# Bioturbation and Reservoir Quality: Towards a Genetic Approach*

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Search and Discovery Article #50900 (2013)**
Posted December 9, 2013

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013


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## Abstract

The process of bioturbation, or the organism/sediment interaction, has a strong impact on reservoir quality and its flow behavior and is capable either to enhance or diminish it. Despite this fact, existing classifications of porosity in carbonates and siliciclastics do not really consider ichnological components as a part, while existing bioturbation-focused classifications are based on the final appearance of burrow-related heterogeneities in the sedimentary rock. A novel approach is made classifying bioturbation-influenced porosity on the basis of the size as well as morphological and compositional features of bioturbate textures and discrete trace fossils. Given the diverse appearance of trace fossils and, consequently, their highly variable influence on the fluid-flow within the sediment, an attempt is made to classify bioturbation-influenced porosity (both, enhancement and diminishing) at different scales and by appreciating the specific burrow nature as a function of the overall behavior of their trace maker. This newly proposed key aims for a better predictability of reservoir quality as an integral part of the reservoir-characterization workflow, together with sedimentological and diagenetic analysis. Selected examples of bioturbation-related modifications of rock properties are presented from platform carbonates of the Permian/Triassic Khuff Formation from the South Pars gas field in the Persian Gulf, from shallow-marine Jurassic siliciclastics of the Norwegian North Sea, and from Upper Cretaceous deep-marine fan deposits of the Norwegian Sea. These case studies show that the porosity in these reservoirs is significantly impacted by diverse bioturbation, which either results in an enhancement or a diminishing of the reservoir quality. Given a solid understanding of the conditions, burrow-related porosity and permeability are predictable to a certain degree.

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# Bioturbation and reservoir quality: Towards a genetic approach

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# Outline:

- Introduction
- Bioturbation and reservoir quality
- New classification key
- Examples
- Conclusions



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# Small-scale heterogeneities → reservoir quality

## Sedimentary

- Lithological composition
- Sedimentary structures

## Ichnological

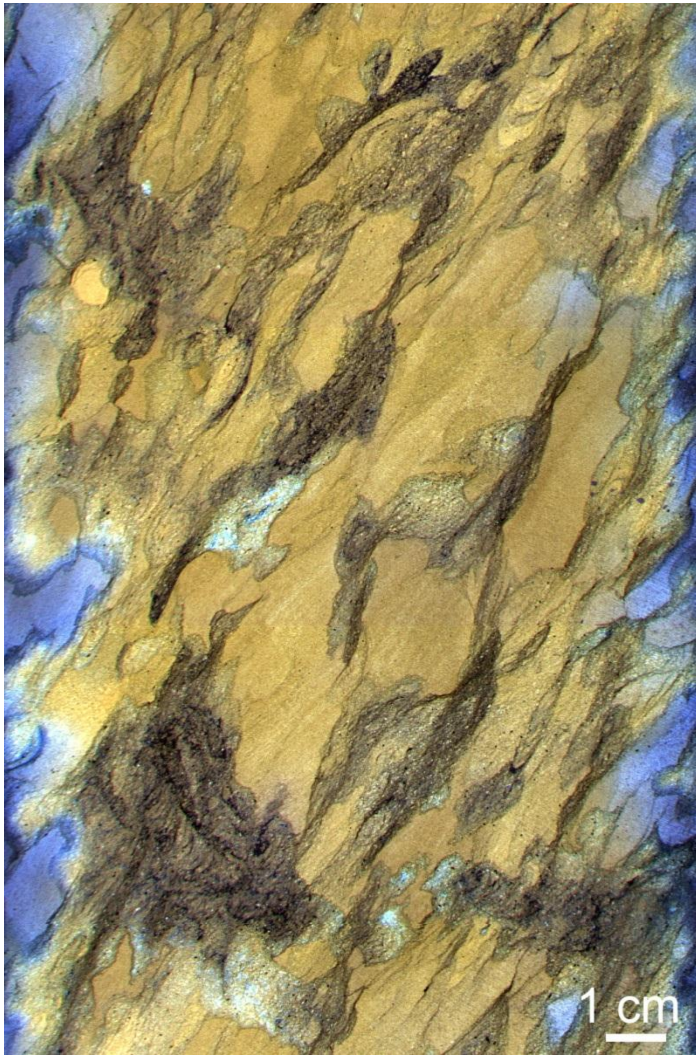
- Trace fossils
- Bioturbate texture

## Diagenetic

- Cementation and dissolution
- Grain coating

Fluvial sandstone
Lower Jurassic
North Sea


Deep-marine chalk
Upper Cretaceous - Palaeogene
North Sea



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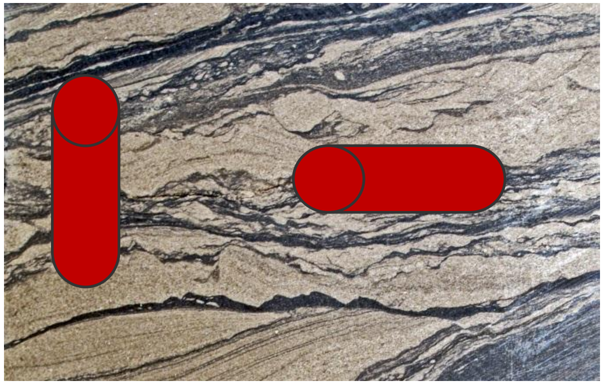
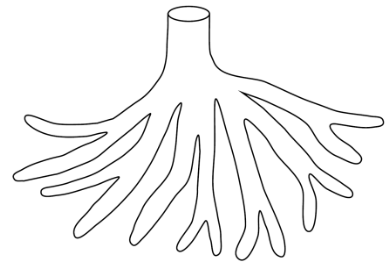
# Architectural elements

