

# Assessment of Temporal Source Rock Variability: An Example from the Lower Jurassic Posidonia Shale\*

Wolfgang Ruebsam<sup>1</sup>, Martin Stockhausen<sup>2</sup>, and Lorenz Schwark<sup>2,3</sup>

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## Abstract

The assessment of the natural temporal variability of source rock units is critical for the understanding of petroleum systems as changes in mineral matrix, organic matter (OM) concentration, and composition can significantly affect expulsion efficiency, primary and secondary migration processes, hydrocarbon quality as well as oil source rock correlation. Already small-scaled fluctuations within sediment successions can critically influence migration efficiency. High-resolution investigation of a well-preserved Lower Jurassic drill core (Toarcian Posidonia Shale) revealed seven discrete and systematic intervals of deviating source rock quality. These were composed of homogenized, non-laminated marls of light grey color, opposed to laminated dark grey background sedimentation. Both lithotypes differentiate not only in mineral composition, but particularly in OM content and quality. An average TOC content of app. 3.9 wt.% reached by the grey marl, is faced by an average TOC content of app. 7.8 wt.% measured for the laminated dark grey marls. Average hydrogen index for grey non-laminated marls was app. 550 mg HC/g TOC, whereas much higher source rock quality with 780 mg HC/g TOC was attained in the dark laminated marls. The marls lower OM concentration and inferior OM quality generates important domains for preferential migration of products, originated from the dark grey layers, or hydrocarbon cluster in case of limited migration into adjacent reservoirs. To assess the potential for preferential intake of hydrocarbons by the coarser-grained light marls and their qualification as migration avenues, artificial maturation experiments were performed with both lithotypes. Hydrocarbon generation was simulated by hydrous pyrolysis in two successive temperature steps 330 °C and 360 °C, covering an early maturity stage, as well as the end of the oil window. Both lithologies show striking differences, not only for the extract yield, but also for the timing of generation. OM quality differences were reflected by variable n-alkane distributions and molecular maturity parameters. High-resolution continuous data produced by non-destructive techniques allows to draw conclusions on i) source rock potential, ii) expulsion and migration processes, and iii) on prediction of petroleum accumulation within the sediment succession. High-resolution investigation in combination with artificial maturation experiments represent an easy-to-use tool in petroleum system analysis.

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# ASSESSMENT OF TEMPORAL SOURCE ROCK VARIABILITY:

## AN EXAMPLE FROM THE LOWER JURASSIC POSIDONIA SHALE

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## **1. Introduction to the Toarcian source rock sequence studied**

Stratigraphy, paleogeography, lithology

## **2. Orbitally tuned cyclicity in Toarcian source rocks**

Controls on organic matter quantity and quality

## **3. Effect of resolution on recognition of source rock variability**

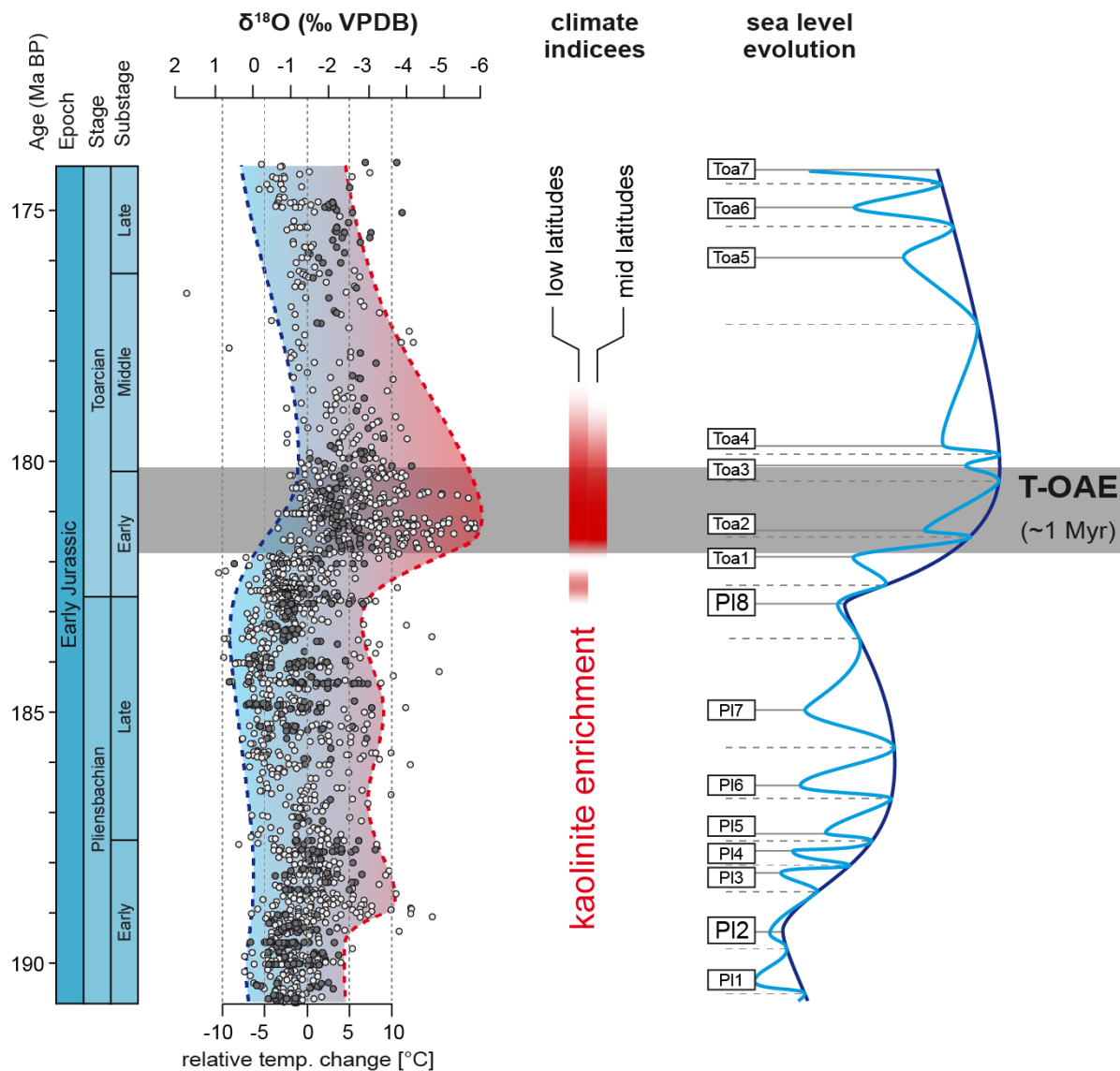
Comparison of two adjacent wells studied at different resolution

## **4. Recommendation for high resolution core scanning approaches**

Time and costs effective, non-destructive core scanning

## **5. Differential petroleum generation potential of cyclic source rocks**

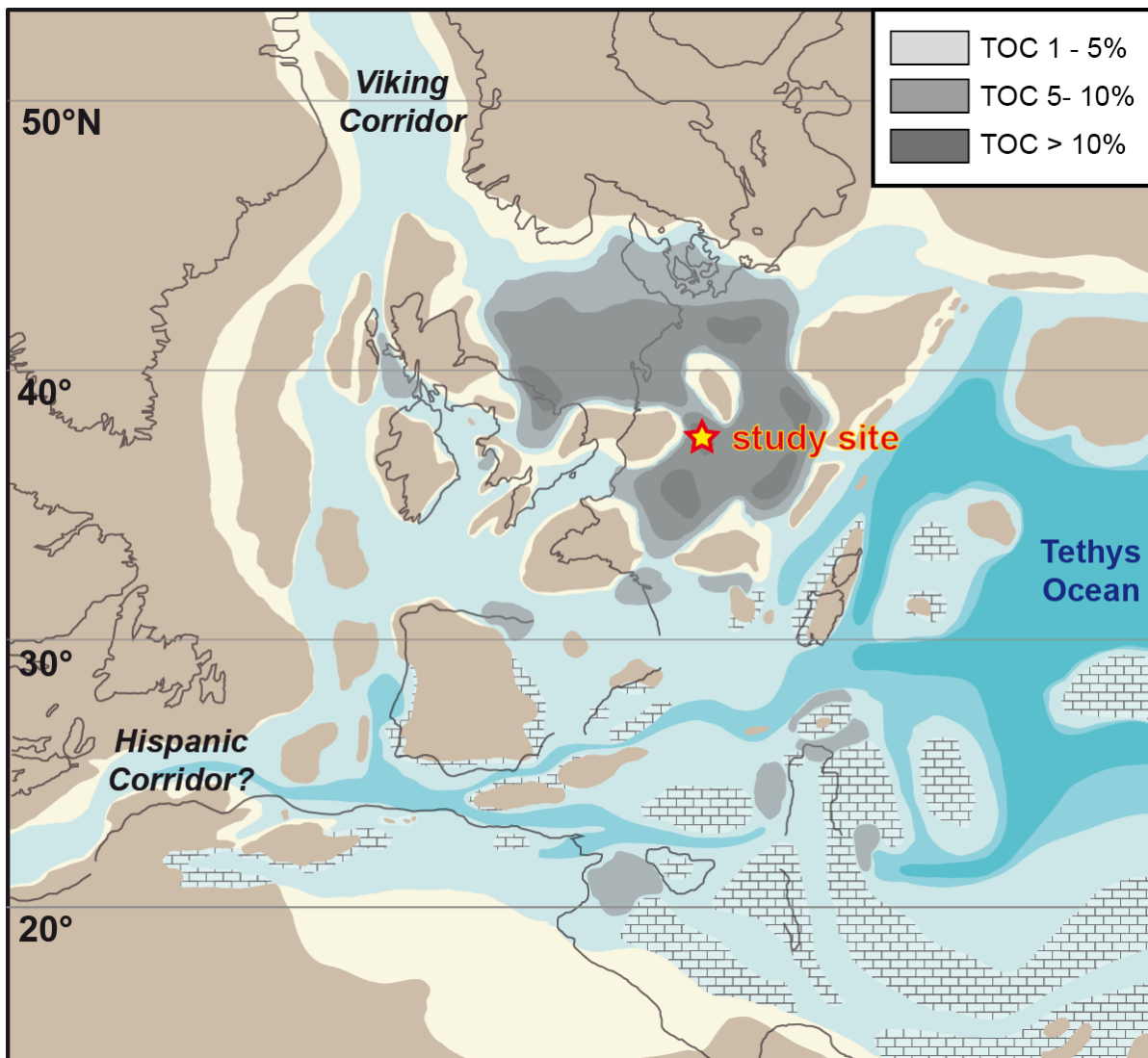
Assessing oil generation potential of alternating source rock intervals via hydrous pyrolysis



During the Lower Jurassic (Early Toarcian; ~183 Ma BP) black shale deposition at global scale has been associated with an Oceanic Anoxic Event, lasting for ~1 Myr.

Enhanced organic matter burial favored by:

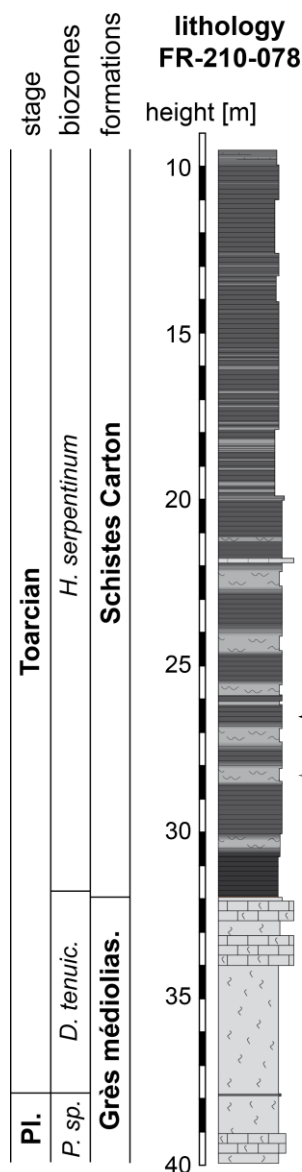
- global warming
- intensified continental weathering
- eutrophication of shelf seas
- sea level rise



Widespread black shale deposition on the Western Tethyan shelf, with TOC concentrations exceeding 10 wt.%.

