Development of Organic and Inorganic Porosity in the Cretaceous Eagle Ford Formation, South Texas*

Neil Fishman[1], John M. Guthrie[2], and Matt Honarpour[2]

Search and Discovery Article #50928 (2014)**
Posted February 11, 2014

*Adapted from oral presentation presented at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013

1Hess Corp., Houston TX (nfishman@hess.com)
[2]Hess Corp., Houston TX

Abstract

Petrographic and SEM, along with RockEval pyrolysis analyses were used to constrain the nature of organic material (OM) that contains porosity in the Cenomanian-Turonian Eagle Ford Formation, South Texas, where the formation is in the oil/condensate window (Ro ~1.2%). Samples used were from a well that contained intervals of both 1) foraminiferal mudstones with high (up to 8 wt%) total organic carbon (TOC) contents, deposited within the trangressive system tract (TST) or near maximum flooding surface (MFS) intervals, and 2) limestones with relatively lower TOC (<1 up to 6 wt%) contents, deposited largely in the overlying high stand systems (HST) track interval.

In mudstones, early diagenetic processes resulted in precipitation of euhedral-subhedral authigenic minerals (e.g., calcite, pyrite, kaolinite) that filled foraminifera and coccosphere tests (intraparticle pores) and partially filled interparticle pores between other detrital grains. In limestones, recrystallization of bioclastic material resulted in euhedral-subhedral microsparry calcite crystals between remaining interparticle pores. In both lithologies, OM coats the euhedral-subhedral minerals and locally fills intraparticle and interparticle pores, but this superposition relationship is particularly well developed in mudstones whereas OM is less common in limestones. Pores in the OM range in size from <0.1 µm to ~1 µm across, and are variably round, elliptical, or irregularly shaped. For both lithologies, OM was clearly emplaced after authigenic mineral precipitation, and porosity development subsequent to its emplacement. For TOC-rich mudstones in the TST, RockEval pyrograms generated on the same samples before and after solvent extraction indicate the presence of a relatively greater amount of extractable phase (i.e., bitumen), observed as a shoulder on the S2 peak of the pyrogram. In contrast, the TOC-lean limestones from the HST contain a relatively lower amount of the extractable phase (S2 shoulder) and a greater amount of "free" hydrocarbons measured as the S1 peak from Rock-Eval relative to the TOC-rich mudstones.

Given its inferred mobility and relative post-depositional timing of emplacement, the OM that coats authigenic minerals is presumed to be the bitumen identified from RockEval analyses. As such, organic porosity in the Eagle Ford appears to be spatially linked to the dispersal of bitumen, whereas free hydrocarbons appear to be lithologically controlled.

References Cited

Hunt, J.M., 1996, Petroleum geochemistry and geology, 2nd edition: W.H. Freeman, New York, 743 p.

Jarvie, D.M., and Tobey, M.H. 1999. TOC, Rock-Evaluation and SR Analyzer Interpretive Guidelines: Humble Instruments and Services, Inc., Geochemical Services Division, Humble, Texas., Application Note 99-4, p. 1-16.

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.

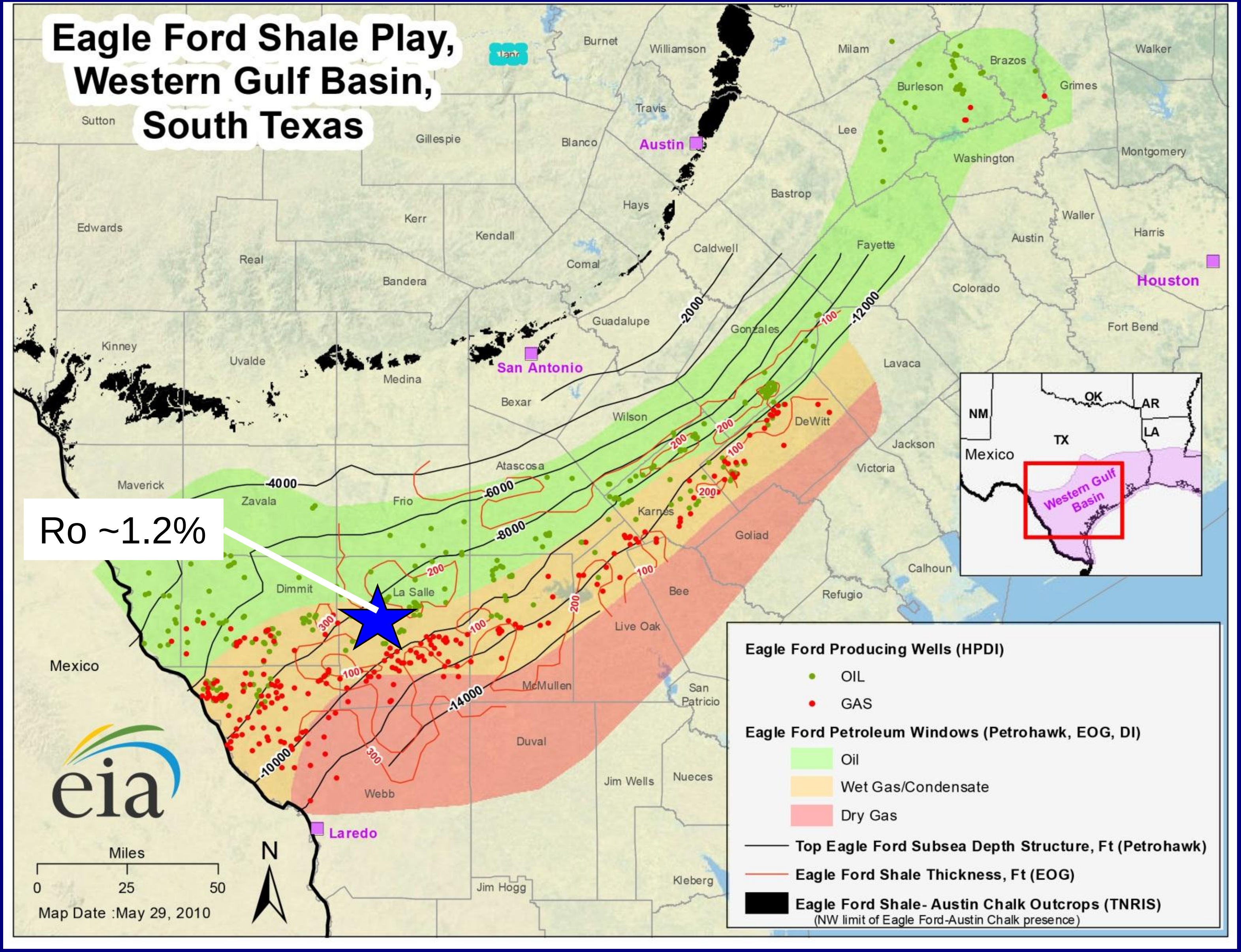
Development of organic & inorganic porosity in the Cretaceous Eagle Ford Formation, South TX