Orientation:

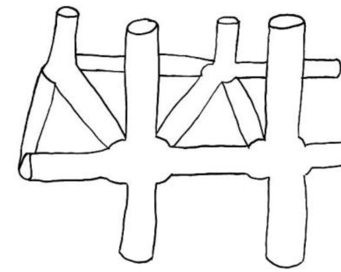


Vertical - horizontal

Branching:

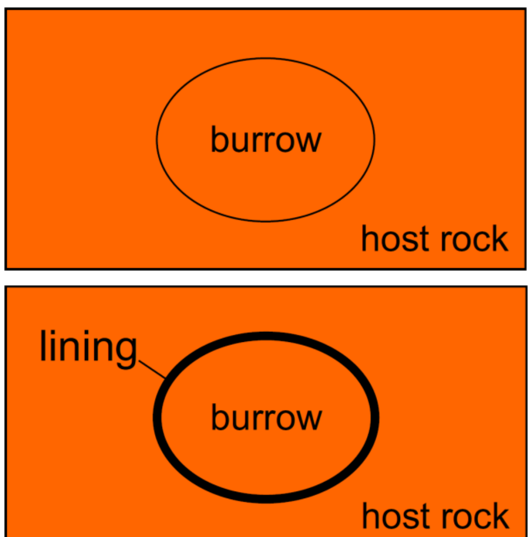


Bifurcation

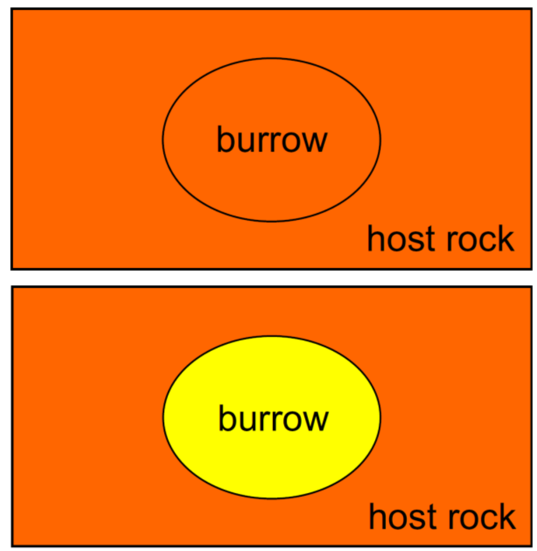


Boxwork

Lining / mantle:

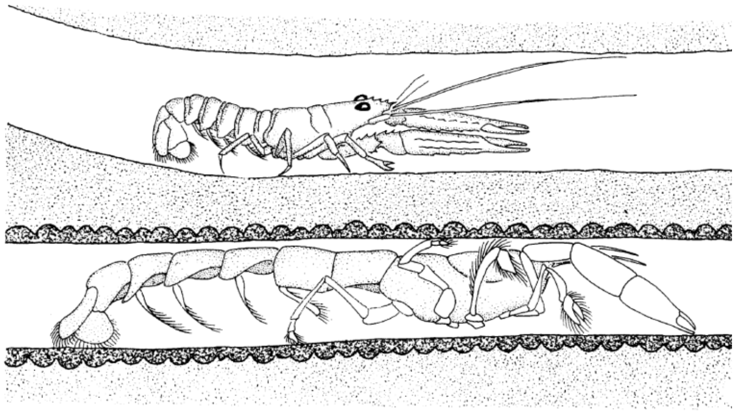



Fill:

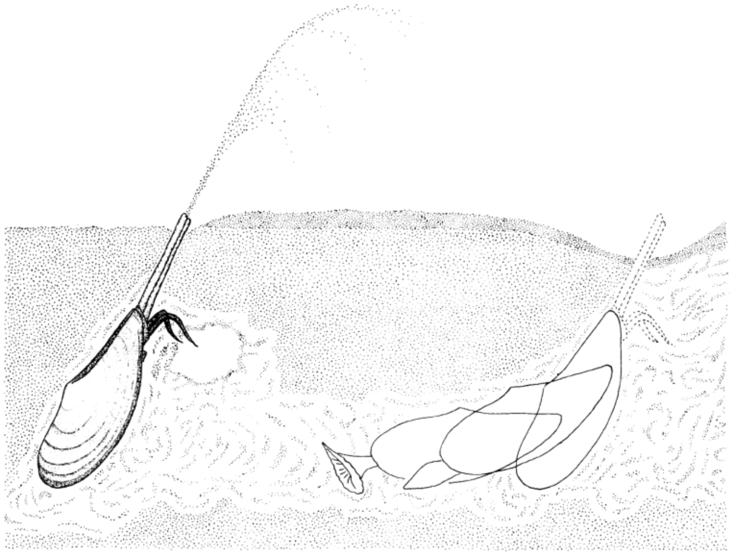


# Tracemaker, behavior, substrate

Dwelling

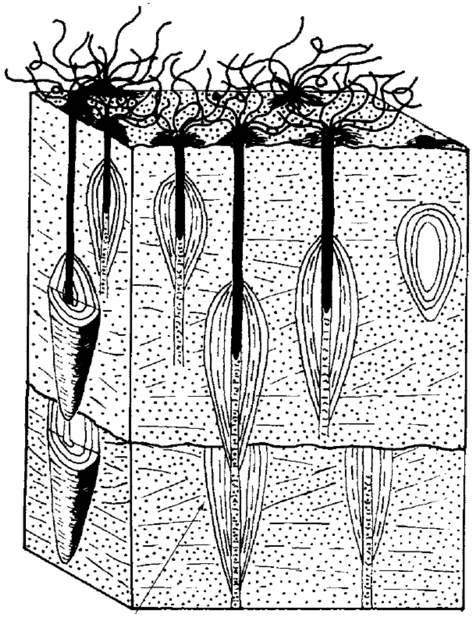


Deposit-feeding



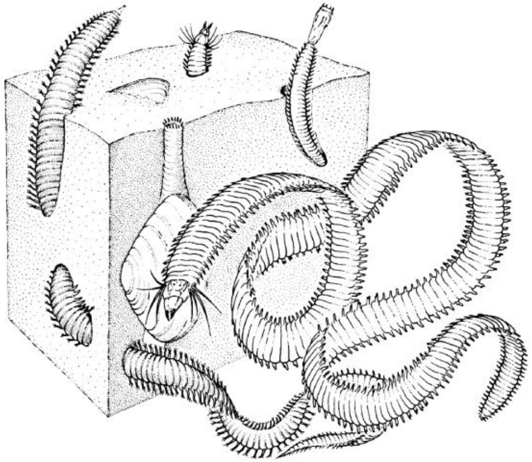
*Bromley (1996)*

Detritus-feeding



*Frieling (2007)*

Scavenger



*Wilson and Ruff (1988)*



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# New classification scheme

| | Bioturbation-influenced porosity | | | | | |
|---|---|---|---|---|---|---|
| **Producer size** | Microfauna | Meiofauna | Macrofauna | | | Macroflora |
| **Process** | Microbioturbation | Meiobioturbation | Macrobioturbation | | | |
| **Pore size** | < 0.0625 mm | 0.0625 - 4 mm | > 4 mm | | | |
| | (micropores) | (mesopores) | (megapores) | | | |
| **Rock texture / trace-fossil group** | Interstitial modification | Cryptic bioturbate texture, small burrows | Bioturbate texture | Burrows | Borings | Root traces |

| **Trace-fossil group** | Burrows | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Orientation** | Subvertical | | | | | | | | Subhorizontal | | | | |
| **Branching** | Yes | | | | No | | | | Yes | | | | |
| **Lining / mantle** | Yes | | No | | Yes | | No | | Yes | | No | | |
| **Fill** | Passive | Active | Passive | Active | Passive | Active | Passive | Active | Passive | Active | Passive | Active | Passive |
| **Ichnogenera (examples)** | *Psilonichnus*[1] | *Schaubcylindrichnus* | *Balanoglossites* | *Chondrites* | *Skolithos*[1] | *Rosselia*[2] | *Skolithos*[1] | *Diplocraterion* | *Skolichnus* | *Asterosoma*[2] | *Spongeliomorpha* | *Phycosiphon* | *Palaeophycus* |
| | *Polykladichnus*[1] | | *Parmaichnus* | | *Lingulichnus* | | *Arenicolites*[1] | *Zoophycos* | *Ophiomorpha*[3] | *Ophiomorpha*[3] | *Thalassinoides* | *Phycodes* | *Helminthopsis* |
| | *Trichichnus*[1] | | *Psilonichnus*[1] | | *Cylindrichnus* | | *Gyrolithes*[1] | *Spirophyton* | | *Rutichnus* | *Rhizocorallium jenense* | | |
| | | | *Polykladichnus*[1] | | *Siphonichnus* | | | *Daedalus* | | | *Virgaichnus* | | |
| | | | *Trichichnus*[1] | | *Arenicolites*[1] | | | | | | | | |
| | | | | | *Gyrolithes*[1] | | | | | | | | |
| | | | | | *Ophiomorpha*[3] | | | | | | | | |
| **Predominant behaviour** | Dwelling | Suspension-feeding | Dwelling | Deposit-feeding | Dwelling | Suspension-feeding | Suspension-feeding | Deposit-feeding | Suspension-feeding | Deposit-feeding | Dwelling | Deposit-feeding | Dwelling |
| **Subordinate behaviour** | Suspension-feeding | Dwelling | Suspension-feeding | Dwelling | Suspension-feeding | Dwelling | Dwelling | Suspension-feeding | Deposit-feeding | Dwelling | Suspension-feeding | | Deposit-feedin |
| **Impact on reservoir** | + | - / + | + + | - | + | - - | + + | + + | + | - - | + + | - / + + | + |

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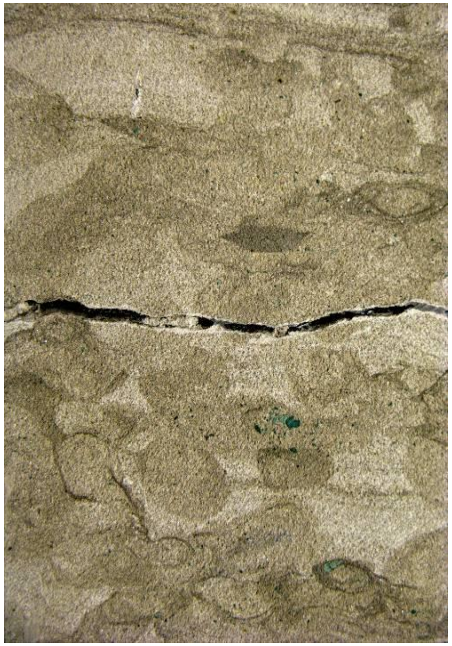
*Ophiomorpha*-diminished reservoir quality:
Upper Cretaceous Springar Formation (deep-marine)
Norwegian Sea

