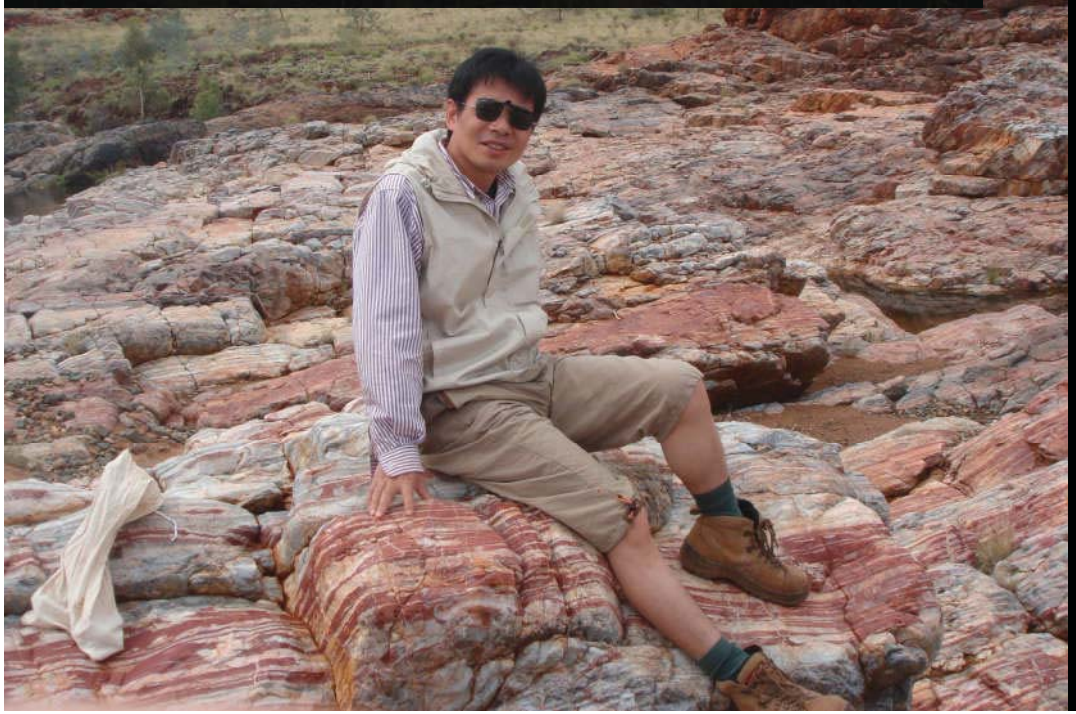
IGCP 630:
Permian-Triassic climatic & environmental extremes and biotic response

现代海洋生态系统的起源与第三次生物大辐射

陈中强

生物地质与环境地质国家重点实验室

E-mail: zhong.qiang.chen@cug.edu.cn



西澳大利亚野外地质考察

第一次海洋大氧化事件

2.2-2.5亿年


2010/06/26


TOYOTA


2010/8/16 8:02


2010/06/17

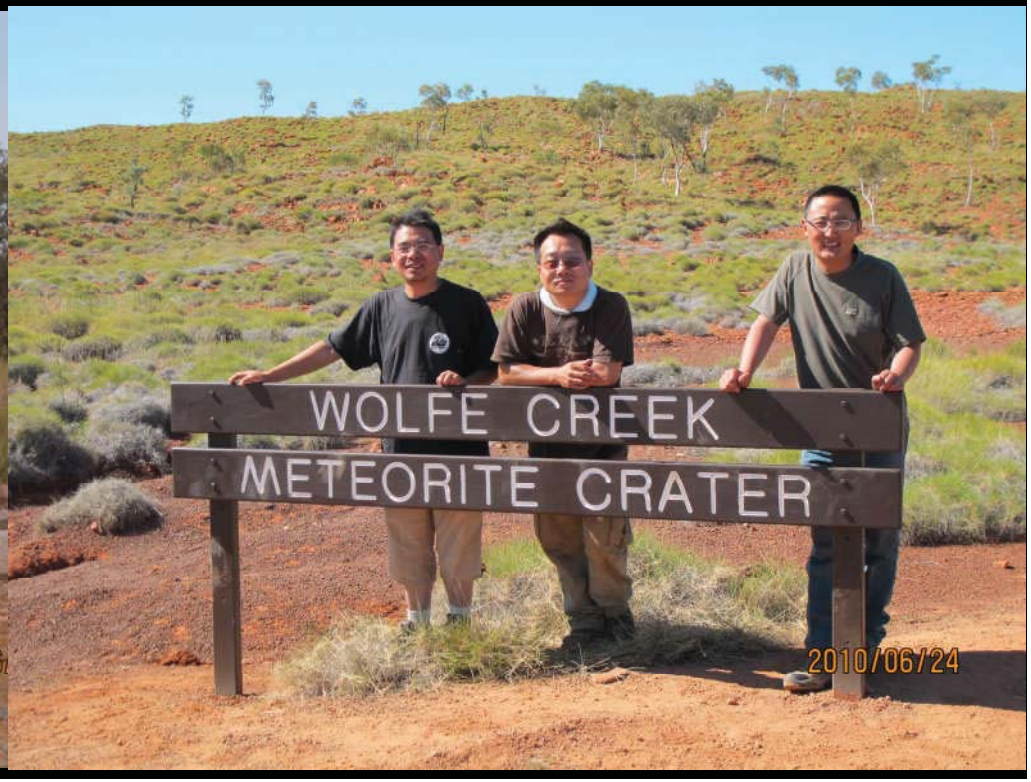

2010/06/17


2010/06/17


2010/06/17


2010/06/27


2010/06


WOLFE CREEK
METEORITE CRATER
2010/06/24


1DJQ 367


2010/8/11 7:56


1DJD-367


2010/8/16 7:05


Budget
2010/8/7 8:07

报告提纲

- 背景资料
- 2. 52亿年前的大绝灭
- 生态系复苏过程与模式
- 第三次生物大辐射
- 现代海洋生态系雏形的建立
- 我们地球的将来？？

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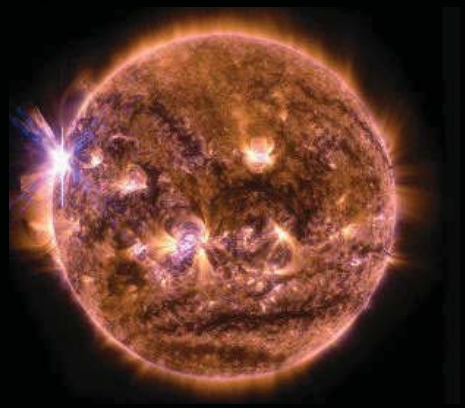
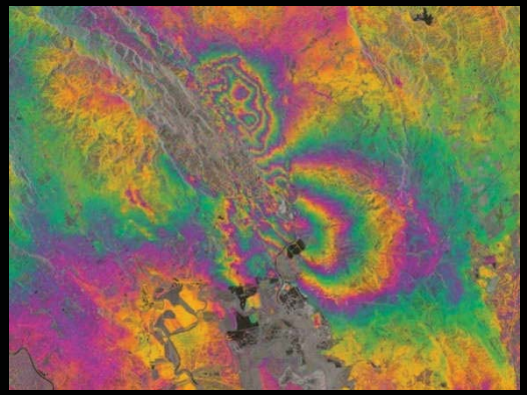
Earth & Space Science News



小行星撞击地球

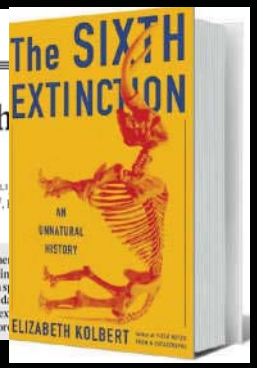


REVIEW

Has the Earth's sixth
already arrived?

Anthony D. Barnosky[1,2,3], Nicholas Matzke[3], Susumu Tomiya[1,2,3], Charles Marshall[1,2], Jenny L. McGuire[2,3,4], Emily L. Lindsey[1,3],

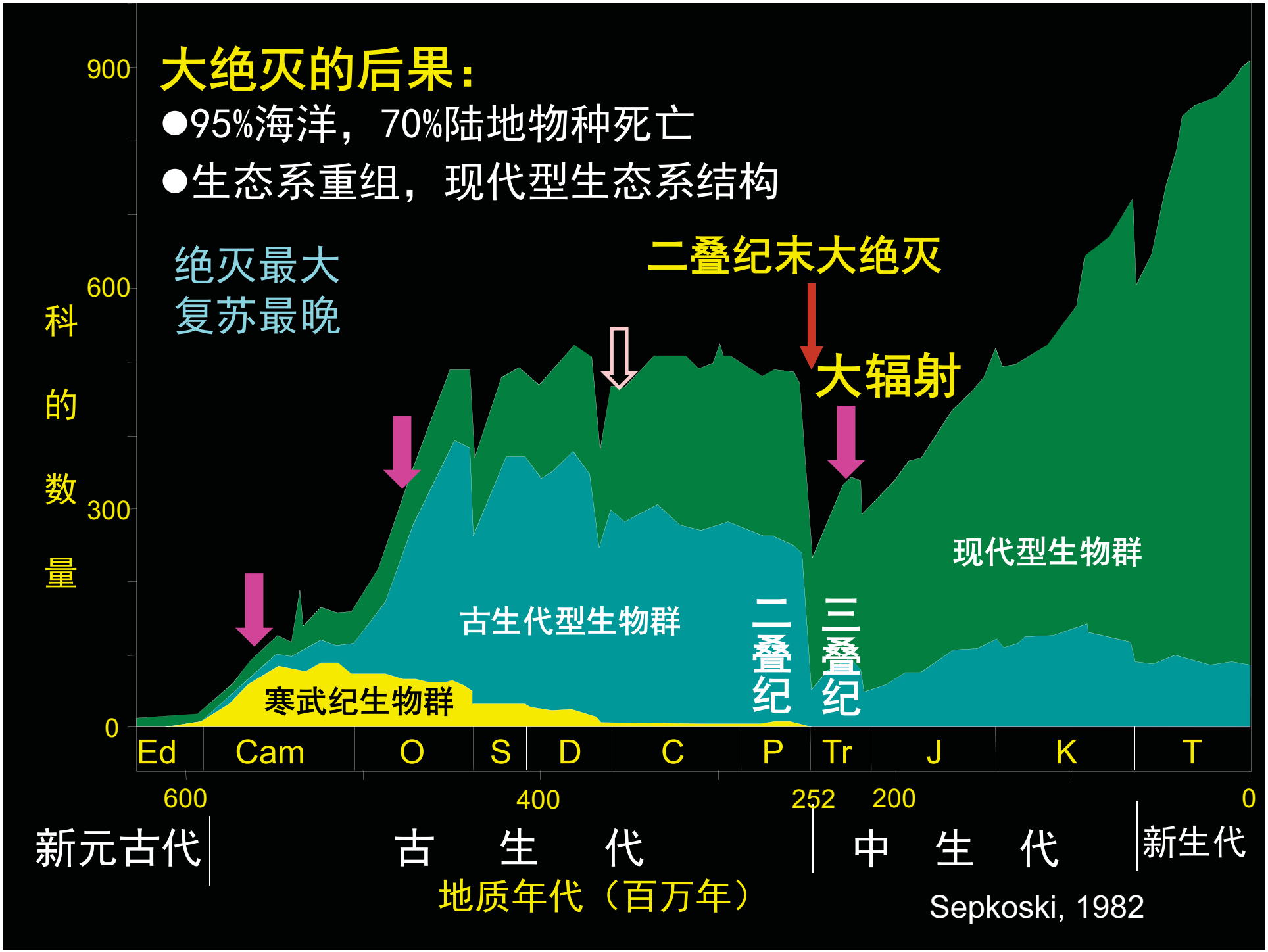
Palaeontologists characterize mass extinctions as times when geologically short interval, as has happened only five times in sixth mass extinction may be under way, given the known s we review how differences between fossil and modern d information influence our understanding of the current ex rates are higher than would be expected from the fossil recor



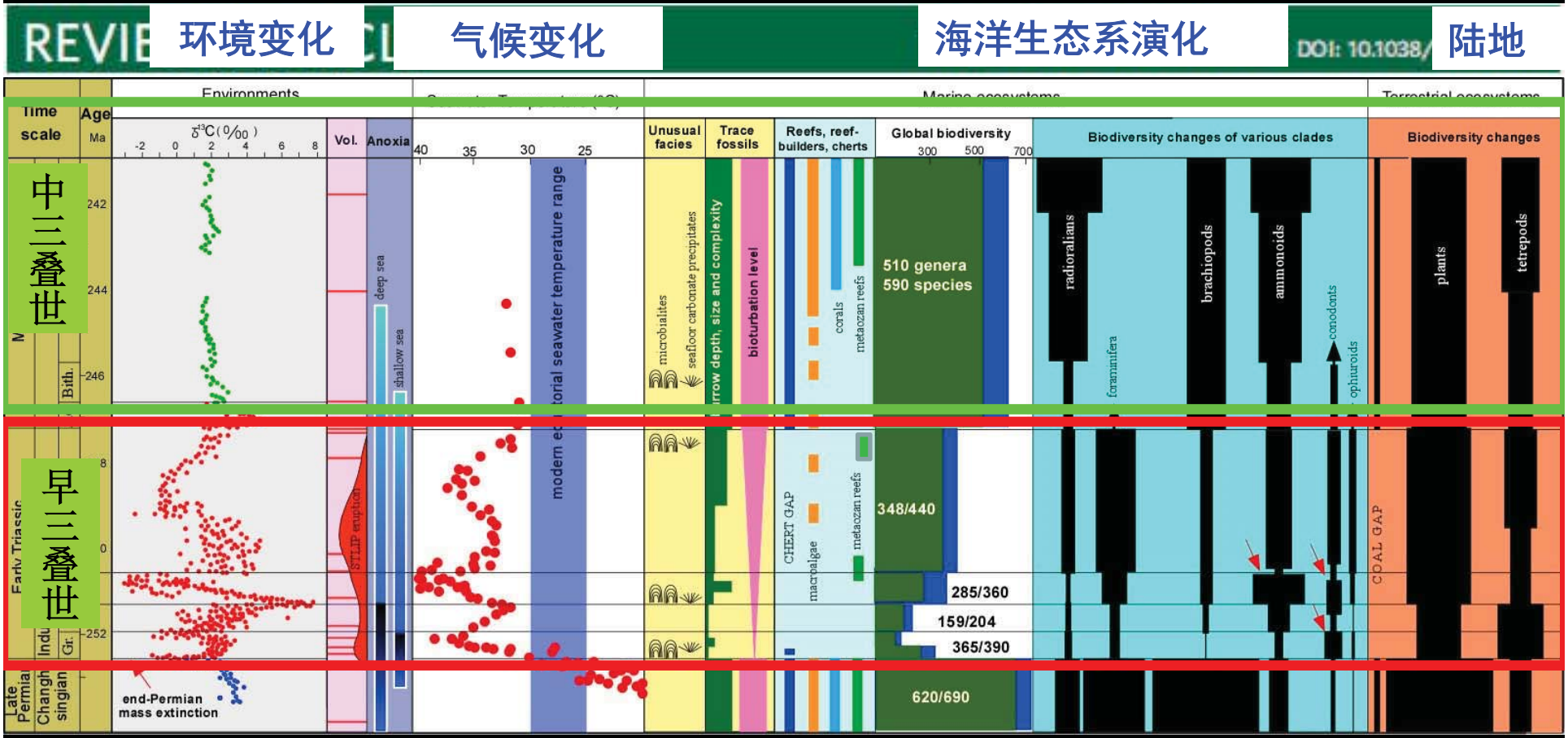
第三次生物大辐射

我们地球家园可谓多灾多难；
回顾地质历史这些事件甚至更为严重的灾难在地球上多次出现，生态系统却能一次一次地灾后恢复重建，重现往日的繁荣

一个生态系统成功重生的例子：
经历了二叠纪末大绝灭一系列的极端环境气候事件的破坏之后，生态系统在早三叠世又遭受类似的灾难多次打击，最后却能成功复苏并辐射，一直演化到当代


大绝灭的后果：
●95%海洋，70%陆地物种死亡
●生态系重组，现代型生态系结构
绝灭最大
复苏最晚
二叠纪末大绝灭
大辐射
科的数量
900
600
300
0
现代型生物群
古生代型生物群
寒武纪生物群
二叠纪
三叠纪
Ed
Cam
O
S
D
C
P
Tr
J
K
T
600
400
252
200
0
新元古代
古生代
中生代
新生代
地质年代（百万年）
Sepkoski, 1982

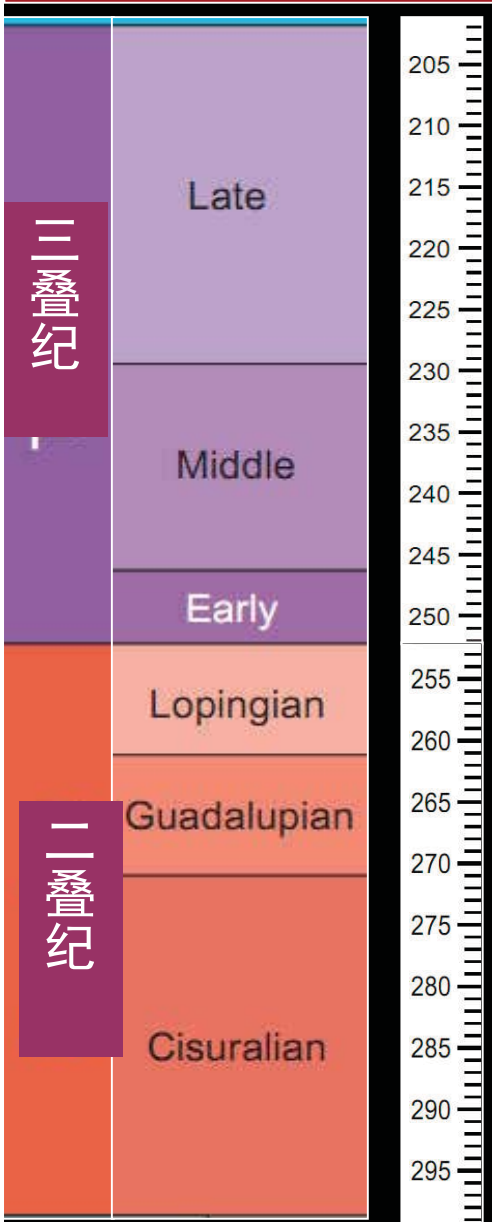
二叠纪–三叠纪之交极端气候、环境事件以及生态系的反馈



Payne et al. (2004); Sun et al. (2012)

Chen & Benton (2012)

高精度　时间
长尺度　格架

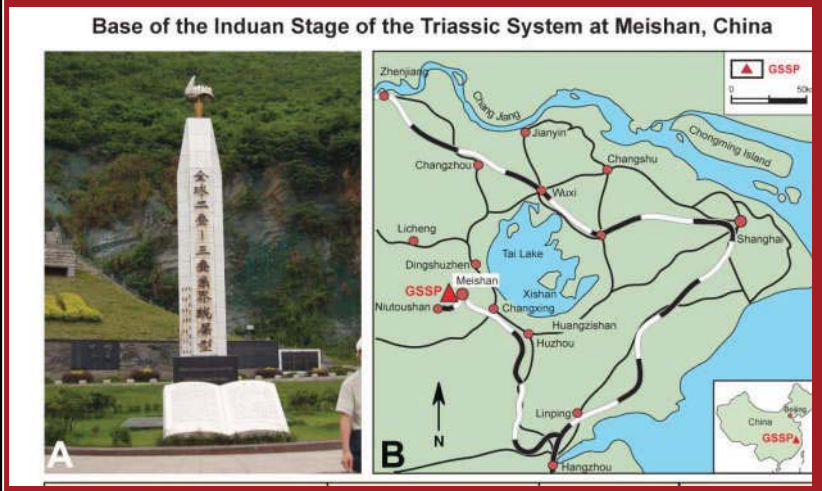


事实真相

- 2万年内绝灭
- 95%海洋物种
- 70%陆地物种

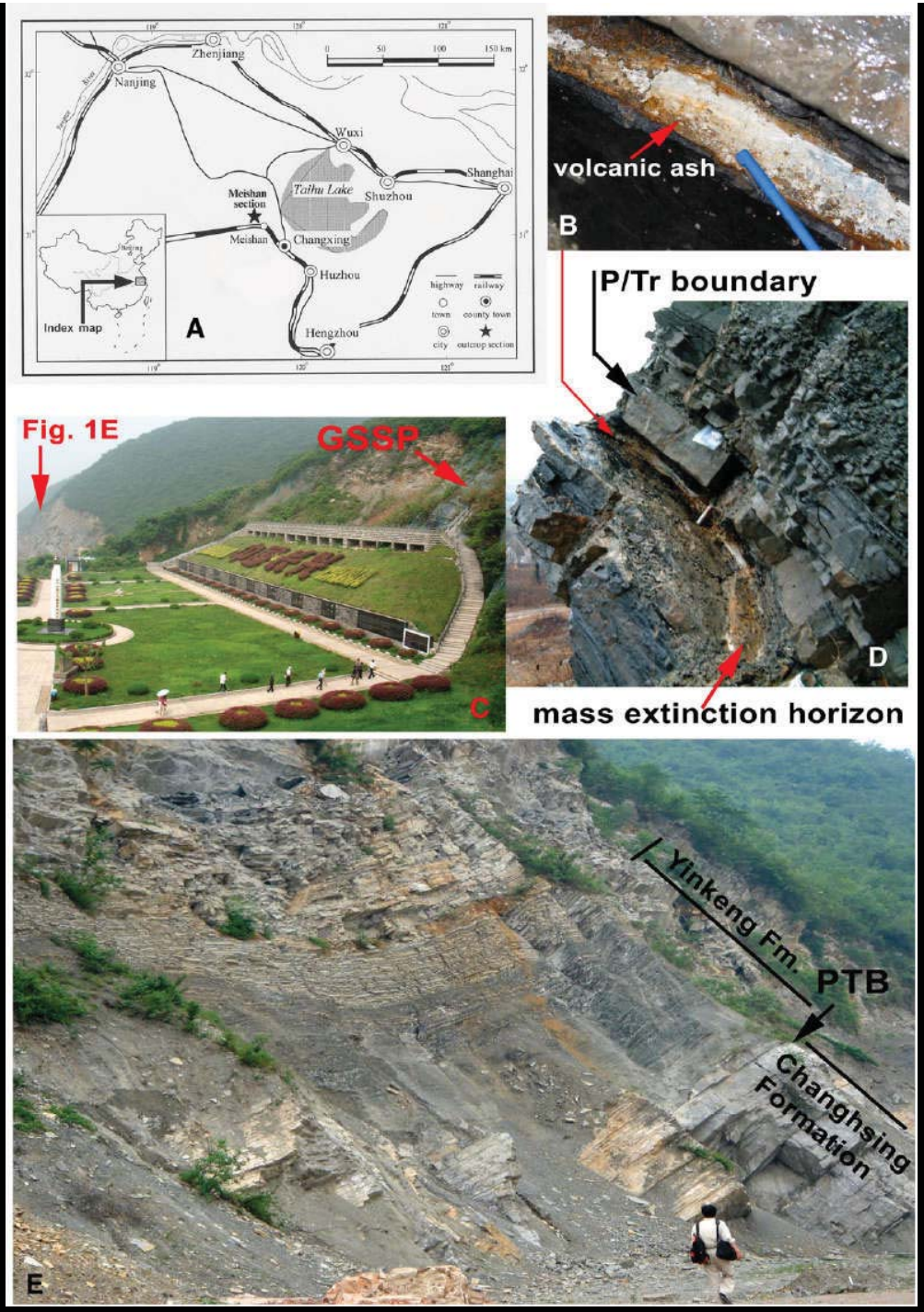
← 2.52亿年前

PTB 金钉子 (GSSP)



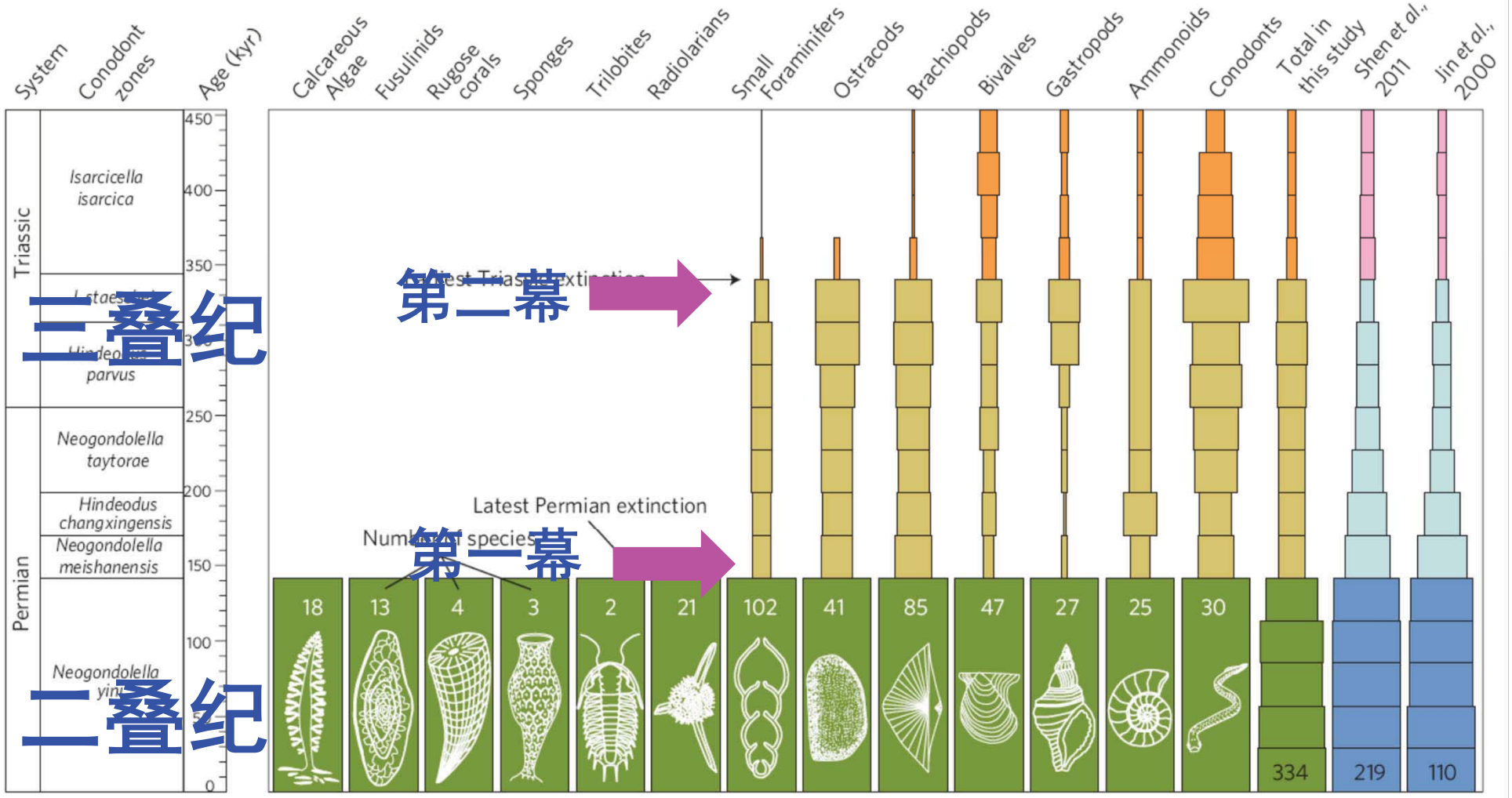
煤山金钉子

- 古生代–中生代界线
- 二叠纪–三叠纪界线
- 长兴阶底界



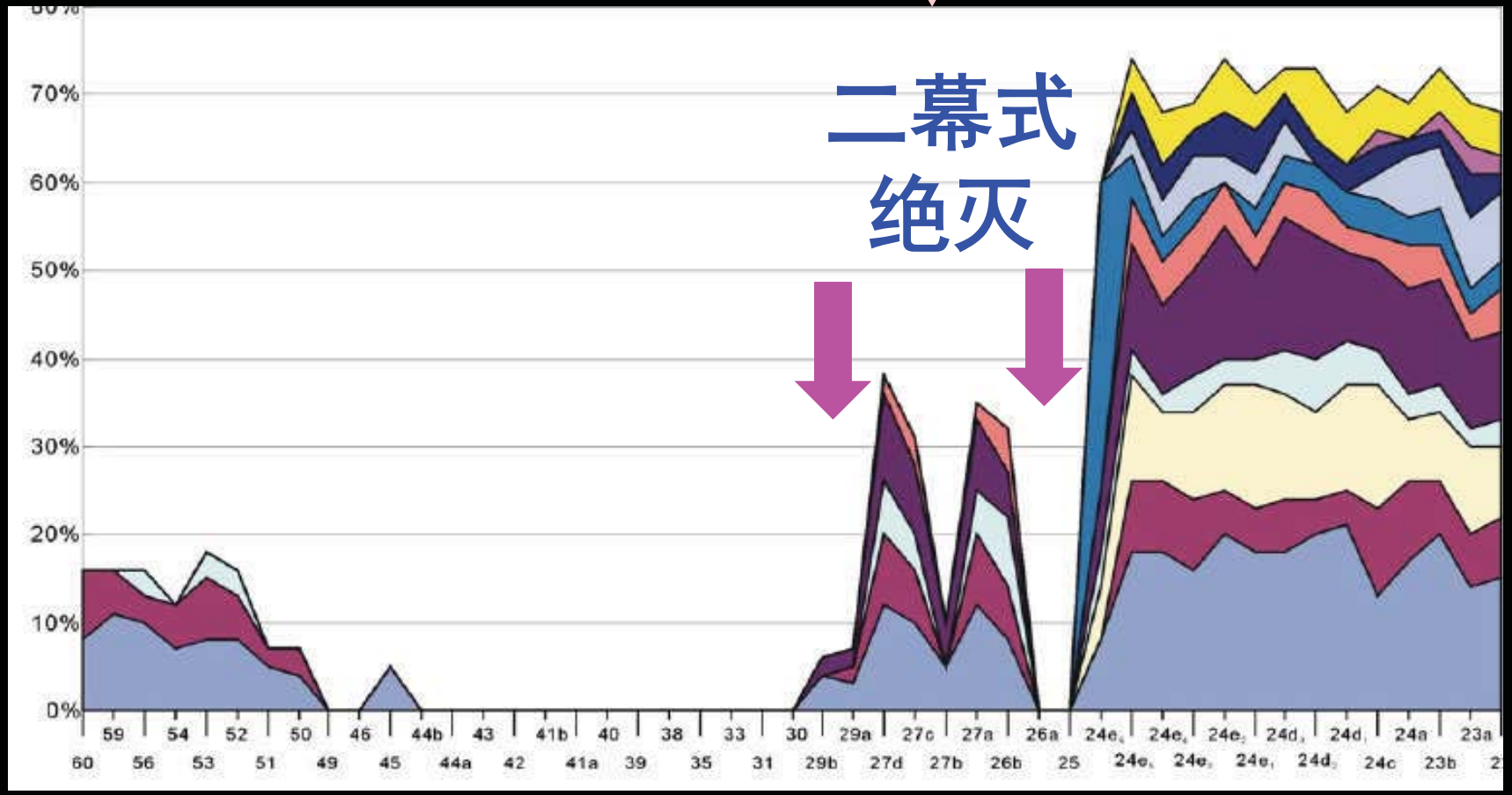
浙江长兴煤山金钉子剖面

二幕式绝灭



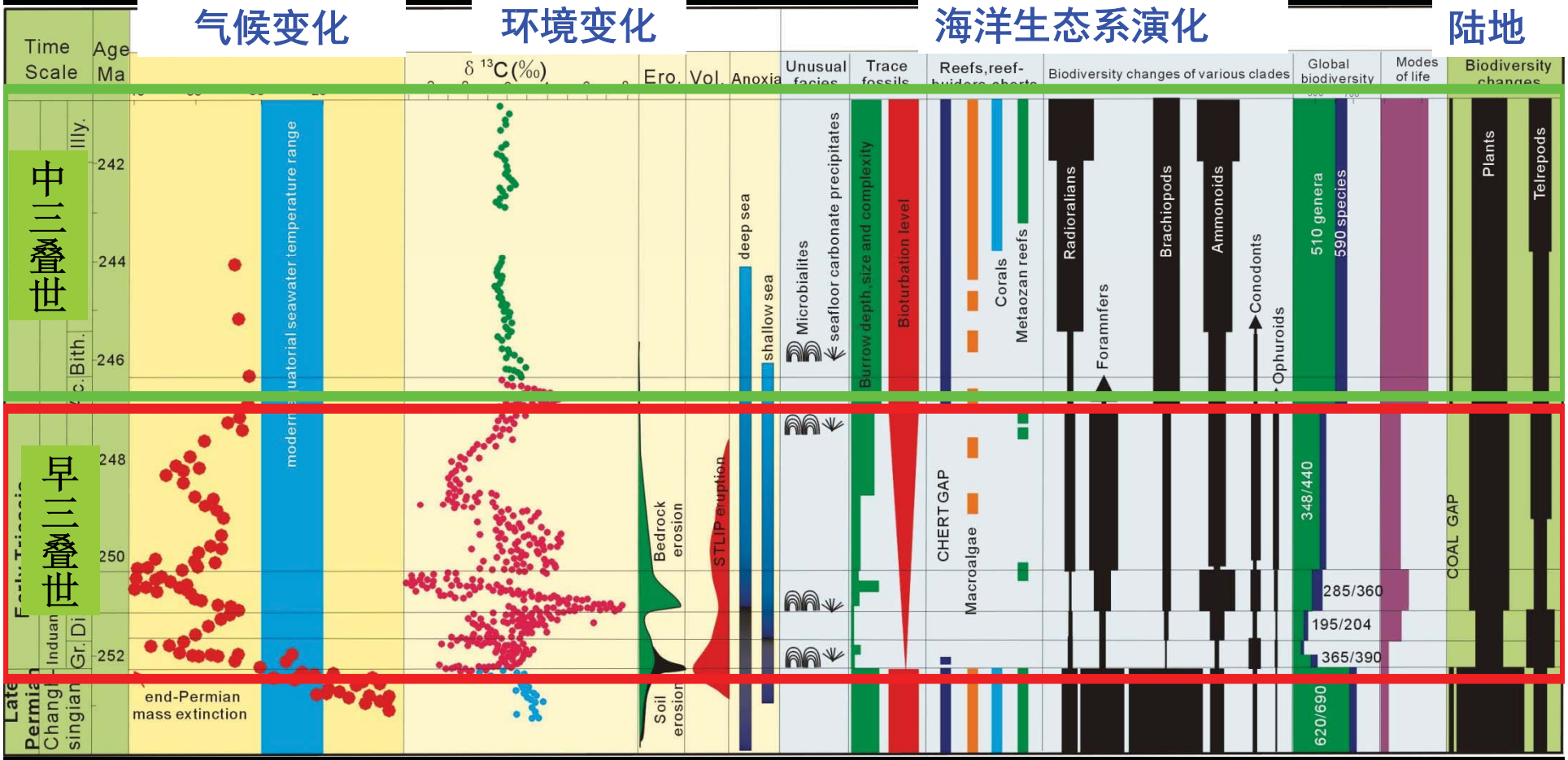
Song et al. (2013, Nature Geoscience)

三叠纪 二叠纪



Chen et al. (2015, Earth-Science Reviews)

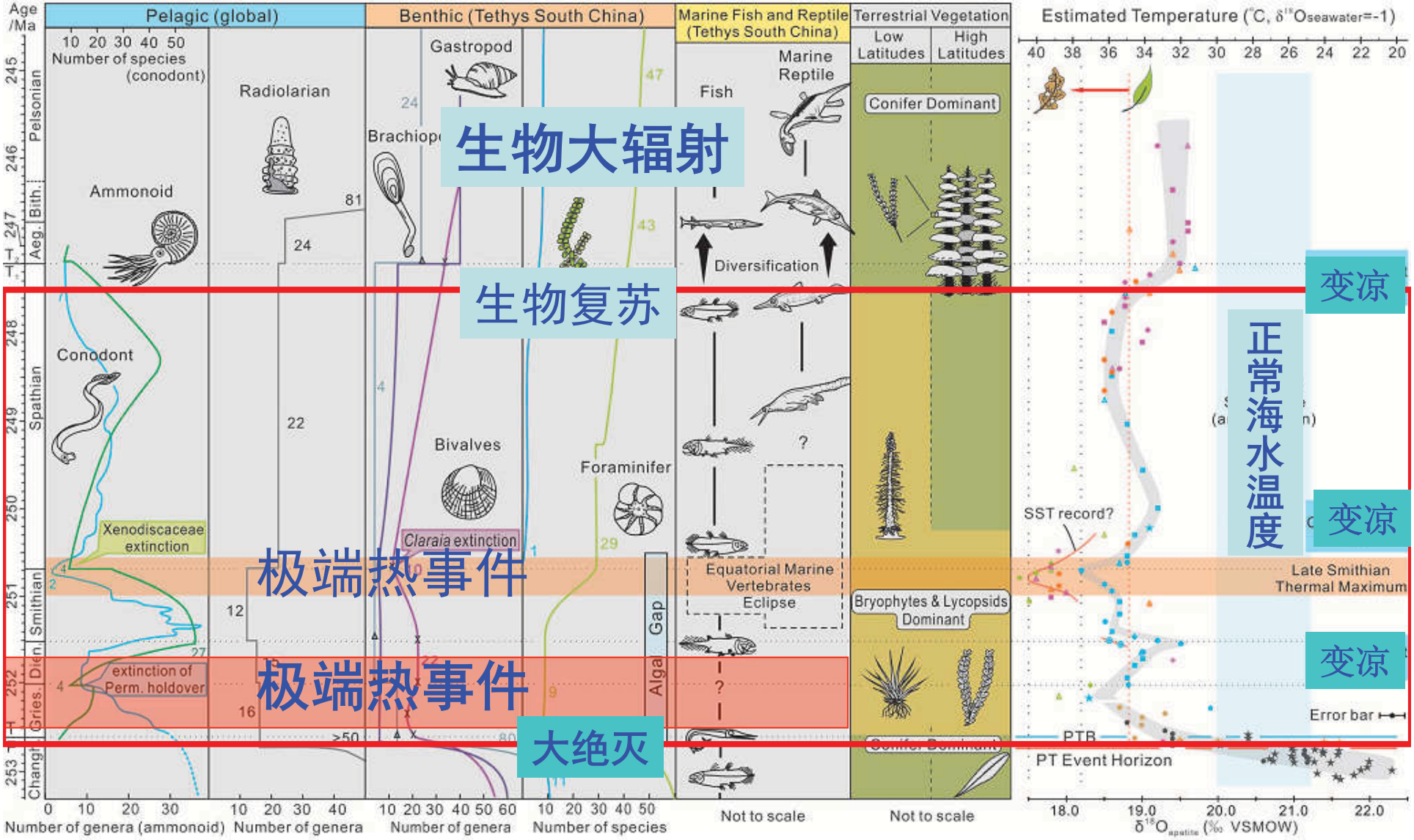
二叠纪-三叠纪之交气候、环境与生物演变过程



Sun et al. (2012, Science)