By Neil Fishman, John Guthrie, Matt Honarpour
Hess Corp., Houston TX

Paleogeographic setting, Eagle Ford

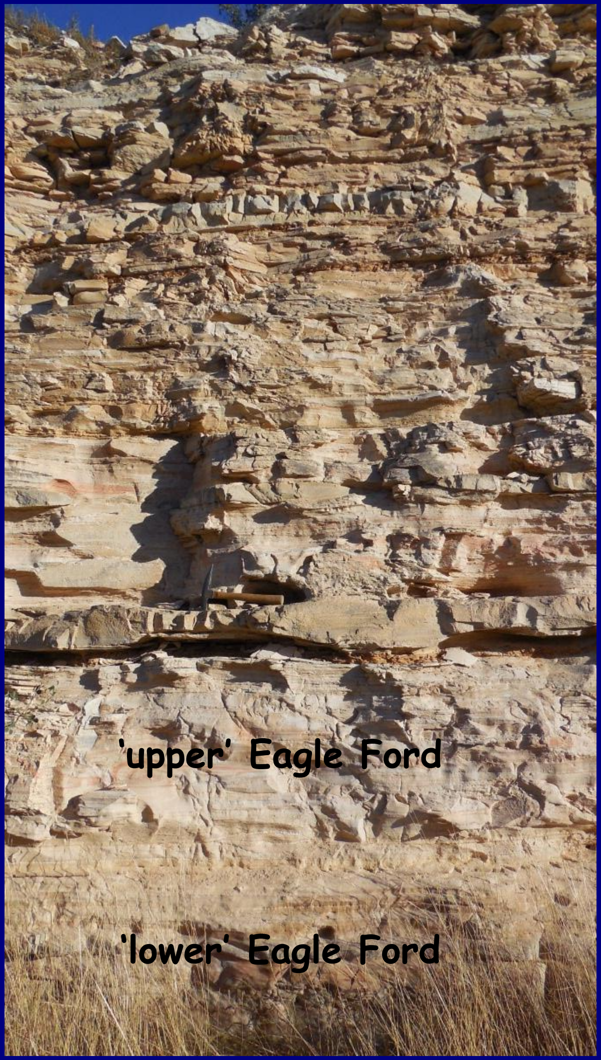
From R. Blakey, http://jan.ucc.nau.edu/~rcb7/nam.html

