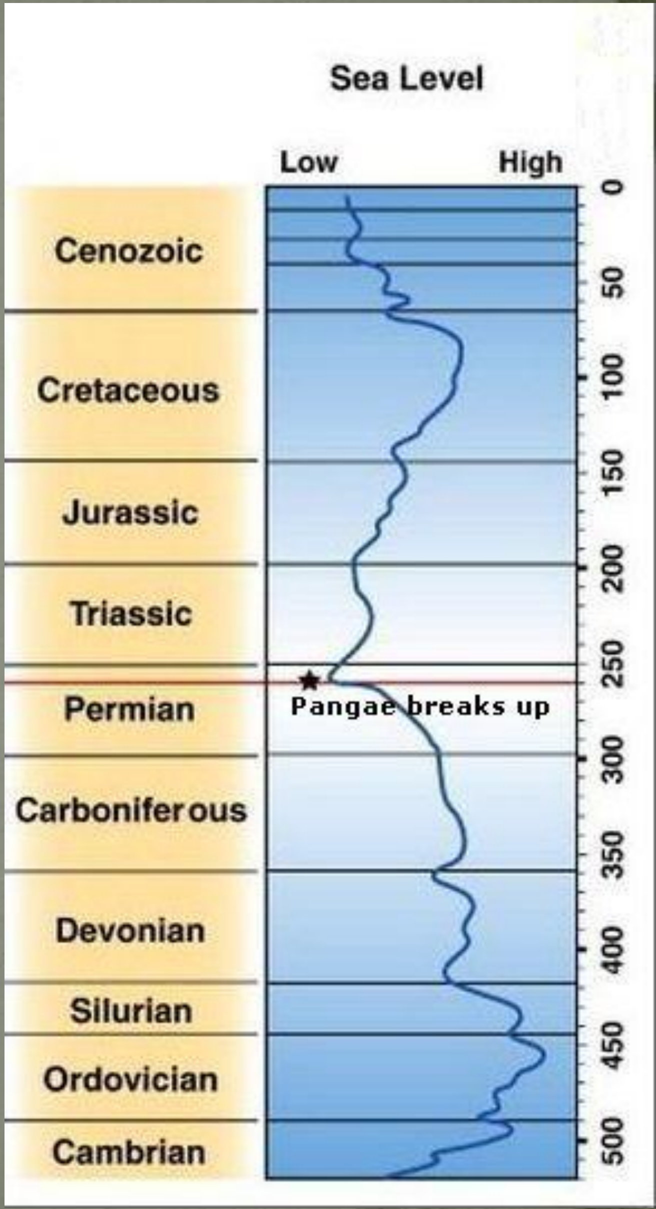
The movement of the continents

- In the Cabrian continents moved from the poles. Some of the continents are now around the Ecuator.
- The glaciers melted, the sea level raised and shallow continental seas were formed. Change in sea level was global.
- The continental seas were the areas where diversification of marine life took place.



Changes during the Phanerozoic Eon

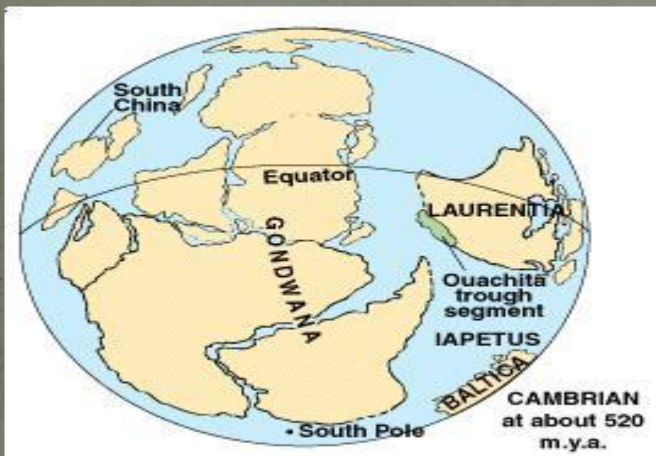
During the Phanerozoic significant world changes in the sea level took place