- No to 5% bioturbation
- 23.8% / 6.69 mD

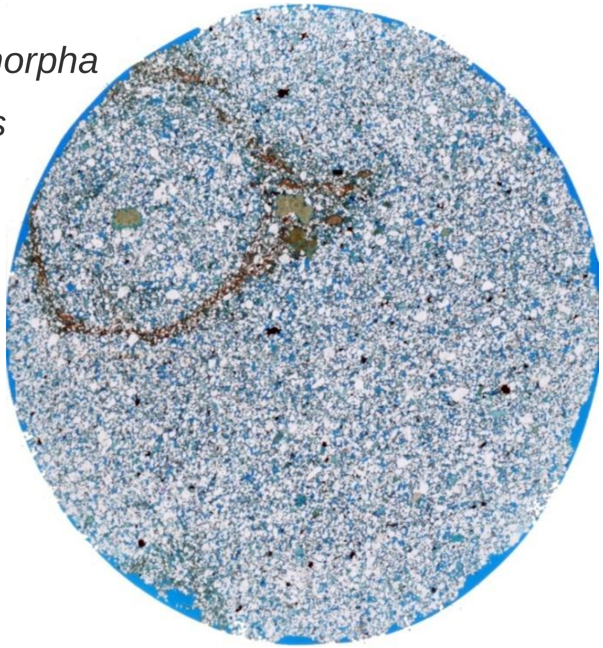
- 70% bioturbation
- 20.9% / 1.29 mD

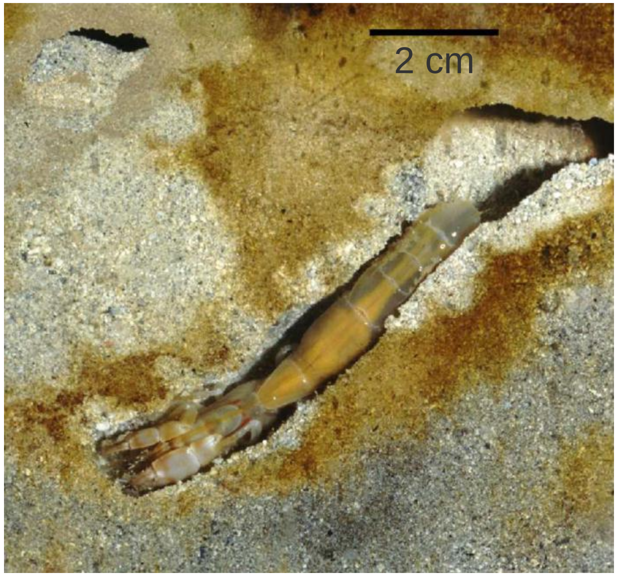


- Increased heterogeneity
- Incorporation of mud

→ Decreased porosity and permeability