Toarcian source rocks are thought to reveal ***monotonous kerogen composition (type II)***, yielding similar oils.

Good source rock quality led to oil accumulation in the Paris Basin and the NW German Basin.



## laminated units

## non-laminated units

### Schistes Carton Fm.

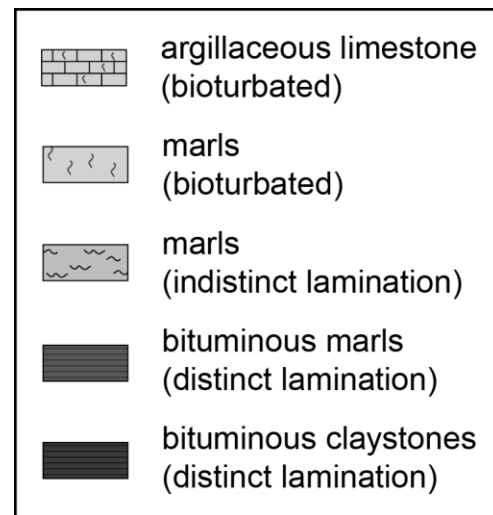
(source rock, coeval to the Posidonia Shale):

- laminated marlstones
- rich in pyrite and organic matter
- intercalated non-laminated marlstones
- homogenous sediment deposited under turbulent conditions and/or affected by bioturbation

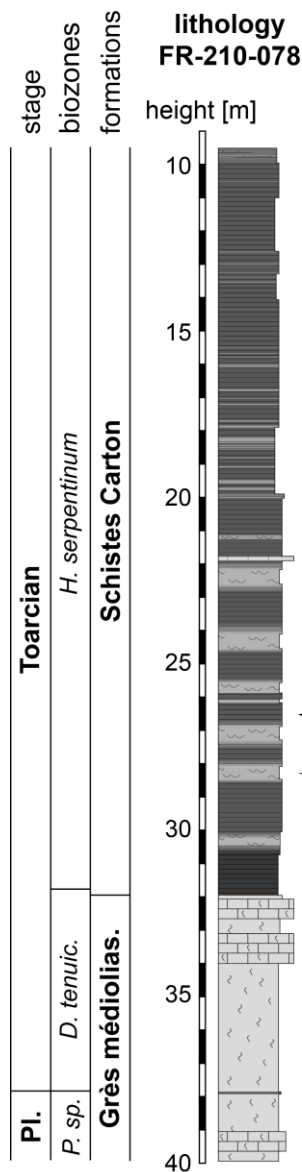
### Grès médioliasiques Fm.

(non-source sequence):

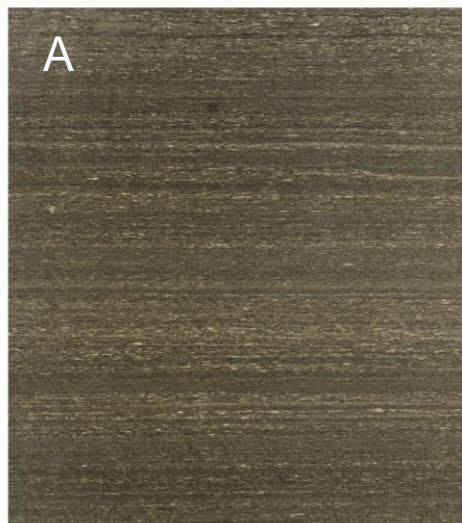
- bioturbated marl-/claystones
- general low in organic matter



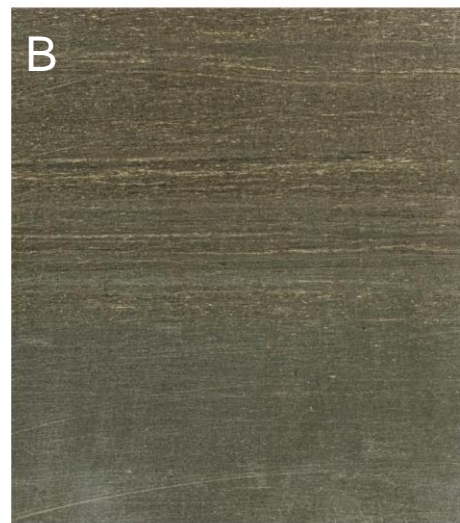




## laminated units

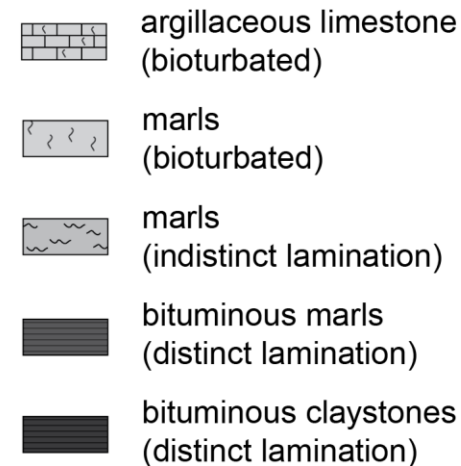


## non-laminated units



## Grès médioliasiques Fm. (non-source sequence):

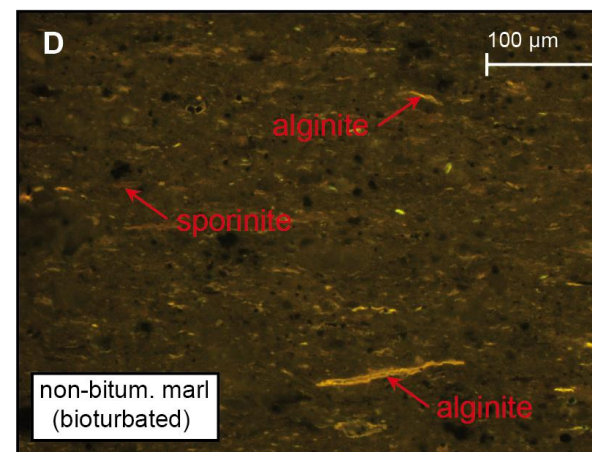
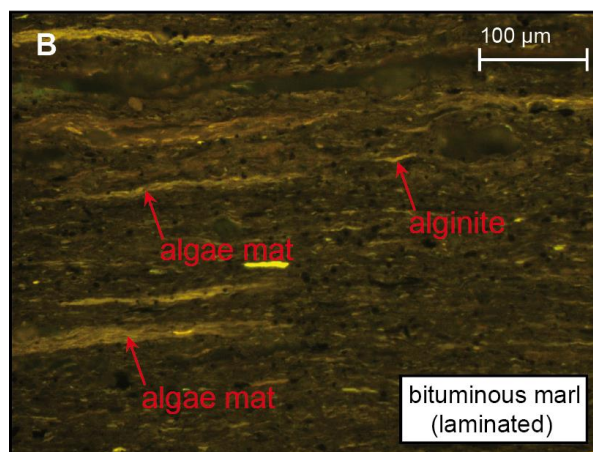
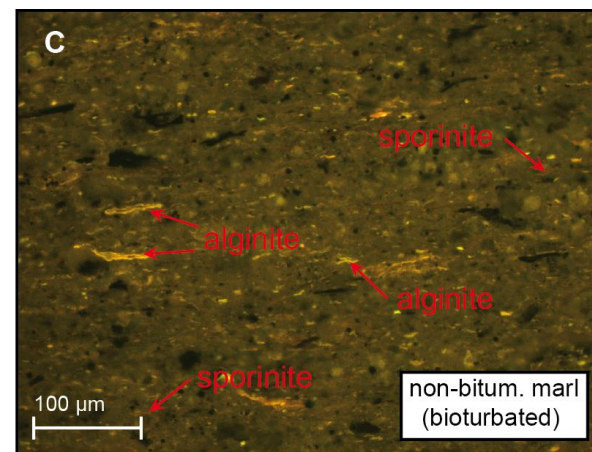
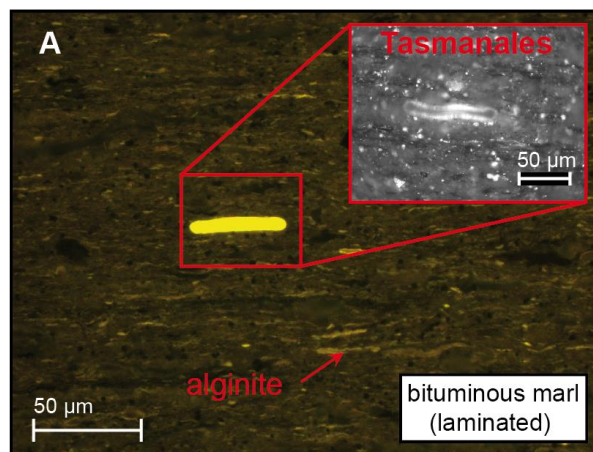
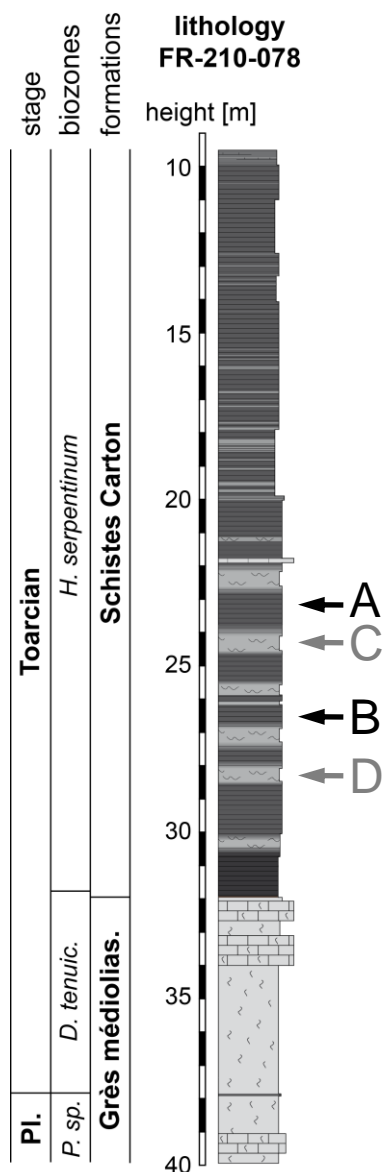
- bioturbated marl-/claystones
- general low in organic matter



