

Porosity in Shales of the Organic-Rich Kimmeridge Clay Formation (Upper Jurassic), Offshore United Kingdom*

Neil S. Fishman¹, Heather A. Lowers², Paul C. Hackley³, Ronald J. Hill⁴, Sven O. Egenhoff⁵

Search and Discovery Article #50620 (2012)**

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Abstract

Petrographic, SEM, and RockEval pyrolysis analyses of organic-rich shale samples from 6 wells that penetrated the Upper Jurassic Kimmeridge Clay Formation (KCF), offshore United Kingdom, were performed to evaluate the nature (physical and chemical) of the organic material and to document changes in organic porosity as a function of increasing thermal maturity. The formation is at depths ranging from ~6,100 ft to ~15,300 ft (subsea). It is thermally immature to marginally mature in the shallowest core samples, where total organic carbon (TOC) contents are as high as 10 wt%, vitrinite reflectance (Ro) values are ~0.6%, and hydrogen indices (HI) are high (>400 mg hydrocarbon/g rock). In contrast, it is thermally mature in the deepest core (Ro values ~1.2%), with high TOC contents (as much as 8 wt%) but low HI values (<30 mg hydrocarbon/g rock). In addition, the KCF has intermediate HI and Ro values in other core samples.

At least four distinct types of organic components were observed in petrographic and SEM analyses, which are, in decreasing abundance: 1) amorphous organic material admixed with clay platelets (as much as 20 µm long); 2) elongate (up to 300 µm) mat-like masses (micro-algal mat?) with small (<0.5 µm) quartz, feldspar, and clay entrained within it; 3) discrete particles (possibly algal?); and 4) Tasmanites microfossils. Regardless of depth and thermal maturity, the following observations were made of porosity in shales of the KCF. On ion-milled surfaces, there are irregular-shaped micropores and nanopores (0.1-0.01 µm across) in some mat-like masses, whereas regularly shaped micropores (up to 1 µm across) are in the discrete organic particles. Other types of pores,

particularly interparticle (i.e., between illite flakes or platelets as well as between authigenic quartz euhedra), and intraparticle (i.e., between crystallites in framboidal pyrite) are also present and are noteworthy because they compose much of the observable porosity in the KCF shales.

No systematic increase in organic porosity was observed in any organic material within the KCF with increasing depth and thermal maturity. As such, organic porosity does not contribute significantly to overall pore volume in the KCF, even in organic-rich shales that are thermally mature. Therefore, the petroleum storage potential in the formation appears to reside largely within interparticle and intraparticle pores between or within inorganic components of the shales, respectively.

Reference

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Approach

Characterize organic macerals (RockEval & petrography)



Evaluate maceral distribution

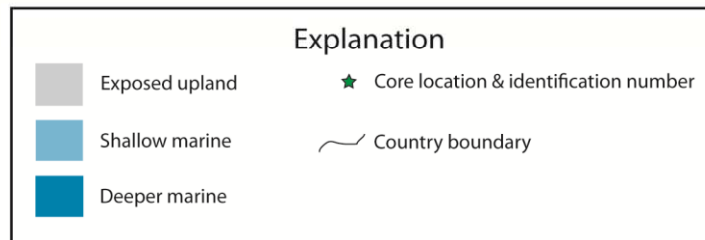
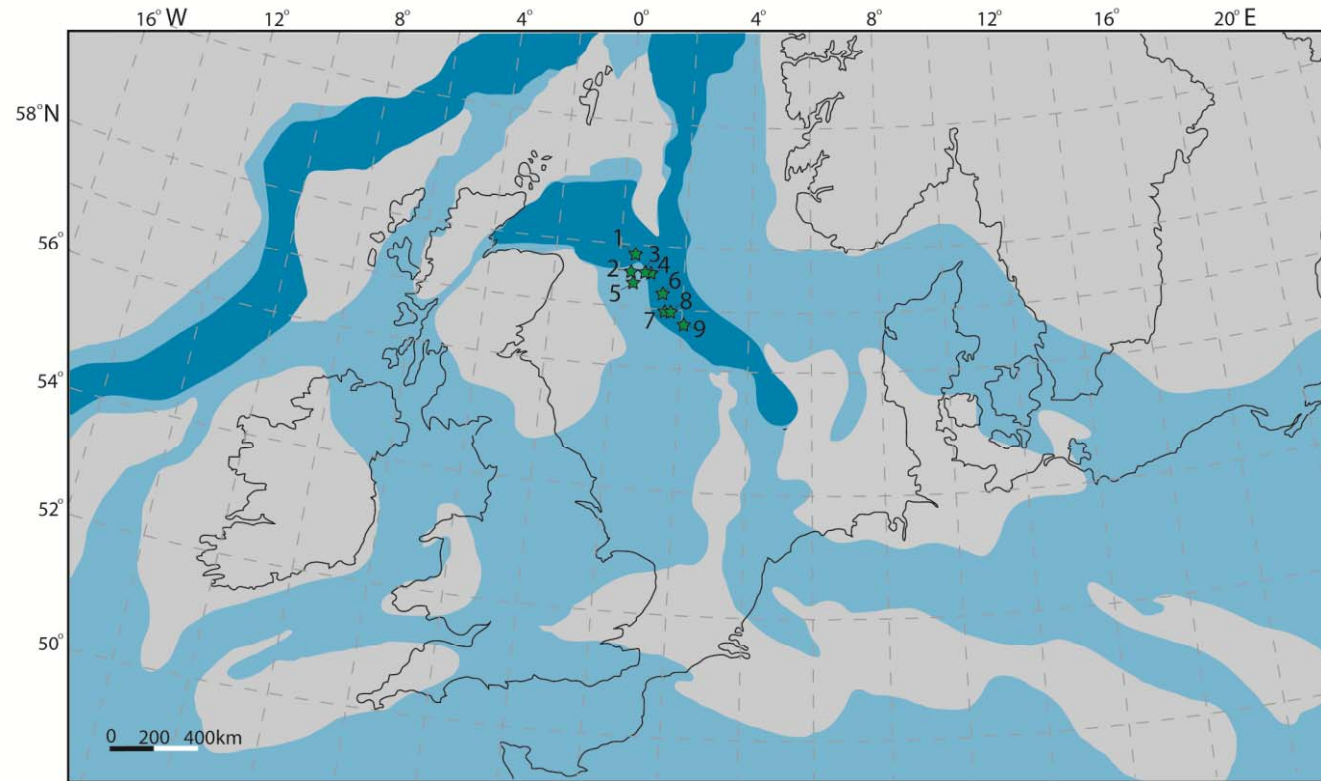


Observe organic pores (maceral type & maturity)



Evaluate inorganic pores

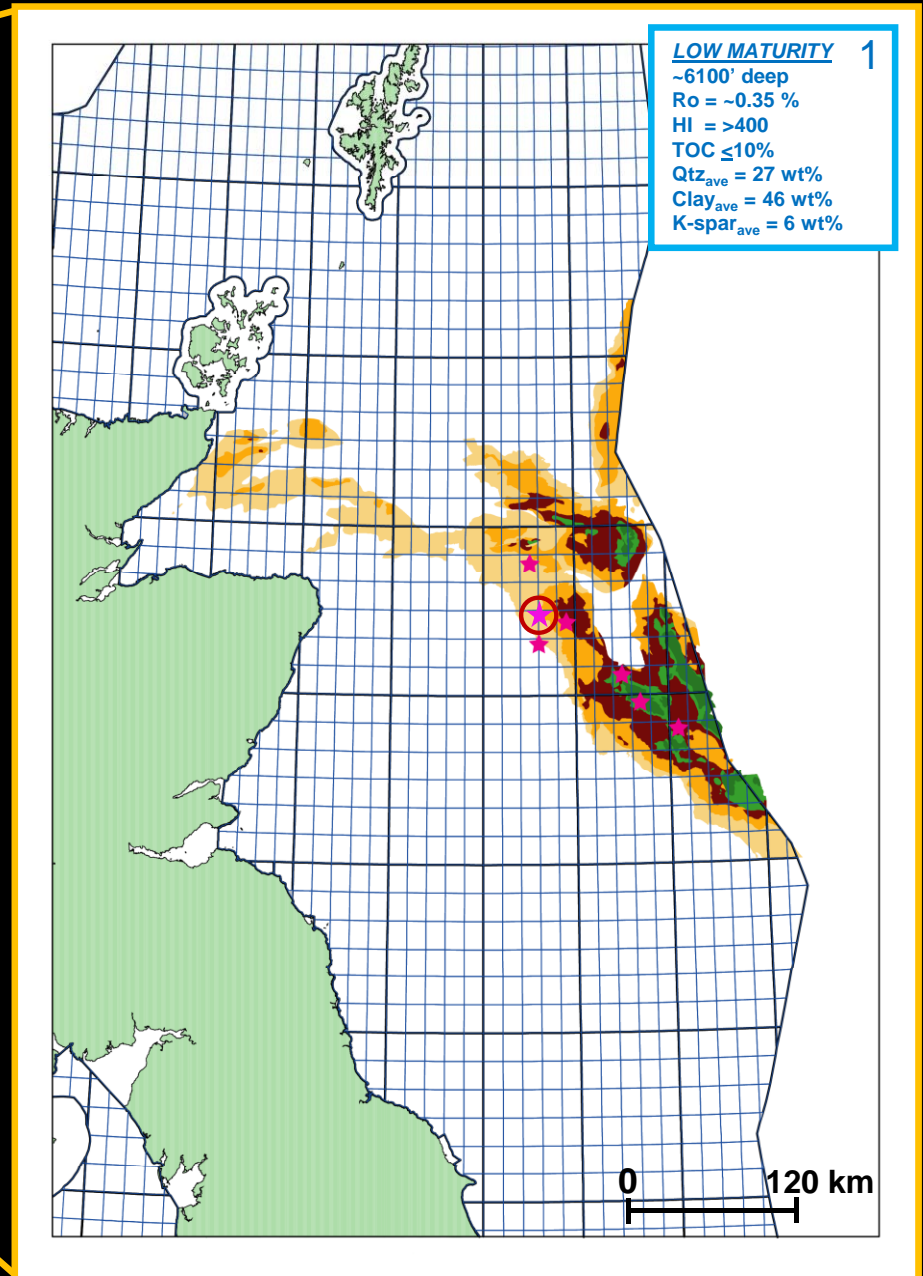
Kimmeridge Clay Fm deposition



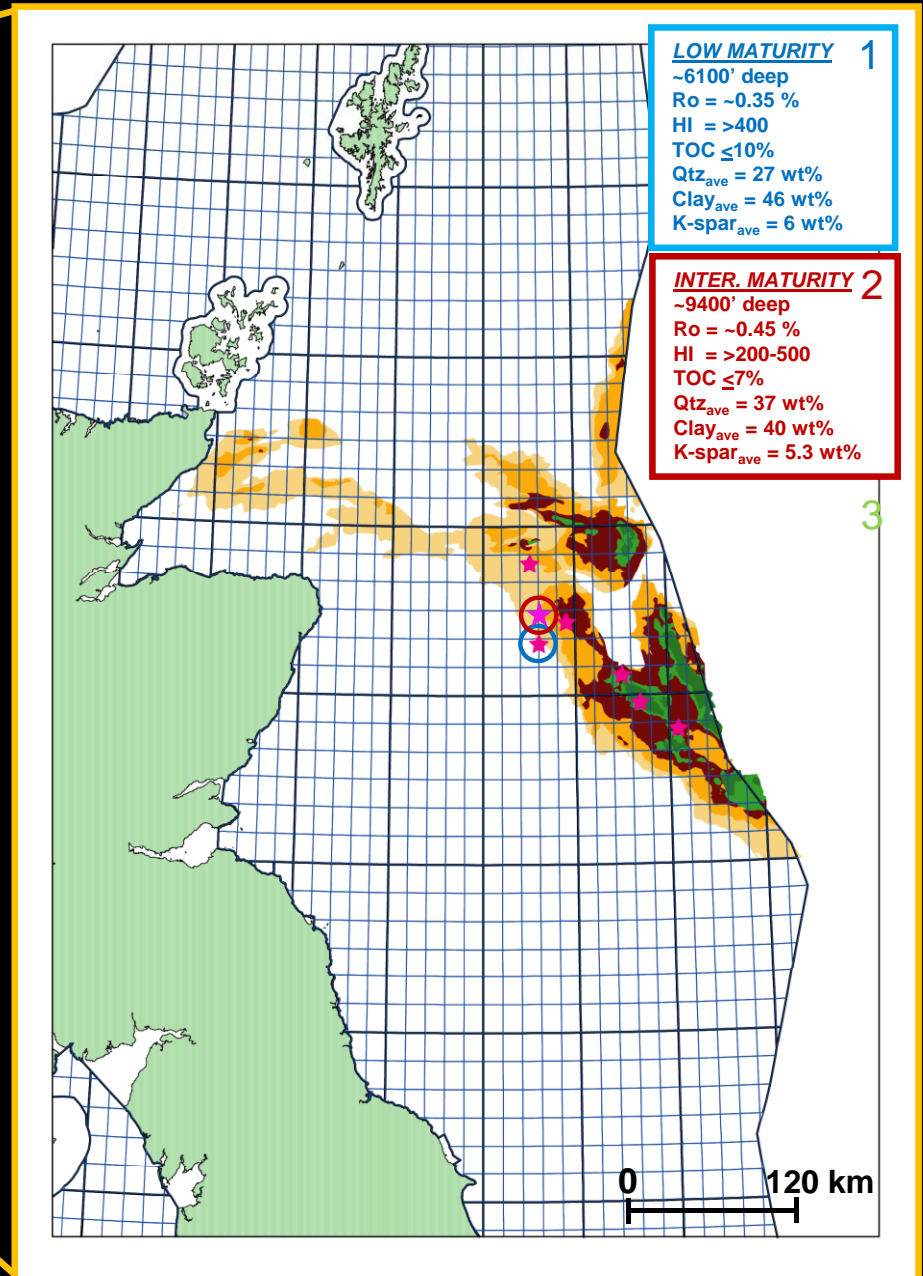
KCF depo during transgression
that also saw connection
Tethys & Arctic (Boreal) seas

Modified from Ziegler, 1990

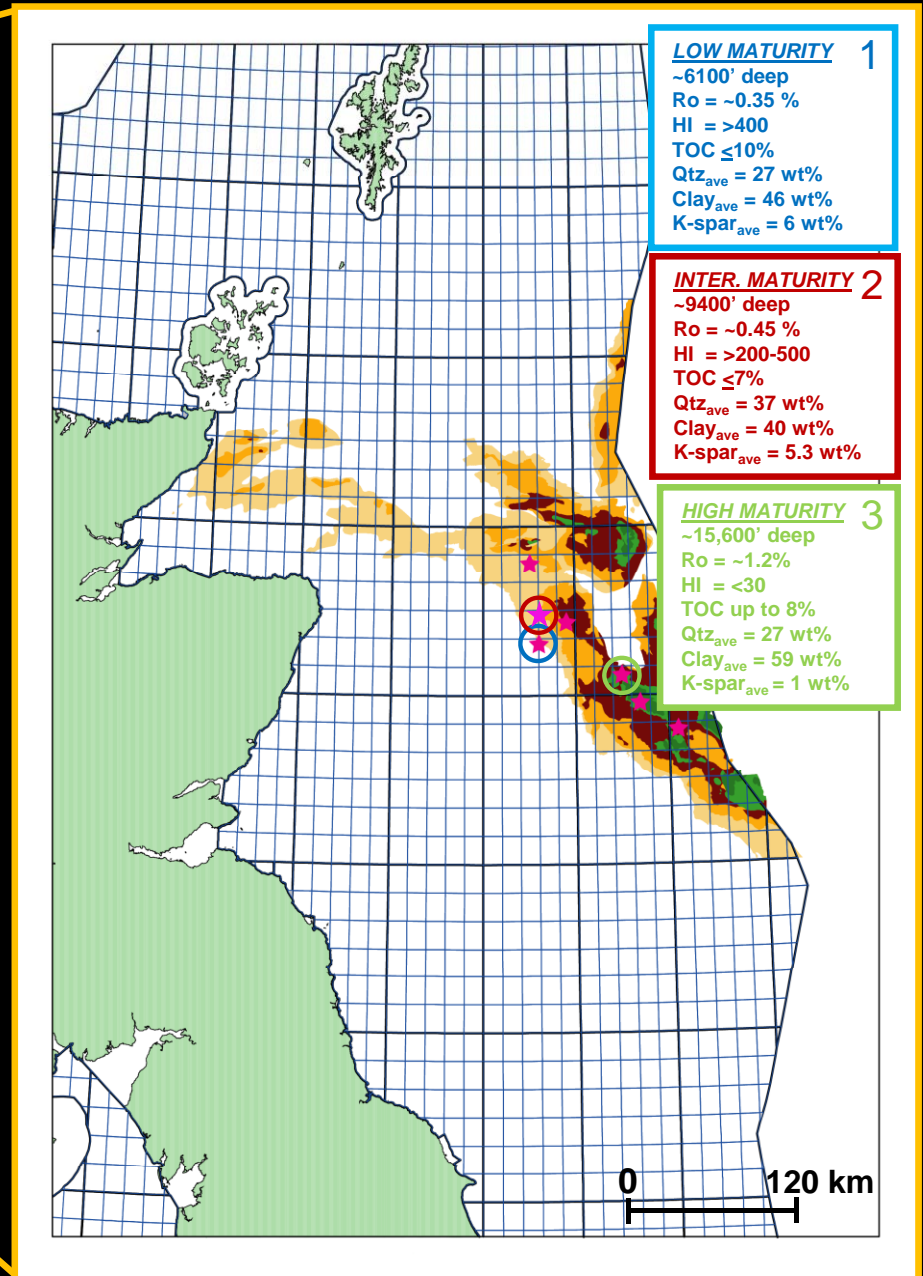
Study area, Kimmeridge Clay Fm, UK



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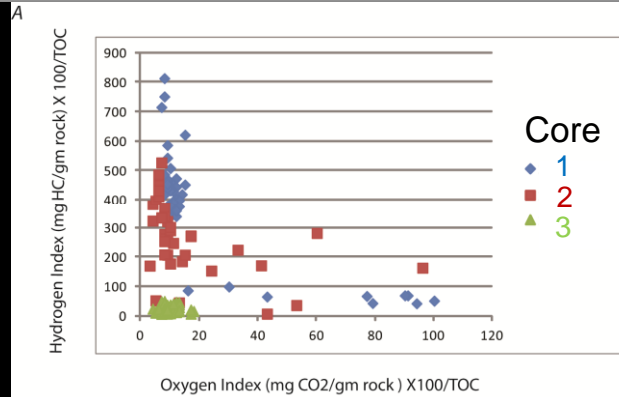


