Biostratigraphy for Understanding Stratal Surfaces and Facies Variability in the Eagle Ford Group of South and West Texas

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ABSTRACT

As recent oil and gas interests have promoted geologic study of the Eagle Ford Group, biostratigraphic data and interpretations have improved to provide constraints on regional and sub-regional sequence correlations in South Texas. Within complex geologic sections, sequence-based correlations using only seismic, petrophysical curves, and elemental geochemistry profiles ultimately breakdown into non-unique solutions. These correlative solutions for wells involve either lateral, lithologic facies changes within coeval units or the erosion of strata along sequence boundaries to juxtapose rocks of different rock properties and apparent thicknesses. As Eagle Ford stratigraphy has proven to be more complicated than initially thought, microfossil biostratigraphy offers additional input to help refine sequence stratigraphic and petrophysical log based correlations.

Several significant sequence boundaries and flooding surfaces were correlated using calcareous nannoplankton abundance data collected from Eagle Ford rocks at Lozier and Antonio canyons of Terrell County, Texas, and Hot Springs and Ojinaga sections of Brewster and Hudspeth counties, Texas. Interpretations from these regional outcrops were integrated with recent subsurface data to create, a simple, reproducible, and age-restricted criterion for classifying the 3rd to 4th order sequences of the Eagle Ford Group. This nannoplankton-based framework, supplemented with foraminifers and palynomorphs, has allowed for both the duration of erosion along some of the most significant sequence boundaries to be quantified and a regional composite section for the upper Eagle Ford to be constructed.

These biostratigraphic results have implications to exploration and production activities of the Eagle Ford within the region. By understanding the timing of sequence

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boundaries and the spatial variation of these stratal surfaces, a clear differentiation of eustatic versus sub-regional uplift controls on sedimentation within the play can be achieved. Within this context, the controversial Eagle Ford to Austin Formation boundary and importance of the Langtry Member of the Upper Eagle Ford is also discussed.

Biostratigraphy for understanding stratal surfaces and facies variability in the Upper Eagle Ford of south and west Texas

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Disclaimer: The statements and illustrations in this presentation are those of the lead author and may not represent the views of the companies or universities who contributed data into the various projects involved.

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Outline of Talk

Statement of Problem – Biostratigraphers not consistently subdividing the Eagle Ford

- Taxonomic inconsistency results in highest confidence events not being used by everyone
- Many published zonal markers fail
- Poor recognition and explanation of timescale differences
- Erroneous regional correlations and lack of confidence in biostratigraphy has resulted

1) **Intro - Basics of sections worked and reference terminology – quick review**

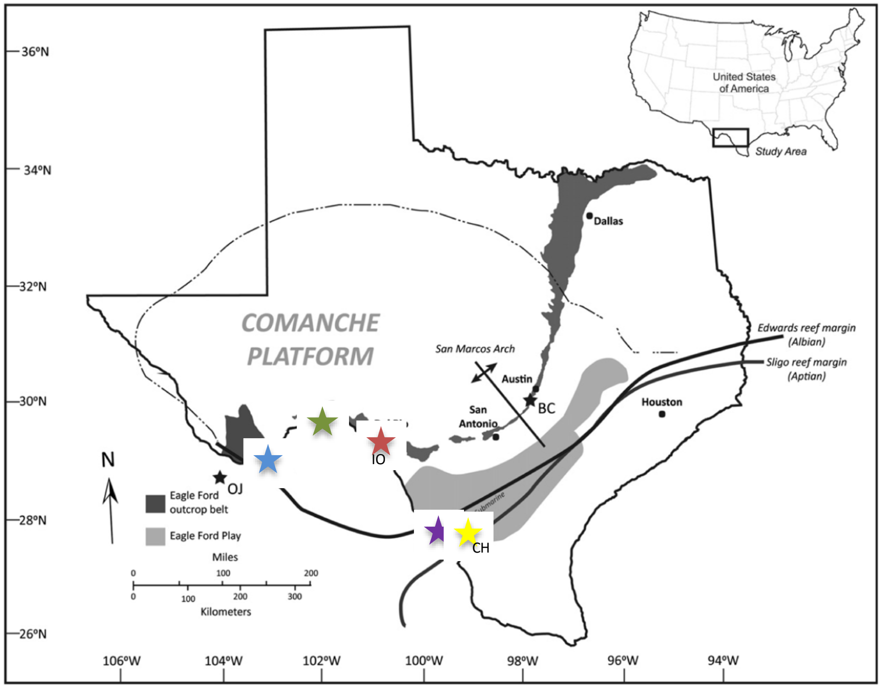
2) **Paleontology and Biostratigraphy**
   - Proposal for events that should be used and those that should be abandoned
   - Two problem species and proposed criteria for providing consistency
   - Relative positions of key taxonomic changes in geologic time and age assignments

