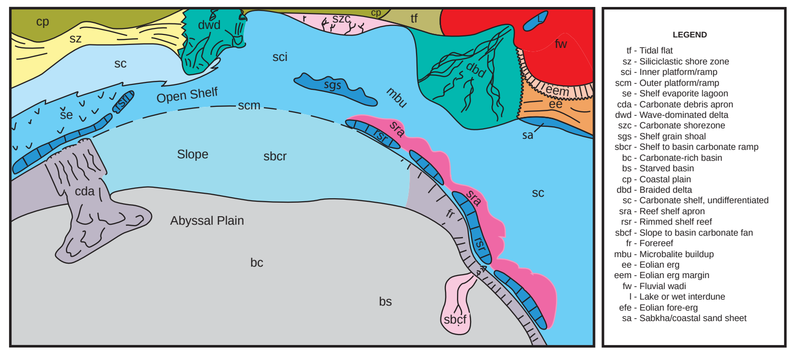
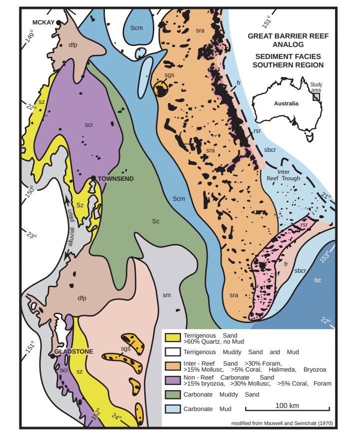
Log Facies Interpretation, Gulf of Mexico Mesozoic

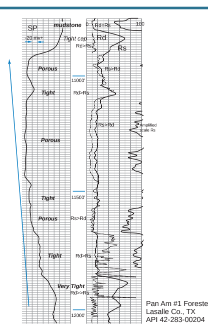
- Classification based upon:
  - Physiographic location (shelf, shelf/margin, DW)
  - Geographic location (Florida vs. Texas)
  - Shape and trend of SP/GR
    - Stacking pattern
    - Bed thickness and vertical trend
  - Thickness of gross interval
  - Comparison of resistivity (Rshallow vs Rdeep) curves
  - Lithology information (anhydrite, dolomite, red beds)
  - Associated sandstones and log motifs
  - Location relative to key sequence stratigraphic surfaces (sb, mfs fs)
  - Modern analogs

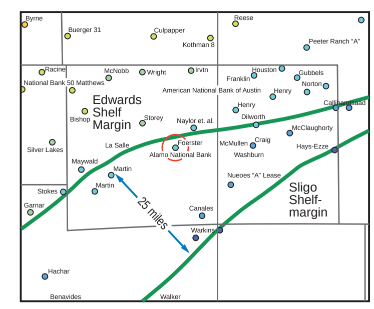




Rimmed Shelf Reef (rsr)

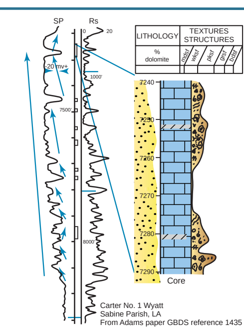
- Thickness > 1000 ft
- Increasing deflection from shale baseline, upward
- SP often >-100 mv from shale baseline
- High resistivity response, Rd >10 ohm-meters
- Variable Rs to Rd ratio, as a function of porosity and permeability and hydrocarbon content
- Thick beds and bedsets
- Alternating porous and tight, often tight cap
- Core contains boundstones and frame-building organisms like caprinid rudistids in Cretaceous.
- Dominated by "Reef wall" of Phelps et al (2011, GBDS reference 1377): shoaling up succession from sponges to stromotoporoids to corals to rudistids
- Great Barrier reef analog

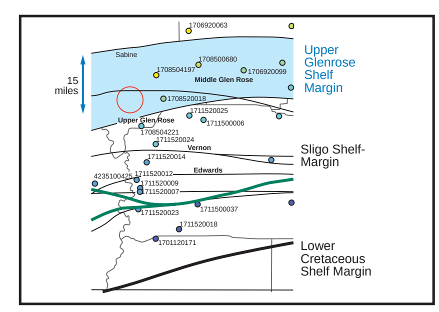




Forereef position on Rimmed Shelf margin (fr)

