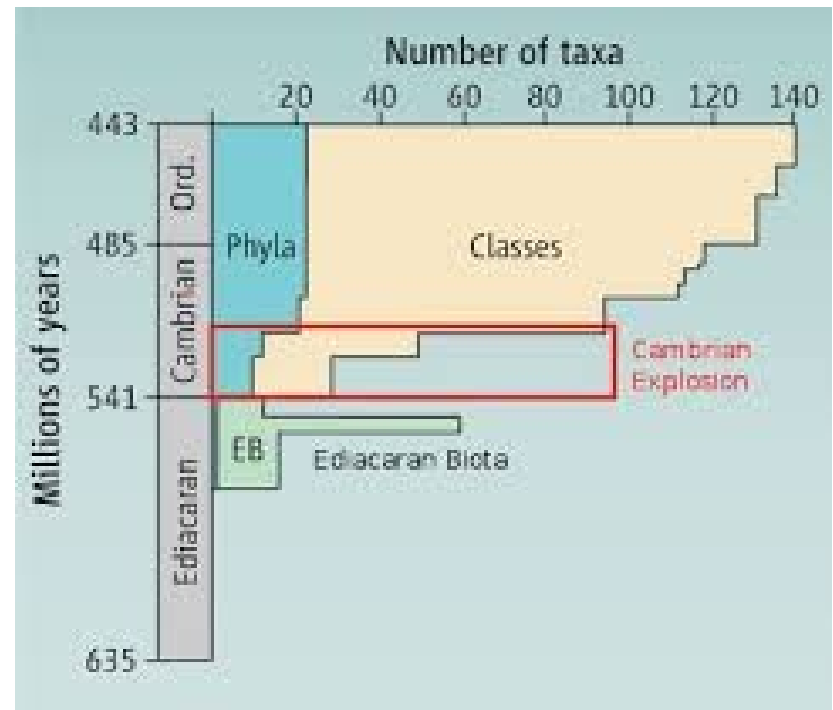
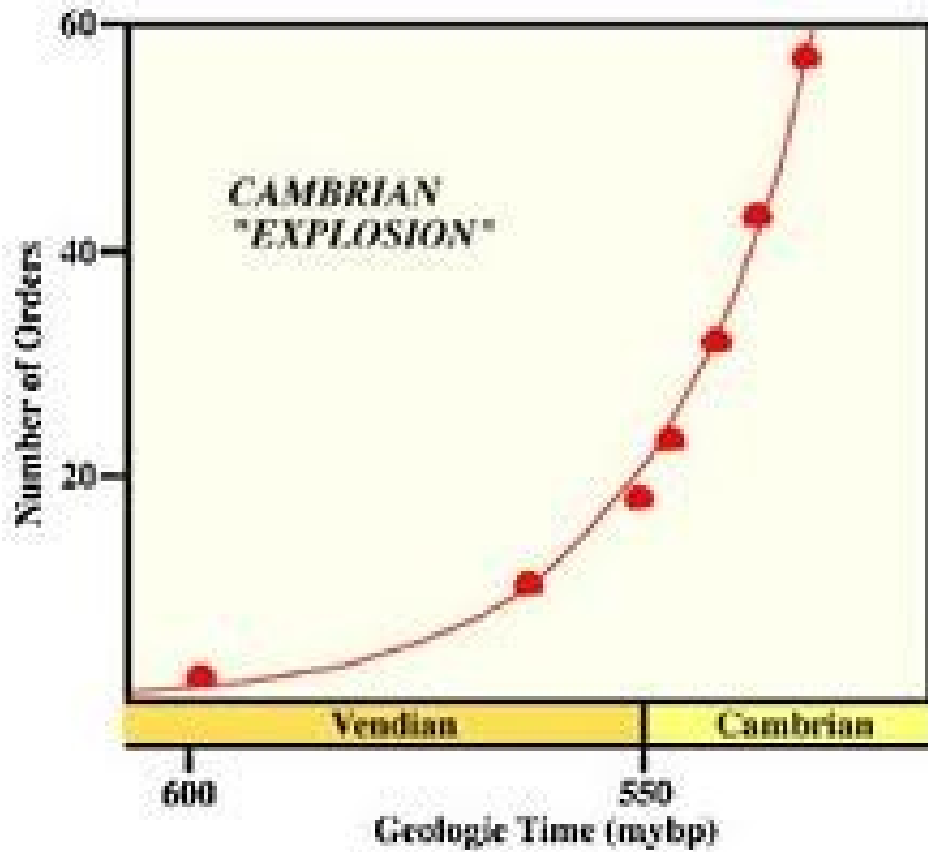


Biotické krize a globální ekosystémy v historii Země – část III.

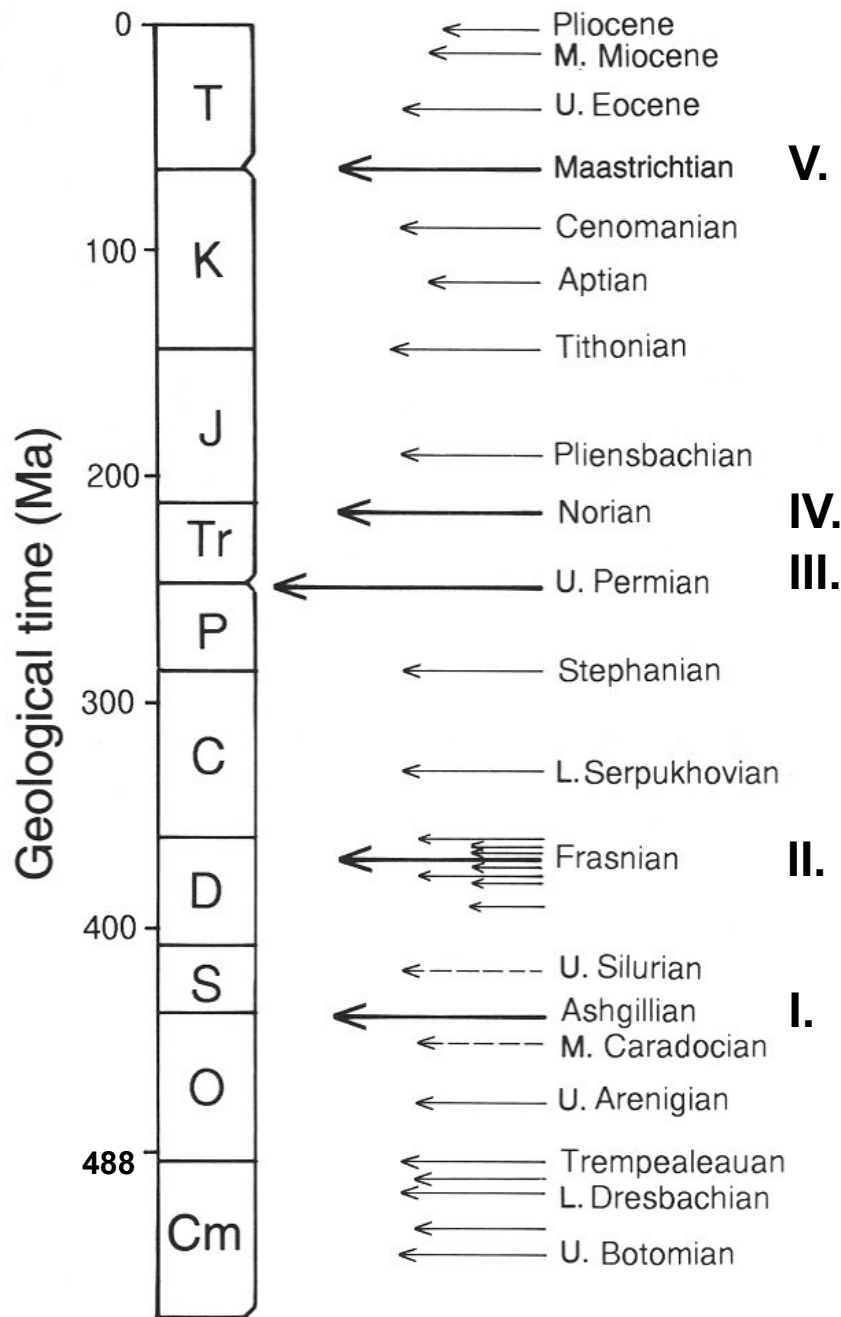
FANEROZOIKUM

Rostislav Brzobohatý

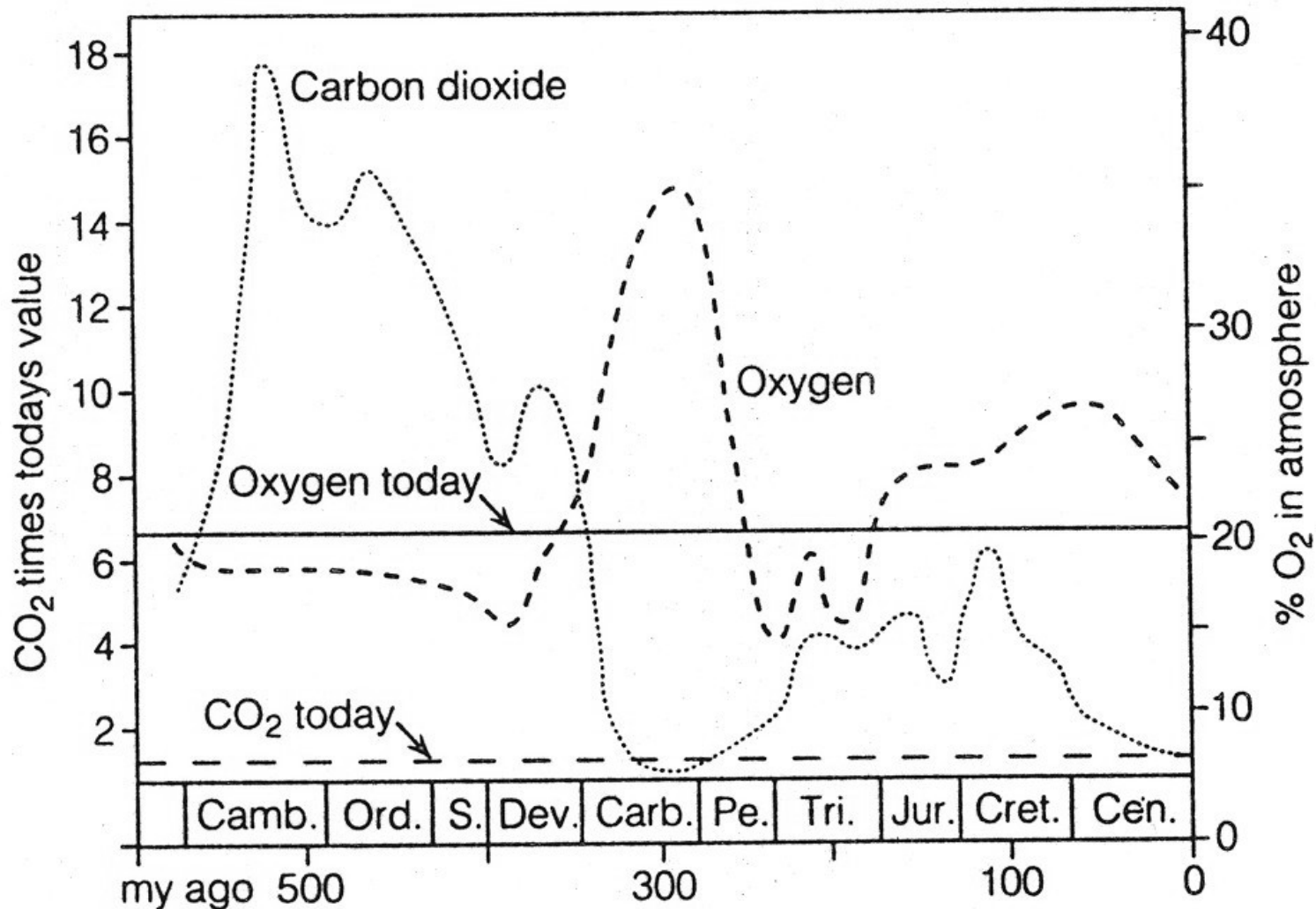
výběrovka 2019



Jak chápat tzv. „kambrickou explozi“ ?



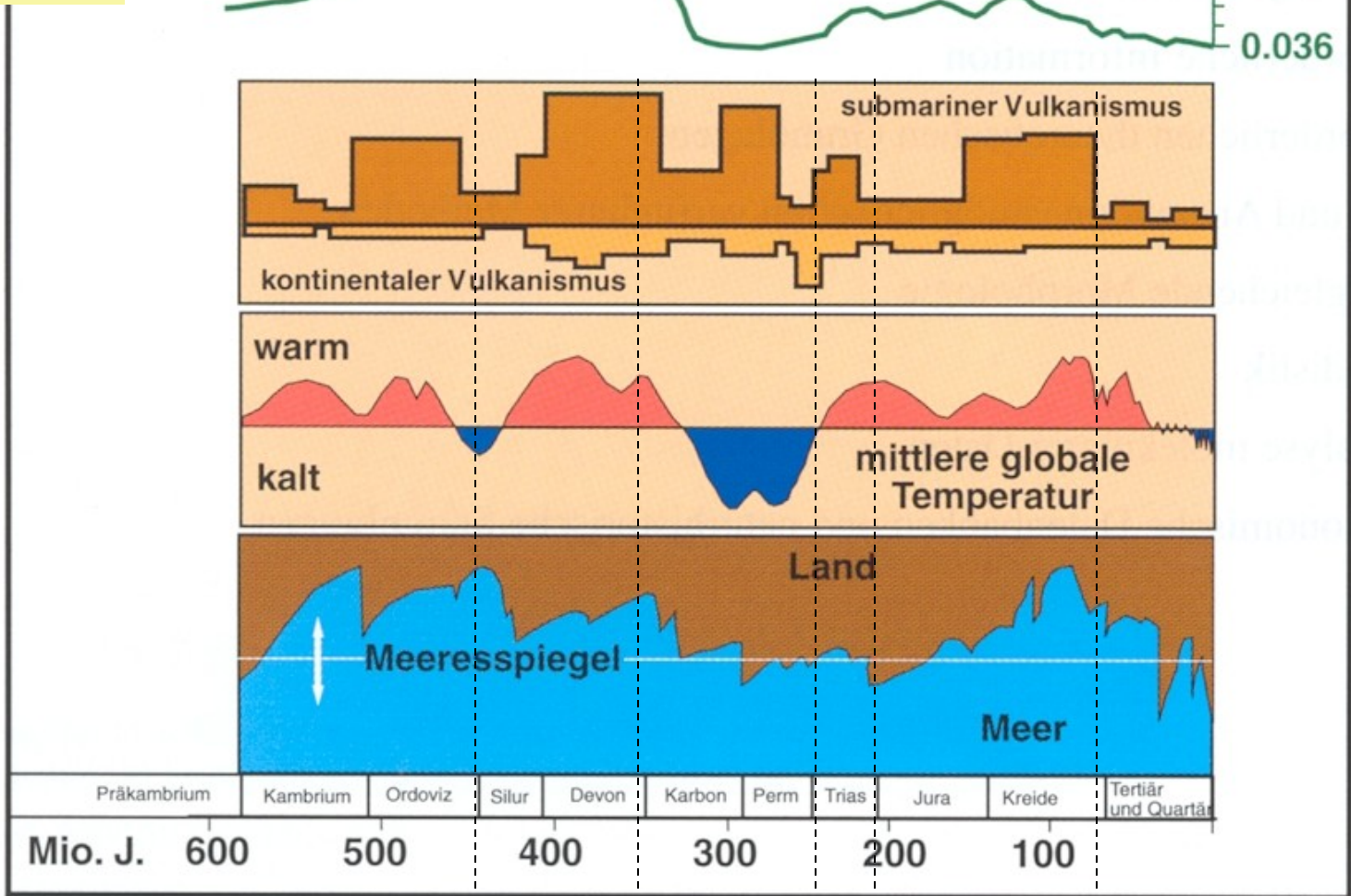
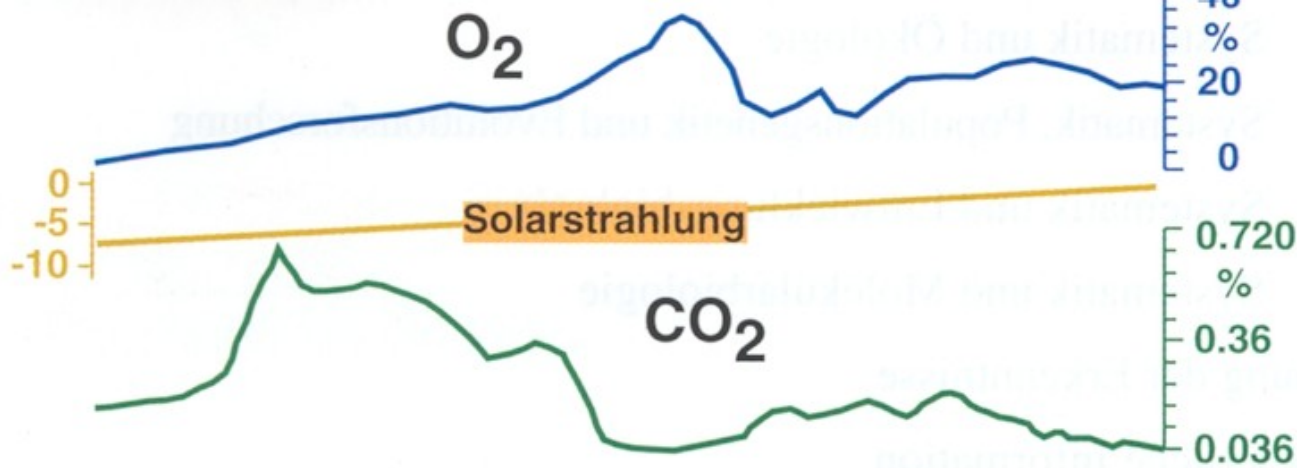
Vztah masových vymírání (tučné šipky) a drobnějších decimací globální diverzity



Kolísání obsahu O₂ a CO₂ během fanerozoika a vztah k současnému stavu

**Fanerozoikum:
intenzita vulkanizmu
a kolísání**

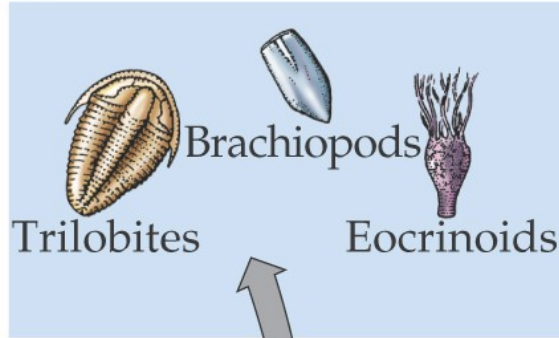
- teplot,
- mořské hladiny,
- O₂ a CO₂



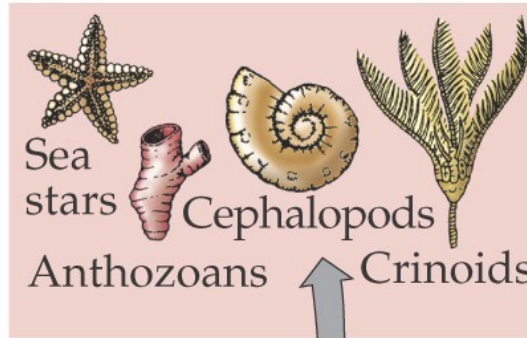
Hromadné vymírání I. II. III. (IV.) V.

3 faunistické skupiny ve fanerozoiku podle Sepkoskiho a jejich vrcholy:
1. - kambrická (modrá), 2. - paleozoická (červená) a 3. - moderní (zelená)

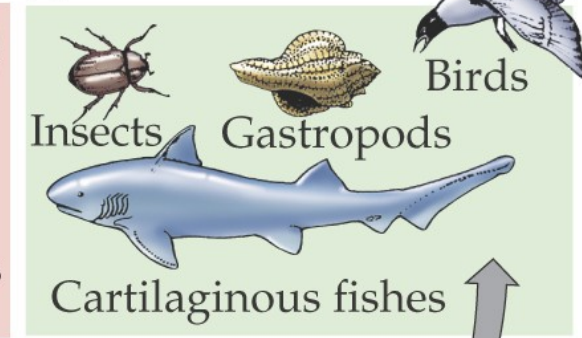
(a) Cambrian fauna



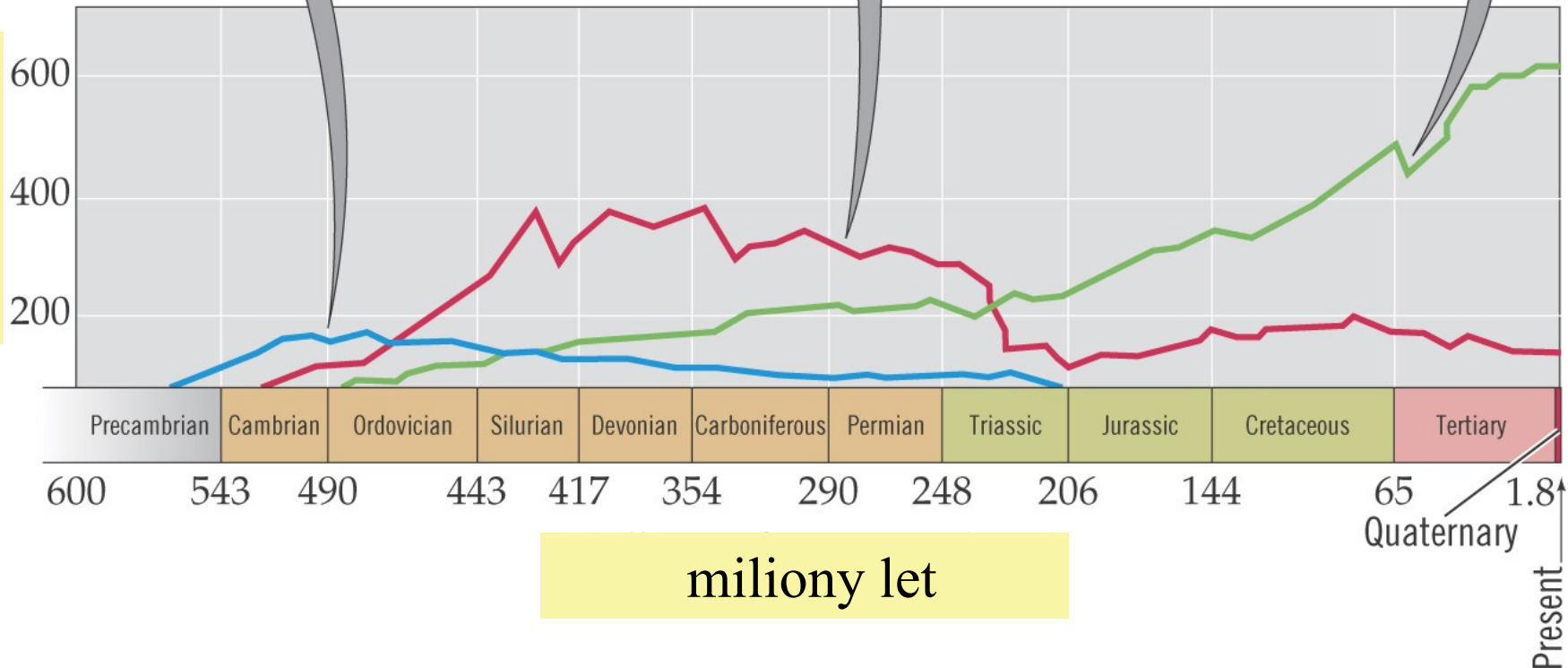
(b) Paleozoic fauna



(c) Modern fauna



Počet čeledí



Diverzita (rozdůrněnost) mořských živočichů v historii Země a epizody masového vymírání I. – V.

