Palaeontology

Lecture 5

Precambrian life – Ediacara fauna

Palaeozoic life

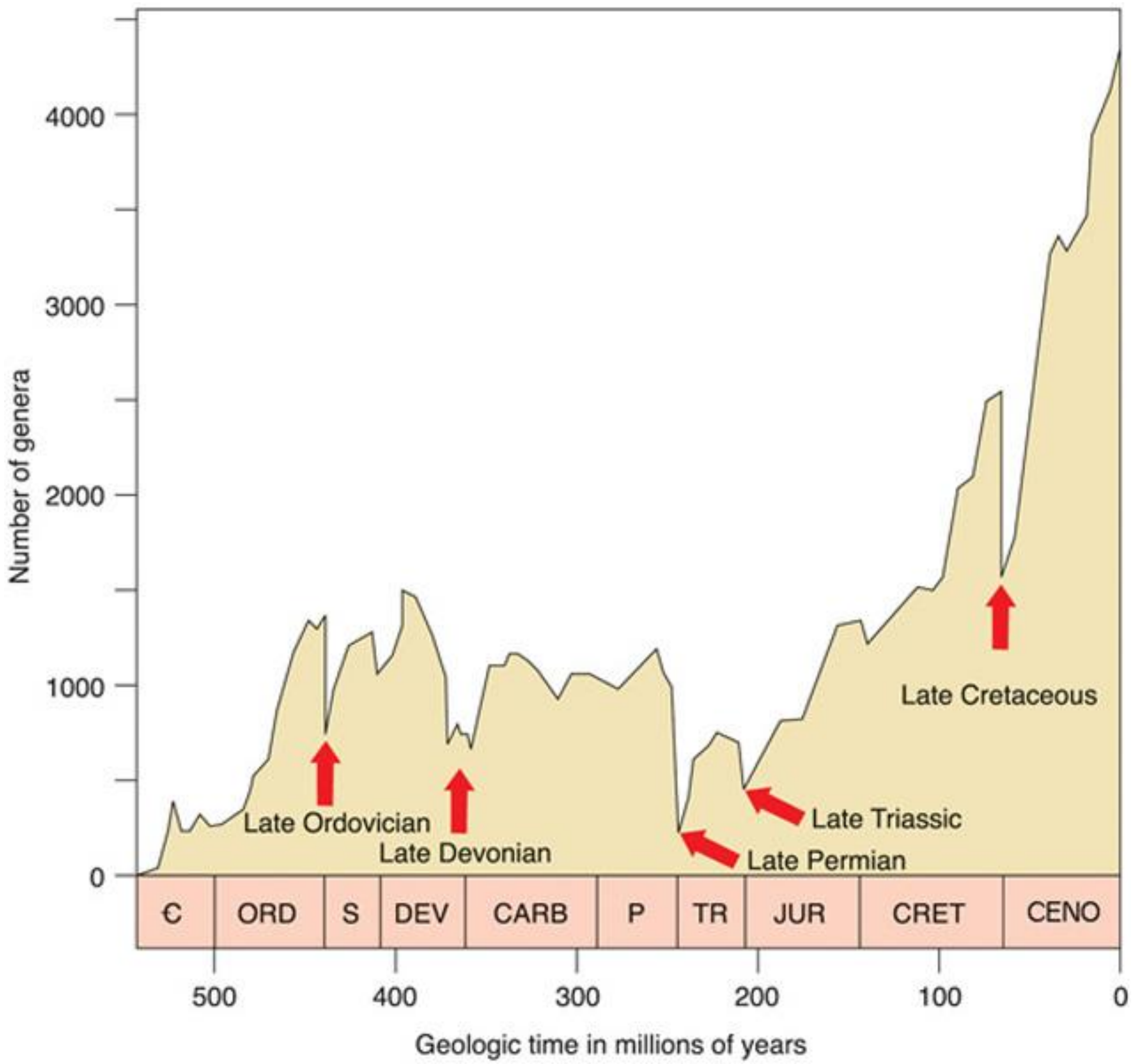
Extinctions

- Phyletic extinction or pseudo-extinction
  One species is lost as it evolves into another
- Ultimate extinction
  The total population of a species is lost without a descendant
- Mass extinction
  Lazarus taxa: Organisms that seem to disappear for a long time from the fossil record and appear again

Mass extinctions

- Occur Worldwide
- Both in the sea and on land
- Involve a large number of different organisms

Mass extinctions



1. L. Ordovician
2. L. Devonian
3. L. Permian
4. L. Triassic
5. L. Cretaceous

What caused extinctions?

- Several hypotheses trying to explain the cause of these losses:
- An external or extra-terrestrial catastrophic cause triggers the incident.
- Events occurring on the earth without external influences.

external or extra-terrestrial catastrophic causes

- Impact with asteroids?
- Impact with Comet?
- Cosmic radiation from a neighboring supernova?

Endoterrestrial factors

- Volcanic eruptions emit large amounts of ash and gases into the atmosphere that lead to a drop in temperature. They emit large amounts of sulfur dioxide, which becomes sulfuric acid in the atmosphere and acid rain, resulting in altering the alkalinity in the oceans, putting plankton (the food chain base) into lethal pressure and indirectly affecting all organisms that depend on it for food

Endoterrestrial factors

- Climate change related to the change of land - sea distribution
- Glaciers and the decline of continental seas related with the drop of sea level
- Methane emission
- Disease? Viruses?
- All this together !!

Other Proterozoic megafossils

- Second oldest type of megafossil assemblage, carbonaceous compressions of spherical *Chuaria,* sausage-shaped *Tawuia* and balloon-like *Longfengshania*
- Worldwide distribution in late Proterozoic sediments
- Abundant occurrences in north-west Canada and north-eastern China
- Time range from 1000-700 million years

Chuaria

Tawuia

- Of particular interest are the carbonaceous compressions of megascopic worm-like organisms abundant in the *Chuaria-Tawuia* assemblage from the Huainan District, Eastern China. *Sinosabellites* (850- 800 ma) and *Pararenicola* and *Protoarenicola* from Jiuliqiao Formation (740 ma) appear quite similar to worms with elongate, cylindrical and flexible bodies. Even differentiated front end (head?)
- Probably primitive pre-Ediacaran metazoans

The first Metazoa

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

Proterozoic metazoan faunas

- The Ediacara Fauna - The first imprints of animals with soft parts were found from Sprigg in the Ediacara Hills in South Australia in the 1940s.
- Eggs and metazoan Embryos in the Upper Neoproterozoic Doushantuo Formation in South China.
- Trace fossils of burrowing metazoan in rocks younger than the Varangian glacial period.
- Animal fauna with tiny shells

Ediacaran metazoans

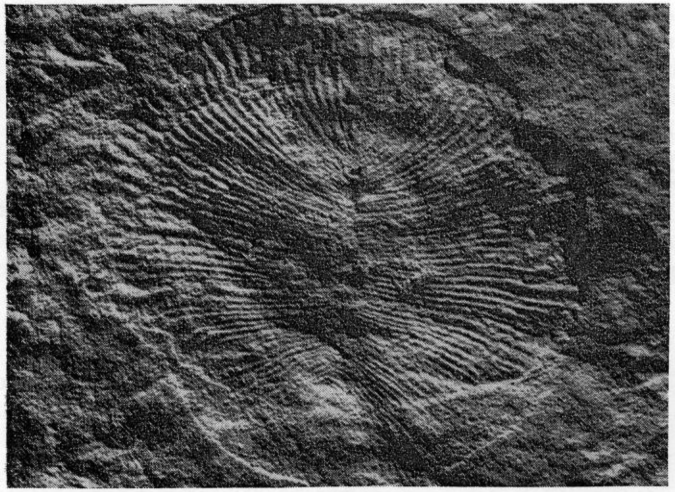
- The fossil record of earliest animals obvious with the Ediacaran type body fossils and simple trace fossils from the end of the Proterozoic (590- 550 ma)
- Found in the 1940s by Sprigg at the Ediacara hills of South Australia
- Today Ediacara type animals are known from more than 20 regions around the world (Russia, England, Namibia, Canada)
- Most important the assemblage from the White Sea Coast in northern Russia
- Strikingly similar to that of South Australia, sharing main forms including the most distinctive *Dickinsonia* and *Tribrachidium*

Dickinsonia costata

Cyclomedusa

S

- There is no trace of hard parts, basically the fossils consist of impressions of soft bodies
- Their size ranges from 1cm to 1m
- Good preservation of casts due to the absence of scavengers and the lack of bio-turbation
- The majority of the fossils appear to be ancient cnidarians (jelly fishes, sea pens), annelid worms, arthropods and other problematic taxa
- As the oldest known metazoans they can be expected to contain many forms, new and different from any known animal
- Some of them could be ancestral to extant groups, others represent extinct branches (even as high as phylum)



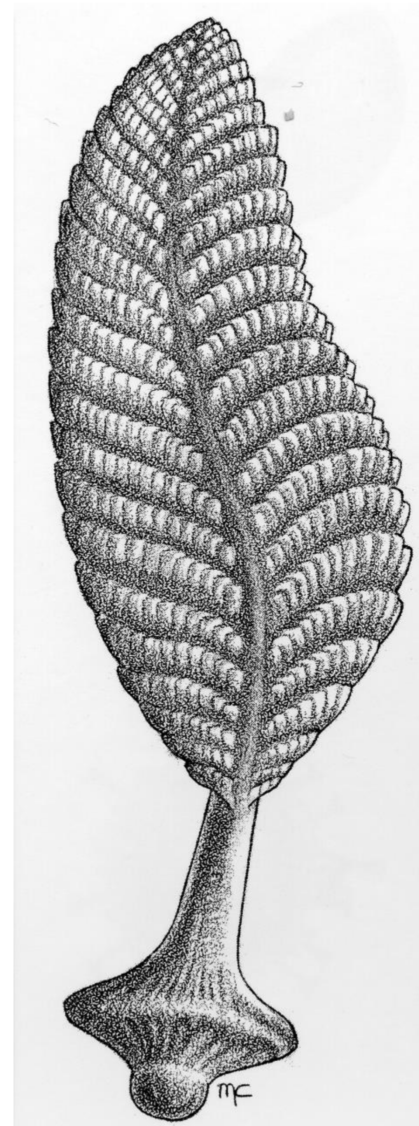
PRE-CAMBRIAN FOSSILS preserved in sandstone are seen in these eight photographs. This is *Dickinsonia costata,* shown actual size.