据Chen and Benton (2012, Nature Geoscience)补充

远洋生物 底栖生物 海洋脊椎 陆生生物 海水温度

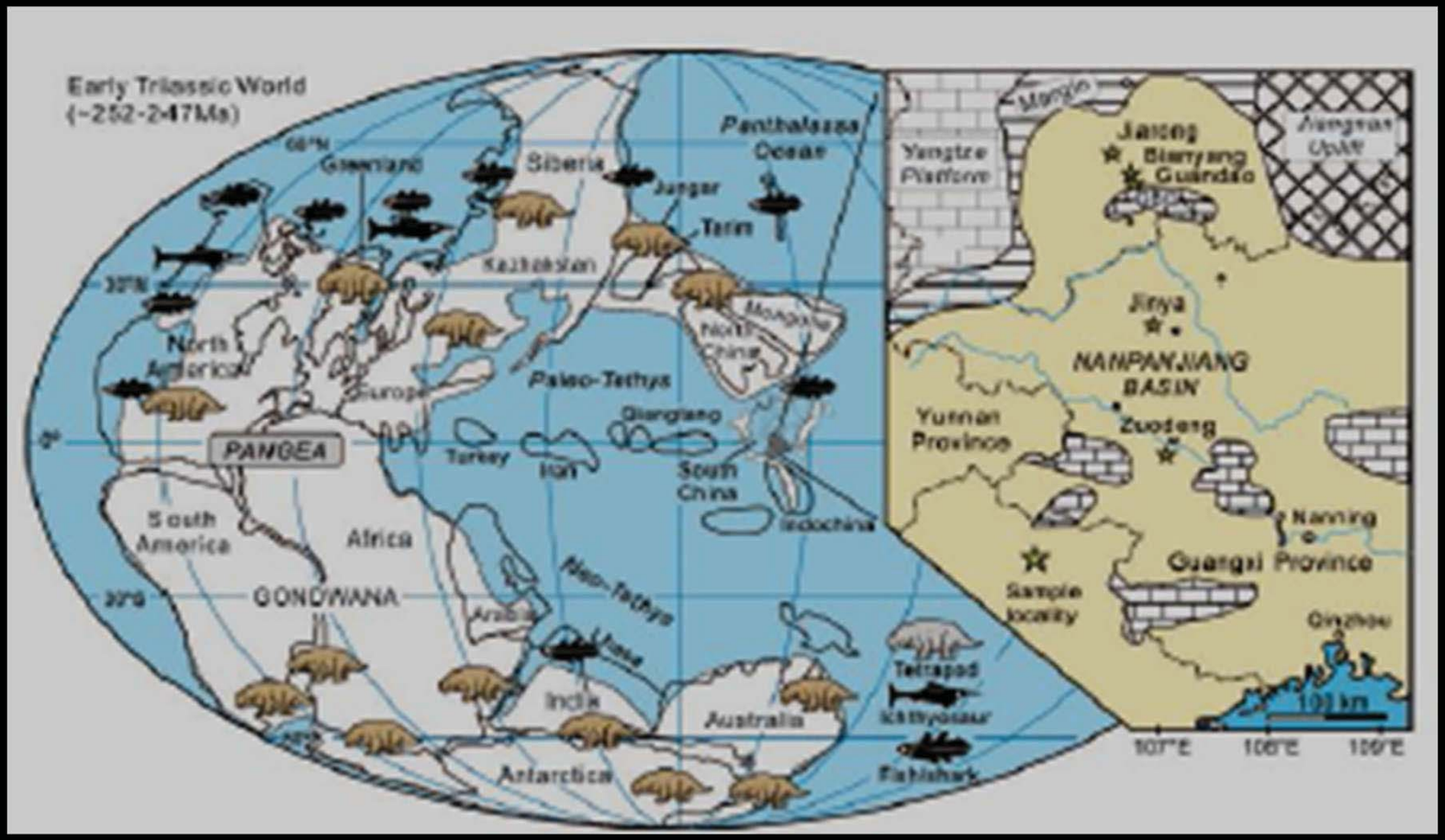


对生物与古海水温度的关系有初步的认识

Sun et al (2012, Science)

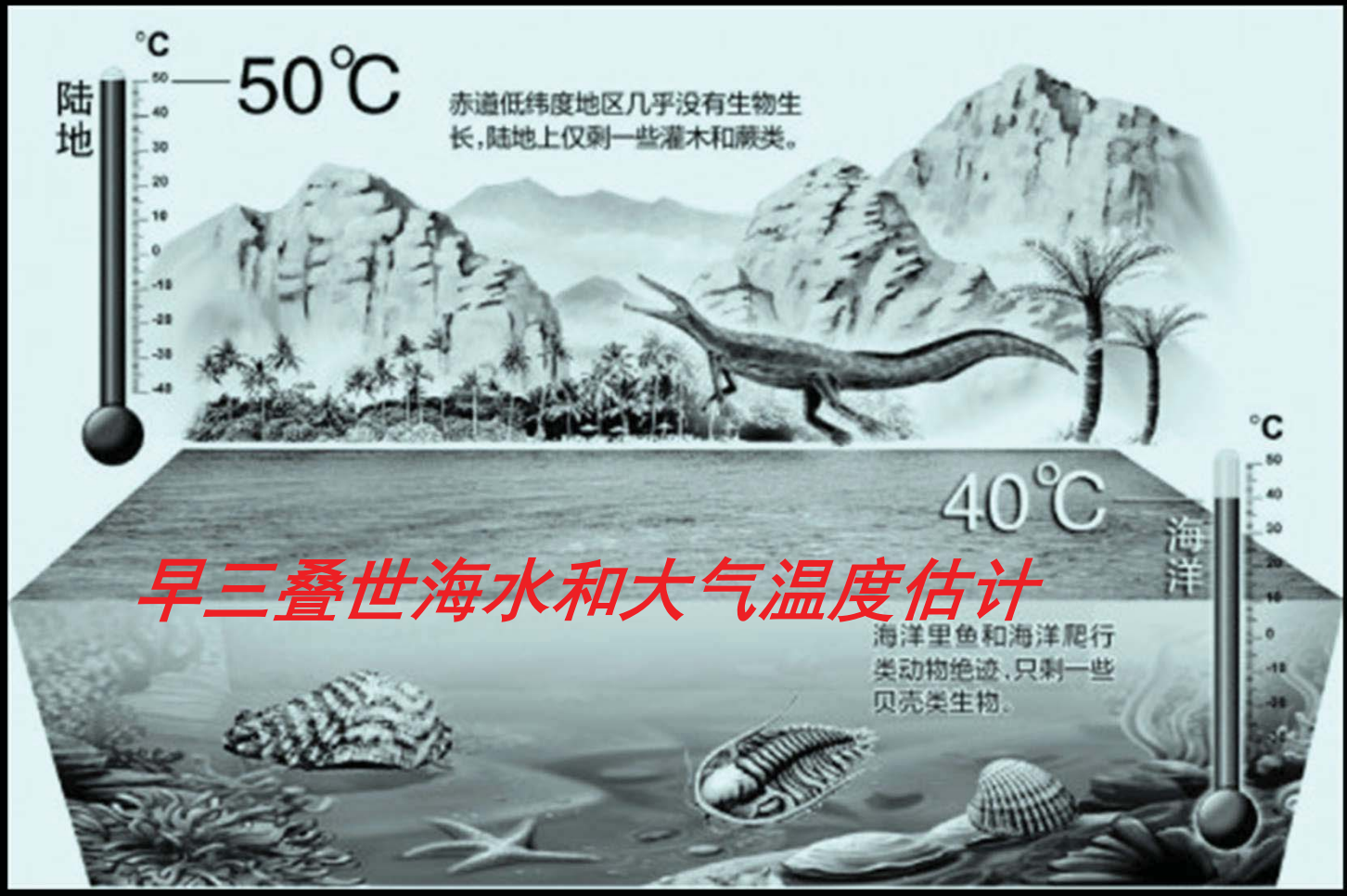
二叠纪-三叠纪生态系：研究进展之海洋古温度

extremely high temperatures in Early Triassic seawater



Sun et al. (2012, Science)

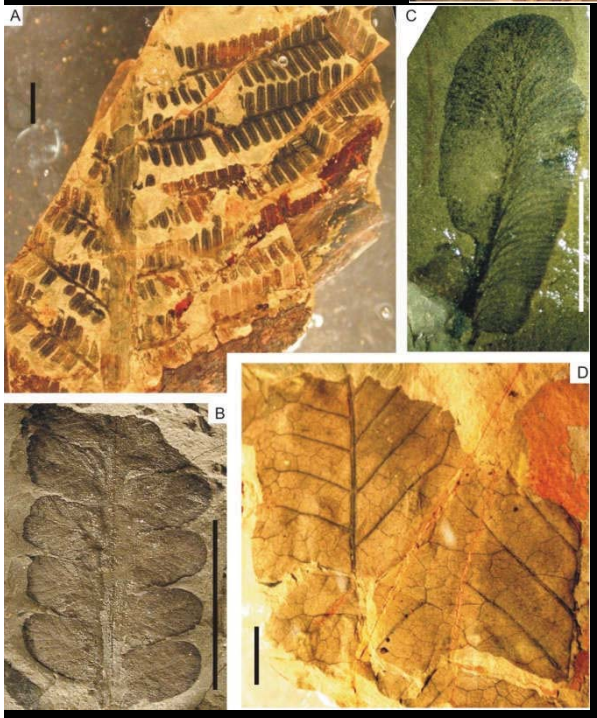
陆地生态系对极端环境、气候事件的反馈



据Sun et al. (2012, Science)结果估计

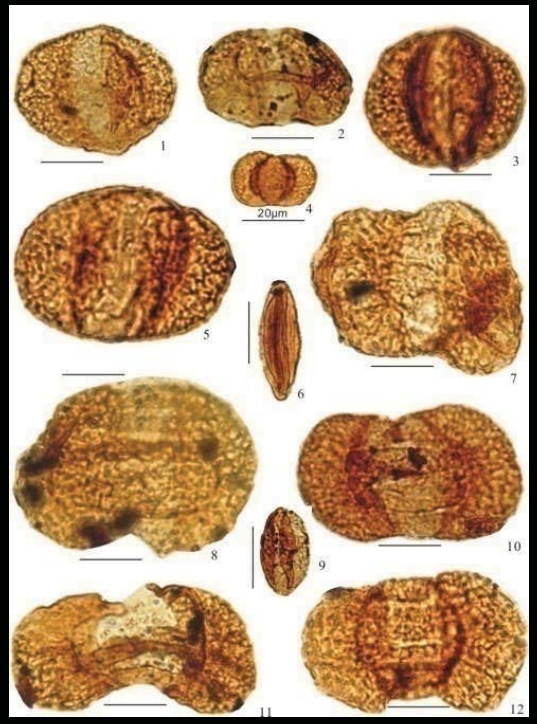
大绝灭之后植物化石

岔河剖面

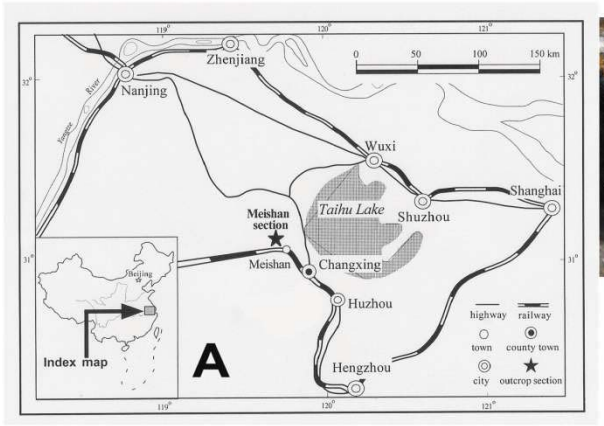


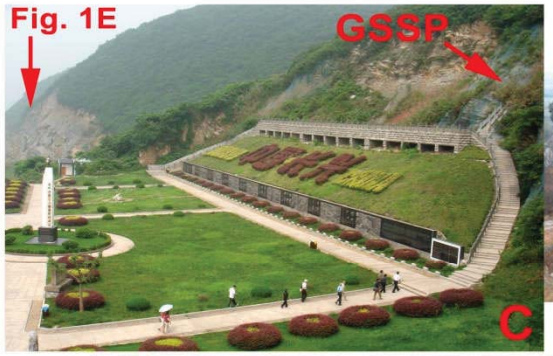
叶片角质层中保存的CO_2信息

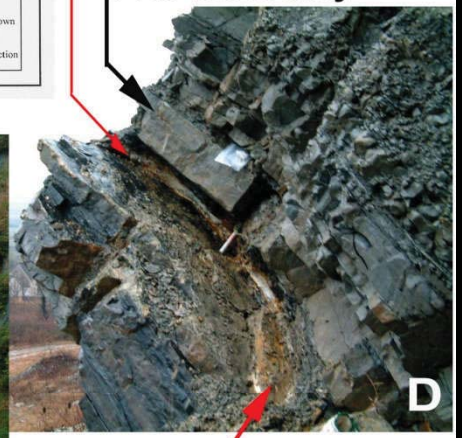
古土壤地化信息和孢粉组合面貌反映气候



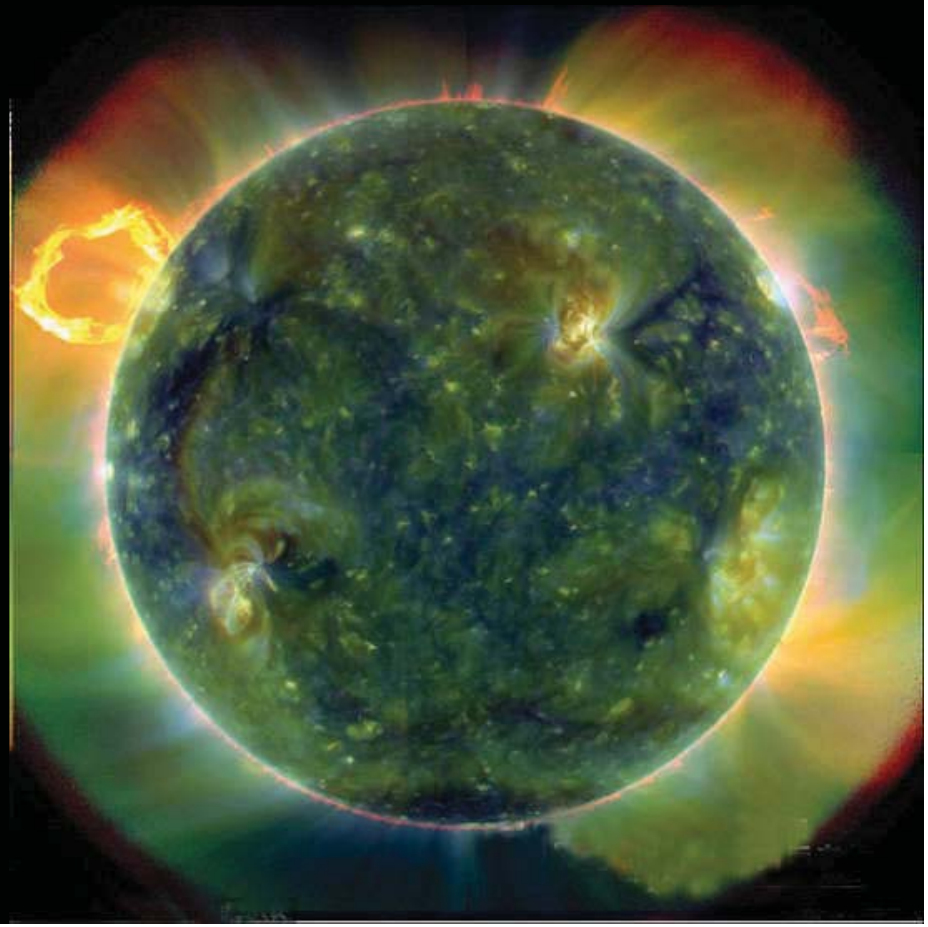
GSSP of PTB
Meishan, Changxing





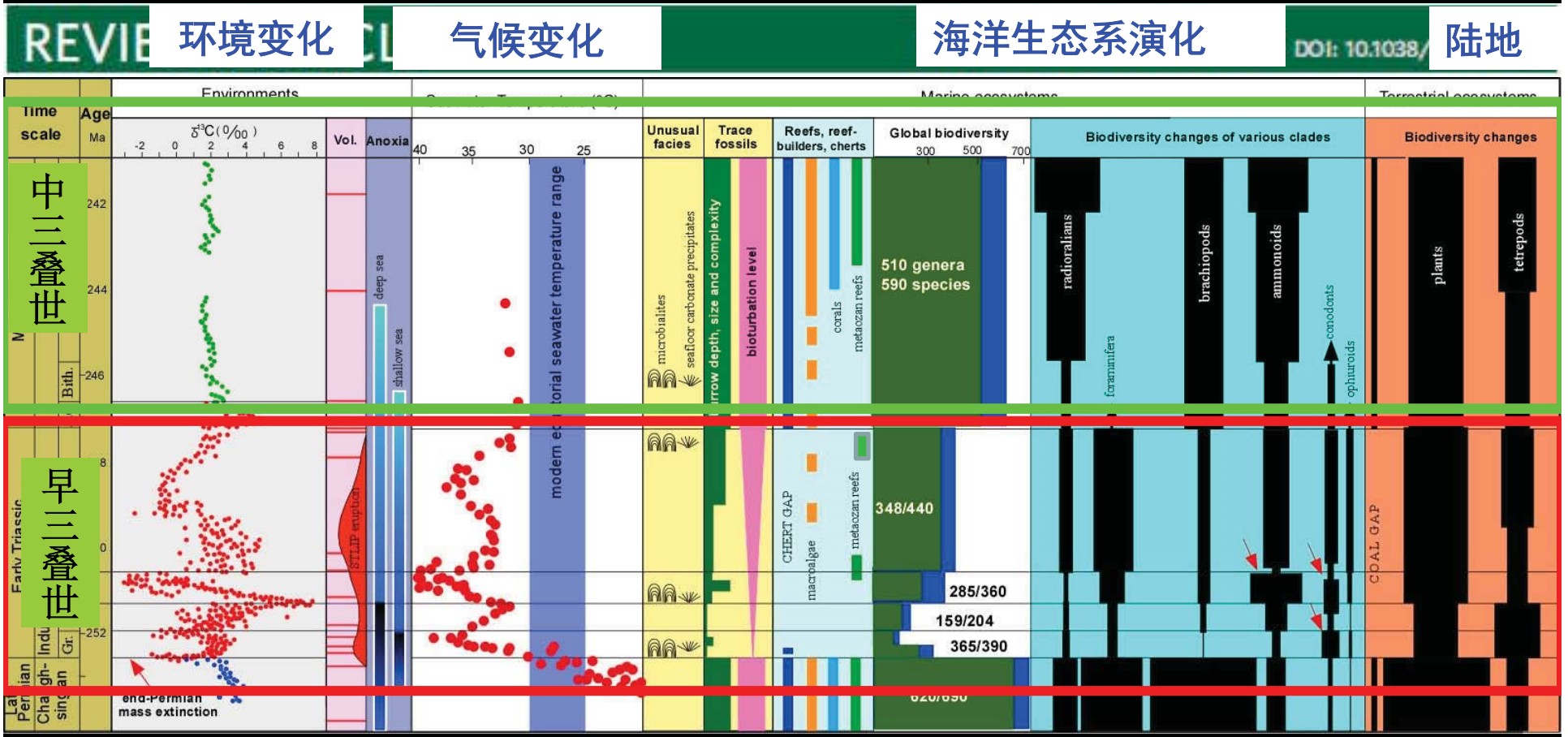


大绝灭元凶？



西伯利亚大火山省
直径1000多公里

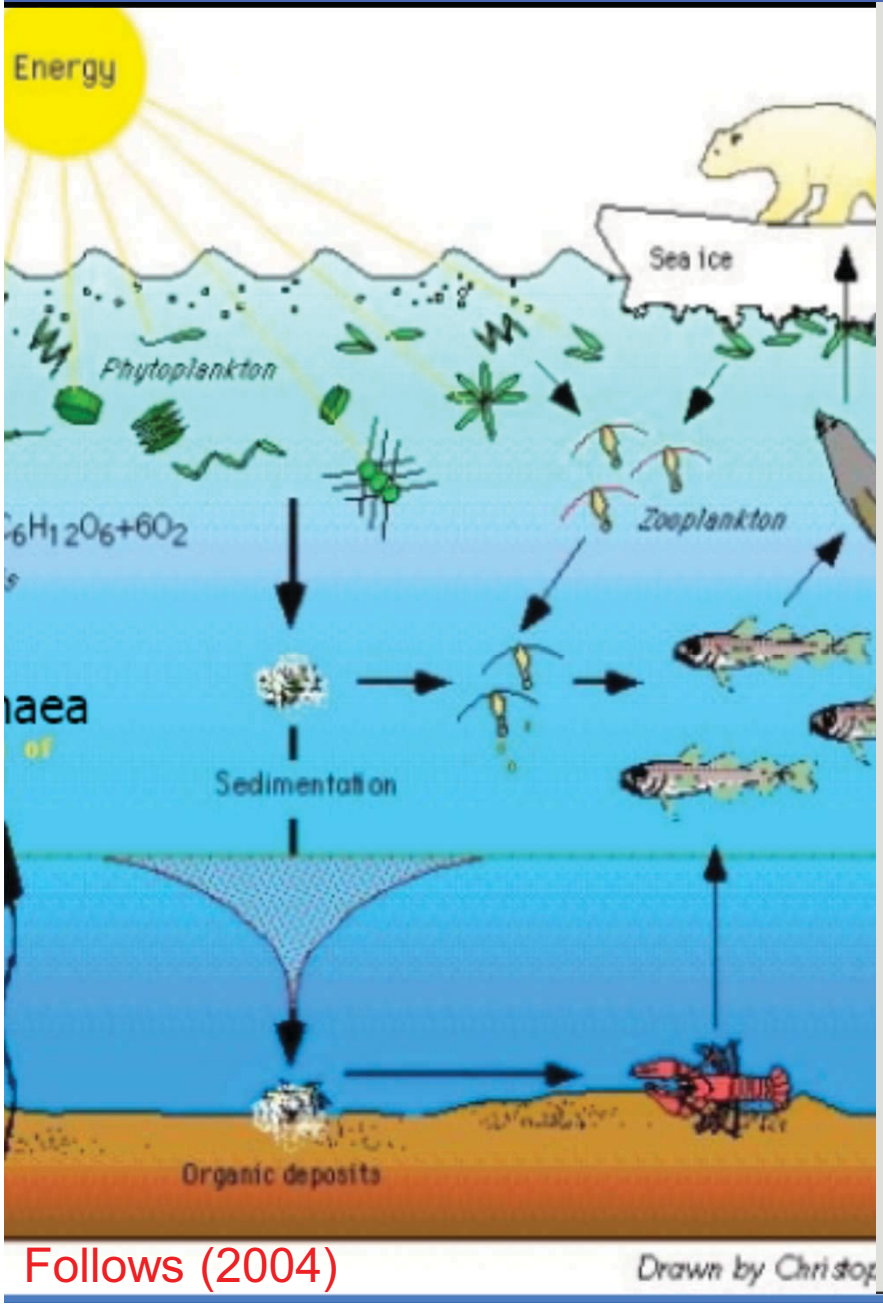
二叠纪–三叠纪之交极端气候、环境事件以及生态系的反馈



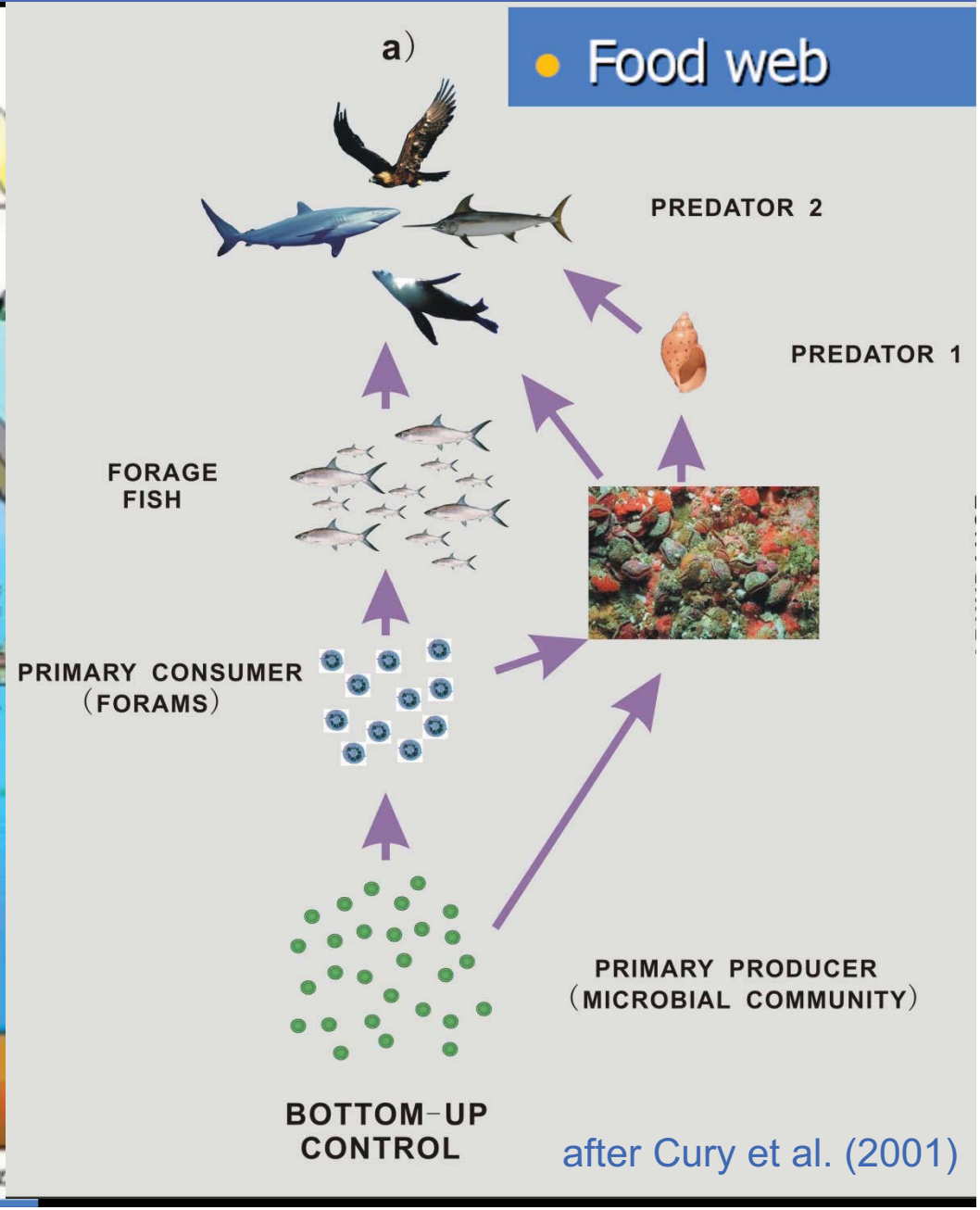
Payne et al. (2004); Sun et al. (2012)

Chen & Benton (2012)

What is the marine ecosystem?



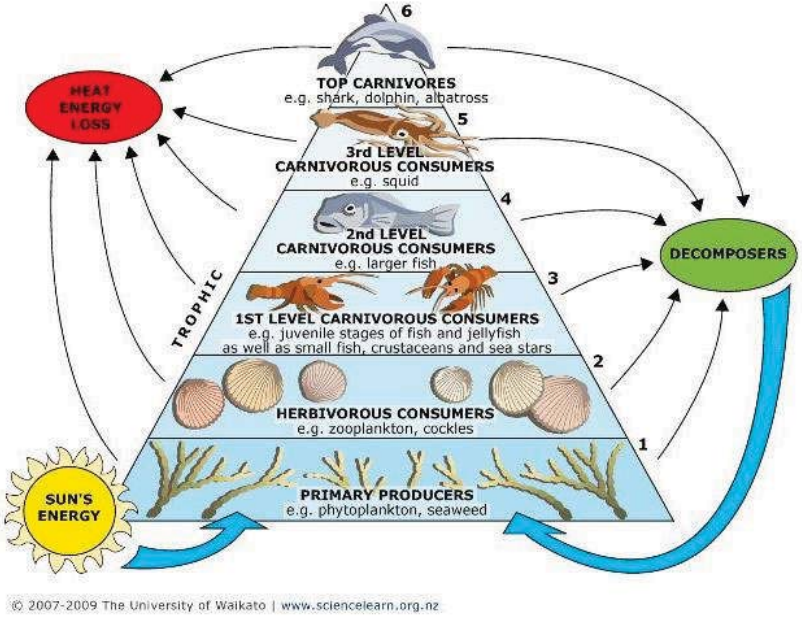
Follows (2004)

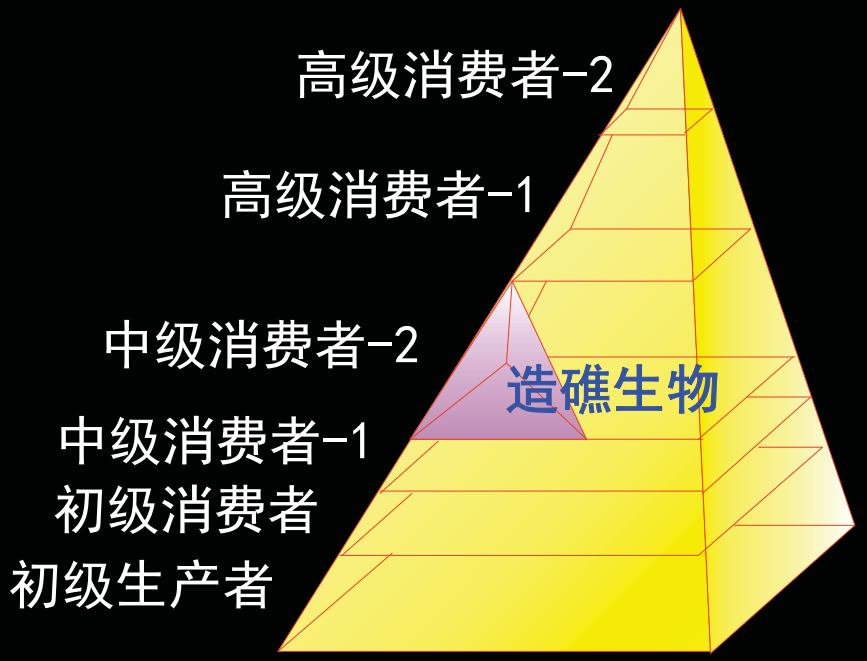


after Cury et al. (2001)

生态系在大绝灭后复苏模式和时间

现代生态系食物链金字塔

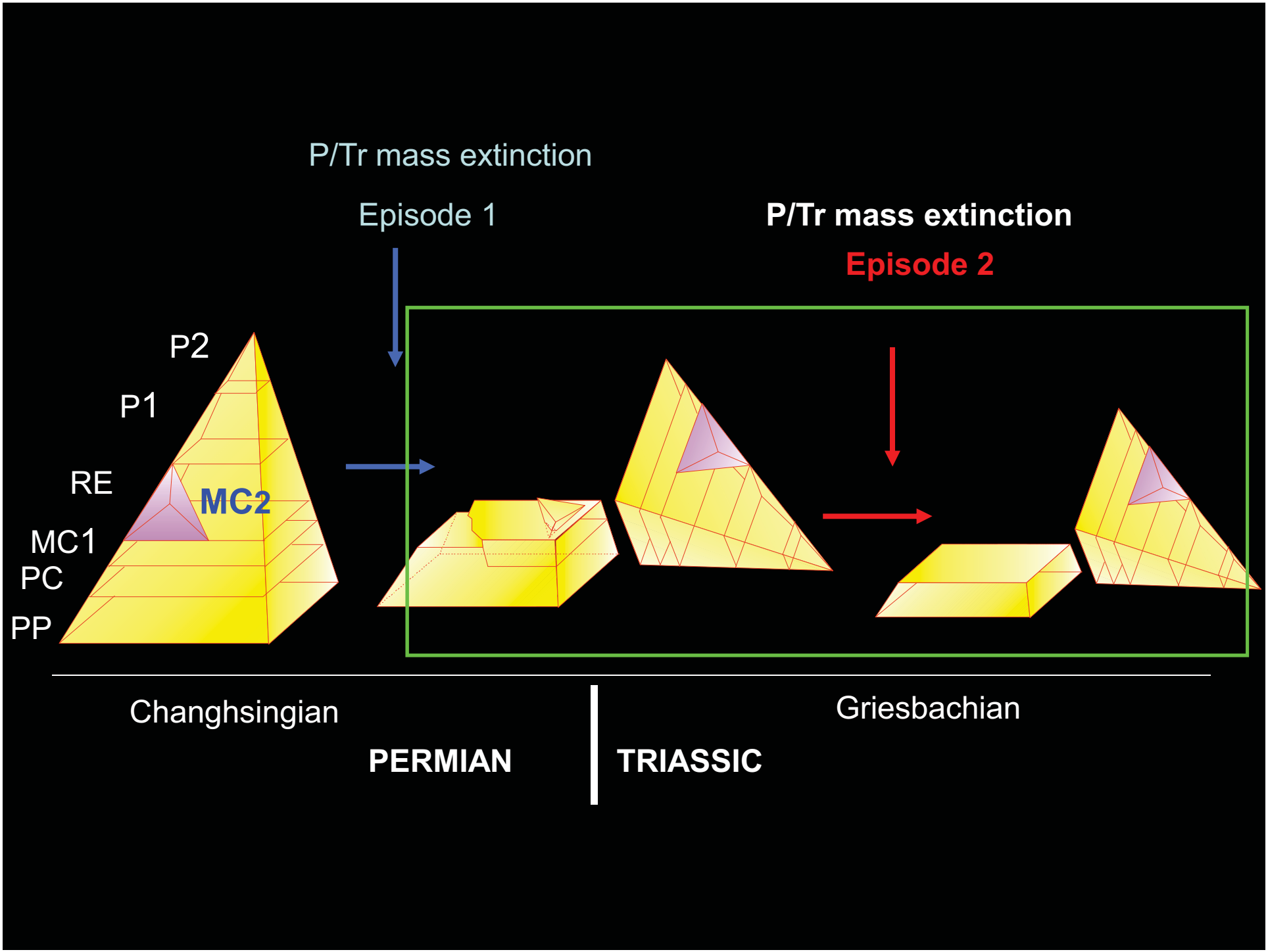




化石生态系模型

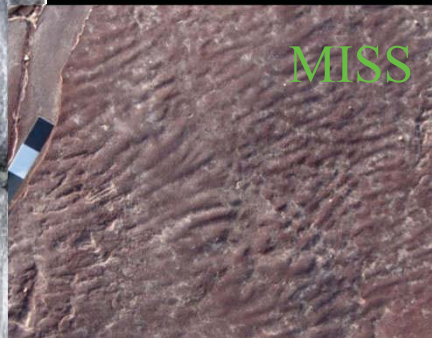
（二叠-三叠纪之交）

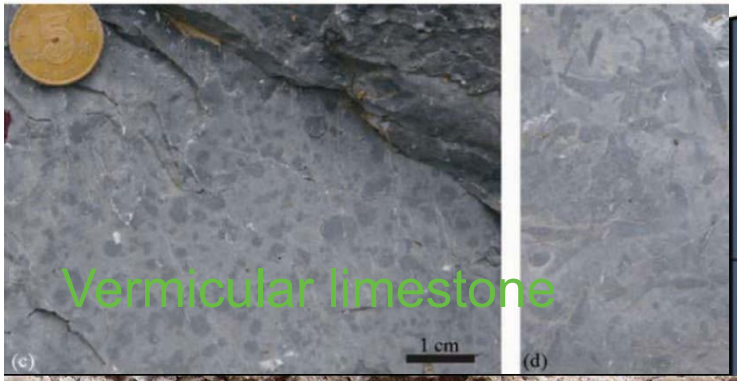
距今2.55-2.40亿年前

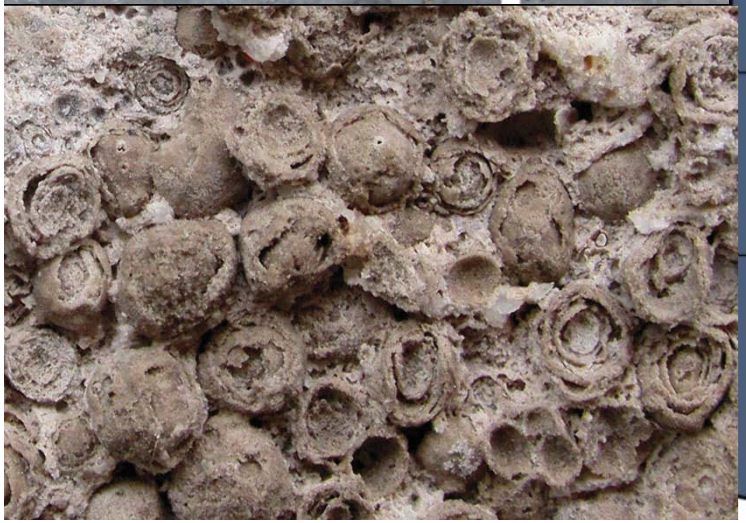

P/Tr mass extinction
Episode 1
P/Tr mass extinction
Episode 2
P2
P1
RE
MC2
MC1
PC
PP
Changhsingian
Griesbachian
PERMIAN
TRIASSIC

