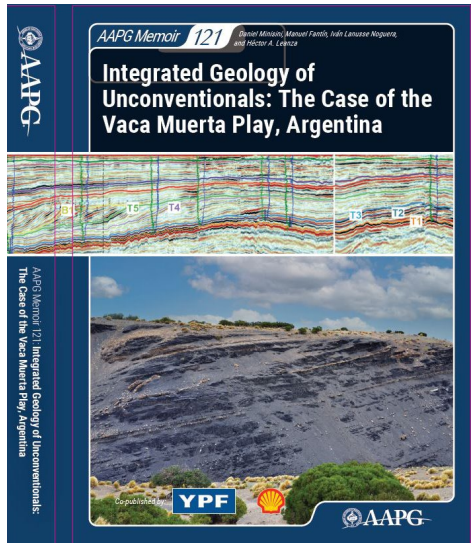
An unusual ichnofauna from oxygen-deficient, organic-rich mudstone and volcanic tuff of the Upper Jurassic-Lower Cretaceous Vaca Muerta Formation (Argentina)

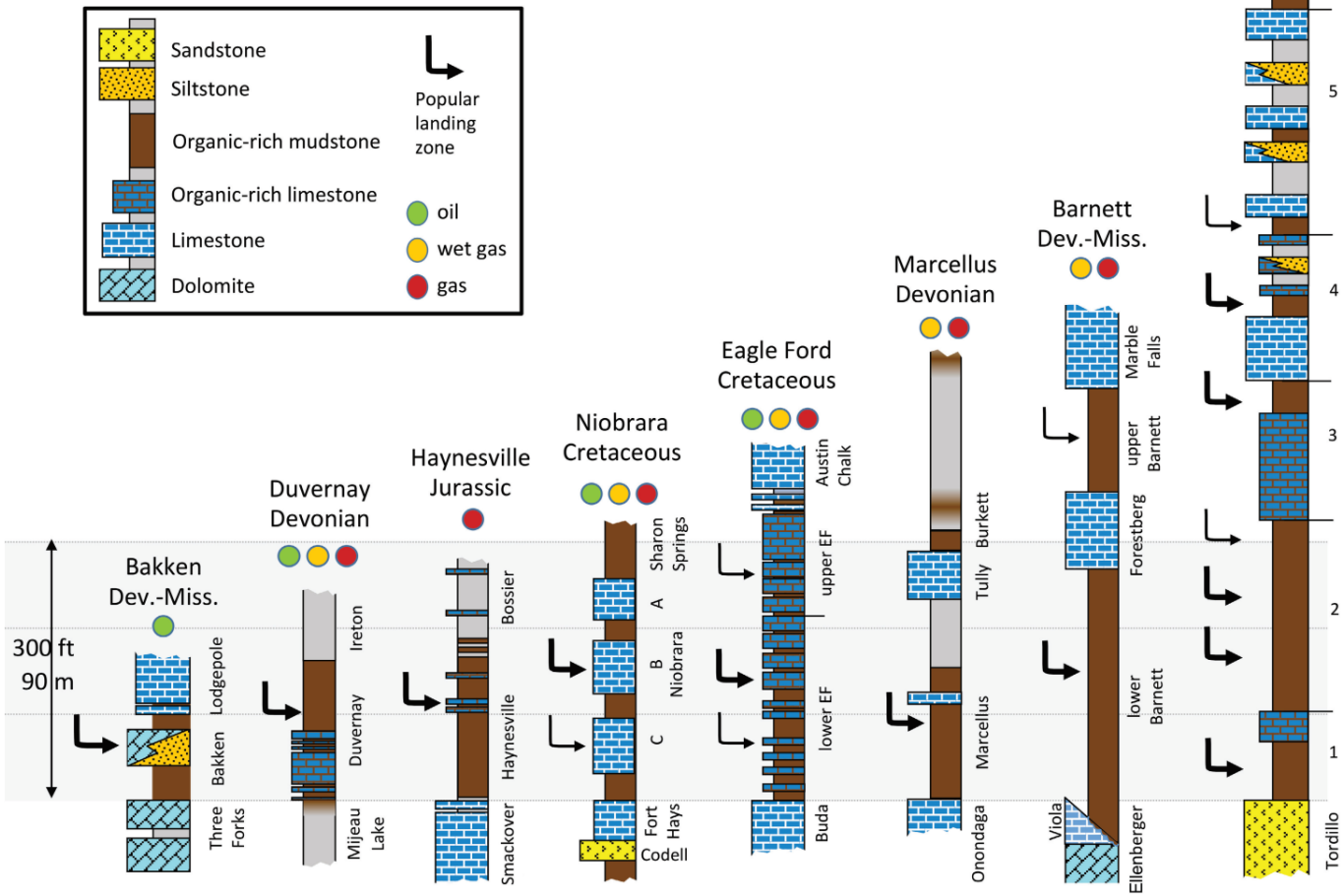
Maximiliano Paz, M. Gabriela Mángano, Luis A. Buatois, Patricio R. Desjardins, Daniel Minisini, Federico González Tomassini, Maximiliano N. Rodríguez, Egberto Pereira, and Martín N. Parada

Vaca Muerta Formation importance

González *et al.* (2018)



Minisini *et al.* (2020)



Minisini *et al.* (2020)

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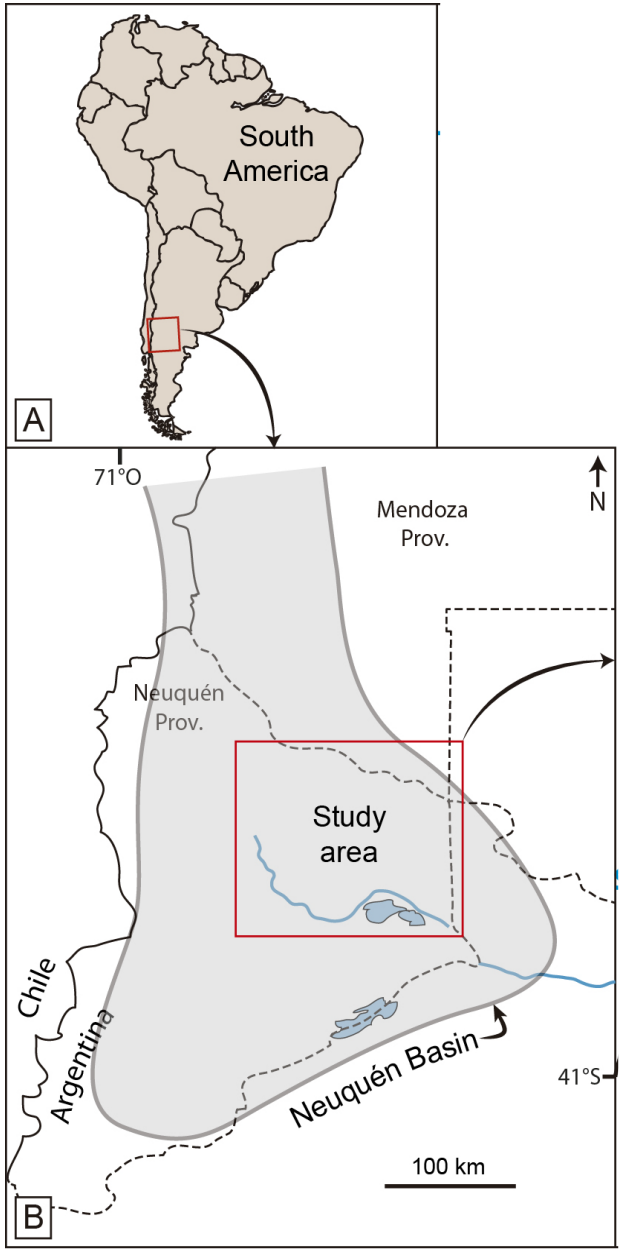
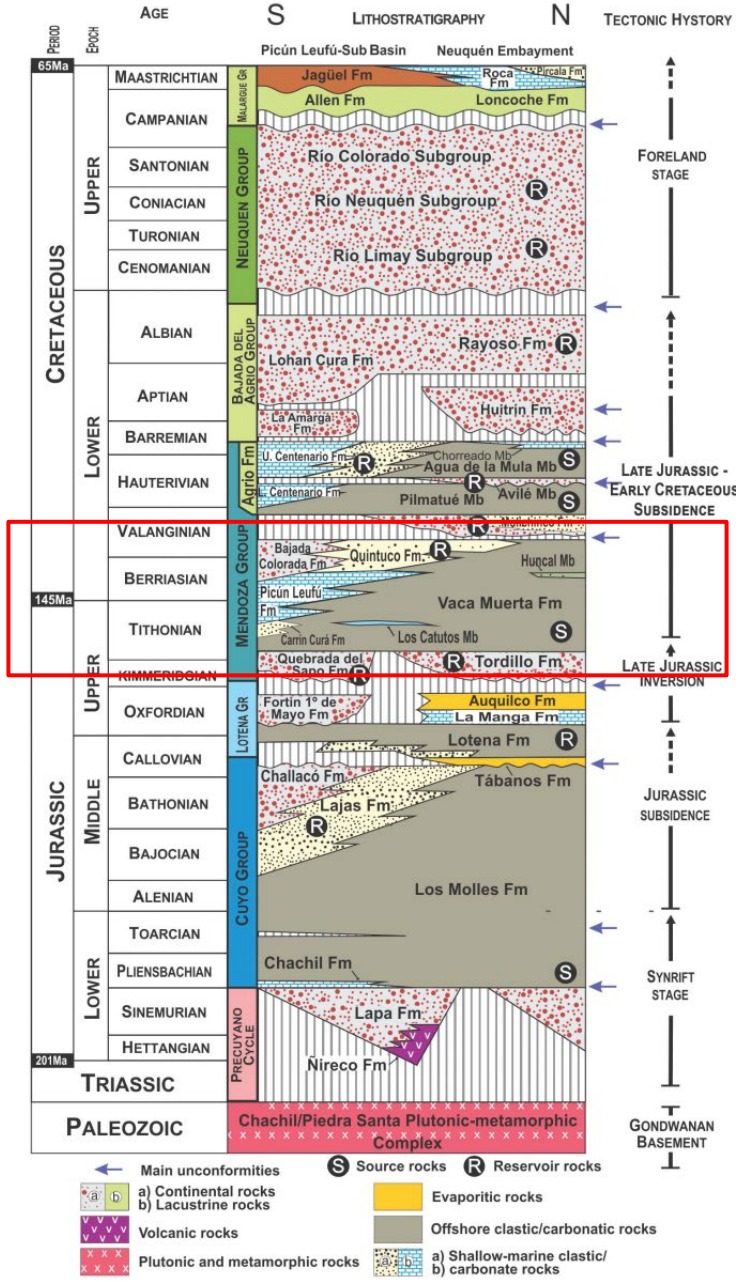
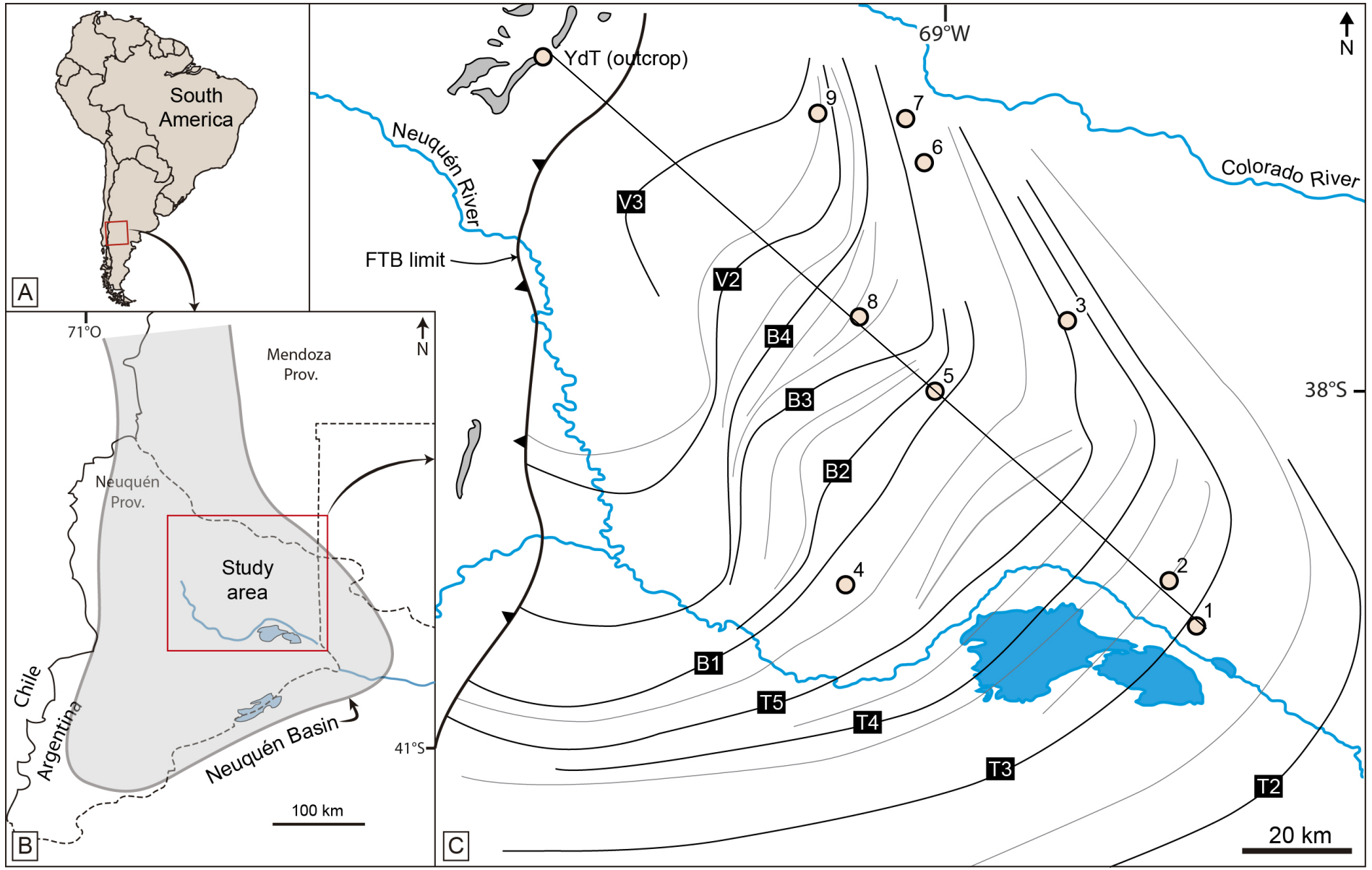
Study area



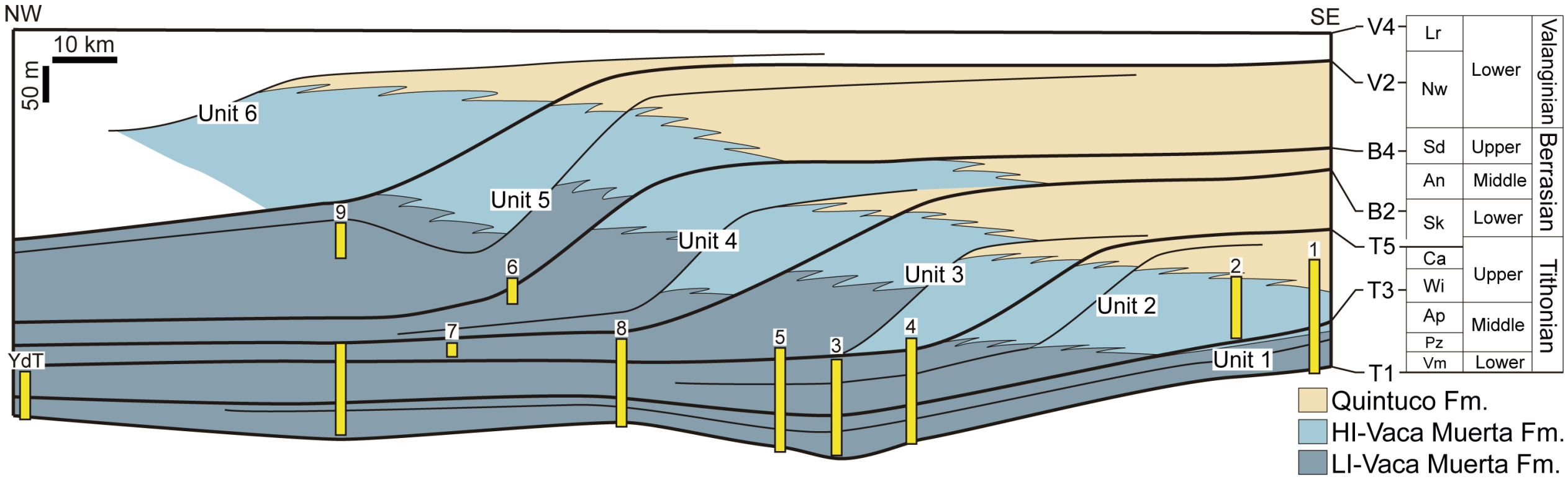


Leanza *et al.* (2020), modified from Howell *et al.* (2005)