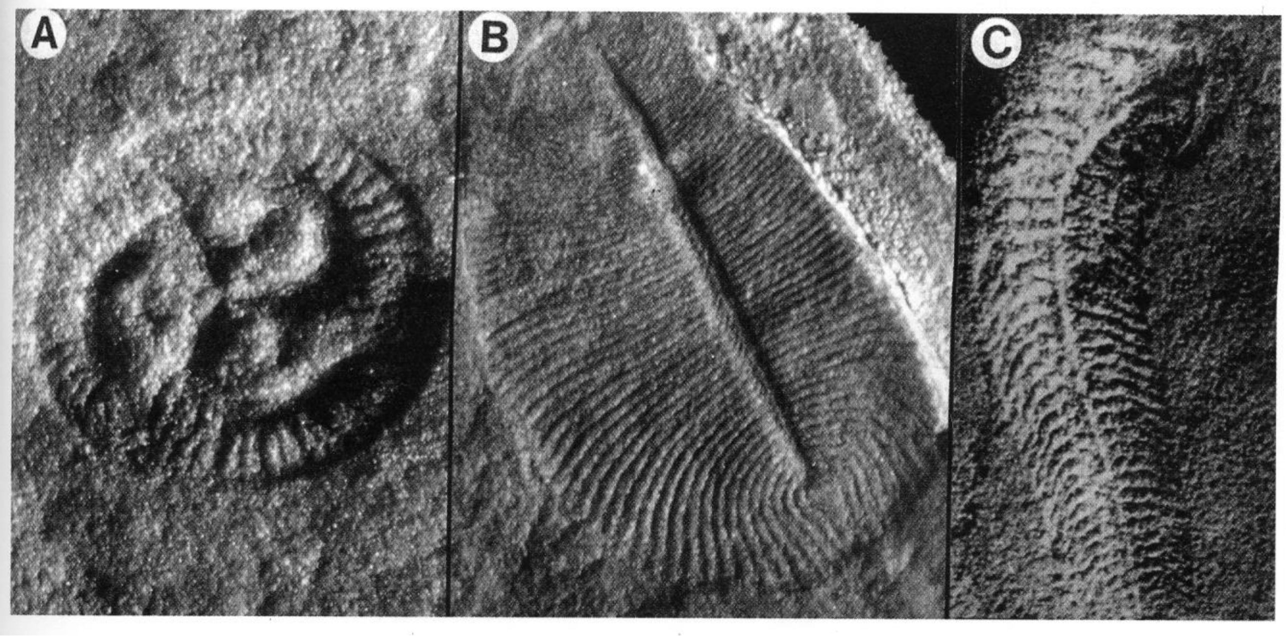
SEGMENTED WORM *Spriggina floundersi,* shown about twice actual size, resembles certain segmented worms living today.

JELLYFISH *Spriggia annulata* is one of the many types of this organism that have been found. The fossil is very slightly enlarged here.

ANOTHER JELLYFISH, *Medusina mawsoni,* is shown nearly three times actual size. Jellyfish were the first fossils found.

- Some species can be compared to living cnidarian groups like the frond-like pennatulaceans (*Charnia, Charniodiscus*) but others are less comparable (the enigmatic *Tribrachidium*)
- In Ediacara type assemblages several kinds of segmented creatures with an apparently highly structural grade. Such representatives are *Dickinsonia* (possibly an annelid worm) and *Springina* (an rudimentary arthropod)
- Recent findings trilobite-like animals and arthropod-made scratch marks seem to confirm the presence of primitive arthropods
- Associated trace fossils seem to have been produced by worm-like infaunal sediment feeders few of which can be related to body fossils. They indicate deep rather than shallow marine environments





Tribrachidium

Dickinsonia

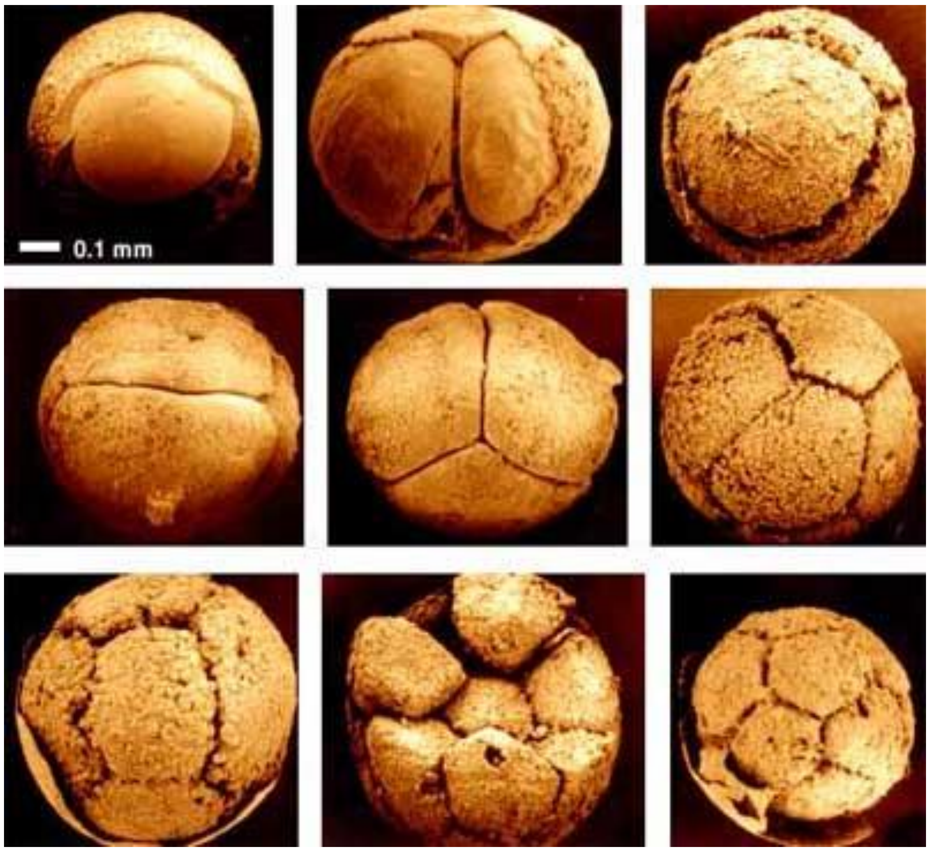
Spriggina

Parvancorina, arthropod

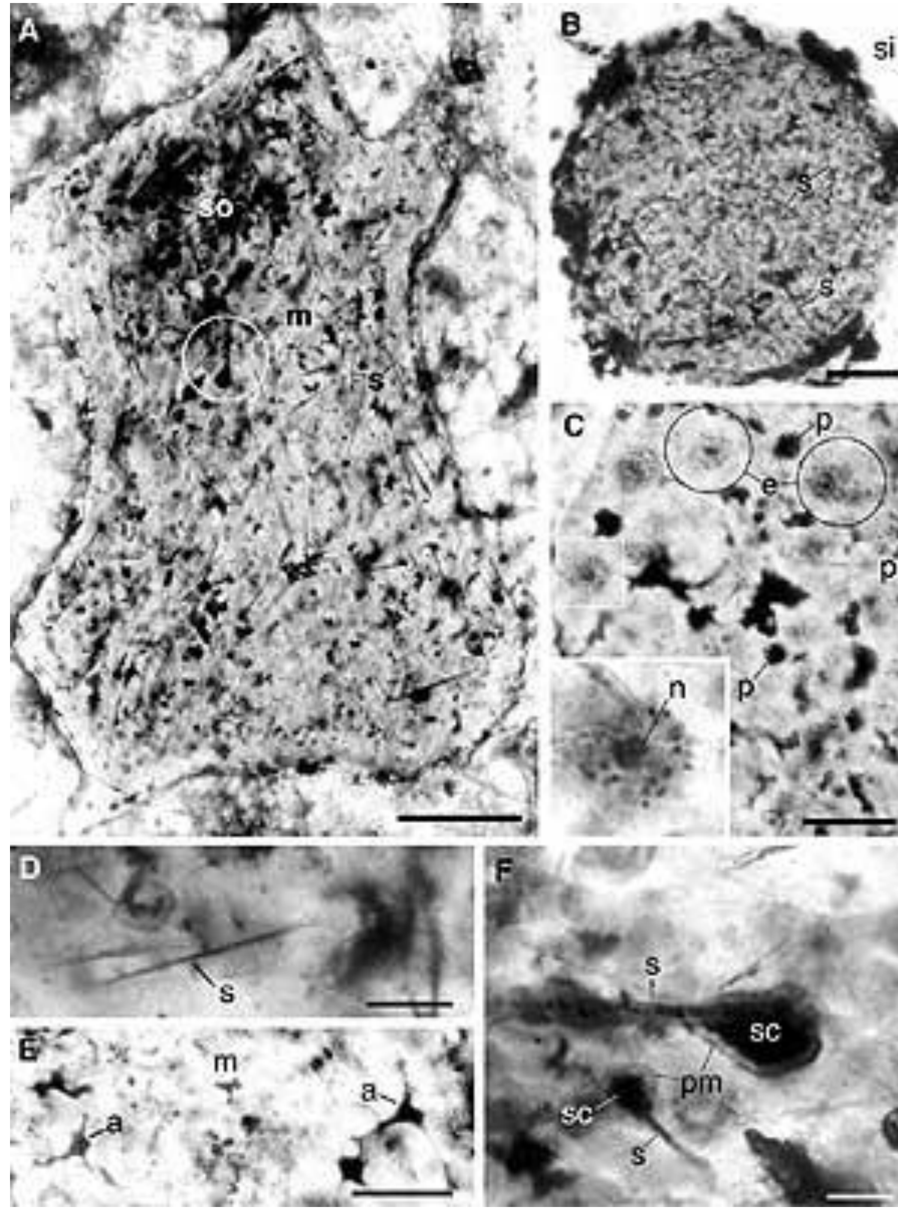
- The absence of pre-Ediacaran animals possibly indicates a very small size and/or delicate structures for survival as body fossils or for the production of trace fossils
- The appearance of a number of worm like organisms indicates that initial metazoan evolution took place before the Ediacaran time
- Composition and preservation of cnidarian dominated assemblages and simple trace fossils reflect adaptations to low oxygen environments
- The environment provided the animals the requirements to live but confined their development (limited oxygen)
- Most creatures lead in well aerated, marine, shallow environments

Ediacara fauna

Doushantuo S. China.