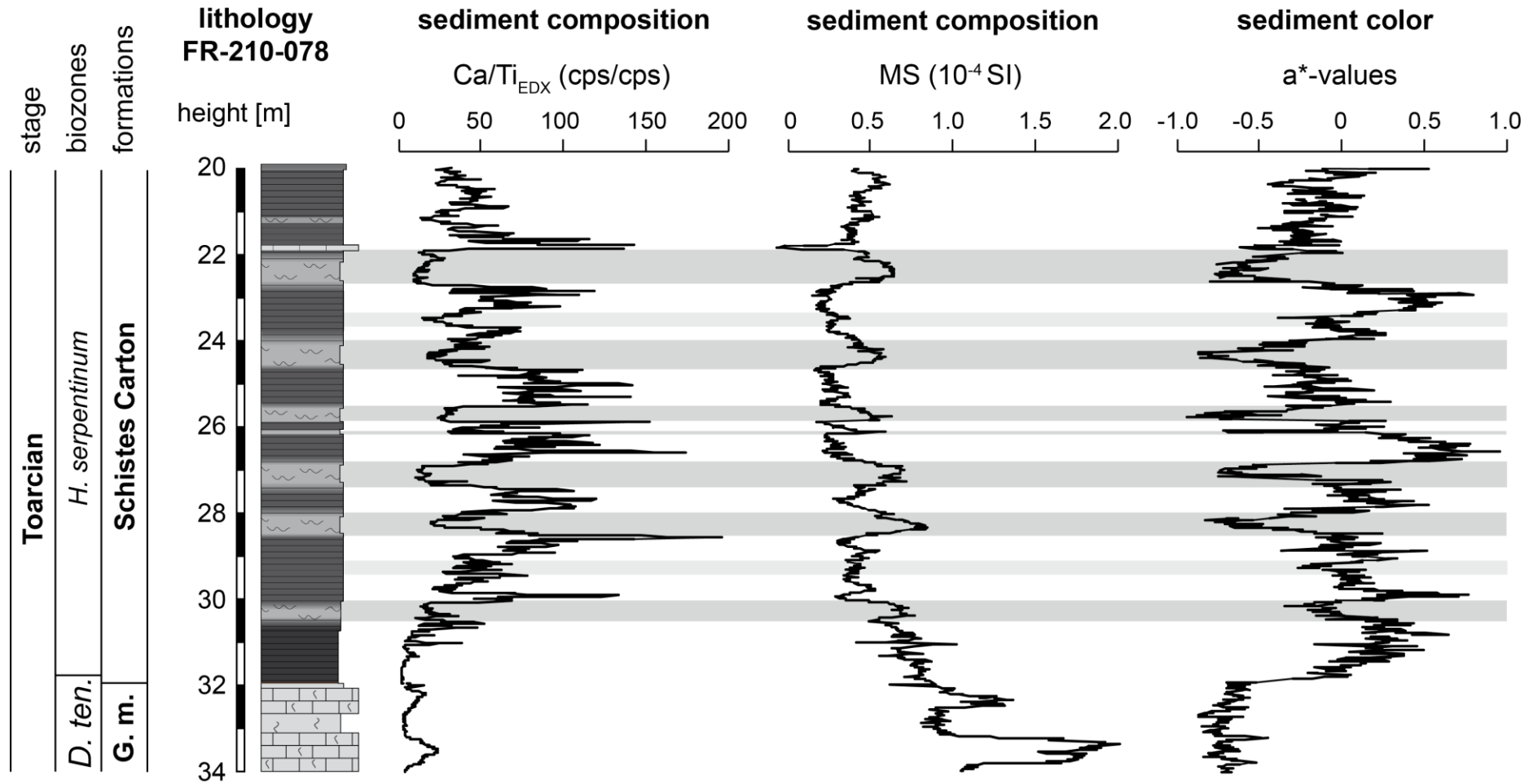


## laminated units

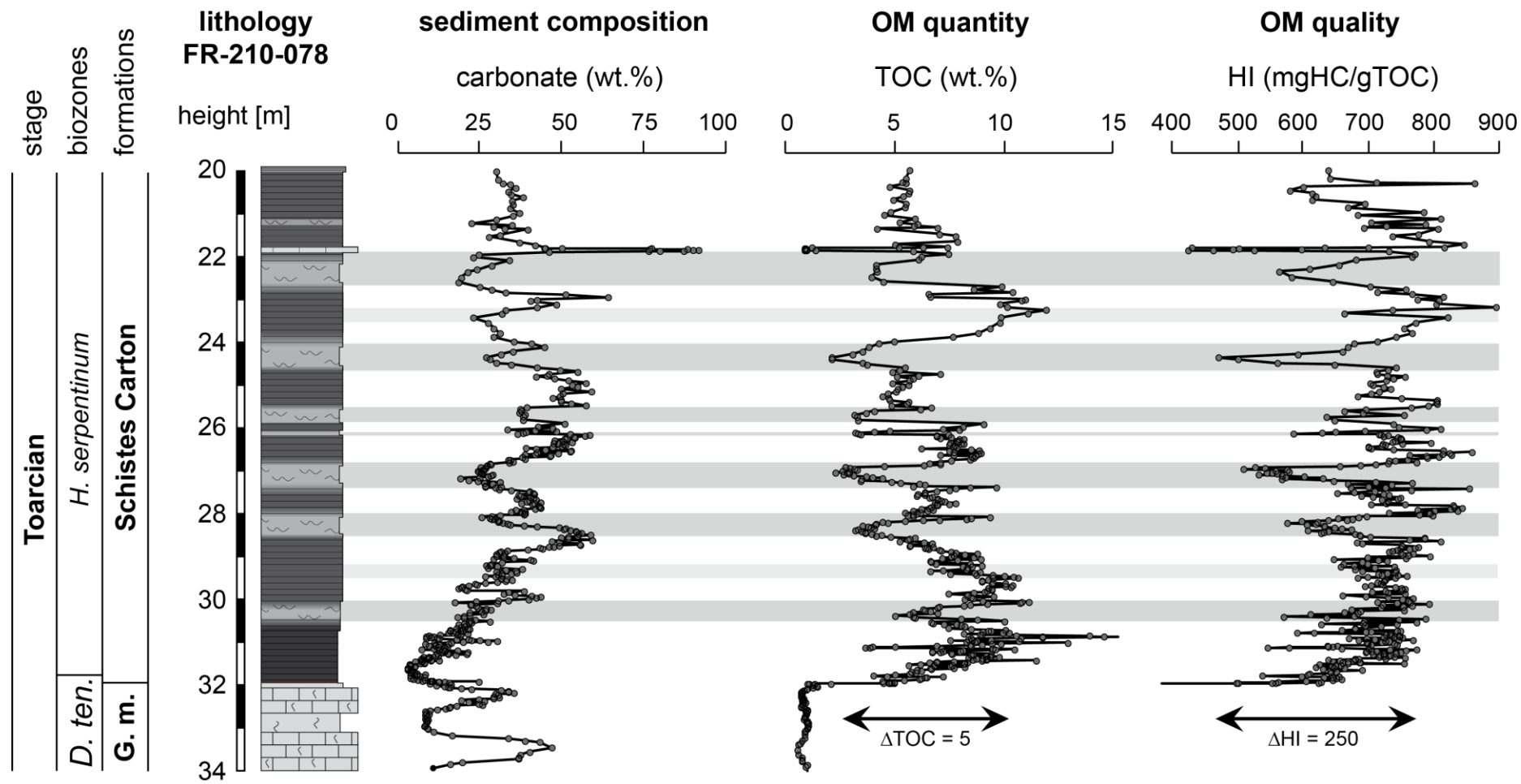
## non-laminated units



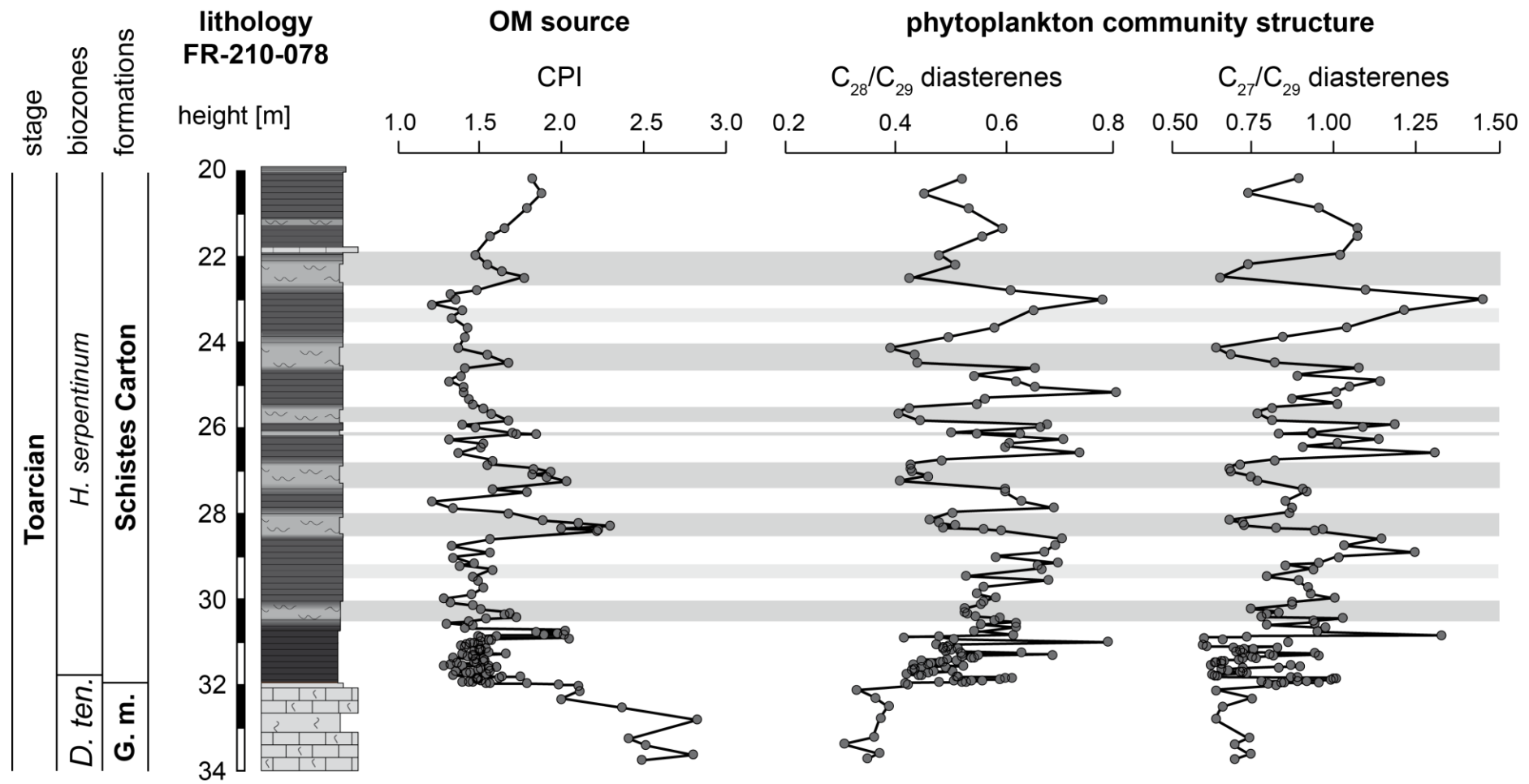
**Source rock sequences,  
previously characterized as monotonous,  
reveals substantial variability!**



Source rock variability expressed in bulk sediment properties. Ca/Ti ratios and MS-values reflect changes in carbonate versus siliciclastic contributions. Changes in sediment color encoded by a\*-values (green – red).

