Preliminary Unconventional Reservoir Characterization of the Lower Cretaceous Skull Creek Shale, Wyoming*

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Abstract

The large Cretaceous Western Interior Seaway in the northwestern part of the United States contains a thick section of mudrocks interbedded with numerous sandstones. Many of these mudrocks were deposited during marine transgressions and are source rocks. The Albian Skull Creek Shale is one of these units and appears to have not been characterized relative to its candidacy as a potential shale-gas system. A characterization is presented based on a description of the Cities Service #1 Federal CM core in Niobrara County, Wyoming.

The Skull Creek interval reaches 250 feet in the center of the seaway. The lack of thick sands and large scale hydrodynamic structures, rare bioturbation, and relatively higher TOC suggest a deeper water setting below storm-wavebase. An anaerobic to dysareobic bottom environment is interpreted on the basis of higher TOC, relative lack of burrow traces, extremely rare fauna, and abundant pyrite framboids. The anaerobic to dysareobic bottom environment implies a stratified water column below the oxygen minimum boundary. Silty, siliceous mudstone is the predominant rock type with various amounts of silt to fine-sand stringers interspersed. Only a few burrow traces were recognized in this core and these were Nereites, which is a common deeper water, low-energy burrower. Ar-ion milled samples were analyzed using a FSEM. Samples show low visual porosity of only several percent. The overall pore network is a mixed pore network. Interparticle pores appear to be the most common and consist of pores between grains and grain-edge pores. Intraparticle pores are relatively common and generally occur within clay grains or pyrite framboids. Organic matter pores are present in the smaller kerogen particles. The larger organic particles are woody material and do not contain nanopores. Mean TOC is 1.2% with a high of 3.2%. TOC appears to have a reverse relationship to sand and silt content, which reflects slower deposition of the muddier facies. Ro in the core ranges from 1.05 to 1.2%. A pseudo Van Krevelen chart shows all data points fall in the lower left corner of the chart, suggesting a thermally mature mixture of Type II and III organic matter. Classification of kerogen quality using a Dembicki-type graph indicates that the weight percent TOC is fair to good but generation potential is poor. Core data in this study suggest marginal potential based on quality of organic material, but other areas may have better quality organic material.

References Cited

Burtner, R.L., and M.A. Warner, 1984, Hydrocarbon generation in Lower Cretaceous Mowry and Skull Creek shales of the northern Rocky Mountain area, *in* J. Woodward, F.F. Meissner, and J.L. Clayton, eds., Hydrocarbon source rocks of the Greater Rocky Mountain region: Rocky Mountain Association of Geologists, p. 449-467.

Loucks, R.G., R.M. Reed, S.C. Ruppel, and U. Hammes, 2012, Spectrum of pore types and networks in mudrocks and a descriptive classification for matrix-related mudrock pores: AAPG Bulletin, v. 96/6, p. 1071-1098.

Wulf, G.R., 1962, Lower Cretaceous Albian rocks in northern Great Plains: AAPG Bulletin, v. 46/8, p. 1371-1415.

AAPG 2014

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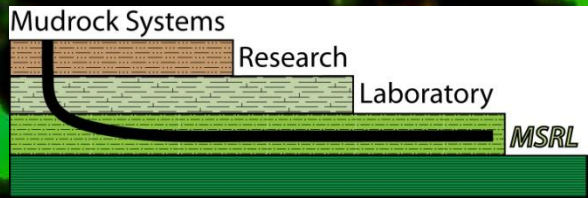
BUREAU OF ECONOMIC GEOLOGY



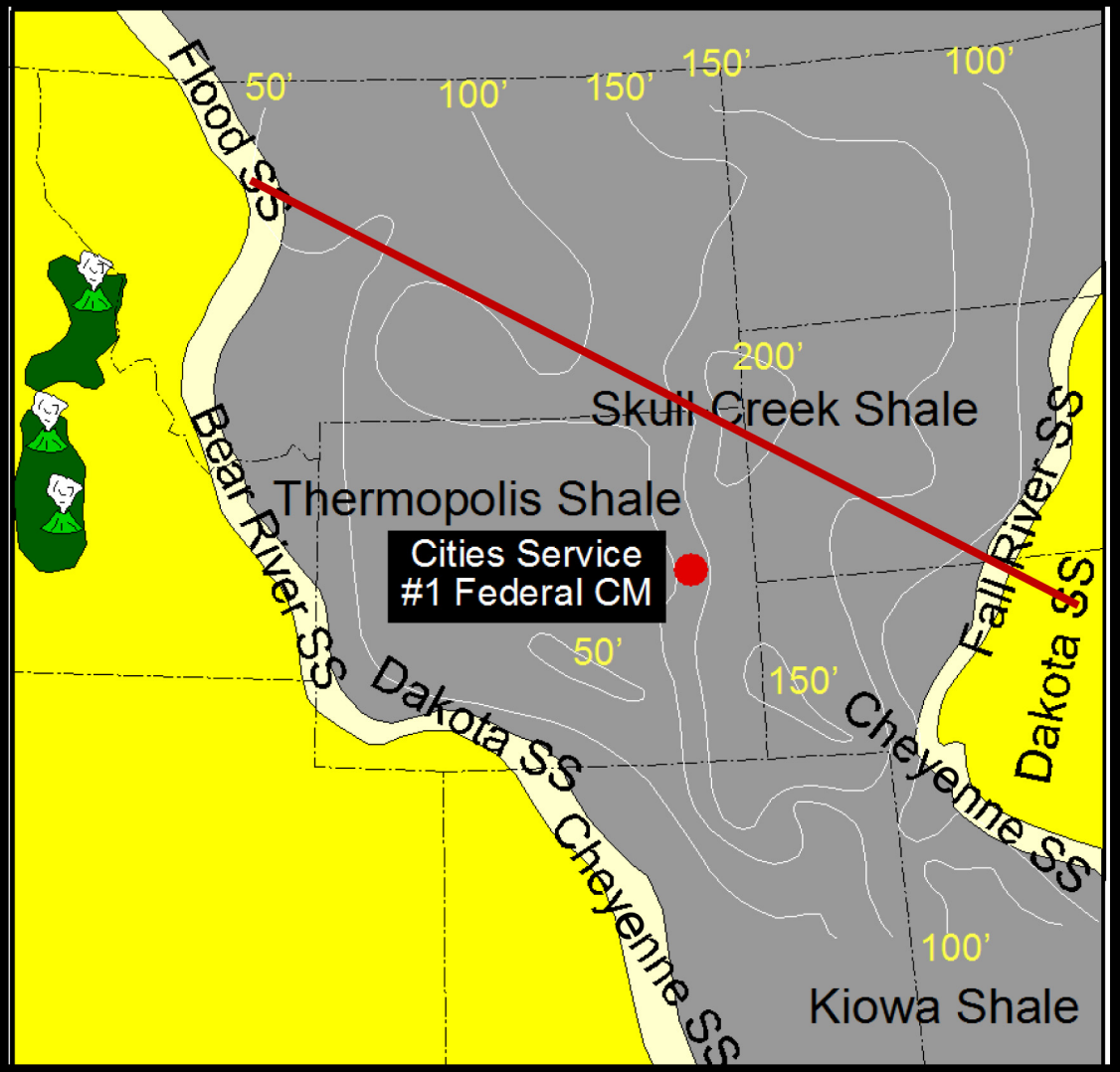
Outline

- General regional setting
- Facies and depositional setting
- Review of pore types
- Review TOC and R_o
- Comments on shale-gas potential

Lower Cretaceous Albian Seaway

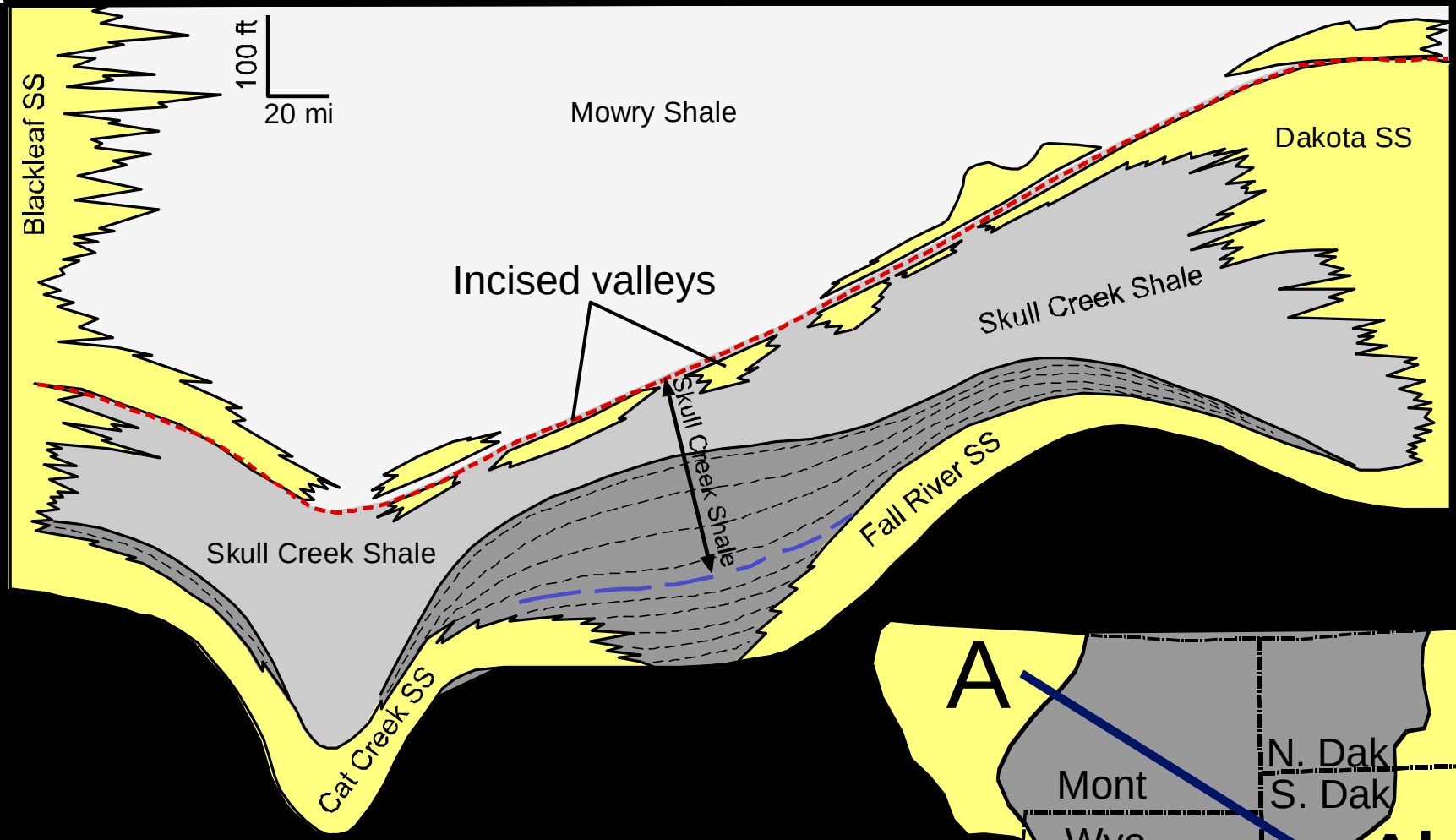
Blakey
http://www2.nau.edu/rcb7/nam.html

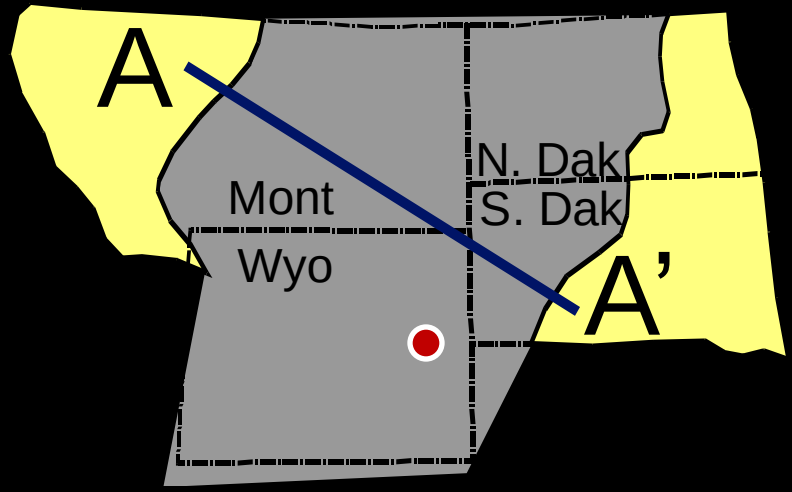
Isopach of Skull Creek Shale



Burtner and Warner (1984)