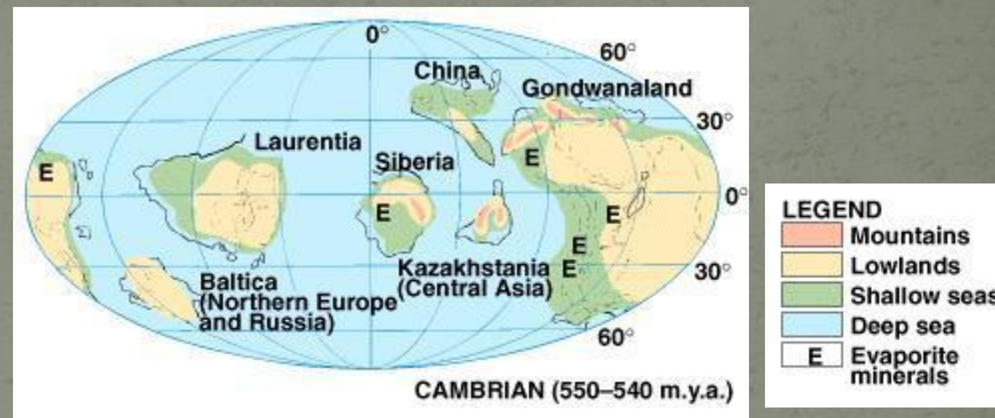


Cambrian (541-485 my)

- It is separated into:
- Georgian (lower)
- Akadian (middle)
- Potsdamian (upper)

Cambrian Palaeogeography

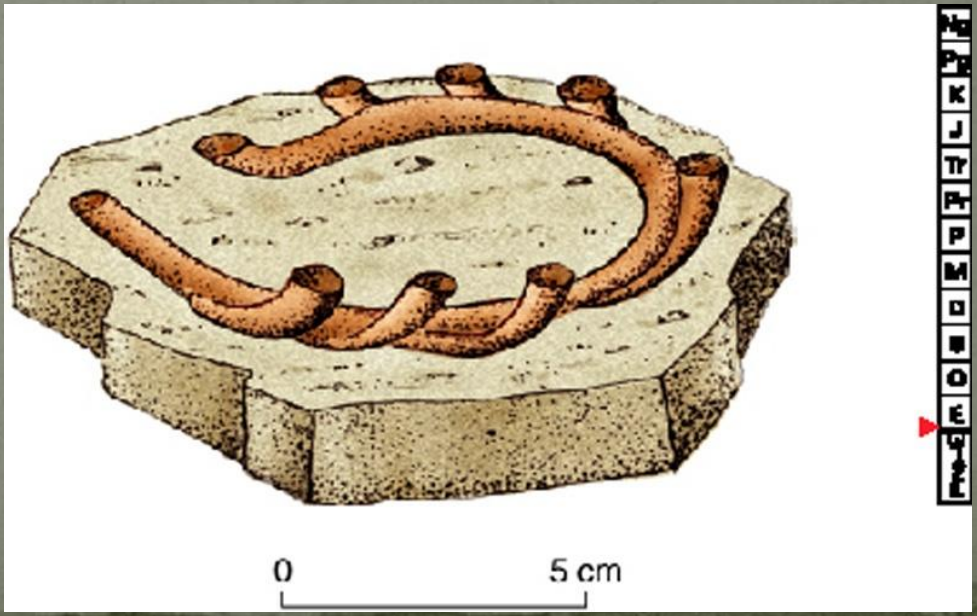




- No continents at the poles. All at the equator.
  Shallow seas cover many continents.
  Evaporites 30º B and N of Ecuator - where the deserts appear today.
  Iapetus ocean between Laurentia and Gondwava.

Early Cambrian

- The beginning of Cambrian is now placed at the first occurrence of the *Treptichnus pedum* tracefossil tunnels, dating back to 541 million years with Uranium-lead from rocks in Oman, coinciding with a chemical disorder known as the Negative Carbon Abnormality (^{13}C).



Cambrian deposits

- During the Cambrian, no terrestrial plants, bare land. Active and intense erosion (nothing to hold the soil).
- Sea regression and extensive deposits of quartz sand near the coastline.
- Carbonate deposits occurred in the shallow seas.

Ordovician (485-444 my)

Χωρίζεται σε:

- Tremadocian
- Arenigian
- Llanvirnian

lower

- Caradoc
- Ashgill

upper

Ordovician

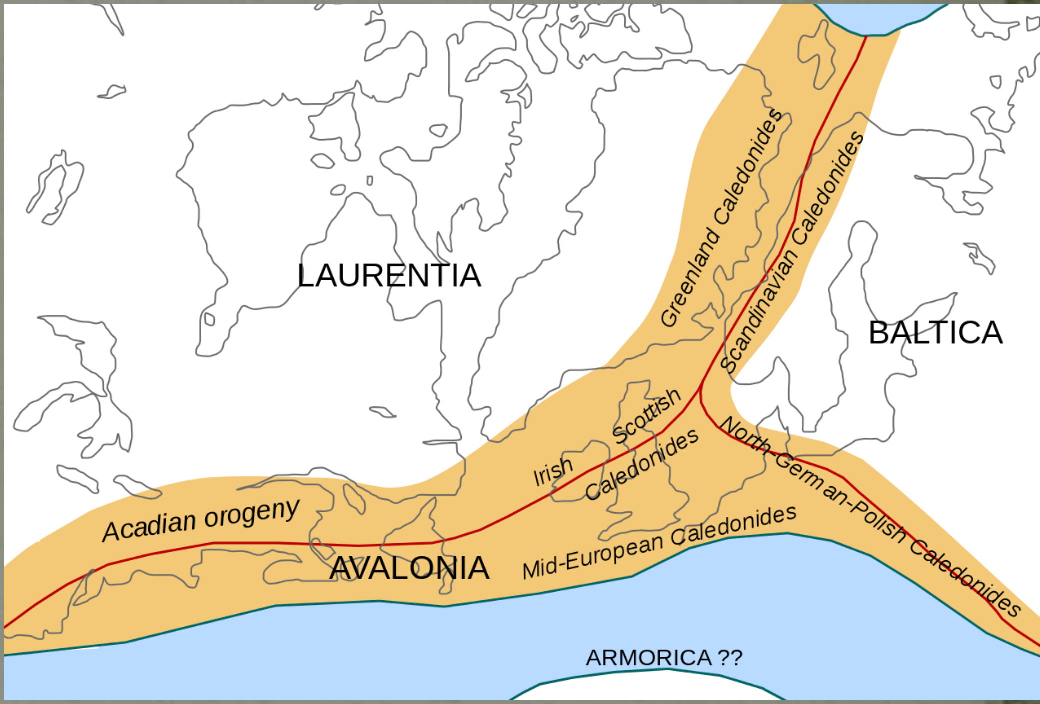
- The global sea level is high. Shallow seas cover large areas of the continents.

Ordovician deposits

- Carbonate deposits of shallow water dominate.
  The scene changes dramatically to the Middle Ordovician.
  Carbonate sedimentation ends.
  Probably because of the partial closure of Iapetus.

Ordovician Palaeogeography

The Calidonian orogenetic zone between Laurentia (North America) and the Baltic (Europe and W Russia) begins in Ordovician .
It reaches its climax shortly afterwards, in Upper Silourian – Lower Devonian.



The closure of Iapetus

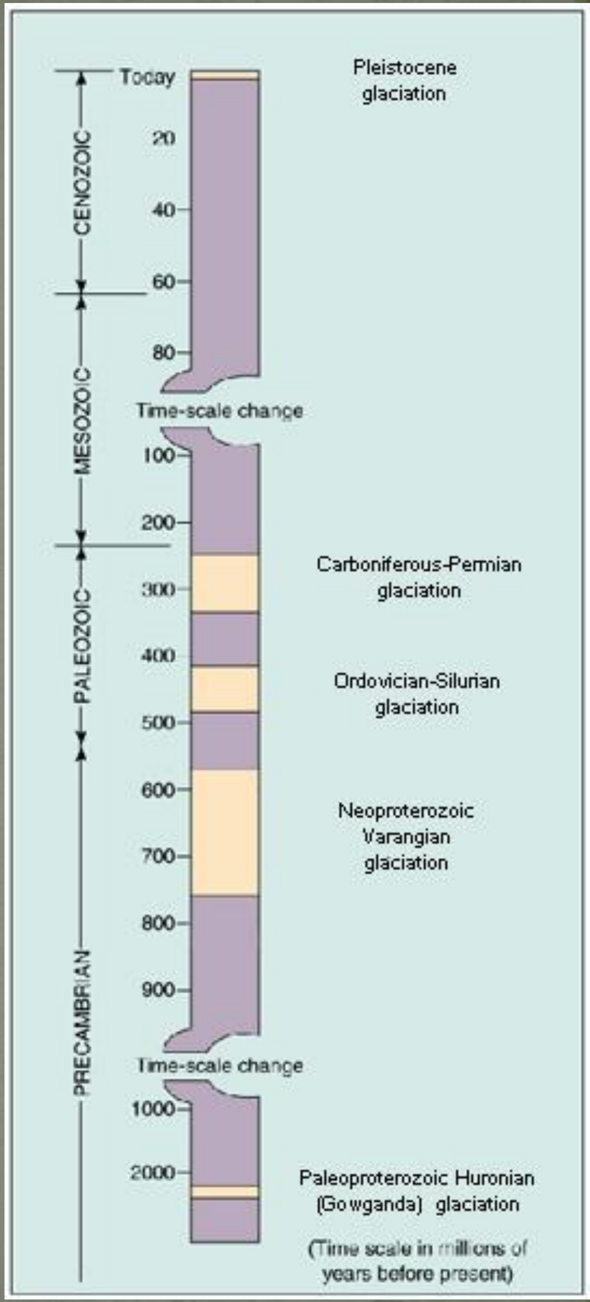
- Convergence of Laurentian - Baltic, formation of volcanic arc, orogenesis, etc.
  Creation of Calidonian Mountains (Scandinavia), Highlands (Scotland), Apalachians (Taconic orogeny North America). 480 - 460 my.