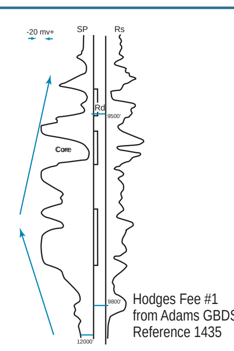
- Thickness > 500 to 1000 ft
- Increasing deflection from shale baseline, upward
- Stacked series of CU cycles
- More serrate pattern than "reef wall"
- High resistivity response, Rd >10 ohm-meters
- Variable Rs to Rd ratio, as a function of porosity and permeability and hydrocarbon content
- Thick beds and bedsets
- Alternating porous and tight, often tight cap
- Core contains peloid-algal packstones and wackestones. Occasional grainstones

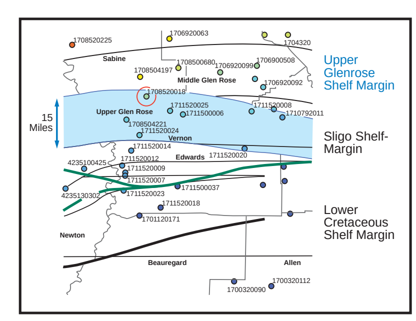




Shelf Reef Apron (sra)

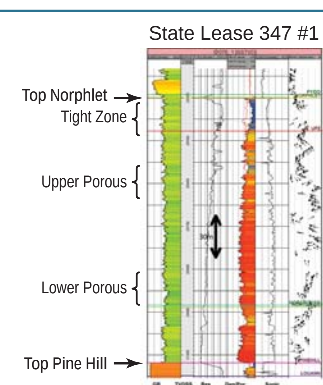
- Multiple CU and FU parasequences in an overall crescentric pattern (bell on funnel)
- 100 to 300 ft overall thickness
- Position just landward of the coeval shelf margin
- Cores show packstones and subordinate amounts of grainstones and boundstones
- In-place growth on overwash does occur
- Belize modern analog



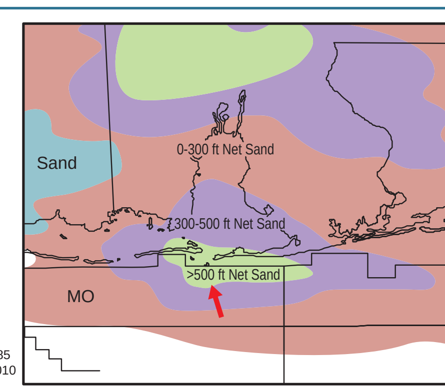


Eolian (central) Erg (ee)-Shelf/onshore

- Norphlet Sandstone of Eastern Gulf of Mexico
- Higher GR activity and lower SP deflection than overlying Smackover and underlying Pine Hill
- 0-300 m (0-990 ft) overall thickness in center of fairway
- Position updip of marine seaway, downdip of downdip of alluvial/fluvial (wadi) systems
- Dominated by medium- to fine-grained sandstones
- Three internal (subseismic) zones
  - Upper Tight zone (5 to 60 m) where P&P: <4%, 0.001 md
  - Upper porosity zone, 4 to 10%, perm < 1 md
  - Lower porosity zone, >10%, perm about 10md
- Cores show repetitive stacked series of high angle cross-bedded sandstones, show paleotransport to south.
- Isopach maps often show elongate N-S oriented, linear dunes, with thinner interdune facies. Part of large coastal sand sea (erg).
- At Mobile Bay, linear dunes often subside into the Louann salt and have significant top and base relief relative to interdune sediments; Underlain by Pine Hill and overlain by Smackover
- Presence of chlorite rim cements mitigates quartz cementation and greatly improves dune reservoir properties