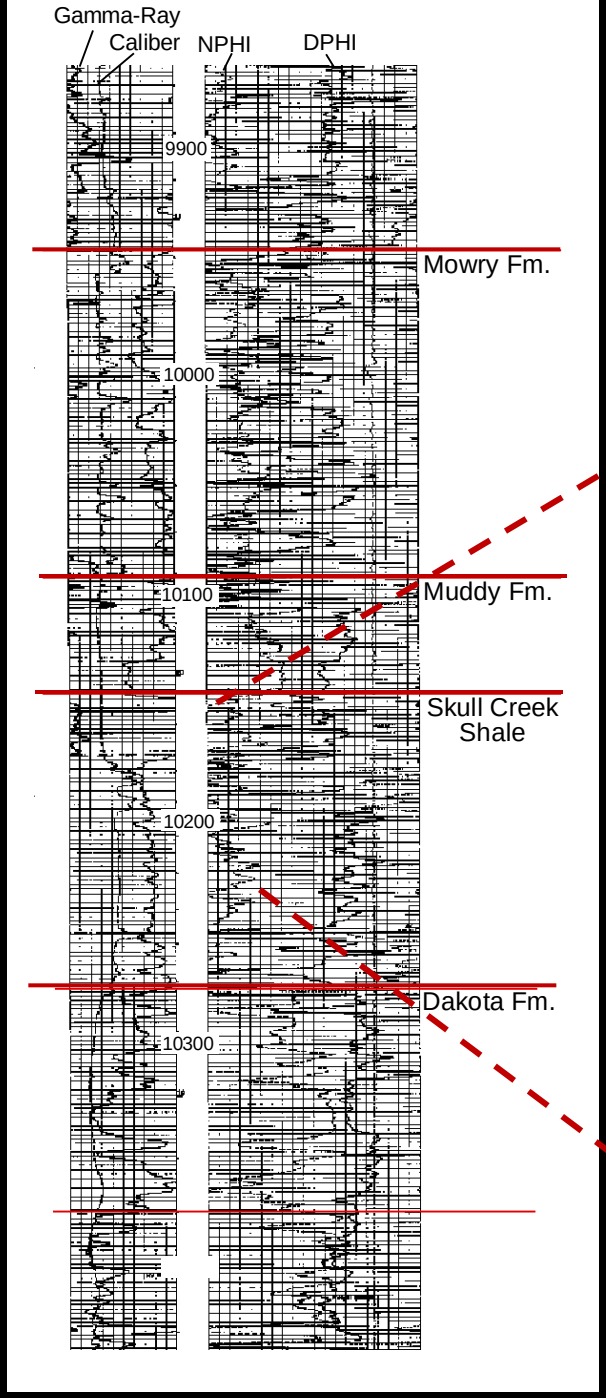
Regional Cross Section

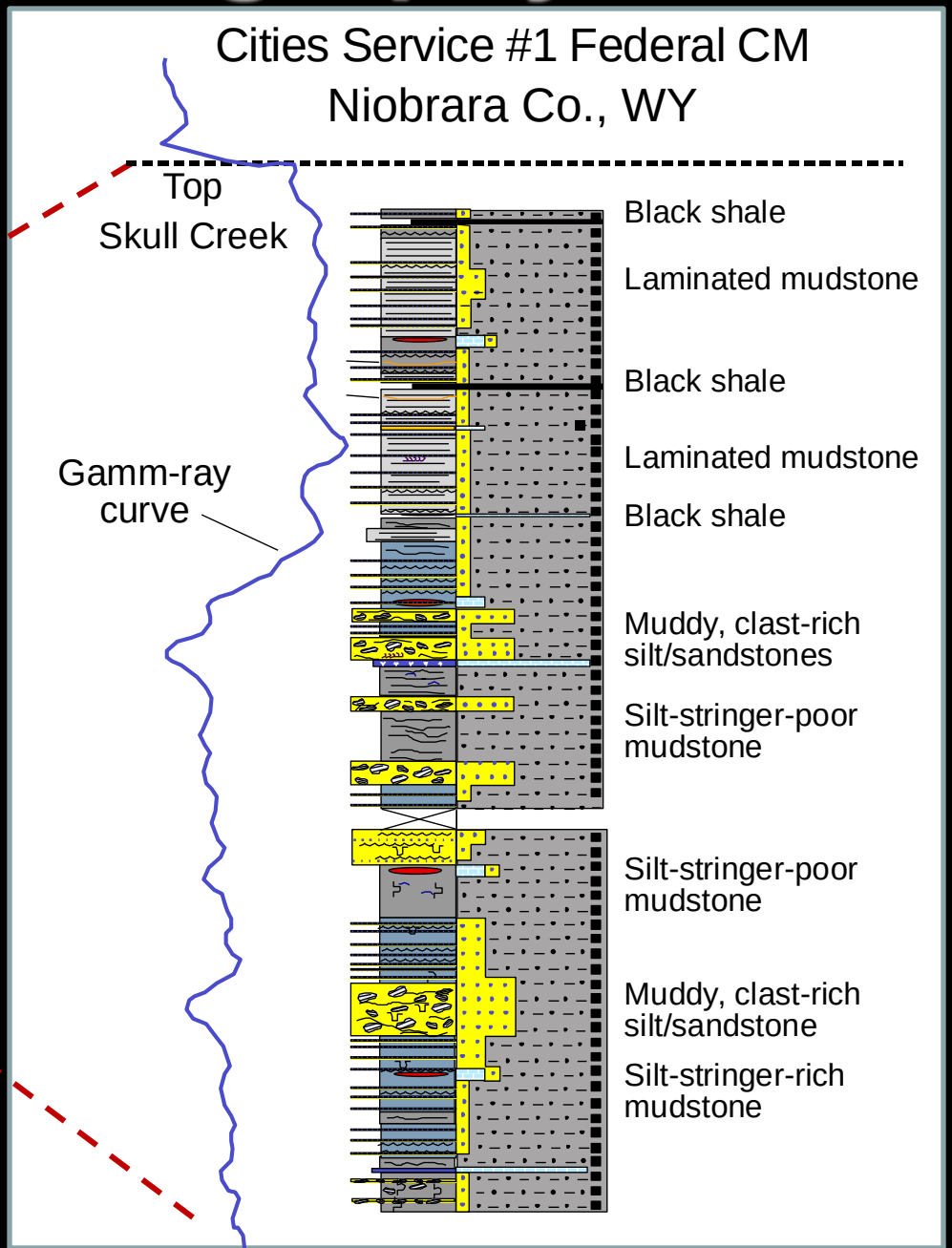




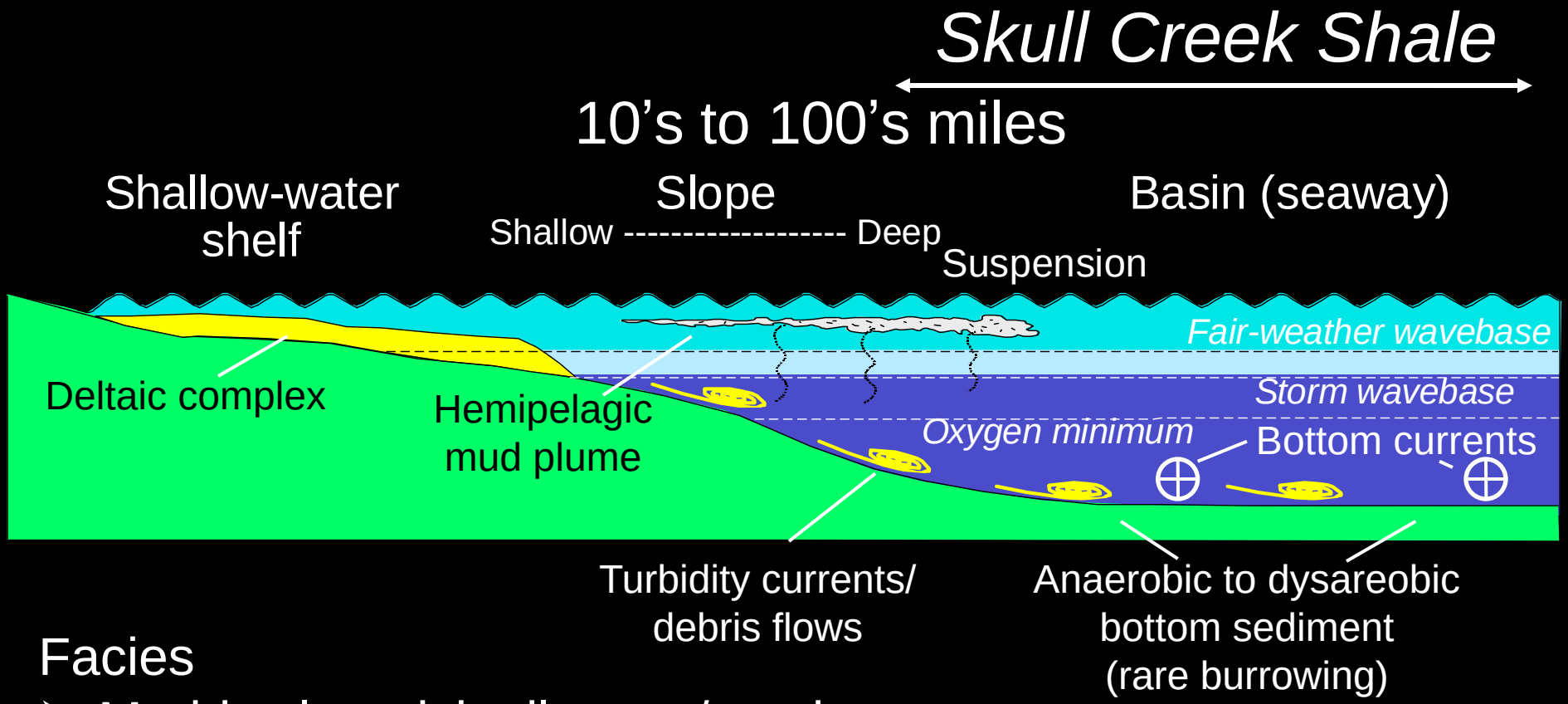
Wulf (1962)

Stratigraphy





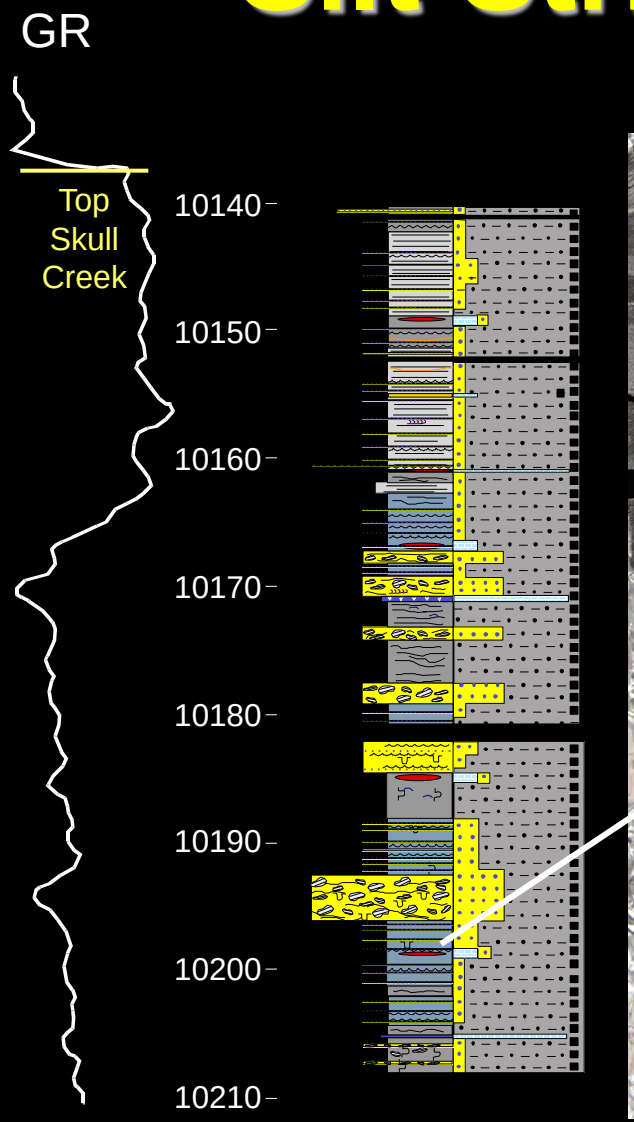
Depositional Model



Facies

- Muddy clast-rich siltstone/sandstone
- Mudstone with common rippled slit stringers
- Mudstone with rare silt stringers
- Laminated mudstone
- Black shale

