Microbial Mats as an Indicator for Pauses during 'Shale' Deposition - Kimmeridge Clay Formation (Upper Jurassic), Offshore UK*

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Abstract

Siliciclastic mudstones commonly consist of a bioturbated matrix made up of silt-size carbonate and quartz, clay minerals, and organic matter. Intense burrowing typically observed in shale successions, however, often homogenizes these fine-grained rocks and destroys sedimentary structures that would help to identify original depositional processes. It, therefore, remains unclear whether thick shales were deposited by a constant rain of material in suspension or how much episodic „events' influenced sedimentation. Small microbial mats present in three cores of the Kimmeridge Clay Formation, UK, a world-class source rock, are used to address this problem.

Microbial mats in Kimmeridge siliciclastic mudstones occur as sub-millimeter-long discontinuous laminae of organic matter. They vary in thickness laterally and characteristically contain minor amounts of clay-size quartz, feldspar, and illite grains equivalent in composition to surrounding detritus. The mats occur just a few tens to hundreds of micrometers apart at irregular intervals within the formation and locally drape over agglutinated foraminifera.

The abundance of microbial mats in the Kimmeridge suggests that mat growth on the seafloor (distal shelf environment) was a common phenomenon. As mat-forming organisms require oxygen, and mat-forming bacteria live at redox boundaries (i.e., sulfate-sulfide interface), their mere presence argues for at least dysoxic conditions on the seafloor during deposition. Their abundance indicates that 1) oxygen levels might have been too low for grazers to thrive; 2) their discontinuous nature reflects some grazing activity with preserved mats representing remains of a larger, more continuous mat; and 3) photic zone water depths were common during deposition.

In order to grow on the seafloor, it is most likely that the microbial mats reflect „quiet' depositional times, with only minor very fine-grained detrital input from suspension settling. During phases of enhanced runoff or storm events, clay and some coarse silt grains were transported even into the most distal parts of the Kimmeridge basin, covering existing mats. Subsequently, another generation of organisms formed a new

mat, the net effect being alternation of mats and sediment; quick burial of mats by the sediment probably aided in their preservation. Microbial mats, therefore, indicate pauses in deposition of shales, likely in a dysoxic environment, alternating with sedimentation pulses during events.

References Cited

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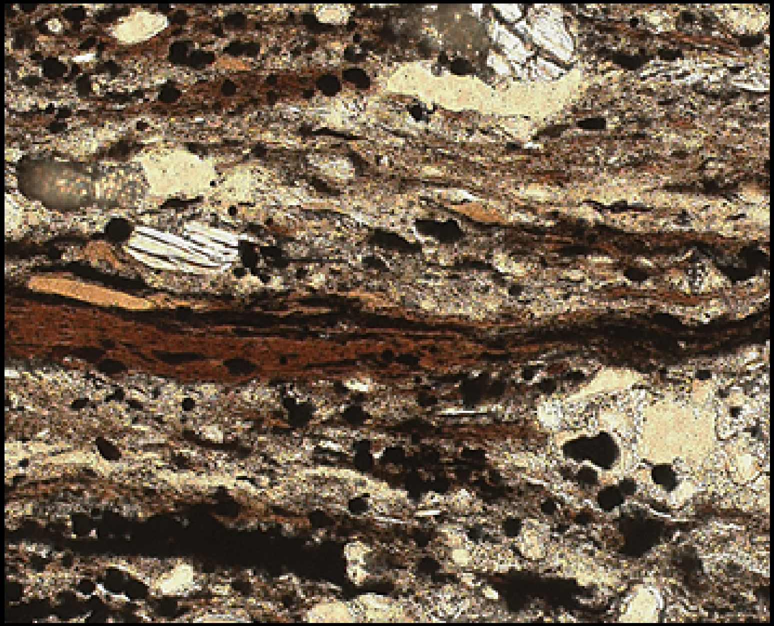
Macquaker, H.S., M.A. Keller, and S.J. Davies, 210, Algal blooms and “marine snow”: Mechanisms that enhance preservation of organic carbon in ancient fine-grained sediments: Journal of Sedimentary Research, v. 80, p. 934-942.

Micromats as an indicator for pauses during shale deposition – Kimmeridge Clay Formation (Jurassic, offshore UK)