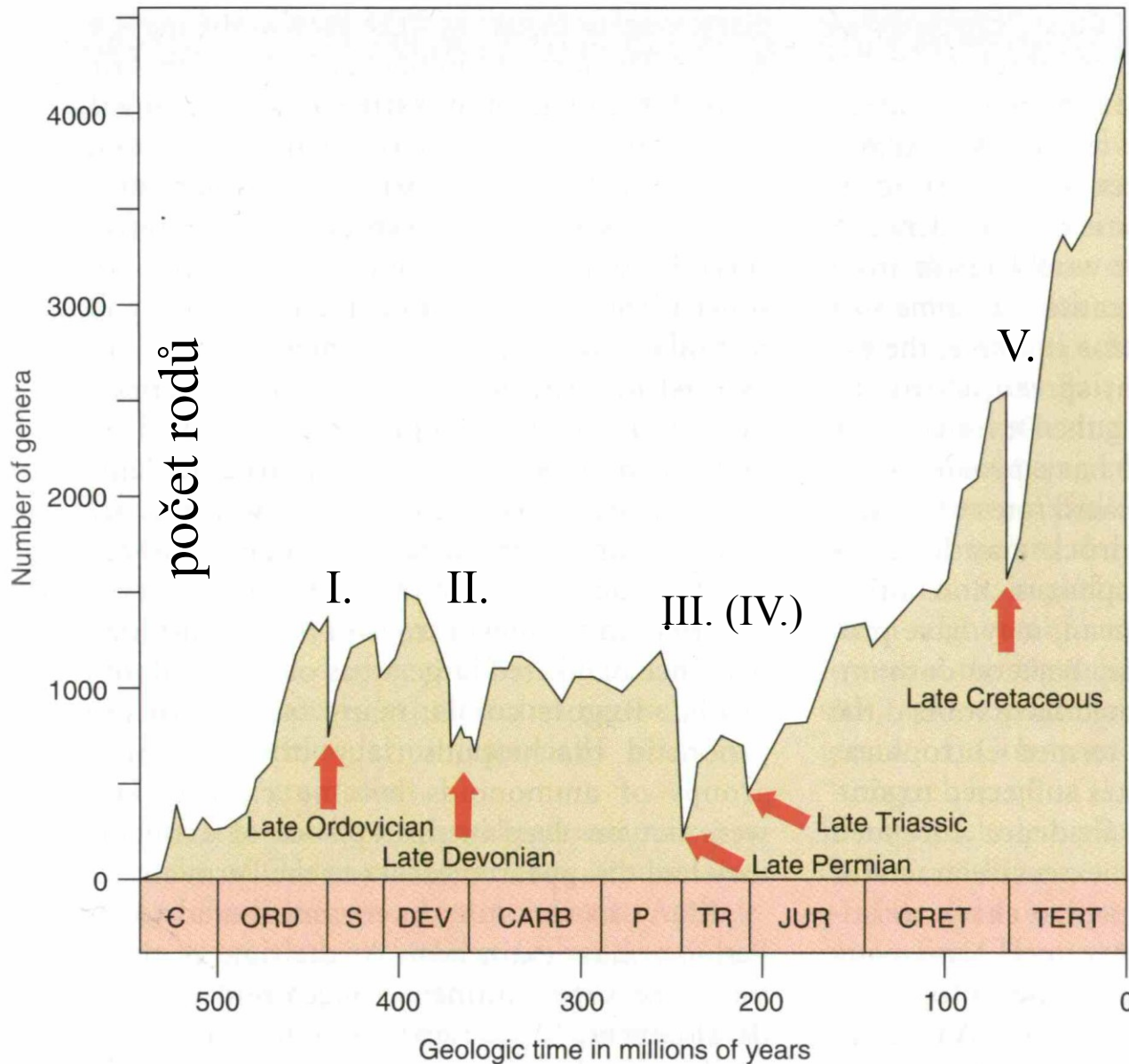
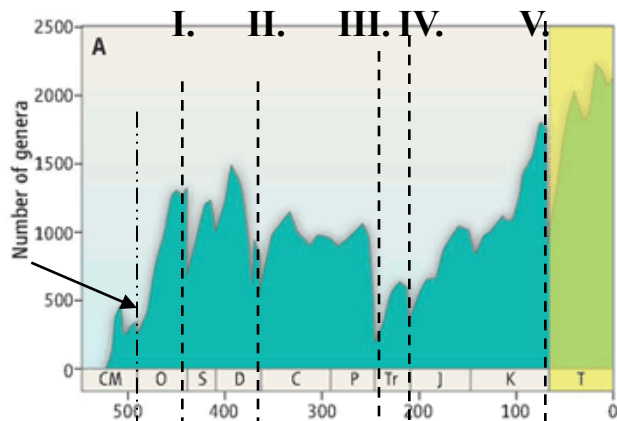
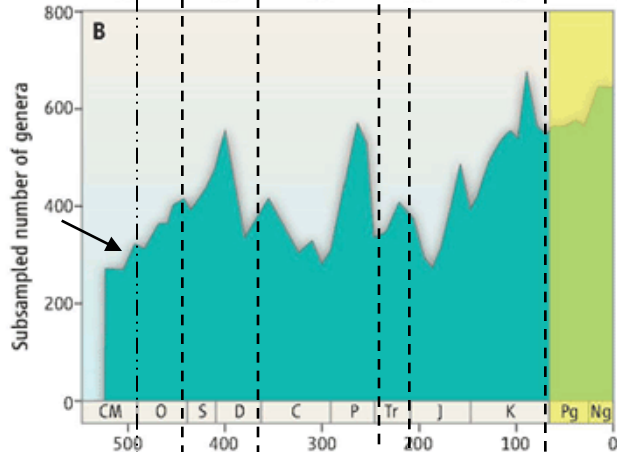


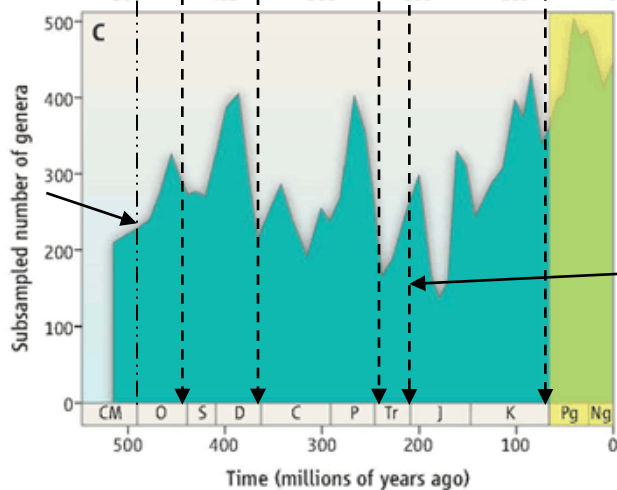
FIGURE 10–84 Diversity of marine animals compiled from a database recording first and last occurrences of more than 34,000 genera. The graph depicts five major episodes of mass extinction (global extinctions over a short span of geologic time). (Adapted from Sepkoski, J. J., Jr. 1994. *Geotimes* 39(3):15–17.)



Diversita podle Sepkoskiho (1997)



Současná křivka diverzity podle Paleobiology Database

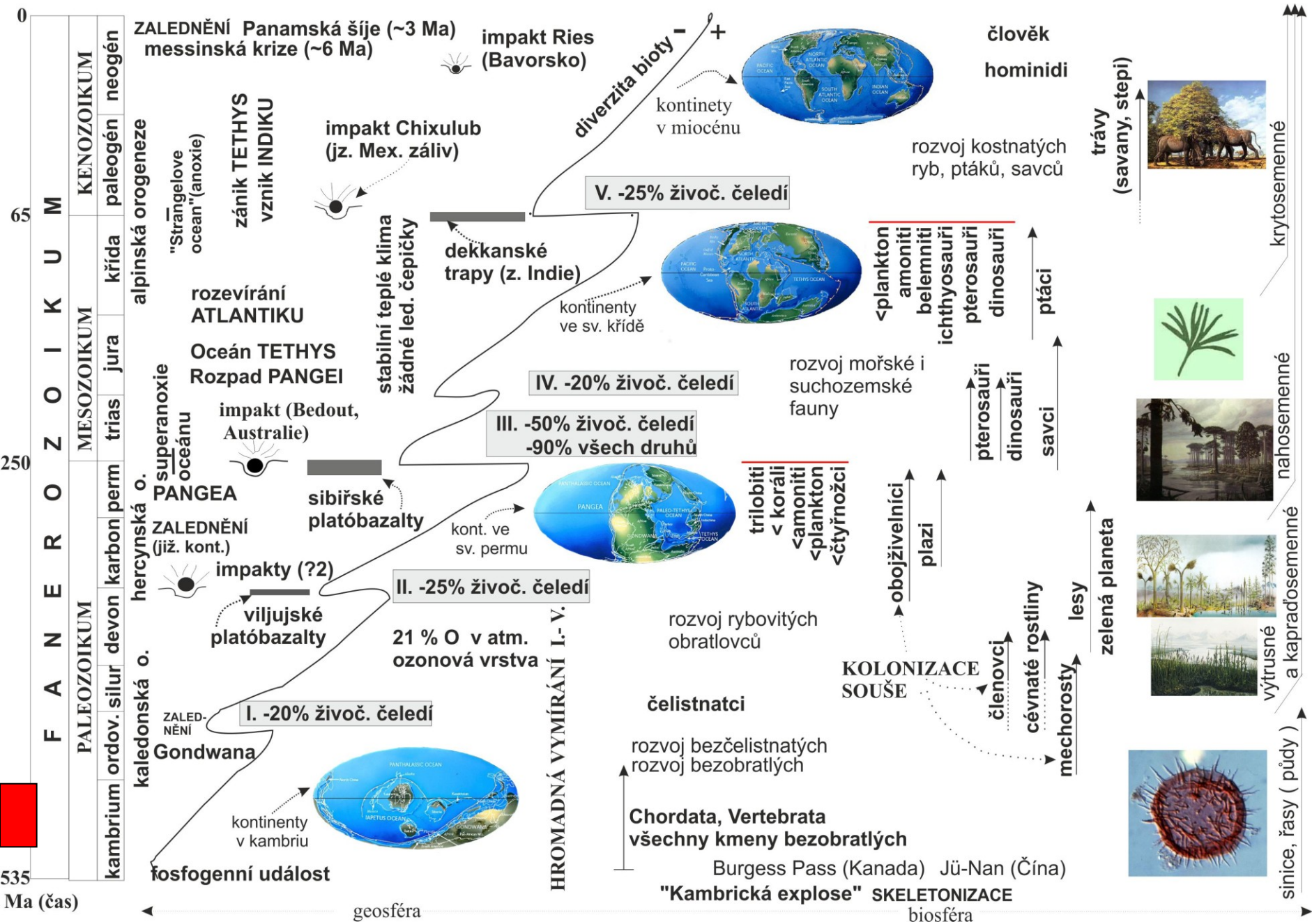


Nejnovejší křivka diverzity podle PBDB (2012) s použitím nové metody pro korekci nerovnoměrného vzorkování – pro kenozoikum (žlutá barva) je shodná s ad A)

Tr = deleatur

šipky ukazují odlišné hodnocení závěru kambria dalších excesů podle různých metod

KAMBRIUM
(542 - 488 Ma)



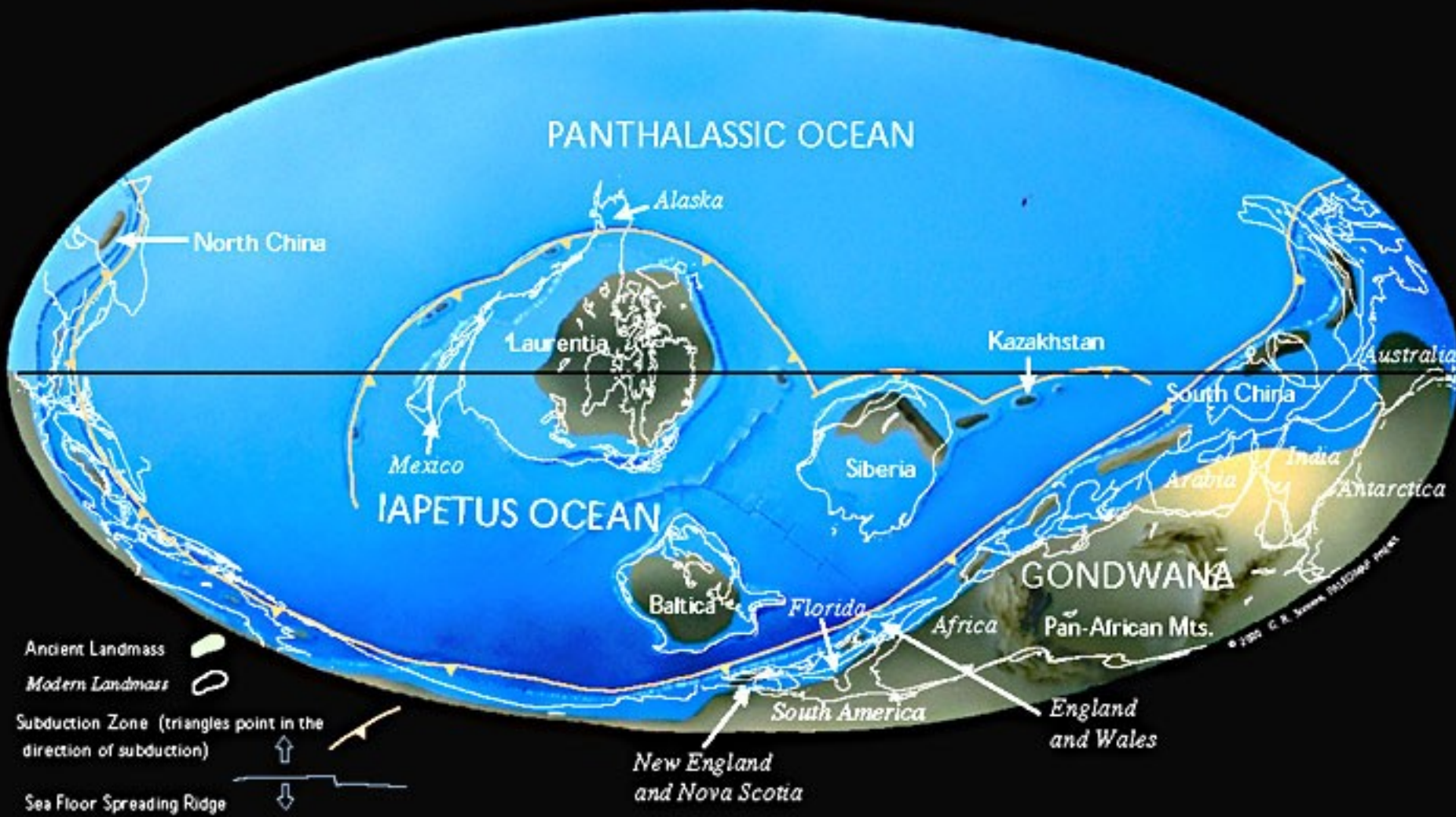
535 Ma (čas)

geosféra

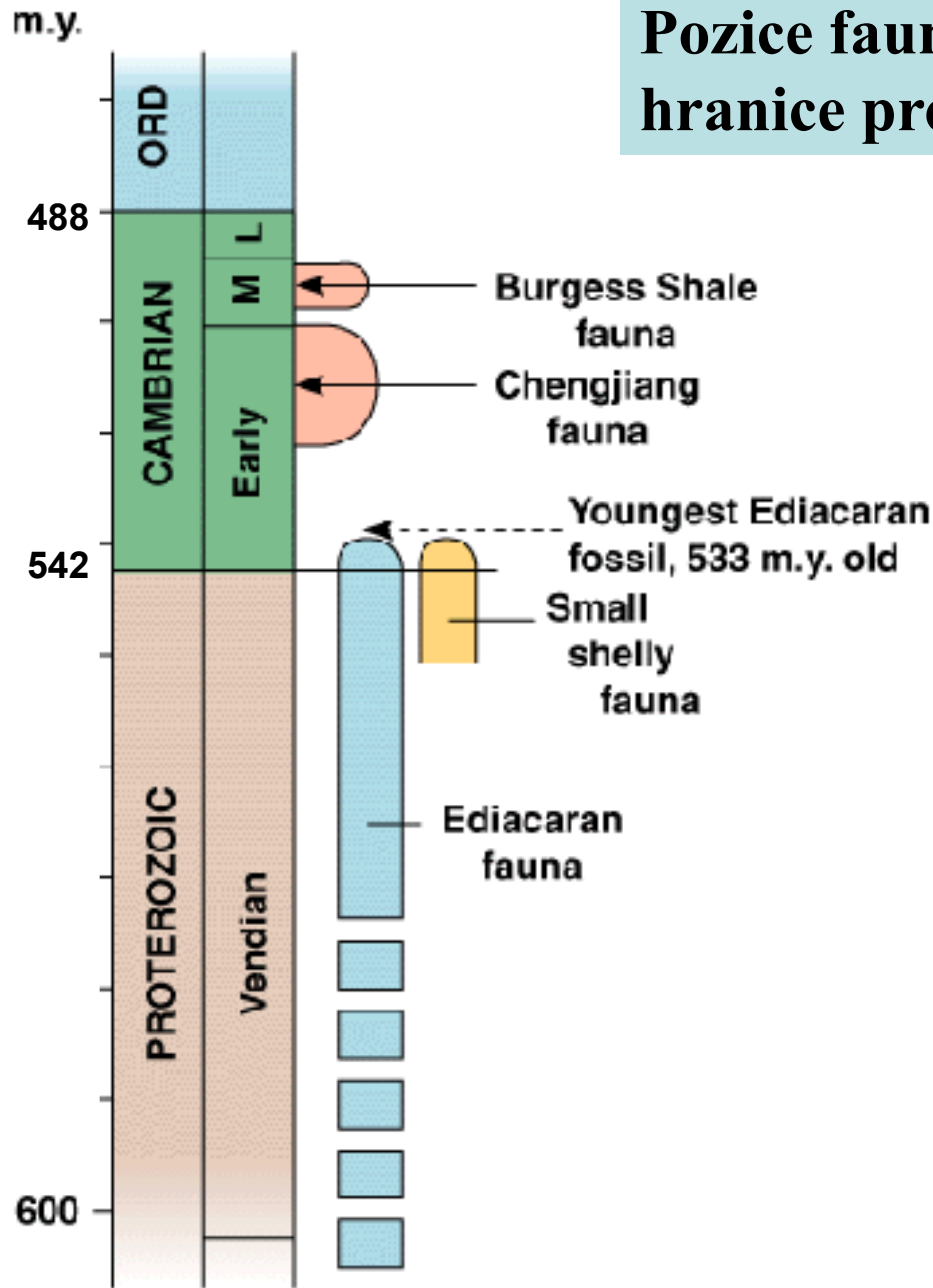
biosféra

Kambrium – rozpad Pannotie, největší kontinent Gondwana

Late Cambrian 514 Ma



Pozice faun a lokalit okolo hranice proterozoikum/fanerozoikum



Život v kambriu

- Báze kambria je většinou geologicky lehce zjistitelná podle nástupu pevných částí fosílií (schránky, kostřičky). Biomineralizace – skeletonizace, její příčiny (viz dále).
- Mluvíme o „kambrické explozi“
- V kambriu nastupují všechny kmeny s tvrdými elementy (? s výjimkou mechovek) a i četné bez pevných částí (problém zjištění?).

Evoluční výhoda schránek a koster:

1. Podpírají svaly, etc.
2. Ochrana vůči prostředí, predátorům
3. Pomoc (opora) při pohybu

Možné vysvětlení nástupu skeletonizace:

- Vysoký obsah solí ve vodách + obrana = detoxikace
- Zvyšující se obsah kyslíku v prostředí a možnost jeho využití pro energeticky náročnou biochemii (srovnání: v dnešních prostředích s nízkým obsahem kyslíku žijí jen malé měkkotělé organizmy).
- Stavba těla (12 – buněk)

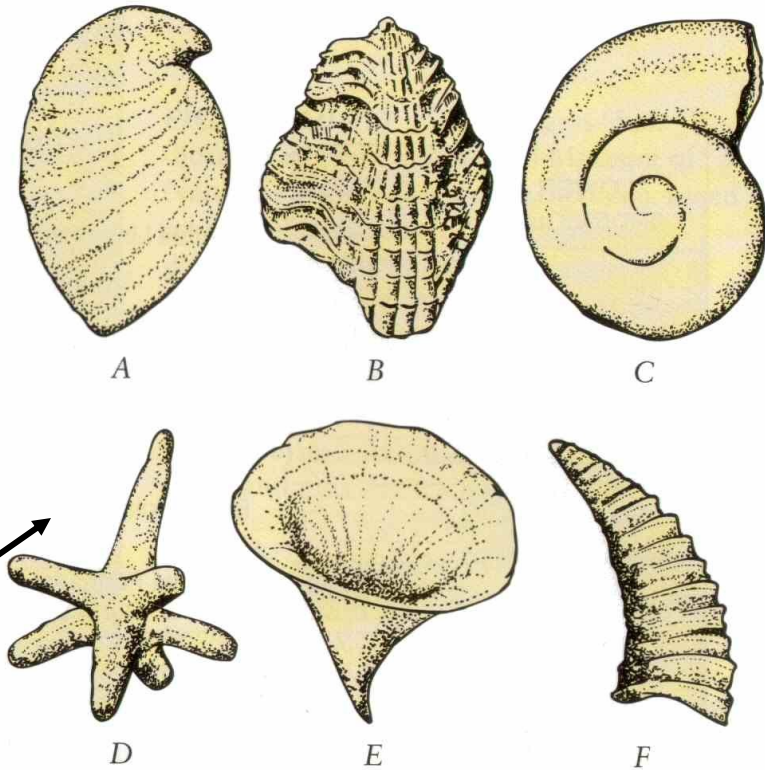
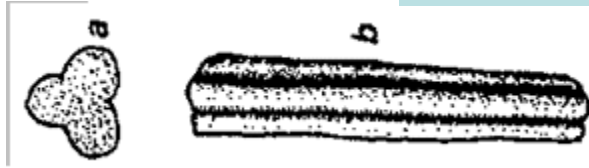


FIGURE 10-13 Late Precambrian and Early Cambrian shell-bearing fossils from Siberia. (A) *Anabarella*, $\times 20$, a gastropod; (B) *Camenella*, $\times 18$, affinity uncertain; (C) *Aldanella*, $\times 20$, a gastropod; (D) sponge spicule, $\times 30$; (E) *Fomitchella*, $\times 45$, affinity uncertain; and (F) *Lapworthella*, $\times 20$. (After Matthews, S. J. and Missarzhevsky, V. V. J. 1975. Geol. Soc. London 131:289-304.)

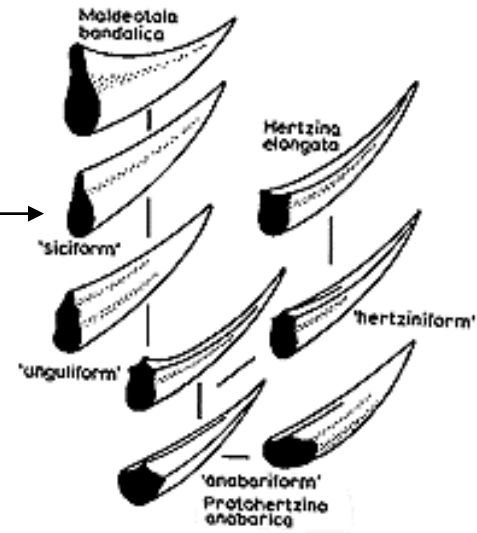
Okolo hranice Prz/Cm se objevuje tzv. „tomotská fauna“:

- drobné (1 – 5 mm) fosfatické schránky, většinou neznámého systematického zařazení a příbuznosti.
- tvar: většinou trubičky, ostny, kuželovité nebo destičkovité fosílie
- zástupci tomotské fauny mizí během kambria.

