RESERVOIR CHARACTERIZATION AND ENHANCED OIL RECOVERY POTENTIAL IN MIDDLE DEVONIAN DUNDEE LIMESTONE

Abrahim Abduslam, William B. Harrison, III and David A. Barnes

Michigan Geological Survey

Western Michigan University

Acknowledgements

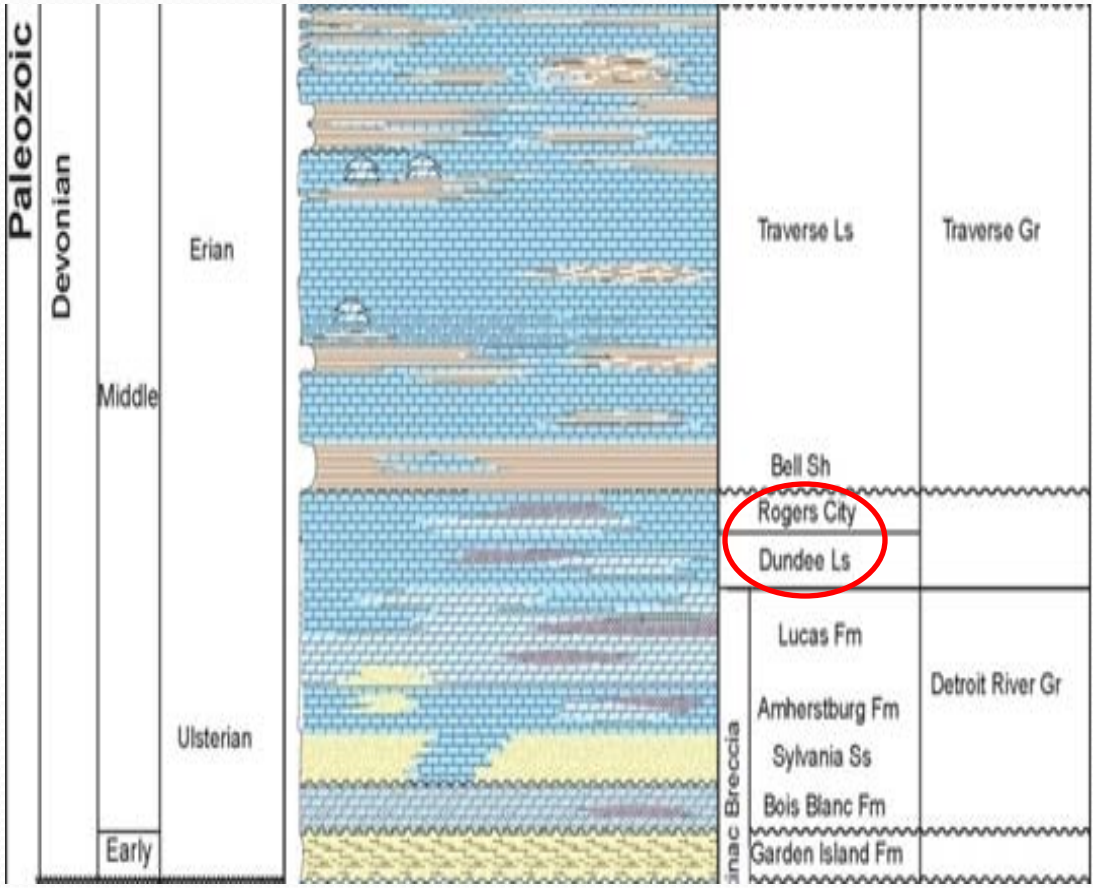
- Most of this presentation is derived from the Master's Thesis of Abrahim Abduslam, 2012
- David A. Barnes was the major advisor for this thesis project
- Core samples and well information and reservoir data was utilized from the collections of the Michigan Geological Repository for Research and Education (MGRRE) at Western Michigan University – now part of the Michigan Geological Survey

Dundee and Rogers City Production History

- Reservoirs in Middle Devonian, Shallow Shelf carbonates
- Cumulative historic oil production reported from over 150 fields is approximately 375 million BBLS
- 40 fields have produced over 1 million BBLS and 10 fields have produced over 10 million BBLS
- Rogers City reservoirs are predominately bottom water-drive, fractured dolomite reservoirs
- Dundee reservoirs are predominately gas expansion drive, depositional facies-controlled limestone reservoirs

Dundee and Rogers City Stratigraphy

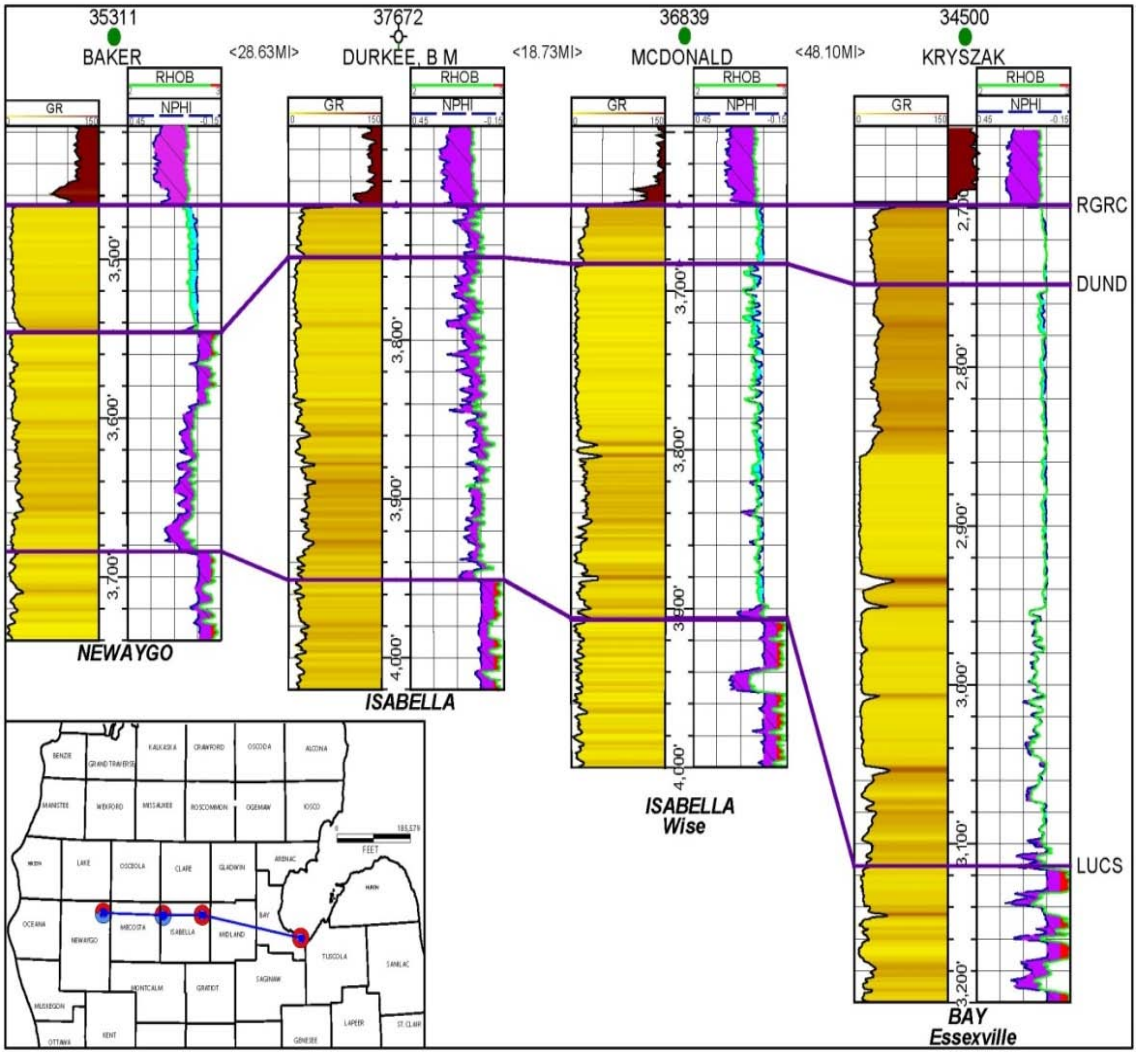
- Rogers City and Dundee Formations are defined from exposures in Quarries in Presque Isle Co.
- Dundee is general name for entire carbonate strata between Lucas Fm. and Bell Shale
- Both can be distinguished in subsurface



(modified from Catacosinos et al., 1990)

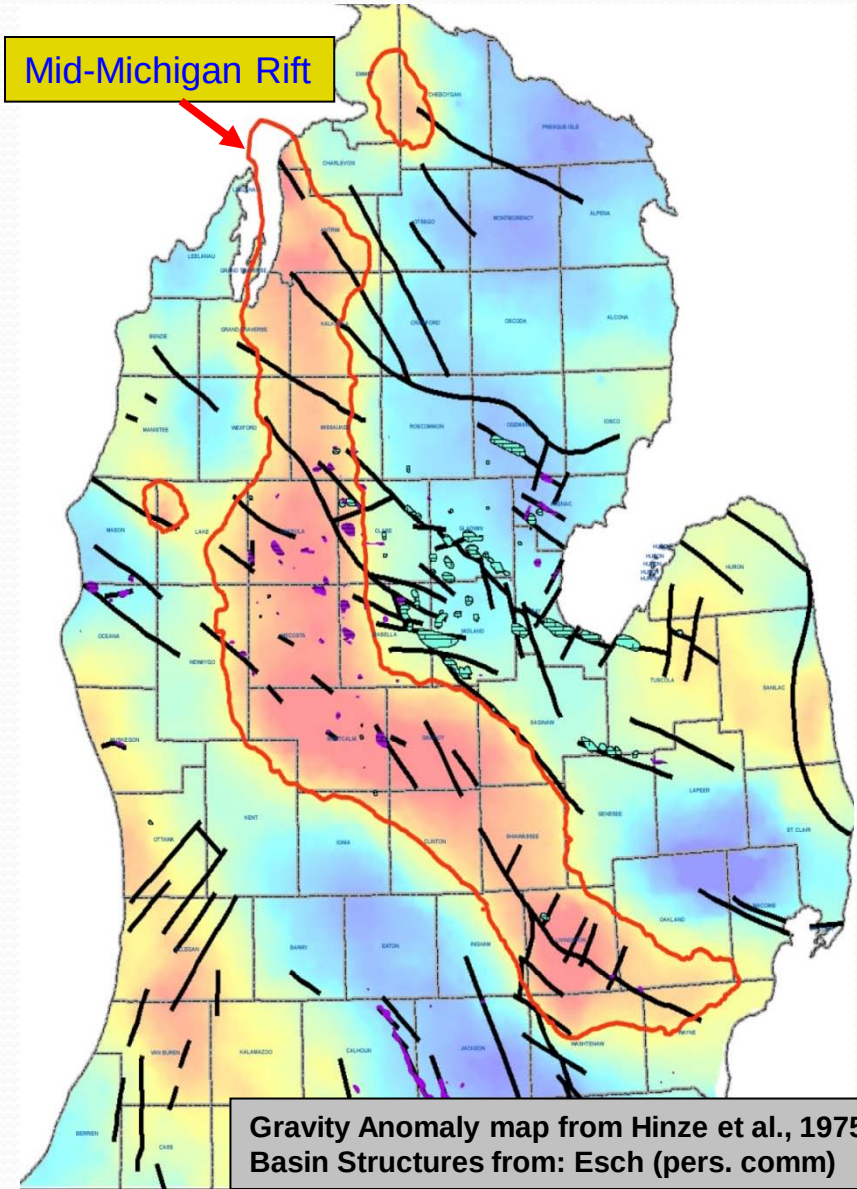
Rogers City/ Dundee Stratigraphy

- Rogers City ranges from 30 to 100 feet thick. It may be limestone or dolomite
- Dundee ranges from 150 to 400 feet thick. It is mostly dolomite in the west and central basin and limestone in eastern basin. Reed City Anhydrite and Dolomite are members of the Dundee in the west



