Facies, Fabrics and Organic Geochemistry of the A-1 Carbonate in Michigan

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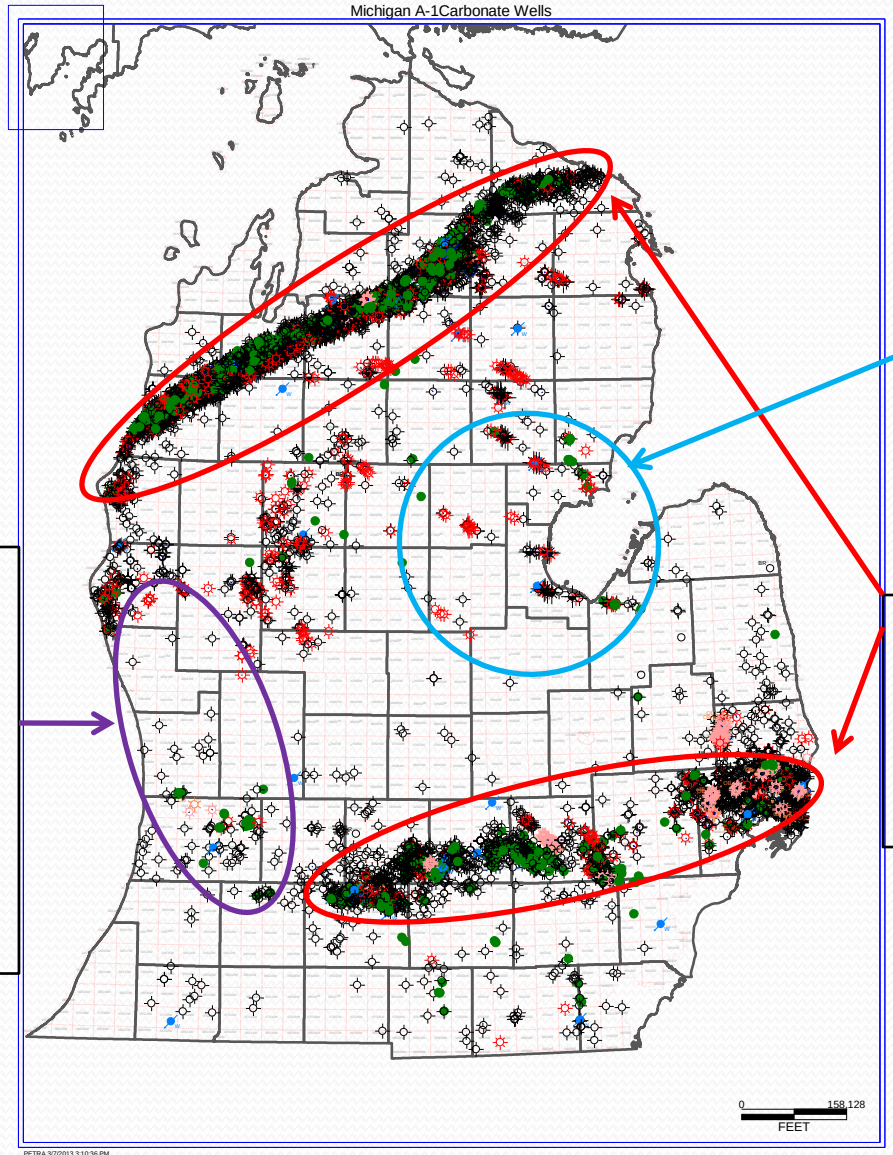
A-1 Carbonate Production in Michigan

- Historic production is a minor component of Michigan's overall production
- Three different geologic settings have historically produced oil or natural gas
  - Within the Silurian Niagaran Pinnacle Reef Trend on top or on flanks of reefs – Selected reefs in Otsego, Manistee, Alpena, St. Clair and Macomb Counties
  - Fractured, partially-dolomitized A-1 and A-2 Carbonate in western Michigan areas of salt withdrawal in the A-1 and A-2 Salt Fracturing and structural closure
  - Central basin fractured and partially dolomitized, not related to salt withdrawal, structural closure uncertain

Wells with A-1 Carbonate tops



Central basin fractured and partially dolomitized

Fractured, partially-dolomitized A-1 and A-2 Carbonate in areas of salt withdrawal

Silurian Niagaran Pinnacle Reef Trend on top or on flanks of reefs

Silurian Niagaran Pinnacle Reef Trend on top or on flanks of reefs

- Chester 06-30N-02W - 1,403,991 BBLS Oil and 1,431,320 MCF Gas
- Cottrellville - 206,574 BBLS Oil and 3,186,606 MCF Gas
- Bear Lake 09 - 23N - 15W - 128,563 BBLS Oil and 14,781 MCF Gas
- Charlton 28-31N-01W - 111,901 BBLS Oil and 3,756,312 MCF Gas
- Chester 05-30N-02W - 99,482 BBLS Oil and 7,725 MCF Gas

Fractured, partially-dolomitized A-1 and A-2 Carbonate in Western Michigan areas of salt withdrawal