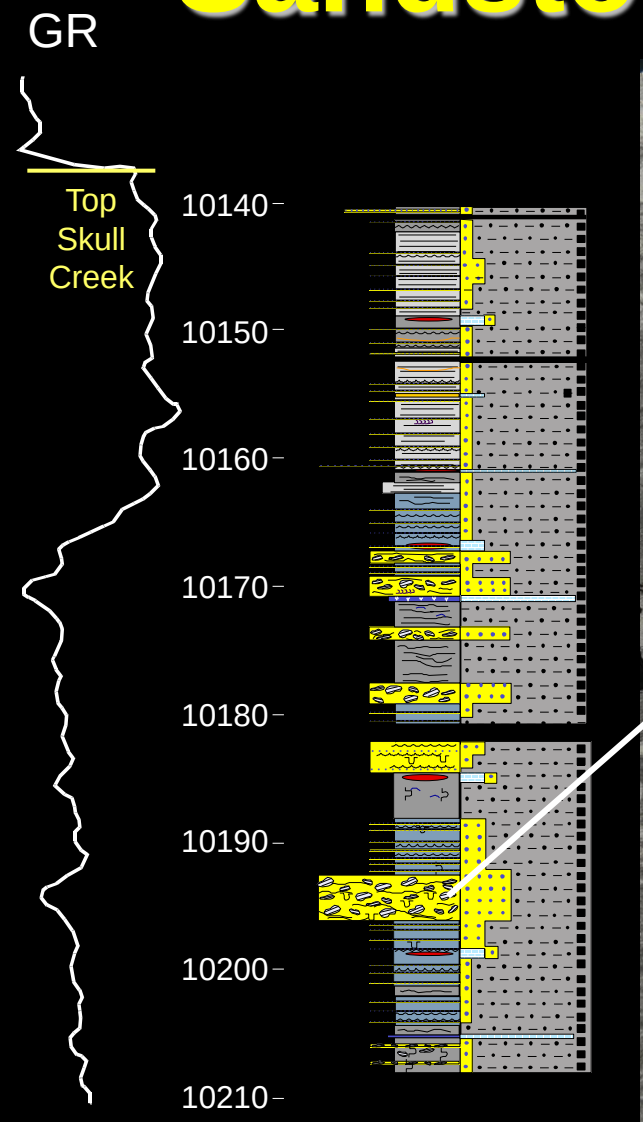
Silt-Stringer-Rich Mudstone

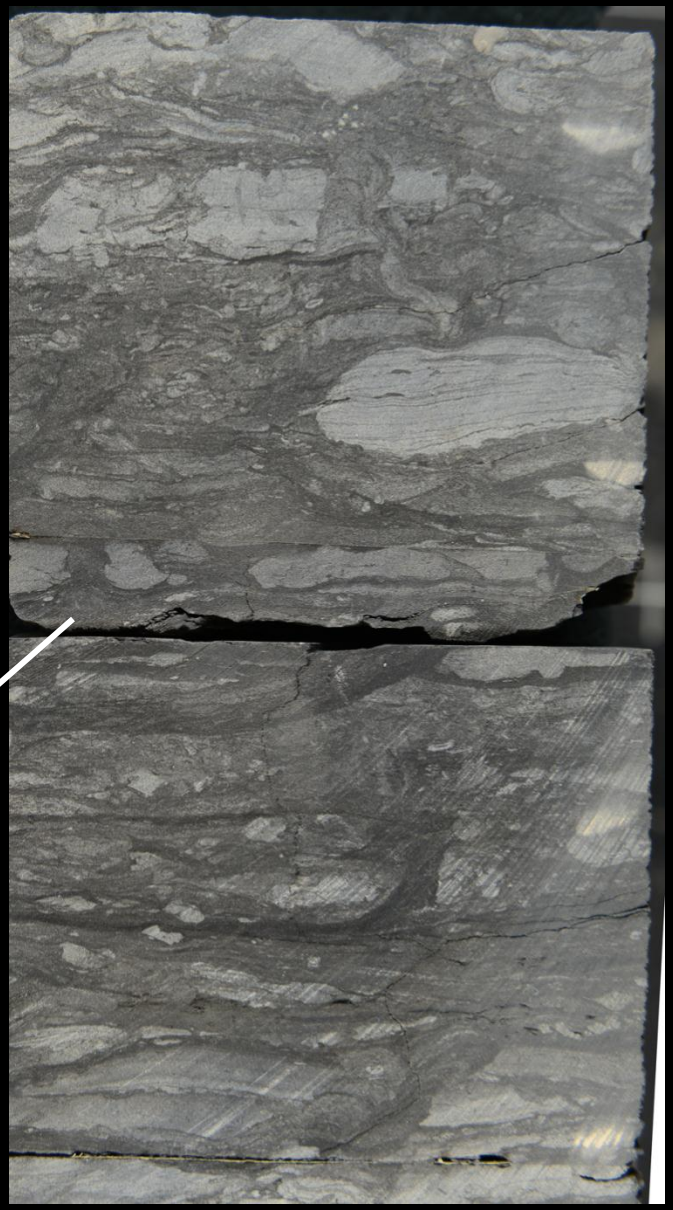


Terrigenous mudstone with starved ripples

10,197 ft

Sandstone Clast Conglomerate

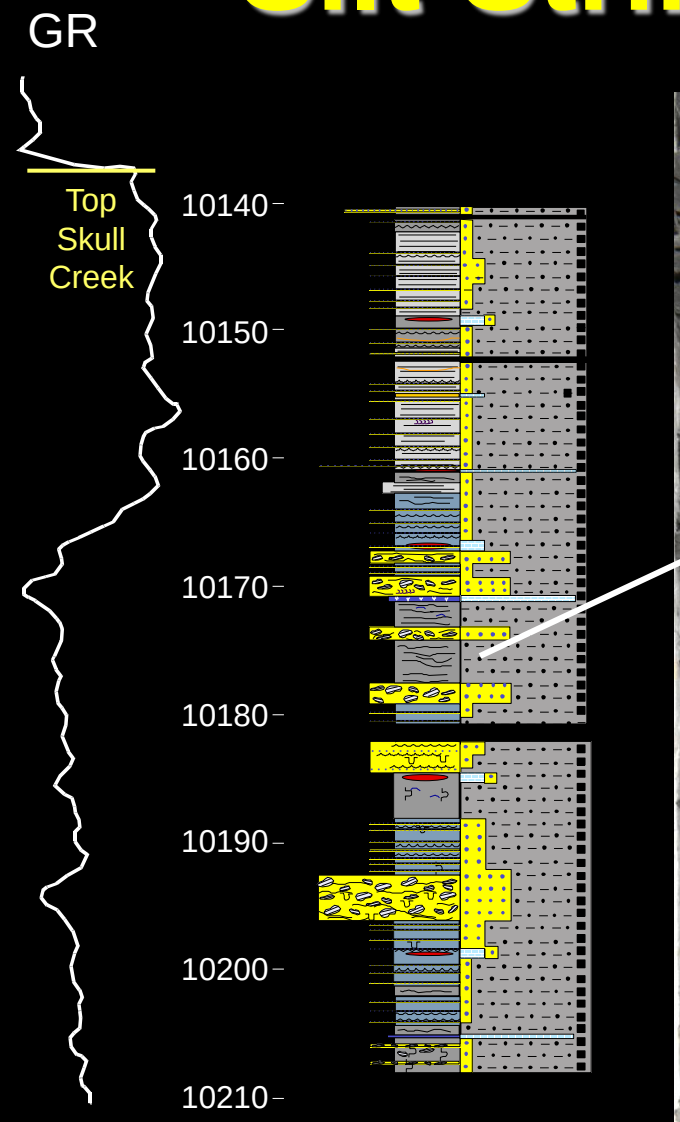




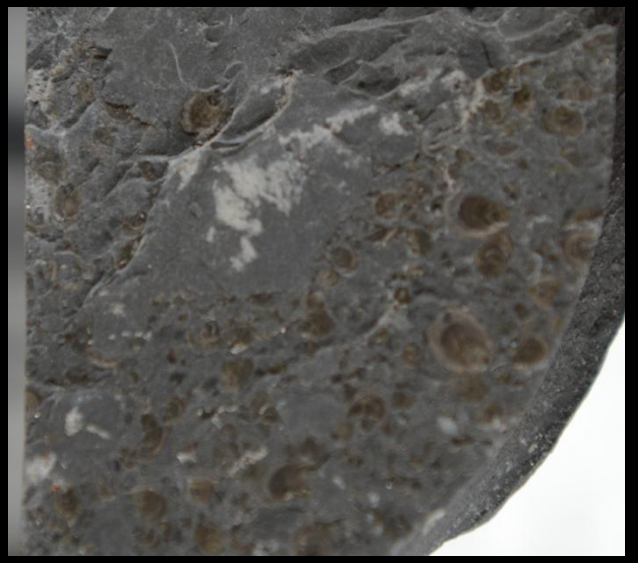
Debris flow composed of laminated sandstone clasts

10,194 ft

Silt-Stringer-Poor Mudstone



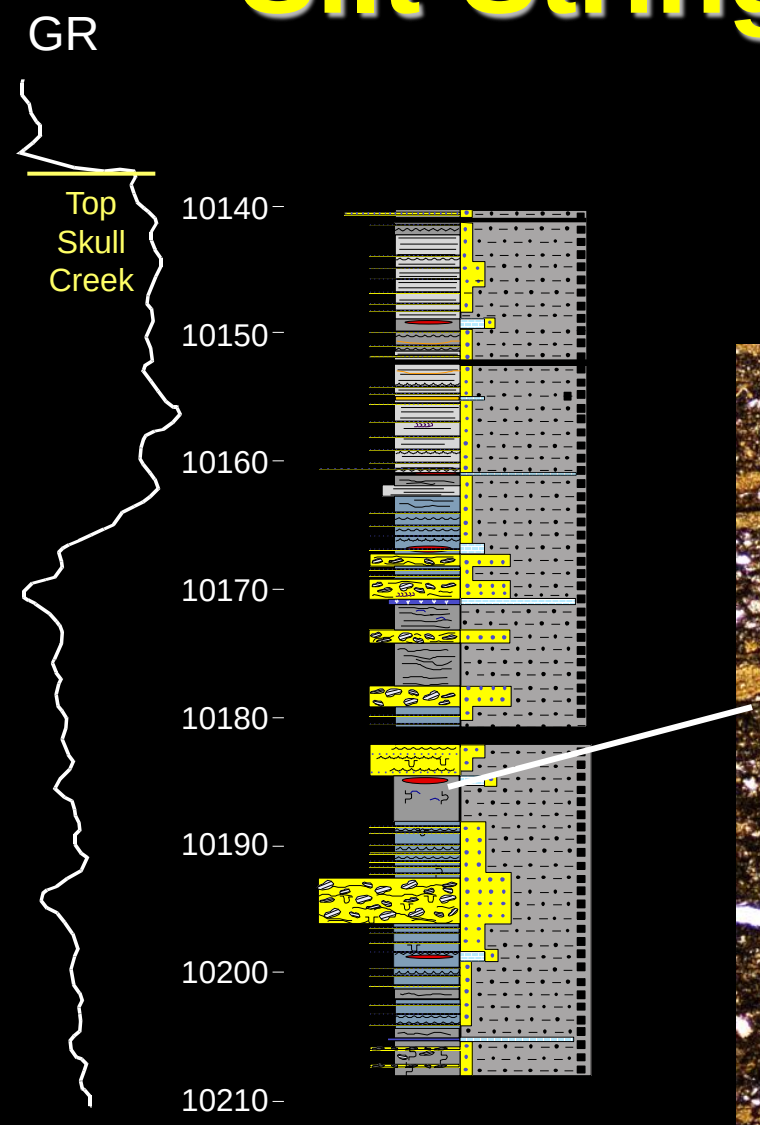
Terrigenous mudstone with rare, thin silt stringers