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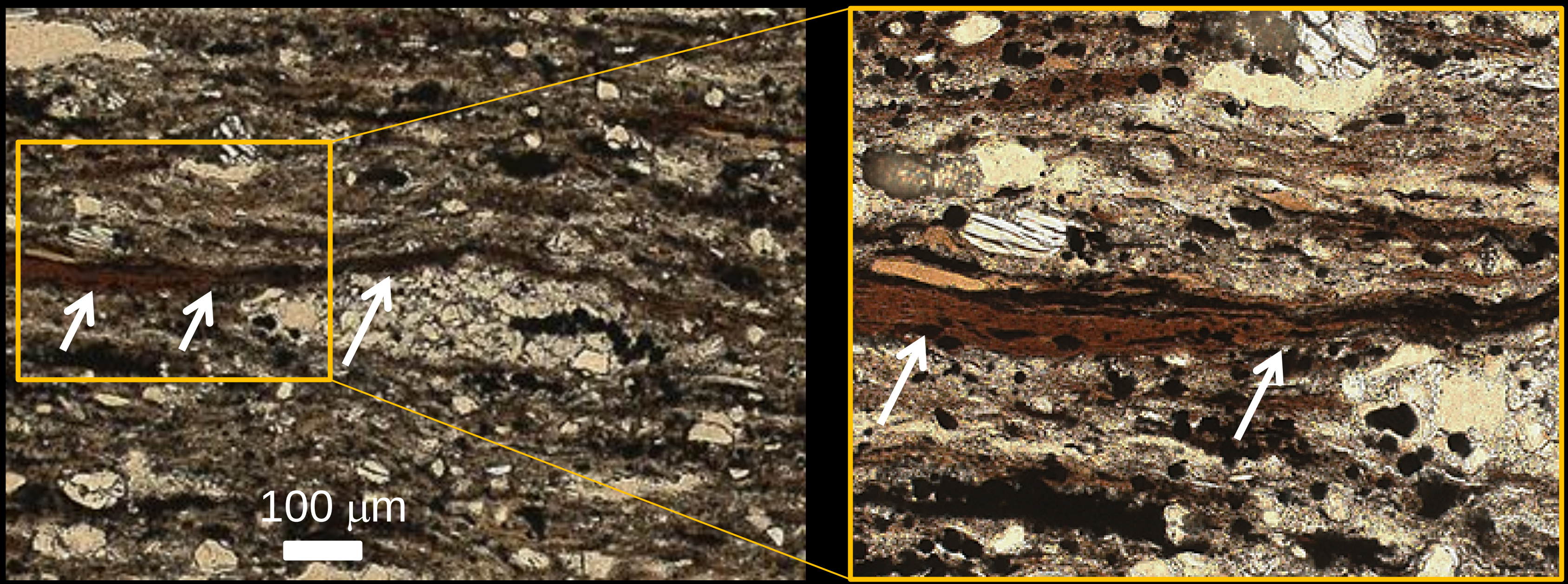
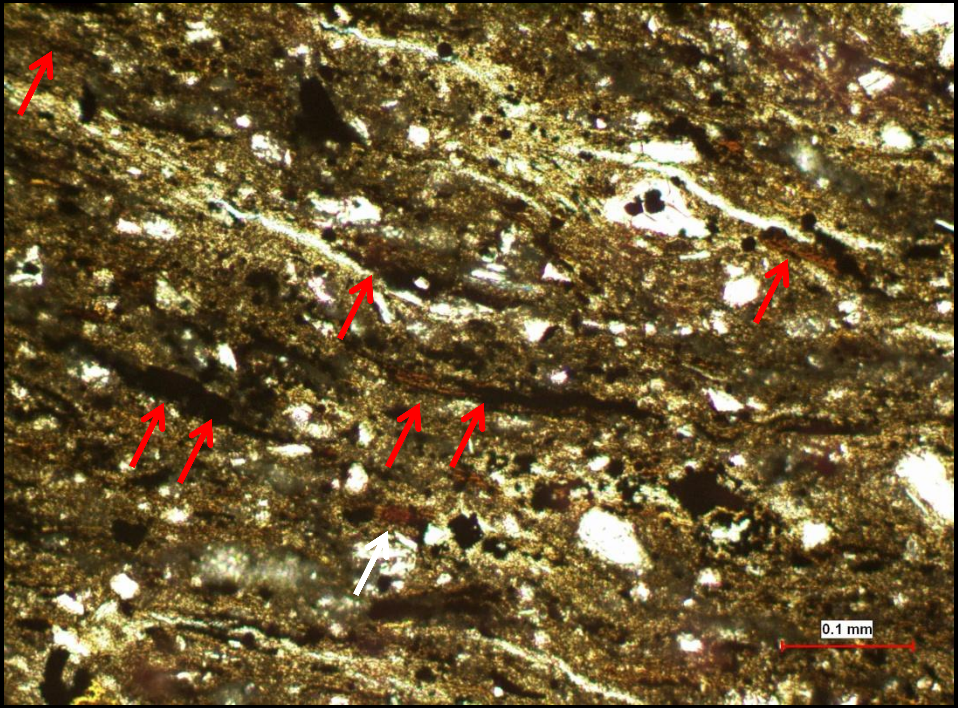
Micromats – what are those?



- ~ 1 millimeter long, tens of micrometers thick
- Organic material, brown to black
- Can cover other grains or organisms (here agglutinated foraminifera)

Micromats…

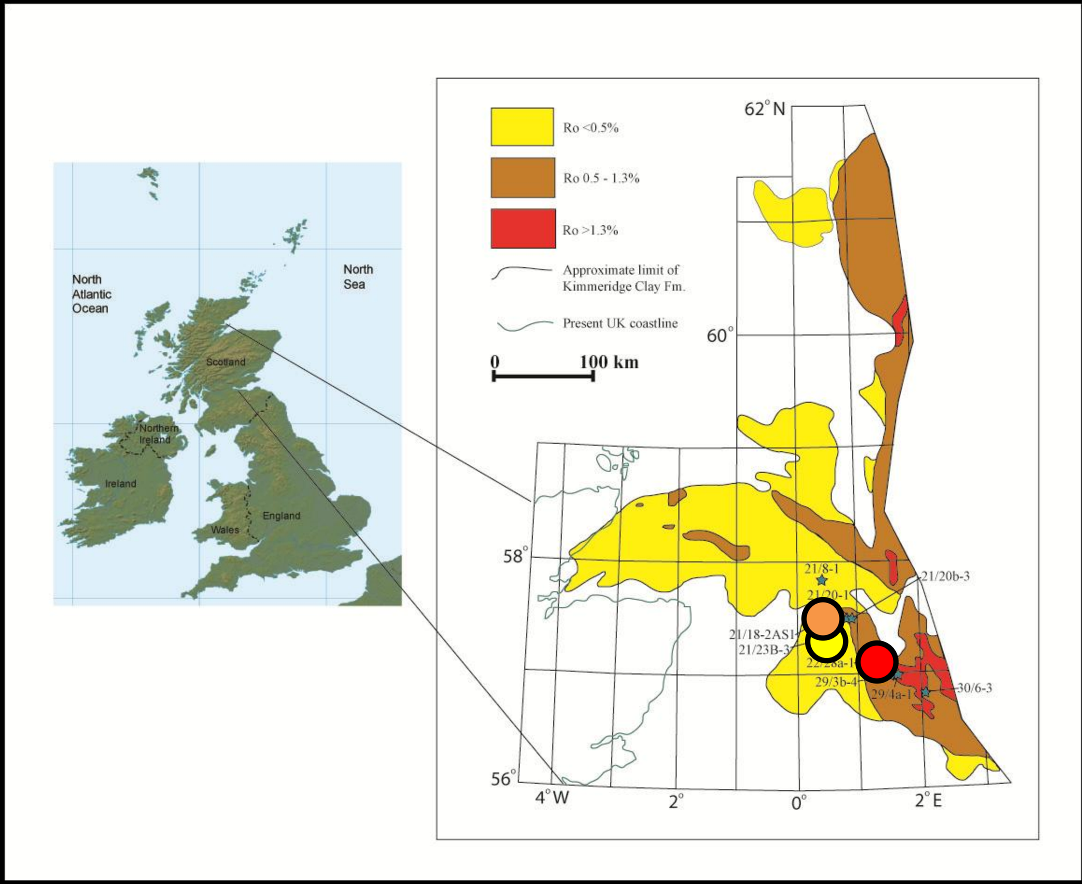
- Importance – why should we care?
- Characteristics of micromats
- Origin – formed where and how?
- Occurrence during sea-level fluctuation, sequence stratigraphic position of micromats



