Sequence Stratigraphy, Depositional Environments, and Production Fairways of the Haynesville Shale-Gas Play in East Texas*

Ursula Hammes[1] and David L. Carr[1]

Search and Discovery Article #110084 (2009)
Posted August 5, 2009

*Adapted from oral presentation at AAPG Annual Convention, Denver, Colorado, June 7-10, 2009; Note: AV version not available.

[1]Bureau of Economic Geology, Jackson School of Geosciences, Austin, TX. (ursula.hammes@beg.utexas.edu)

Abstract

The upper Jurassic (Kimmeridgian) Haynesville shale is an important shale-gas resource play in East Texas and Louisiana. Estimated recoverable reserves are as much as 60 Tcf, with each well producing on the average of 6.5 Bcf. Haynesville carbonates are known for their excellent production from carbonate shoals and pinnacle reefs in the East Texas Salt Basin. However, sequence stratigraphy and depositional setting of the Haynesville shale is not well documented. Therefore, a sequence stratigraphic model of basinal shale to shelfal carbonate sequences was established to determine the extent of the shale-gas play and reservoir characteristics of the Haynesville shale-gas formation using wireline logs, seismic, and cores. We also estimated TOC from a petrophysical log model calibrated to cores.

The upper Jurassic Smackover-Buckner-Cotton Valley Lime-Haynesville-Bossier Formations make up parts of two second-order supersequences (SS1 and SS2). The Haynesville composes the transgressive systems tract of the SS2 second-order sequence above the 144-m.y. sequence boundary, part of a supersequence from the lower Kimmeridgian to Berriasian (144 - 128.5 m.y.), where carbonates formed on the shelf and pre-existing, salt-cored highs, and organic-rich shales were deposited in the basin. Four to five regionally correlative third-order sequences compose the transgressive systems tract of the second-order supersequence. These cycles were correlated from basin to shelf, reflecting smaller-scale, sea-level fluctuations within the overall second-order transgression. Typically, each third-order sequence is characterized by a condensed section with TOC higher than the more calcite-rich shale intervals toward the top of each cycle. A marine condensed section marks the top of the Haynesville shale, coinciding with the second-order maximum flooding surface. Upper Bossier shale highstand deposits represent distal parts of the overlying Cotton Valley siliciclastic wedge that downlaps this maximum flooding surface. The upper Bossier is less organic rich, containing less TOC than the Haynesville. This study will define the extent, and sweet spots, of the Haynesville shale-gas play in East Texas.

References

Blakey, 2005, Global paleogeographic views of earth history - Late Precambrian to Recent: http://jan.ucc.nau.edu/~rcb7/150_Jurassic_2globes.jpg (accessed 07/24/09)

Ewing, Thomas E., 2001, Review of Late Jurassic depositional systems and potential hydrocarbon plays, northern Gulf of Mexico Basin: GCAGS Transactions, v. 51, p. 85-96.

Goldhammer, R. K., 1999, Mesozoic sequence stratigraphy and paleogeographic evolution of northeast Mexico, *in* C. Bartolini, J. L. Wilson, and T. F. Lawton, eds., Mesozoic Sedimentary and Tectonic History of North-Central Mexico: GSA Special Paper 340, p. 1-58.

Goldhammer, R.K., and Johnson, C.A., 2001, Middle Jurrassic-Upper Cretaceous paleogeographic evolution and sequence-stratigraphic framework of the northwest Gulf of Mexico rim, *in* C. Bartolini, R.T. Buffler, and A. Cantú-Chapa, eds., The Western Gulf of Mexico Basin: Tectonics, Sedimentary Basins, and Petroleum Systems: American Association of Petroleum Geologists Memoir 75, p. 45-81.

Goldhammer, R.K., 2002, Second-Order Accommodation Cycles and Points of "Stratigraphic Turnaround": Implications for Carbonate Buildup Reservoirs in Mesozoic Carbonate Systems of the East Texas Salt Basin and South Texas (abstract):GCAGS Transactions, v. 52, p. 362.

Loucks, Robert G., and Stephen C. Ruppel, 2007, Mississippian Barnett Shale: lithofacies and depositional setting of a deep-water shale-gas succession in the Fort Worth Basin, Texas: AAPG Bulletin, v. 91, p. 579-601.

Passey, Q.R., S. Creaney, J.B. Kulla, F.J. Moretti, and J.D. Stroud, 1990, A Practical Model for organic richness from porosity and resistivity logs: AAPG Bulletin, v. 74, p. 1777-1794.

Petrohawk website:Web accessed 25 July 2009 http://www.petrohawk.com/home/.