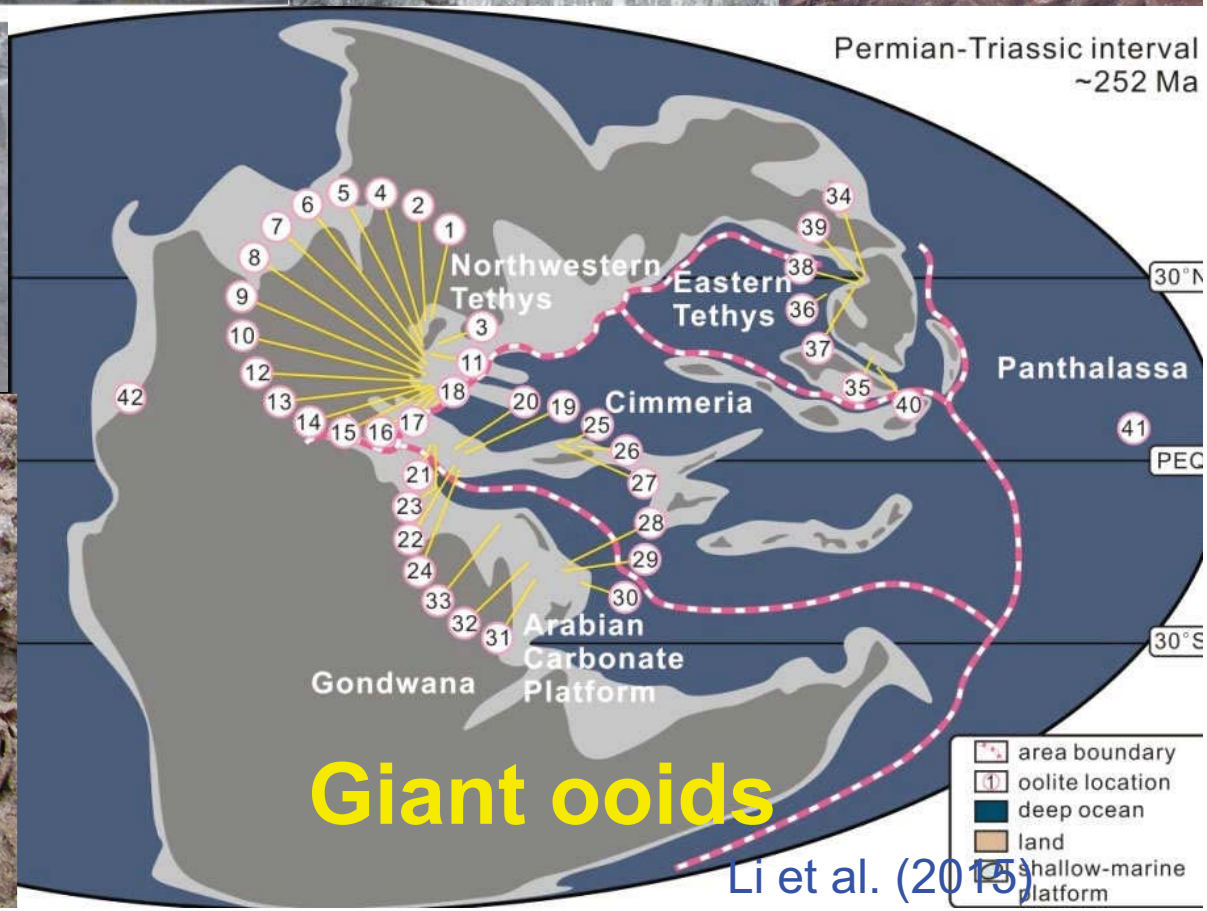
Microbially induced sedimentary products:

Anachronistic facies



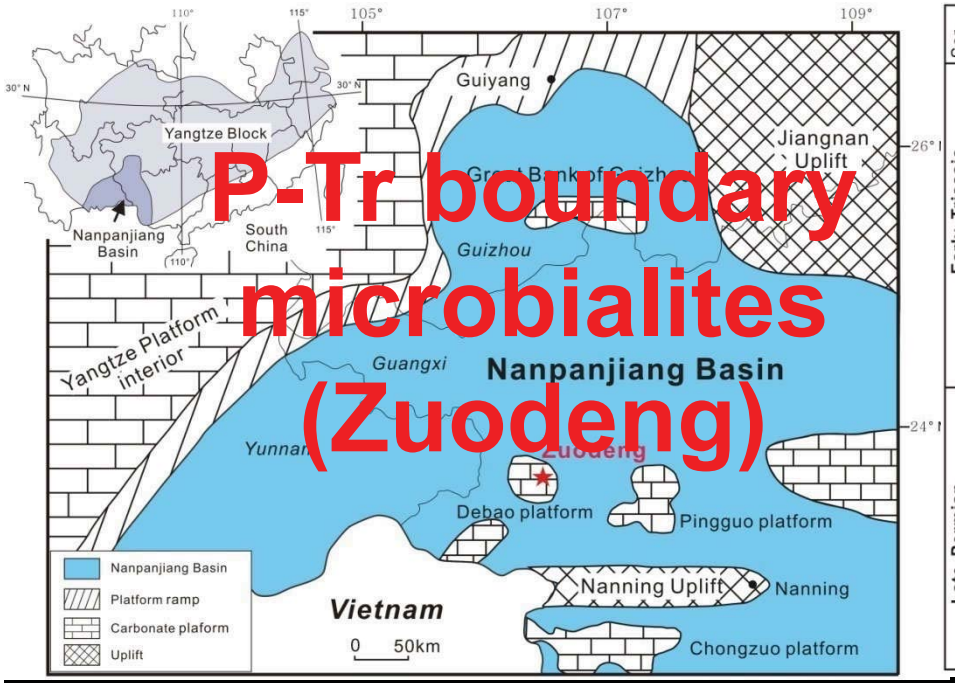


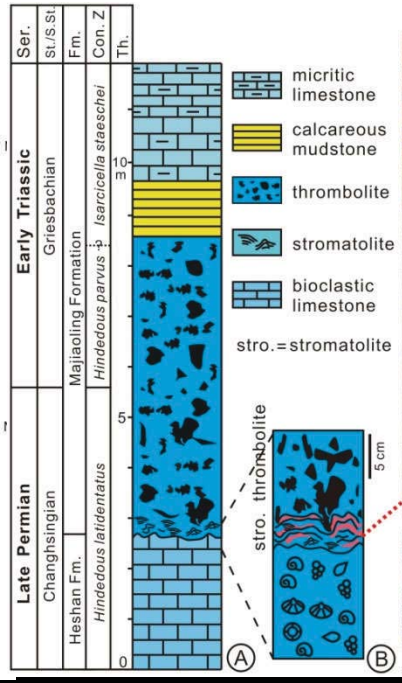


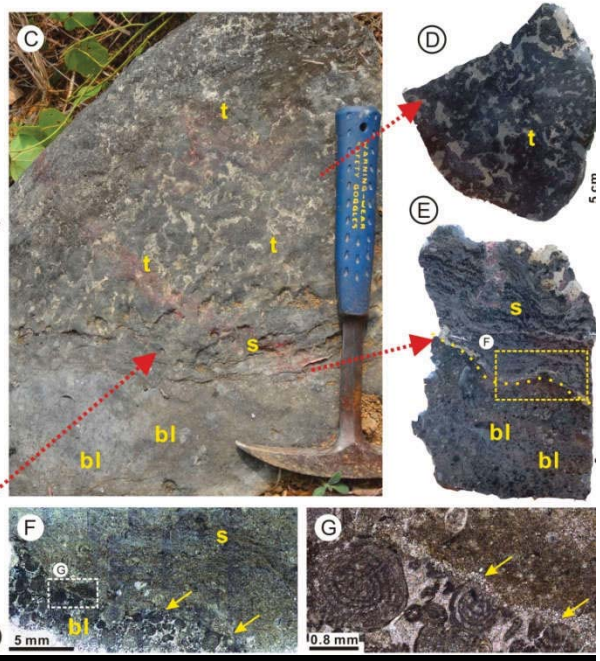


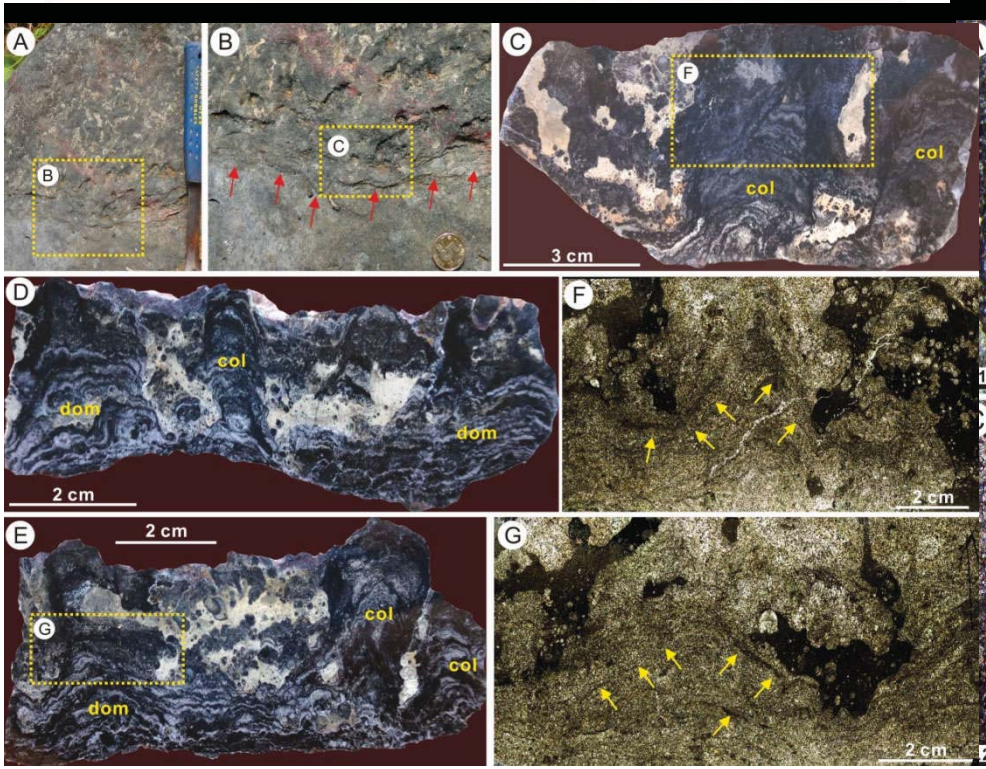
Li et al. (2015)

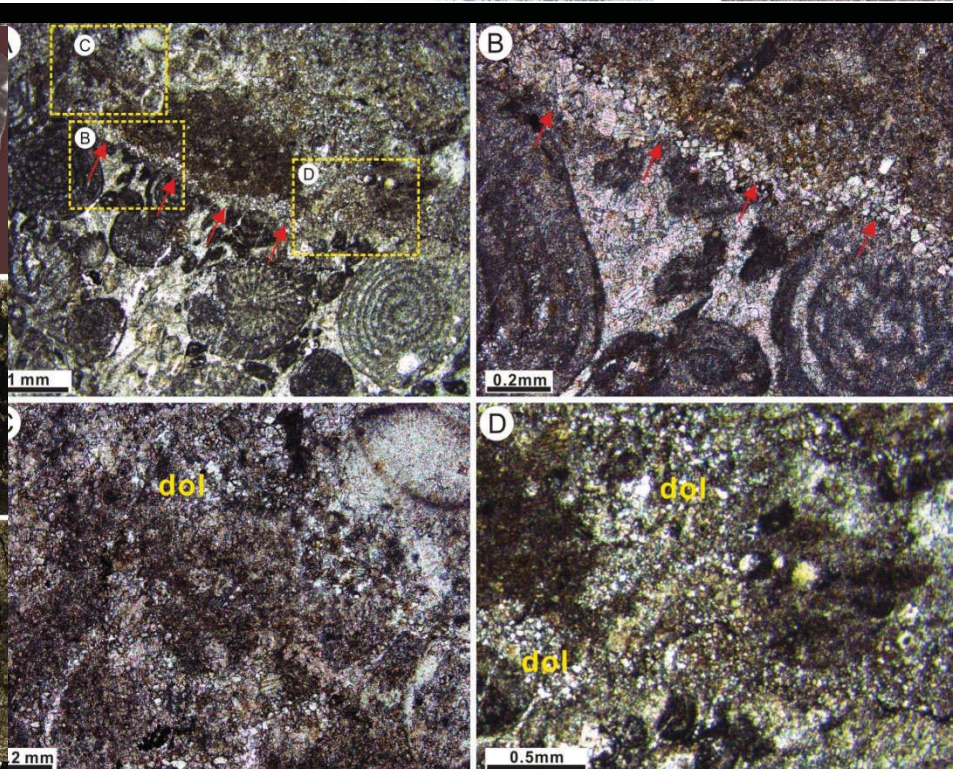
P-Tr boundary microbialites (Zuodeng)

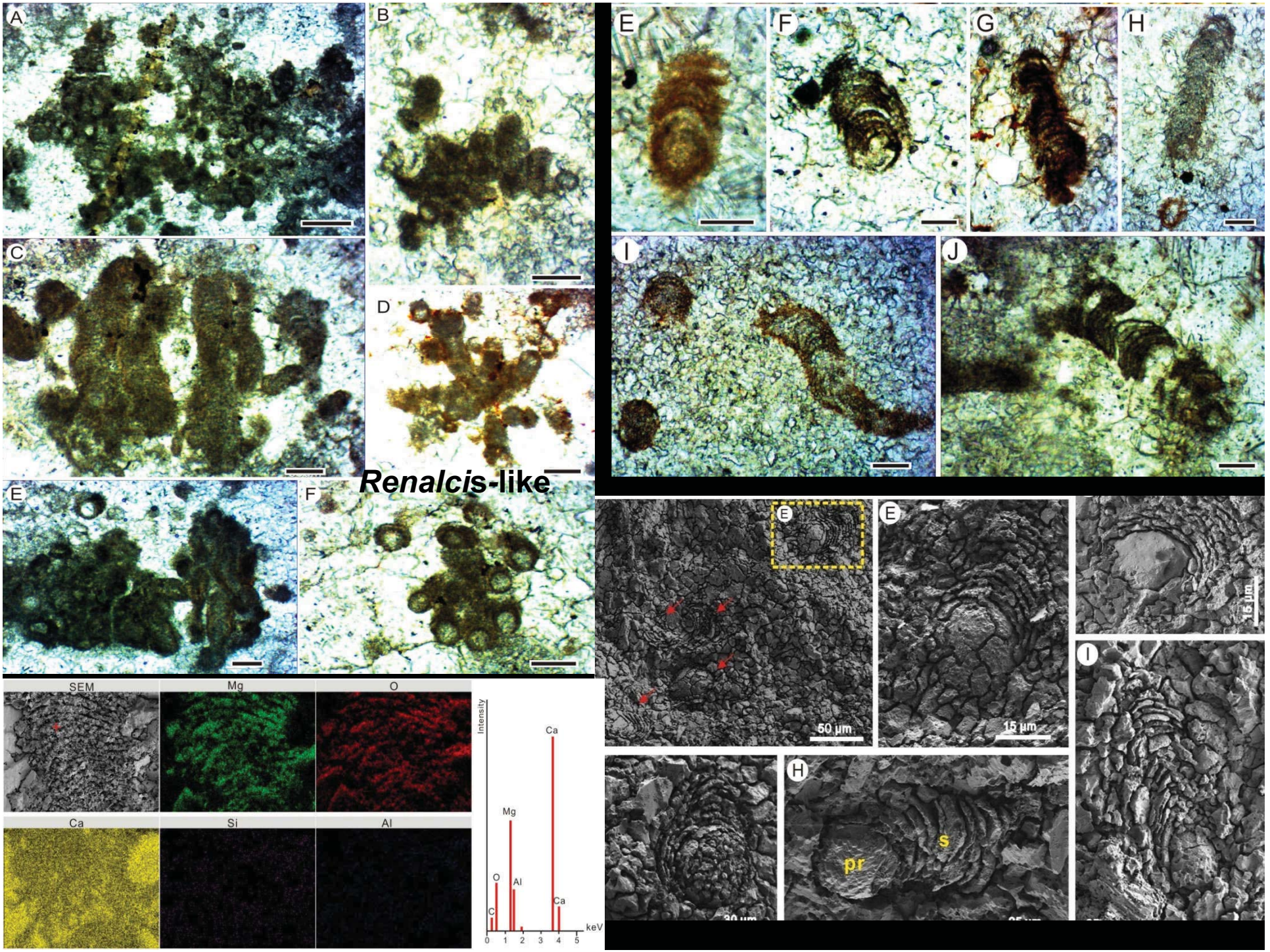


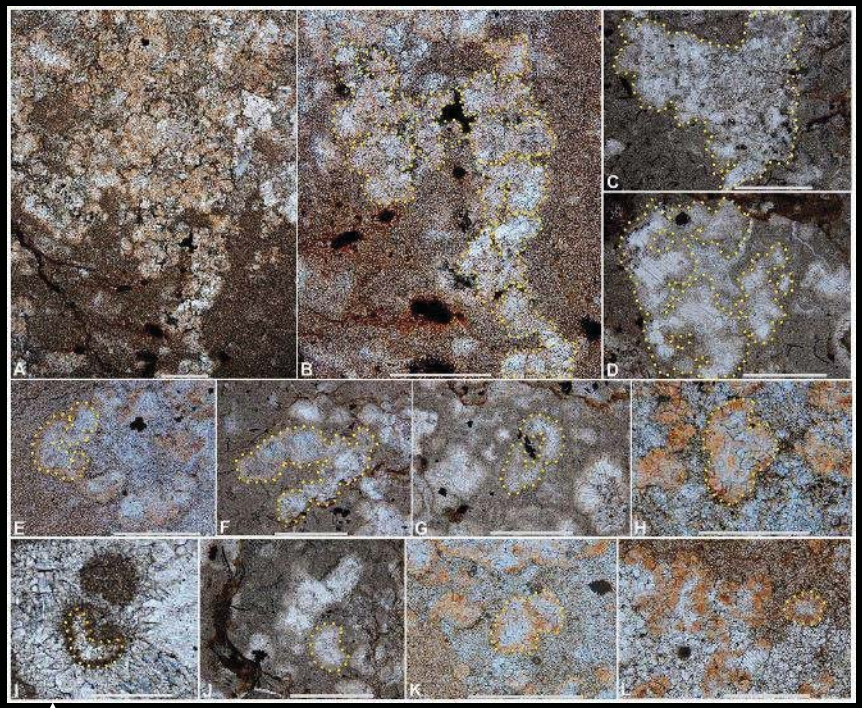






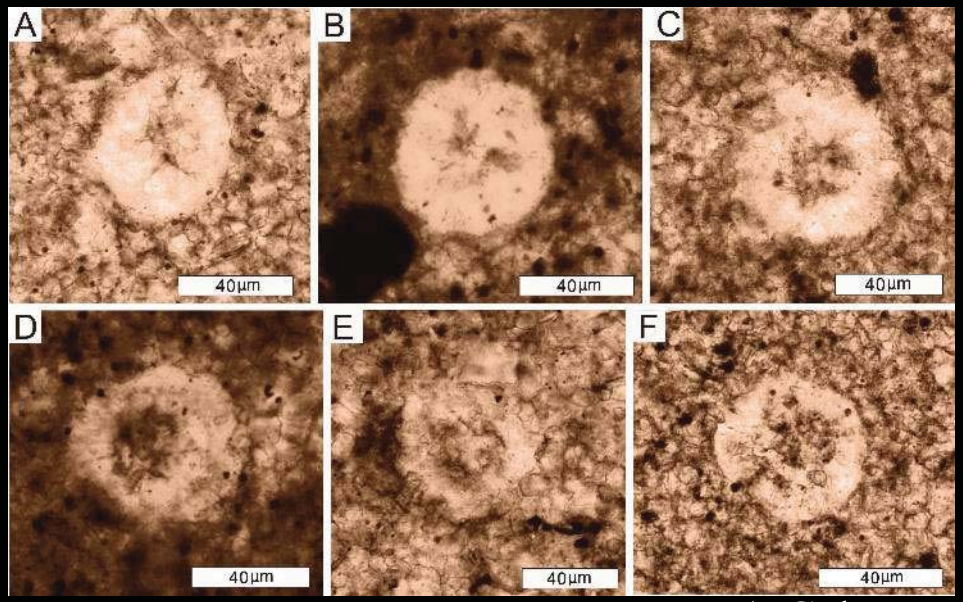


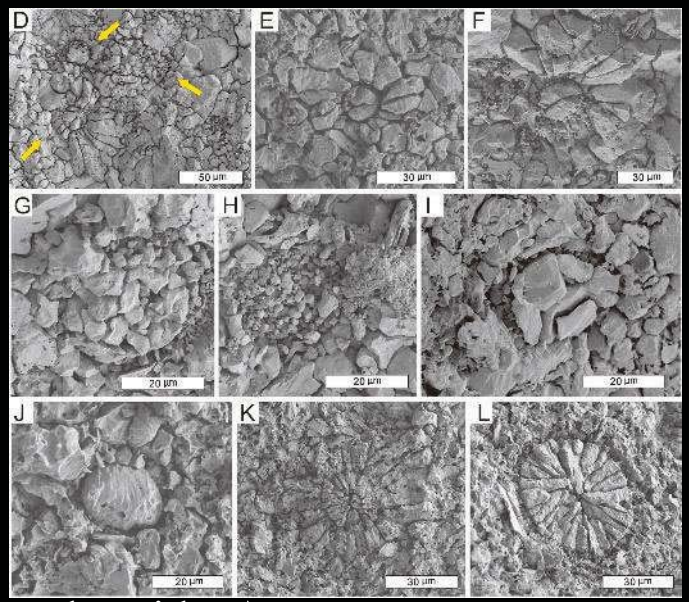

A
B
C
D
E
F
G
H
I
J
Renalcis-like
E
F
E
50 µm
E
15 µm
15 µm
I
H
pr
s
SEM
Mg
O
Ca
Si
Al
Intensity
C
O
Mg
Al
Ca
Ca
keV
0
1
2
3
4
5



Microcystis-like microbes (Wu et al., 2014)

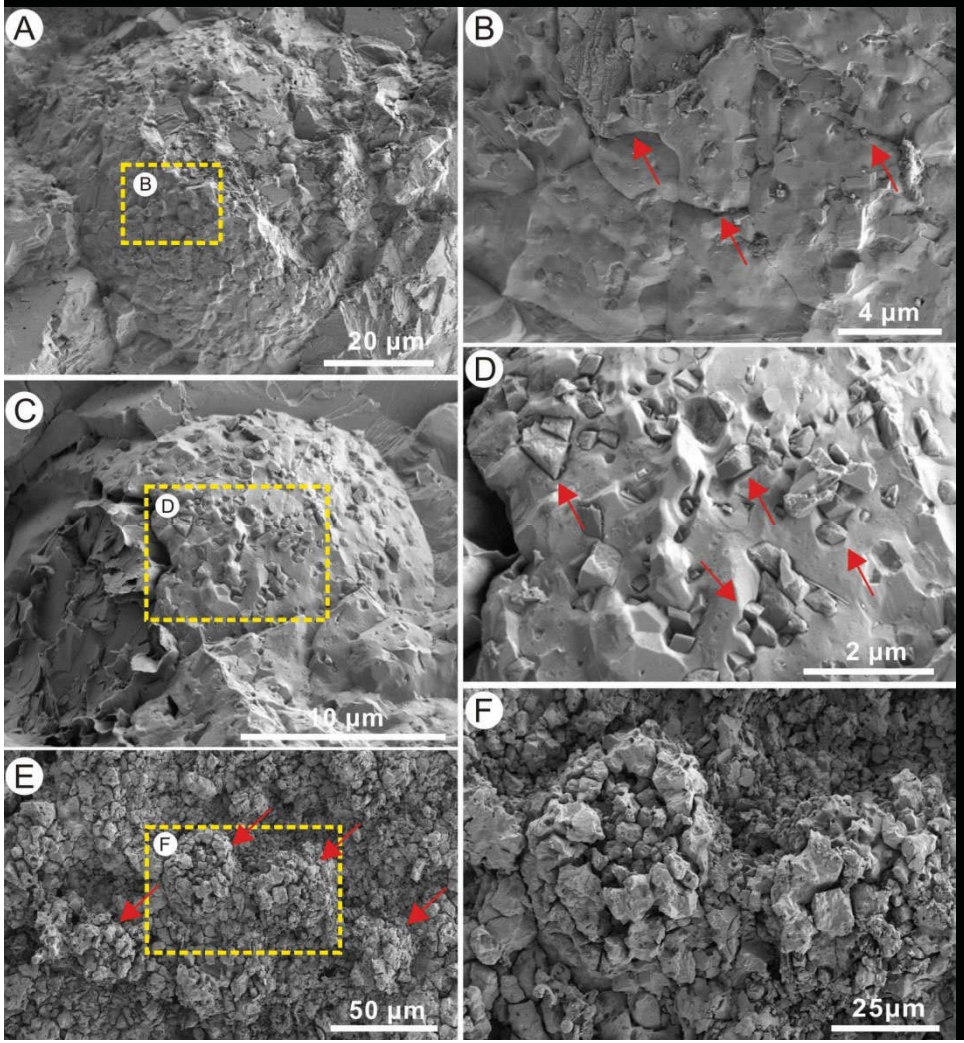
Present-day *Microcystis*

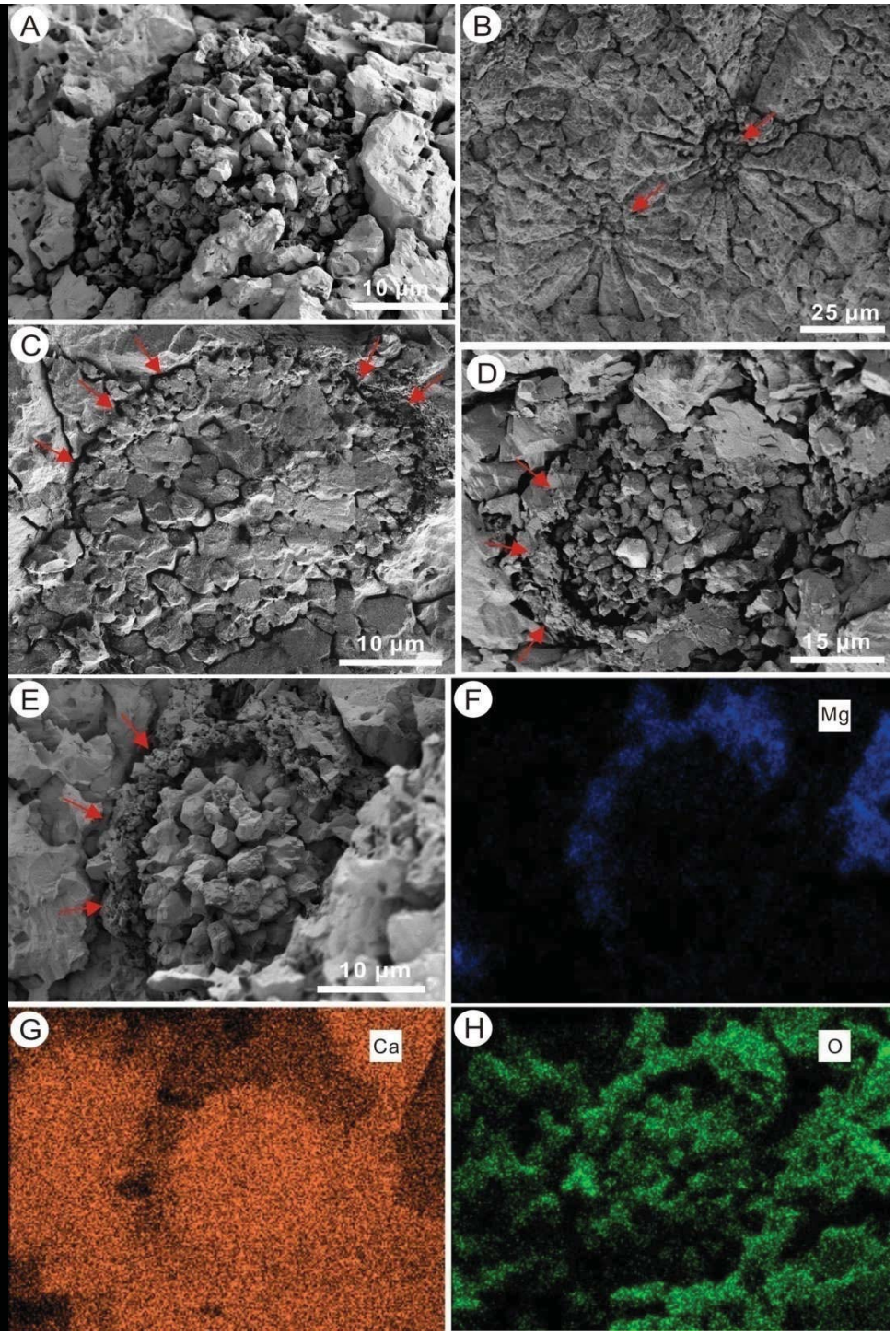


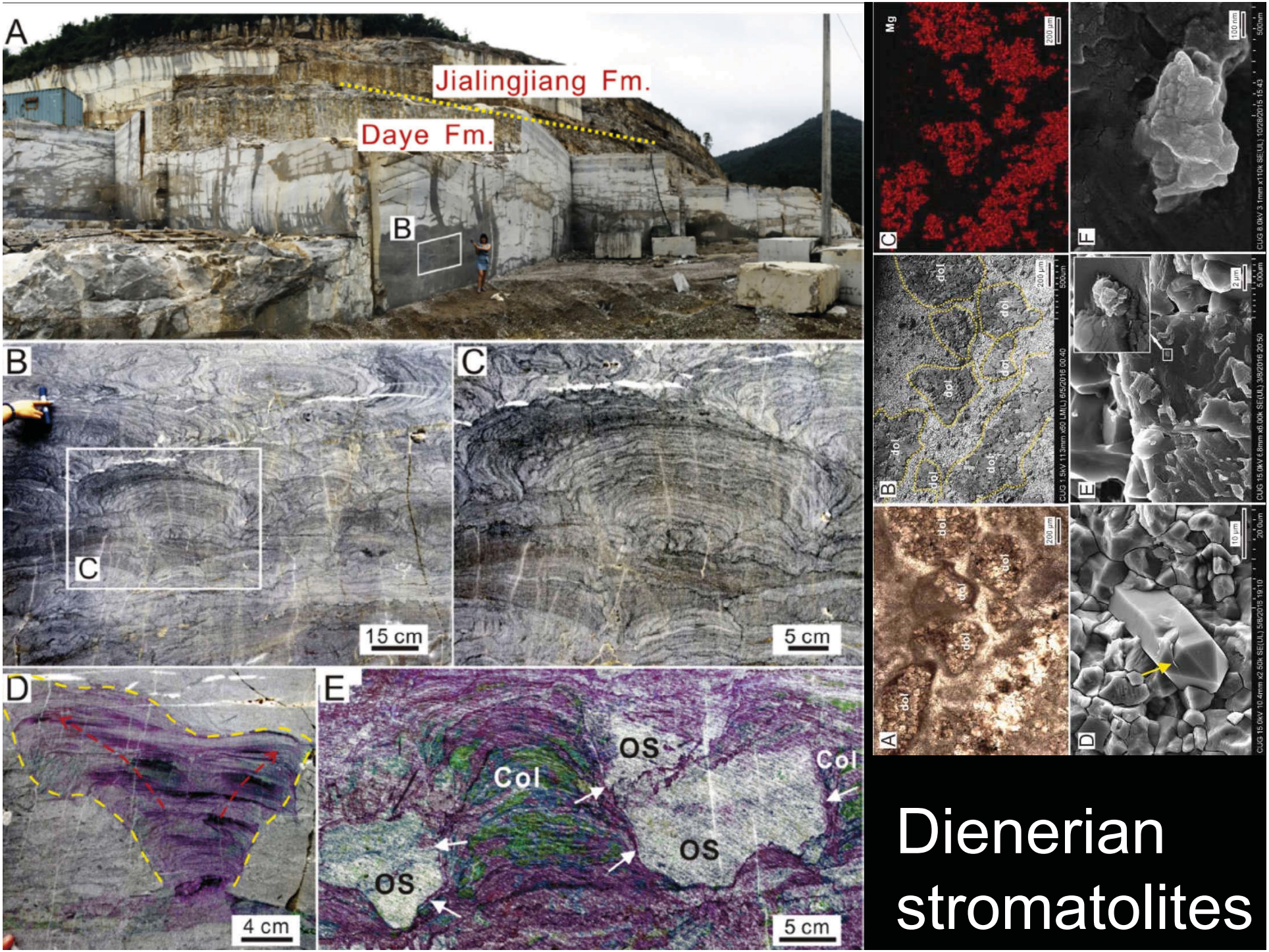


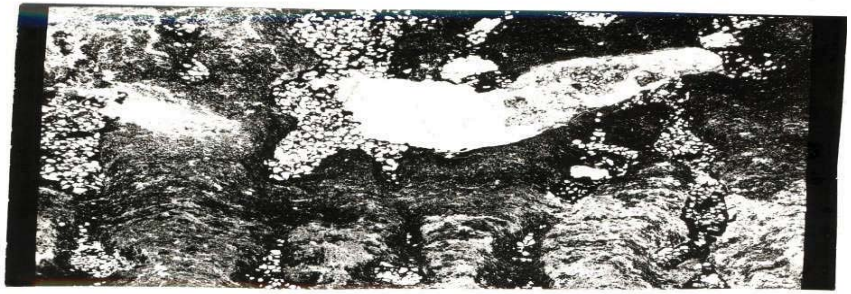
Calcareous spheroids

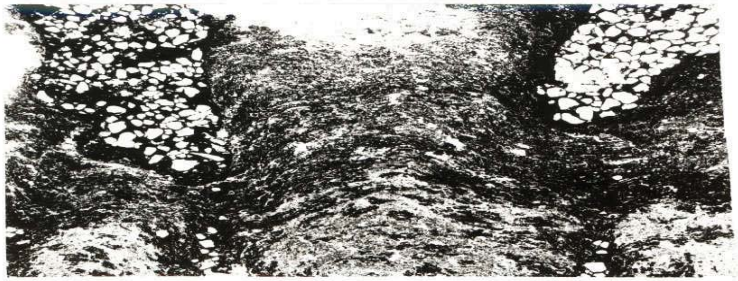
microspheroids

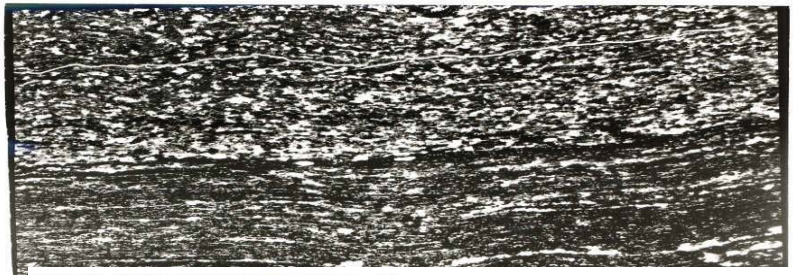


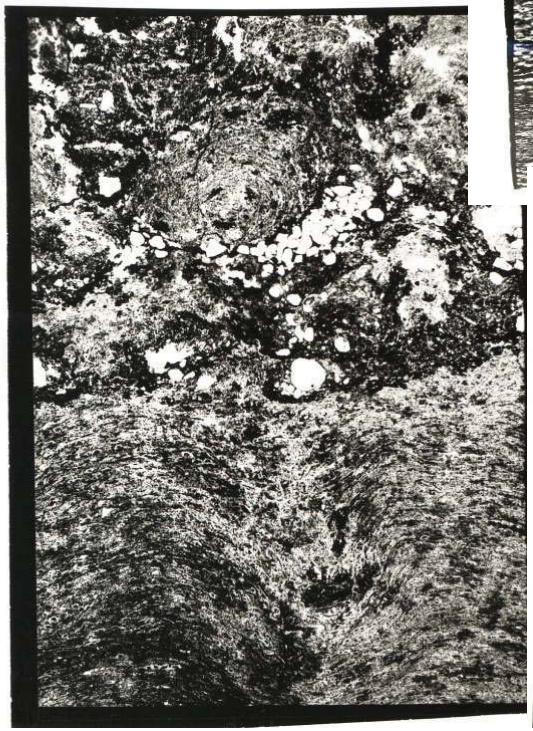



A
Jialingjiang Fm.
Daye Fm.
B
B
C
15 cm
C
5 cm
D
4 cm
E
OS
Col
OS
Col
OS
5 cm
Mg
200 μm
C
100 nm
F
dol
B
2 μm
E
200 μm
A
10 μm
D
Dienerian
stromatolites