Michigan Structural Features and Dundee Fields

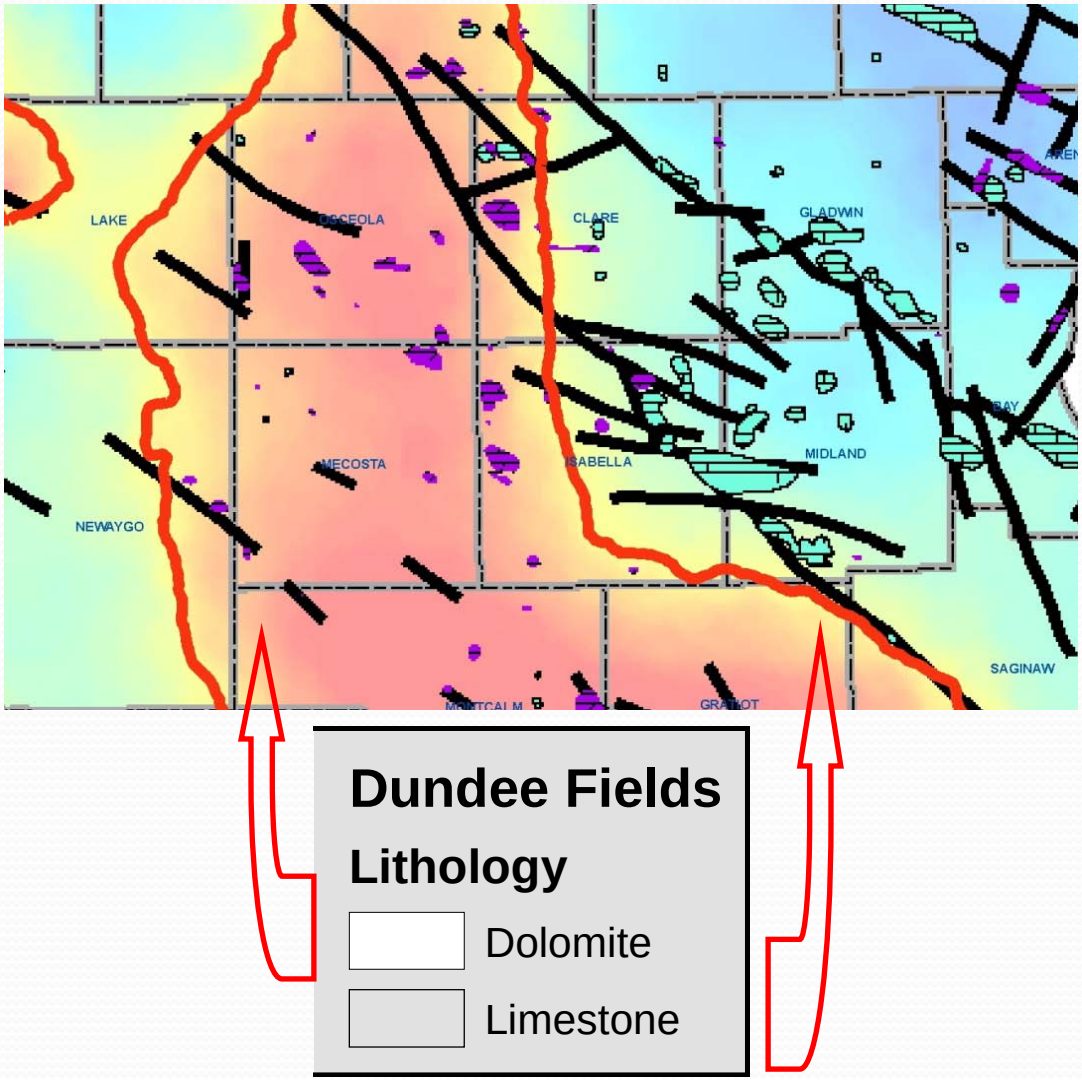
- Many Dolomite fields are related to the mid-Michigan Rift/Gravity Anomaly
- Most Dolomite fields are formed by hydrothermal processes
- Most Limestone fields are in the eastern half of the basin
- Most Limestone fields reflect original depositional facies



Gravity Anomaly map from Hinze et al., 1975;
Basin Structures from: Esch (pers. comm)

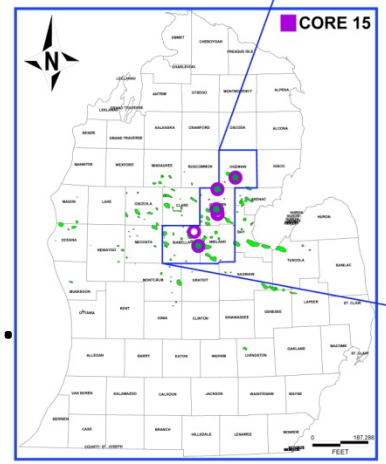
Dundee and Rogers City Fields

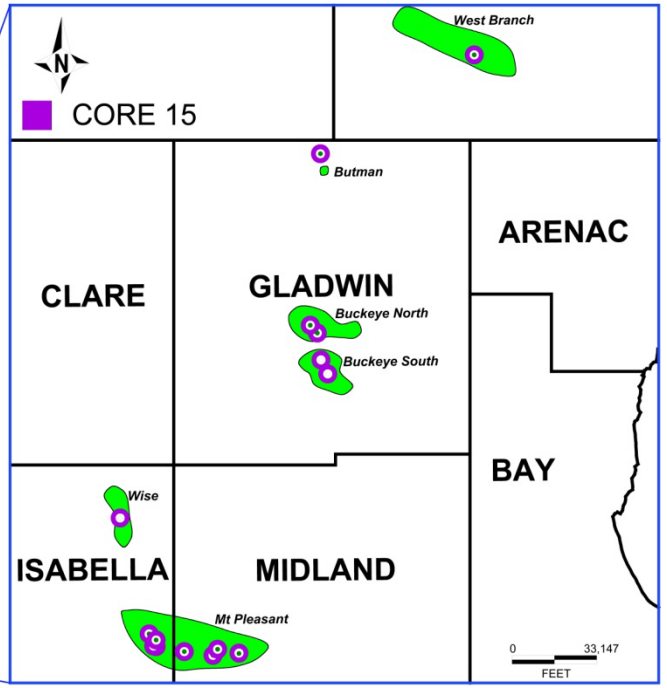
- Dolomite fields have most of reservoir interval in Rogers City Fm. with Bell Shale as seal
- Limestone fields have reservoir in Dundee Fm. With tight limestone of Rogers City Fm. as seal



Dundee Fields Core Study

- 15 cores from 6 Dundee Limestone fields were studied in this project
- Wise – Isabella Co.
- Mt. Pleasant – Isabella/Midland Co.
- S. Buckeye – Gladwin Co.
- N. Buckeye – Gladwin Co.
- Butman – Gladwin Co.
- West Branch – Ogemaw Co.

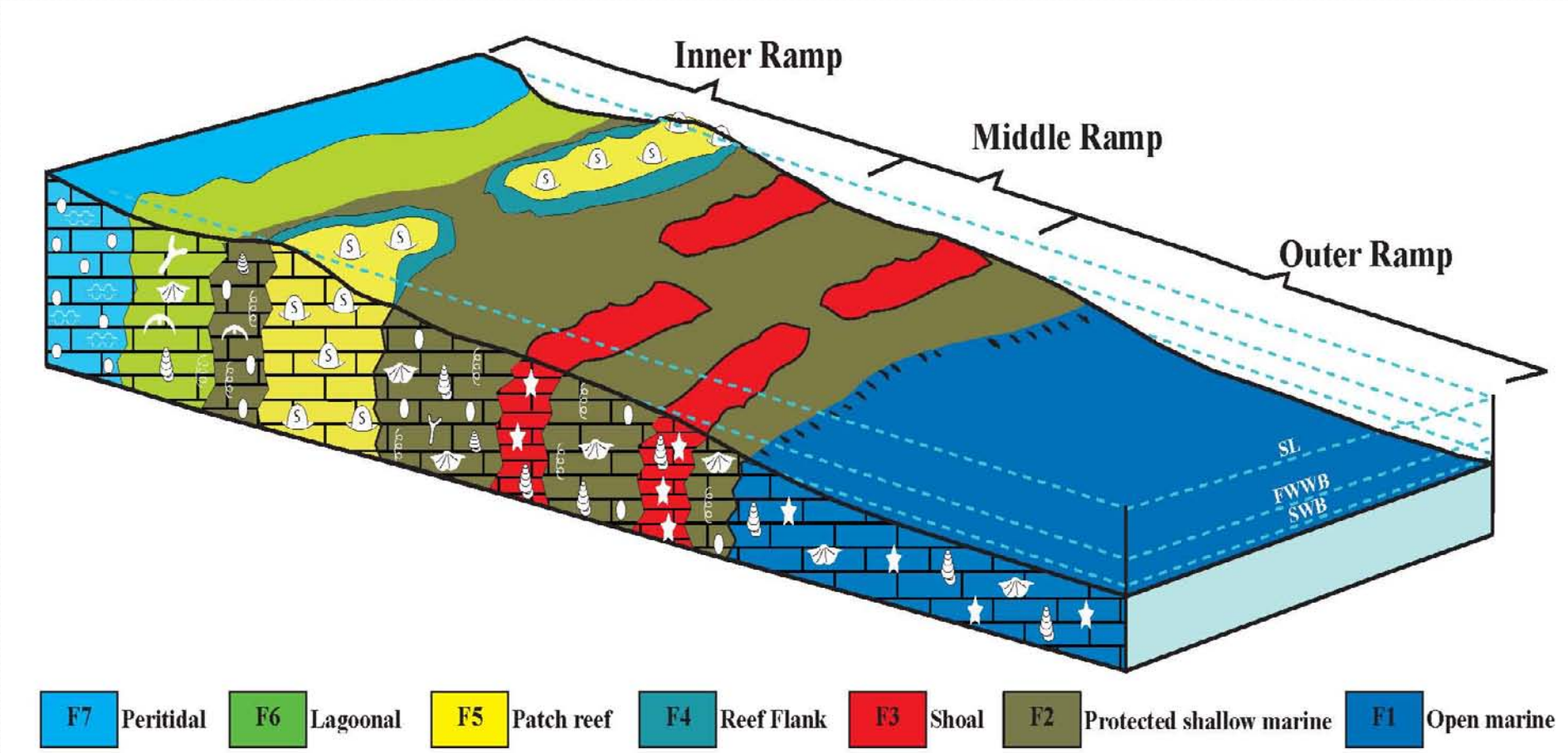




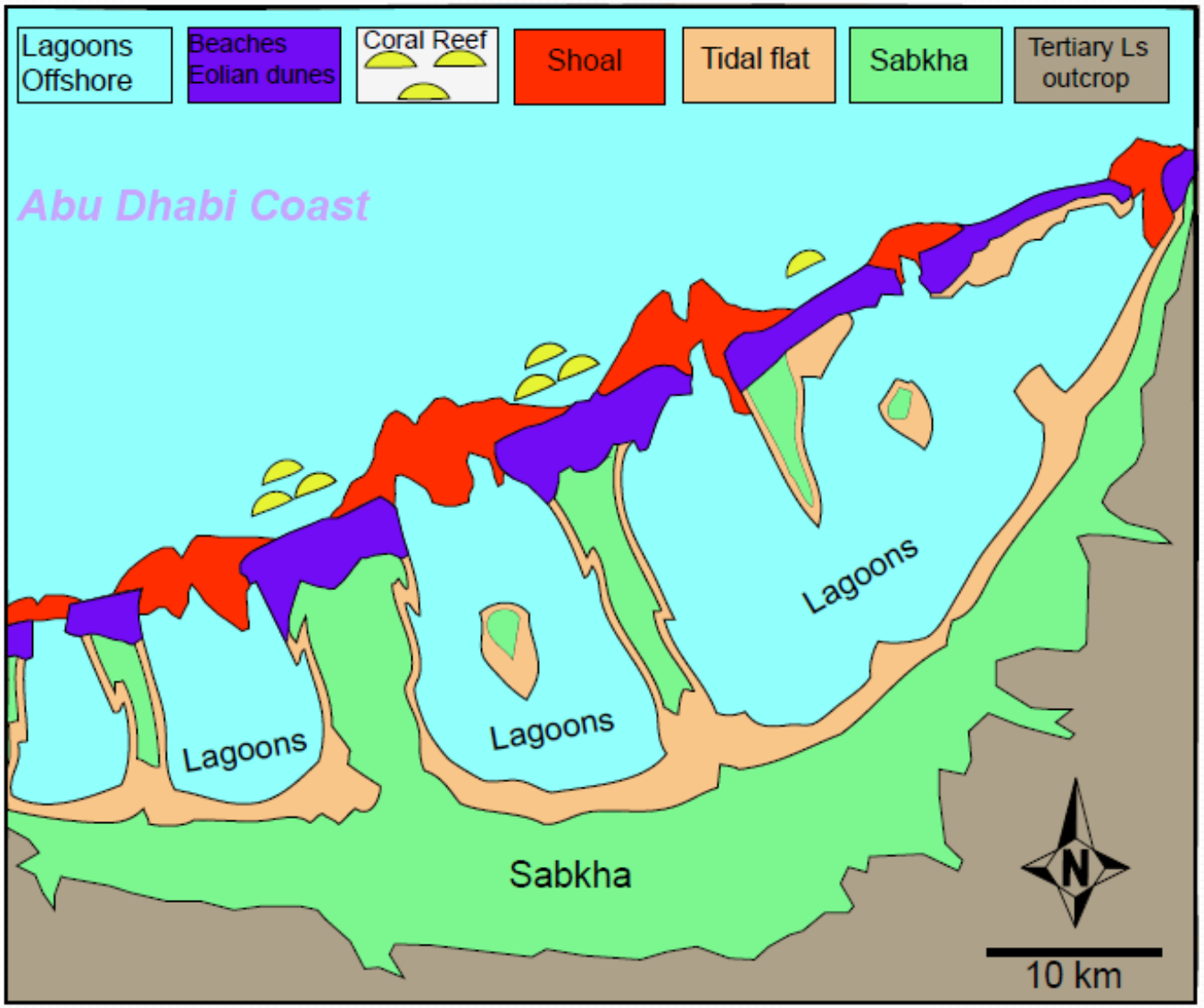
Rogers City and Dundee Facies Defined from Cores