3) **Examples - Austin to EF sequences from outcrop and subsurface**

4) **Structural and Age Implications Austin to EF sequences from outcrop and subsurface**
   - Time transgressive, transitional Langtry contact with Austin observed in some sections
   - Timing of major erosional events at Hot Springs and Webb County age events
   - Simple timescale correction and age interpretation for top of Langtry Unit at Lozier

5) **Summary of Results and Conclusions**
   - Currently, inconsistency among paleo practitioners is creating correlation
   - Adherence to criteria for E. eximius and E moratus provides high confidence surfaces
   - Result aid in understanding key time surfaces and constrains timing of structural events

1a Intro – Sites and stratigraphic interval discussed in this talk



modified from Lowery et al., 2014

- Hot Springs outcrop
- Lozier Canyon outcrop
- Shell Iona-1 core
- Swift Fasken A1H core
- Lewis Chamberlain State core

_Swift_Fasken State A1H

Corbett et al., (2014)

Events referenced to gamma logs or hand-held gamma profile derived lithology interpretations (for detailed lithologies see Donovan et al., 2012; Frebourg et al., 2015)

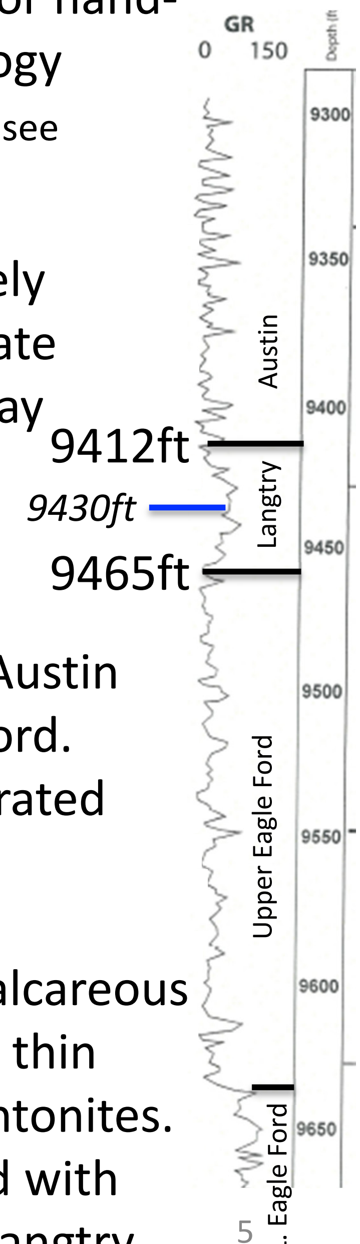
Austin Formation – massive, largely homogenous fine grained carbonate blocky to finely serrated gamma ray

Key biostratigraphic event

Langtry Mbr of Upper Eagle Ford

Lithology is transitional between Austin carbonate and underlying Eagle Ford. Gamma log signature is highly serrated with some thick bentonites

Upper Eagle Ford - organic rich, calcareous mudstone with some pronounced thin limestone beds and a few thin bentonites. Gamma log is moderately serrated with lower maximum values than the Langtry