Sequence Stratigraphy, Depositional Environments, and Production Fairways of the Haynesville Shale-Gas Play in East Texas

Ursula Hammes and David Carr

100 Years of Scientific Impact

PROJECT STARR

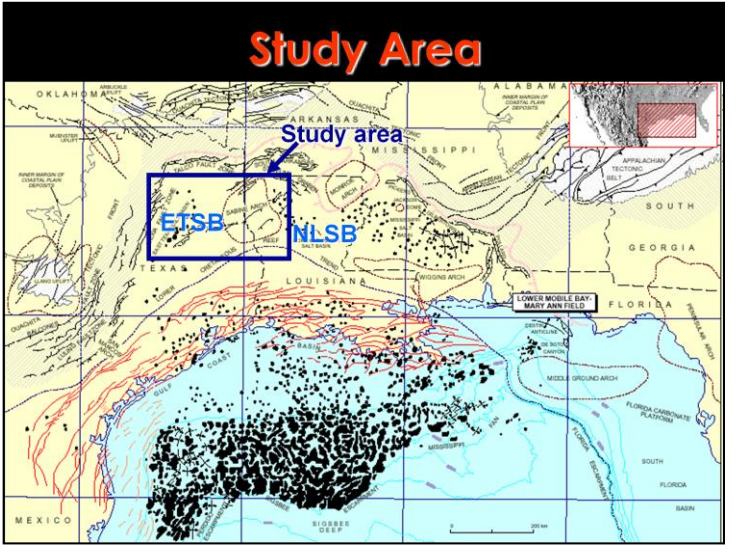
Goal of Study

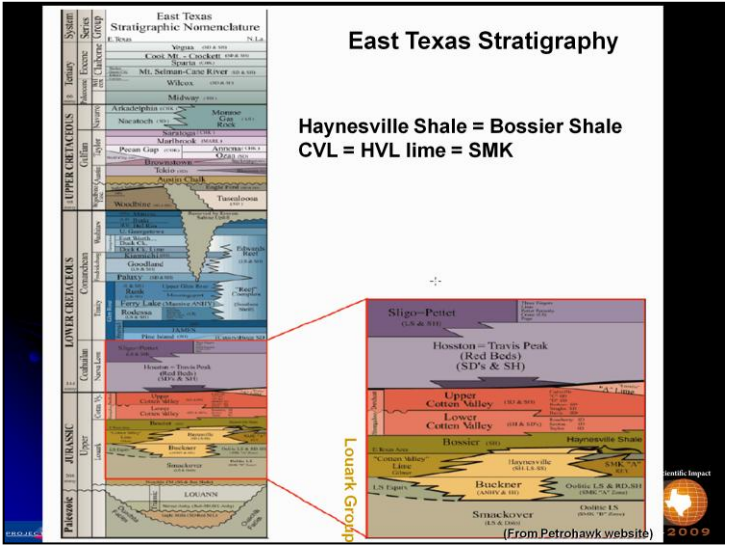
- Sequence stratigraphy
- Depositional environment
- Facies
- Extent of Haynesville shale
- TOC core/log assessment

Outline

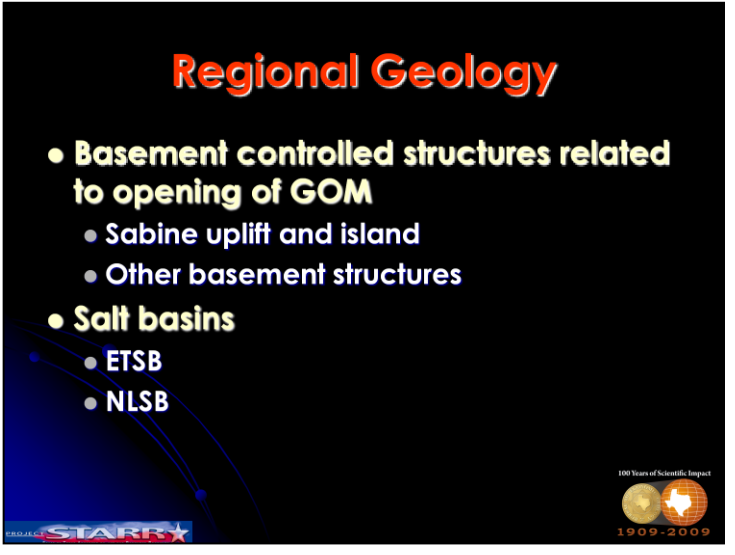
- Structural Setting
- Paleogeography
- Sequence Stratigraphy
  - Possible extent of Haynesville play
- Rock Work
  - Facies
  - Depositional setting
  - TOC/log correlations
- Conclusions

Study Area


Study area
ETSB
NLSB
OKLAHOMA
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TEXAS
LOUISIANA
SOUTH
LOWER MOBILE BAY-
MARY ANN FIELD
MEXICO
SIGSBEE
DEEP
MIDDLE GROUND ARCH
FLORIDA CARBONATE
PLATFORM
SOUTH
FLORIDA
BASIN
APPALACHIAN
TECTONIC
BELT