Ordovician glaciers

- In the middle of Ordovician , Gondwana moved to S. Pole, so that at the end of the Ordovician it was covered by glaciers.
  Glacial deposits are now found in NW Africa that show that this area was in the area of S. Pole.

Ordovician glaciers

The sea level was shrinking during Ordovician , and dropped sharply at the end of the Ordovician , coinciding with the glacial period.



Silurian (444-419 my)

- Llandovery
- Wenlock
- Ludlow
- Přídolí

lower

upper

Ordovician - Silurian Palaeogeography

- Laurentia remains at the equator
  Iapetus ocean closes
  Gondwana moves to S. Pole

- The sea level in Silurian was high, due to the melting of the glaciers of the Ordovician.
  The second great regresion of the Paleozoic.

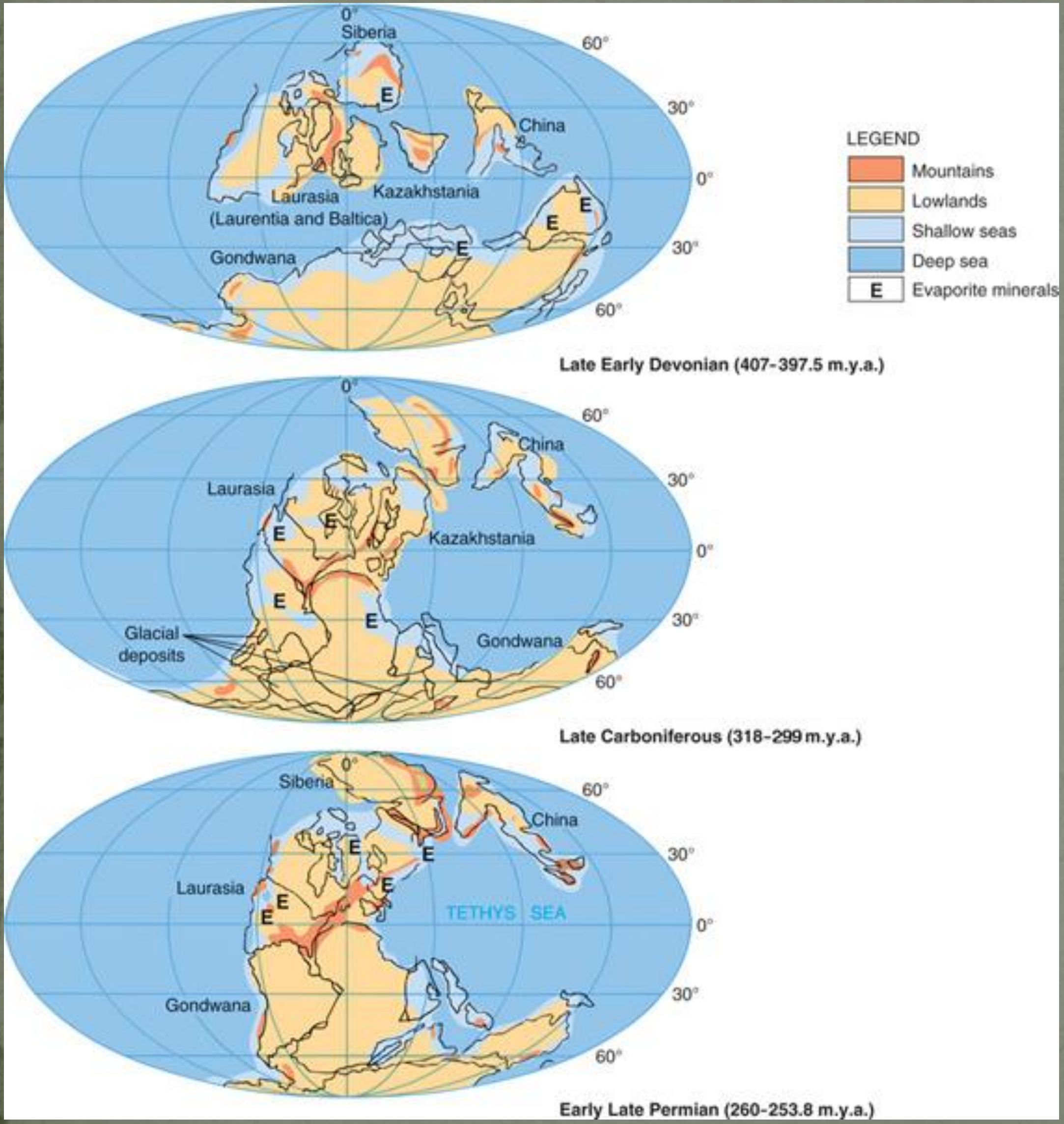
Silurian seas

- In the middle of the Silurian, shallow seas seem to have covered most of the continents than ever before.
- The continental seas were withdrawn towards the end of the Silurian.