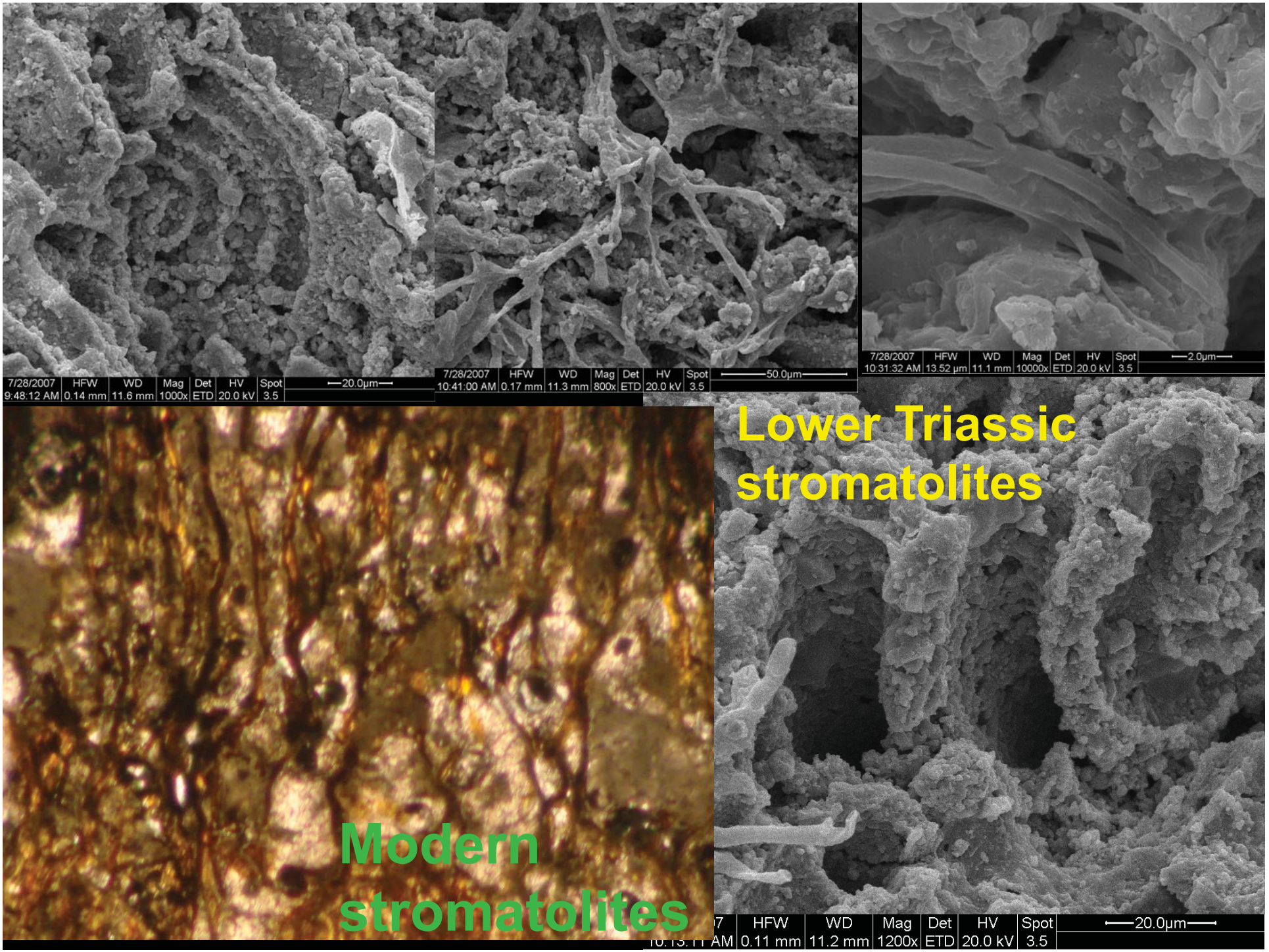




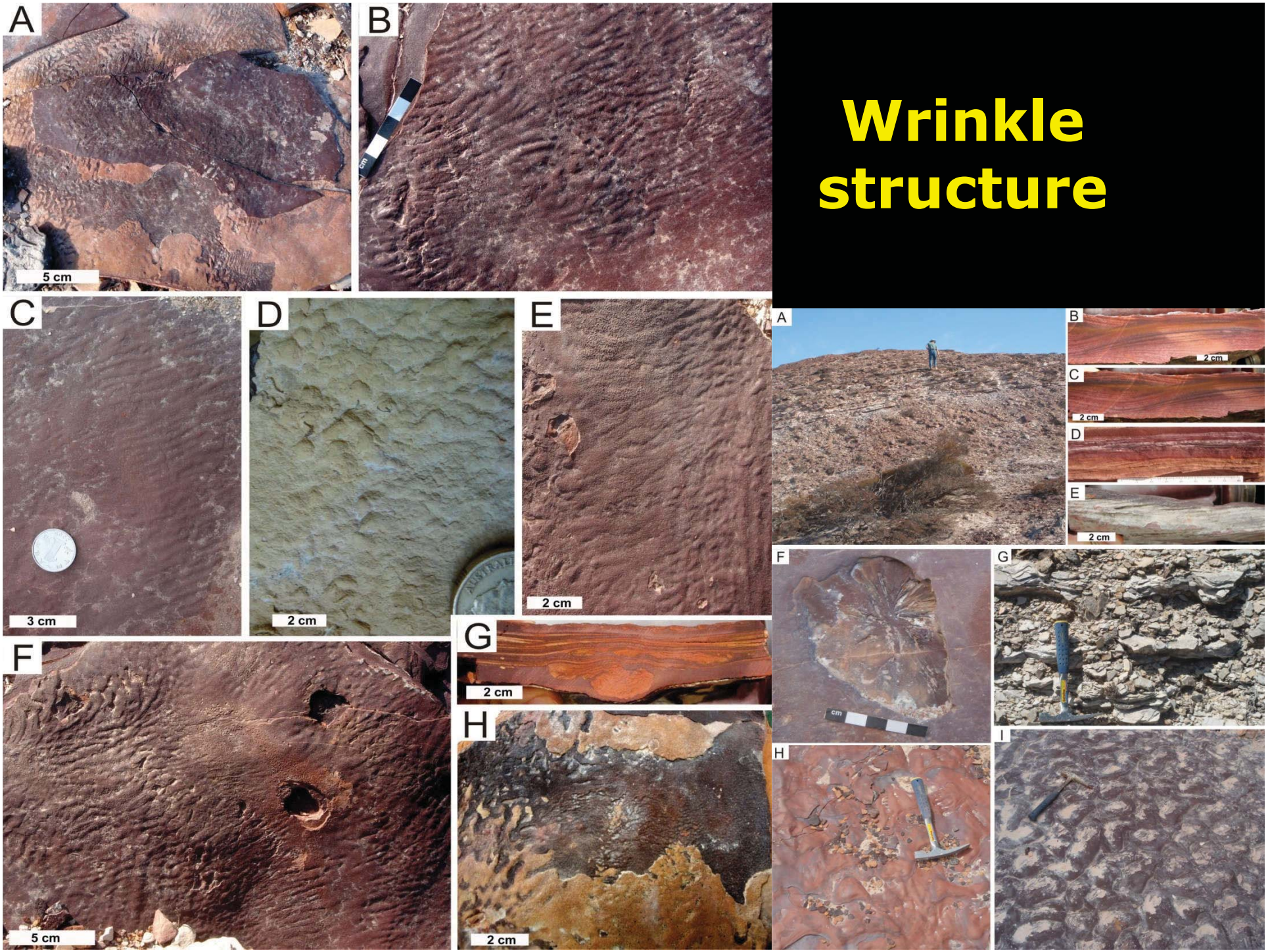




Smithan stromatolites

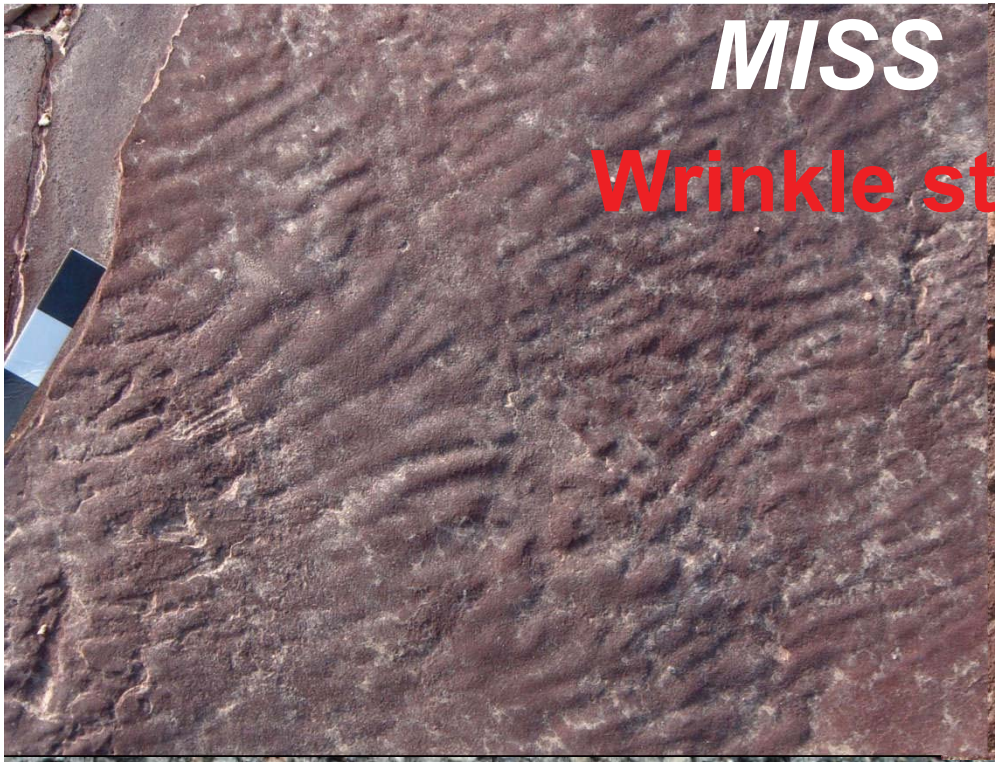

7/28/2007 9:48:12 AM | HFW 0.14 mm | WD 11.6 mm | Mag 1000x | Det ETD | HV 20.0 kV | Spot 3.5 | 20.0µm
7/28/2007 10:41:00 AM | HFW 0.17 mm | WD 11.3 mm | Mag 800x | Det ETD | HV 20.0 kV | Spot 3.5 | 50.0µm
7/28/2007 10:31:32 AM | HFW 13.52 µm | WD 11.1 mm | Mag 10000x | Det ETD | HV 20.0 kV | Spot 3.5 | 2.0µm
Modern stromatolites
Lower Triassic stromatolites
HFW 0.11 mm | WD 11.2 mm | Mag 1200x | Det ETD | HV 20.0 kV | Spot 3.5 | 20.0µm

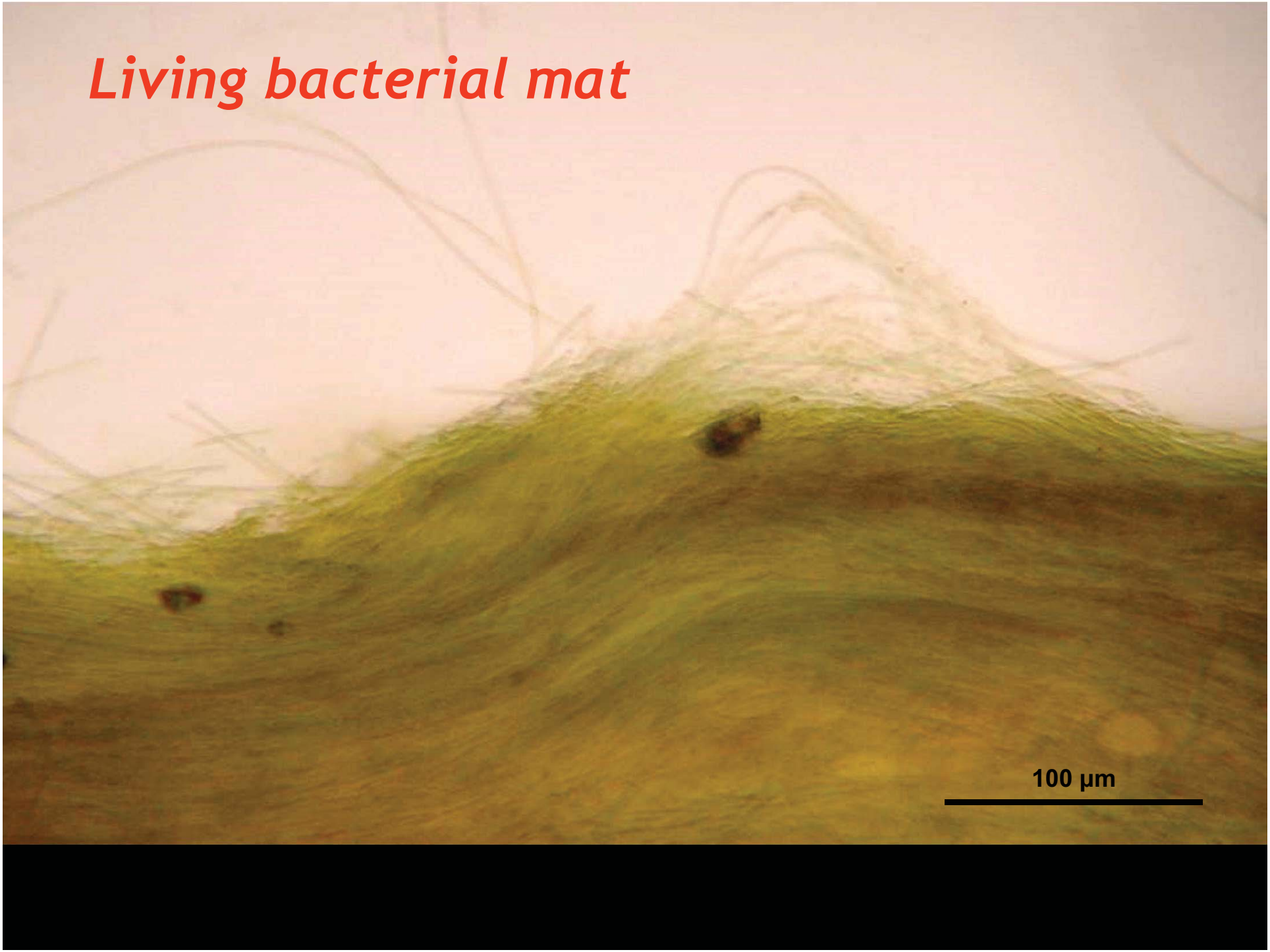
Wrinkle structure

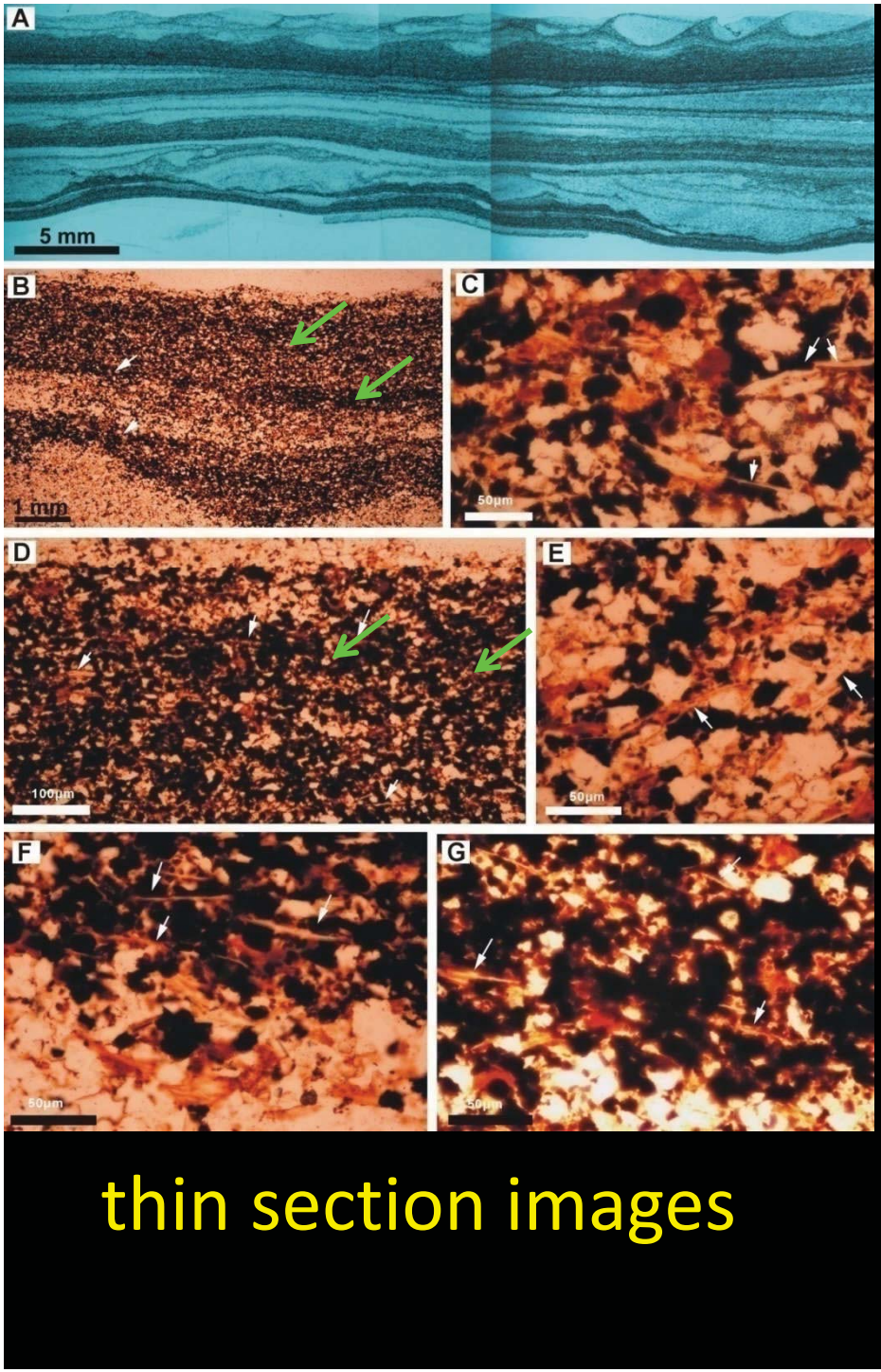


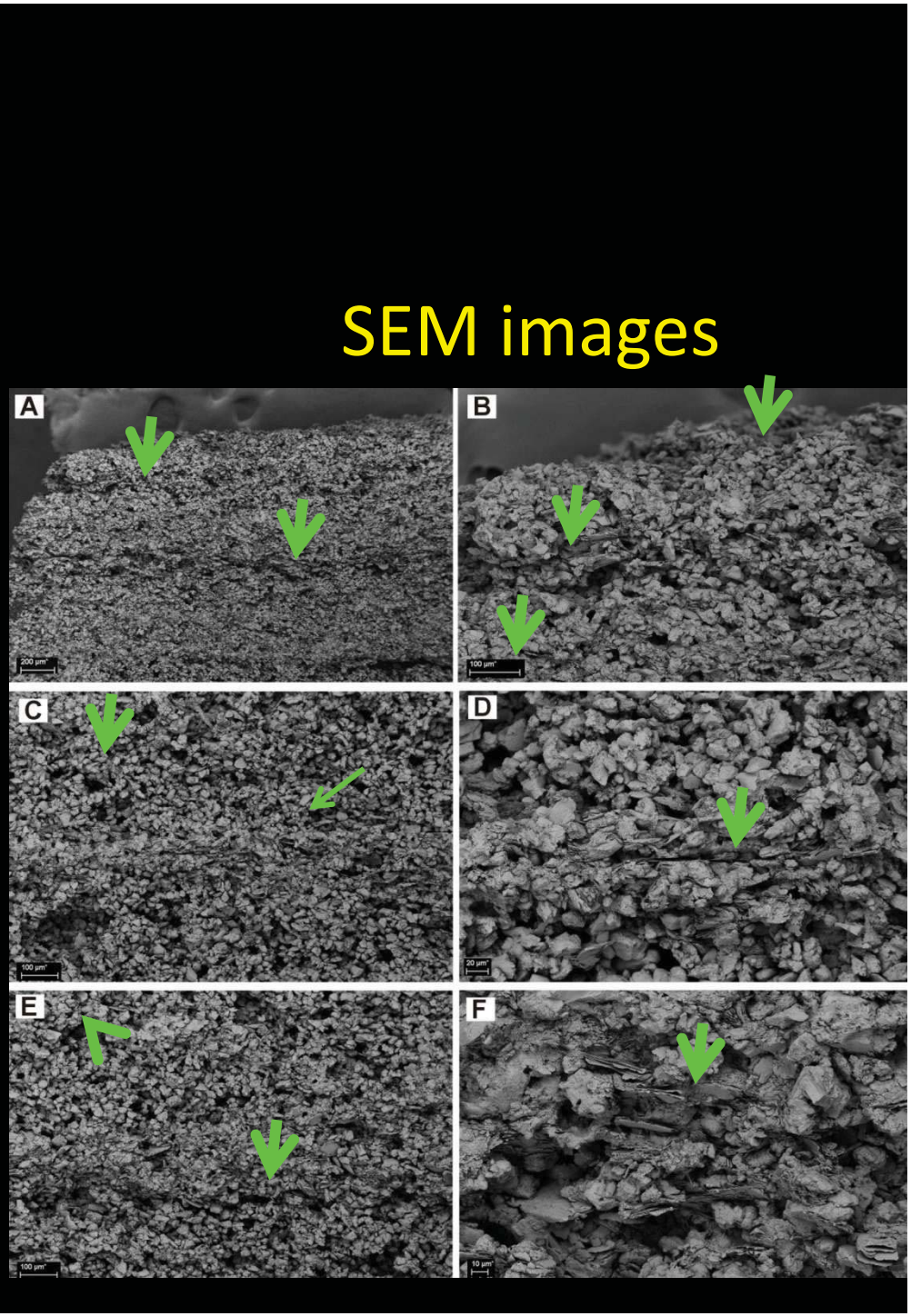
MISS

Wrinkle structures

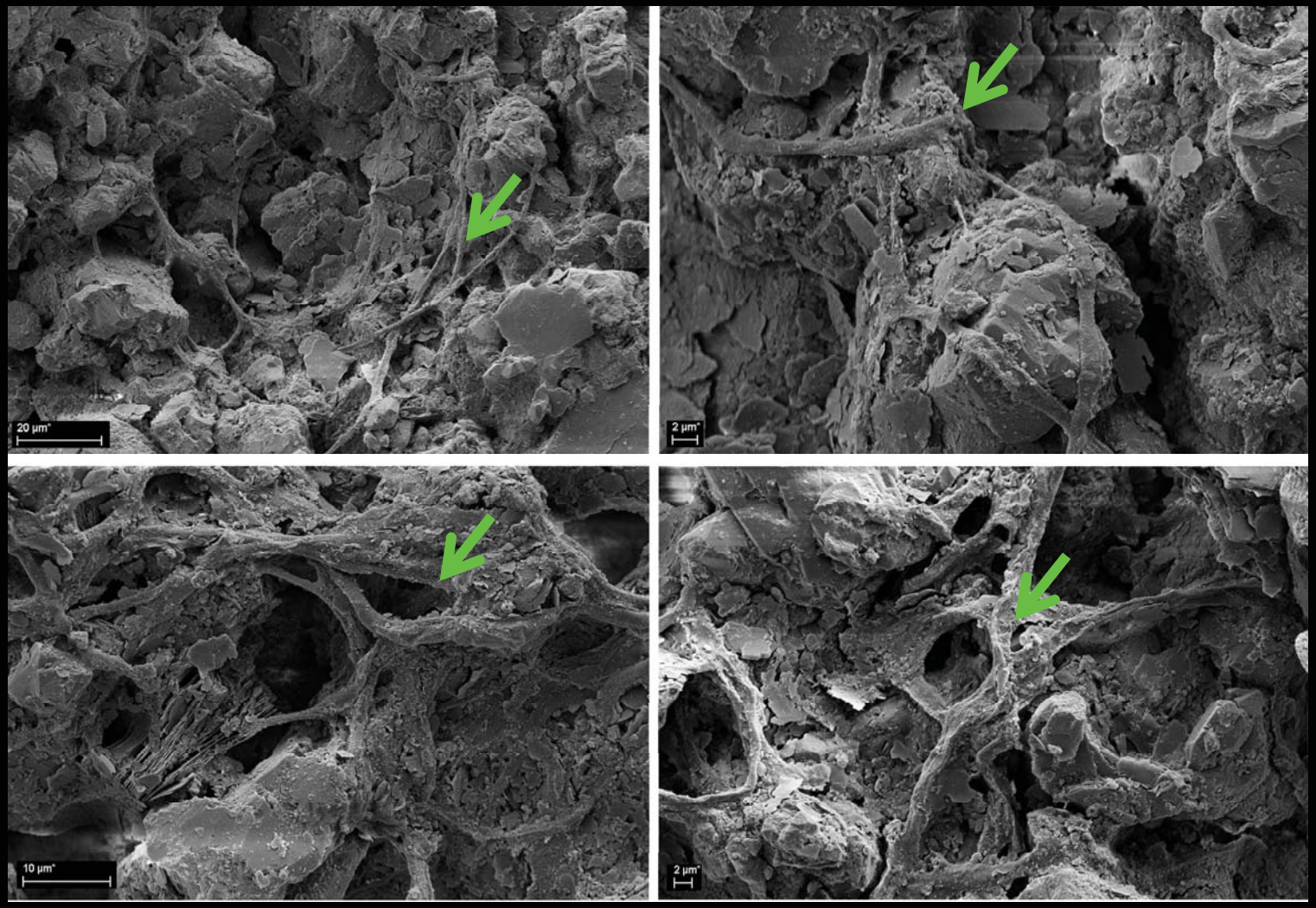



Living bacterial mat
100 µm

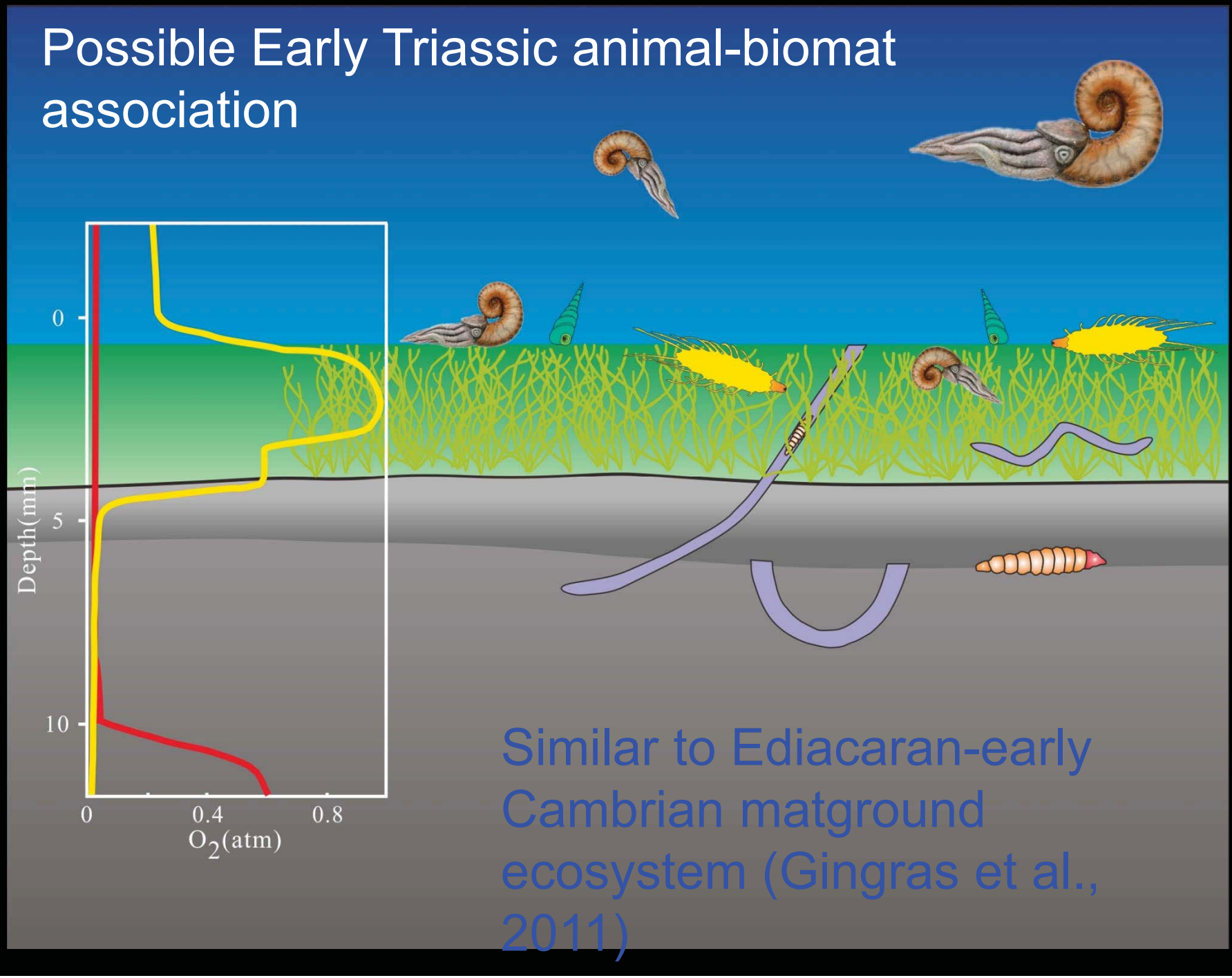

A
5 mm
B
1 mm
C
50µm
D
100µm
E
50µm
F
50µm
G
thin section images


SEM images
A
B
C
D
E
F

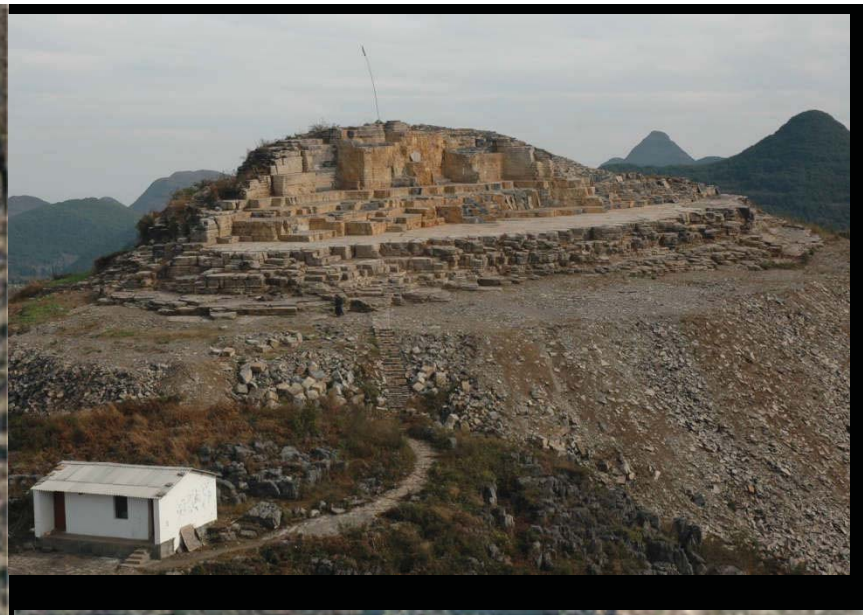
SEM images



Possible Early Triassic animal-biomat association



Similar to Ediacaran-early Cambrian matground ecosystem (Gingras et al., 2011)

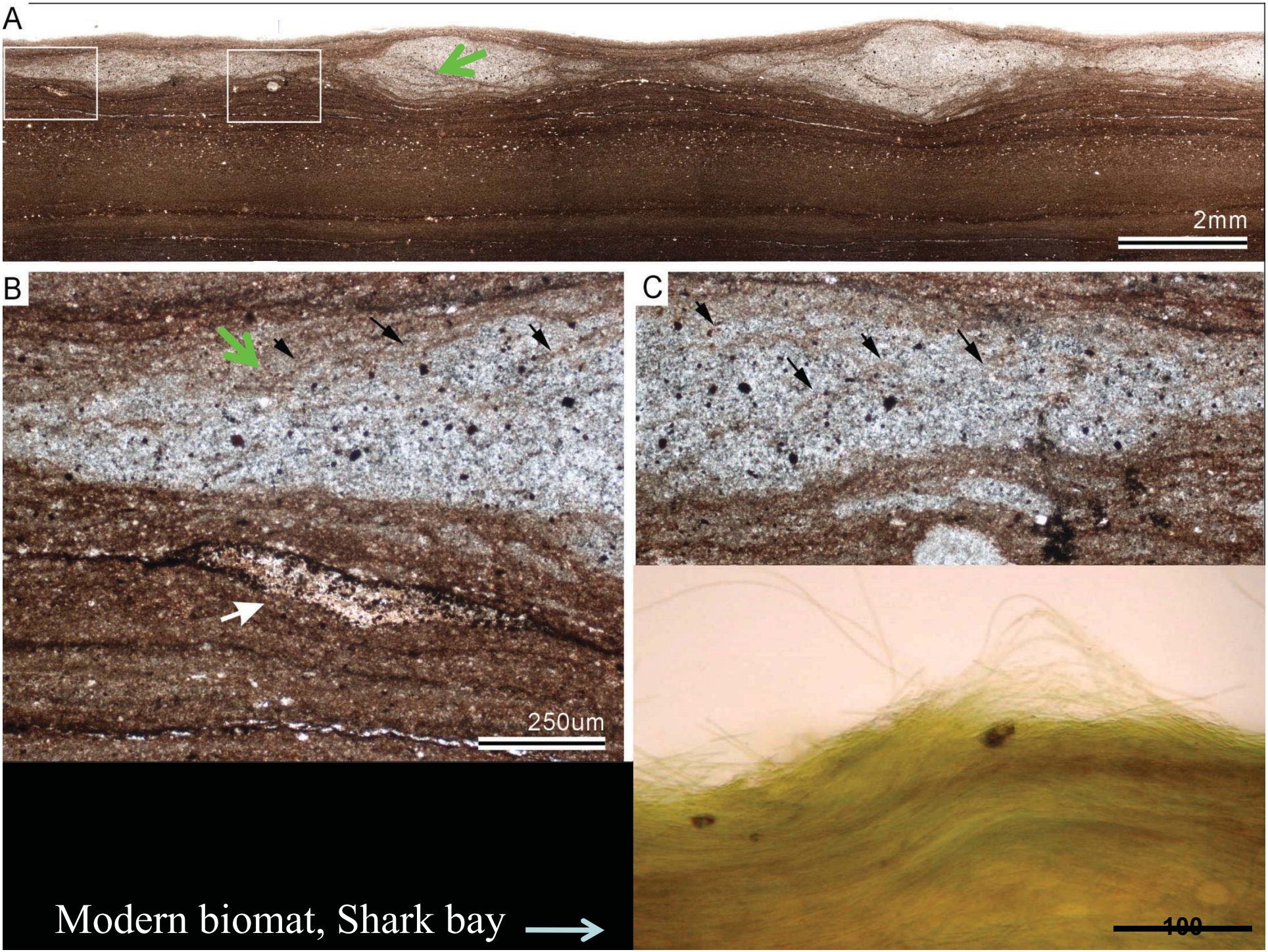


Microbial mats

Luoping biota

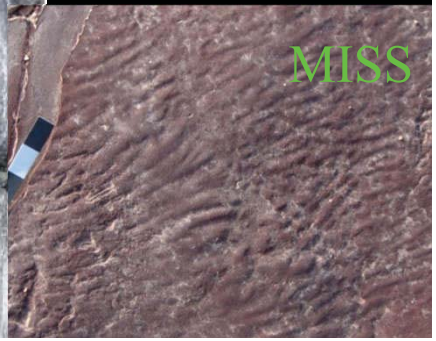
(Mid-late Anisian)