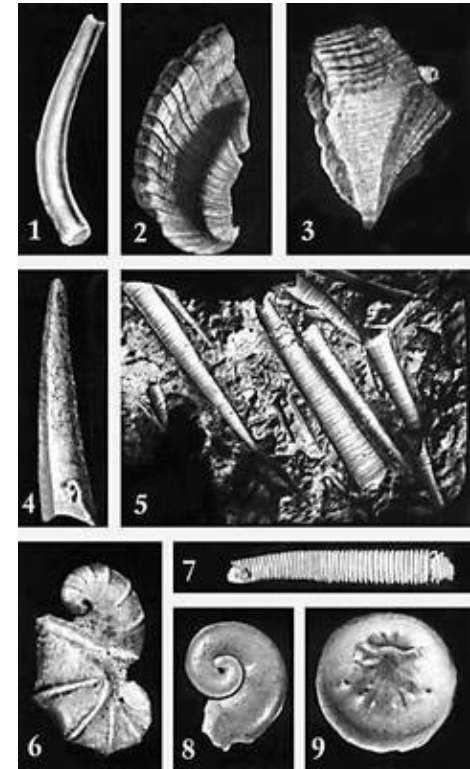
Další ukázky tomotských zkamenělin, Sibiř



Protohertzina



Anabarites sp., proterozoikum/kambrium, Sibiř, v hornině a rekonstrukce



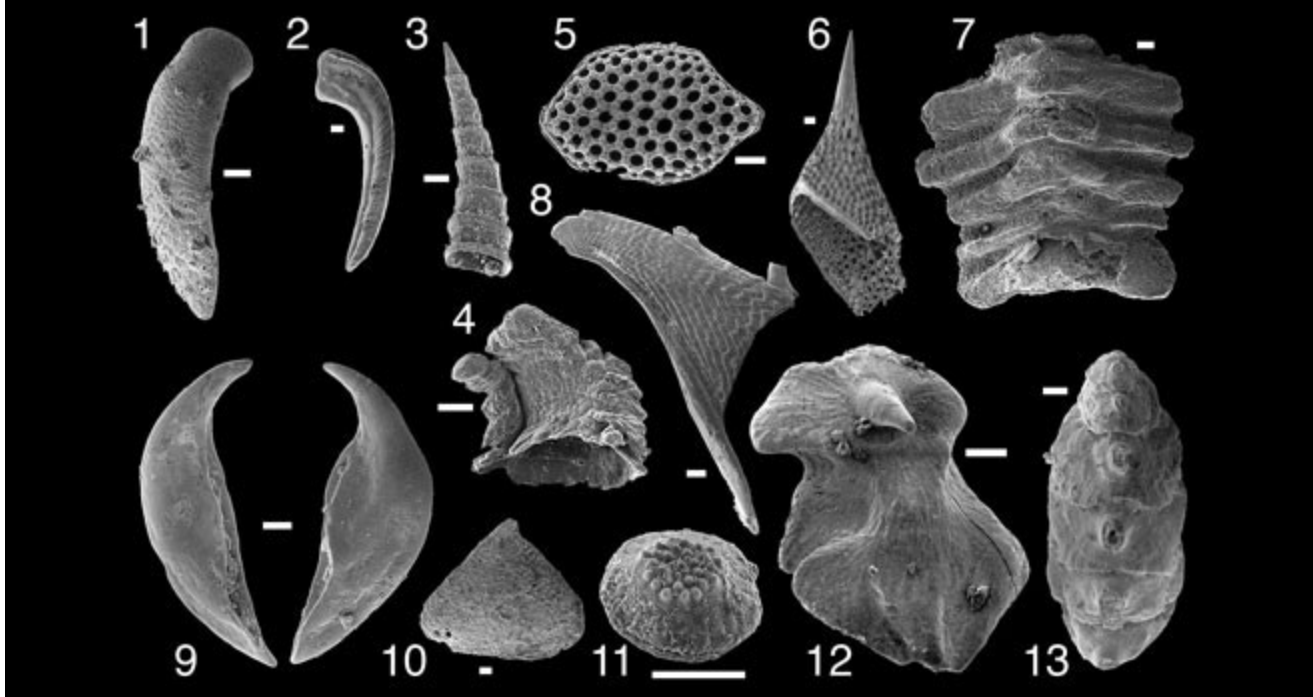


Fig. 1 Early Cambrian **sclerite-bearing** animals. 1, *Siphogonuchites*. 2, *Hippopharangites*. 3, *Lapworthella*. 4, *Eccentrotheca*. 5, 6, *Microdictyon*. 7, *Tumulduria*. 8, *Scoponodus*. 9, Jaw-like elements of *Cyrtochites*. 10, *Porcauricula*, 11, Dermal element of *Hadimopanella*. 12, *Cambroclavus*. 13, *Paracarinachites*. Scale bars = 0.1 mm.

© Swedish Museum of Natural History. Photos: Stefan Bengtson.

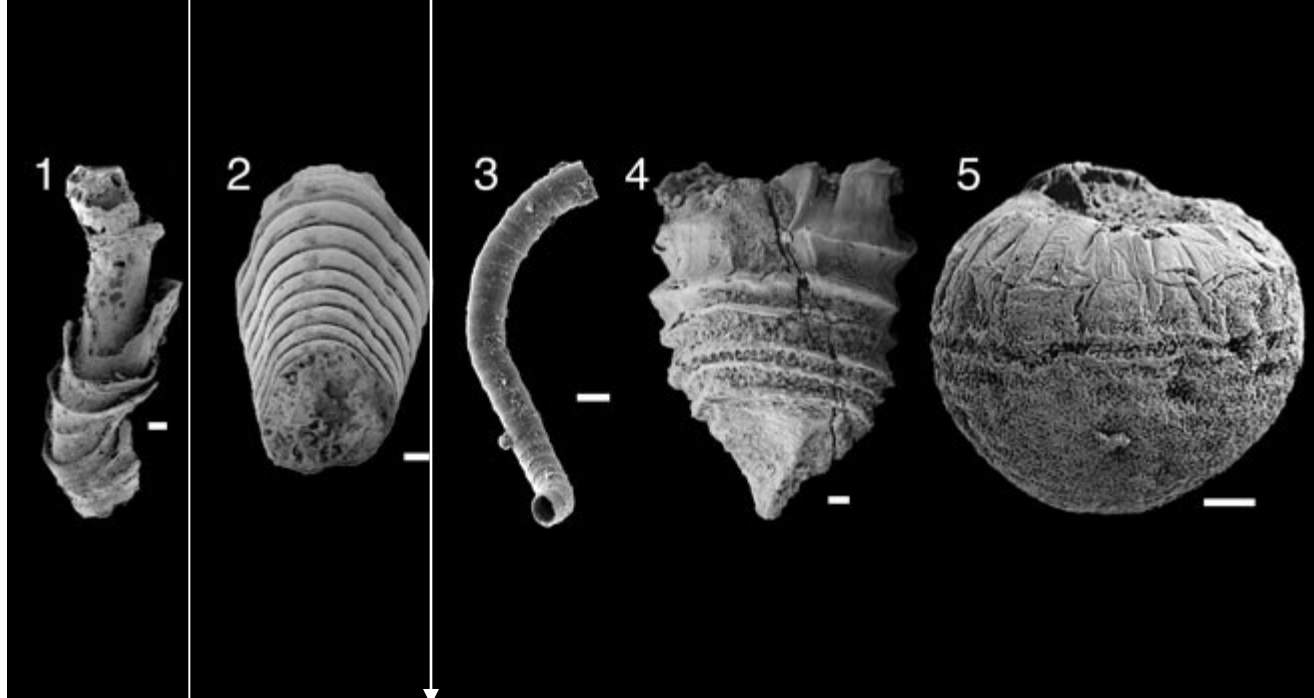


Fig. 2 Early **tube-dwelling** animals. 1, *Cloudina*, one of the earliest animals with a mineralized skeleton reinforced with calcite (late Neoproterozoic). 2, *Aculeochrea*, with an aragonite-reinforced tube (Precambrian-Cambrian boundary beds). 3, *Hyolithellus*, an animal reinforcing its tube with calcium phosphate (early Cambrian). 4, *Olivoides*, possibly a thecate scyphozoan polyp. 5, Pre-hatching embryo of *Olivoides*. Scale bars = 0.1 mm.
© Swedish Museum of Natural History. Photos: Stefan Bengtson.

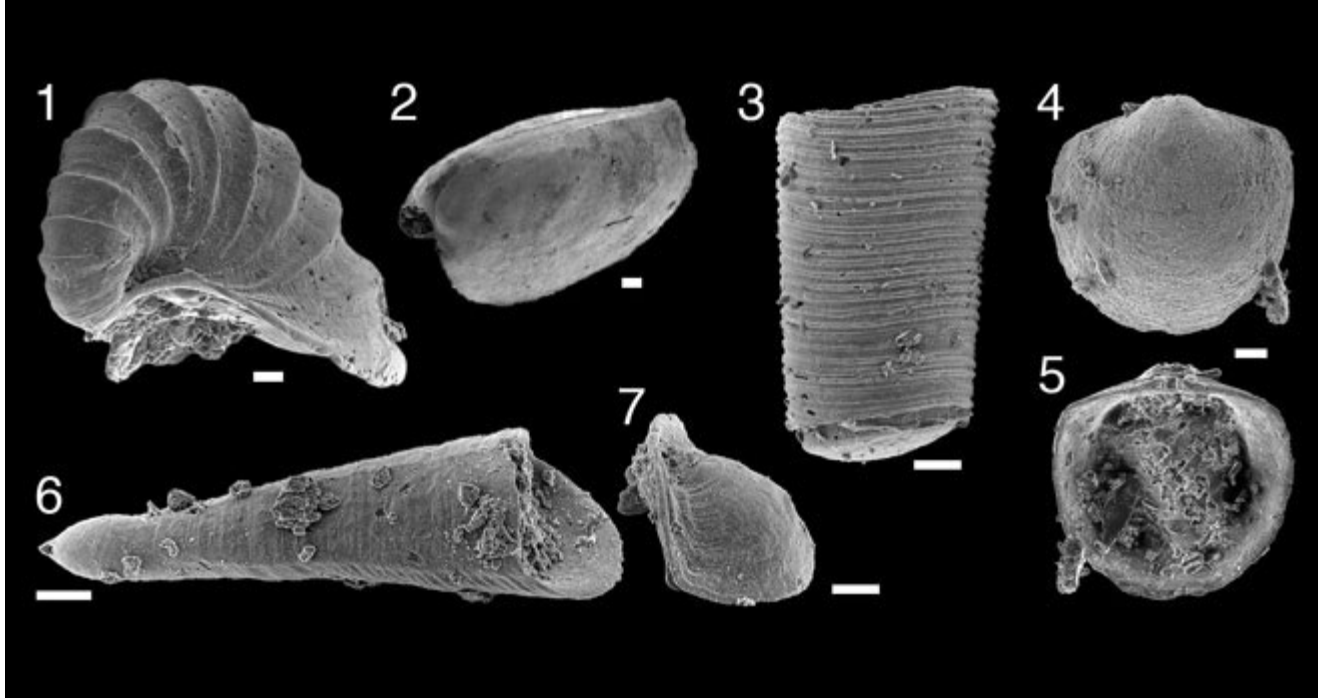


Fig. 3 Early Cambrian **shell-bearing** animals. 1, *Archaeospira*, a possible gastropod. 2, *Watsonella*, a possible mollusc. 3, *Cupithecina*. 4, 5, *Aroonia*, a probable stem-group brachiopod. 6, 7, Conch and operculum of *Parkula*, a hyolith. Scale bars = 0.1 mm.

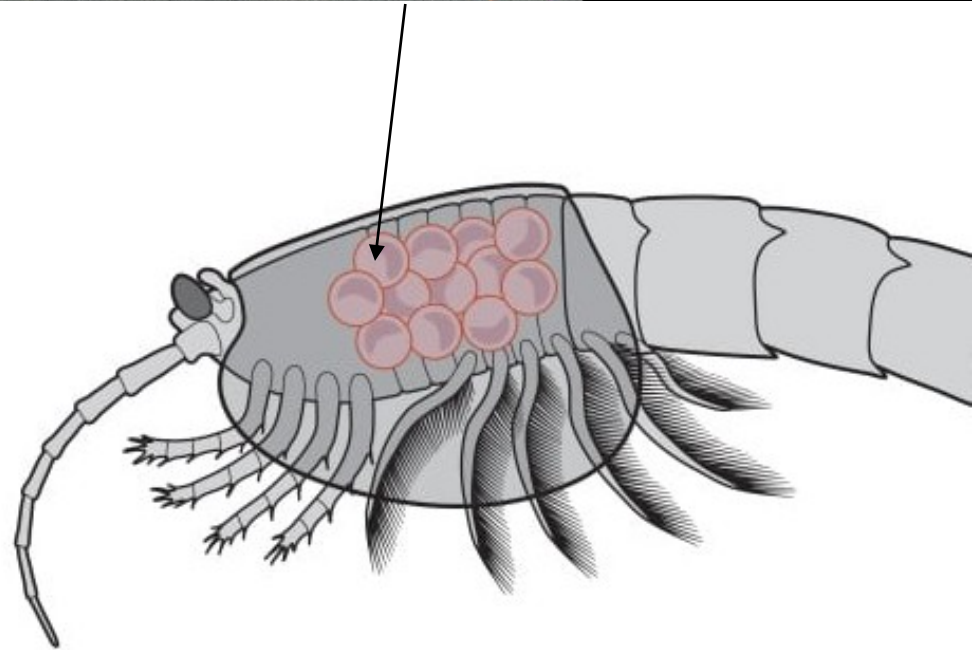
© Swedish Museum of Natural History. Photos: Stefan Bengtson.

Péče o potomstvo – korýši (*Waptia*) – 508 Ma

Fossils of a female crustacean — the oldest known example of a female animal with eggs — suggest that parental care is almost as ancient as animals themselves. Jean-Bernard Caron at the Royal Ontario Museum in Toronto, Canada, and Jean Vannier of Claude Bernard University Lyon in France report the discovery of 5 well-preserved, 508-million-year-old fossils of the extinct crustacean *Waptia fieldensis*, with remnants of embryos visible. The specimens showed that *Waptia* carried broods of around 24 large eggs, each measuring up to 2.5 millimetres across, in a crevice between the body and the shell. The shell may have helped **parental care** to evolve by providing a safe environment to incubate eggs. The findings suggest that parental care appeared less than 50 million years after the evolution of animals.

***Curr. Biol.* <http://doi.org/989>**

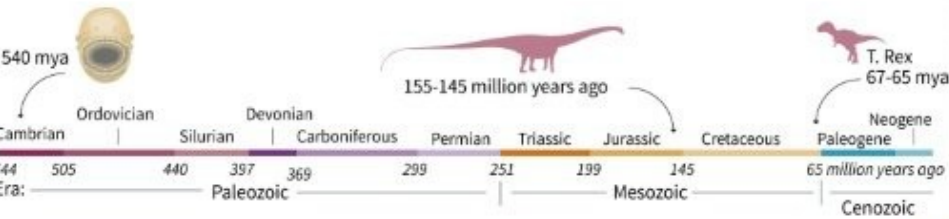
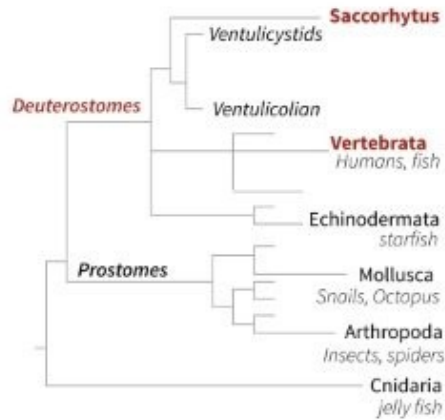
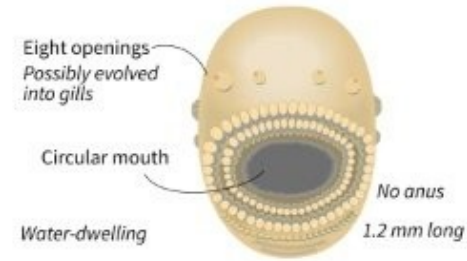
(2015)



A very distant relative

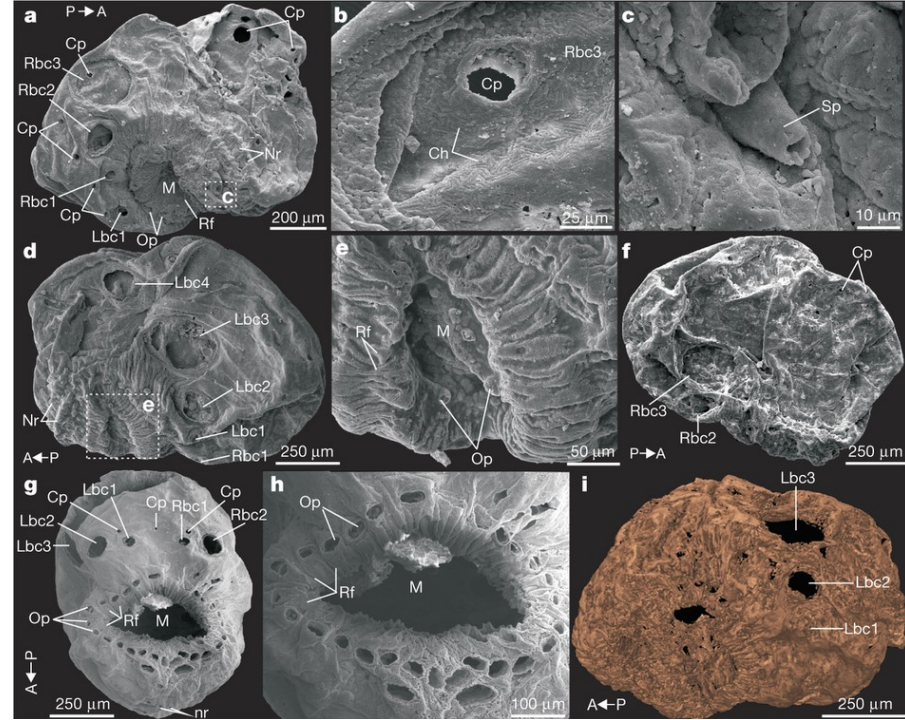
New study describes a 540 million-year-old lifeform related to all vertebrates

Saccorhytus coronarius



Source: Nature -- Han, Morris, Ou, Shu, Huang

© AFP



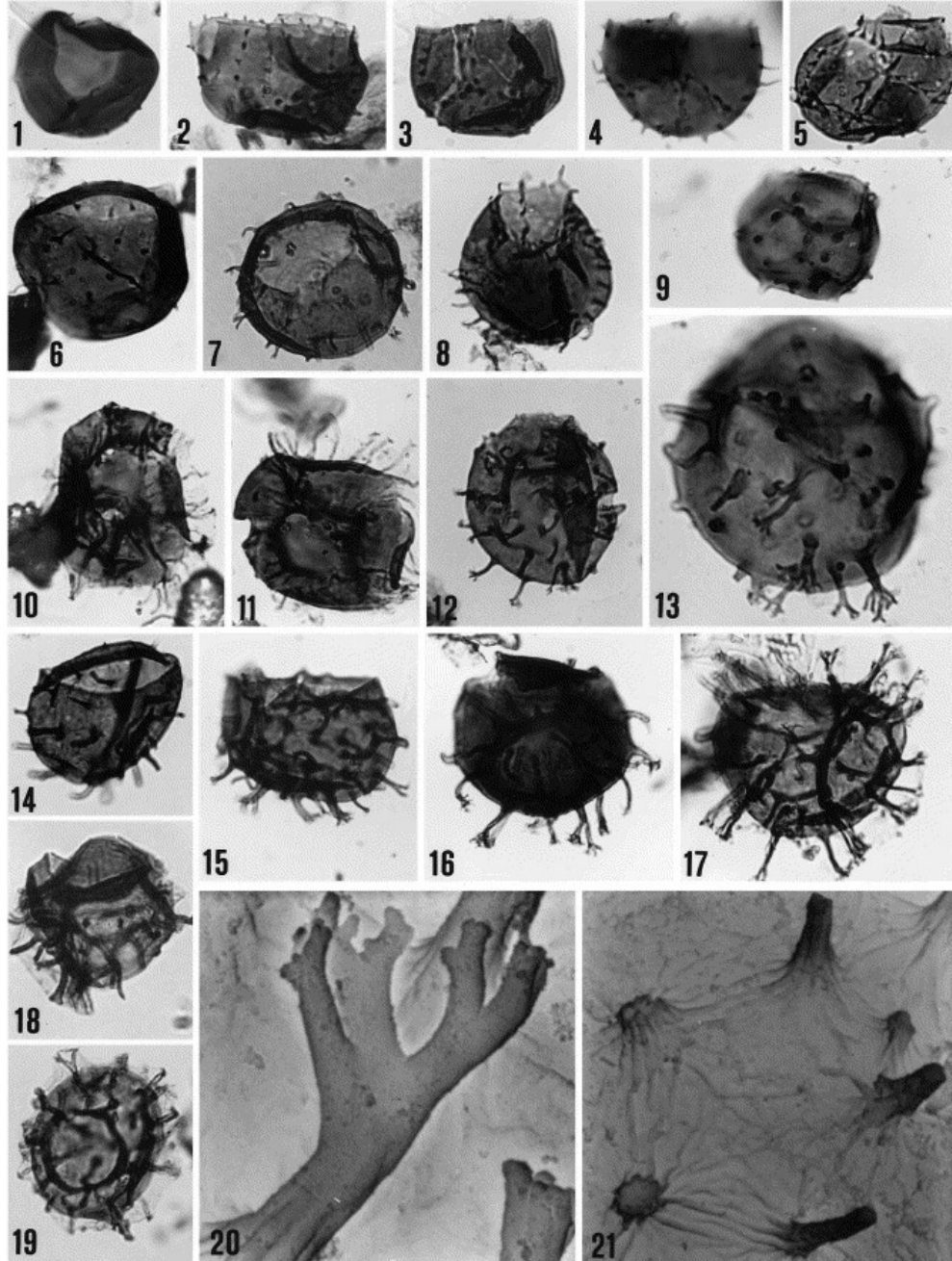
? ... nejstarší doložená deuterostomia

Saccorhytus coronarius gen. et sp. nov.
from the Cambrian Kuanchuanpu
Formation,
South China

Báze kambria, 540 Ma

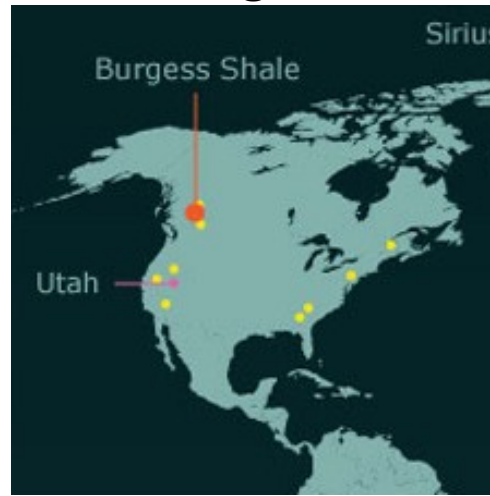
Han et al. 2017: Meiofaunal deuterostomes from the basal Cambrian of Shaanxi (China)
Nature 21072 (leden 2017)

Rychlý přehled kambrického života



Kambricko-ordovická acritarcha

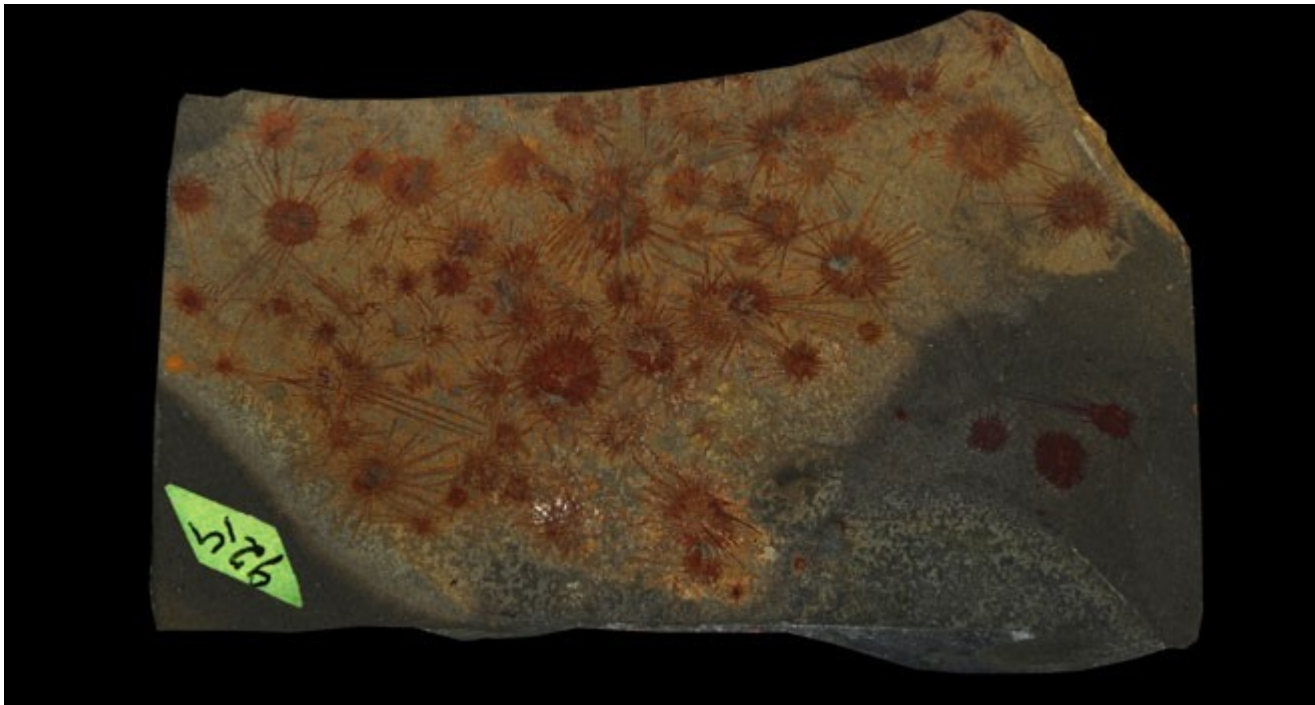
**Ch. Walcott, 1912, Burgess Pass,
str.Cm**



Burgess Quarry dnes



**Locality: Yoho
National Park,
Canadian Rockies,
southern British
Columbia, Canada
Stratigraphy:
Stephen Formation
Age: Late Middle
Cambrian. ca 505 Ma**



Choia ridleyi, Porifera

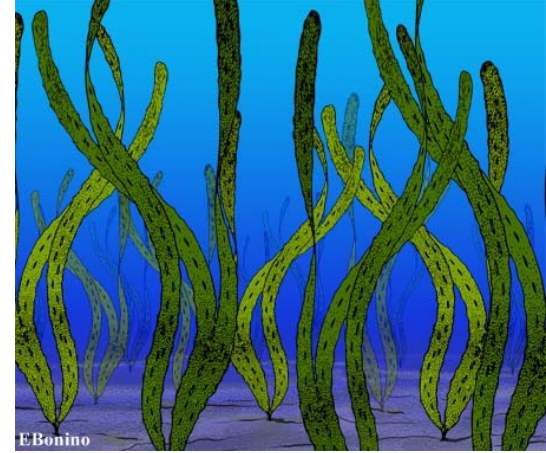
stř. Cm, Burgess Shales

? Chlorophyta



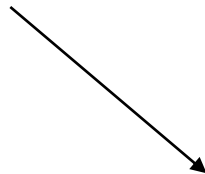
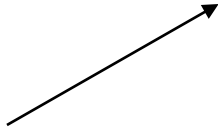
Margaretia dorus (Wal.)