Maceral identification

RockEval—"gross" evaluation

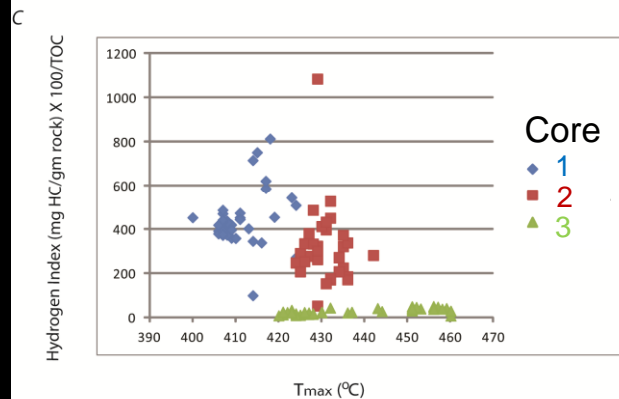
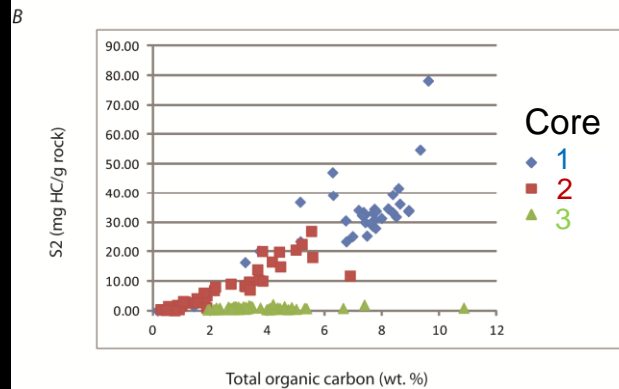
Petrography—"fine" evaluation

RockEval data

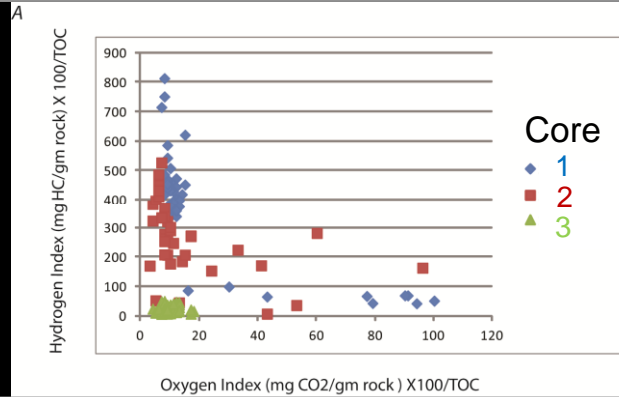


HI vs OI

largely marine algal, but mixed

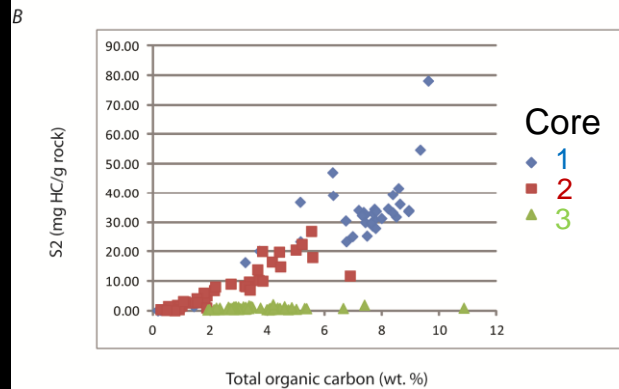


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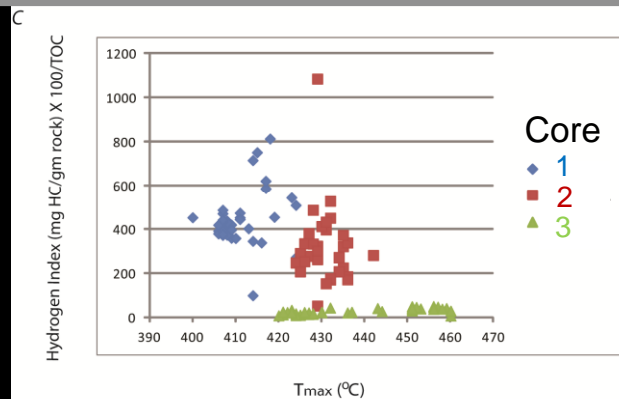
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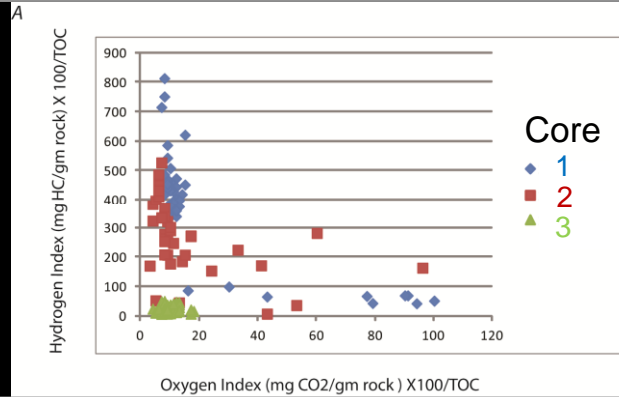


S₂ vs TOC

Generatable HC greatest in
Core 1, decreasing to Core 3

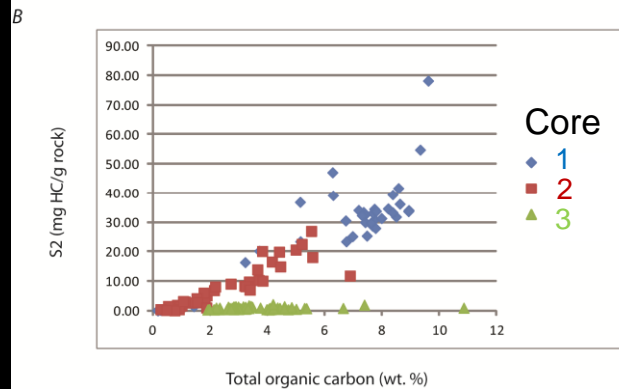


RockEval data



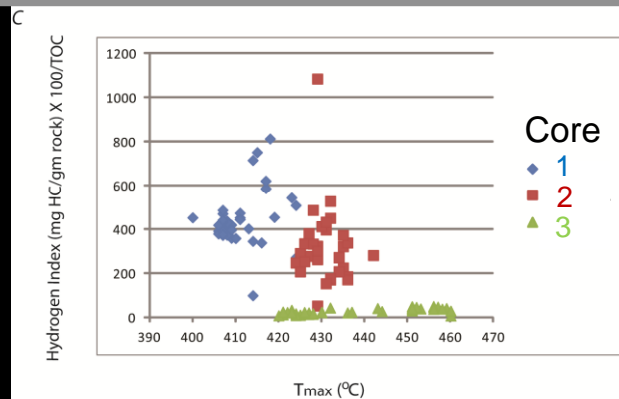
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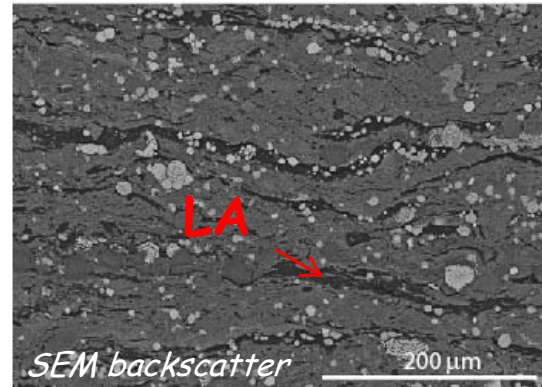
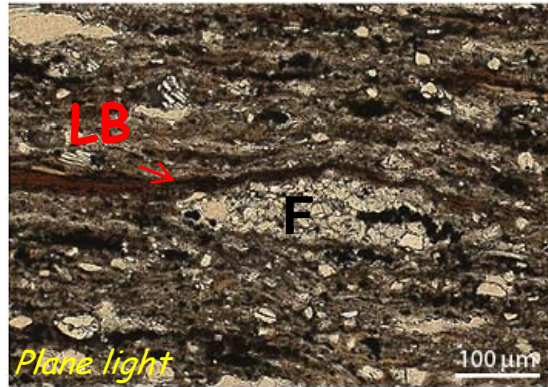
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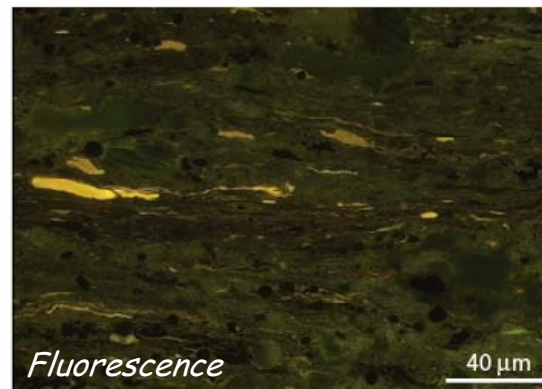
HI vs T_{max}

Increasing maturity from
Core 1 to Core 3

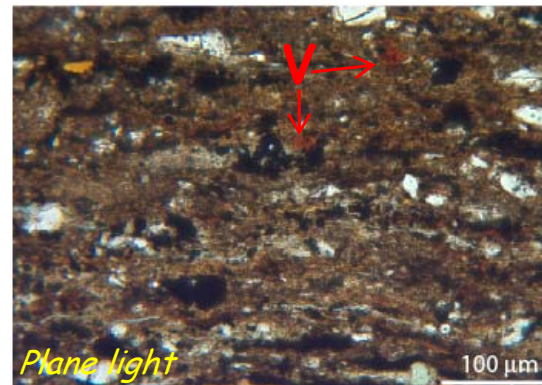
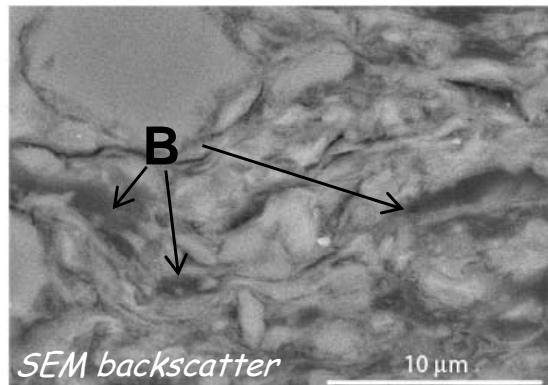
Macerals (Type II & III)



Lamellar
bituminite
& alginite



Lamellar
alginite &
bituminite,
Telalginite
(*Tasmanites*)



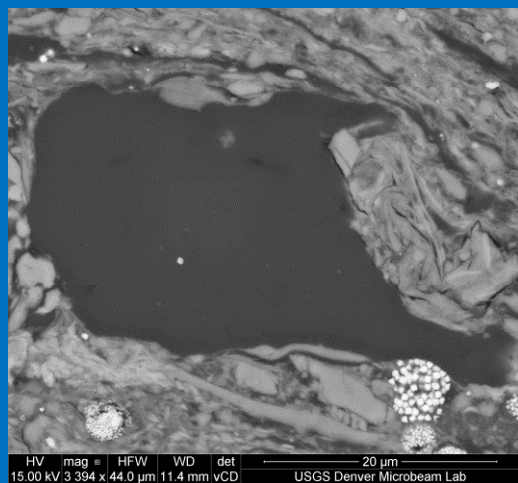
Vitrinite,
Bituminite
(Bituminous
mineral
groundmass)

Distribution of macerals

Where are macerals as a function of core location/
depositional system?

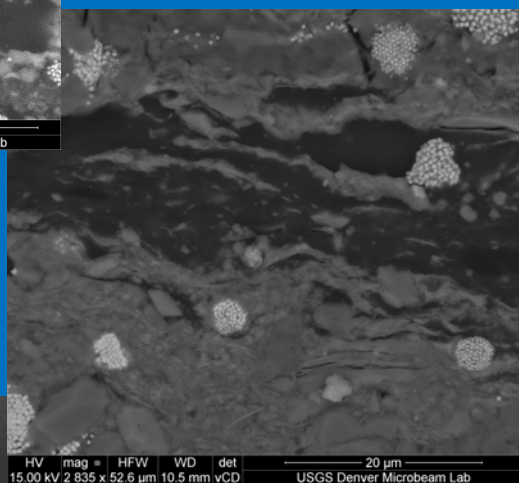
Organic macerals, low & high mat. wells

Low maturity well

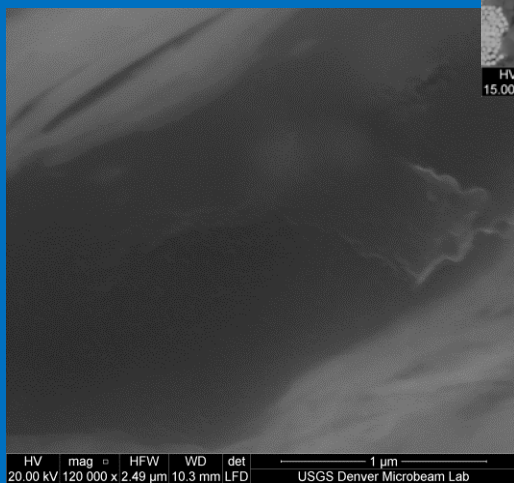


Terrestrial_{low}

Lamellar
alginite_{low}

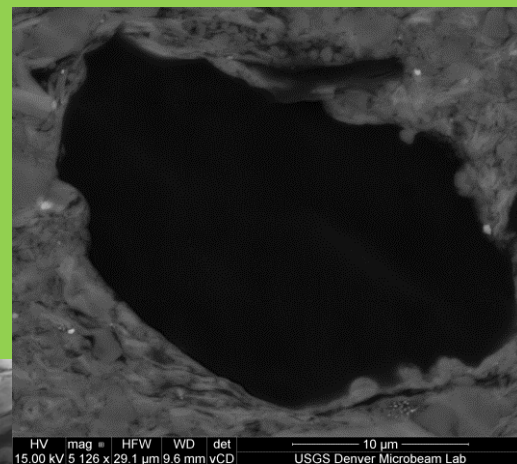


Bituminous
mineral
groundmass_{low}

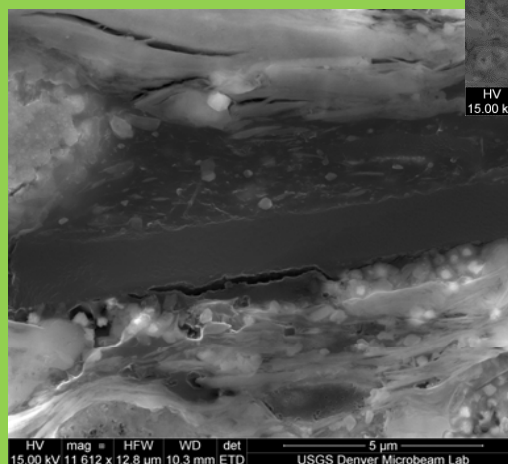


High maturity well

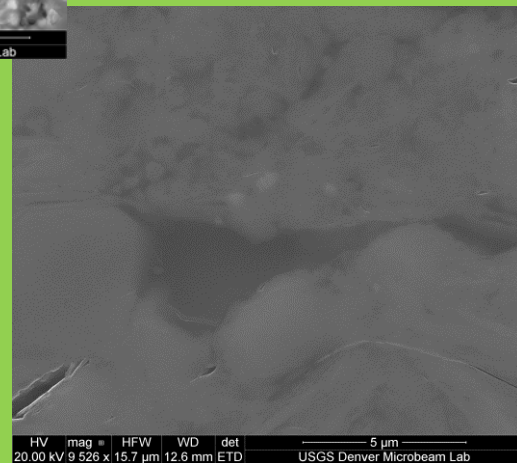
Terrestrial_{high}



Lamellar
alginite_{high}



Bituminous
mineral
groundmass_{high}



Maceral porosity

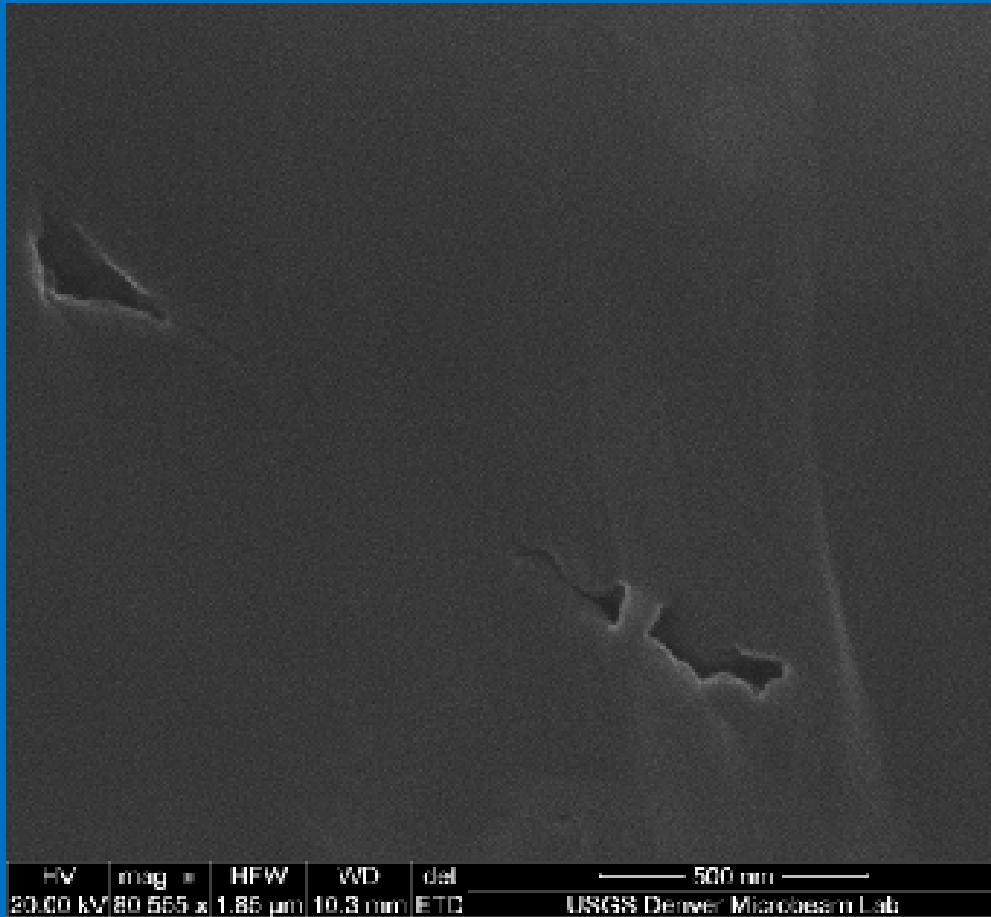
Similar macerals in KCF across
study area (not same amnts)