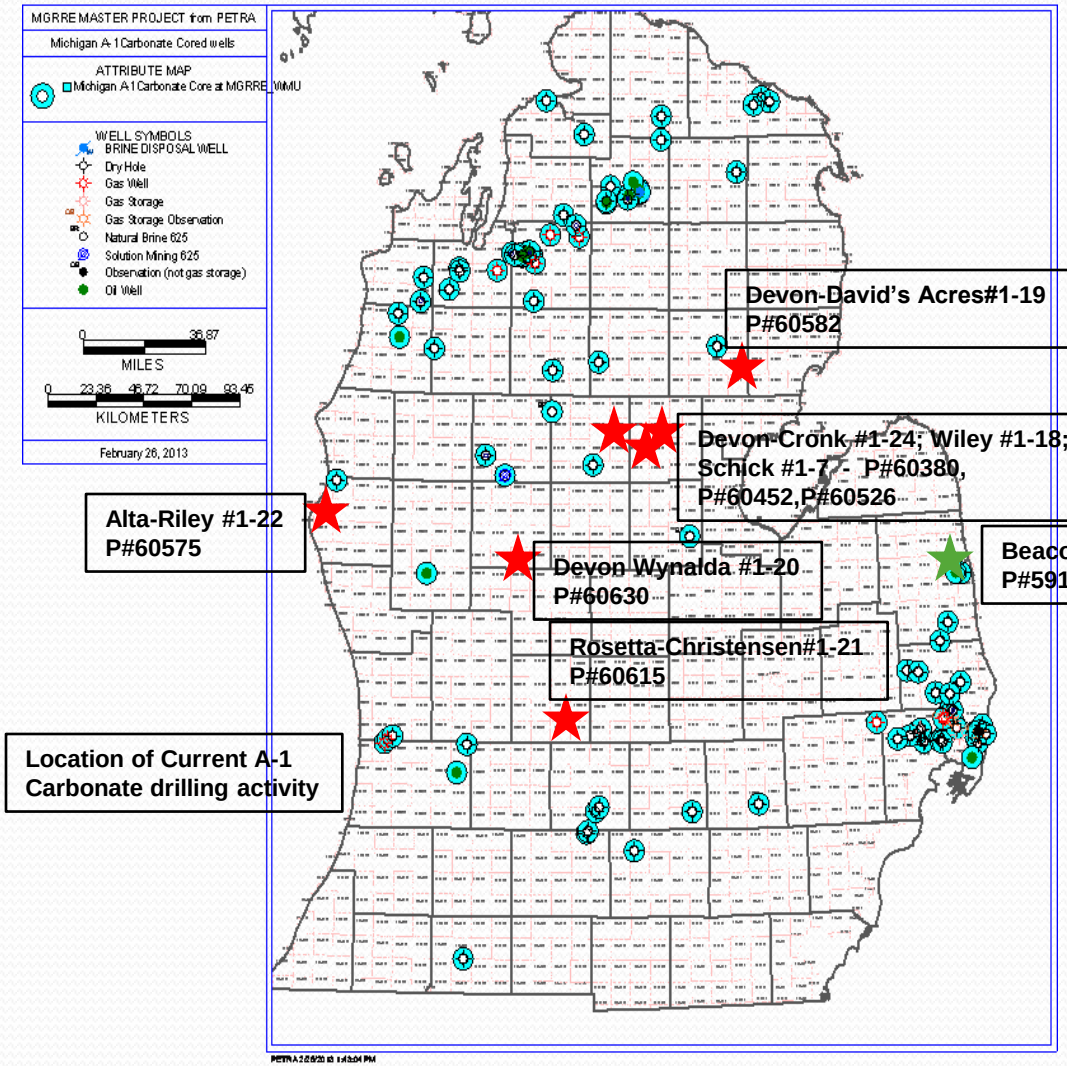
- Dorr - 386,025 BBLS Oil and 1,729,764 MCF Gas
- Wayland - 186,499 BBLS Oil and no Gas
- Diamond Springs - 112,176 BBLS Oil and no Gas
- Caledonia - 51,435 BBLS Oil and no Gas
- Hopkins West - 43,061 BBLS Oil and no Gas
- Hilliards - 23,975 BBLS Oil and 2,458,231 MCF Gas
- Salem - 2,973 BBLS Oil and 11,337,204 MCF Gas
- Overisel – no Oil and 14,937,949 MCF Gas
- Fillmore – no Oil and 5,972,038 MCF Gas

Central basin fractured and partially dolomitized

- Au Gres - 159,262 BBLS Oil and 1,511,379 MCF Gas
- Akron - 11,709 BBLS Oil and 56,763 MCF Gas

- This is the geologic setting of Devon's Central Basin Exploration attempts

Current and Recent A-1 Carbonate Exploration Tests



Recent A-1 Carbonate Test Wells

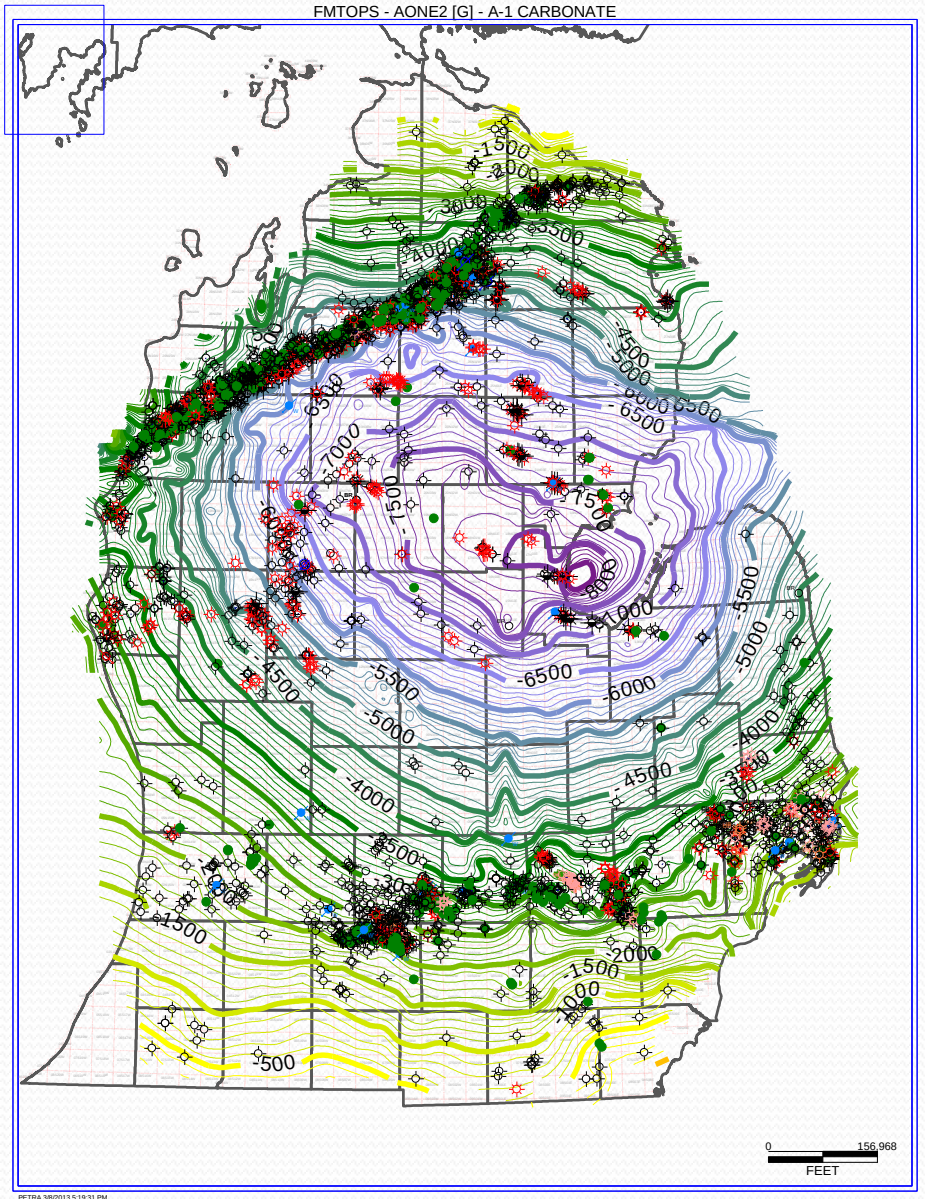
- Devon-Cronk #1-24P, (P#60379) Gladwin Co., 24-19N-1W (vertical pilot hole)
- Devon-Cronk #1-24HD1, (P#60380) Gladwin Co., 24-19N-1W
  - Tested - 198 MCF/D Nat. Gas
- Devon Wiley #1-18P, (P#60451) Gladwin Co., 18-18N-2W (vertical pilot hole)
- Devon Wiley #1-18HD1, (P#60452) Gladwin Co., 18-18N-2W
  - Tested – 178 MCF/D Nat. Gas
- Devon-Schick #1-7P, (P#60525) Clare Co., 7-19N-3W (vertical pilot hole only)
- Devon-Schick #1-7HD1, (P#60526) Clare Co., 7-19N-3W
- Devon-David's Acres #1-19P, (P#60581) Ogemaw Co., 19-22N-4E
- Devon-David's Acres #1-19HD1, (P#60582) Ogemaw Co., 19-22N-4E
- Devon-Wynalda #1-20, (P#60630) Mecosta Co., 20-13N-8W