(Pozn. pův. Octocorallia)



EBonino

Porifera



Diagonella sp.
(Porifera)



Adler



Choia sp.
(Desmospongia)

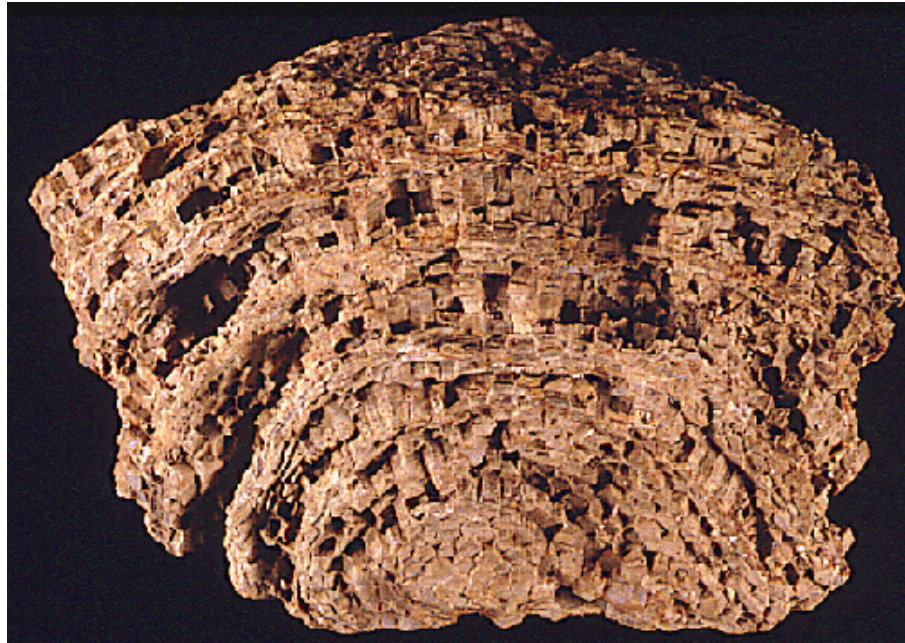


Burgesské
břidlice (stř. kambrium)

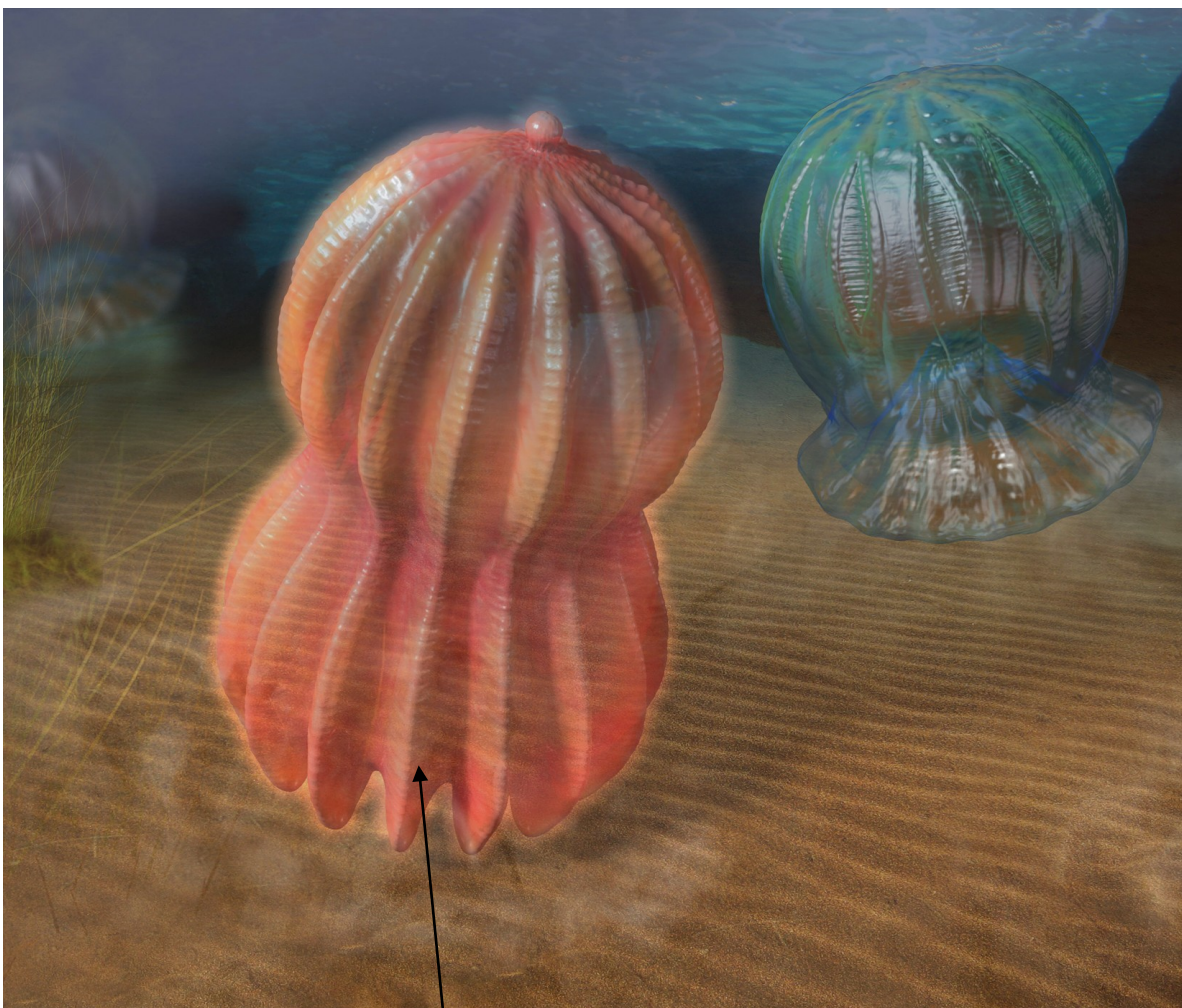


Ctenorhabdotus scapulus, Ctenophora

stř. Cm, Burgess Shales



Moorowipora
chamberensis,
dosud považovaná
za nejstarší tabulata,
Cm, jižní Austrálie



Martianoascus

medúza ??

stř. Cm, Burgess Shales

Archeocyāti (příbuzní živočišných hub) – stavitelé spodnokambrických útesů

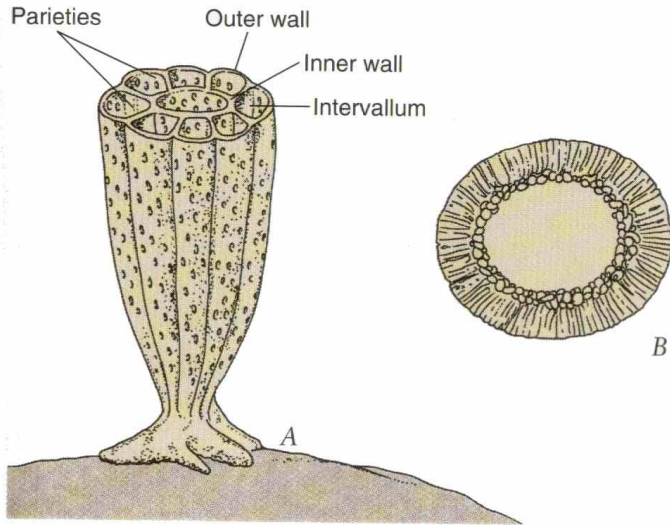
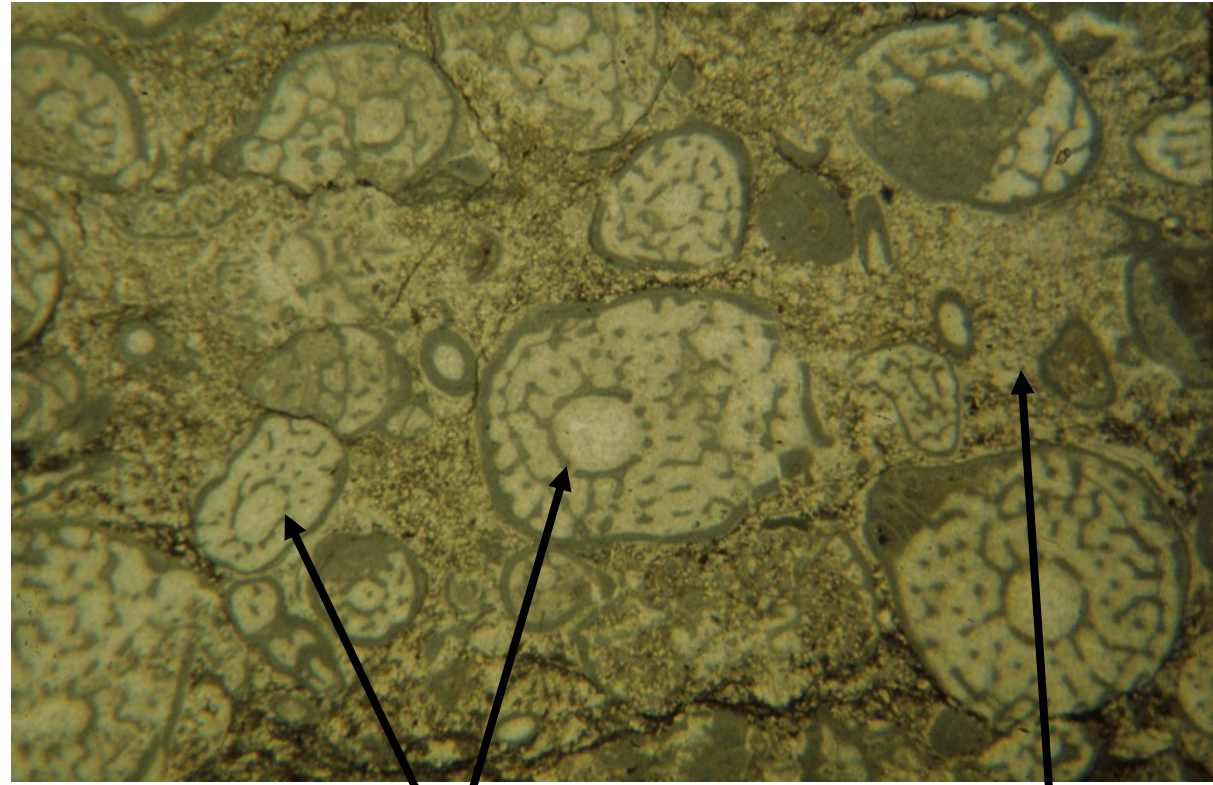


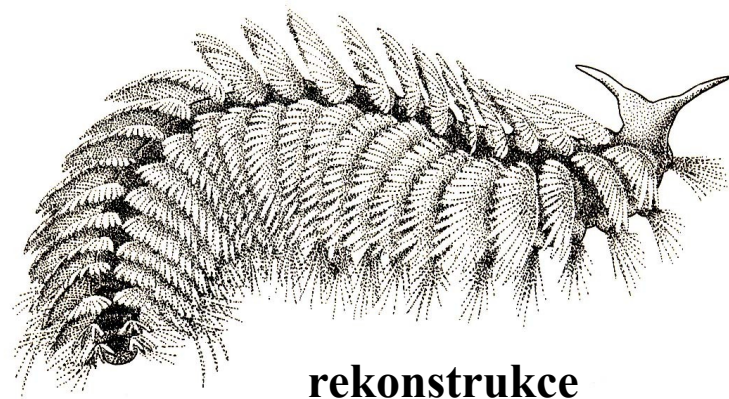
FIGURE 10-25 The archaeocyathan skeleton. (A) Longitudinally fluted cup of an archaeocyathan, about 6 cm in height. (B) Transverse section of a nonfluted archaeocyathan having closely spaced parietes and vesicular inner wall. (Maximum diameter is 4 cm.)



Řez biohermou archeocyátů s mezerní hmotou kalcimikrobů, spodní kambrium, lemdadské souvrství, Vys. Atlas, Maroko



Canadia spinosa, Annelida



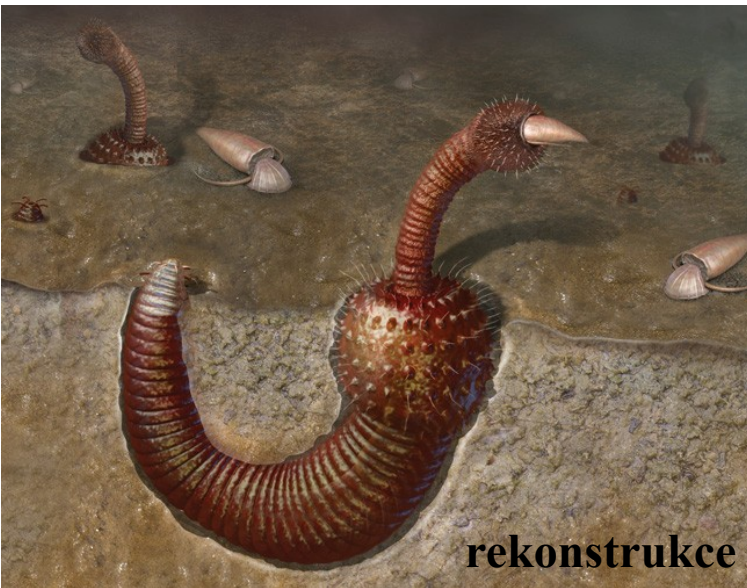
rekonstrukce

stř. Cm, Burgess Shales



Selkirkia columbia, Priapulida

stř. Cm, Burgess Shales



rekonstrukce



***Halucigenia*, Lobopodia (fossil tax.),
blížkost k červům ?**



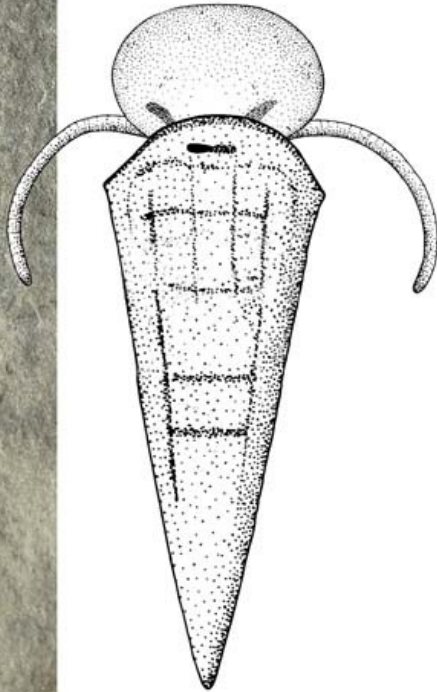
rekonstrukce

stř. Cm, Burgess Shales

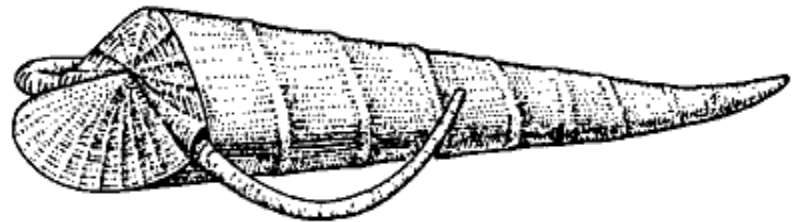
Hyolitha, mořští, dnes k měkkýšům,
rozvoj v kambriu, vymírají ve stř. permu



Hyolithes sp.,
kambrium, Utah



Haplopherensis reesei,
kambrium, Utah





Odontogriphus omalus, Mollusca ?



stř. Cm, Burgess Shales



Odontogriphus

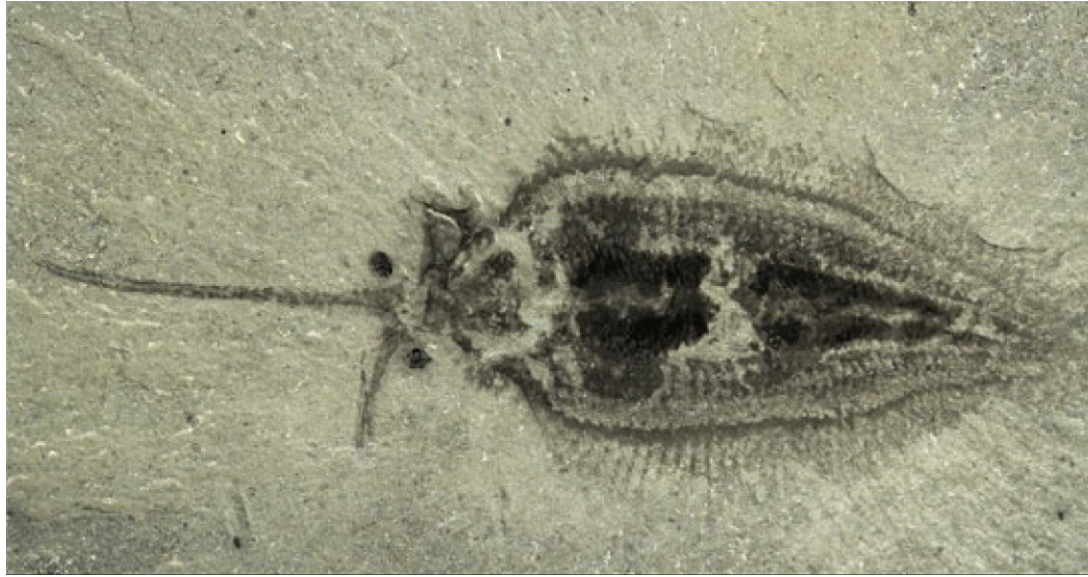
rekonstrukce



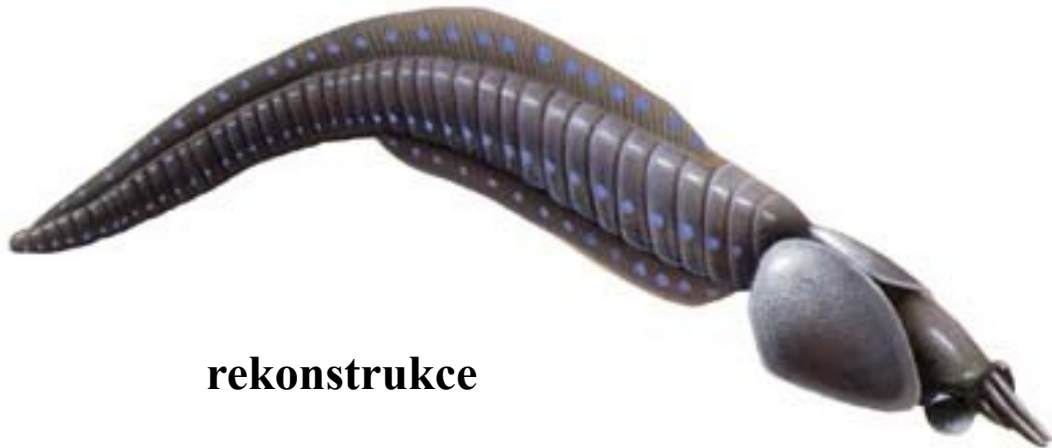
Wiwaxia, Mollusca stř. Cm, Burgess Shales



rekonstrukce



Nectocaris, Mollusca



rekonstrukce

stř. Cm, Burgess Shales



Micromitra burgessensis, Mollusca

stř. Cm, Burgess Shales

• **Brachiopoda:**

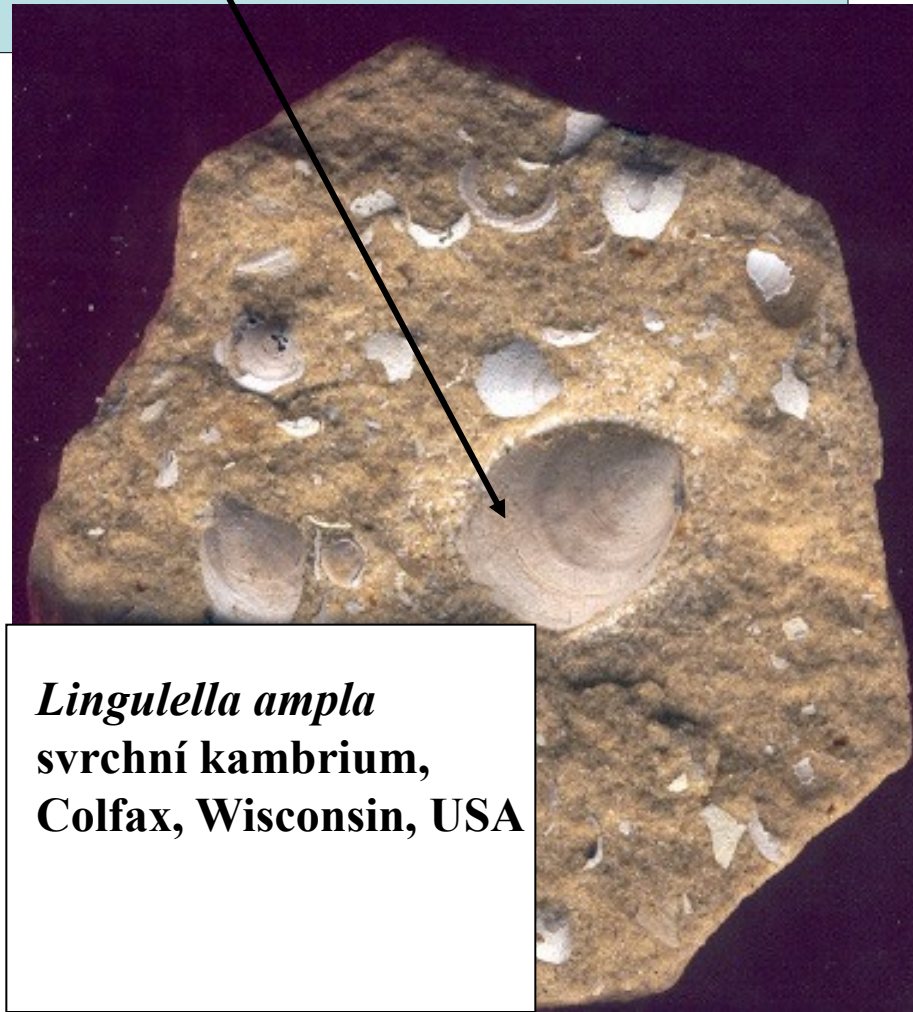
• Dvouchlopněvá schránka, filtrátoři

• Dominantní skupina v kambriu jsou “**inartikulátní**” (bezoporní): < infauní formy se schránkami z fosforečnanu vápenatého a epifauní formy s Ca CO₃ schránkami)

• Nastupují i **artikulátní brachiopodi** (se zámkem, epifauní, kalcitové schránky)



Bohemiella romingeri, Skryje,
střední kambrium, barrandien.