Metazoan embryos



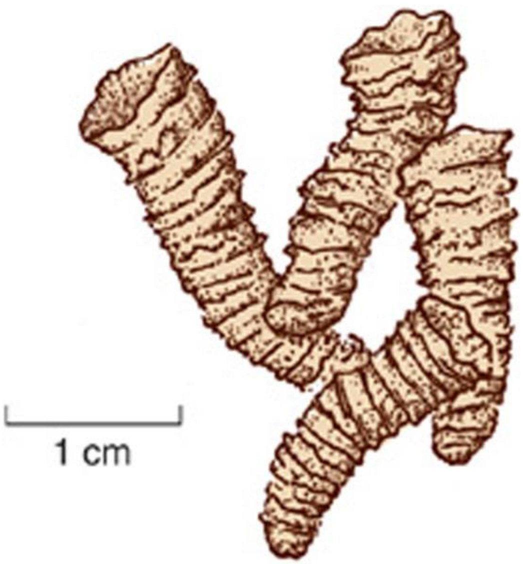
Sponges

Animal fauna with tiny shells
The first hard parts

- Although most Ediacara animals were soft bodied exceptions existed
- Calcareous tubes of *Cloudina* from Namibia and various *Cloudina* like fossils have been found around the world
- Tubular fossils with cone-in-cone structures attributed to periodical external secretions of small worm-like suspension feeders (polychaetes or cnidarian like organisation)
- Global distribution indicates bio-mineralisation, not a local phenomenon. However extensive acquisition of hard skeleton did not appear before the beginning of the Phanerozoic

- At the end of the Proterozoic a series of glaciations took place
- These glaciations could destabilise shallow water communities and decrease the area of distribution and diversity of stromatolites
- The main glacial episode, the Varanger episode (610- 590 ma) was the prominent
- Diverse Ediacaran faunas are restricted stratigraphically to succession above Varanger glaciogenic rocks and below the base of the Cambrian
- The great success of the Cambrian explosion was at the cost of displacement or the extinction of the Ediacaran fauna

Cloudina the first fossil with hard parts



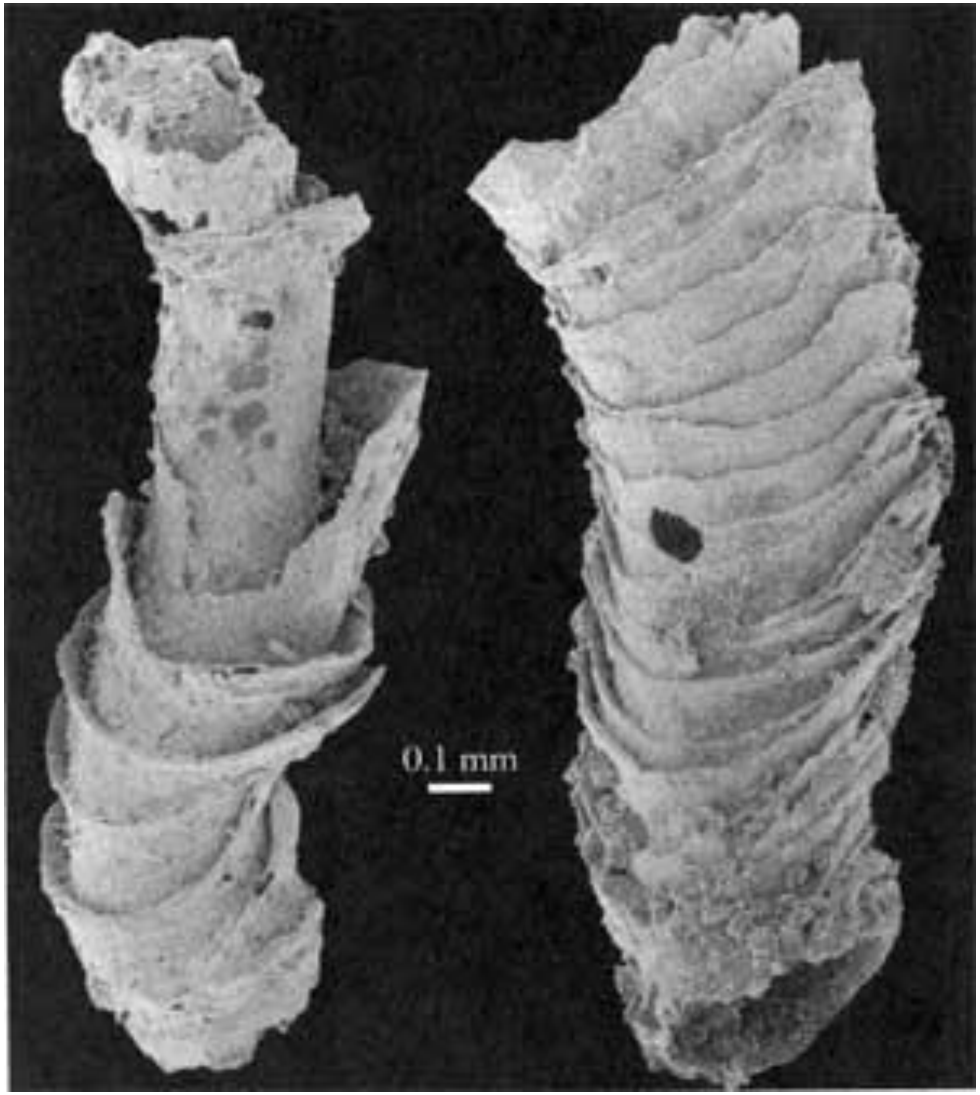
Cloudina, a body with a small tubular shell made of calcium carbonate ($CaCO_3$).

It resembles the structures made by the annelids living in tubes.

The first organism with a $CaCO_3$ shell.

Found in Namibia, Africa.

Cloudina the first fossil with hard parts



Animal fauna with tiny shells
The first hard parts

Other neoproterozoic or Lower Cambrian small fossils with shells include:

- Possible primitive molluscs (halkyerioids)
- Sponge needles,
- Tubular or conical shells
- Tiny tusk like fossils (Ioliths)
- Shells made of calcium phosphate (Tomotoids).

Halkieria

Υόλιθος

Acquisition of hard parts

- Appeared almost instantaneously at the transition from the Proterozoic to the Phanerozoic
- The most visible boundary in the fossil record
- Below the boundary trace fossils of soft bodied animals, above the boundary shells, bones and teeth (the basis of palaeontological research)
- Biomineralization a prerequisite for skeleton formation
- Organisms used materials that were already largely available

Acquisition of hard parts

- However, biomineralized skeletons only a part of the actual life
- In the past, the key innovation that triggered the “explosion of life”
- New findings of numerous soft-tissued animal fossils, indicate that most likely it is just a bias of the fossil record (Early and Middle Cambrian Lagerstatten with soft bodied preservation suggests that mineralized metazoan taxa about 20%)
- Important, but not the decisive event in the history of life
- Except from fossils, hard parts important as they influence the chemistry of waters and sediments and thus the processes on the surface of the earth

The advantages of hard parts

- Except from degradation resistant and thus potentially preserved fossils
- Skeletons provide support and attachment to soft parts and muscles
- Protection against predators and parasites
- Handle food (e.g. teeth)
- Protect vital organs (e.g. filtration chambers, sensitive sensory organs)
- Improve grip on substrate
- Prevent water loss
- Serve as stores for essential elements (Ca, P, Si, etc.)

What are they made of?

- Most skeletons complex composites of organic and inorganic mineral components
- All contain smaller or larger amounts of organic components, not all contain minerals
- Structural organic molecules (e.g. collagen and chitin (proteins) form arthropod cuticles) can form entirely organic skeletons, resistant enough to degradation to become fossilised
- Usually, these molecules are impregnated with minerals forming a composite organic-inorganic material
- Minerals either obtained from the surrounding environment of the animal (agglutinated skeletons), or formed within the tissues of the animal through a process called biomineralization

Biomineralization

- Controlled by the organism itself
- Involves the mediation of nonstructural, soluble, acidic macromolecules
- Occurs through:

  a. concentration of ions into a supersaturated solution

  b. initiating and governing mineral growth

  c. positioning the mineral bodies in the organic components
- Biomineralization is not equivalent to skeleton formation
- Diverse and complex systems employed by organisms
- Current state of knowledge incomplete; now a prolific field of research

Minerals used

- About 60 biominerals are known
- Most of them occur only as intra- or extracellular granules or ather structures without connection to skeletons
- Mainly three types of minerals in skeletons

    a. carbonates ($CaCO_3$, mostly calcite, aragonite and magnecian calcites)

    b. calcium phosphates (mostly apatites and particularly dahlite, $Ca_5(PO_4,CO_3)(OH)_2$)

    c. silicates (opal, a hydrated gel of silica SiO_2)

- “biologically induced mineralization” vs “biologically controlled mineralization
- Even early prokaryotes produced minerals as byproducts of their metabolic processes (sulphur minerals from reducing bacteria)
- However, there are other bacteria (magnetotactic bacteria) that form intracellular iron-sulphur minerals (such as magnetite)
- Thus, earliest biomineralization involved iron and sulphur
- Iron biomineralization long history as evidenced by 2by old bacterial magnetite

- Most skeletal biominerals are Ca salts
- Calcium carbonates and phosphates are also connected with basic life processes
- First biogenic $CaCO_3$ in the Archaean (calcified cyanobacteria); biologically controlled $CaCO_3$ probably started in the Neoproterozoic
- Although P is connected with origin of life, and apatite formation is easy in Ca saturated cells, no undisputable record of biologically controlled apatite until the Cambrian

First skeletal fossils

- Evidence for biologically induced mineralization in the Archaen-Proterozoic, sparse evidence for biologically controlled
- Neoproterozoic eukaryotes produced calcareous and siliceous skeletons; few examples and no metazoans
- First convincing metazoan skeletons at the very end of the Neoproterozoic
- First fossils belong to tubular organisms
- Fossil tubes of various composition, sclerites of Ca-carbonate or Ca-phosphate, mollusc like shells, calcareous and siliceous spicules of sponges, arthopod carapaces, calcareous archaeocyathans, brachiopod shells, tooth-shaped objects, etc. are components of the earliest Cambrian faunas

First skeletal fossils

- *Cloudina* the earliest known metazoan with a mineralised skeleton, tubular fossil with worldwide distribution, late Neoproterozoic
- The ancestors of molluscs instead of a shell spicules that covered their body. Link between the two the halkieriids (slug like animal covered with dorsal scales and spines, as well as with an anterior and a posterior shell plate)
- Phosphatic sclerite aggregations of the Cambrian Tommotiids. A skeleton of irregularly distributed growth centres over a wrinkled epithylium
- Siliceous skeletons are widespread in protists and sponges. Neoproterozoic chrysophyte-like scales, radiolarians as well as siliceous sponges in the Cambrian. Shapes of the earliest forms indistinguishable from those existing today

Costs-disadvantages

- Building material availability
- Building takes time and energy; distraction from other functions
- Maintenance
- Burden: more weight and more bulky
- Restrict movement
- Changes in body shape, growth and diffusion of gases and nutrients across the body

Why skeletons were made?

- Detoxification response to an environmental calcium shock (Degens and coworkers)
  - Clashes with sedimentological evidence, substantial $CaCO_3$ precipitation from the middle Archaean. Why organisms maintained excreted minerals in their skeletons

Why skeletons were made?

- Phosphorus

  Phosphatic skeletons were more widespread in the early Cambrian. Increased P concentrations in waters, released from deep waters. This could cause an expansion of biomass that promoted rapid radiation, however the origination of phosphatic skeletons cannot be tested

Why skeletons were made?

- Predation

  Need of soft-bodied organisms to protect themselves against predators

  there are several other strategies to avoid predation: a. run away, b. hide, c. fight back, d. become toxic or distasteful, e. stay small or grow too large
- Different strategies stimulus for speciation and diversification that occurred during the Cambrian

- Although certain selective pressures (other than predation) may have influenced early skeletogenesis in some groups, only predation would have such a broad influence to explain the nearly simultaneous appearance of animal skeletons in a large number of groups. Later modifications of the skeletons, despite their possible success and significance were not as important

Trace fossils

- Track traces, burrows and other trace fossils in the upper Neoproterozoic.
- The rocks after the Varangian glacial period
- Simple shallow burrows

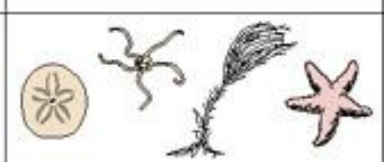
Trace fossils

Possibly from a mollusc

What caused the appearance of the metazoans?