1b Intro – Sequence Terminology that you'll see in this talk

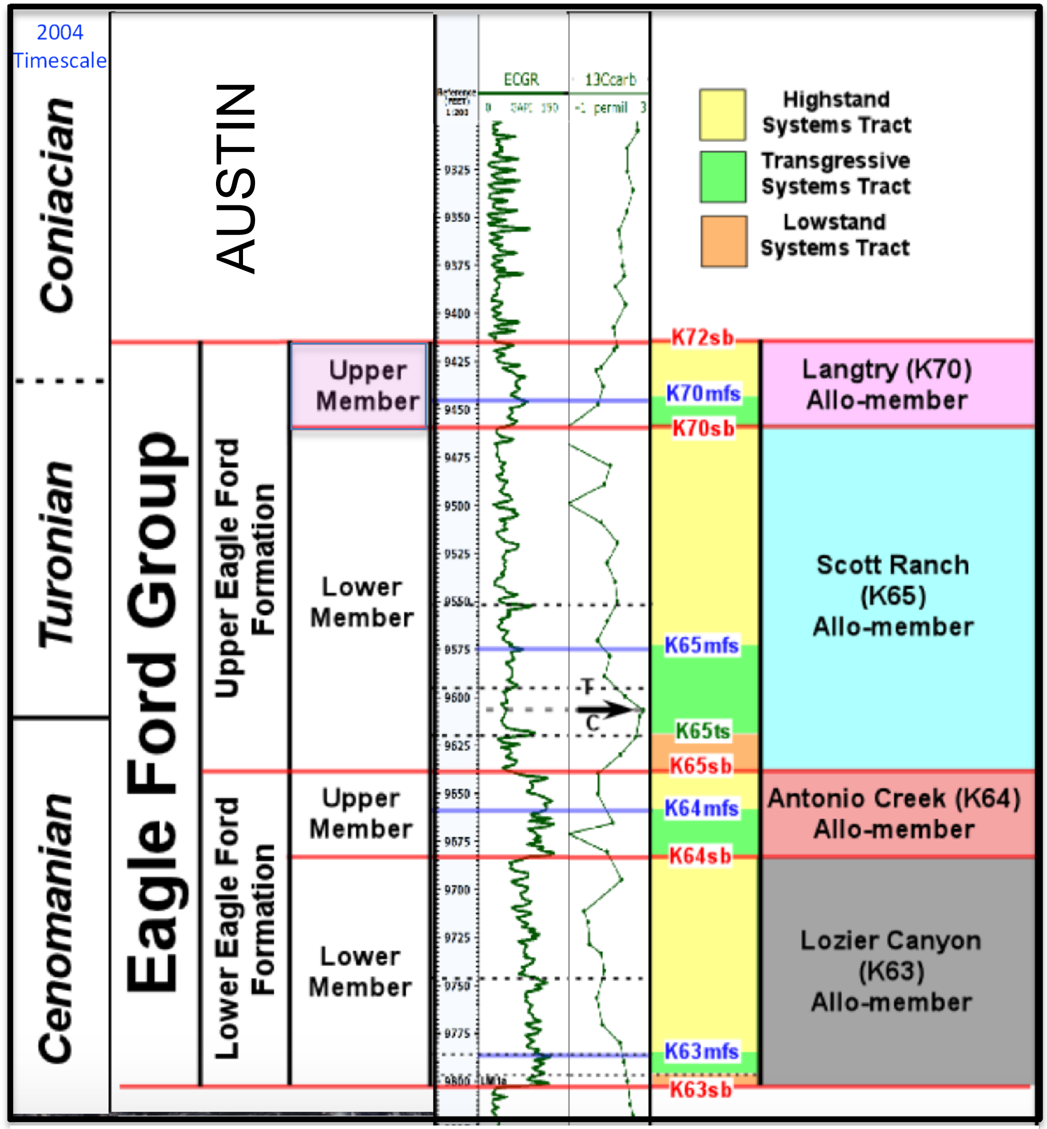
Sequence boundary and maximum flooding surface designations follow that described by Donovan and Staerker (2010) and Donovan et al, (2012)

K72 SB = sequence boundary at approximately the contact between the Austin and uppermost Eagle Ford unit, which we call the Langtry

K70 mfs = the maximum flooding surface that occurs in the Langtry unit as described in south and west Texas.