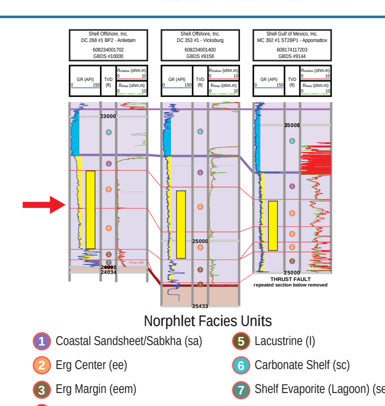


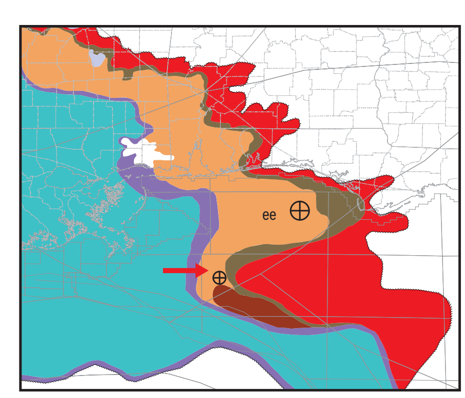
GBDS reference 985
Adjukiewicz et al., 2010



Eolian (central) Erg (ee)-Deepwater

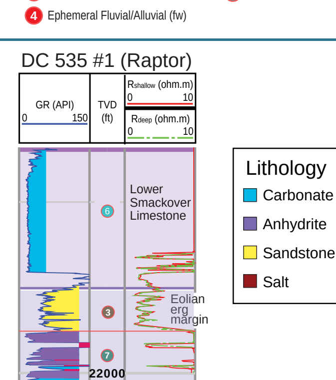
- Norphlet Sandstone of Eastern Gulf of Mexico
- Higher GR activity and lower SP deflection than overlying Smackover and underlying Pine Hill
- 0-300 m (0-990 ft) overall thickness in center of fairway
- Position updip of marine seaway, downdip of alluvial/fluvial (wadi) systems
- Dominated by medium- to fine-grained sandstones; Blocky log motifs
- In core recognition of
  - Drying up cycles, bounded by high-resistivity breaks (bounding surfaces: deflation, reactivation, stabilization)
  - Grain flow deposits (large cross-beds, 20 to 35^{o} dips)
  - Wind-ripple deposits (finer grained, low-angle bed)
  - Wet and dry interdune deposits (fine to very fine grained)
- Cores show repetitive stacked series of high angle crossbedded sandstones, show paleotransport to south.
- Dipmeter data suggests sinuous and straight-crested transverse dunes.
- In Desoto Canyon and Mississippi Canyon, flat top may be due to ravinement during Smackover transgression.
- Underlain by Pine Hill and overlain by Smackover
- Presence of chlorite rim cements mitigates quartz cementation and greatly improves dune reservoir properties
- In some wells (Vicksburg, DC353#1), solid (immovable) hydrocarbons found in pores of better quality, coarser facies (Godo et al. 2011).
- Porosities of 20% in this facies, preserved by chlorite rim cements on quartz grains

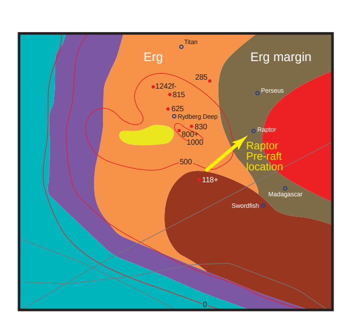


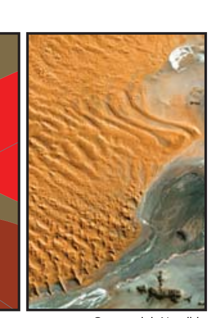


Eolian erg margin (em)

- Norphlet Sandstone of Eastern Gulf of Mexico
- More serrate GR pattern than the central erg (ee), often with 20 to 30 fining bed-scale upward cycles
- Lateral to central erg
- Thinning in erg margin: Norphlet can be thinner than in Eolian Erg system (363 gross ft in MO 950 than in Mary Ann Field (>600 ft gross sand; 118 thick in Raptor)