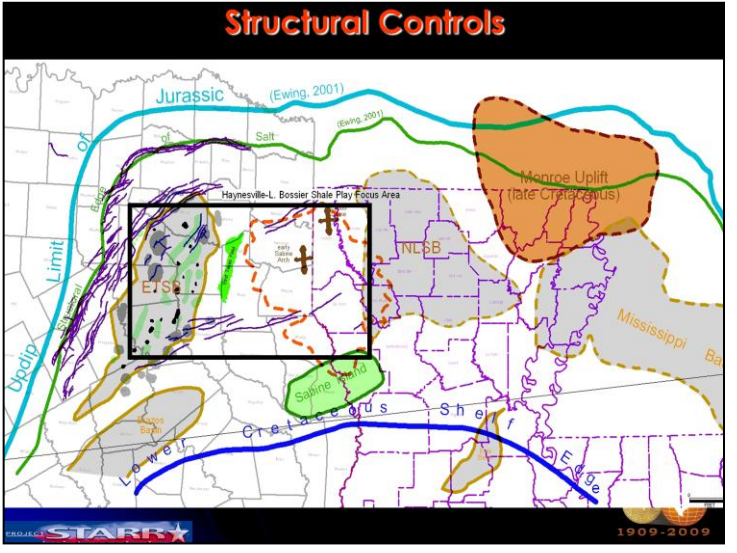


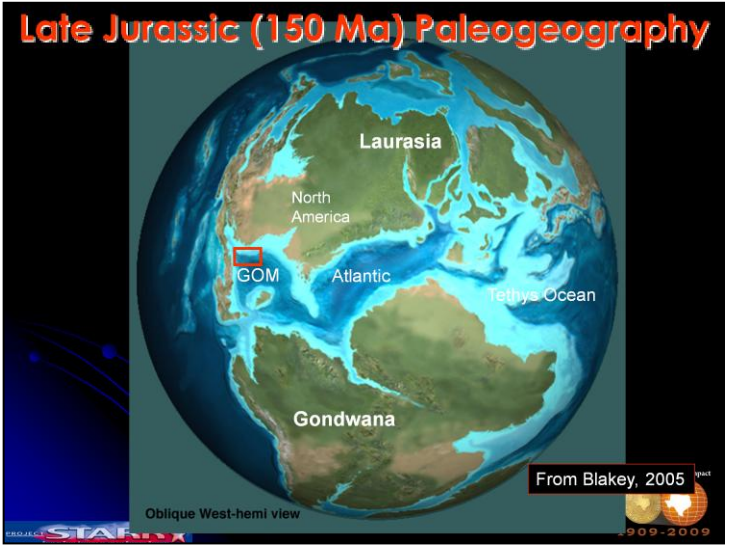
Presenter's Notes: Close-up of section shows Bossier/Haynesville time equivalent and dilemma of what to call formations. For example CVL, HVL, and SMK are all time equivalent carbonate overlain by Haynesville shale. But it's not that simple…



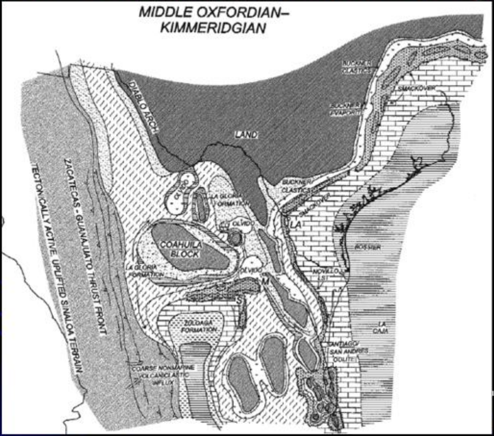
Presenter's Notes: To understand Haynesville Shale extent and deposition knowledge of evolution of basin is important.

Structural Controls




Late Jurassic (150 Ma) Paleogeography
Laurasia
North America
GOM
Atlantic
Tethys Ocean
Gondwana
From Blakey, 2005
Oblique West-hemi view

Middle Oxfordian-Kimmeridgian

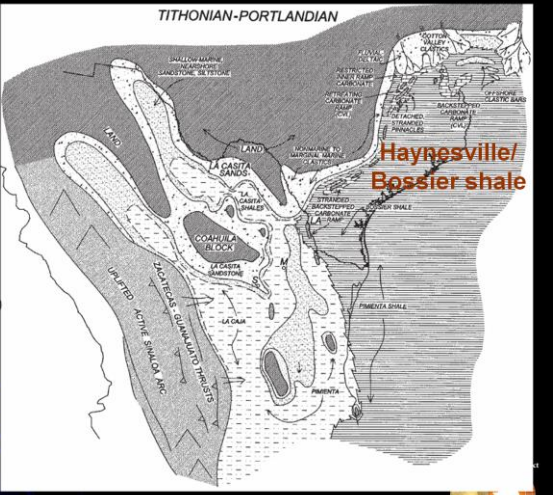


Goldhammer and Johnson, 2001

PROJECT STARR

100 Years of Scientific Impact
1909-2009

Tithonian-Portlandian



Haynesville/ Bossier shale

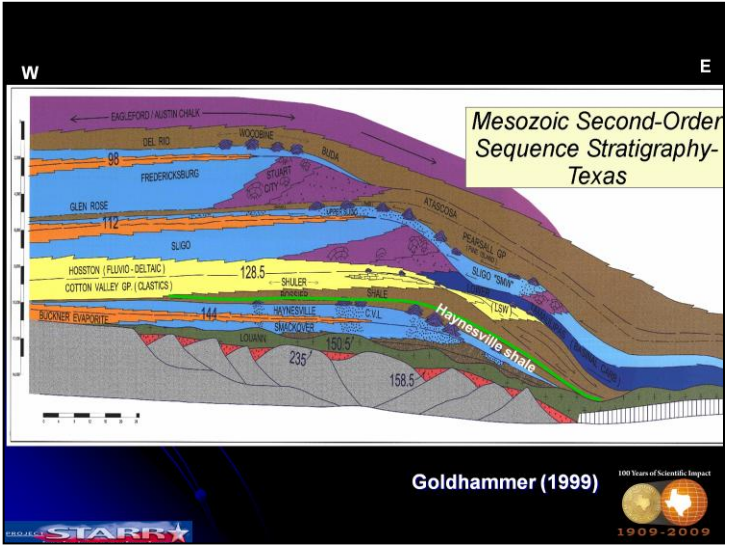
Goldhammer and Johnson (2001)