Silurian orogenesis

- Caledonian orogeny was more pronounced in Norway as Iapetus closed.
  The folded Caledonian rocks end in Ireland but can also be found in Greenland and Canada.

Upper Palaeozoic



- The supercontinent Pangaea is formed by the collision of the then continents. Gradually the continents grew up with the addition of new tracks. Plants set on the land.

Pangaea


Eurasia
North America
Africa
South America
India
Antarctica
Australia

Upper Palaeozoic orogenies

- Acadian and Caledonian orogenesis
  It is completed in the middle Devonian.
  Laurentia and the Baltic form Laurasia.
  At the end of Palaeozoic we have the Alleganian orogeny in North America and the Hercynian in Central Europe.
  Upper Carboniferous
  Both Gondwana and Laurasia collide.

Devonian (419-359 my)

- Lochkovian
- Pragian
- Emsian

lower

- Eifelian
- Givetian

middle

- Frasnian
- Famennian

upper

Devonian palaeogeography

- In the N. hemisphere the continents were broken, while in the south Gondwana was near or on the S. pole.
  The sea level was high.
  Extensive deposits of sedimentary rocks are observed

Devonian deposits

- Extensive deposits of clay shale, limestone with coral deposited on sands.
  In areas with reduced water circulation, deposits of evaporites.
  Reefs and carbonate sediments indicate a warm climate.
  Evaporates show dry conditions.
  Red layers of Devonian age are observed everywhere.
  Old Red Sandstone is known in Europe.
  Red color shows deposition under oxidation conditions in land or non-marine environments.

Carboniferous (359-299 my)

- Tournaisian
- Visean
- Namurian
- Westphalian
- Stephanian

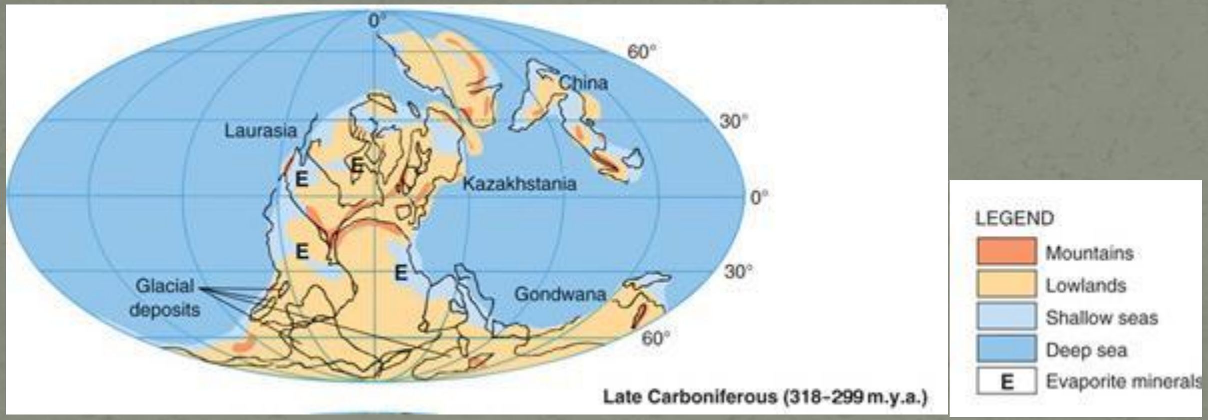
lower

upper

Carboniferous sediments

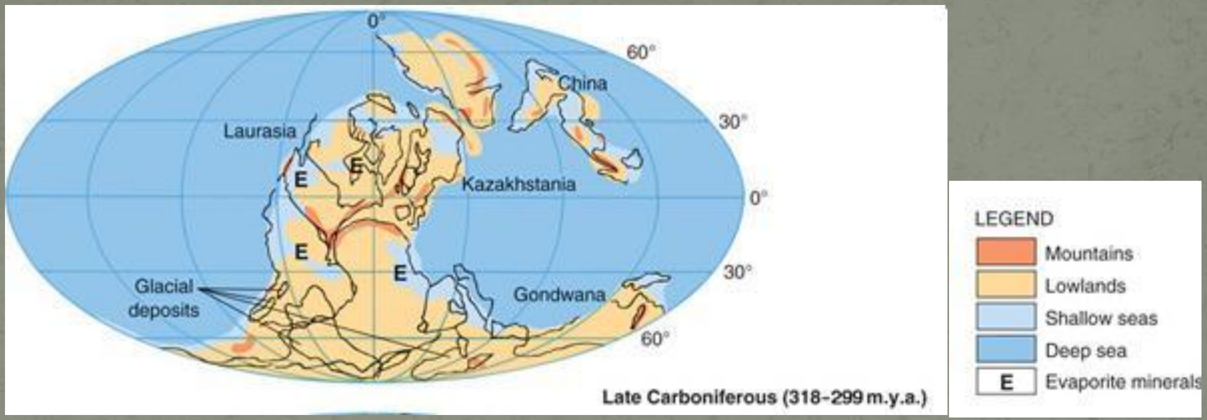
- Sands, clays, limestones rich in crinoids, blastoids, bryophytes, fusulinids.
  Evaporates due to dry climatic conditions.
  Formation of deposits of oil and coal.