*Ophiomorpha rudis*






Modern *Callianassa*

*(Dworschak et al., 2006)*



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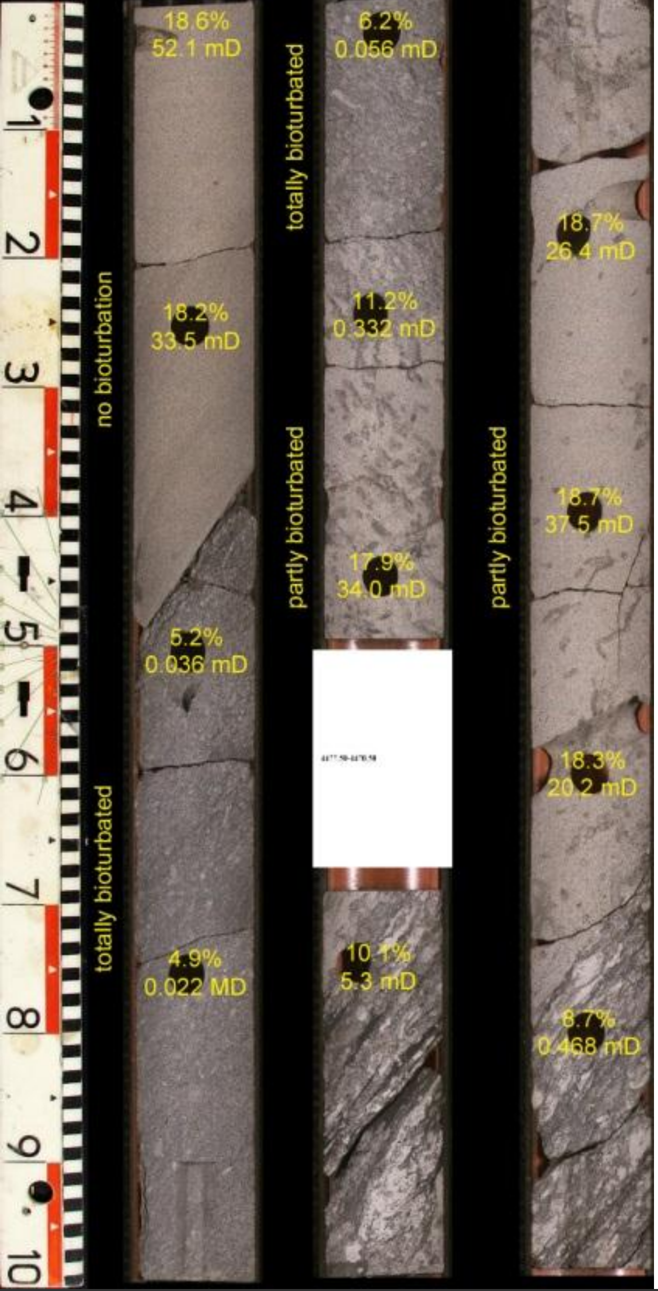
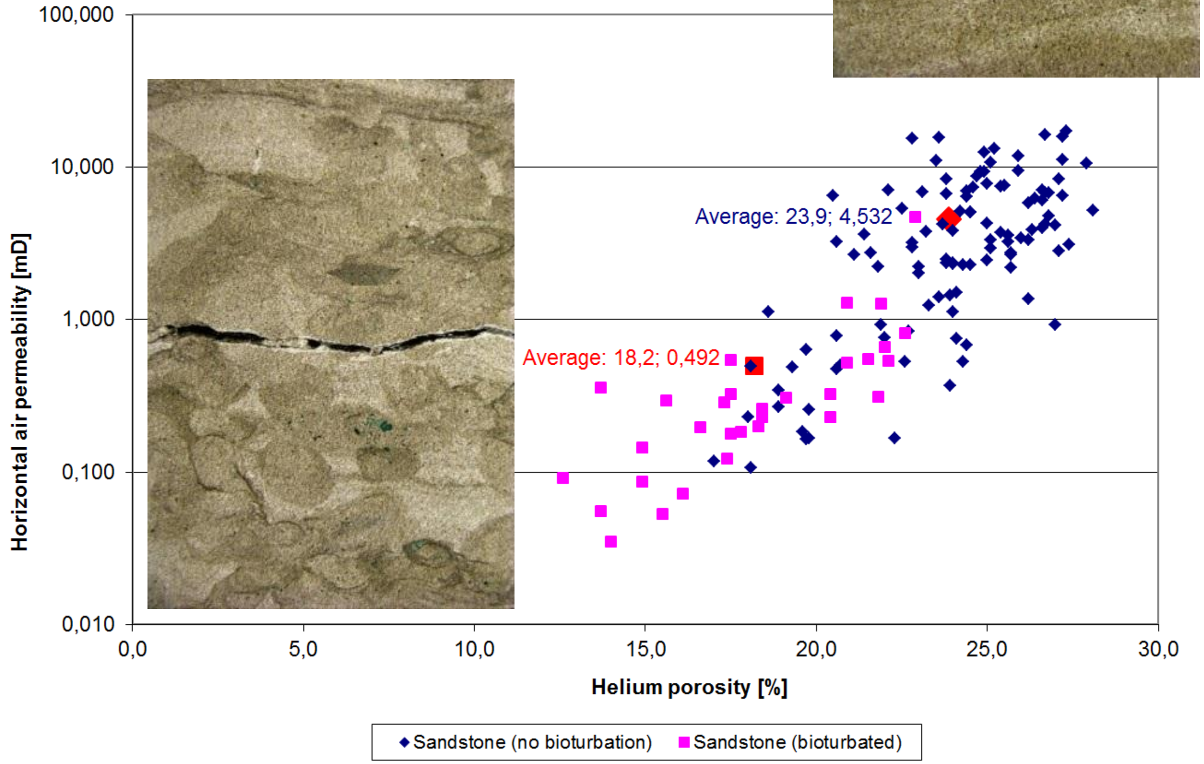