Haynesville Sequence Stratigraphy

- Transgressive systems tract of GOM–wide 2nd-order supersequence boundary.
- Regionally retrogradational carbonate facies belts.
  - 3 – 5 3rd-order sequences in shales and carbonates

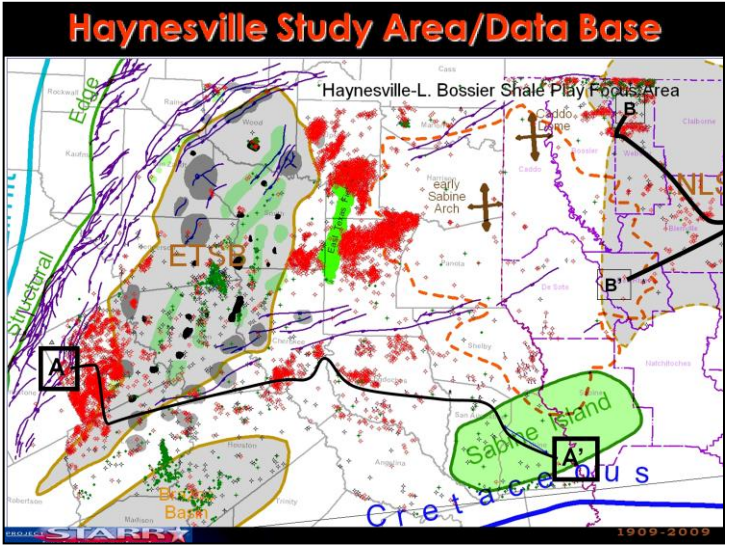
Haynesville Sequence Stratigraphy

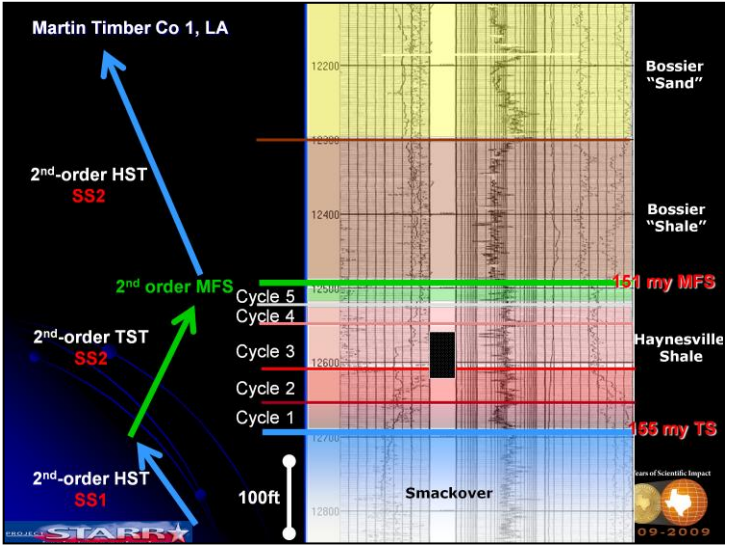
- Upper Jurassic consists of two 2nd-order supersequences SS1 and SS2:
  - Smackover limestone= late TST and HST of SS1
  - Buckner evaporite = latest HST of SS1 and LST of SS2
  - Haynesville/CVL = TST of SS2
    - Top of Haynesville shale = MFS
  - Bossier shale = HST of SS2


W
E
Mesozoic Second-Order Sequence Stratigraphy-Texas
EAGLEFORD / AUSTIN CHALK
DEL RIO
WOODBINE
BUDA
98
FREDERICKSBURG
STUART CITY
GLEN ROSE
112
SLIGO
HOSSTON (FLUVIO - DELTAIC)
COTTON VALLEY GP. (CLASTICS)
128.5
SHULER
SHALE
BUCKNER EVAPORITE
144
HAYNESVILLE
C.V.L.
SMACKOVER
LOUANN
235
150.5
158.5
ATASCOSA
PEARSALL GP
SLIGO "SMP"
(LSW)
Haynesville shale
Goldhammer (1999)
100 Years of Scientific Impact
1909-2009
PROJECT STARR