- It may be related to the concentration of enough oxygen in the atmosphere to support Oxygen-based metabolism.
- The first metazoans could have lived in Oxygen Oases of marine plants.
- Entiacarian life may have evolved gradually from earlier forms that have not been fossilized.

Life in the Palaeozoic Era

PHYLUM	BRIEF DESCRIPTION	EXAMPLES
SARCODINA	Single-celled eukaryotes with pseudopodia, including foraminifera and radiolarians	
PORIFERA	Simple, multicellular animals forming colonies and with bodies preforated by many pores. The sponges.	
ARCHAEOCYATHA	Extinct, double-walled, vase- or cup-shaped animals with pores in walls.	
CNIDARIA	Radially symmetrical animals with stinging cells, including corals, jellyfish, and sea anemones	
BRYOZOA	Tiny, colonial animals with U-shaped row of tentacles, often building branching colonies.	
BRACHHIOPODA	Marine invertebrates with shell composed of two parts (valves), one dorsal and the other ventral.	
ARTHROPODA	Animals with jointed appendages, segmented body, and armor-like exoskeleton.	
MOLLUSCA	Unsegmented, mostly shell-bearing invertebrates, including bivalves (clams, oysters) snails, chambered nautilus, and octopods.	
ECHINODERMATA	Spiny-skinned invertebrates with radially symmetrical adult bodies and water vascular system. Starfishes, sea urchins, crinoids.	

Life in the Palaeozoic Era

- Life in Paleozoic includes some Precambrian forms that survived in the Paleozoic, as well as more advanced forms:
  Unicellular eukaryotic
  Animals
  Invertebrates
  Vertebrates
  Plants

Palaeozoic invertebrates

- Representatives of the main invertebrate Phyla were present during the Paleozoic (sponges, corals, bryophytes, brachiopods, mollusks, arthropods, echinoderms)
- Almost all of the common invertebrate phyla that live today had appeared at least until the Ordobician.

Palaeozoic vertebrates

- The vertebrates evolved during the Paleozoic period:
  Fish
  Amphibia
  Reptiles
  Synapsids ("mammal like reptiles")
  The first vertebrates were jawless fish, found in the Cambrian rocks of China.

Palaeozoic vertebrates

- An advanced branch of fish with primitive lungs and strong fins led to tetrapods.
- The transition from aquatic to terrestrial vertebrates was based on the evolution of the amniotic egg.

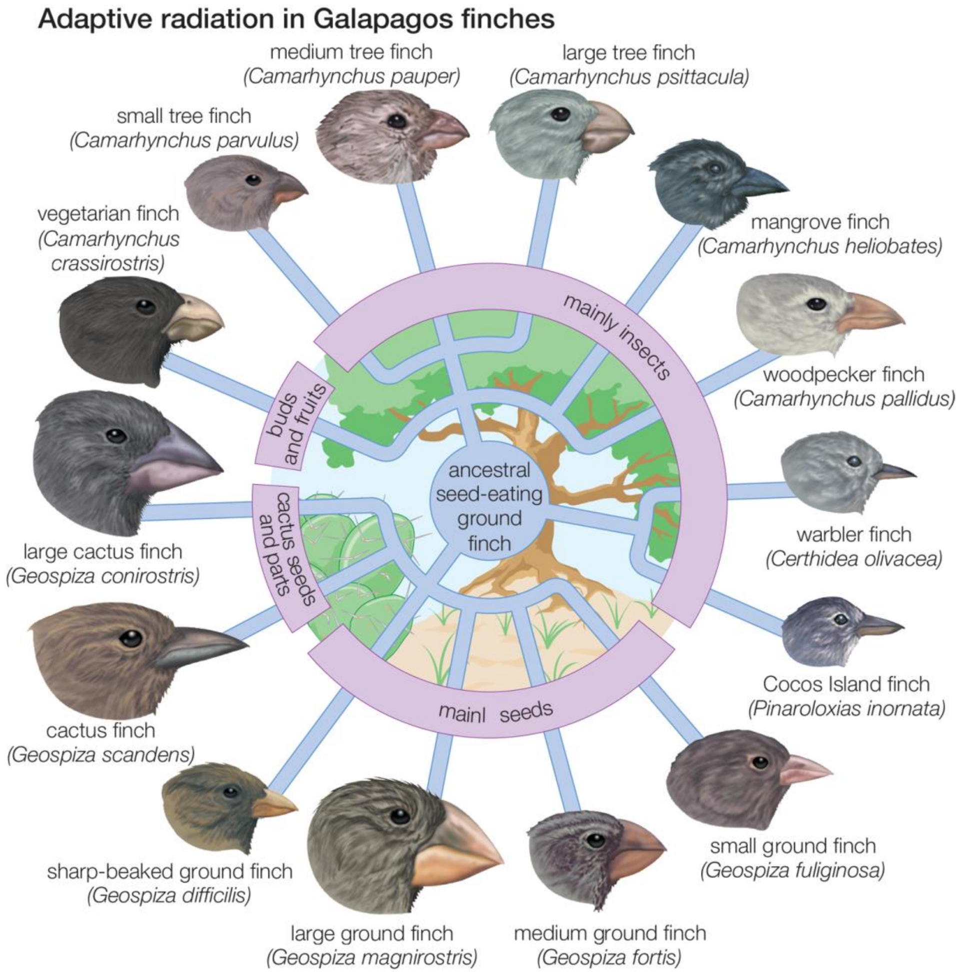
Palaeozoic plants

- The first primitive terrestrial plants appeared near the end of the Ordobician.
- Trachyophyte plants spread on earth, forming large forests in the Devonian.
- Plants progressed from seedless bearing spores (pteridophytes) to plants with seeds but without flowers (gymnosperms).

Adaptive radiations and Mass Extintions

- The Paleozoic was a time of several adaptive radiation and mass extinction events.
- Many geological Periods began with adaptive radiations.
- Many Periods ended with mass extinction events of varying intensity.

Adaptive radiations



The evolution of an ancestral species adapted to a particular lifestyle in many diverse species, each of which is adaptively specialized in a particular ecological niche with specific environmental conditions

Animals with soft parts

- Animals with soft parts of the Ediacarian type continued their expansion in the Cambrian.
- Fossils with soft parts are rarely preserved.
- Preservation improved markedly with the arrival of animals with hard parts.

The “Big Bang” of life…

- (Cambrian explosion of Life)
- The initial differentiation of the Paleozoic life forms. A sudden and rapid appearance of many life forms about 535 million years ago, followed by rapid evolution.
- In this episode of "explosive" evolution, within 10 million years, all the main Phyla of the invertebrates first appeared as fossils (except Bryozoans), including the first chordate (*Cathaymyrus diadexus*) and the first fish (*Myllokunmingia*), and groups which lived only in the Palaeozoic, graptolites, trilobites, blastoids, cystoids, etc.
- Some call this event as the "big bang" of evolution.

The “Big Bang” of life…

- A third of the Cambrian phyla do not exist today. Although they were represented by fewer species than extant phyla today, their number was greater
- Variation in body forms remarkable with abundant new innovations
- One such important innovation the acquisition of mineralised hard parts
- However, once these phyla were formed they became all there is. Those that survived the Cambrian continued to present day

The Cambrian revolution of the substrate

- Endofaunal burrowing organisms evolved very quickly during the Cambrian, as trace fossils and sediment bioturbation show.
- This dramatic change in the character of the sediments (from undisturbed to over excavated) was called “Cambrian revolution of the substrate".

causes of this revolution

- Physico-chemical
- Biological

Setting

- Tectonics: breaking up of the proterozoic supercontinent
- Worldwide transgression of shelf seas, following the Varanger glaciation (new shallow water niches)

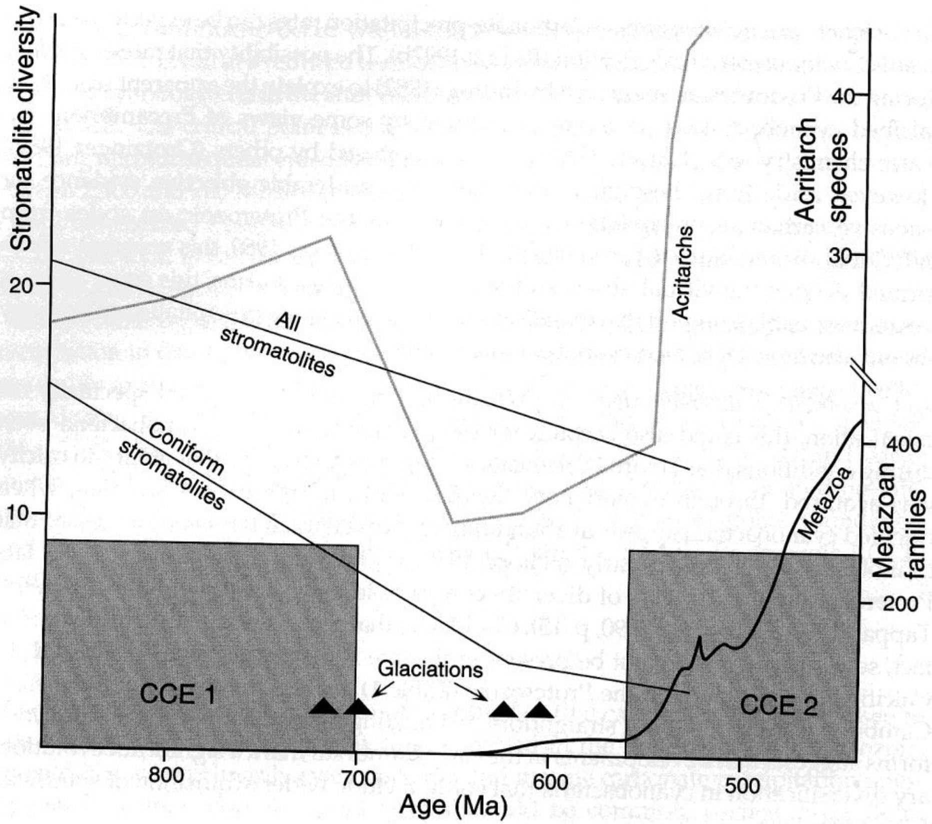


Figure 3 Synthesis of events at the Proterozoic–Palaeozoic transition. It is proposed that (a) decline in stromatolite and acritarch diversity and termination of the middle–late Riphean CCE (CCE1) are linked to temperature fall in the latest Proterozoic also reflected by glacial episodes around 700–600 Ma, and (b) commencement of the Cambrian – early Ordovician CCE (CCE2) near the beginning of the Tommotian is linked to temperature rise which also stimulated acritarch, metazoan, and cyanobacterial diversification. CCE1 and CCE2 are separated by an RCCE. During CCE2 calcified cyanobacteria created widespread dendrolite and skeletal thrombolite fabrics in reefs. Biomineralization also took place in a variety of metazoan groups during the early Cambrian. (Sources: acritarchs – Vidal 1984, p. 54; stromatolites – Walter & Heys 1985, Fig. 5B; metazoan diversity – Sepkoski 1979, Fig. 7; glaciations – Harland *et al.* 1990; CCE's – Riding 1992b, this paper.)