Study area


A
South America
B
71°O
N
Mendoza Prov.
Neuquén Prov.
Study area
Chile
Argentina
Neuquén Basin
41°S
100 km
C
69°W
N
YdT (outcrop)
Neuquén River
Colorado River
FTB limit
V3
V2
B4
B3
B2
B1
T5
T4
T3
T2
38°S
1
2
3
4
5
6
7
8
9
20 km

Geological setting



Units and stratigraphic surfaces are from Desjardins *et al.* (2019). Adapted from Sattler *et al.* (2016) and Reijenstein *et al.* (2017)

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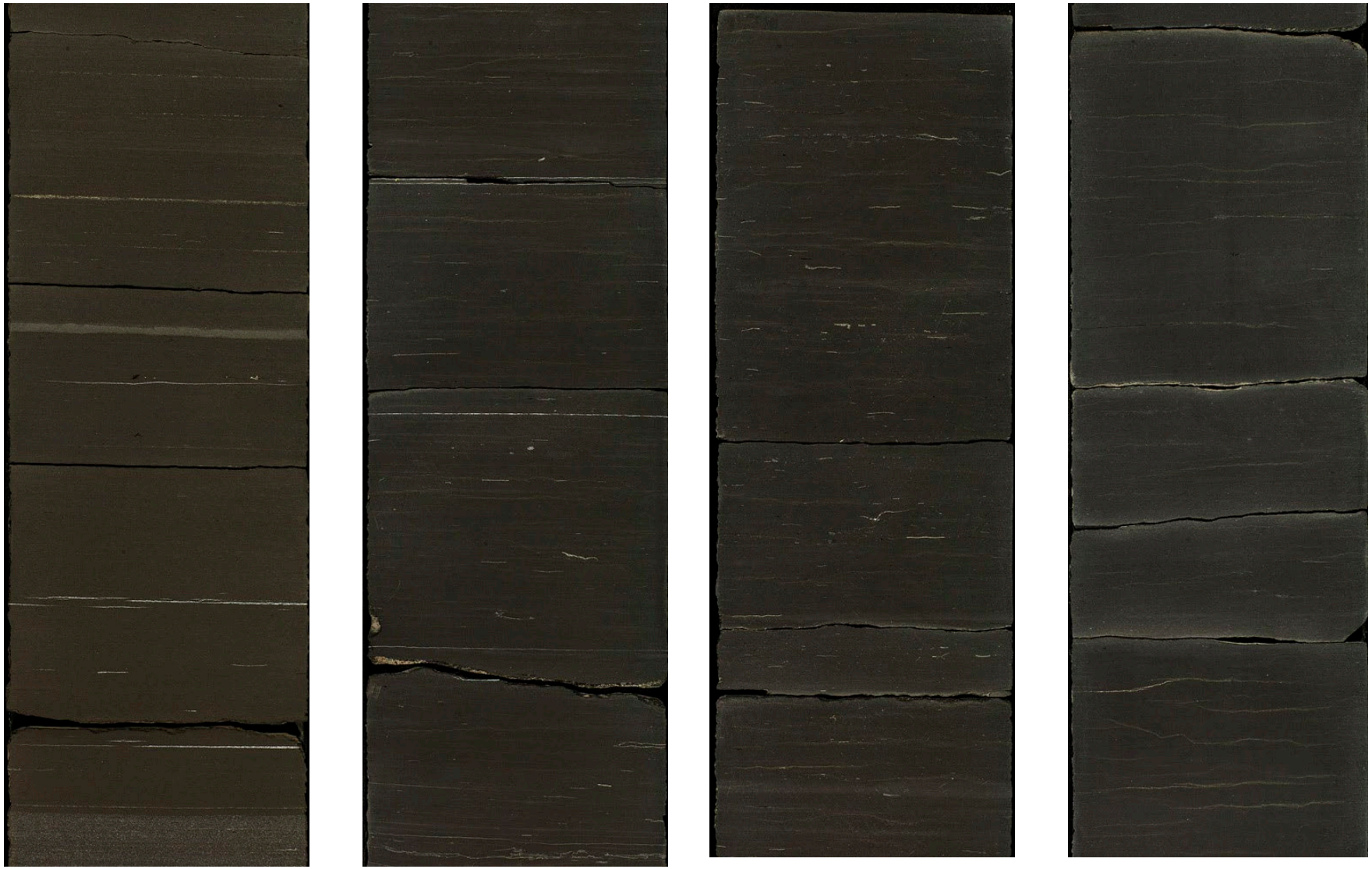
Objectives

- Collect sedimentologic, ichnologic, and sequence stratigraphic data from the Vaca Muerta Formation
- Analyze these datasets in order to construct a depositional model
- Characterize trace fossils and their bioturbation metrics to evaluate environmental stress factor
- Determine ichnocoenoses and compare with other case studies globally

Methods

- Dataset: one outcrop section (148 m-thick), nine core sections (19-186 m thick). Total of 1352 m of sections
- Facies and facies association description
- Thin sections from outcrop samples (n=18). Additional thin sections provided by oil companies owning the cores (n=59). Seven samples analyzed under BSE and SEM
- Ichnological approach: description of ichnotaxa, ethologies, tiering structures, ichnodiversity, degree of bioturbation, burrow size and penetration depth
- 311 examples of oxygen-related ichnocoenoses. >1000 examples of ichnocoenoses.

Methods



Methods

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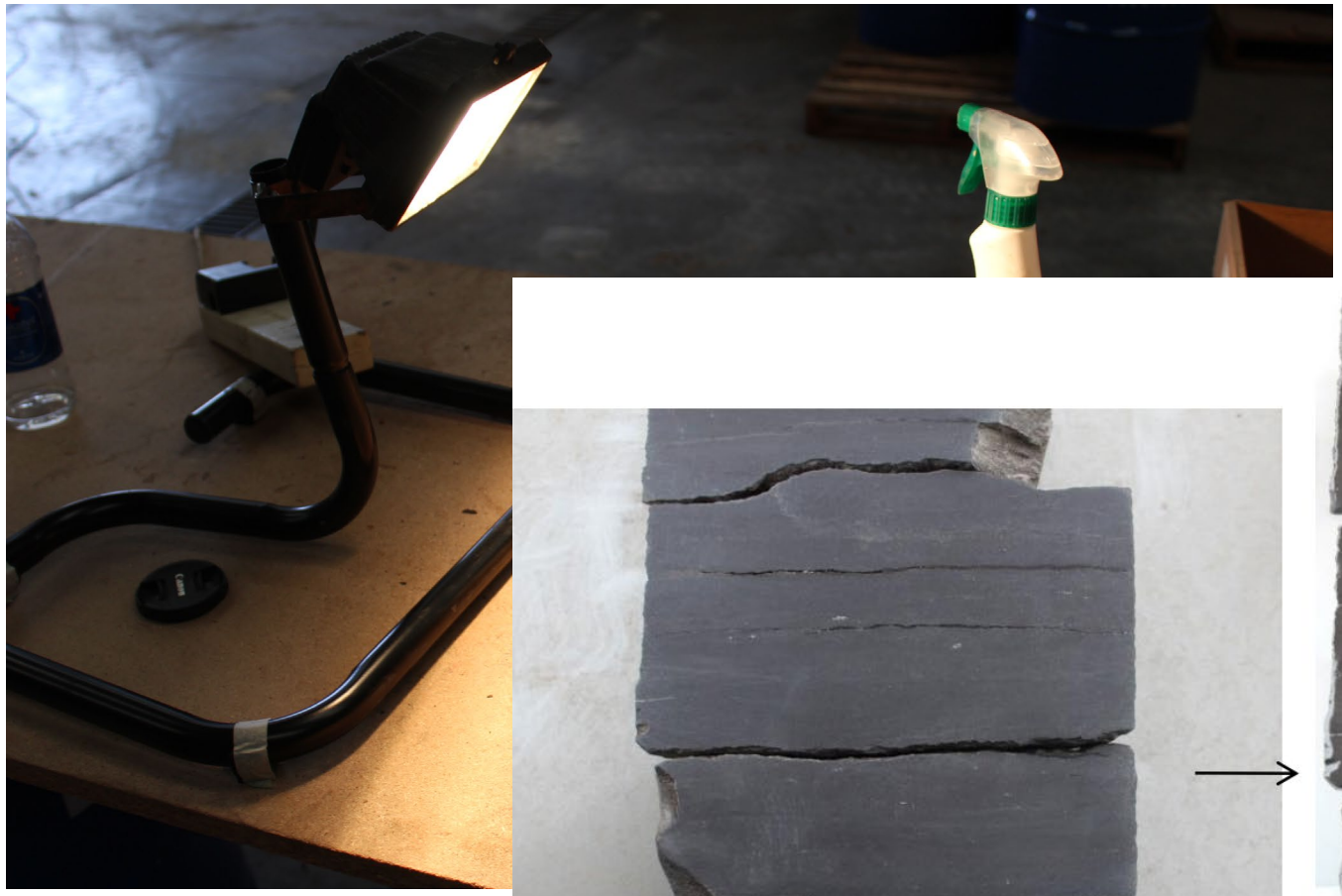

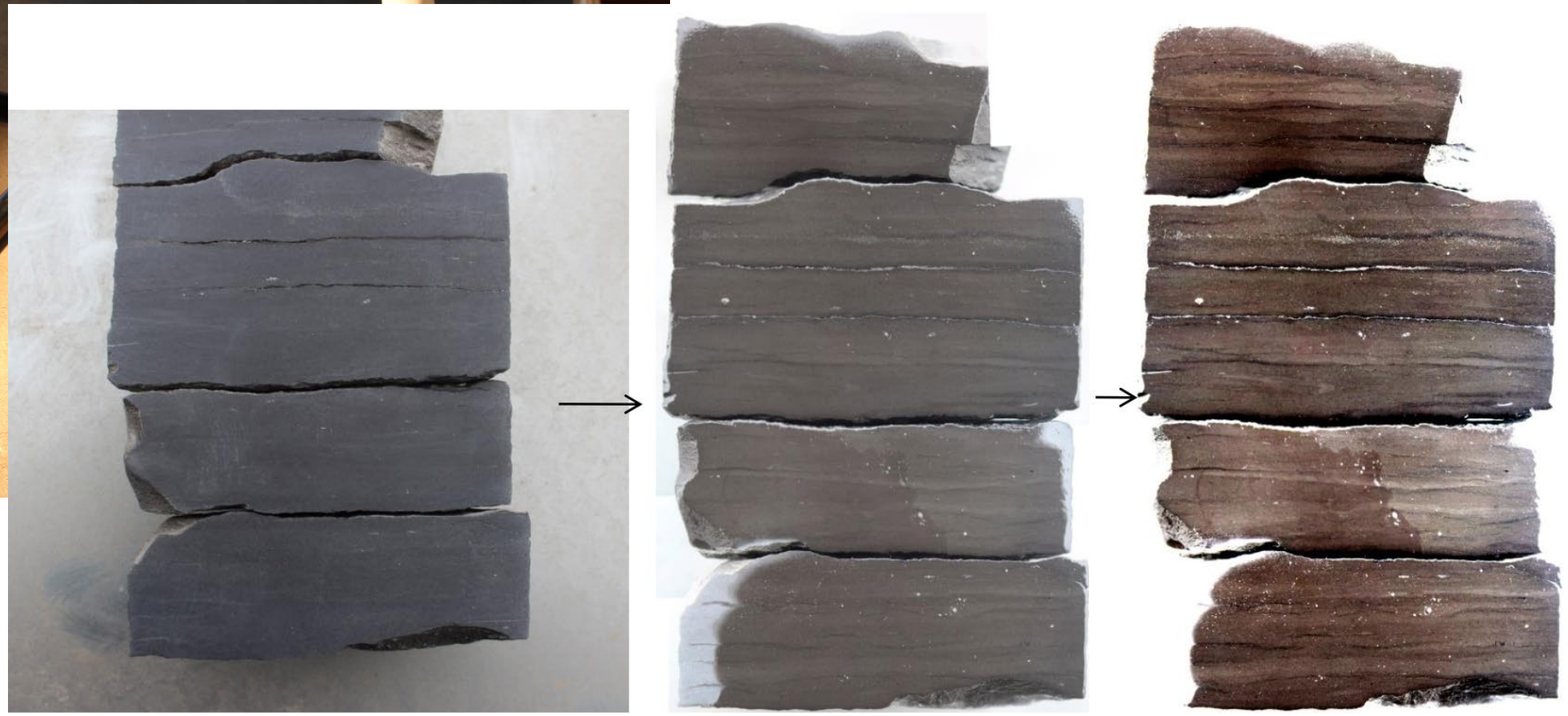

Published data

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Sedimentology

Contents lists available at ScienceDirect
Sedimentary Geology
journal homepage: www.elsevier.com/locate/sedgeo

Bottomset and foreset sedimentary processes in the mixed carbonate-siliciclastic Upper Jurassic-Lower Cretaceous Vaca Muerta Formation, Picún Leufú Area, Argentina

SEDIMENTOLOGY
the journal of the International Association of Sedimentologists
Sedimentology (2021) **68**, 2732–2764 doi: 10.1111/sed.12872

The Vaca Muerta transgression (Upper Jurassic), Neuquén Basin, Argentina: Insights into the evolution and timing of aeolian–marine transitions

Contents lists available at ScienceDirect
Marine and Petroleum Geology
journal homepage: www.elsevier.com/locate/marpetgeo

Organic-rich, fine-grained contourites in an epicontinental basin: The Upper Jurassic-Lower Cretaceous Vaca Muerta Formation, Argentina

JGS
Research article *Journal of the Geological Society*
https://doi.org/10.1144/jgs2022-055 | Vol. 180 | 2023 | jgs2022-055

Basin circulation affecting sediment partitioning in a fine-grained carbonate–siliciclastic, subaqueous clinoform: the Upper Jurassic–Lower Cretaceous Vaca Muerta Formation, Neuquén Basin, Argentina

Ichnology

PALAIOS
Emphasizing the impact of life on Earth's history
PALAIOS, 2022, v. 37, 201–218
Research Article
DOI: http://dx.doi.org/10.2110/palo.2020.028
1926 SEPM Society for Sedimentary Geology

ICHNOLOGY OF MUDDY SHALLOW-WATER CONTOURITES FROM THE UPPER JURASSIC–LOWER CRETACEOUS VACA MUERTA FORMATION, ARGENTINA: IMPLICATIONS FOR TRACE-FOSSIL MODELS

Contents lists available at ScienceDirect
Sedimentary Geology
journal homepage: www.elsevier.com/locate/sedgeo

Environmental controls on trace-fossil distribution in the Upper Jurassic-Lower Cretaceous Vaca Muerta Formation (Argentina): Implications for the analysis of fine-grained depositional systems

Lethaia
AN INTERNATIONAL JOURNAL OF PALAEONTOLOGY AND STRATIGRAPHY

An unusual oxygen-deficient ichnofauna from the fine-grained Vaca Muerta Formation: implications for the ichnofacies model