- Facies 1: Crinoidal skeletal wackestone (Open Marine)
- Facies 2: Bioturbated peloidal grainstone/packstone (Protected Shallow Marine)
- Facies 3: Crinoidal grainstone (Shoal)
- Facies 4: Coral-stromatoporoid rudstone (Reef Flank)
- Facies 5: Stromatoporoid boundstone (Patch Reef)
- Facies 6: Skeletal wackestone (Lagoon)
- Facies 7: Fenestral peloidal grainstone/packstone (Peritidal)

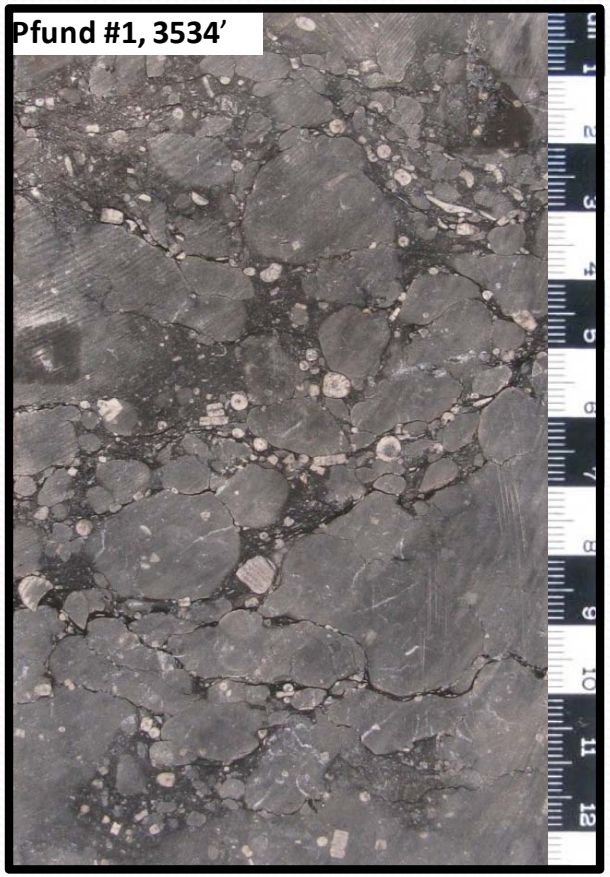
Dundee and Rogers City Depositional Facies Interpreted from Cores

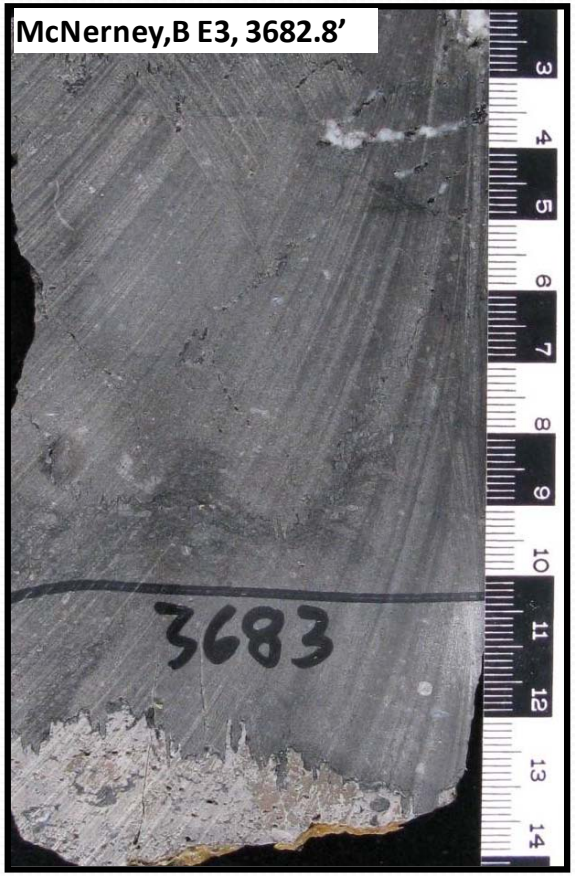


Abu Dhabi Coast – Modern Analog

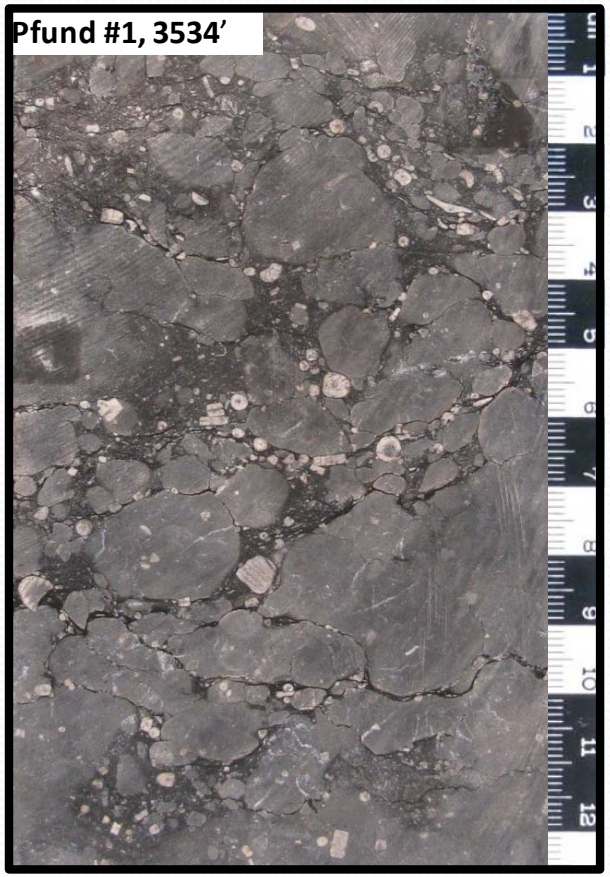


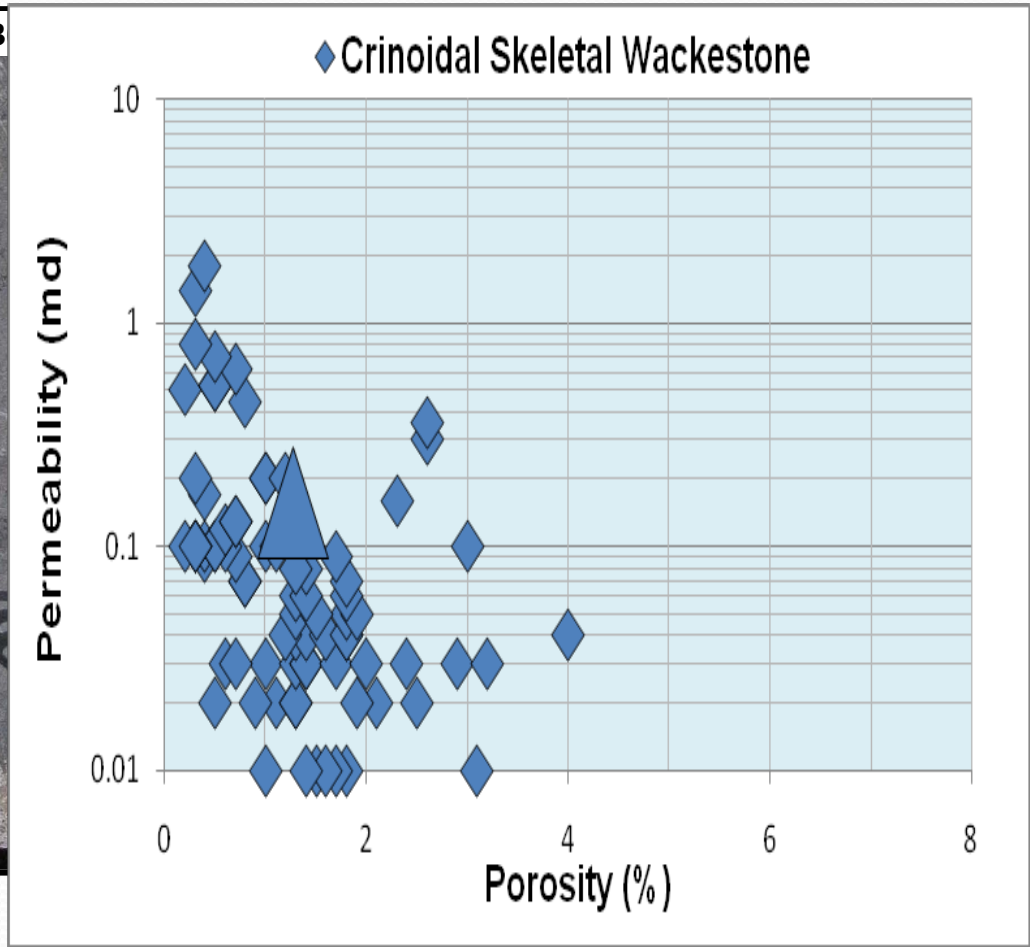
Facies 1: Crinoidal skeletal wackestone (Open Marine)





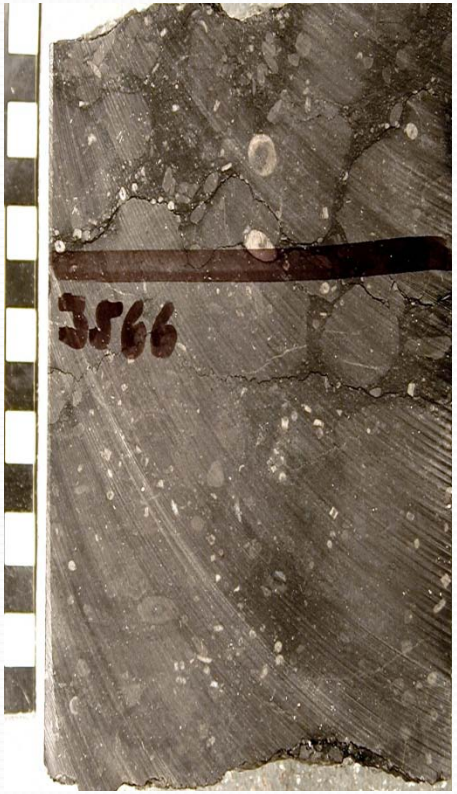
Facies 1: Crinoidal skeletal wackestone (Open Marine)





Rogers City Dolomite Reservoirs

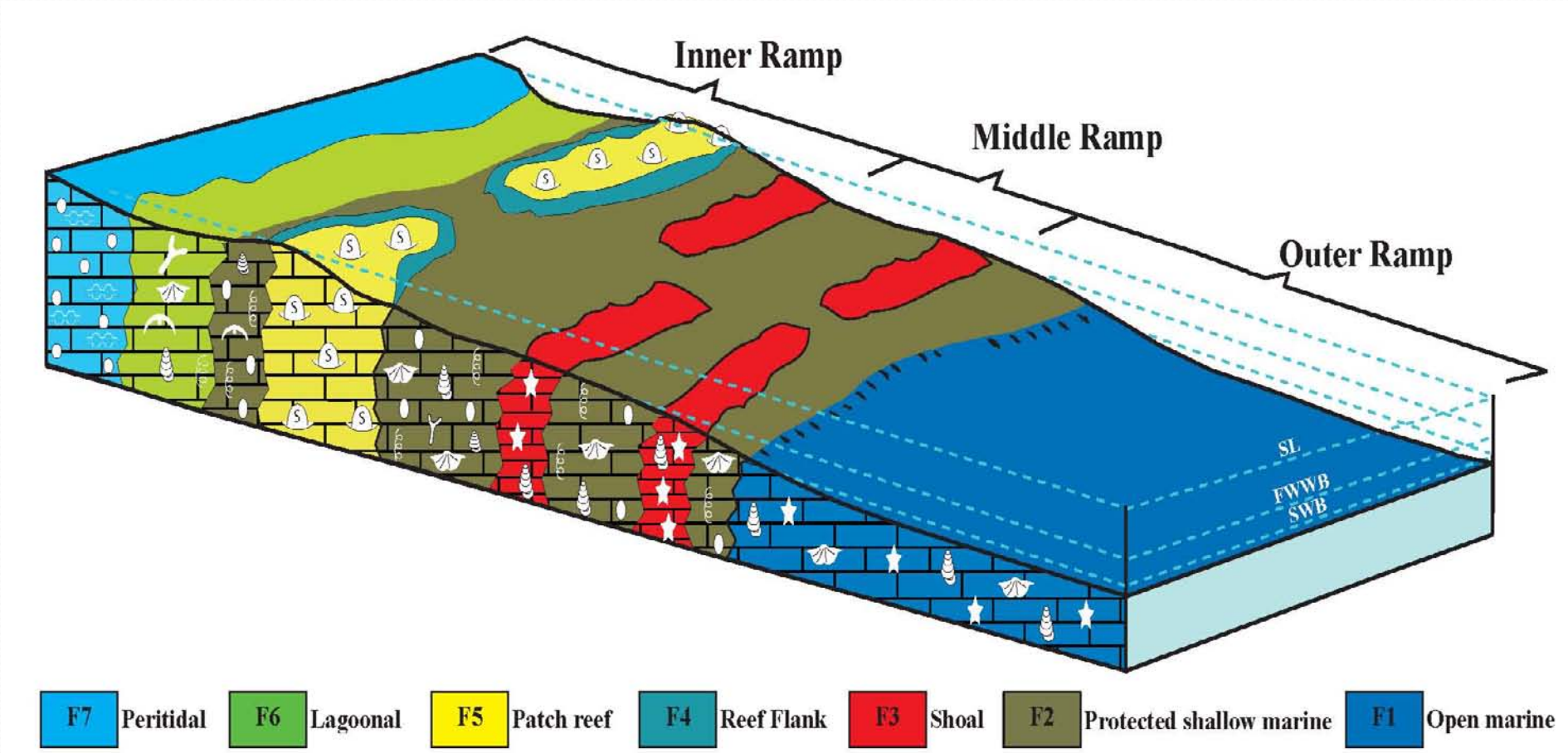
- Primarily Crinodial Skeletal Wackestone Facies
- Non-reservoir when Limestone
- Good reservoir when Fractured and dolomitized
- Most dolomite appears to be hydrothermal in origin