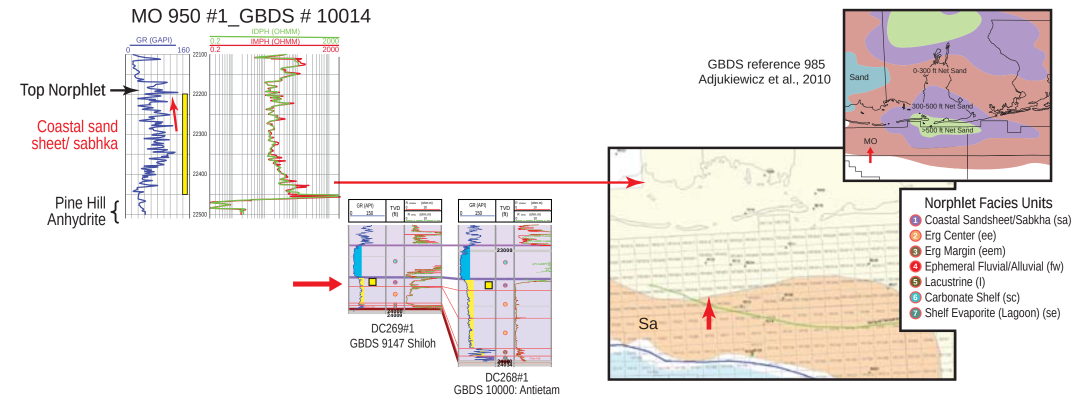


Sossusvlei, Namibia

Jan 2016

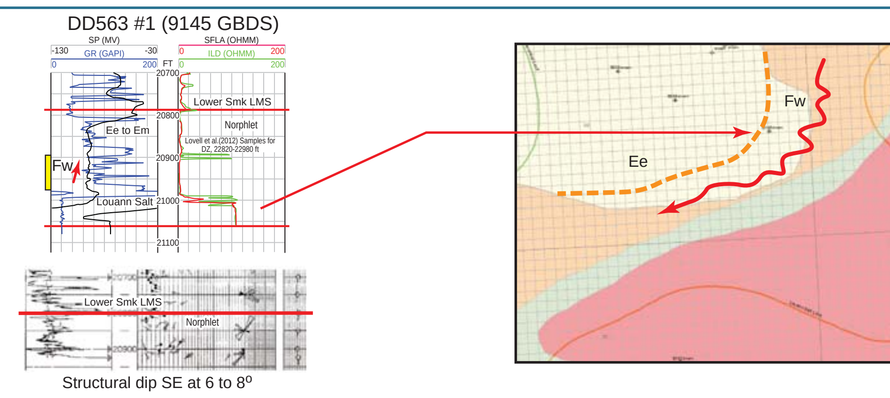
Coastal Sand Sheet/sabhka (sa)

- Norphlet Sandstone of Eastern Gulf of Mexico
- Coarsening upward /fining up log motif
- Can be found at Top of Norphlet (transition to Lower Smackover limestone) or at base (transition to Pine Hill Anhydrite)
- <100 ft thick in Mobile Bay, variable in deep-water areas
- Evidence of water-lain bedding in sabkha



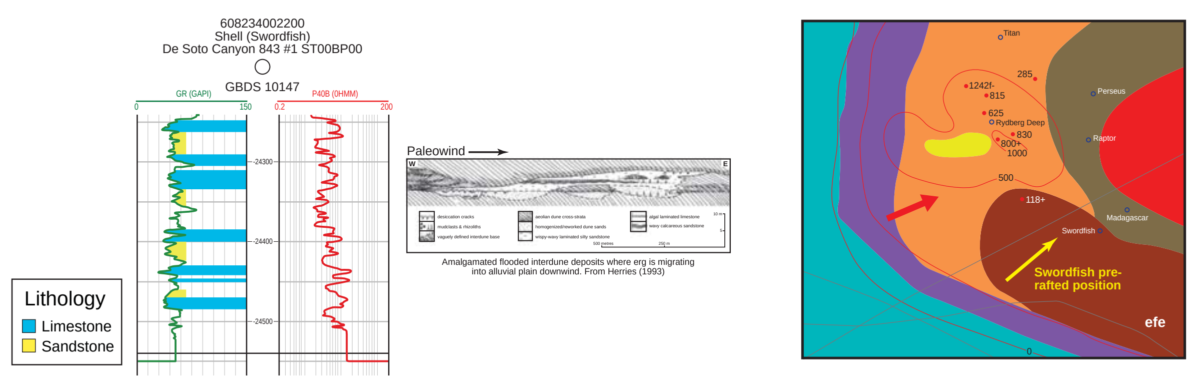
Fluvial wadi (fw)