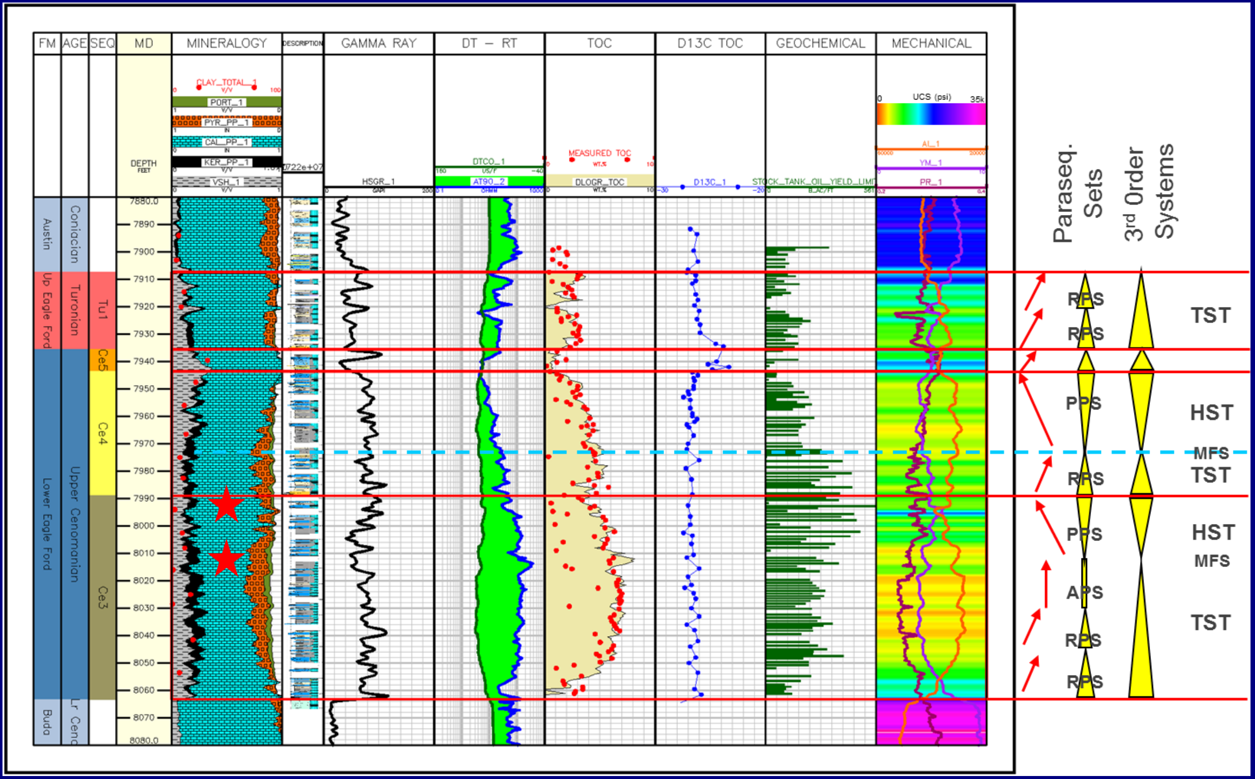
Study well location



Sequence stratigraphic framework

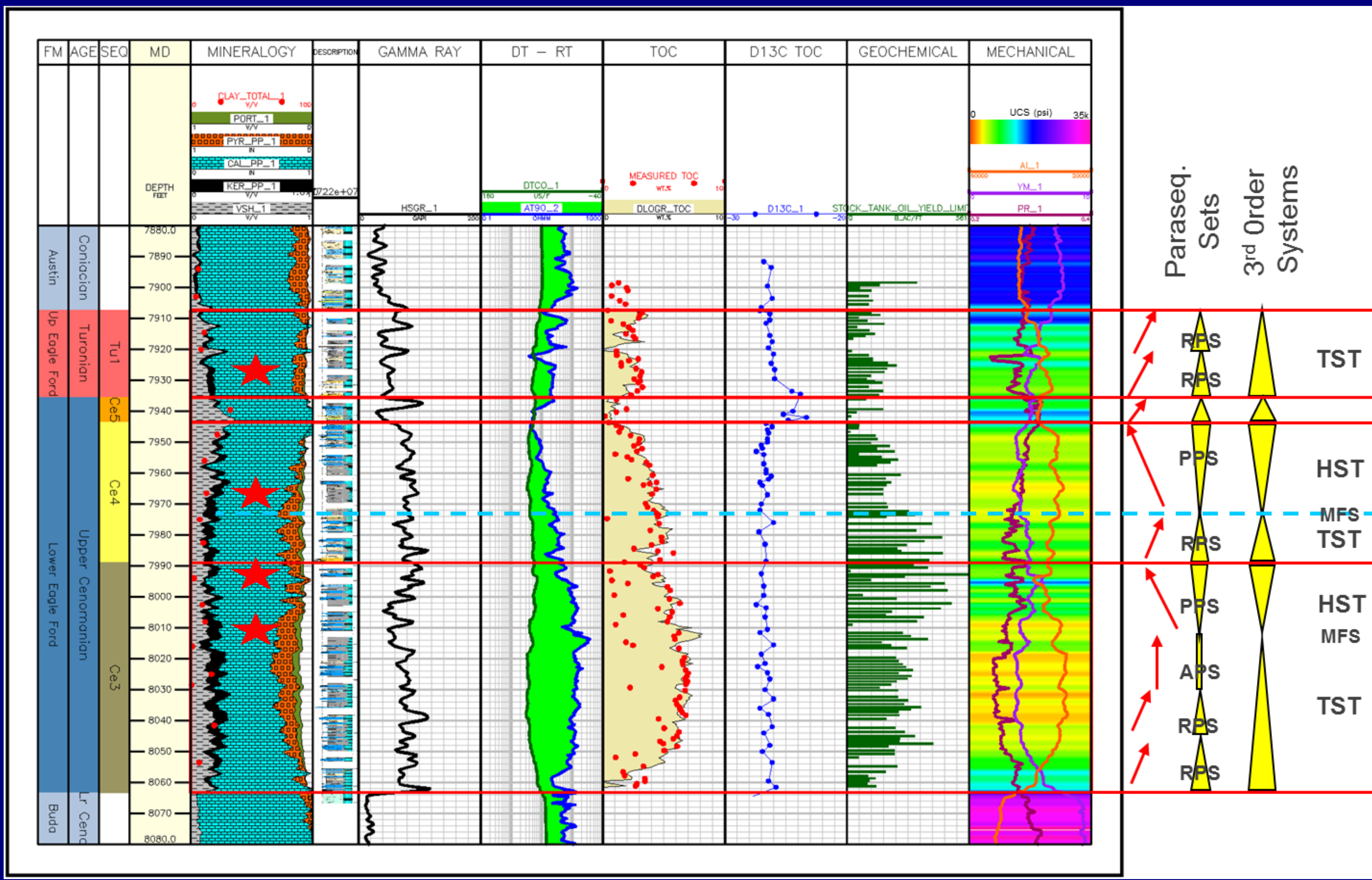
Eagle Ford, near Del Rio, TX

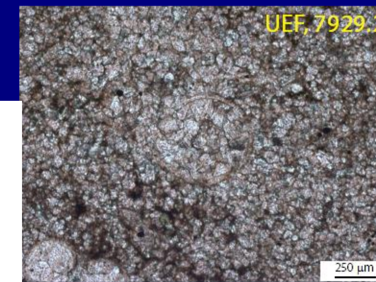


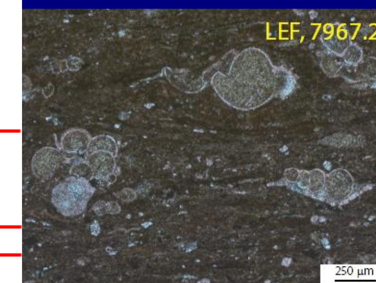


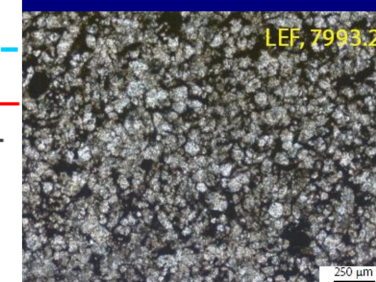
Broadly, two lithologies of interest

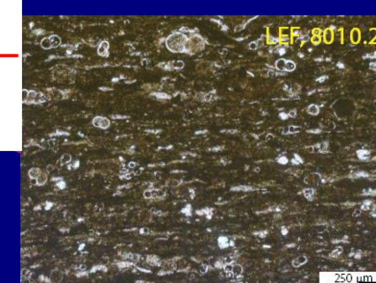
Org-rich mudst, TST-MFS, up to 8% TOC, Φ = 8-9%, k_{eff} = 50 nD











Limestones, HST, <1 locally up to 6% TOC, Φ = 6-7%, k_{eff} = 300 nD

Petrologic goals for porosity studies

Place inorganic & organic porosity development within a temporal framework for lithologies of interest (organic-rich mudst & ls)