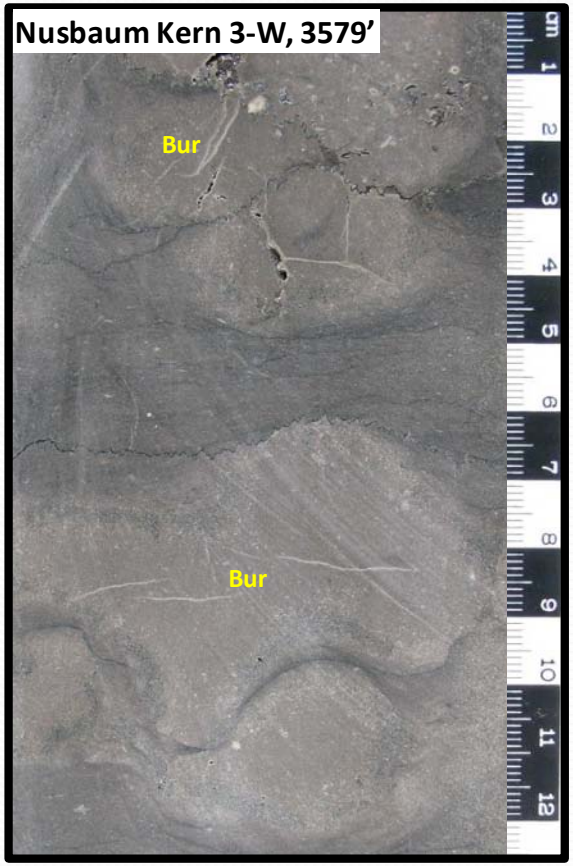
Tight Limestone –
Sturm #4-0
S. Buckeye Field

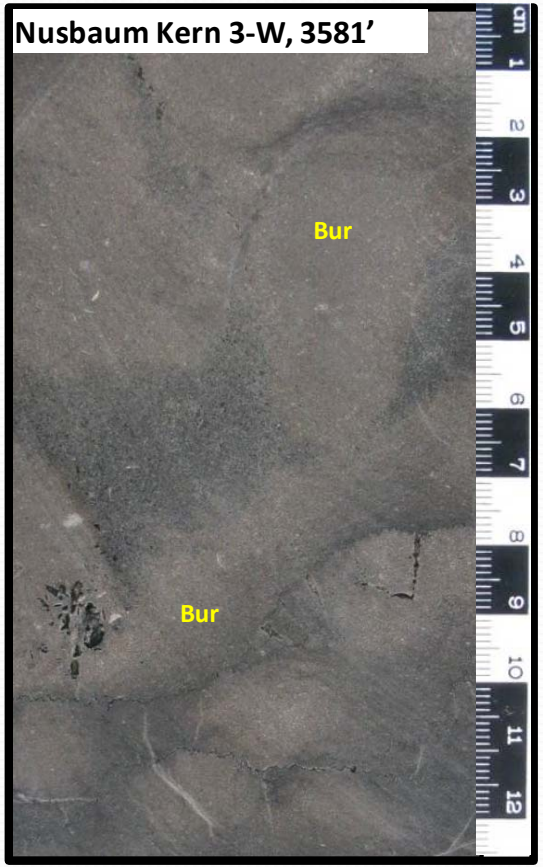
Fractured Dolomite –
Rousseau #1-12
Fork Field

Dundee and Rogers City Depositional Facies Interpreted from Cores

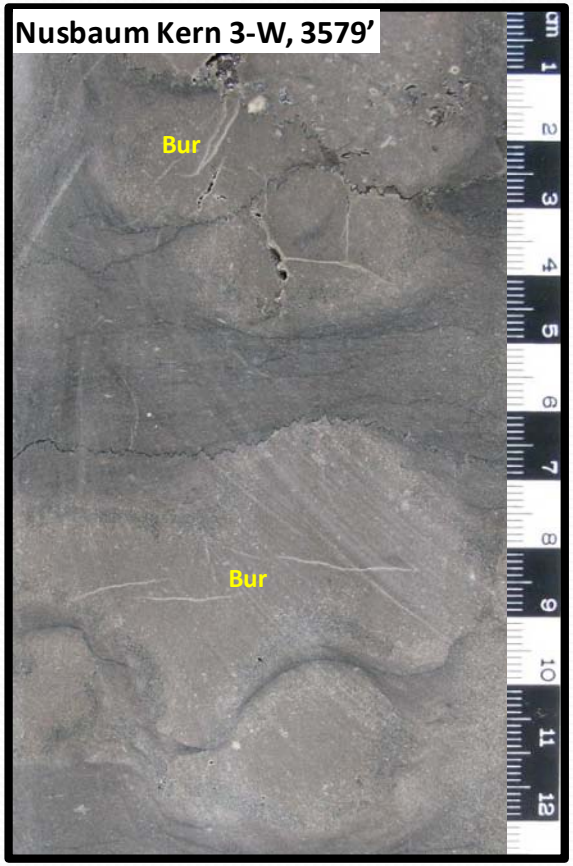


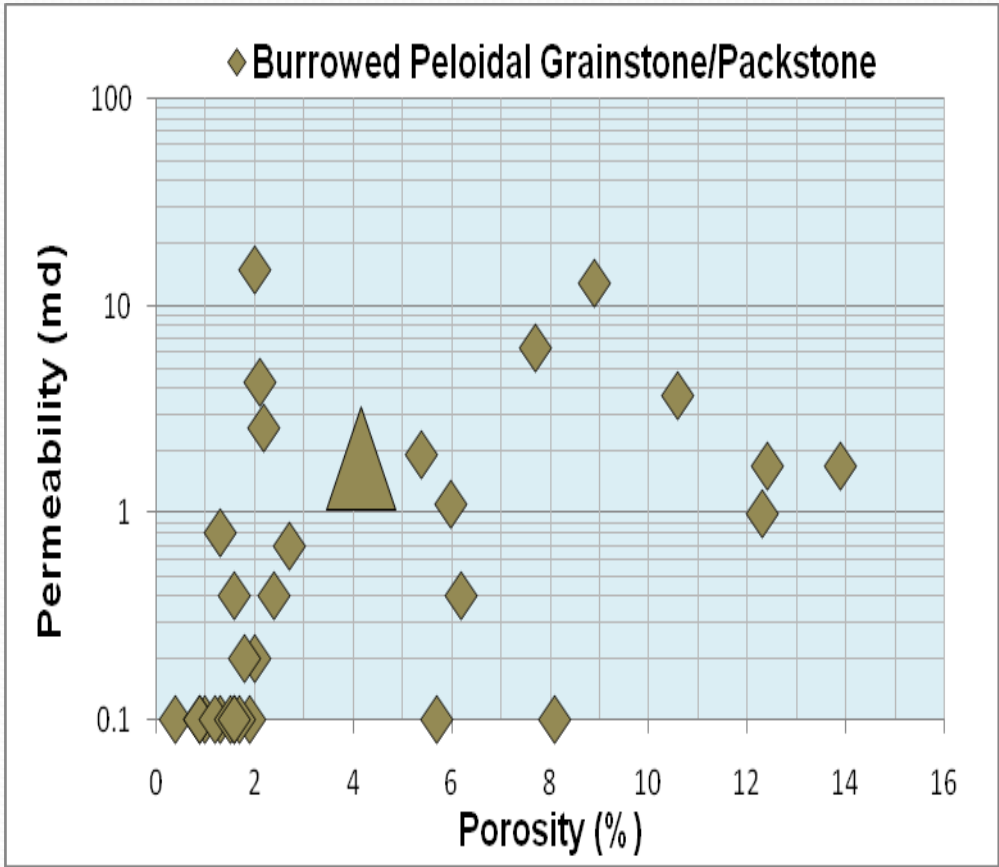
Facies 2: Bioturbated peloidal grainstone/packstone (Protected Shallow Marine)



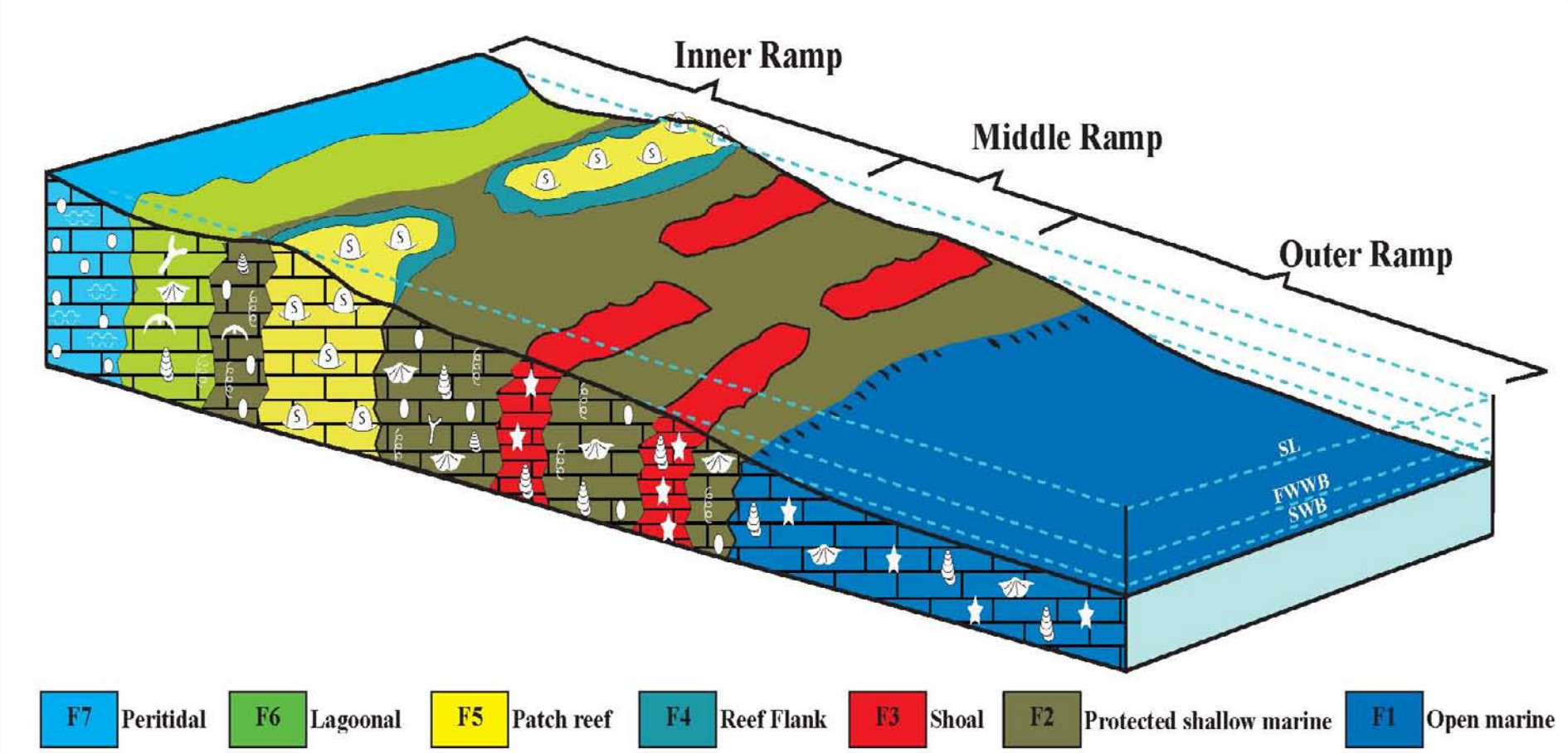


Facies 2: Bioturbated peloidal grainstone/packstone (Protected Shallow Marine)



