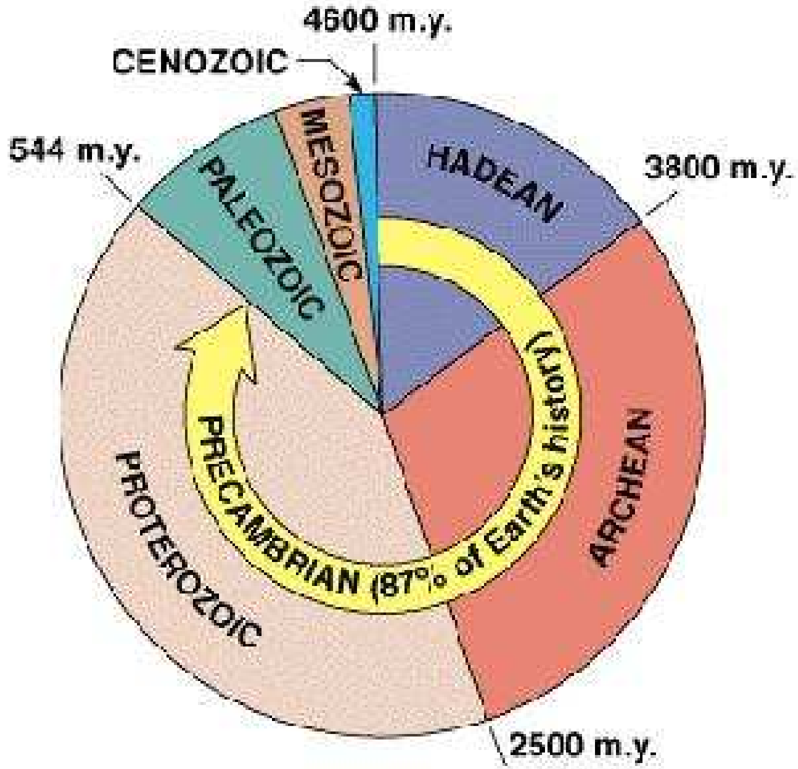
## TABLE 6–2 Time Divisions for the Precambrian

| Time in Billions of Years | Time Divisions Followed in This Book* | Events |
|---|---|---|
| | 0.54 | |
| | Late Proterozoic | Glaciation<br>Grenville orogeny |
| 1.0 | 1.0 | |
| | Middle Proterozoic | |
| 1.5 | | |
| | 1.6 | |
| 2.0 | Early Proterozoic | Red beds<br>Glaciation |
| 2.5 | 2.5 | Kenoran orogeny |
| | Late Archean | |
| 3.0 | 3.0 | Earliest BIF |
| | Middle Archean | |
| | 3.4 | |
| 3.5 | Early Archean | |
| | 3.8 | Origin of life |
| 4.0 | | Oldest sediments |
| | Hadean | Major outgassing<br>Development of internal structure |
| 4.5 | | Origin of Earth |
| | 4.6 | |

*As recommended by the International Union of Geological Sciences.




**The beginning of the Proterozoic Eon was marked by the appearance of the first continent-sized cratons and the beginning of a long-term rise in atmospheric oxygen. It ends with the widespread appearance of metazoan fossils. Currently, our coverage consists of an essay on the Cryogenian ice ages of the Middle Neoproterozoic, and a variety of materials on the Ediacaran Period, emphasizing the odd soft-bodied metazoan fauna of that time**

## The Proterozoic Eon (2.5-0.543 Ga)

Proterozoic rocks are easier to study than Archean rocks because they are less altered. But they are more difficult to study than Phanerozoic rocks because they lack the abundant fossils. Designation of the beginning of the Proterozoic at 2.5 by is somewhat arbitrary, but it marks:

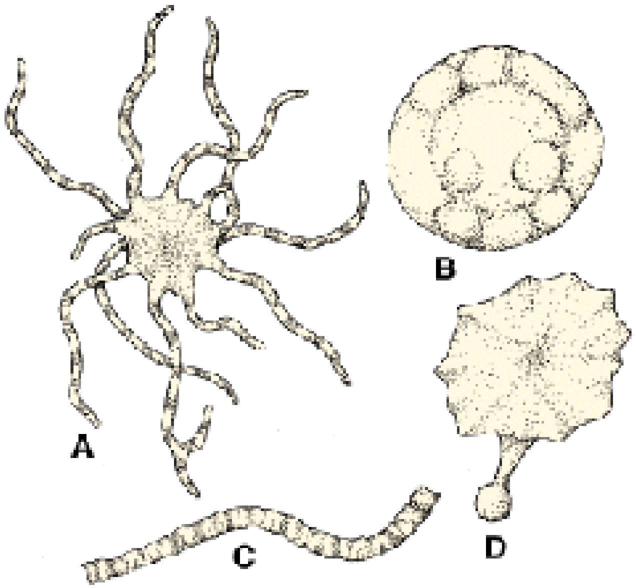
1. Beginning of **modern style of plate tectonics**. Lateral plate motion, subduction, rifting, and sea floor spreading.
2. Beginning of more **modern style of sedimentation**.
   Continents had developed with wide **continental shelves**. Deposition of clastics and **carbonates** in shallow water.
   Tranistion from banded iron formations to red beds.
3. **Glaciations** in both Early and Late Proterozoic (about 2.1 to 2.6 by, and later at 1.0 by to 0.54 by = 544 my).
4. **Buildup of oxygen in the atmosphere**
   Consequences of oxygen buildup:

a. Development of **ozone layer** which absorbs harmful UV radiation

**b. End of banded iron formations** which only formed in low, fluctuation O2

**c. Beginning of red beds** - red beds are clastic sedimentary rocks such as sandstones and siltstones with red iron oxide cement. The presence of iron oxide indicates that there was a relatively abundant, constant level of oxygen in the atmosphere at the time the rocks were deposited.


2500-2100 million years ago
(2.5 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!




The **Gunflint Chert**, within the BIF sequence, contains **fossil remains of prokaryotic organisms**, including cyanobacteria. Age = 1.9 by.

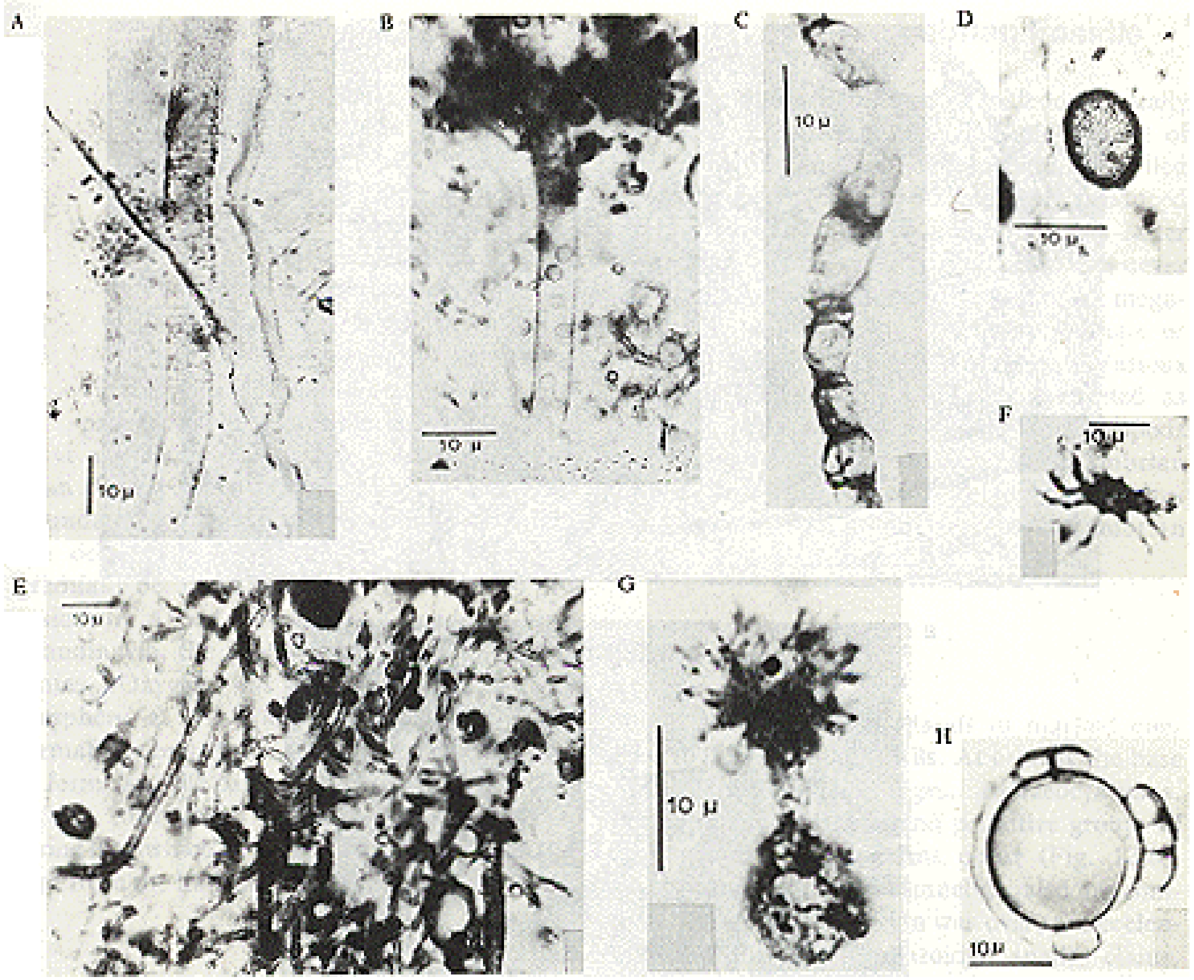
*Diagrams of organisms in the Gunflint Chert.*

*A =* ***Eoastrion*** *( = dawn star), probably iron- or magnesium-reducing bacteria*

*B =* ***Eosphaera****, an organism or uncertain affinity, about 30 micrometers in diameter*

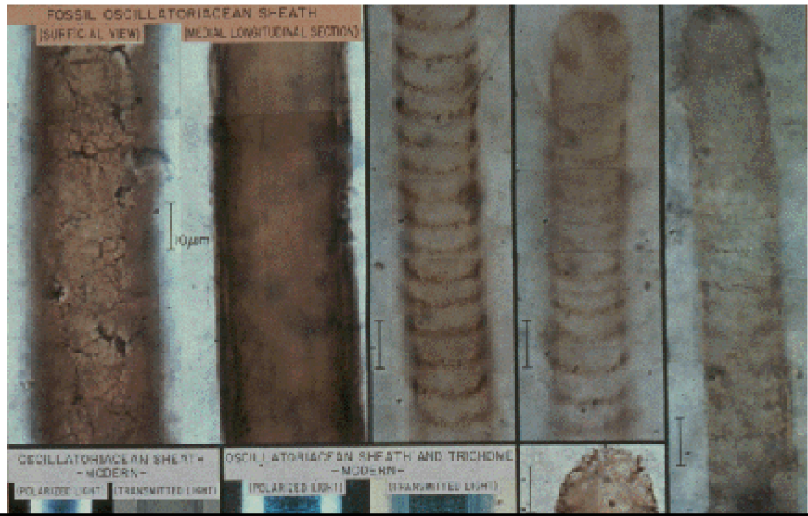
*C =* ***Animikiea*** *(probably algae)*

*D =* ***Kakabekia****, an organism or uncertain affinity*




**Gunflint Chert Fossils. A-C. blue-green algae; *Animikia, Entosphaeroides,* and *Gunflintia; D. Huroniospora,* an algal spore; *E. Gunflintia* and *Hurionospora; F. Euastrion,* a bacterium, and enigmatic forms, *G. Kakabekia; H. Eosphaera***

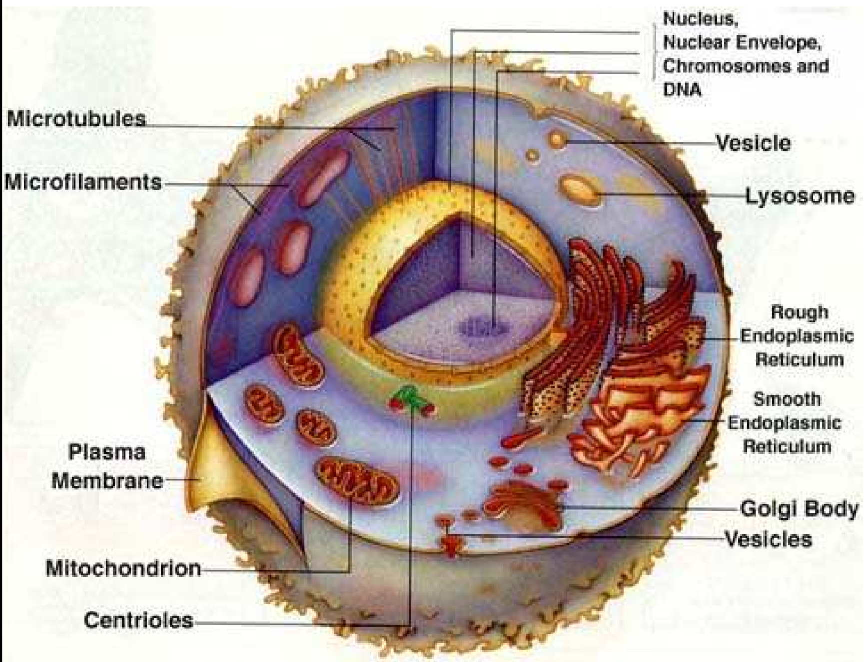

Precambrian filamentous cyanobacteria. Cyanobacteria (Nostocales) from the Bitter Springs Chert of Central Australia, 850 million years old. Optical photomicrographs showing eceptionally well preserved Oscillatoriacean, Nostocacean and, possibly, Rivulariacean trichomes in petrographic thin sections of Black chert



# 2100 million years ago

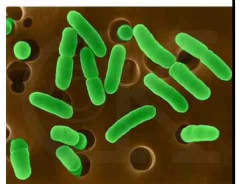
## (1.7 billion years ago)

## Single-celled Eukaryotes Appear




**Cells get a nucleus!**

**Still Present:**



**EUKARYOTIC CELLS.**

**SYMBIOSIS =** The mutually beneficial relationship between two individuals or two species. Both individuals, or the members of both species benefit more or less equally from their association.

May have been unable to diversity until oxygen levels reached a critical threshold

**First fossil eukaryotic cells** appeared by at least 2,1 Ga.

**Eukaryotes are cells which have a nucleus and organelles**. They are larger than prokaryotes.

**Procaryotic cells** then could have become the **organelles** and **mitochondria** of eucaryotic cells.

**Eucaryotic** cells then reproduce **sexually** by mitosis and meiosis, sexual reproduction leads to **genetic variation**, genetic variation leads to **increased evolutionary rates** and diversity.

**PRE-CAMBRIAN EUKARYOTES**

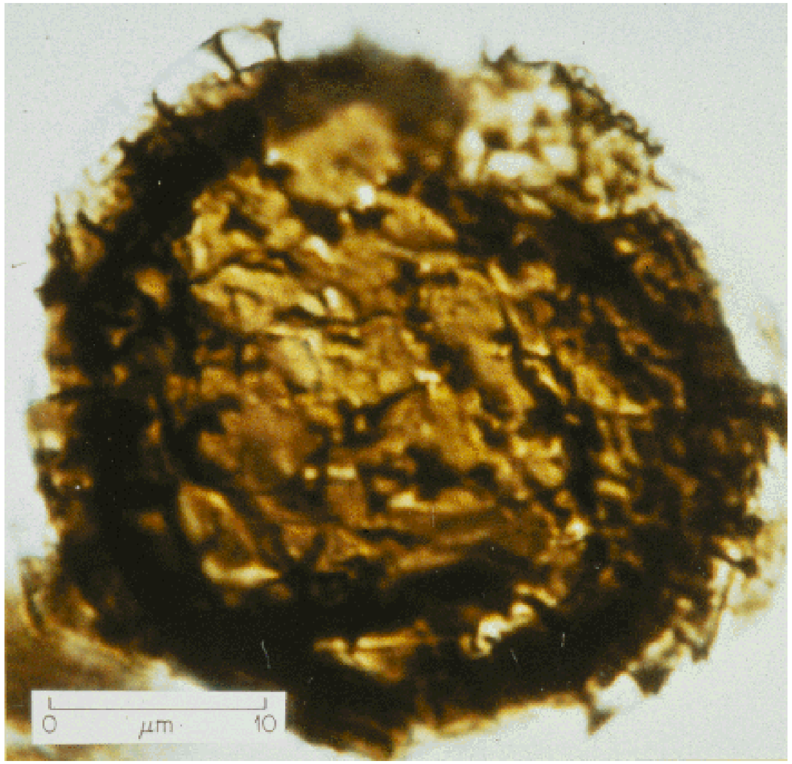
They are now thought to have originated much earlier than paleontologists have previously thought.

**FIRST EUKARYOTES**

The first widely accepted date is at about **2.1 BILLION** years ago.

These first fossils that are certainly eukaryotic are those of an algal form called ***Grypania spiralis***. They are found in filaments.

***Grypania spiralis***




**Acritarch**: *Vandalosphaeridium walcottii*, a spiny acritarch from a palynological preparation of carbonaceous mudstone of the Awatubi Member, Kwagunt Formation, Chuar Group of the Grand Canyon. Late Precambrian, 850 million years old.

