The Early Paleozoic World: Cambrian Period (544-459 MY)

Jarðsaga 1
-Saga Lífs og Lands -
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The Cambrian Period: Precambrian Supercontinent has broken up and life explodes...

- Sea level rose throughout the Cambrian - very widespread deposition of marine sediments
- Rodina Supercontinent broken up
- Skeletal animals appear in the fossil record
- Predation becomes a way-of-life
- Trilobates appear on the scene, and develop rapidly
- A major diversification of large animals
- Trilobate mass extinctions towards the end of the period
Cambrian was named by the 19th-century English geologist Adam Sedgwick, who first studied the great sequence of rocks characteristic of the period near Cambria, Wales.
Rodina had broken up by early Cambrian, and Laurentia, Siberia and Baltica were separated from “Proto-Gondwana”
Early Cambrian climate was warm, but not too hot, and there is no evidence of any glacial ice at the poles. Transgression of sea onto continental cratons!

http://www.scotese.com/
What caused the Cambrian transgression?

**What can cause globally rising sea-levels?**

1. A decrease in ocean basin volume due to:
   • Formation of new mid-ocean ridges
   • Increased area of continents (rifting)
   • Accumulation of sediments on the sea-floor
2. An increase in water volume by melting of glaciers on land

**What can cause regionally/locally rising sea-levels?**

1. Subsidence of land along a passive continental margin
2. Local/regional glacio-isostatic loading
The evidence for a global Cambrian transgression

1. Wide-spread marine sediments on all cratons
2. The sediments change upwards from shallow marine facies to deeper, offshore facies
3. Cambrian rocks become increasingly thinner toward the interior of the cratons: In North America from more than 3000 m at the coasts to less than 150 m in the higher inlands
The Cambrian transgression occurred because

1. The rifted passive margins of the continents subsided
2. The stretched continental crust from rifting covered more area (the ocean crust covered less area)
3. The ridges formed by rifting and sea-floor spreading displaced water from the deep ocean basins
4. Intense sedimentation in the ocean basins decreased their volume.
Warm, shallow seas: optimal for development of life

Early Paleozoic life was confined to the seas. It may be speculated that certain simple types of protists and fungi had made their way into freshwater habitats, there is no fossil record to substantiate that.

The Reef-builders of Early Cambrian were the *Archaeocyaths* - a primitive group of sponges.
Early Cambrian Globe

No continental landmasses on the Poles

Active rifting and subduction occurring as Rodina Supercontinent is being broken up

http://jan.ucc.nau.edu/~rcb7/globaltext.html
What sets the Cambrian apart from older geological Periods?

The period occupies a special place in the study of paleontology, because it is in the sediments of Cambrian age that fossils ‘suddenly’ become common for the first time. This effect has come to be known as the “Cambrian Explosion of Life.”
Cambrian explosion of Life

- Biological Big Bang 540 million years ago
- Most modern animal groups appear

Why did it happened, when it happened?
Metazoans – vefdýr, fjölfrumungar

• There is no good record of evolution from single to multicellular life
  - Vendian metazoans (multicelled) soft-body fossils
    • resemble jelly fish, worms, flat, cushion-like
    • soft-bodied fossils hard to find/interpret: record is scanty
  - Precambrian rocks barren of fossils
  - Overlain by Cambrian rocks full of fossils!

Increase of Orders (ættálkar) in early Cambrian
The Cambrian explosion of Life

- Small shelly fossils appeared first
  - Quickly became abundant and diverse

- Why the sudden explosion?
  - Varangian glaciation wiped out microorganisms
  - Increase in oxygen to support multicelled animals
  - Widespread rifting - increased shelf habitat, increase in nutrients in sea-water
  - Increased O2 and nutrients allowed calcite shells
  - Small invertebrates grazed stromatolites and cleared ocean floor habitat for newcomers
  - Developing more complex ecological relationships
    - predators encourage evolution of protection
Cambrilian fauna

- **Trilobites** (*príbrotar*)
  - many legged arthropods (*liðdýr*) - diverse!
- **Archeocyaths** (*frumbikardýr*)
  - sponge like, reef builders
- **Brachiopods** (*armfætlur*)
  - double-shelled creature with filterfeeding lophophore (*krans*)
- **Molluscs** (*samlokur*)
  - tube, cone, and cap-shaped snail-like critters
- **Echinoderms** (*skrápdýr*)
  - spiny-skinned animals with calcite plates
The archaeocyaths appear during the Lower Cambrian. Classification controversial. They diversified into 100s of species and contributed to creating the first reefs.