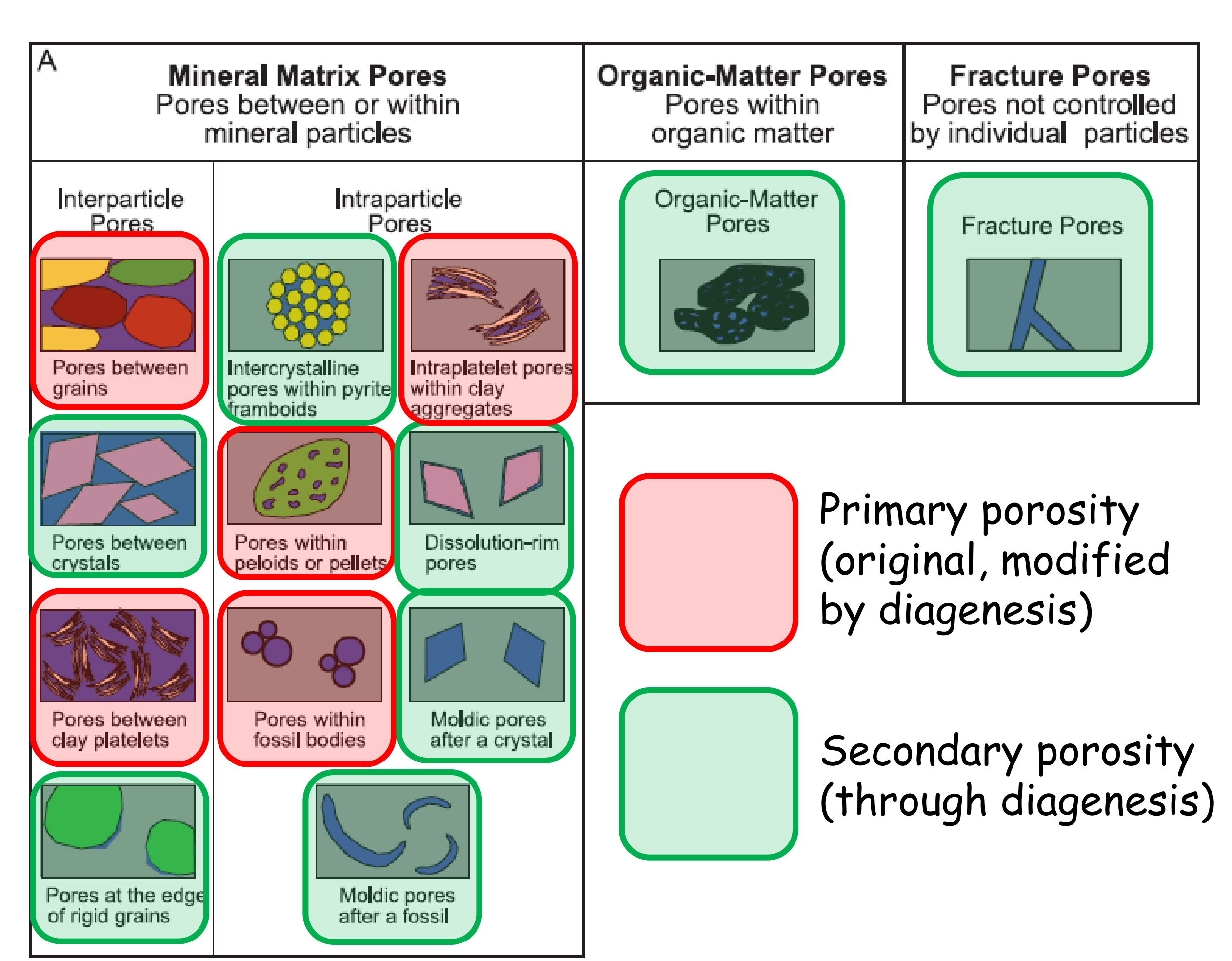
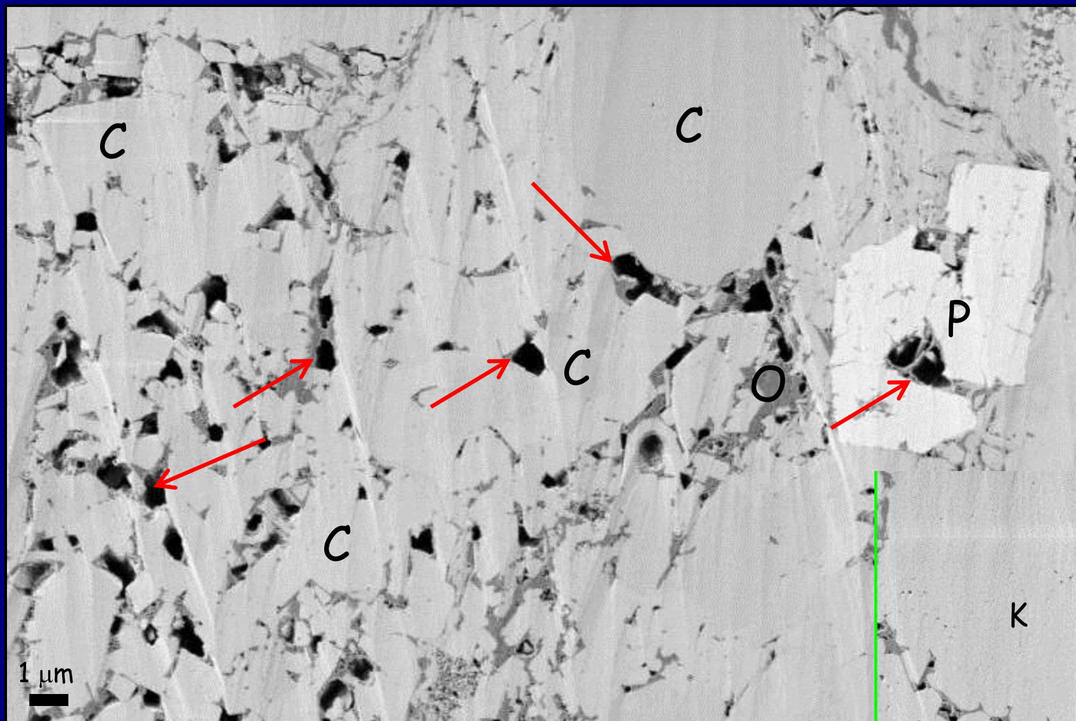
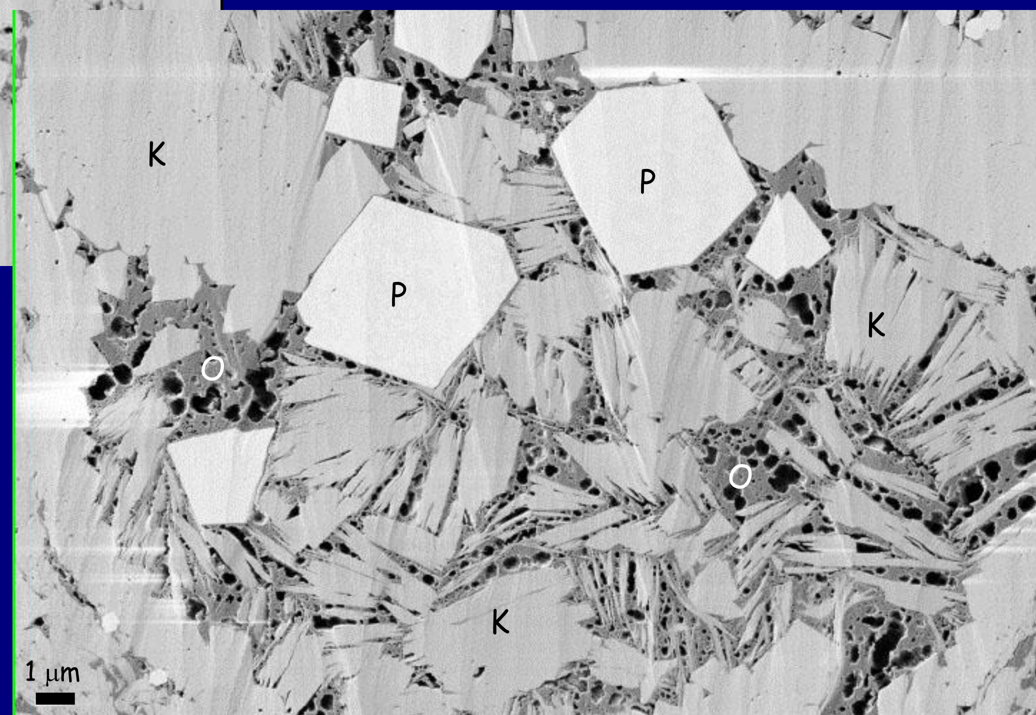


Figure modified from Loucks et al., 2012; AAPG Bulletin

Nature of pores, mudstone & limestone

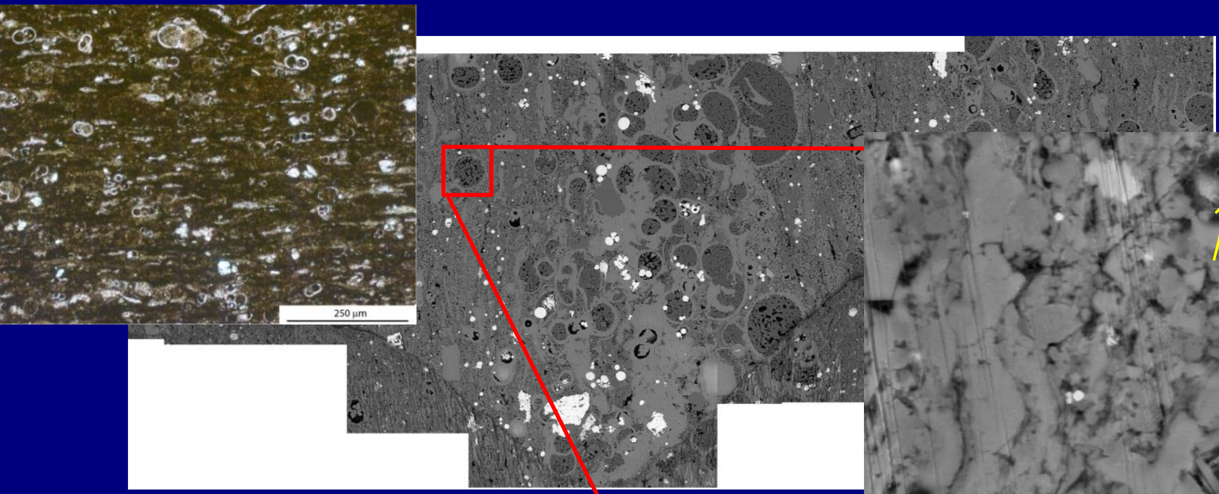


Recrystallized ls, interparticle pores (secondary porosity through diagenesis) between authigenic calcite (C) & pyrite (P) crystals. Interparticle pores also referred to as 'pendular' pores

