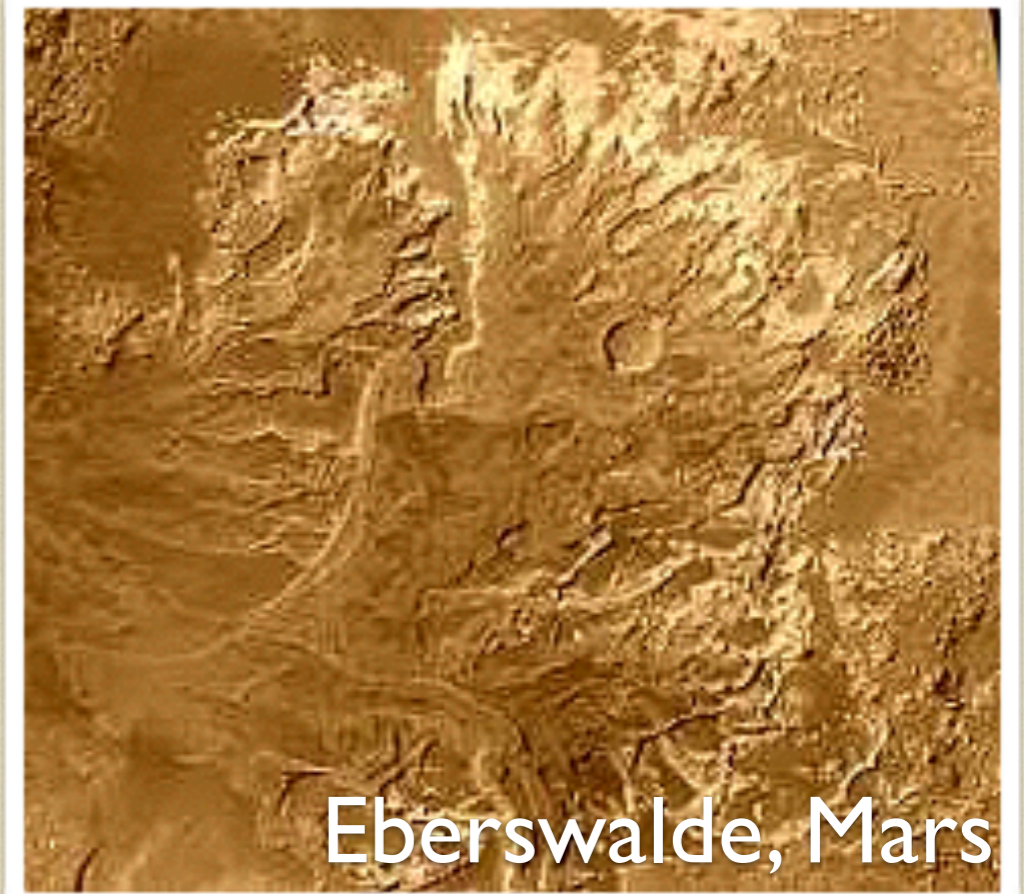




Nile Delta, Earth



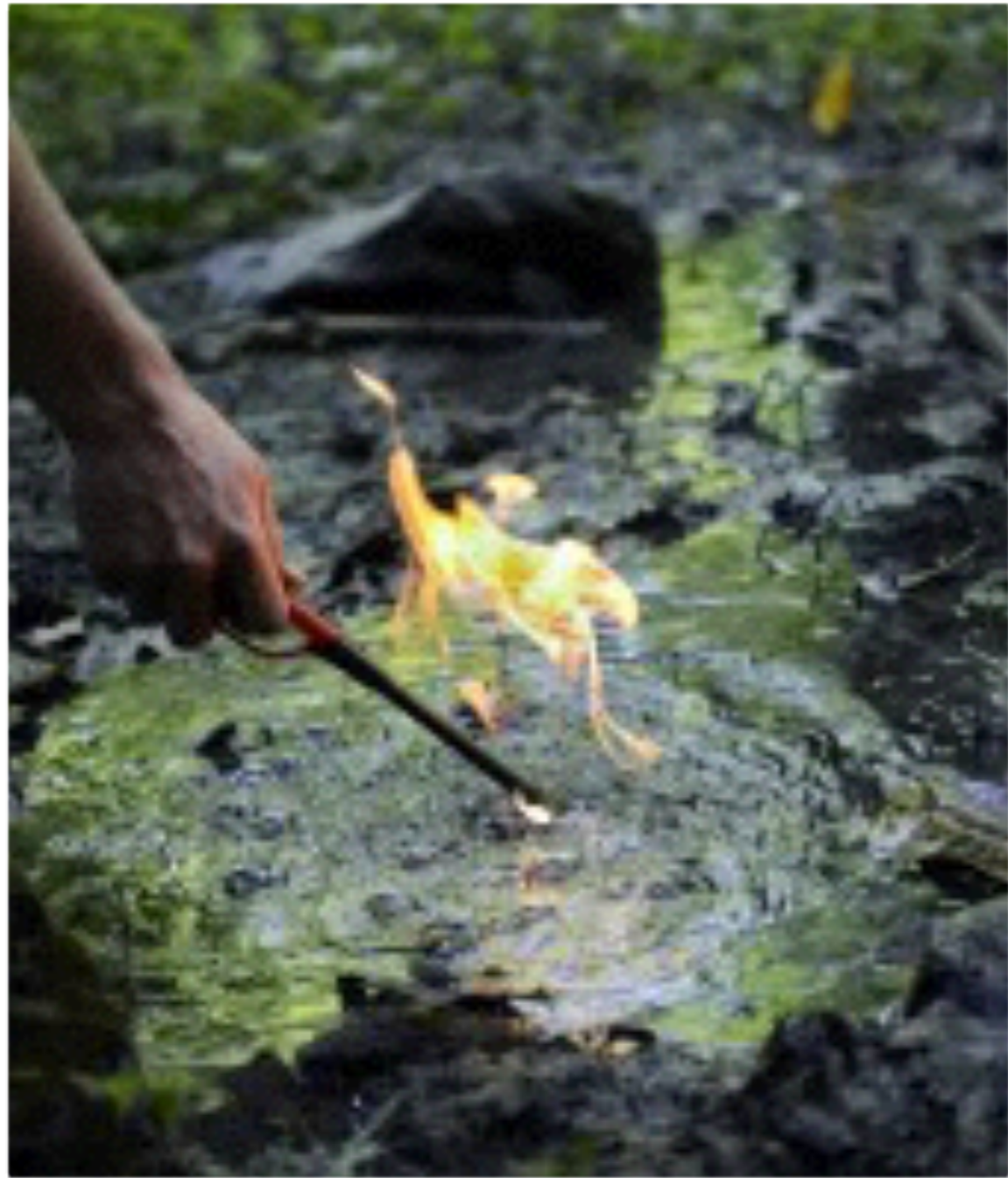
Eberswalde, Mars

Deltas On Earth And Mars: An Environment For Deposition And Preservation Of Organic Matter And Biosignatures