Recent A-1 Carbonate Test Wells

- Alta-Riley #1-22, (P#60574) Oceana Co., 22-15N-18W (vertical pilot hole)
- Alta-Riley #1-22HD1, (P#60575) Oceana Co., 22-15N-18W
- Rosetta-Christensen #1-21P, (P#60614) Ionia Co., 21-6N-6W (vertical pilot hole)
- Rosetta-Christensen #1-21HD1, (P#60615) Ionia Co., 21-6N-6W

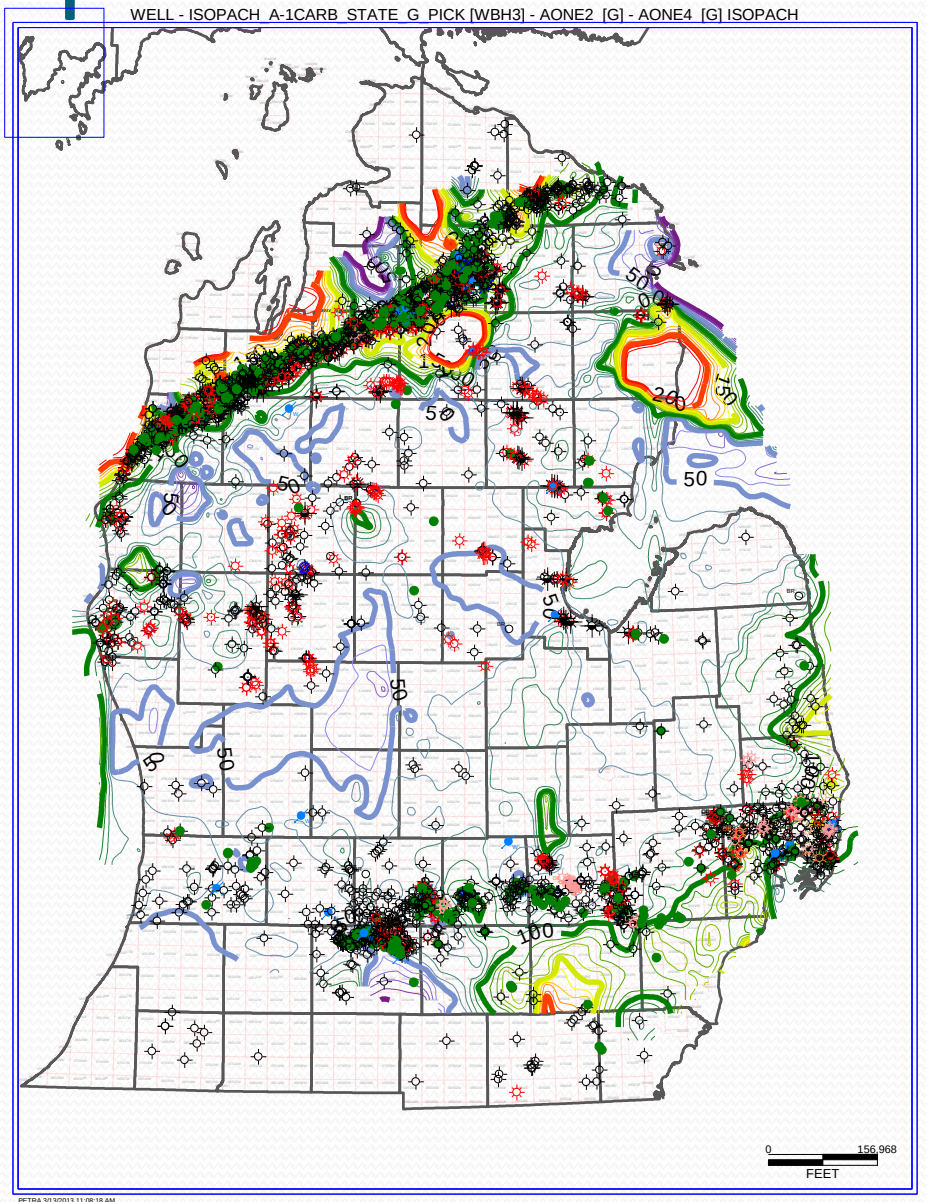
Top of A-1 Carbonate Structure (subsea depths)

- Slightly oval, deep central structural basin
- Maximum subsea depth around -8000 feet or slightly over 9000 feet drilled depth
- Subsea depths in front of reef trend from -3500 to -5500 feet