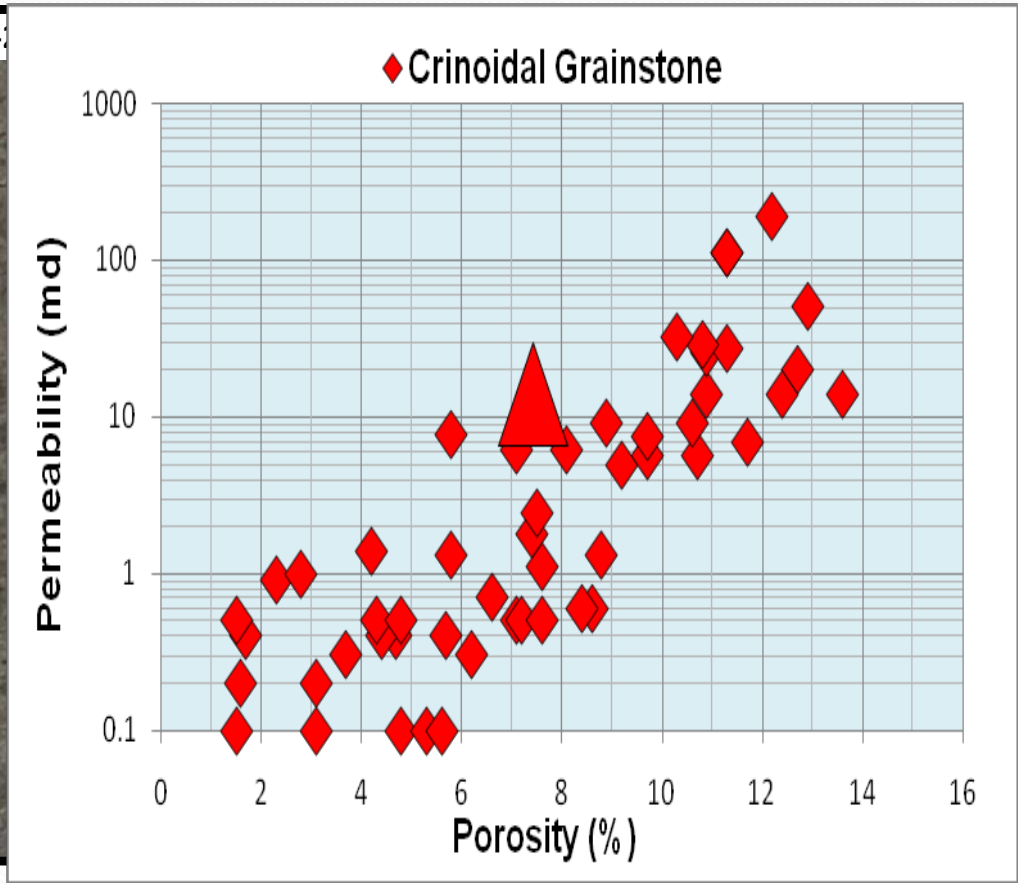


Dundee and Rogers City Depositional Facies Interpreted from Cores

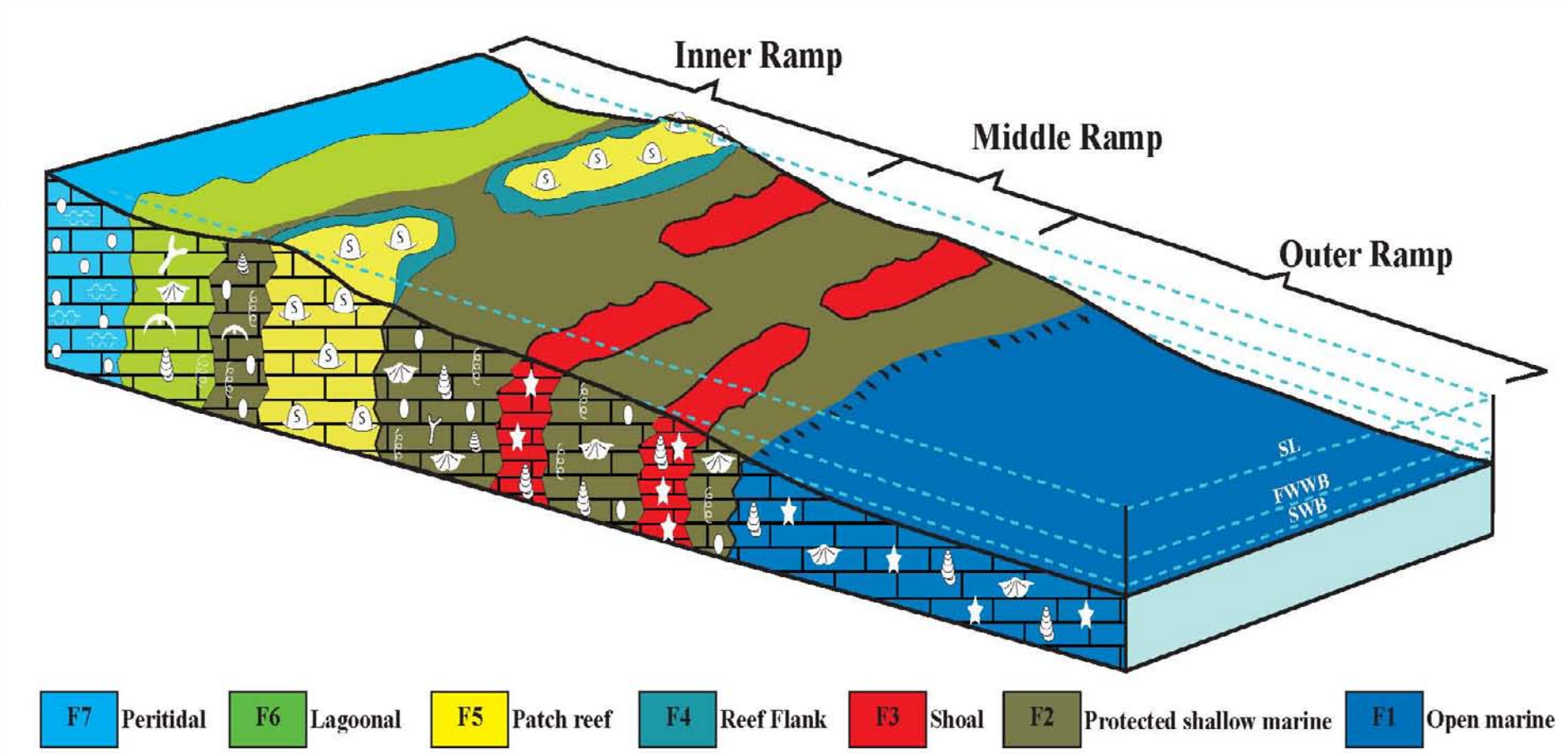


Facies 3: Crinoidal grainstone (Shoal)

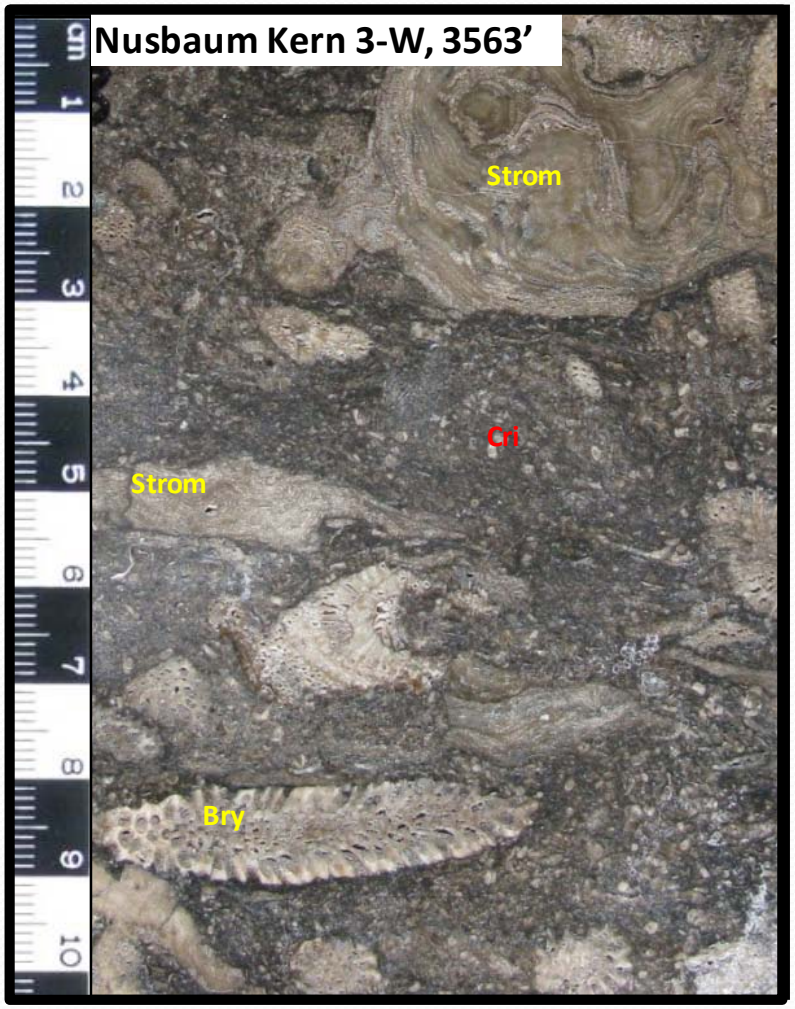
Facies 3: Crinoidal grainstone (Shoal)