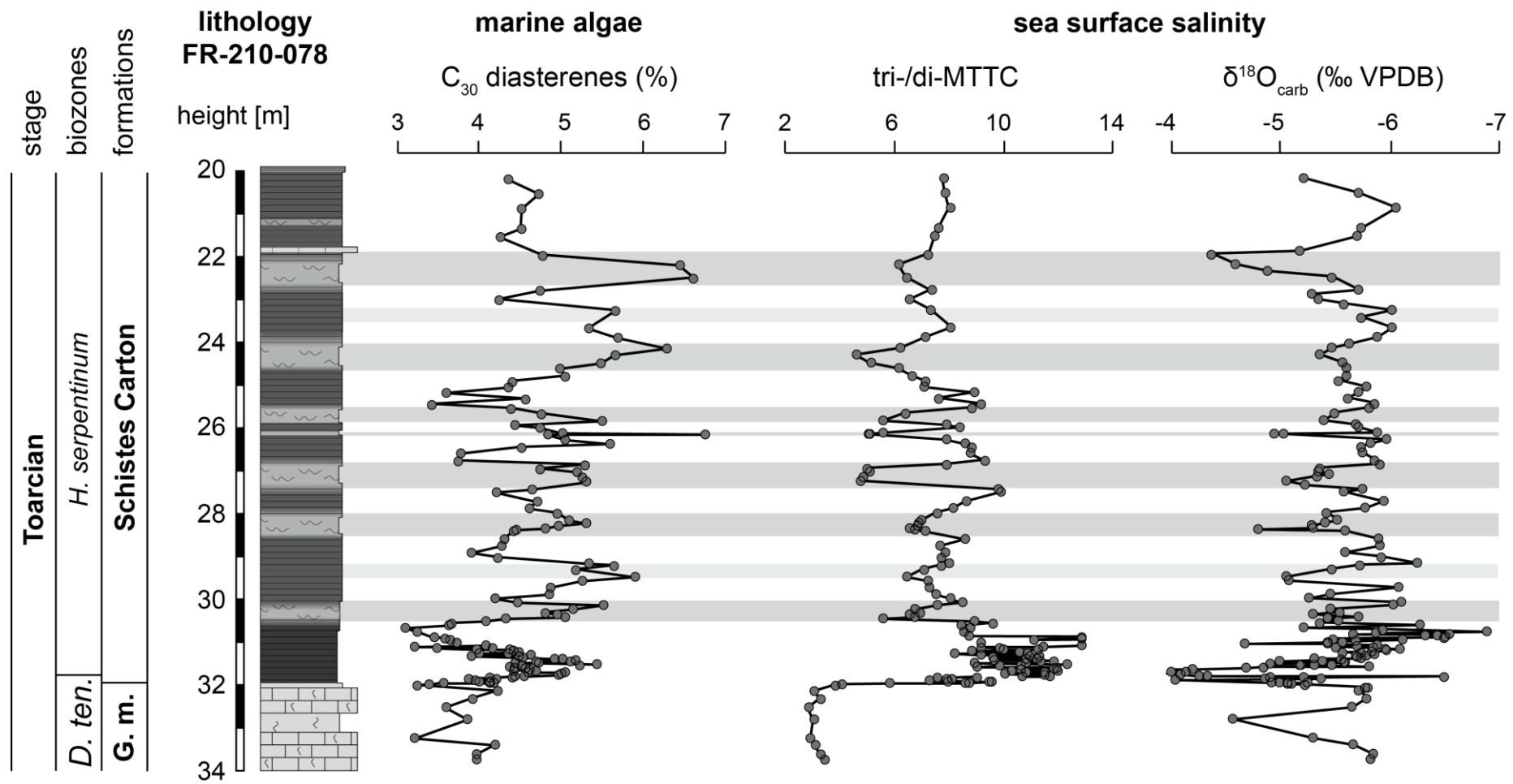


Variations in lithology are associated with changes in sediment composition as well as with changes in organic matter quantity and quality.



Variations in biological sources of organic matter, including changes in relative contributions of terrestrial plant versus marine organic matter and changes in the phytoplankton community structure.

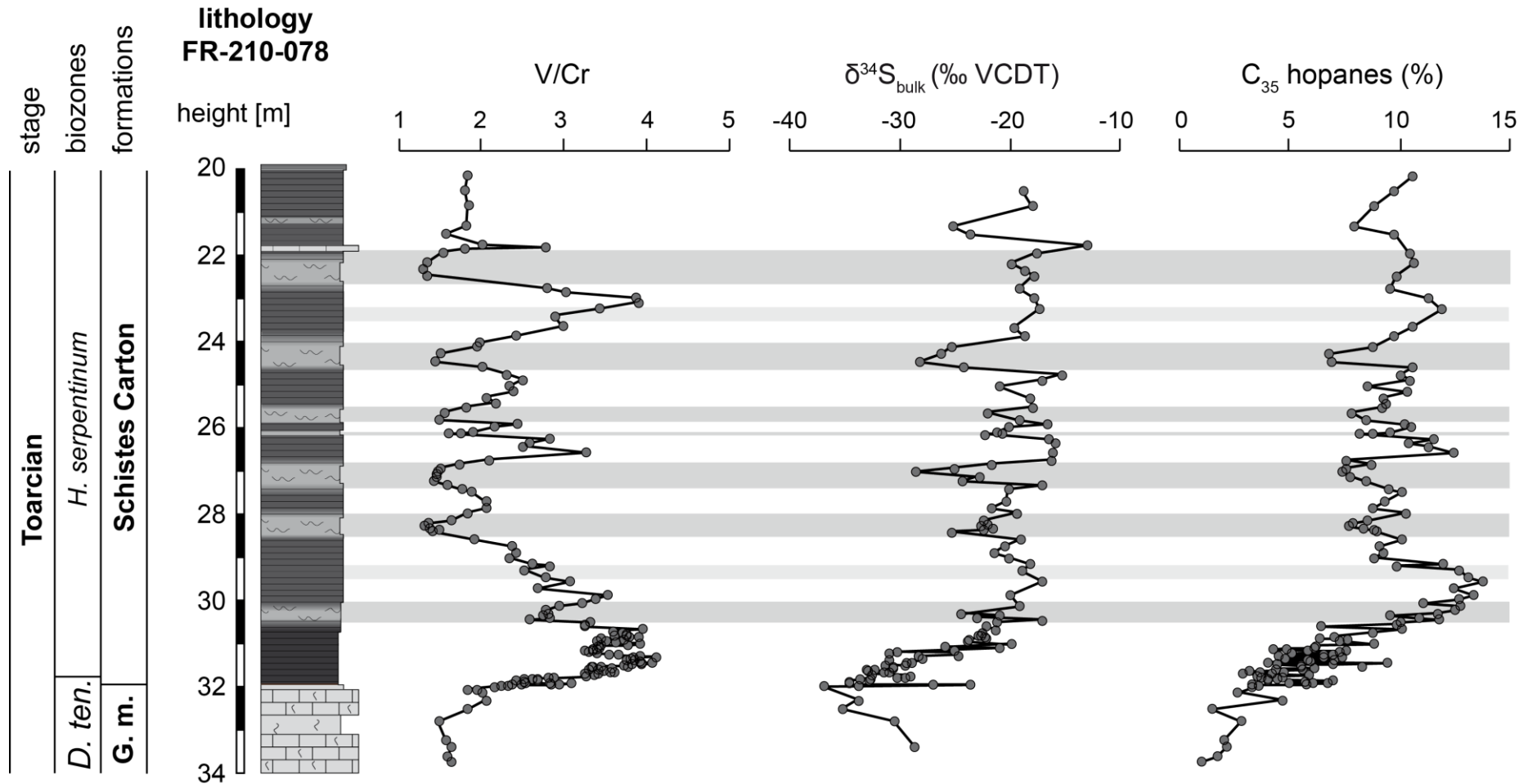




Changes in phytoplankton align with fluctuations in sea surface salinity. Laminated, TOC-rich units correspond to periods of enhanced freshwater discharge.







Fluctuation in sea surface salinity are associated with redox cycles. More reducing conditions during periods of enhanced freshwater supply favoring water column stratification and organic matter preservation.

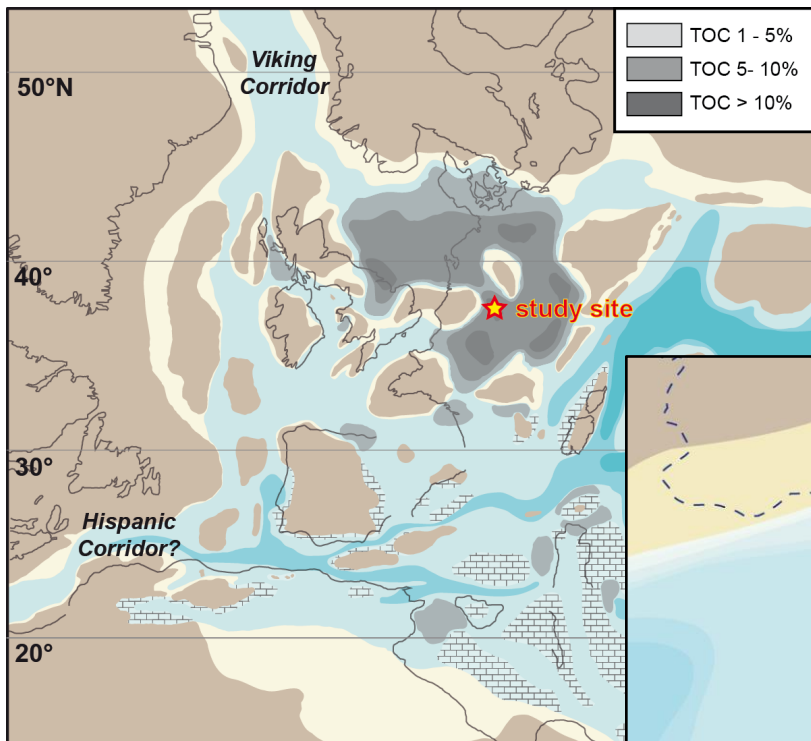


**Detecting cyclicity in  
source rock sequences?**

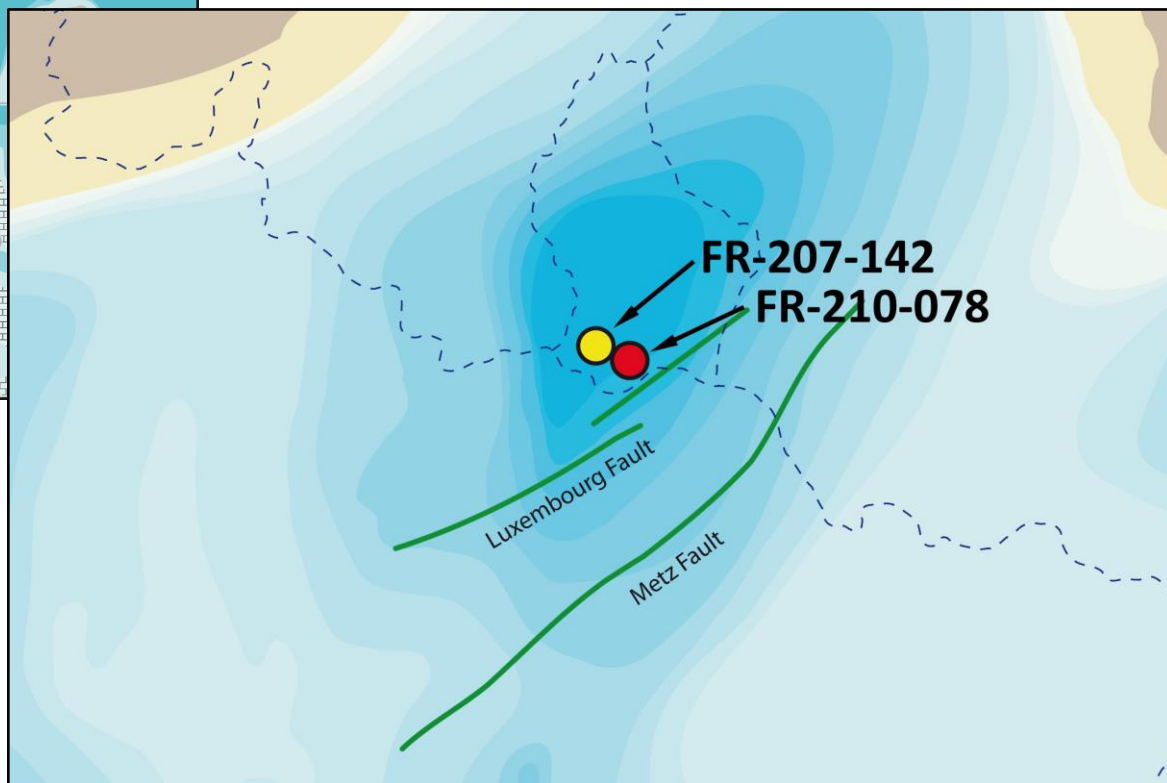
**A matter of resolution !!!!!**

Is the resolution required routinely  
achieved?