During the glaciation

- Regression of the sea
- Reduced cyanobacterial calcification
- Low acritarch production
- Declining stromatolites
- Increased CO_2 in atmosphere
- Higher erosion (evidence from increased $^{87}Sr/^{86}Sr$ in carbonates) thus increased P content in ocean waters

End of Precambrian-Early Cambrian

- Extensive transgression of the sea
- Thus extensive upwelling of sea waters, bringing nutrient rich waters to the surface waters and the shallow waters of the photic zone
- P was brought up in the photic zone
- P essential to life and could trigger the evolution of organisms
- Evidence: extensive phosphorite deposits, major changes (increase) in the $^{32}S/^{34}S$ isotopes which are usually found in deep stagnant anoxic waters

End of Precambrian-Early Cambrian

- Acritarch production increases
- Cyanobacterial calcification increases
- Thus removal of carbon from continents and shallow marine environments deposited as carbonates on ocean floor (increased $\delta^{13}C$)
- Thus atmospheric oxygene levels increase, providing more energy to support advanced multicellular organisms

Favourable conditions

- On the onset of the Cambrian shallow marine environments were enriched both in nutrients (like P) as well as in oxygene, two essential components that could trigger and facilitate the evolution and diversification of multicellular eukaryotic organisms

Biological factors

- Eukaryotic cells have far more genetic material than prokaryotic cells, of which only a small portion is used for protein production and functions
- Underutilised genetic information is a potentially powerful force for change
- eukaryotic cells took advantage of favourable conditions, high oxygene levels, nutrients and phosphorus

Biological factors

- Some biologists consider that the trigger mechanism was not the oxygene but genetics itself
- Primitive animals have fewer regulatory or trigger genes, than complex forms
- A minimum number of such genes is required
- Chance production of regulatory genes from existing genetic codes in eukaryotic cells
- This innovation occurred possibly after or before the oxygene rise
- In any case regulatory genes triggered the explosion of body types

Absence of predators

- Another contributing biological factor to rapid appearance of different body types, absence of other animals in the same ecological niches to compete with
- Complex multicellular animals equipped to take advantage of different environments, forming many different body plans
- However, once competition became intense (due to overcrowding for example) predation started
- Evidence of predation in the later Proterozoic

Artefact of the geologic record

- The sudden appearance of shelled animals in the Cambrian was considered an artefact, and that they were directly descended from earlier soft bodied ones
- Recently detailed analysis of sediments revealed large number of soft bodied animals also in the Cambrian
- Thus the explosion of life in the Cambrian not an artefact
- However, in the future discoveries of earlier fossils cannot be ruled out

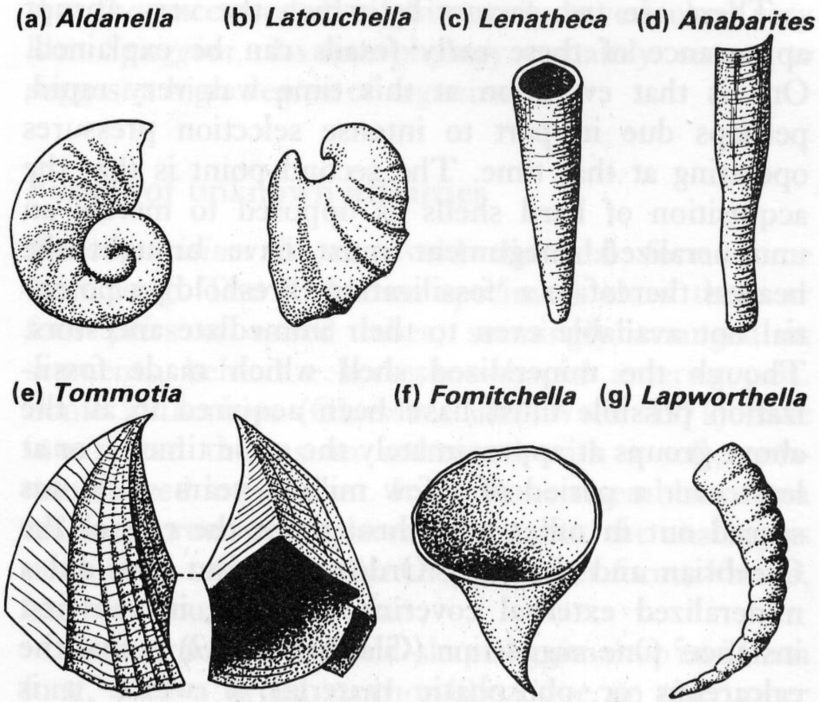


Figure 3.2 Latest Precambrian (*Anabarites*) and earliest Cambrian (others) small, shelly fossils from the Siberian Platform. (a) ×20; (b)–(e), (g) ×15 (approx.); (f) ×40. (Redrawn from Matthews and Missarzhevsky 1975)

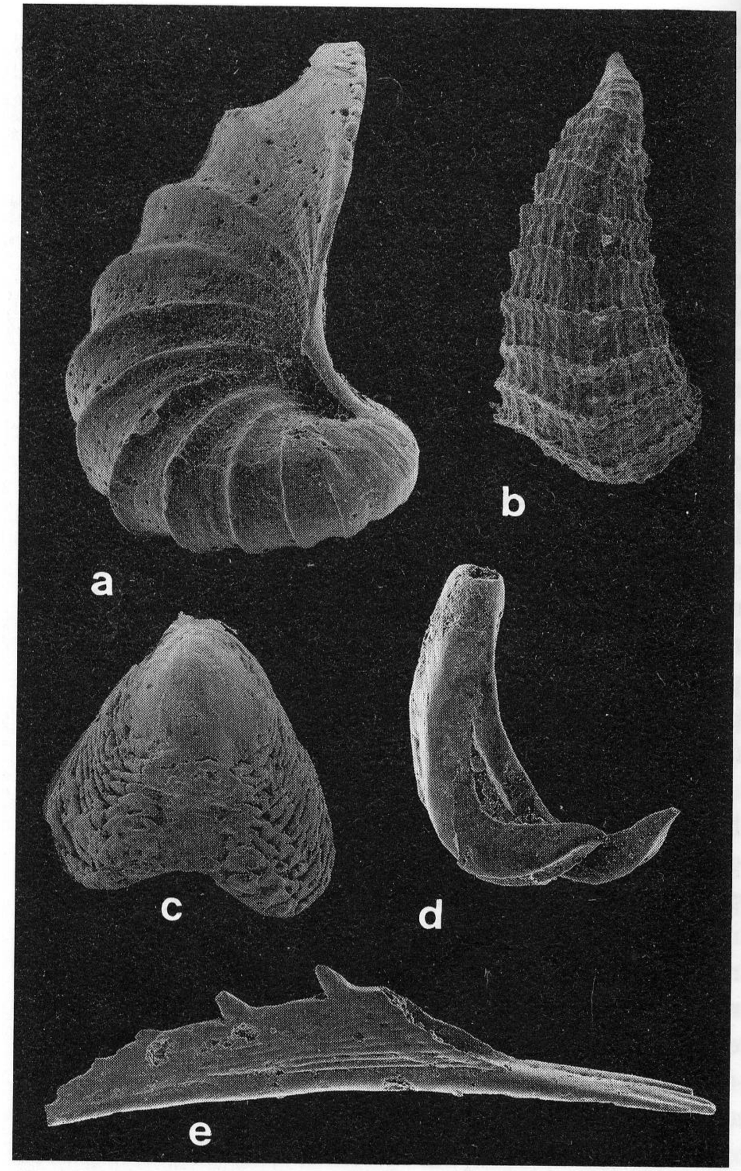
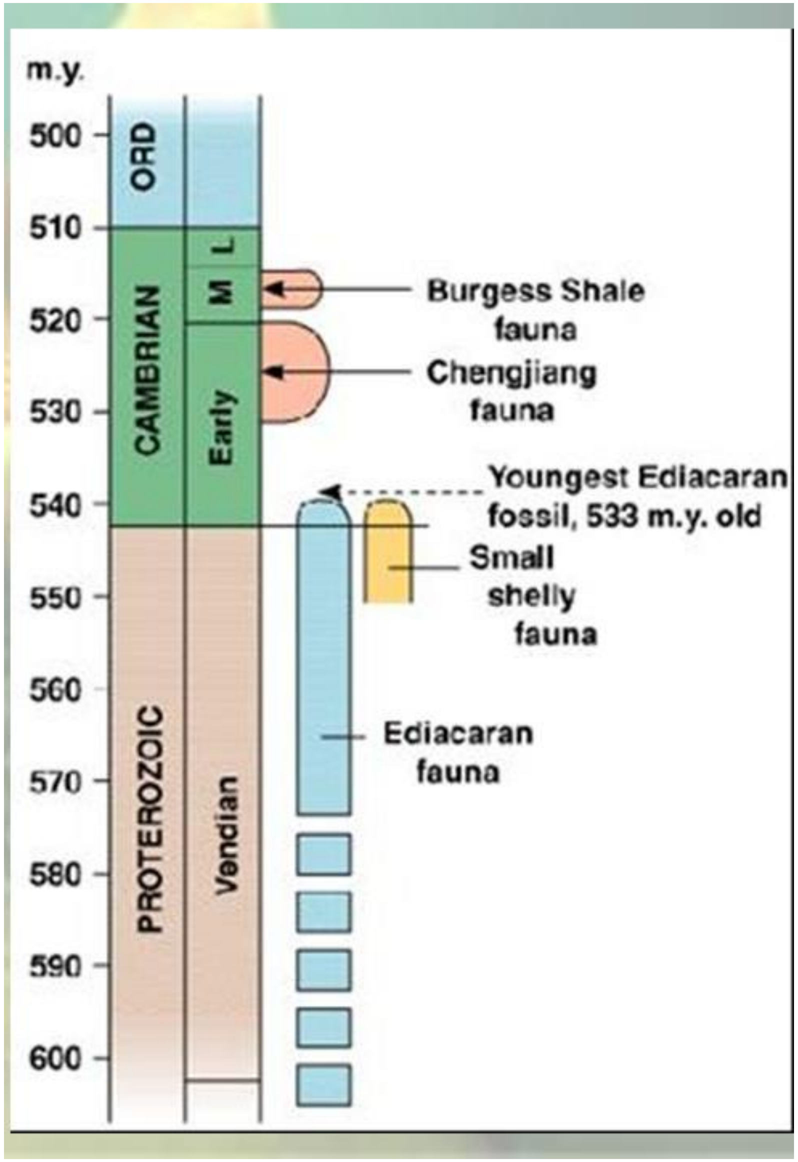


Figure 3.3 (a) *Archaeospira ornata* (×35); (b) *Lapworthella fasciculata* (×70); (c) *Maikhanella pristinis* (×35); (d) *Drepanochites dilatatus* (×35); (e) *Scoponodus renustus* (×35). (Photographs reproduced by courtesy of Dr Stefan Bengtson)

Cambrian faunas



- Ediacaran faunas
- Faunas with animals with tiny shells
- Chengjiang fauna
- Burgess shale fauna

Chengjiang fauna

- Until 1984 Burgess shale was considered the oldest and most important site of the Cambrian explosion
- In1984, Chengjiang was discovered in Yunnan province of China with an age of Lower Cambrian (535 million years).
- More than 100 species of invertebrates have been found to date with excellent preservation, including several forms with soft bodies.