- Norphlet Sandstone of Eastern Gulf of Mexico
- Fining upward on GR log;
- Lower Net Sandstone than Eolian Erg
- Thinner overall than Eolian erg (here 200 ft versus 600 ft (shelf) to 900 ft +(deepwater) in adjacent areas
- Transition into anhydrite (Pine Hill?) and Salt (Louann) downward.
- Sharp upper contact with lower Smackover Limestone (hot GR boundary)
- Dipmeter log shows dip scatter or different trend than eolian transport (here to south)



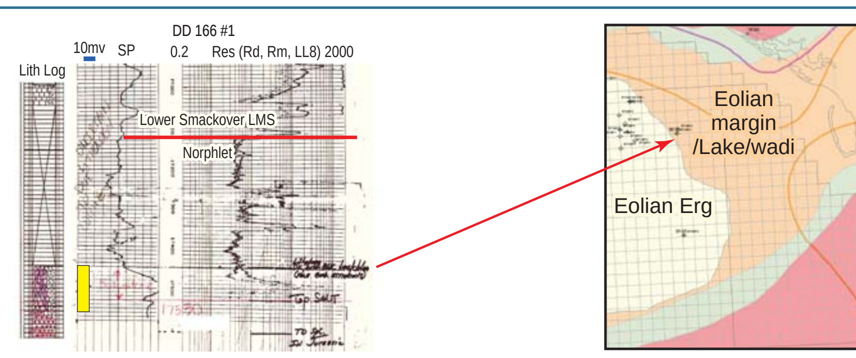
Eolian Fore Erg (efe)

- Norphlet Sandstone of Eastern Gulf of Mexico
- Leading edge of wind-driven migration of erg into adjacent non-erg areas.
- Inter-fingering of eolian and other facies
- Distinct from sabkha (seaward of erg) or erg margin (landward of erg).
- Flooding of interdune areas common
- Erg expands during dry periods while ephemeral fluvial systems transgress erg during wetter climatic episodes



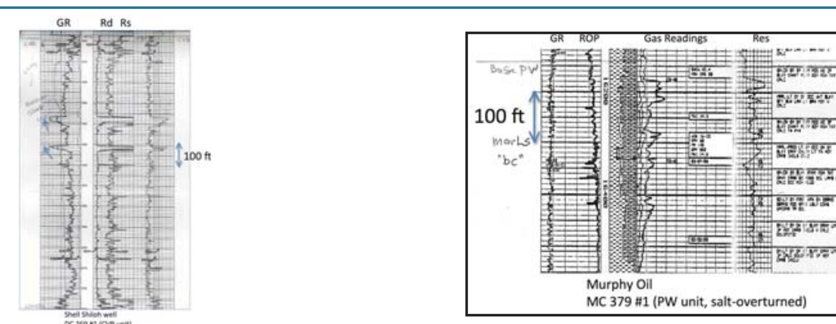
Lake (l)

- Norphlet Sandstone of Eastern Gulf of Mexico;
- Wet interdune and lake, interbedded within eolian margin
- Interbedded sandstones and carbonates (limestones, dolostones)
- Common ostracods
- FU cycles on logs; alternating high and low resistivity (shales)
- Gamma Ray and SP logs suggest lower Net Sand
- Pine Hill anhydrite sometimes absent



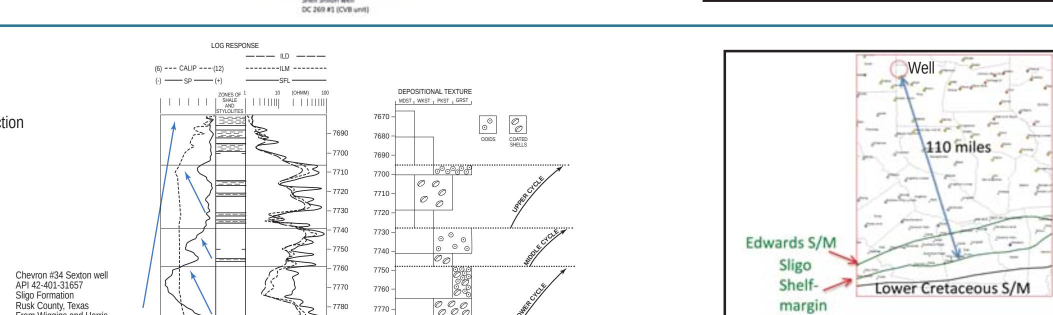
Basinal carbonate (bc)