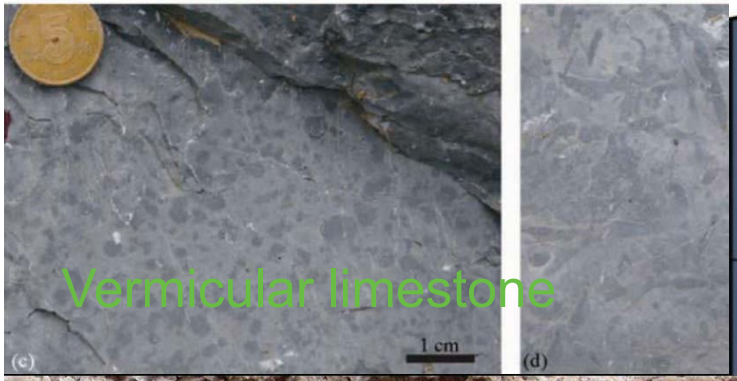
Luoping county, Yunnan Province

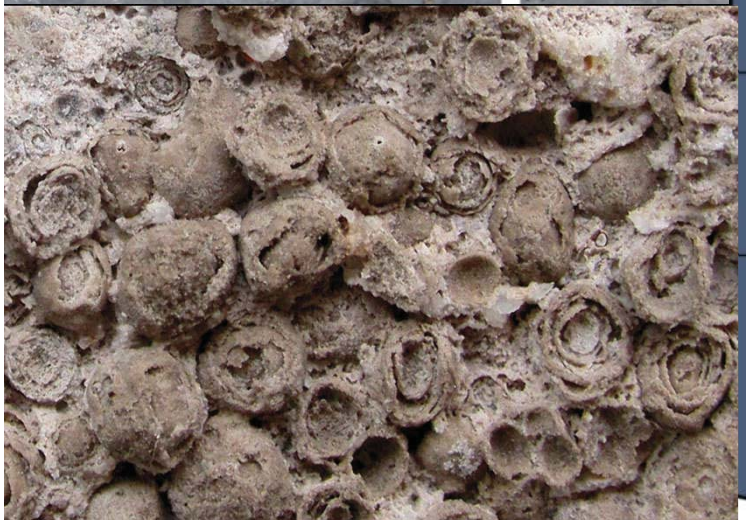

A
2mm
B
250um
C
Modern biomat, Shark bay
100

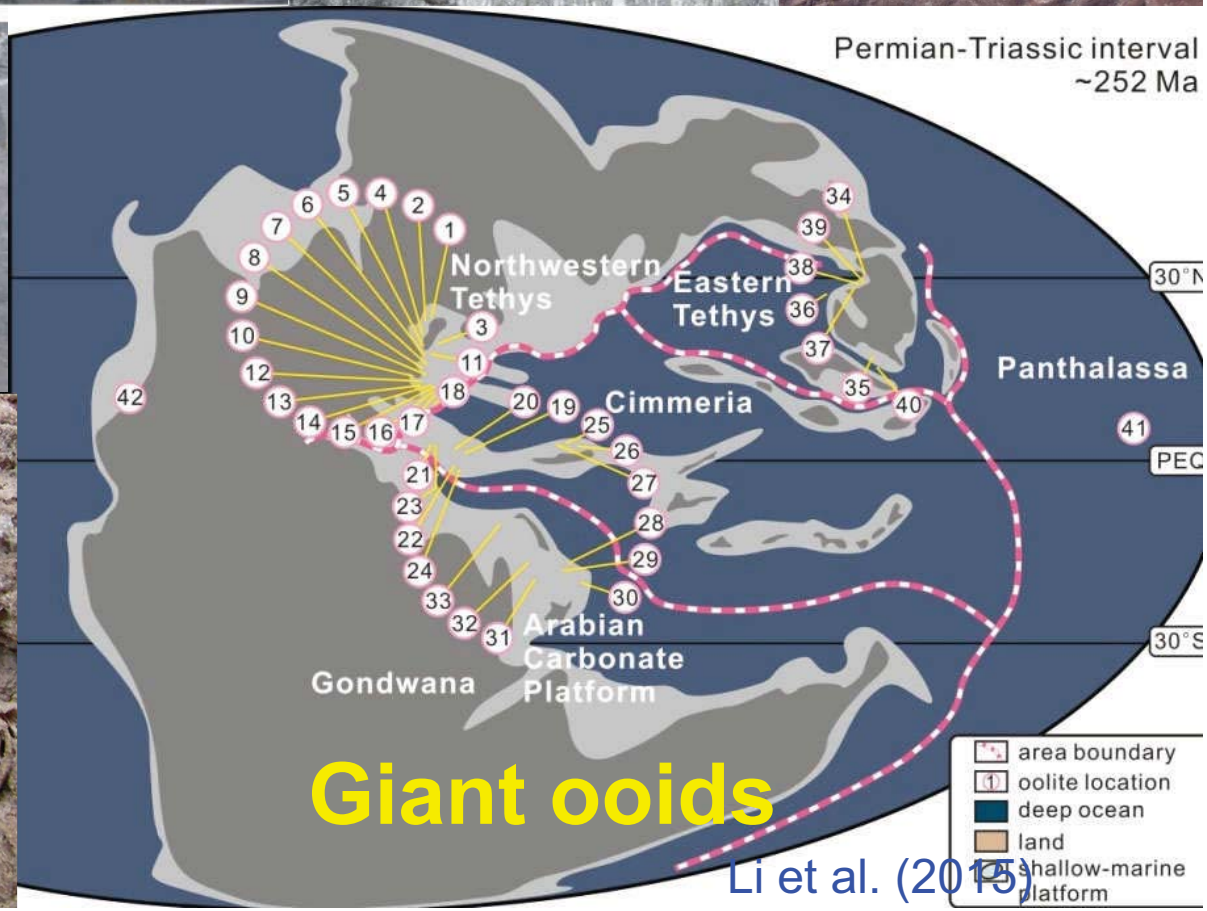
Microbially induced sedimentary products:

Anachronistic facies

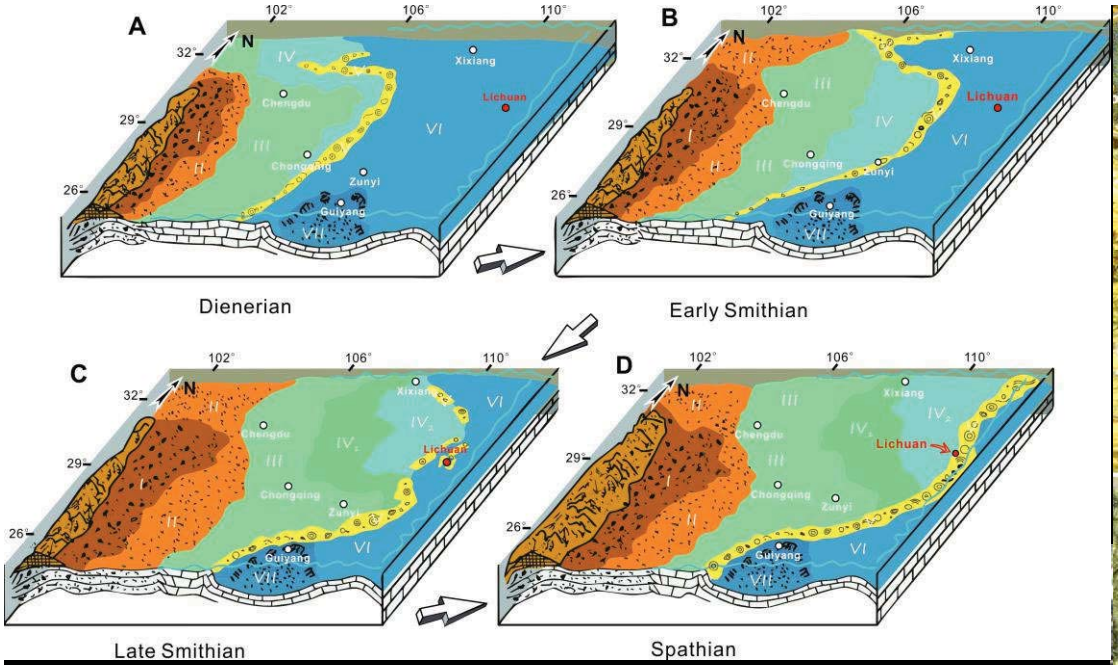




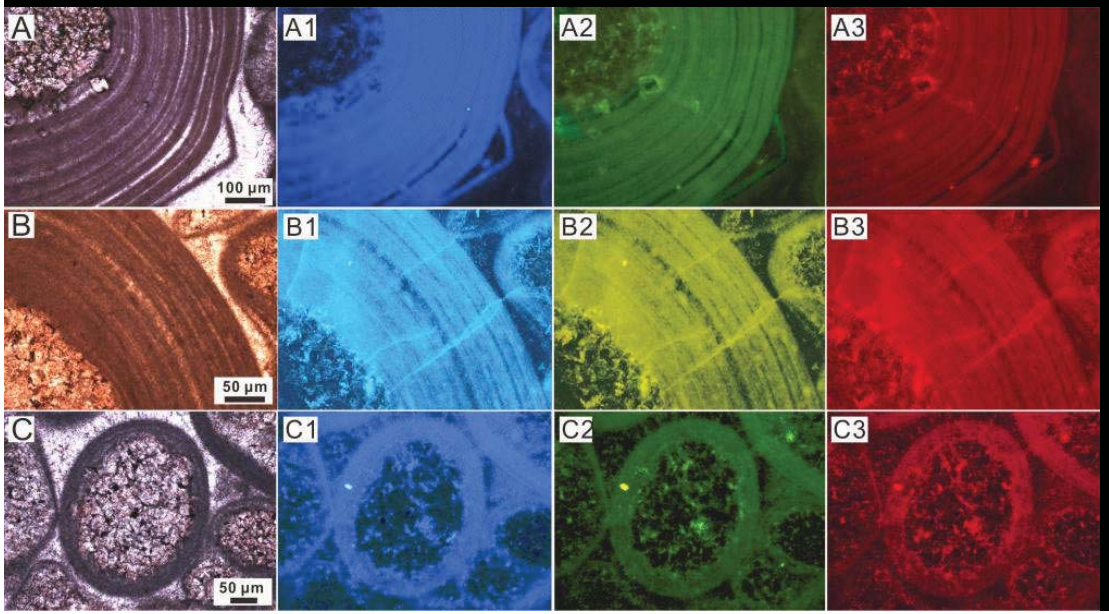


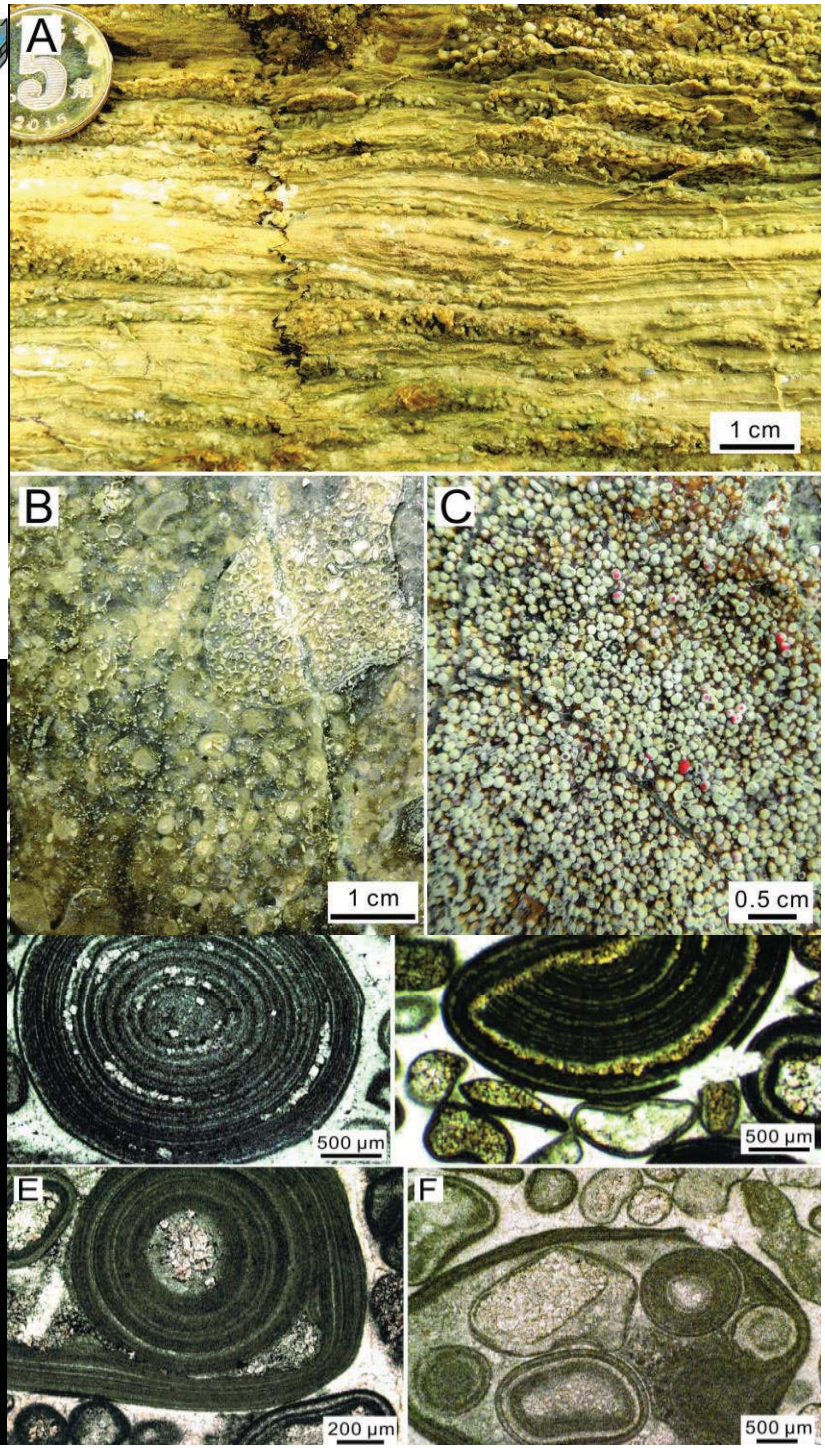


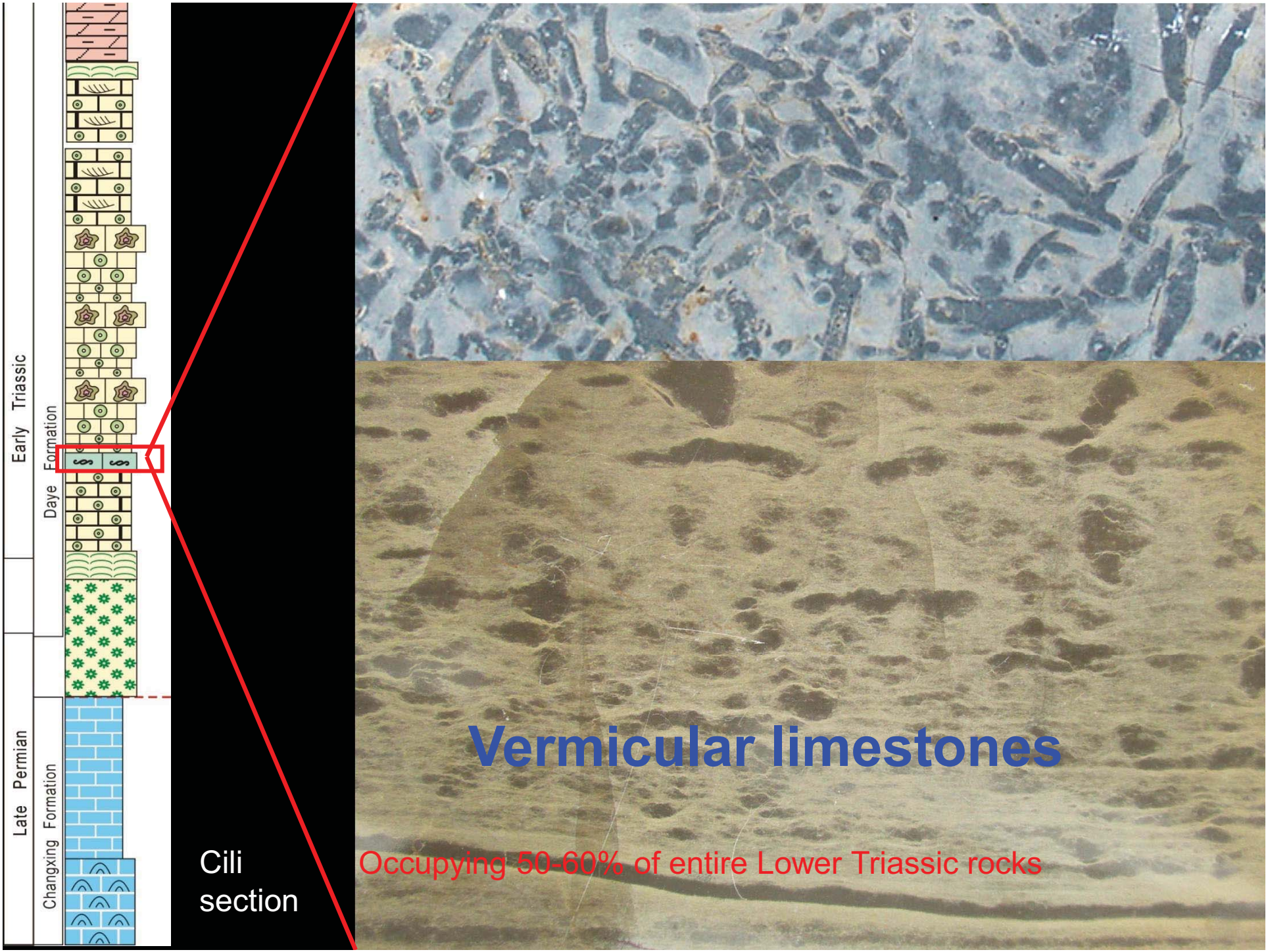
Li et al. (2015)



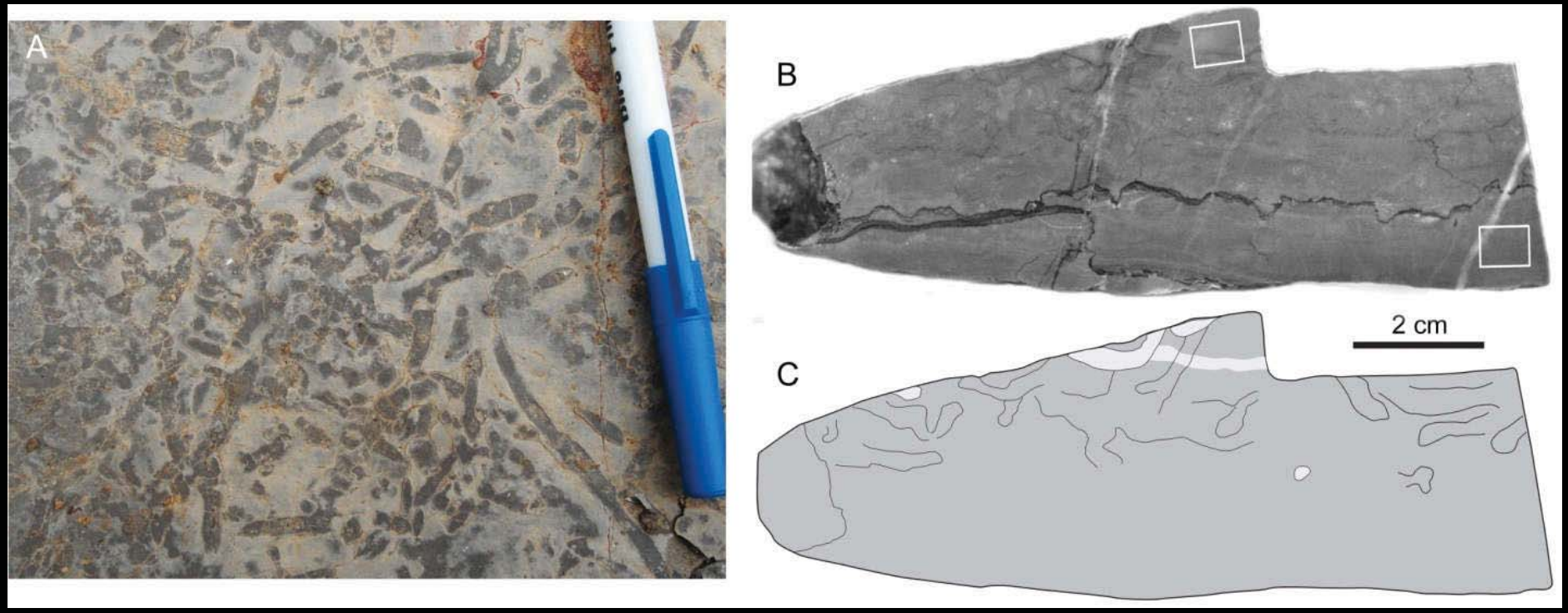
Giant ooids: biogenicity



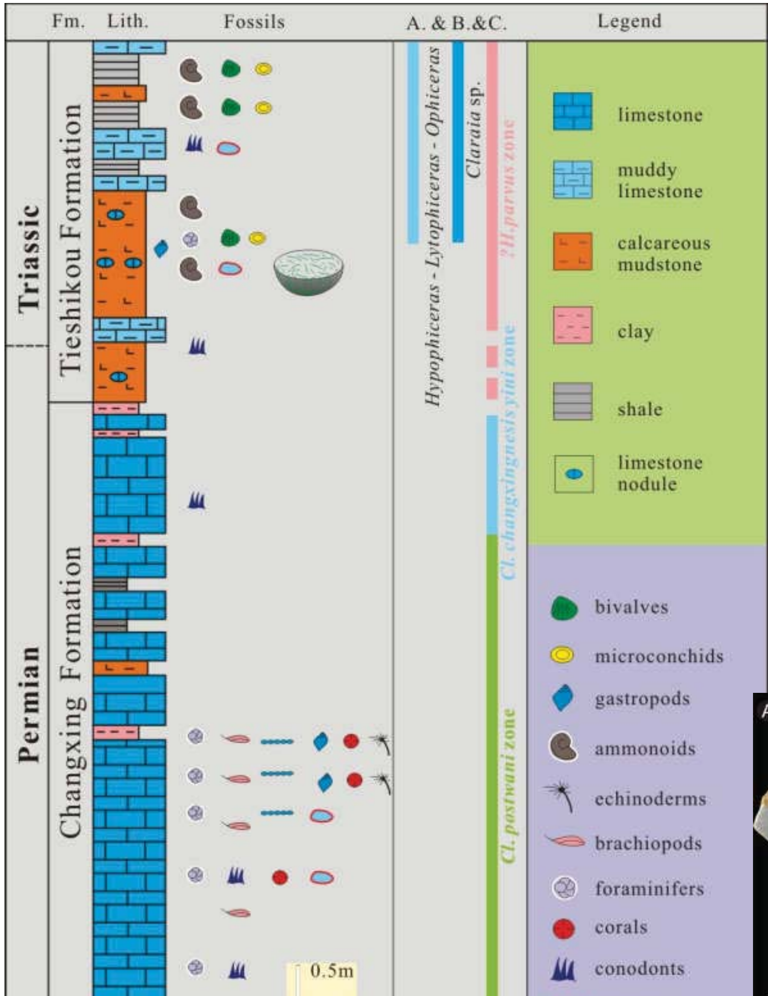



Early Triassic
Daye Formation
Late Permian
Changxing Formation
Cili section
Vermicular limestones
Occupying 50-60% of entire Lower Triassic rocks

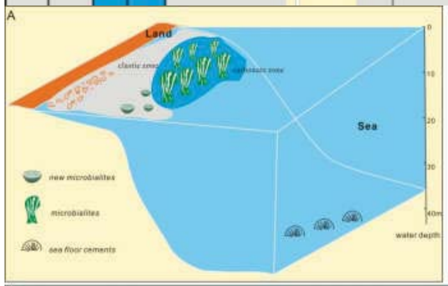
Vermicular limestone

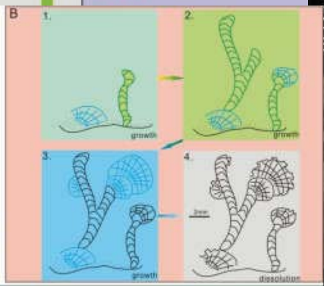


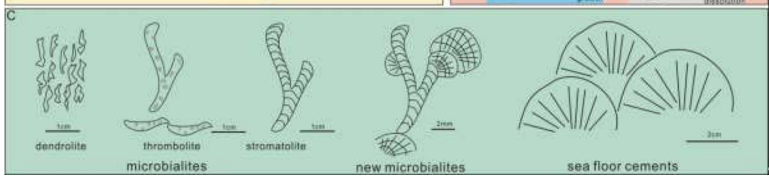
Very common in the Lower Triassic (occupying 50-60% of entire succession)