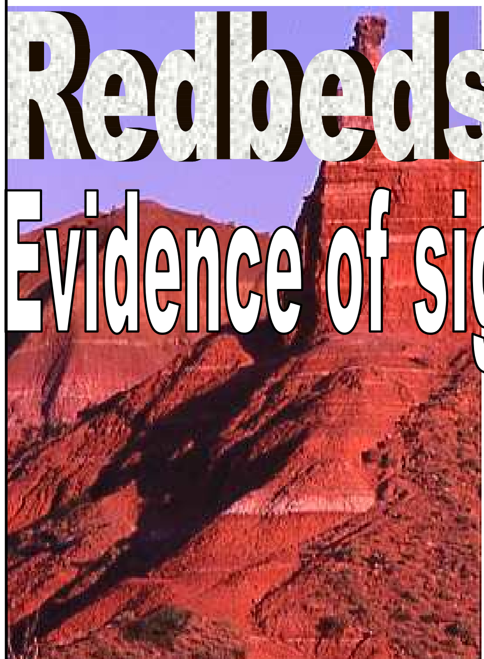
*Acritarchs first appear in the rock record about **1.6 billion** years ago. They probably represent a group of planktic algae, and they are considered the first eucaryotic cells because of their larger size and more complex, ornamented outer wall.*

# 2000 million years ago

(2.0 billion years ago)

## Beginning of Oxygenated Atmosphere

*First Pollution Crisis!*

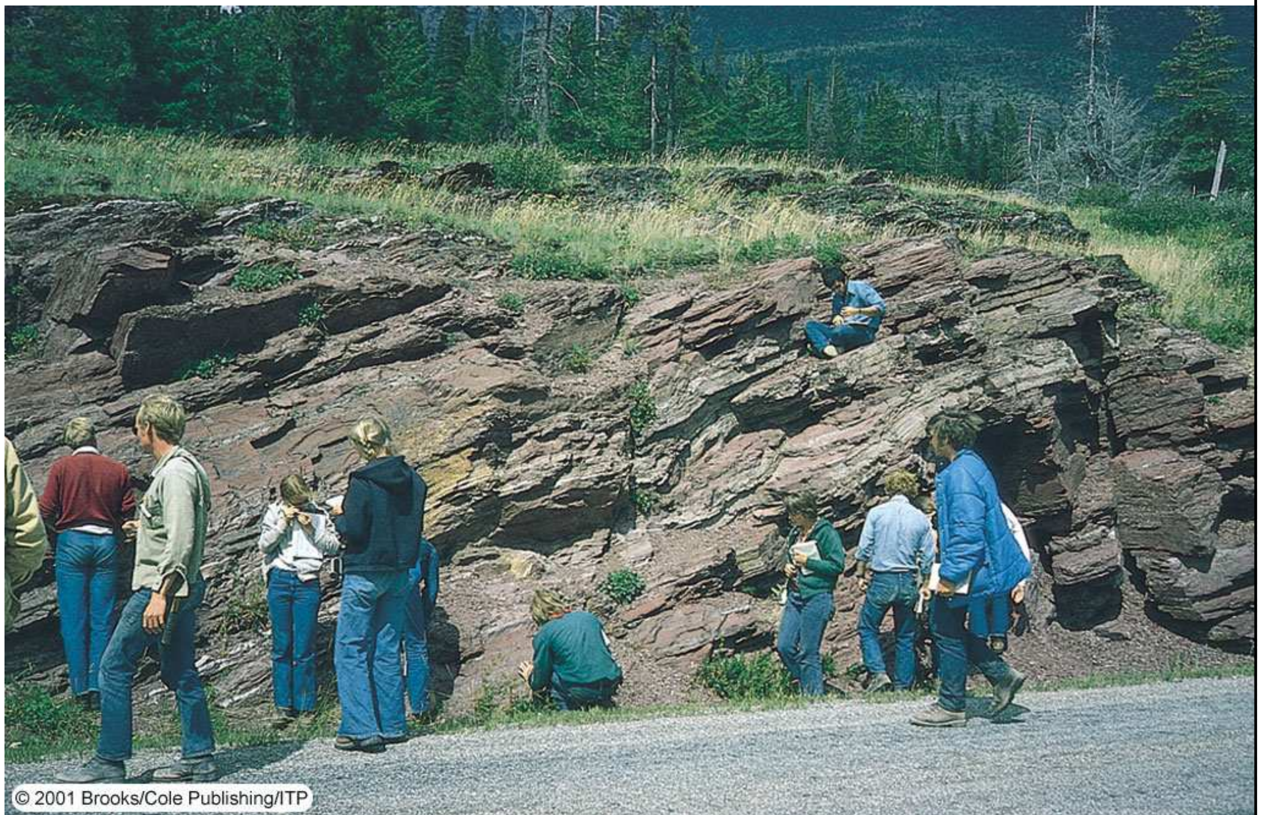


**Redbeds**

Evidence of significant free oxygen

# Continental Red Beds

- Obviously continental red beds refers
  - to red rocks on the continents,
  - but more specifically it means red sandstone or shale
  - colored by iron oxides,
  - especially hematite ($Fe_2O_3$)



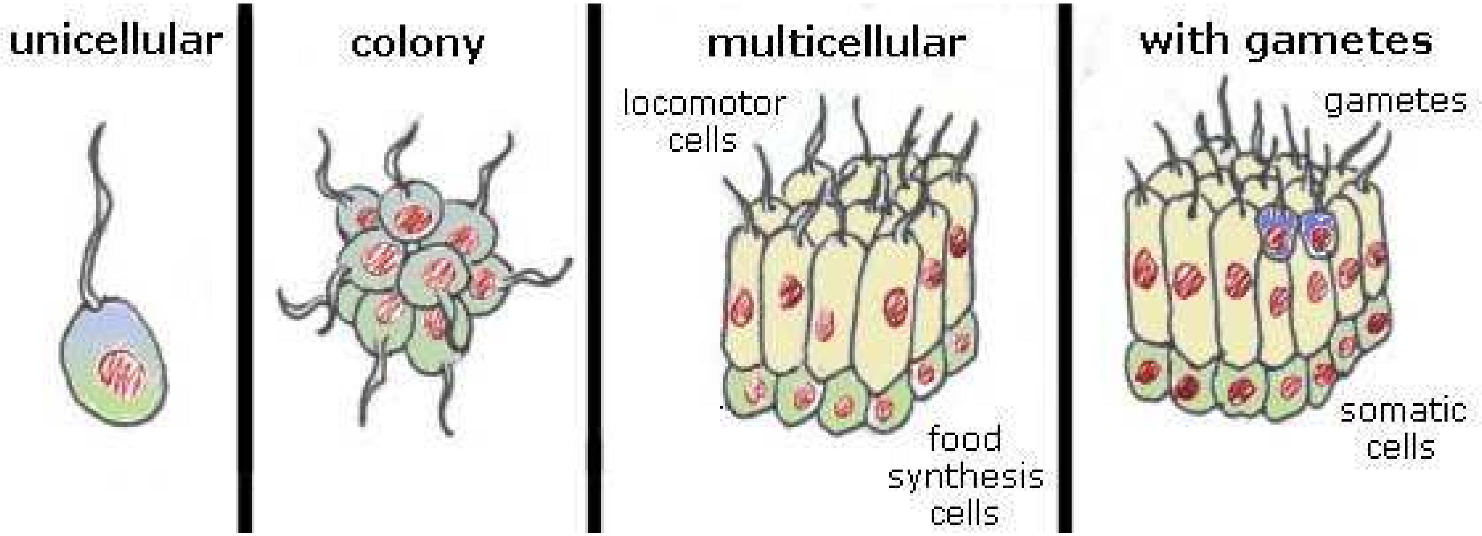

Red mudrock in Glacier National Park, Montana

The first "**pollution crisis**" hit the Earth about 2.2 billion years ago. Several pieces of evidence -- the presence of iron oxides in paleosols (fossil soils), the appearance of "red beds" containing metal oxides, and others -- point to a fairly rapid increase in levels of oxygen in the atmosphere at about this time. Oxygen levels in the Archaean had been less that 1% of present levels in the atmosphere, but by about **1.8 billion years ago, oxygen levels were greater than 15%** of present levels and rising. (Holland, 1994) It may seem strange to call this a "pollution crisis," since most of the organisms that we are familiar with not only tolerate but require oxygen to live. However, oxygen is a powerful degrader of organic compounds. **Even today, many bacteria and protists are killed by oxygen**. Organisms had to evolve biochemical methods for rendering oxygen harmless; one of these methods, **oxidative respiration**, had the advantage of producing large amounts of energy for the cell, and is now found in most **eukaryotes**.

Where was this oxygen coming from? Cyanobacteria, photosynthetic organisms that produce oxygen as a byproduct, had first appeared 3.5 billion years ago, but became common and widespread in the Proterozoic. Their photosynthetic activity was primarily responsible for the rise in atmospheric oxygen.


1500 million years ago
First multicellular algae

# Multicellular organisms




**Multicellularism** probably arose as unicellular ancestors (unicellular green algae like the biflagellated *Chlamydomonas*) joined into **loose colonies**, probably taking a form similar to *Volvox*-a hollow, fluid-filled ball similar to the blastocyst stage in animal development. The cells in this colony may then have become more **specialized** for singular functions, and thus **dependent on each other**. For instance, cells that kept a flagellum could have assumed responsibility for the locomotion of the colony, while other cells could have assumed digestive or metabolic tasks, and others could have been specialized for gamete production. The evolution of multicellularism is diagrammed to the left.

**The first fossilized evidence of multi-cellular cells goes back to about 1.5 billion years ago.**

# 700 million years ago

(1.0 billion years ago)

# Multicellular Organisms Appear

## Marine Invertebrates
## Soft Bodies

600 million years ago
Ediacara Fauna
Earth View
Australia
Mozambique Ocean
India
PDZ
East Antarctica
LHB
Accreted Arcs
Subduction?
EAO
ANS
Congo
Damara
WDM
Kalahari
SFC
60 S
30 S
Paleo-Pacific Ocean
Laurentia
Brasiliano Ocean
Rio Plata
Rifting
West Africa
Amazonia
Iapetus Ocean
Siberia
Ægir Sea
Baltica
565-580 Ma
Relative motion vectors
600-500 Ma shear zones/sutures
Still Present:

## EDIACARA BIOTA

Oldest occurrence of **multicellular animals**
- 700 - 545 m.y.
- best known from Pound Fm., at Ediacara, South Australia

Ediacara biota known from occurrences on most continents

Biota consists of soft-bodied metazoans, preserved as impressions in sandstone and shales

Includes:

•jellyfish-like forms (common)

•worm-like forms

•possible molluscs

•possible arthropods

•possible echinoderms

•large, flat forms of unknown affinities

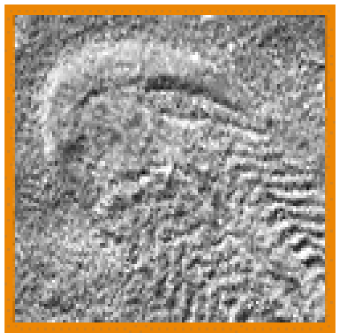
VENDOBIONTA

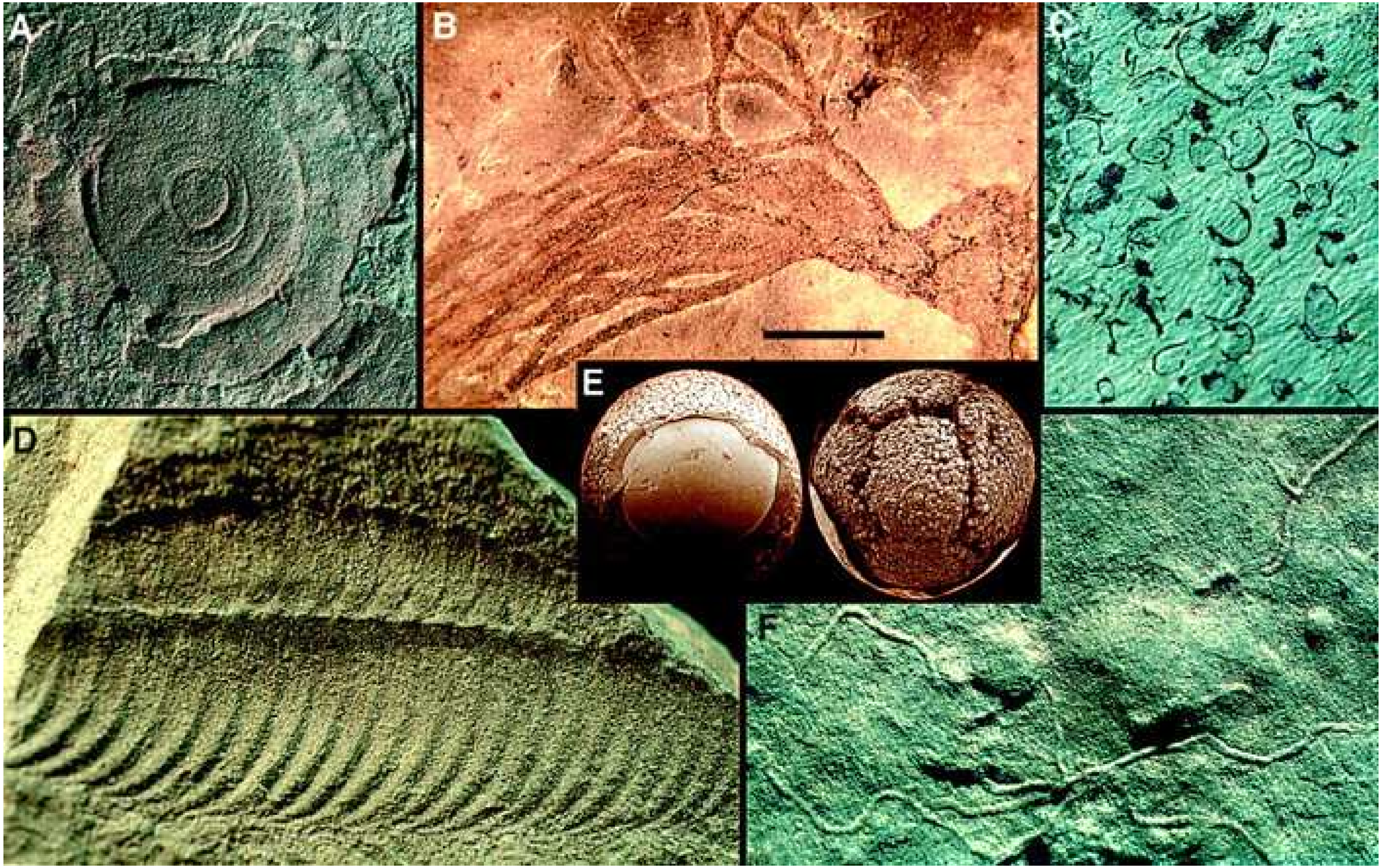
There are hints from trace fossils and molecular biology that animals may have appeared as much as **1 billion years** ago. However, the oldest relatively non-controversial, well-studied animal fossils appear in the last hundred millions of years of the Proterozoic, just before the Cambrian radiation of taxa.
For some years a number of authors (*e.g.* Seilacher 1984, McMenamin 1986) have argued that the Ediacarans were **unrelated to any living group of organisms**; that they represented a new kingdom (**Vendobionta** Seilacher 1992) which disappeared around the Vendian-Cambrian boundary, perhaps wiped out by a mass extinction event. However, this view has always encountered opposition and now appears to have lost much of its support.







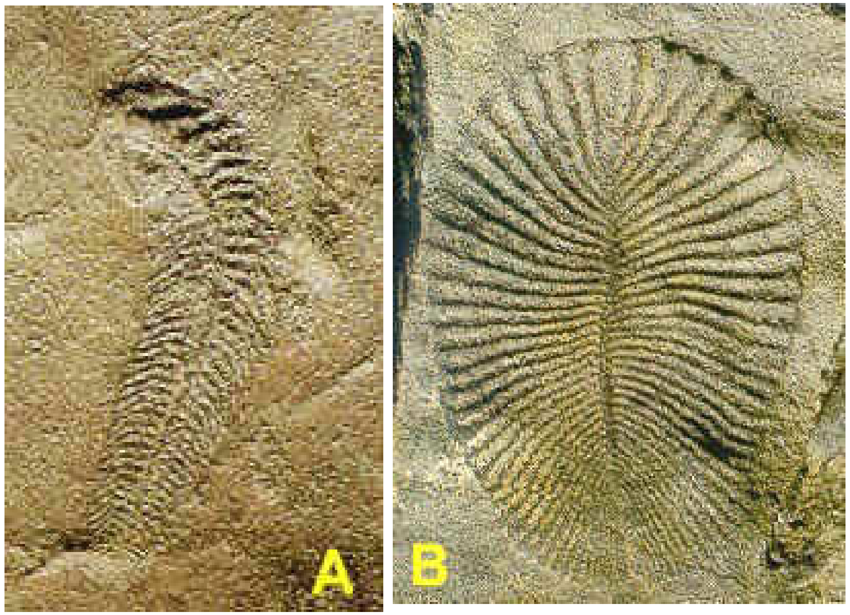





The nature of the terminal Proterozoic fossil record. (**A**) *Ediacaria*, a radially symmetrical cast preserved on the underside of a sandstone bed, Rawnsley Quartzite, South Australia. (**B**) Macroscopic alga preserved as a carbonaceous compression in shales of Doushantuo Formation, China. (**C**) Calcified fossils in limestones of the Nama Group, Namibia. (**D**) *Pteridinium*, a frondose Ediacaran fossil consisting of three vanes built of repeating units (two visible in specimen) that are joined along a central axis. (**E**) Phospatized animal egg and early cleavage-stage embryo, Doushantuo Formation. (**F**) Simple trace fossils of bilaterian animals, Rawnsley Quartzite. Bar = 2.5 cm for (A), 3 mm for (B), 1.5 cm for (C) and (D), 250 μm for (E), and 2 cm for (F).

1. **Oldest Metazoan Body Fossils = EDIACARA FAUNA**
2. **Originally discovered in Pound Qtzt, Ediacara Hills, S. Australia; later found worldwide (including Piedmont area of NC) at low paleolatitudes.**
   **0.59 - 0.7 by (590 - 700 my)**
   **impressions and molds of animals (associated with trace fossils)**


*1.* ***Tribrachidium heraldicum*, Echinoderm?, from Australia**




**Examples Of The Ediacaran Fauna**
*A*. Genus *Spriggina*.   *B*. Genus Dickinsonia.
These bodies of these spe*cimens are preserved as* ***impressions*** *in fine grained sandstone of the Pound Quartzite (Ediacaran age, Australia).   Similar appearing, soft-bodied fossils are known from over two dozen localities worldwide.  These organisms were all small, had thin bodies with a quilted outer surface, and lacked any internal or external hard parts*.  Specimens about 4 to5 cm in length.


**1. Unnamed "spindle-shaped organism" from Newfoundland**


***1.*** ***Tribrachidium heraldicum*, Echinoderm?, from Australia**

- Life may have developed from nonliving materials as early as 3.9 billion years ago