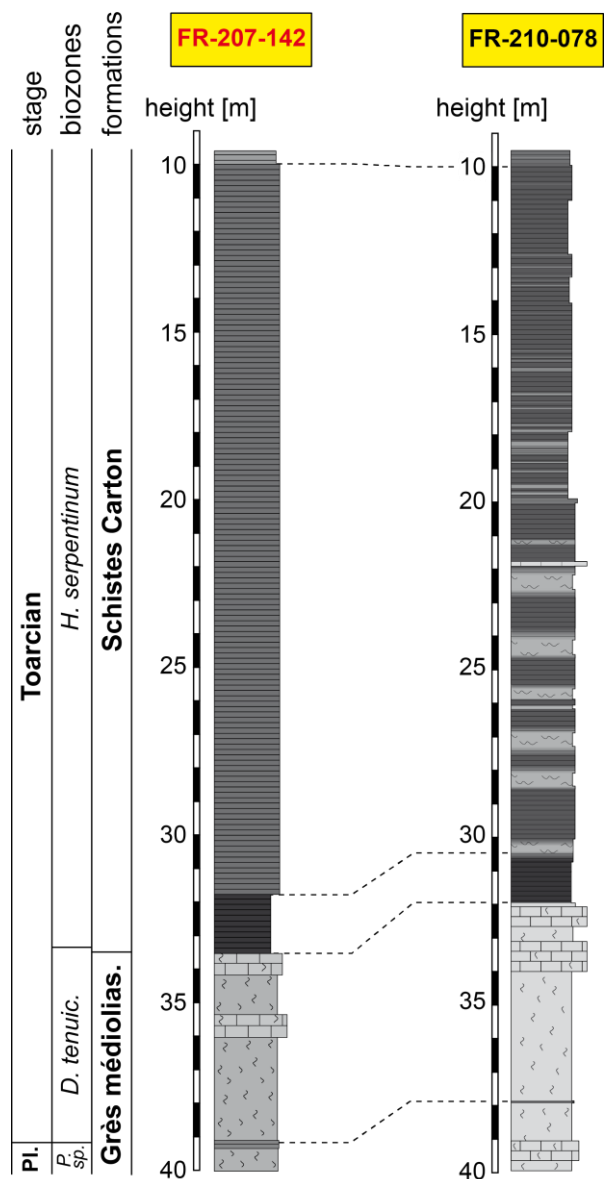
### 3. Effect of resolution



Two parallel cores from the NE Paris Basin studied at different resolution (distance in field approx. 2 km).



### 3. Effect of resolution



## Two wells studied at different resolution

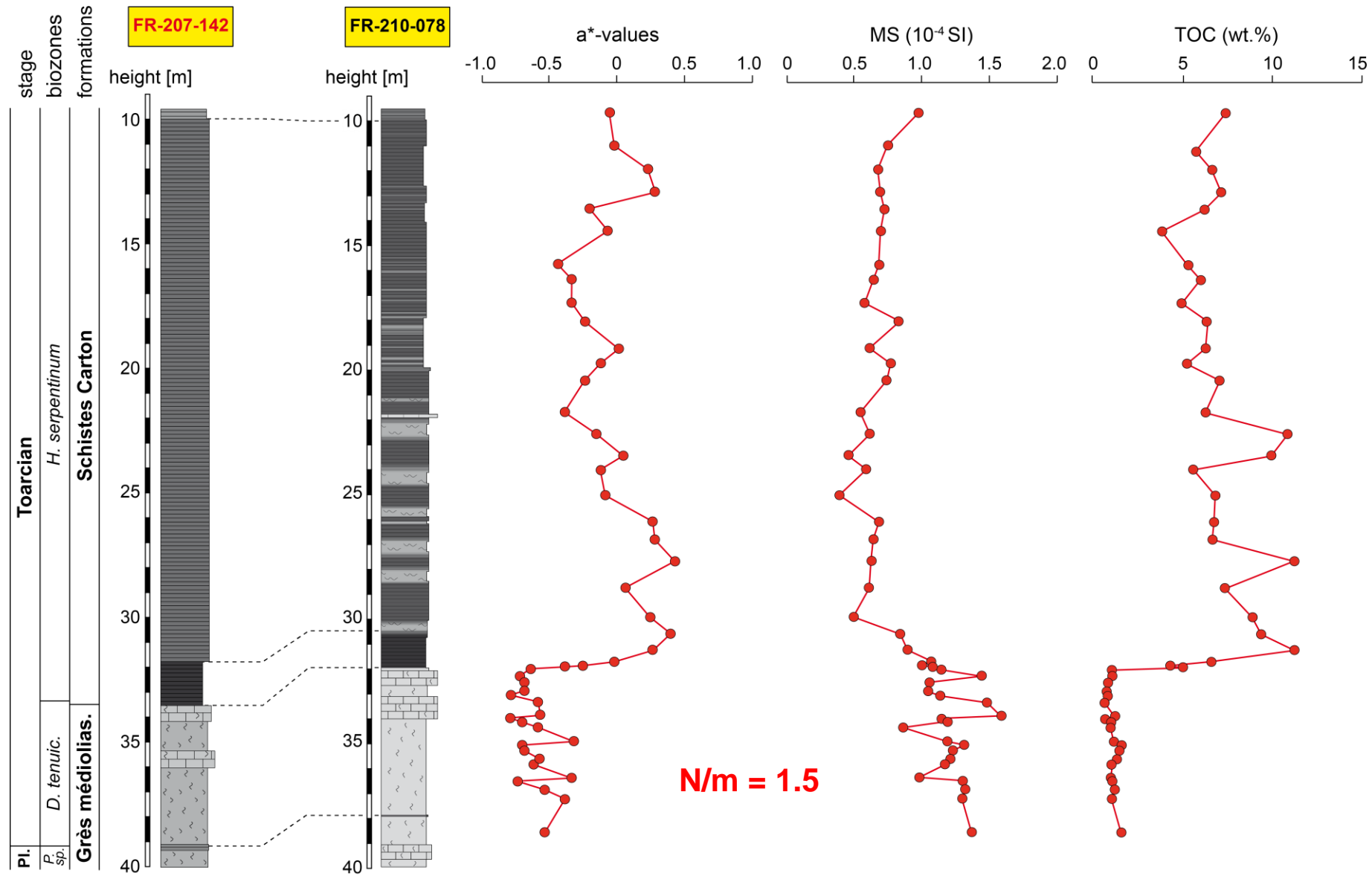
### Core 207-142:

Core description of the non-split core 207 indicated monotonous lithology and sedimentology.

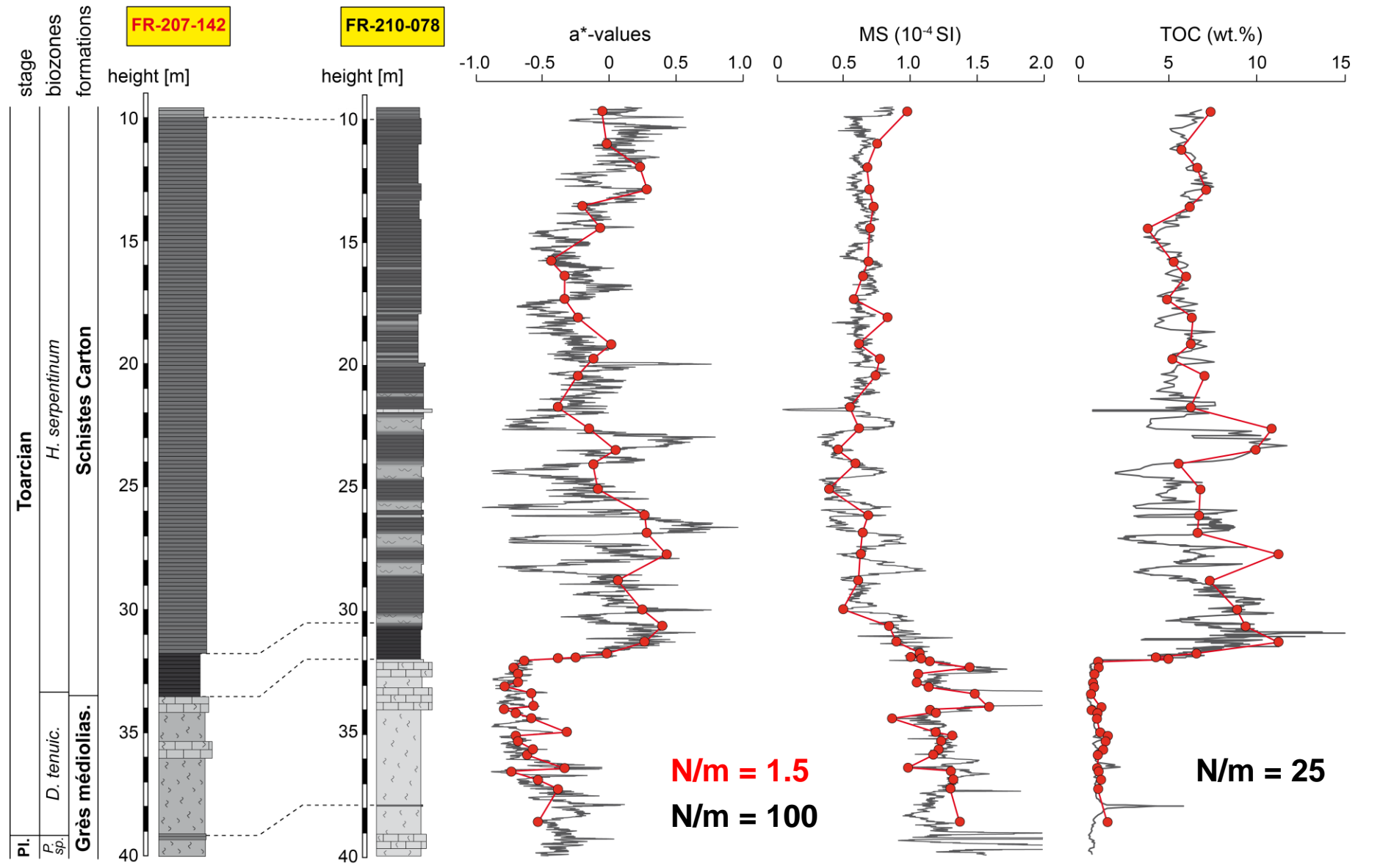
### Core 210-078:

Detailed inspection of polished core half surface of core 210 revealed subtle differences in lithology and sedimentology with a cyclic pattern.