- Low net carbonate (30 to 50 ft net in 1000 to 1300 ft gross section. Often marl-rich (see MC379 mud log).
- Sharp-based, thin parasequences with pronounced upward-descreasing resistivity patterns on amplified SEDP log curve
- Map position quite distant from reef or forereef
- Limestone-only, very tight, high resistivity units individually as thick as 20 ft. Described in cuttings as light gray, microcrystalline
- Marls as Light gray to gray, calcareous and shale-rich. Marls have low ROP, Low GR, High resistivity.
- Shales described as gray-colored and waxy (Bossier shale example), Occasional sandstones (<10 ft), relatively high silt content



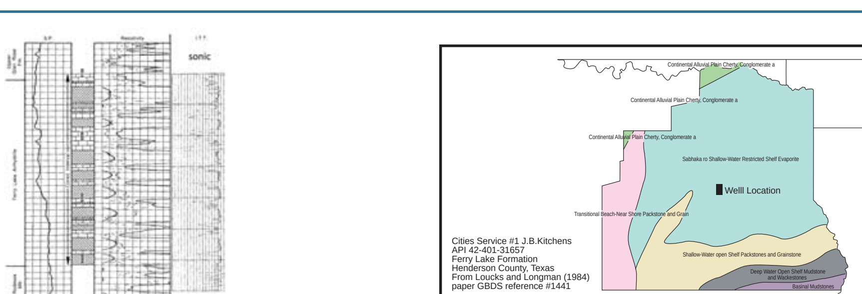
Shelf Grain Shoal (sgs)

- Multiple CU parasequences in an overall upward fining pattern (SP log motif)
- 100 ft overall thickness
- Position on the shelf, updip of coeval shelf margin
- Cores show grainstones grading downward to packstones, with wackestones and mudstones in overlying maximum flooding section
- Porous zones at top of each cycle (grainstones)



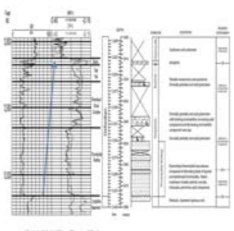
Shelf evaporite - Restricted Hypersaline Lagoon (se)

- Weak CU or no pattern in SP or GR log motif
- 100-400 ft overall thickness
- Position on the shelf, updip of shelf margin barrier and downdip of alluvial plain
- Dominated by anhydrite
- The Rd (deep resistivity) has higher resistivity than the shallow (Rs) curve, except in zones of shaley anhydrites where Rd< Rs. Both curves show high resistivity with Rd > 10 ohms, usually offscale.
- Cores show plamate and bedded anhydrite; original gypsum deposition in subaqueous conditions, with a few beds of intertidal to subtidal muddy limestones
- Ostracods are only fauna, rare gastropods, indicating stressed conditions
- Salinity fluctuations controlled depositional cycles so no clear vertical pattern
- Highly correlative bedsets and cycles over large distances;
- Cycles range in thickness from 1.5 to 9m (6 to 33 ft)

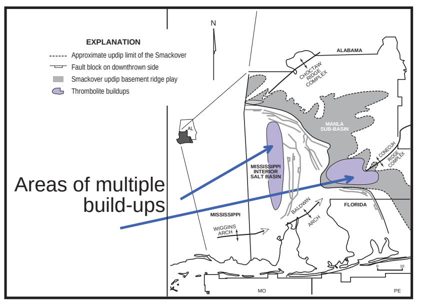


Microblite Buildup (mbu)

- General FU pattern on GR log reflects stacked, "catch up" to "keep-up" carbonate parasequences
- 100-200 ft overall thickness
- Position on mid-ramp, often underlain by basement structure
- Dominated by anhydrite
- Cores show ooid-oncoid-peloid grainstones and packstones of shoal crest capped by intertidal and tidal flat wackestones and mudstones (Upper Smackover).
- Microbial boundstones and bindstones of reef tend to form just seaward of ooid shoals in some areas (tend to lie below the grainstones vertically).
- Build-ups range in thickness from 10 to 130 ft (3.3 to 40 m).
- Underlain by organic-rich Middle Smackover mudstones. Overlying sabkha deposits (Buckner)
- Porosity decreases upward (tighter intertidal deposits). Porous Smackover has density of 2.65 gm/cc versus non-porous carbonates of 2.80 gm/cc
- Locally developed microbial patch reefs, built upon flanks or crests of paleobathymetric highs such as basement.
- Dolomitization greatly improves thrombolite reservoir properties; microporosity elsewhere.