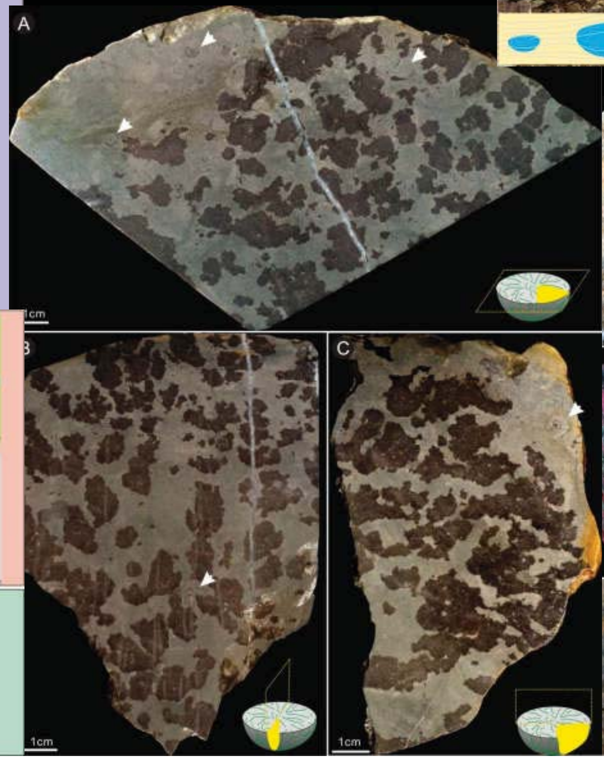


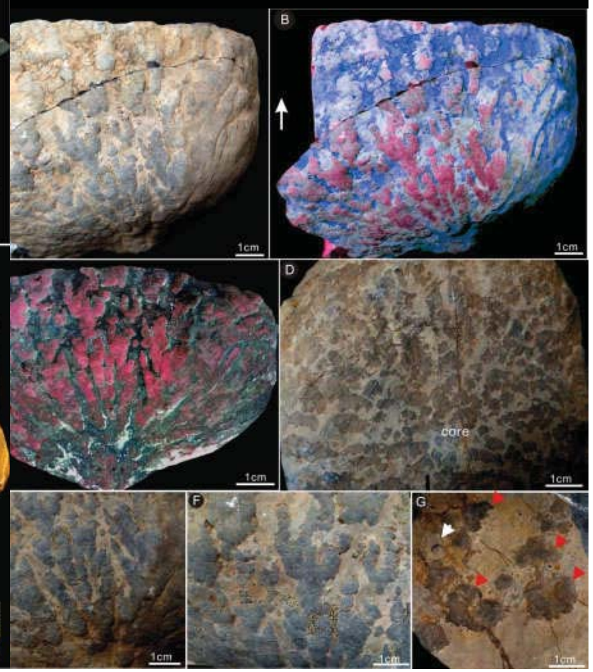
PTB nodules Tieshikou section



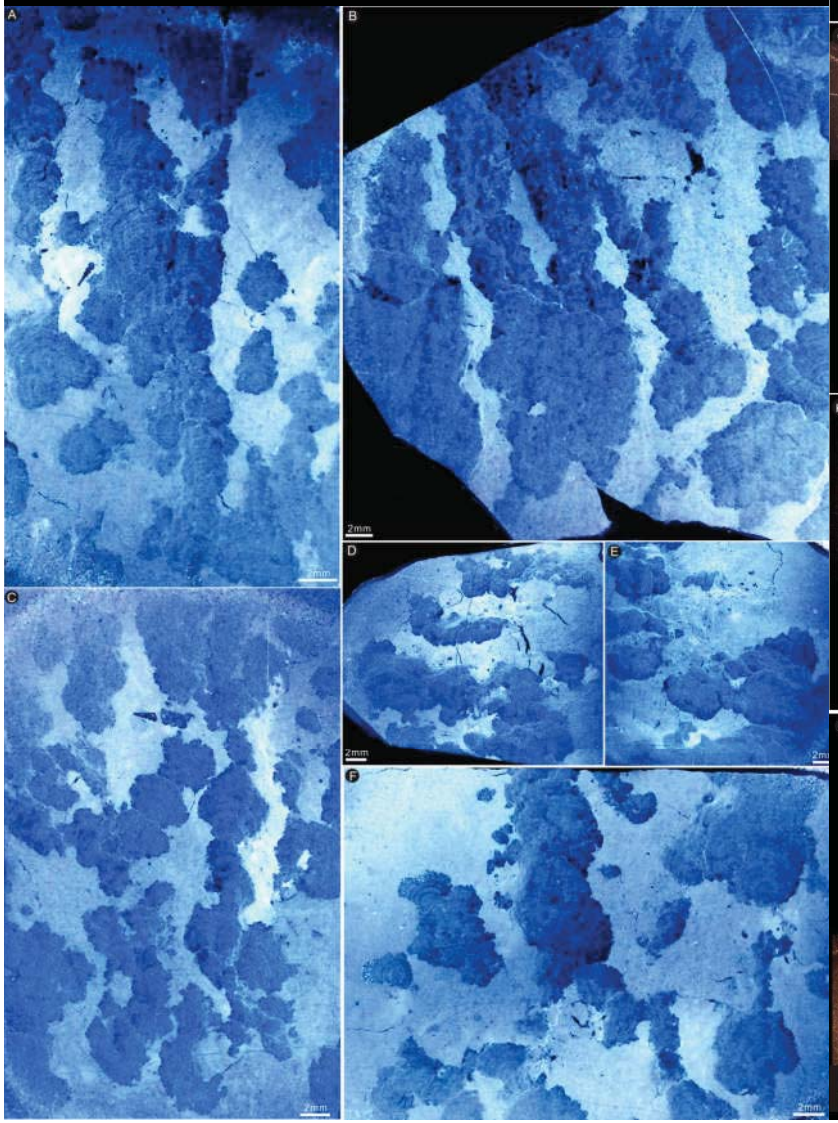


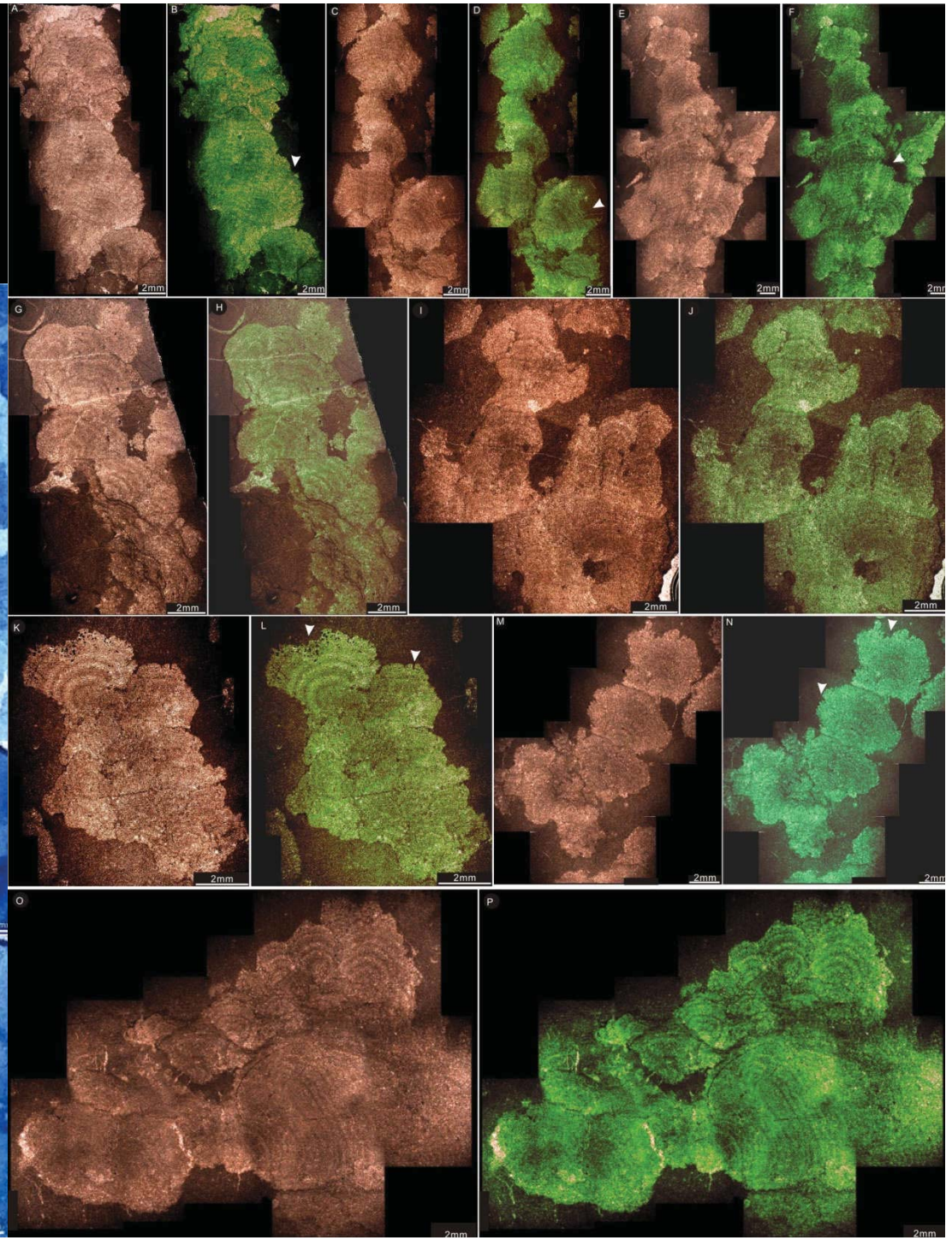


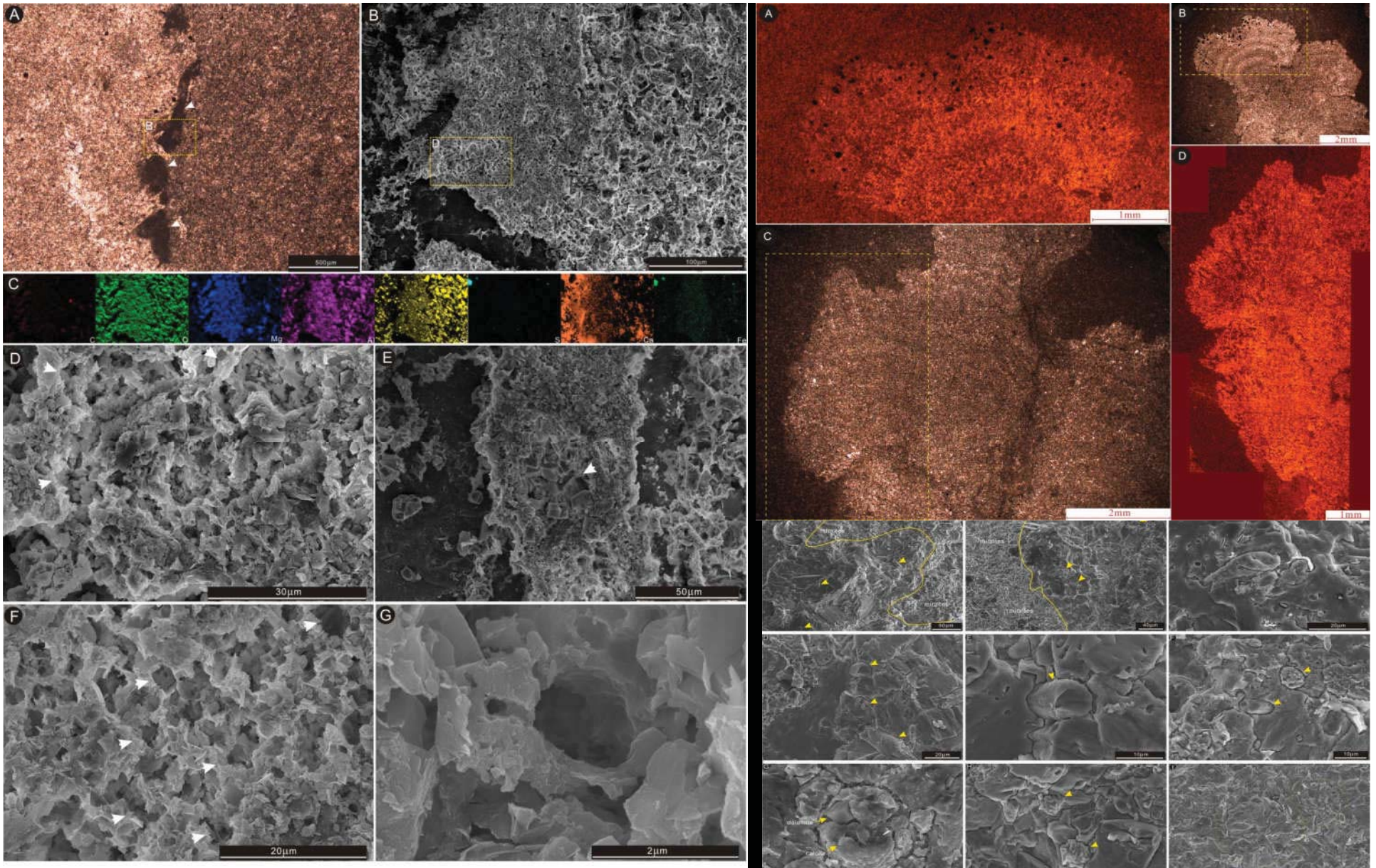




PTB nodules
Tieshikou section



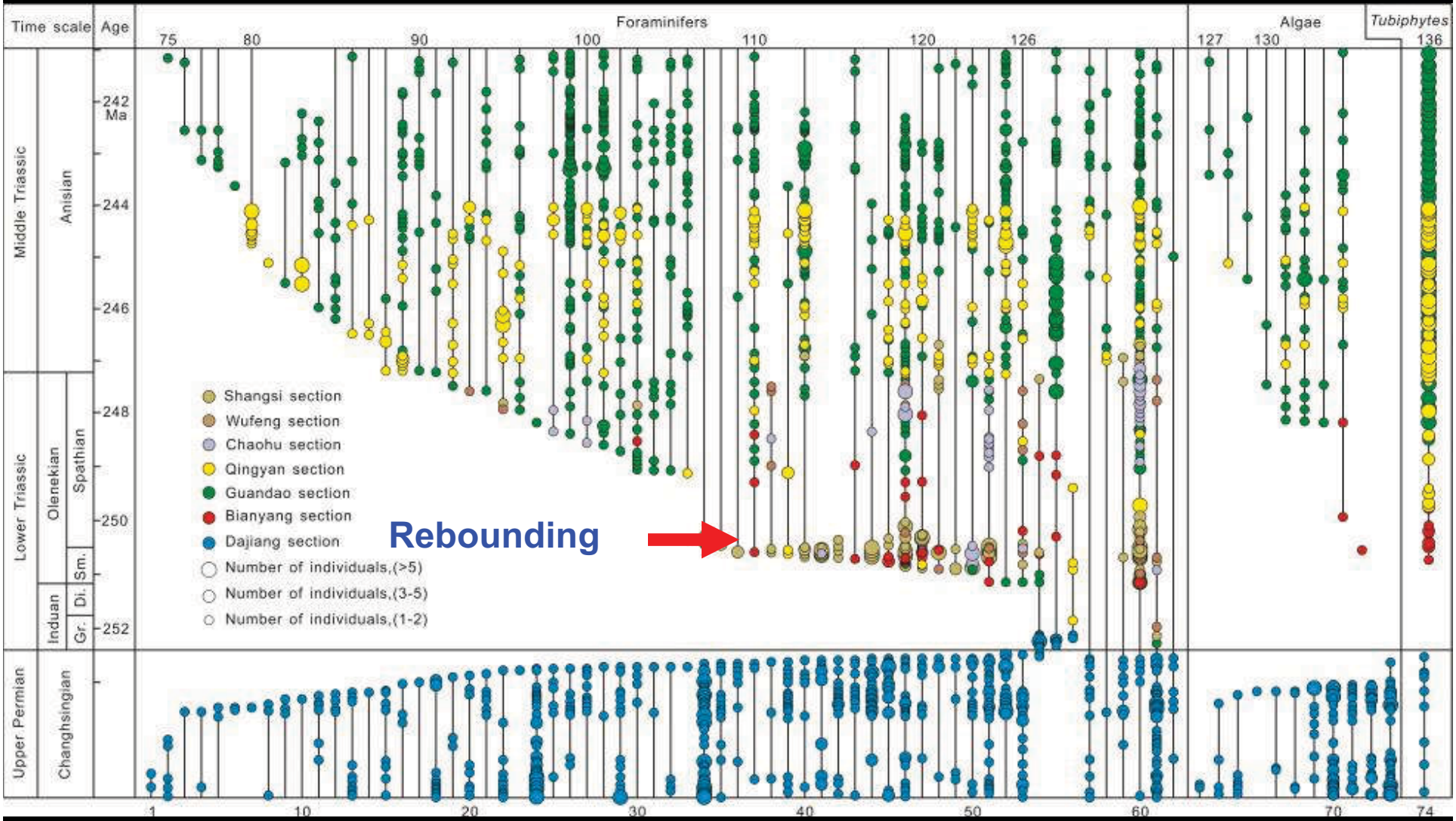




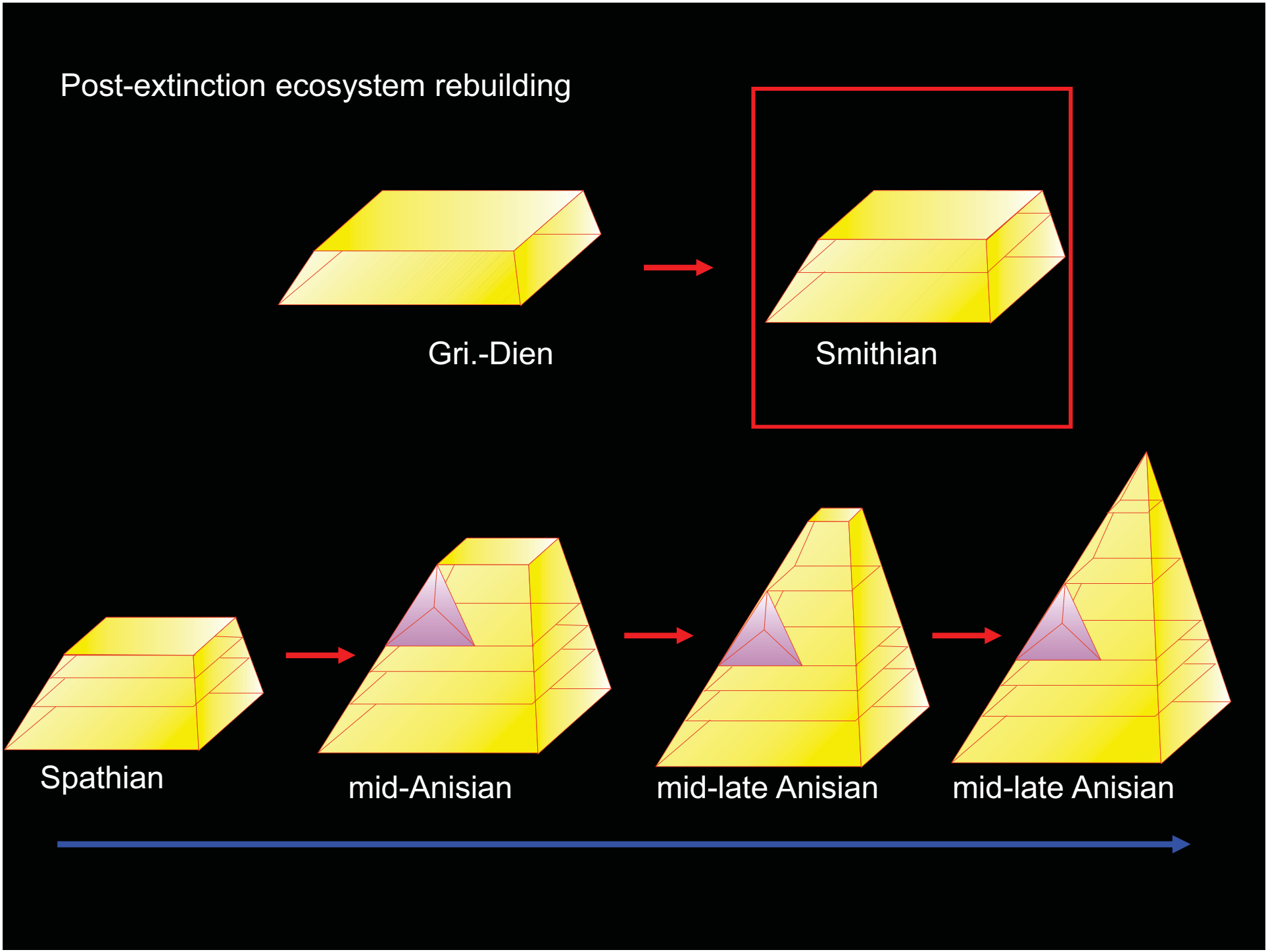
PTB nodules
Tieshikou section

Extinction-Survival-Recovery

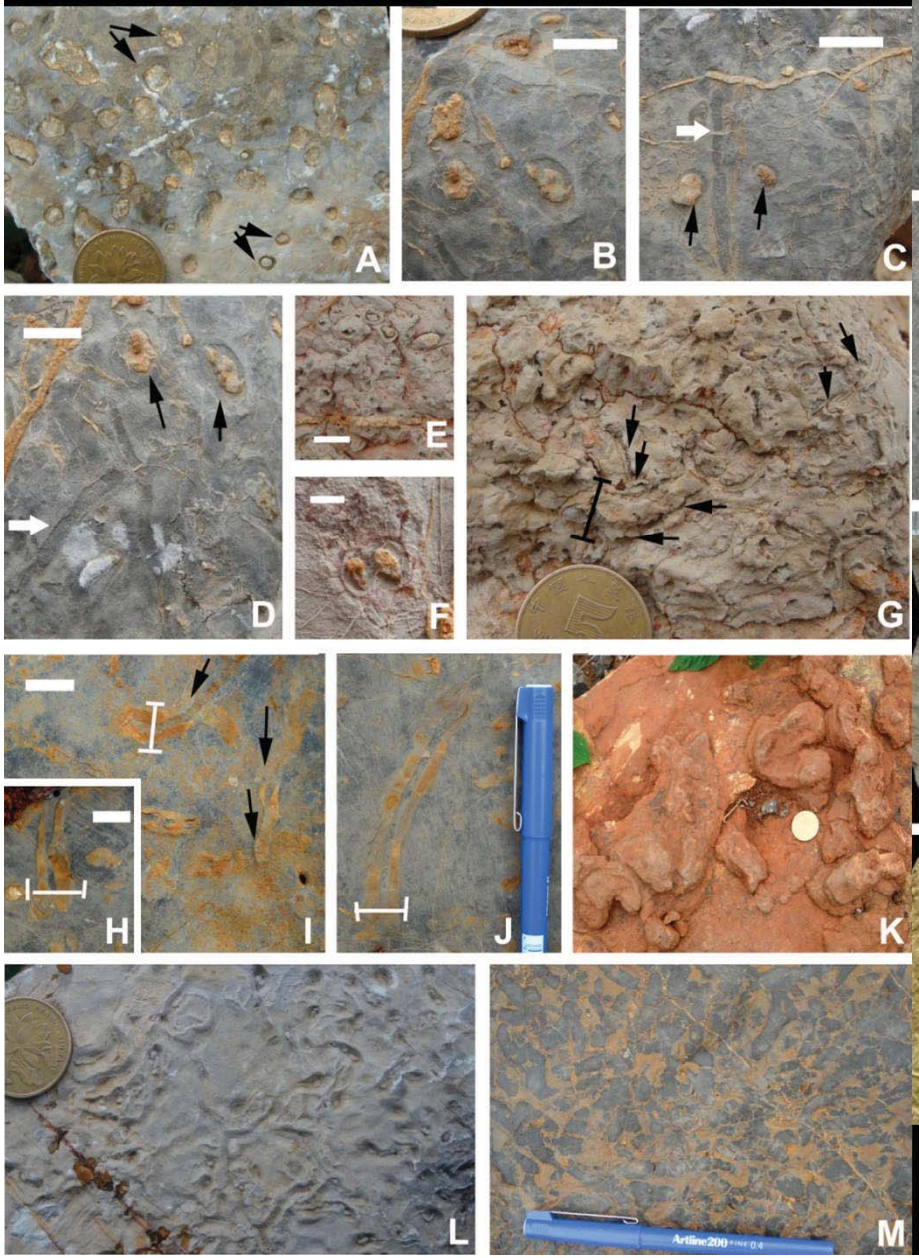
Biotic distributions during P-Tr transition in Nanpanjiang, SW China

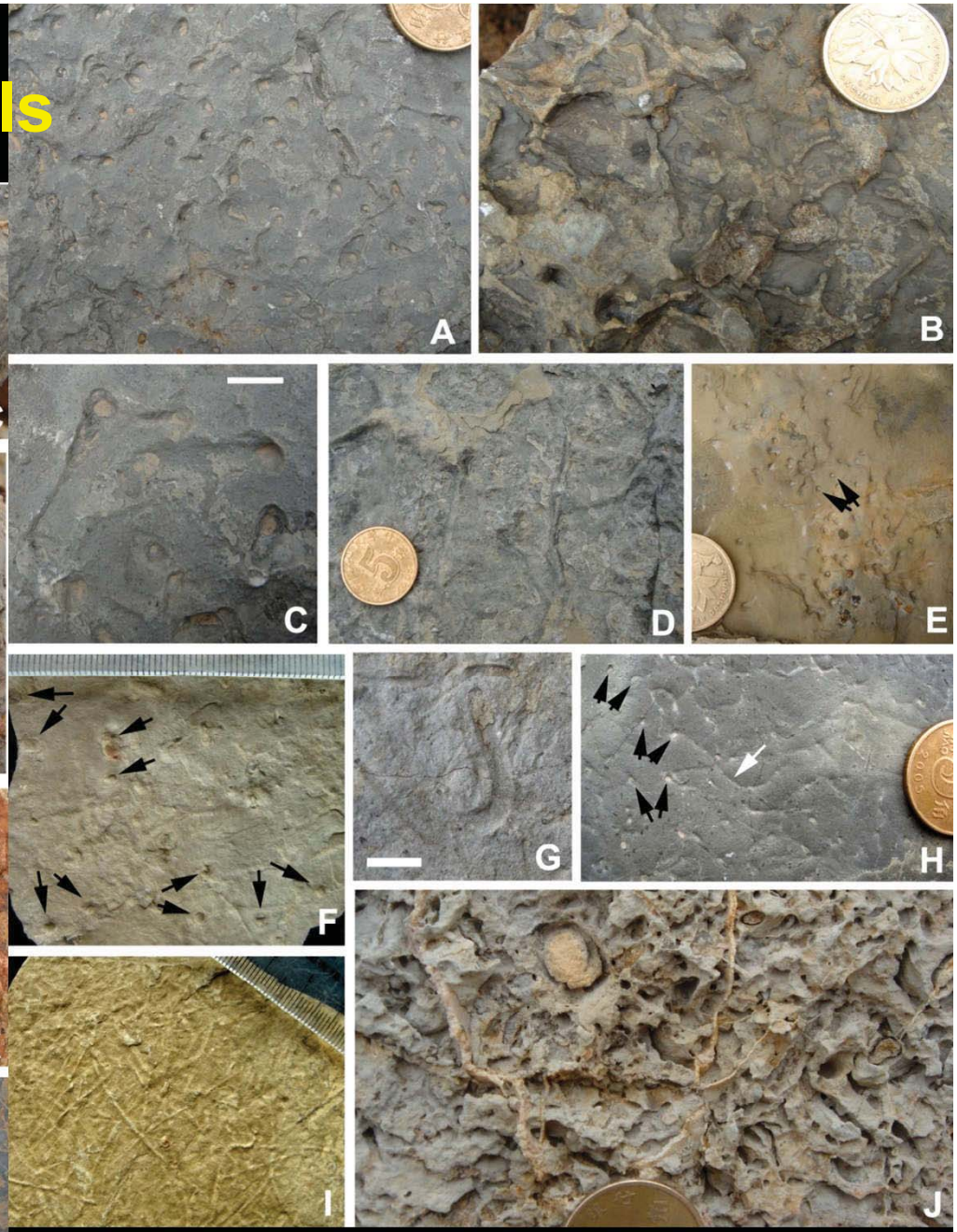


Song et al. (2011)


Post-extinction ecosystem rebuilding
Gri.-Dien
Smithian
Spathian
mid-Anisian
mid-late Anisian
mid-late Anisian

Early Triassic trace fossils



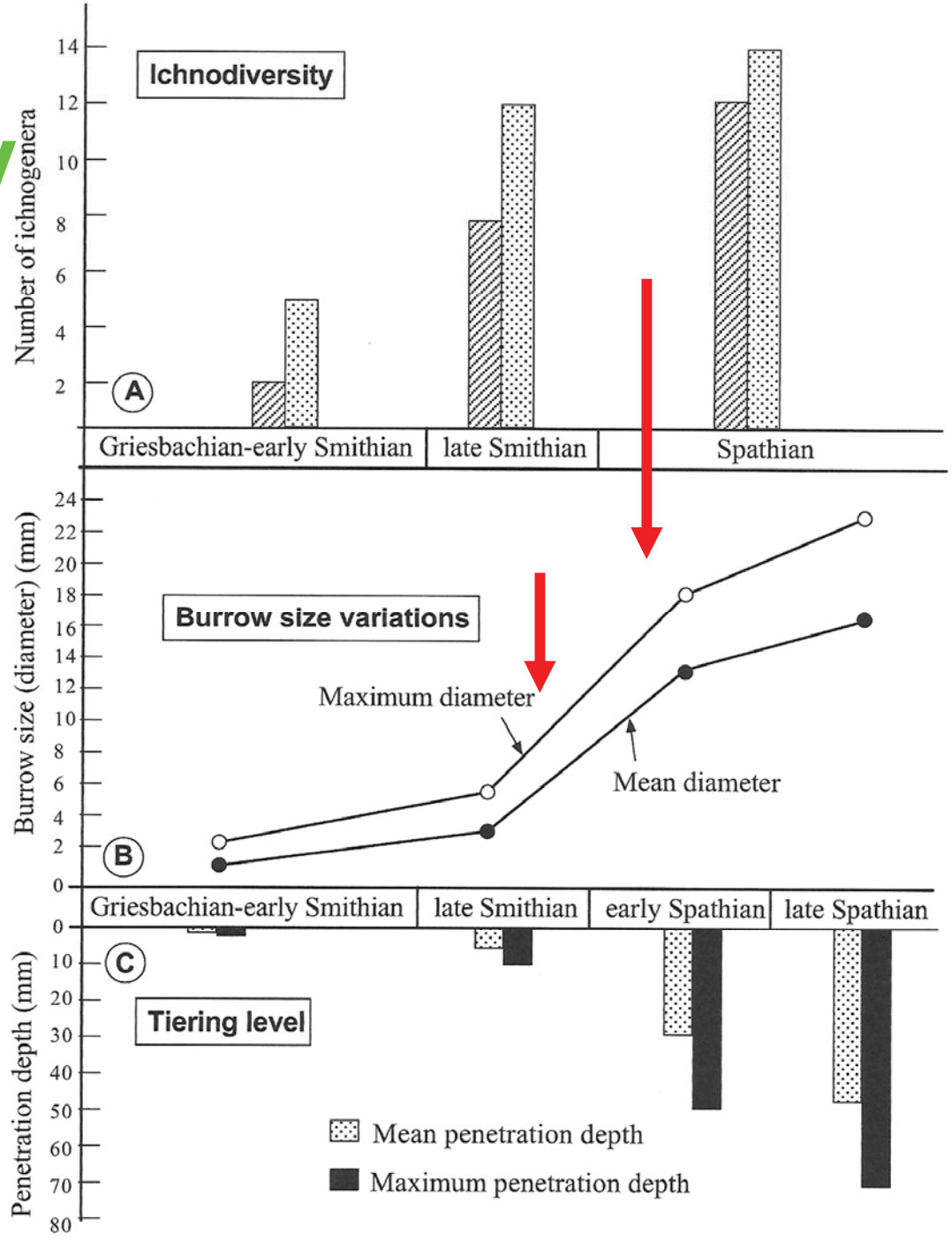


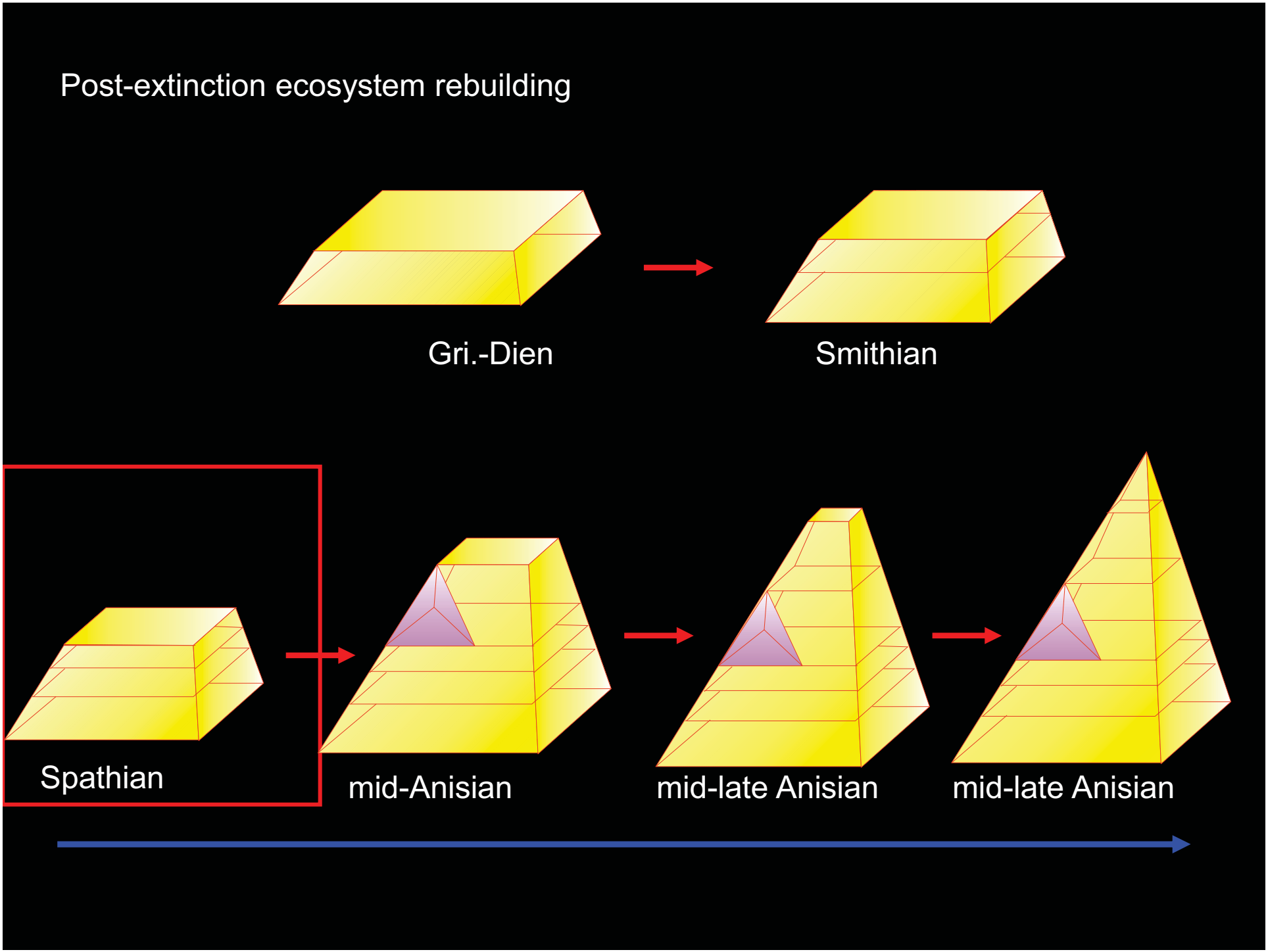
Chen et al. (2011)

Trace-making faunal recovery

South China

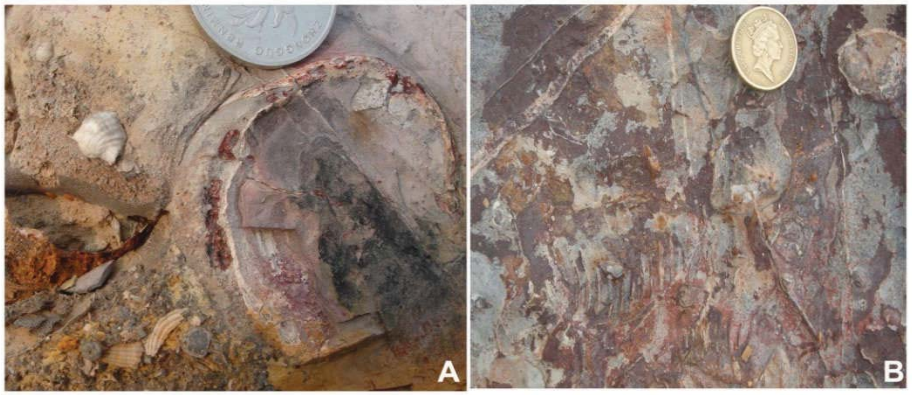
Spathian, Yunan, SW China



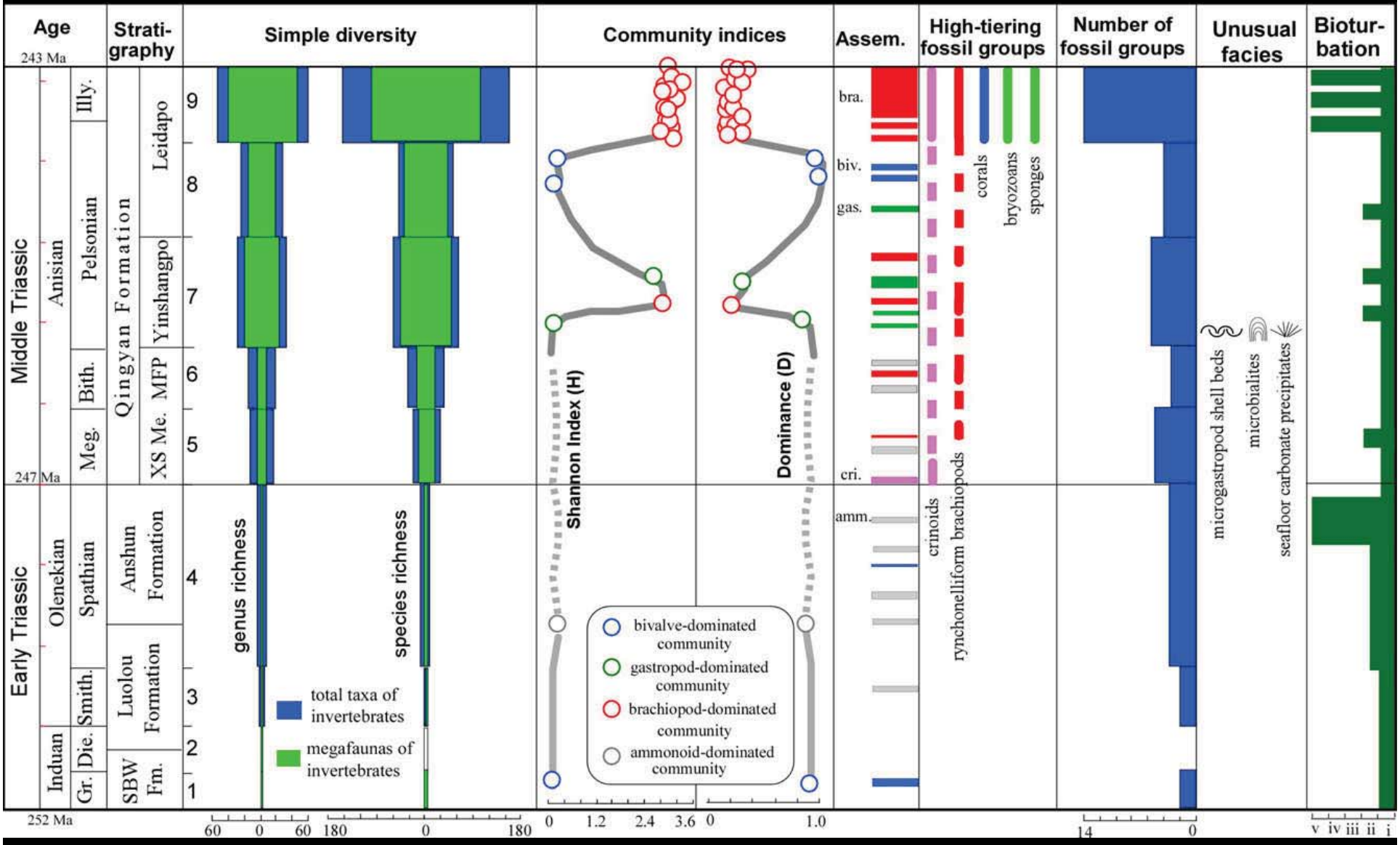

Post-extinction ecosystem rebuilding
Gri.-Dien
Smithian
Spathian
mid-Anisian
mid-late Anisian
mid-late Anisian

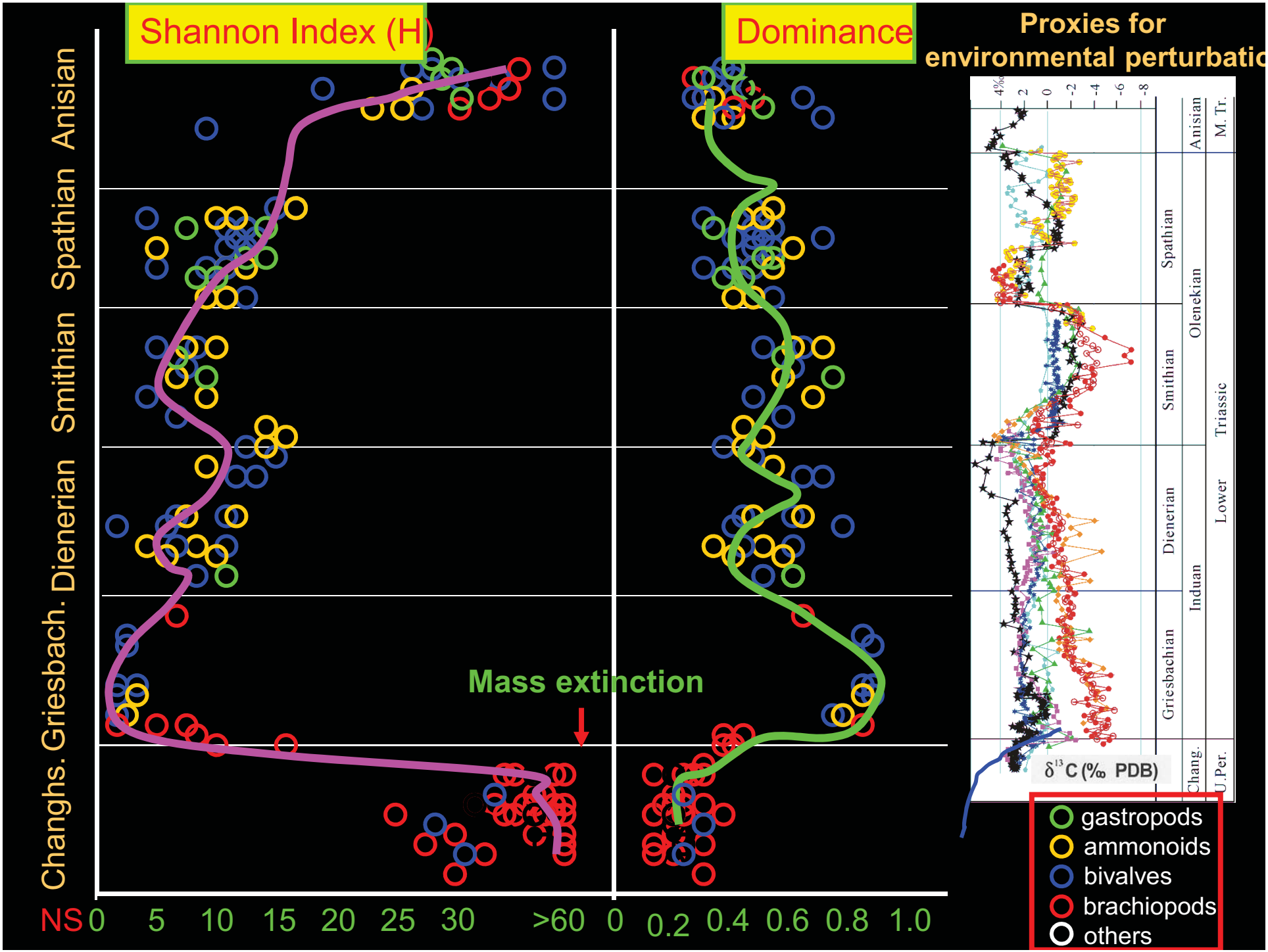
Marine community

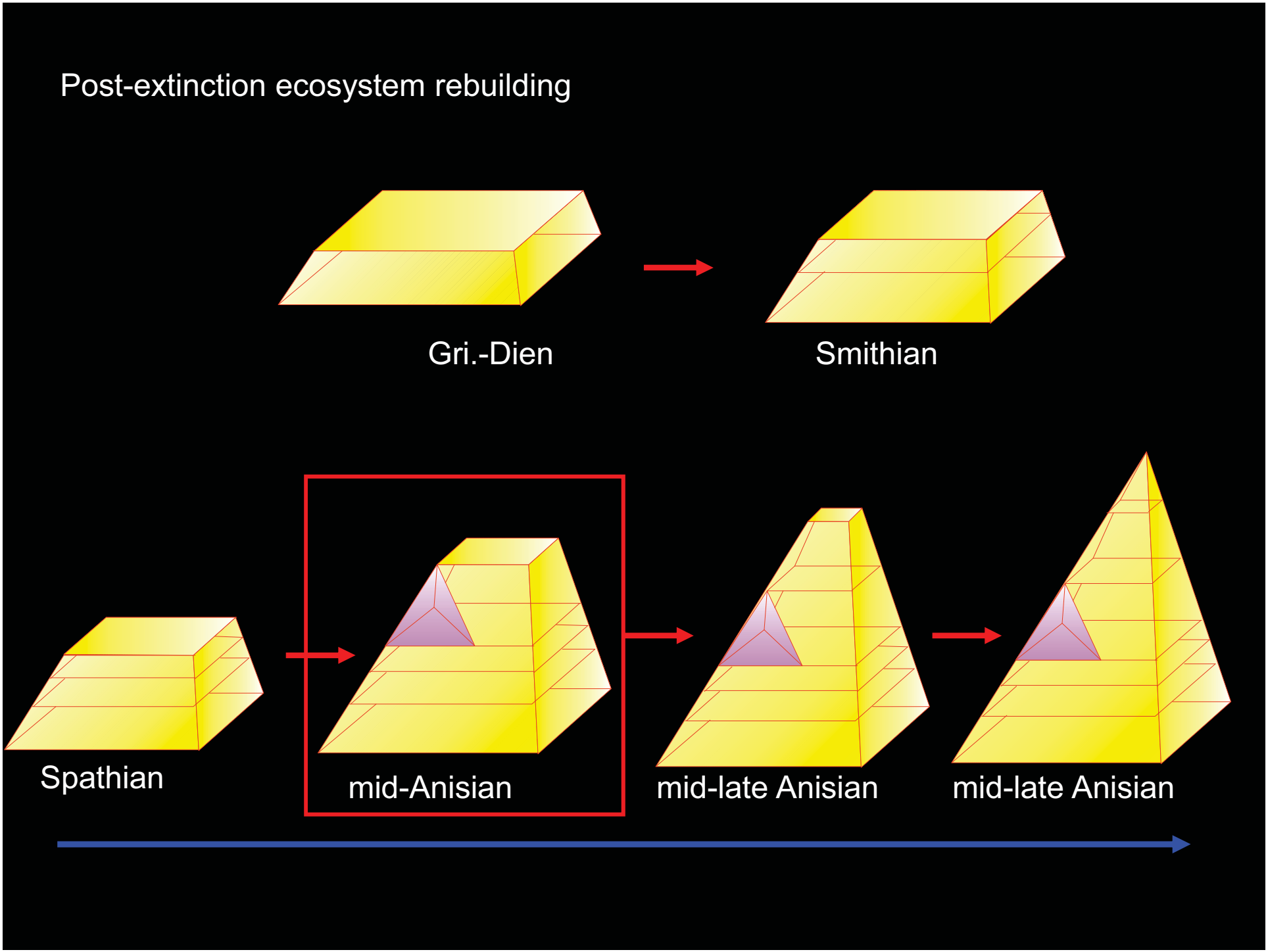
End-Permian



Biodiversity, community structural changes and other ecologic assessment through Early-Middle Triassic




Shannon Index (H)
Dominance
Proxies for environmental perturbatio
Mass extinction
Changhs.
Griesbach.
Dienerian
Smithian
Spathian
Anisian
NS
0
5
10
15
20
25
30
>60
0
0.2
0.4
0.6
0.8
1.0
4‰
2
0
-2
-4
-6
-8
M. Tr.
Triassic
Lower
U.Per.
Chang.
Induan
Griesbachian
Dienerian
Smithian
Spathian
Olenekian
Anisian
δ13C (‰ PDB)
gastropods
ammonoids
bivalves
brachiopods
others


Post-extinction ecosystem rebuilding
Gri.-Dien
Smithian
Spathian
mid-Anisian
mid-late Anisian
mid-late Anisian