Chengjiang fauna

Jellyfish
Worms (Annelids)
Cnidaria
Porifera (sponges)
Brachiopods
Arthropods
Primitive chordates (*Cathaymyrus diadexus*)
The oldest known fish (Myllokunmingia)
Other types of indeterminate phyla

Eoredlichia intermedia

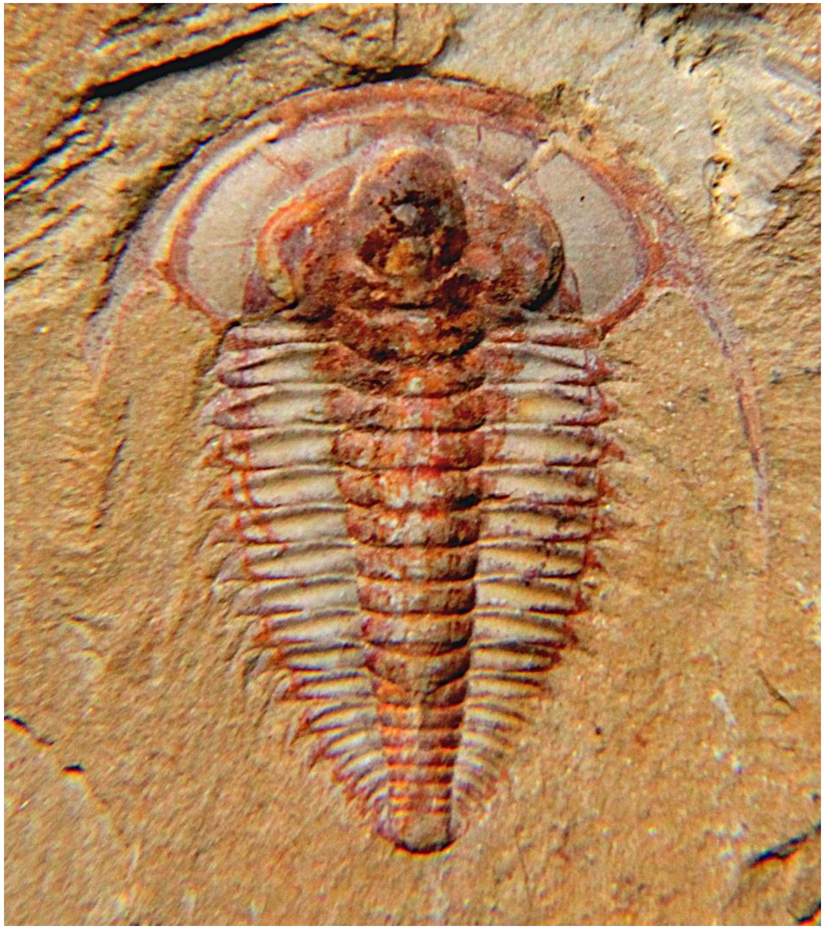


Fig. 59. The Chengjiang arthropod *Leanchoilia illecebrosa* from South China. Specimen is about 2.5 cm long. [Photograph courtesy of Hou Xianguang (Museum of Natural History, Stockholm and Institute of Palaeontology, Nanjing).]

Fig. 60. The Chengjiang lobopodian *Microdictyon sinicum* from South China. Specimen is about 2 cm across. [Photograph courtesy of Hou Xianguang (Museum of Natural History, Stockholm and Institute of Palaeontology, Nanjing).]

The oldest chordate

- *Cathaymyrus diadexus*
- 535 my
- Primitive chordates as well (Yunnanozoa) *Yunnanozoon and Haikouella*

The oldest fish

The oldest fishes (535 my):

Myllokunmingia fengjiaoa

Haikouichthys ercaicunensis

Zhongjianichthys rostratus

Exceptional preservation

- Places containing fossils in abundance with unusual preservation are called lagerstatten (Exceptional preservation).
- Chengjiang and Burgess Shale faunas are considerd lagerstatten.

Burgess shale fauna

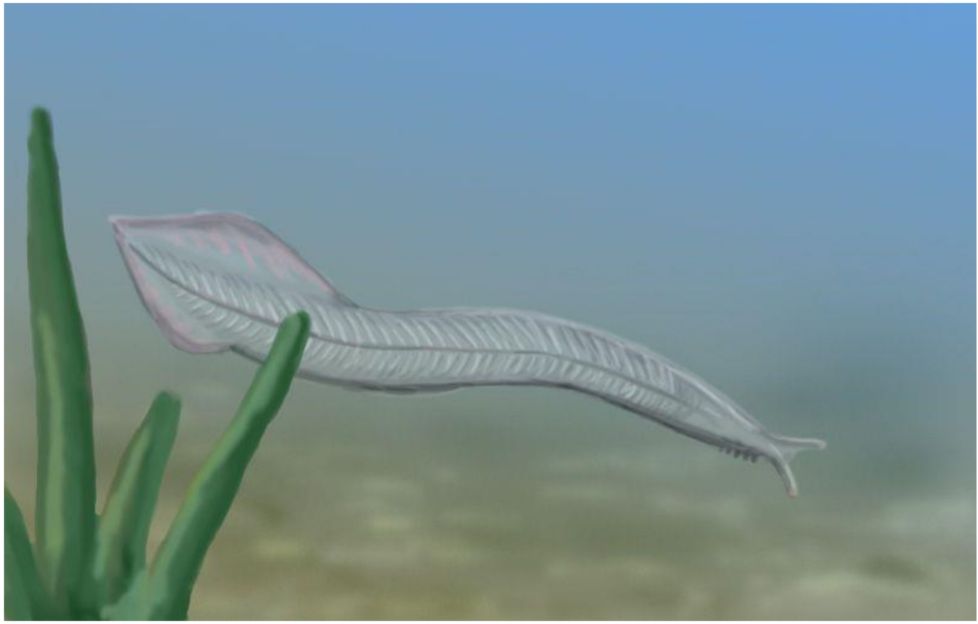
- Extremely preserved Cambrian fauna from Canada gives us a window to the incredible diversity of Mid- Cambrian.
- Its importance is that it records organisms with soft parts, and soft parts of organisms with shells such as legs and gills.
- Very well studied

Burgess shale fauna

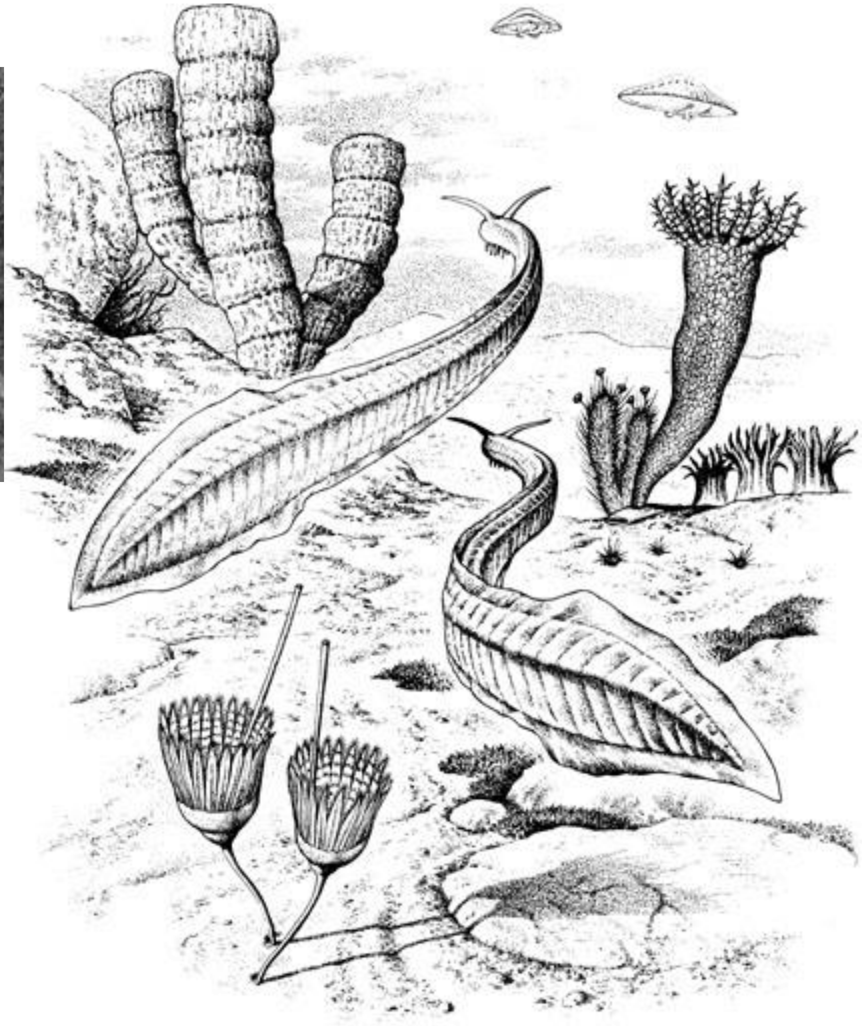
1. Several arthropod groups, including trilobites.
2. Sponges
3. Onychophorans
4. Crinoids
5. Molluscs
6. Corals
7. Three phyla of worms
8. Chordates (Pikaia)
9. Several indeterminable

Pikaia – One of the oldest chordates

- Pikaia a fishy chordate
- Modern representatives belong to the Amphioxus genus.
- It is believed that vertebrates evolved from organisms like Pikaia.