Pangaea



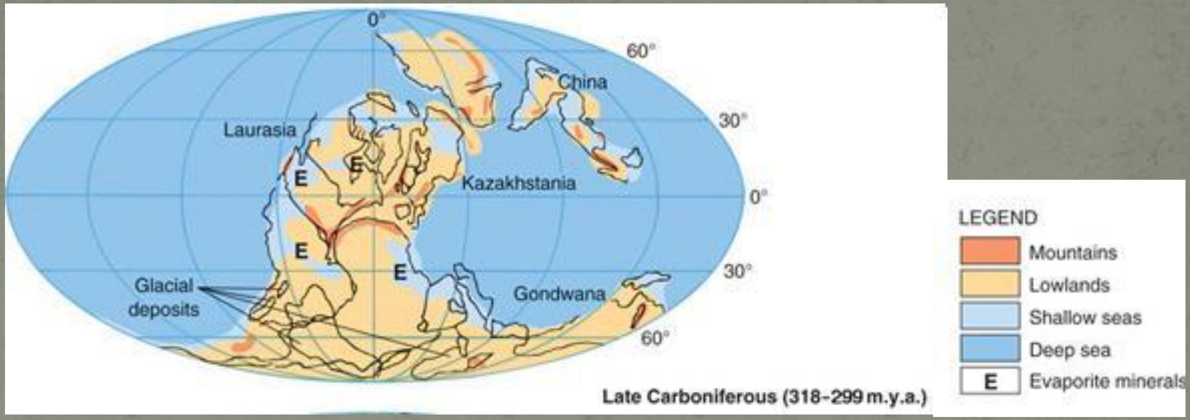
- At the end of the Carboniferous, the enormous overpass, Pangaea, was created from the collision between Laurasia and Gondwana.

Pangaea at the S. Pole



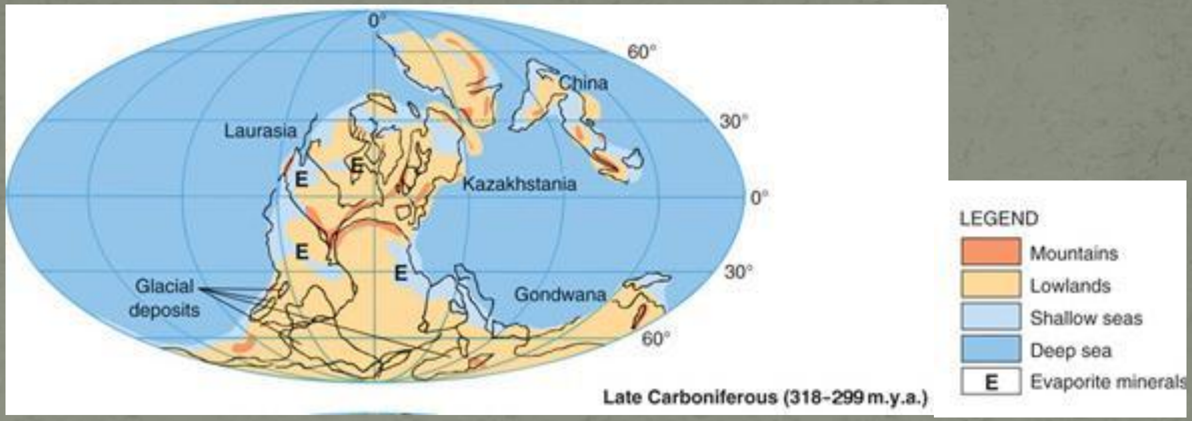
- A large part of Pangaea occupied a position above S. Pole. As a result we had the creation and coverage of glaciers. And so;

Iapetus closed



- The Iapetus Ocean (Proto-Atlantic) closed completely at the end of the Carboniferous. Its closure has disturbed global ocean circulation and forced the currents to divert from the tropics to more polar regions, thus contributing to the creation of glaciers.