Small, thin bivalves on bedding plane

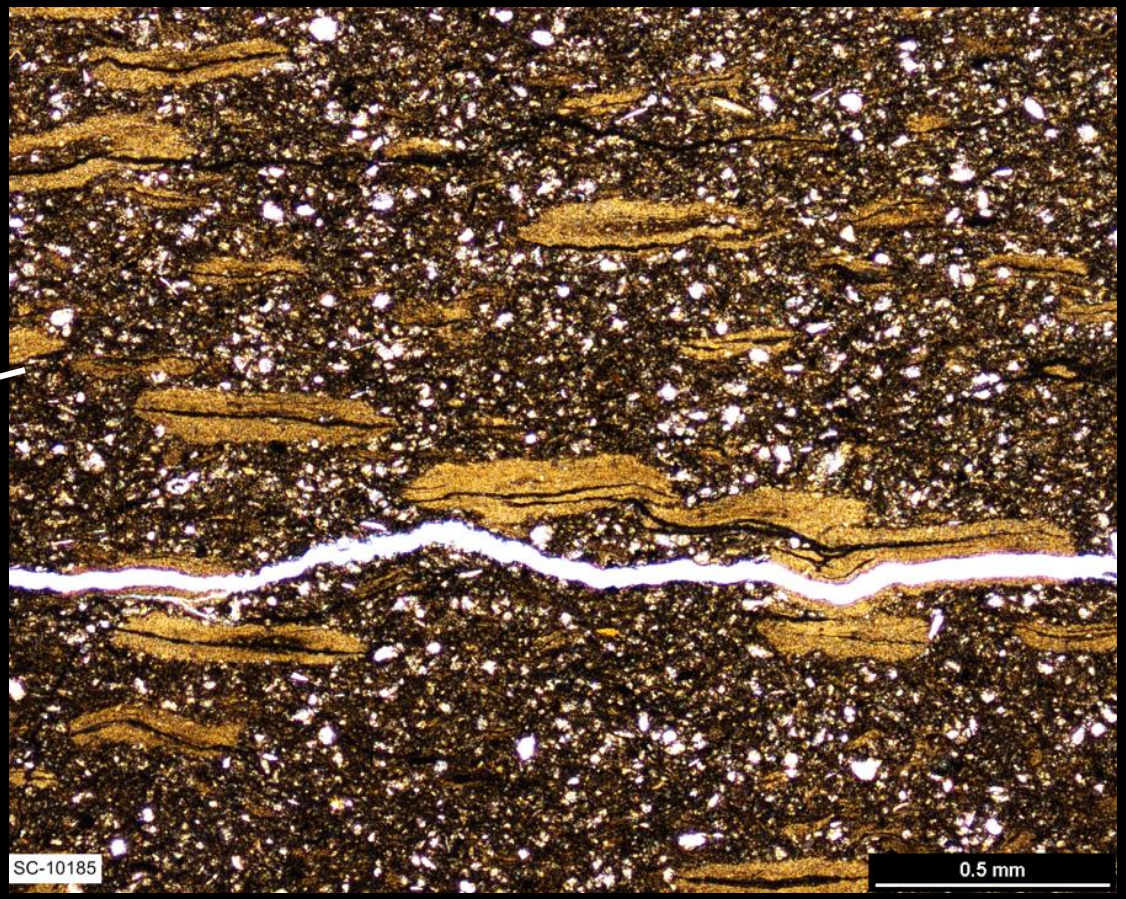
10,175 ft

Silt-Stringer-Poor Mudstone

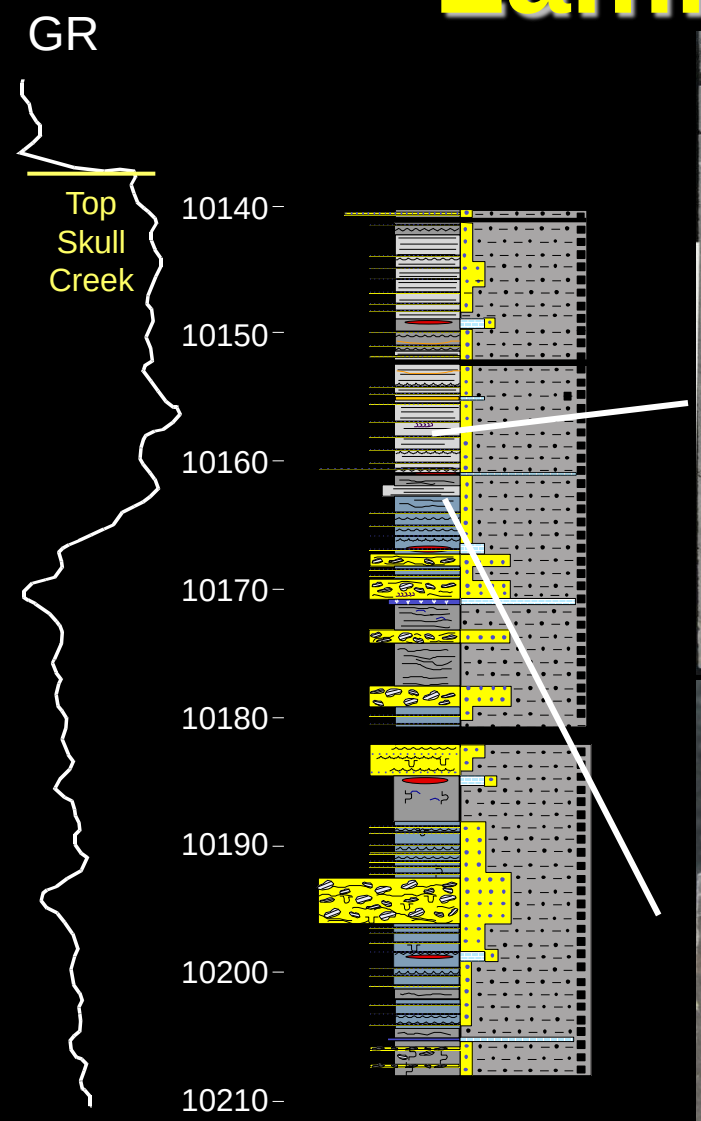


10,185 ft

Terrigenous mudstone with rip-up clay clasts (deepwater algal mat?)



Laminated Mudstone



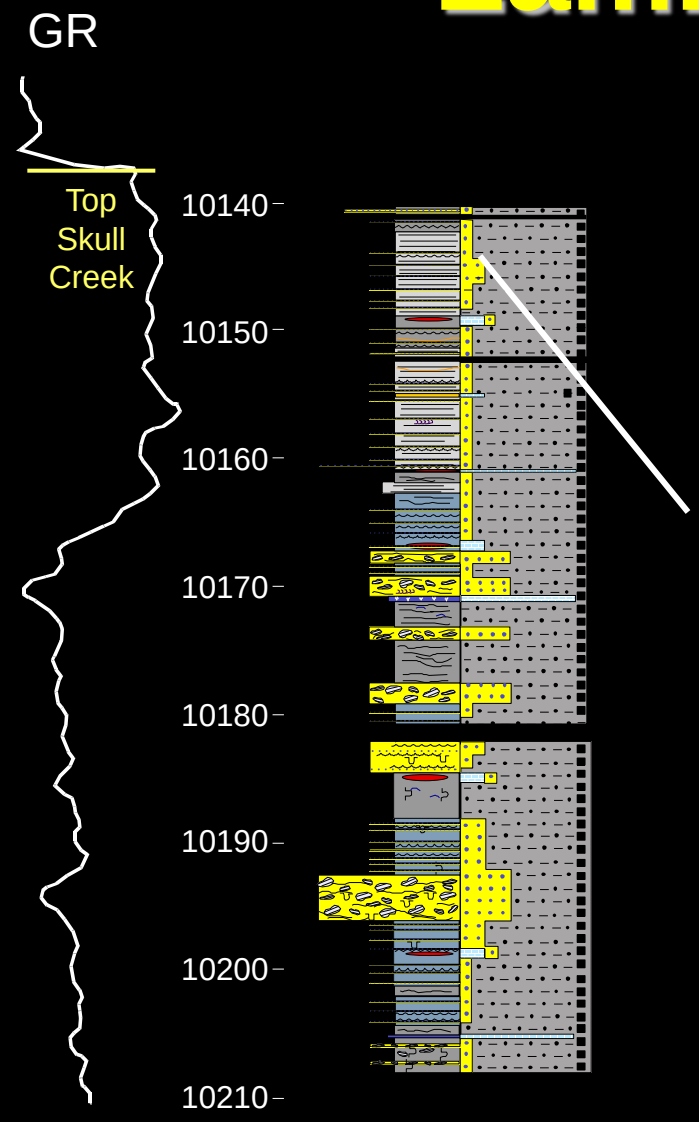
Laminated mudstone with truncated starved ripple