Facies associations

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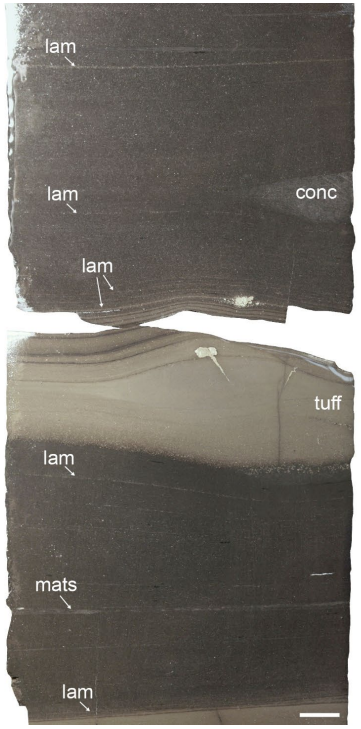
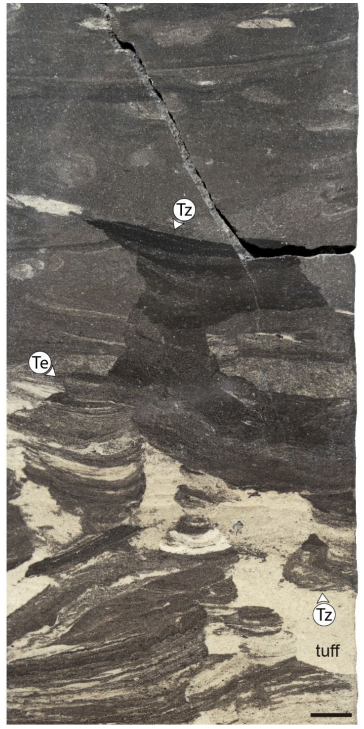
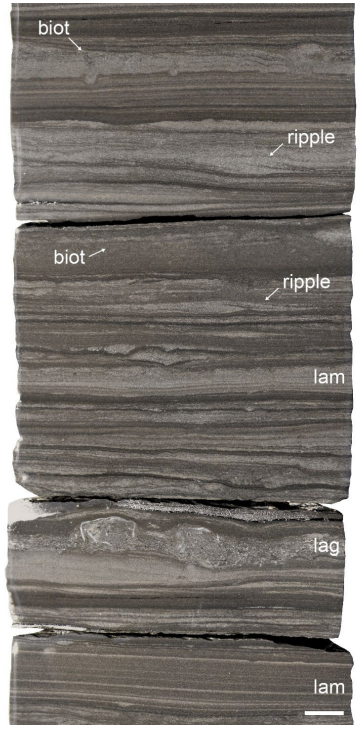
Marginal marine



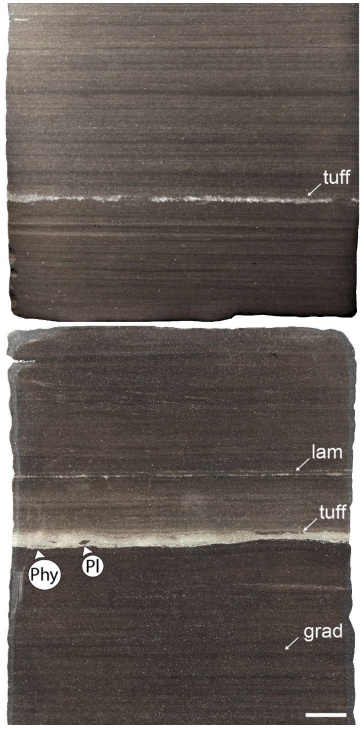
Starved to anoxic basin



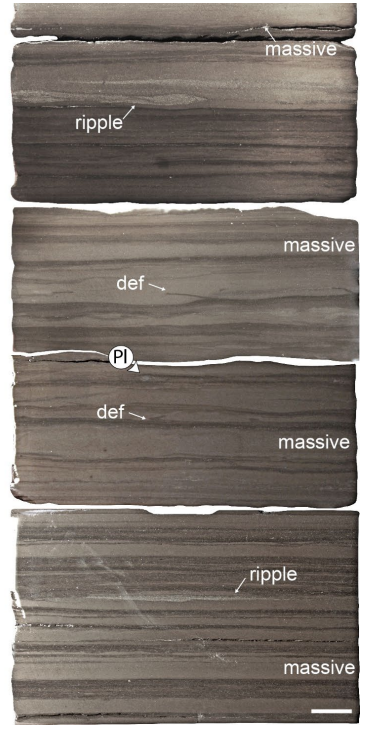
Dysoxic to oxic basin



Contourite drift



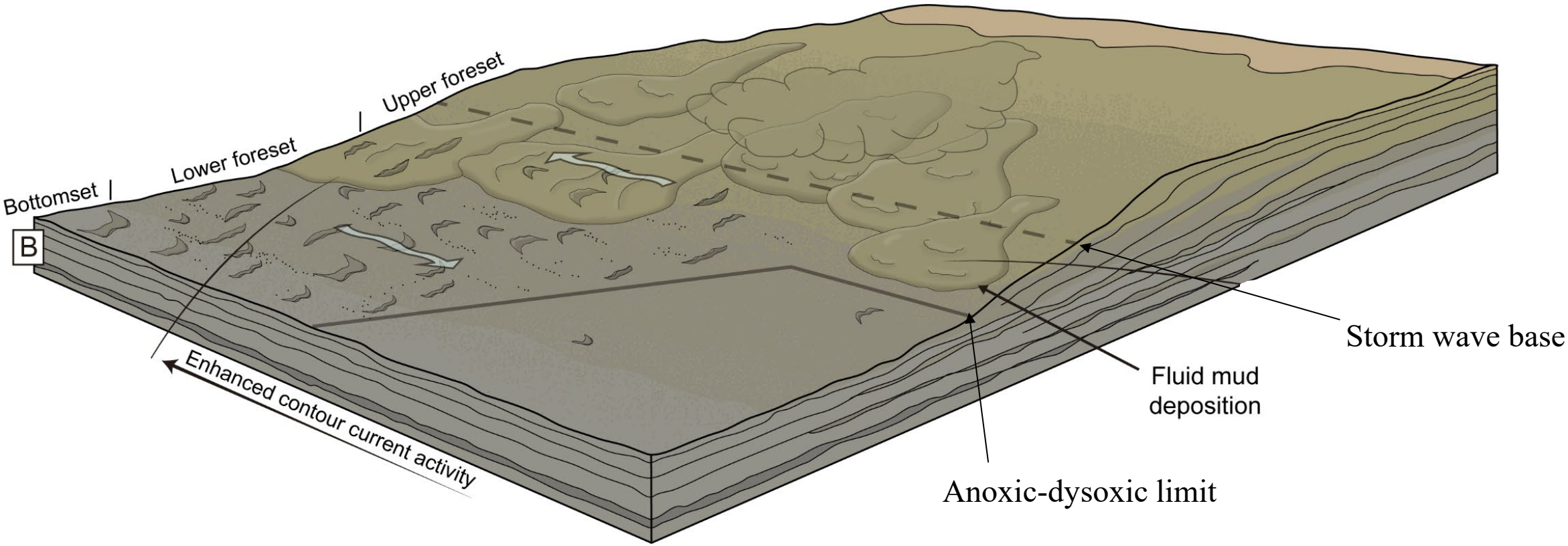
Slope



Fluid mud-rich slope

Outer ramp

Depositional model



Paz *et al.* (2023)

Ichnology: indistinct bioturbation structures

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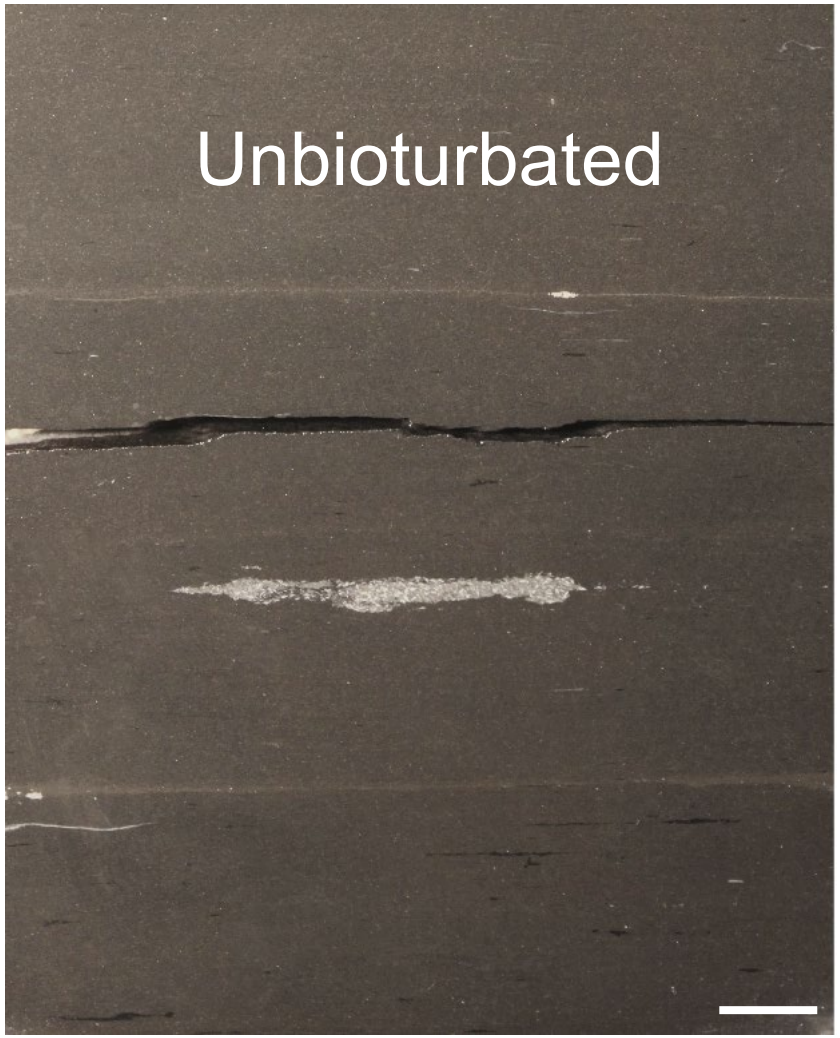
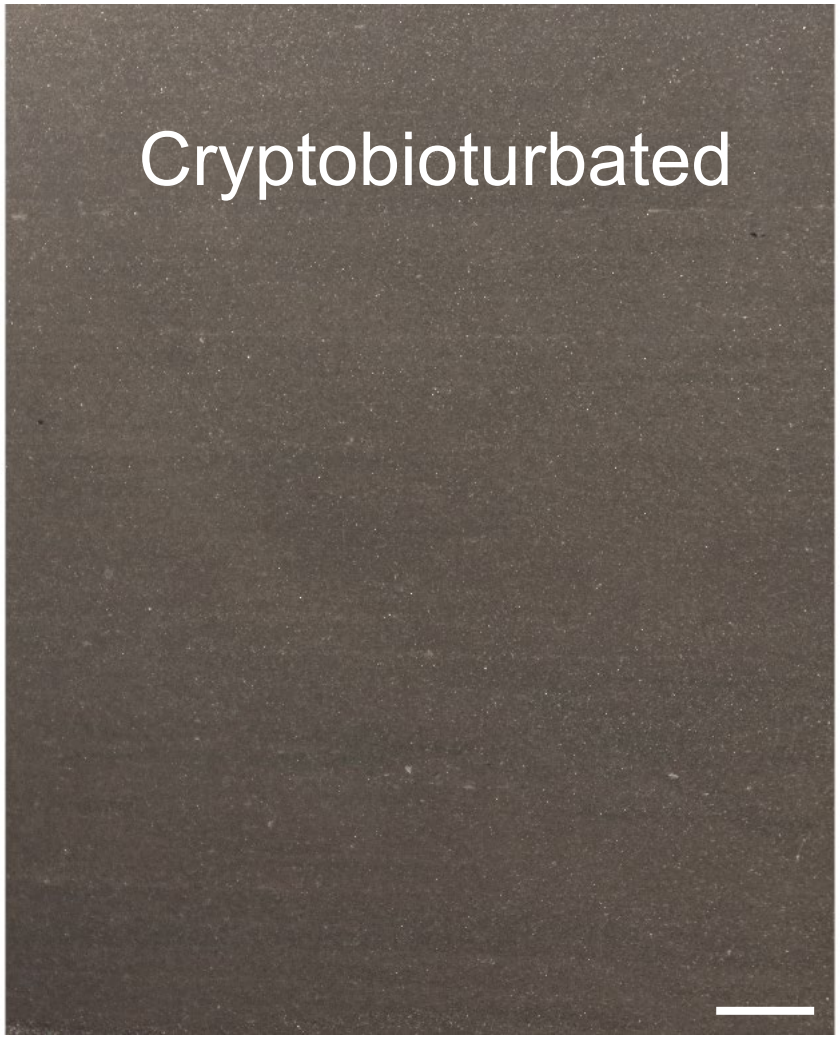
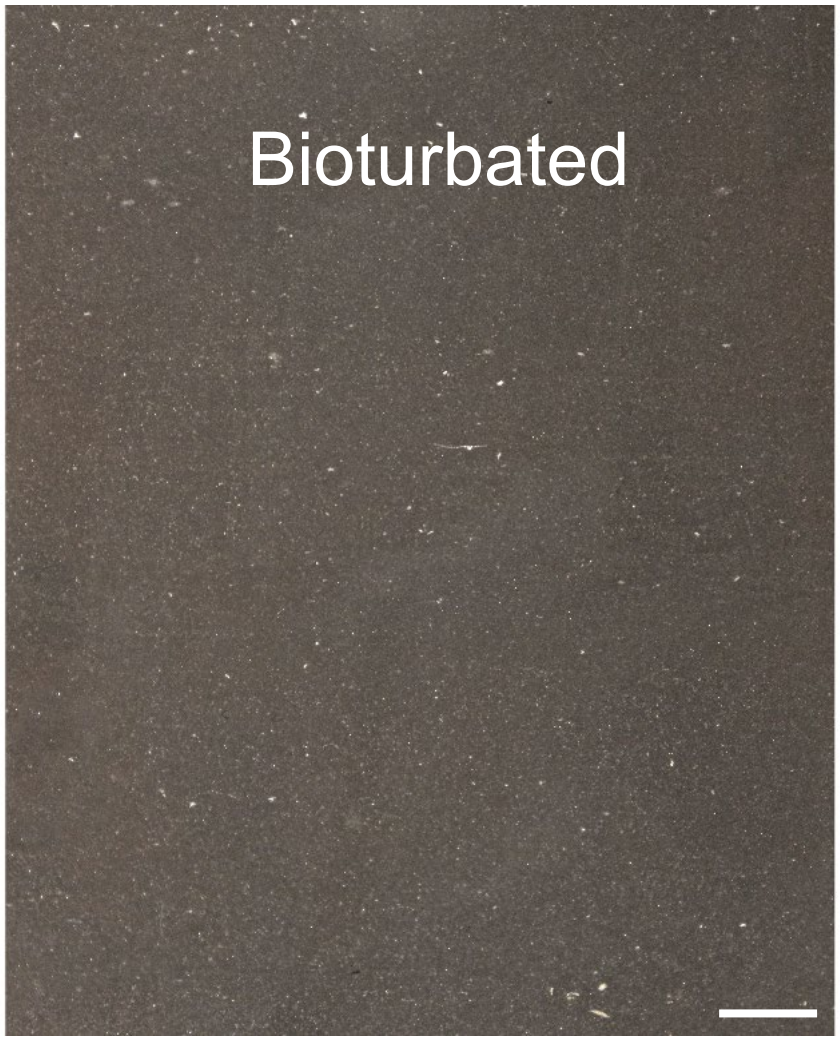
Parallel-laminated fabric
<1 mm continuous laminae,
with sharp contacts

Irregular-laminated fabric
1-10 mm discontinuous laminae,
with gradational contacts

Massive fabric
No laminae







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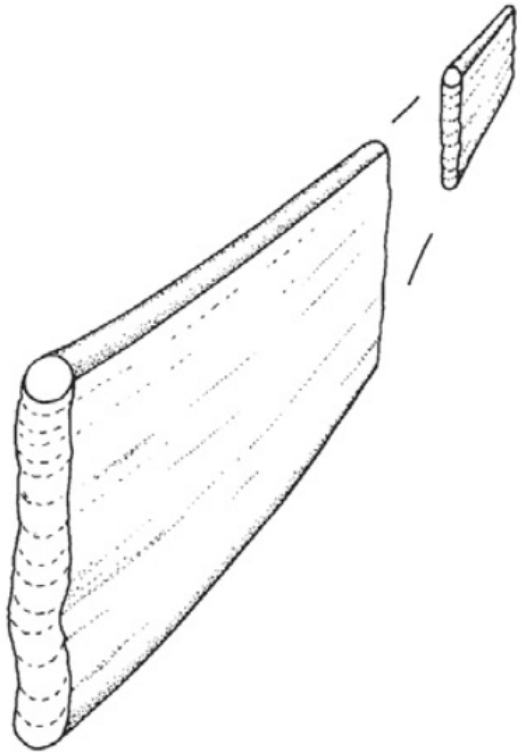
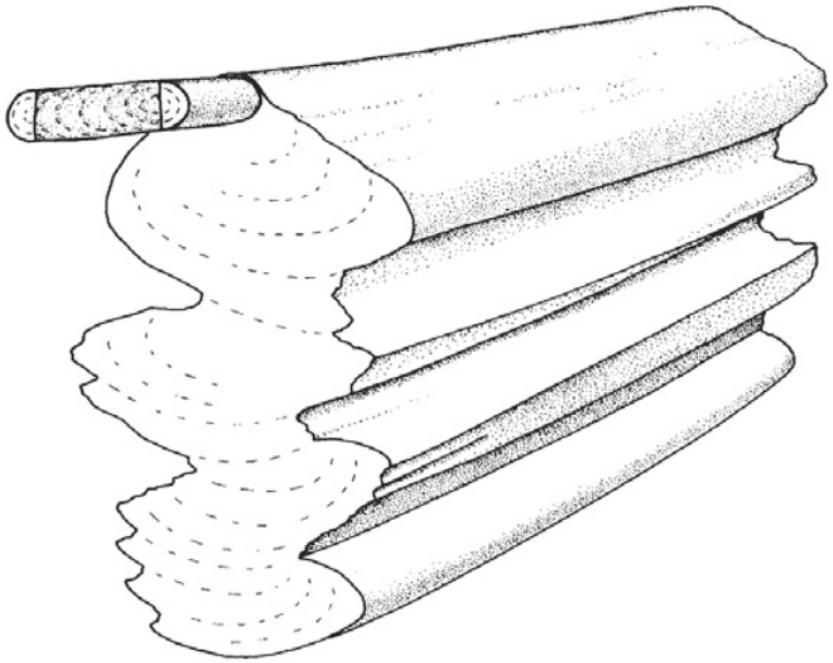


