Mudstone and Claystone Units: Seals for Ancient Microbial Gas Accumulations in the Upper Cretaceous Milk River Formation, Alberta and Saskatchewan*

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Abstract

More than 3 TCF of dry (>99% methane) microbial gas ($\delta^{13}C$ -65 to -71‰) has been produced from shallow wells (generally <1500 ft) in the Upper Cretaceous Milk River Formation, southeastern Alberta and southwestern Saskatchewan. The likely source of gas is organic-bearing mudstones (total organic carbon <0.5 to 3.29%) that are interbedded with and encase productive intervals (as much as 90 ft thick). Production is from numerous thin (<<1 ft) silty to sandy layers/lenses within these intervals. Petrologic, isotopic, and burial history studies indicate that methanogenesis commenced during deposition and continued for possibly 20 m.y. Questions remain concerning how early-formed gas could remain trapped in the formation to the present.

Mercury injection capillary pressure data from core samples of the Milk River and overlying Upper Cretaceous Pakowki Formation were collected to evaluate pore apertures and permeabilities of various lithologies. Milk River fine-grained sandstones (n = 11) exhibit generally greater median pore apertures (0.05 to 7.6 μm) and permeabilities (0.01 to 121 mD) compared to mudstones (n = 9), which have pore apertures and calculated permeabilities ranging from 0.03 to 0.17 μm and 0.002 to 0.53 mD, respectively. Pakowki claystones have small pore apertures (0.03 to 0.07 μm) and low calculated permeabilities (0.002 to 0.017 mD). The characteristics of mudstones and claystones point to the likelihood that buoyancy pressure never exceeded their capillary entry pressures, so these units inhibited vertical migration of Milk River gas. Thus, mudstones and claystones helped gas accumulations in the formation to persist for millions of years.

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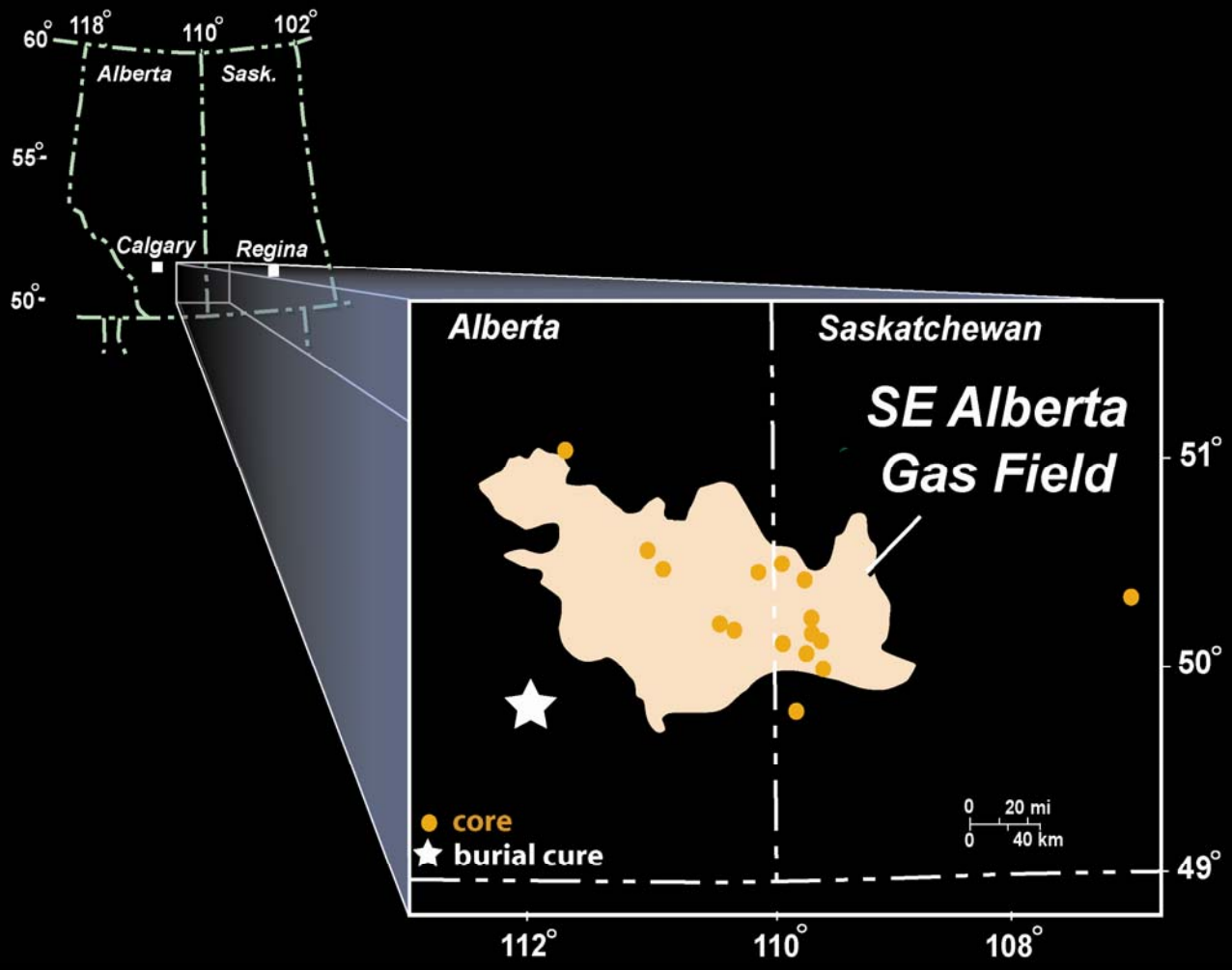
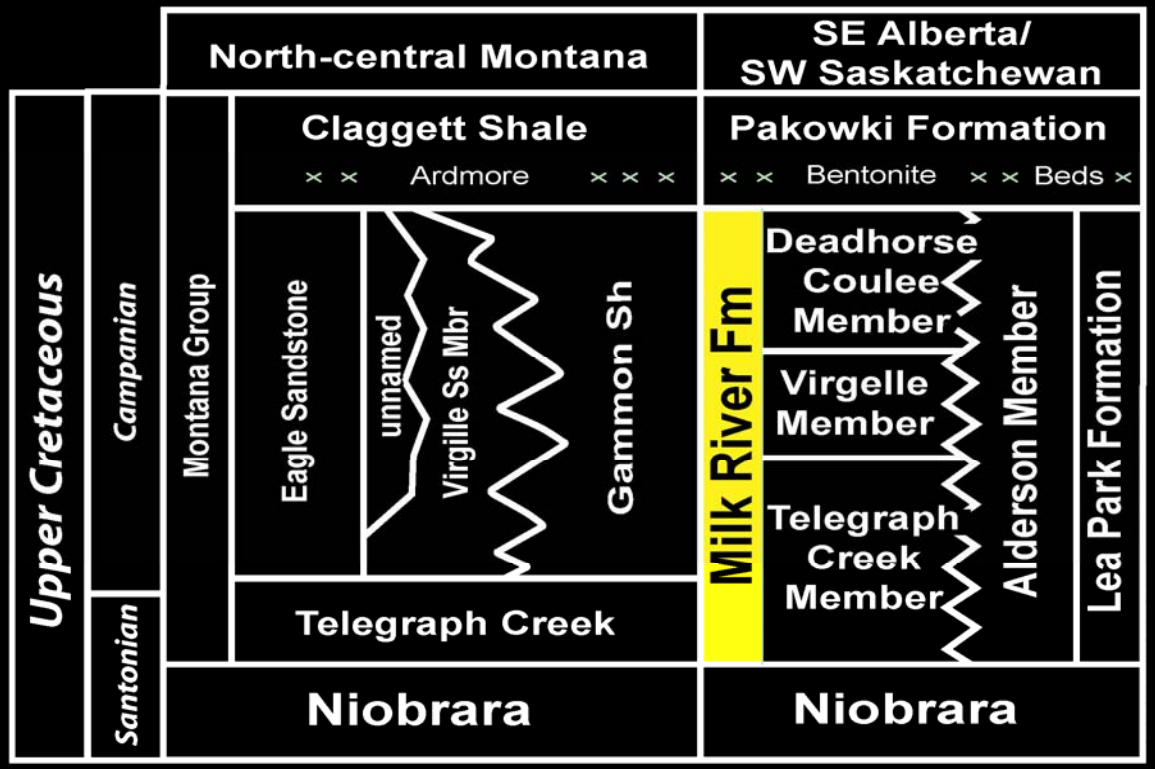
Milk River Study Area