Lingulella ampla
svrchní kambrium,
Colfax, Wisconsin, USA



Portalia mira, inc. sed.

stř. Cm, Burgess Shales



Aisheaia pedunculata, Onychophora



rekonstrukce

stř. Cm, Burgess Shales



Naraoia compacta, Arthropoda

str. Cm, Burgess Shales

Trilobita



Sao hirsuta, střední kambrium, Skryje



Conocoryphe sulzeri, střední kambrium, Jince, barrandien



Olenellus fowleri,
Spodní kambrium,
Lincoln County,
Nevada

Ptychoparia striata
střední kambrium
Jince, barrandien



Členovci



Canadaspis



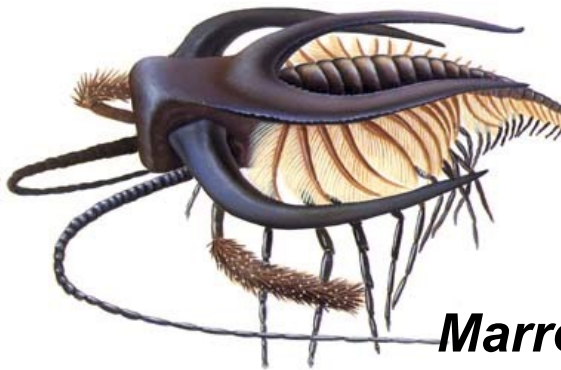
Anomalocaris



Sanctacaris



Yohoia



Marrella



Opabinia



Anomalocaris, Arthropoda

stř. Cm, Burgess Shales



Opabinia, Arthropoda



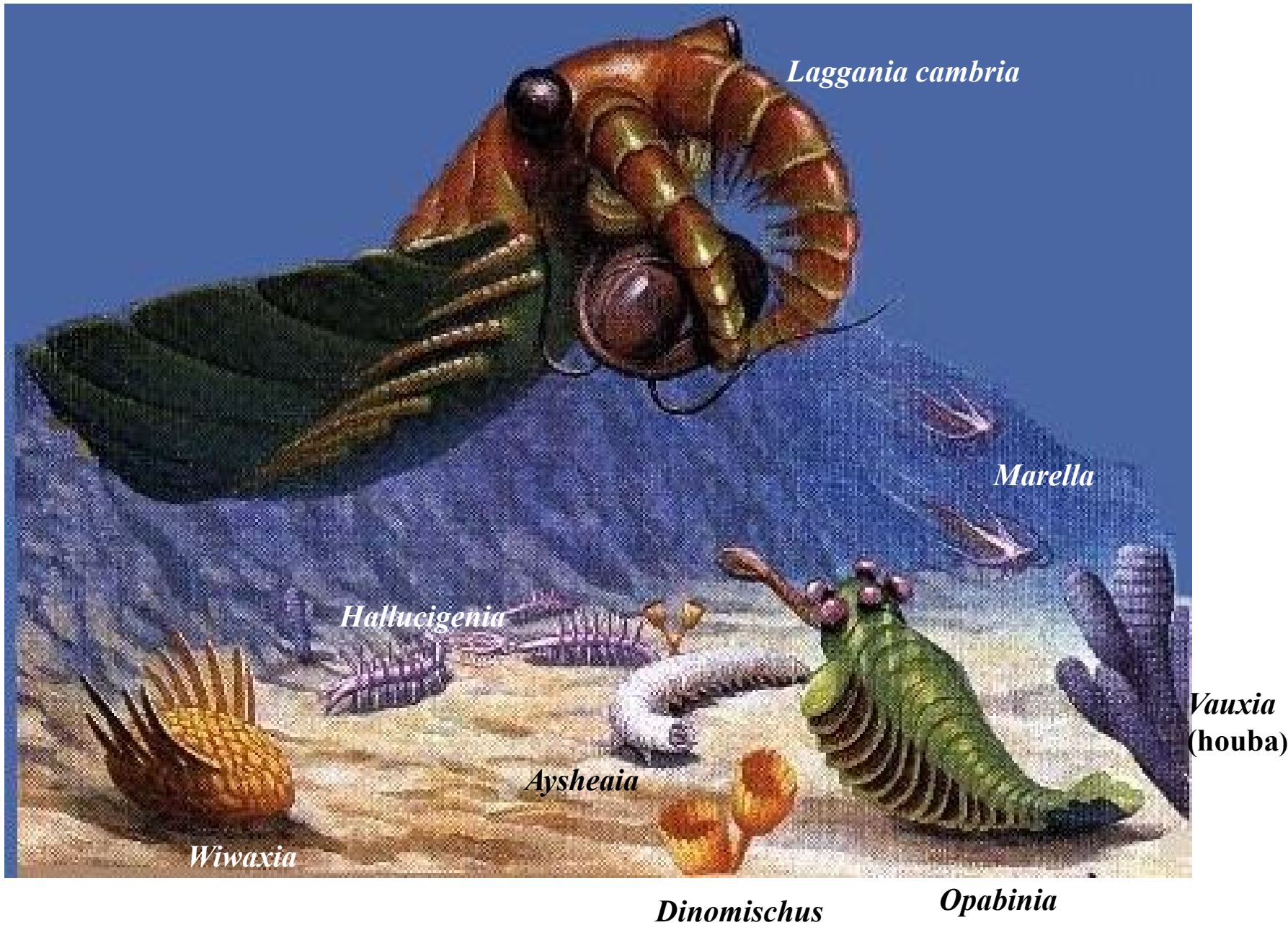
Diania, rekonstrukce

stř. Cm, Burgess Shales



Anomalocaris, Arthropoda

Rekonstrukce života během sedimentace burgesských břidelic (střední kambrium, Britská Kolumbie)



Laggania cambria

Marella

Hallucigenia

Vauxia
(houba)

Wiwaxia

Aysheaia

Dinomischus

Opabinia



Laggania cambria (Anomalocarida) – model přední části z ventrálního pohledu



Hurdia, Anomalocarida

Pozn. : - u nás Barrandien



Fuxianhuia protensa
Hou, 1987

Arthropoda, Chelicerata

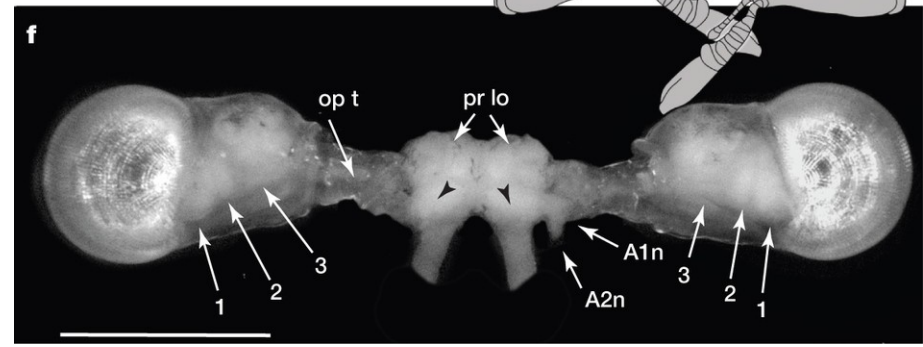
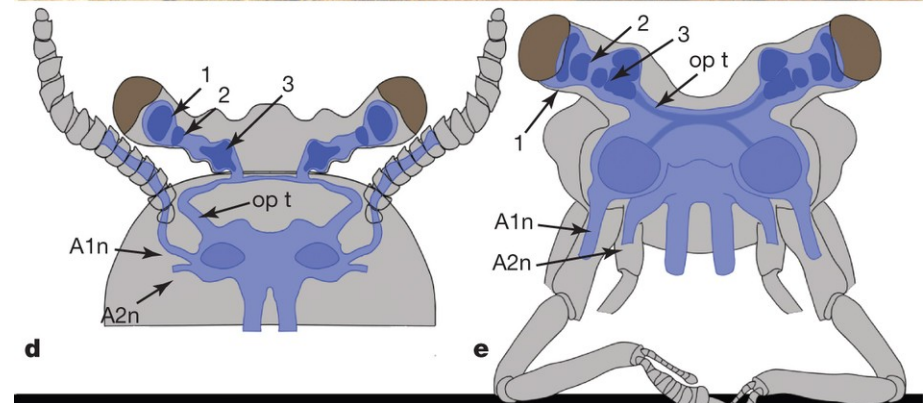
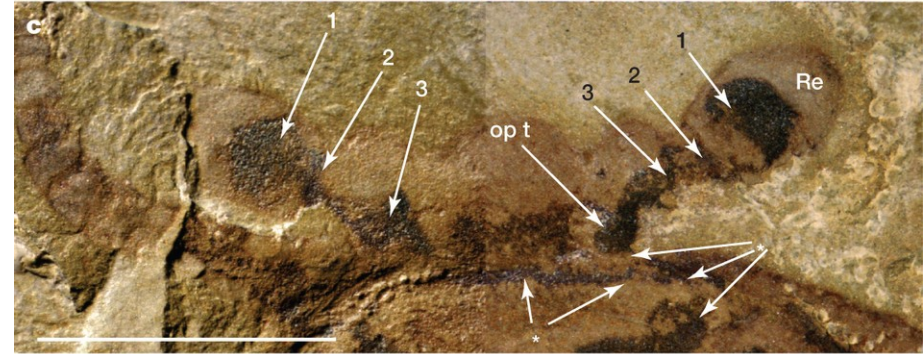
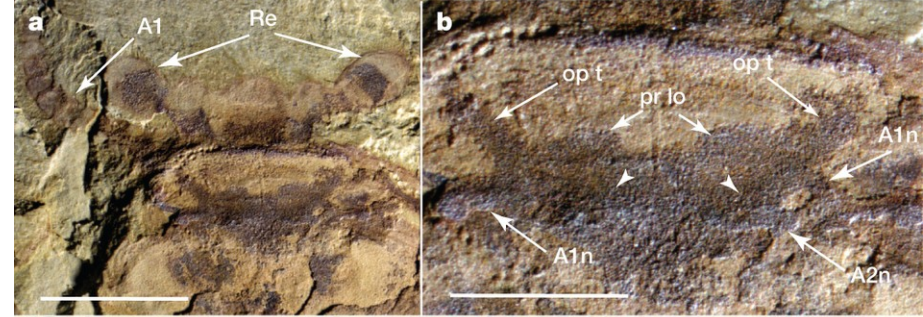
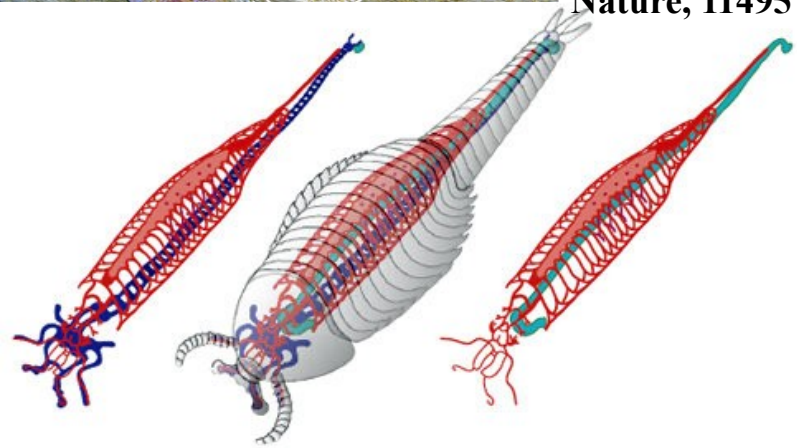
sp. kambrium (525 Ma)

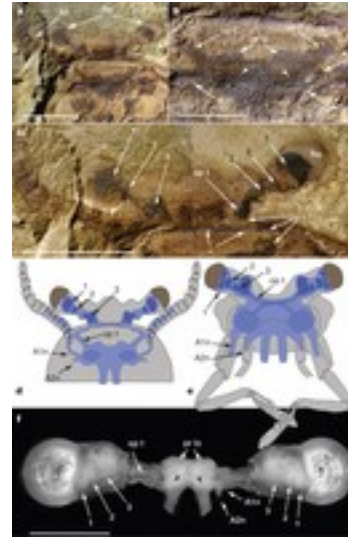
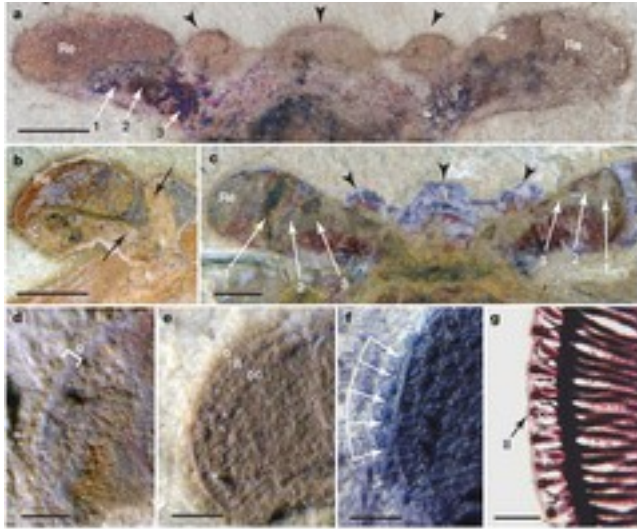
Chengjiang, Jün-nan

Čína,

nejstarší srdeční a
cévní systém doložený
fosilně

Nature, 11495 (2014)





The nervous system provides a fundamental source of data for understanding the evolutionary relationships between major arthropod groups. Fossil arthropods rarely preserve neural tissue. As a result, inferring sensory and motor attributes of Cambrian taxa has been limited to interpreting external features, such as compound eyes or sensilla decorating appendages, and early-diverging arthropods have scarcely been analysed in the context of nervous system evolution. Here we report exceptional preservation of the brain and optic lobes of a stem-group arthropod from 520 million years ago (Myr ago), *Fuxianhuia protensa*, exhibiting the most compelling neuroanatomy known from the Cambrian. The protocerebrum of *Fuxianhuia* is supplied by optic lobes evidencing traces of three nested optic centres serving forward-viewing eyes. Nerves from uniramous antennae define the deutocerebrum, and a stout pair of more caudal nerves indicates a contiguous tritocerebral component. *Fuxianhuia* shares a tripartite pre-stomodaeal brain and nested optic neuropils with extant Malacostraca and Insecta, demonstrating that these characters were present in some of the earliest derived arthropods. The brain of *Fuxianhuia* impacts molecular analyses that advocate either a branchiopod-like ancestor of Hexapoda or remipedes and possibly cephalocarids as sister groups of Hexapoda. Resolving arguments about whether the simple brain of a branchiopod approximates an ancestral insect brain or whether it is the result of secondary simplification has until now been hindered by lack of fossil evidence. The complex brain of *Fuxianhuia* accords with cladistic analyses on the basis of neural characters, suggesting that Branchiopoda derive from a malacostracan-like ancestor but underwent evolutionary reduction and character reversal of brain centres that are common to hexapods and malacostracans. The early origin of sophisticated brains provides a probable driver for versatile visual behaviours, a view that accords with compound eyes from the early Cambrian that were, in size and resolution, equal to those of modern insects and malacostracans.



Fuxianhuia, Arthropoda



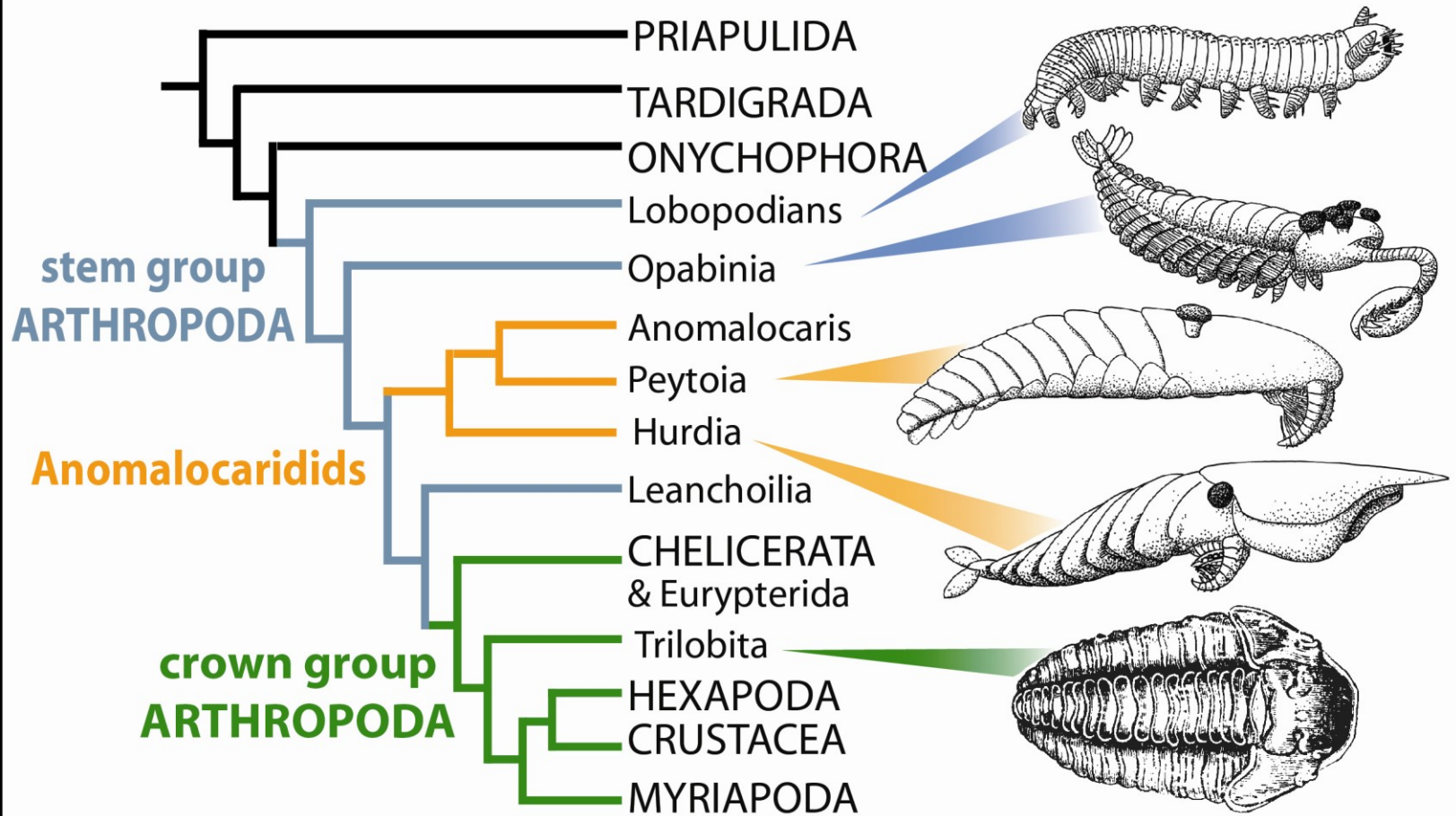
***Herpetogaster*, ? červi, ? hvězdice
rekonstrukce**

Neznámá (?) příbuznost



Dinomischus

Phylogeny of stem and crown Arthropoda



Pozice kambrických Arthropodů

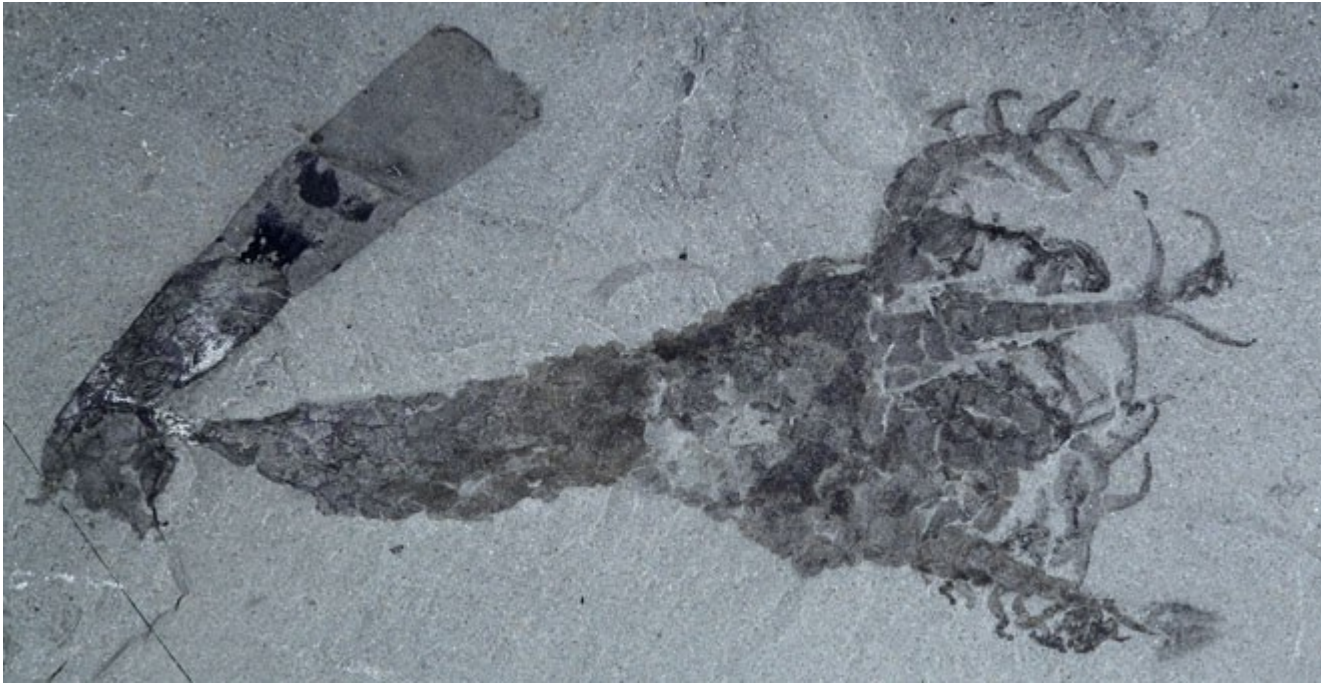
• **Echinodermata (ostnokožci):**

- Druhoústí s 5-ti čtenou symetrií, vápnitými schránkami, speciální rozvod vody (ambulakrální soustava)
- Většina kambrických ostnokožců měla stonek (přísedlí)



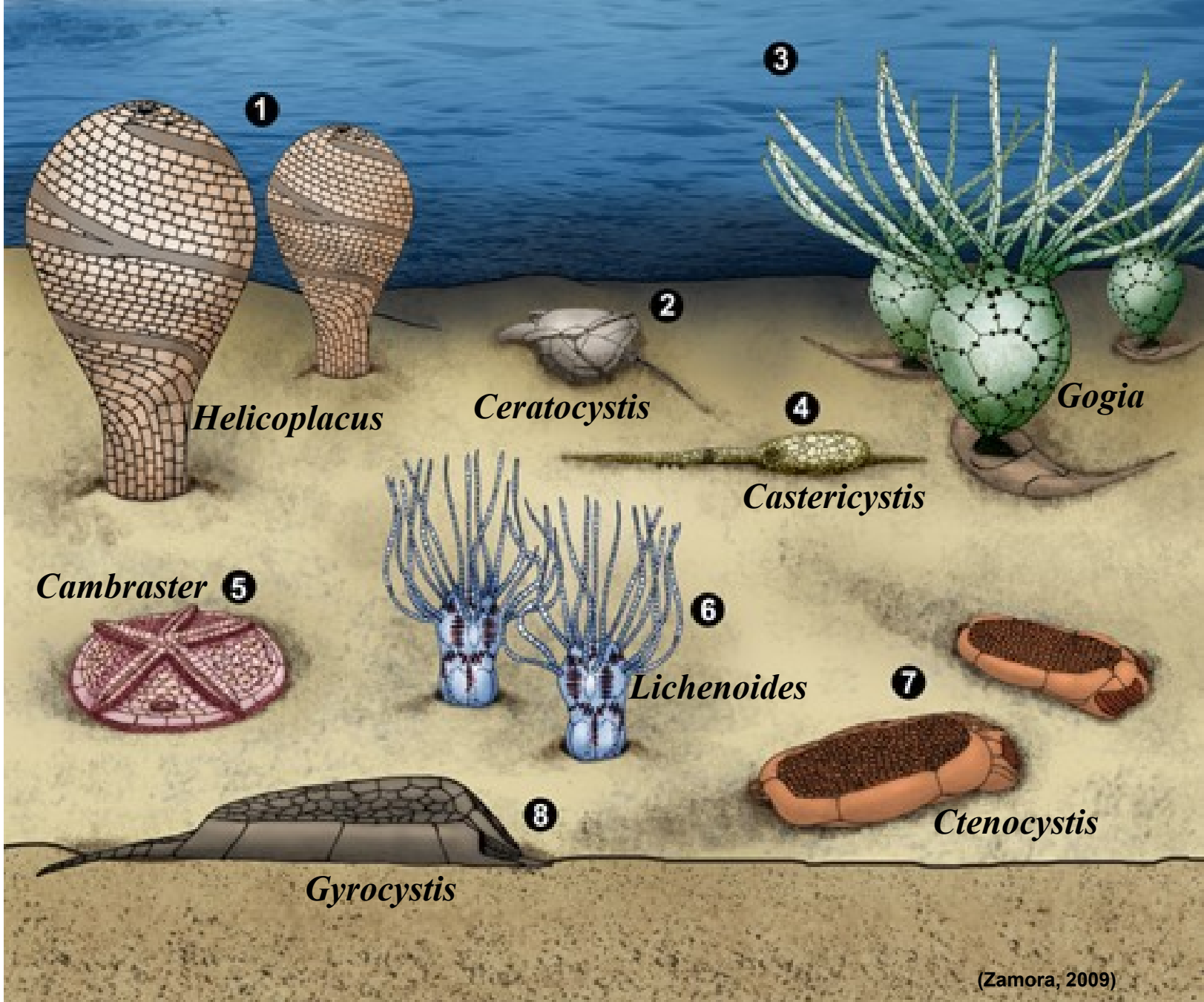
***Gogia* sp., stř. kambrium, House Range, Utah.**

Eocrinoidea (kambrium-silur) patří k časným zástupcům ostnokožců.