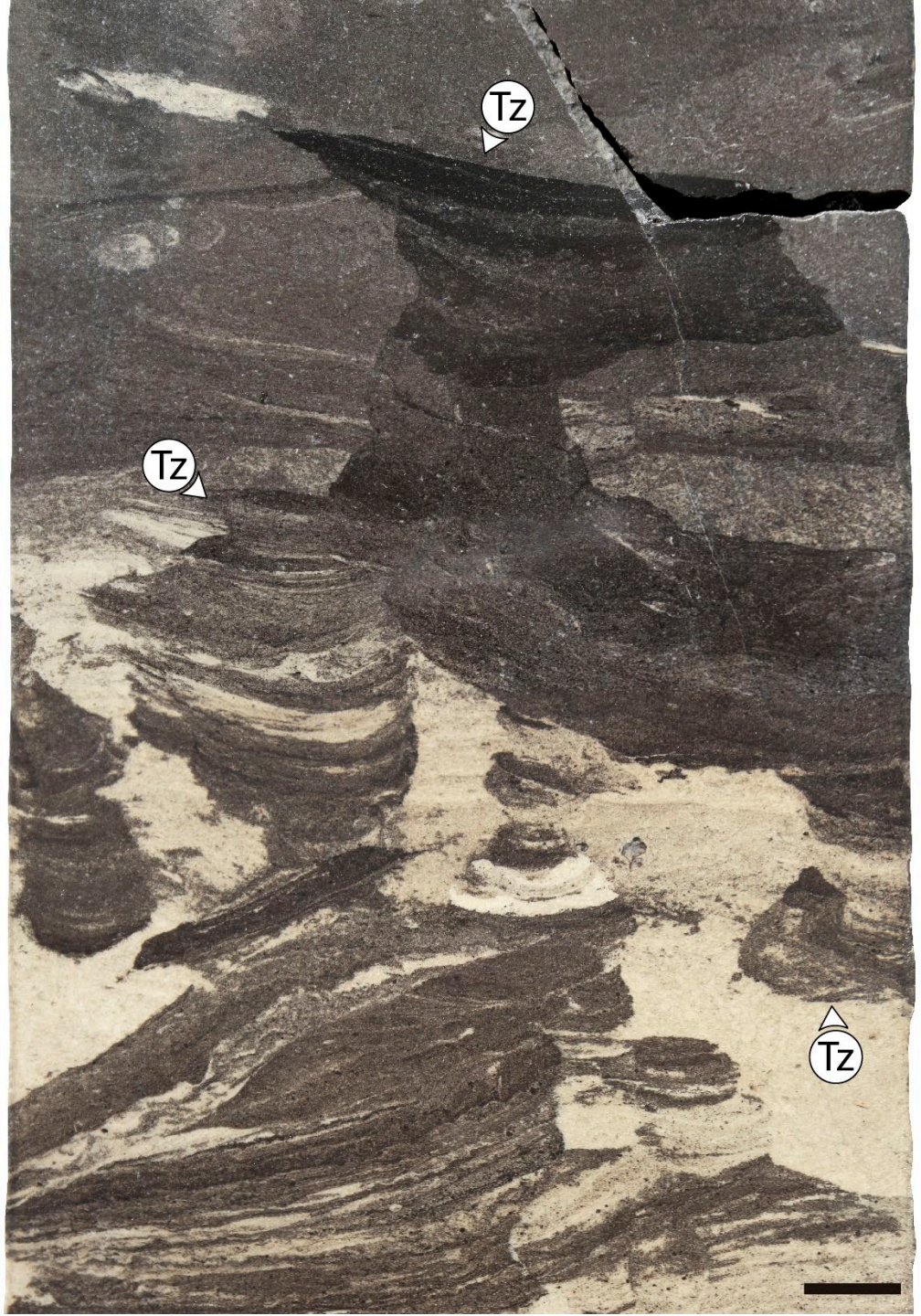
Teichichnus rectus

Frey and Bromley (1985)

Ichnology



Frey and Bromley (1985)



Teichichnus zigzag

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Ichnology

Alcyonidiopsis isp. / *Alcyonidiopsis longobardiae*

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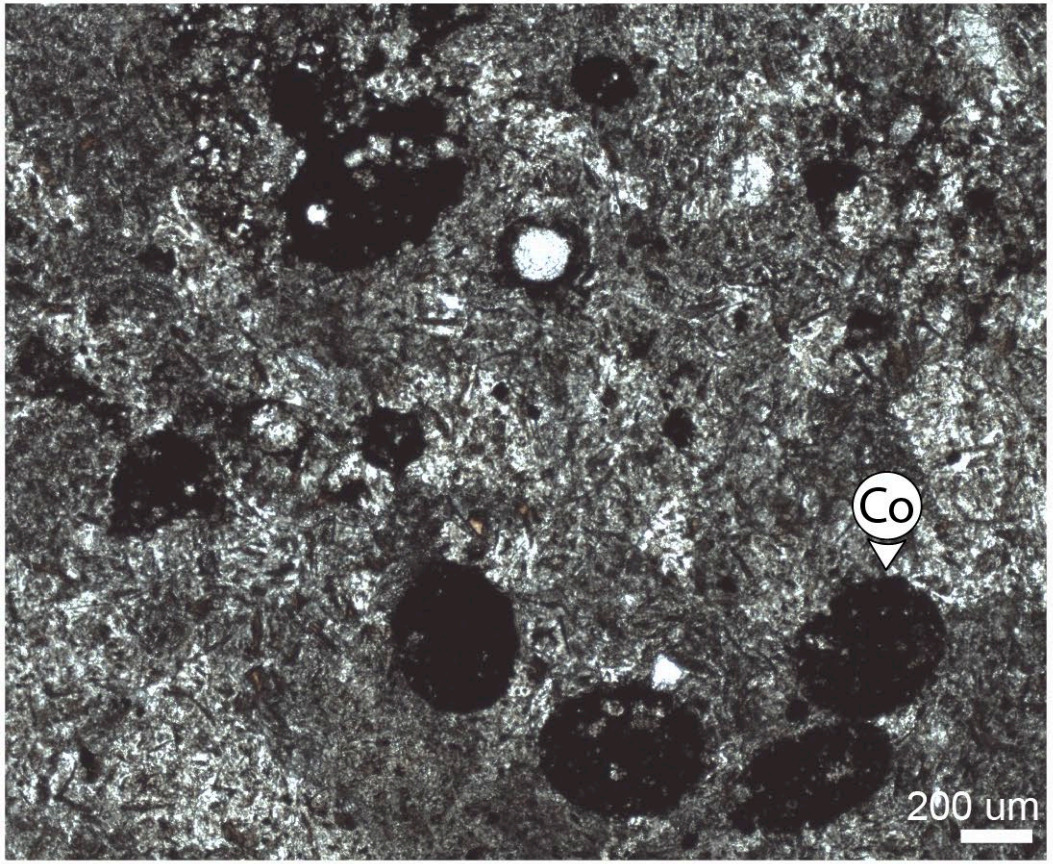
Alcyonidiopsis isp. / *Alcyonidiopsis longobardiae*



Coprulus oblongus (pellet)

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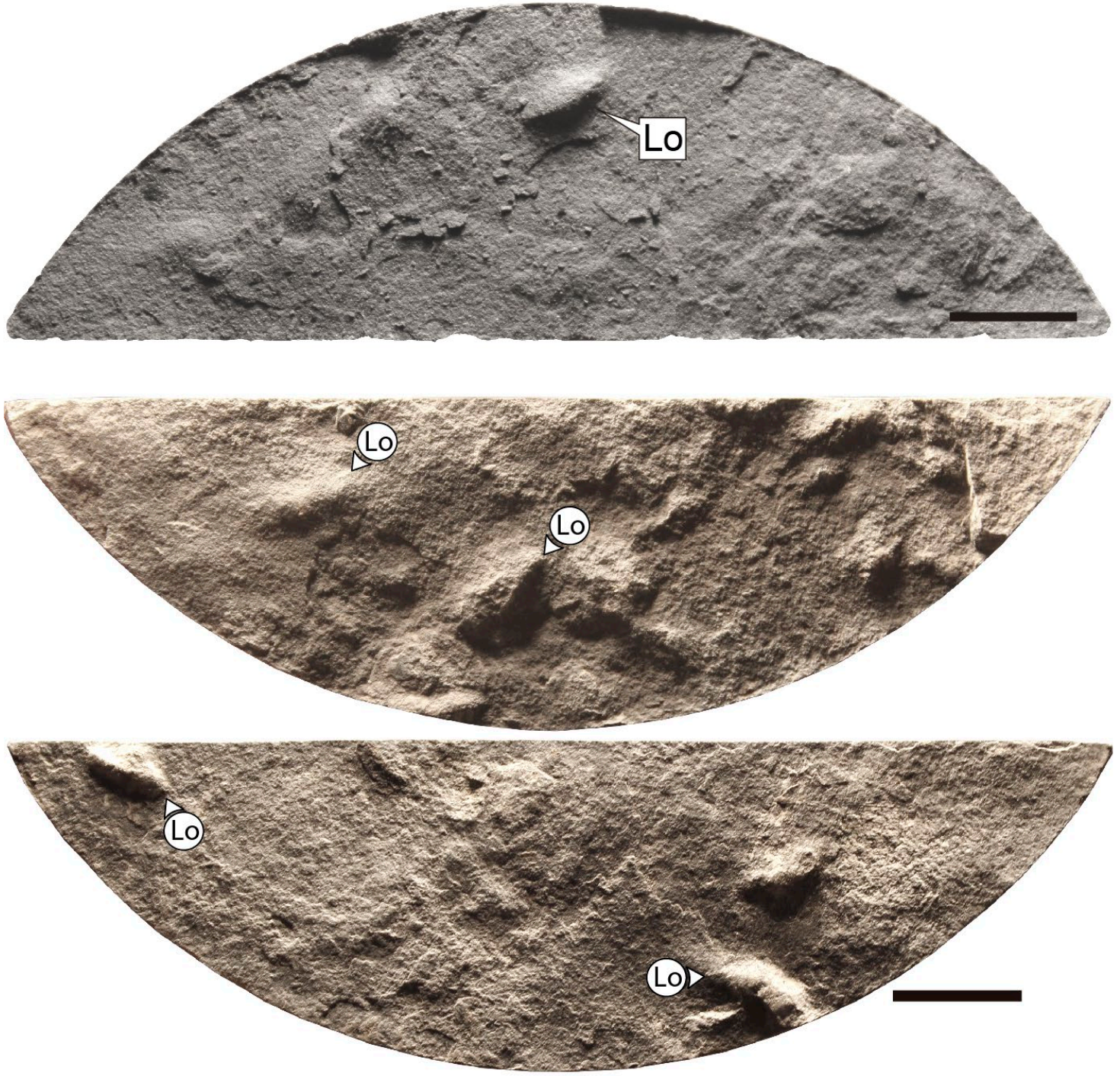

Lockeia siliquaria

Anaerobic intervals

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Oxygen-related ichnocoenosis 1

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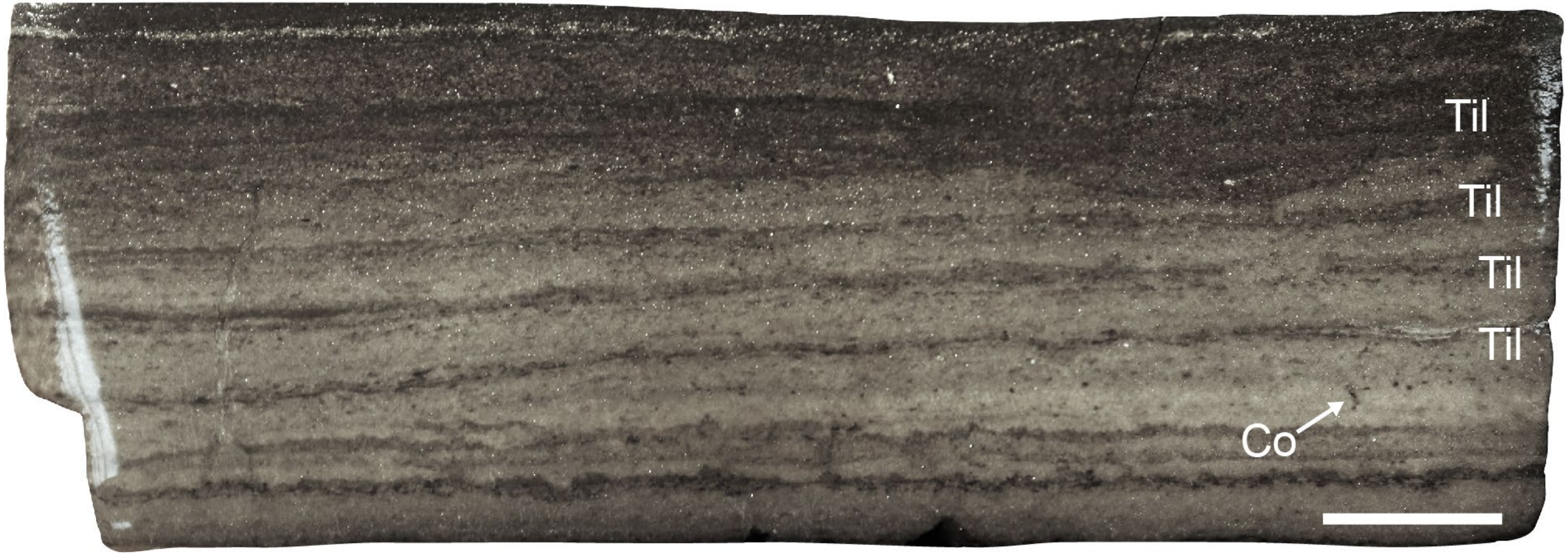