A-1 Carbonate Isopach

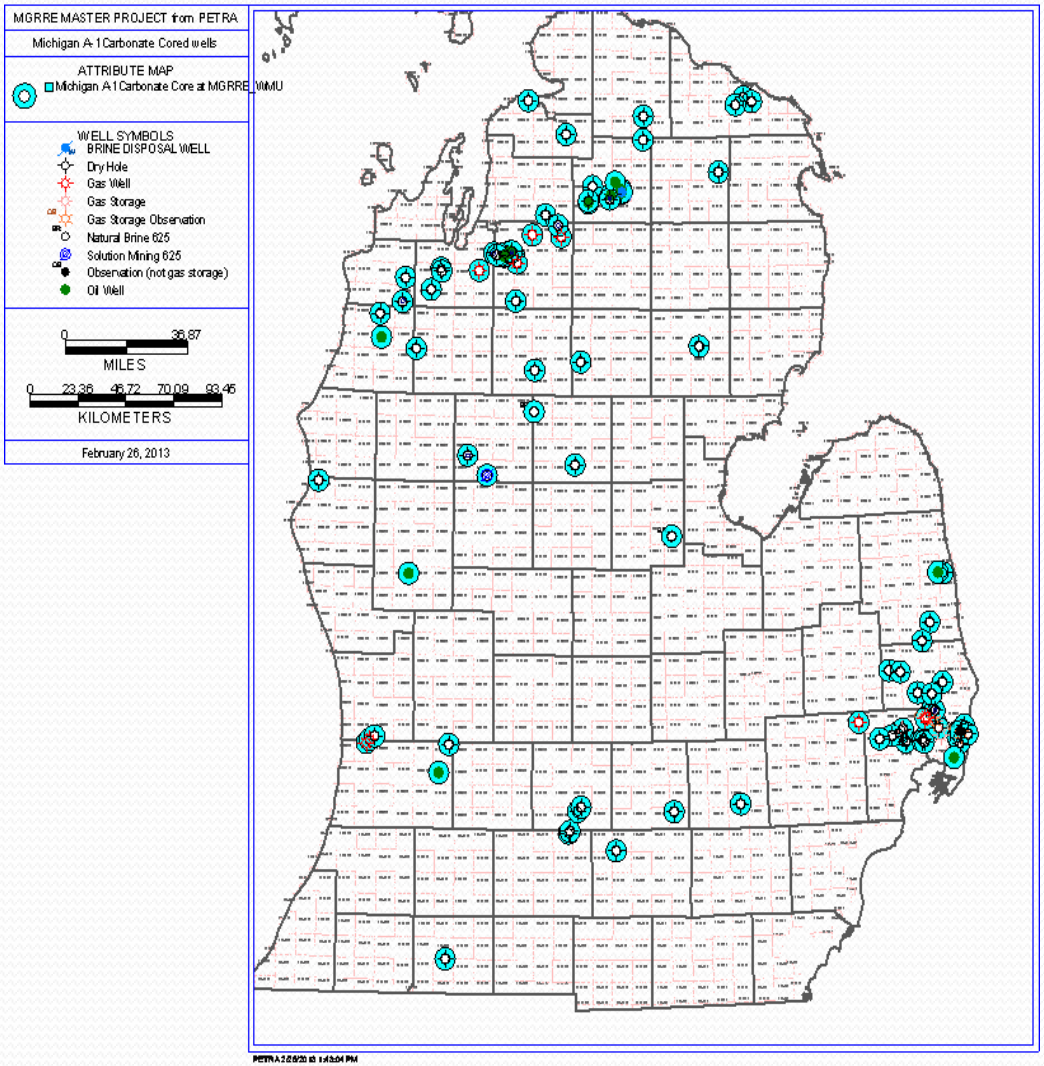
- Relatively uniform thickness in basin center from 50 to 75 feet thick
- Encased in two thick salts several hundred feet thick each
- Thickness increases in and around the Pinnacle Reef Trends to around 100 to 150 feet thick



Lithologic Properties of the A-1 Carbonate

- Generally laminated to massive micritic limestone or dolomite. Laminae alternate with organic-rich and carbonate rich layers, often at millimeter scale. Occasional anhydrite laminae or small nodules also interbedded.
- Sparse macrofossil content due to restricted environment of deposition.
- Burrowing very limited or absent.
- Fractures, vugs and intercrystalline pores often contain clear halite.

A-1 Carbonate Cored Wells at MGRRE



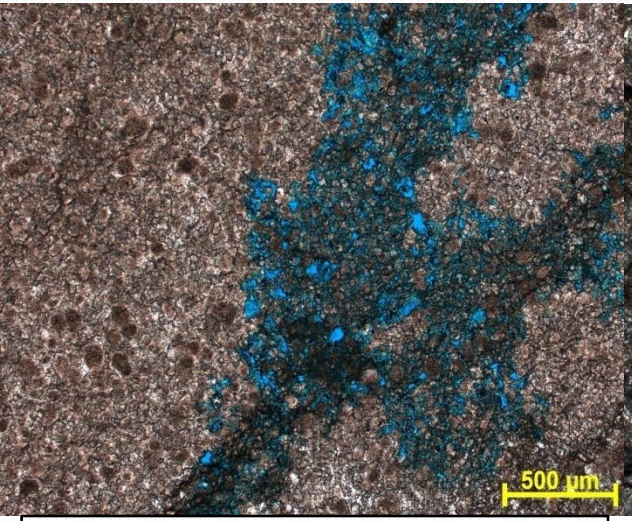
A-1 Carbonate Facies in and around Pinnacle Reef Trend

David #1, Calhoun Co.

Francis #1, Sanilac Co.

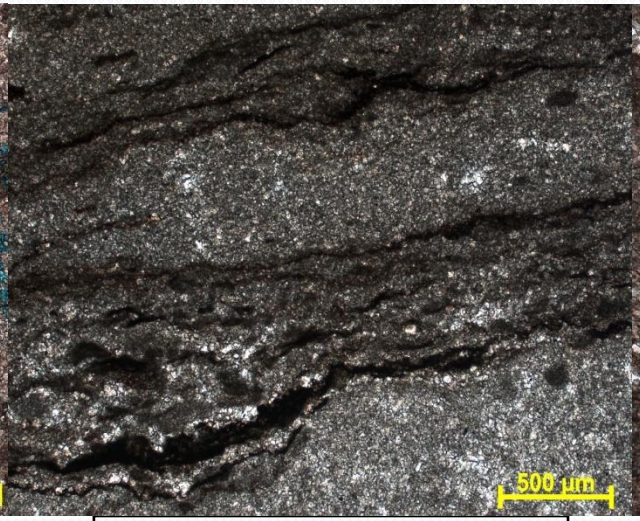
Halmich #2-1, St. Clair Co.

Thin Section in and Around the Pinnacle Reef Trend



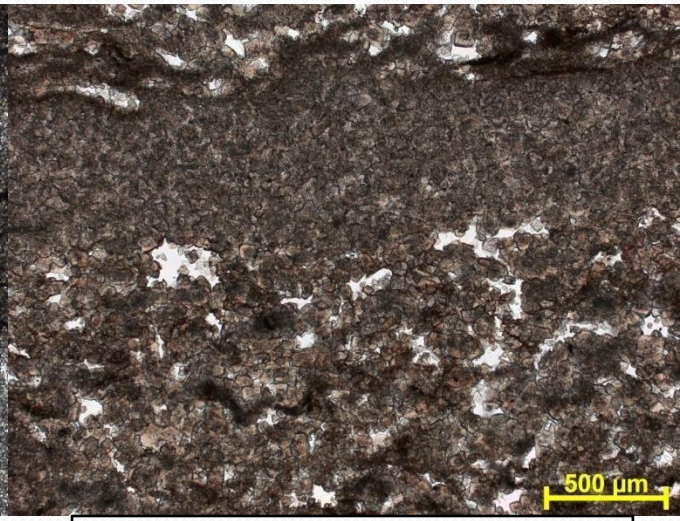
Partly porous (Blue) and Cemented skeletal and ooid grainstone

Cook #1, St. Clair Co.