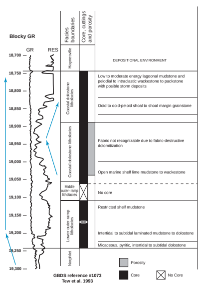


D.W. McMillan Trust 12-4
Well permit 4633-B,
Appleton field, Alabama
Smackover Formation
From Mancini et al (2004)
paper GBDS reference #1124

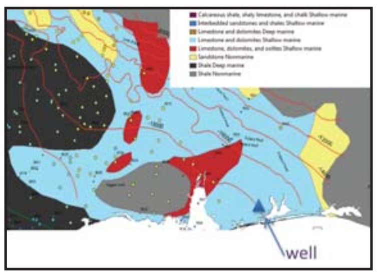


Shelf carbonate undifferentiated (sc)

- Blocky log motif on GR
- SP may be more serrate
- Up to 500 ft thick
- High resistivity except where interbedded with grain shoal carbonates which can be porous and have lower resistivity, depending on HC content
- Shoaling up succession in cores with lagoonal mudstones and storm washover deposits near top and intertidal to subtidal mudstones and micaeous dolostones at base
- Example from the Smackover Formation of Alabama.

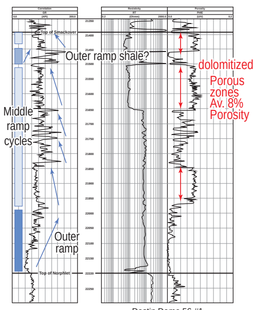


GBDS reference #1073
Tew et al. 1993

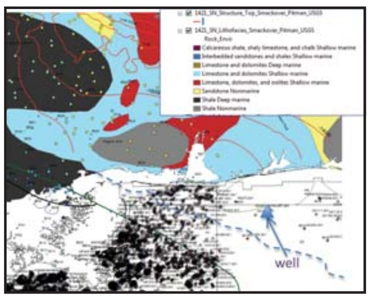


Shelf carbonate middle (scm)

- Stacked CU and FU cycles on GR
- SP may be more baseline
- Anhydrite is generally absent; dolomite can be present (next page)
- Can be confused with reef by thickness but not by log motifs
- Up to 900 ft thick, relatively high net carbonate
- High resistivity (100 ohm-m) except where interbedded with dolomitized zones which can be porous and have lower resistivity (10 ohm-m), depending on HC content
- Shoaling up succession in cores from outer ramp to middle ramp but no shoreline deposits (further from shoreline than 8a);
- Cores show storm transported carbonate debris from ebb return flows. Caps to thin cycles contain enough mud to make logs "serrate"
- Example from the Smackover Formation of Federal waters (Destin dome) where thin dolomites vs onshore.

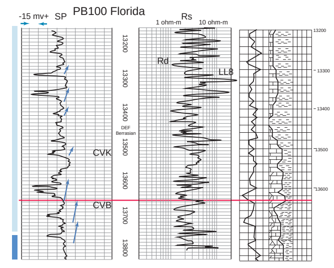


Destin Dome 56 #1
GBDS reference #1073 Tew et al. 1993



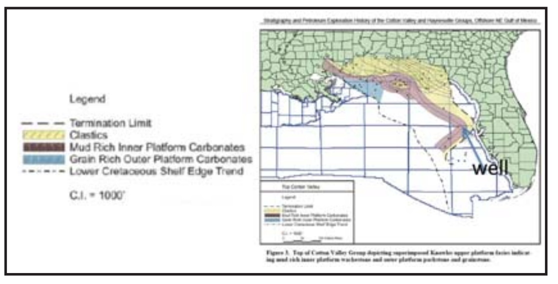
Shelf carbonate inner (sci)