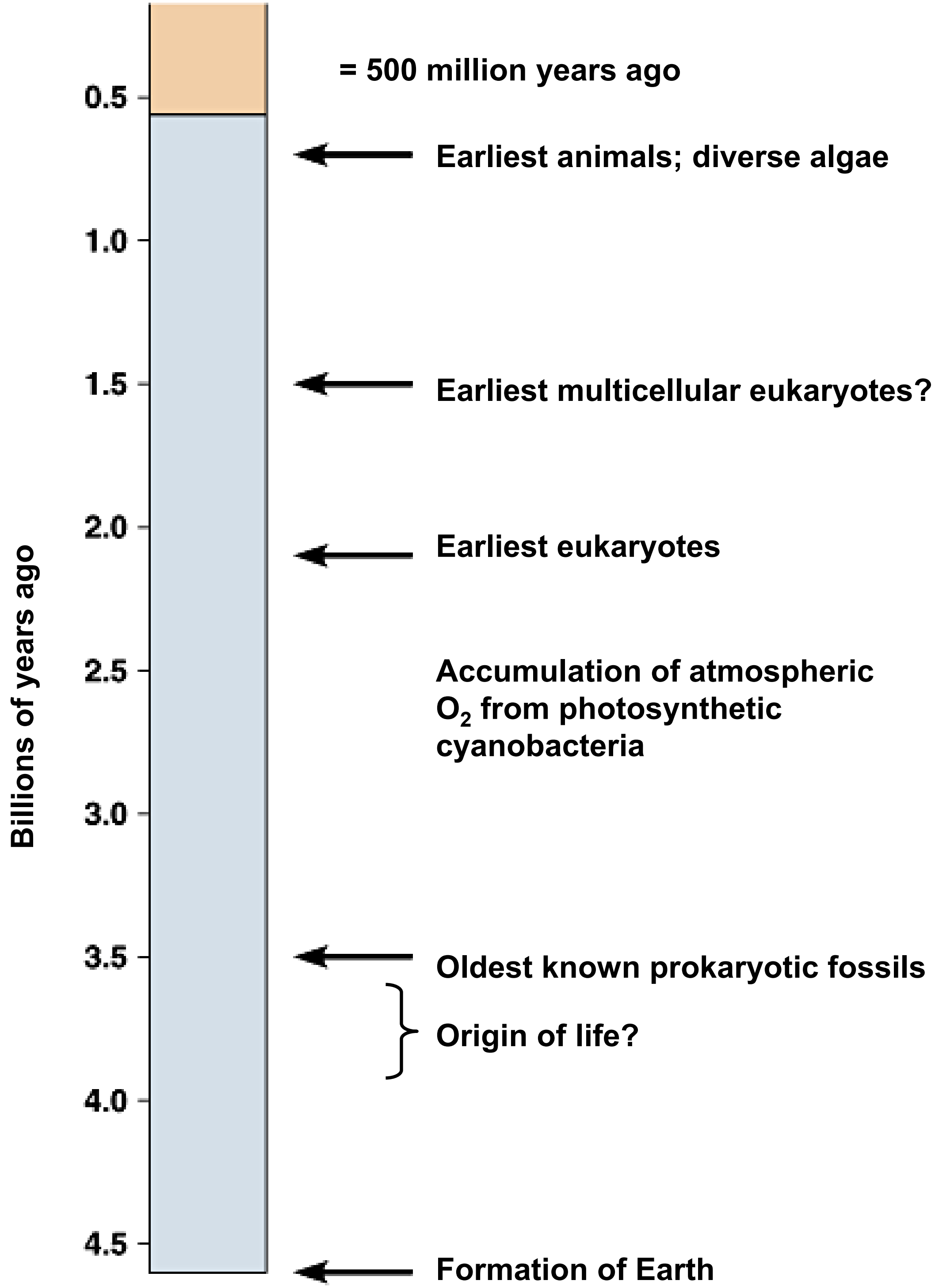
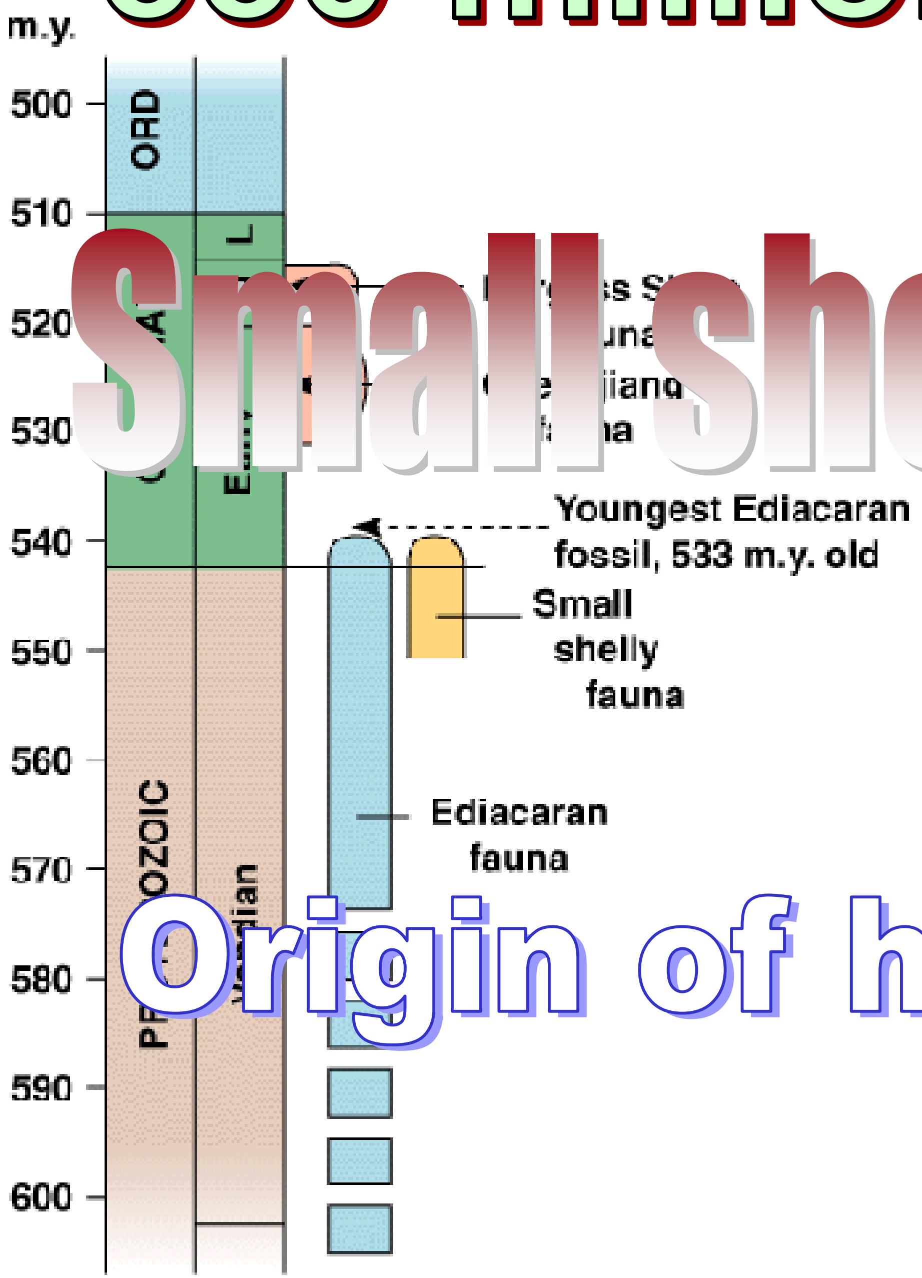



Figure 16.1C

# 550 million years ago



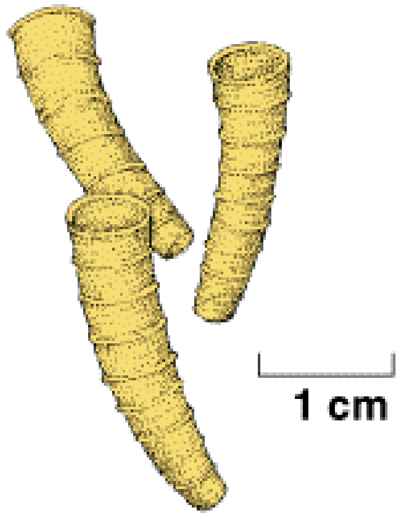

# Small shelly fauna

# Origin of hard parts

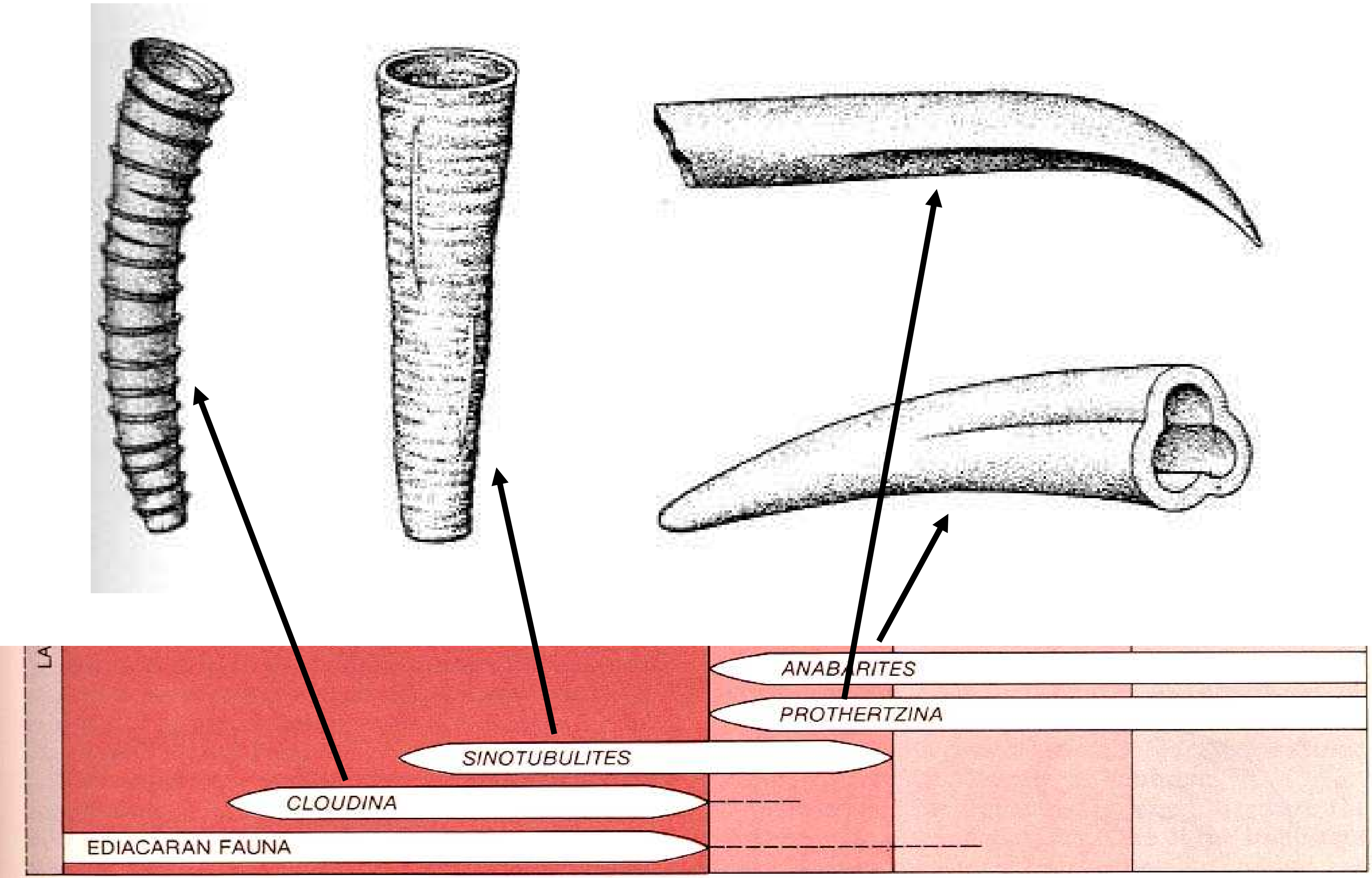
**Small Shelly Fauna: The Origin of Hard Parts**

Small fossils with hard parts or shells (mostly a few mm long ) appeared in the Vendian (see yellow bar on time scale above).

*Cloudina*, an organism with a small (few cm long), tubular shell of calcium carbonate is interpreted as a tube-dwelling worm. It is the earliest known organism with a $CaCO_3$ shell. Found in Namibia, Afric



# Small Shelly Fauna



## 1. Proterozoic life

Extensive **stromatolites**.

May have been more resistant to UV radiation because of sediment covering.
Presence of stromatolites and blue-green algae (photosynthetic) led to buildup of oxygen in atmosphere.
**Gunflint** chert (Ontario, Canada, 1.9 by) contains extensive remains of **prokaryotic organisms** including bacteria and algal filaments

**First fossil eukaryotic cells** appeared by at least 2,1 Ga.

**Eukaryotes are cells which have a nucleus and organelles**. They are larger than prokaryotes. Reproduce through mitosis and meiosis

i. First fossil cells with what appear to be organelles
1.8 - 1.2 by

ii. Bitter Springs Fm, chert, Australia
0.8 - 0.9 by
impressive eukaryote fossils

**First trace fossils** (burrows and trails) indicate the presence of multicellular organisms.

oldest are about 0.7 by (700 my)

**First multicellular animals= Ediacaran Fauna** Metazoans appeared in the Late Proterozoic. Metazoans are multicellular animals with various types of cells organized into tissues and organs. Metazoans lived during the Vendian (the end of the Late Proterozoic), and first appeared about 630 my ago (0.63 by). What stimulated the appearance of metazoans? May be related to the accumulation of oxygen in the atmosphere.

**Small organisms with hard parts** (few mm long) appeared in the Late Proterozoic

Late Proterozoic small fossils with shells include possible primitive molluscs, sponge spicules, tubular or cap-shaped shells, and tiny tusk-shaped fossils called hyoliths. Early shelly material is made of calcium carbonate and calcium phosphate.

# THREE MAJOR TYPES OF ROCKS:

- 1. **Widespread Shallow-marine Quartzite-Carbonate-Shale Assemblages**
- REPRESENT DEPOSITION ON & AT PASSIVE CONTINENTAL MARGINS OF WIDESPREAD STABLE CRATONS
- 2. **Tillites/Diamictites** (pebbly mudstones)
- REPRESENT **TWO** (2) EPISODES OF CONTINENTAL GLACIATION
- Late Archean/Early Proterozoic (2700-2300 my ago) - Bruce & Gowganda sequences in North America; numerous localities elsewhere
- Late Proterozoic (900-600 my ago) globally, even on continents along the equator!
- Continental glaciation also in the Ordovician-Silurian, Pennsylvanian-Permian, & Cenozoic
- 3. **Iron Ores**
- RECORD CHANGING OXYGEN CONTENT OF ATMOSPHERE
- Atmospheric oxygen content is a balance between sources & sinks
- *main source of oxygen is photosynthetic organisms, which developed in the Archean* [~*3.5 by ago* ]
- *main sink for oxygen during the Archean & Earliest Proterozoic was previously dissolved iron* (*Fe+2* )
- *main sink for oxygen after the Latest Early Proterozoic* (*from ~2000 my ago to the present* ) *has been weathering of iron-rich rocks*
- Latest Archean/Earliest Proterozoic - **Banded Iron Formations (BIFs)** [iron oxide & chert] {mostly (92%) Earliest Proterozoic}
- *Archean & Earliest Proterozoic oxygen combined with previously dissolved iron (Fe+2) to form BIFs & did NOT accumulate in the atmosphere*
- *By the end of Early Proterozoic time, the iron sink was used up & free oxygen began to accumulate in the atmosphere*
- Latest Early Proterozoic to the present (after 1800 my) - **Redbeds**
- *Redbeds result from hematite produced during weathering of iron-rich rocks in an oxidizing atmosphere*
- 4. **Note**: **Proterozoic greenstone belts do occur**, but **without ultramafic volcanics**

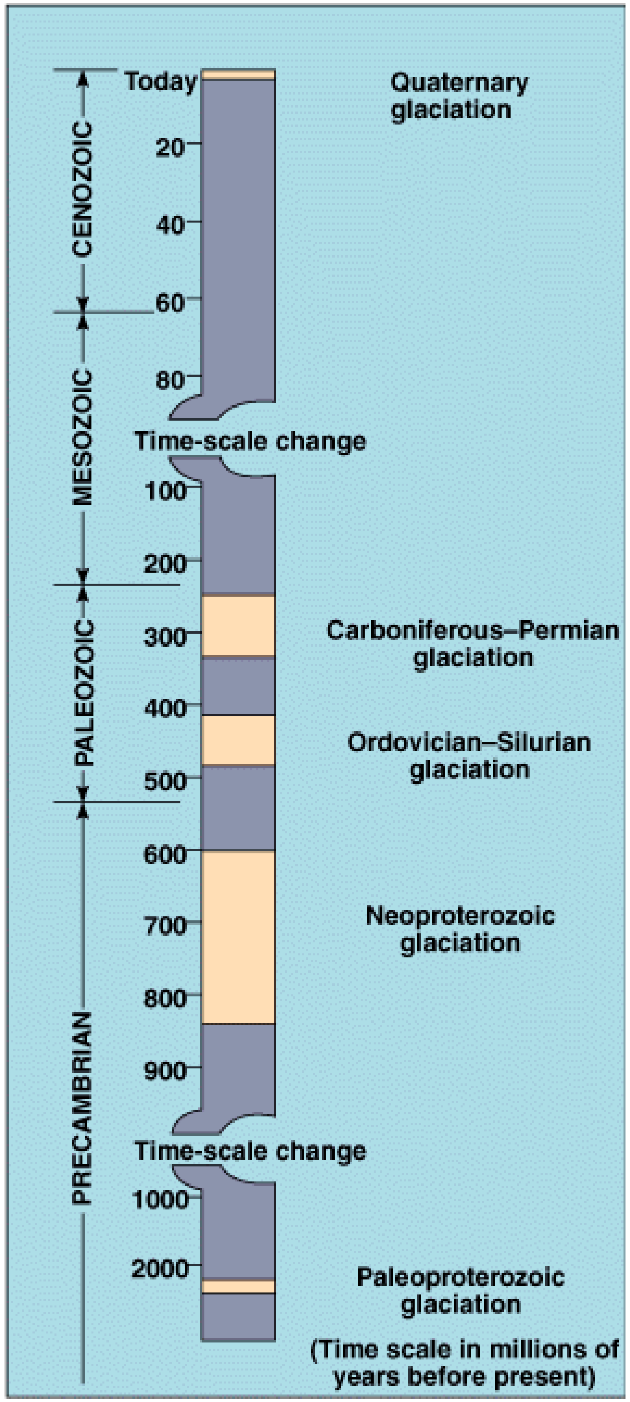
**Granites and gneisses** are present but less common in the Proterozoic than the Archean. An unusual type of plutonic rock called **anorthosite** **is very common** in the Proterozoic (in particular during the Grenville orogeny) but uncommon in earlier or later rocks. Anorthosite is composed of greater than 90 percent **plagioclase**, and represents a puzzle for geologists who study the origin of igneous rocks (igneous petrologists) because it requires very unusual conditions for its production in the mantle and emplacement in the crust.

Both **komatiite** lavas which represent large percents of partial melt, and alkaline lavas which represent small percents of partial melt are **rare** in the Proterozoic. Most of the modern sediment types were common except **gypsum** ($CaSO_4.H_2O$) and **anhydrite** ($CaSO_4$) which require higher amounts of dissolved oxygen than was present in the Proterozoic ocean.

**Proterozoic greenstone belts do occur**, but **without ultramafic volcanics**

# Glaciations

in both Early and Late Proterozoic (about 2.1 to 2.6 by, and later at 1.0 by to 0.54 by = 544 my).



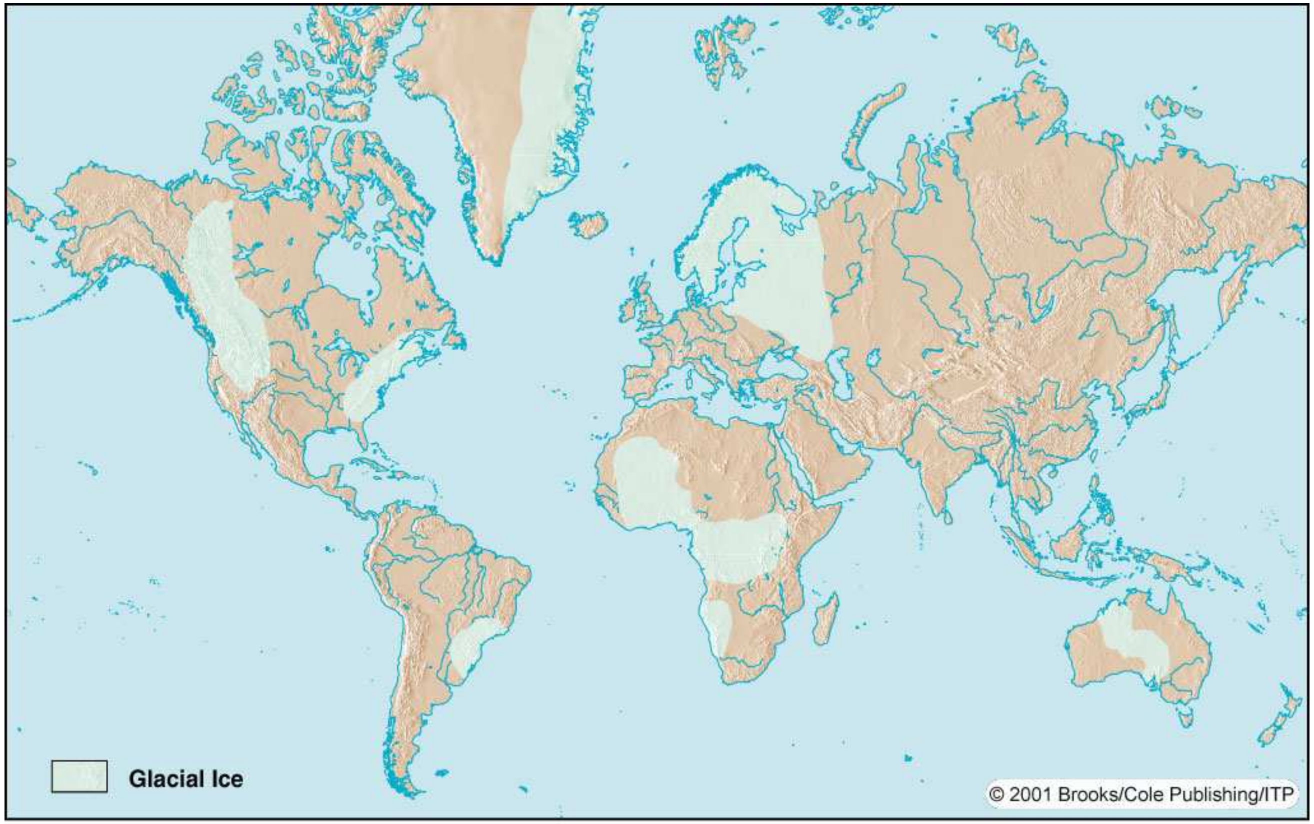

**2.0 GA Glaciation**

Evidence for global cooling comes from the first glacial deposits found in the rock record at about **2.0 Ga** (Gowgonda Tillite, Huronian Supergroup, Canada).