Micritic Limestone With Organic Laminae

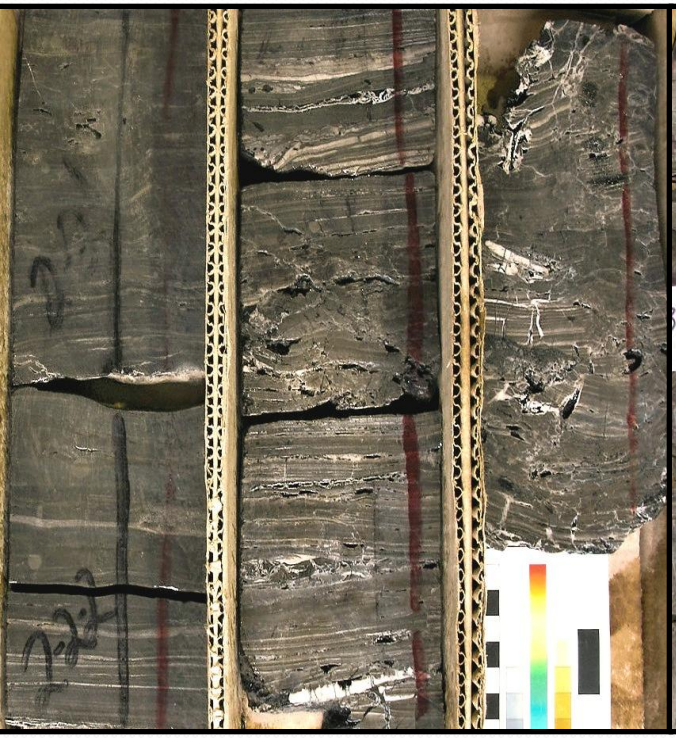
Kenney #3-22, Otsego Co.



Salt filled Porosity in white

Ruff #1-36, St. Clair Co.

Fractured, partially-dolomitized areas of salt withdrawal

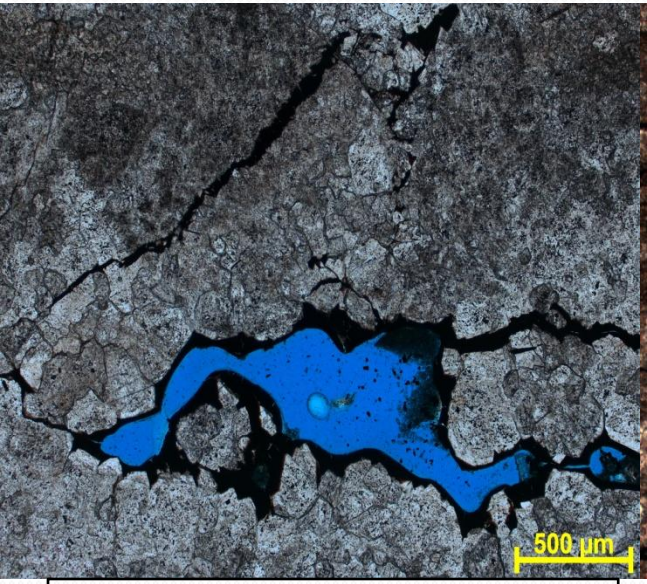


Mulder #1, Ottawa Co.

Lauber 12, Oceana Co.

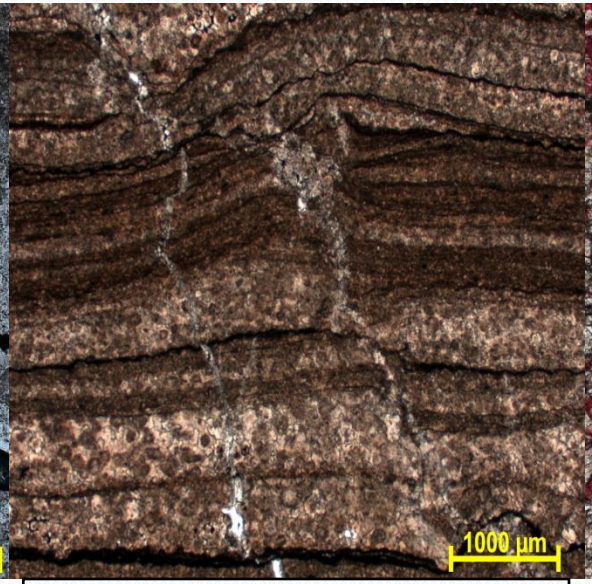
Bradley #4, Newaygo Co.

Thin Section Photos from Fractured, Dolomitized Salt Withdrawal Area



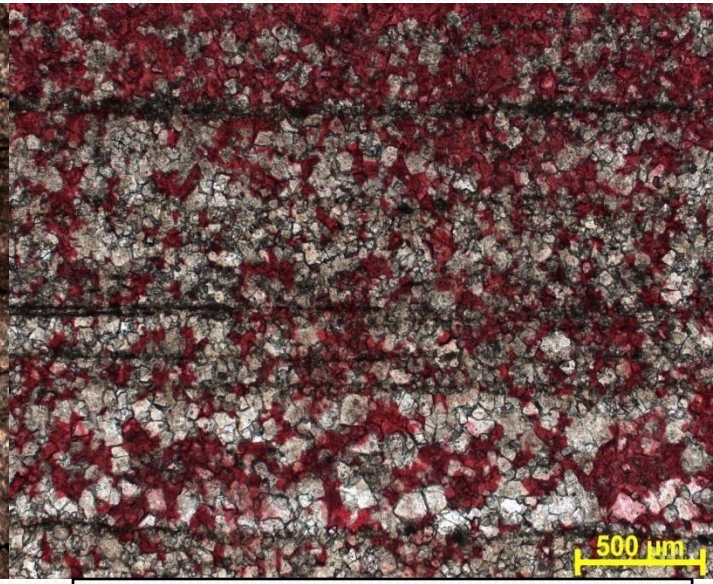
Porous vug with oil residue

Mulder #1, Ottawa Co.



Organic and CO3 Laminae and cemented Fractures

Mulder #1, Ottawa Co.



Partial replacement of Calcite (red) with Dolomite

Mulder #1, Ottawa Co.

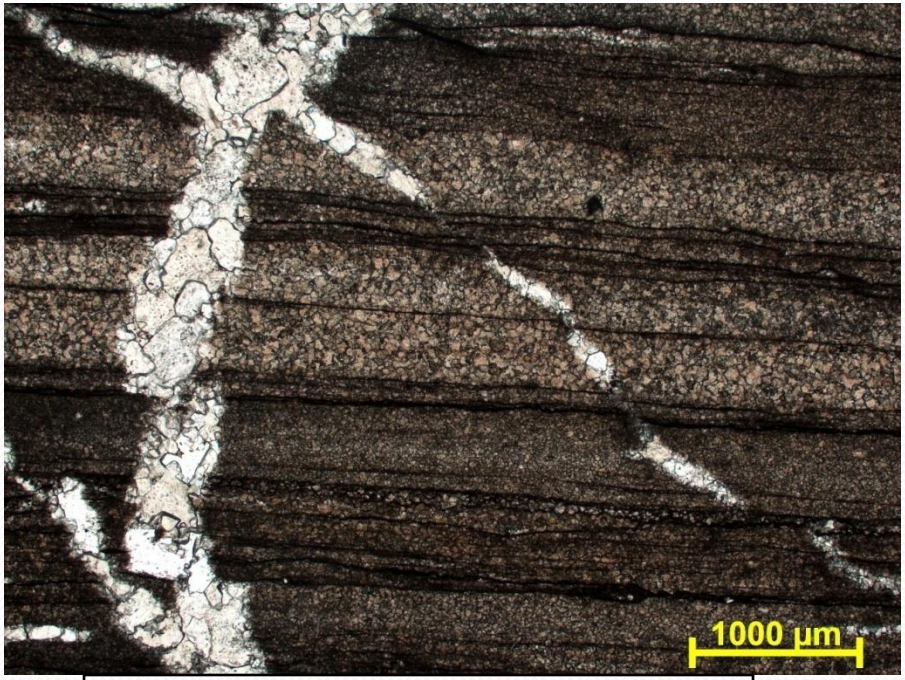
Central Basin, Fractured, Partially-Dolomitized

Bruske #1-26A, Osceola Co.