Nature of porosity—function
of maceral type

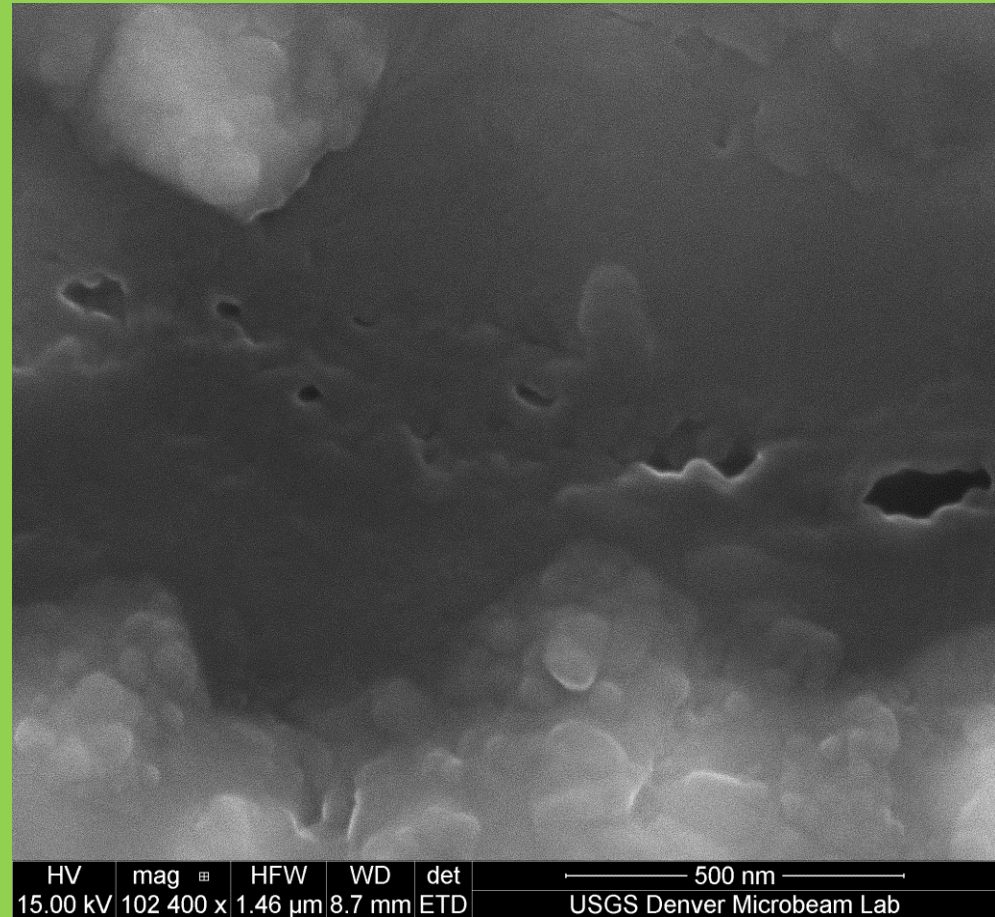
Nature of porosity—function
of maturity

Pores—bituminous mineral groundmass

Low maturity well



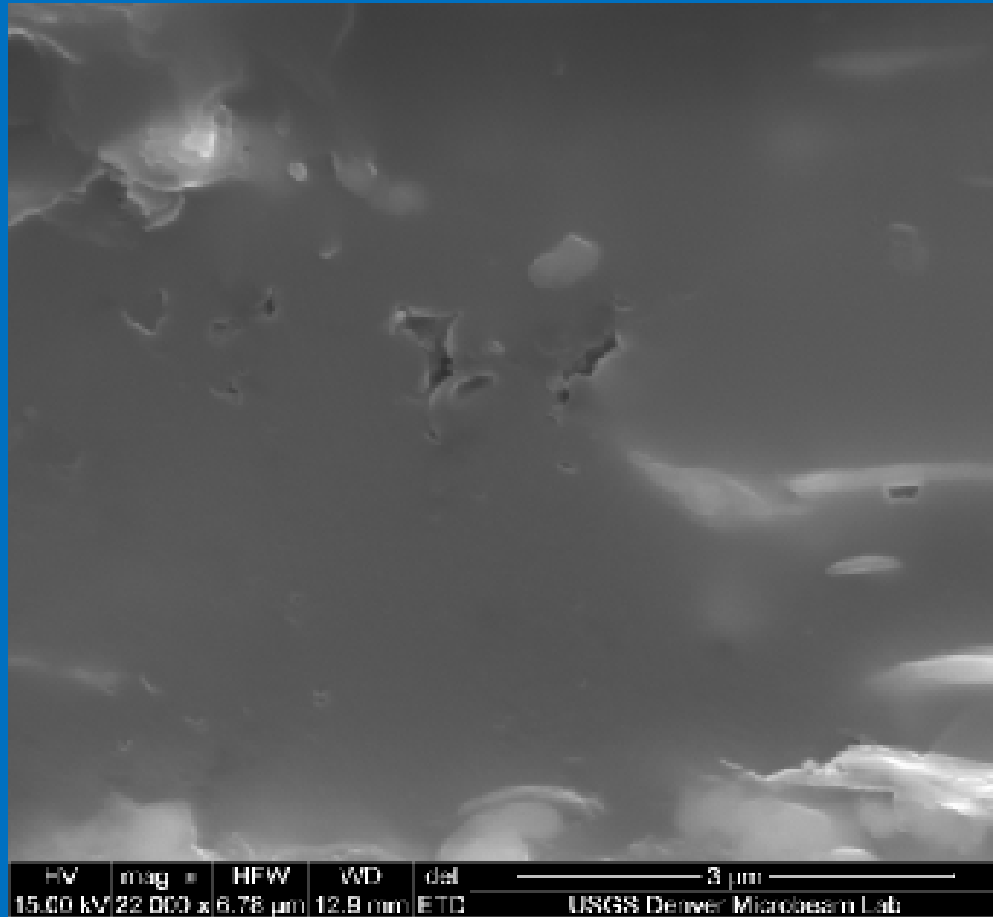
High maturity well



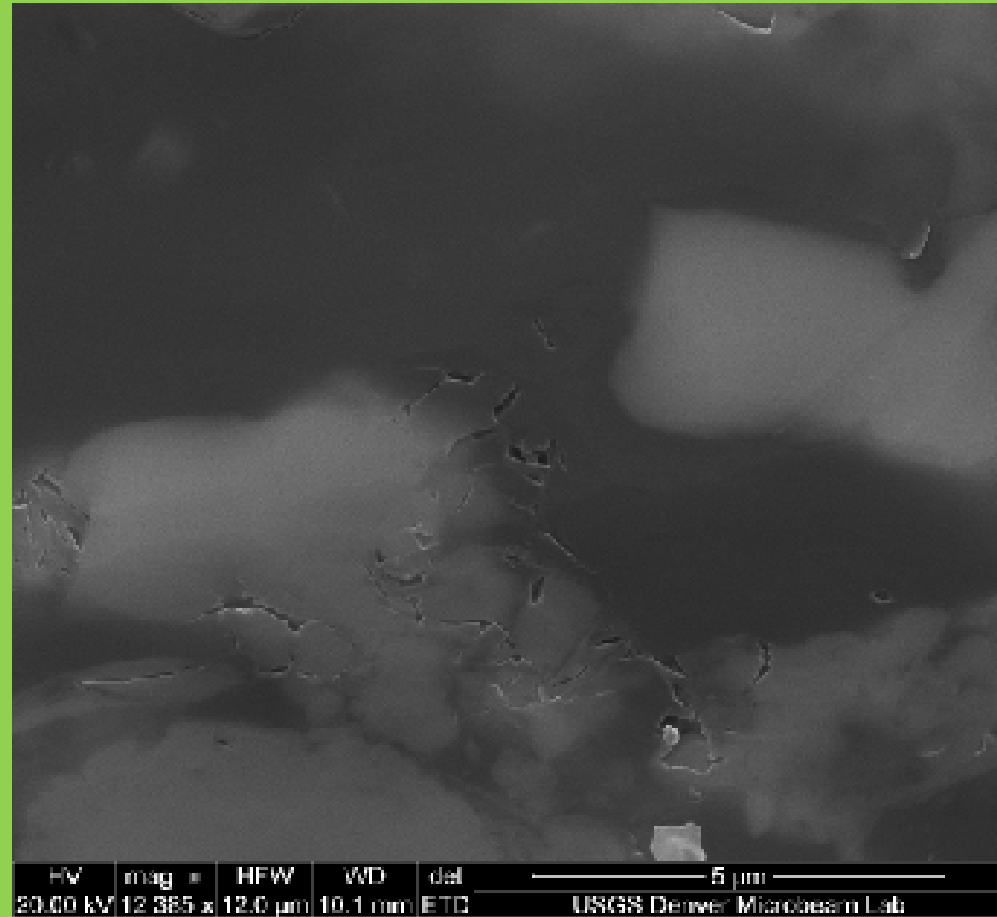
BMG, somewhat similar micro/nanopore shape & size, but pores not abundant in either low or high maturity well

Pores in lamellar alginite

Low maturity well



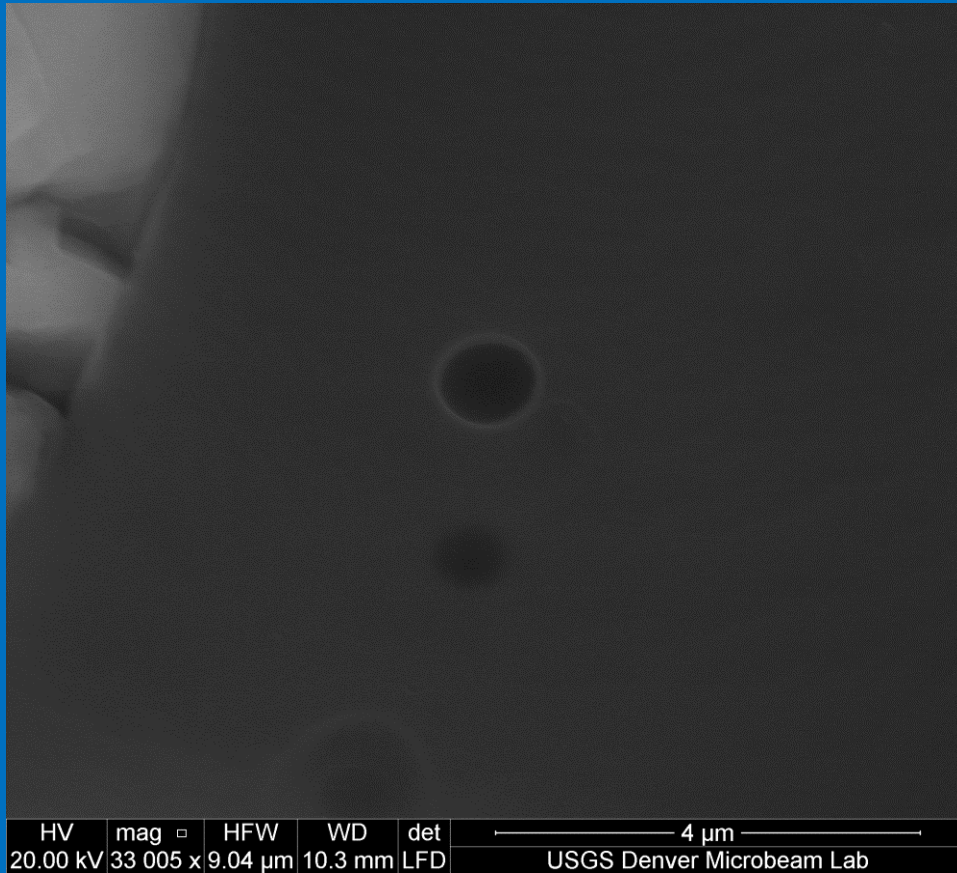
High maturity well



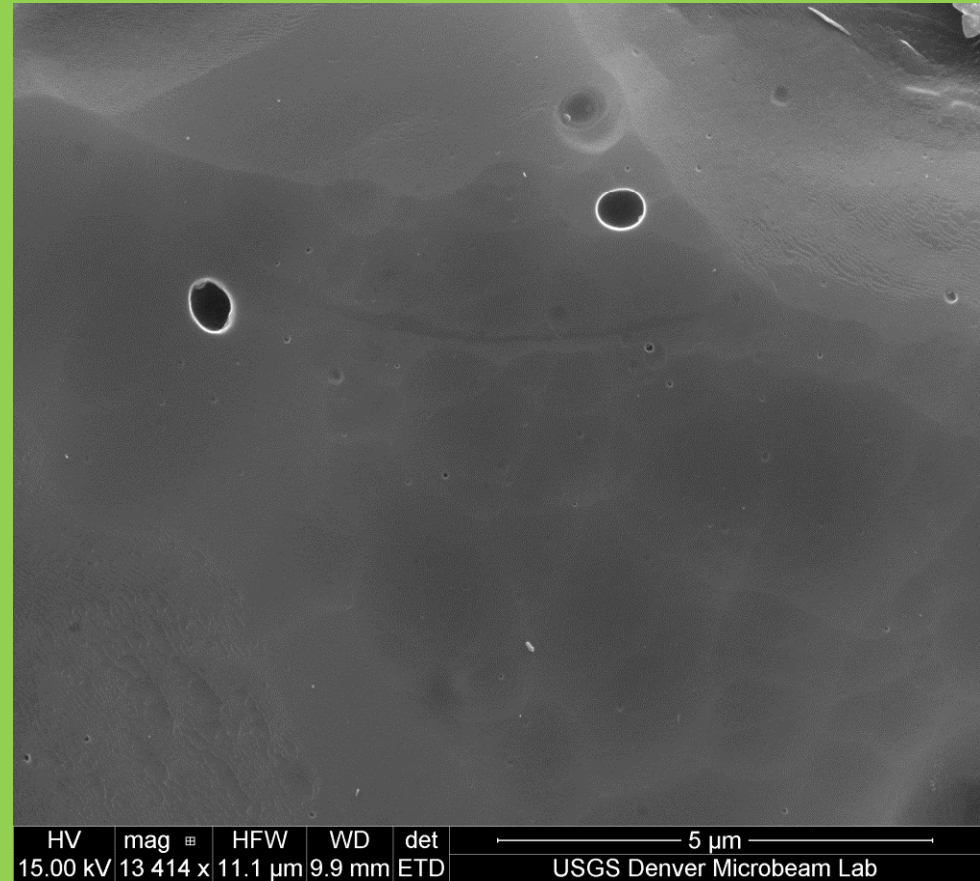
Micro/nanopores at low and high maturity, no apparent difference in size or shape