Global cooling and the formation of high latitude ice sheets caused cold polar water to begin to flow through the deep ocean, mixing the formerly stratified water column. This mixing and oxygenation of the deep ocean prevented the buildup of large amounts of iron (iron released into the water was oxidized immediately and locally) and shut down the production of BIFs.

second, apparently more extensive series of glaciations occurred in the Late Proterozoic between about 850 and 600 Ma. Glacial deposits from this age are found as a series of formations on all continents but Antarctica, suggesting a widespread and prolonged episode of cooling of the Earthâs climate.

25 **Tillites and glacial features on all continents except Antarctica 900 to 600 m.y. ago, not continuous, but 4 episodes. Greatest extent in Earth history, with some in apparent near- equitorial areas.**



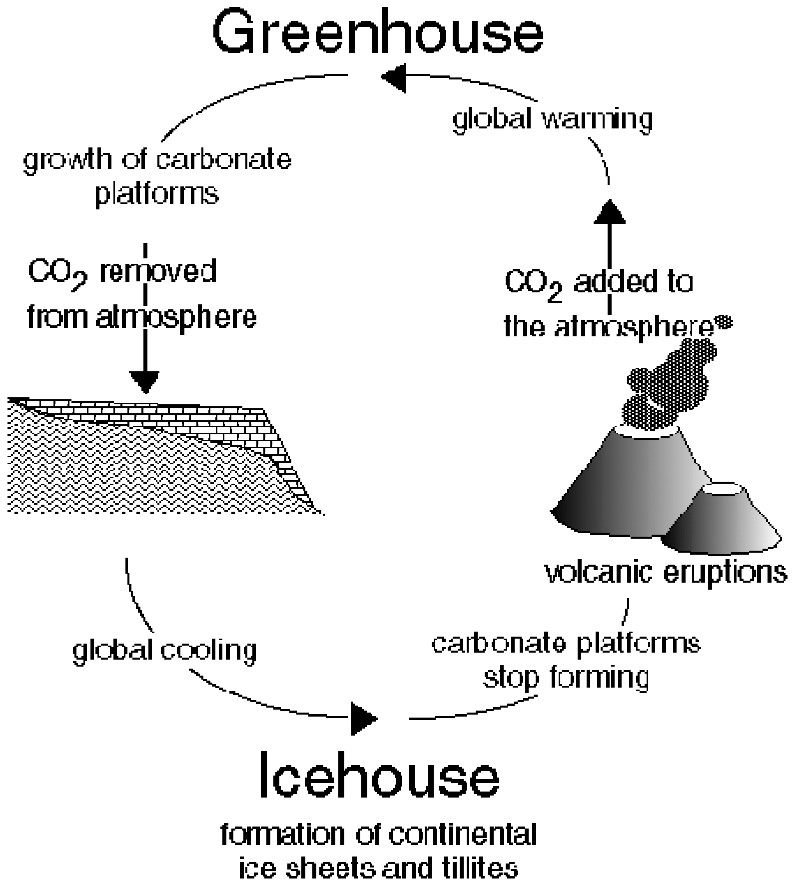

**Ice sheets shown above may not have been present at the same times.**

**Carbon Dioxide**

By the early Proterozoic, large regions of continental shelf existed. These new expanses of shallow water covered with algal mats led to the production of extensive **carbonate platforms** (such as exist today in tropical regions - e.g. the Bahamas).

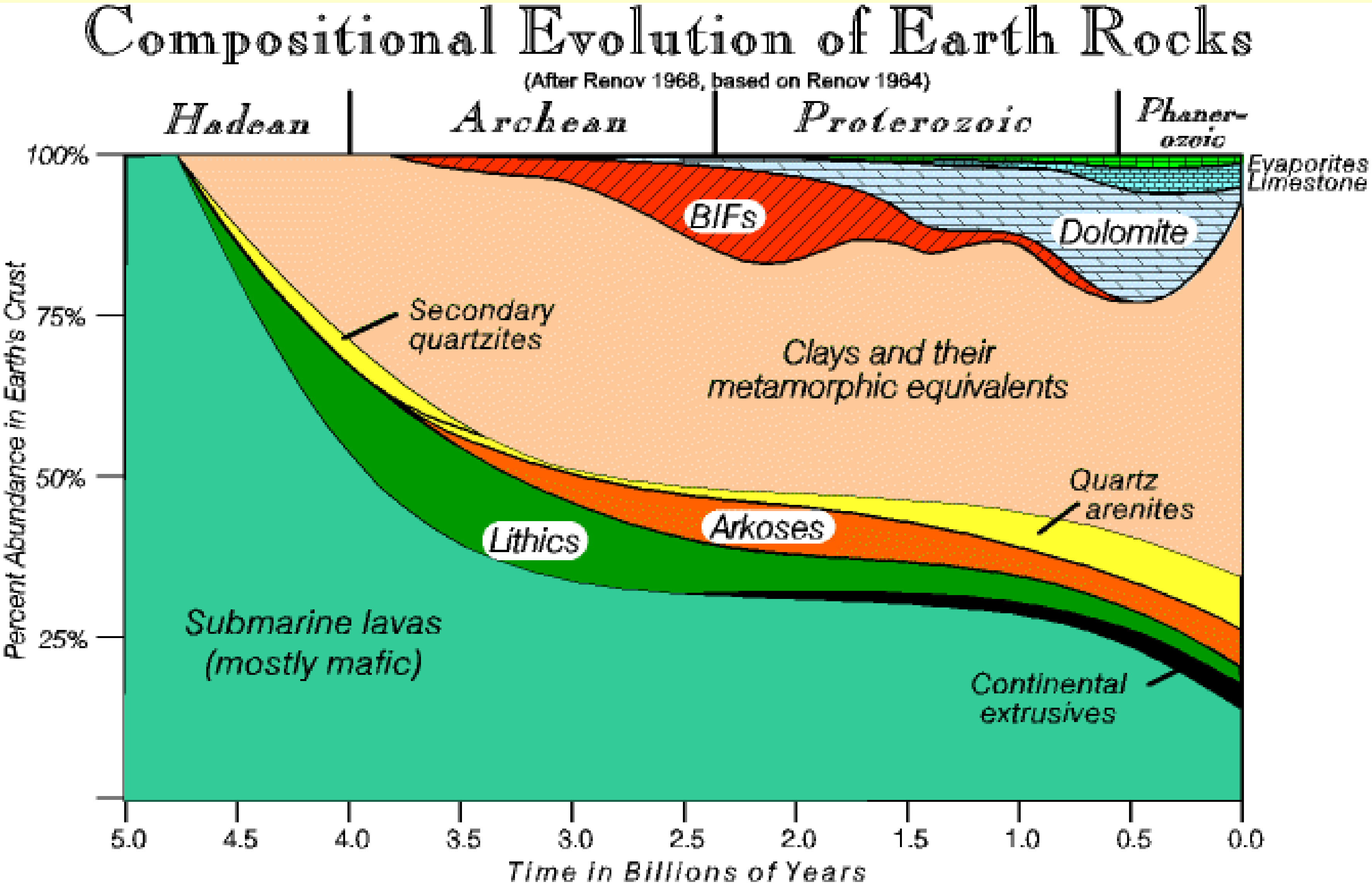
**Carbonate formation**, like photosynthesis, uses **atmospheric $CO_2$** as the raw material. However, unlike the organic matter produced by photosythesis which is rapidly reoxidized, releasing $CO_2$ back into the atmosphere, carbonate is deposited as sedimentary rock, removing the $CO_2$ for geological spans of time. Thus the **growth of carbonate platforms led to a decline in atmospheric $CO_2$** and a decrease in the global greenhouse.

Even more remarkable is the fact that paleogeographic reconstructions for this time suggest that most continents were in **low latitude**, equatorial positions. Glaciers do not usually form in equatorial regions except at high altitudes. The presence of thick deposits of **carbonates** (developed in equatorial to subtropical oceans) interlayered with glacial **tillites** (found in the Rapitan Group of the Canadian Cordillera and in Namibia) argues strongly for a rapidly shifting climate that brought glacial conditions almost to the equator. Such an extreme icehouse climate may have been triggered by the presence of so much highly reflective **landmass distributed across the equator** (equatorial oceans are much better collectors of solar heat) combined with extensive carbonate shelves drawing CO2 out of the atmosphere.

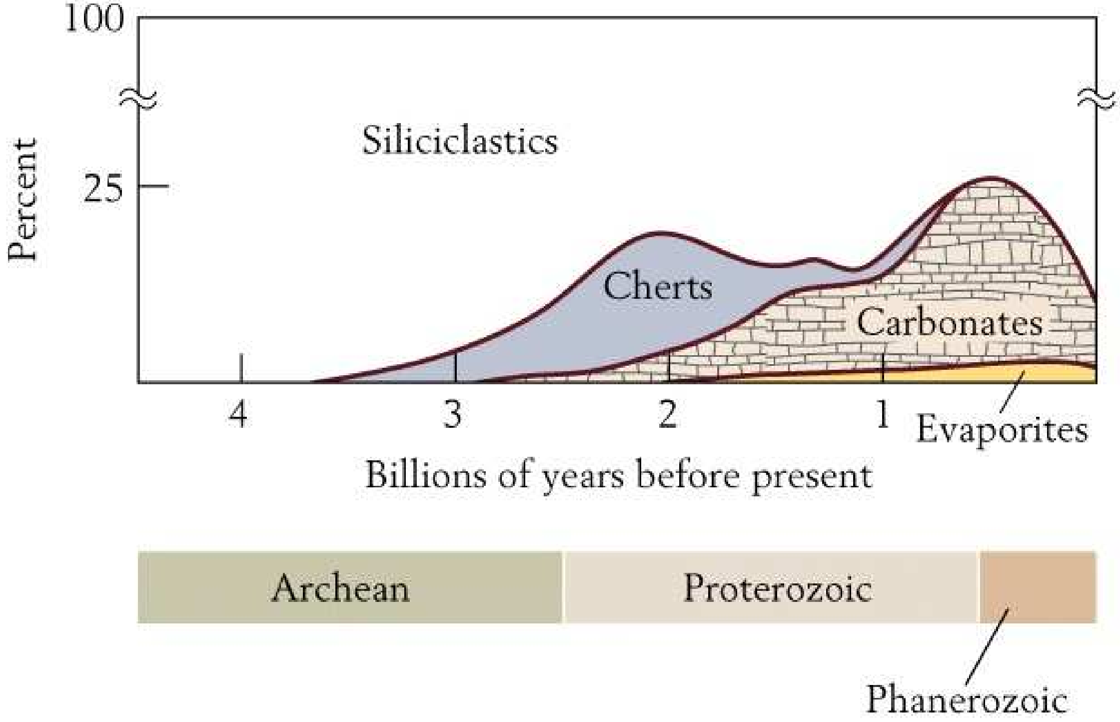


# Sediments

**Shelf sediments** including clean quartz sandstone, **limestones**, arkoses, and shales are common in the Proterozoic as are deeper-water, poorly-sorted sandstones (graywackies). Most of the modern sediment types were common except **gypsum** ($CaSO_4.H_2O$) and **anhydrite** ($CaSO_4$) which require higher amounts of dissolved oxygen than was present in the Proterozoic ocean.

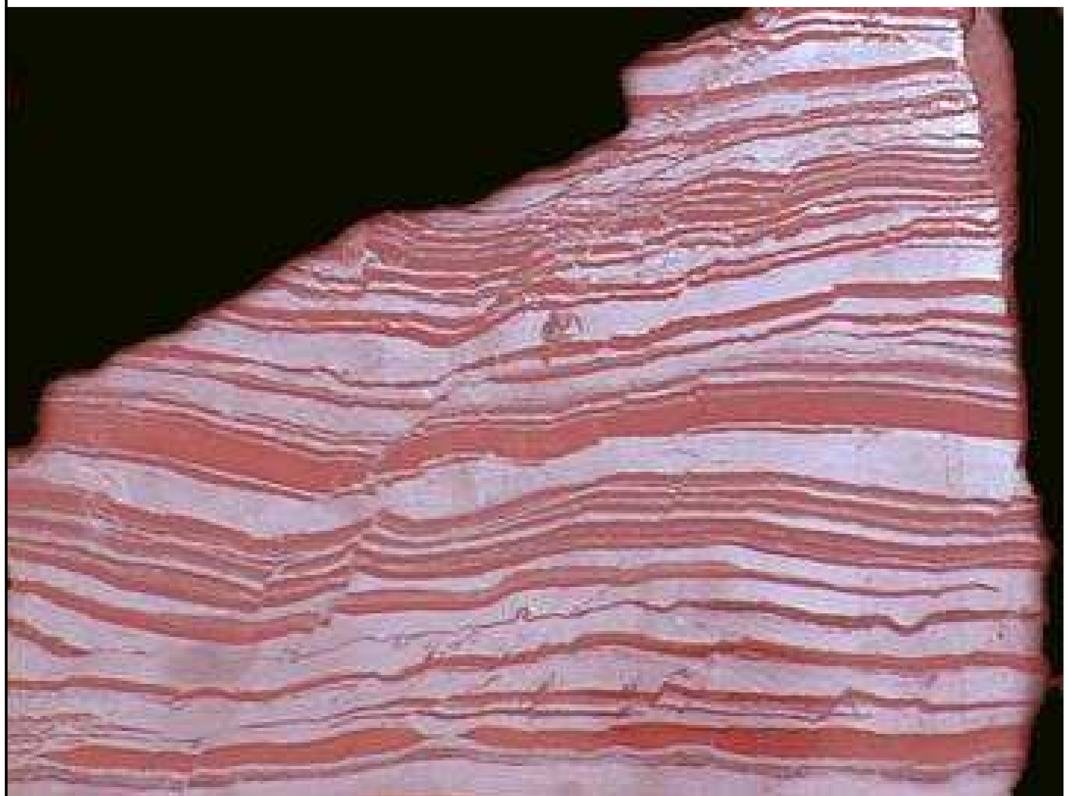


# Archean rocks



**Banded iron formations** in the Proterozoic provide the majority of the worlds iron ore deposits. These rocks are composed of alternating layers of **hematite** (Fe2O3)and **quartz** (SiO2)precipitated in the marine environment. One suggestion is that they represent a mechanism by which primitive life, for which oxygen was a poison, was able to remove oxygen from the environment. the hematite layers are **sinks for excess oxygen** while the quartz layers represent a silica gel in which these organisms lived.

- 92% of BIF are Proterozoic (2.5-2.0 Ga)