# Bioturbated *vs.* unbioturbated sandstone



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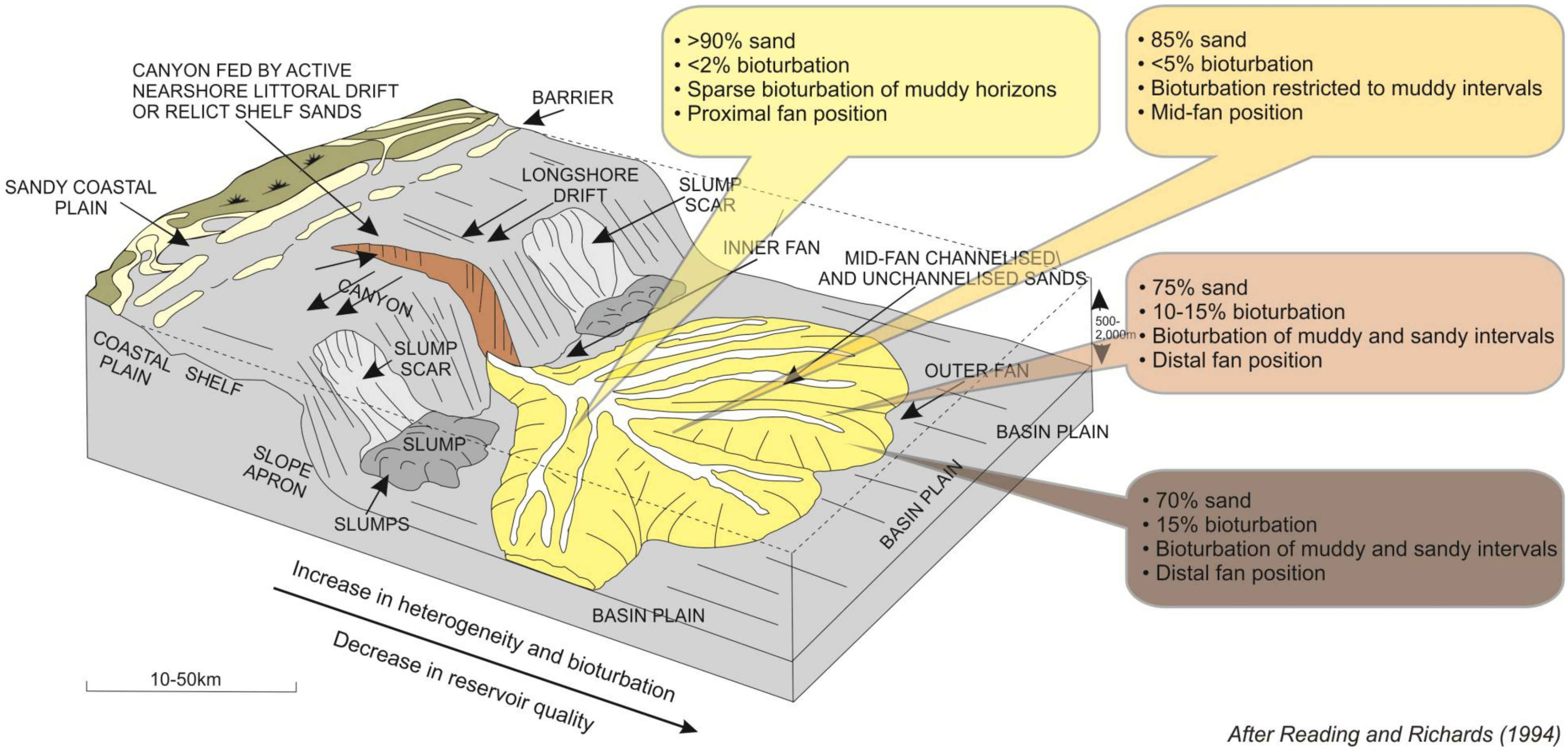
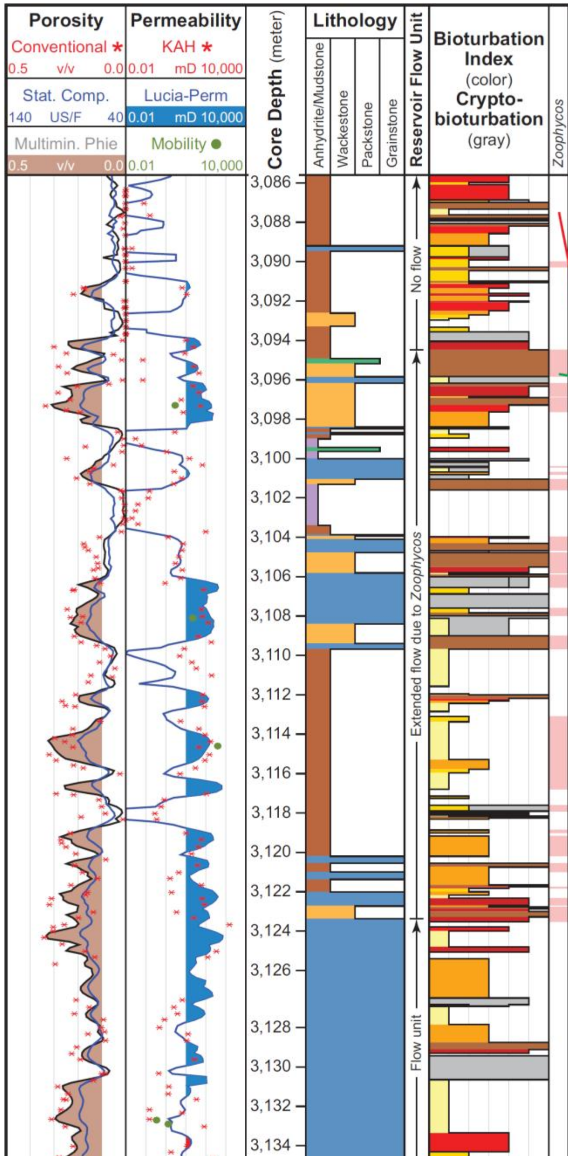
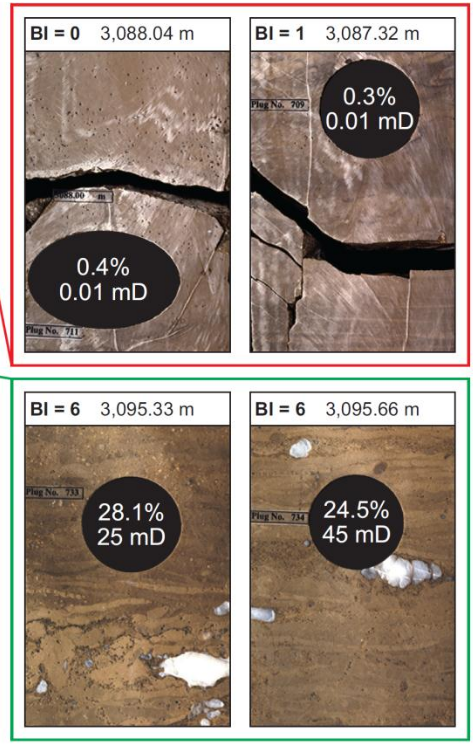
Submarine fan system, proximal-distal trends (bioturbation)