10,157 ft

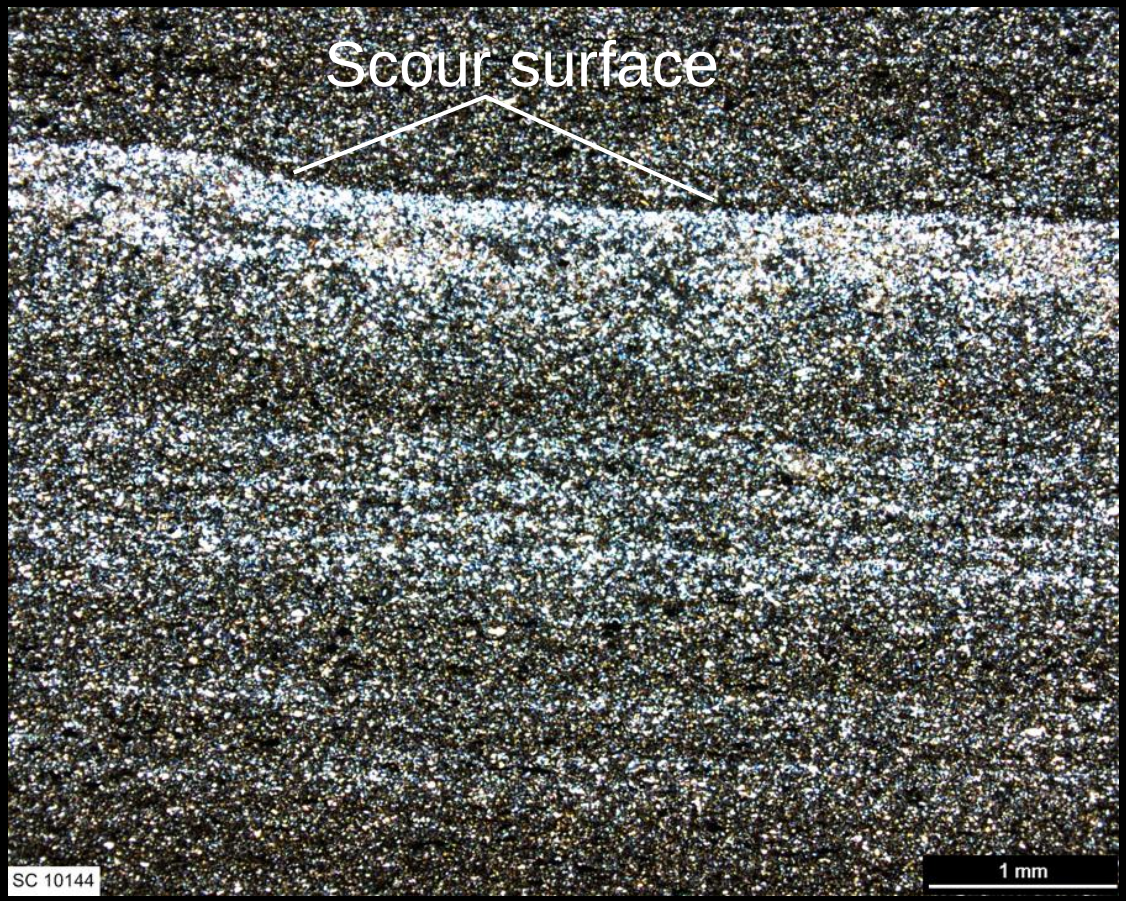
Laminated mudstone with pyrite layers

10,161 ft

Laminated Mudstone



Laminated silty mudstone



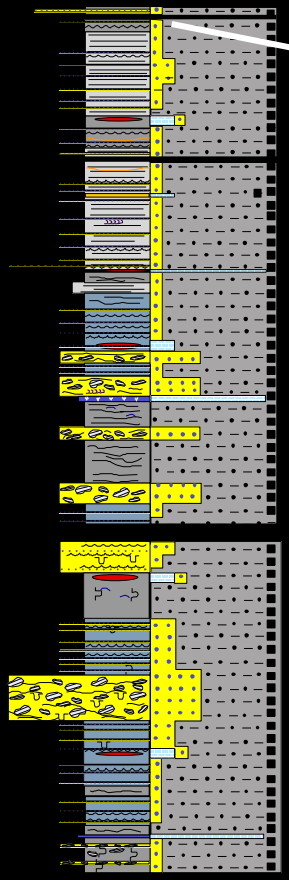
10,144 ft

Shale

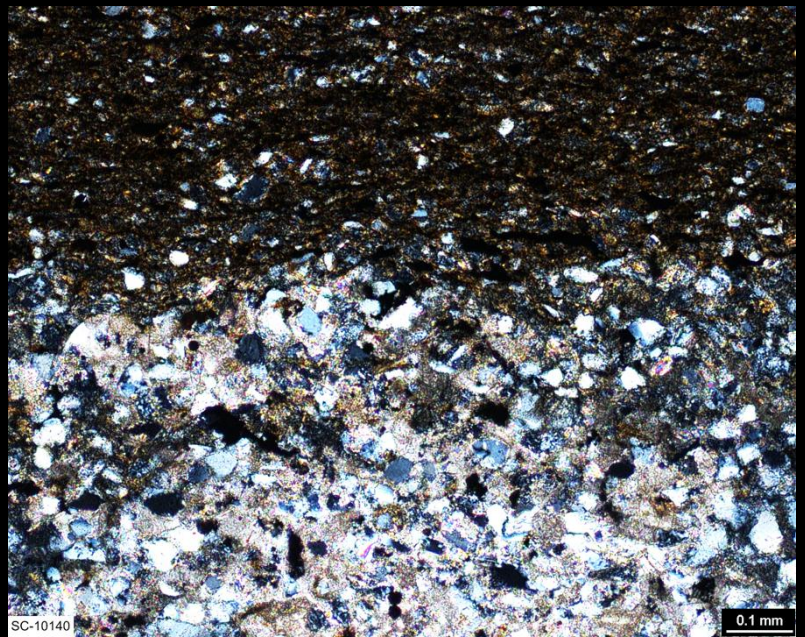
GR

Top Skull Creek

10140
10150
10160
10170
10180
10190
10200
10210

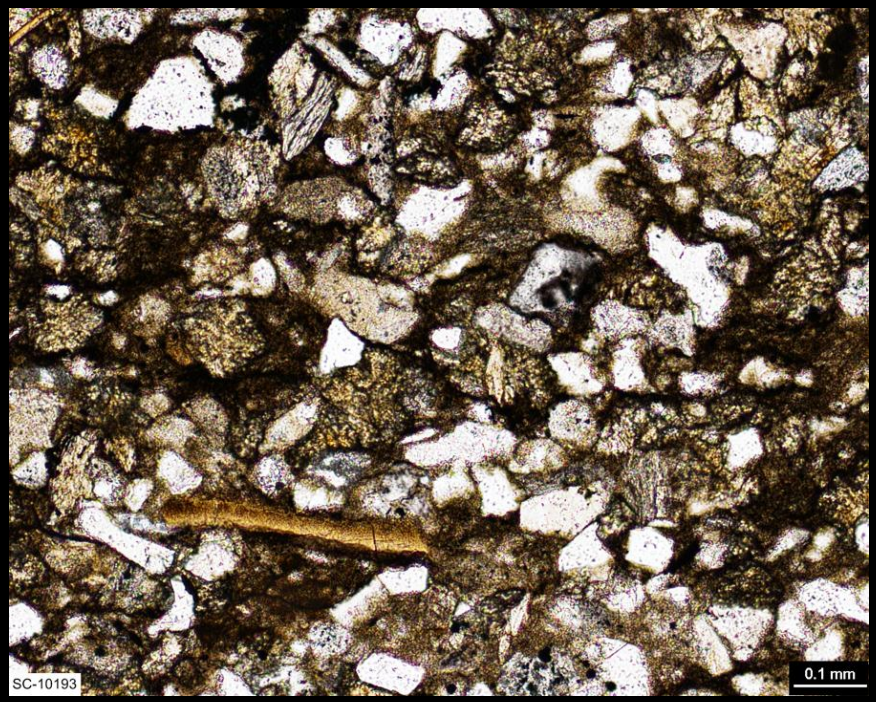


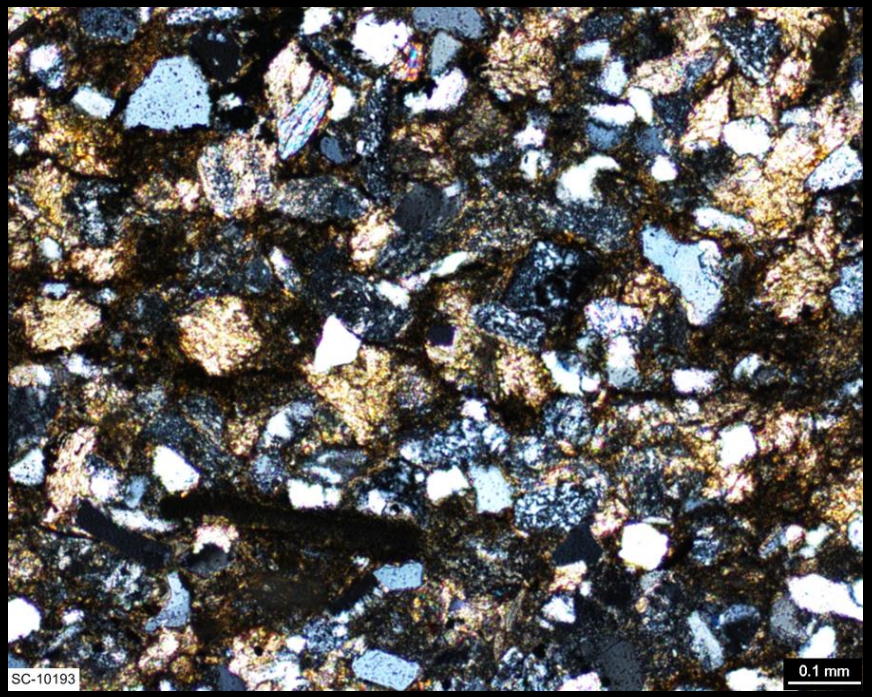
Silty shale over rippled siltstone (starved ripple)



10,140.7 ft

Sand and Silt Mineralogy

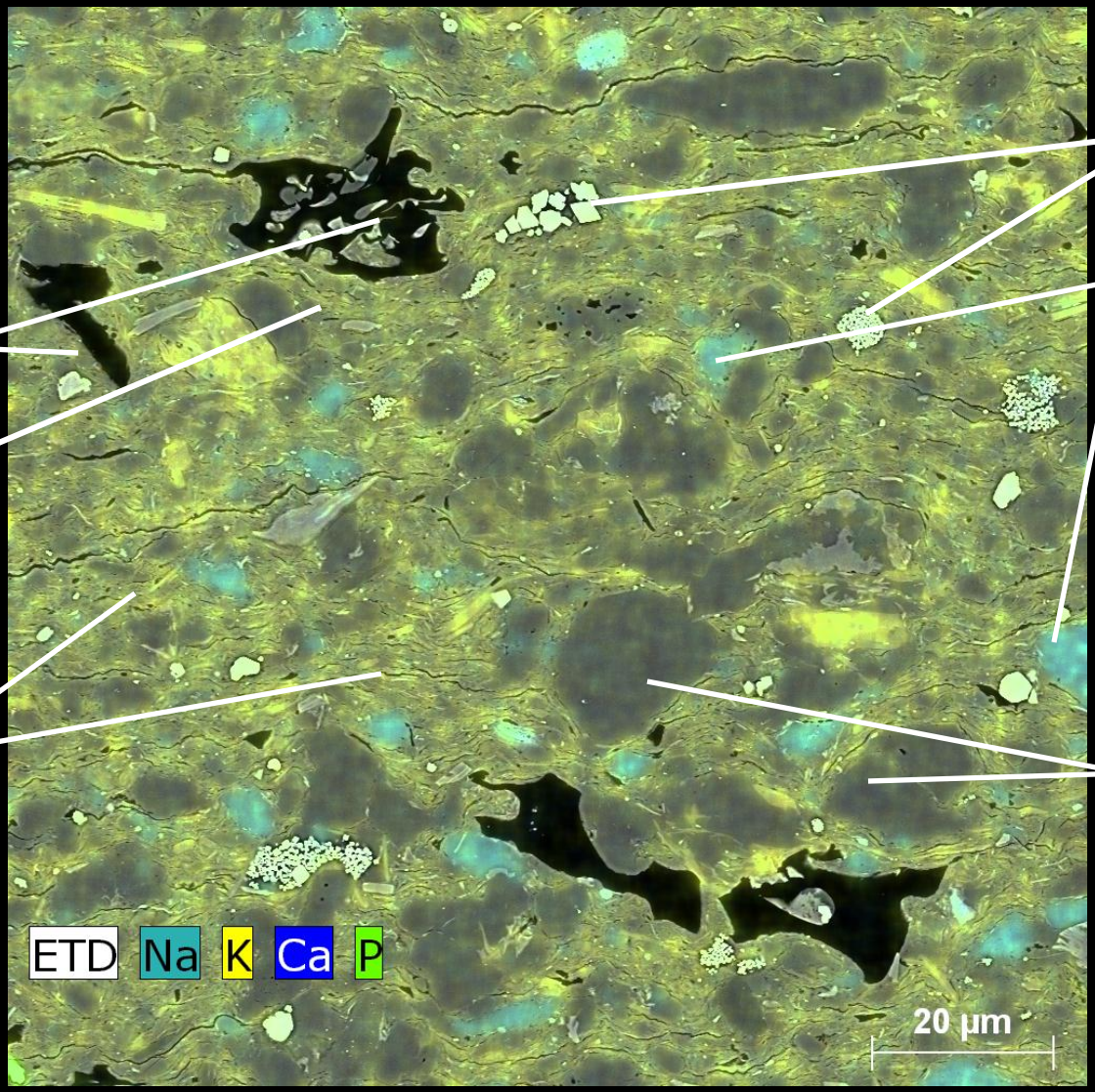




Immature volcanic litharenite

- Grains
  - Quartz
  - Chert grains
  - Silicified volcanic rock fragments
  - Schist rock fragments
  - Feldspar (albite)
  - Muscovite
  - Chlorite grains
  - Phosphate bone/teeth/scale
  - Diagenetic siderite crystals (clusters)