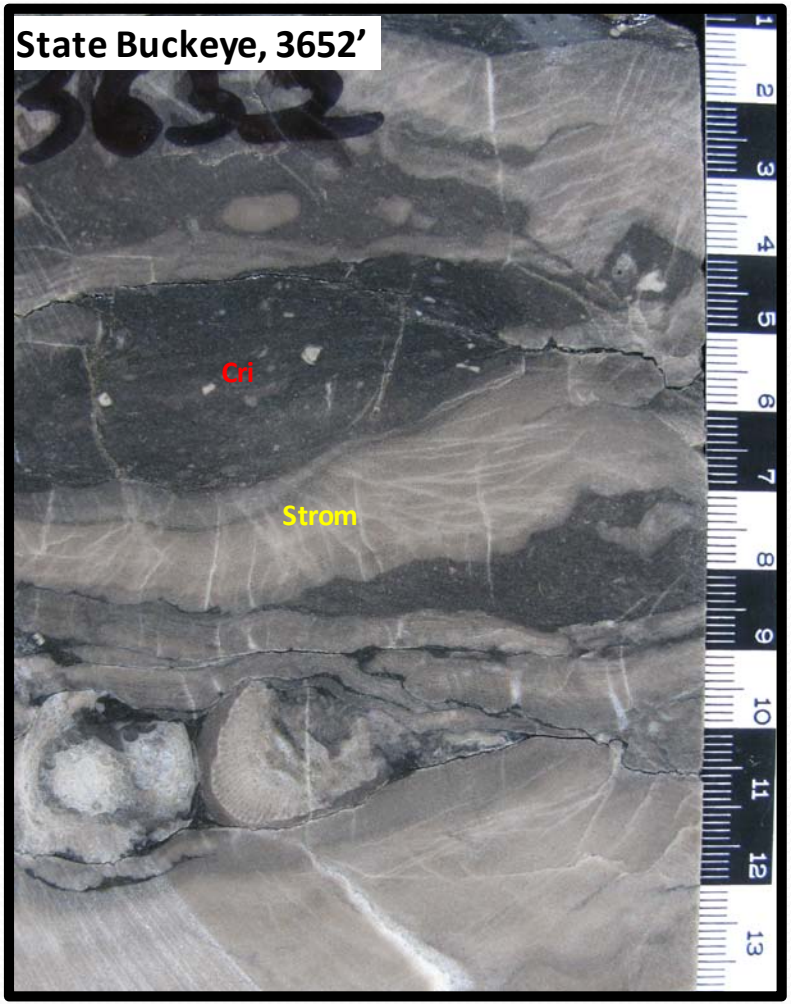


Dundee and Rogers City Depositional Facies Interpreted from Cores

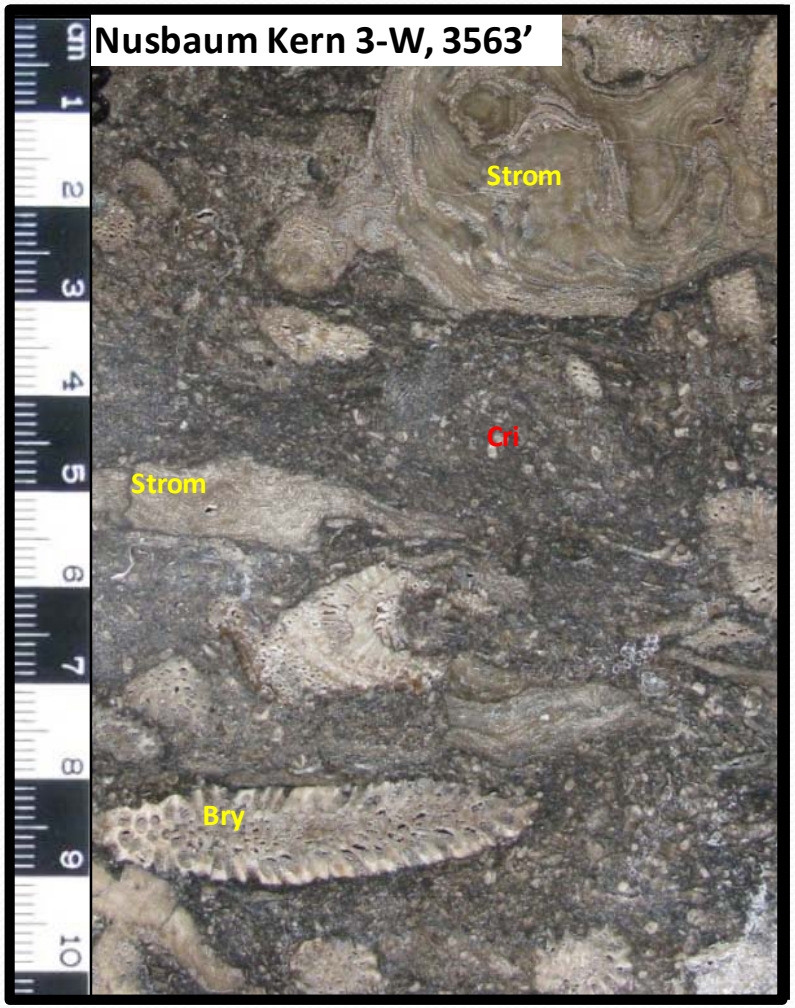


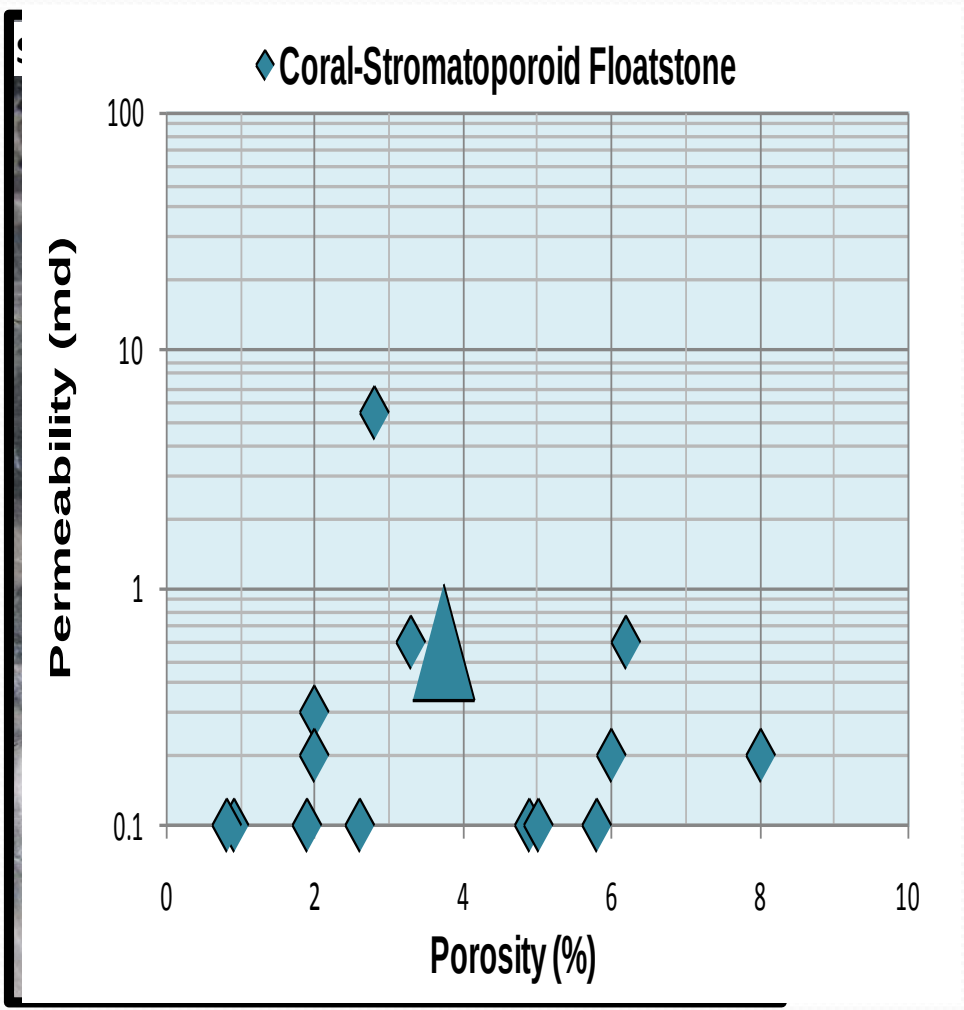
Facies 4: Coral-stromatoporoid Rudstone (Reef Flank)



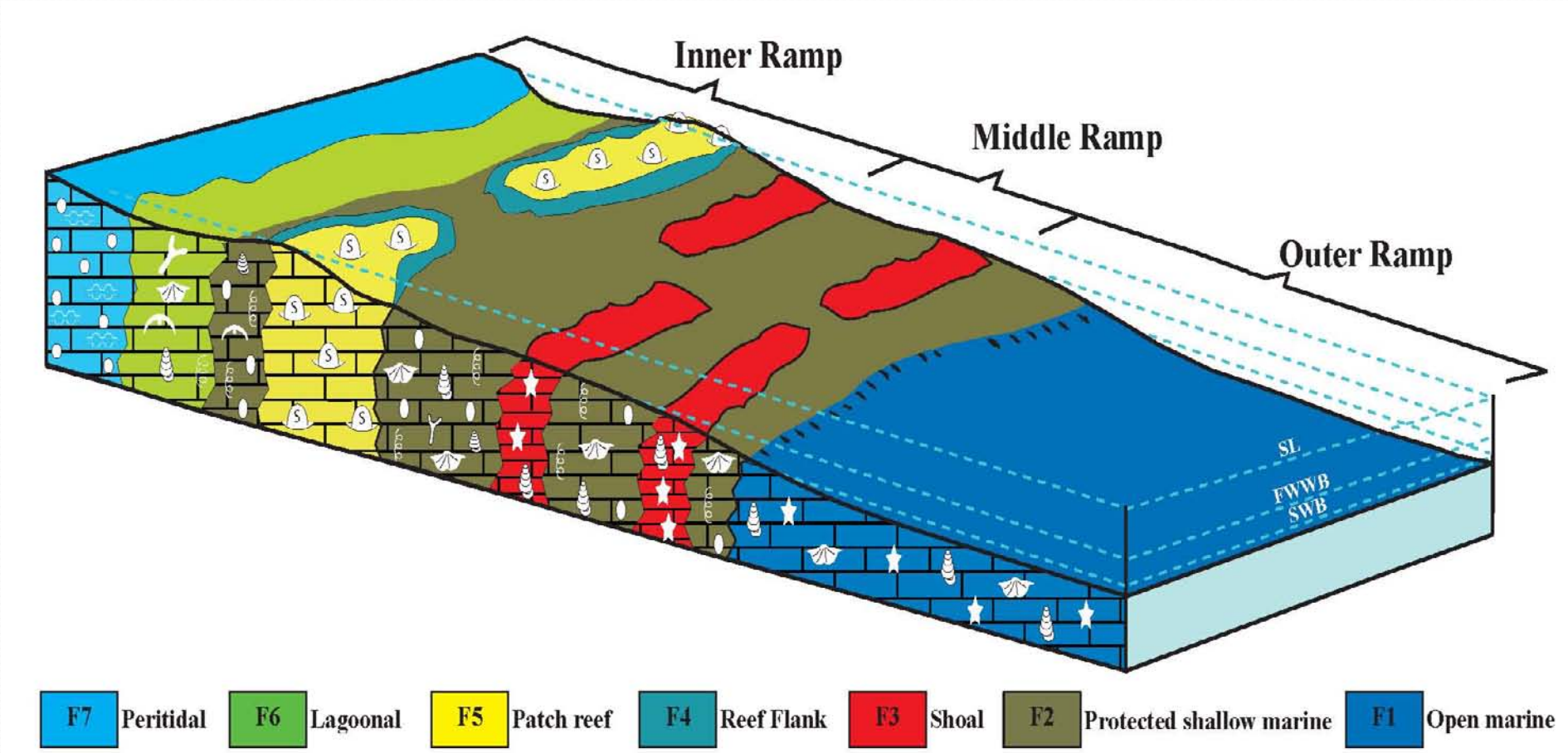


Facies 4: Coral-stromatoporoid Rudstone (Reef Flank)