K70 SB = sequence boundary at approximately the contact between the Langtry member of the Eagle Ford and the Scott Ranch Member of the Eagle Ford, which together comprise the Upper Eagle Ford Formation

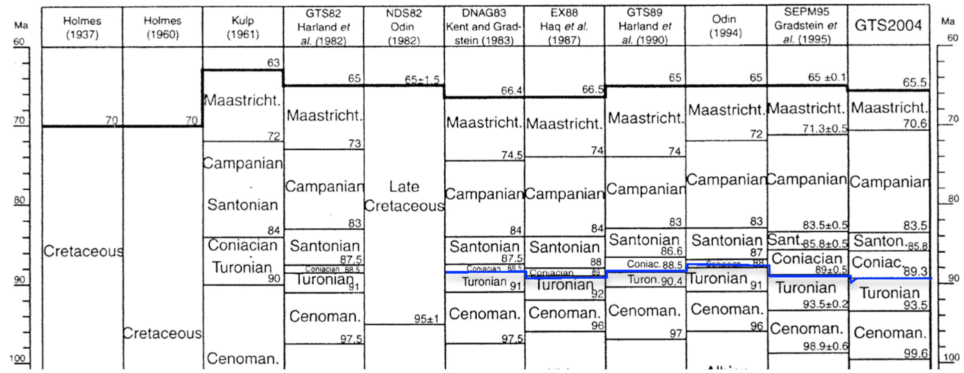
Correlative conformities become the challenge!

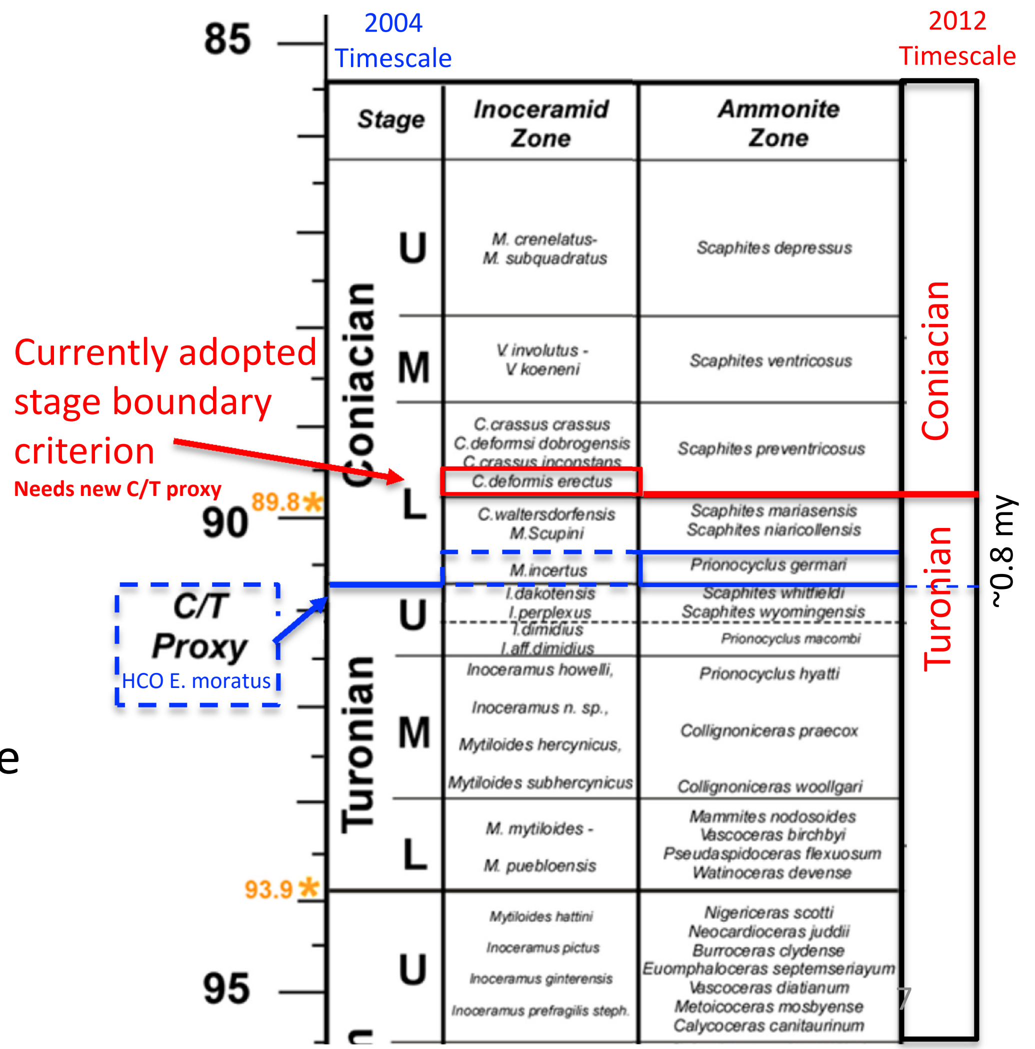


Modified from Donovan et al. (2012)