Dow Chemical 8SM, Midland Co.

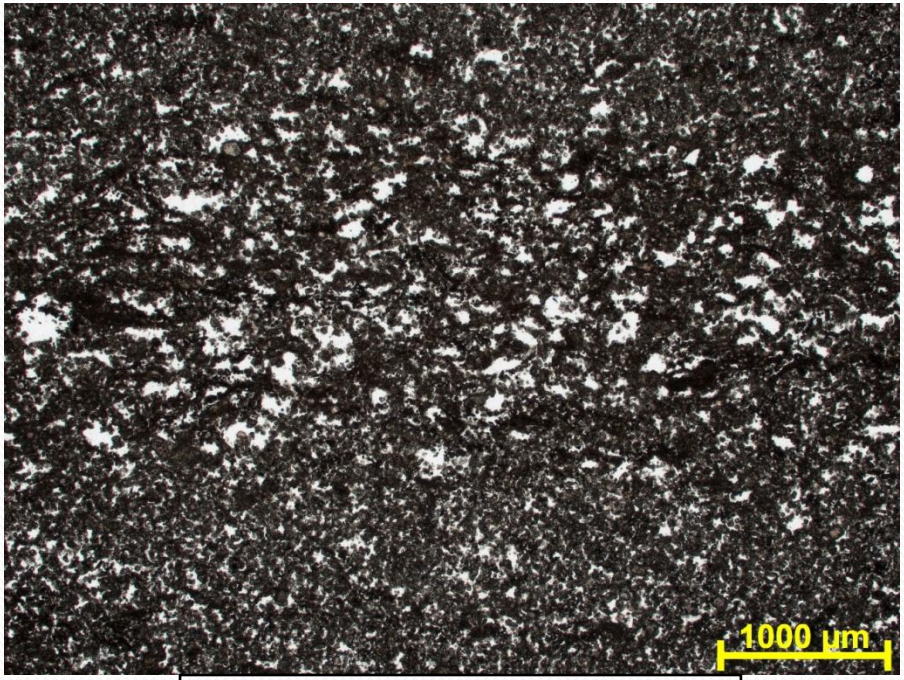
Dalrymple #1-16, RoscommonCo.,

Thin Section Views from Basin Center Facies



Organic and Carbonate Laminae

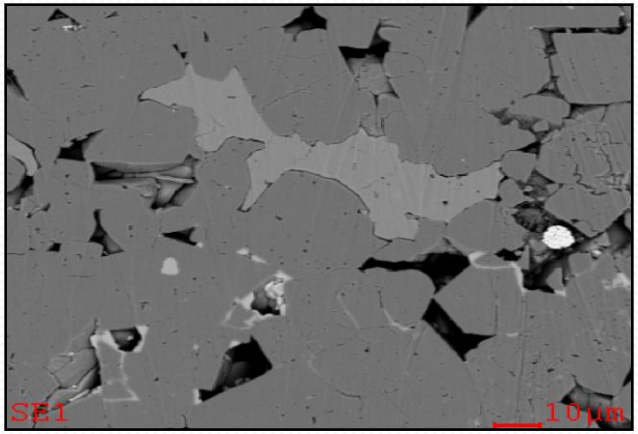
ABG Hunt Club #1, Ogemaw Co.

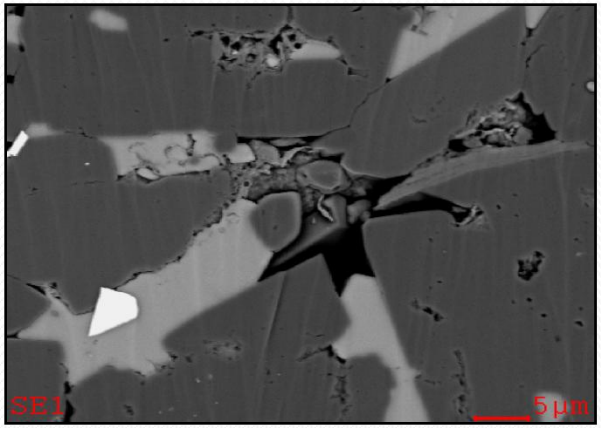


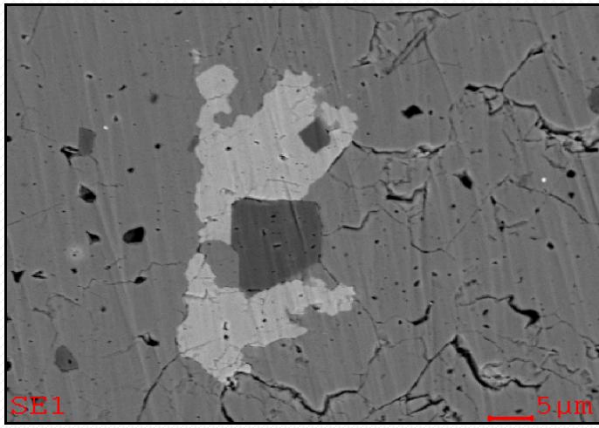
Salt filled Porosity in white

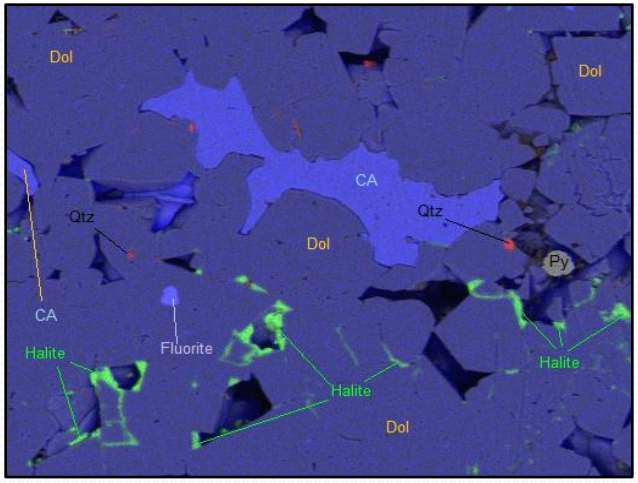
ABG Hunt Club #1, Ogemaw Co.