Predatory evidence

Anisian

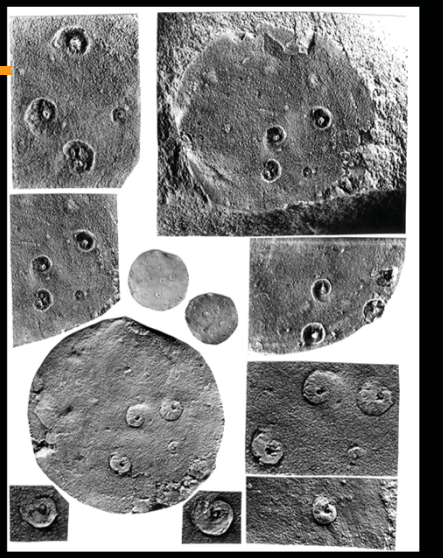
Isarcicella isarcica Zone

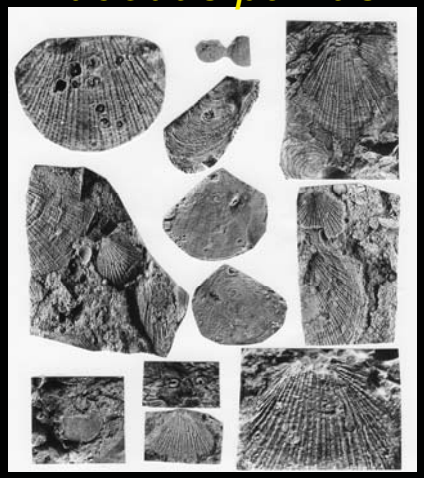
Tr

Grie.-Anisian

Hindeodus parvus Zone

4





3

End-Permian

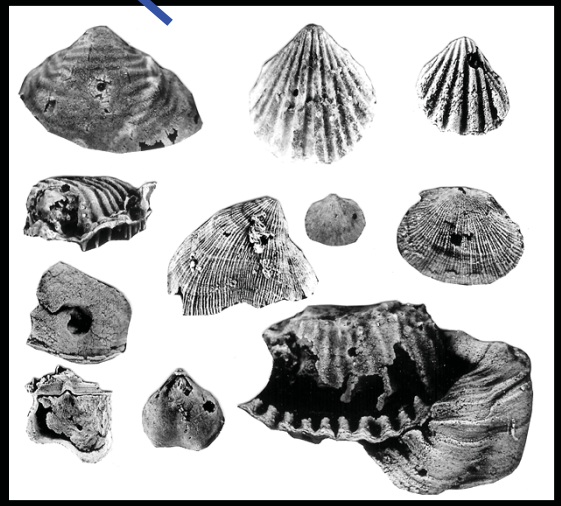
Mass Extinction

P

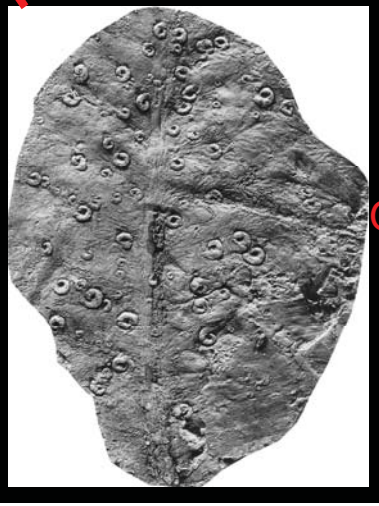
Changhsingian

Meishan, Zhejiang

Huangzhishan, Zhejiang



Late Changhsingian



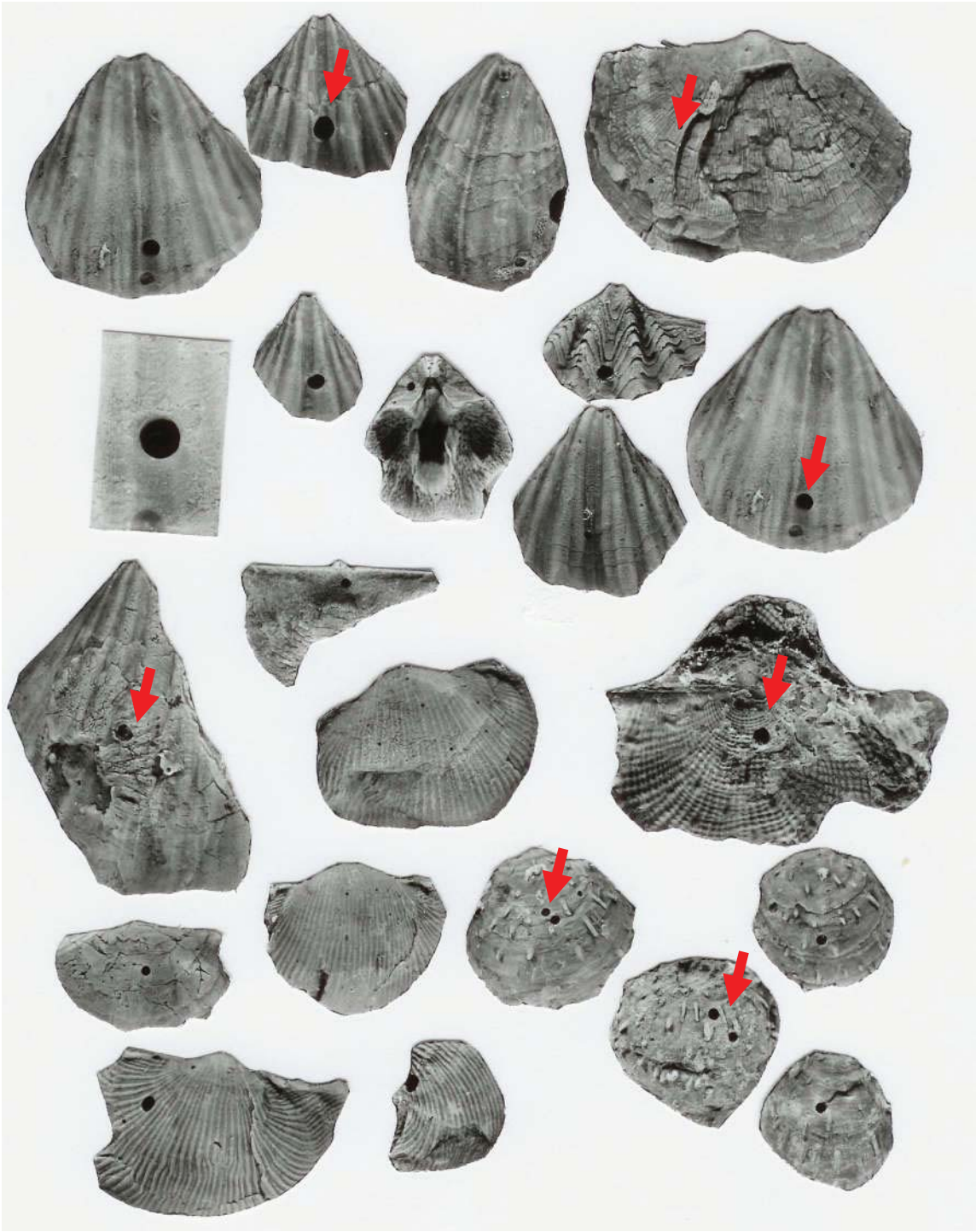
Nianxian, Guangdong

Dongluo, Guangxi

1

2

Pseudotirolites, Palaeofusulina Zones



Predatory drillholes

Permian

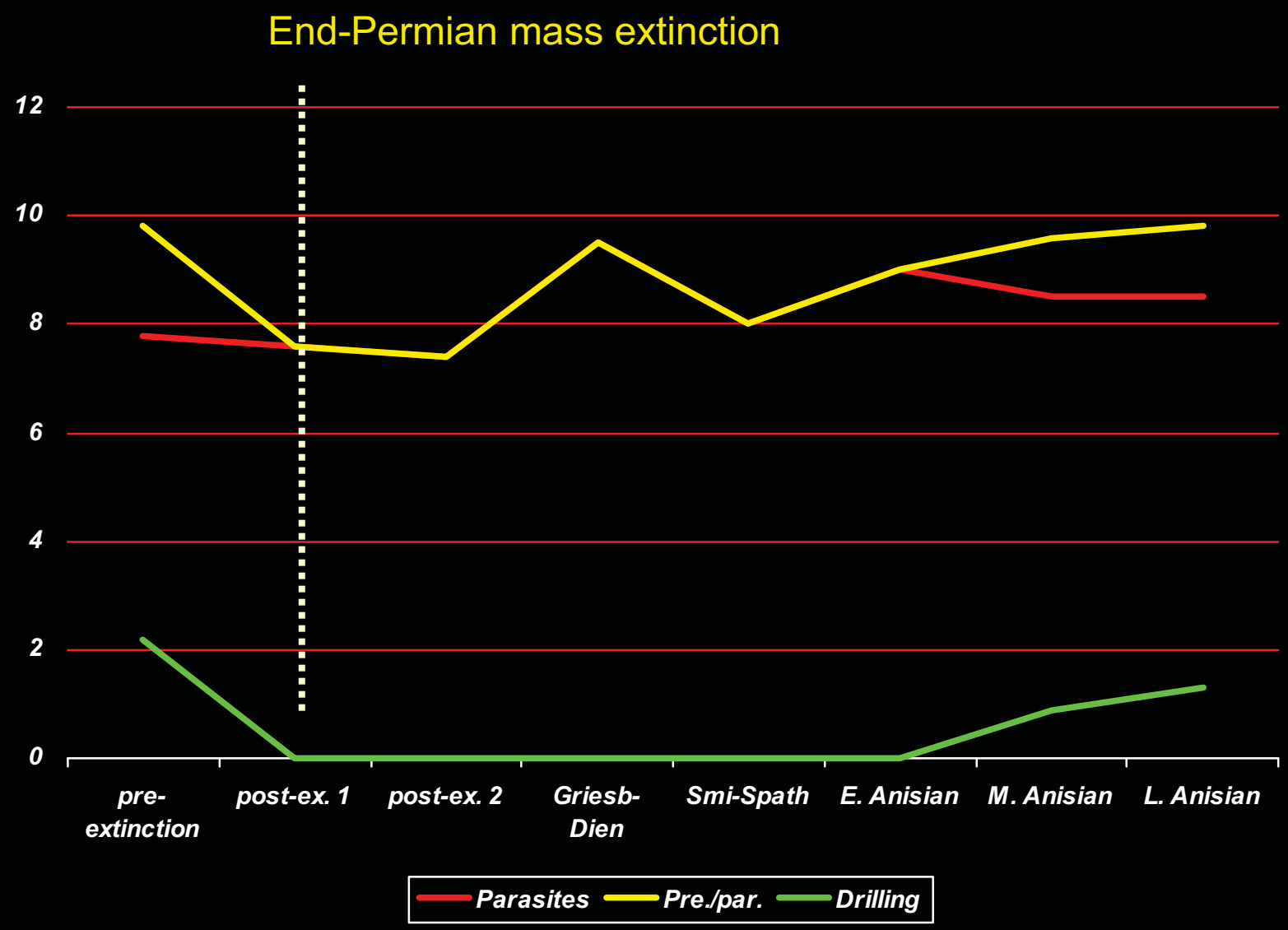


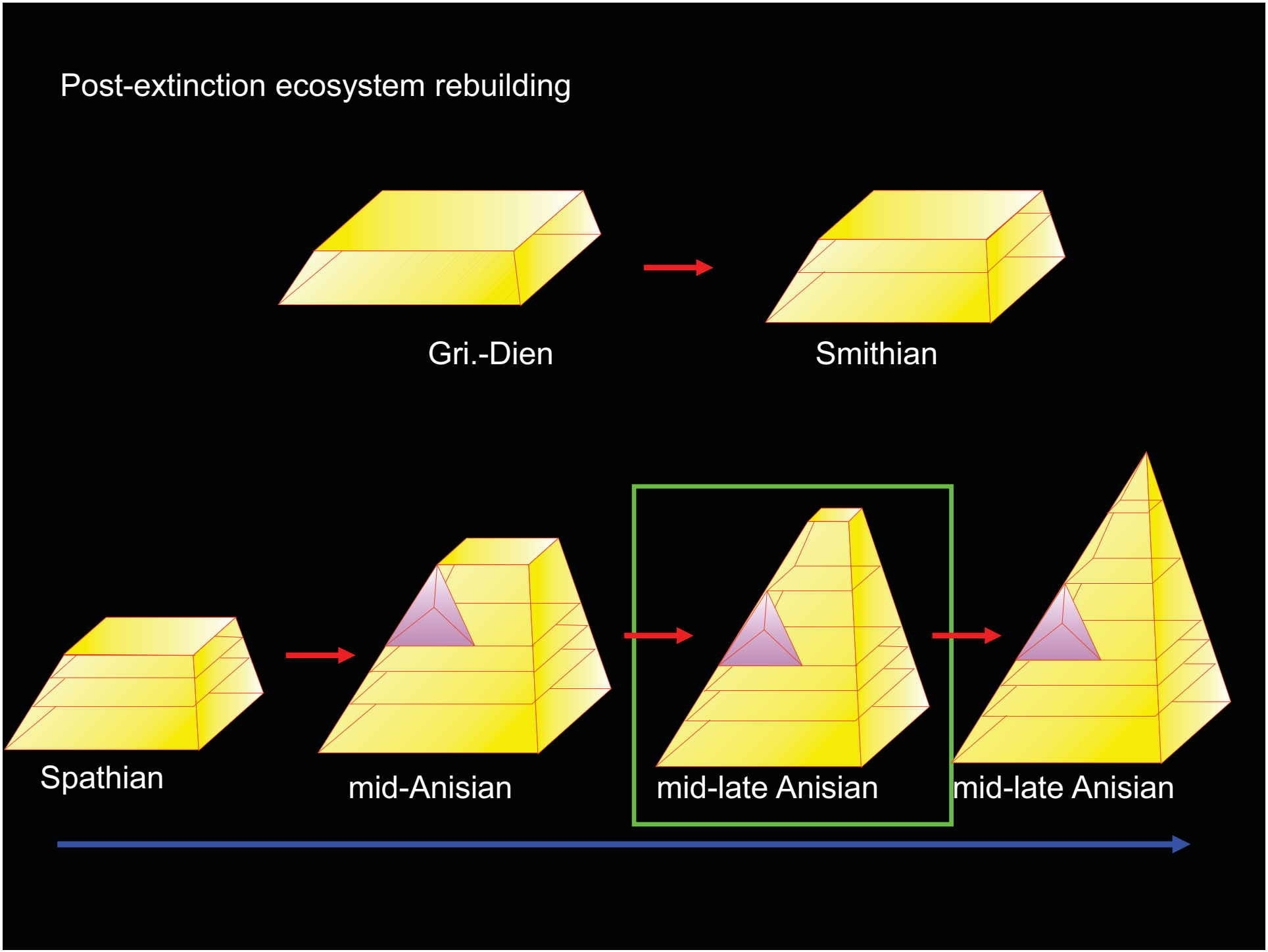
Mid-late Anisian drillholes & parasitic marks

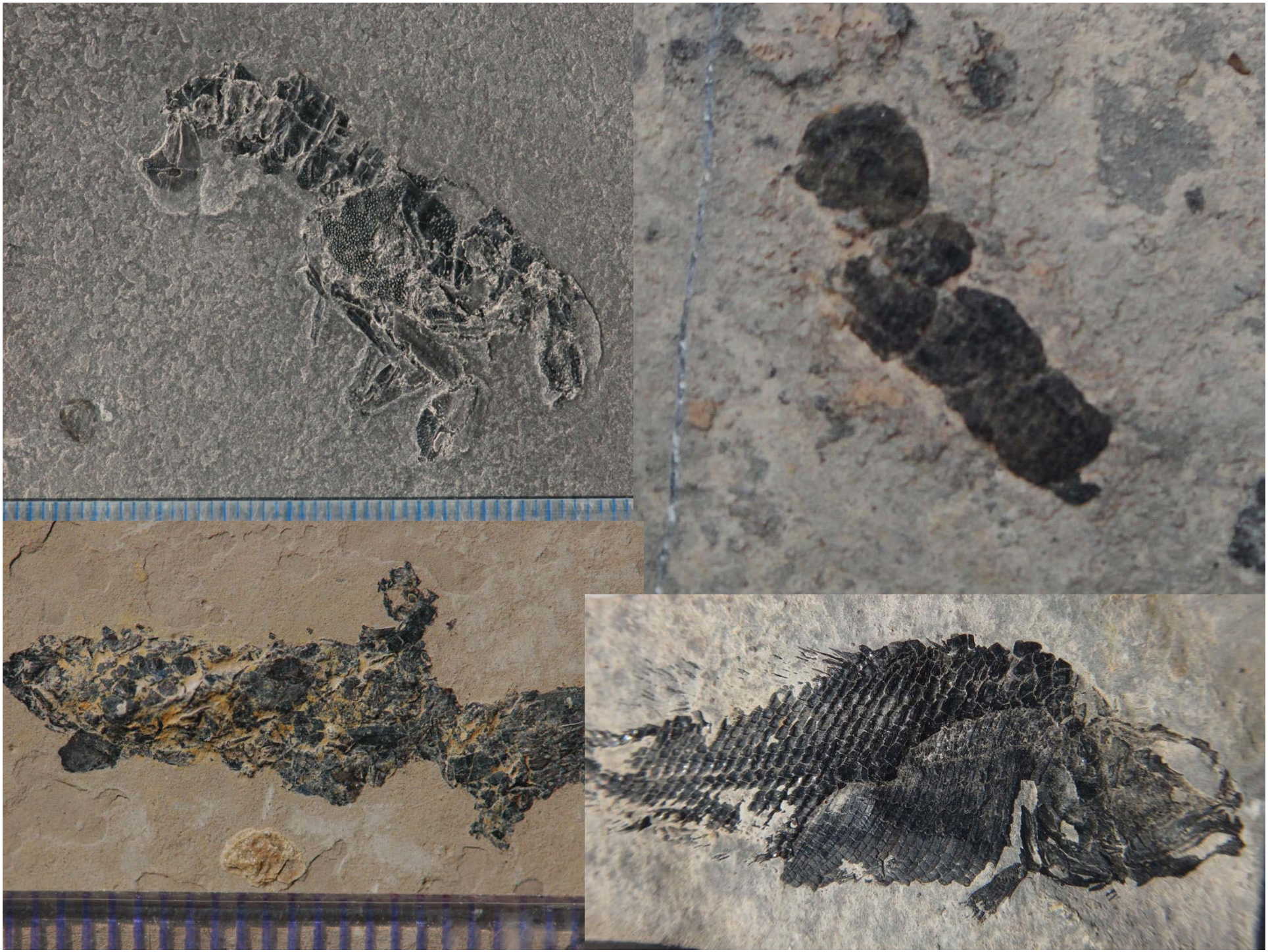
Qingyan Formation, Guizhou, South China



Predatory/parasitic frequencies across P/T extinction




Post-extinction ecosystem rebuilding
Gri.-Dien
Smithian
Spathian
mid-Anisian
mid-late Anisian
mid-late Anisian



New discovery of exceptionally preserved fossils from Early-Middle Triassic

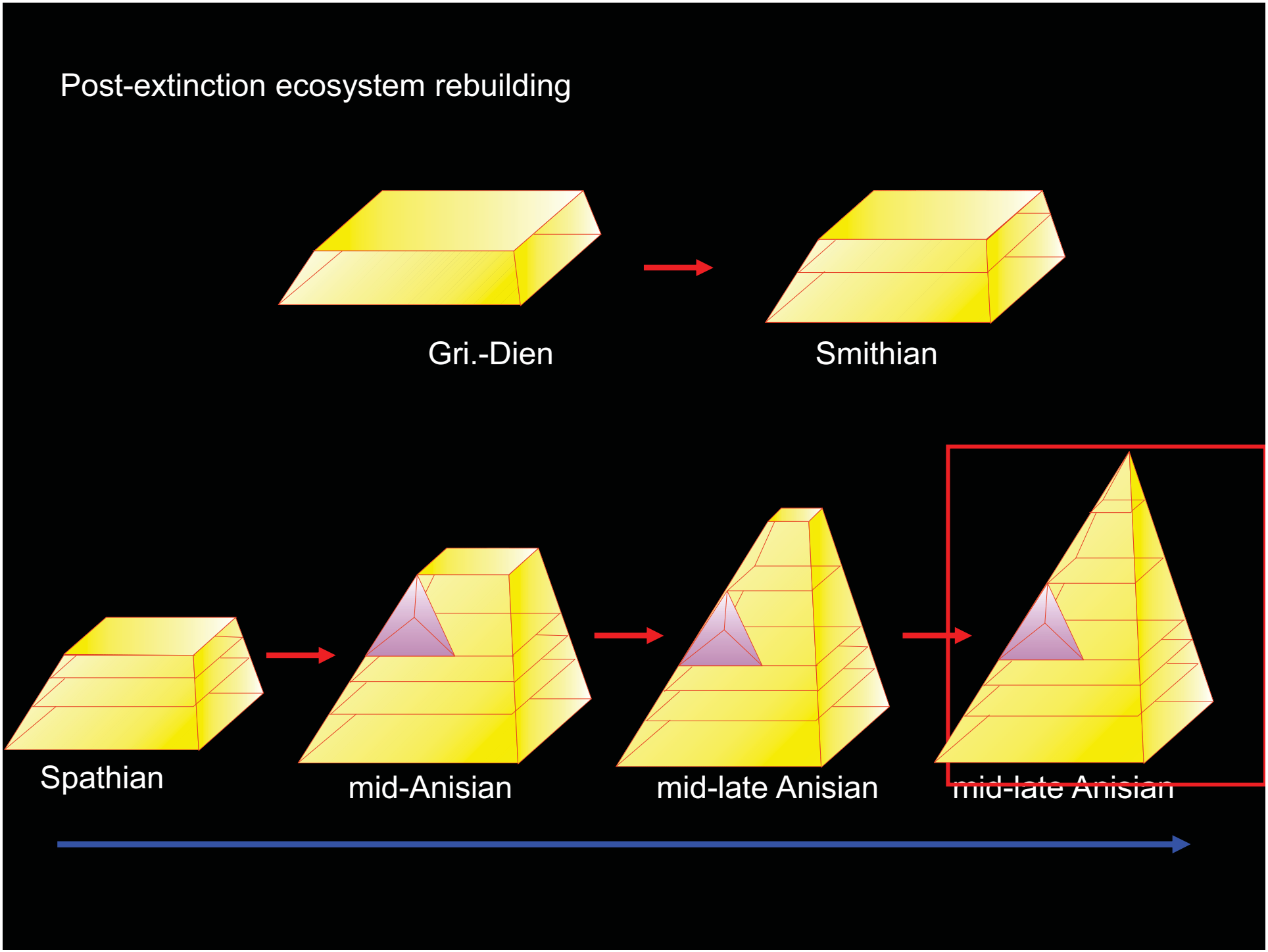
Anisian Luoping biota, Yuannan, South China (Zhang et al. 2008)

Newly obtained SHRIMP date: 241.8 ± 1.5 Ma (Chen et al. in prep.)

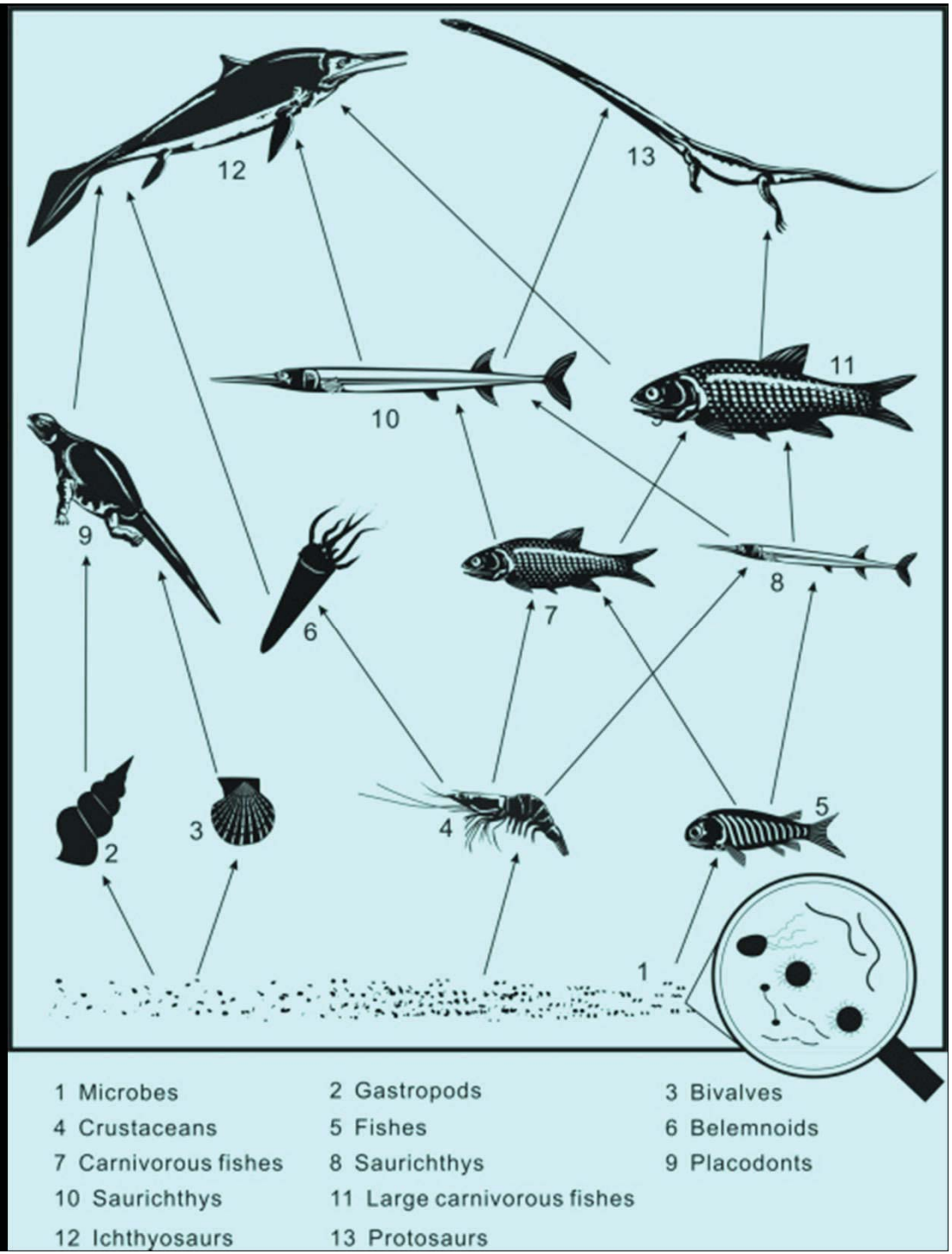
王者归来：生态系的全面复苏

诞生了现代海洋生态系的雏形

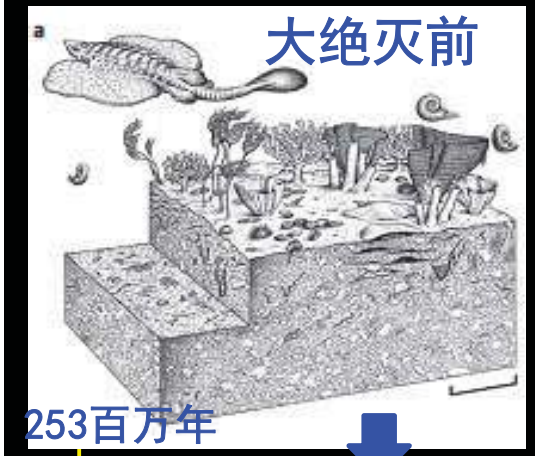
中安尼期
罗平生物群


Post-extinction ecosystem rebuilding
Gri.-Dien
Smithian
Spathian
mid-Anisian
mid-late Anisian
mid-late Anisian

Ecosystem trophic structure and functional groups

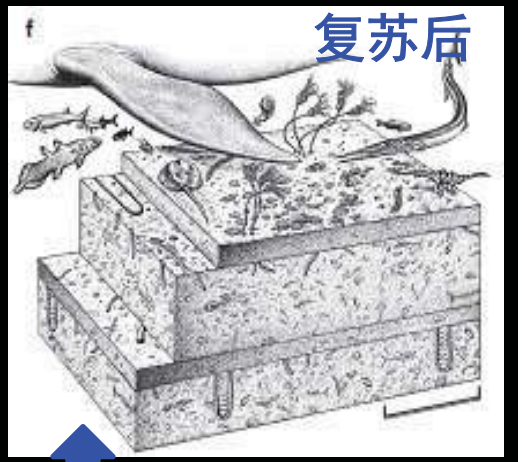


生态系复苏模式及复苏时间

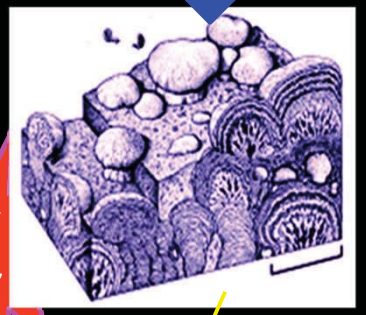


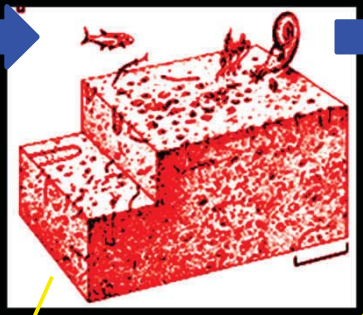
海洋生态系在大灾难之后的重建过程

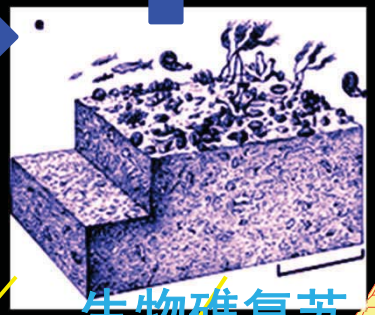
需要近1000万年完成重建？



253百万年

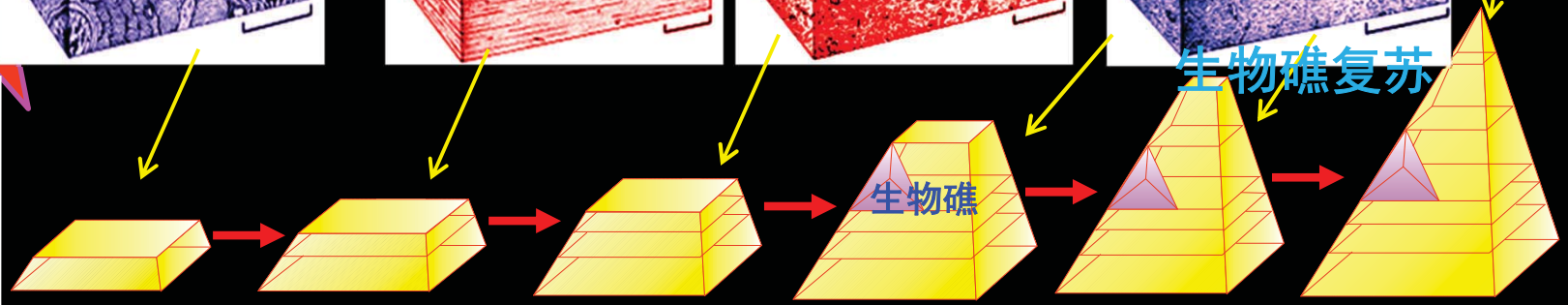






大绝灭

生物礁复苏



印度期 早奥仑尼克期晚奥仑尼克期 中安尼期 中-晚安尼期

252.2 251 250 247 245 242.5 百万年

nature geoscience

REVIEW ARTICLE

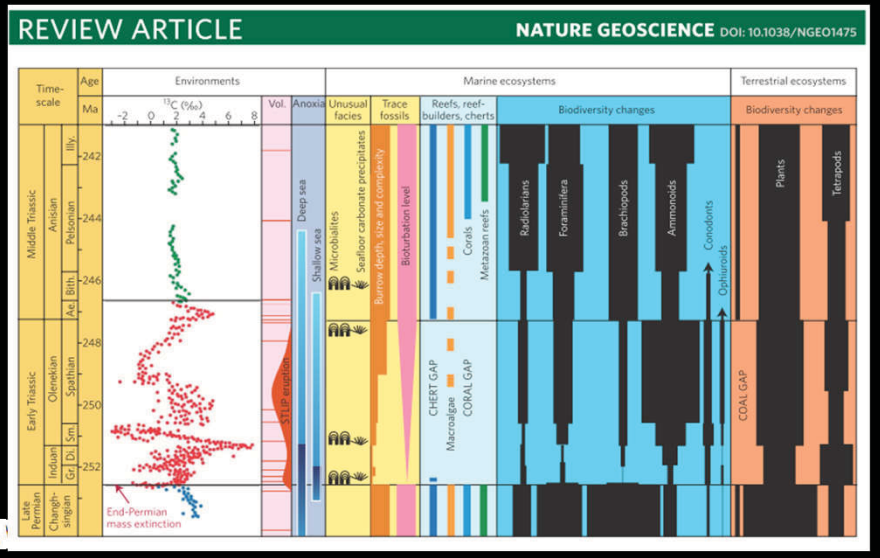
PUBLISHED ONLINE: 27 MAY 2012 | DOI: 10.1038/NGEO1475

The timing and pattern of biotic recovery following the end-Permian mass extinction

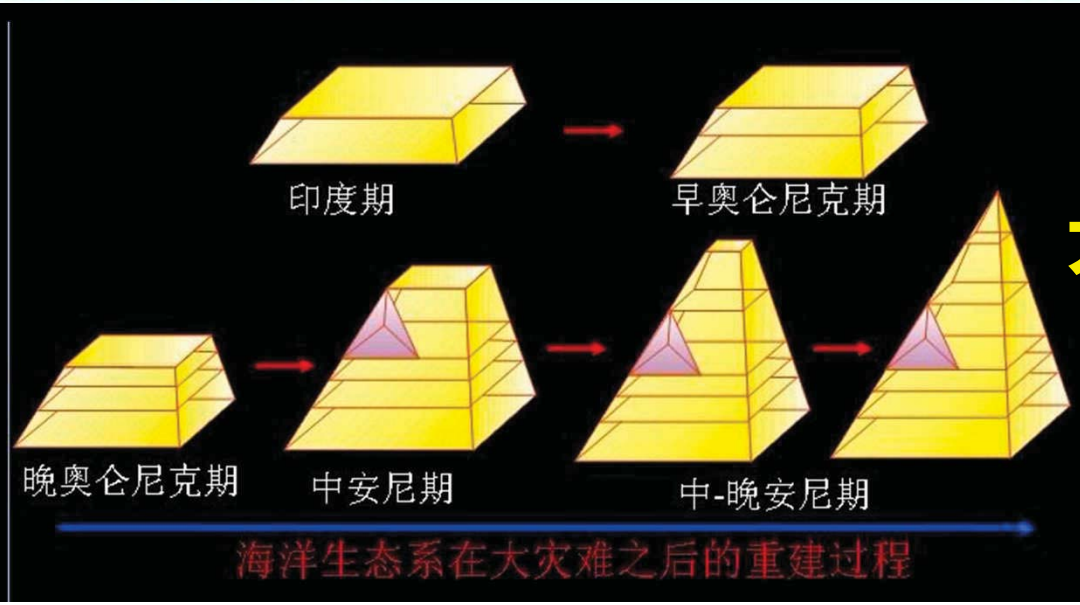
Zhong-Qiang Chen[1] and Michael J. Benton[2]*

The aftermath of the great end-Permian period mass extinction 252 Myr ago shows how life can recover from the loss of >90% species globally. The crisis was triggered by a number of physical environmental shocks (global warming, acid rain, ocean acidification and ocean anoxia), and some of these were repeated over the next 5–6 Myr. Ammonoids and some other groups diversified rapidly, within 1–3 Myr, but extinctions continued through the Early Triassic period. Triassic ecosystems were rebuilt stepwise from low to high trophic levels through the Early to Middle Triassic, and a stable, complex ecosystem did not re-emerge until the beginning of the Middle Triassic, 8–9 Myr after the crisis. A positive aspect of the recovery was the emergence of entirely new groups, such as marine reptiles and decapod crustaceans, as well as new tetrapods on land, including — eventually — dinosaurs. The stepwise recovery of life in the Triassic could have been delayed either by biotic drivers (complex multispecies interactions) or physical perturbations, or a combination of both. This is an example of the wider debate about the relative roles of intrinsic and extrinsic drivers of large-scale evolution.

[1]State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences,



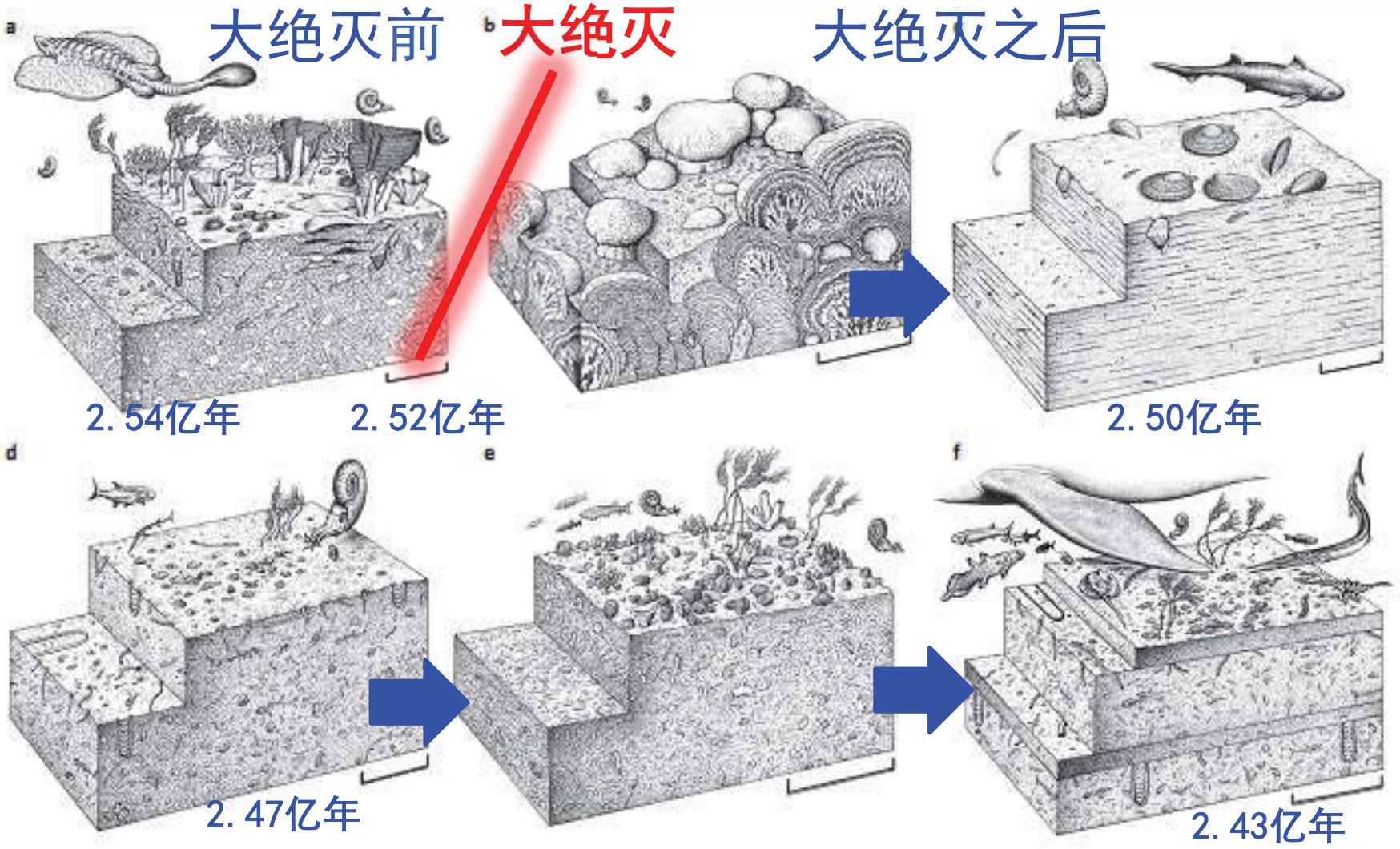
REVIEW ARTICLE NATURE GEOSCIENCE DOI: 10.1038/NGEO1475



大灾难后生态系复苏需要近1000万年？


Nature Geoscience
nature geoscience
WiredUK
WIRED.co.uk
Earth took ten million years to recover from Permian-Triassic extinction
"Chen and Benton examined analyses of rock sections found in China and across the world to try and get an idea of the timeline of extinction.
大灾难后生态系复苏
需要近1000万年?