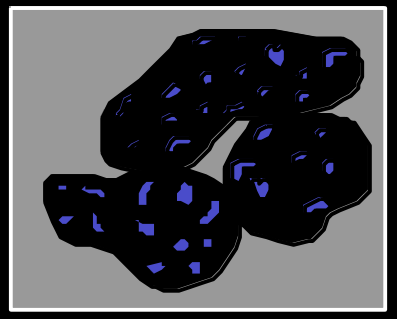
Mudstone Elemental Map



10,207 ft

Clay- to silt-sized grains

Mudrock Pore Network Classification



Organic matter pores

Pores more hydrophobic

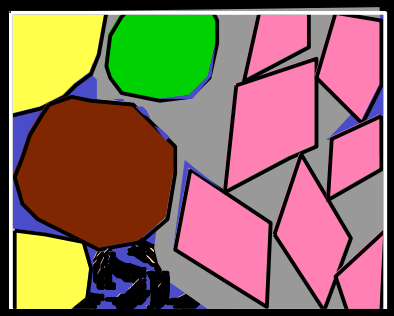
Pores more hydrophilic

50%

50%

Mixed-pore network

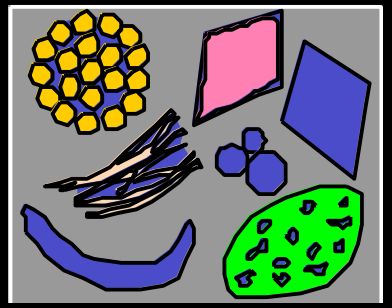
Effective porosity increases



Interparticle pores

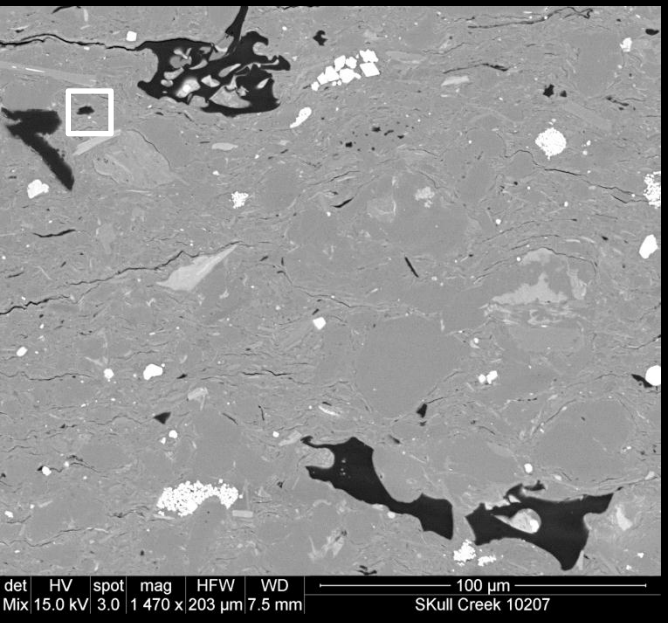
50%

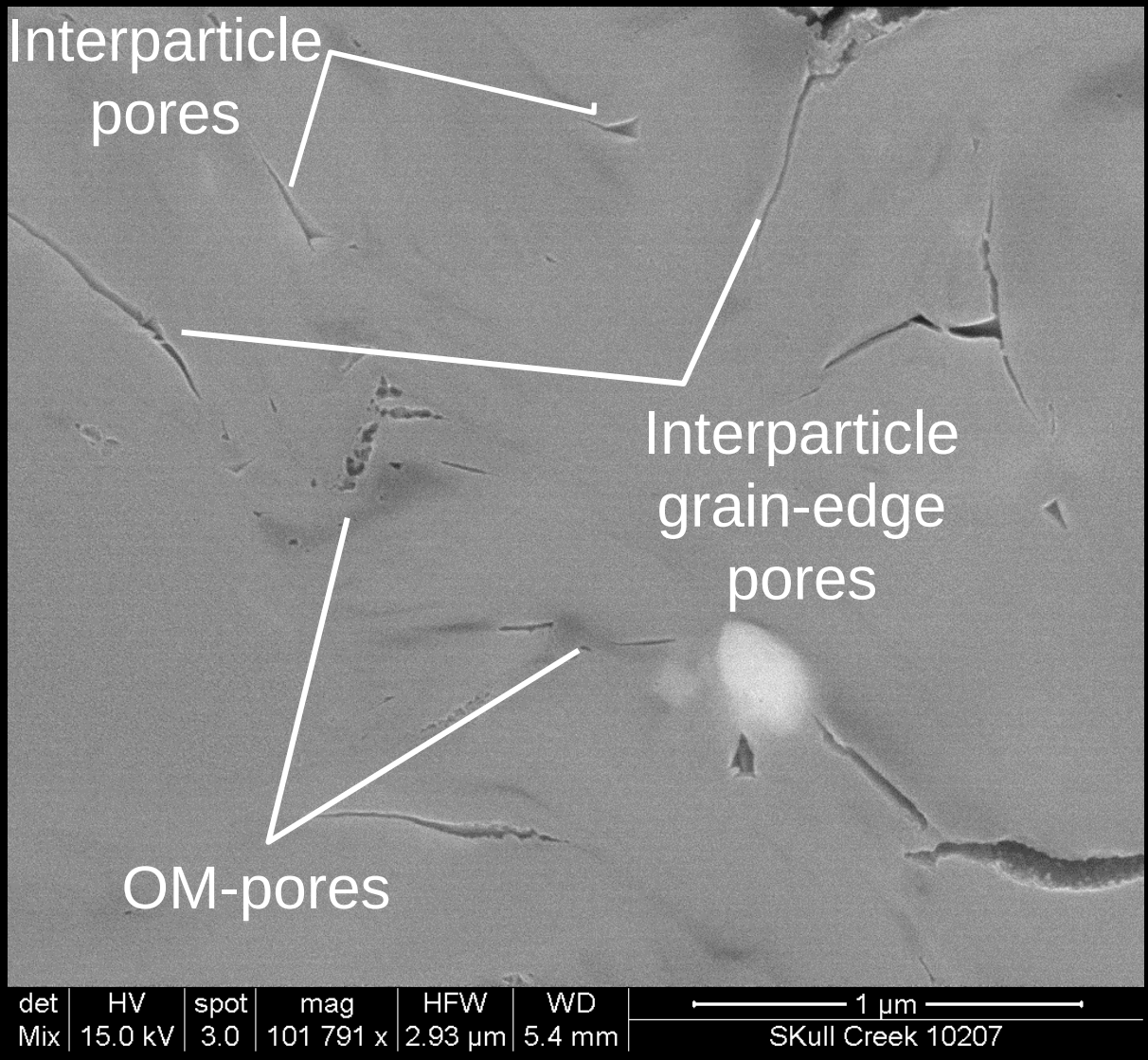
Intraparticle pores



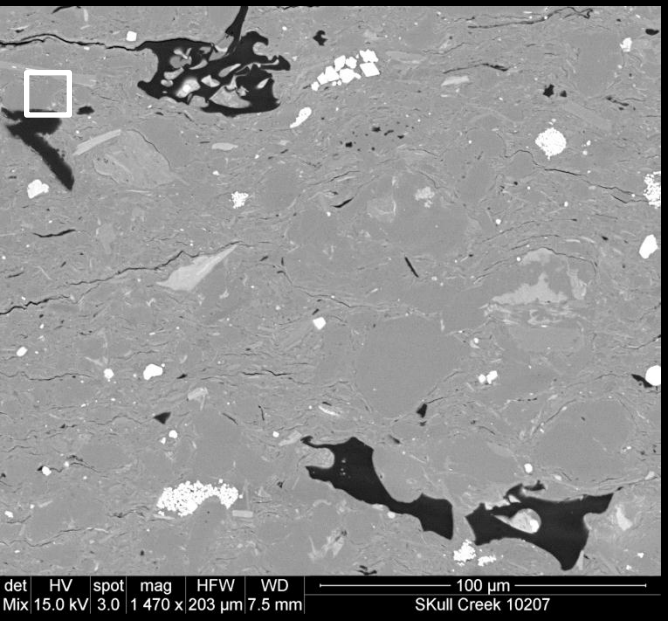
Mod. from Loucks et al., 2012

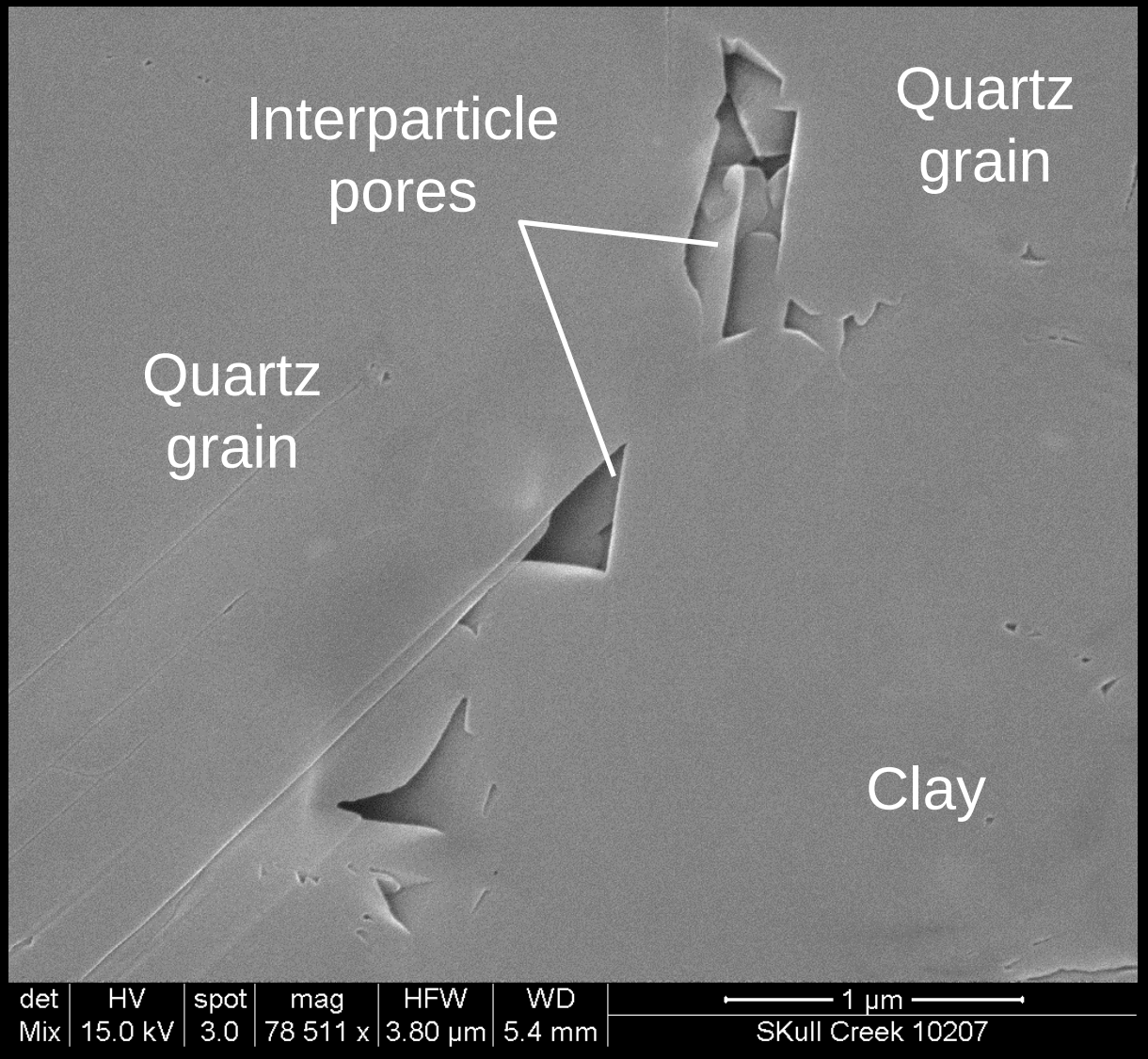
Pore Types


det HV spot mag HFW WD
Mix 15.0 kV 3.0 1 470 x 203 µm 7.5 mm
100 µm
SKull Creek 10207