Reef ecosystems support a variety of organisms both in the present and in the past. The Archaeocyatha was a shallow water tropical group. Fossils are always found with photosynthesizing cyanobacteria. Possibly symbiosis.

Despite their great success in terms of numbers, the archaeocyaths were a short-lived group. They disappeared in middle Cambrian, some 10 to 15 million years after their first appearance.
Reef builders through time
A distinctive fauna of small shelly animals, called the Tommotian fauna, appeared at the base of Cambrian. The biota represents the first appearance of diverse skeletal material in the fossil record, some 10 MY before the first trilobites evolved. A major rise in the level of marine carbonates and phosphates triggered the sudden appearance of phosphate-rich shelly-organisms.
Why Do So Many Metazoans Have Skeletons?

1. Receptacles for excess mineral matter
   - note Kidney Stones and Gallstones in humans

2. Storehouses for scarce minerals
   - bones and teeth, some shells composed of calcium phosphate
   - phosphate rather scarce in nature, but essential for metabolism and is also key component of genetic material
   - **calcium** essential for heart, nerve, muscle functions, enzyme activation

3. Support-muscle attachment areas for locomotory organs

4. Serves as protective cage for soft internal organs

5. In shelled organisms, serves as a box to ensure controlled environment for metabolic functions

6. Protection from predators
Life in the Sea

Following the earliest Cambrian (Tommotian) fauna, there was a rise of herbivore grazers (e.g. gastropods), and consequent decline of algal stromatolites. There were almost no large animals, and only a few predators. Cyanophyte algae mats encouraged mat scratchers (diverse ancestral mollusks).
Enter the Trilobates
The Trilobates

- The first body fossils of trilobites appeared in the Early Cambrian Period, about 540 MY ago.
- It seems likely that trilobites were preceded by soft-bodied ancestors: at several localities, sedimentary rocks with trace fossils of trilobite activity underlie the oldest rocks with trilobite body fossils.
- Trilobites underwent several radiations in the Cambrian; by the end of the Cambrian, about 500 million years ago, they were as diverse as they would ever be.

They were present throughout Paleozoic, but went extinct by the end of the Permian (245 MY).
The Trilobates - ecology

Most trilobites lived in fairly shallow water, walking on the bottom and feeding on detritus. A few may have been pelagic, floating in the water column.

Food particles were stirred up by the legs and passed forward to the mouth. Since the mouth had no large mandibles, we infer that trilobites were not usually predatory and were restricted to soft food. Some trilobites had long spines on the first leg segment; these may have been able to tear up larger pieces of food, and probably scavenged for a living.
Trilobites developed one of the first advanced visual systems in the animal kingdom.

Trilobite eyes had rigid, crystalline lenses, and therefore no accommodation. Instead, two lens layers of different refractive indices acting in combination corrected for focusing problems that result from rigid lenses. The shapes of some trilobite lenses match those derived by optical scientists over 400 million years later to answer similar needs.
Different types of Eyes

**Holochroal** Eyes have lenses directly in contact. Found in nearly all Orders; few to very many lenses (to >15,000!); lens size small.

**Schizochroal** found in some Phacopida only; typically fewer lenses (to ca 700); lenses very large.

**Abathochroal** found in Cambrian Eodiscina only; few lenses (to ca 70); lens size small.
The rigid trilobite doublet lens had remarkable depth of field (allowed objects both near and far to be in relatively good focus), even without the benefit of accommodation, and minimal distortion of image.