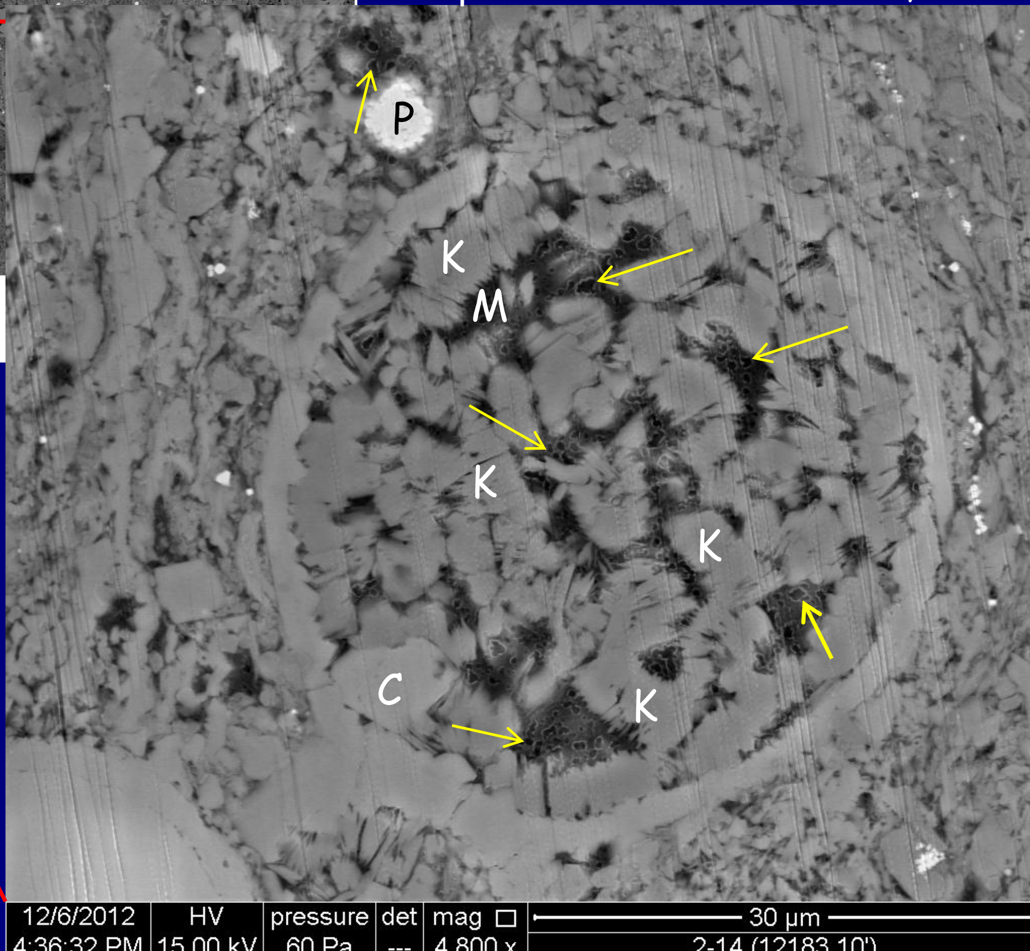


Organic-rich mudstones, intraparticle pores (primary porosity) within foram. Foram filled with authigenic kaolinite (K), pyrite (P), & organic material (O) as well as 'spongy' organic pores

Timing of events, org-rich TST mudstones

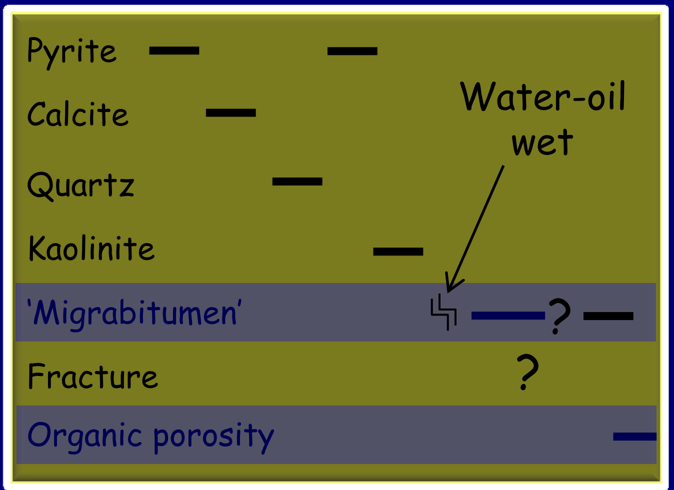


Authigenic kaolinite (K), pyrite (P), calcite (C), & 'migrabitumen' (M) as intraparticle cements in foram, etc.



Minimal compaction of forams prior to authigenic mineral ppt —authigenic minerals early