# THE LESS-PRIMORDIAL EARTH

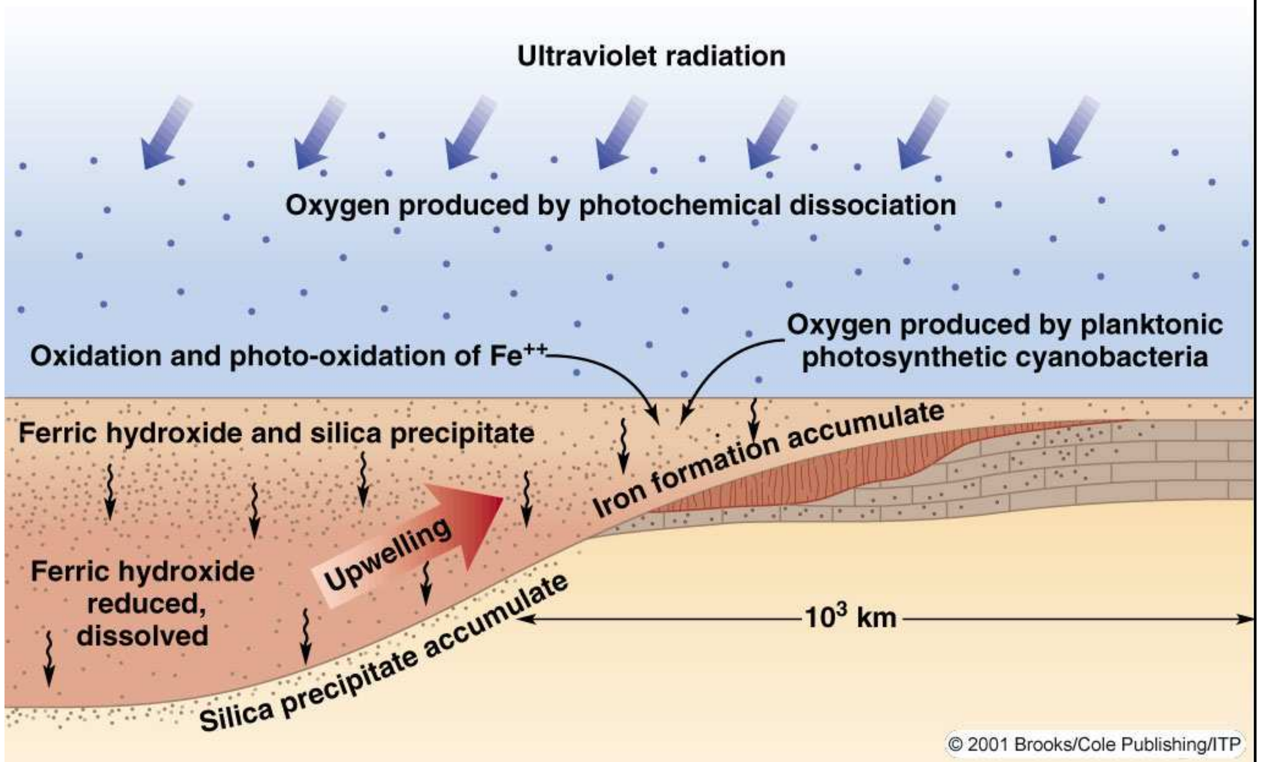
## The Paleoproterozoic Era

**Banded Iron Formation Animikie Group**
**western margin of Lake Superior**

**Indicates that photosynthesis was occurring and $O_2$**

# Model for origin of BIF

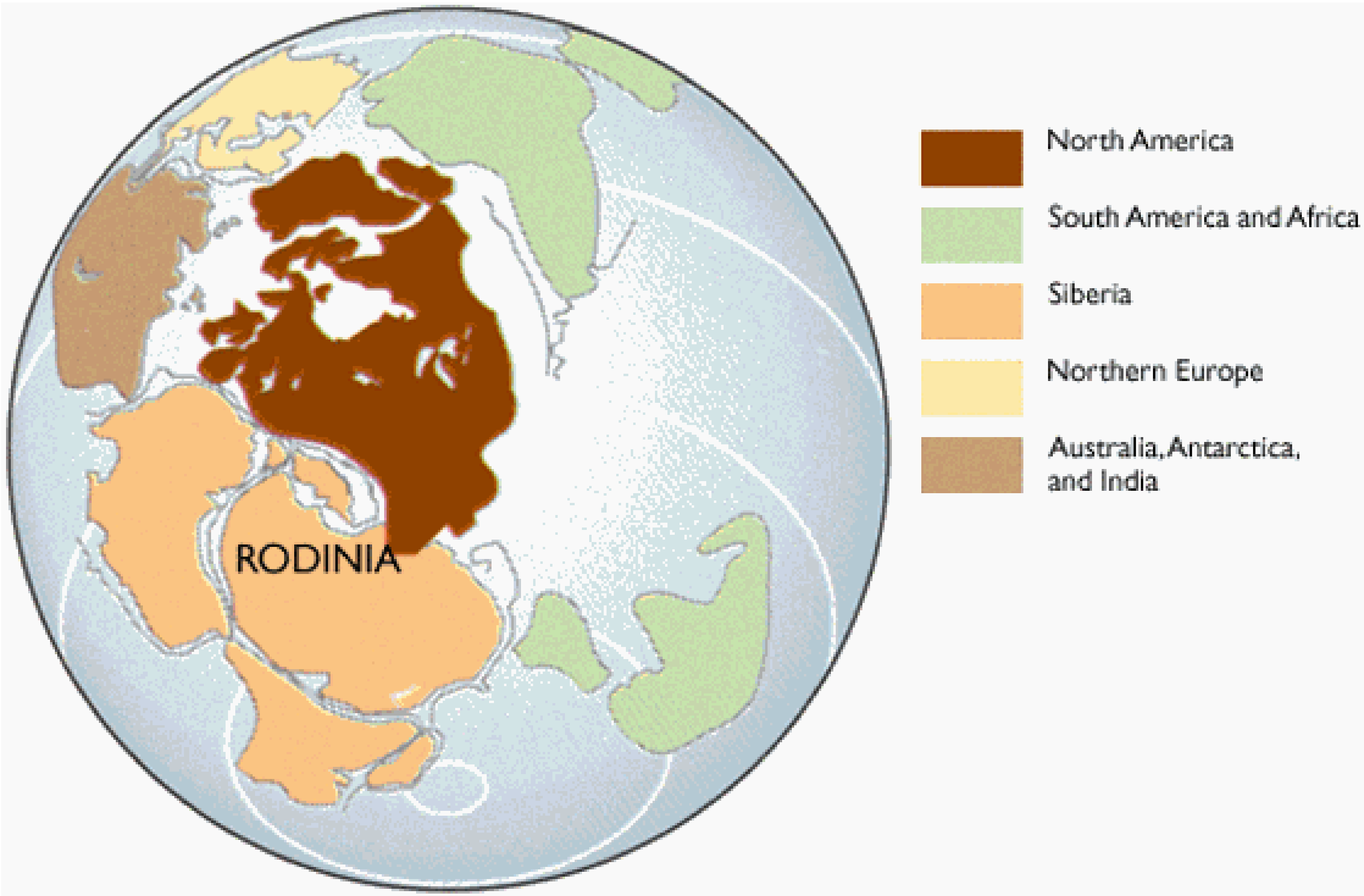
- Oxygen-rich upper ocean
- Oxygen-poor deep ocean
- Upwelling brings Fe and Si-rich water up
- Precipitation occurs



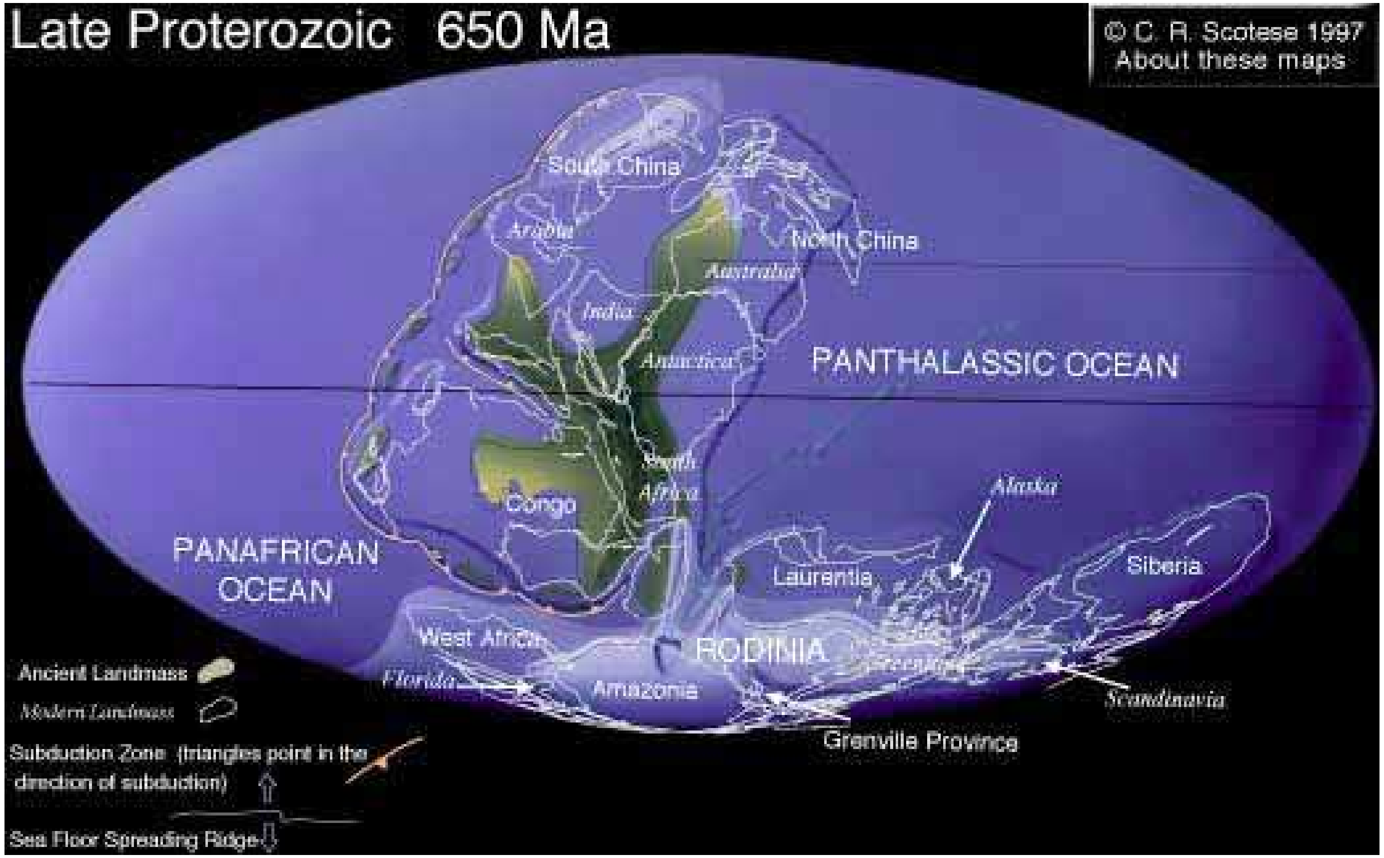
# SUMMARY OF PRECAMBRIAN CRUSTAL EVOLUTION & TECTONIC PATTERNS

**DOMINATED BY WILSON CYCLES** (rifting of "supercontinents" into smaller fragments followed by dispersal, & subsequent consolidation of continental crust into "supercontinents")

•**THE EARTH'S SURFACE IS EXTREMELY MOBILE = PLATE TECTONICS**
•**PLATE SIZE GETS LARGER THROUGH TIME -> CONVECTION INTENSITY DECREASES THROUGH TIME AS THE SUPPLY OF HEAT DECREASES & THE EARTH COOLS**
•**ARCHEAN "continents" - 100-500 km in width**
•**Proterozoic continents - 1000-2000 km in width**
•**Phanerozoic continents - 5000-10000 km in width**

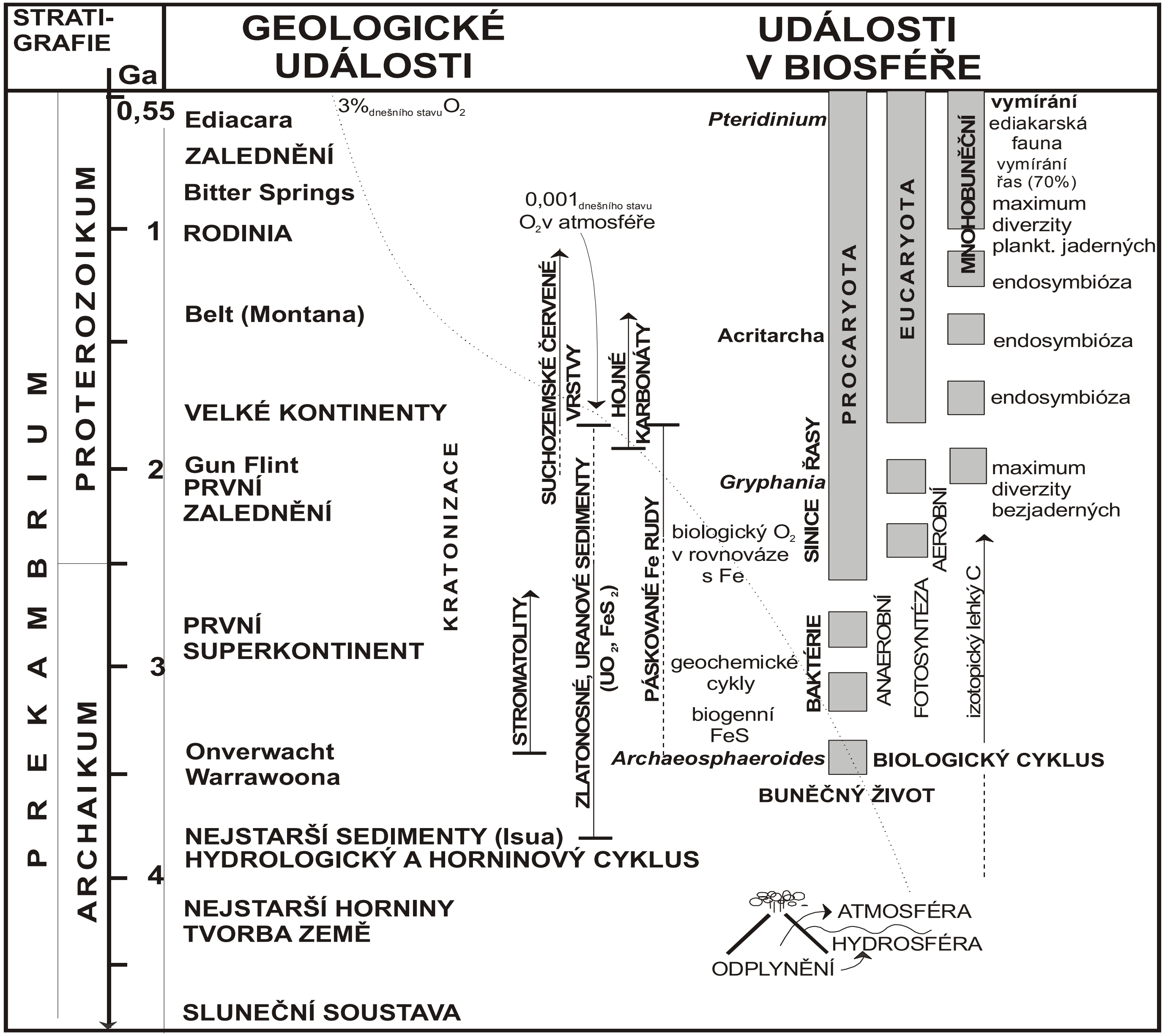



(a) Late Proterozoic
(750 million years ago)

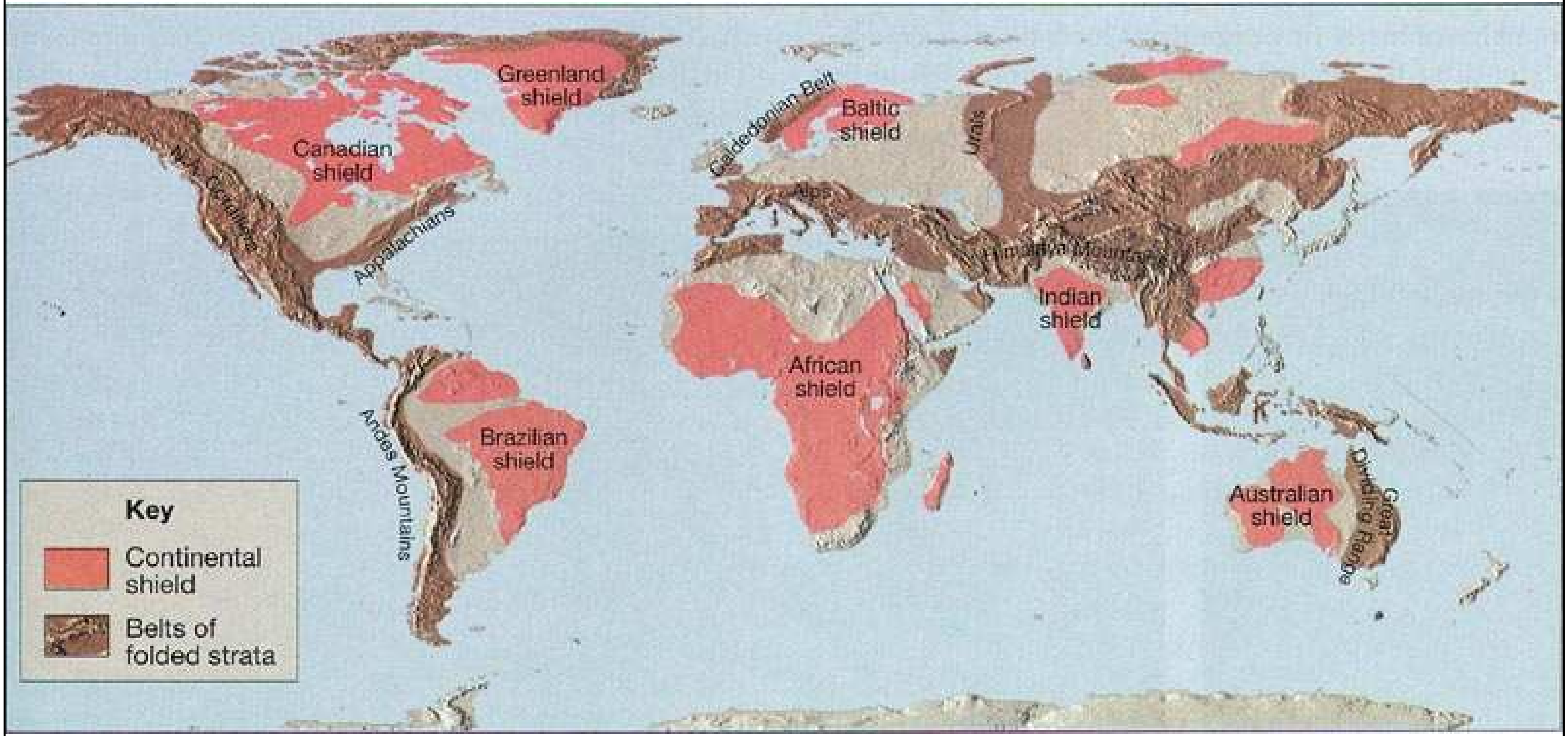


Late Proterozoic 650 Ma
© C. R. Scotese 1997
About these maps
South China
Arabia
North China
Australia
India
Antarctica
PANTHALASSIC OCEAN
South
Africa
Alaska
Congo
PANAFRICAN
OCEAN
Siberia
Laurentia
West Africa
RODINIA
Ancient Landmass
Greenland
Modern Landmass
Florida
Amazonia
Scandinavia
Grenville Province
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge

**Hlavní geologické a biologické události v archaiku a proterozoiku.**
**(upraveno dle různých pramenů)**



# Regional occurrences


Greenland shield
Canadian shield
Baltic shield
Caledonian Belt
Urals
Alps
Appalachians
Himalaya Mountains
Indian shield
African shield
Brazilian shield
Andes Mountains
Australian shield
Great Dividing Range
Key
Continental shield
Belts of folded strata

0 250 500 mi
0 250 500 750 km
ATLANTIC OCEAN
1,000
200
NORTH SEA
BALTIC SHIELD
BALTIC SEA
RUSSIAN PLATFORM
URAL MTS.
PYRENEES
ALPINE SYSTEM
CAUCASUS MTS.
CASPIAN SEA
MEDITERRANEAN SEA
©1998, Encyclopædia Britannica, Inc.
Alpine
Hercynian
Caledonian
Precambrian
OROGENIC BELTS
Salt domes
Active volcanism
Shield boundaries
Structural trends
Faults
Tectonic sutures
Depth contours in metres

# Východoevropský kraton se člení na

Fennoscandii – tvořena baltickým štítem a přilehlou platformou

Sarmatii

Volžsko.-uralskou oblast

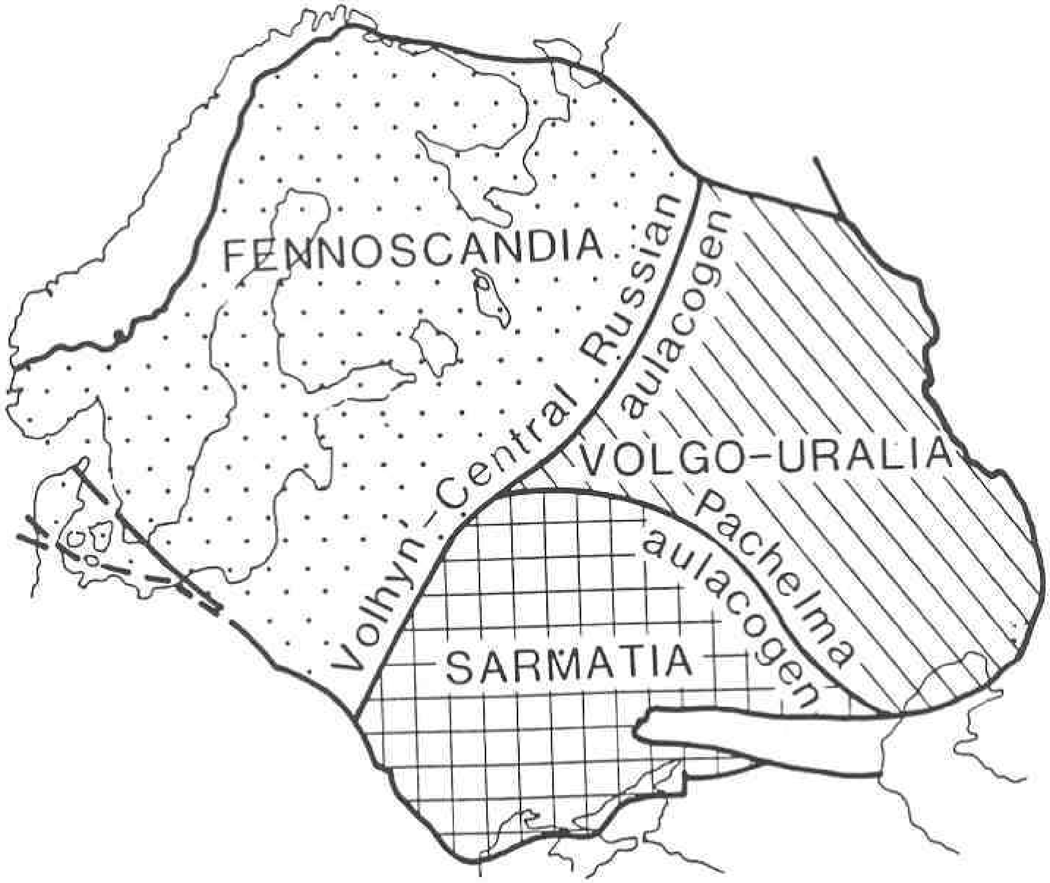



Fig. 2 Crustal segments of the East European Craton seperated by Paleozoic rifts. Here, Fennoscandia applies to the Baltic Shield and its buried equivalent [Gorbatsheev, 1993 #6].