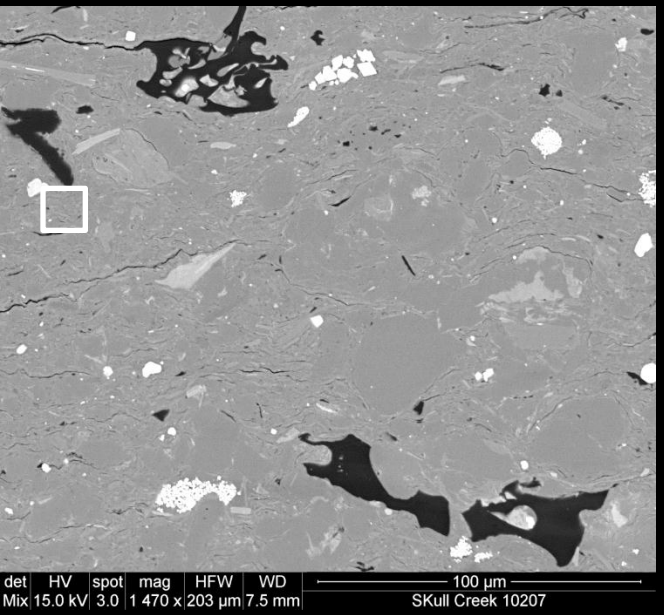

Interparticle pores
Interparticle grain-edge pores
OM-pores
det HV spot mag HFW WD
Mix 15.0 kV 3.0 101 791 x 2.93 µm 5.4 mm
1 µm
SKull Creek 10207

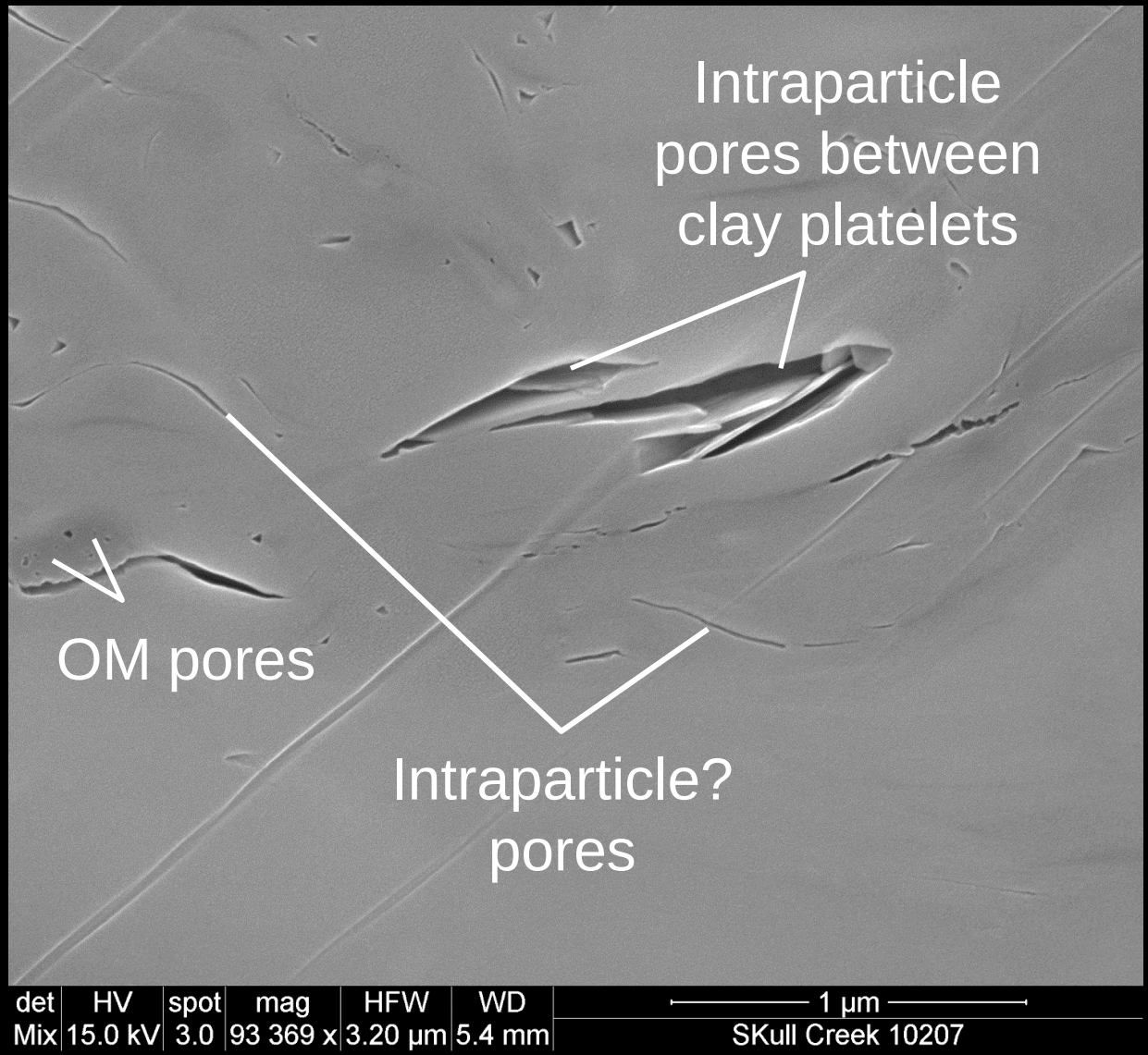
Pore Types


det HV spot mag HFW WD
Mix 15.0 kV 3.0 1 470 x 203 µm 7.5 mm
100 µm
SKull Creek 10207

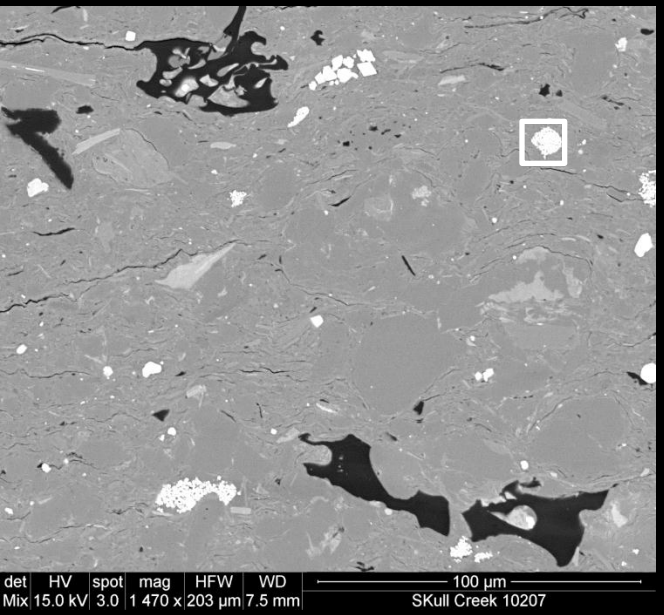

Interparticle pores
Quartz grain
Quartz grain
Clay
det HV spot mag HFW WD
Mix 15.0 kV 3.0 78 511 x 3.80 µm 5.4 mm
1 µm
SKull Creek 10207

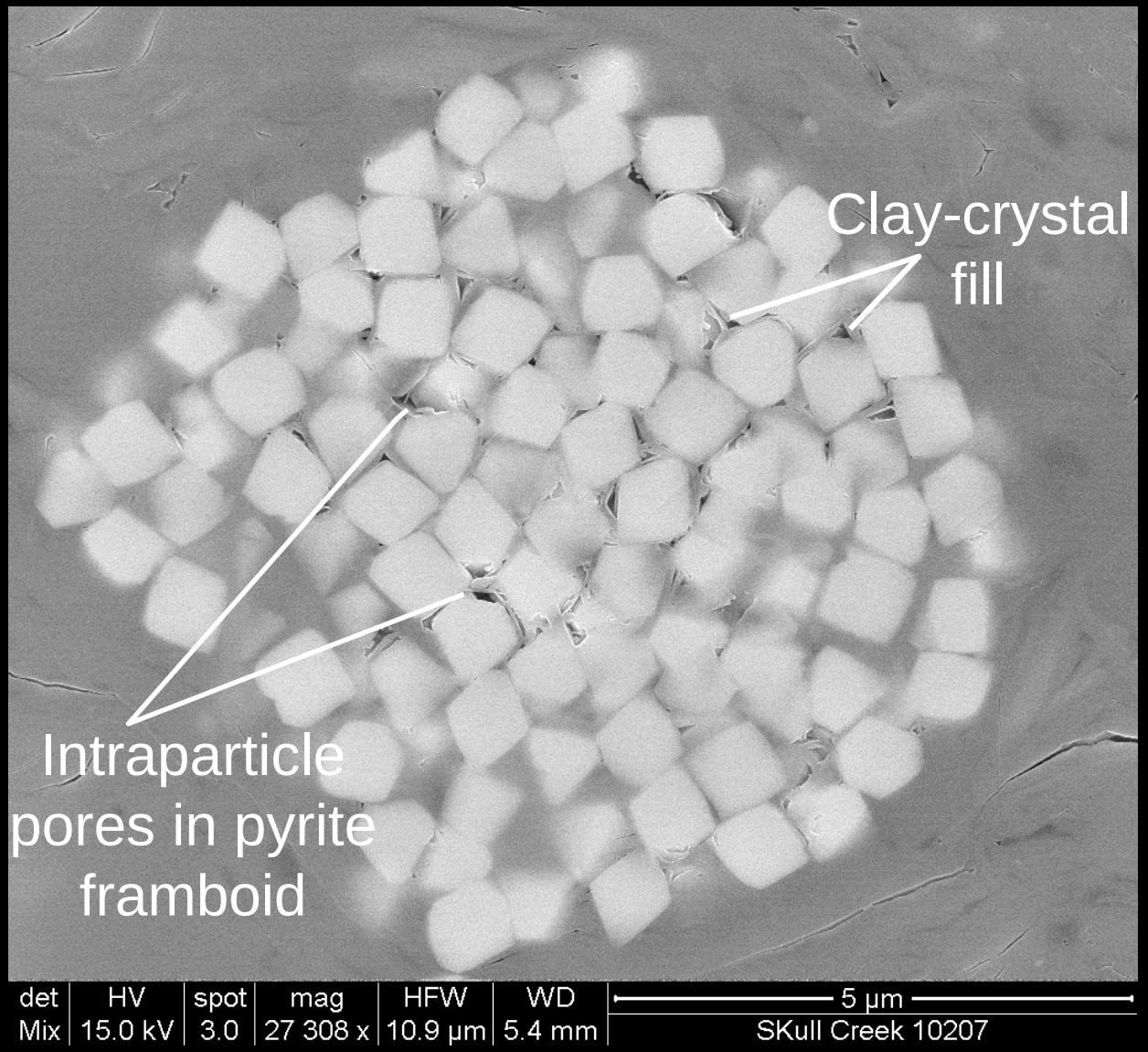
Pore Types


det HV spot mag HFW WD
Mix 15.0 kV 3.0 1 470 x 203 µm 7.5 mm
100 µm
SKull Creek 10207

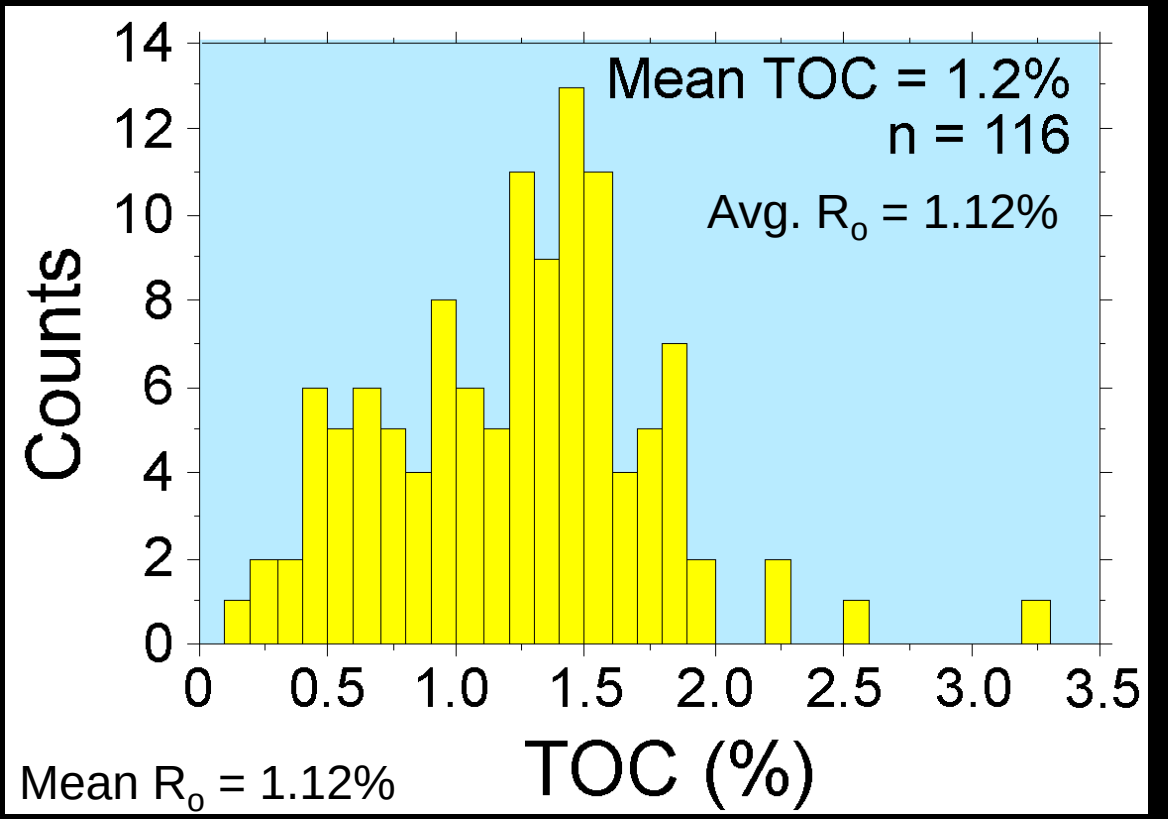

Intraparticle pores between clay platelets
OM pores
Intraparticle? pores
det HV spot mag HFW WD
Mix 15.0 kV 3.0 93 369 x 3.20 µm 5.4 mm
1 µm
SKull Creek 10207