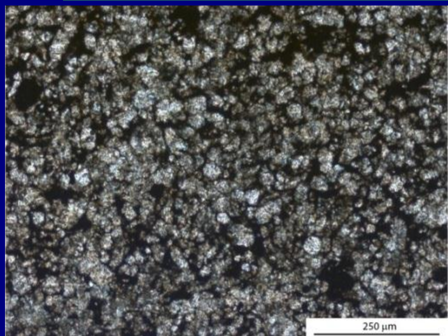
Paragenetic sequence

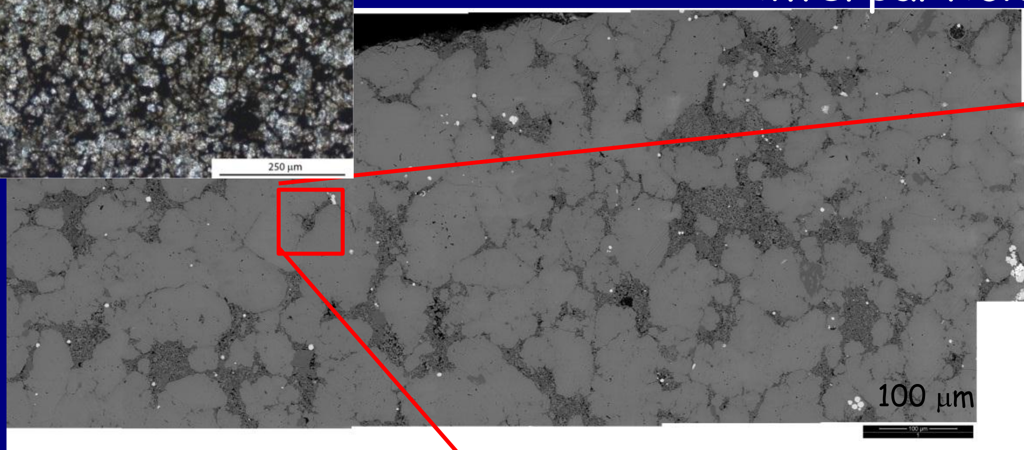


'Migrabitumen' fills remaining intraparticle pores

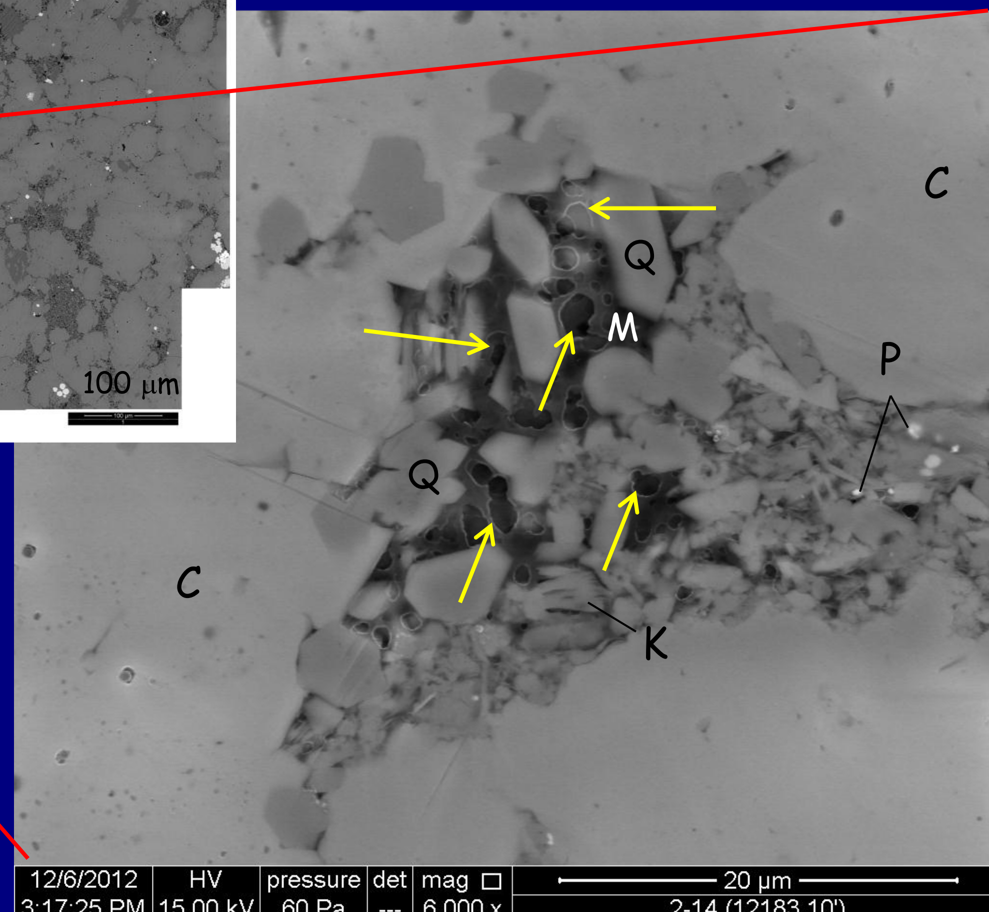
Organic pores develop 'late' diagenesis

Timing of events, HST recrystallized limestones

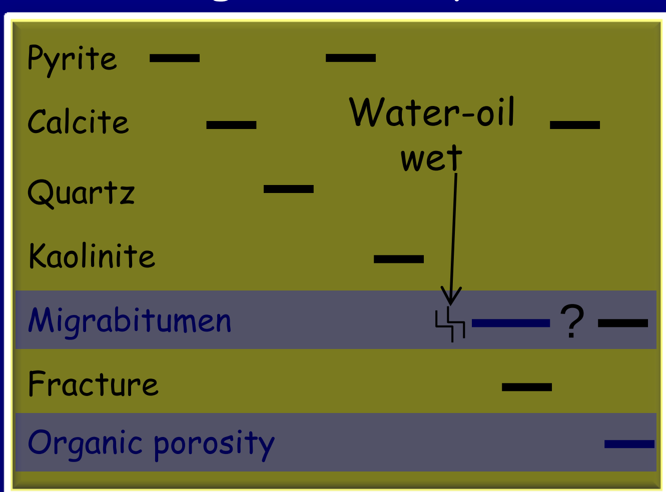




Authigenic pyrite (P), quartz (Q), calcite (C), Kaolinite (K), & 'migrabitumen' (M)—interparticle cements



Paragenetic sequence

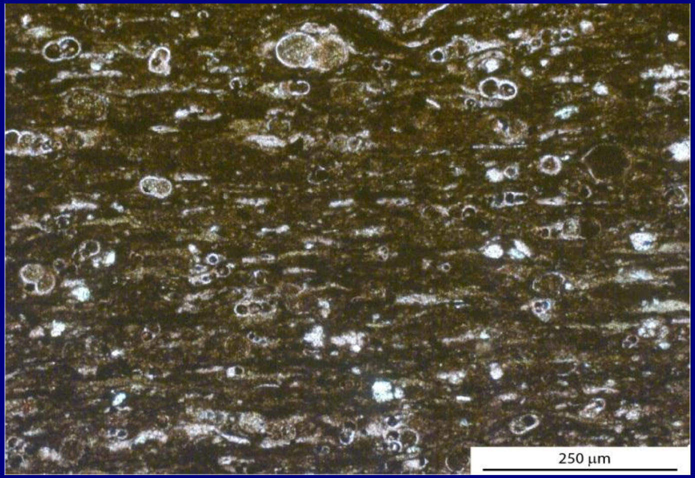


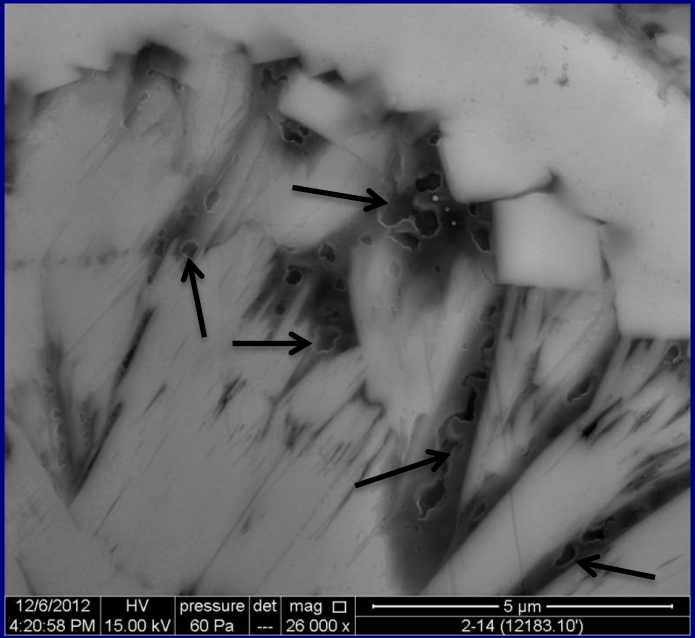
'Migrabitumen' fills remaining interparticle pores

Organic pores develop 'late' diagenesis

Integrating petrology & RockEval

Org-rich, foraminiferal TST mudstone



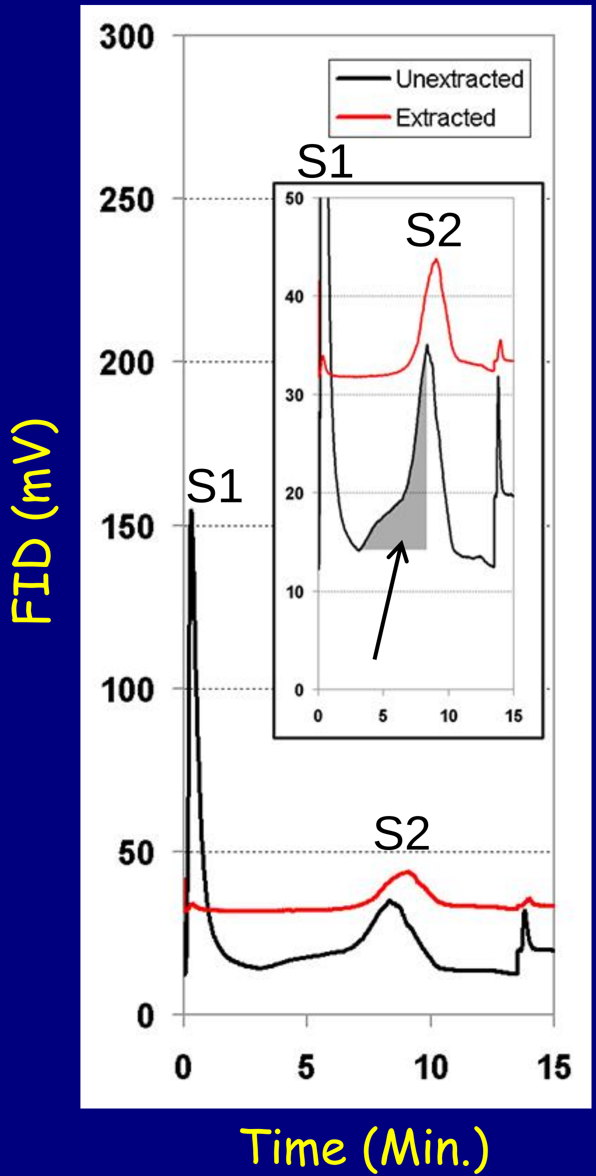


A) Organic porosity & associated storage best developed in organic-rich foraminiferal TST mudstones, less so in limestones

B) Organic porosity & associated storage, developed in organic matter ('migrabitumen') that fills pores remaining *after* ppt of earlier-formed calcite, pyrite, kaolinite, etc.