Pores in Type III macerals

Low maturity well



High maturity well

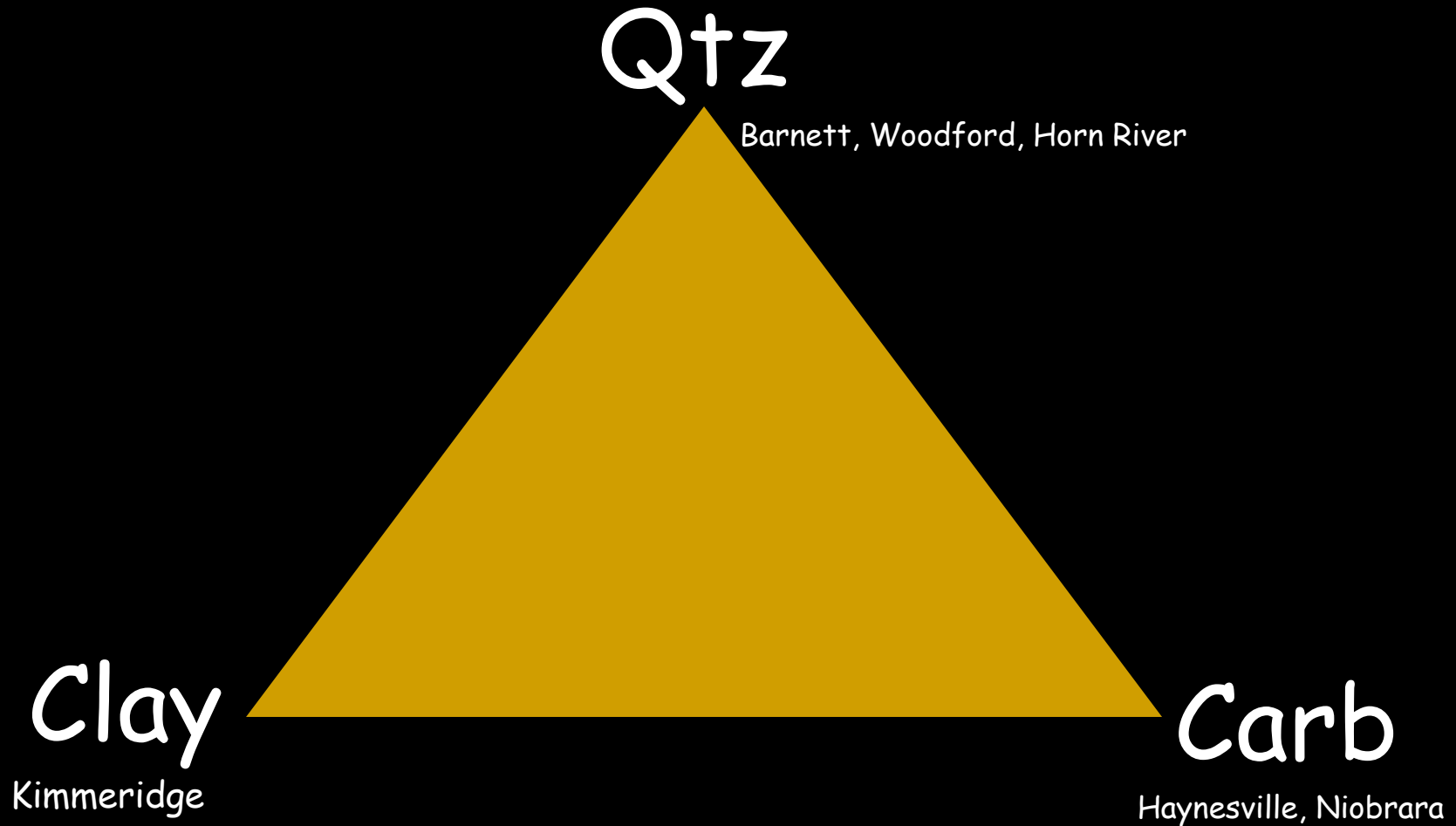


Similar micropore shape & size, regardless of maturity

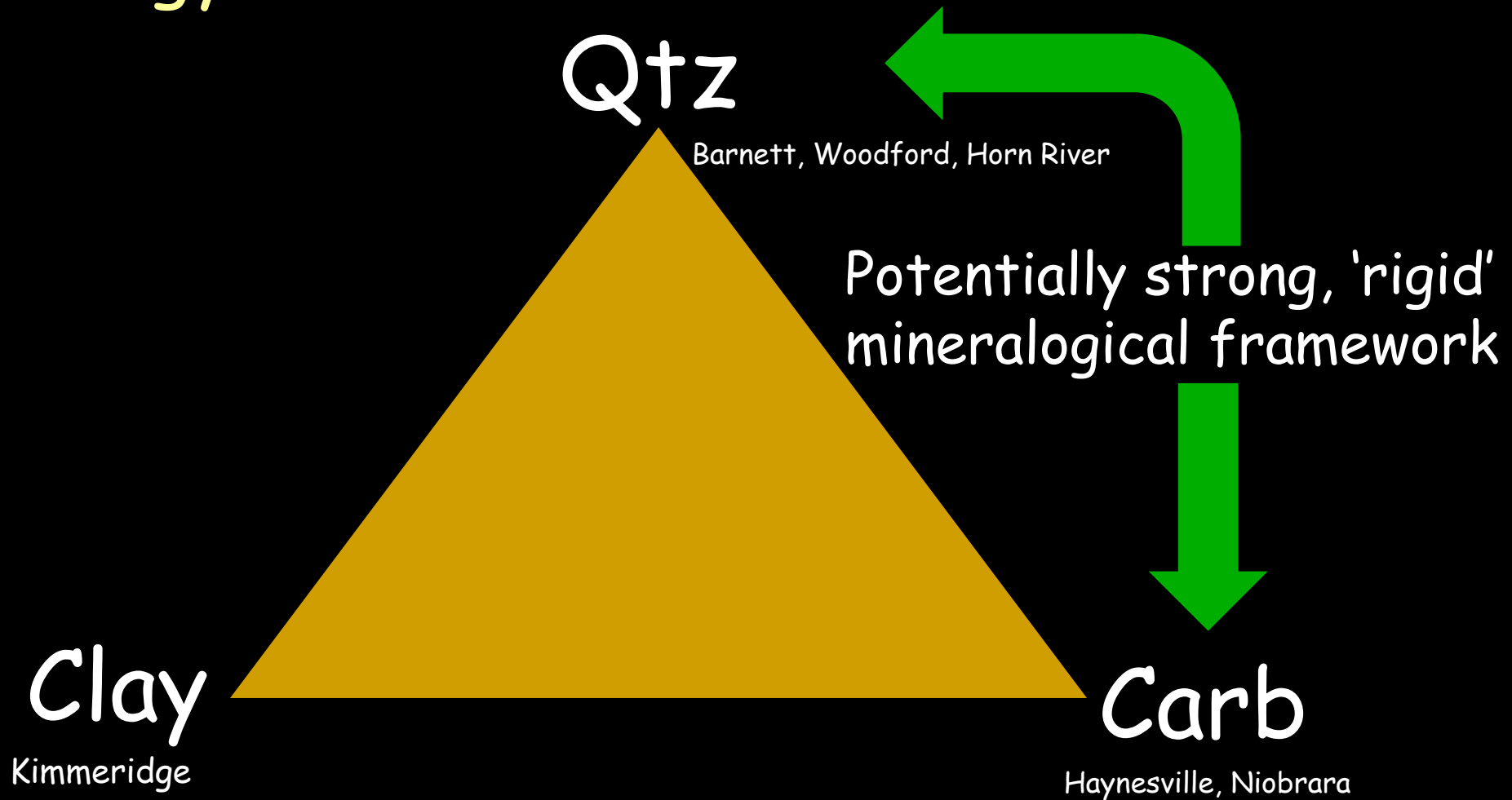
Evidence lacking systematic maturity-induced development Corg porosity



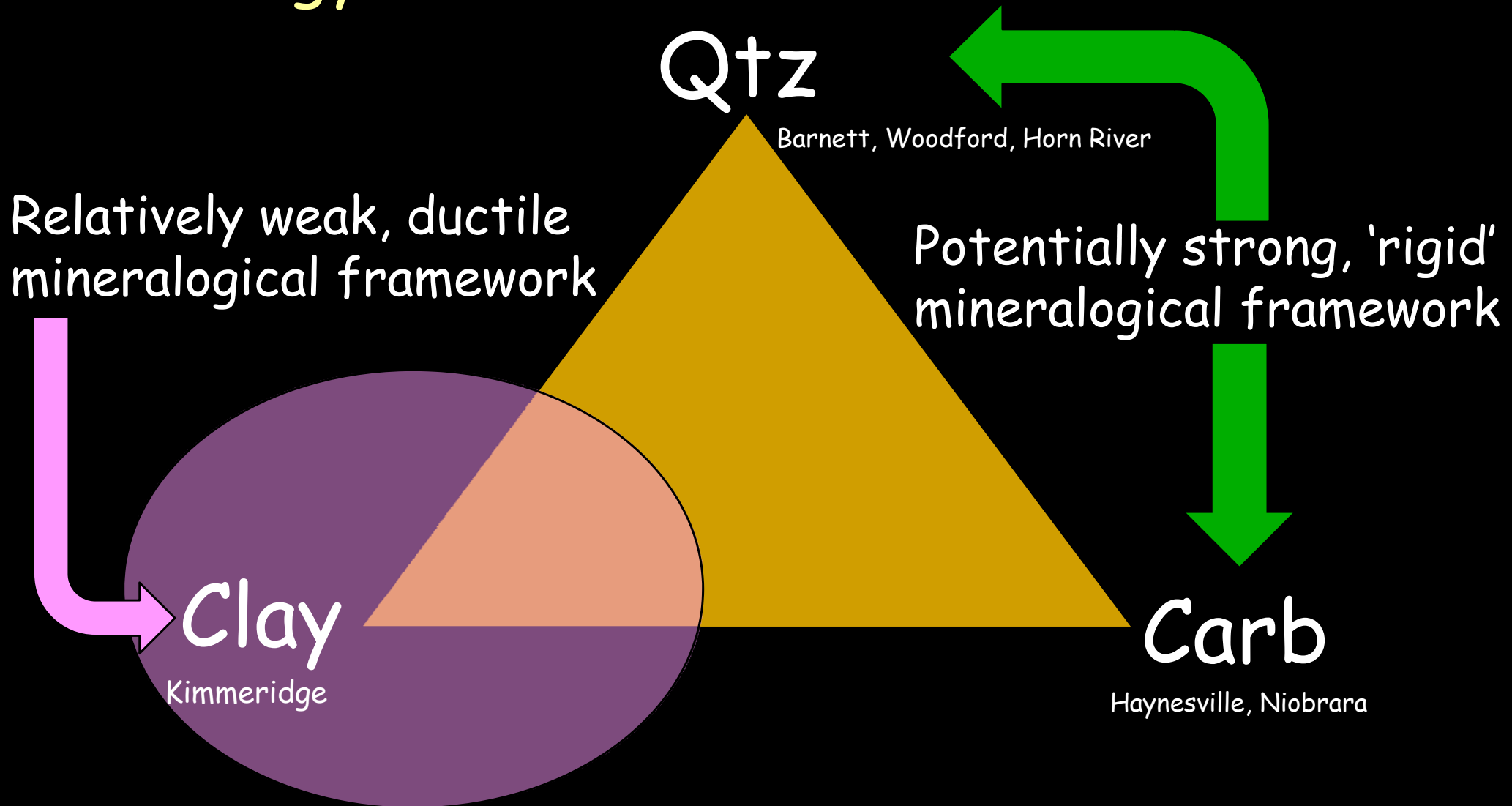
Organic porosity preservation related to mineralogy?



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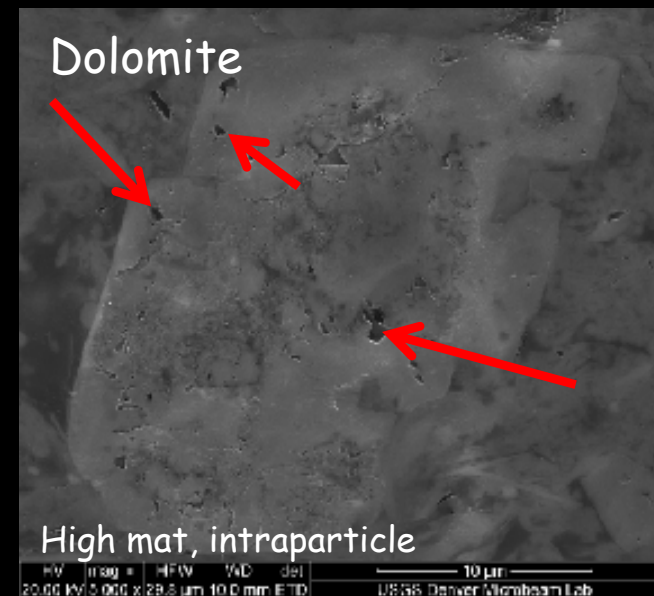
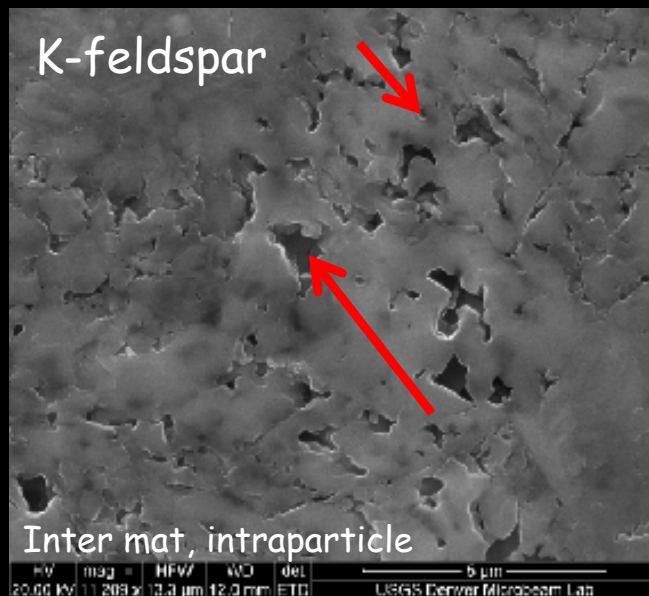
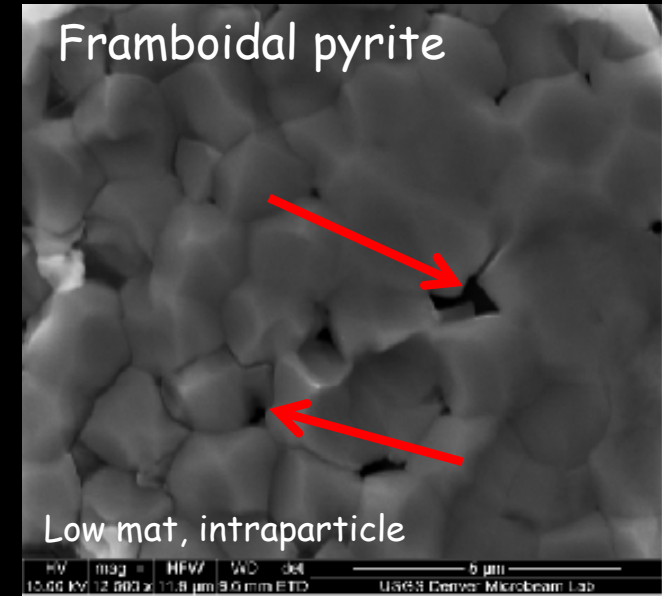
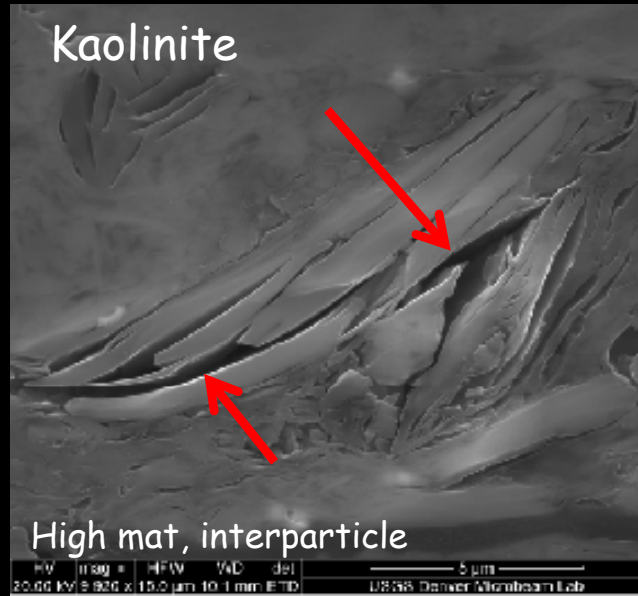
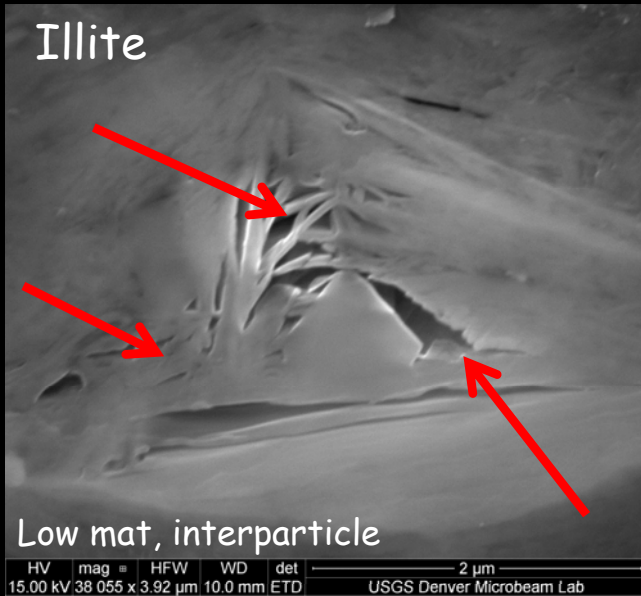
Organic porosity preservation related to mineralogy?