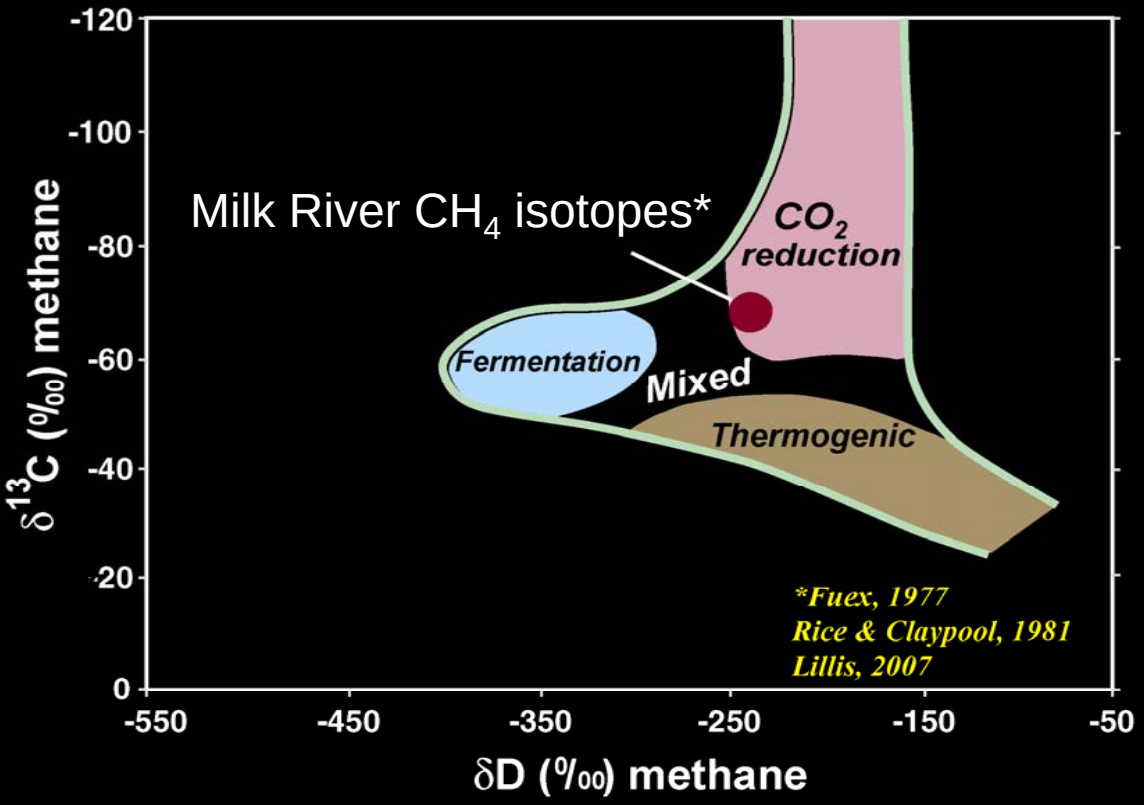
Background information



- WIS, marine
- Ss/mud
- Sands produce
- Mudst source
  (0.29-3.26% TOC)
  Lean but mean!
- >3 tcf, GIANT
- Non-associated
- Pakowki