Kimmeridge Clay KCF-8

Study area

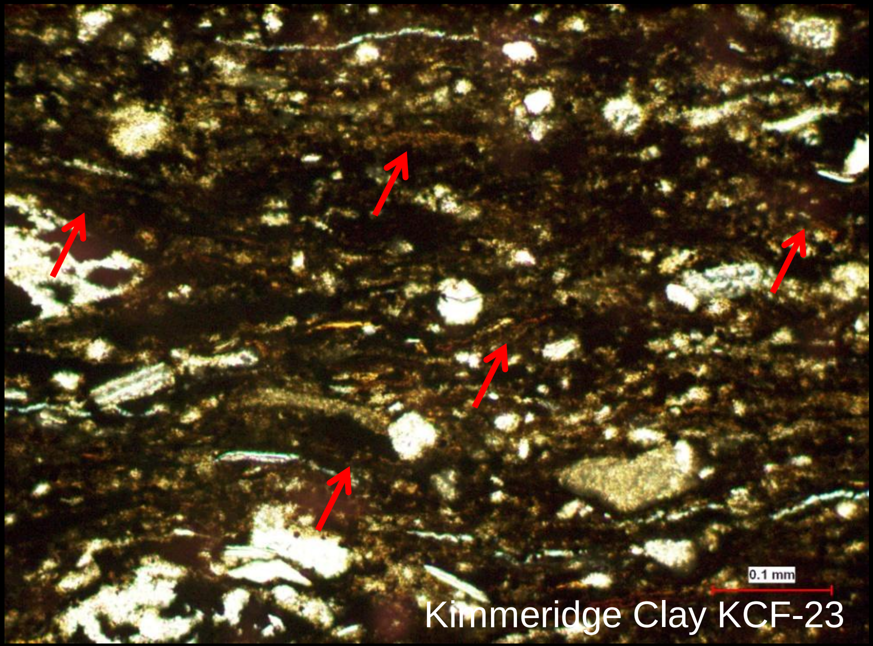
- Samples from 3 wells offshore Scotland
- Drilled by Shell/Esso
- High, medium, and low maturity wells
- Here: mostly data from low-maturity well

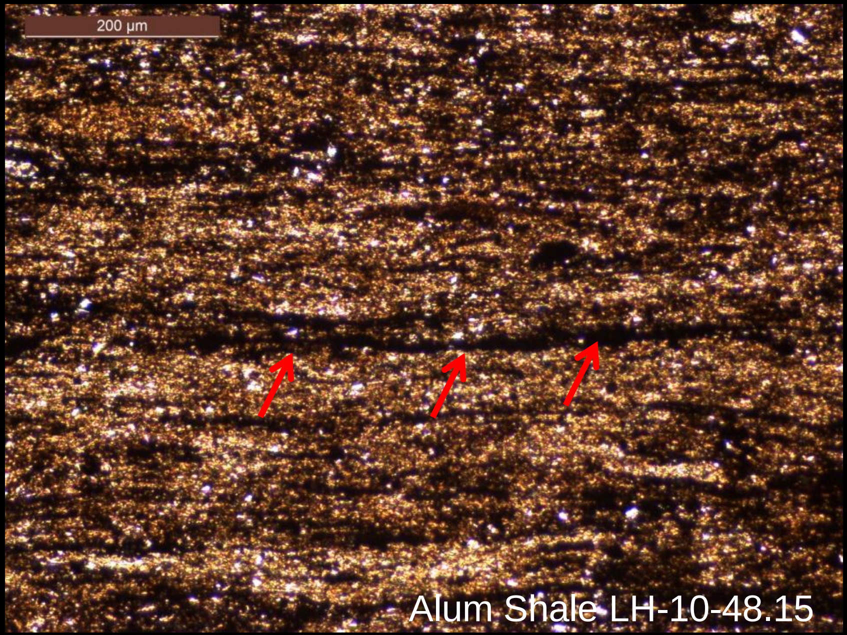


Fishman et al., 2012

Importance of micromats?