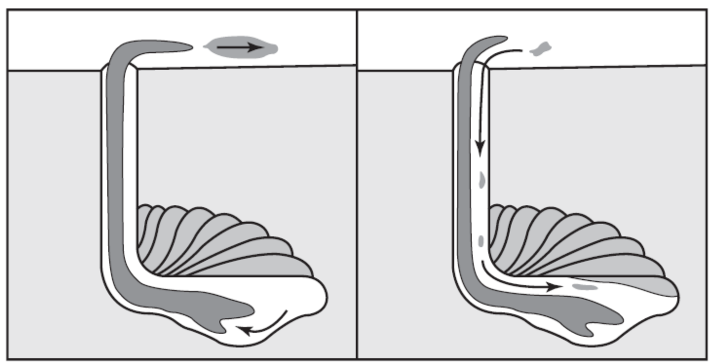



*After Reading and Richards (1994)*

*Zoophycos*-enhanced reservoir quality:
Upper Permian Khuff Formation (carbonate platform)

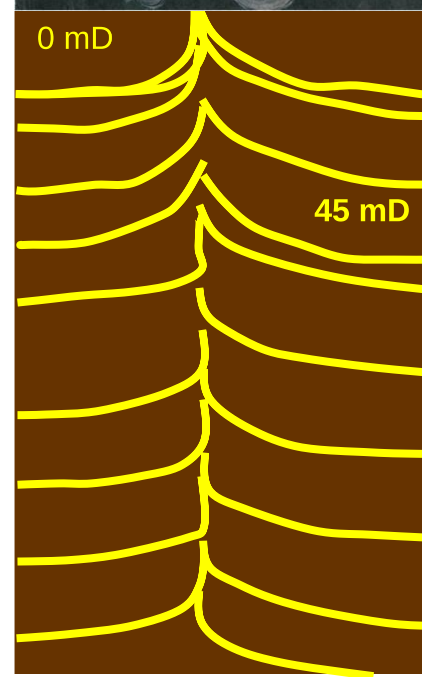


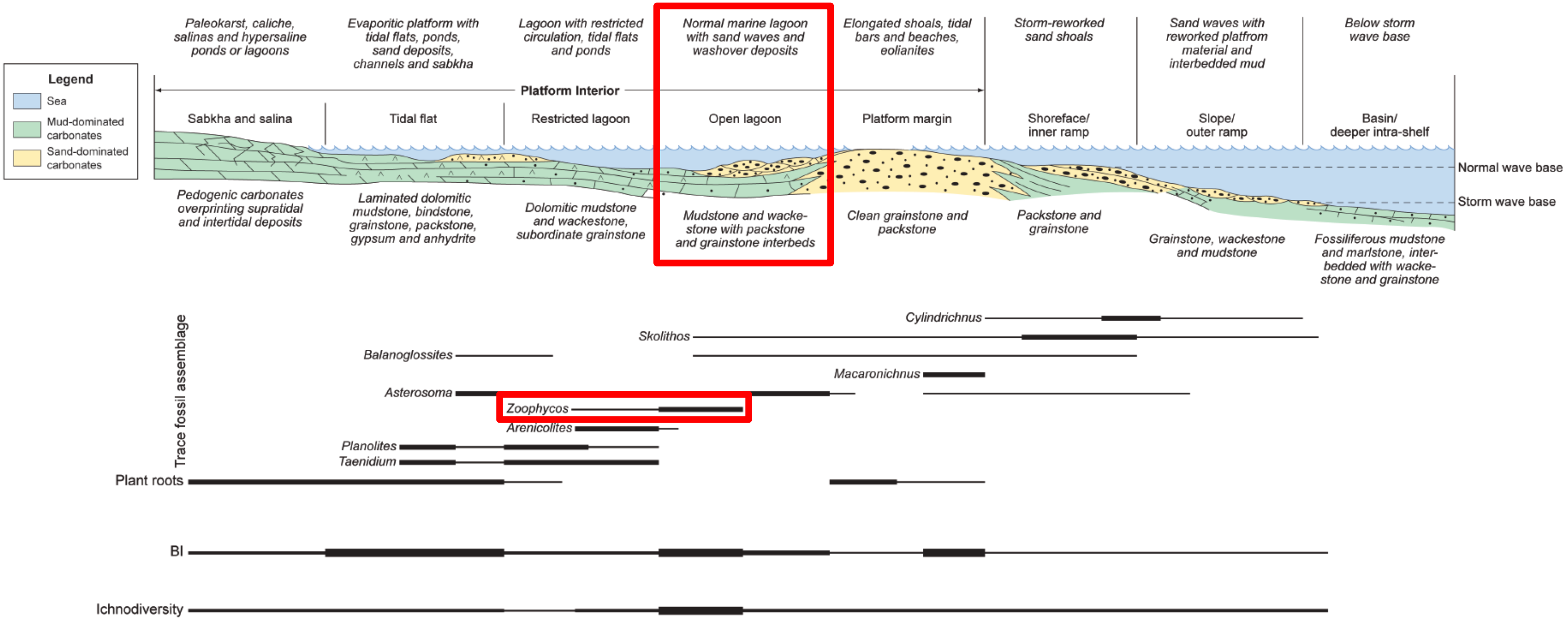



(Löwemark et al., 2004)