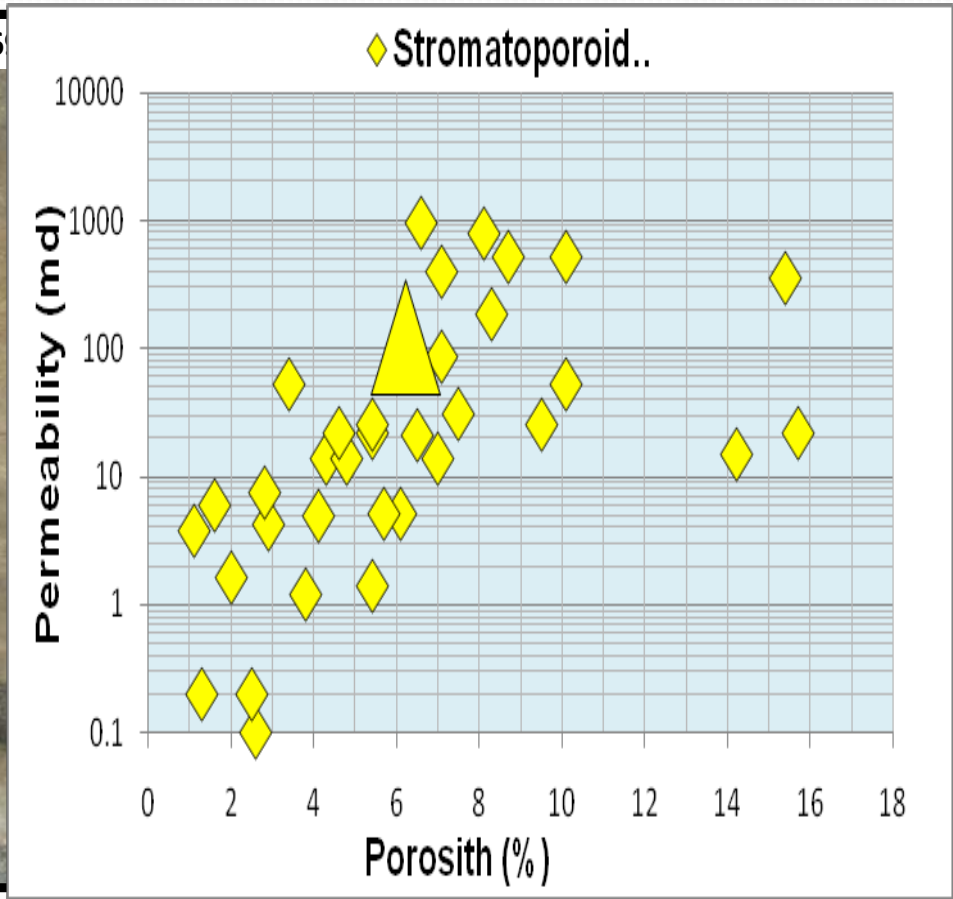


Dundee and Rogers City Depositional Facies Interpreted from Cores

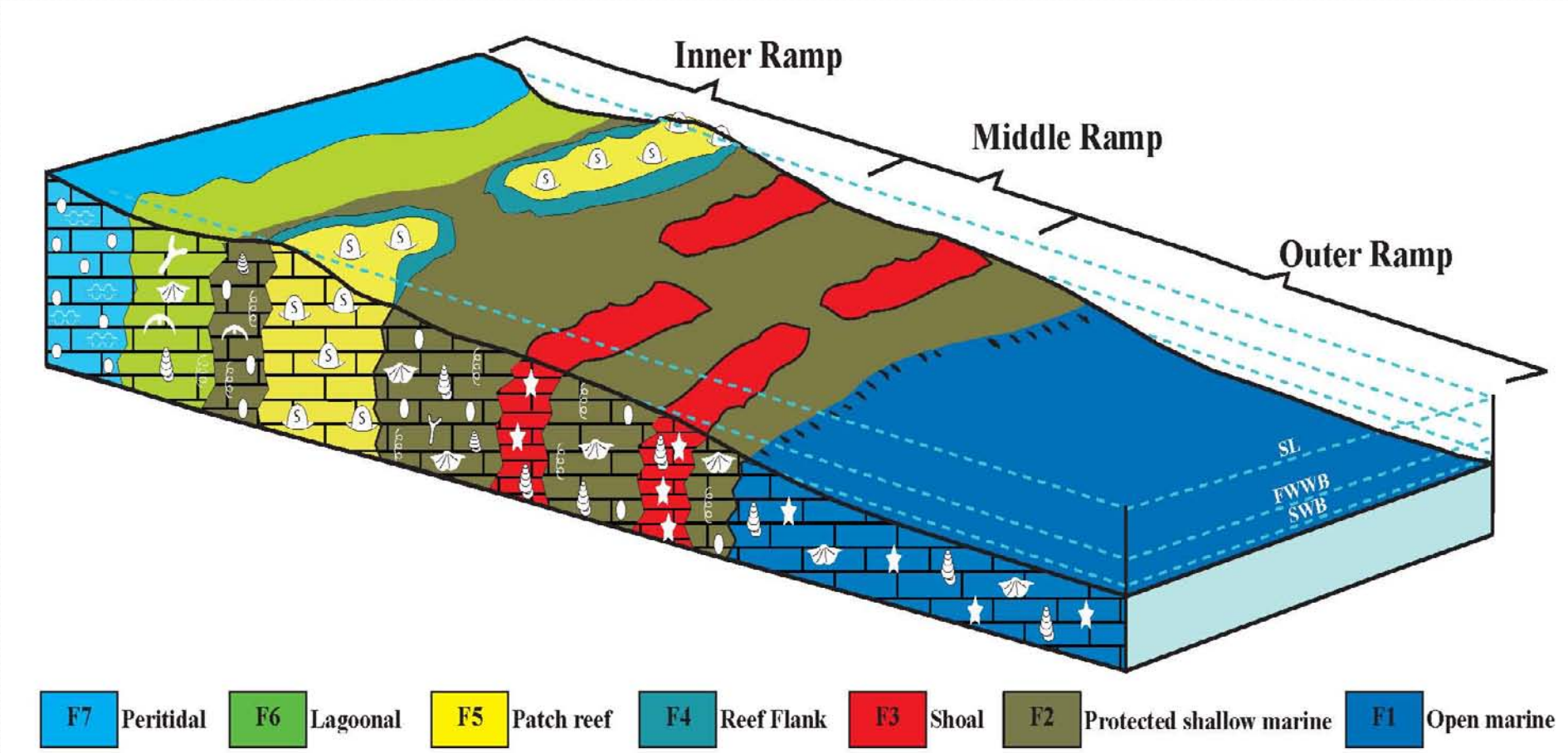


Facies 5: Stromatoporoid boundstone (Patch Reef)

Facies 5: Stromatoporoid boundstone (Patch Reef)

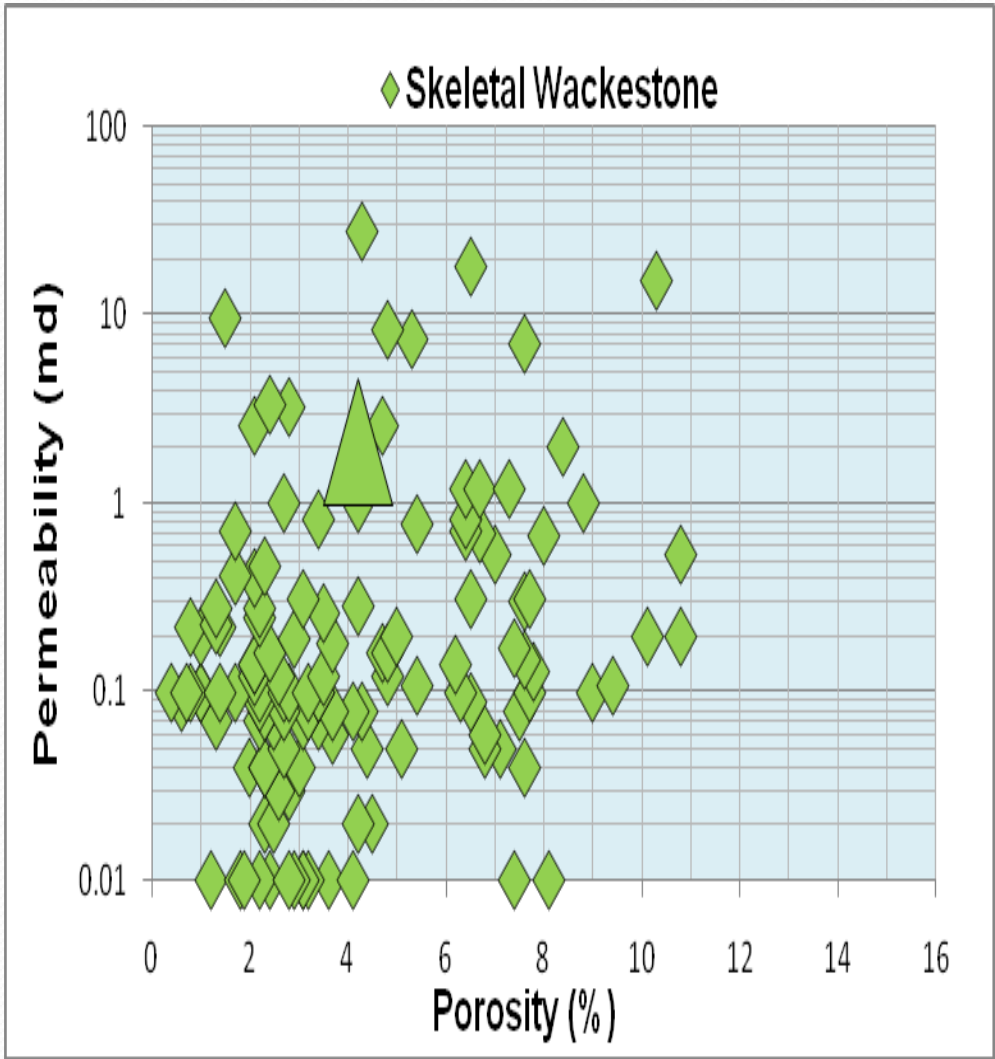


Dundee and Rogers City Depositional Facies Interpreted from Cores

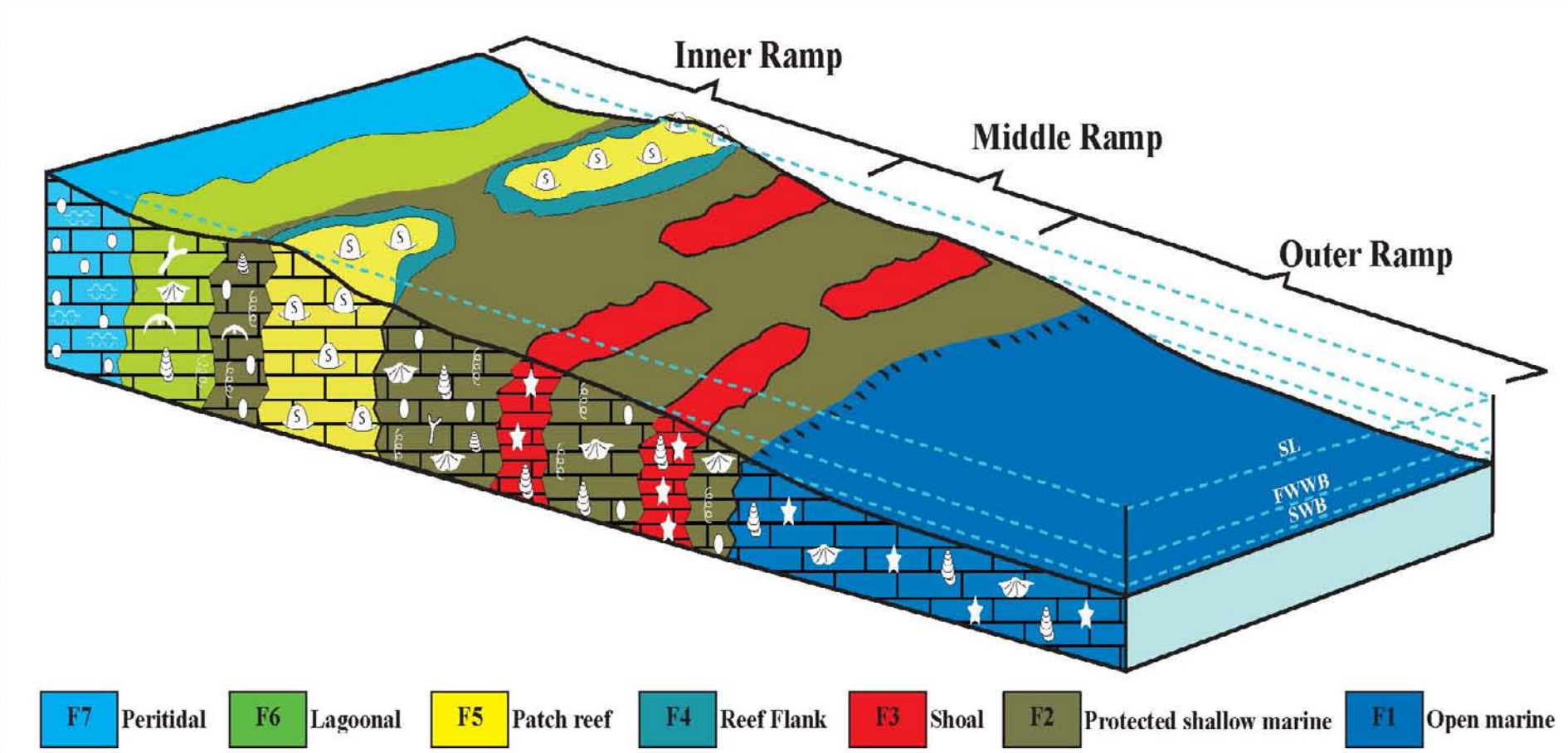


Facies 6: Skeletal wackestone (Lagoon)

Facies 6: Skeletal wackestone (Lagoon)

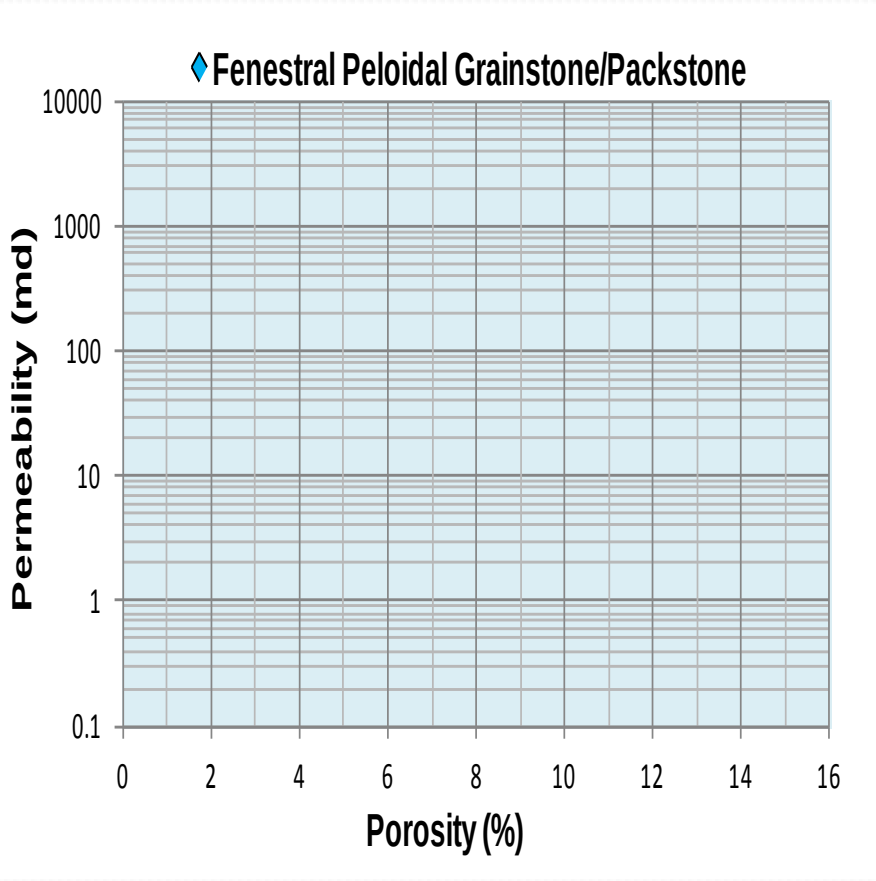


Dundee and Rogers City Depositional Facies Interpreted from Cores



Facies 7: Fenestral peloidal grainstone/packstone (Peritidal)

Facies 7: Fenestral peloidal grainstone/packstone (Peritidal)