Jennifer Eigenbrode

NASA Goddard Space Flight Center

Deltaic Sediments Are A Major Source Of Gas/Oil Reserves On Earth



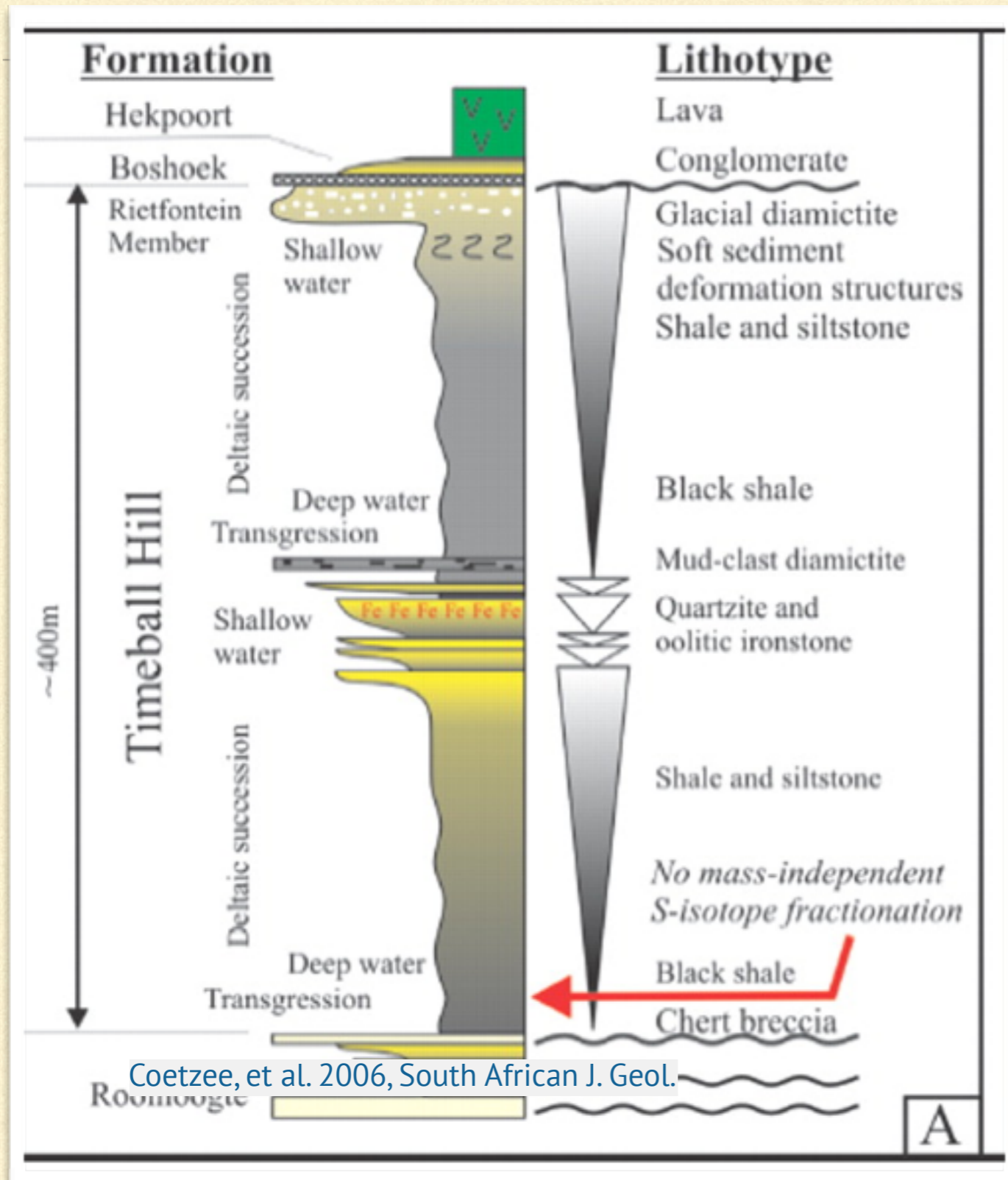
Example
Marcellus Shale,
Appalachian Basin

...poor analog for ancient
Mars deltas

Clastic Deposition + Hydrothermal Spring Alkalinity + Salt



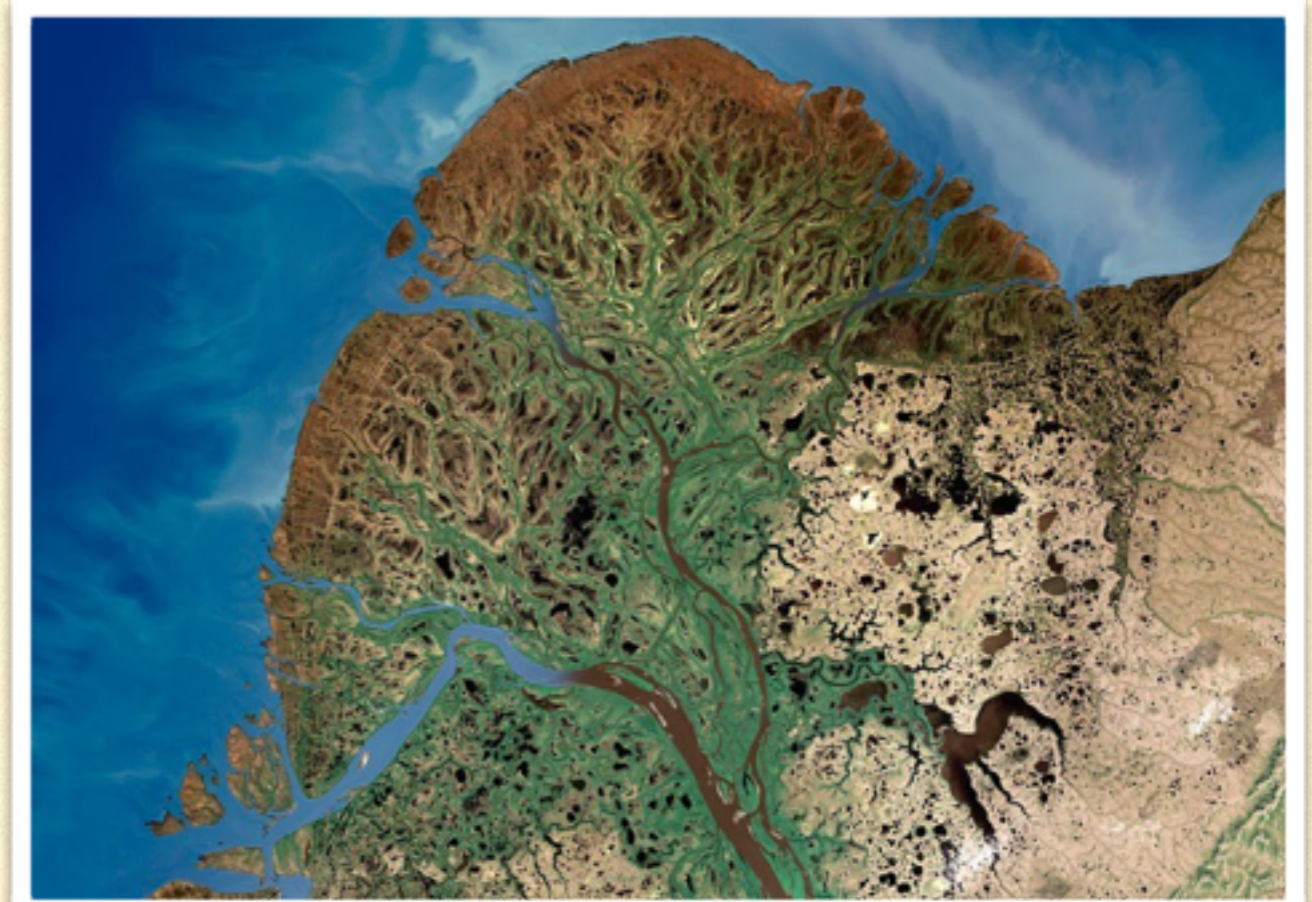
Deltaic/Lacustrine Sediments In The Precambrian



- ~2.35 Ga Timeball Hill Formation, Pretoria Group, Transvaal Province- great example
- Other examples:
 - base of the Archean Fig Tree Group, Barberton Greenstone belt
 - 2.7 Ga Mingah Mbr, Tumbiana Fm., Hamersley Province (?)
 - 1.1 Ga Nonesuch Fm., Keweenaw Supergroup
 - ~2.7 Ga Duparquet Fm., Abitibi greenstone belt (?)
 - and many others known or suspect

Why do we associate deltas with the search for biosignatures on Mars?

“Deltas indicate a sustained water body was present.”