Pikaia – One of the oldest chordates



Hallucigenia

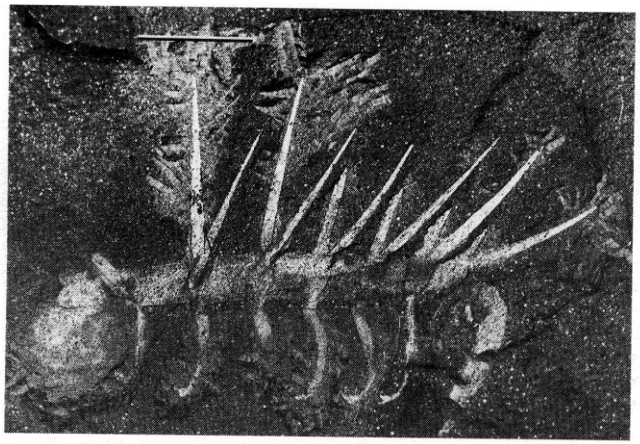
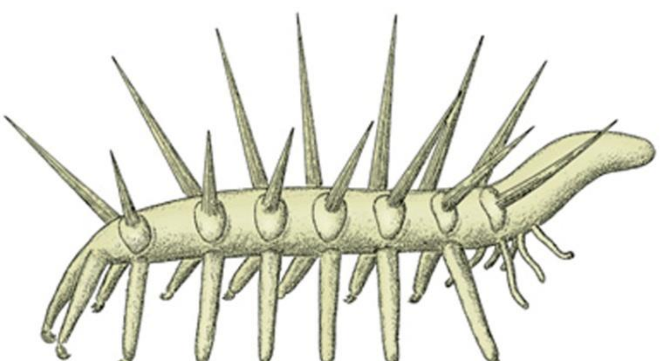
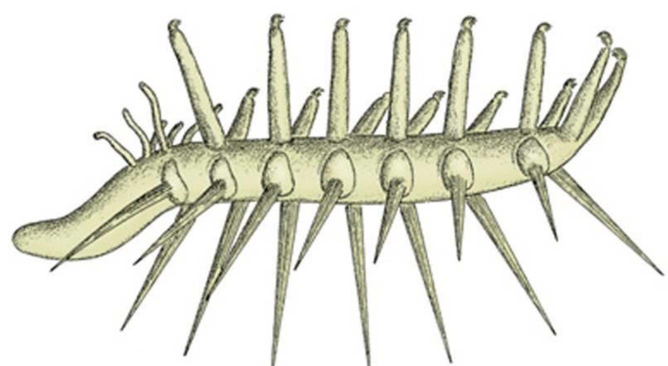


Fig. 18. The best-preserved specimen of *Hallucigenia sparsa* from the Burgess Shale. Scale bar (top left) is equivalent to 5 mm.

- ***Hallucigenia*,** an Onychophoran, originally had been interpreted as walking with his spines until nails were discovered in its "tentacles".





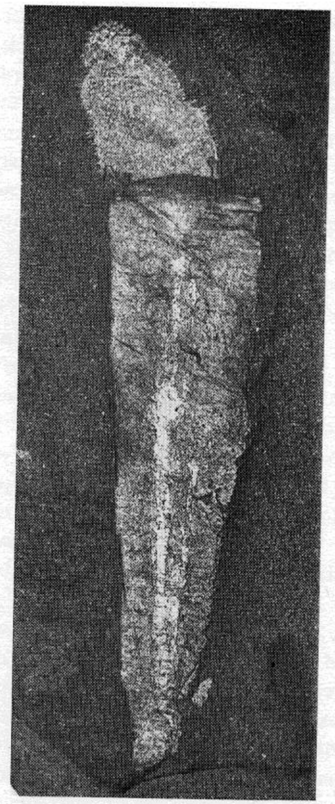


Fig. 26. The Burgess Shale priapulid *Selkirkia columbia*, showing the spiny proboscis projecting from the tube. Specimen is about 4 cm high.

Fig. 33. The Burgess Shale pennatulacean *Thaumaptilon walcotti*. Specimen is about 20 cm long.

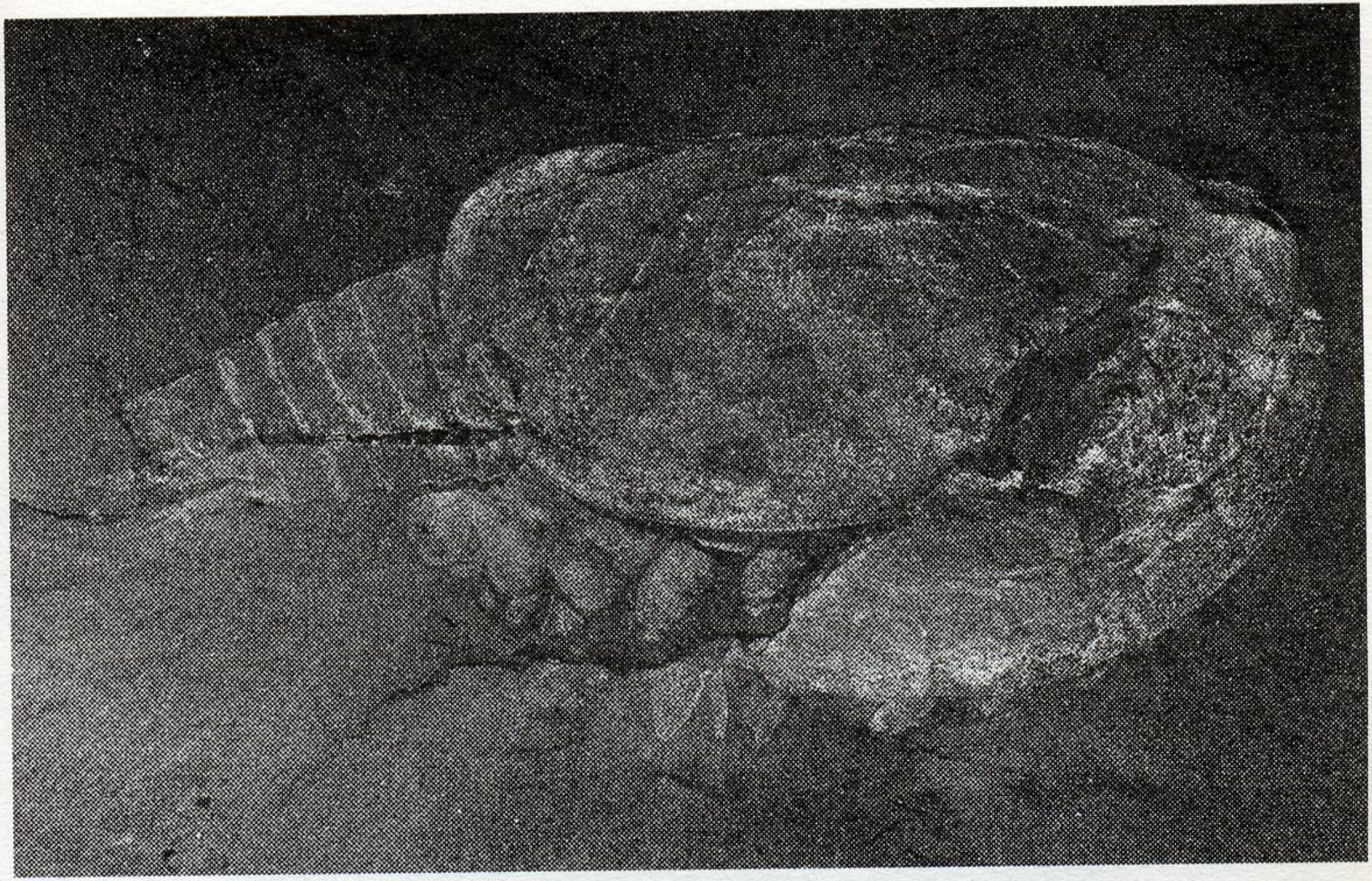
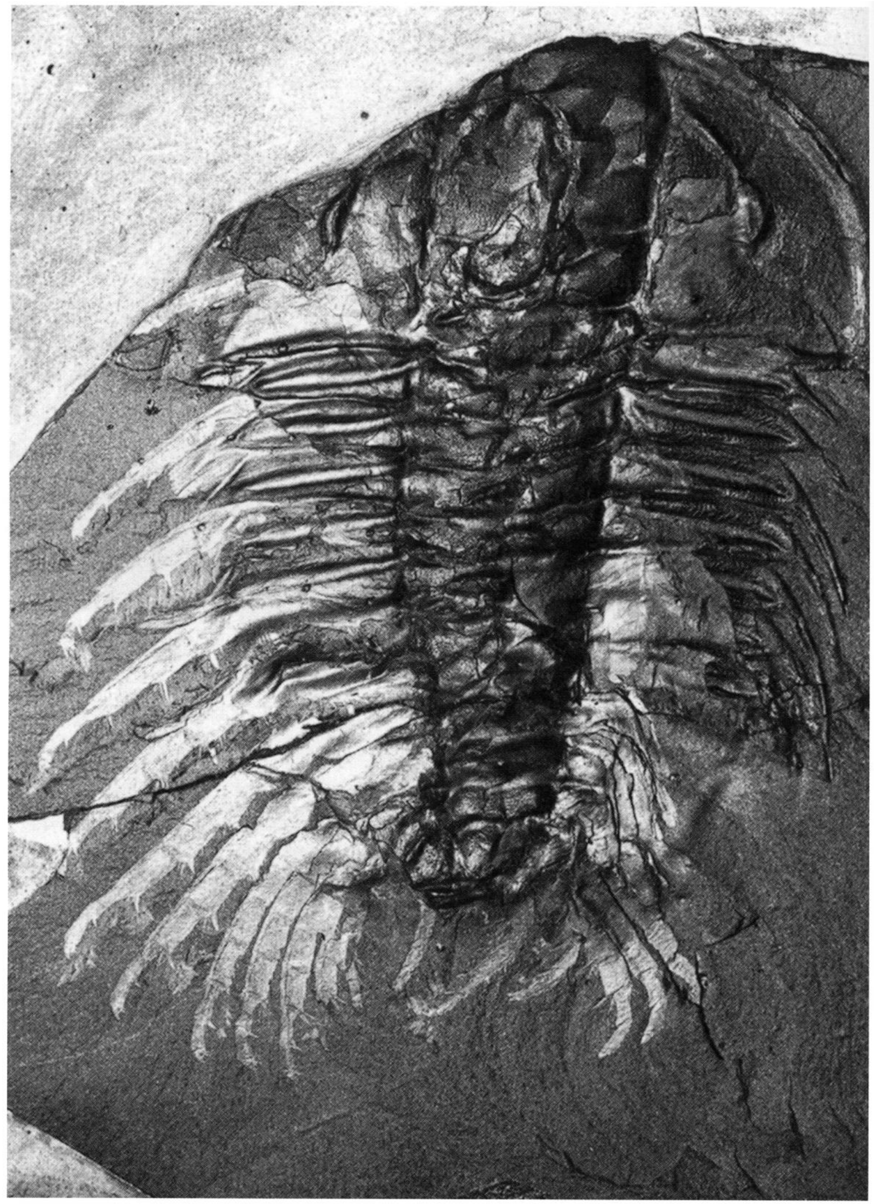
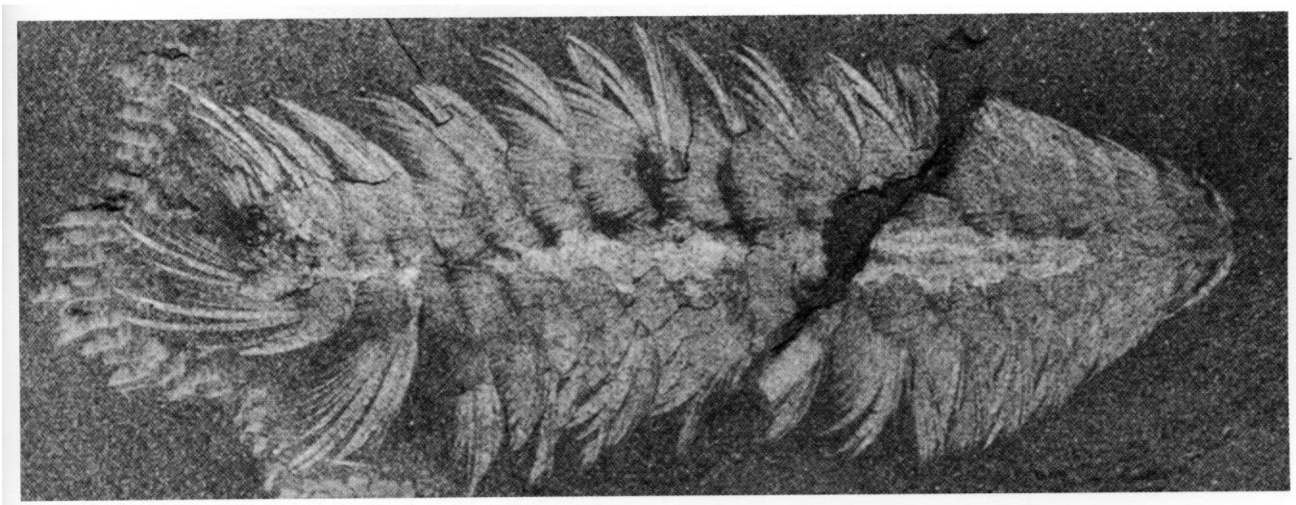


Fig. 73. The Burgess Shale arthropod *Canadaspis perfecta*. Specimen is about 5.5 cm across.