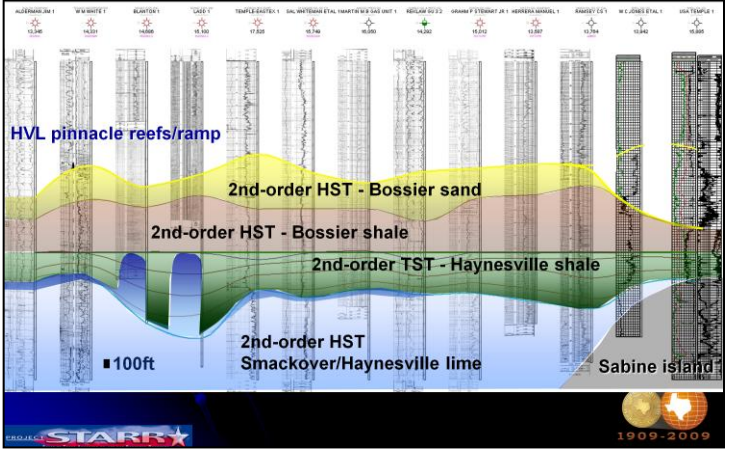
STARR Haynesville Study Data Base

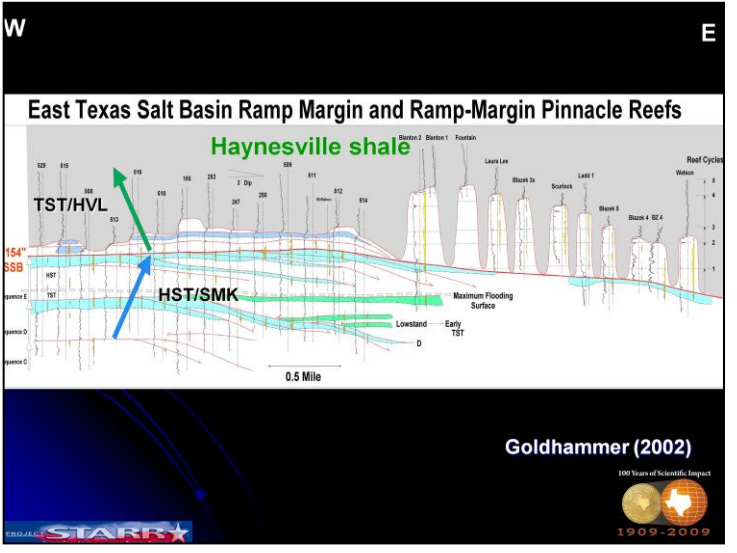
- Petra™ data base:
  - 20,000+ wells
  - 6,900 wells with rasters
  - 10 LAS files (need more…)
- Cores (need more!)
  - Facies
  - Geochemical analyses
  - Thin-section analyses

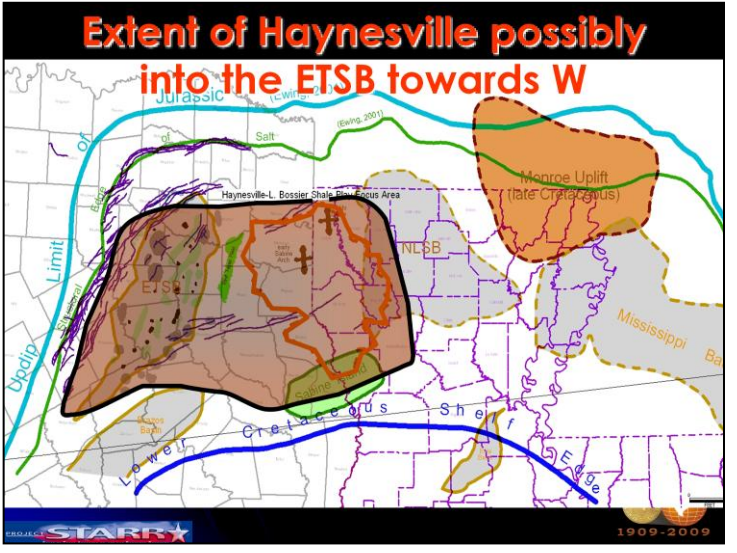

Haynesville Study Area/Data Base
Haynesville-L. Bossier Shale Play Focus Area
Structural Edge
ETSB
early Sabine Arch
Sabine Island
Cretaceous
A
A'
B
B'
NL
Black Bayou
1909-2009


Martin Timber Co 1, LA
2nd-order HST
SS2
2nd order MFS
2nd-order TST
SS2
2nd-order HST
SS1
100ft
12200
12400
12600
12700
12800
Bossier "Sand"
Bossier "Shale"
151 my MFS
Cycle 5
Cycle 4
Cycle 3
Cycle 2
Cycle 1
Haynesville Shale
155 my TS
Smackover
09-2009

Cross section A-A'