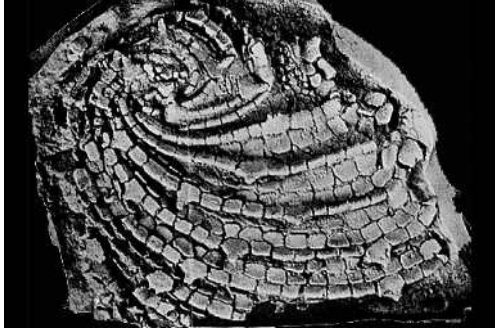


Echmatocrinus capulus, Echinodermata

stř. Cm, Burgess Shales



Pohled na společenstvo echinodermat v kambrickém moři



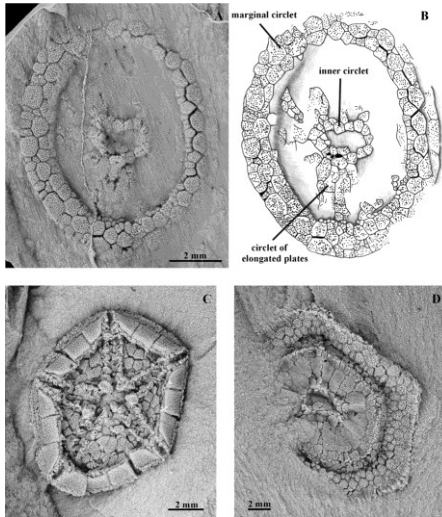
Helicoplacus, sp. Cm



Ceratocystis, Cm



Gogia, Cm, Utah



Cambraster, Cm

Dtto předcházející
slajd - fosílie



Castericystis, stř. Cm



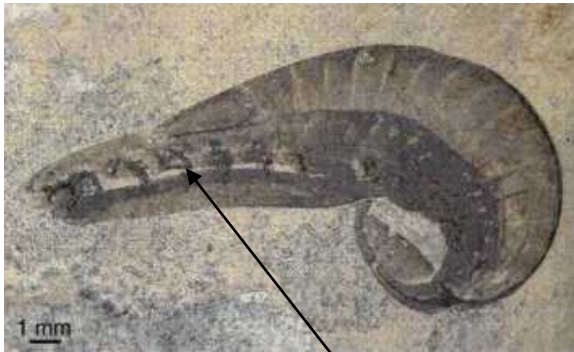
Gyrocystis, Cm



Lichenoides, Cm



Ctenocystis, Cm, Utah

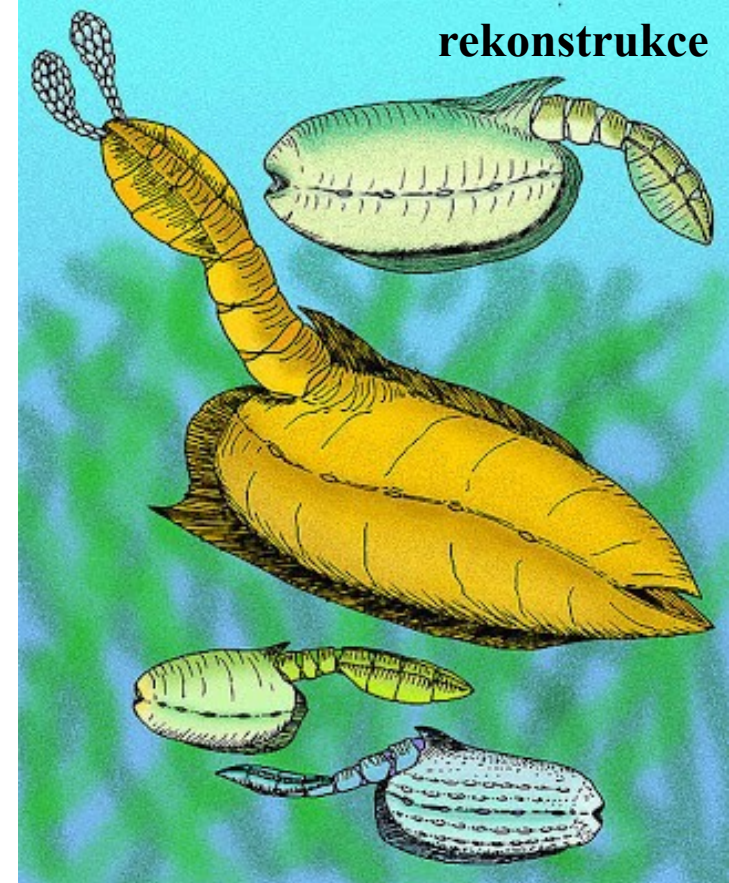


Yunnanozoon

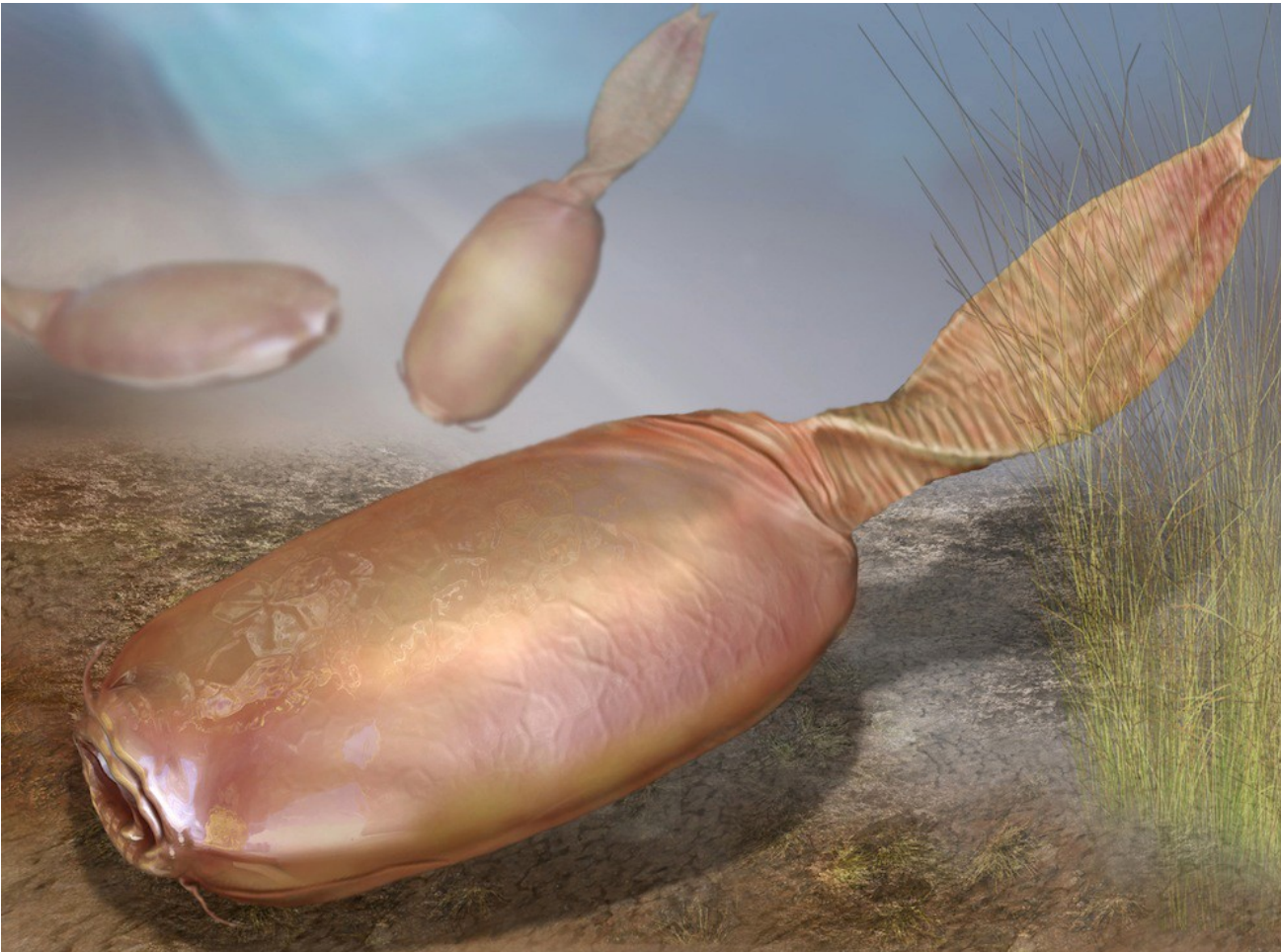
**Vetulicolia – spodní kambrium, Čína,
nový kmen živočichů
blízký předkům strunatců (žaberní
štěrbiny etc.), detritofágní nekton,**



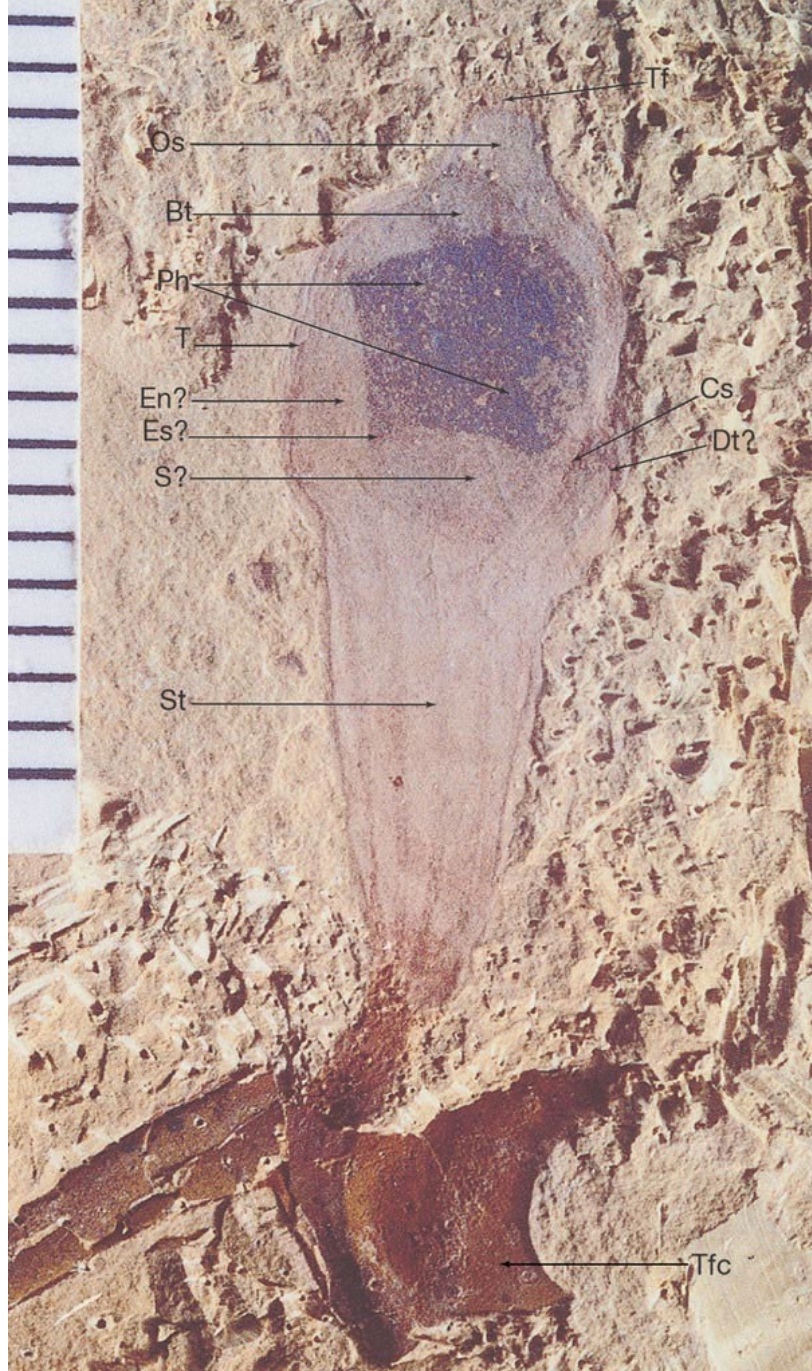
Three vetulicolians. Front to back: Vetulicola, Xidazoon, Didazoon



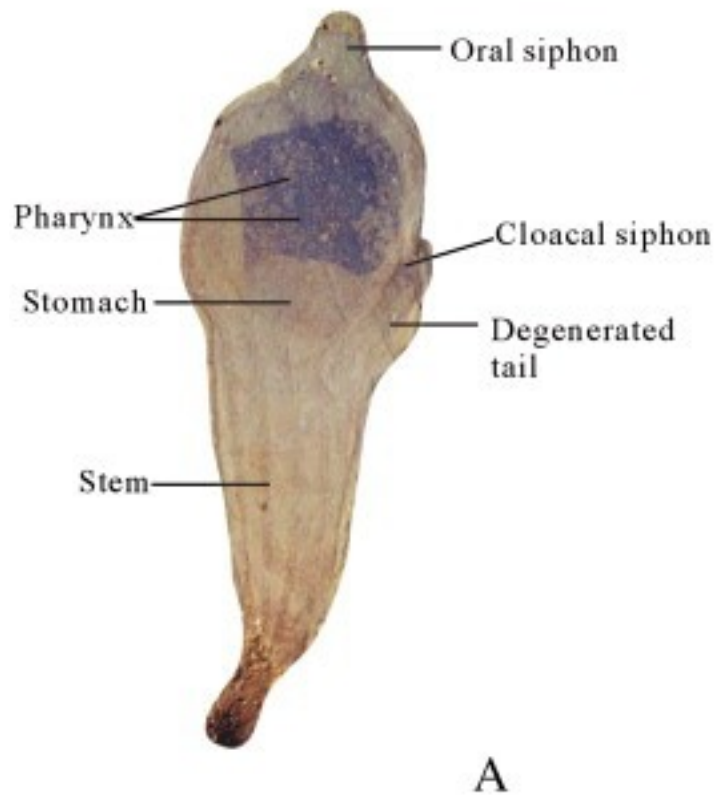
Banffia constricta, Vetulicolia,
Burgess Shales, stř. Cm



***Banffia*, jiná možná rekonstrukce**



Cheungkongella
 --the oldest-known urochordate



Ha

***Cheungkongella ancestralis*,**
Tunicata, sp. Cm, Čína, Chengjiang

Nejstarší doložená akrania

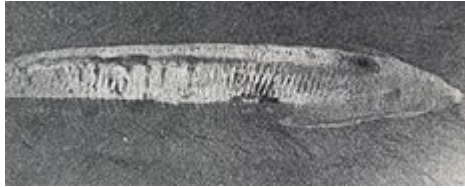
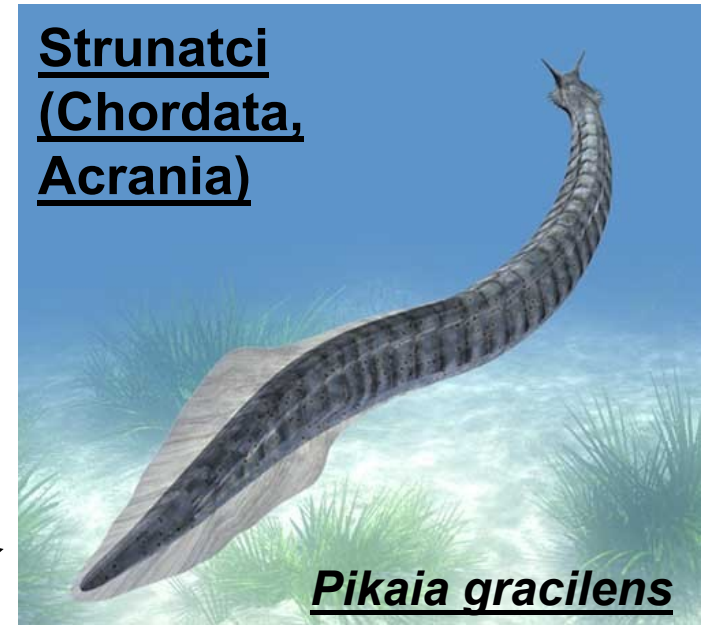


foto z burgeských břidelic

Pikaia gracilens, Burgess Pas,
Kanada, stř. Cm

Strunatci (Chordata, Acrania)

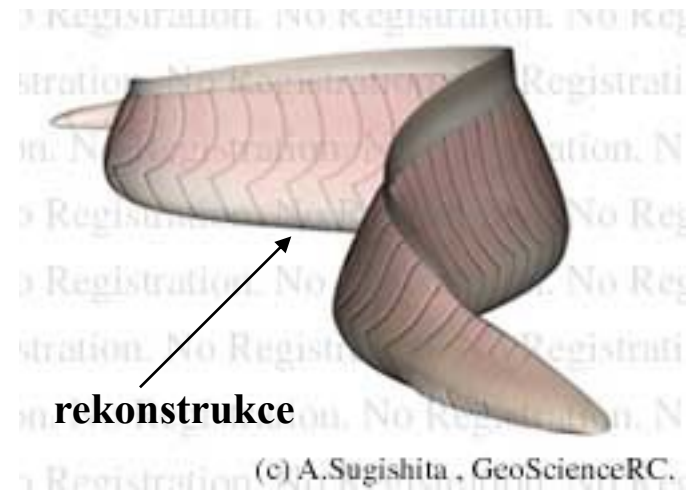


Pikaia gracilens

rekonstrukce



foto



rekonstrukce

(c) A.Sugishita, GeoScienceRC,

Cathaymyrus diadectus, sp. Cm, Jünan, Čína



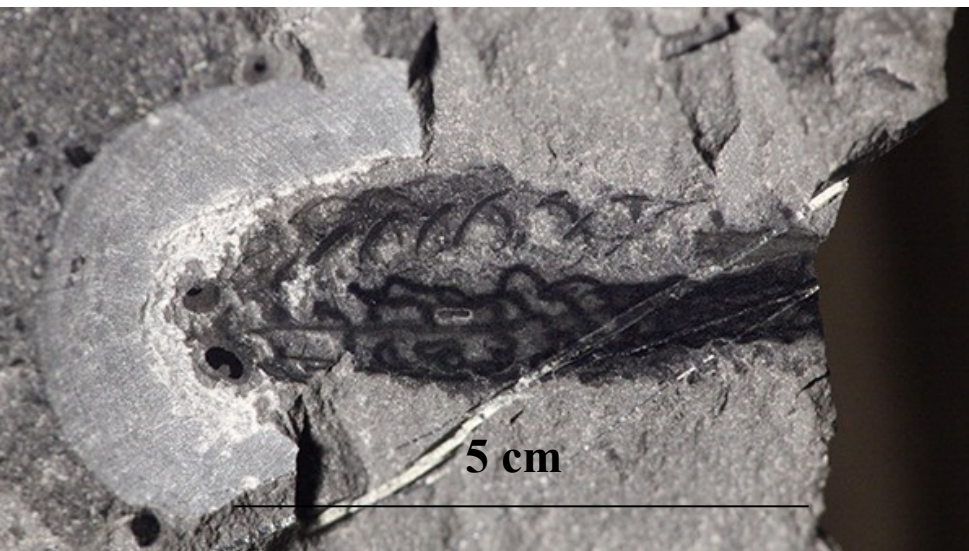
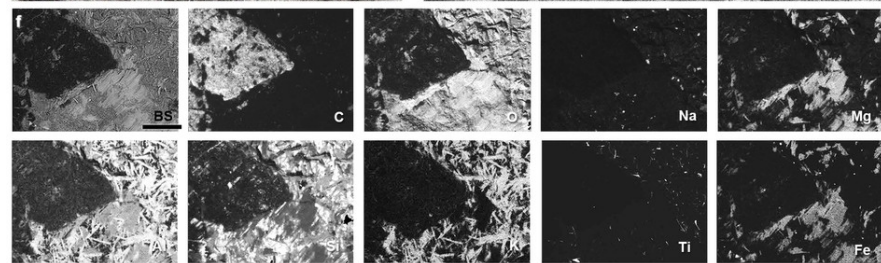
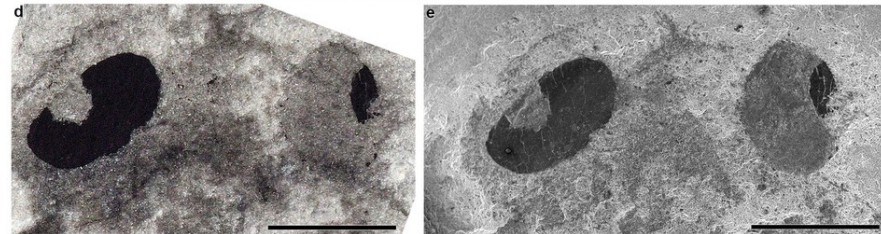
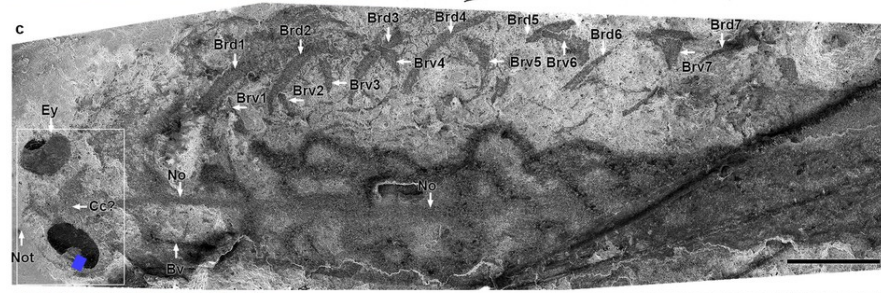
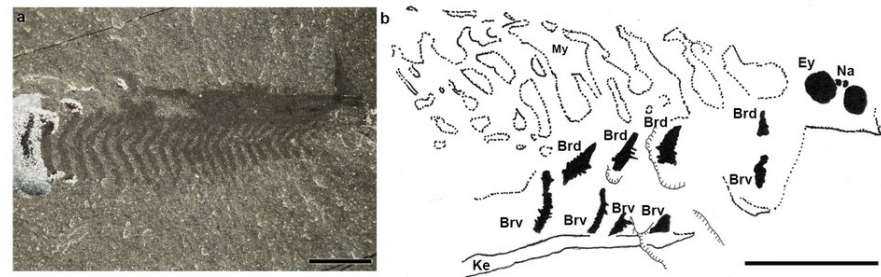
Pikaia gracilens, Chordata