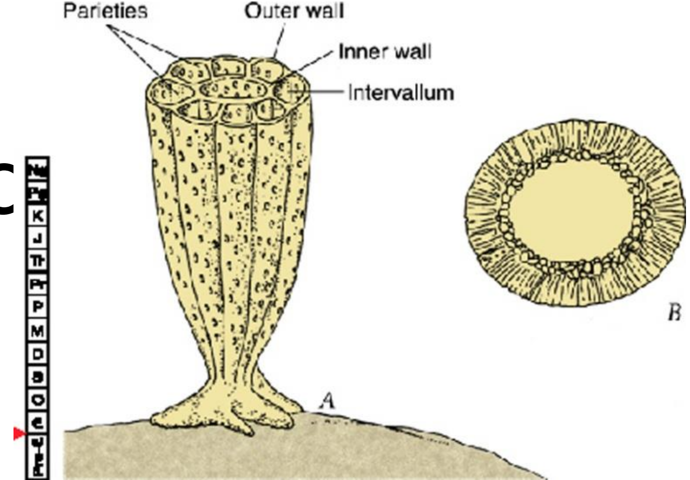
Olenoides

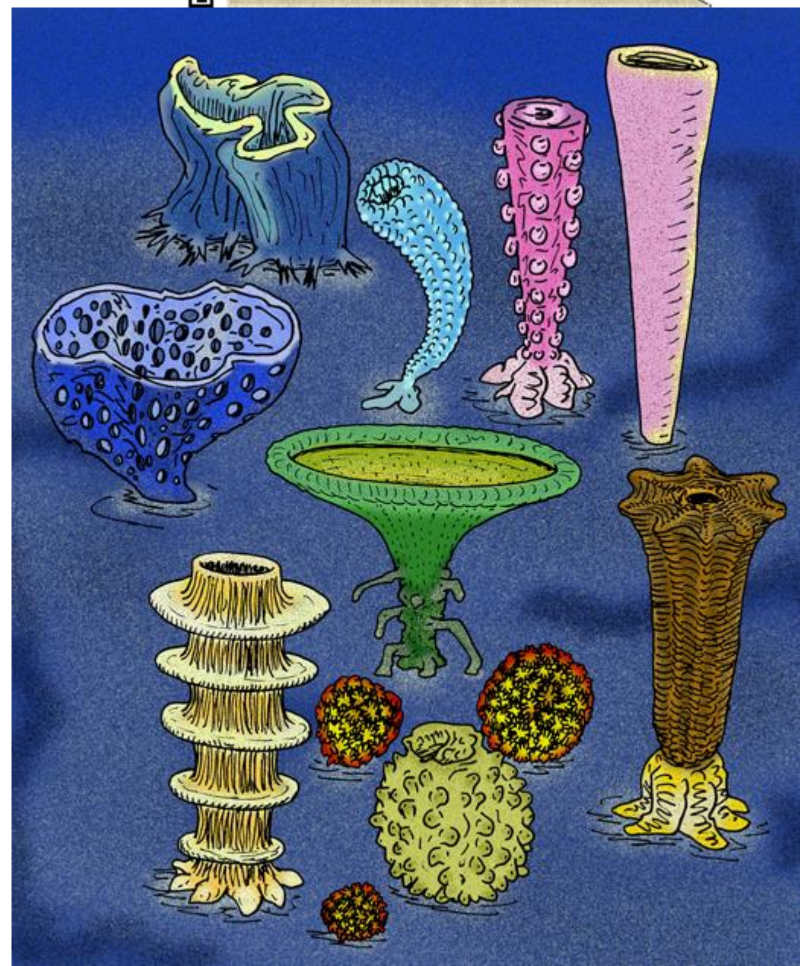


Canadia

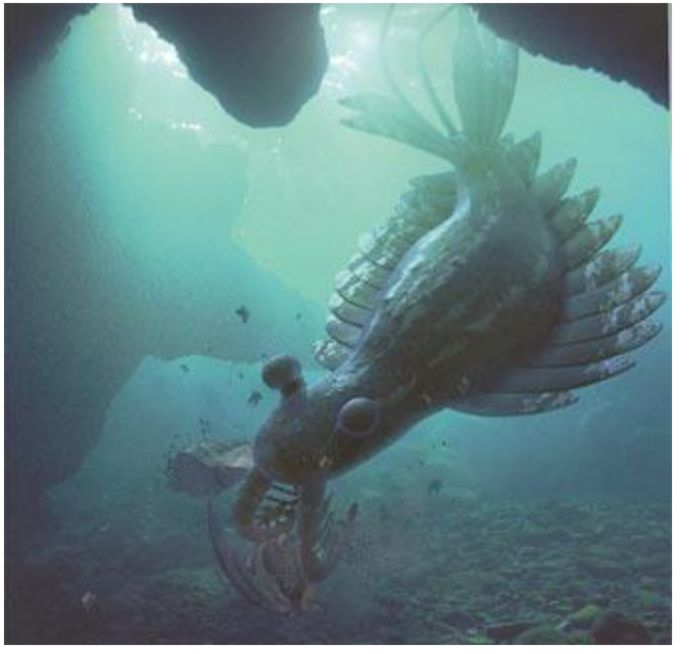
Phylum Archaeoc

- «ancient mugs»
- Conical or vase-shaped skeletons made of calcium carbonate. Double wall with partitions and pores.
- Age: Cambrian.
- Attached to a stable substrate. Reef manufacturers.





The predators of Cambrian seas



- For the first time the seas are dominated by predators
- The most prominent predator of the Cambrian seas, the giant Anomalocaris, 60 cm long.
- They would have caused selective pressures on their game. The need to protect them would lead to the development of hard shells and the development of endobiotic lifestyles.
- Hunting would also cause an increase in game diversity, as they would evolve to better treat predators.


Anomalocaris

Opabinia

Colour plate 3. In the foreground *Anomalocaris* has captured a hapless trilobite, seized in its anterior giant appendages which are manoeuvring the prey towards the armoured mouth. On the sea-floor from left to centre respectively are a solitary specimen of *Wiwaxia* and three specimens of *Hallucigenia*. Note in both animals the defensive arrays of spines, although the bifid termination in the left individual of *Hallucigenia* is an error. Further to the right is the lobopodian *Aysheaia* with its anterior prongs around the mouth, as well as the primitive arthropod *Opabinia* which is a close relative of the larger *Anomalocaris*. Descending to the sea-floor are two individuals of the arthropod *Marrella*. Also visible in this scene are sessile epifauna in the form of *Dinomischus* (yellow) and the sponge *Vauxia* (blue).

The Cambrian explosion of life

- Definitely the roots of the Cambrian explosion can be traced back to the Ediacaran faunas
- Some animals as we saw earlier like *Thaumatoptilon* from Burgess shale represent Ediacaran survivors
- However the differences are more striking than the similarities
- The great success of the Cambrian explosion was at the cost of displacement or the extinction of the Ediacaran fauna

Colour plate 2. This picture emphasizes the epifaunal elements of the Burgess Shale community. Attached to the sea-floor are various types of sponge including the large *Vauxia* (blue; note the lobopodian *Aysheaia* crawling around the edge of the osculum (far mid-right)), *Pirania* (lower left, with prominent projecting spicules), and *Choia* (centre, resembling a pin-cushion). Further in the background are examples of *Dinomischus* (yellow), *Mackenzia* (green), and *Chancelloria* (purple). The prominent group of three frond-like organisms on the mid-upper left are examples of the sea-pen *Thaumaptilon*. Moving across the sea-floor are also two trilobites.

Colour plate 4. The emphasis in this picture is on the swimmers and floaters. In the foreground and ascending upwards is the arthropod *Odaraia*, while higher in the water column are two individuals of the chordate *Pikaia* (left) and the ctenophore *Ctenorhabdotus* (right). The gelatinous discoidal object on the left is *Eldonia*, possibly a primitive echinoderm. On the opposite side is the enigmatic *Nectocaris*. Crawling across the sea-floor is a specimen of the polychaete annelid *Canadia*, whilst the attached forms include the sponge *Pirania* with its elongate spicules upon which are attached some symbiotic brachiopods (which display their marginal setae), and also examples of *Dinomischus*.

Colour plate 1. Both mud-dwellers (infauna) and mud-stickers (sessile epifauna) are shown, with some of the latter in the process of dislodgement by the scoop of the time-travellers submersible. The infauna is dominated by priapulid worms, of which the most abundant was *Ottoia*. In this scene three individuals are visible: one on the floor of the large excavation, another in the process of consuming hyoliths (mid-right), whilst the third is emerging from its burrow and displaying its spinose proboscis (lower right). Two other priapulids are visible in the excavation: the elongate, more-or-less horizontal worm is *Louisella*, shown here in its life position as a sedentary animal occupying an elongate burrow with openings to the overlying sea water at either end. The animal inclined downwards, with its posterior end just emerging from the sea-floor, is an example of *Selkirkia*. It inhabited a parchment-like tube, and in common with other priapulids had a spiny proboscis that was employed, when necessary, for burrowing. The other type of worm visible in the excavation are two examples of the polychaete annelid *Burgessochaeta*, with one individual wriggling on the floor and the other in its burrow with anterior tentacles extending sideways (far left). The sessile epifauna is represented by the enigmatic *Dinomischus* (lower left), the sponge *Vauxia* (blue), the ?cnidarian *Mackenzia* (green), and the ?sponge *Chancelloria* (upper left, purple). Also present is a trilobite (centre) strolling across the sea-floor, and swimming through the water a solitary *Pikaia* (a primitive chordate).

The Cambrian explosion of life

- The diversity of forms, of body patterns of the Cambrian is unique in the fossil record and in the history of the earth
- Possibly the mode of feeding was also important for this diversification
- Despite the rich, exceptionally preserved fossil findings from the Cambrian localities, thousands of species will for ever remain in ignorance, thus the Cambrian record is seriously incomplete
- Many of the Cambrian fossils are enigmatic and will probably remain enigmatic