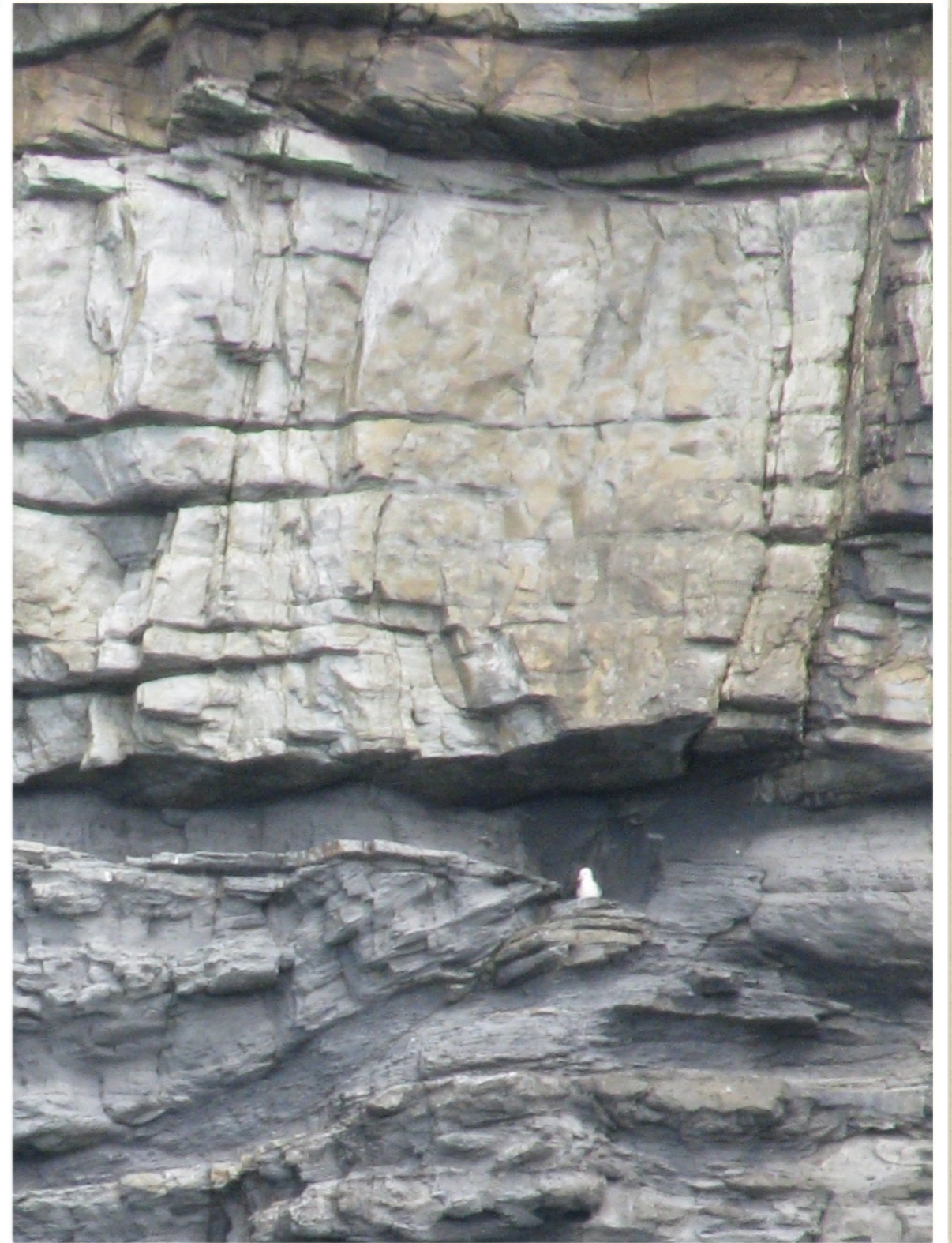
- key support for habitability
 - biosignature formation possible in multiple subenvironments
 - retention of biosignatures formed in the delta or water body
-

Why do we associate deltas with the search for biosignatures on Mars?

“Deltas deposit clays. Clays are great because they ...

- ... preserve organics”
- ... decrease permeability”
- ... prevent oxidation”

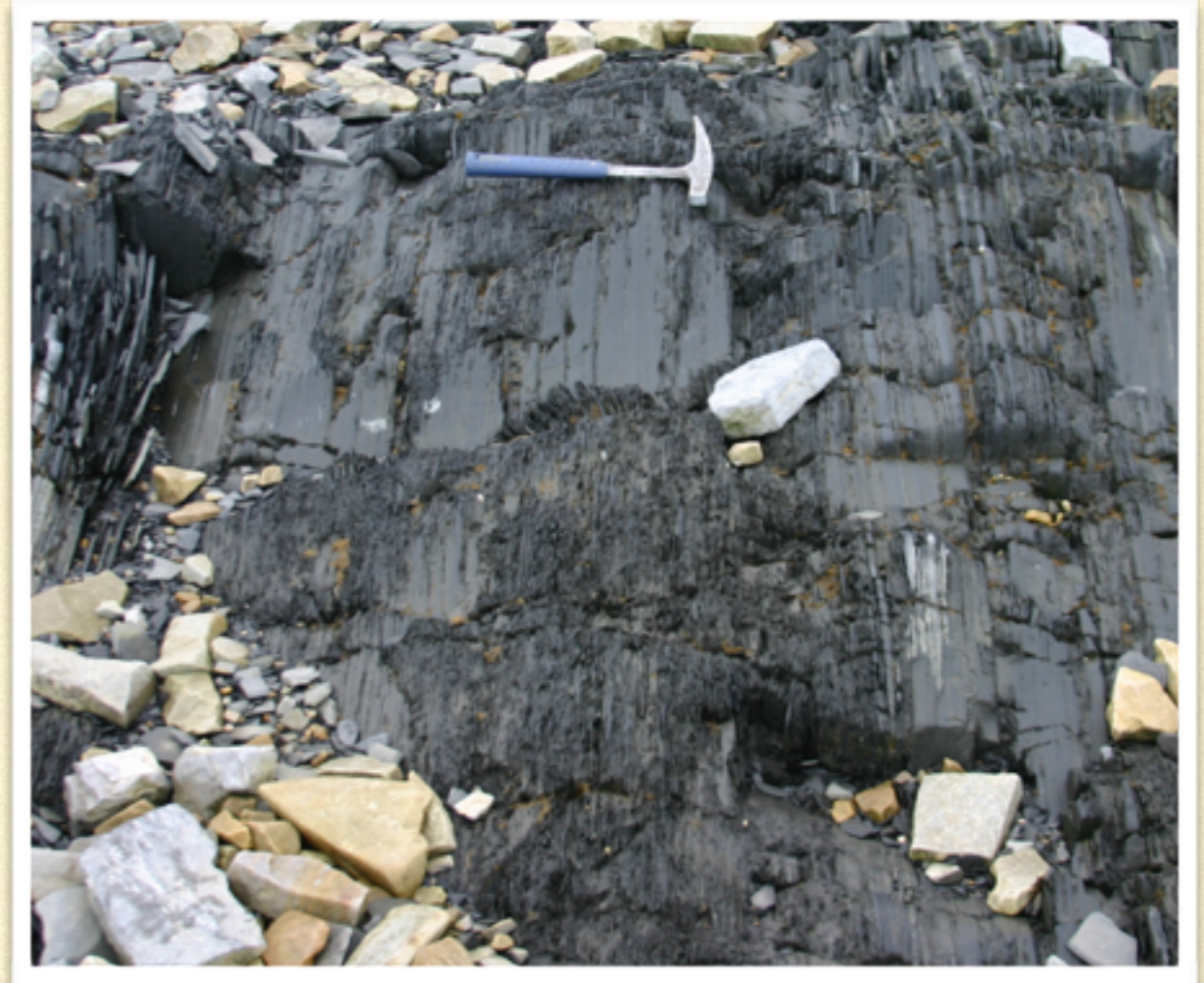
Which clay? mud or phyllosilicates?