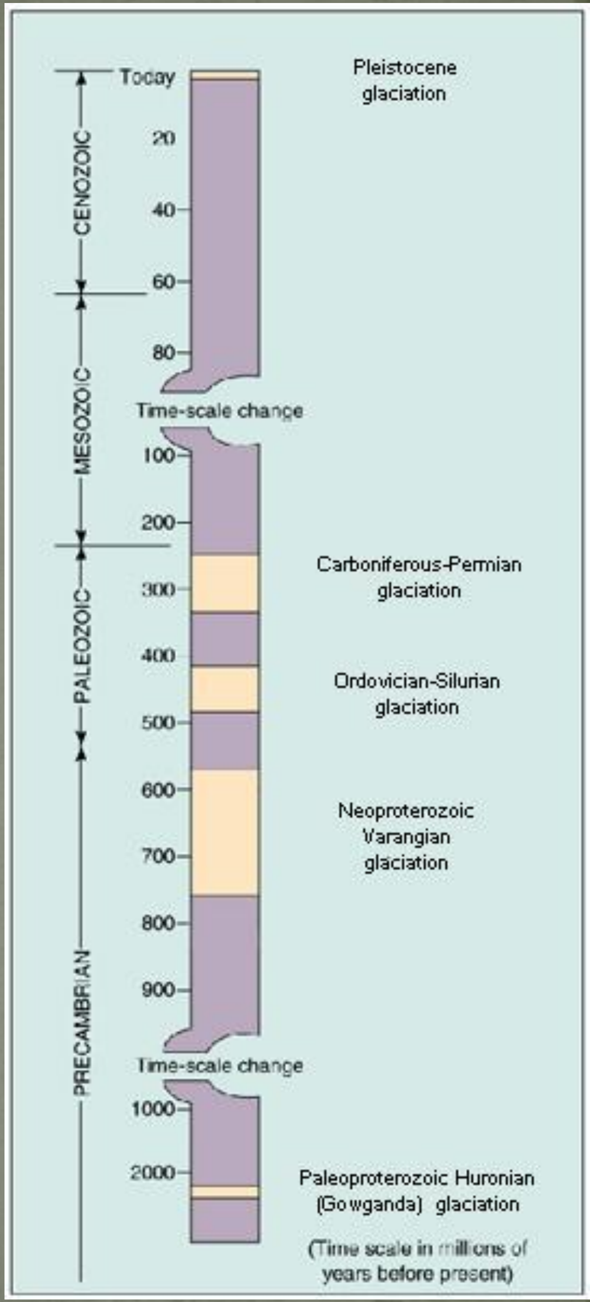
Evaporites



- Their presence (E) suggests that the climate in the upper Paleozoic, at least locally, was dry. Probably this was due to the changes made in the global ocean and atmospheric circulation caused by the closure of Iapetus, as well as by orogeny.

Carboniferous – Permian glaciers

There are indications that at least 4 glacier propagations occurred during the Carboniferous – Permian in Gondwana.



Marine and terrestrial deposits

- Continuous alternations of sea and continental deposits are observed:
  Either due to local subduction and uplift episodes, or
  Eustatic (global) sea level changes associated with
  Gondwana glaciers.

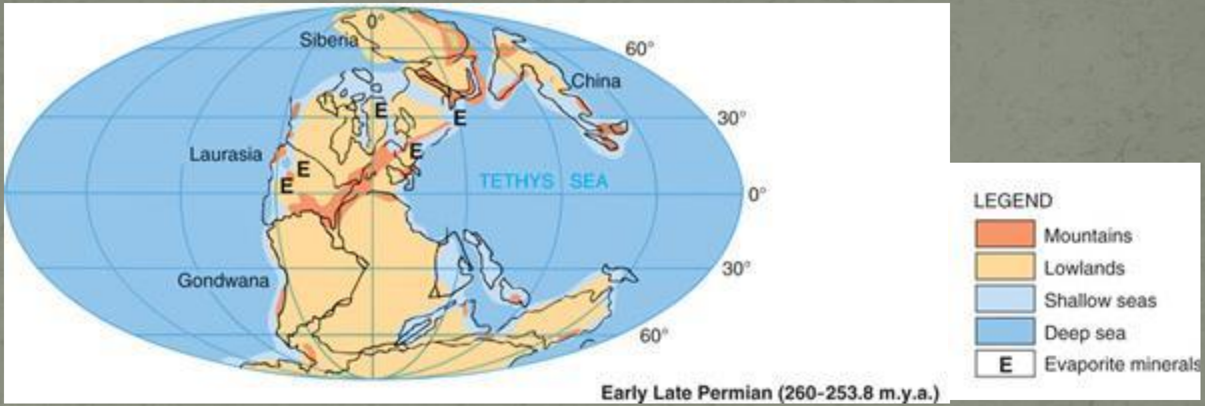
Coal and plant fossils

- The deposits of plant matter that have been carbonized mainly during the Carboniferous, but also during the Permian, have created extensive coal deposits in many regions of the world, as well as in Europe, which are mined and used even today. The industrial revolution in Northern Europe was based on these deposits.
  These natural rocks naturally contain innumerable plant fossils, pteridophytes, spermatophytes and gymnosperms.