What other role might mineralogy play?



Inorganic porosity



Inorganic porosity

- Pores (intra-interparticle), function of grain types (clays, K-spar, etc.)
- Inorganic porosity significance (2nd)
- Porosity potentially significant, function of bulk mineralogy

Conclusions, Kimmeridge Clay Fm., UK

- At least 3 types of organic macerals in KCF
 - a) Bituminous mineral groundmass (Type II)
 - b) Microbial mats—lam. al. & bit. (Type II)
 - c) Terrestrial (Type III)
- Micro- & nanopores exist in all maceral types
- No clearly systematic increase in micro- or nanoporosity w/increasing maturity
- Inorganic porosity exists at all maturities & variability (mineralogy) is possible
- Inorganic porosity variability has potential for mineralogical control on porosity
- Lack of 'rigid' mineralogical fabric_{KCF} resulted in minimal organic porosity preservation

Acknowledgments

- USGS, Energy Resources Program (funding, permission)
- Shell (access to materials)
- Hess (permission to present)

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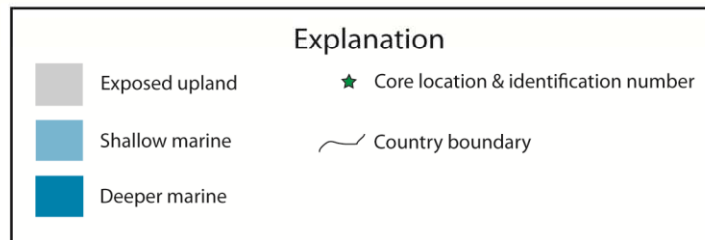
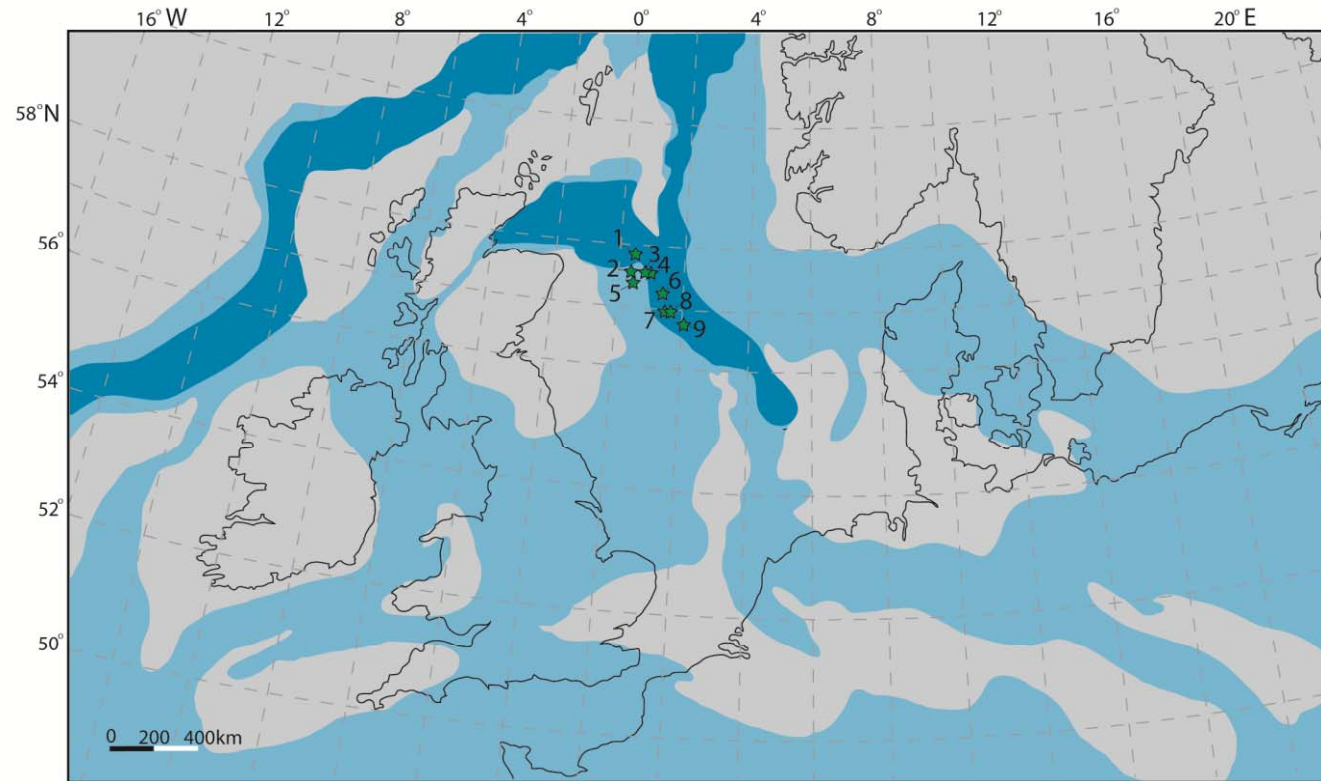


Observe organic pores (maceral type & maturity)



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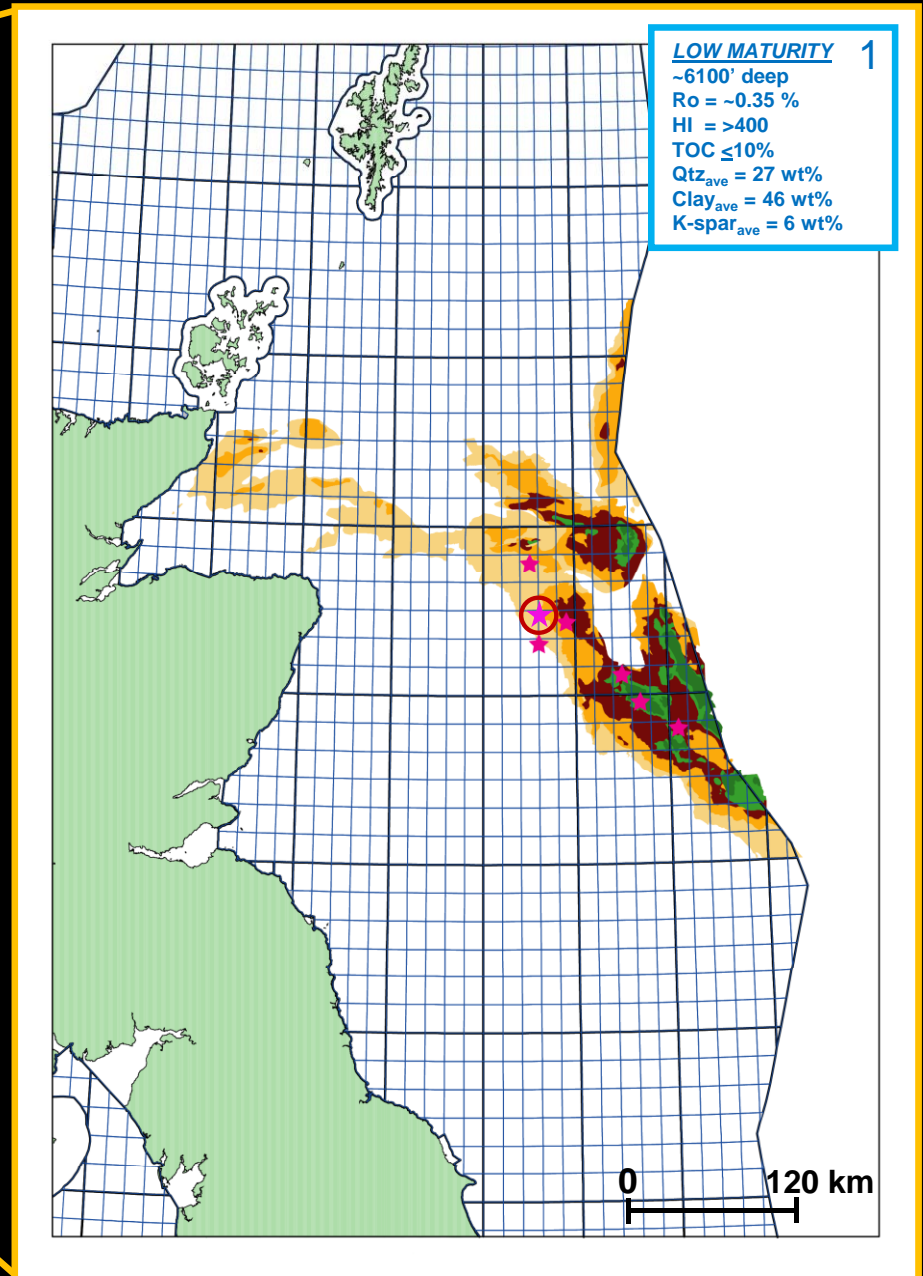
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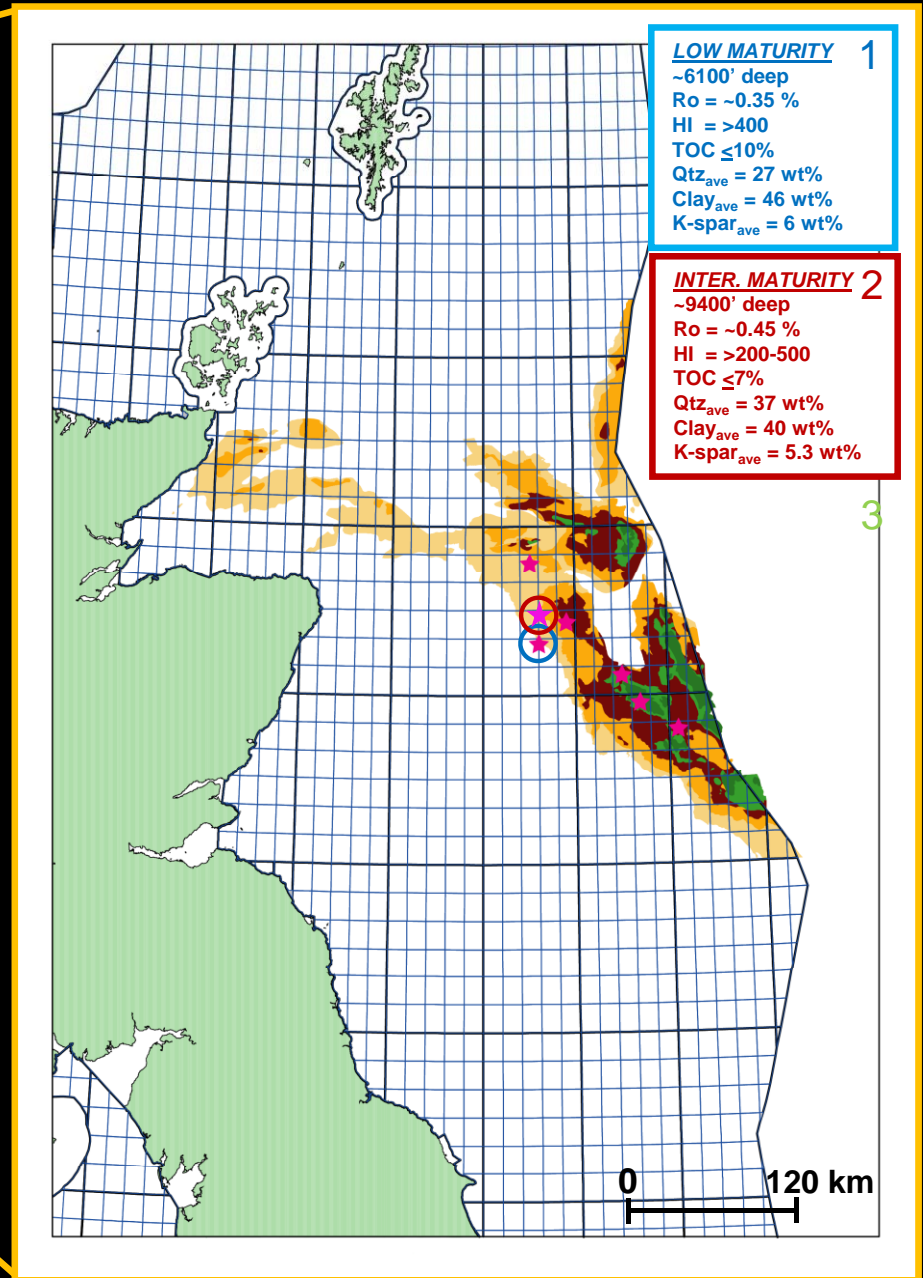
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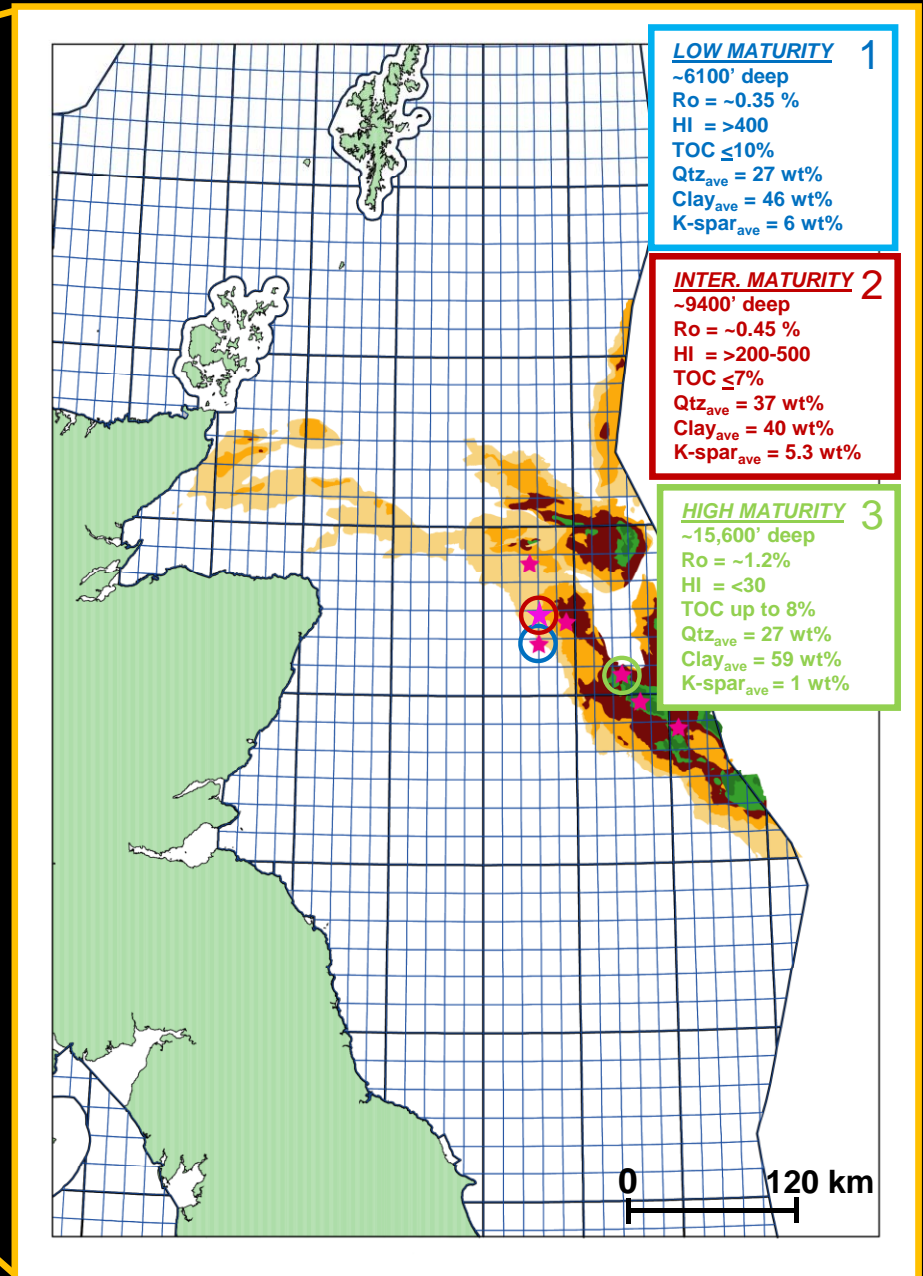
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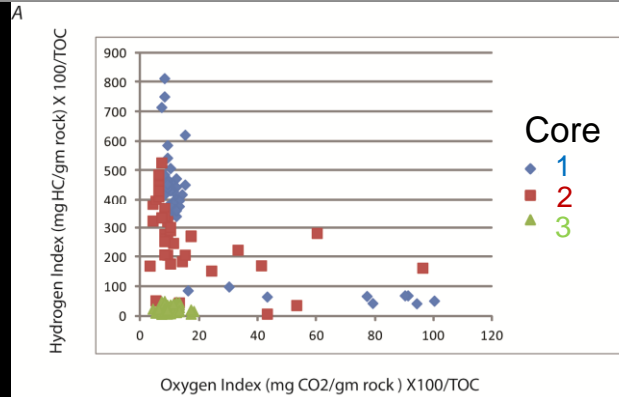