stolen from Sanjeev Gupta's talk

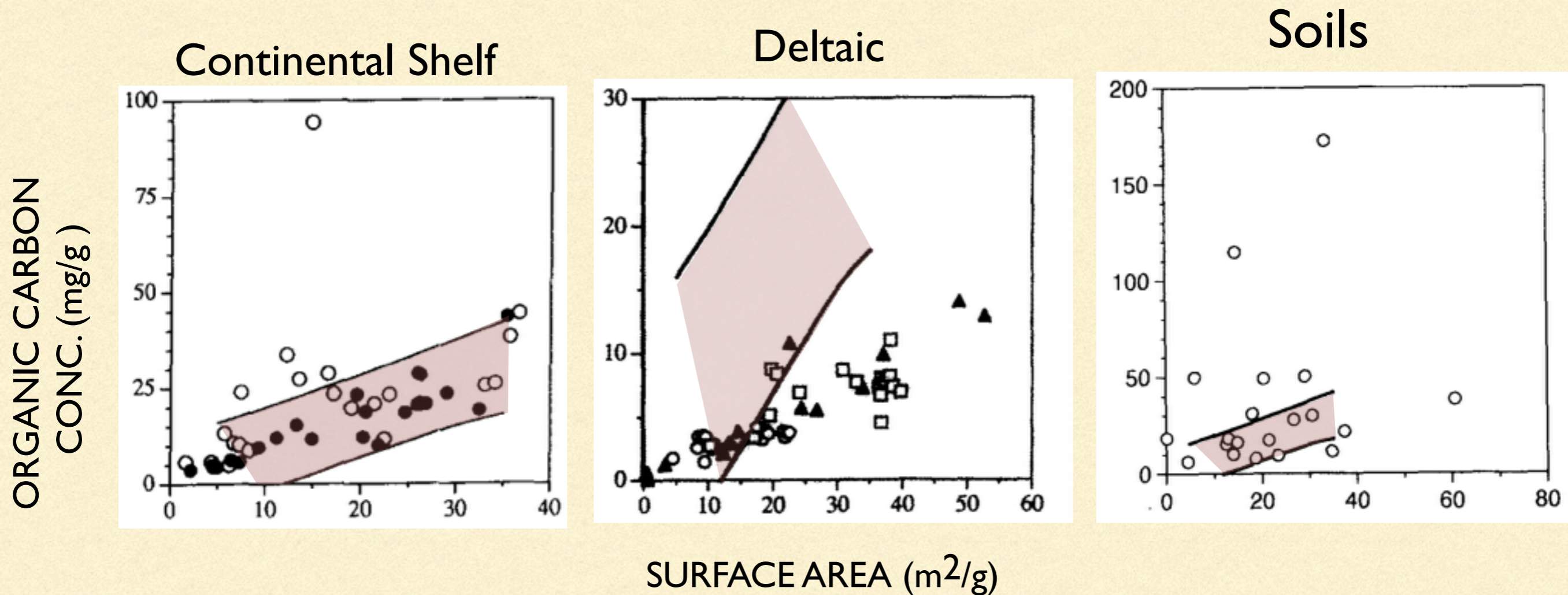
Why Is Mudstone Deposition In The Pro Delta Important?

- mud deposition lowers porosity and permeability



(Neoproterozoic MacDonaldryggen Shale,
Photo credit: Galen Halverson).

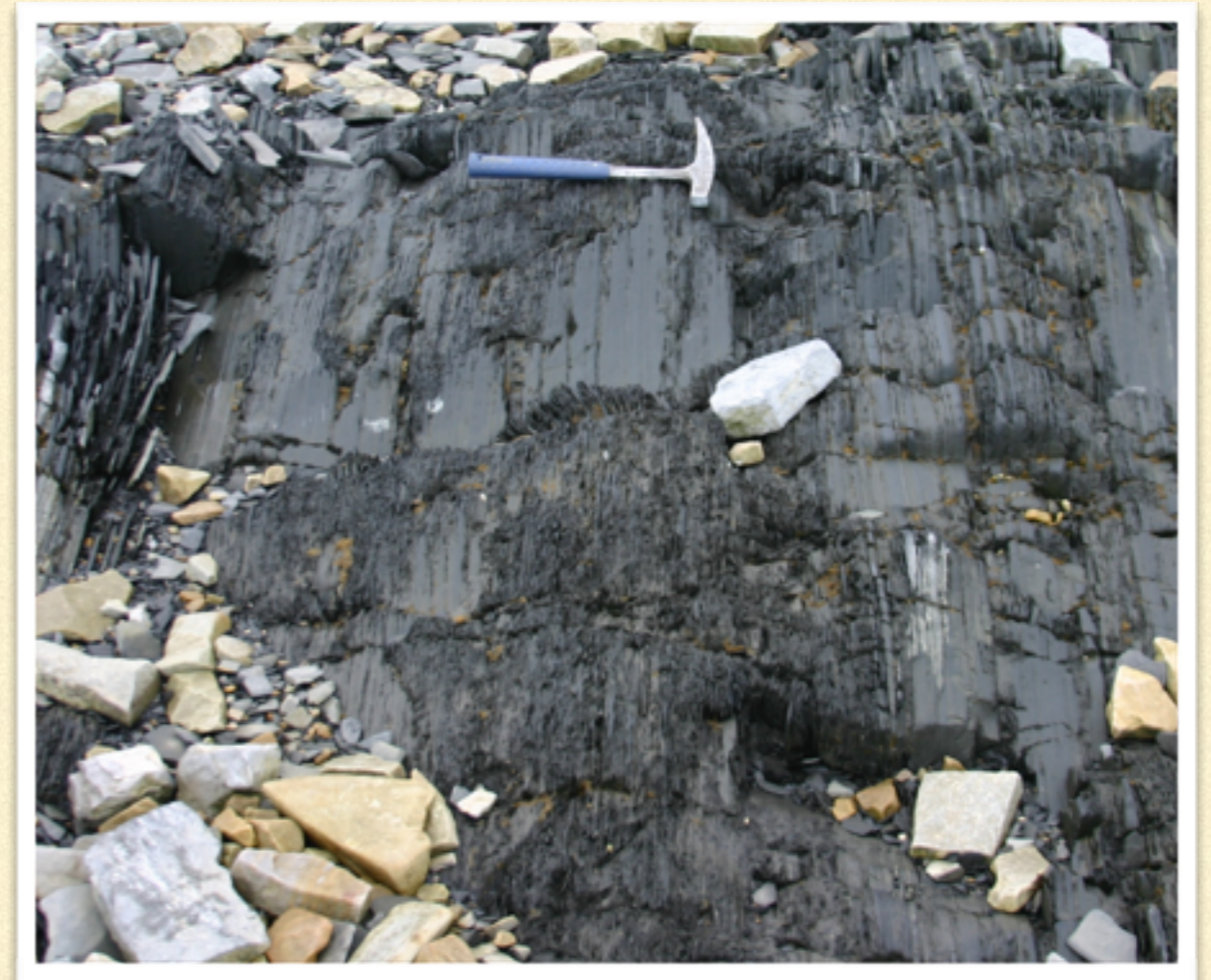
Organic Carbon Concentration Vs. Surface Area For Samples From The Sediment-Water Interface Vs Soils



Critical observation!! Points to adsorption of organics on mineral surfaces that is to some degree dependent on depositional environment.