Methane composition—key

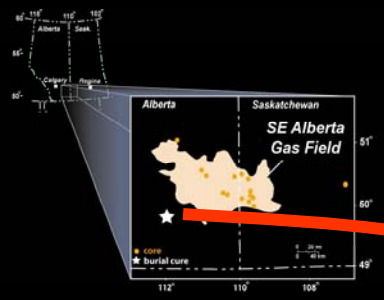
Isotopes and dryness = bacterial

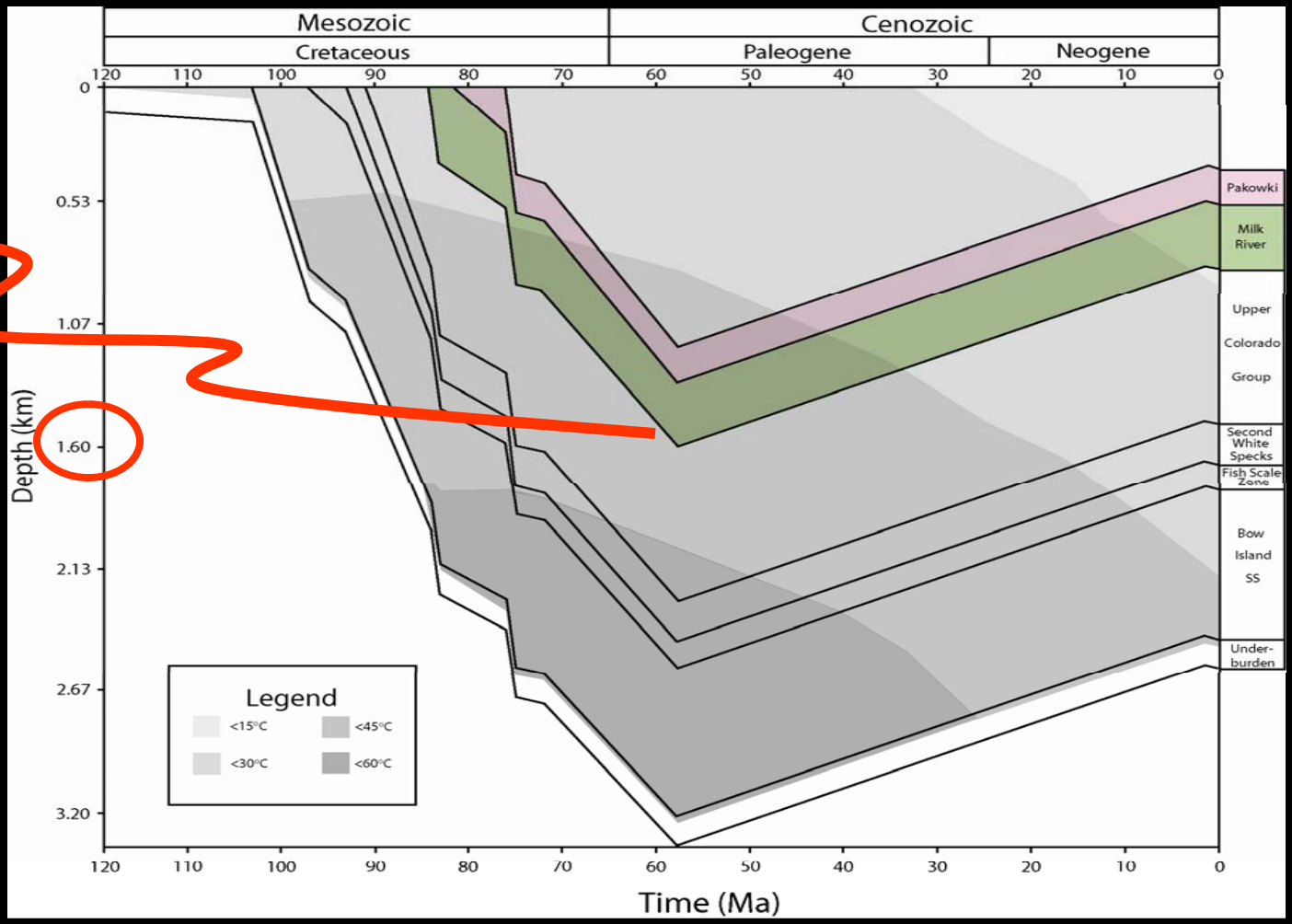


>98% CH_4

Diagram mod. from Whiticar et al, 1986

Milk River, shallow burial



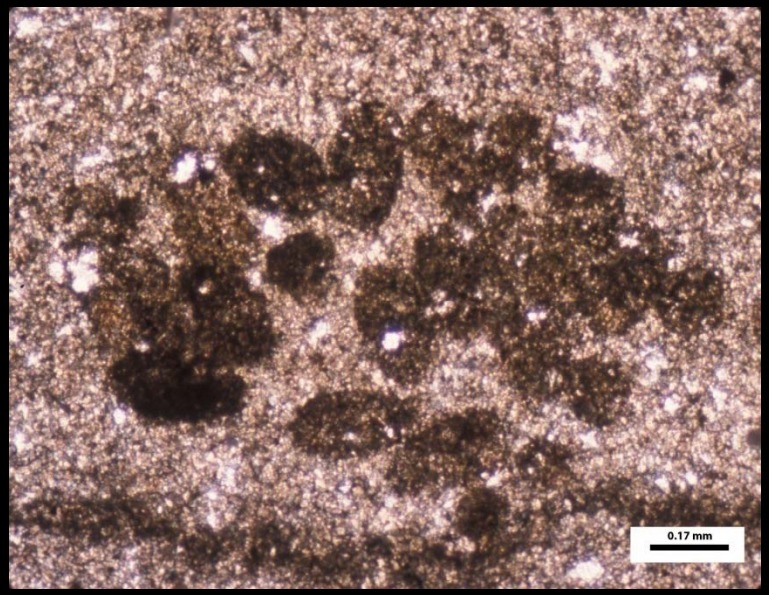


Timing & duration of methanogenesis??

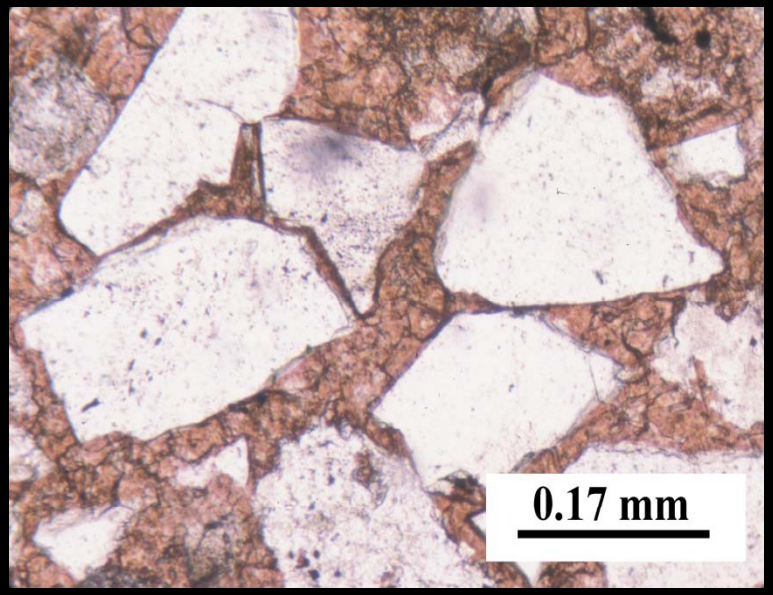
Petrologic studies

Petrologic studies

- **Place gas generation in context of diagenetic/burial history of MR**
- **Requires studies of various lithologies**
- **Temporal link between diagenesis & methanogenesis?**