Compound eye in living arthropods such as insects are very sensitive to motion, and it is likely that they were similarly important in predator detection in trilobites. It has also been suggested that stereoscopic vision was provided by closely spaced, but separate eyes.
Cambrian marks the beginning of the ever continuing arms race...
*Anomalocaris*: a large, swimming predator of Cambrian ecosystems.
Artistic images of Anomalocaris
The Burgess Shale is an exceptional Cambrian age (about 540 million years ago) fossil locality located in Yoho National Park in the Rocky Mountains, British Columbia, Canada. The locality is special because of the soft-bodied preservation of a wide diversity of fossil invertebrate animals. The locality has been intensely studied since its discovery in 1909 by Charles Walcott, and has been declared a World Heritage Site. A popular introduction to the Burgess Shale can be found in Steven J. Gould's book, "Wonderful Life".
The depositional environment
Why Burgess Shales are so important

- The animals were buried in an underwater avalanche of fine mud that preserved amazingly fine details of the structure of their soft parts. (Only hard parts are preserved in most other Cambrian deposits, obviously limiting information within the geologic record.)
- They represent an early snapshot of the complexity of evolving life systems. The Burgess Shale fossils as a group have already developed into a variety of sizes and shapes from the much simpler, pre-Cambrian life forms.
- Many of them appear to be early ancestors of higher forms; from algae to the chordates (seildýr - a major group of animals that includes us humans). Others appear unrelated to any living forms and their later disappearance presents an intriguing mystery.

The Smithsonian's Museum of Natural History currently house over 65,000 specimens, the largest collection of these fossils in the world. The Museum also has a permanent exhibit of the Burgess Shale fauna in the Dinosaur Hall.
Burgess Shale sediments and fossils

At the time of deposition, this area was near the equator, and was the continental margin of North America.
Burgess Shale animals

Vauxia - sponge

Vauxia “forest” with Leanchoilia
Burgess Shale animals

Wiwaxia: A worm, a mollusc, or something completely different?
Burgess Shale animals

Peytoia: A jellyfish?

Marella: An early arthropod (related to trilobites)
The great *Hallucigenia* flip-out
Hallucigenia
Presently classified as onychophoran

Modern “velvet worms” (onychophorans): in tropical rainforests

Onychophoran - numerous velvety-skinned wormlike carnivorous animals common in tropical forests having characteristics of both arthropods (líðýr) and annelid worms (líðormar)
Are arthropods (*liððýr*) just onychophorans (*liðormar*) with exoskeletons?
Ottoia was about 80 mm in length. It was one of the largest and most abundant of the worms found in the Burgess Shale. The spines on Ottoia's body have been interpreted as teeth used to capture prey. Gut contents show that this worm was a predator. Cannibalism, common in priapulids today, was observed in Ottoia as well. Ottoia may have burrowed and tunneled through the sediment. 1500 specimens are known.
Pikaia is regarded as the earliest known primitive chordate. It was about 40 mm in length and swam above the sea-floor. Pikaia may have filtered particles from the water as it swam along. Only 60 specimens have been found to date.
The Burgess Shale environment

A typical Cambrian outcrop might produce only trilobites, brachiopods (2), mollusks (3), and crinoids (4). That is a tiny fraction of the full Cambrian biota, better represented by the roster of the Burgess Shale Cambrian Konservat-Lagerstatten. That community includes sponges *Vauxia* (5), *Hazelia* (6), and *Eifellia* (7); brachiopods *Nisusia* (2); priapulid worms *Ottoia* (8); trilobites *Olenoides* (1); other arthropods such as *Sidneyia* (9), *Leanchailia* (10), *Marella* (11), *Canadaspis* (12), *Helmetia* (13), *Burgessia* (14), *Tegopelte* (15), *Naraia* (16), *Waptia* (17), *Sanctacaris* (18), and *Odaraia* (19); lobopods *Hallucigenia* (20) and *Aysheaia* (21); mollusks *Scenella* (3); echinoderms *Echmatocrinus* (4); and chordates *Pikaia* (22); among other oddities, including *Haplophrentis* (23), *Opabinia* (24), *Dinomischus* (25), *Wiwaxia* (26), *Amiskwia* (27), and *Anomalocaris* (28).
Dominant animals: Trilobites, Worms, Inarticulate brachiopods

Dominant life modes:
- Slow, surface-dwelling detritus feeding
- Few filter feeders, herbivores or carnivores
- Few burrowers or swimmers

Local Diversity:
- ~7 species in stressed zones
- ~13 species in near shore regions
- ~20 species in open marine
References, web resources etc

Stanley, *Earth System History*, chapter 13


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