(Pemberton et al., 2001)



# Khuff carbonate platform (S-N cross section)




Knaust (2009): GeoArabia 14: 17-38



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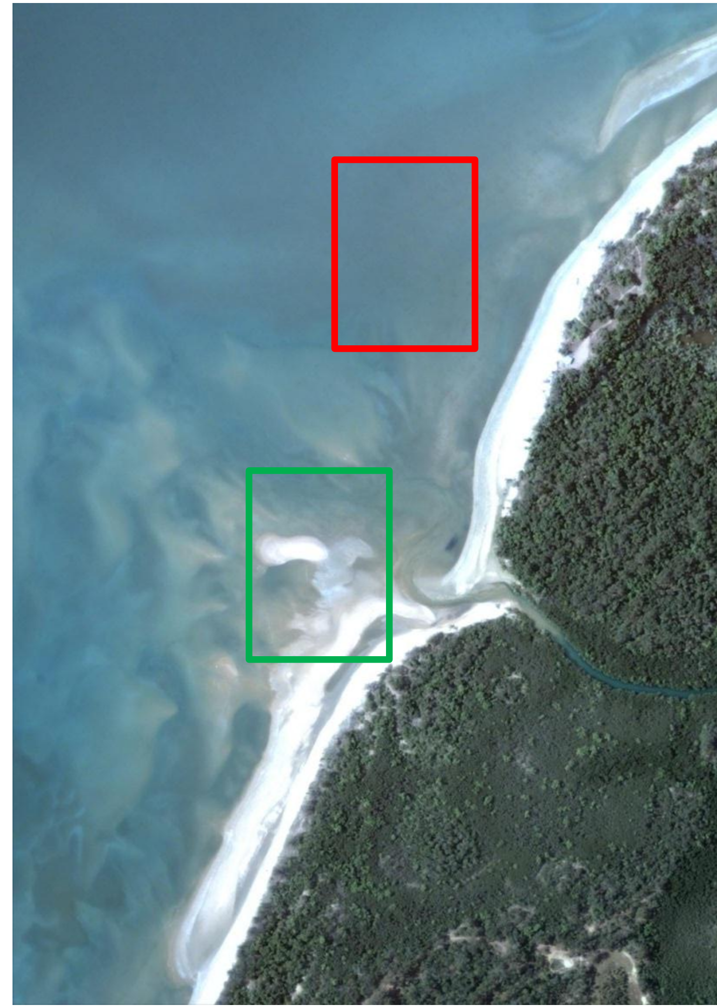
Bioturbation-influenced reservoir quality:
Middle Jurassic Hugin Formation (marginal-marine)
North Sea

- Sandstone with mud drapes
- Moderate bioturbation
- Poro-perm 16%, 23 mD

- Lower shoreface

- Sandstone, cross-stratified
- No bioturbation
- Poro-perm 19%, 1477 mD

- Mouth bar



# Conclusions

- Bioturbation has a strong impact on reservoir quality and its flow behaviour
- Influence on subsequent diagenetic processes
- Newly proposed classification of bioturbation-influenced porosity:
  - ✓ Size
  - ✓ Morphology
  - ✓ Composition

  } Trace fossils
- Process-based, behaviour of the tracemaker in a particular environment
- Better predictability of reservoir quality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## TRACE FOSSILS AS INDICATORS OF SEDIMENTARY ENVIRONMENTS

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Over recent decades, the study of trace fossils (ichnology) has evolved into a broad and global subject. Given its interdisciplinary and complex nature, bridging sedimentology and palaeontology, it tends to remain a specialized field when ichnological concepts and methods are applied in the interpretation of sedimentary environments. The value of trace fossils in facies reconstructions was recognized early and all major sedimentary environments were extensively documented in the 1980s.

This book provides a comprehensive overview of all major sedimentary environments from the continents to the deep sea in respect to their characterization by trace fossils and ichnological means. Over 80 specialists have contributed, thus ensuring a wide spectrum of perspectives. The purpose of the book is to provide the non-specialized sedimentologist and geologist with easily accessible data, concepts, methods and references for integrated ichnological-sedimentological studies. Sedimentologists and palaeontologists in both academia and industry will benefit from it.

The book is subdivided into five parts and includes 28 chapters. Part I deals with the historical aspect of ichnology and introduces common concepts and methods. Parts II to IV treat major sedimentary environments of continental and glacial systems, shallow-marine siliciclastic systems, deep-marine siliciclastic systems, and marine carbonate systems. Part V is dedicated to ichnology in hydrocarbon reservoir and aquifer characterization.

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ISBN 978-0-444-53813-0

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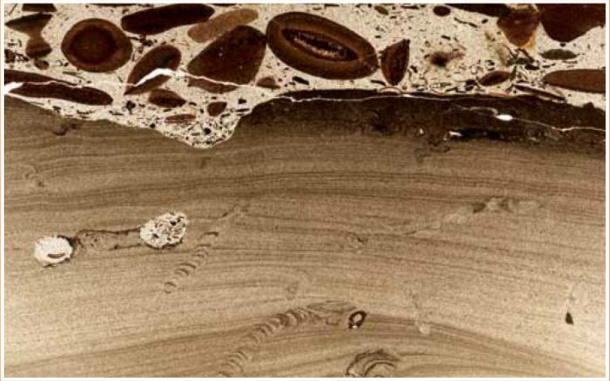

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