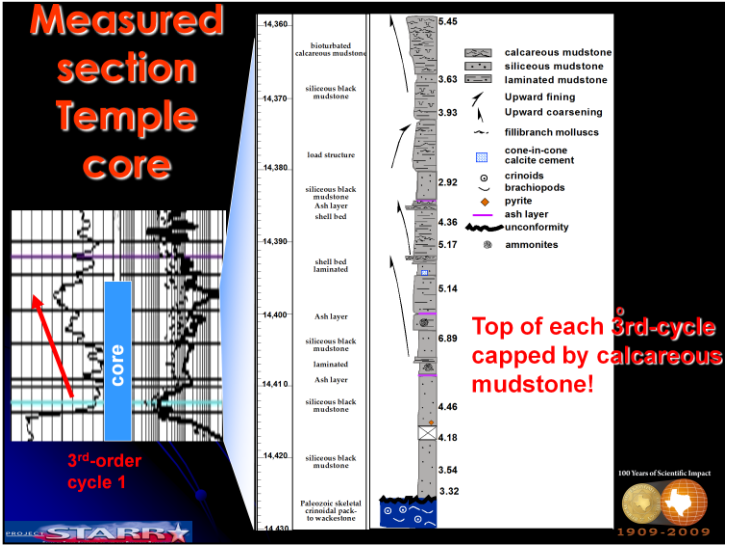



W
E
East Texas Salt Basin Ramp Margin and Ramp-Margin Pinnacle Reefs
Haynesville shale
TST/HVL
HST/SMK
154"
SSB
HST
TST
Maximum Flooding Surface
Lowstand
Early TST
D
0.5 Mile
Blanton 2
Blanton 1
Fountain
Laura Lee
Blazek 3x
Scurlock
Ladd 1
Blazek 6
Blazek 4
BZ 4
Watson
Reef Cycles
Goldhammer (2002)
100 Years of Scientific Impact
1909-2009
PROJECT STARR


Extent of Haynesville possibly into the ETSB towards W
Jurassic
Salt
Updip Limit
Haynesville-L. Bossier Shale Play Focus Area
ETSB
NLSB
Monroe Uplift (late Cretaceous)
Mississippi
Lower Cretaceous Shelf Edge
PROJECT STARR
1909-2009

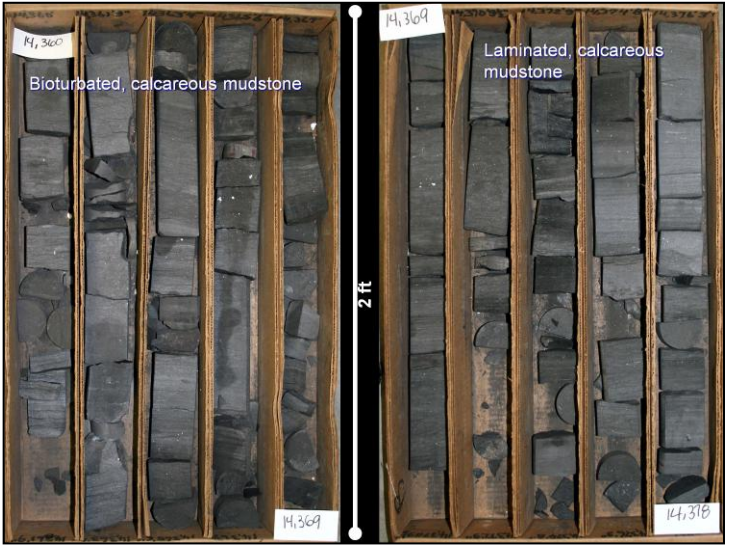
Core Work

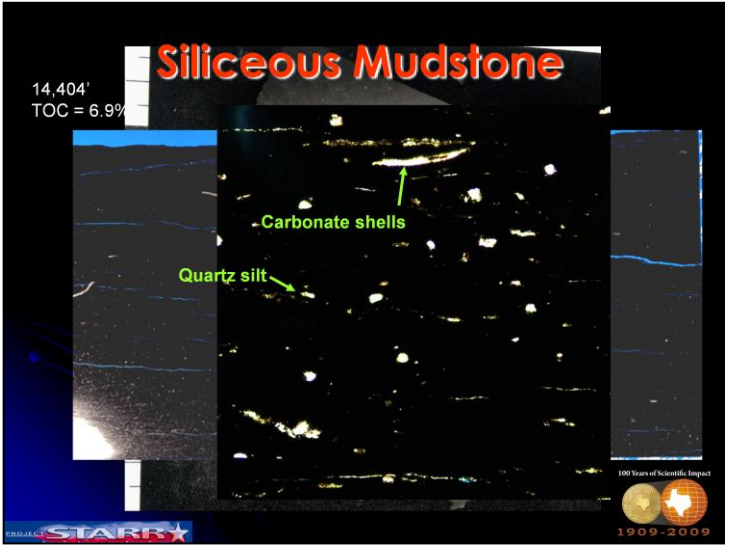
- Cores from Shell Temple #1 and Jones #1, San Augustine and Sabine Counties
- Core and thin-section descriptions
- Geochemical analyses: TOC, XRD, XRF, SEM


Measured section Temple core
core
3rd-order cycle 1
14,360
14,370
14,380
14,390
14,400
14,410
14,420
14,430
bioturbated calcareous mudstone
siliceous black mudstone
load structure
siliceous black mudstone
Ash layer
shell bed
shell bed laminated
Ash layer
siliceous black mudstone
laminated
Ash layer
siliceous black mudstone
siliceous black mudstone
Paleozoic skeletal crinoidal pack-to wackestone
5.45
3.63
3.93
2.92
4.36
5.17
5.14
6.89
4.46
4.18
3.54
3.32
calcareous mudstone
siliceous mudstone
laminated mudstone
Upward fining
Upward coarsening
fillibranch molluscs
cone-in-cone calcite cement
crinoids
brachiopods
pyrite
ash layer
unconformity
ammonites
Top of each 3rd-cycle capped by calcareous mudstone!
PROJECT STARR
100 Years of Scientific Impact
1909-2009