Concretions



Siltstones/vfg sandstones

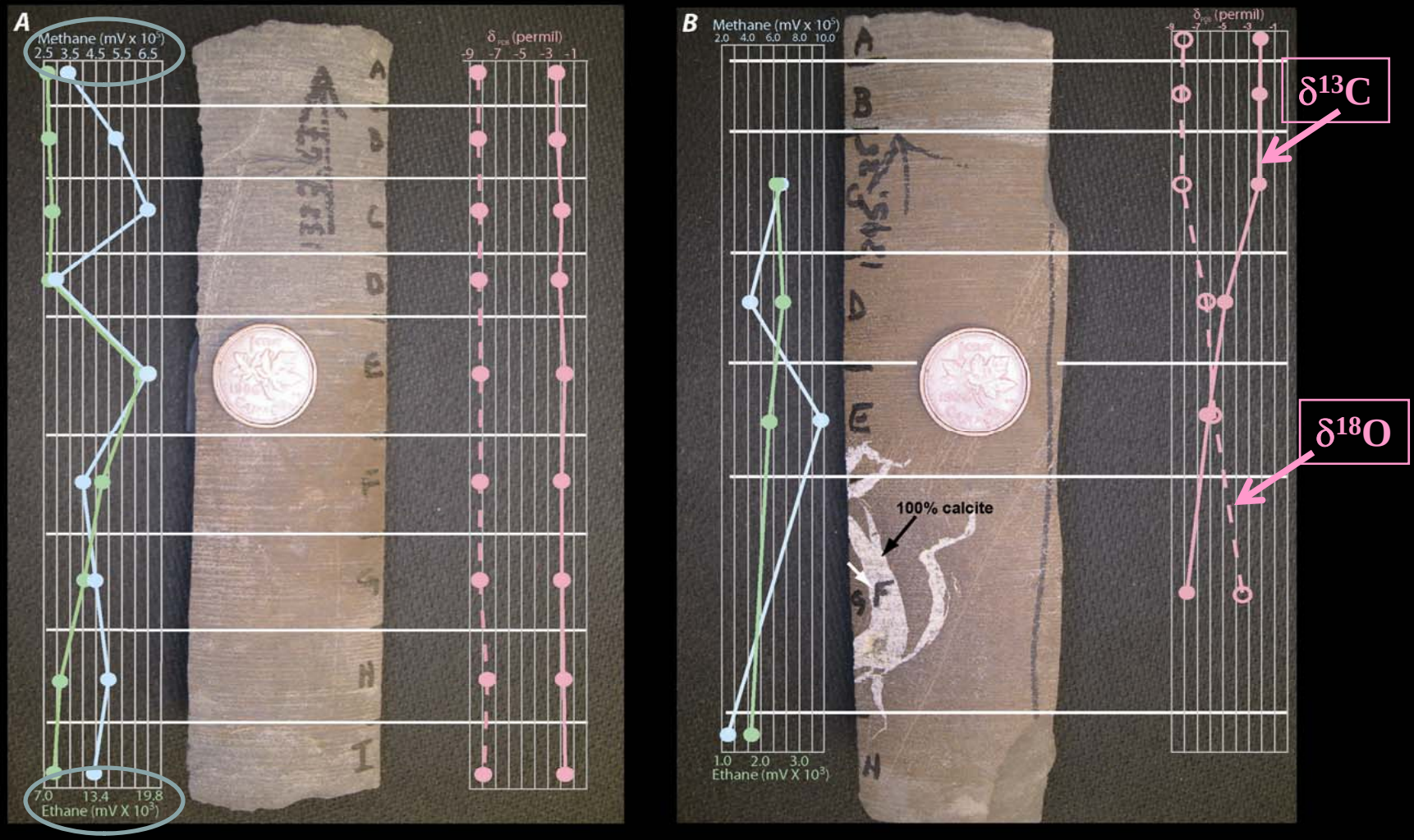
Early-formed concretions

Sediment deformation points to early concretionary growth

Concretions—early diagenetic

Early-formed, vary mineralogically, isotopically

but all contain methanic fluid inclusions

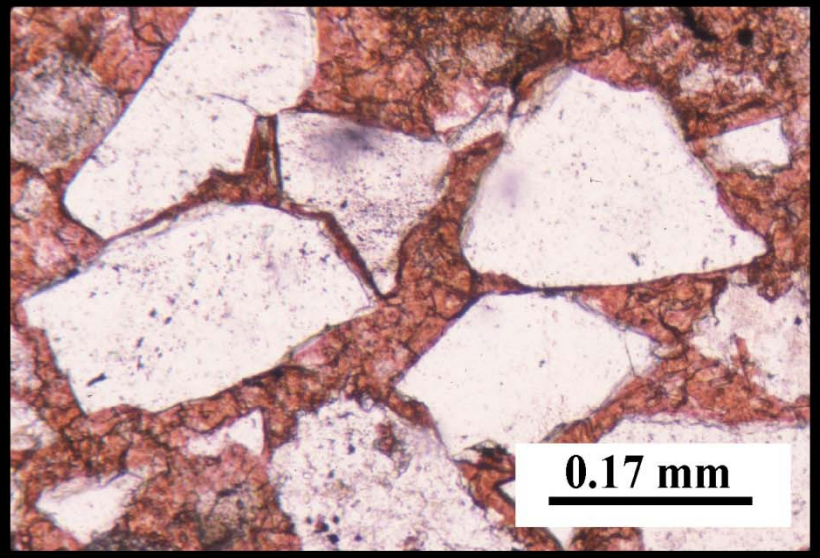


Methanogenesis occurred during active concretion growth

Additional gas timing info—from ss petrology

Initial IGV of vfg-fg, moderately sorted ss ~37% ***(after Beard & Weyl, 1973)***