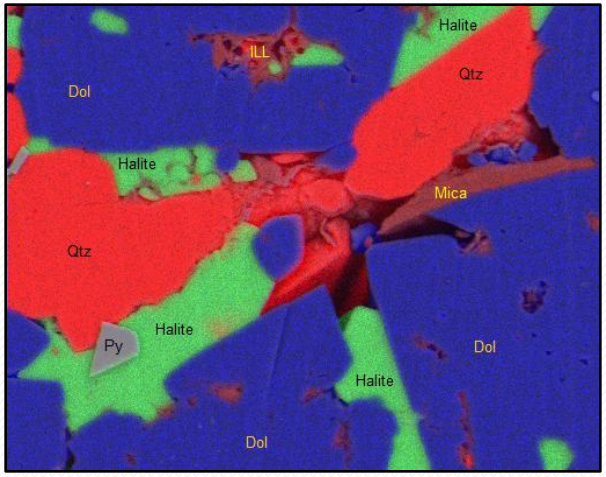
Electron Backscatter and EDS Mineral Mapping

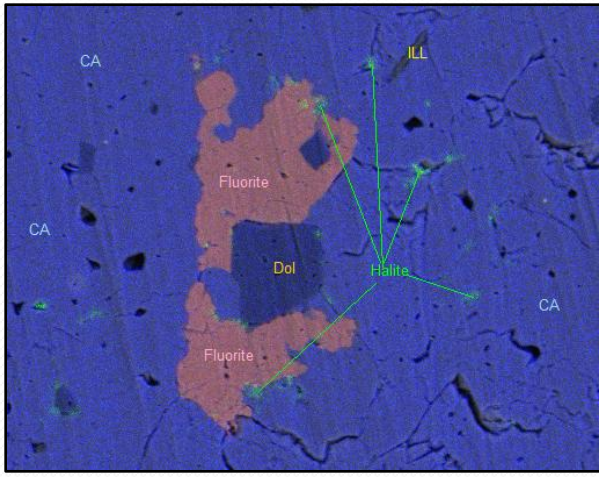












Lauber 12, Oceana Co.

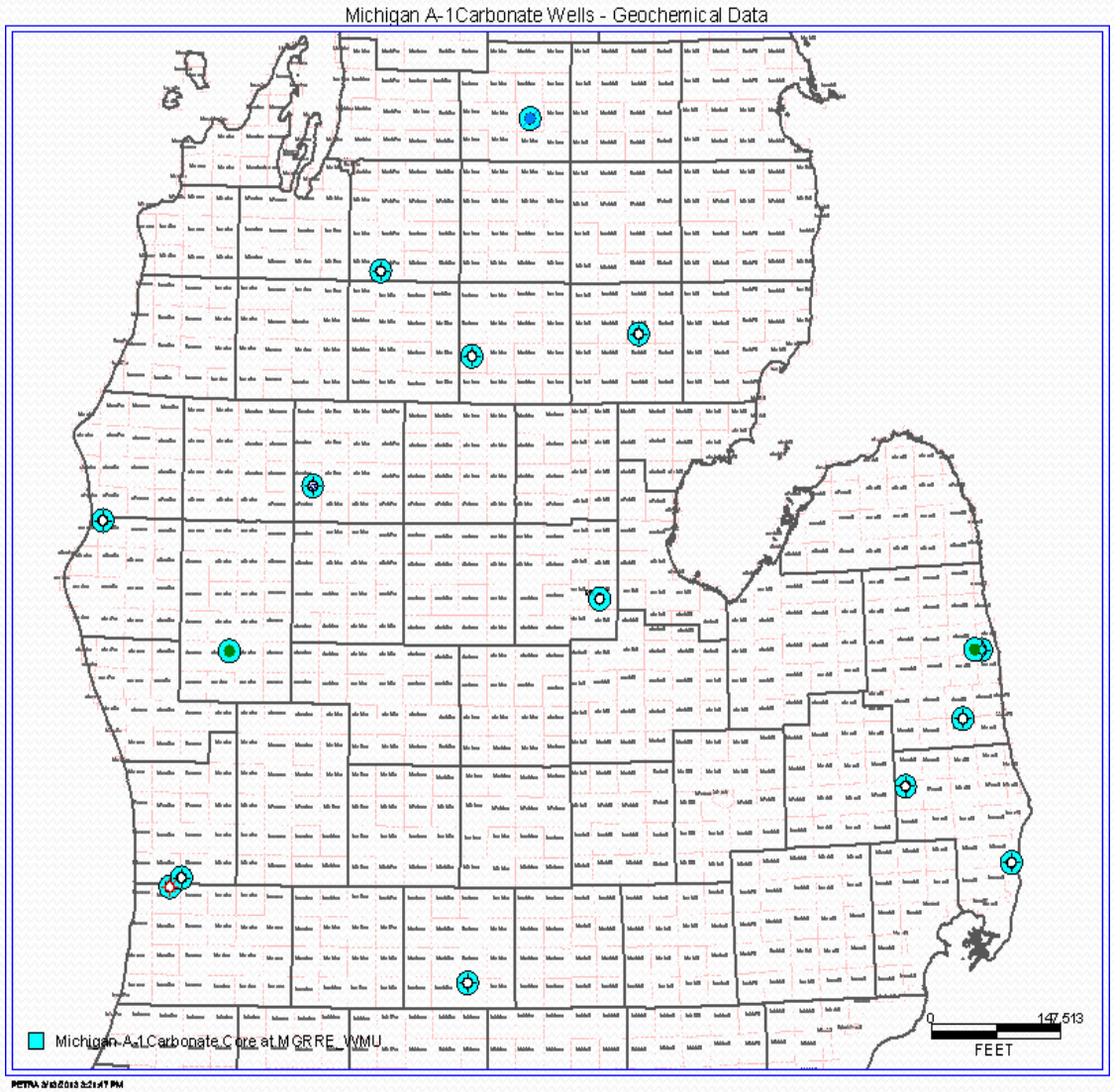
Dalrymple #1-16, Roscommon Co.

Kenney #3-22, Otsego Co.