- Stacked FU cycles on SP log
- Low net carbonate, up to 80% shale or anhydrite by cuttings analysis
- Anhydrite prominent but generally thinner than found in se (shelf evaporite)
- Up to 500 ft thick
- Low to moderate resistivity (>10 ohm-m)
- Rarely associated with dolomite or dolostones
- No obvious vertical trend, grades downward to shales
- Lies between siliciclastic shoreline deposits and reef to reef apron
- Example from the Cotton Valley Formation of Federal waters (Destin dome area)



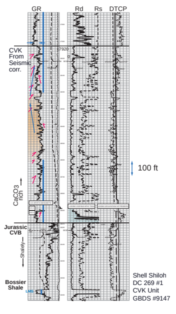
GBDS reference #1149 Petty et al. 2008

Top Cotton Valley



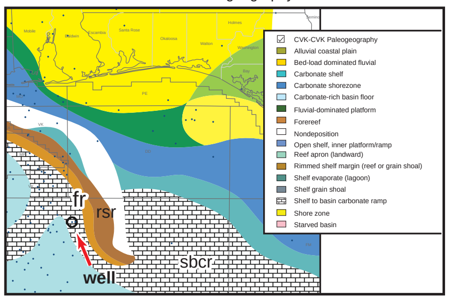
Slope to Basin carbonate ramp (sbcr)

- Found seaward of forereef (fr) or in areas where no pronounced rimmed shelf reef exists.
- Multiple FU parasequences (bell-shaped log motifs) with rare CU motifs (in contrast to forereef.
- Increasing carbonate upward
- 500 to 1000 ft overall thickness, with 500 to 600 feet of net limestone (lower net than fr or rsr)
- Position well seaward of rimmed shelf reef (rsr).
- Generally tight carbonates (high-resistivity)
- Cuttings descriptions: Limestone, light gray to dark gray, slightly silty to pyritic, occasional green-grey.



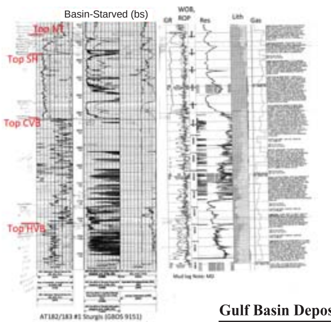
Shell Shiloh
DC 269 #1
CVK Unit
GBDS #9147

CVK Paleogeography

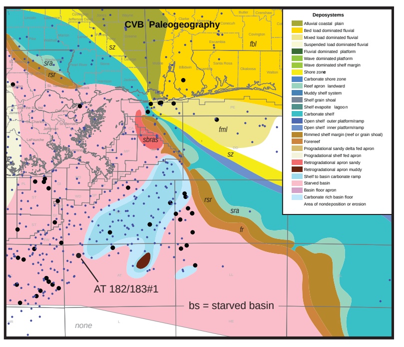


Basin-Starved (bs)

- Greatly condensed stratigraphic section: in AT 182/183, Top Cret. To Jurassic only 1200ft
- Stratigraphic units missing or condensed beyond recognition by cuttings biostrat (e.g. missing CVK here)
- Can be but is not restricted to salt carapace structures
- Dominated by Limestone and shale
- Shales are often organic-rich, petroliferous, and exhibit a "hot shale" response (gamma ray > 150 api, wraparound). Cuttings description from AT183: shale, black, oc, gray, carbonaceous, trace bitumen stains
- Limestones described as two types:
  - Micritic, dense white to grey, microcrystalline to sucrosic texture, fractured with fracture-fills of calcite, hydrocarbons and "peat like" organics (SH, right)
  - Shaley, argillaceous limestones with wavy laminations (HVB, right)
- Limestones are very high resistivity (reflects density)
- Shales also have moderately high resistivities (reflects source rock maturity)
- Laterally continuous on a gross unit basis, subject to considerable structural discordance by salt and/or faulting
- Similar appearance in LL 399 (Cheyenne)
- In some cases, stratigraphic section can be overturned.



AT182/183 #1 Sturgis (GBDS 9151)
SH to HVB supersequences (TVD log)



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Gulf Basin Depositional Synthesis
GBDS
20 yrs
The University of Texas at Austin