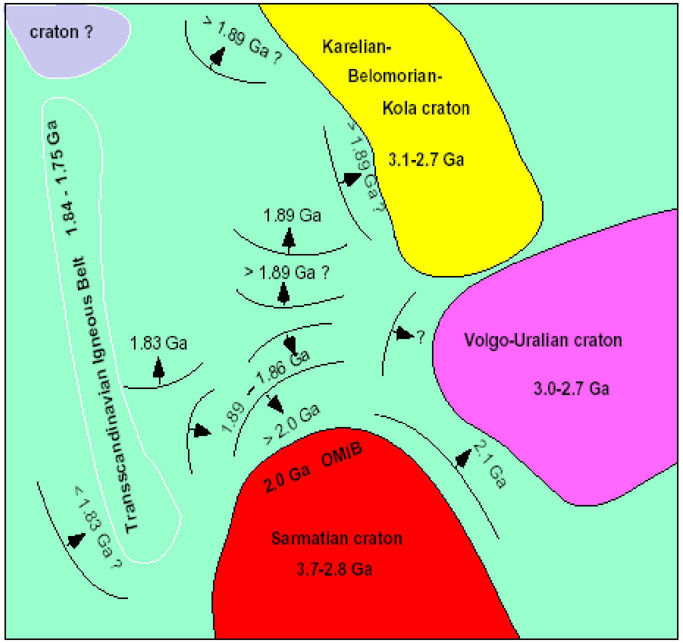
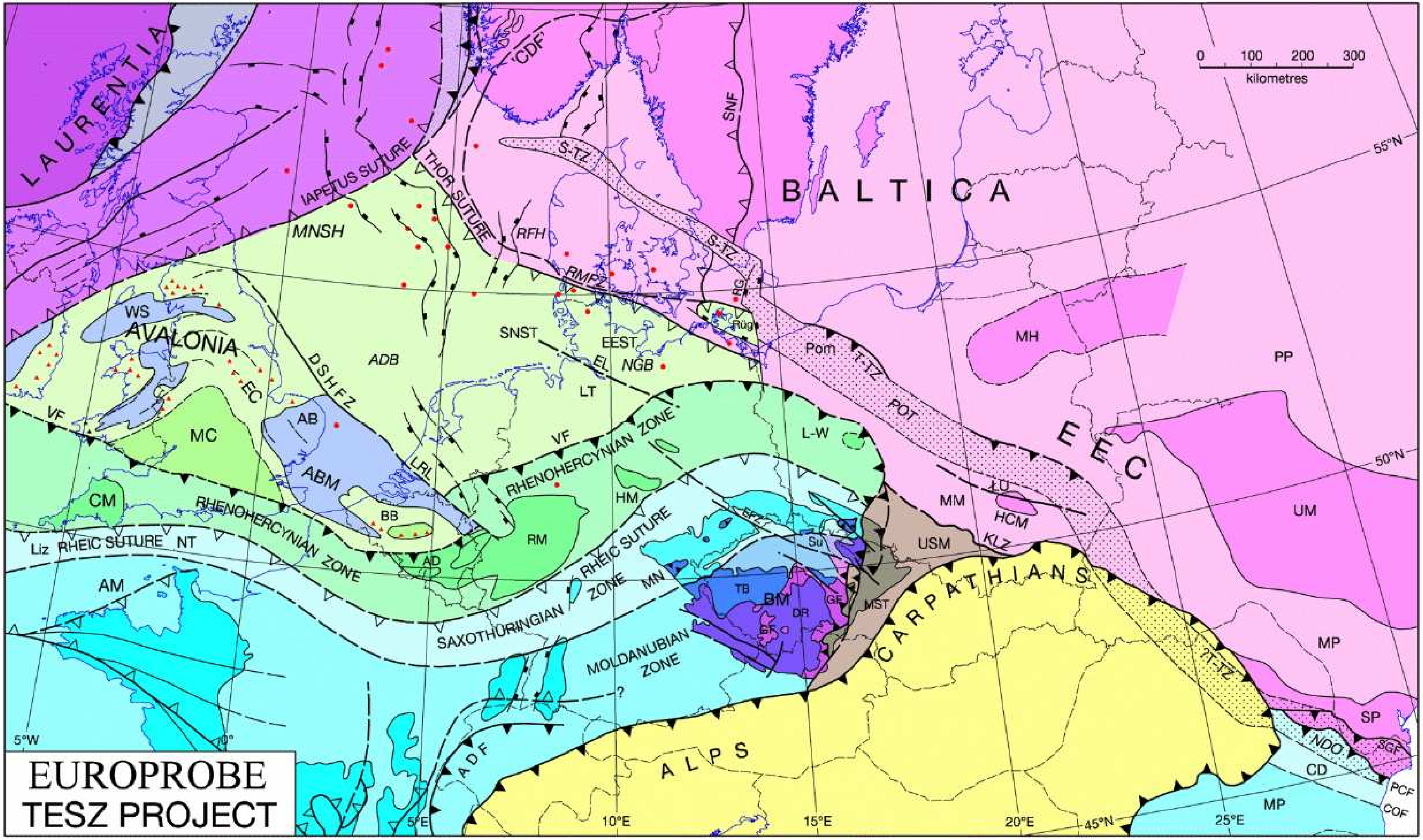



*Figure 7.3: Sketch showing the axes of Svecofennian magmatic arcs and the times of Palaeoproterozoic accretion in the western part of the East-European Craton.*


LAURENTIA
BALTICA
AVALONIA
EEC
IAPETUS SUTURE
THOR SUTURE
CDF
S-TZ
SNF
MNSH
RFH
RMPZ
RG
Rüg
SNST
EEST
EL
NGB
ADB
DSHFZ
WS
EC
VF
MC
AB
ABM
LRL
BB
CM
LT
L-W
RHENOHERCYNIAN ZONE
RHEIC SUTURE
Liz
NT
AM
AD
RM
HM
SAXOTHURINGIAN ZONE
MN
MOLDANUBIAN ZONE
EFZ
Su
TB
BM
DR
GF
MST
USM
MM
LU
HCM
KLZ
Pom
T-TZ
POT
MH
PP
UM
MP
SP
NDO
SGF
CD
PCF
COF
CARPATHIANS
ALPS
ADF
?T-TZ
0
100
200
300
kilometres
55°N
50°N
45°N
5°W
0°
5°E
10°E
15°E
20°E
25°E
EUROPROBE
TESZ PROJECT

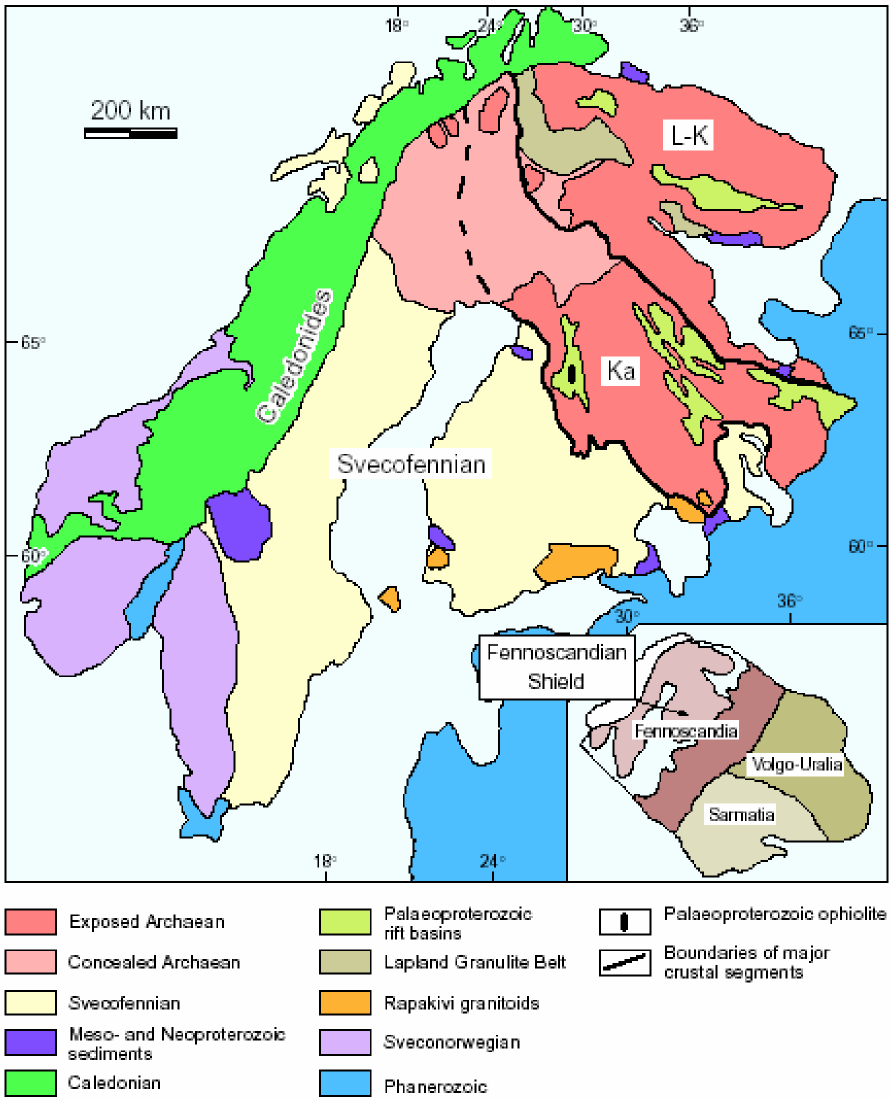



*Figure 5.1: Simplified geological map of the Baltic Shield and surroundings (modified from Boyd et al., 1985 and Öhlander et al., in Gorbatschev, 1993; inset showing the subdivision of the East-European Craton from Gorbatschev and Bogdanova, in Gorbatschev, 1993). Generalized tectonic boundaries between the Lapland-Kola Orogen (L-K) and the Karelian Province (Ka) and between the latter and the Svecofennian Orogen are shown as heavy lines, dashed to indicate greater uncertainty. Proterozoic rift basins are omitted in the region labelled 'concealed Archaean'.*

| | | |
|---|---|---|
| Saamská orogeneze | cca 3 Ga | kolize svekobaltského(SVK) a karelského kontinentu(KK) |
| Kuhmo-belomorská orogeneze | 2,8 Ga | Wilsonův cyklus mezi SVK a KK |

| | | |
|---|---|---|
| Sfekobaltská orogeneze | 2,2 Ga | další Wilsonův cyklus mezi SVK a KK |
| Sfekofenská orogeneze | 2,0 Ga | další Wilsonův cyklus mezi SVK a KK |
| Gotská orogeneze | 1,7-1,5 | ?? Akrece oblouků, mikrokontinentu, Amazonie |
| Sfekonorvegská orogeneze | 1,0 | kolize s Laurentii |

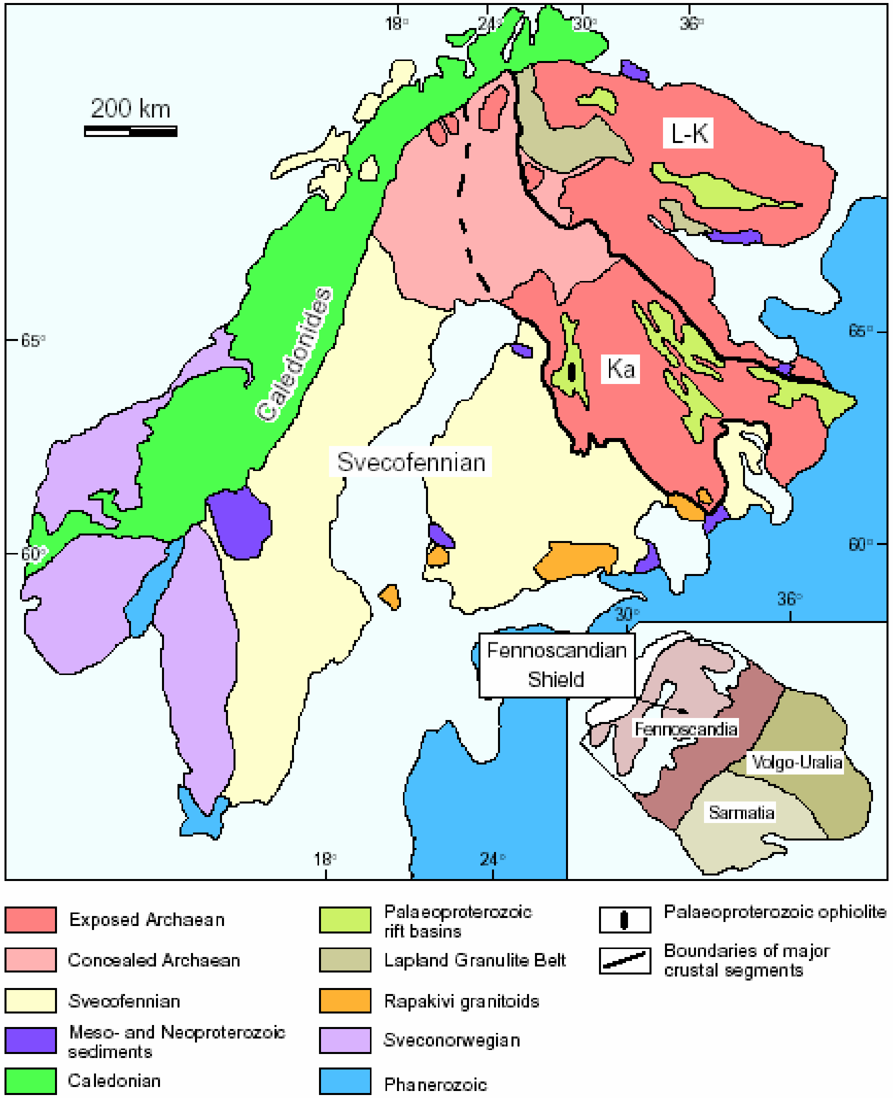



*Figure 5.1: Simplified geological map of the Baltic Shield and surroundings (modified from Boyd et al., 1985 and Öhlander et al., in Gorbatschev, 1993; inset showing the subdivision of the East-European Craton from Gorbatschev and Bogdanova, in Gorbatschev, 1993). Generalized tectonic boundaries between the Lapland-Kola Orogen (L-K) and the Karelian Province (Ka) and between the latter and the Svecofennian Orogen are shown as heavy lines, dashed to indicate greater uncertainty. Proterozoic rift basins are omitted in the region labelled 'concealed Archaean'.*

# Český masiv

Představuje hrásťovou strukturu variského orogenu ovlivněnou alpínskou orogenezí. Období proterozoika a paleozoika formovaly území Českého masívu dvě orogeneze, někdy také označované jako geotektonické cykly:

•**kadomský**

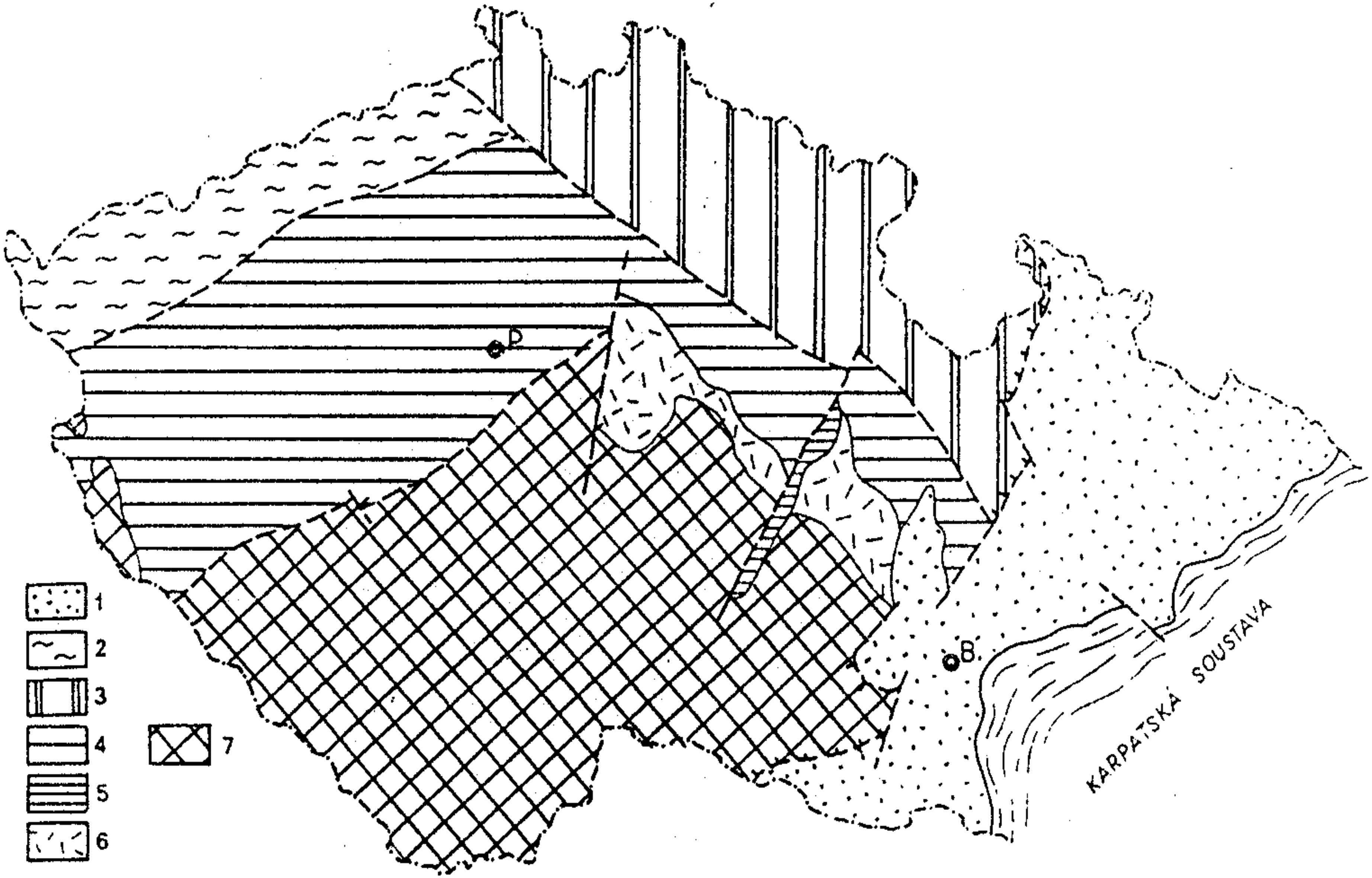
v podstatě vytvořil původní stavbu Českého masívu, dnes jsou produkty kadomské orogeneze (obr. 41) zachovány nejlépe v moravsko-slezské (např. brněnský masív) a lugické oblasti (lužický pluton)