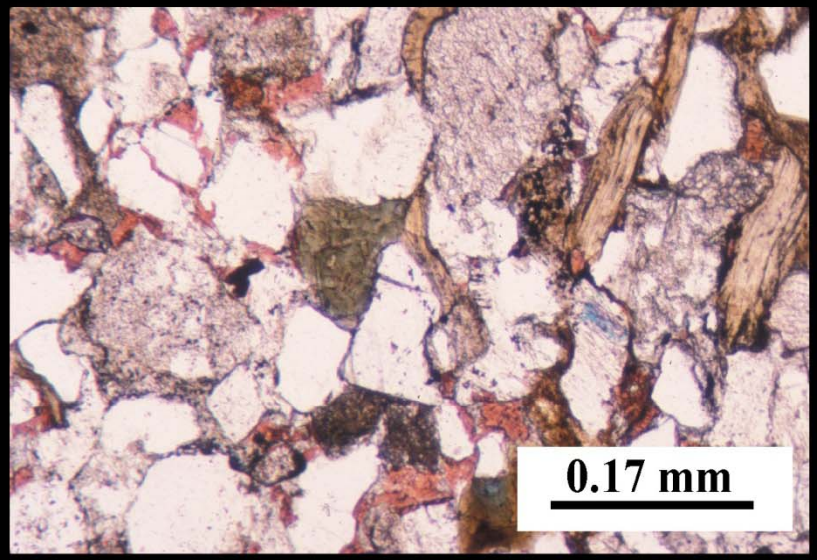
~34% IGV, largely cal/dol filled



Minor compaction, IGV preserved by carbonate cement

<100's meters of burial*

~22% IGV, largely calcite filled



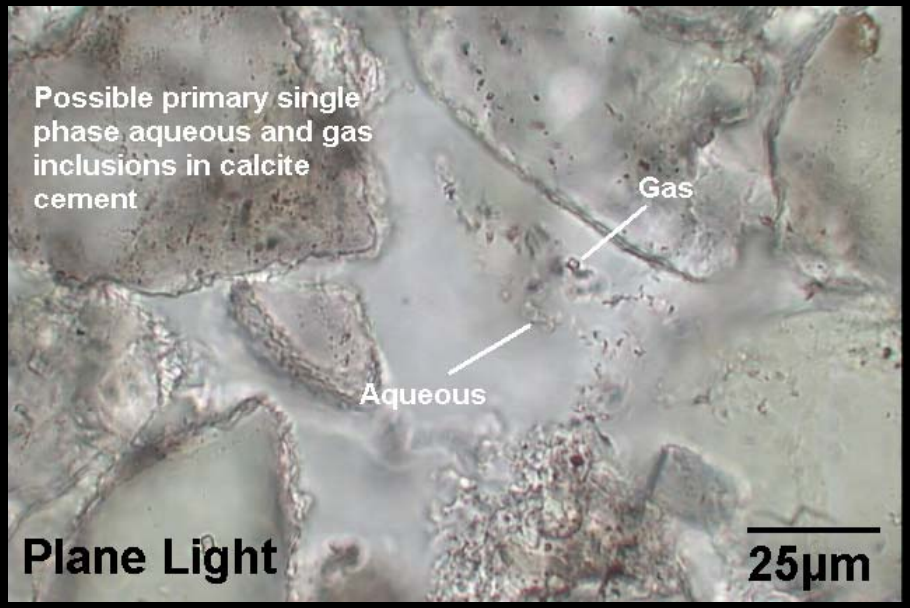
Significant compaction, IGV records carbonate cementation after porosity loss

~1.2-1.3 km of burial*

Some ss contain little/no cement <22% IGV

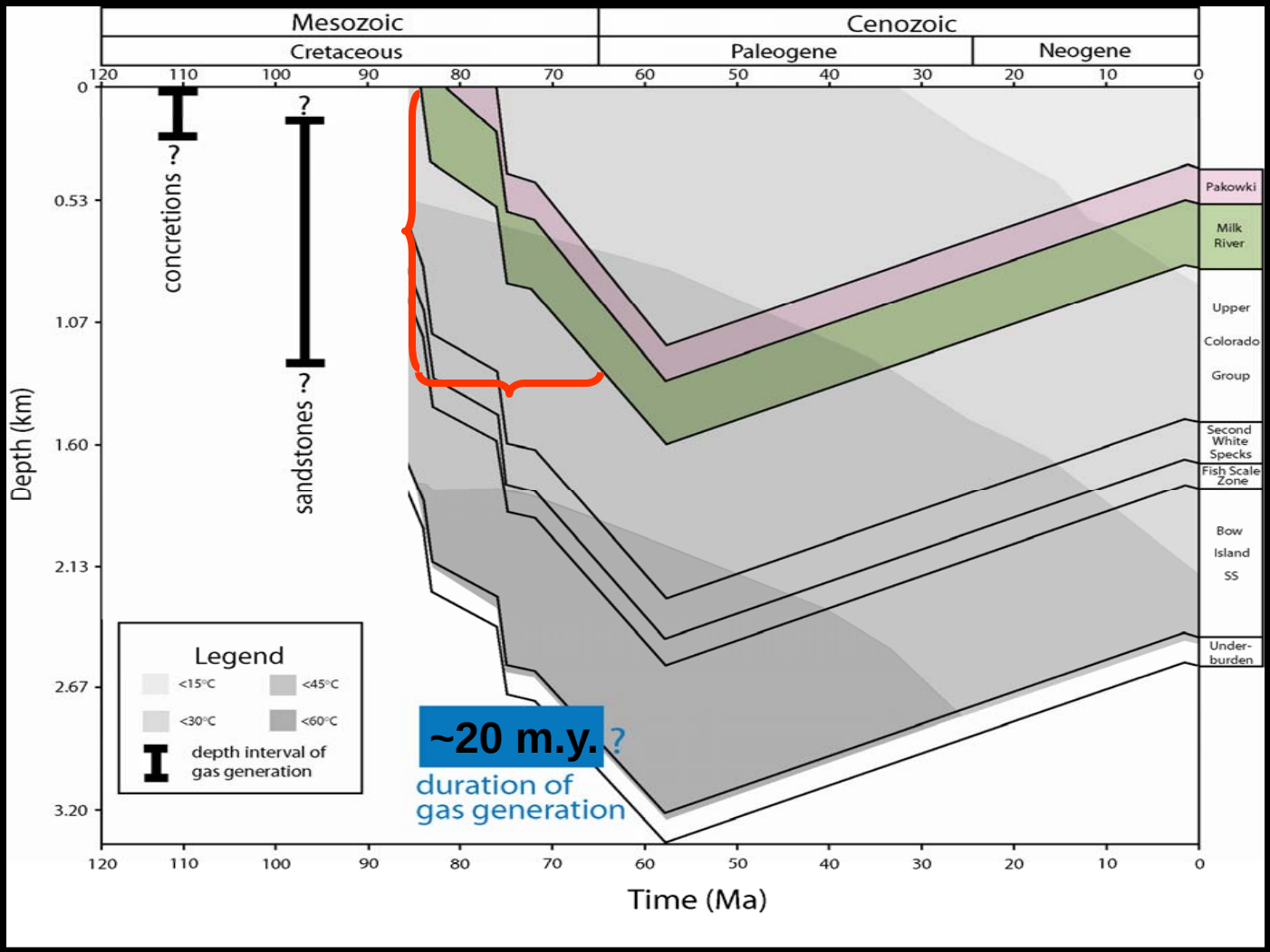
****based on studies by Pittman & Larese, 1991***