Oxygen-related ichnocoenosis 2

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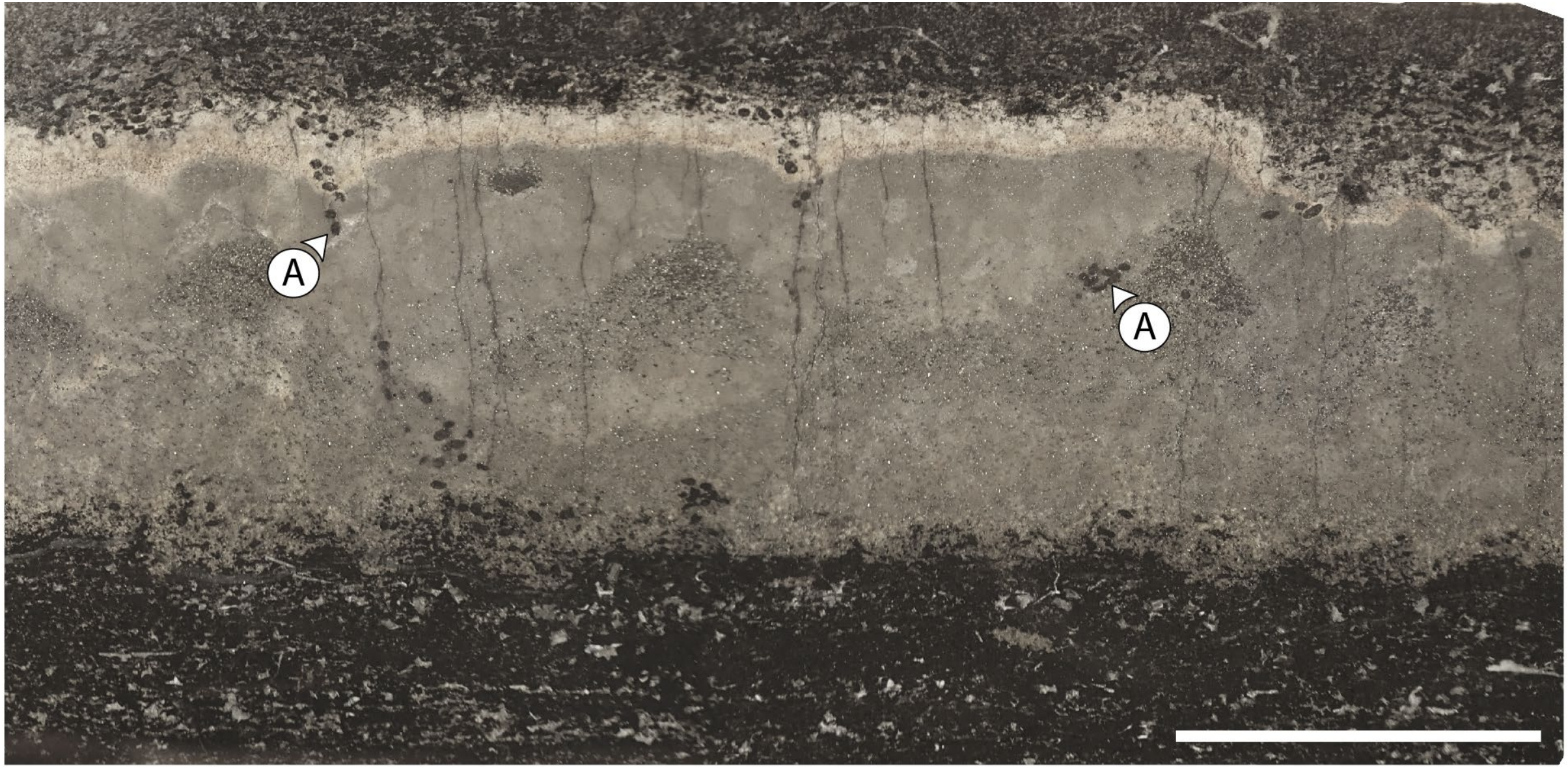
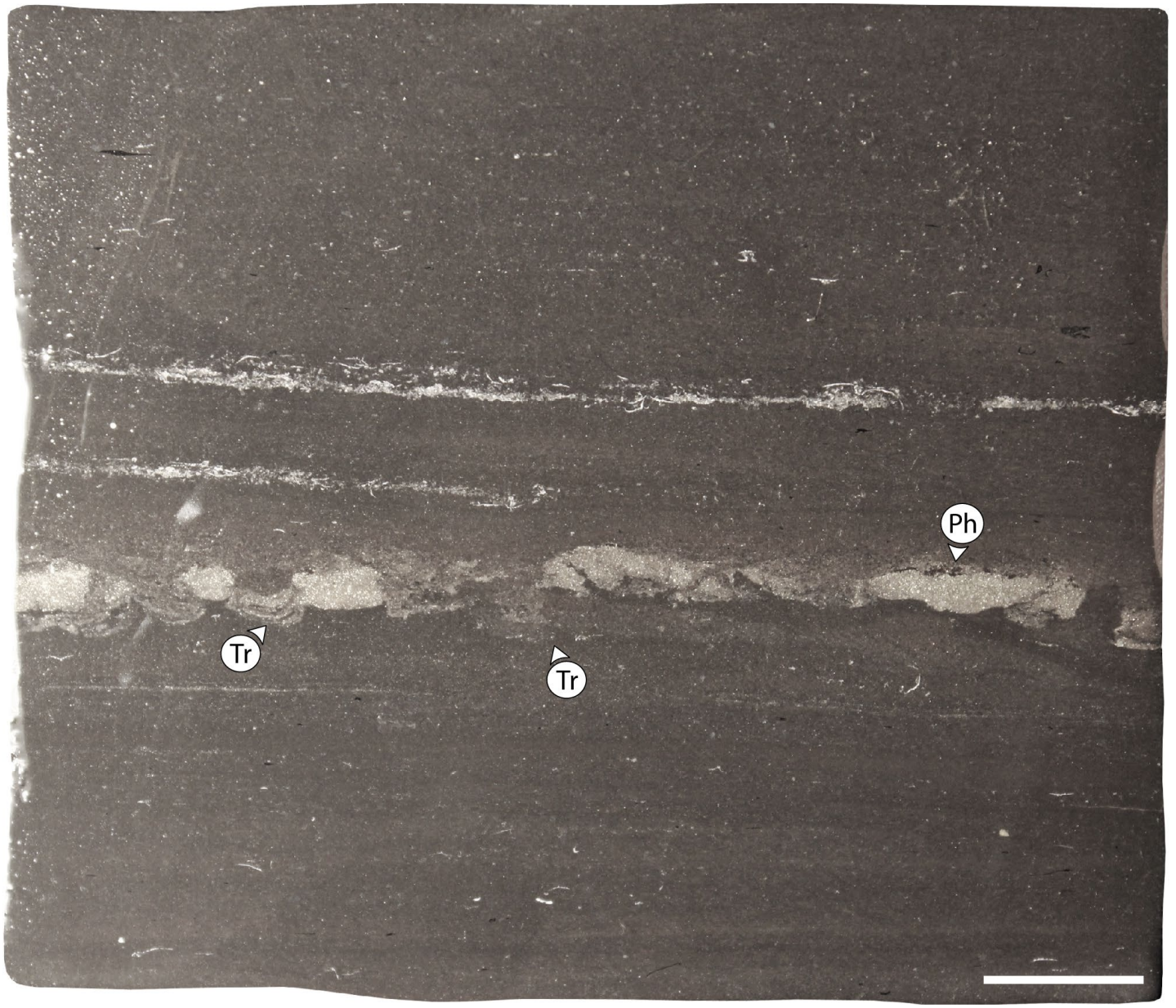


Oxygen-related ichnocoenosis 3



Oxygen-related ichnocoenosis 4

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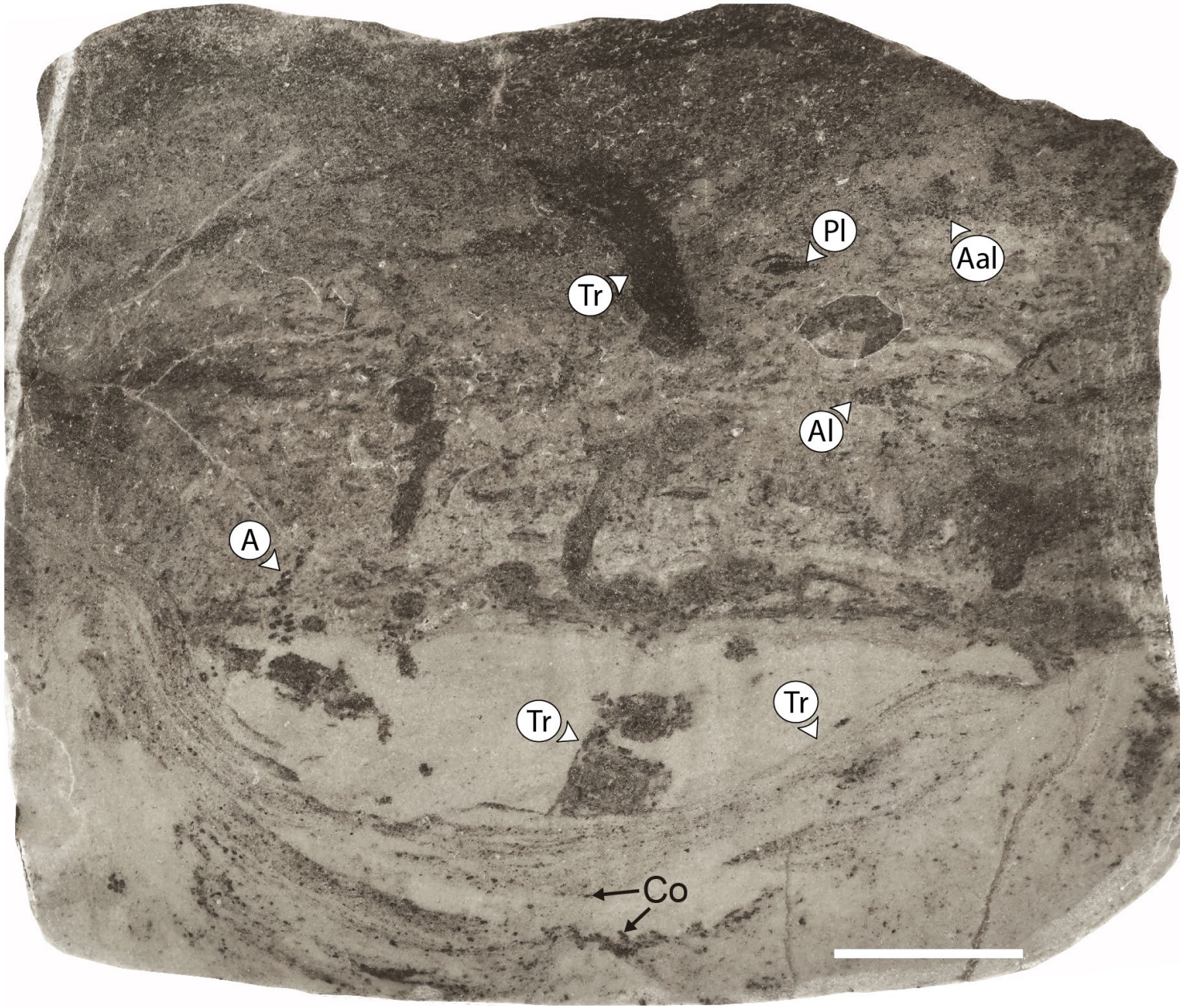
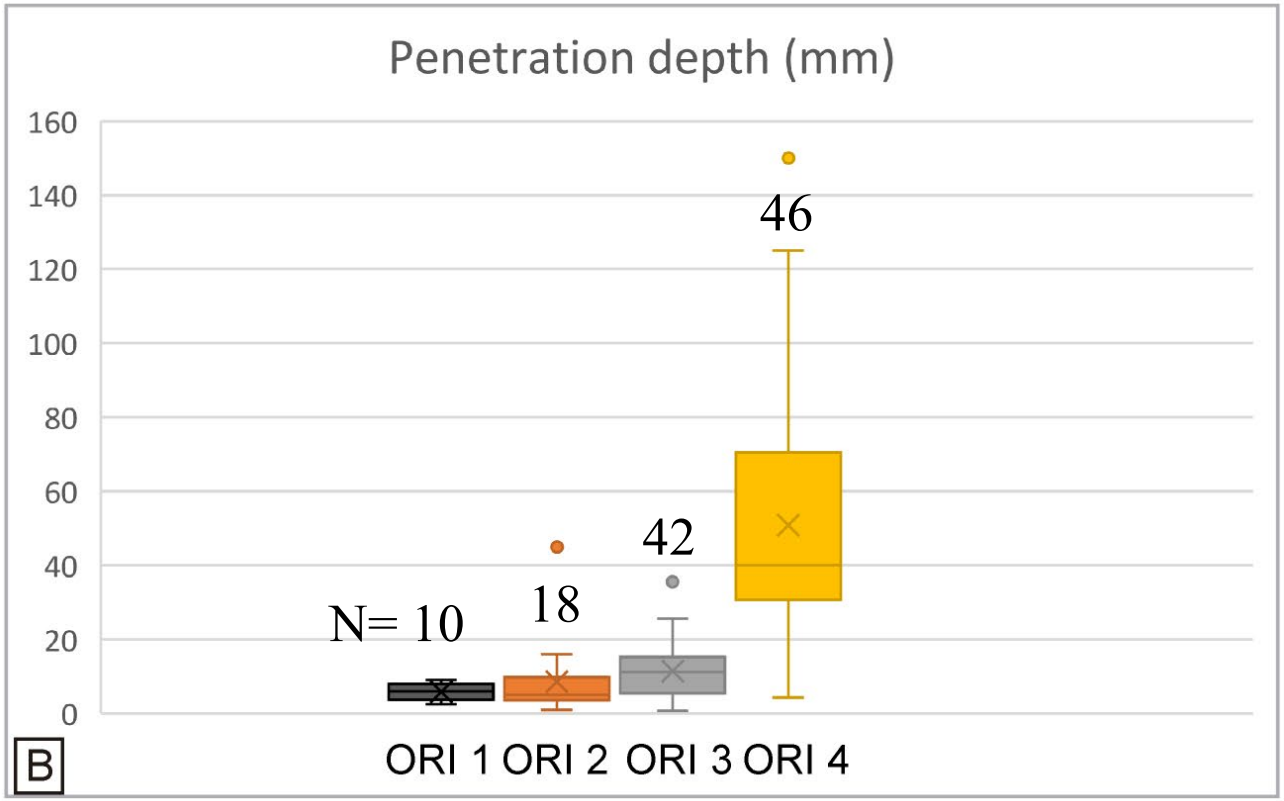
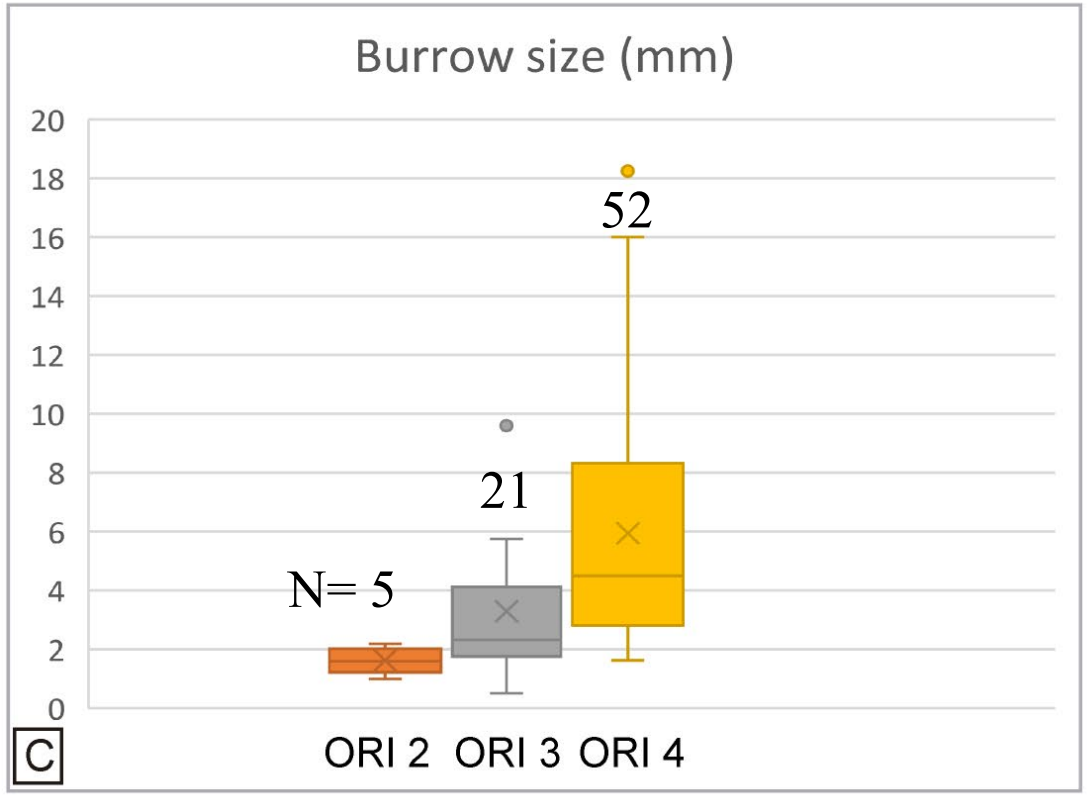