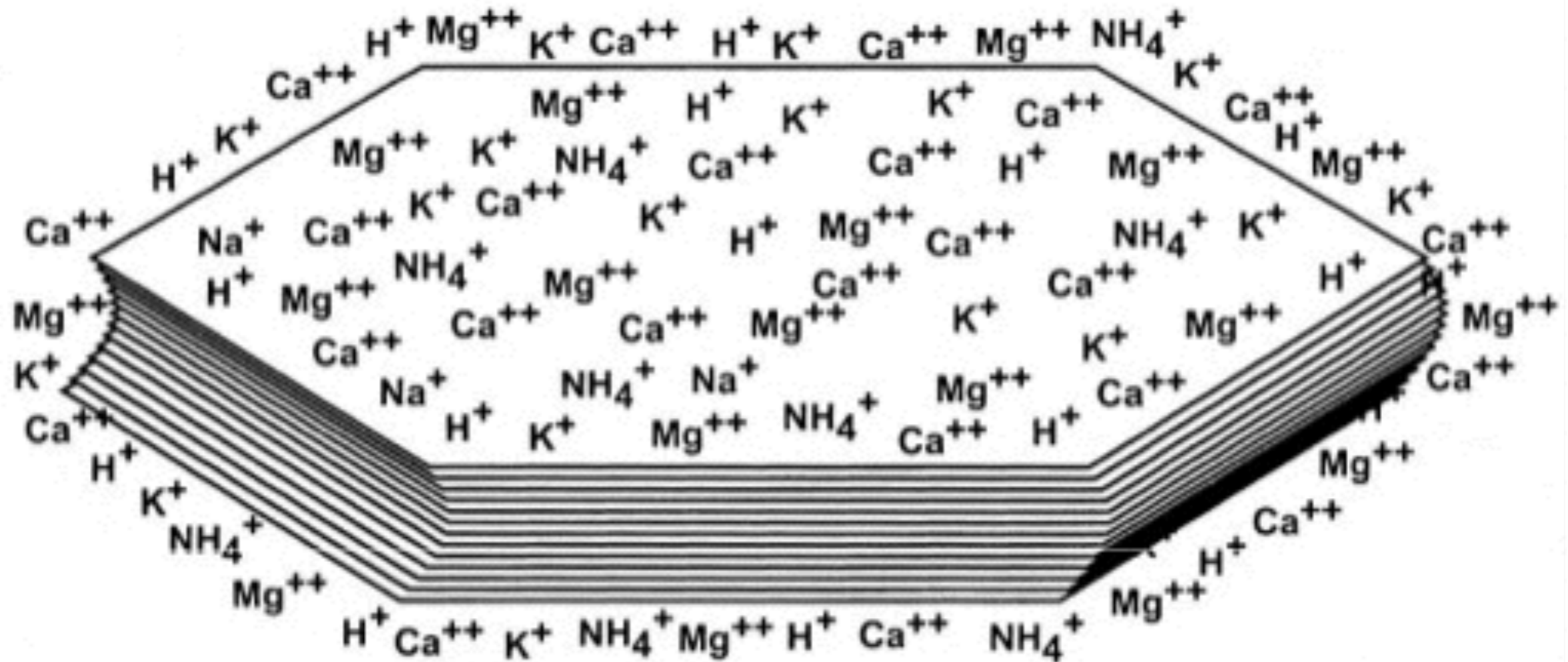
Why Is Mudstone Deposition In The Pro Delta Important?

- mud deposition lowers porosity and permeability
- muddy waters support adsorption of organics and formation of “colloidal glue”
 - faster burial of suspended mud
 - further lowers porosity and permeability
 - supports chemical metastability



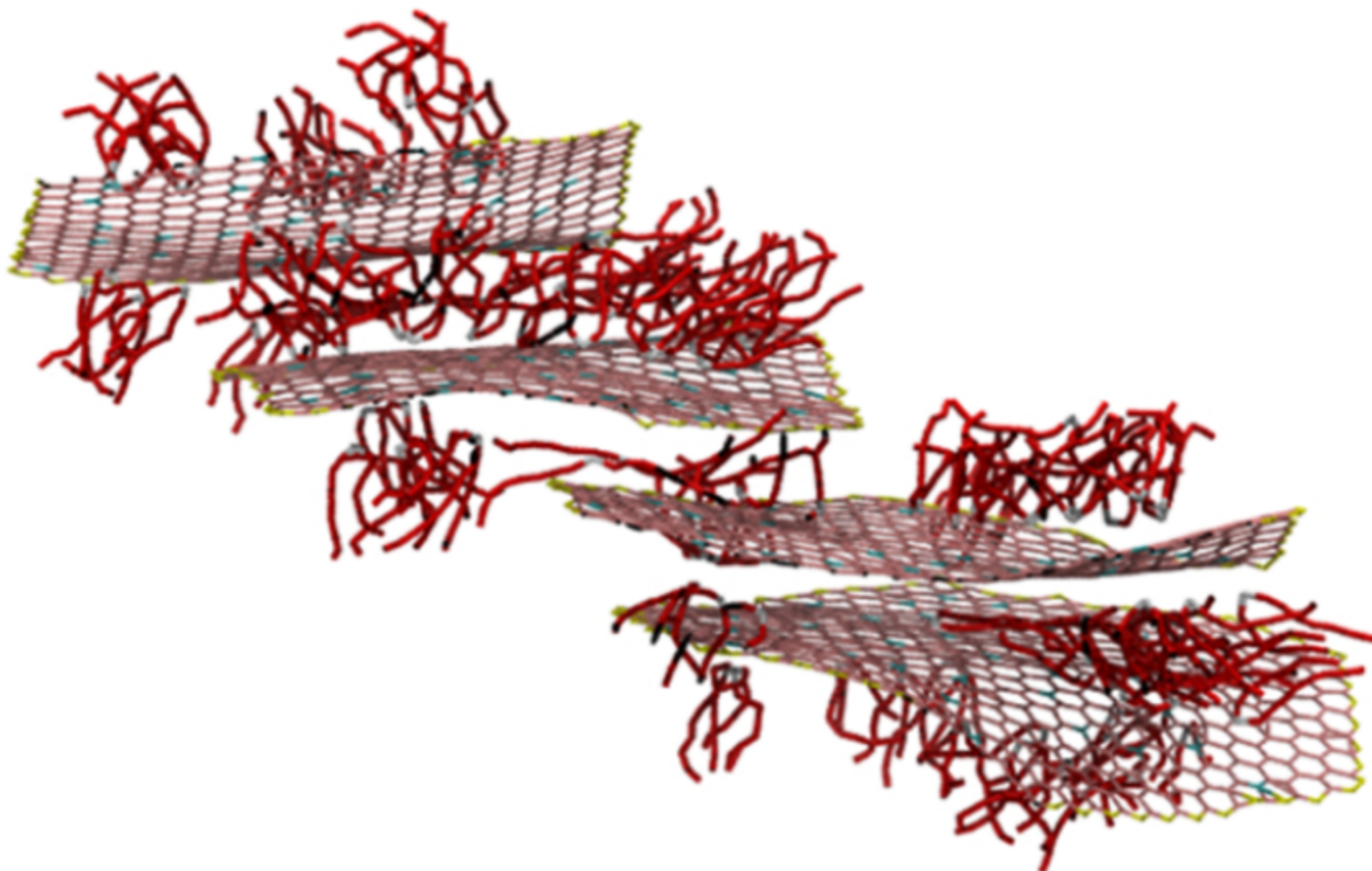
(Neoproterozoic MacDonaldryggen Shale, Photo credit: Galen Halverson).

Phyllosilicates, Al-Fe oxyhydroxides and other surface charged minerals



Negatively-charged clay platelets attract positively-charged cations; "adsorption"