# 3. Effect of resolution

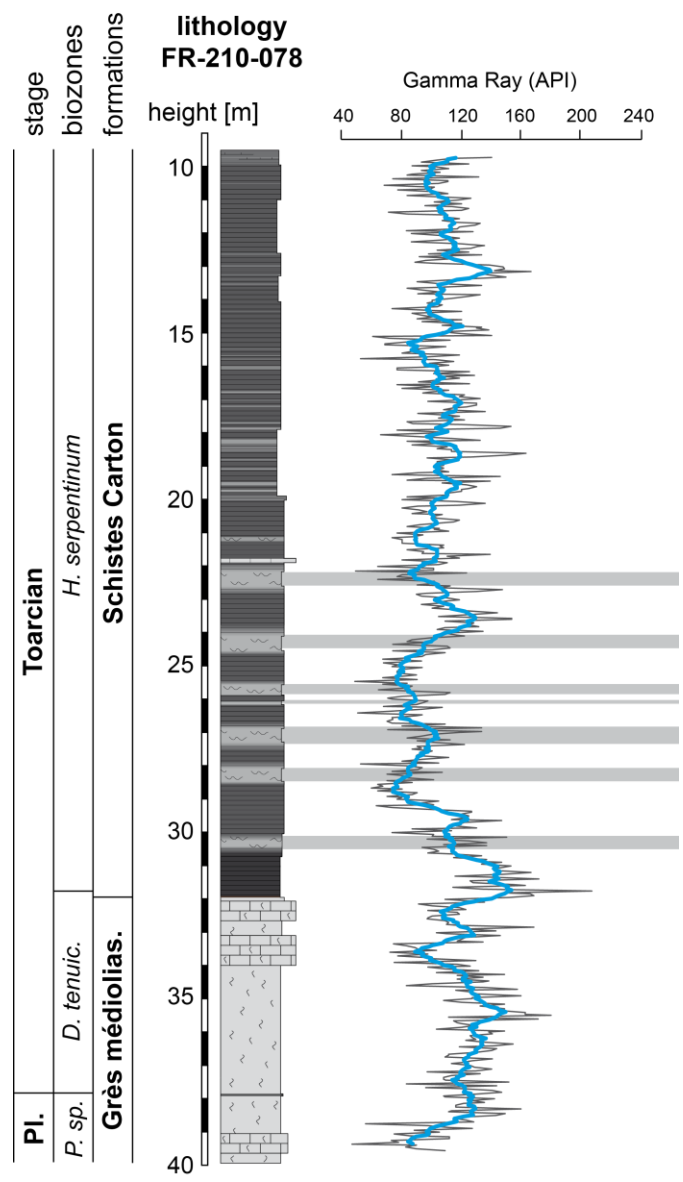


# 3. Effect of resolution



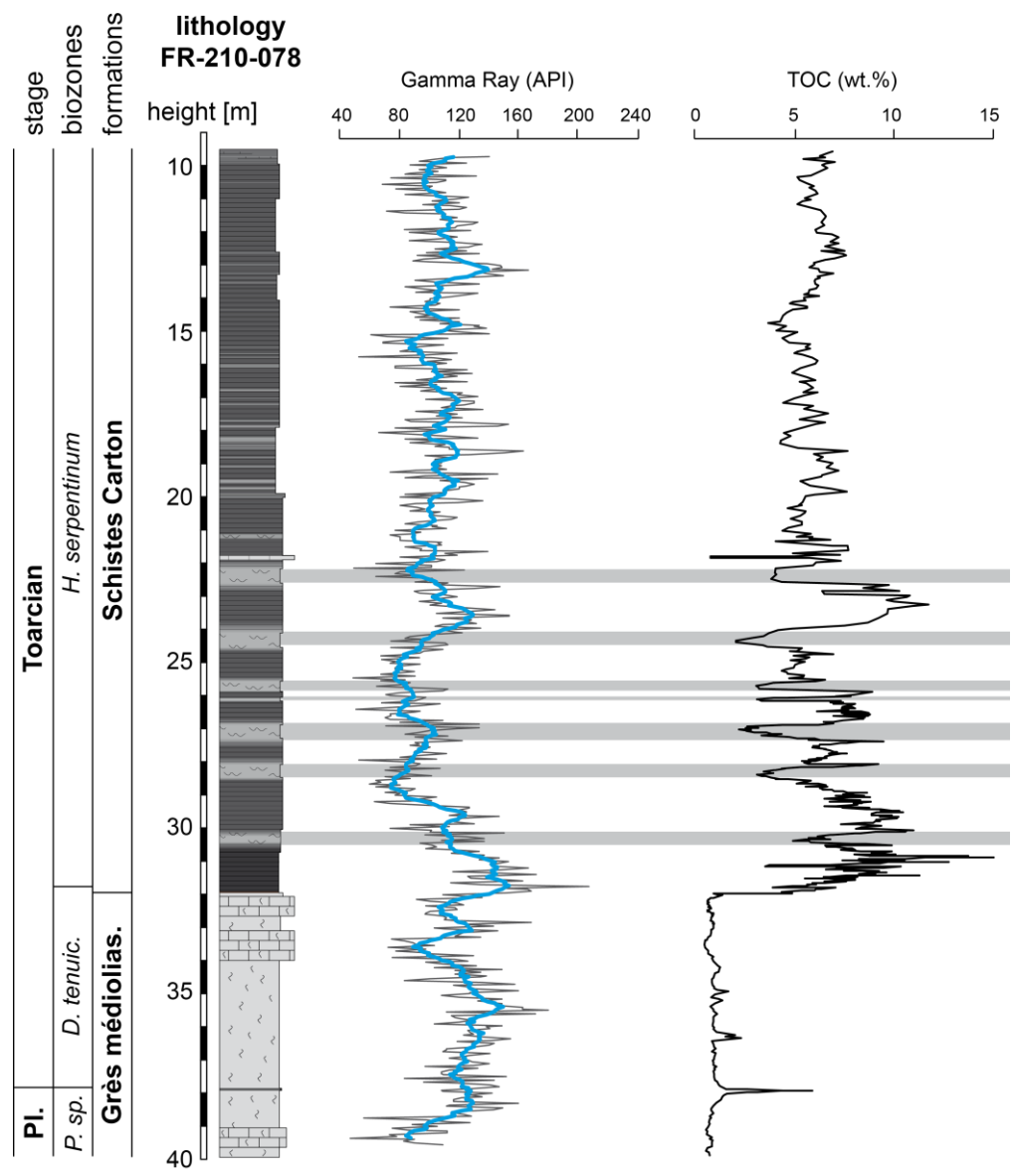
**Which information can high resolution core scanning provide that is not already available in equivalent quality from wireless logging?**