C) 'Migrabitumen' defined geochemically as the extractable S2-shoulder seen in RockEval

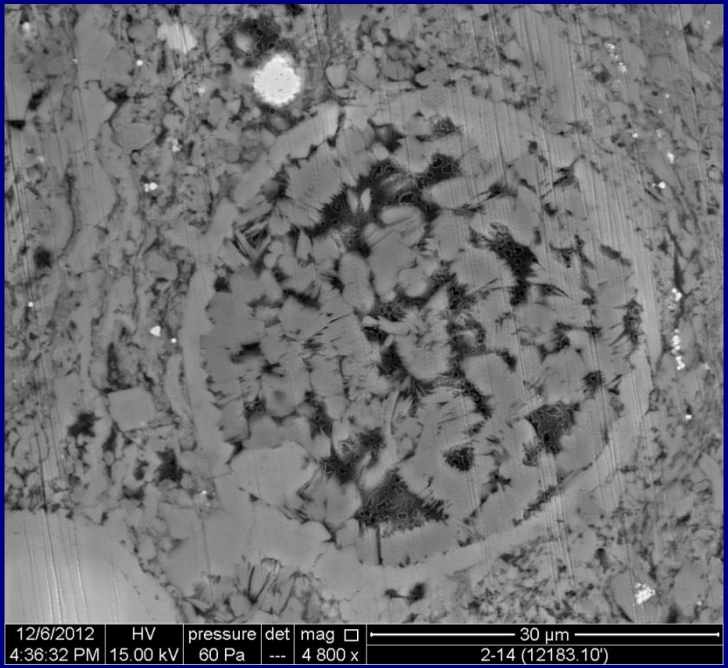
Rock-Eval Pyrogram



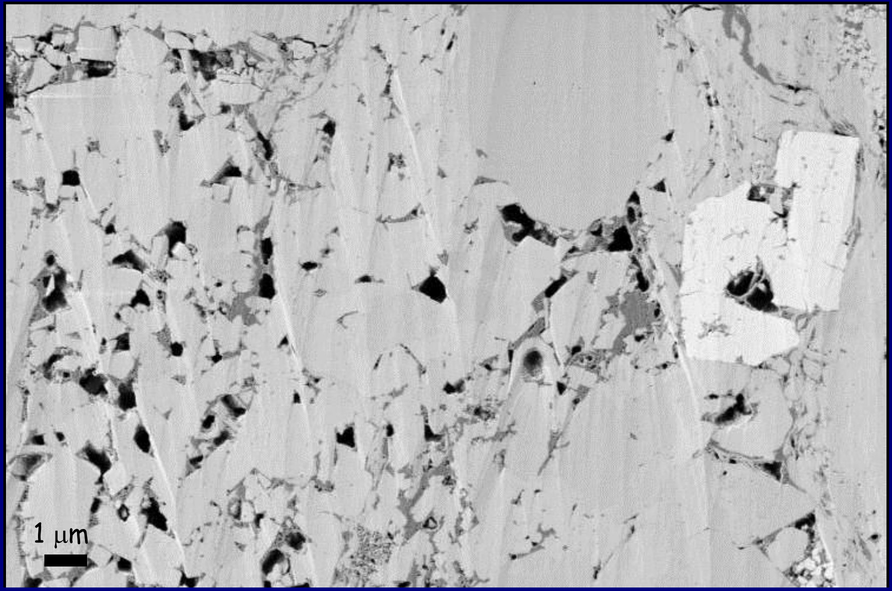
Summary of petrology/RockEval

- Pore type varies by lithology
  - OM pores dominate in org-rich mudstones
  - 'Pendular' pores largely in limestones
- Organic porosity developed in 'migrabitumen'
  - Mobile phase that moved into previously water-wet pores
  - Introduced after ppt of various authigenic minerals