Model Of Phyllosilicates With Sorbed Organics

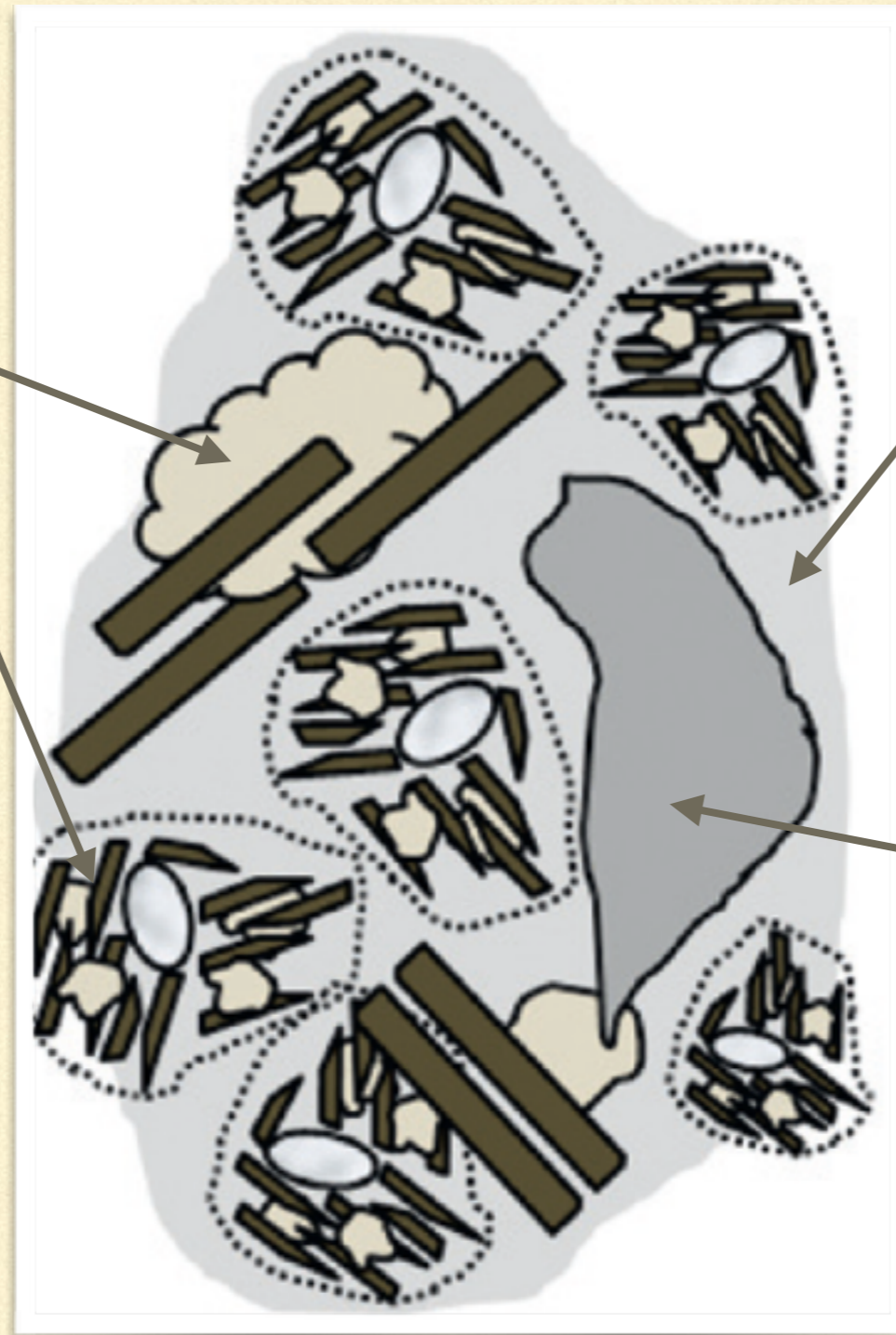


Suter et al., 2015 NanoLetters

Schematic Representation Of The Development And Protective Power Of Organomineral Complexes

younger, more bioreactive organic matter, including EPS and proteins

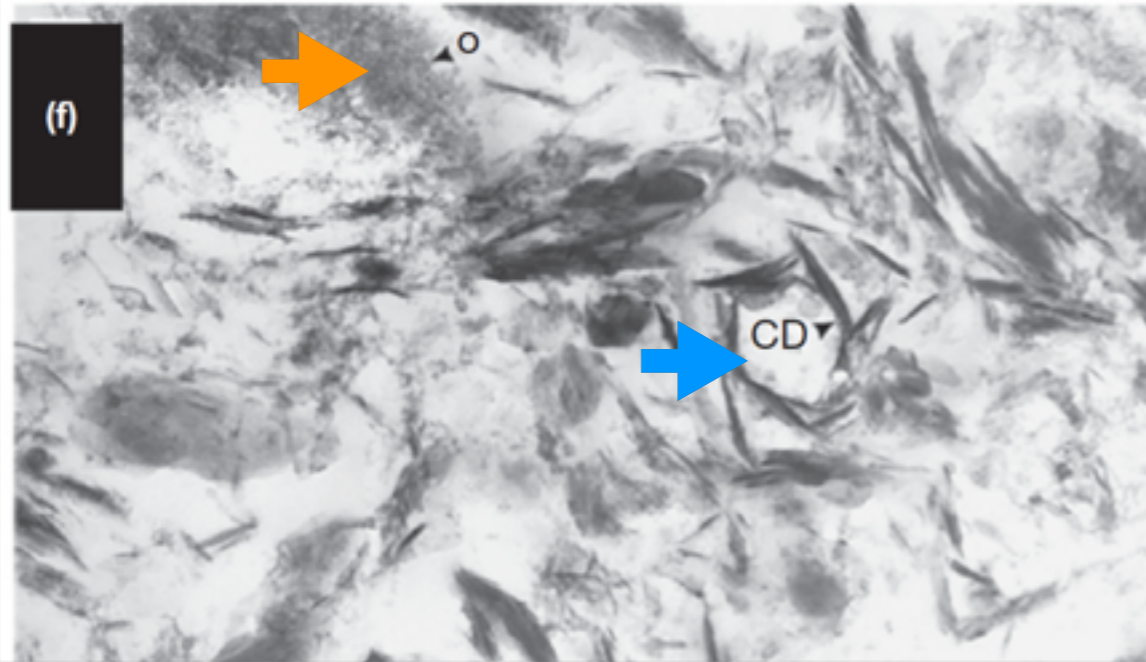
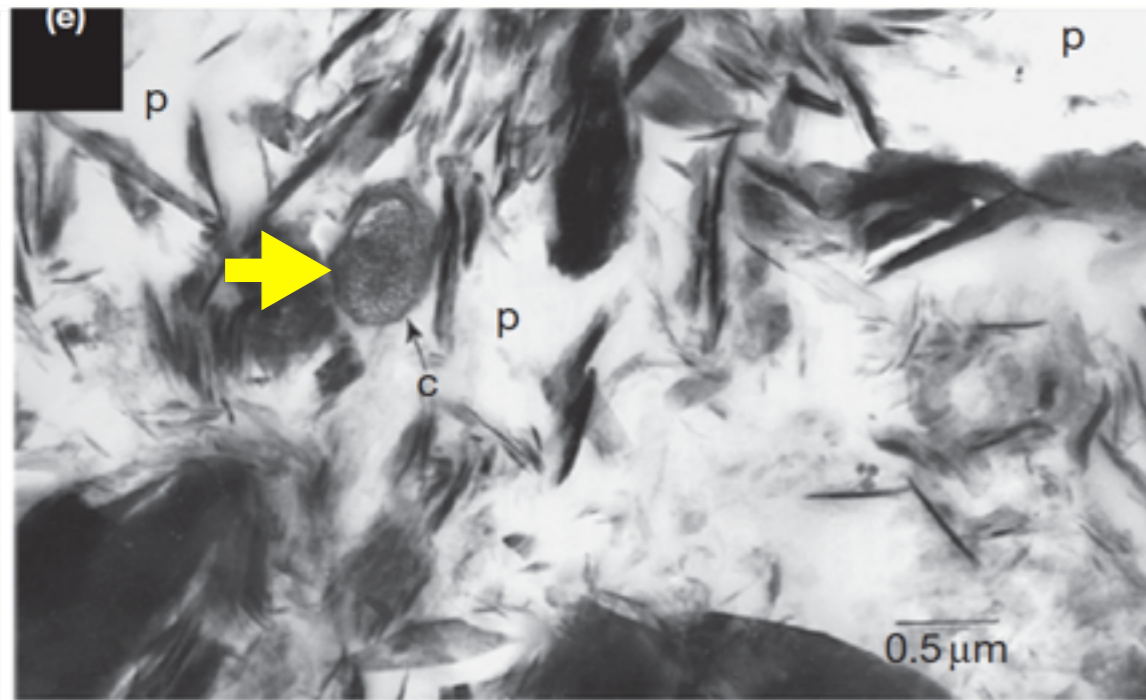
Protection is a function of nature of sorption, diffusion into pore spaces, and physical processing



older (^{14}C -dead), more refractory, degradation resistant organic matter

Oxides with precipitated organics

Mineral-Organic Aggregates



TEM images illustrating clay fabric and...