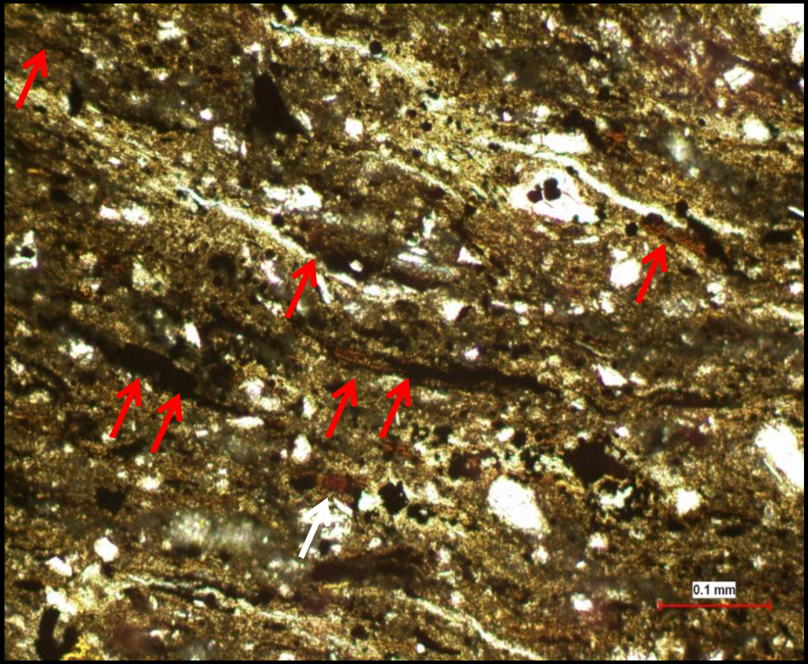
- Alginite and bituminite → generate hydrocarbons
- In Kimmeridge Clay: dominate the OM present
- Often overlooked, but common in many formations: Kimmeridge Clay (Jurassic), Alum Shale (Cambrian), Niobrara (Cretaceous)
- Not well described (only Fishman et al., 2012)





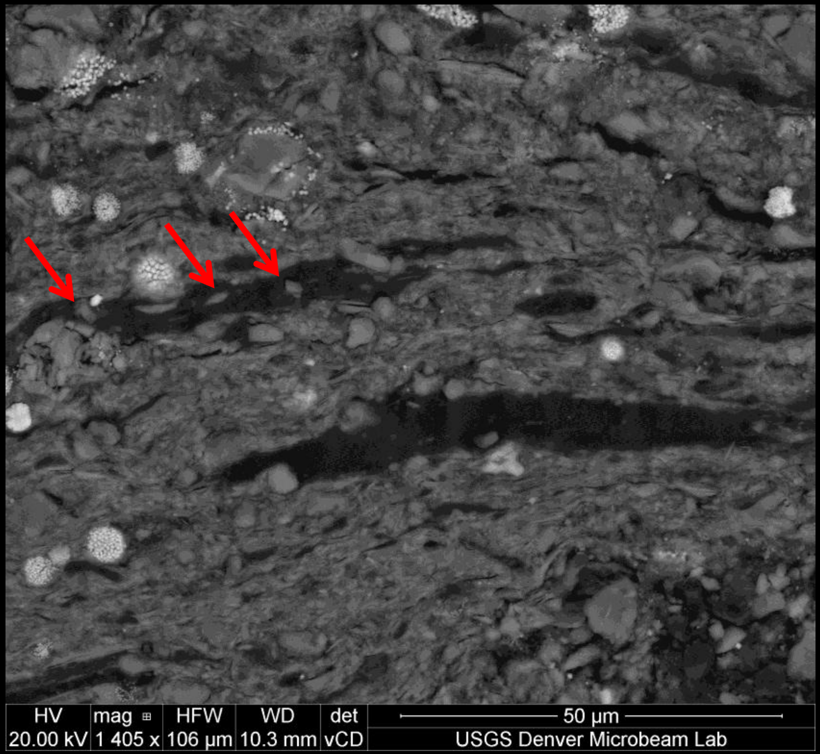
Characteristics of micromats

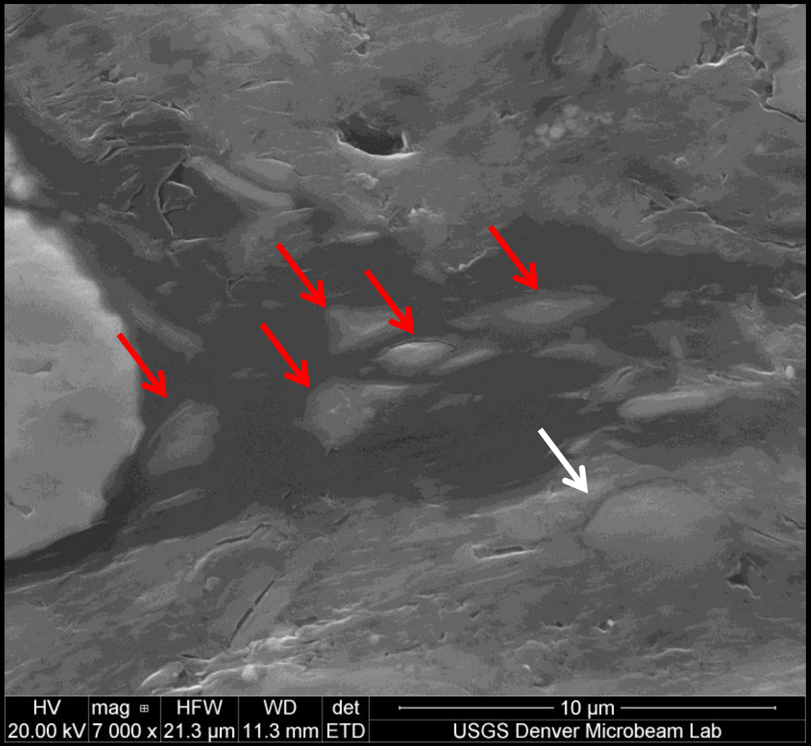
- Elongate, lamellar masses of organic matter
- Arranged parallel to sub-parallel to bedding
- Flat or wavy/crinkly, cover or encase other constituents
- Well defined outer boundaries
- Thickness irregular, ~1 mm in length and 40 μm thick



Characteristics of micromats

- Contains small detrital grains in μm range: quartz, K-feldspar, illite
- Interpreted as "dirt" fallen as suspension through the water column → often smaller than surrounding grains!