Carbonate cement linked to methanogenesis



Gas inclusions temporally link carb cmnt to methanogenesis

Petrologic constraints timing/duration, Milk River bacterial gas



- **Geologic evidence points to early start and >20 m.y. of methanogenesis, but…**
- **How did gas stay around for >60 m.y.???**

Look at rock properties using

Mercury Injection Capillary Pressure data

Sandstone MICP data

"Reservoir", uncemt. ss

- **Porosity 27.2% (22.4-27.2%)**
- **Pore aper 7.6 μm (0.33-7.6 μm)**
- **Perm 120.8 mD (6.2-121 mD)**

"Non-reservoir", cnmt ss

- **Porosity 1.1%**
- **Pore aperture 0.13 μm**
- **Permeability 0.00057 mD**

Interbedded/overlying rock MICP data

Milk River muddy siltst

- **Porosity 14.3% (11.6-24.1%)**
- **Pore aper 0.0614 μm (0.02-0.17 μm)**
- **Perm 0.0116 mD (0.002-0.4 mD)**

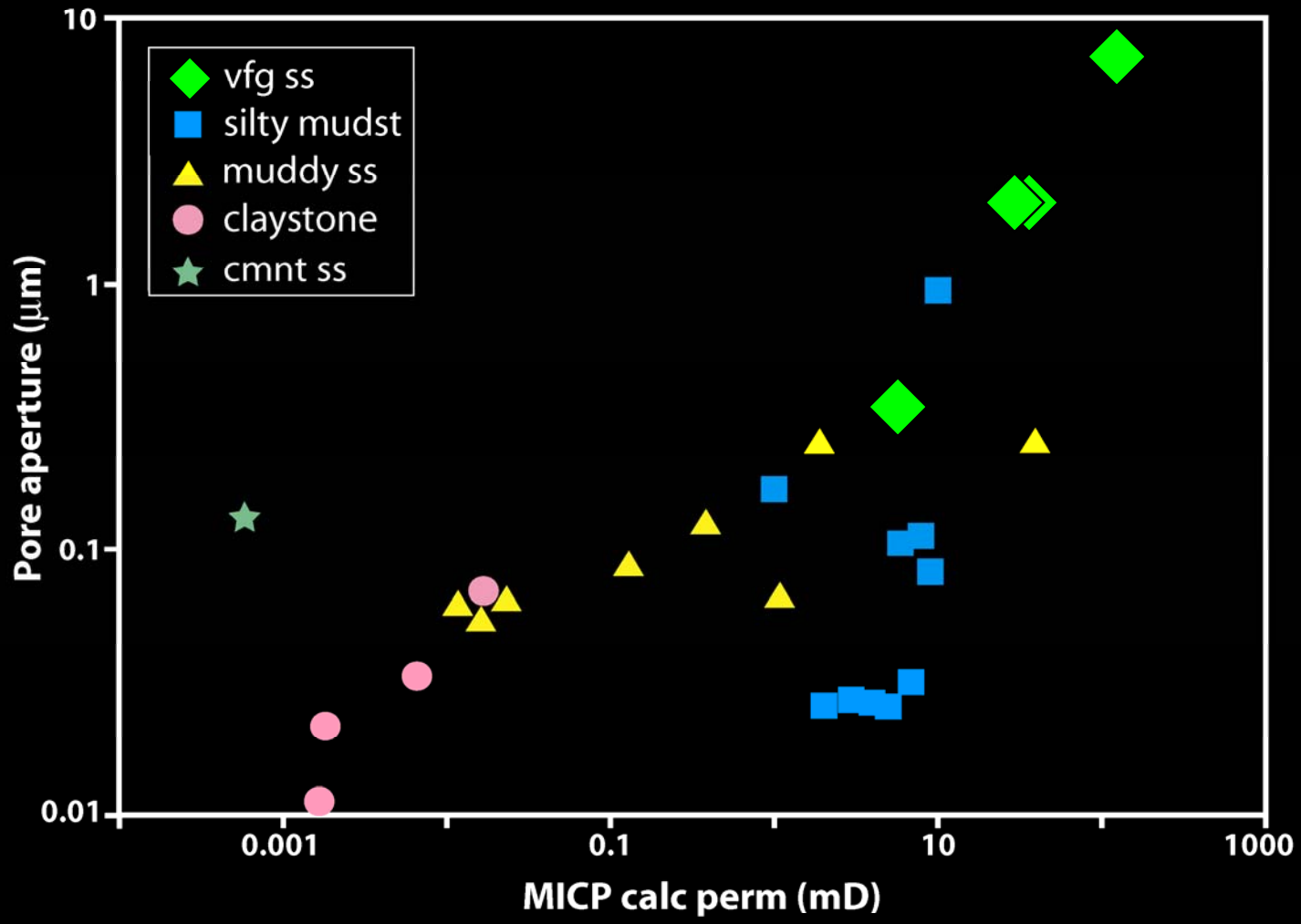
Pakowki claystone

Porosity 23.5% (13.1-23.5%)