Permian (299-252 my)

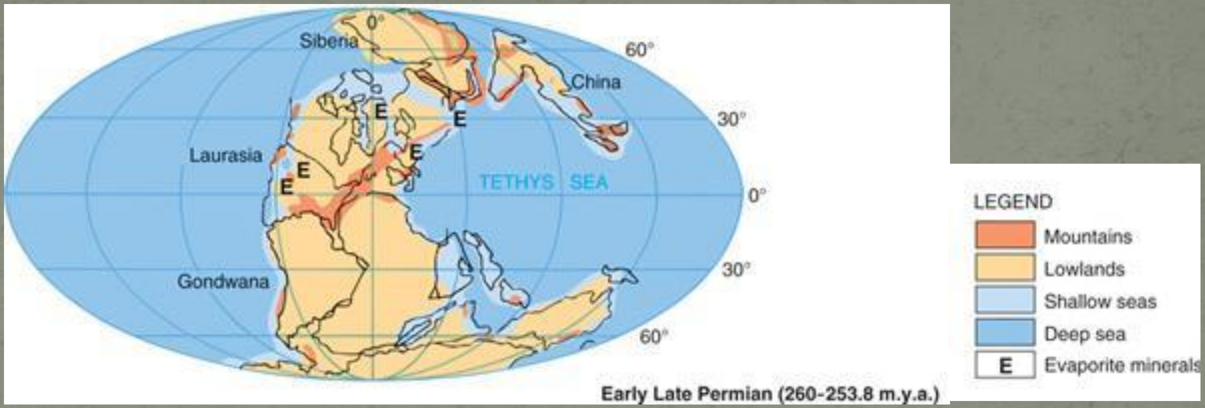
- Cisuralian
- Guadalupian
- Lopingian

Permian palaeogeography



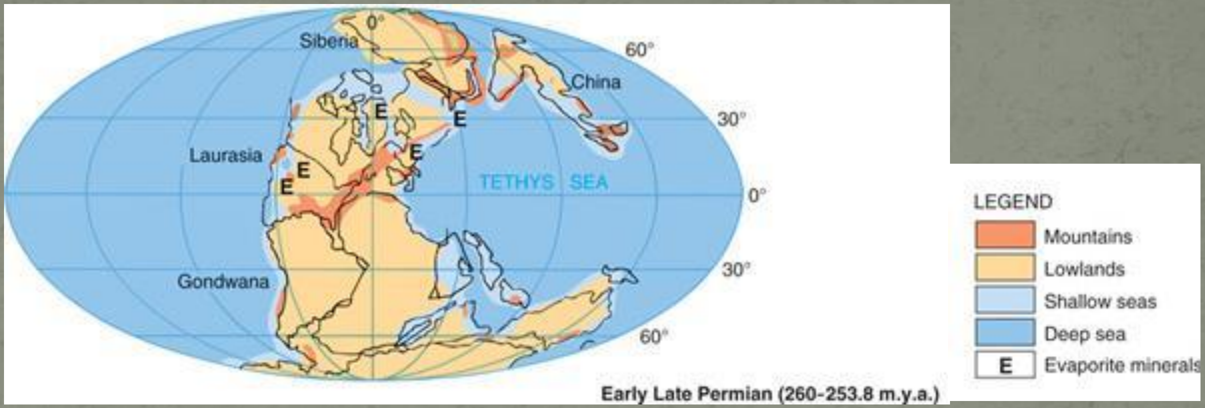
- During the Permian, there was only the supercontinent Pangaea.
  Pangaea was surrounded by a huge ocean called Panthalassa.
  In the east of Pangaea, the area between Gondwana and Laurasia (between today's Eurasia and Africa) was called the ocean of Tethys.

Permian palaeogeography



- The upper Permian was an era of extended sea transgression.
  The global map shows that the sea level was low everywhere.
  The vast continental seas that hitherto covered large continental regions were lost.

Permian palaeogeography



- The part of Pangaea that was Gondwana continued to be in S. Pole and the glaciers continued in Permian.

The end of the swamps

- Dry climates at low latitudes led to a reduction in the extent of the swamps in which plant matter was trapped and resulted in the disappearance of sporophytes and amphibians in need of humid conditions.
  Because of the dryness gymnosperms replaced many sporophytes that required humid conditions.

Orogenies and climate

- Orogenesis, with the creation of extensive mountainous ranges, affects the climate. Mountain locations affect the climate and control rainfall.