Bioturbation metrics





Palaeophycus heberti-Crininicaminus isp. ichnocoenosis

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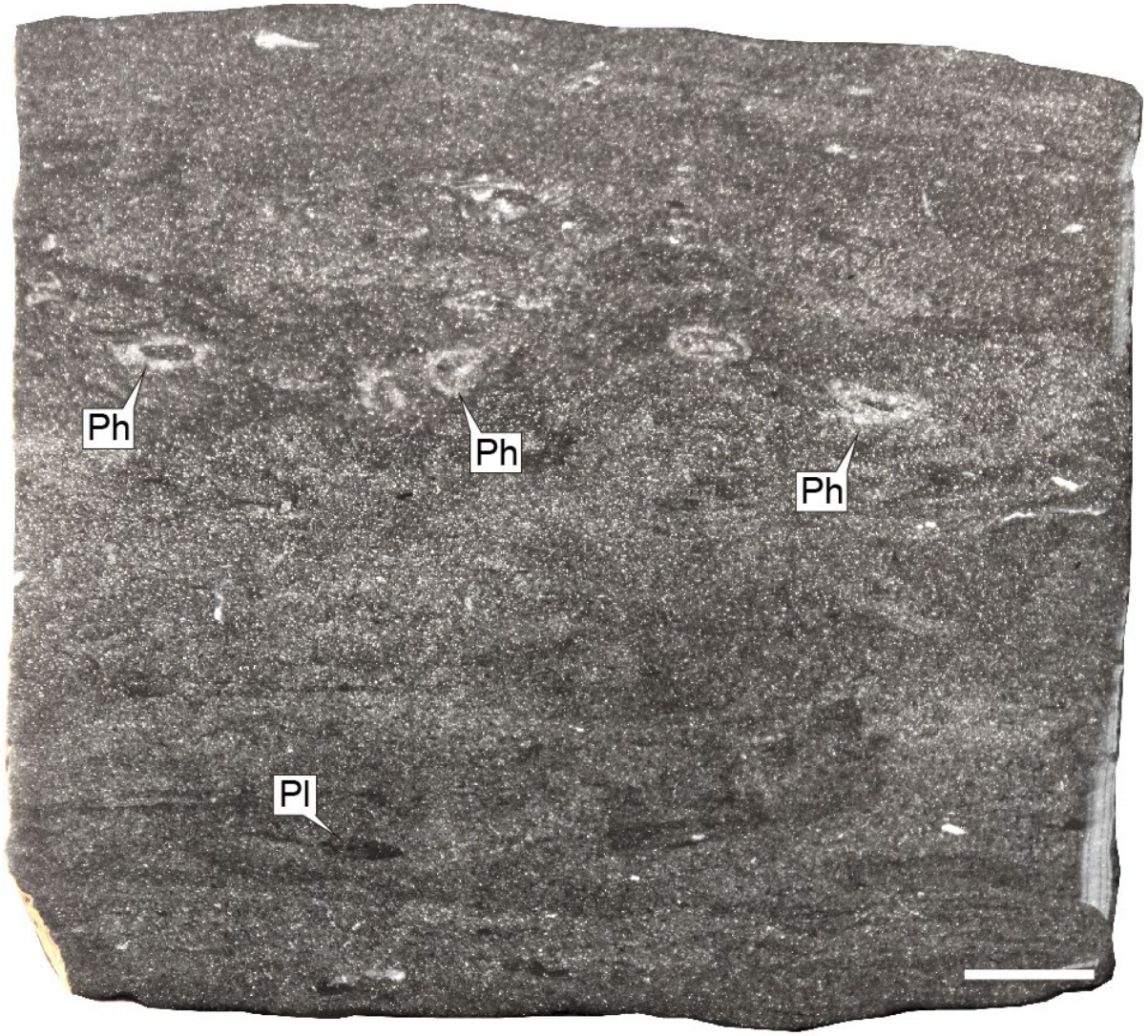

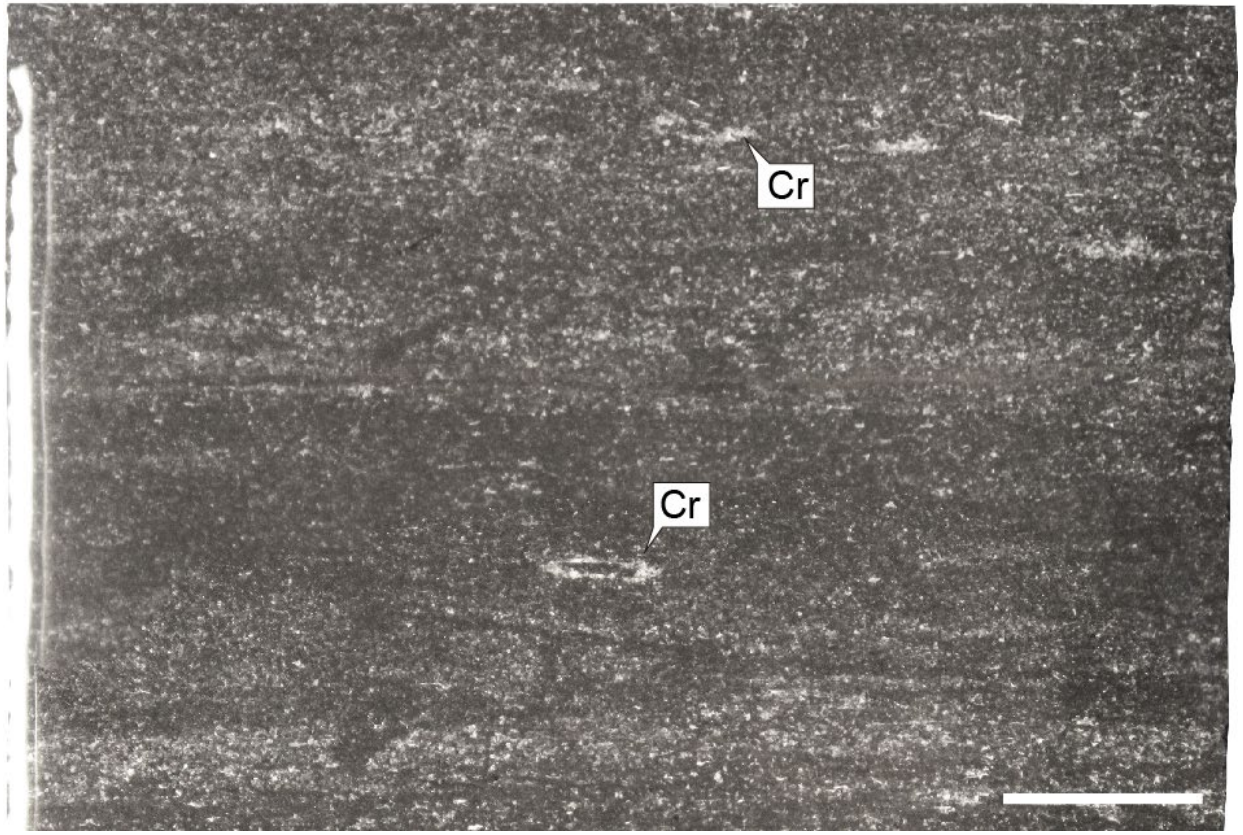

Nereites isp. ichnocoenosis

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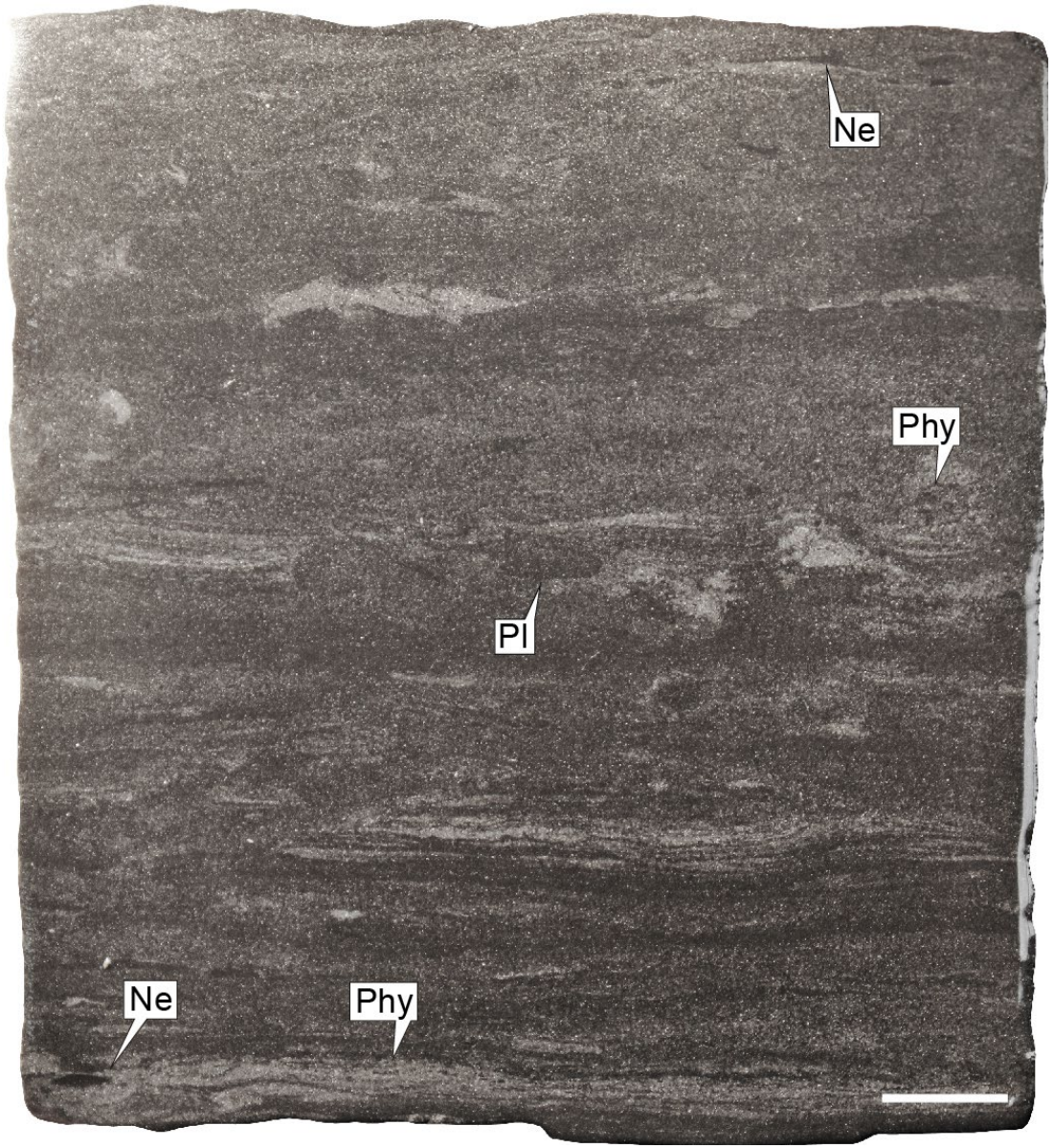
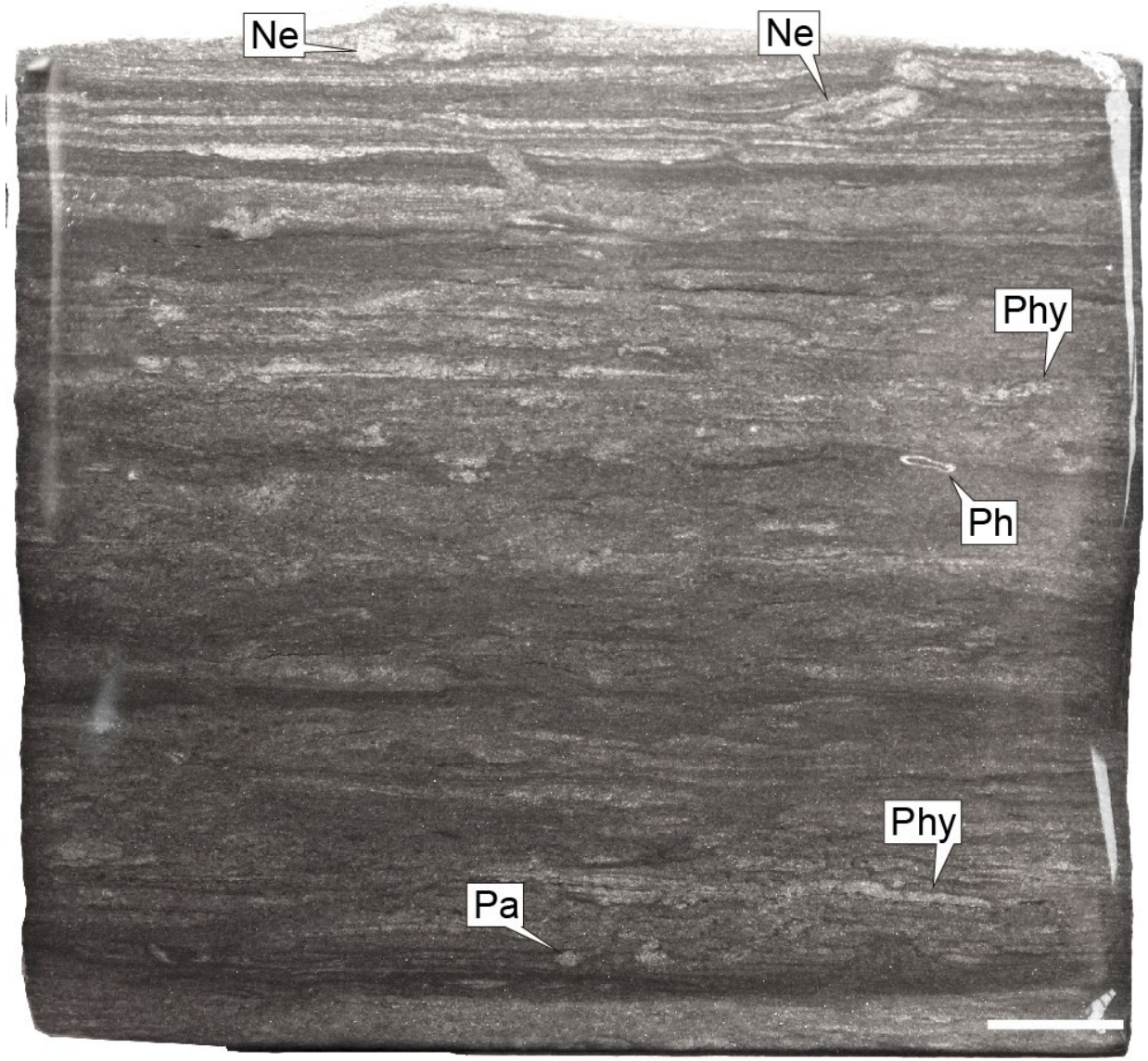
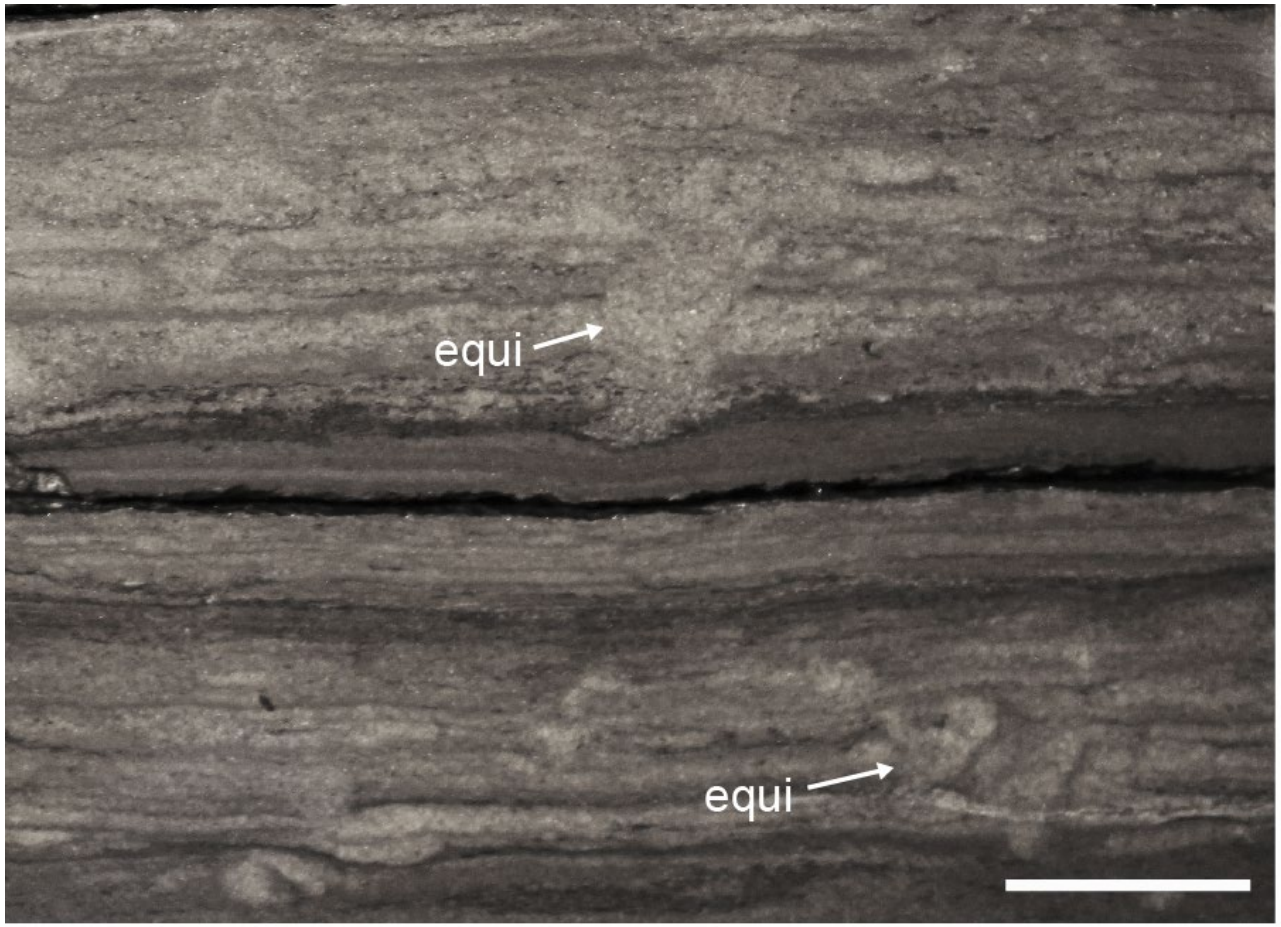
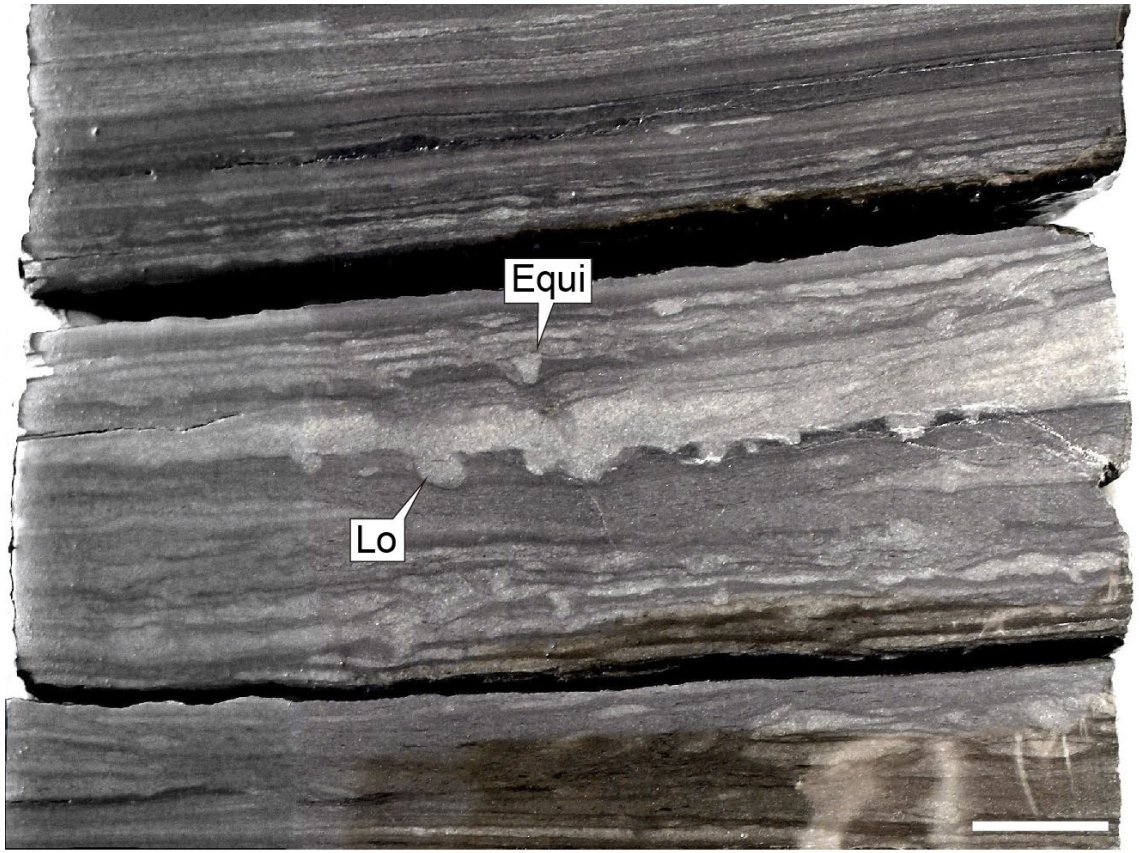
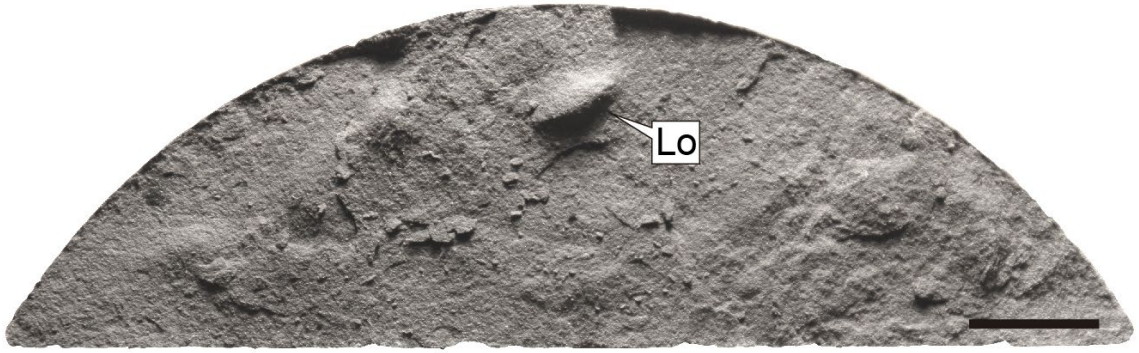