Pore Types


det HV spot mag HFW WD
Mix 15.0 kV 3.0 1 470 x 203 µm 7.5 mm
100 µm
SKull Creek 10207

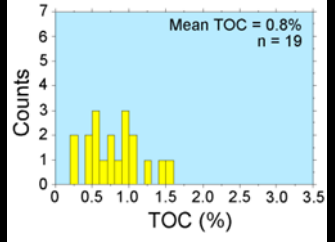

Clay-crystal fill
Intraparticle pores in pyrite framboid
det HV spot mag HFW WD
Mix 15.0 kV 3.0 27 308 x 10.9 µm 5.4 mm
5 µm
SKull Creek 10207

TOC

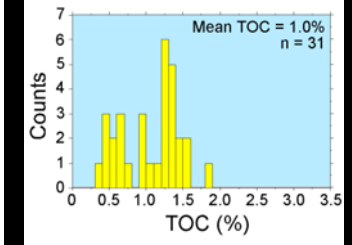


All data

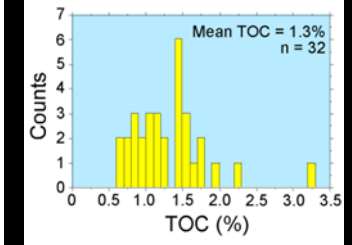
General inverse relationship between TOC and silt/sand content (*dilution effect*)



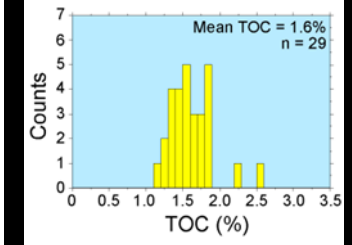
Muddy clast-rich siltstone/sandstone



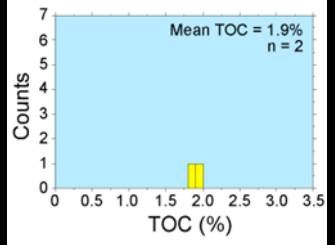
Mudstone with common rippled silt stingers



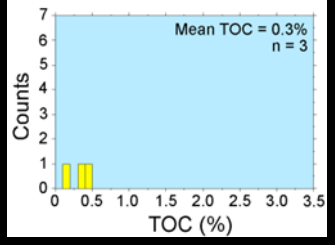
Mudstone with rare silt stingers



Laminated mudstone

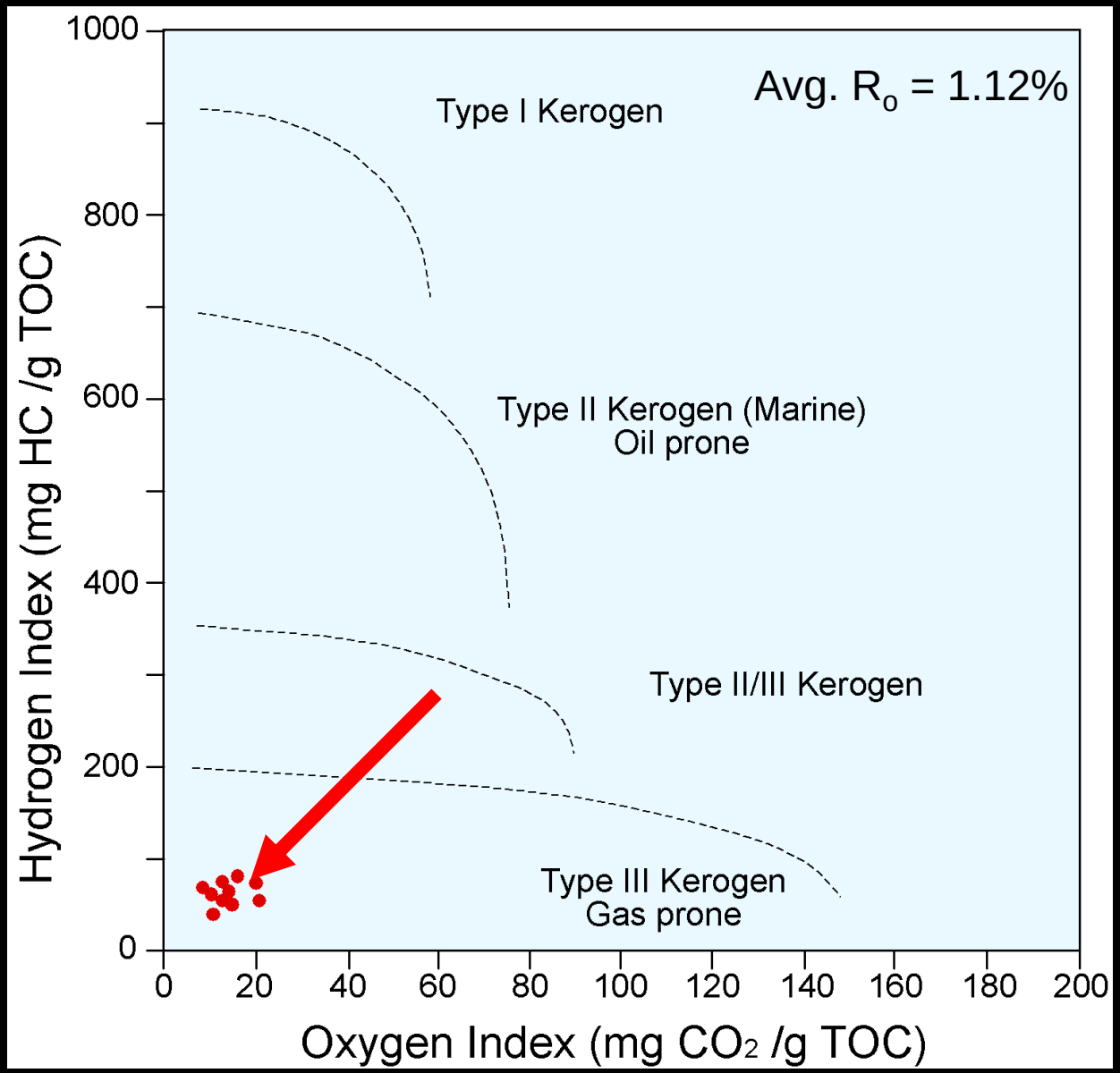


Black shale

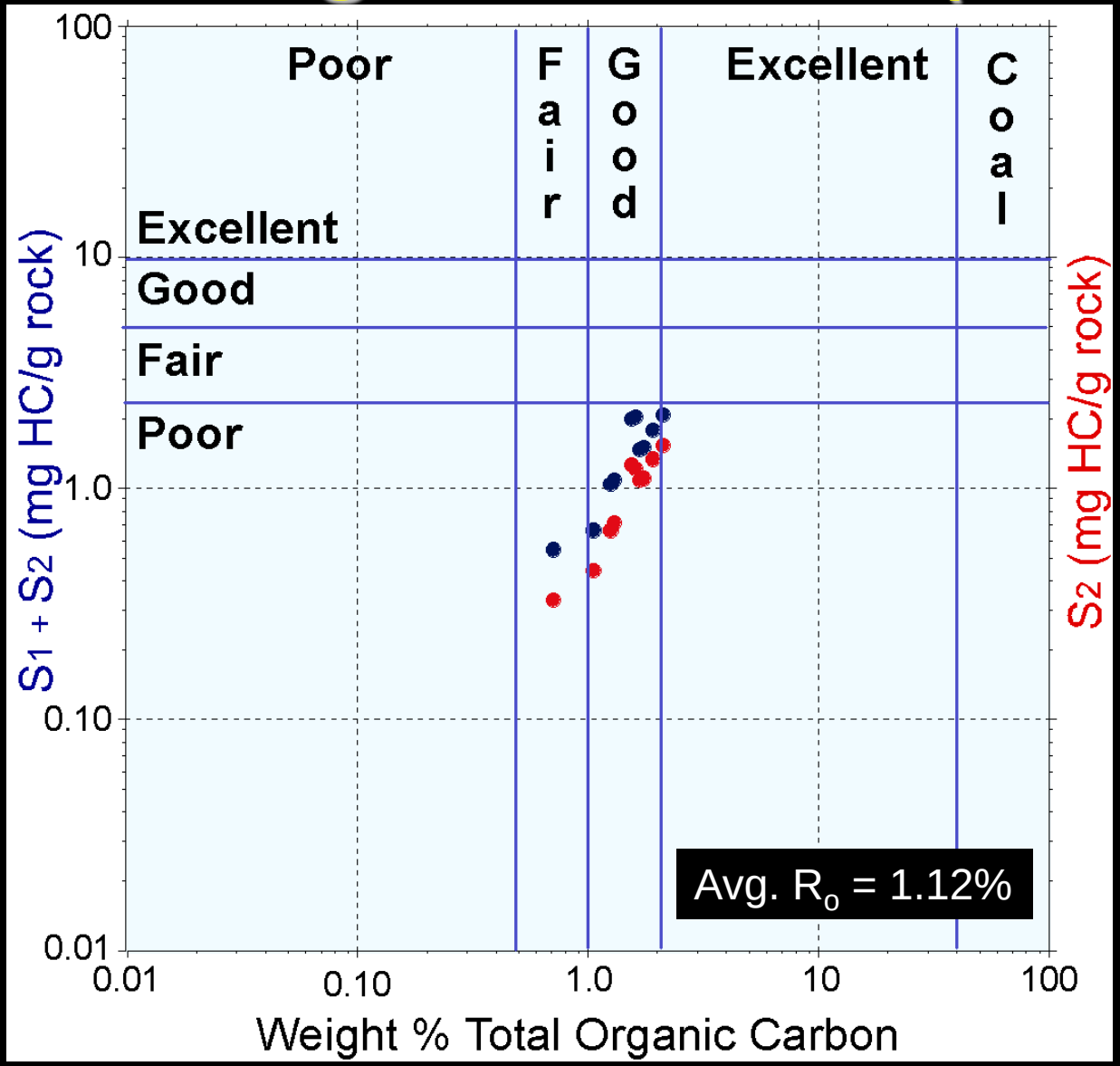


Concretions

Pseudo-Van Krevelen Plot



Classification of Kerogen Quantity Using Dembicki's (2009) Scheme



- Based on RockEval data
- S_1 is hydrocarbons already generated
- S_2 is current potential of a kerogen to generate additional hydrocarbons

Conclusions

- Deposited in a transgressive system during the Albian
- Major depositional processes were gravity-flow currents and bottom currents, producing mixtures of muddy silts and sands to shales
- Depositional setting was anaerobic to dysareobic
- Visual porosity low
- Pore types are a mixture of interparticle, intraparticle, and OM pores
- TOC averages between 1.2 to 1.5% (predominately type III but may be some type II)
- R_o averages 1.12%
- Moderate risk of being a shale-gas candidate based on type of organics