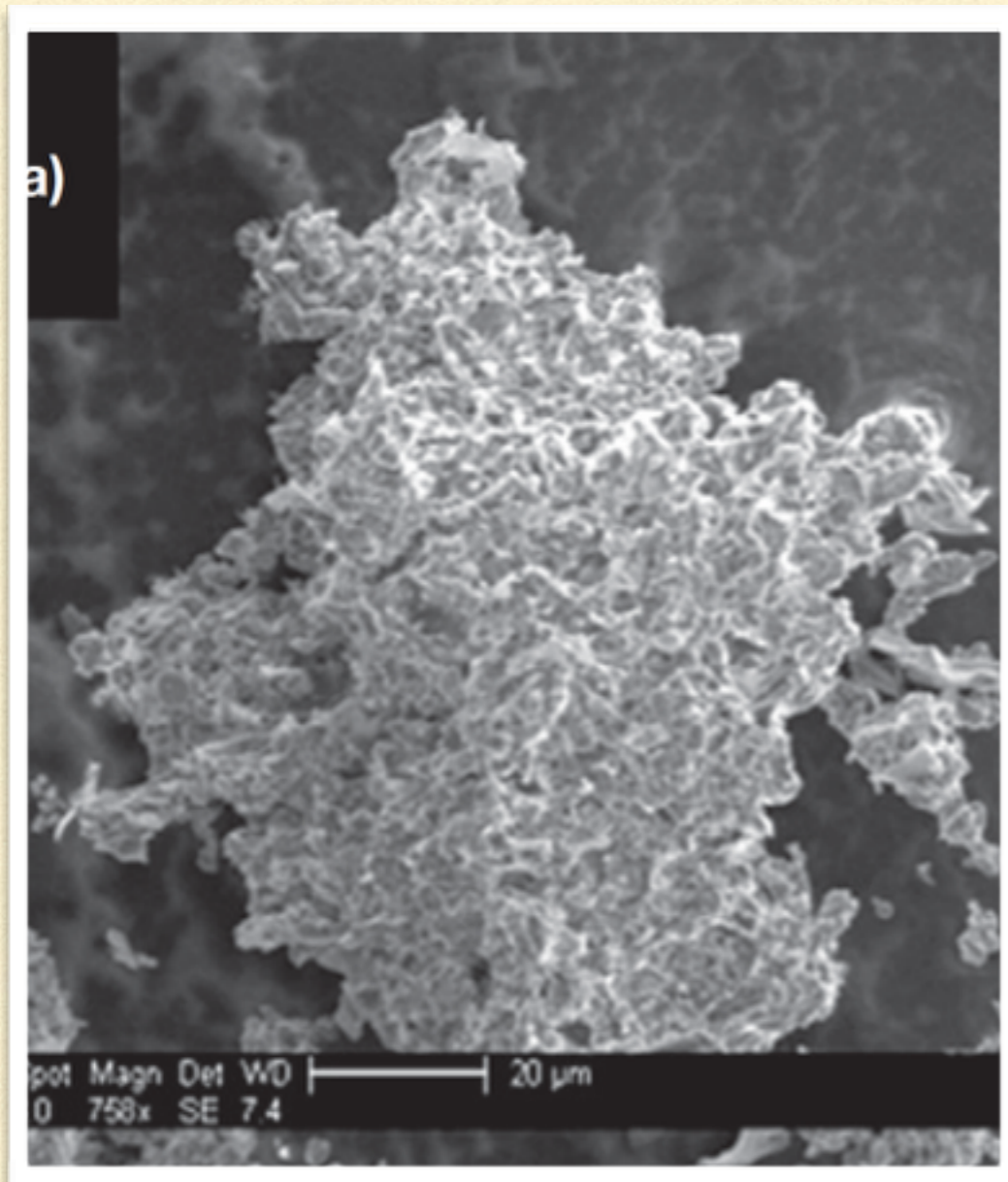
YELLOW - a prokaryotic cell

ORANGE - organic matter

BLUE - clay domains reminiscent of the particle arrangements that commonly occur around single bacterial cells

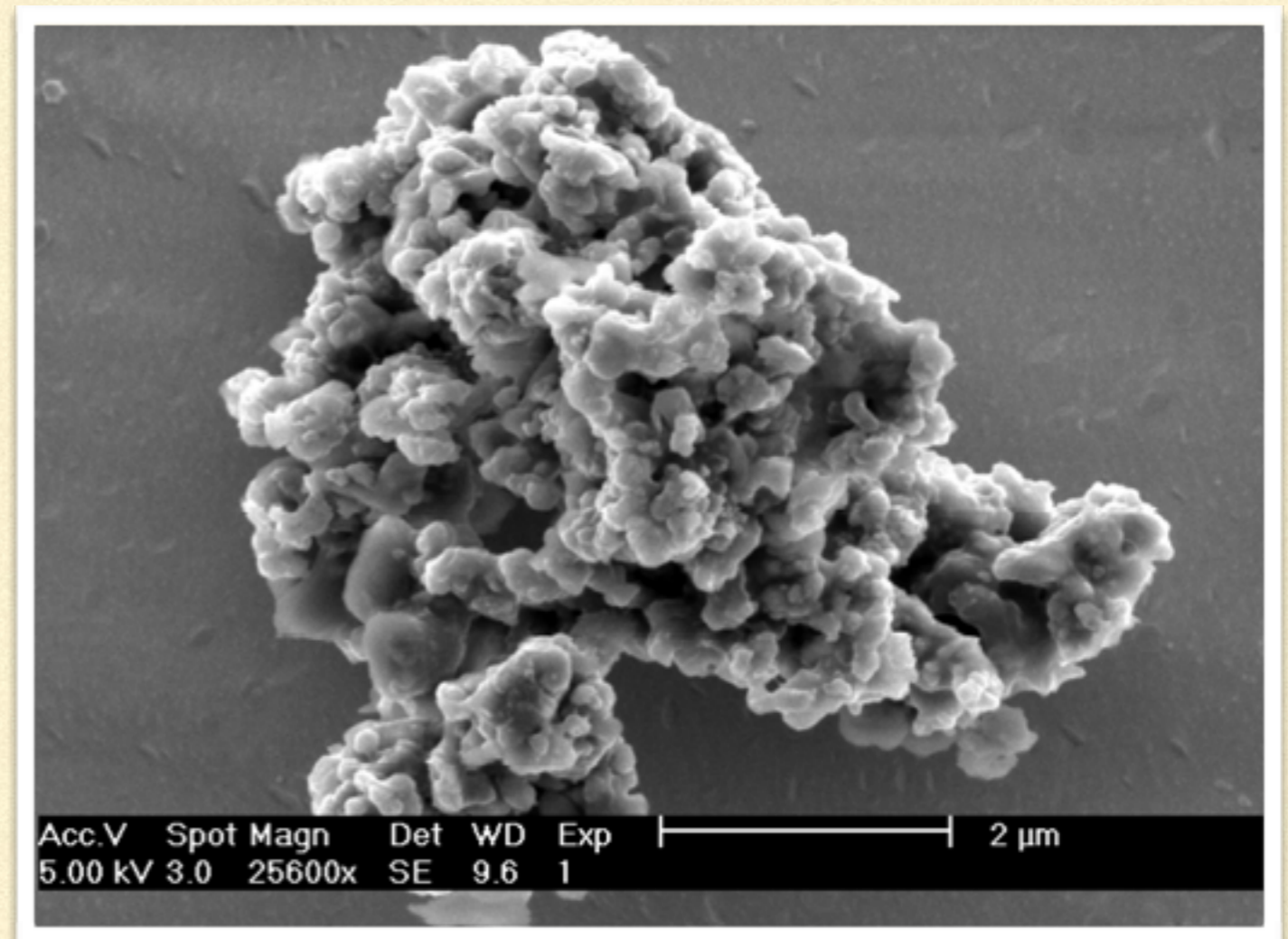
SEM of Mineral-Organic Aggregates

from the Washington margin



Arnarson and Keil, 2007

a carbonaceous IDP



(Image Credit: N. Spring)

Muds and organics GLUE sediments together.

Life can initiate this —> biofilms, EPS

Does not require water, but aqueous environments support the formation.