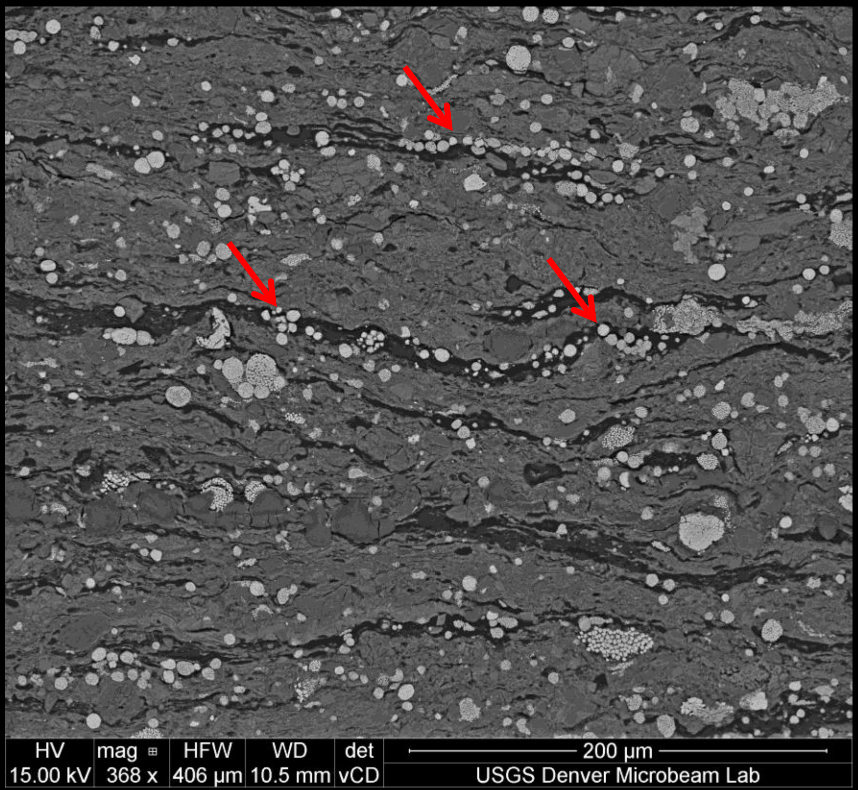




Fishman et al., 2012

Characteristics of micromats

- Contain a lot of diagenetic framboidal pyrite
- Alginite fluoresces, bituminite does not (see photo)

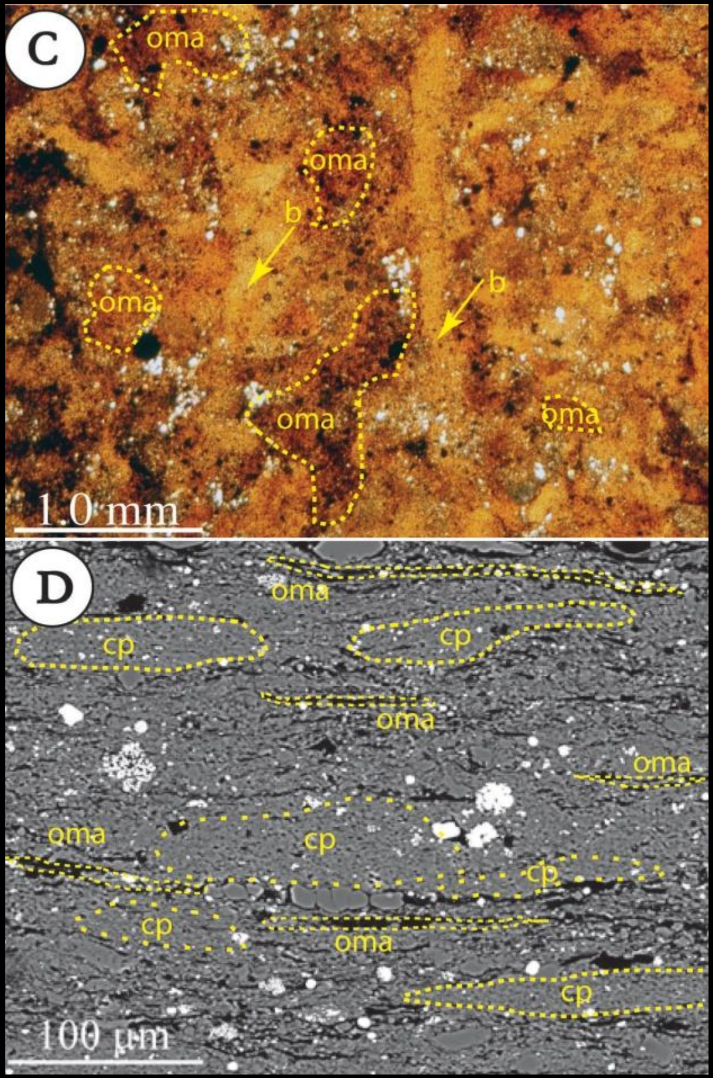


Fishman et al., 2012

Distinction from marine snow

What is marine snow? Why important?