Pore aper 0.011 μm (0.01- 0.17 μm)

Perm 0.0017 mD (0.0017- 0.017 mD)

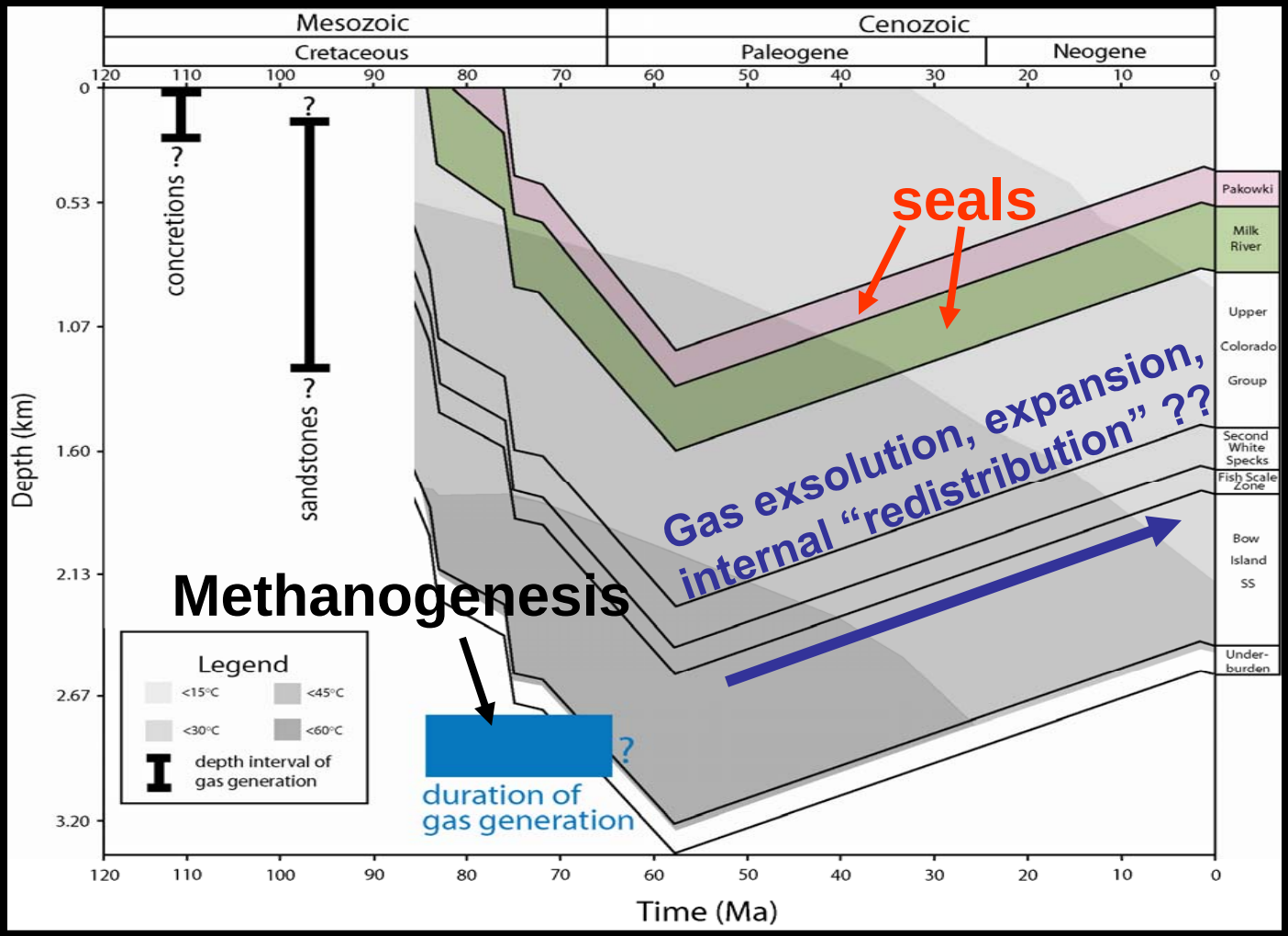
MR pore aperture/permeability



Summary, MICP data

- **Milk River**
  - **Uncemented ss are “reservoir” rocks**
  - **Cemented ss are internal seals (minor)**
  - **Mudstones (sandy or silty) are internal seals (major)**
- **Pakowki**
  - **Overlying Pakowki claystones are external seals (major)**

Milk River petroleum system



Conclusions

- **Milk River—complete, multi-tcf petroleum system**
- **Generation started early, duration of ≥20 m.y.**
- **Internal & overlying seals—keep gas for >60 m.y.**
- ***Transcending messages***
  - **Ancient bacterial gas systems in WIS rocks can be giants, not to be underestimated**
  - **Lean rocks can produce economic accumulations**
  - **Bacterial systems contribute significantly to NA reserves**
  - **Lean, immature rocks in WIS (other places??) are indeed reasonable targets**

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