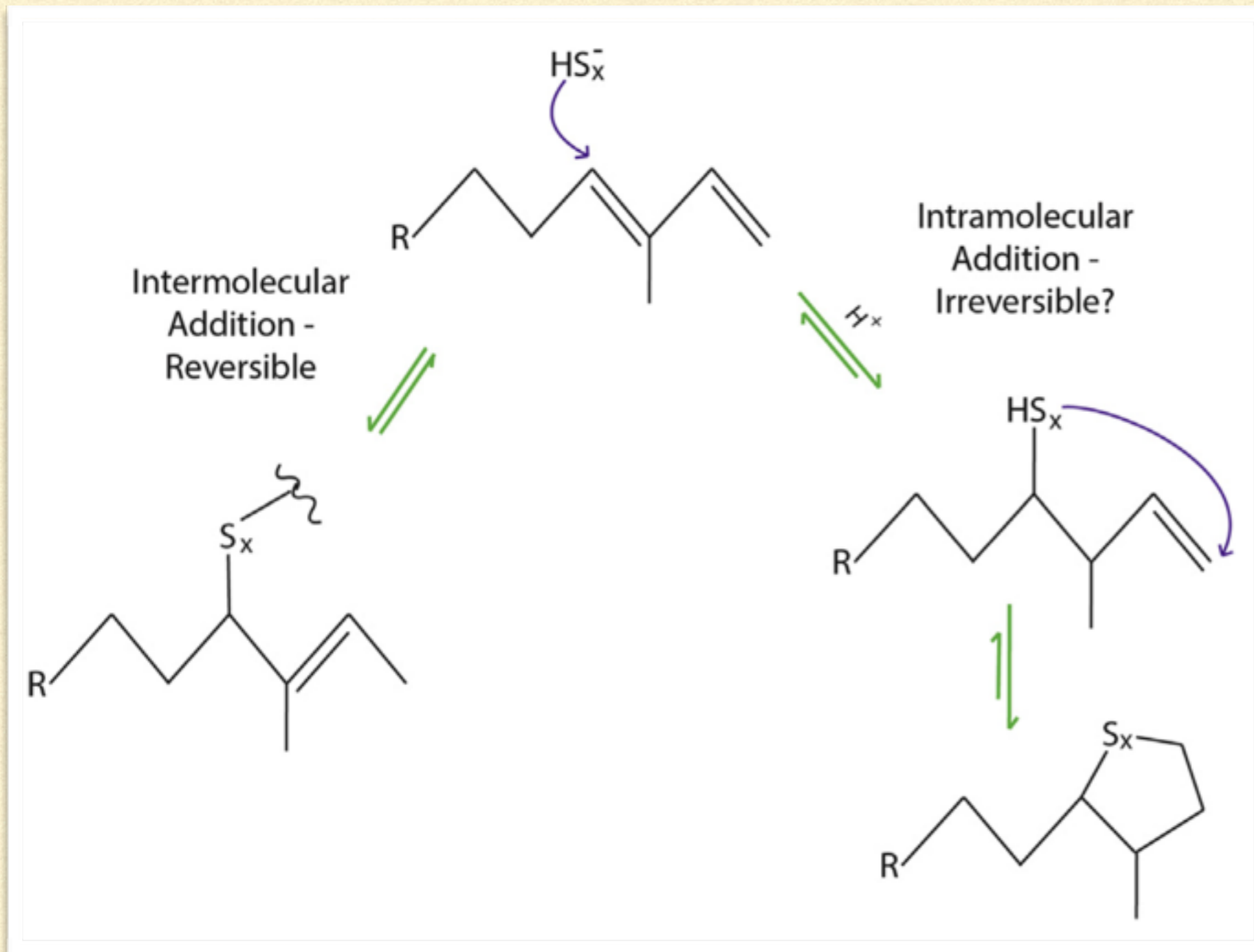
Why Is Mudstone Deposition In The Pro Delta Important?

- mud deposition lowers porosity and permeability
- muddy waters support adsorption of organics and formation of “colloidal glue”
 - faster burial
 - further lowers porosity and permeability
 - supports chemical metastability
- muddy benthic zones tend to development of reducing conditions, which support early diagenetic mineralization and sulfurization of organics



(Neoproterozoic MacDonaldryggen Shale, Photo credit: Galen Halverson).

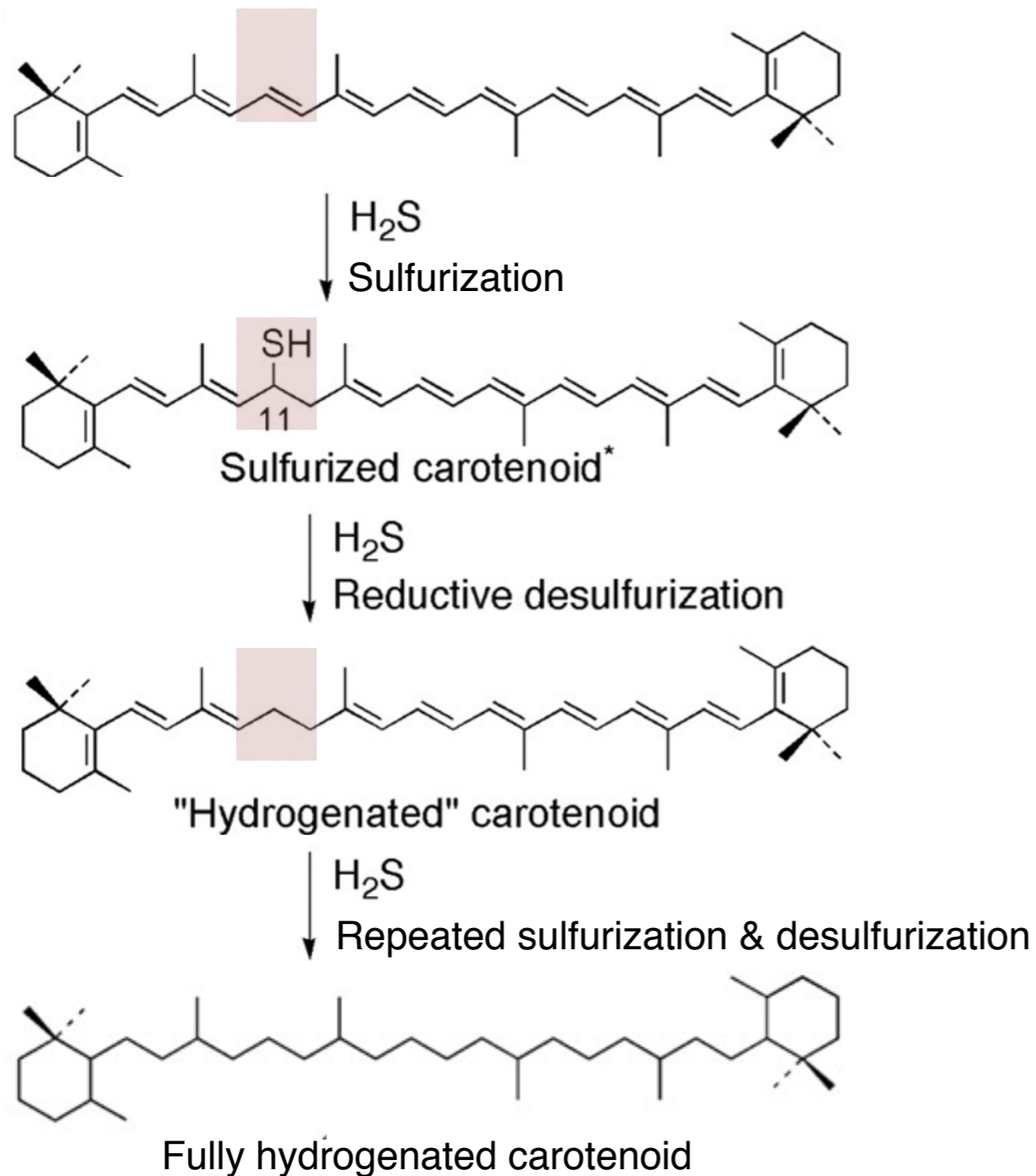
Early diagenetic sulfurization of organic matter



Sulfurization aids macromolecular formation

Raven et al., 2015, Org. Geochem.

Early diagenetic hydrogenation of organic matter



The role of H_2S in the initial preservation of organic matter goes beyond sulfur addition.

Deltaic environments are unique.

- Channel erosion and depositional sorting of grains.
- Three possible sources of biosignatures and organics and all of them can get concentrated in mudstone:
 1. eroded and transported
 2. water column formation
 3. benthic sediment formation

Organic matter, or its molecules,
need not be the biosignature.

Organics are a (bio)geochemical material that, like minerals,
can aid the preservation of a biosignature assemblage
(molecules, morphologies, fabrics/textures, etc.)

Deltas are part of planetary depositional systems that have sufficient water to flow and pond across a rocky surface. And, if there is life, there is also a high probability of muddy organic deposits that have a high potential to preserve the biosignature assemblage