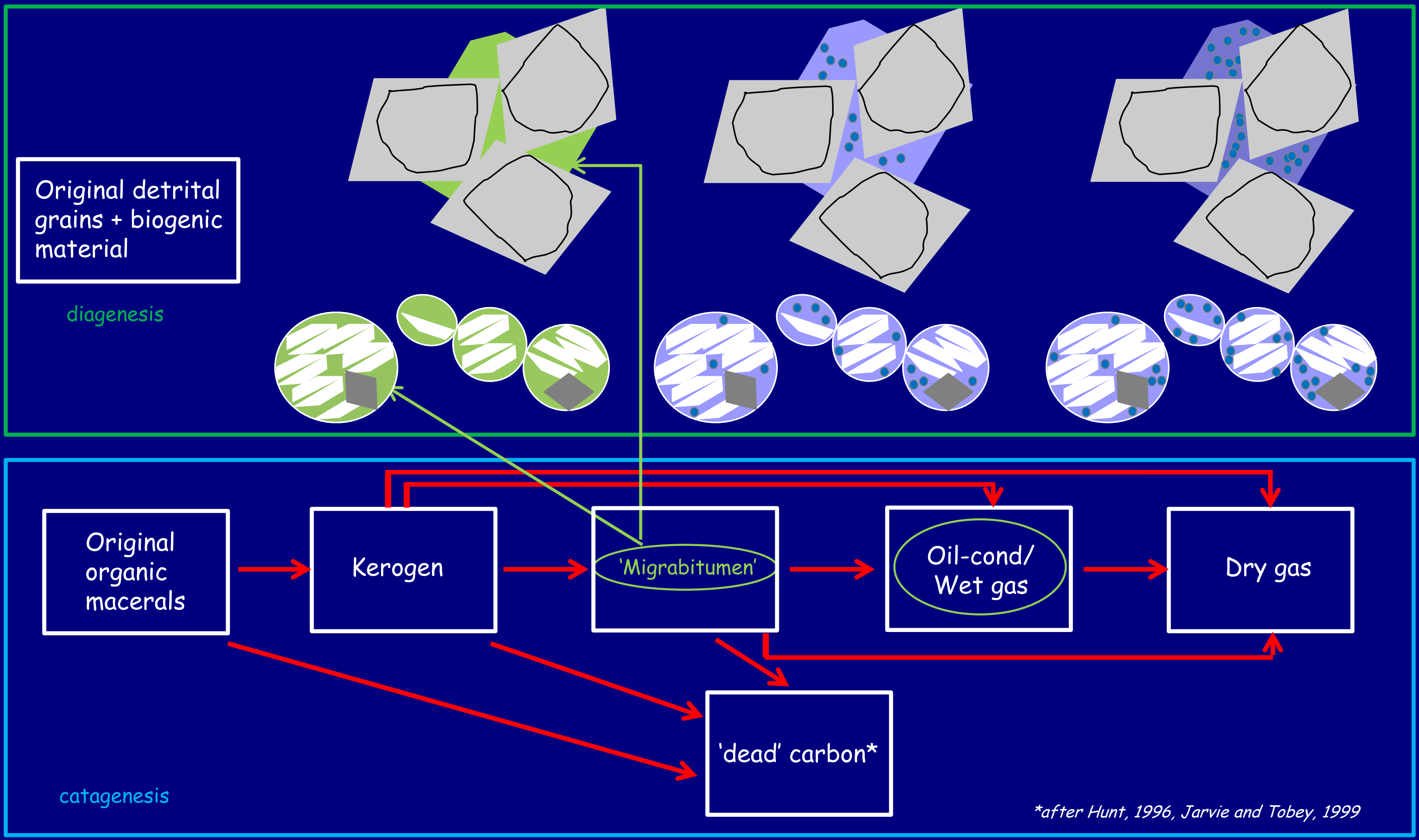
Organic-rich mudstone



Recrystallized limestone



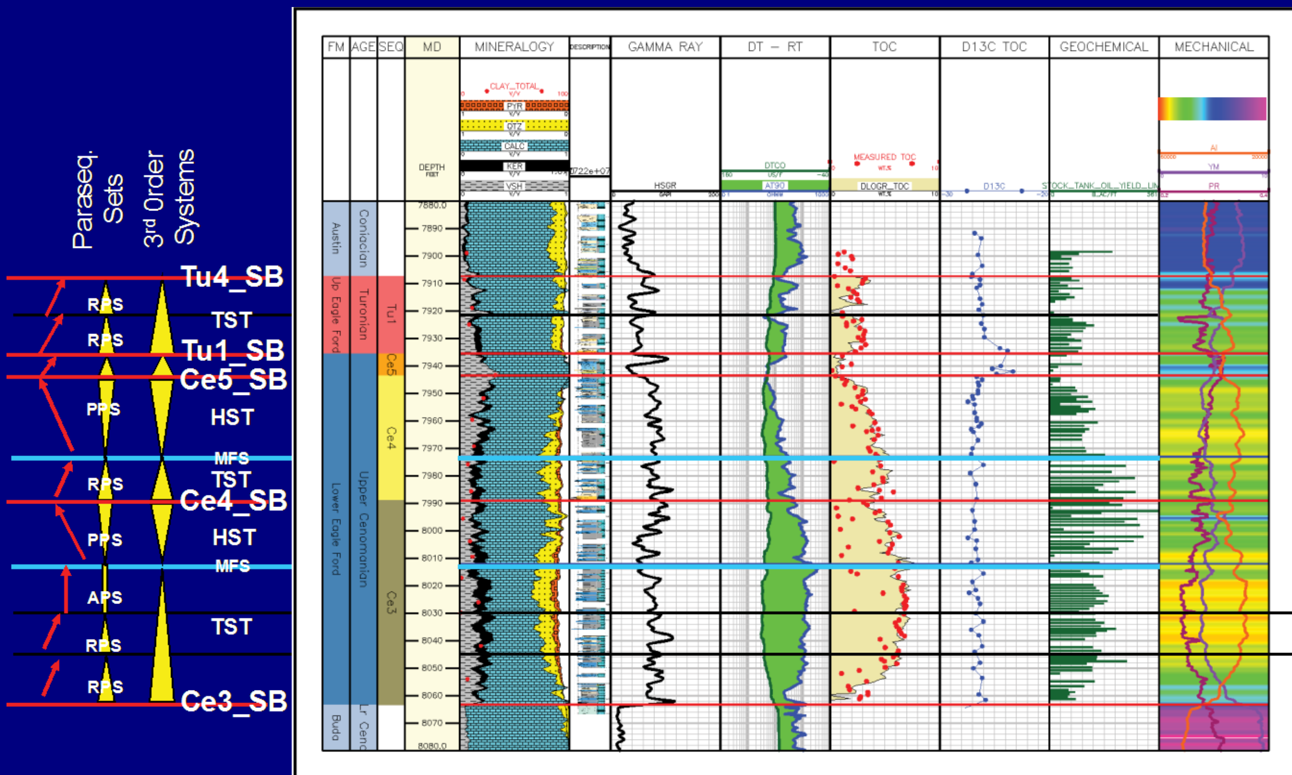
Pairing diagenesis with catagenesis



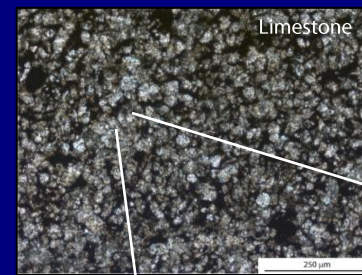
Time, burial, heat

Influences of lithology on production

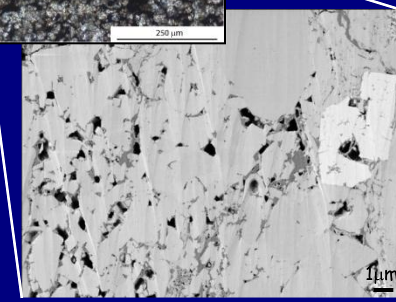
Lithologic (sequence strat) controls on pore types?
Pendular in limestones vs spongy in mudstones

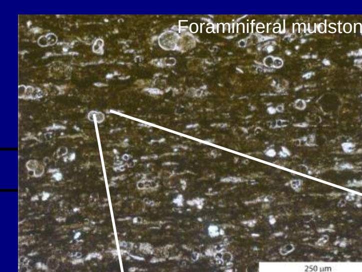


From John Guthrie and Randy Mitchell

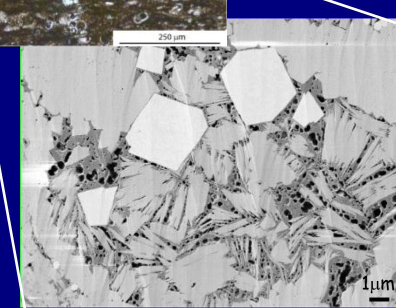


TOC = <2%
Φ = 6-7%
S_w = 40-50%
k_{eff} = 300 nD
'Pendular' org pores
Zone of moveable oil





TOC = 5-8%
Φ = 8-9%
S_w = 20%
k_{eff} = 50 nD
'Spongy' org porosity
Lower moveable oil



Moveable HC in low TOC Is with 'higher' perm

Conclusions

- Inorganic & organic pores—important storage for HC
- Porosity development—diagenesis (inorganic) & catagenesis (organic)
- Early diagenesis (water-wet) in organic-rich TST/MFS mudstones
  - Ppt of pyrite, kaolinite, calcite, etc. in intraparticle pores
- Early diagenesis (water wet) in HST limestones
  - Ppt of calcite, quartz, pyrite, kaolinite, etc in interparticle pores
- Migrabitumen (oil-wet) related to early HC generation
  - Observed as shoulder on S2 peaks, RockEval pyrograms
  - Mobile phase that coats previously formed authigenic minerals
  - Post-dates diagenesis in both mudstones & limestones
- Organic pores ('spongy') formed in migrabitumen
- 'Pendular' pores—just interparticle pores in ls
- Organic porosity spatially related to dispersal of 'migrabitumen'
- Moveable HC in higher perm. limestones

Acknowledgments

Hess Corp. for permission to present results