- Organomineralic aggregates consist of clay and organic matter
- Silt to sand size
- Irregular in thin sections parallel to bedding
- Elongate perpendicular to bedding (compaction)



Macquaker et al., 2010

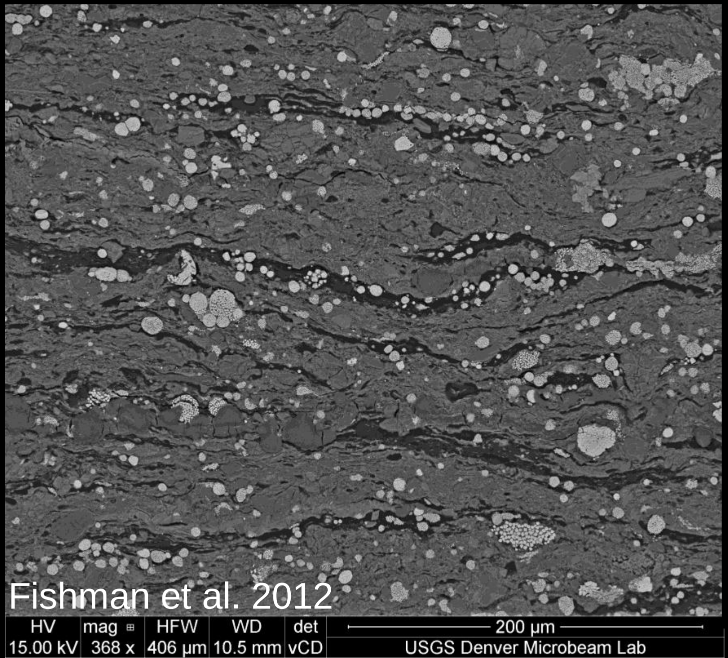
Identification/distinction from marine snow

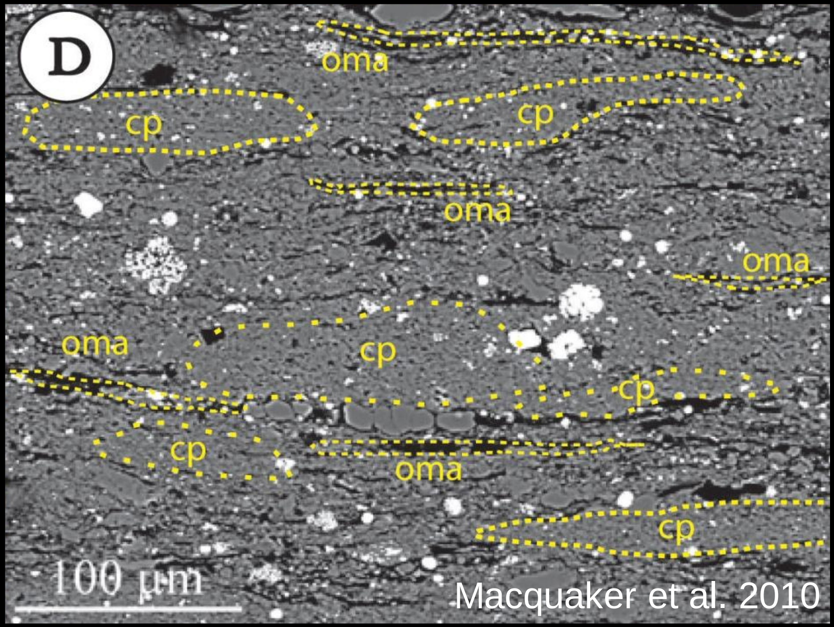
Micromats:

- Laminated
- Accumulation of pyrite at edges and within
- Consists of OM only
- Elongate ll to sub-ll to bd

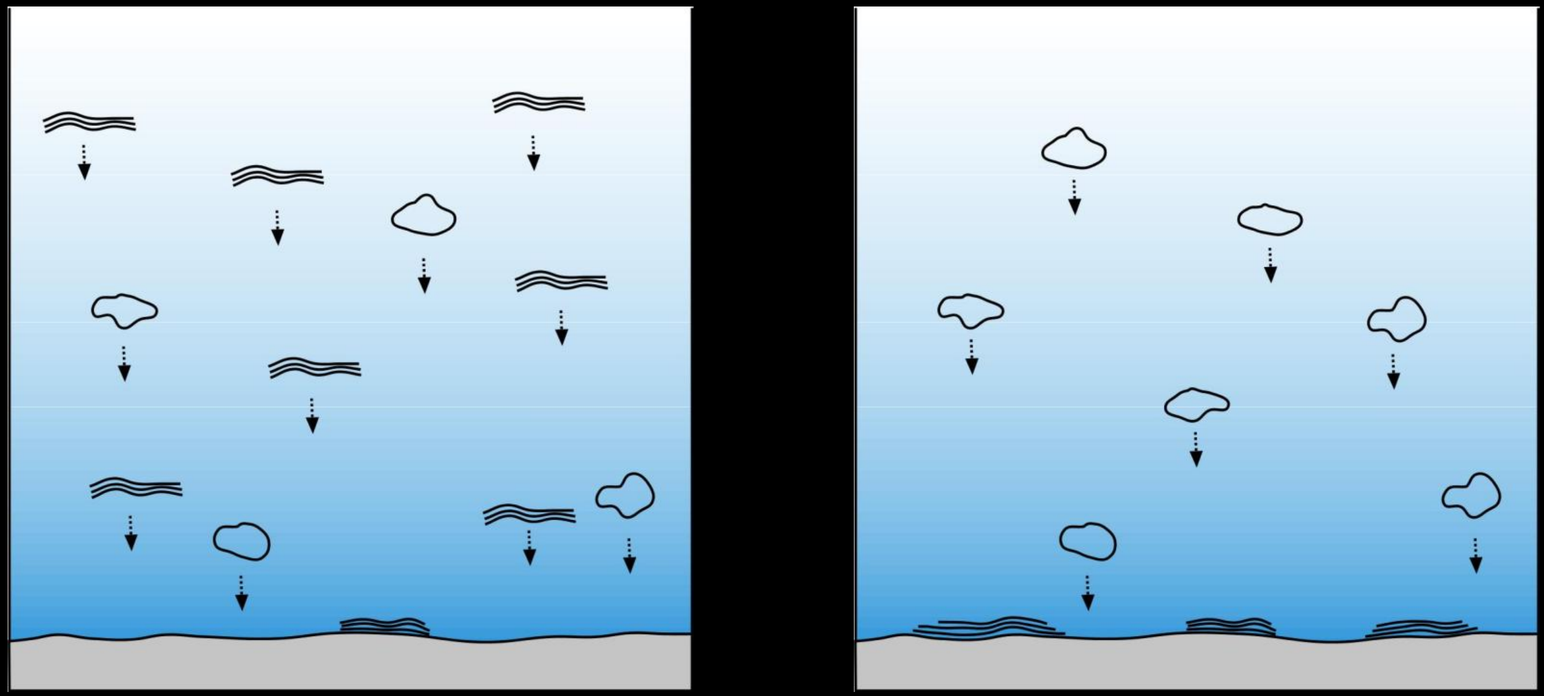
Marine snow:

- Not laminated
- No pyrite accumulations
- Consists of OM and clay
- Elongate ll to sub-ll to bd





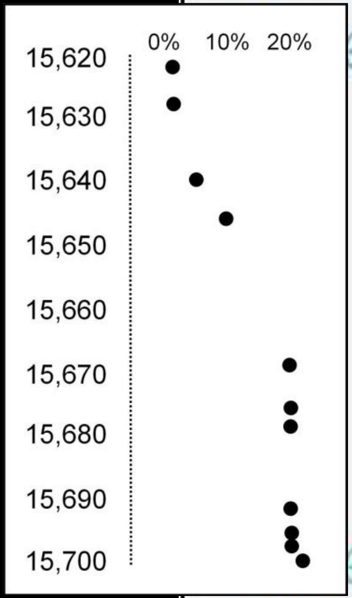
Origin of micromats

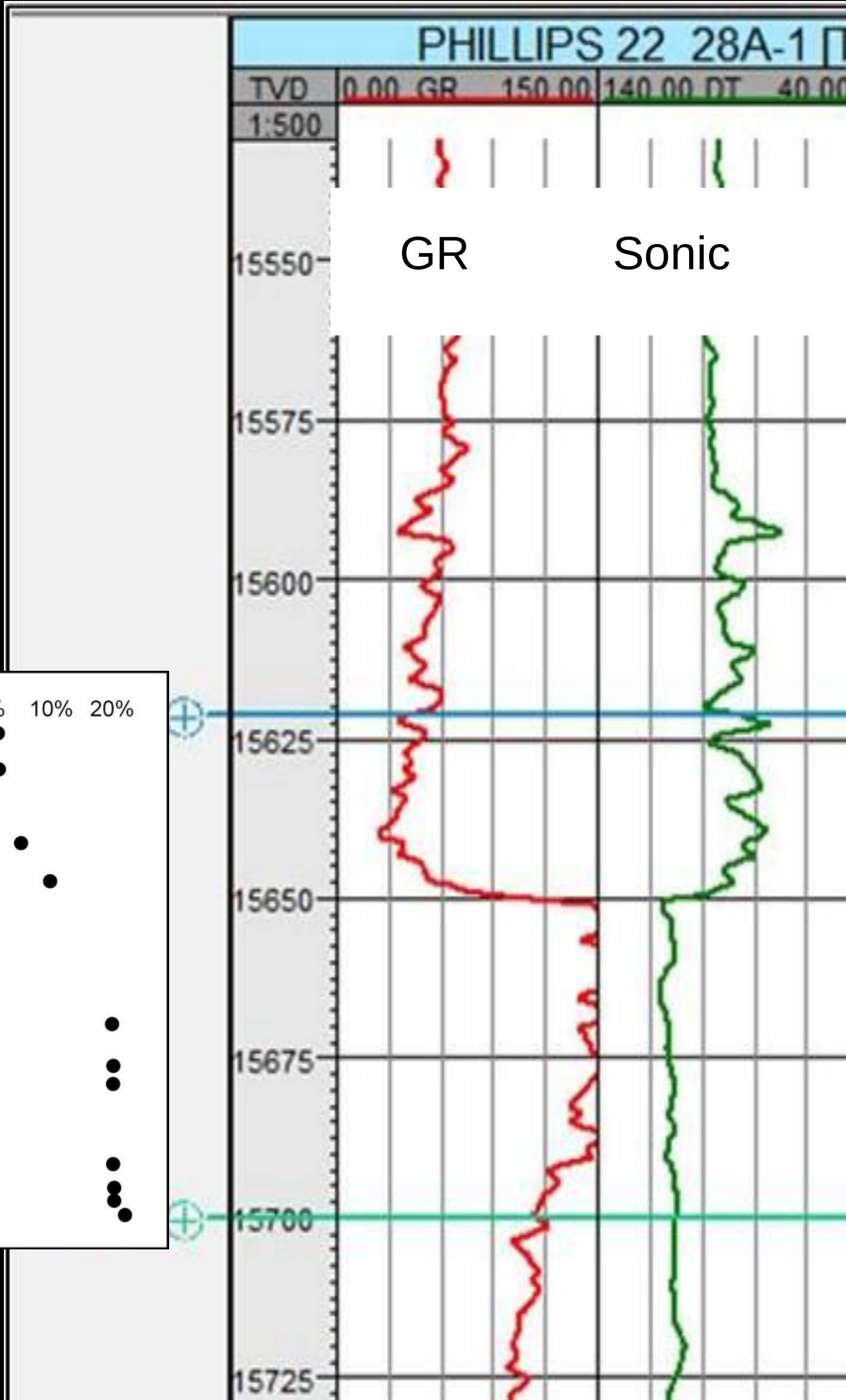


- Two possible models – growth in water column and/or on seafloor
- Discontinuous → small patches on seafloor? Small particles in water column?
- If water column → what do they grow on?