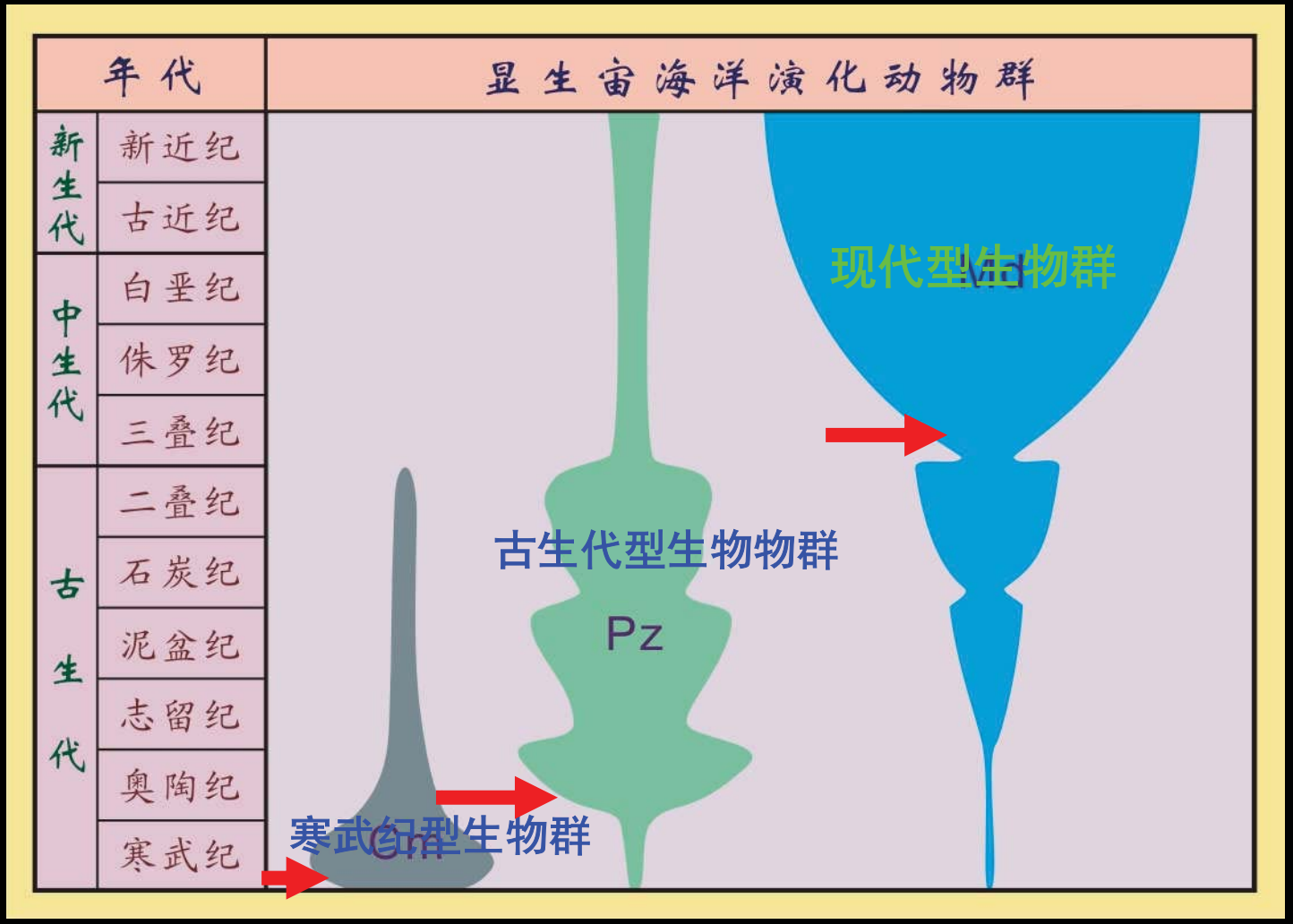
NATURE GEOSCIENCE DOI: 10.1038/NGEO1475 REVIEW ARTICLE



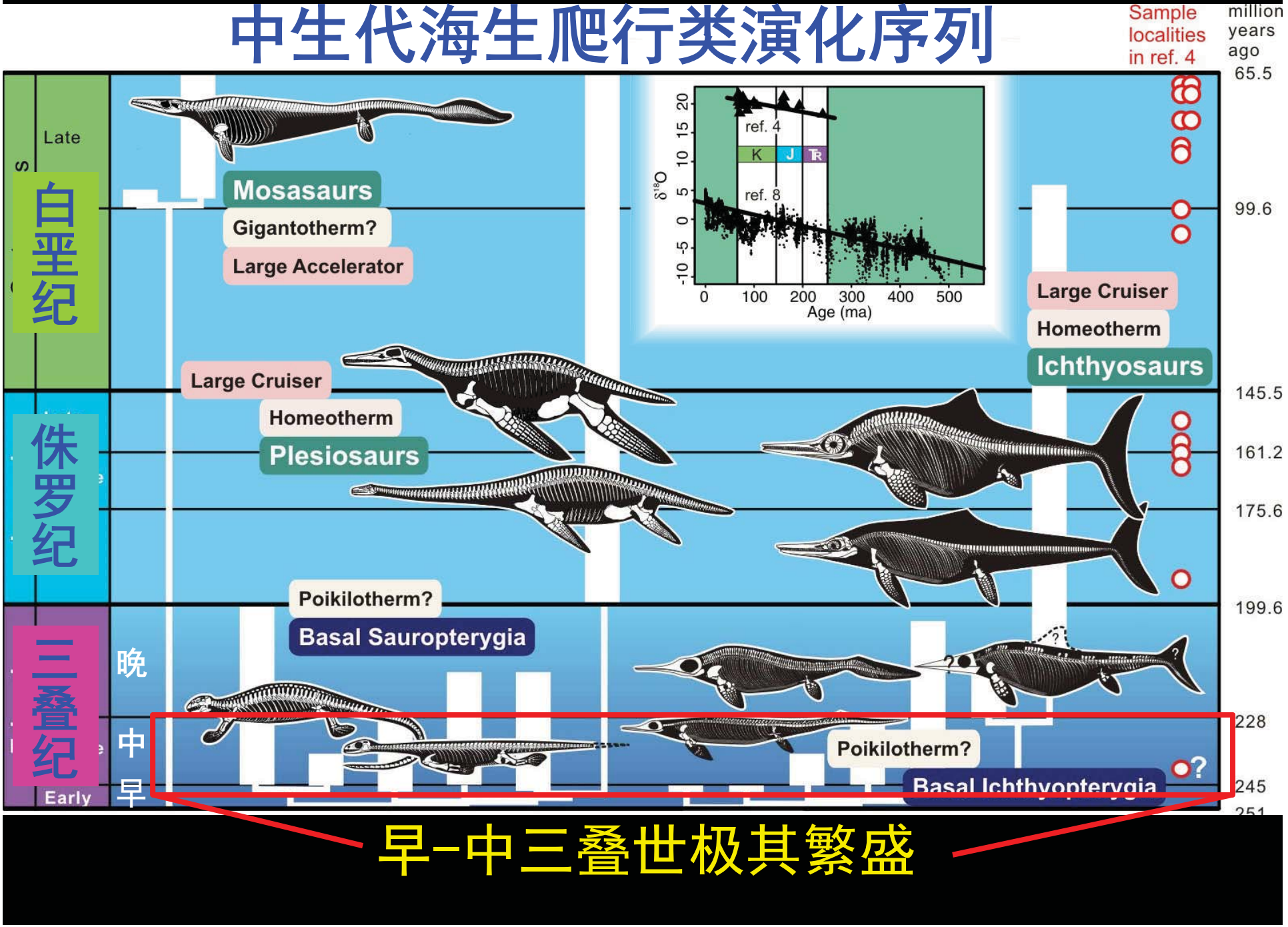
海洋生态系在二叠-三叠纪之交的变化过程

Chen and Benton (2012)

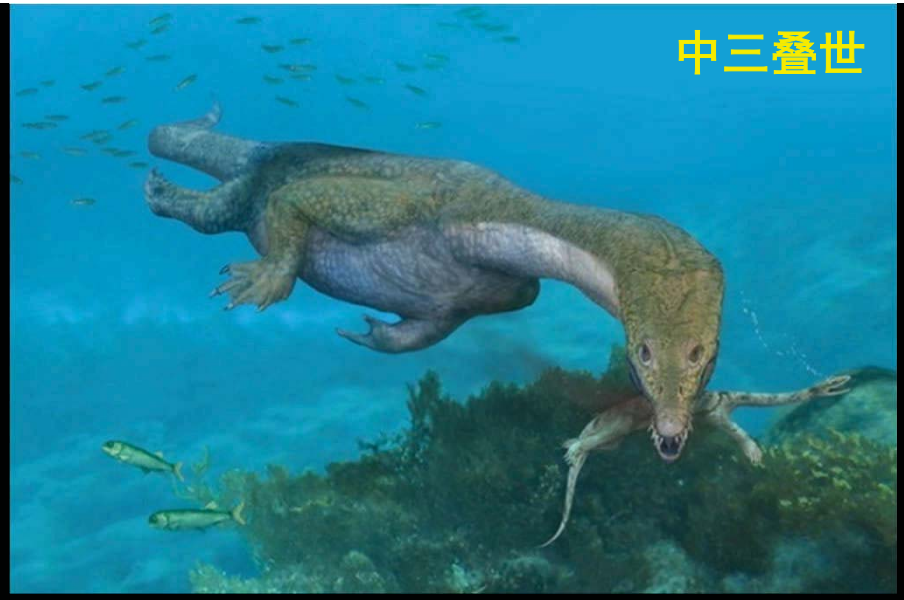
显生宙海洋生物三次大辐射和三个演化动物群



中生代海生爬行类演化序列



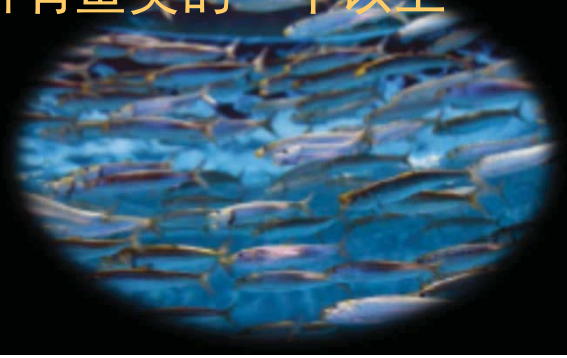
早–中三叠世极其繁盛



罗平生物群具有典型的现代海洋生态系组成结构特征

1. 8万块鳍鱼类标本

现代海洋中辐鳍鱼类占所有鱼类的一半以上

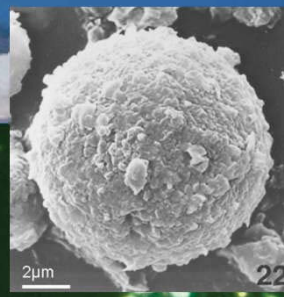


真正的远洋沉积和浮游生物出现：

晚三叠世早期（确定）

早-中三叠世（可能）

白垩：远洋沉积物

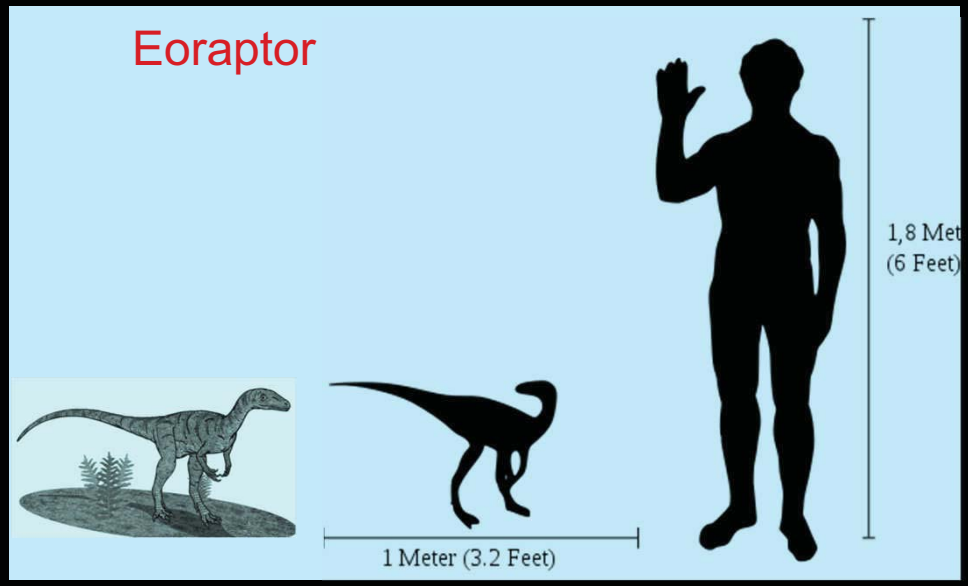


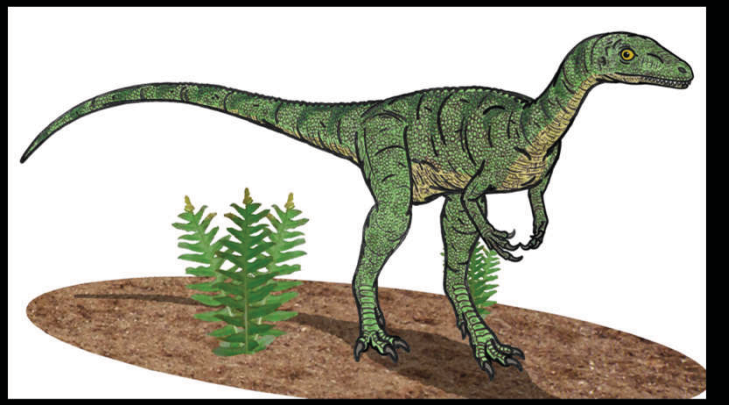
超微化石

我国西秦岭早三叠世有报道

赵江天等，1993

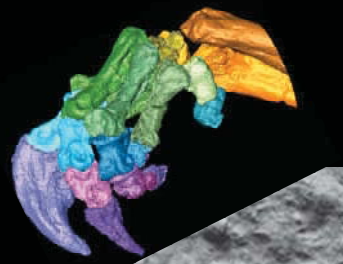
早期恐龙



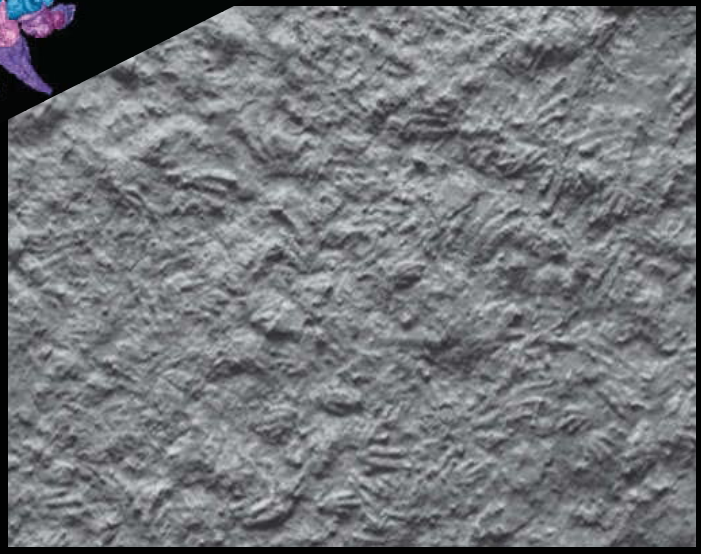


阿根廷晚三叠最早期（卡尼期）

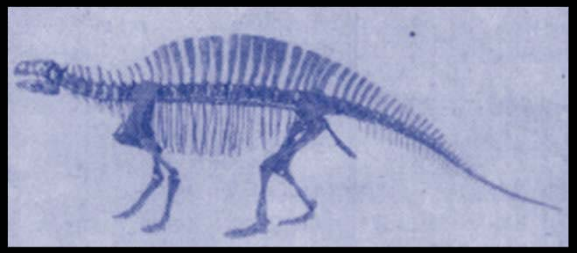
Sereno et al. (1993, Nature)



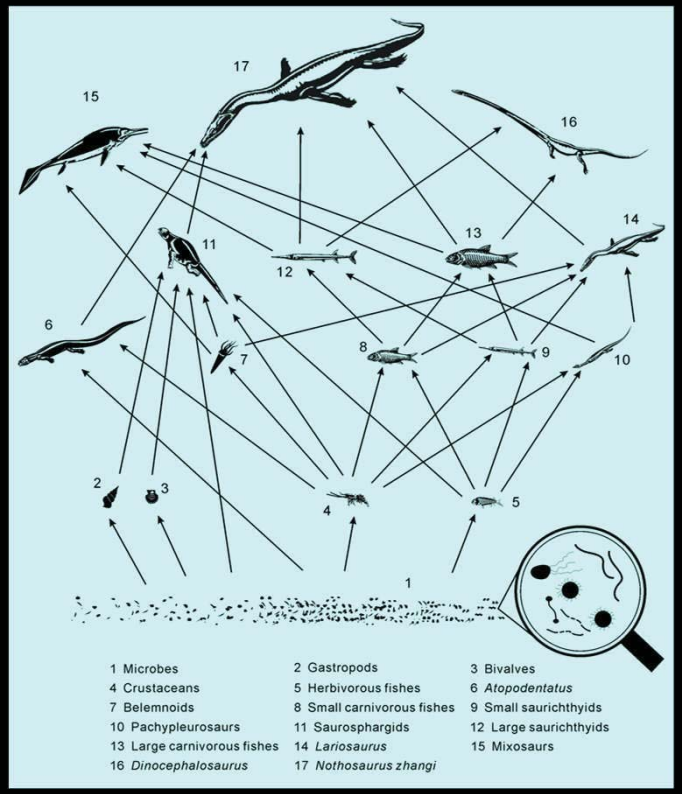
早三叠世恐龙脚印化石



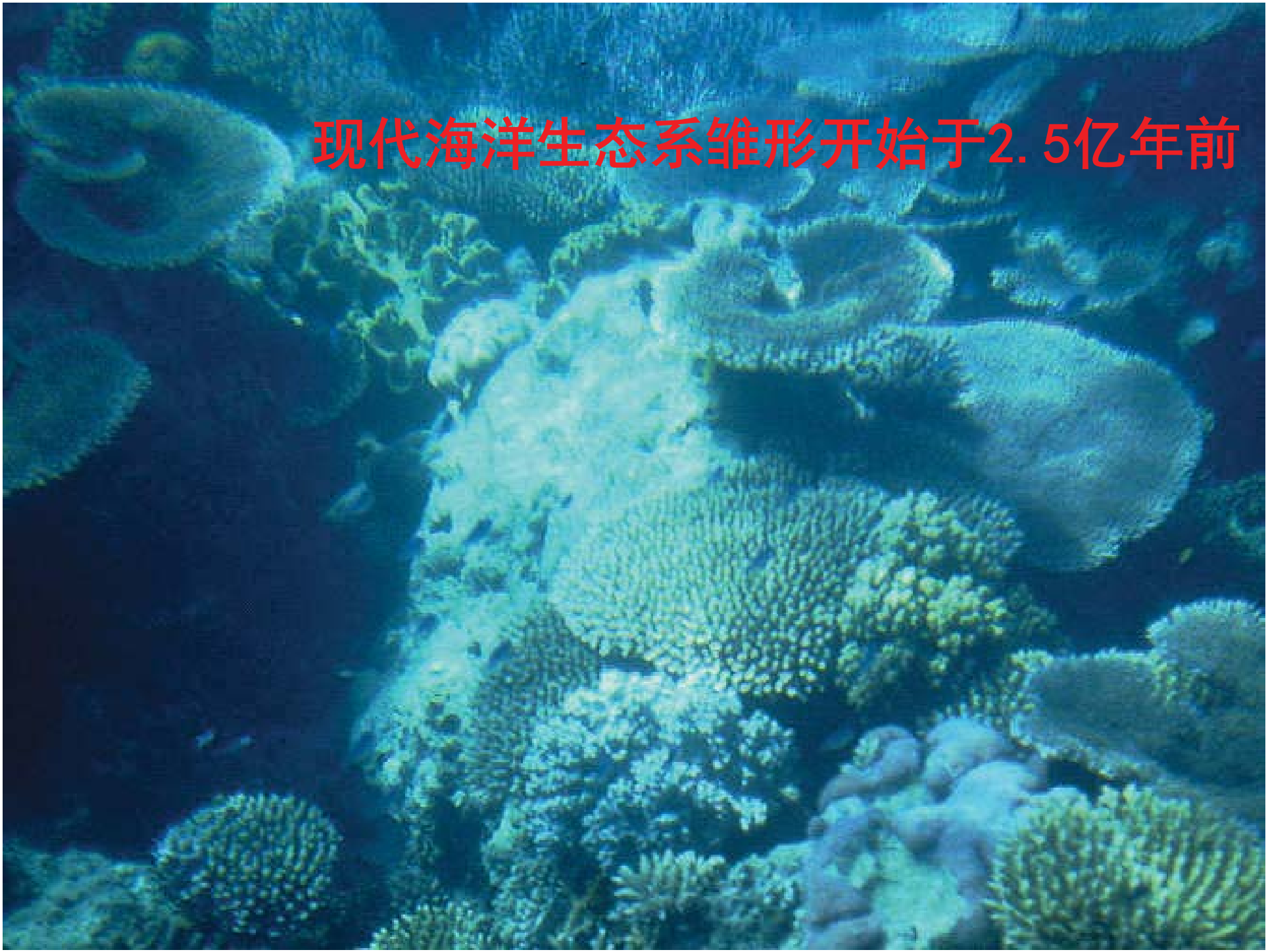
湘西中三叠巴东组的芙蓉龙



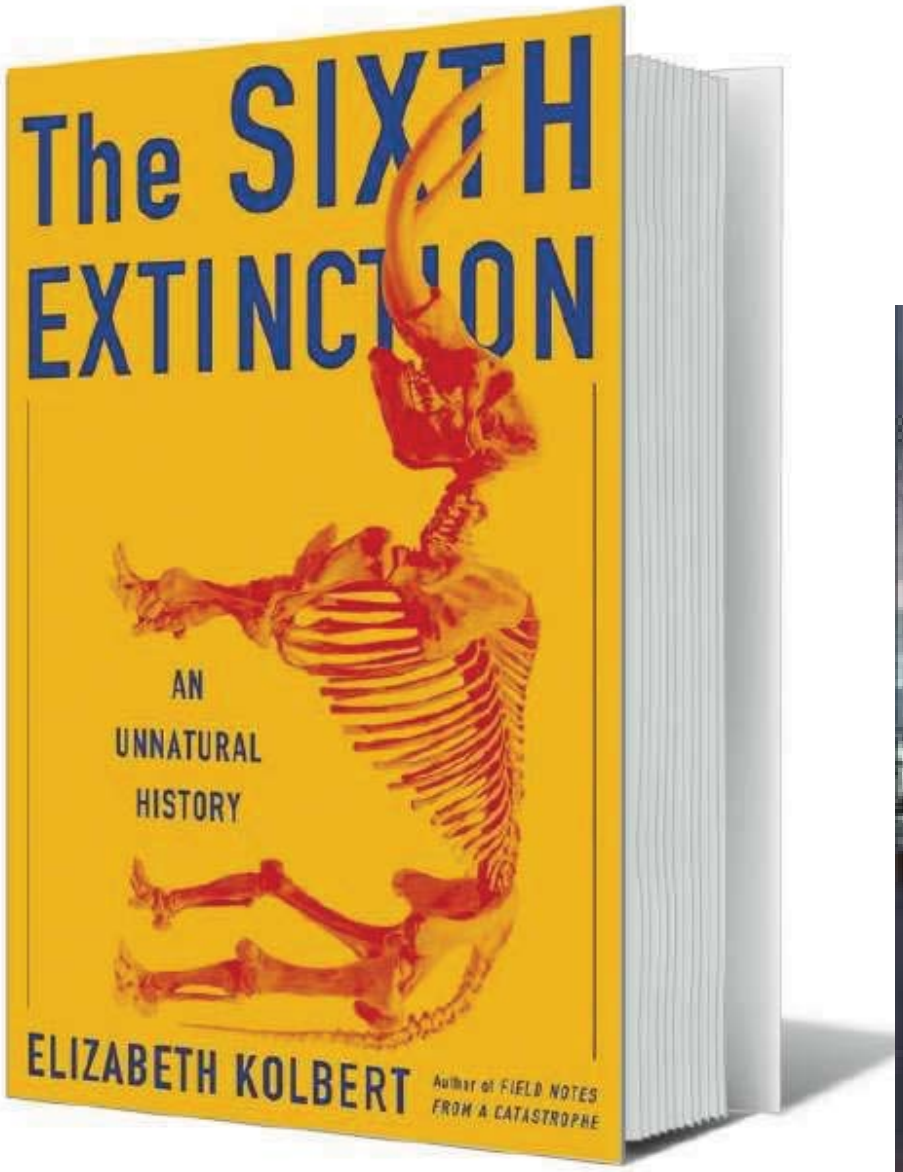
罗平生物群食物链



为数学模拟提供材料、参数

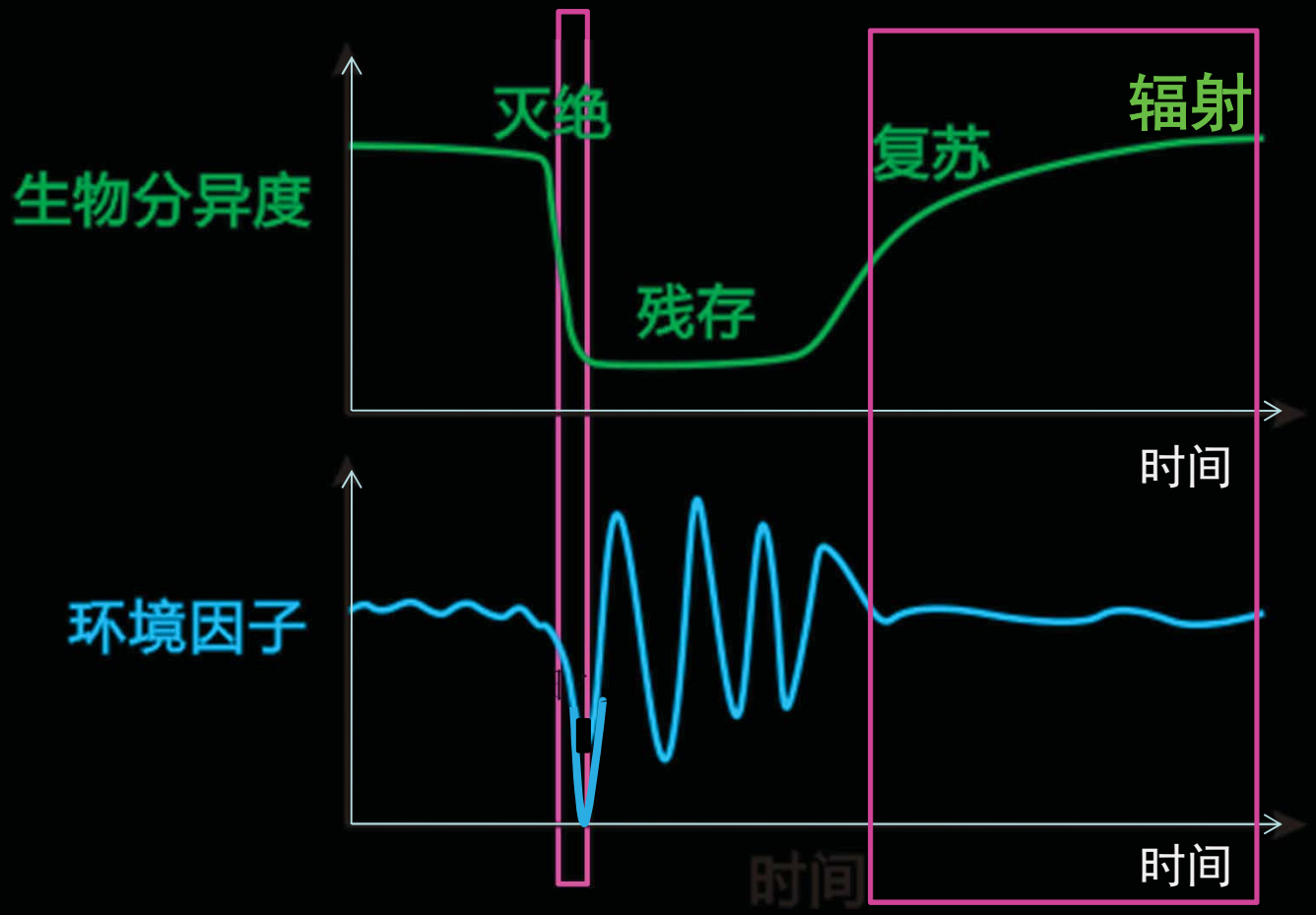

现代海洋生态系雏形开始于2.5亿年前

地球的将来？？


The SIXTH EXTINCTION
AN UNNATURAL HISTORY
ELIZABETH KOLBERT
Author of FIELD NOTES FROM A CATASTROPHE


第6次大灭绝
人类能挺过去吗

生物与环境的抗灾恢复能力(Resilience)模型



环境与生物的Resilience

PERMIAN-TRIASSIC ECOSYSTEMS

IGCP572: Restoration of marine ecosystems following the Permian-Triassic mass extinction

LESSONS FOR THE PRESENT

联合国教科文组织和国际地质科学联合会国际地学对比研究计划第572项（IGCP572)

（IGCP572：海洋生态系在二叠末大绝灭之后的重建模式：对当代脆弱生态系管理的启示，2008—2013年）

主席：陈中强；童金南等8个共同领导人

- 该时期全球研究P-T大绝灭事件唯一大型国际合作研究组织
- 全球26国家130研究人员参加
- 年280-300人次参加
- 10次专题会场，8次野外现场讨论会
- 每年被评为优秀
- 12个国际SCI期刊专辑

IGCP 630:

Permian-Triassic climatic & environmental extremes and biotic response

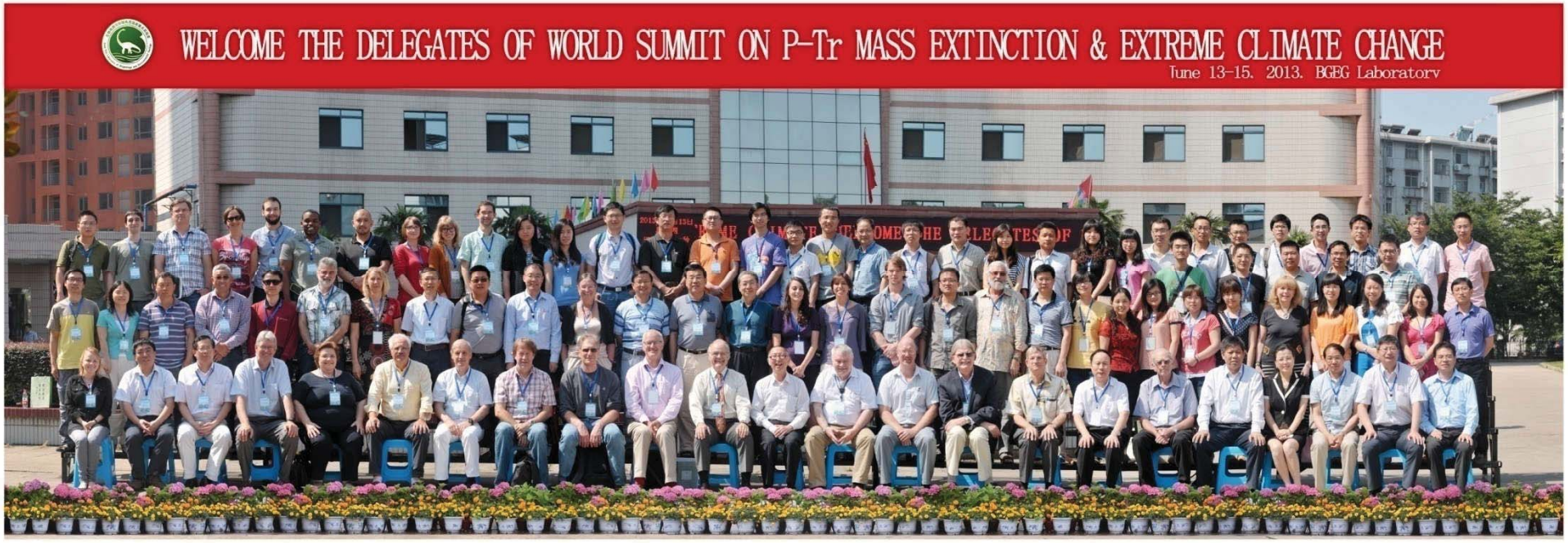
联合国教科文组织和国际地质科学联合会**国际地学研究计划第630项（IGCP630)：二叠纪-三叠纪之交极端气候与环境事件及生物的反馈机制（2014-18年）：**

- 联合国教科文组织和国际地质科学联合会联合资助
- 陈中强为主席；童金南等12个国际专家为共同领导人
- 27个国家150名研究人员参与
- 2014年组织（1）意大利北部山区和（2）印度北部喀什米尔地区野外地质研讨会

IGCP 630:

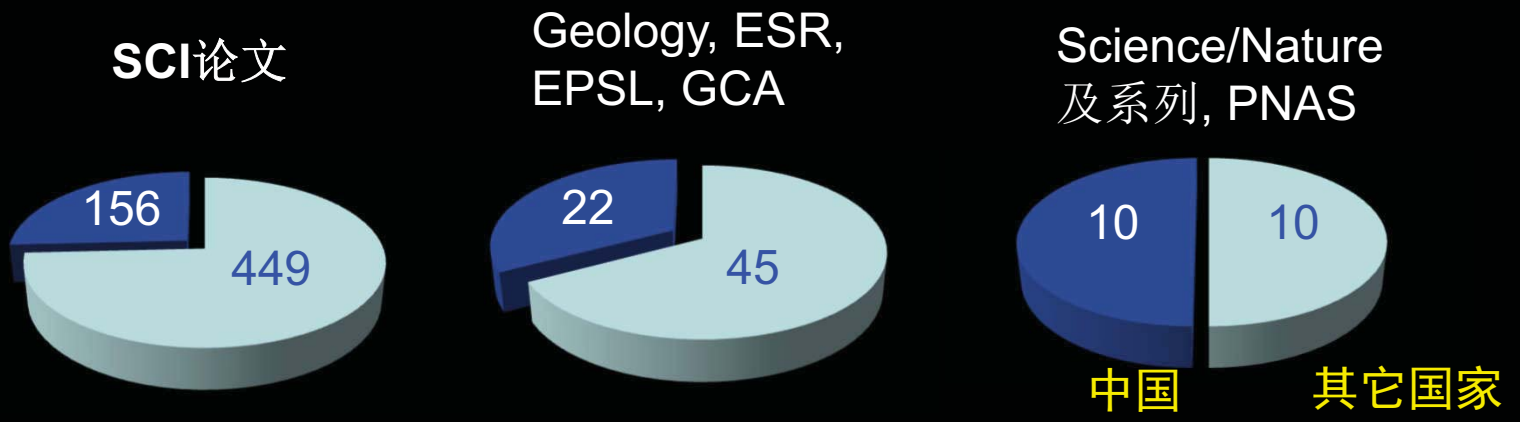
Permian-Triassic climatic & environmental extremes and biotic response

P-Tr之交大绝灭和极端气候变化全球峰会
2013年6月， 武汉



总体上，领域内处于世界前列、领导地位

近5年来国内外P-Tr 和三叠纪 SCI文章对比：



- SCI论文：全球605篇；中国一作156篇
- Geology, ESR, EPSL, GCA：全球67篇；中国22篇
- Science/Nature及系列、PNAS：全球20篇，中国一作10篇： [Science (3), Nature (1), Nat Geosci (7), Nat Comm (4), PNAS(2), Sci Rep (3)]

总体上，美国、欧洲、中国三足鼎立局面


加入我们，学好古生物学，以古示今
尽情享受大自然的美景吧