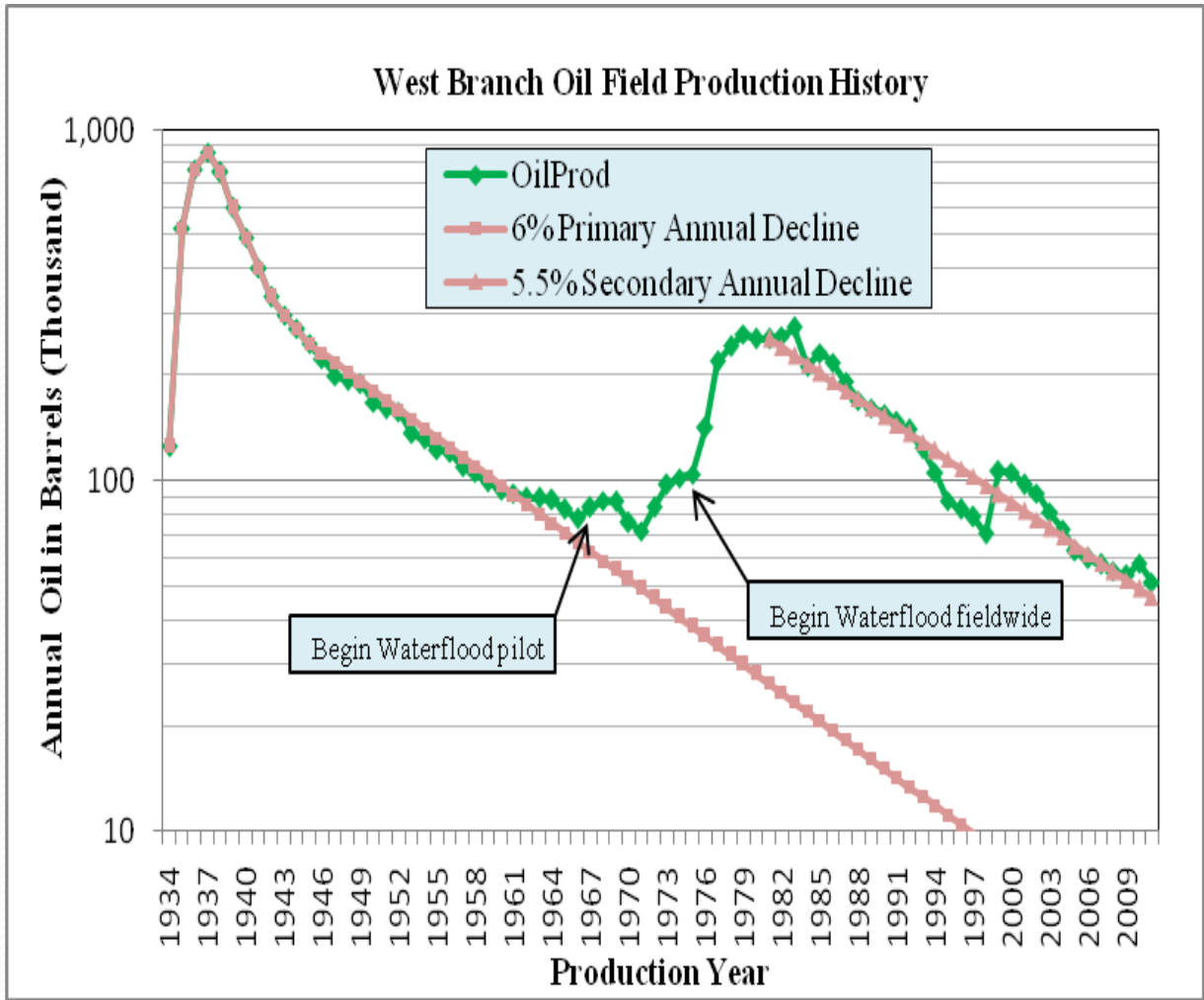


Primary Reservoir Facies in Study Fields

- South Buckeye and Butman - Facies 5: Stromatoporoid boundstone (Patch Reef)
- West Branch - Facies 3: Crinoidal grainstone (Shoal)
- Mt. Pleasant, North Buckeye and Wise - Facies 7: Fenestral peloidal grainstone/packstone
- Secondary reservoirs in several fields are:
  - Facies 2: Bioturbated peloidal grainstone/packstone (Protected Shallow Marine)
  - Facies 4: Coral-stromatoporoid rudstone (Reef Flank)
- Non-reservoir (except when fractured and dolomitized)
  - Facies 1: Crinoidal skeletal wackestone (Open Marine)
  - Facies 6: Skeletal wackestone (Lagoon)

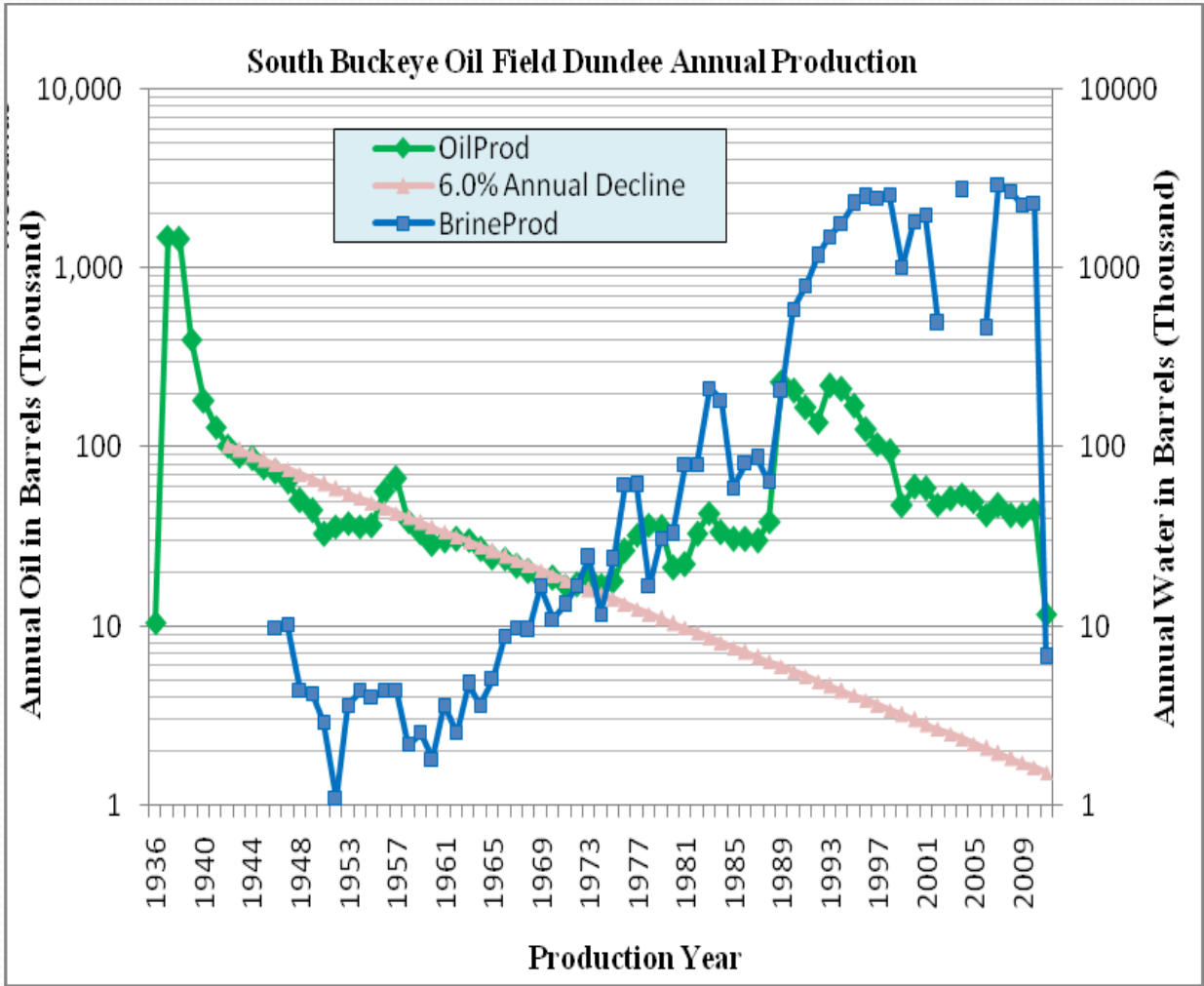
Secondary and Enhanced Recovery Potential of Dundee Facies

- West Branch Field - Facies 3: Crinoidal grainstone (Shoal)
- Excellent waterflood performance
- Likely exceed 50% recovery factor



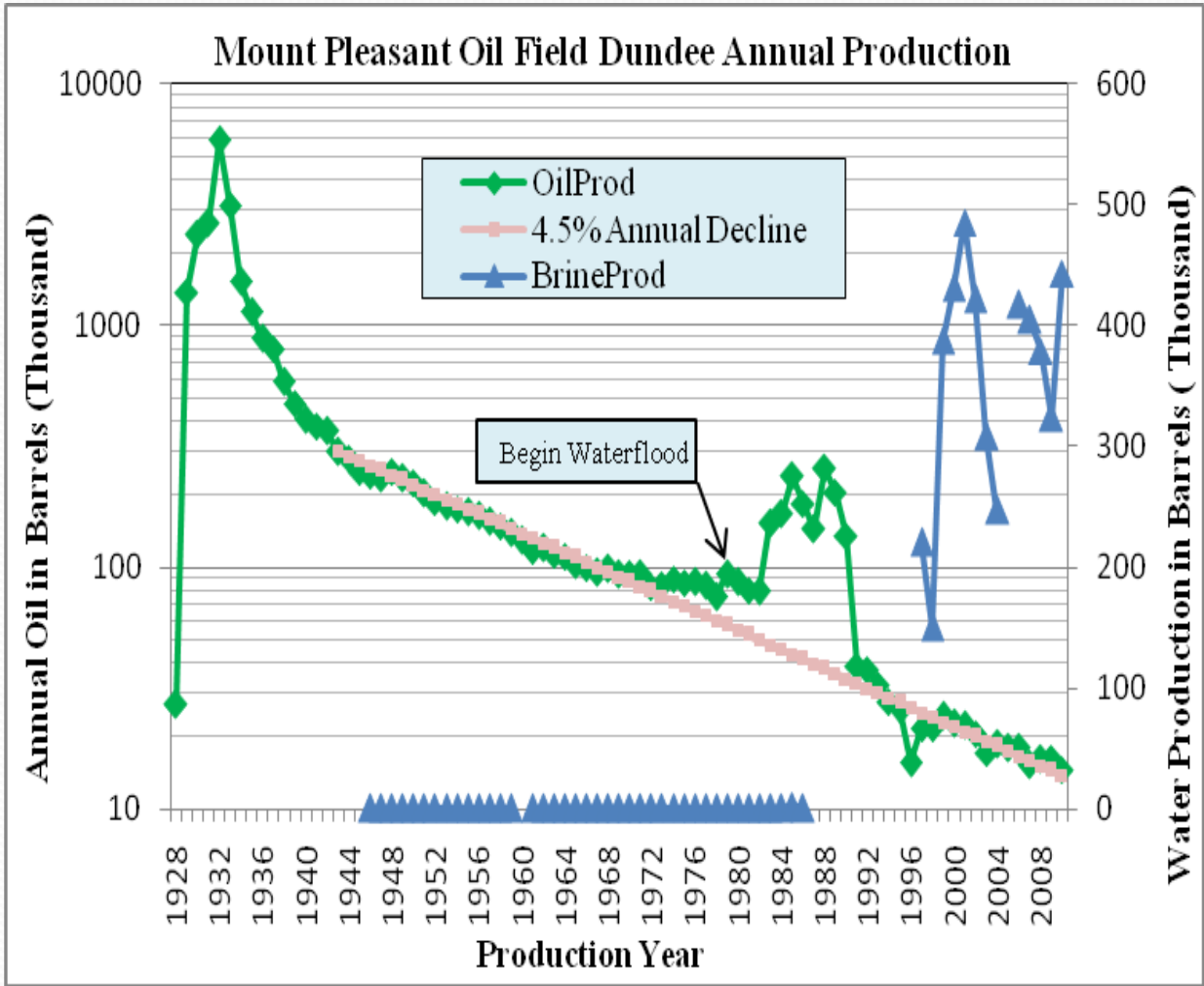
Secondary and Enhanced Recovery Potential of Dundee Facies

- South Buckeye and Butman - Facies 5: Stromatoporoid boundstone (Patch Reef)
- Responds to waterflood
- Recoveries depend on well placement



Secondary and Enhanced Recovery Potential of Dundee Facies

- Mt. Pleasant, North Buckeye and Wise - Facies 7: Fenestral peloidal grainstone/packstone
- Poor secondary response, efficient primary recovery



Summary

- Reservoir facies in the Dundee Limestone is controlled by primary depositional processes
- Different facies can be the main reservoir in different fields
- In six fields studied 3 facies are the primary reservoir
  - Crinoidal grainstone
  - Stromatoporoid boundstone
  - Fenestral peloidal grainstone/packstone
- Two facies may be secondary reservoirs in some fields
  - Bioturbated peloidal grainstone/packstone
  - Coral-stromatoporoid rudstone
- Two facies are non-reservoir (unless fractured and dolomitized
  - Crinoidal skeletal wackestone
  - Skeletal wackestone