Micromats and well log signature

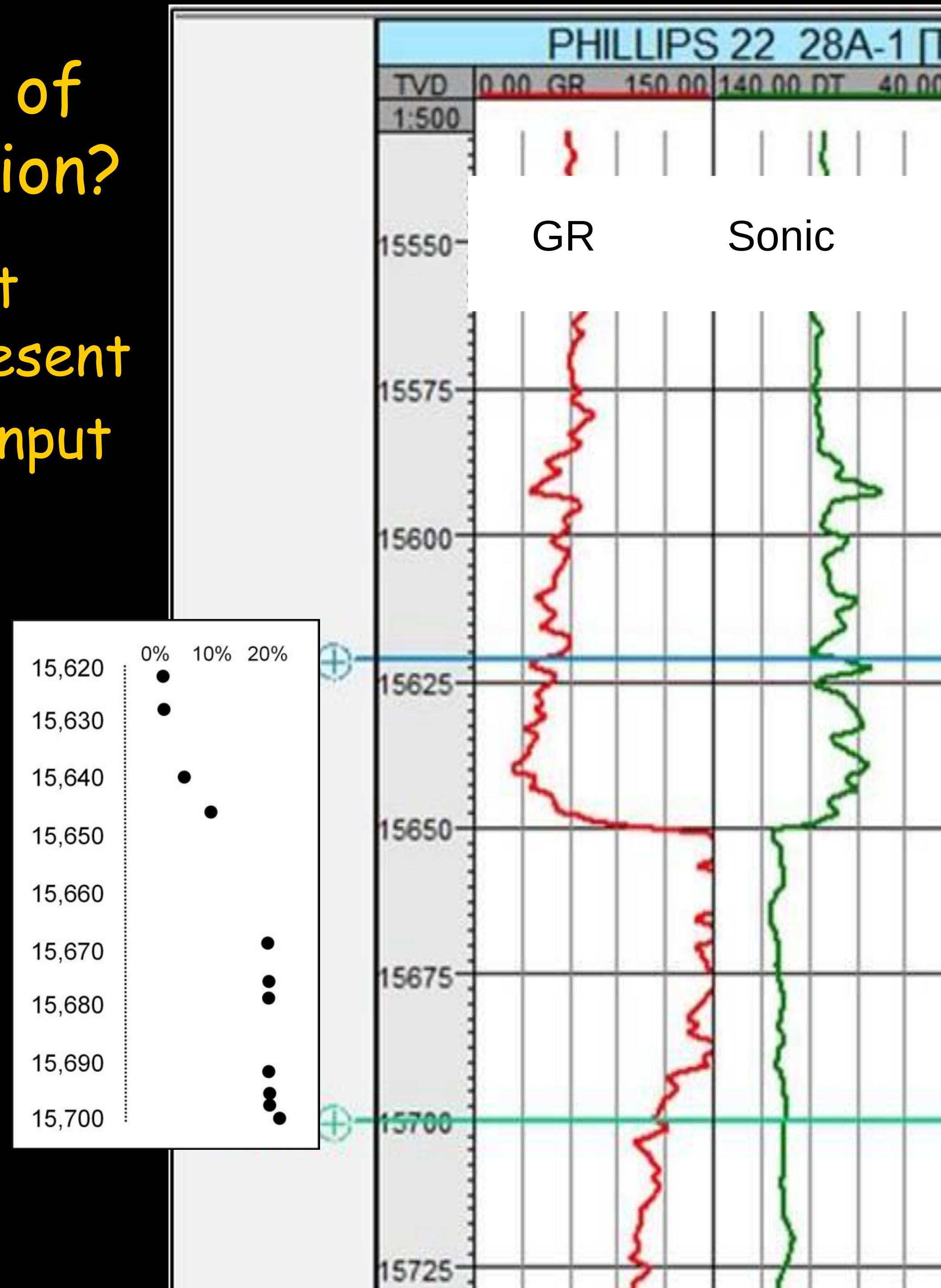
- GR log – sharp increase in API units at ~15650'
- Maximum amount of micromats also increases at same depth
- Also lithological change from silty mudstone to mudstone: In Sonic log travel time goes down when effective porosity goes up





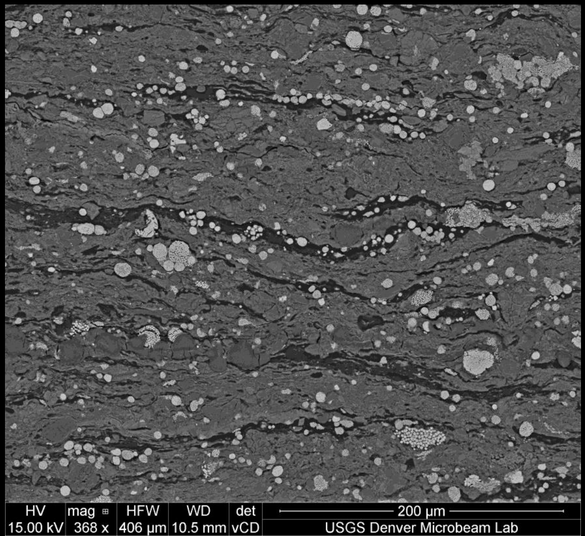
Micromats – indicators of pauses in sedimentation?

- Micromats more frequent when finer lithologies present
- → times when sediment input low
- Probably more frequent during highstands and transgressions



Conclusions

- Micromats present in many source rocks and unconventional reservoirs
- Can make up significant amount of OM present (up to 20% and more)
- Log signature seems to indicate greater abundance during deposition of finer grained mudstone lithologies
- Therefore likely indicators of times of low sedimentation rate = transgressions and early highstands



Thank you!