1c Intro – All Events Referenced to a Geologic Time Scale

- **Problem for Eagle Ford** - The Austin to Upper Eagle Ford interval presents a unique time scale issue that must be accounted for
- Unlike most timescale updates, the criterion for the base of the Coniacian was completely redefined ~2006
- A stratigraphically higher and younger paleontological criterion was proposed and first published in a timescale by Ogg et al., (2008)
- Some fossil events that were formerly considered Coniacian were now considered Turonian
- Most stratigraphers prior to 2008 (and some afterwards) referenced stage boundaries to the older criterion
- See Donovan et al. (2012) for discussion

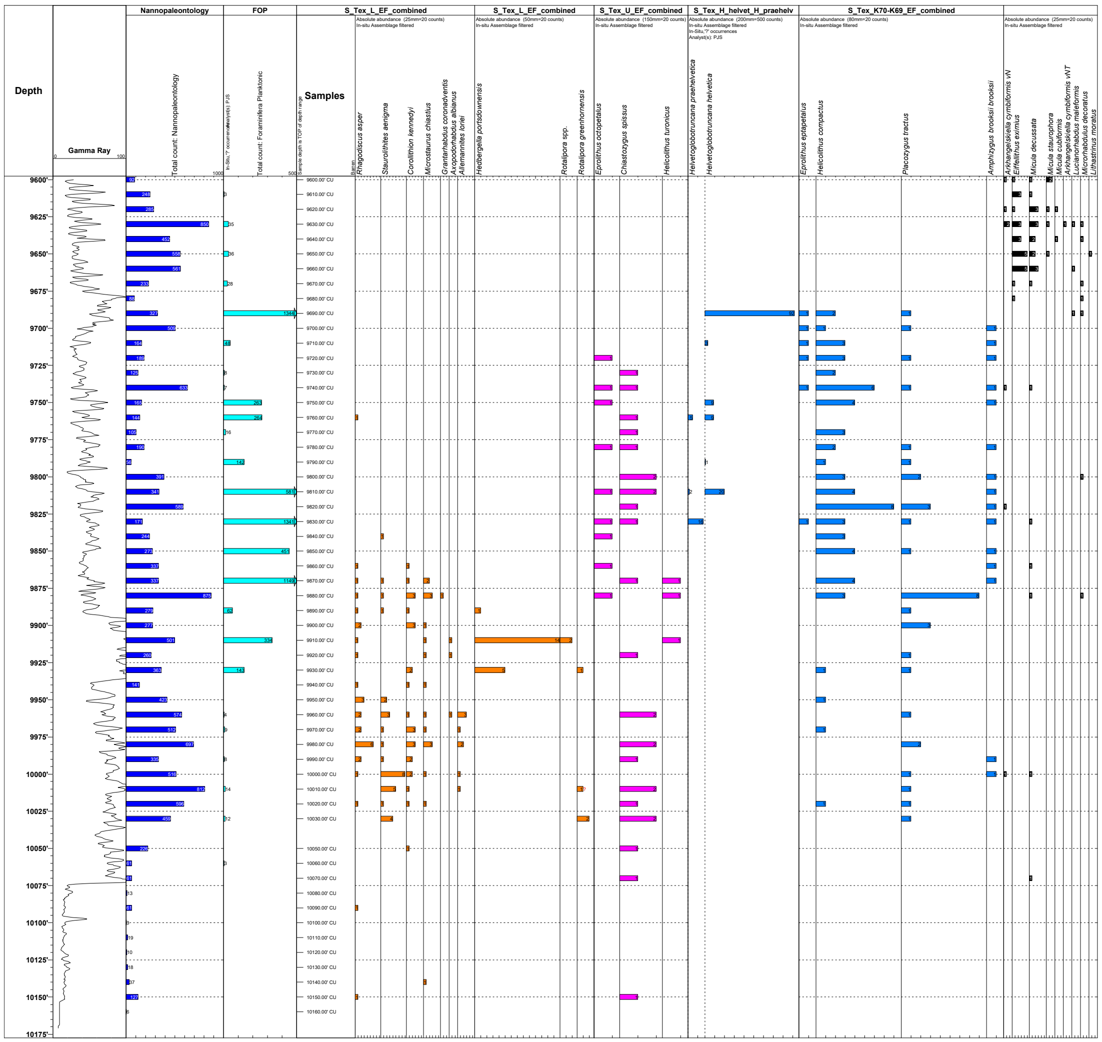




1d Intro - Biostratigraphic data versus interpreted events, which are not data!

Taxonomic abundance data

- Spreadsheets or graphical display
- Essential for quality re-interpretation
- Often grouped for maximizing interpretation

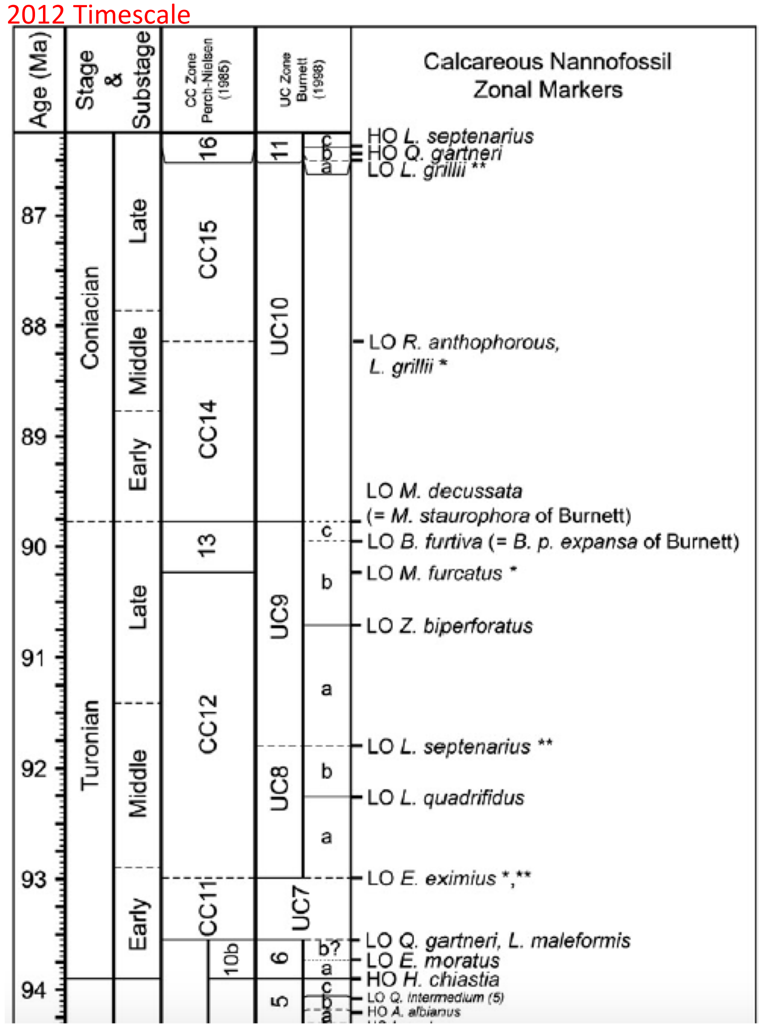


Modified from unpublished, Donovan et al. (2014), SEPM/AAPG Unconventional Reservoirs Field Seminar