•**variský (někdy označovaný jako hercynský)**

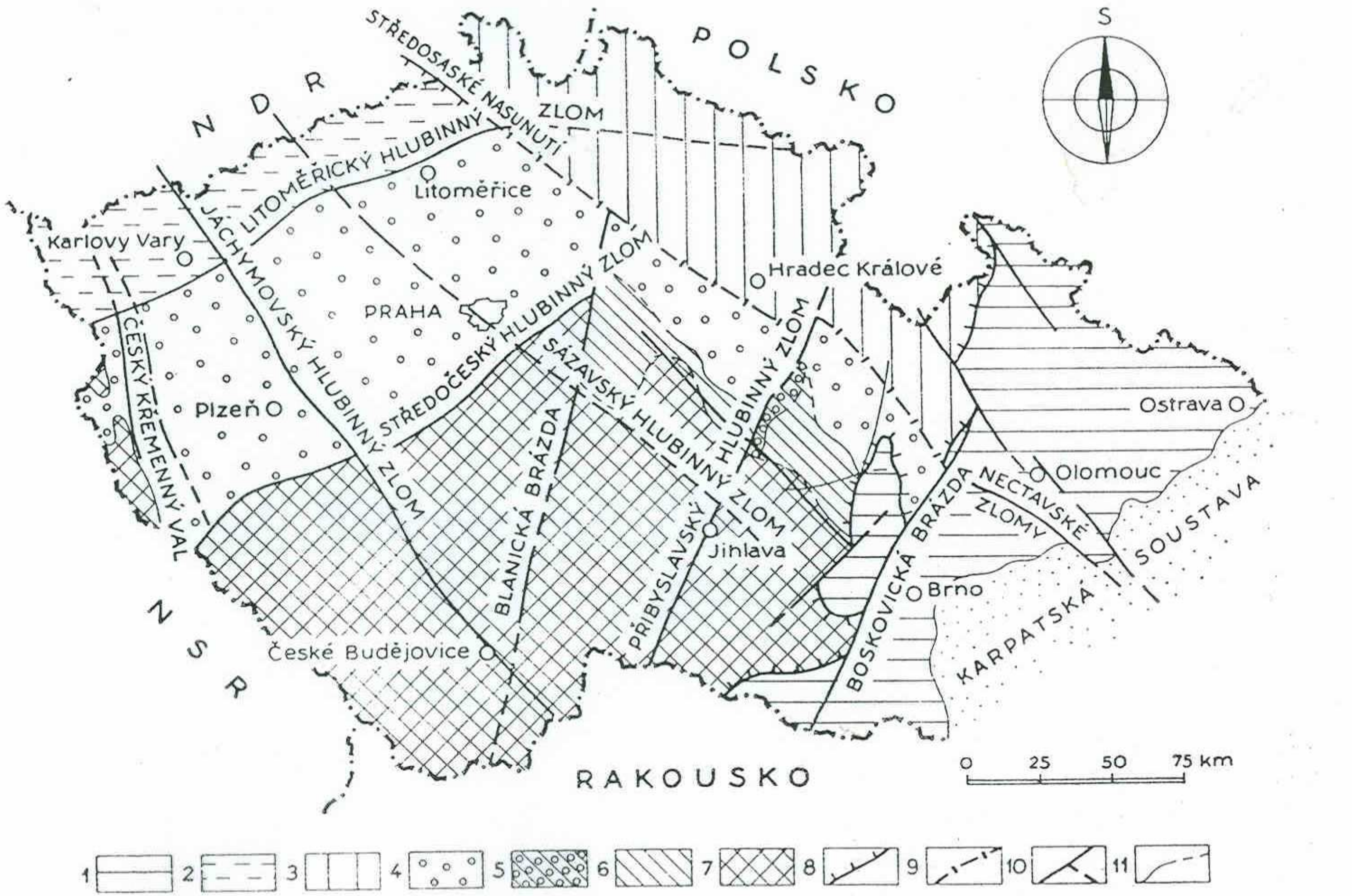
výrazně přetvořil především centrum Českého masívu - spojen s metamorfními pochody v celé oblasti a vznikem velkých těles vyvřelých hlubinných hornin, např. centrální masív moldanubika a středočeský pluton (obr. 42).

Poslední orogeneze **alpínská** Český masív jen ovlivnila, ale nepřetvořila. Způsobila tektonické pohyby bloků podél hlubinných zlomů, které se označují jako ***saxonská tektonika***.

Vývoj Českého masívu je dělen na dvě etapy:
•**předplatformní,** tzn. do úplného skončení variského geotektonického cyklu (konec prvohor). K předplatformním krystalinickým jednotkám a zvrásněnému paleozoiku se řadí:
•**moldanubická oblast**
•**kutnohorsko-svratecká oblast**
•**středočeská oblast**
•**krušnohorská oblast**
•**lugická oblast**
•**moravsko-slezská oblast**
Zvláštní postavení mají **sedimenty limnického permokarbonu**, které tvoří přechod mezi předplatformním a platformním vývojem Českého masívu (v počátcích jejich sedimentace ještě doznívaly poslední pohyby patřící do variského geotektonického cyklu).
•**platformní -** celá oblast je stabilní a postupně ji překrývají pouze další komplexy sedimentárních hornin. K platformním jednotkám patří**:**
•**jura**
•**křída**
•**terciér**
•**kvartér**



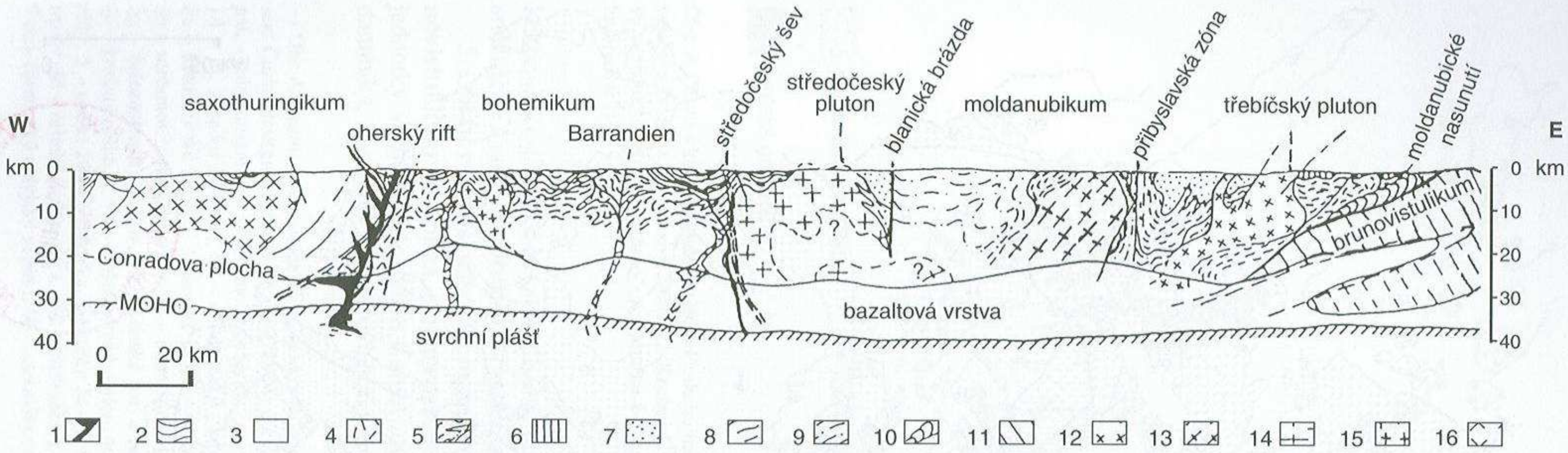

Bloková stavba Českého masívu. Oblasti: 1 - moravsko-slezská, 2 - krušnohorská, 3 - lugická, 4 - středočeská, 5 - hlinská zóna, 6 - kutnohorsko-svratecká, 7 - moldanubická.




1 Základní rozdělení Českého masívu na oblasti na území ČSSR a nomenklatura používaná dále v textu (orig.); 1 moravskoslezská oblast, 2 krušnohorská oblast, 3 lugická oblast, 4 středočeská oblast, 5 hlinská zóna středočeské oblasti, 6 kutnohorsko-svratecká oblast, 7 moldanubická oblast, 8 moravskoslezské zlomové pásmo, 9 jižní okraj lugické oblasti, 10 základní zlomy důležité pro vymezení oblastí, 11 hranice oblastí

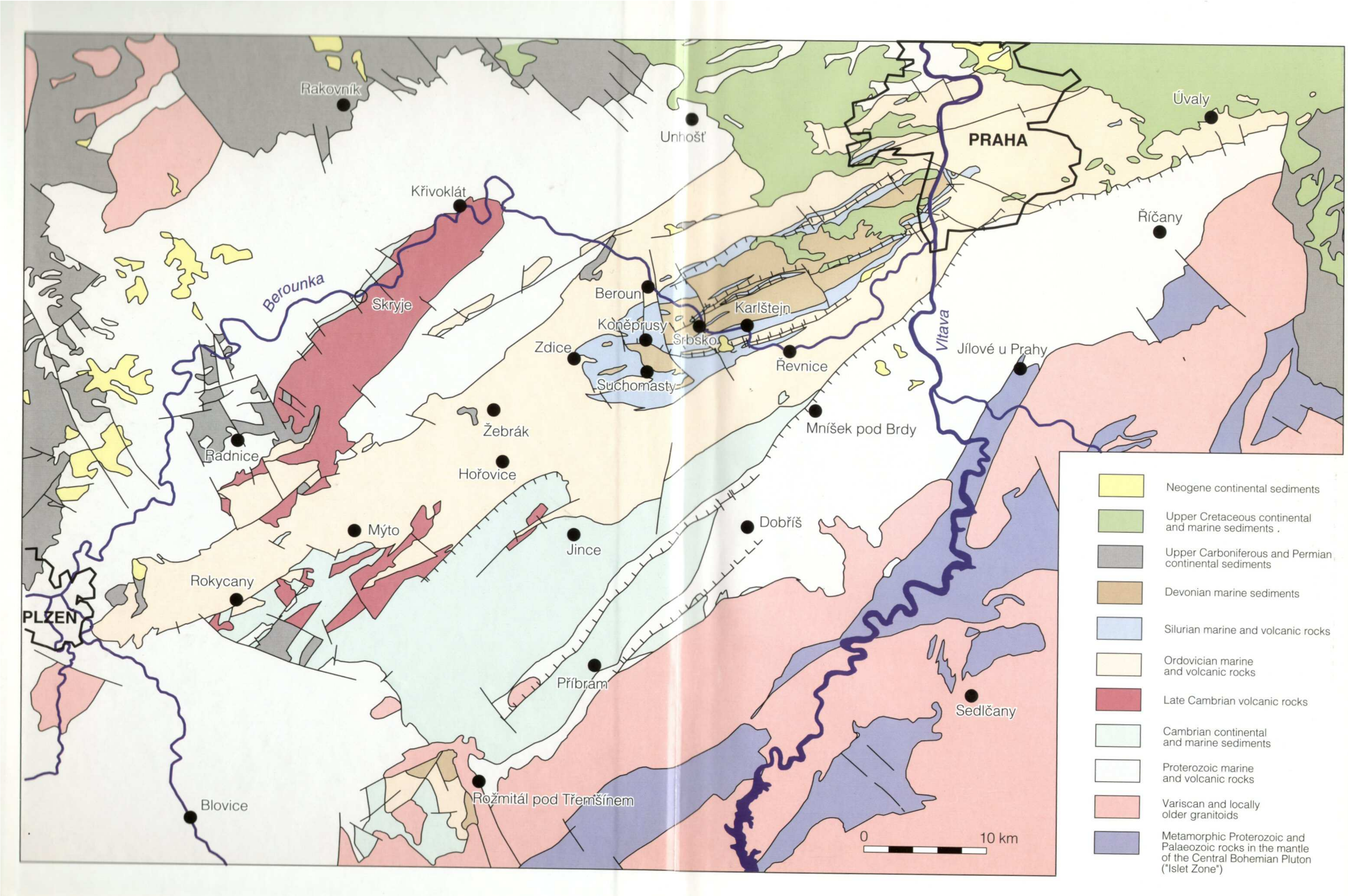
# Cadomian orogenic cycle

# Proterozoic of Tepla-Barrandian region

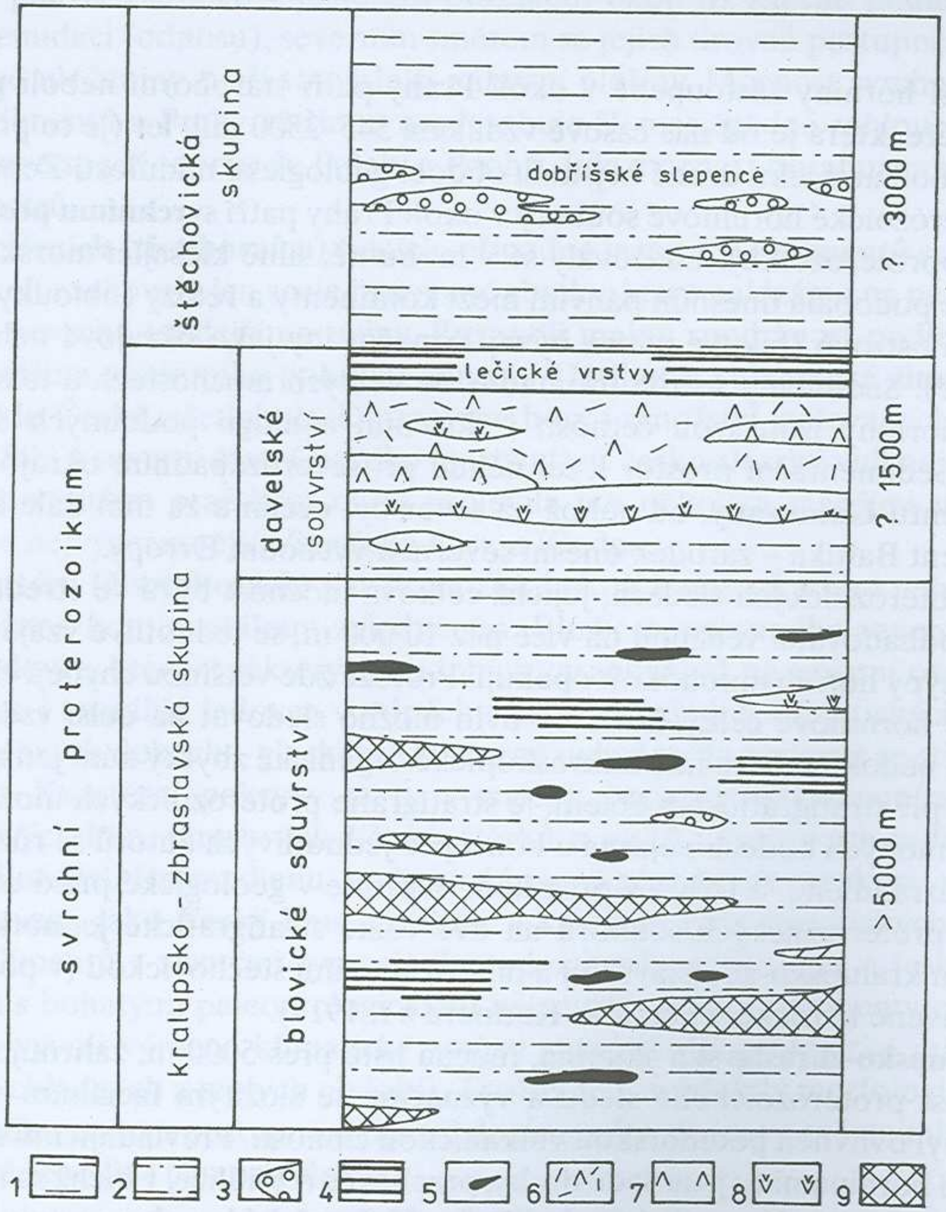



Obr. 5. Hypotetický profil Českým masivem od Saska po západní Moravu (podle Z. Mísaře 1992, průběh Conradovy a Mohorovičičovy plochy podle M. Suka – J. Weisse 1981, zjednodušeno). 1 – neovulkanity; 2–5 – proterozoické a paleozoické sedimenty a vulkanity; 6–9 – moldanubikum (6 – gföhlská jednotka, 7, 8 – pestrá skupina, 9 – jednotvárná skupina); 10 – moravikum; 11 – brunovistulikum; 12–16 – převážně variské granitoidy.

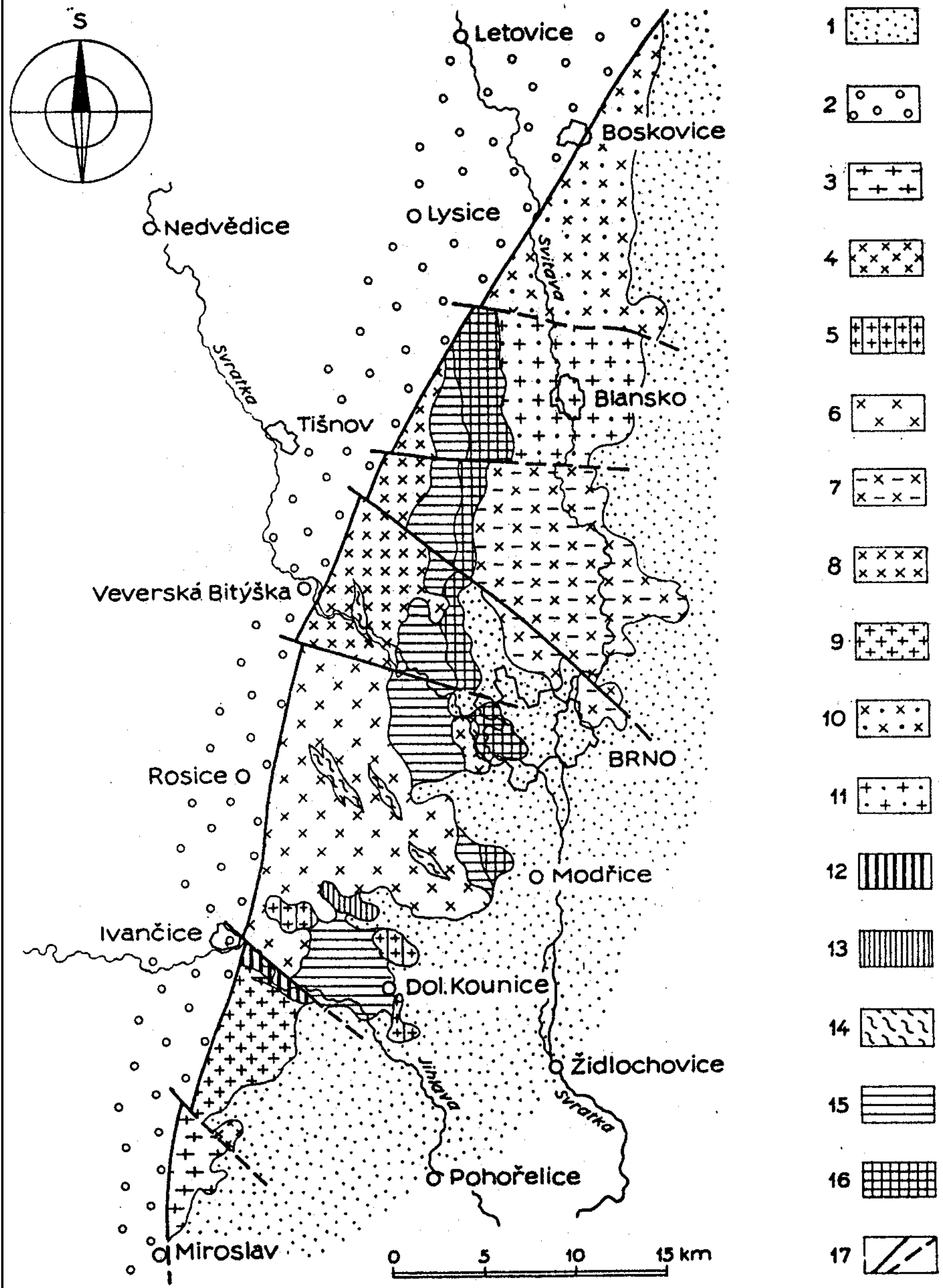
*Pozn. k obr. 5.* Dosavadní koncepce o hlubší stavbě Českého masivu a stylu jeho tektonické stavby jsou velmi rozdílné. Zatím co celková shoda panuje o hloubce Mohorovičičovy diskontinuity (MOHO), tj. rozhraní, které odděluje zemskou kůru od svrchního pláště Země pod Českým masivem mezi 30–40 km, význam tzv. Conradovy diskontinuity novější výzkumy nepotvrdily. Značnou dávkou subjektivity i vlivem jednotlivých geologických škol jsou pak poznamenány představy o stavbě mělčích částí zemské kůry, zejména krystalinických celků. Zde proti sobě stojí hypotézy zdůrazňující převahu klenbových a vrásových struktur (např. obr. 5), blokových staveb a koncepce dalekosáhlých plochých násunů a příkrovů směřujících z centra masivu na periferii (např. Matte et al. 1991). Mezi jednotlivými směry pak existuje řada kompromisních variant. Veškeré celkové geologické řezy Českým masivem je proto třeba hodnotit v současném stavu výzkumů jako značně hypotetické.