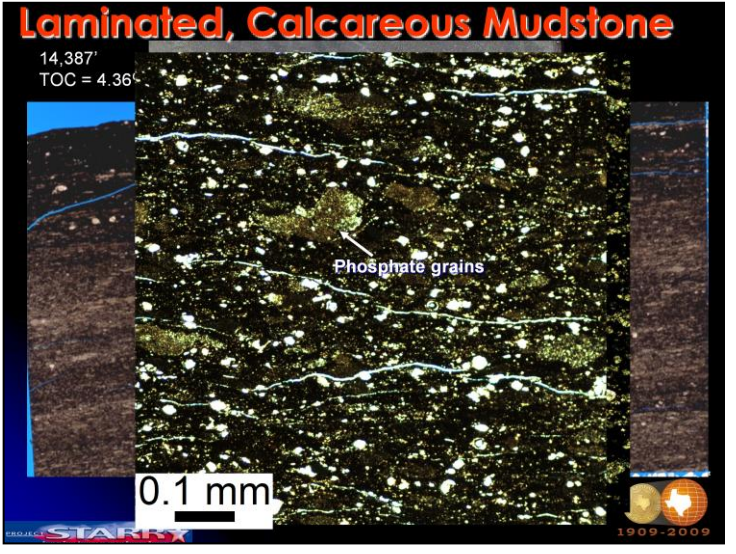
Haynesville Facies (from bottom to top of 3rd-order sequence)

- Siliceous mudstone
- Laminated, calcareous mudstone
- Calcareous, bioturbated mudstone

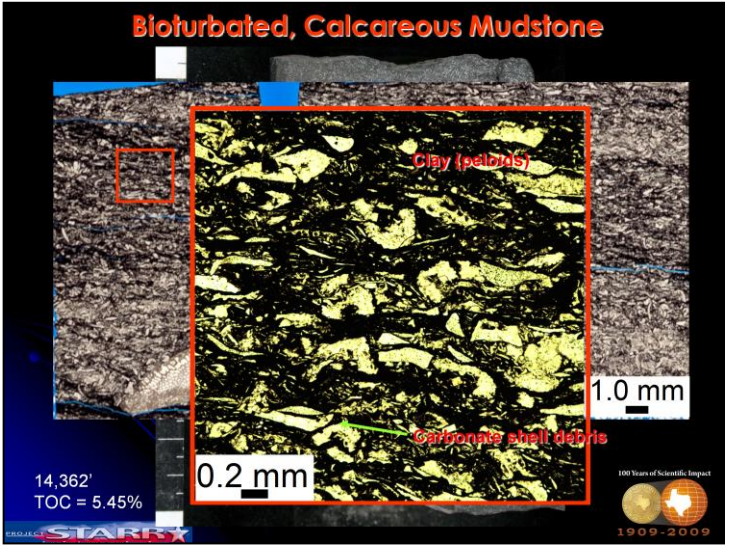

14,360
Bioturbated, calcareous mudstone
14,369
2 ft
14,369
Laminated, calcareous mudstone
14,378



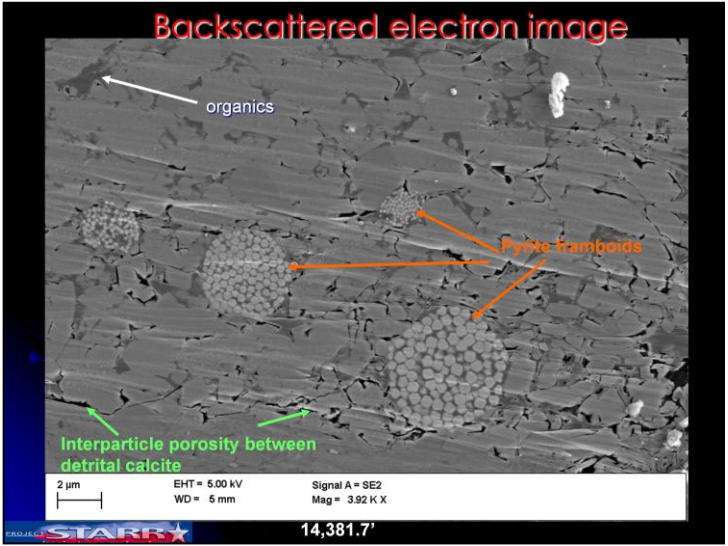
Presenter's Notes: Suspension settling, mud plumes



Presenter's Notes: Laminations from turbidity currents.

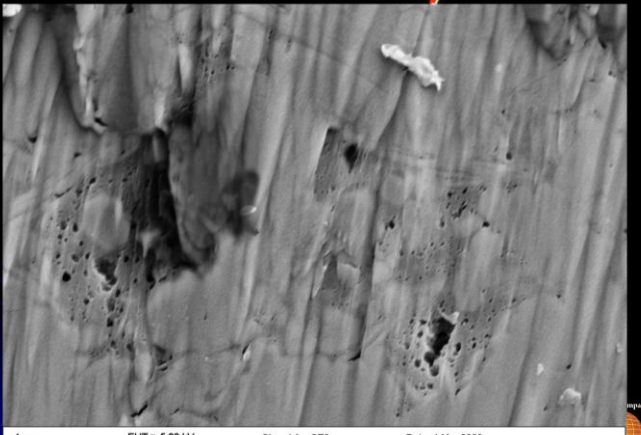


Presenter's Notes: Carbonate shells from platform; laminations are organics and peloids, possibly debris flow.