# 4. High-res. core scanning approaches

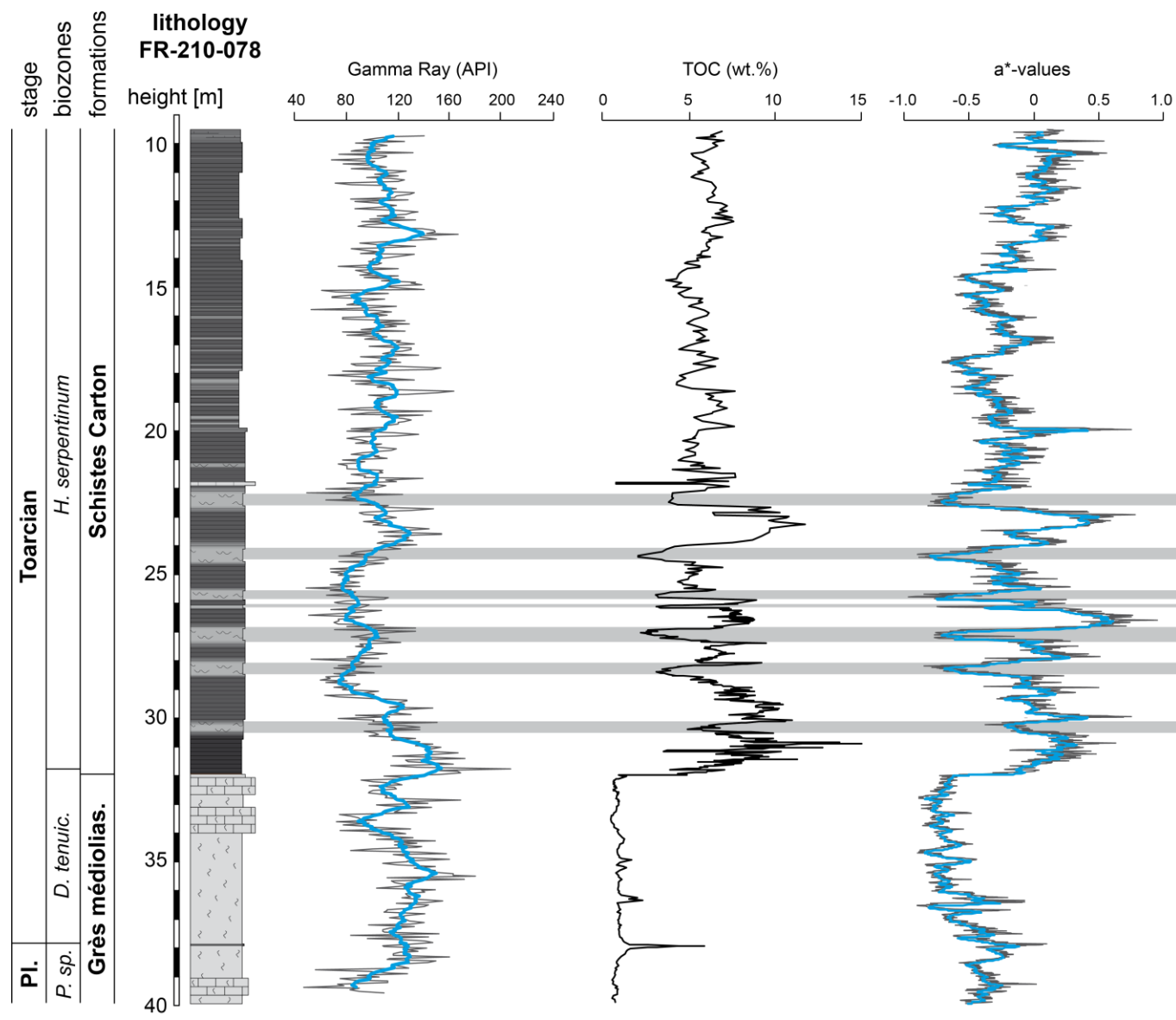




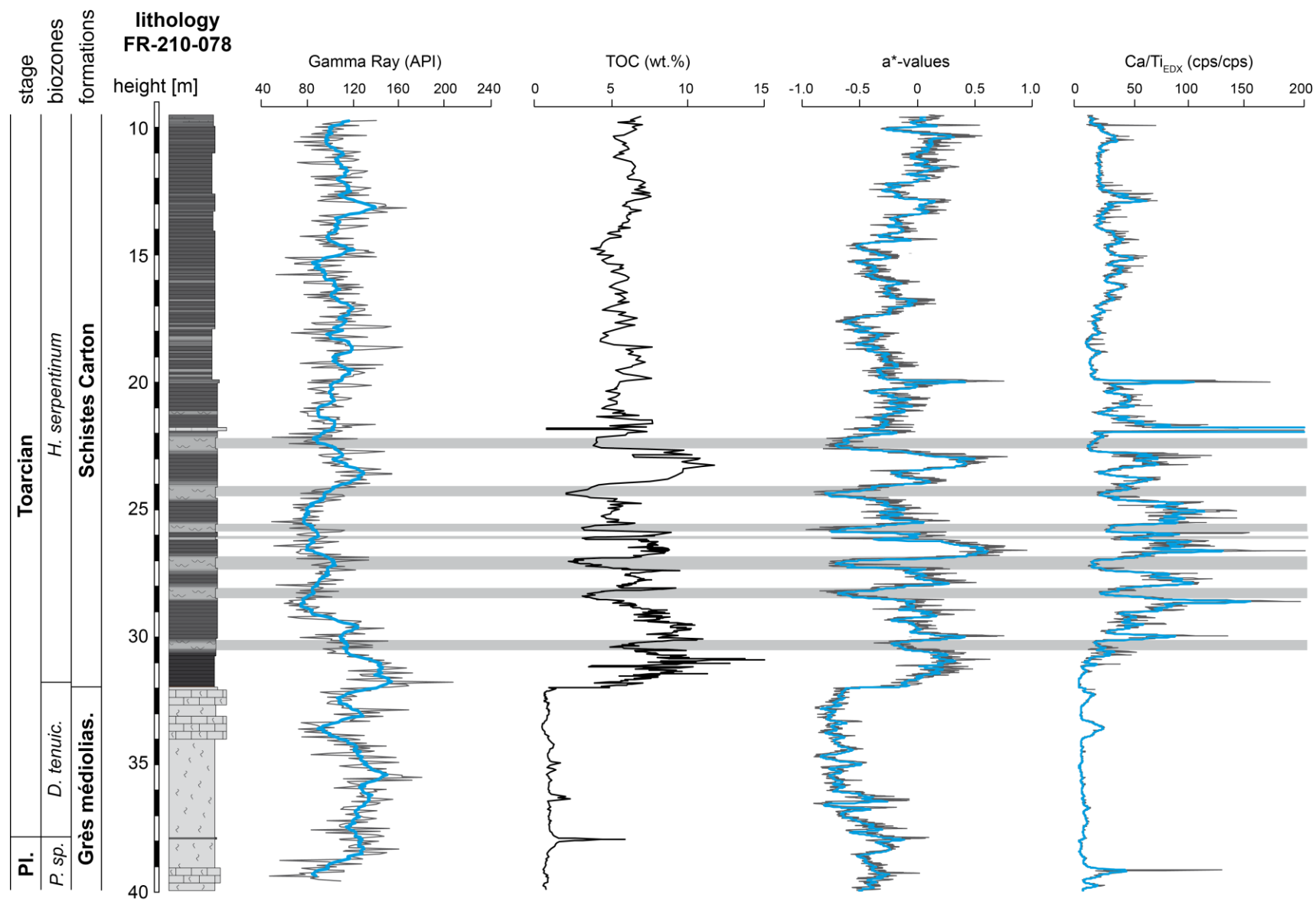
# 4. High-res. core scanning approaches



# 4. High-res. core scanning approaches



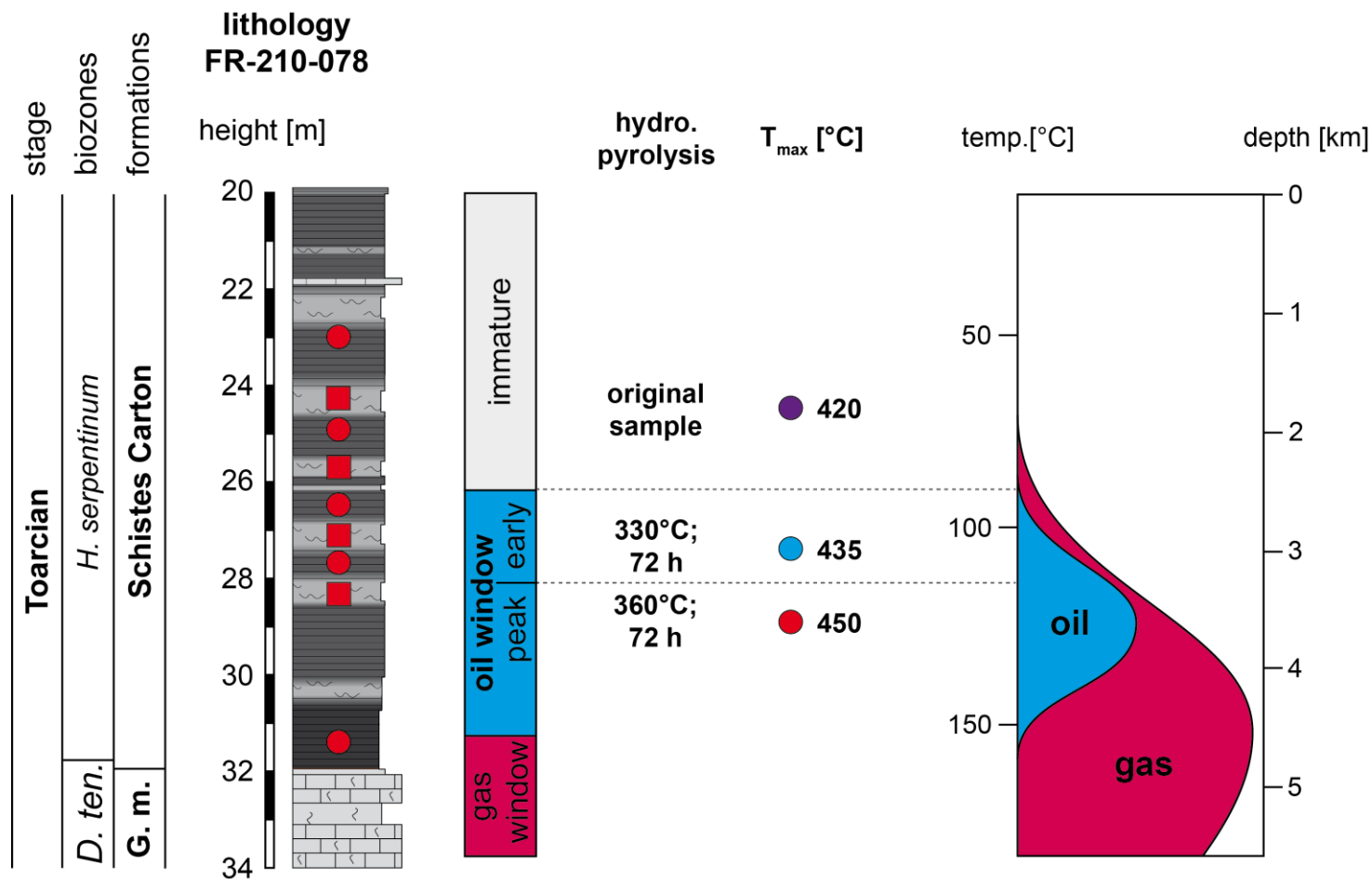
# 4. High-res. core scanning approaches



**Do alternating layers in cyclically deposited source rocks yield different amounts/types of oil?**

Is there a need to consider this in basin modeling or development of unconventional plays?

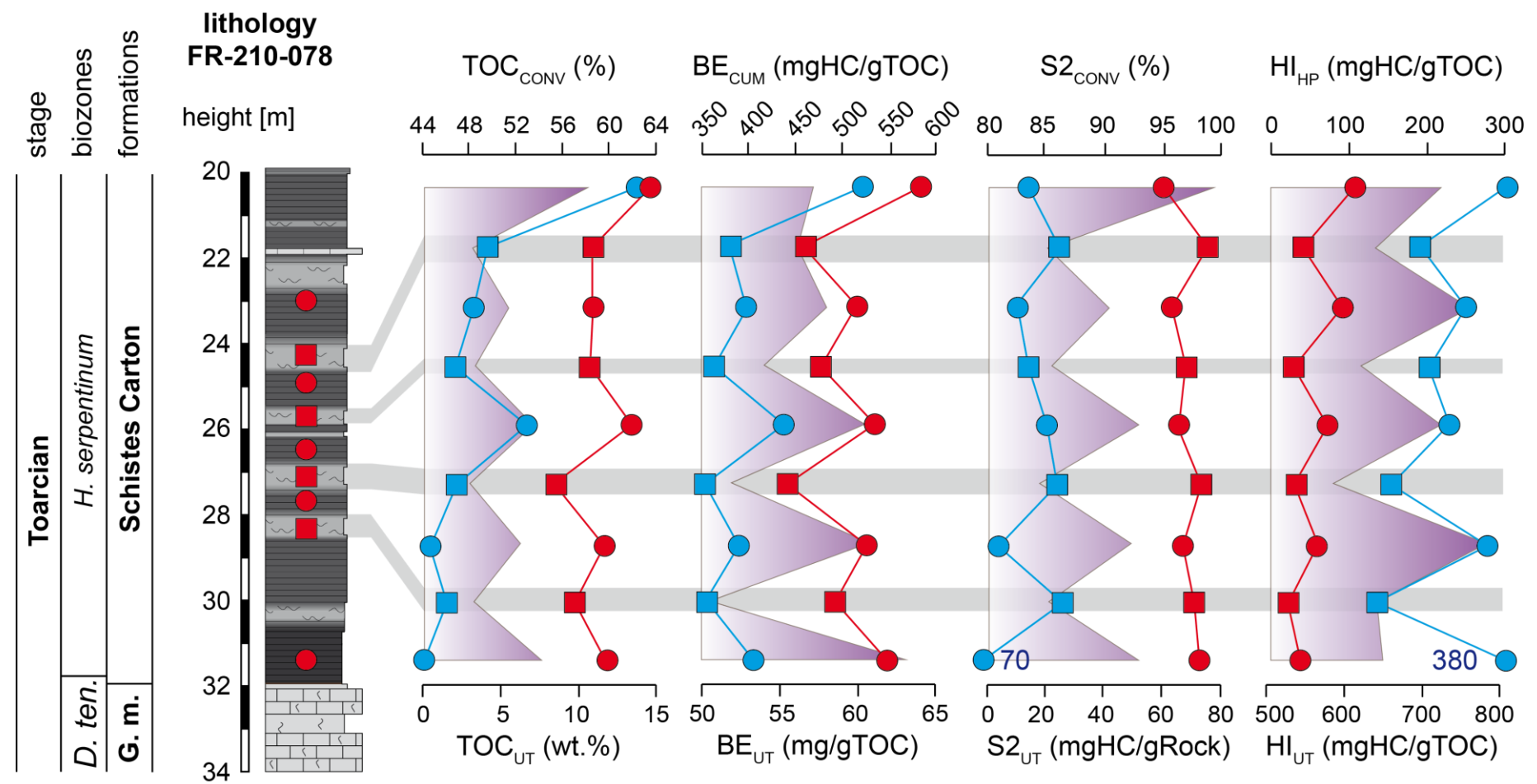
# 5. Petroleum generation potential



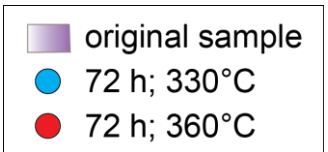
Samples from the different sub-units subjected to hydrous pyrolysis at:

1. 330°C; 72 h → early oil window
2. 360°C; 72 h → peak oil window

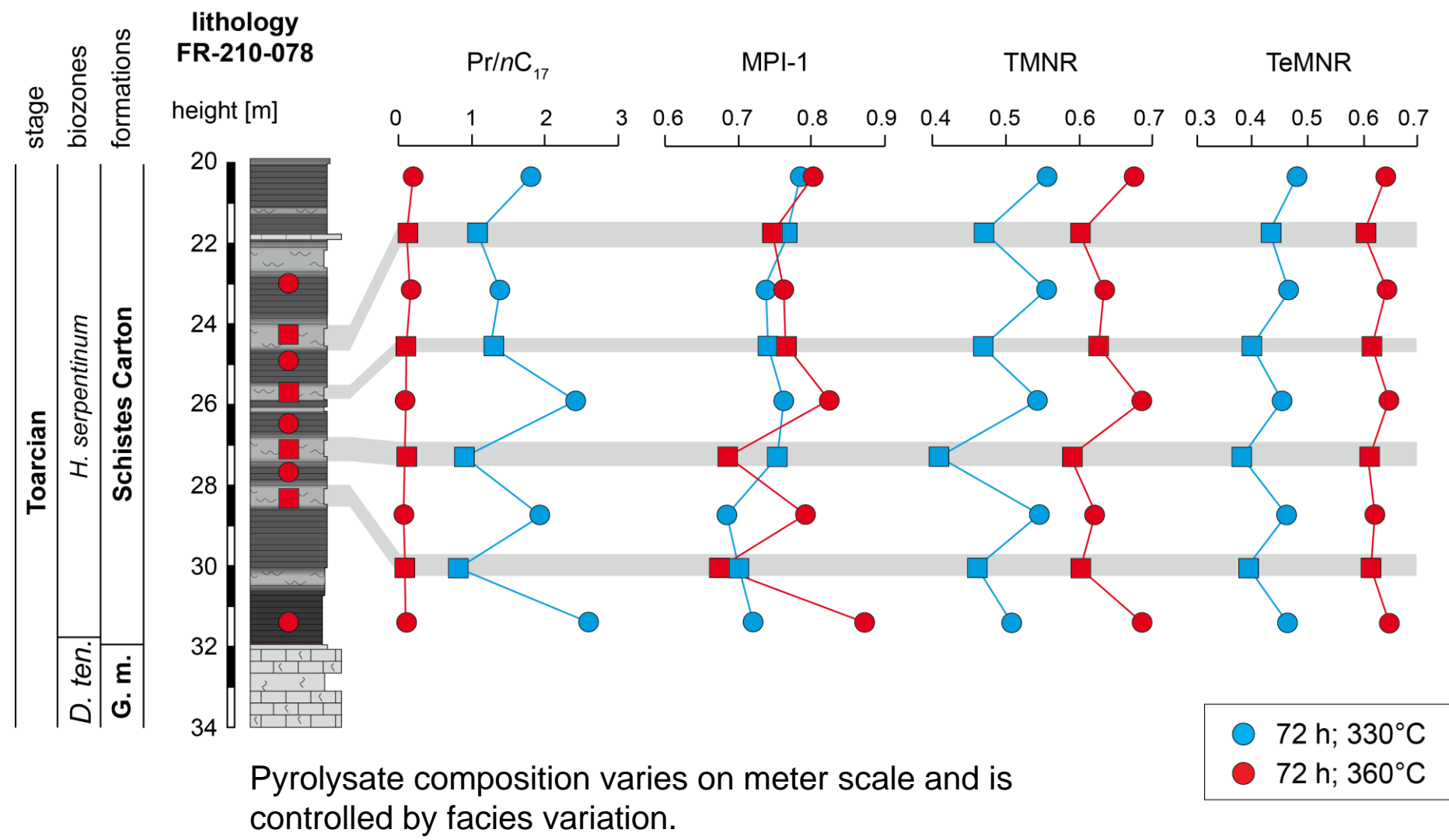
# 5. Petroleum generation potential



Systematic variations in organic matter conversion and bitumen yields (BE: bitumen extract) indicate variable source rock potential. Higher residual source potential for TOC-rich units.



# 5. Petroleum generation potential



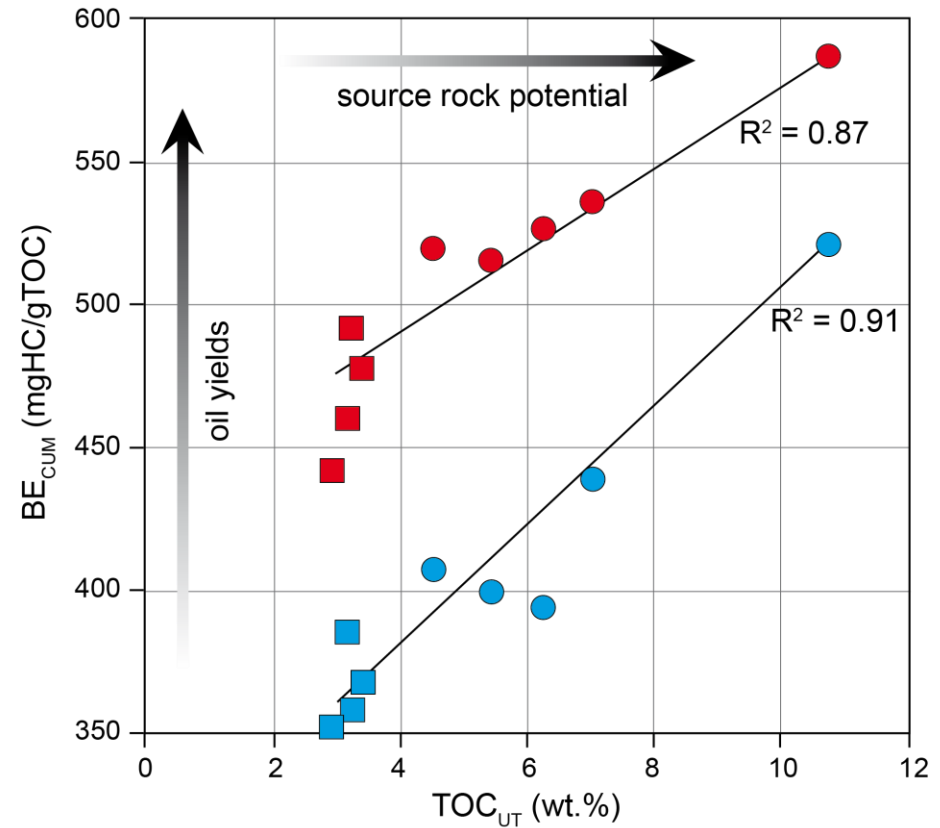
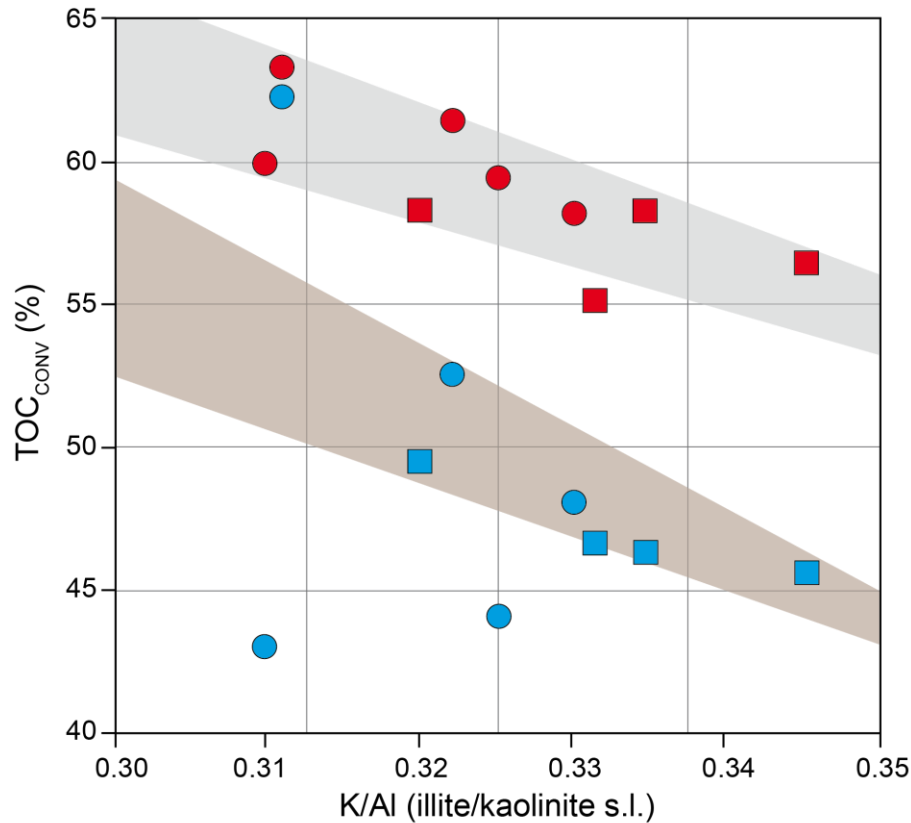


## Conclusions and take home message

- Source rocks of sufficient thickness are typically deposited over a duration of  $>100$  ka and reflect orbitally controlled variability in environmental conditions.
- The Posidonia shale interval of 10 m thickness represent 400 kyr sediment accumulation (4 x 100 kyr eccentricity cycles).
- The variability can be noted when applying high-resolution monitoring techniques, in particular sediment color, magnetic susceptibility or EDX-scanning.
- Based on source rock variability established with continuous analysis techniques, representative sampling for highly sophisticated analysis can be conducted and effective source potential be calculated.
- Improved knowledge in high-frequency source rock variability may be implemented in basin modeling and may guide in more effective development of unconventional plays.

**Thank you for your attention!**

## 5. Petroleum generation potential

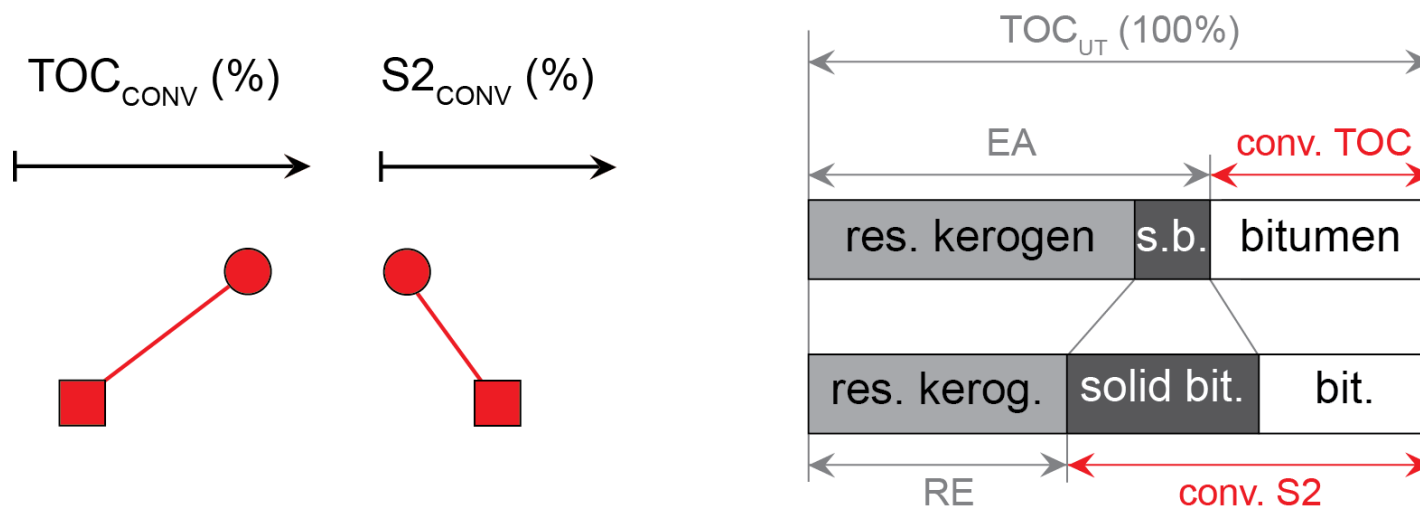


Differences in lithology impact on TOC conversion ratio and thus on the oil generation potential. This effect is most pronounced for the main oil generation phase.

Bitumen (oil) yields are bound to the kerogen quality, whereby TOC-rich units yield higher bitumen amounts.

- 72 h; 330°C
- 72 h; 360°C

## 5. Petroleum generation potential



EA: elemental analysis (combustion at 1200°C)

RE: Rock Eval analysis (pyrolysis at 550°C)

Relative proportions of solid bitumen higher in samples from non-laminated units, due to higher aromaticity of the kerogen.

Solid bitumen not detected by RE, interpreted as higher S2 conversion rates.