Rakovník
Unhošť
PRAHA
Úvaly
Křivoklát
Říčany
Berounka
Skryje
Beroun
Karlštejn
Koněprusy
Srbsko
Zdice
Suchomasty
Řevnice
Vltava
Jílové u Prahy
Žebrák
Mníšek pod Brdy
Radnice
Hořovice
Mýto
Dobříš
Jince
Rokycany
PLZEN
Příbram
Sedlčany
Rožmitál pod Třemšínem
Blovice
0
10 km
Neogene continental sediments
Upper Cretaceous continental and marine sediments .
Upper Carboniferous and Permian continental sediments
Devonian marine sediments
Silurian marine and volcanic rocks
Ordovician marine and volcanic rocks
Late Cambrian volcanic rocks
Cambrian continental and marine sediments
Proterozoic marine and volcanic rocks
Variscan and locally older granitoids
Metamorphic Proterozoic and Palaeozoic rocks in the mantle of the Central Bohemian Pluton ("Islet Zone")




*Obr. 4.* Stratigrafické schéma proterozoika Barrandienu (podle J. Maška 1982).
1 – střídání prachovců a jílových břidlic; 2 – střídání prachovců, drob a jílových břidlic; 3 – s
ce; 4 – černé břidlice; 5 – buližníky; 6 – pyroklastika kyselých a intermediálních vulkanitů;
selé vulkanity; 8 – intermediální vulkanity; 9 – bazické vulkanity („spility“).




**•Brunovistulikum**

Spolu s moravikem a silesikem součást moravskoslezské oblasti.

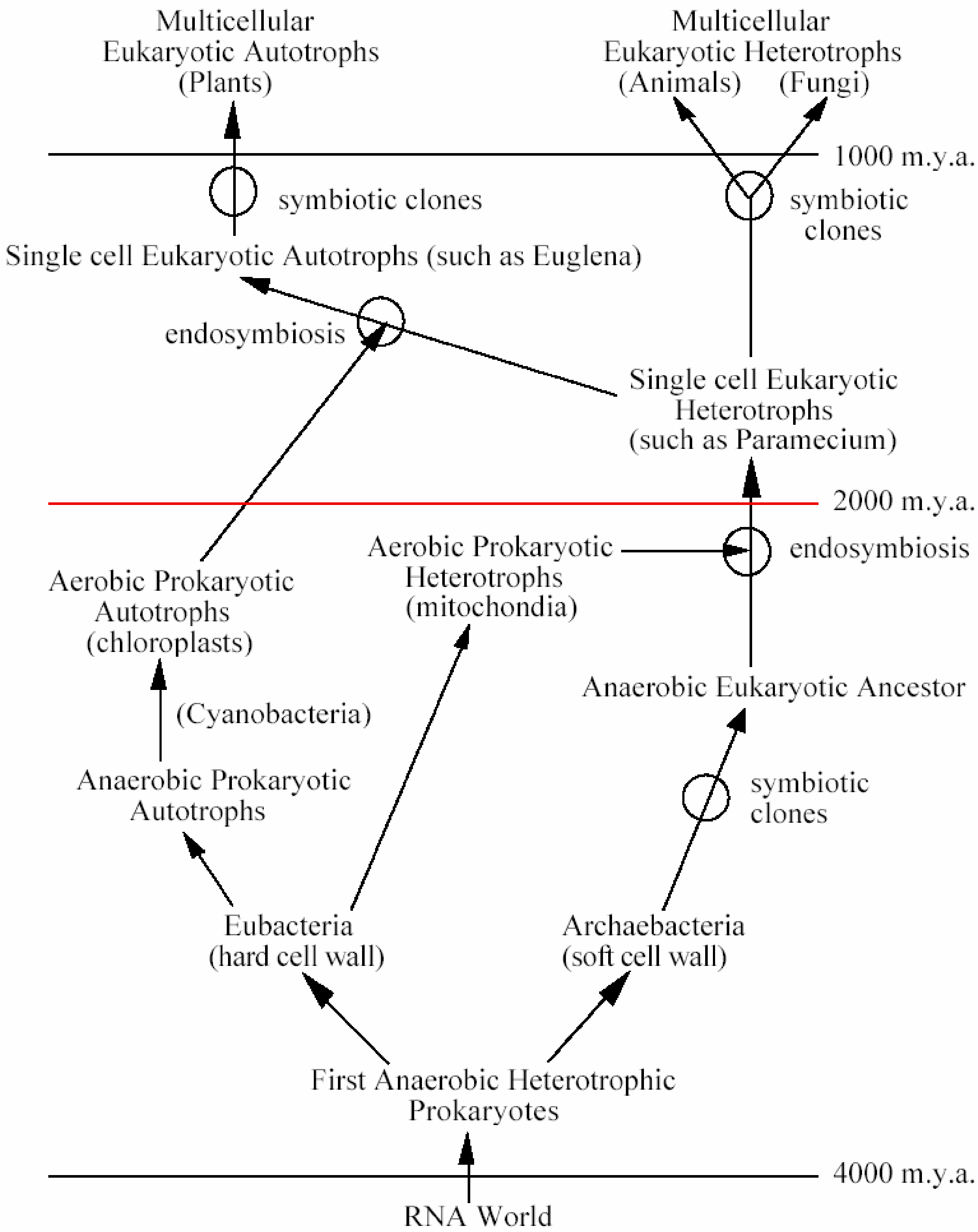
Je to velká krystalinická jednotka tvořená převážně hlubinnými magmatickými horninami a částečně metamorfity, která se nachází v podloží téměř celé Moravy a Slezska. Z větší části je zakryta sedimentárními horninami. Na východ se brunovistulikum noří pod karpatské příkrovy a jeho východní okraj není znám. Na povrch vystupuje jako brněnský masív a drobná tělesa granitoidů v okolí Olomouce.

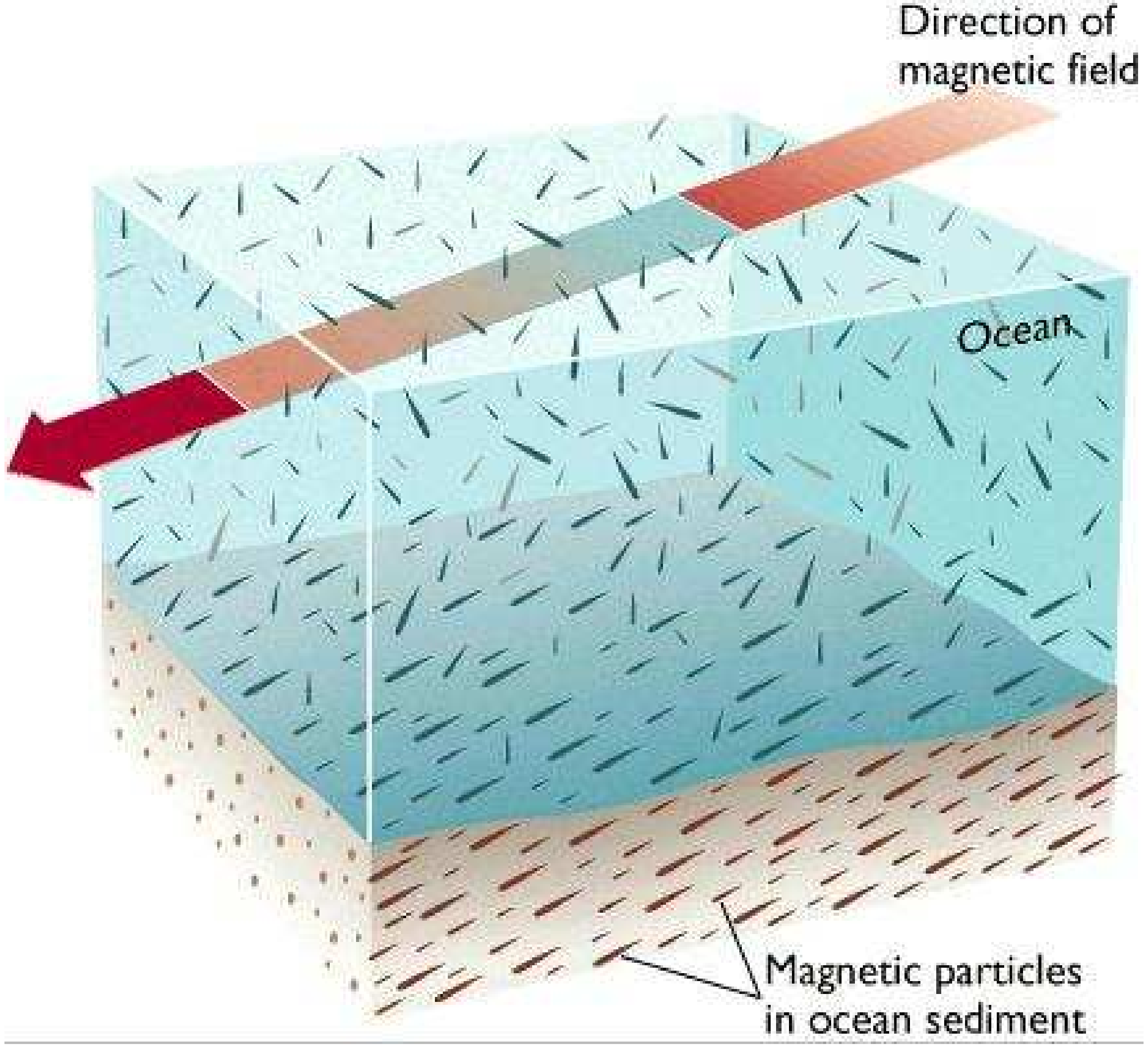
# Late Proterozoic "mobile belts" (orogens)

- a supercontinent formed in the Neoproterozoic (Rodinia)
- pan-African orogeny (ca. 950-450 Ma)
  - very long-lasting, certainly diachronous, maybe multiple events, many areas not well dated
  - clear evidence for modern-style plate tectonics
  - ophiolites, calc-alkaline batholiths, major horizontal displacements, flysch and molasse
  - also much granulite facies metamorphism (extensive uplift after continental collision?)
- Pan-African is best developed in East Africa
  - also includes West African orogens (Dahomeyan-Pharusian)
  - Braziliano (Brazil)
  - Cadomian (Europe)
  - Avalonian?

Beginning 2.3 Bya, iron minerals in soils on land began to be oxidized (rusted) during weathering.  Soils turned red.  The atmosphere must have contained $O_2$ for this to occur.

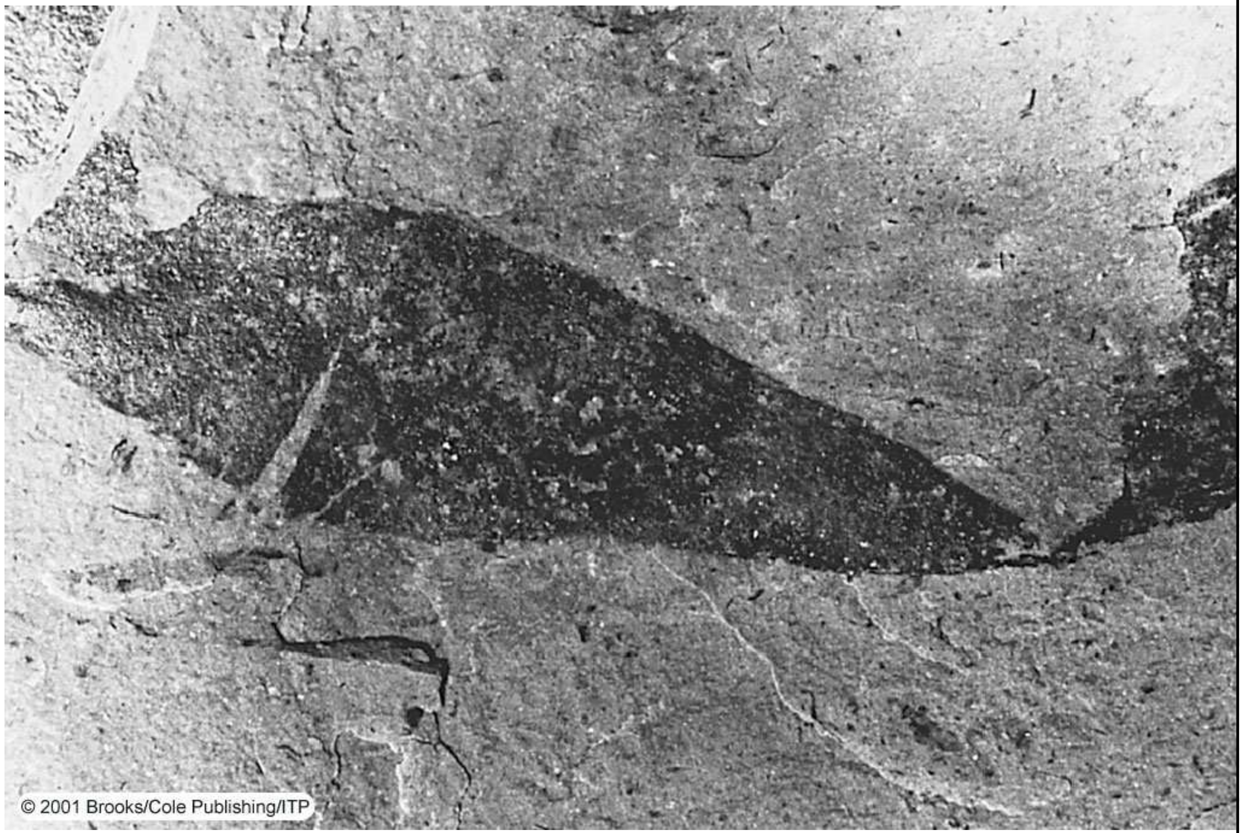
**Endosymbiosis & Eukaryotic Cells**




Direction of
magnetic field
Ocean
Magnetic particles
in ocean sediment

# Next step:

- 1.4 Ga multicellular algae (?) Montana



- The evolutionary links between unicellular and multicellular organisms were probably colonial protists

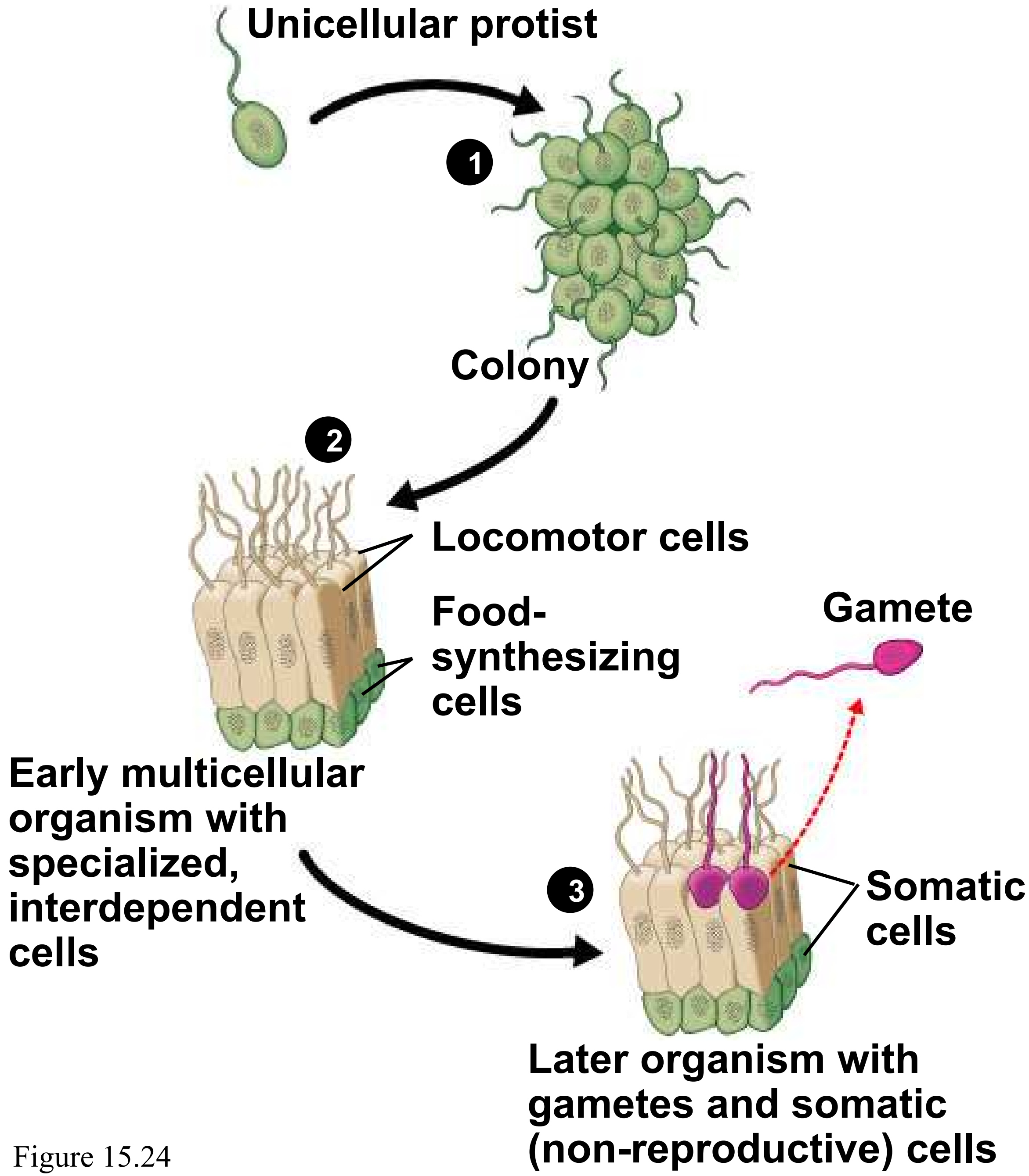



Figure 15.24

# Diversification of Multicellular Algae

- Early Multicellular EK
- Allowed for larger size and cell specialization
- Oldest multicellular organism (Fig 4.9)
  - Red Algea about 1.0 Ga

# Cambrian-Precambrian Transition