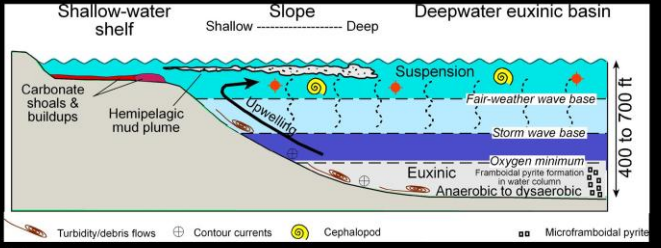
Presenter's Notes: Anomalously high-porosity zone in USA Temple 1 well, 14,381.7'. Darker non-porous areas are organic material; lighter areas are pyrite framboids. Size of pyrite framboids is compatible with euxinic conditions during deposition. Bedding is parallel to long axis.

Nano-Porosity



Temple 14,411'

Depositional Environment



Fauna

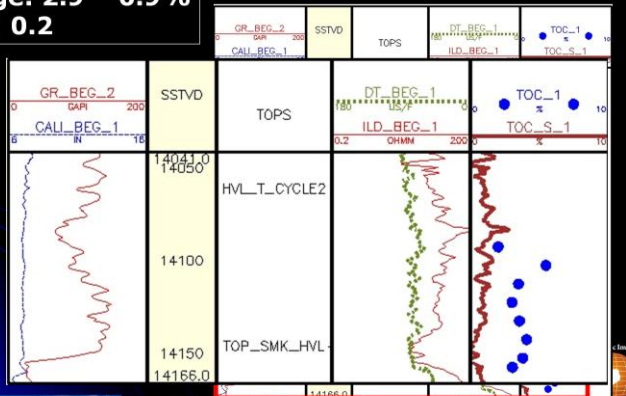
- Burrows — rare
- Corals
- Benthic foraminifera
- Fillibranch molluscs
- Brachiopods
- Cephalopods
- Oysters
- Planktonic foraminifera

Presence in basin indicates downslope transportation

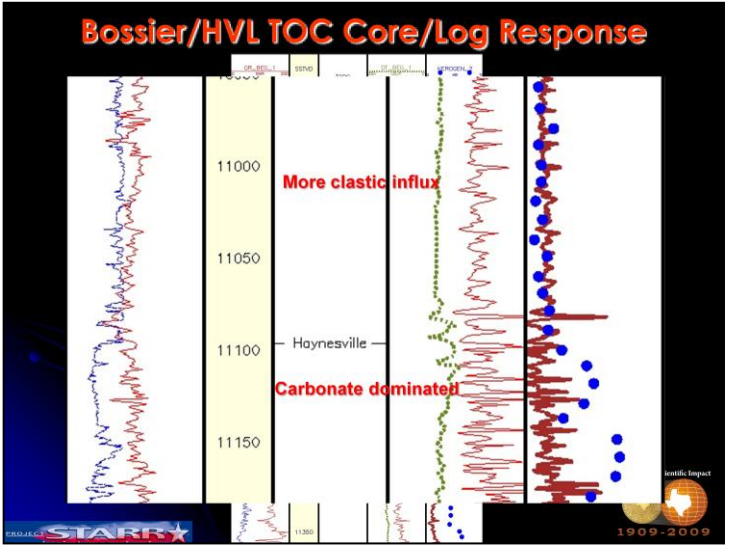
Modified from Loucks and Ruppel (2007)

Shell Temple #1 TOC/log response

Avg. TOC = 4.4%
Range: 2.9 – 6.9%
S2 < 0.2



TOC calculations after Passey et al. (1990)


Bossier/HVL TOC Core/Log Response
11000
11050
11100
11150
More clastic influx
Haynesville
Carbonate dominated
1909-2009

Conclusions

- Haynesville = transgressive systems tract of Upper Jurassic 2nd-order supersequence.
- 3 to 5 3rd-order cycles correlatable to HVL pinnacle reef cycles.
- Each 3rd-order cycle composed of coarsening-upward sequences
  - (siliceous mudstone – laminated mudstone – calcareous, bioturbated mudstone)

Conclusions cont.'d

- Deposition in basinal, euxinic environment
  - debris flows (transported broken skeletal material),
  - turbidity currents (laminated facies),
  - framboidal pyrite,
  - peloidal clay,
  - suspension settling.
- Extent of Haynesville shale possibly into ETSB in basinal settings and between pinnacle reefs.
- Log TOC underestimated vs. measured TOC
  - Which method is wrong? core measurements or log calculations?

Acknowledgements

- Bob Loucks
- Steve Ruppel
- Rob Reed
- Kitty Milliken
- Harry Rowe
- The STARR project
- MJ Systems