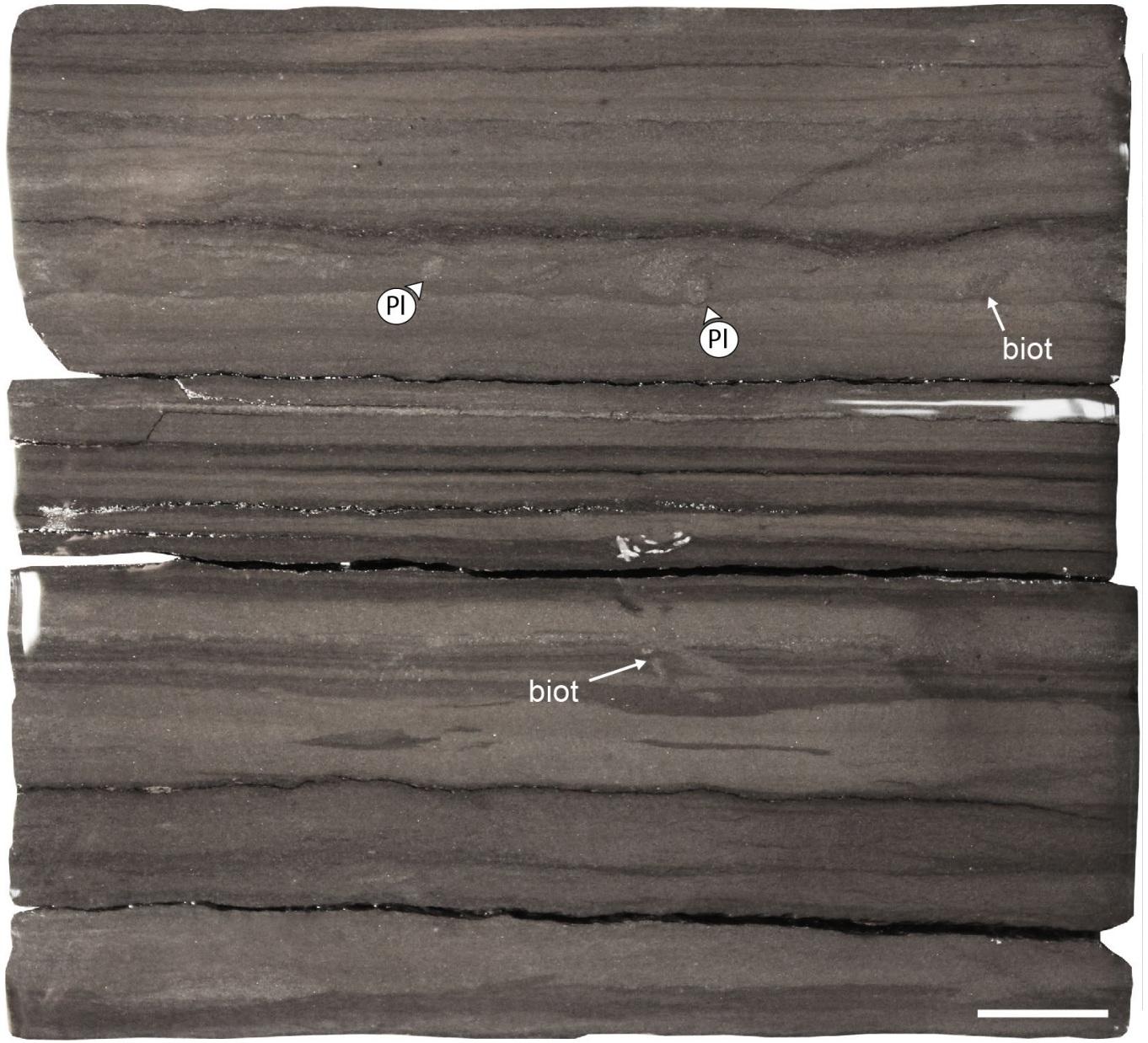
Equilibrichnia-Fugichnia ichnocoenosis



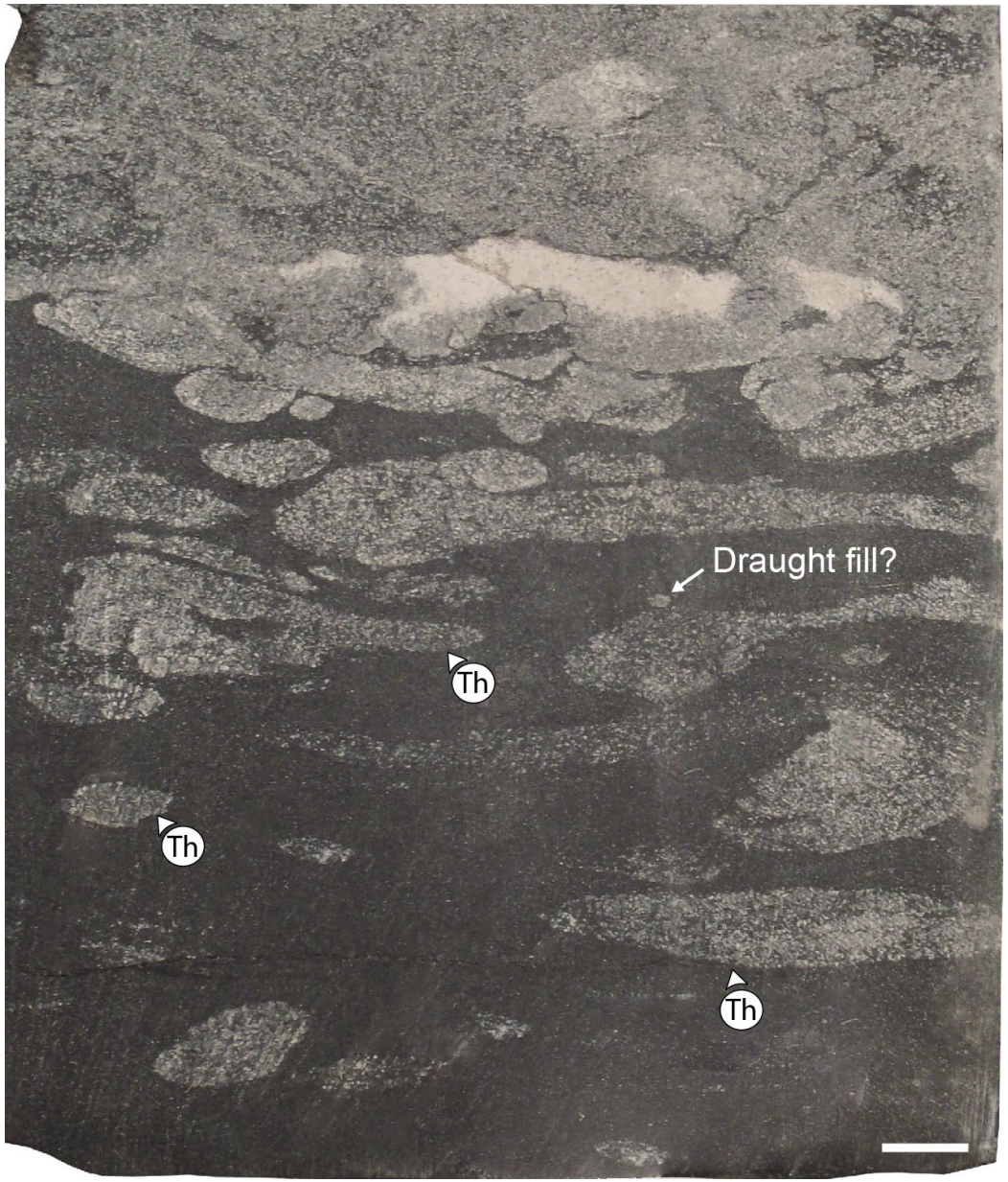




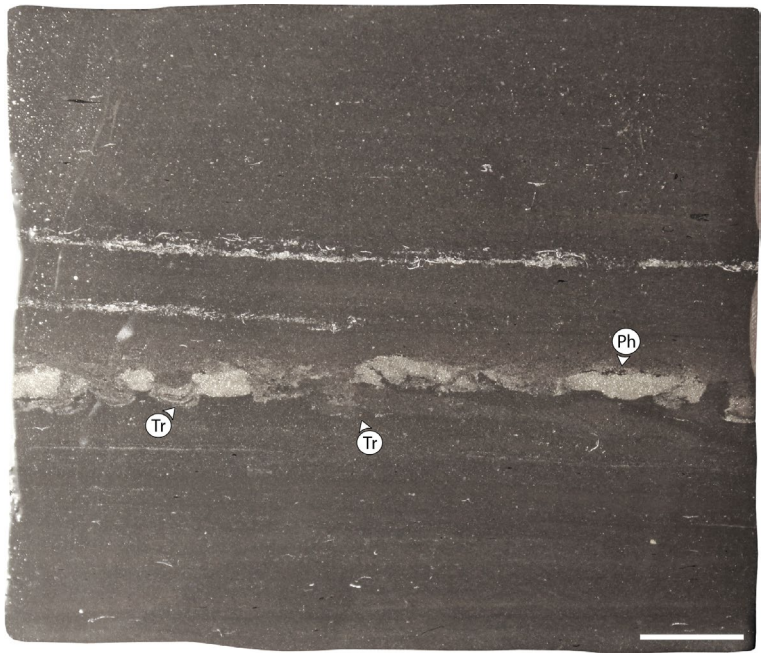
Planolites isp. ichnocoenosis

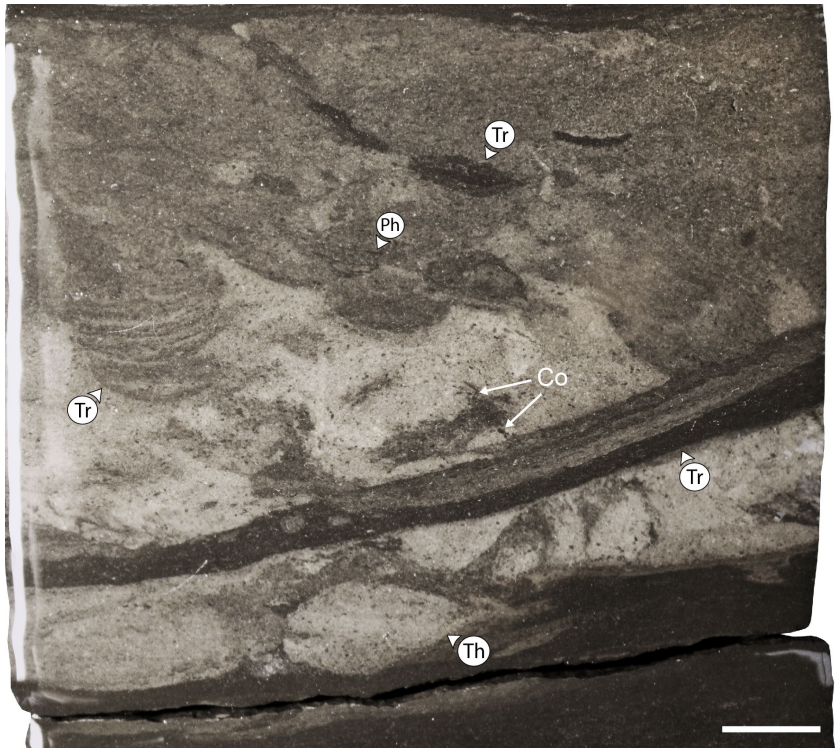


Thalassinoides isp. ichnocoenosis



Oxygen control on trace fossils





Palaeoenvironmental controls on trace fossils

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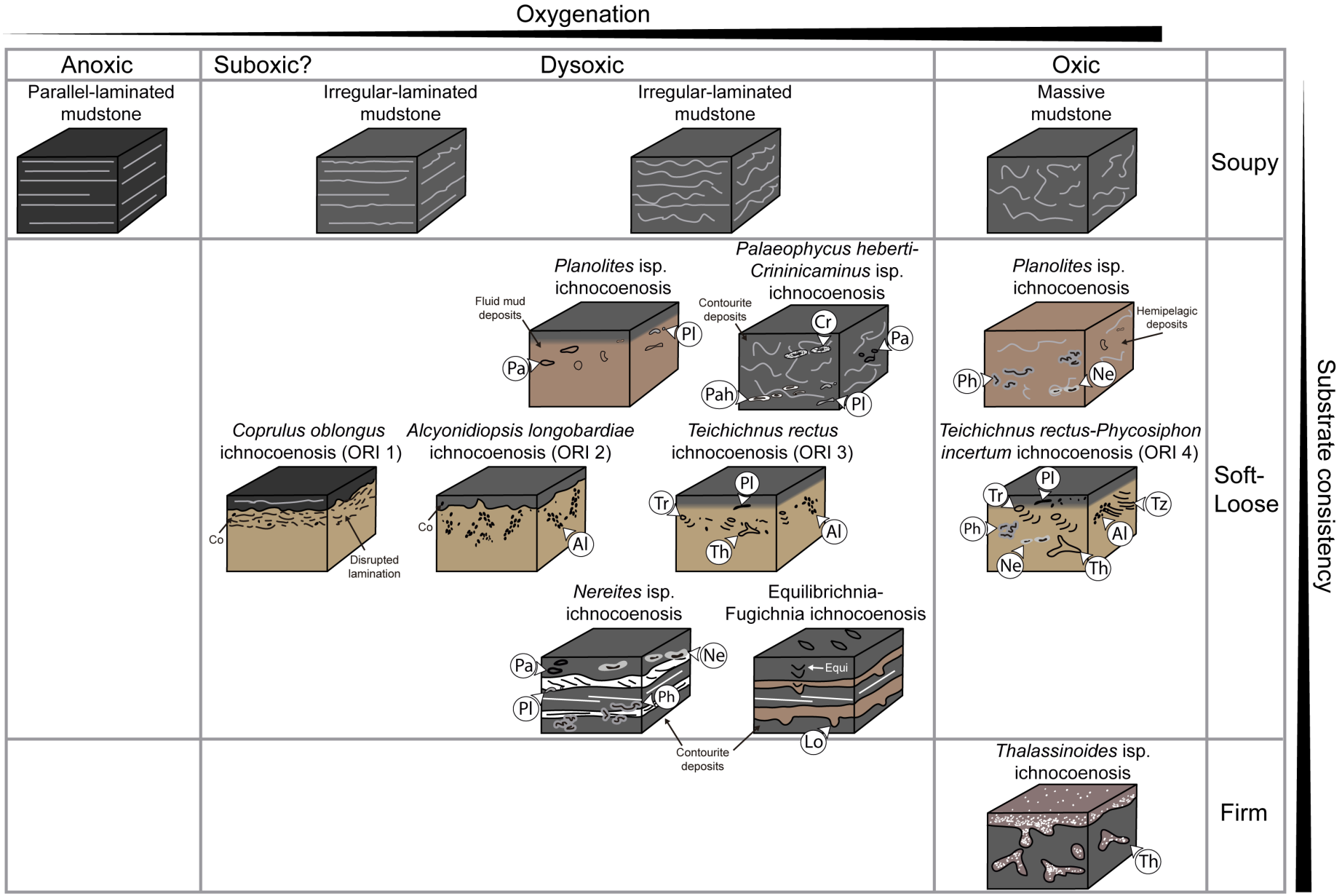

Unusual trace fossils

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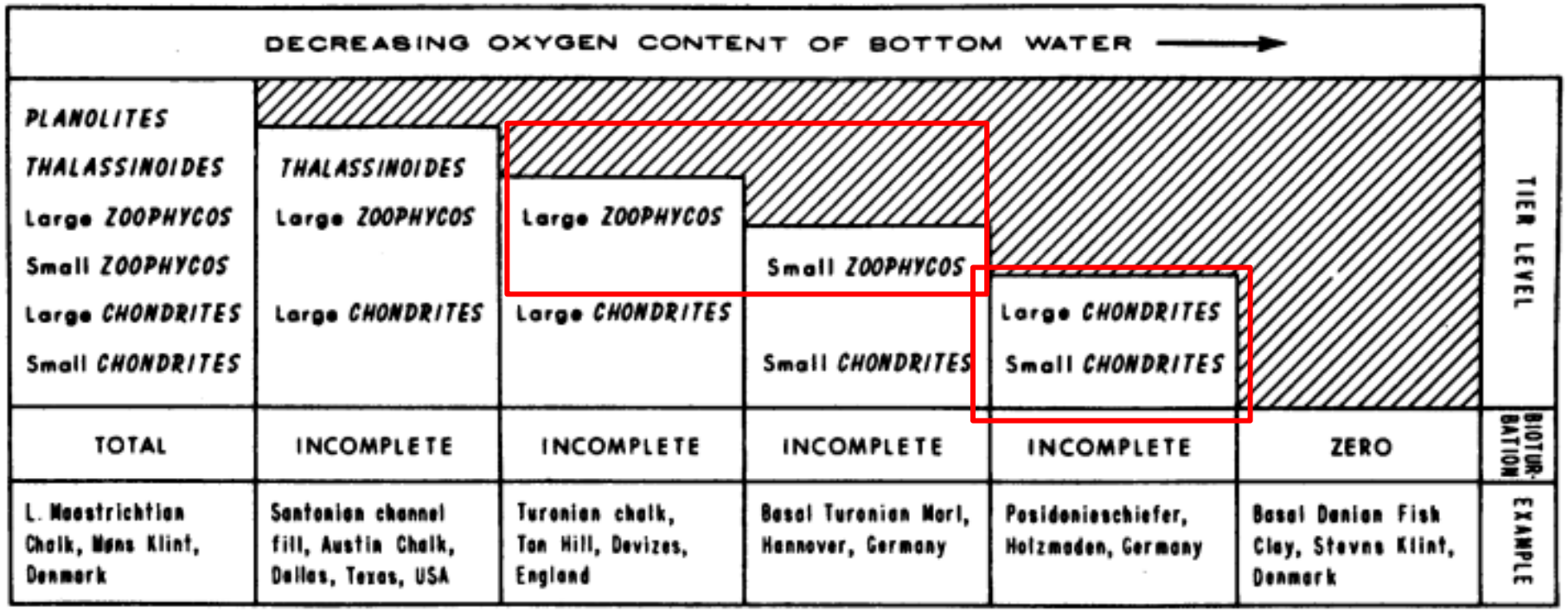
***Chondrites*: A Trace Fossil Indicator of Anoxia in Sediments**

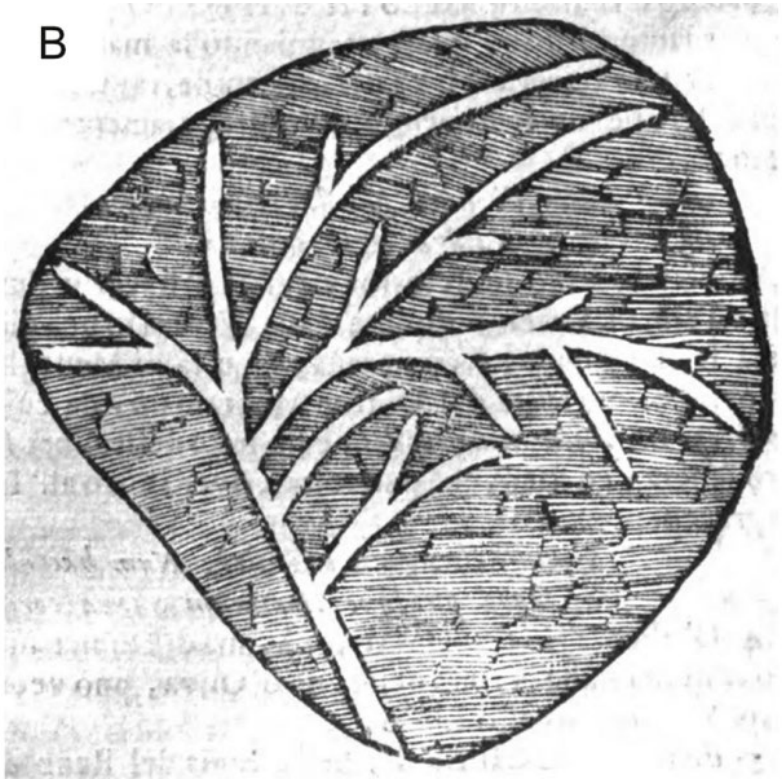
SCIENCE, VOL. 224 (1984)

RICHARD G. BROMLEY
Institute of Historical Geology and Palaeontology, 1350 Copenhagen K, Denmark
A. A. EKDALE
Department of Geology and Geophysics, University of Utah, Salt Lake City 84112



DECREASING OXYGEN CONTENT OF BOTTOM WATER →						
PLANOLITES THALASSINOIDES Large ZOOPHYCOS Small ZOOPHYCOS Large CHONDRITES Small CHONDRITES	THALASSINOIDES Large ZOOPHYCOS Large CHONDRITES	Large ZOOPHYCOS Large CHONDRITES	Small ZOOPHYCOS Small CHONDRITES	Large CHONDRITES Small CHONDRITES		TIER LEVEL
TOTAL	INCOMPLETE	INCOMPLETE	INCOMPLETE	INCOMPLETE	ZERO	BIOTURBATION
L. Maastrichtian Chalk, Møns Klint, Denmark	Santonian channel fill, Austin Chalk, Dallas, Texas, USA	Turonian chalk, Tan Hill, Devizes, England	Basal Turonian Marl, Hannover, Germany	Posidonienschiefer, Holzmaden, Germany	Basal Danian Fish Clay, Stevns Klint, Denmark	EXAMPLE