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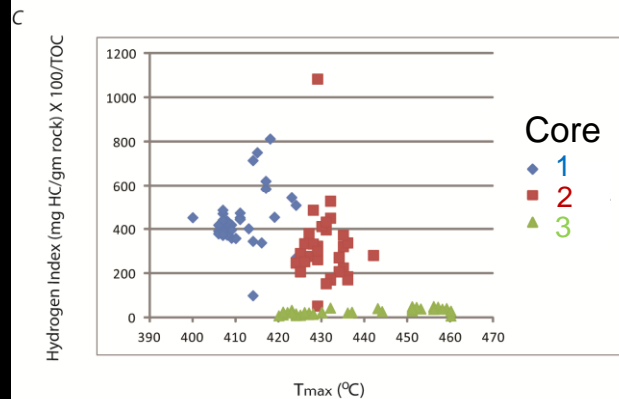
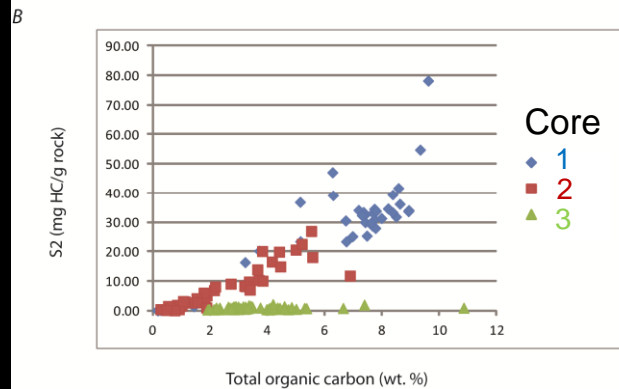
Petrography—"fine" evaluation

RockEval data

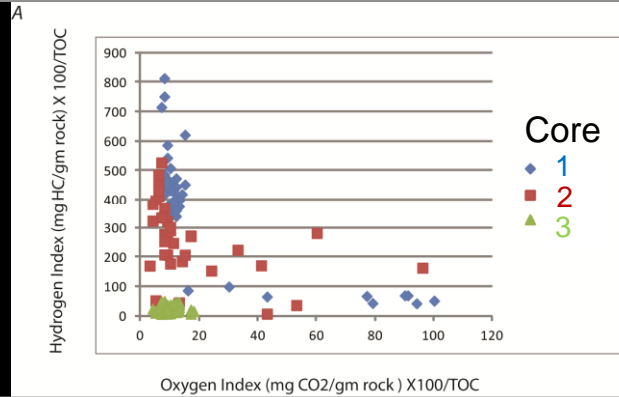


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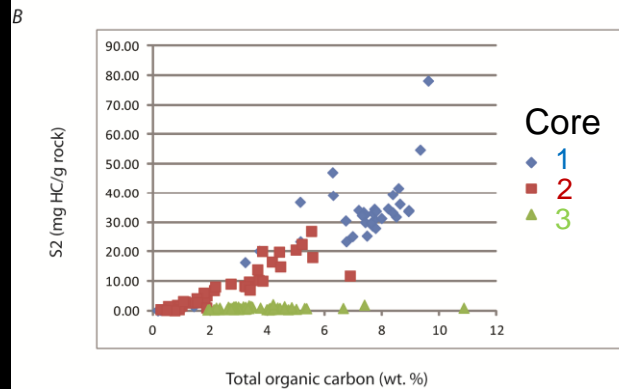


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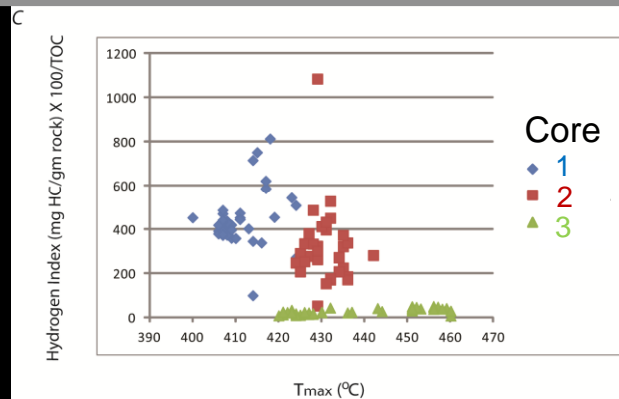
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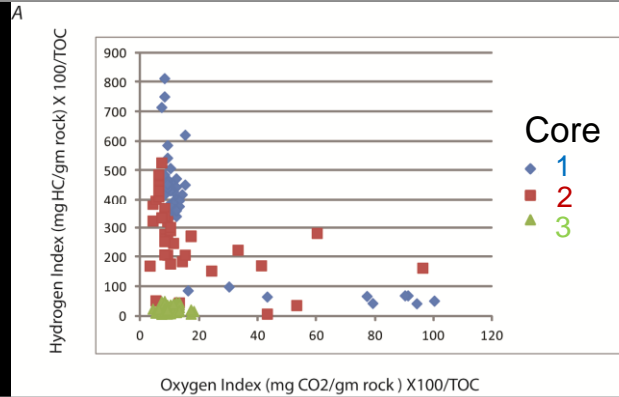


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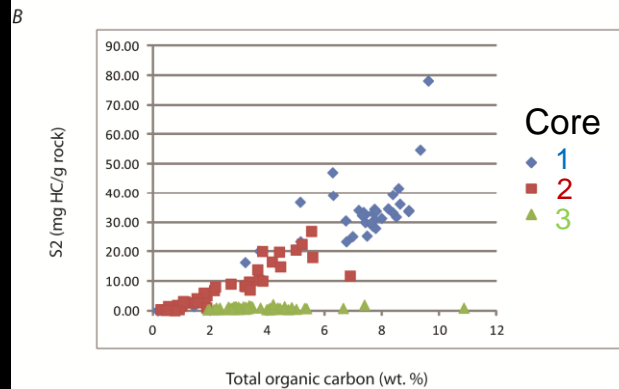


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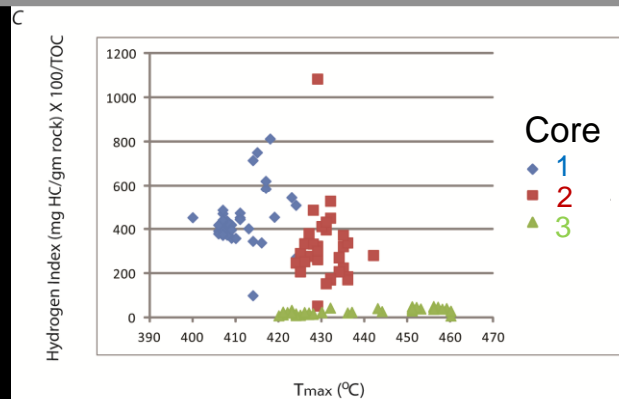
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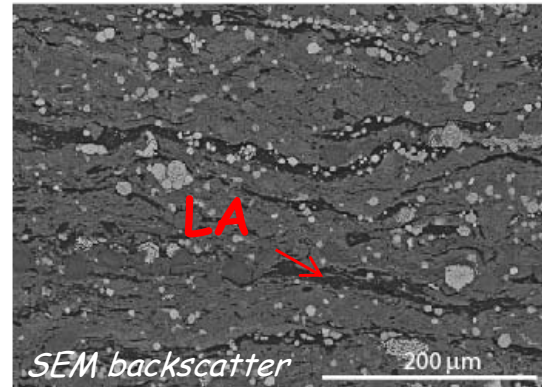
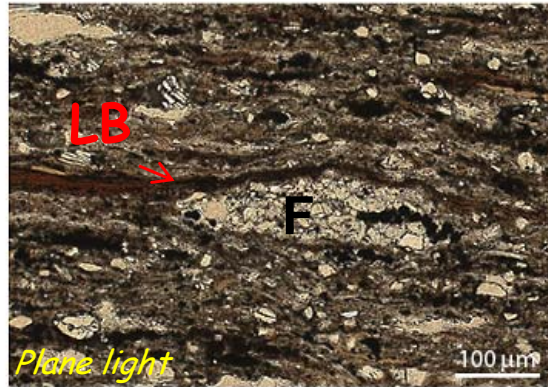
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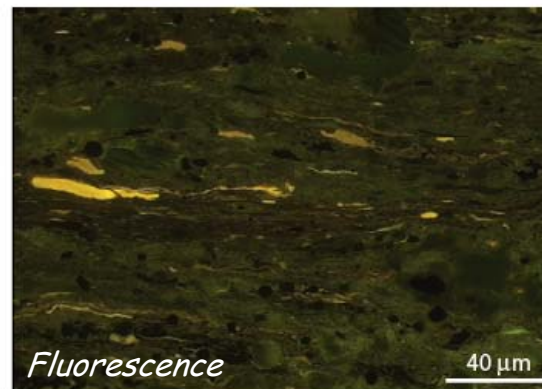
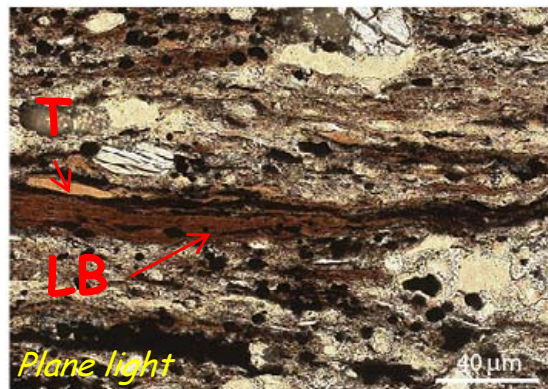
HI vs T_{max}

Increasing maturity from
Core 1 to Core 3

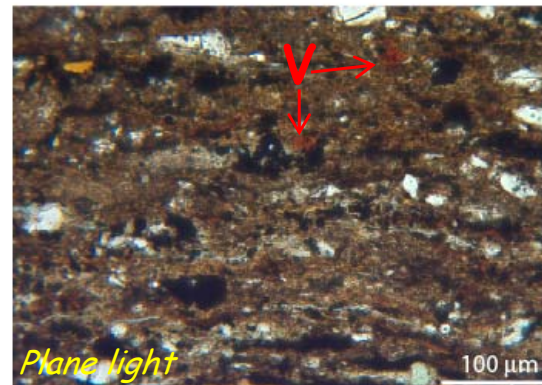
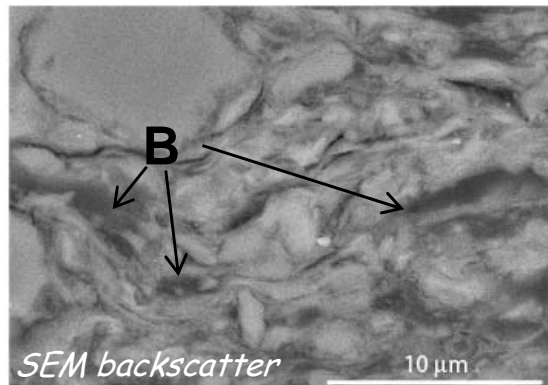
Macerals (Type II & III)



Lamellar
bituminite
& alginite



Lamellar
alginite &
bituminite,
Telalginite
(*Tasmanites*)



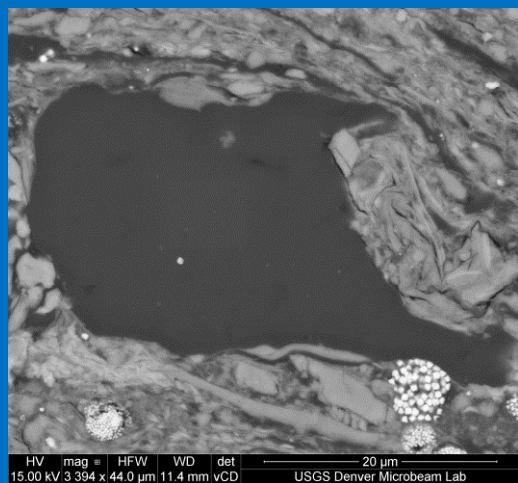
Vitrinite,
Bituminite
(Bituminous
mineral
groundmass)

Distribution of macerals

Where are macerals as a function of core location/
depositional system?

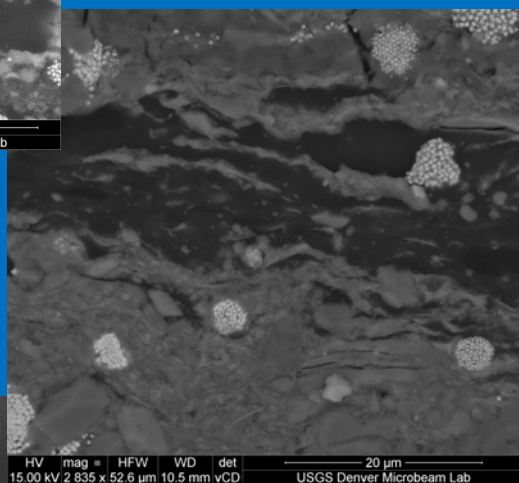
Organic macerals, low & high mat. wells

Low maturity well

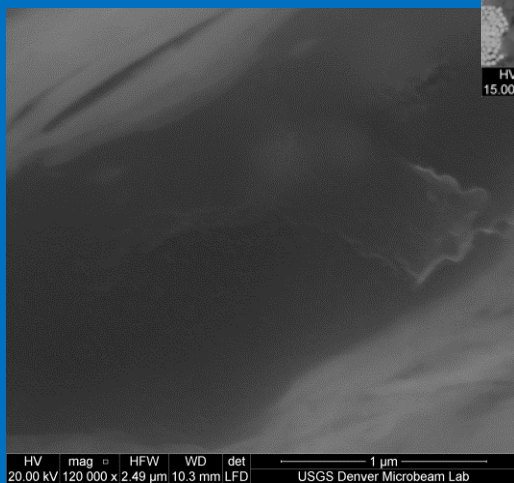


Terrestrial_{low}

Lamellar
alginite_{low}

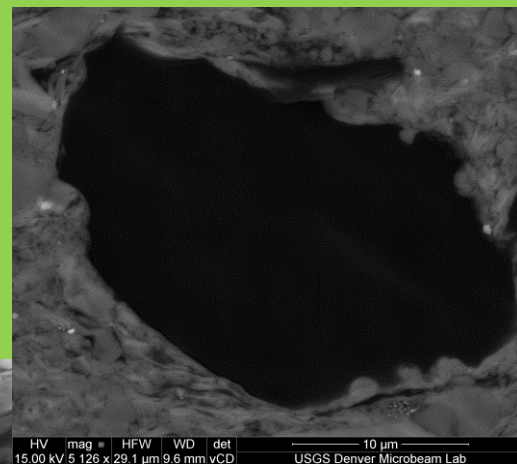


Bituminous
mineral
groundmass_{low}

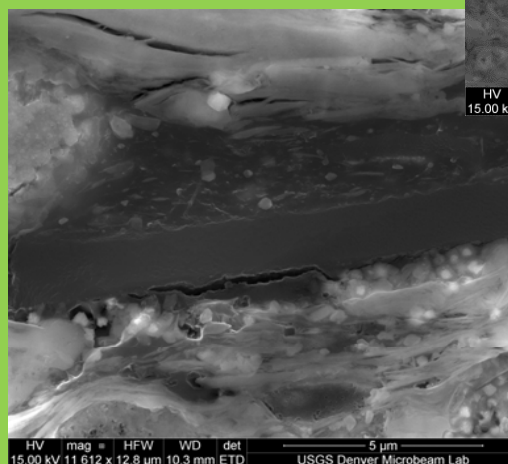


High maturity well

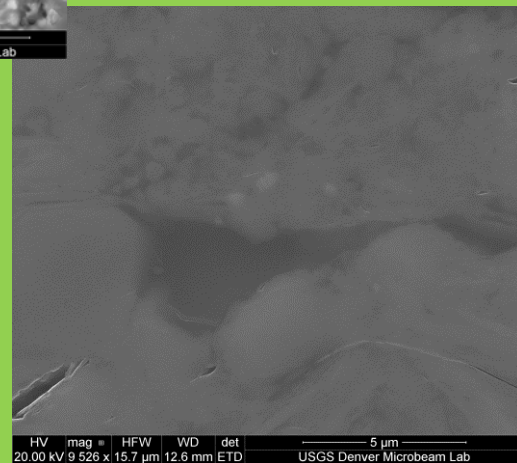
Terrestrial_{high}



Lamellar
alginite_{high}



Bituminous
mineral
groundmass_{high}



Maceral porosity

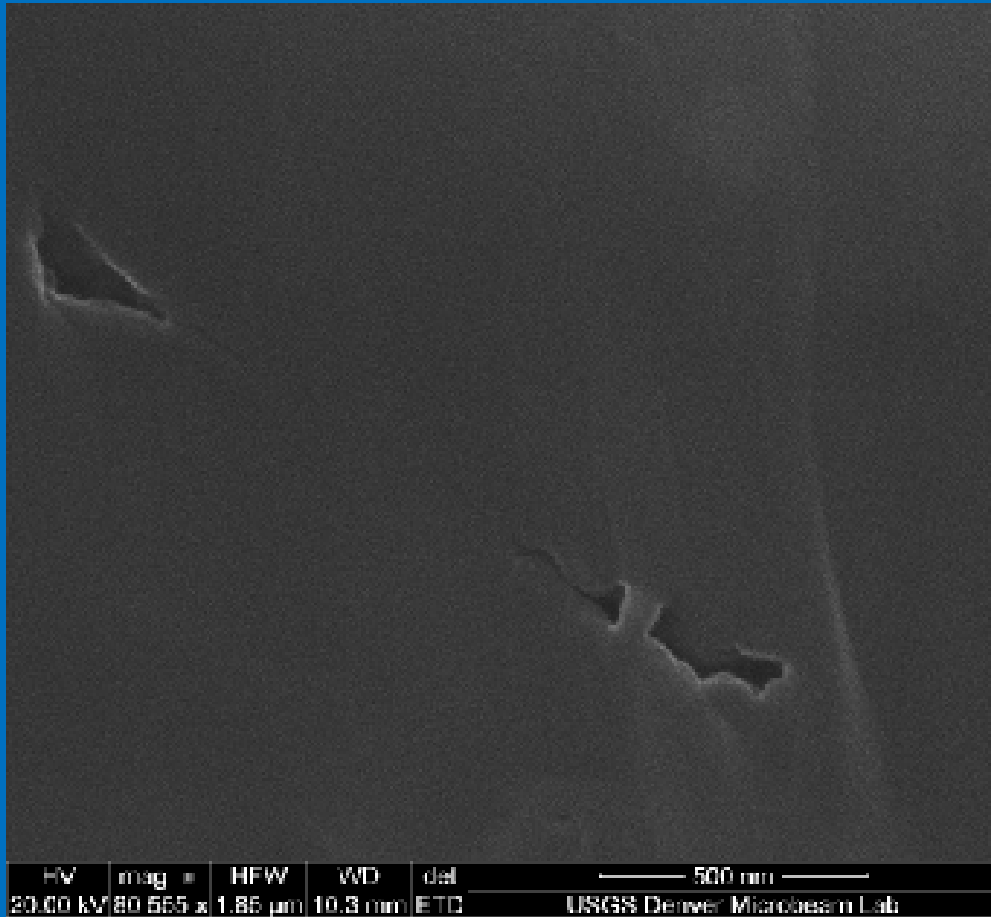
Similar macerals in KCF across
study area (not same amnts)