stř. Cm, Burgess Shales



Pikaia

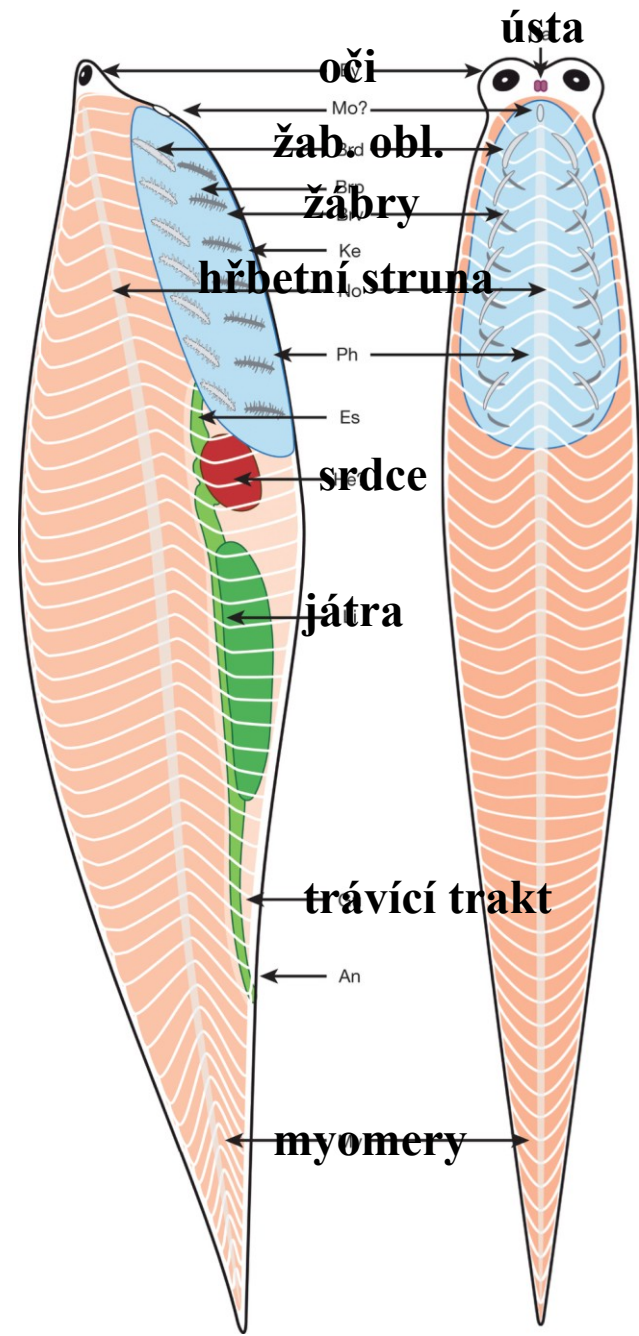
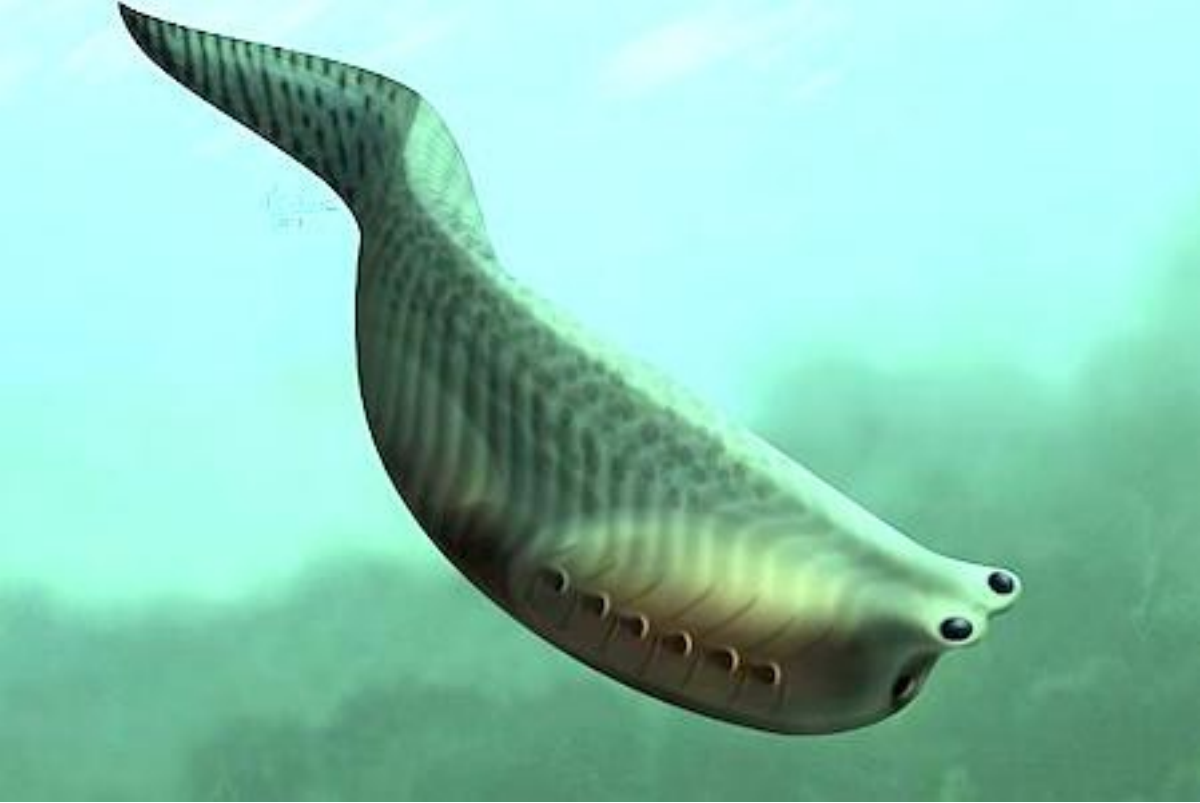
rekonstrukce



Metaspriggina walcotti, Chordata,
Craniata, Burgess Shale,
sp. kambrium, 510 Ma

+ notochord

J.B. Caron (2014)



Dtto, interpretace živočicha a jeho stavba

Vertebrata

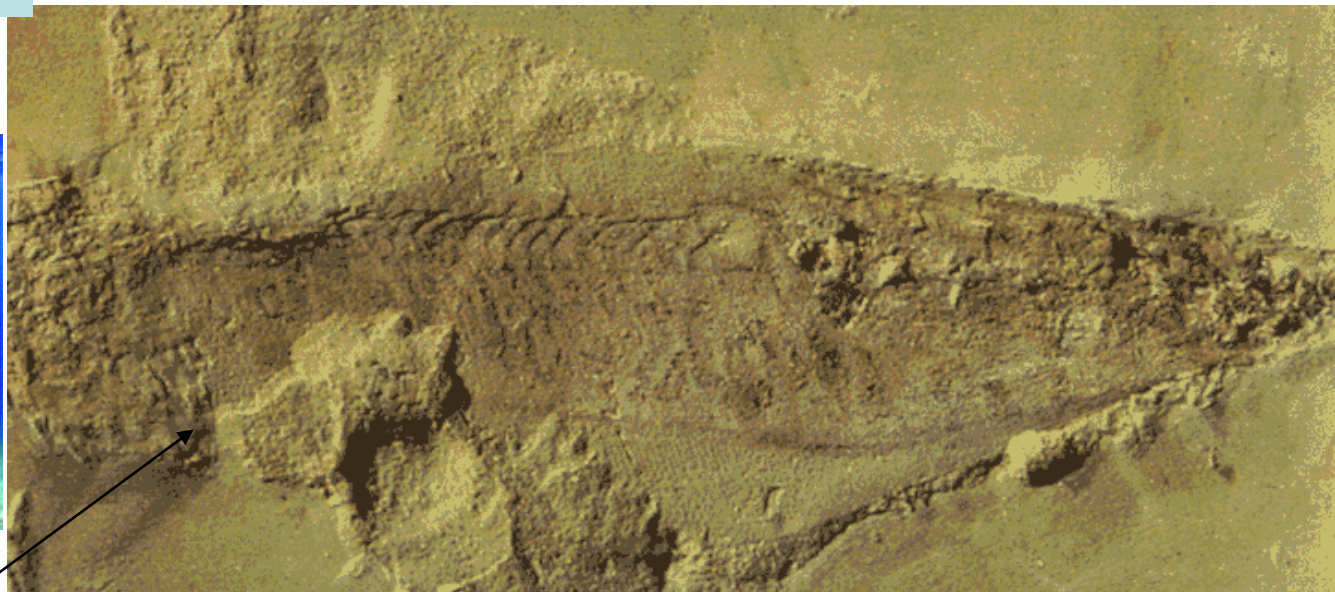
nastupují rovněž už ve
sp. Cm.

Myllokunmingia jeví
podobnosti s recentními
sliznatkami

Haikouichthys pak spolu s
eukonodonty je řazena na
počátek nástupu
bezčelistnaticů (Agnatha)



Myllokunmingia fengjiana, Haikou, Čína, sp. Cm



Haikouichthys ercaicuensis, Haikou, Čína, sp. Cm

rekonstrukce

otisk

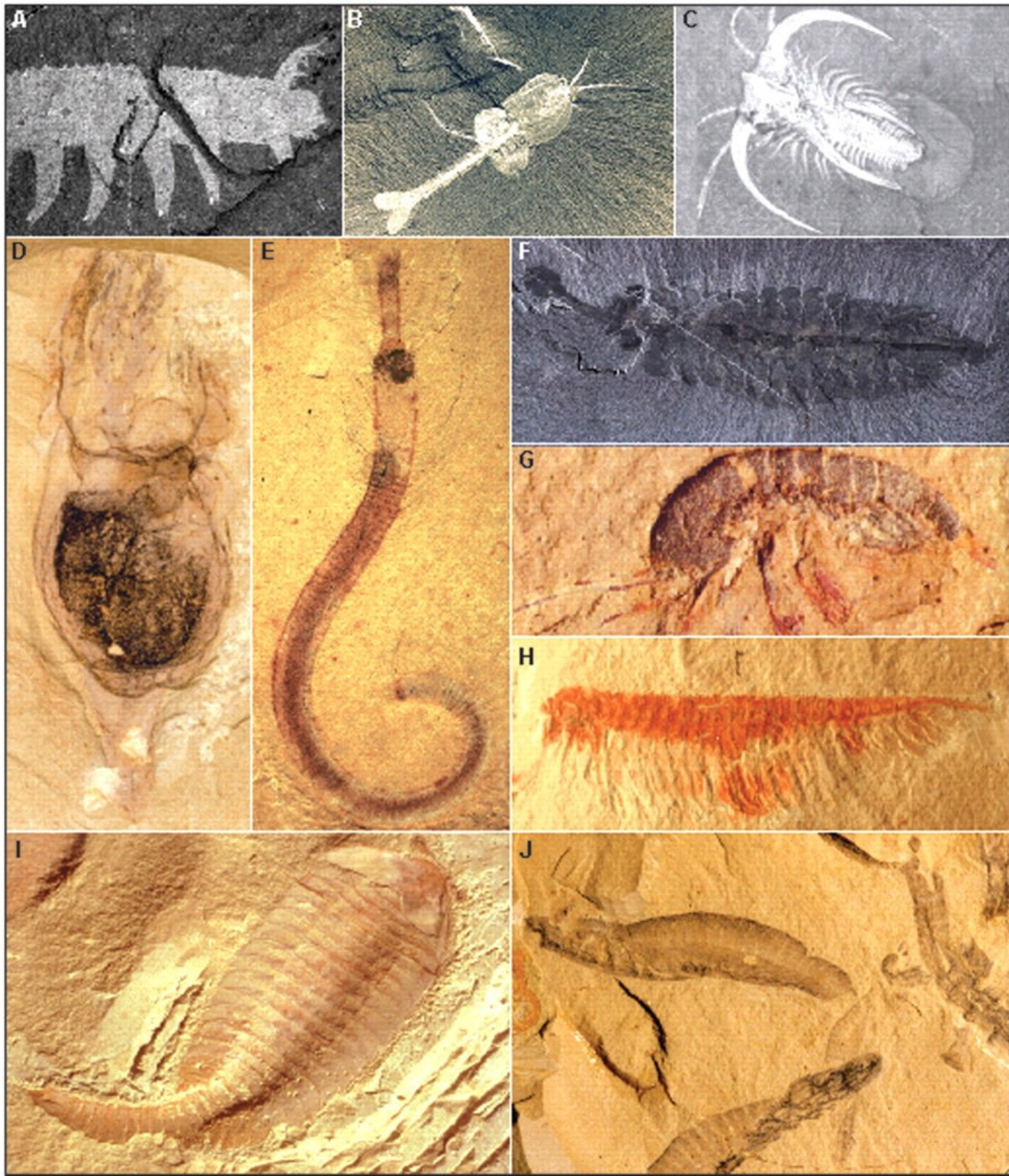


Myllokunmingia, chordata

Stavební plány burgesských živočichů

- (A) Onycophoran: *Aysheaia pedunculata*;
 (B) arthropod: *Waptia fieldensis*;
 (C) arthropod: *Marrella splendens*;
 (D) possible ascidian: *Phlogites*;
 (E) priapulid: *Maotianshania cylindrica*;
 (F) pan-arthropod: *Opabinia regalis*;
 (G) arthropod: *Leanchoilia illecebrosa*;
 (H) arthropod: *Jianfengia multisegmentalis*;
 (I) arthropod: *Fuxianjuia protensa*;
 (J) chordate: *Haikouella lanceolata*;

[(A) to (C)] and (F) are from
 D. H. Erwin, Smithsonian Institution;
 (D), (E),
 and [(G) to (J)] are courtesy of J.-Y. Chen,
 Nanjing Institute of Geology and
 Palaeontology,
 China (13).



Relative Abundance of Different Lifestyles in the Burgess Shale (in % of Species)

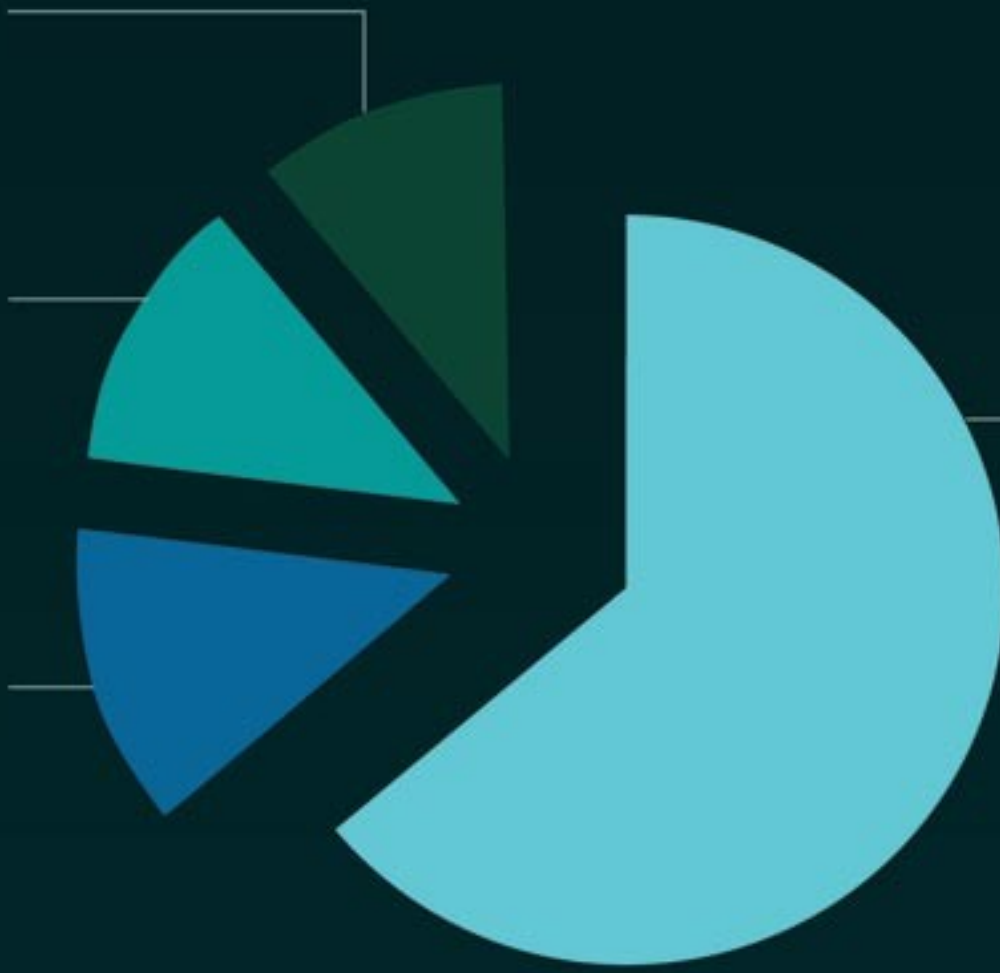
Nektonic 11%
e.g. *Anomalocaris*



Nektobenthic 12%
e.g. *Marrella*



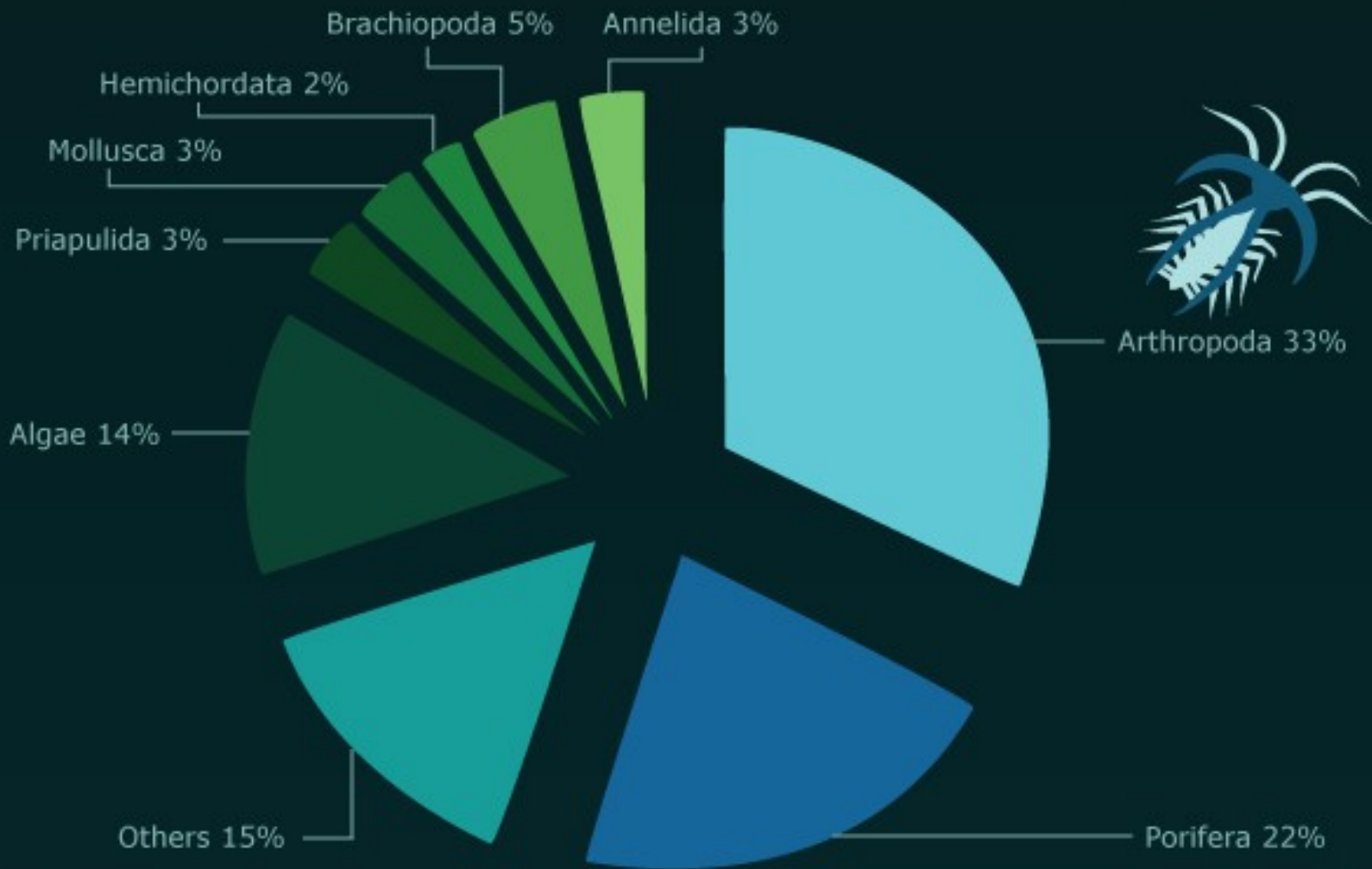
Endobenthic 13%
e.g. *Ottoia*



Epibenthic 64%
e.g. *Wiwaxia*



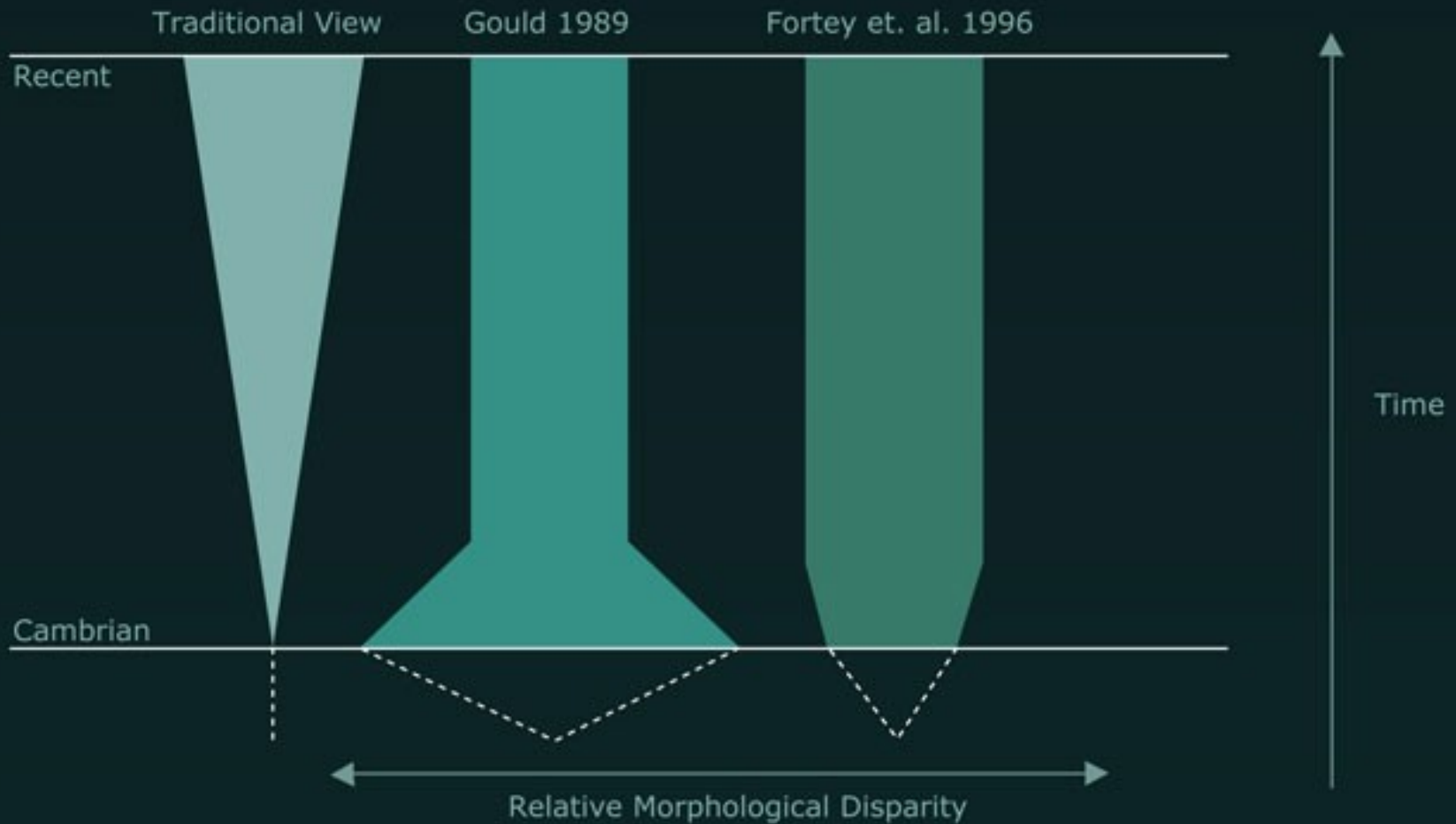
Relative Abundance of Species in the Burgess Shale (Walcott Quarry)