Unusual trace fossils



Chondrites

Legati (1677) in Baucon *et al.* (2020)

Unusual trace fossils

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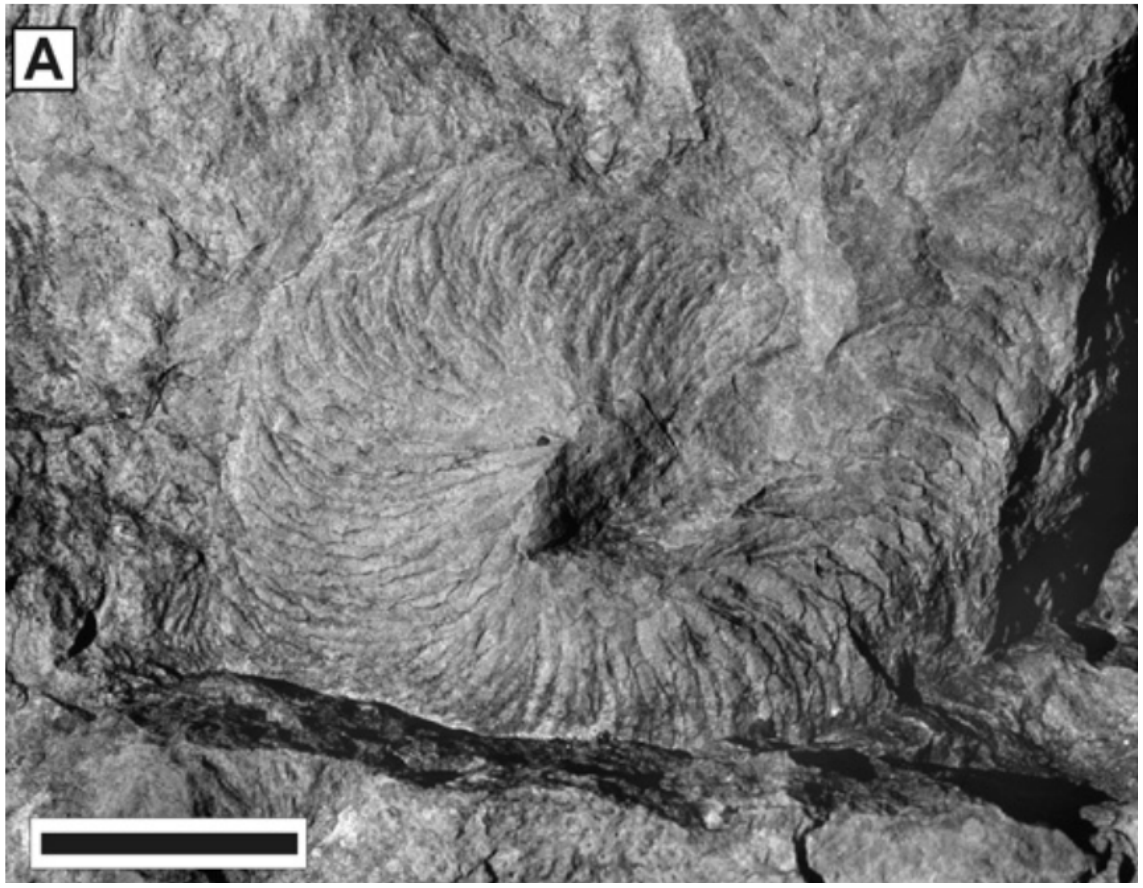
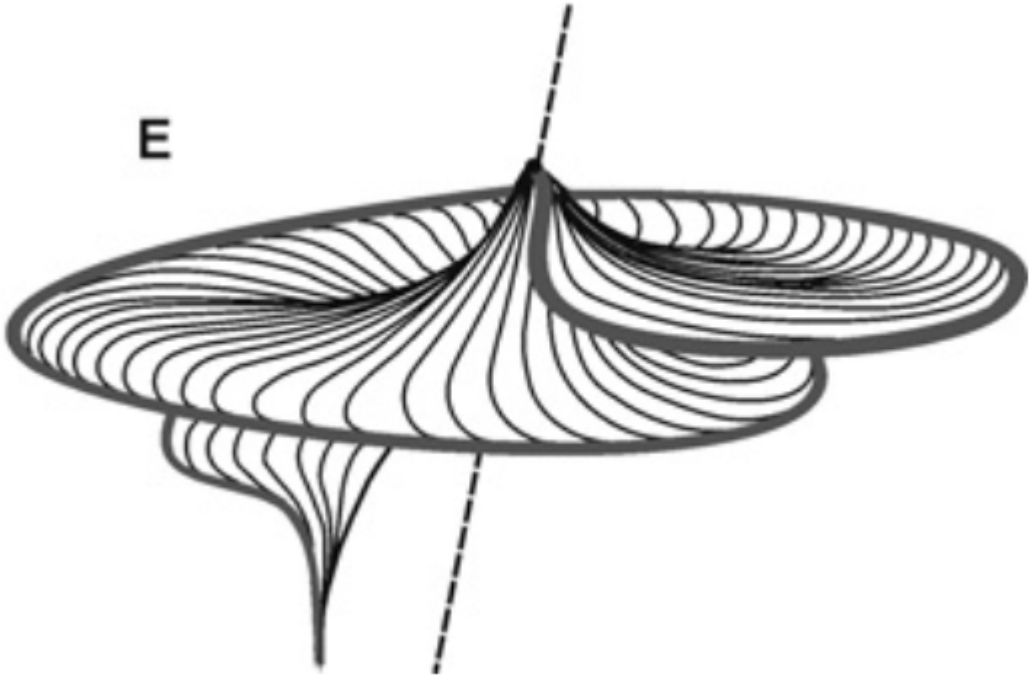
Chondrites is absent. Only 4 *Zoophycos* have been recorded (over >1000 examples of ichnocoenoses)

- High food environment with a lack of seasonality?
- Salinity?





Zoophycos

Olivero and Gaillard (2007)

Conclusions

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• The Vaca Muerta Formation shows nine ichnocoenoses and two indistinct bioturbation fabrics recording organism-sediment interactions in mudstone and tuff.

• Four ichnocoenoses (ORIs) show a change in burrow size, bioturbation depth, bioturbation index, and ichnodiversity, indicating an oxygen control on trace fossil distribution.

• All ichnocoenoses suggest a strong control of substrate consistency and/or food on trace fossils, with indistinct bioturbation being prevalent in mudstone.

• The lack of *Chondrites* and scarcity of *Zoophycos* is unusual for an organic-rich mudstone succession (black shale). More studies are needed to determine the variable ichnofaunas of these deposits.

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Thank you for listening!