Nature of porosity—function
of maceral type

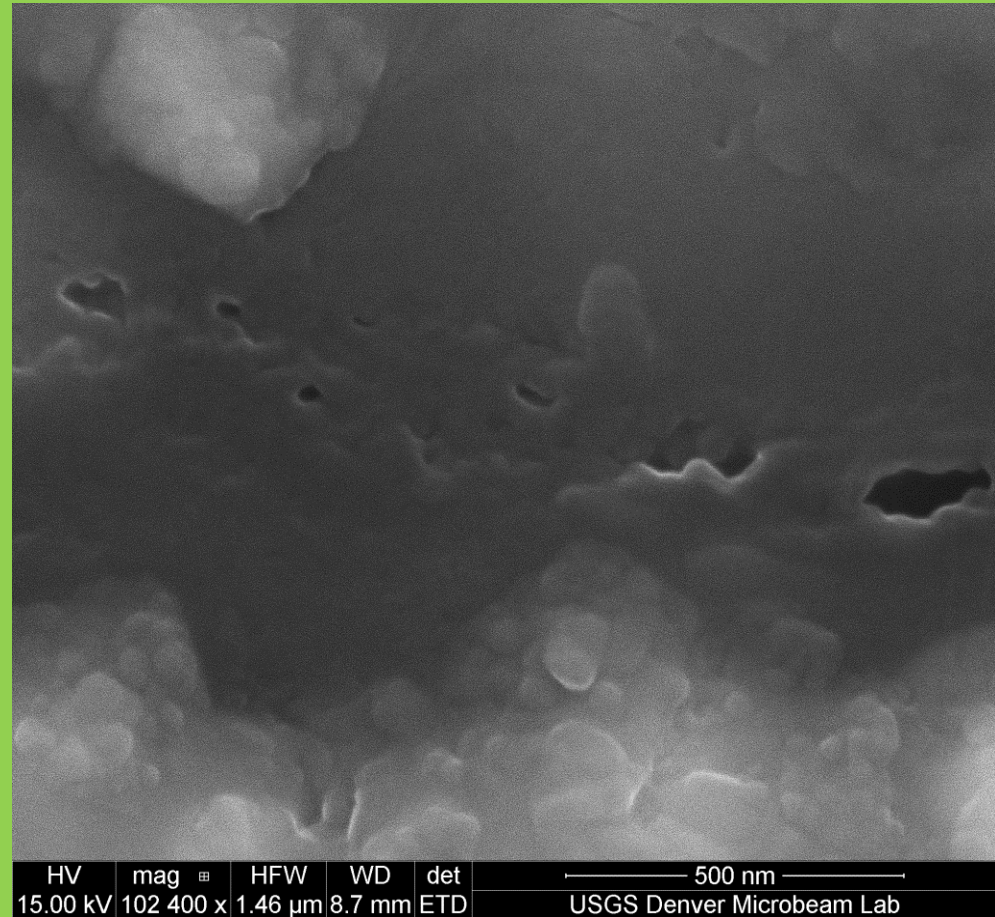
Nature of porosity—function
of maturity

Pores—bituminous mineral groundmass

Low maturity well



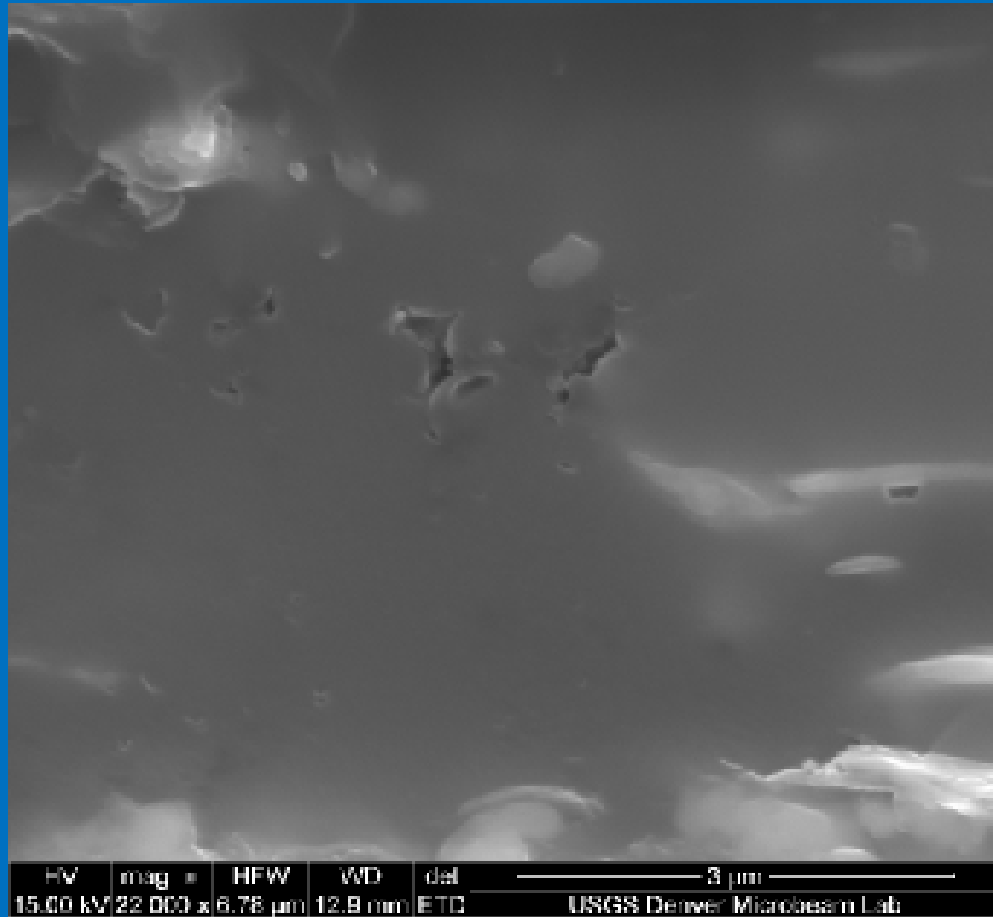
High maturity well



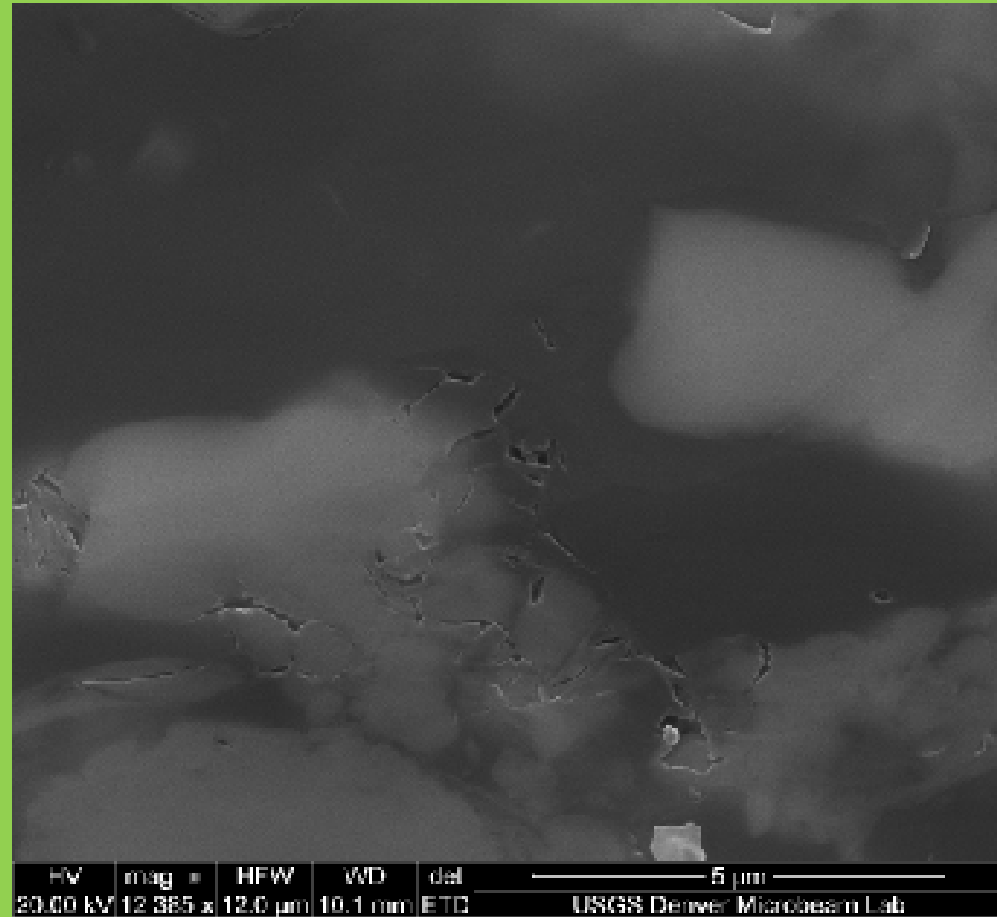
BMG, somewhat similar micro/nanopore shape & size, but pores not abundant in either low or high maturity well

Pores in lamellar alginite

Low maturity well



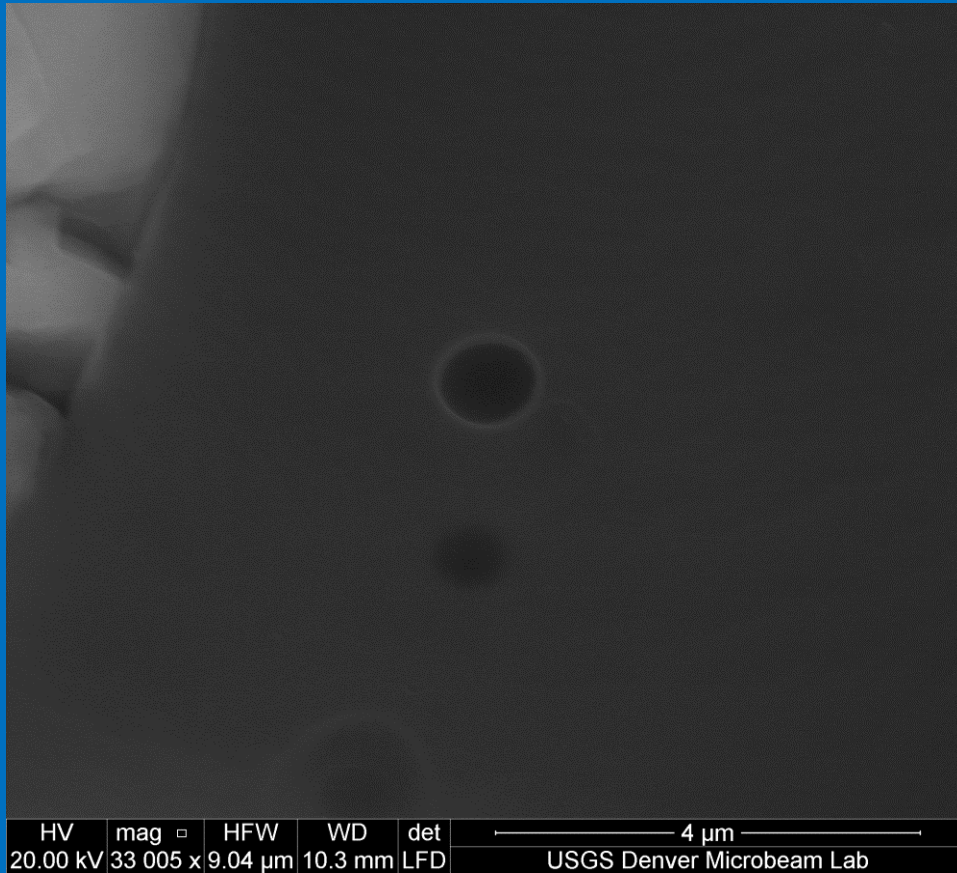
High maturity well



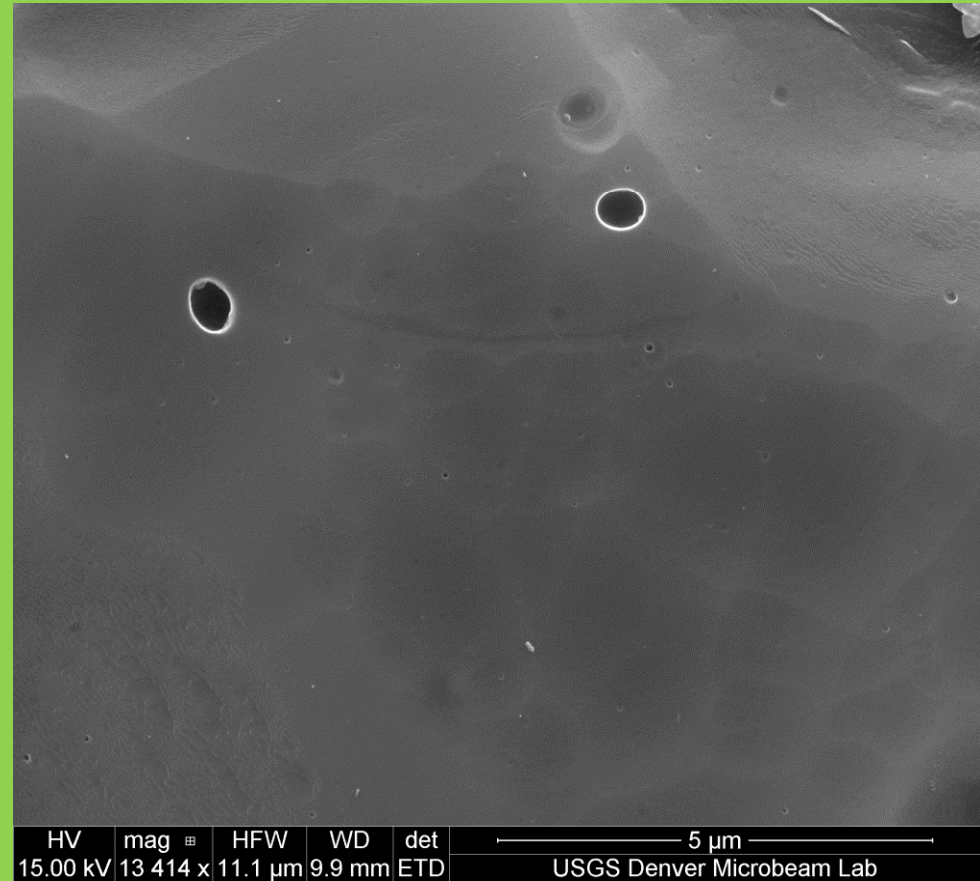
Micro/nanopores at low and high maturity, no apparent difference in size or shape