Number of Species = 153

© Royal Ontario Museum

Models of Relative Morphological Disparity Over Time



488

K A M B R I U M

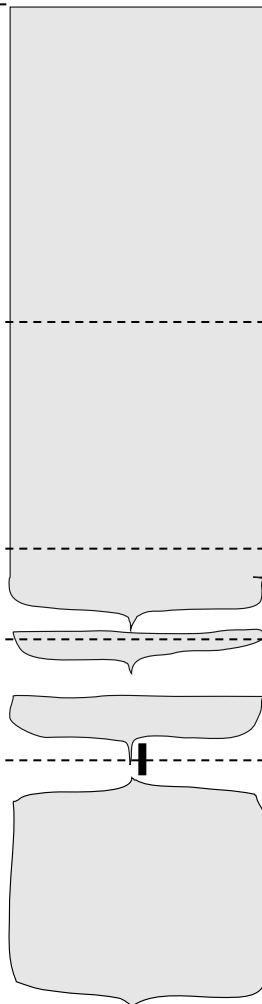
svrchní

střední

spodní

530

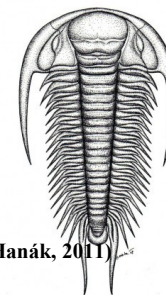
542



radiace velkých organismů



dominance trilobitů



(Hanák, 2011)

„kambrická exploze“

tommotská fauna

stopy + drobné sklerity



archaocyath. rify



ediakarská fauna



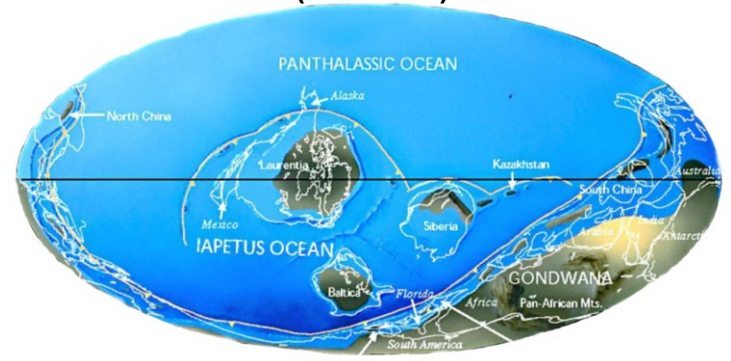
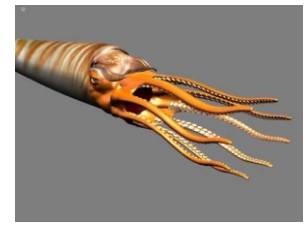
Významné bioeventy v biosféře kolem hranice Prz/Fnz

K A M B R I U M

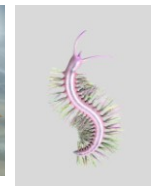
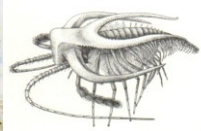
rozpad kontinentů

kaledonská o.

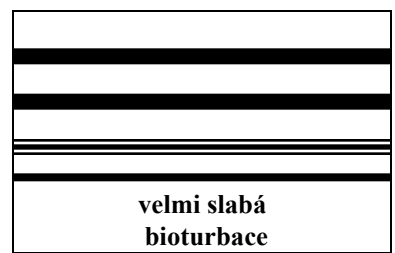
SPICE (Steptoean Positive C Isotop Exc.), anoxie, výrazné vymírání trilobitů a nautiloideí po ní nárůst O₂ v atm. na 30 % s.s. => nárůst života na Zemi (~ordovik)



520 Ma, Burgess Shale

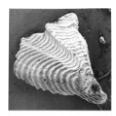


530 Ma, Chengjiang Sections



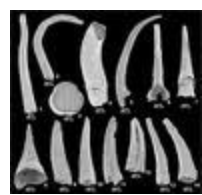
velmi slabá bioturbace

tommotská fauna



první velká radiace

drobné sklerity, rozvoj skeletonizace



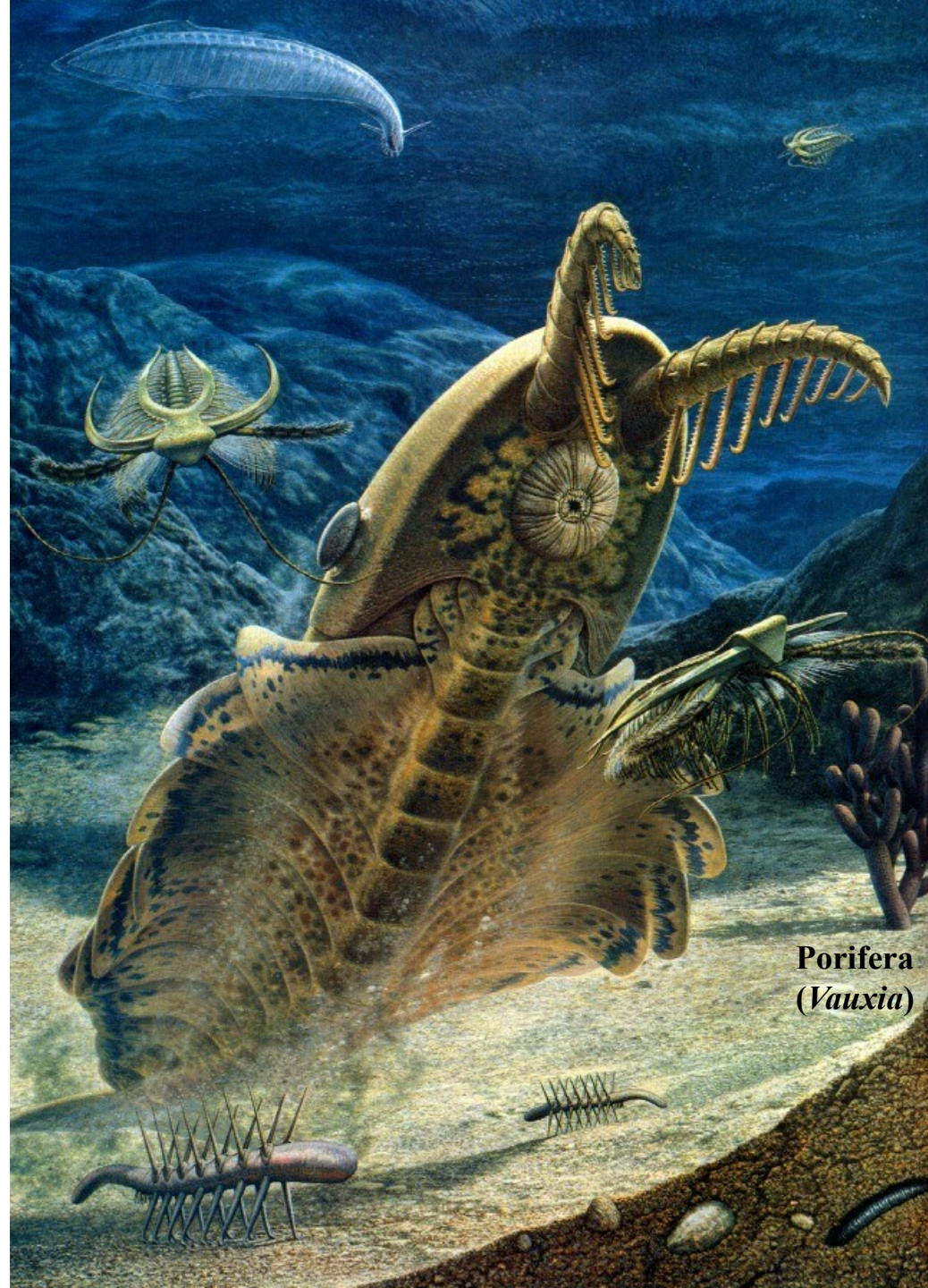
útesy: Archaeocyatha, Porifera, mikrobi dominance 1. fauny

Pikaia

Marella

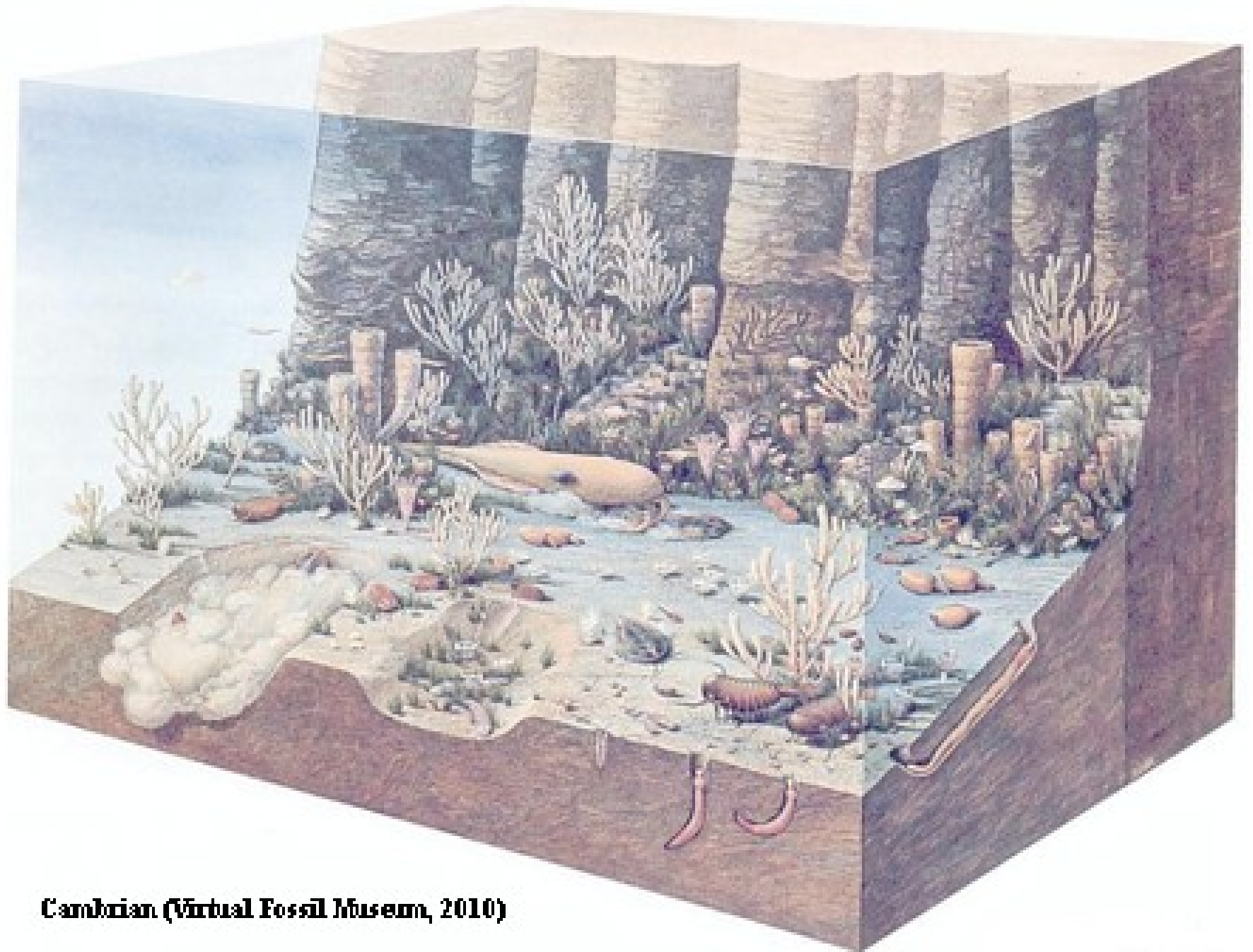
Anomalocaris

Halucigenia

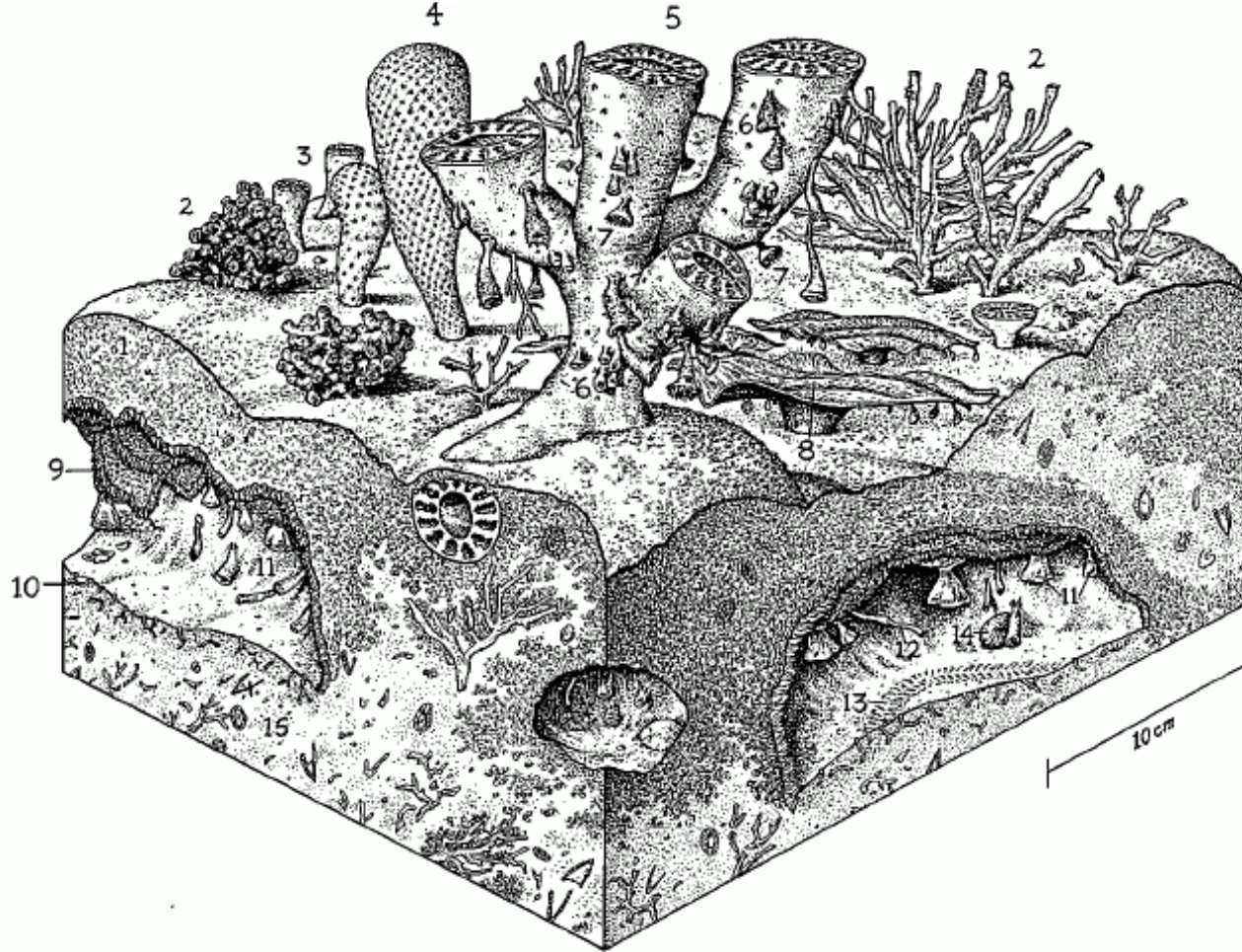


Porifera
(*Vauxia*)

Pohled do kambrického moře

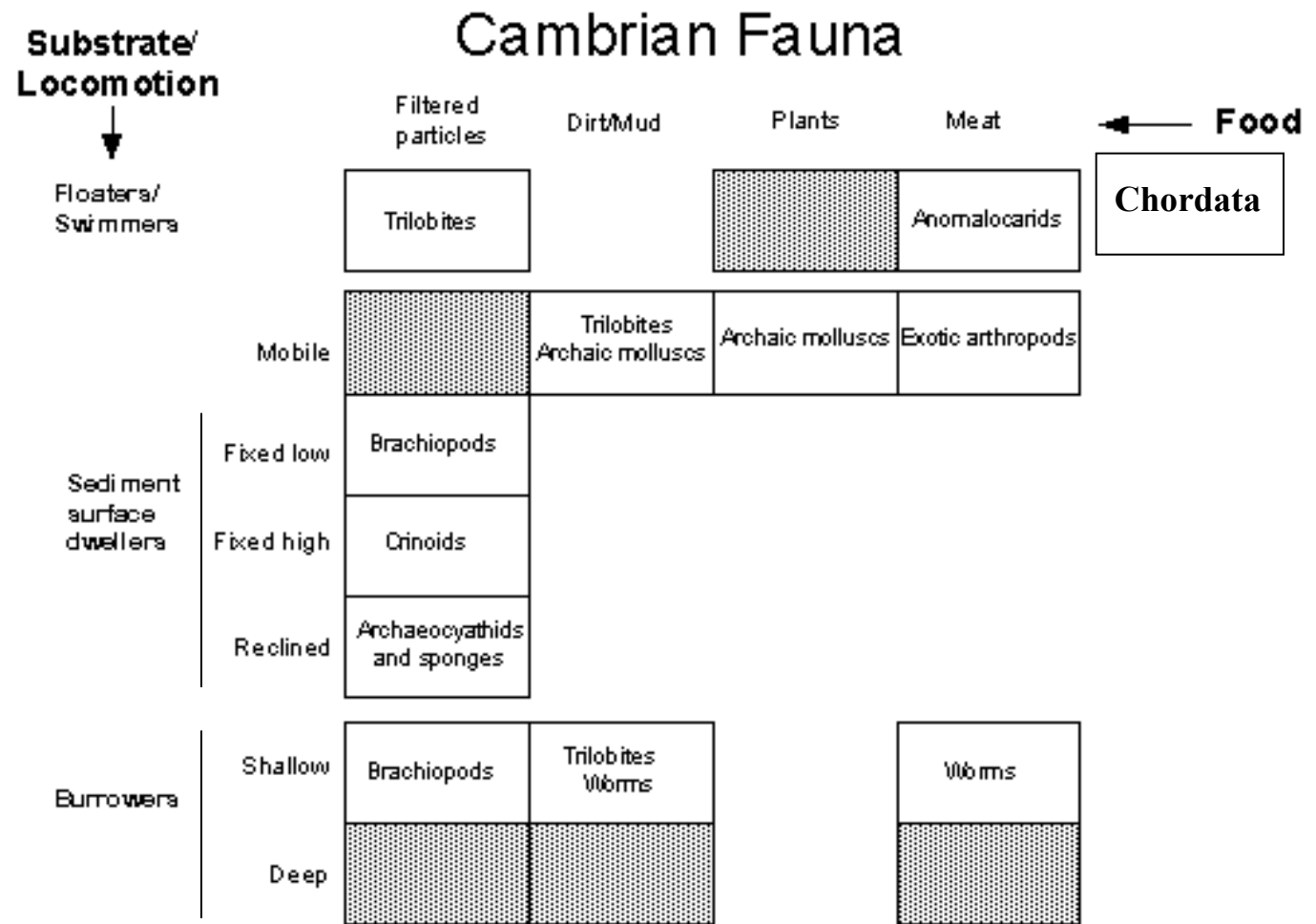


Cambrian (Virtual Fossil Museum, 2010)



Reconstruction of an Early Cambrian reef community (from 97). 1. *Renalcis* (calcified cyanobacterium); 2: branching archaeocyath sponges; 3: solitary cup-shaped archaeocyath sponges; 4: chancellorid (?sponge); 5: radiocyath (?sponge); 6: small, solitary archaeocyath sponges; 7: cryptic "coralomorphs"; 8: *Okulitchicyathus* (archaeocyath sponge); 9; early fibrous cement forming within crypts; 10: microburrows (traces of a deposit-feeder) within geopetal sediment; 11: cryptic archaeocyaths and coralomorphs; 12: cryptic cribricyaths (problematic, attached skeletal tubes); 13: trilobite trackway; 14: cement botryoid; 15: sediment with skeletal debris.

Kambrický ekosystém (dno)



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

Explosivní vývoj (Gould: nestálost genetických kontrolních mechanismů + volné niky, poté upevnění genetické paměti – variace na dané téma)

Fosfogenní událost, vzrůst O₂ (v závěru Cm anoxie), **biomineralizace**, **skeletonizace**

Nový ekosystém moří: vznik úplné potravní pyramidy (diverz. fytoplankton + radiace zooplanktonu = rozvoj heterotrofie a velkých konzumentů)

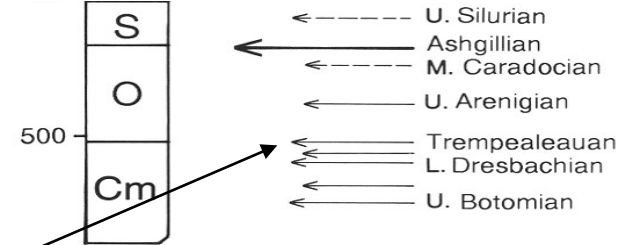
Specializace způsobů života:

potrava: dravci, filtrátoři, spásající organizmy, detritofágové etc.

pohyb: plankton, bentos (sesilní, vagilní), nekton (nedokonalý)

Systematika: převládají skupiny, jejichž rozkvět je vázán na kambrium, a které poté výrazně ustupují a hrají již malou roli = **1. kambrická fauna**
V závěru kambria je 1. fauna ve vlnách **redukována**

Vymírání:



Ve svrchním kambriu – ??? 2 vlny redukce fauny

Mizí:

- tomotská fauna, řada čeledí trilobitů a loděnkovitých,
- již dříve archeocyāti,
- ovlivněny jsou však všechny skupiny především 1. fauny

Redukce fauny je spojena s

- transgresí a následující regresí (stres v šelfových prostředích)
- vyšší tvorba černých břidelic (anoxie u dna)
- delta C13 poklesl = odraz poklesu produktivity fytoplanktonu
- zalednění ?? (Avalon)
- plošný vulkanismus (rozsáhlý v Australii)

O krizi koncem kambria víme poměrně málo.

Použité prameny:

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Internet – různé databáze (především obrazová dokumentace)