Core and Analytical Data Available at MGRRE, Western Michigan University

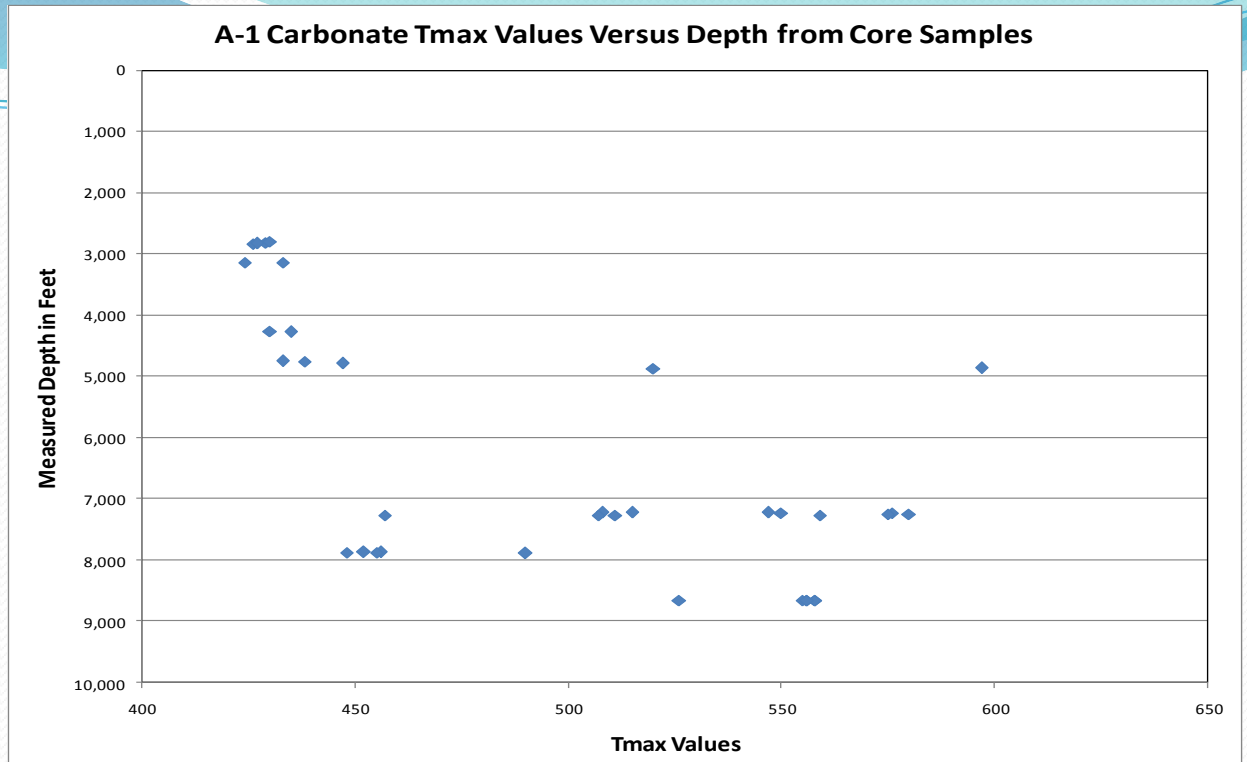
- Cores from 104 wells that are located in all three of the primary geologic settings with historical production
- Drill cuttings from hundreds of additional wells
- Selected thin section of core samples and some drill cuttings
- Geochemical data for selected wells
  - TOC
  - Rock Eval
  - Thermal Maturity Analyses

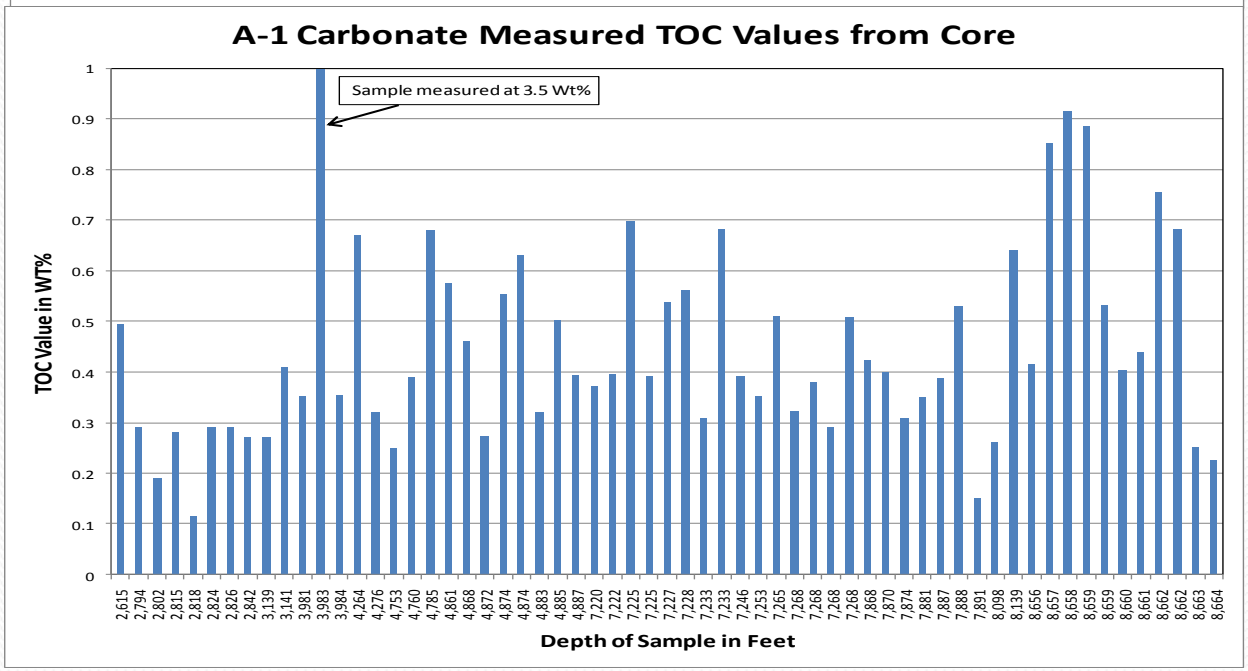
Cores with Geochemical Data



Geochemical Data from Cores

- Rock Eval data for Tmax is somewhat questionable due to low S2 values
- TOC Values range from 0.1 to 3.5, with most samples from 0.3 to 0.8 Wt%





Summary

- A-1 Carbonate historic production has occurred in three separate geologic settings
  - Within the Silurian Niagaran Pinnacle Reef Trend on top or on flanks of reefs – Selected reefs in Otsego, Manistee, Alpena, St. Clair and Macomb Counties
  - Fractured, partially-dolomitized A-1 and A-2 Carbonate in western Michigan areas of salt withdrawal in the A-1 and A-2 Salt Fracturing and structural closure
  - Central basin fractured and partially dolomitized, not related to salt withdrawal, structural closure uncertain
- Facies are restricted, laminated with interlayered organic and carbonate and more carbonate-rich near the Pinnacle reef trends

Summary

- Formation is thinnest and deepest in basin center and thickens around margin in pinnacle reef trend
- TOC is low ranging from 0.1 to 3.5 Wt.%, mostly around 0.5 Wt%
- Tmax from Rock Eval analysis shows some increasing trend with increasing depth
- Porosity seems to be limited and isolated vuggy or intercrystalline (in dolomite), but fractures and secondary dissolution may enhance porosity and permeability