Pores in Type III macerals

Low maturity well



High maturity well

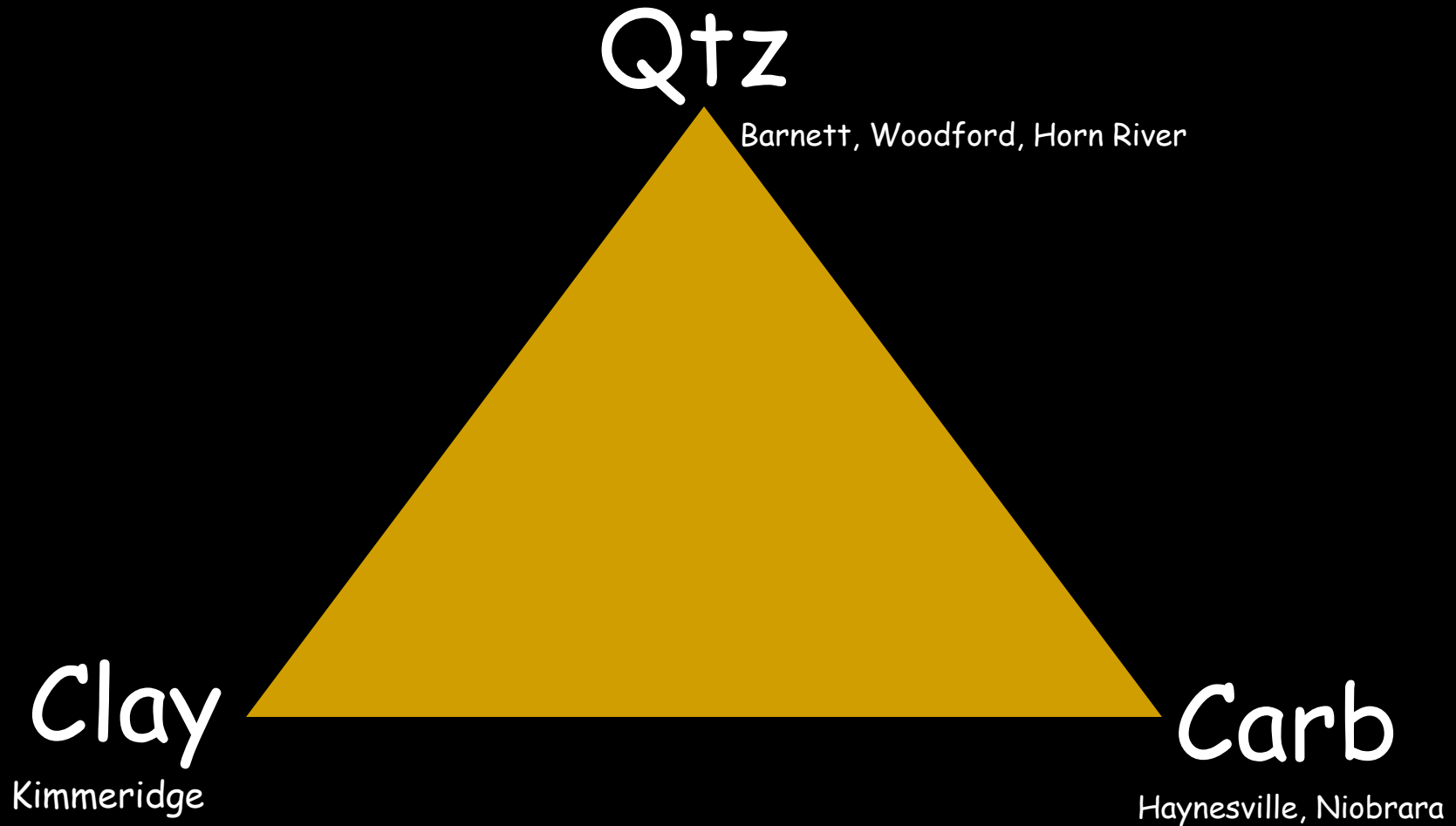


Similar micropore shape & size, regardless of maturity

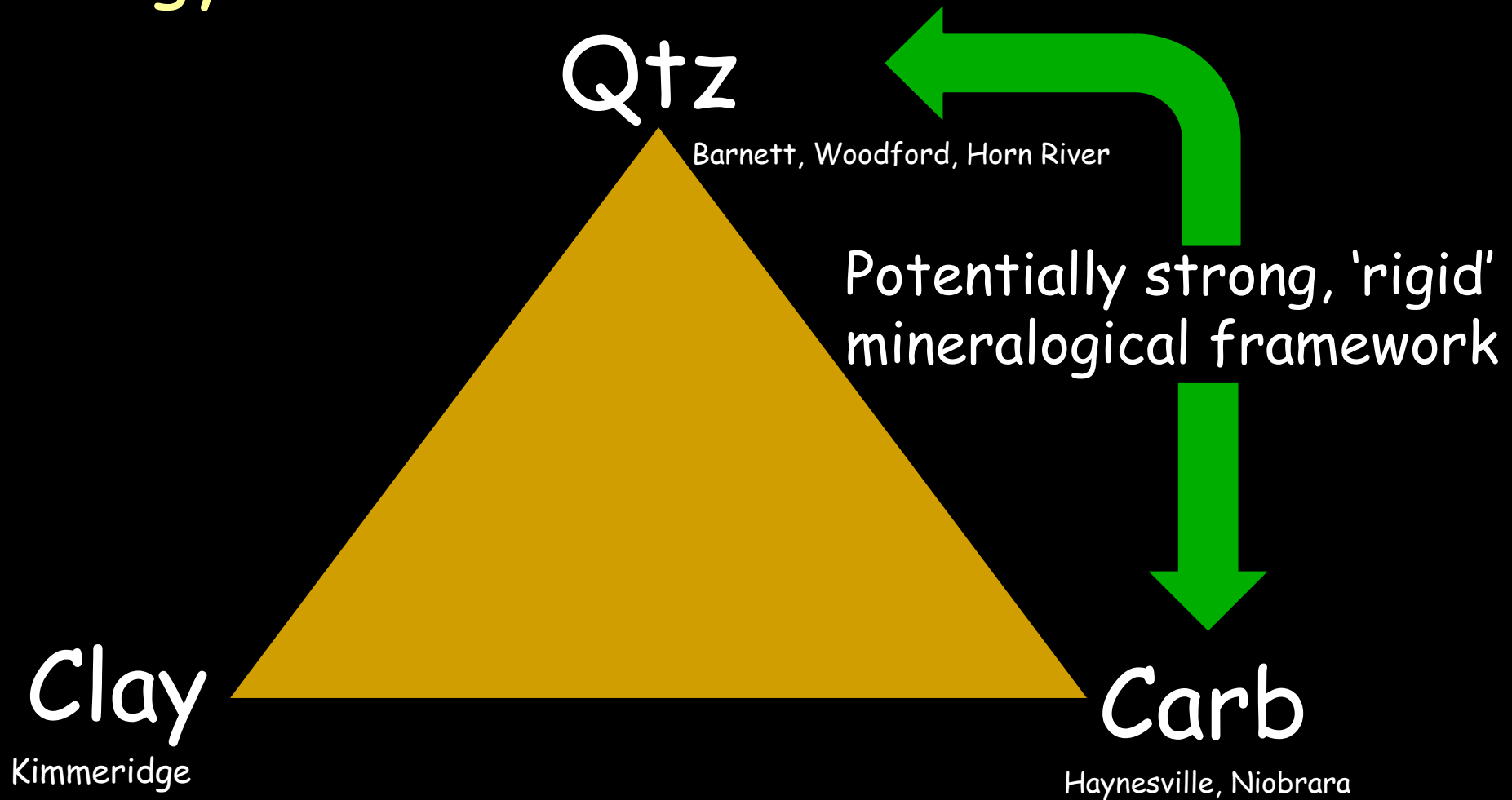
Evidence lacking systematic maturity-induced development Corg porosity



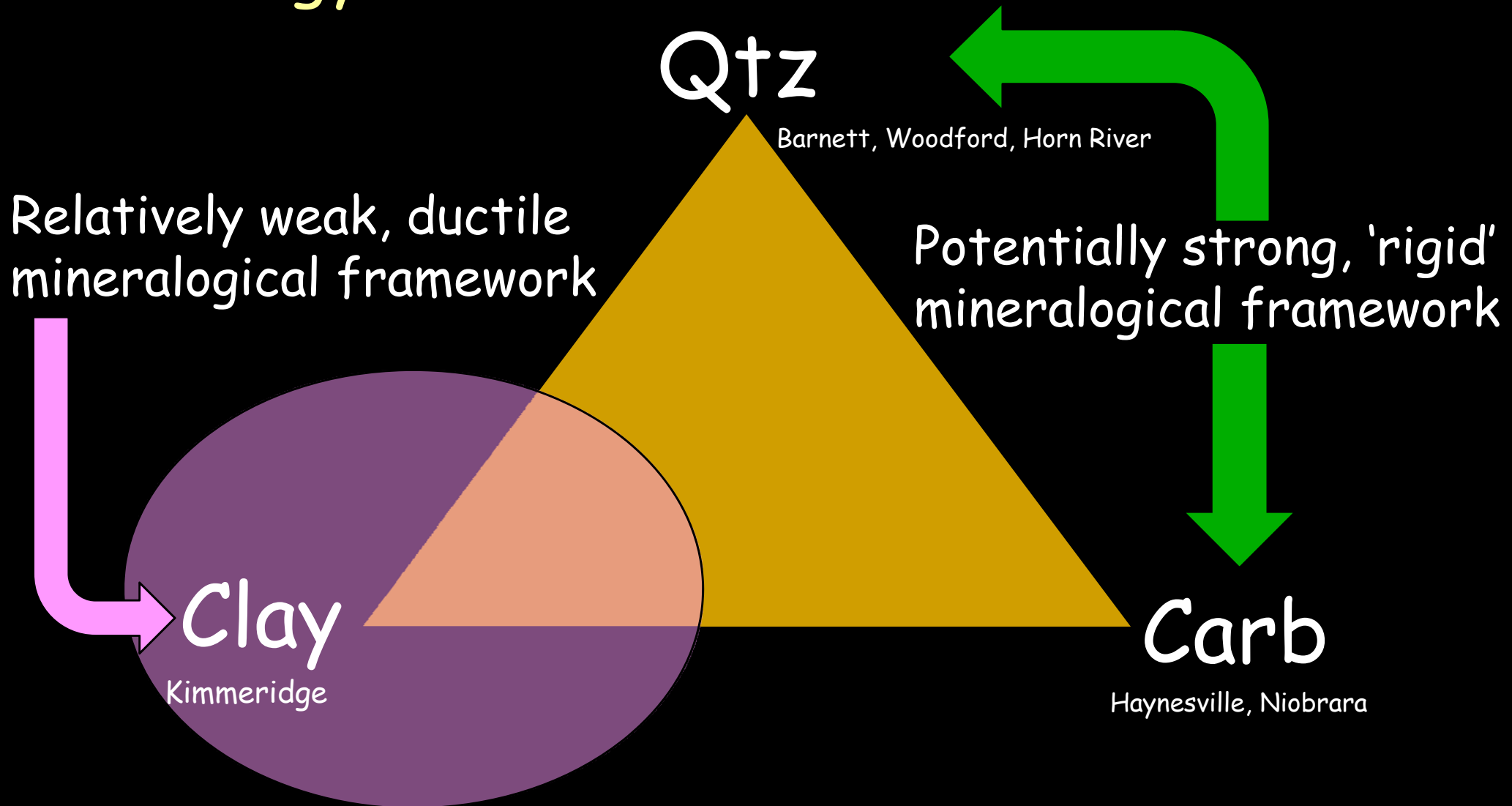
Organic porosity preservation related to mineralogy?



Organic porosity preservation related to mineralogy?



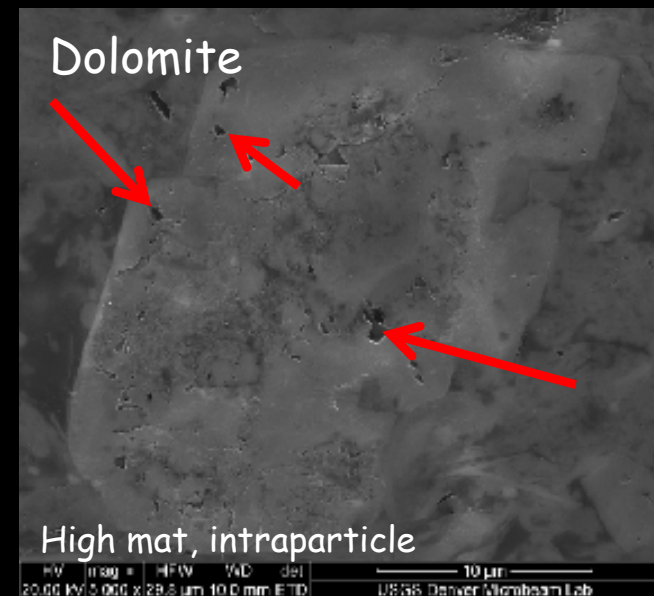
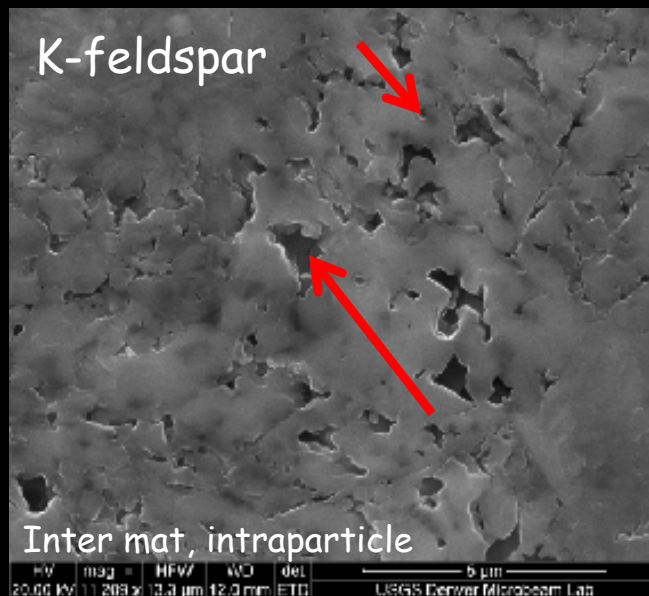
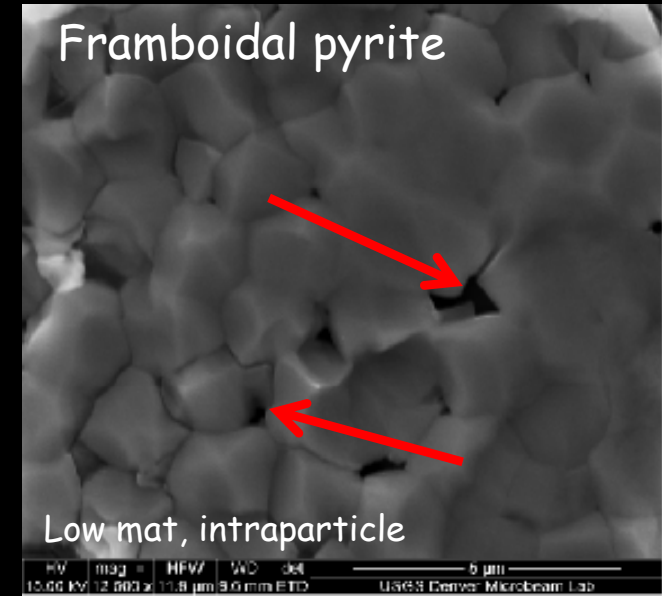
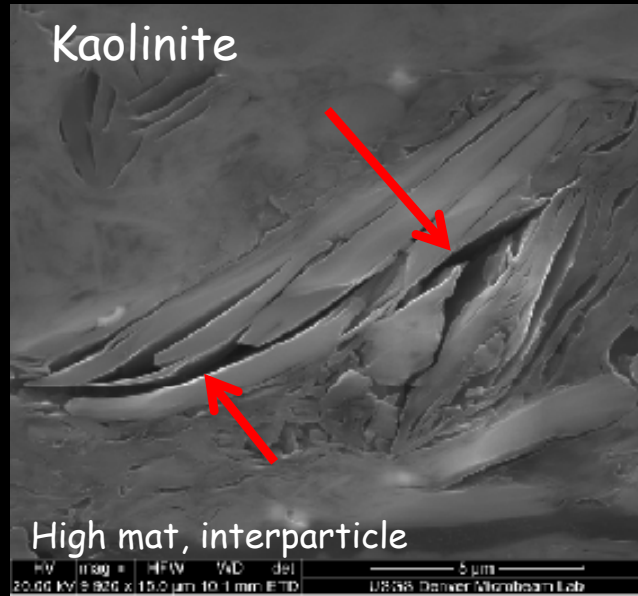
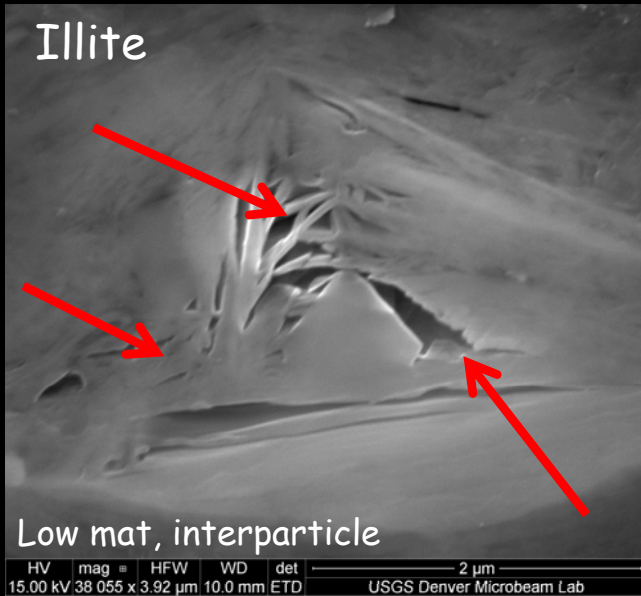
Organic porosity preservation related to mineralogy?



What other role might mineralogy play?



Inorganic porosity



Inorganic porosity

- Pores (intra-interparticle), function of grain types (clays, K-spar, etc.)
- Inorganic porosity significance (2nd)
- Porosity potentially significant, function of bulk mineralogy

Conclusions, Kimmeridge Clay Fm., UK

- At least 3 types of organic macerals in KCF
 - a) Bituminous mineral groundmass (Type II)
 - b) Microbial mats—lam. al. & bit. (Type II)
 - c) Terrestrial (Type III)
- Micro- & nanopores exist in all maceral types
- No clearly systematic increase in micro- or nanoporosity w/increasing maturity
- Inorganic porosity exists at all maturities & variability (mineralogy) is possible
- Inorganic porosity variability has potential for mineralogical control on porosity
- Lack of 'rigid' mineralogical fabric_{KCF} resulted in minimal organic porosity preservation

Acknowledgments

- USGS, Energy Resources Program (funding, permission)
- Shell (access to materials)
- Hess (permission to present)