Interpretation from data

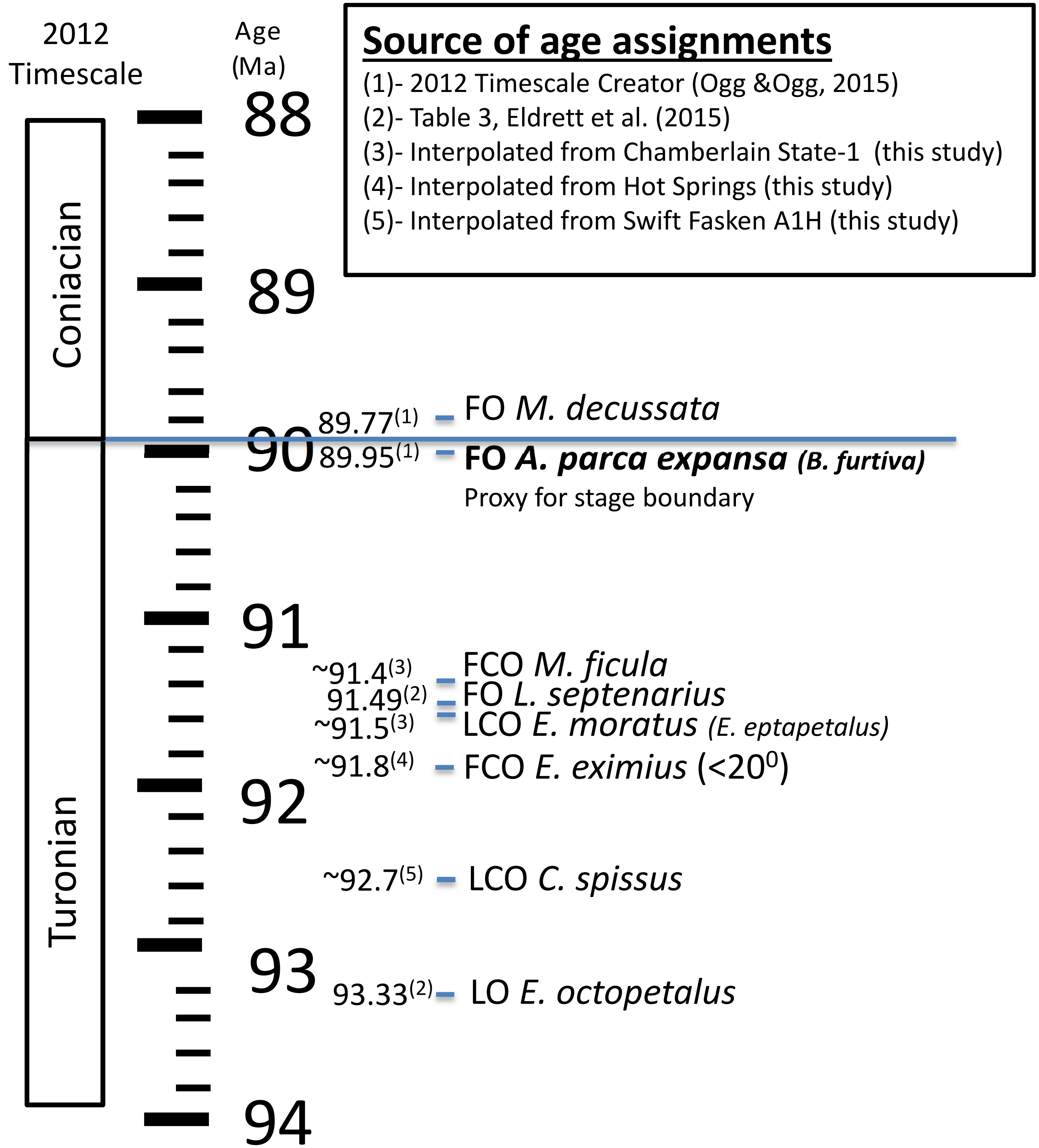
- Must not be confused for data
- Quality of data or confidence in the interpretation is lacking

2012 Timescale



Corbett et al. (2014)

2a - Proposal for EF events that should be used and those that should be abandoned



Species variants that require taxonomic consistency to be used as stand-alone time events

Lithastrinus septenarius
Eprolithus moratus (E. eptapetalus)
Eiffellithus eximius (<20° = sensu strictu)

Previous published zonation markers that should be abandoned as stand-alone time events

FO - *Marthasterites furcatus*
FO - *Lucianorhabdus maleformis*
FO - *Zeugrhabdotus biperforatus*
FO - *E. eximius* (>20° = sensu latu)
LO - *E. moratus* (sensu latu)

2b - Our Criteria is well vetted in Western Interior of U.S.

Eprolithus lineage and Eiffellithus eximius are two taxa that are creating problems

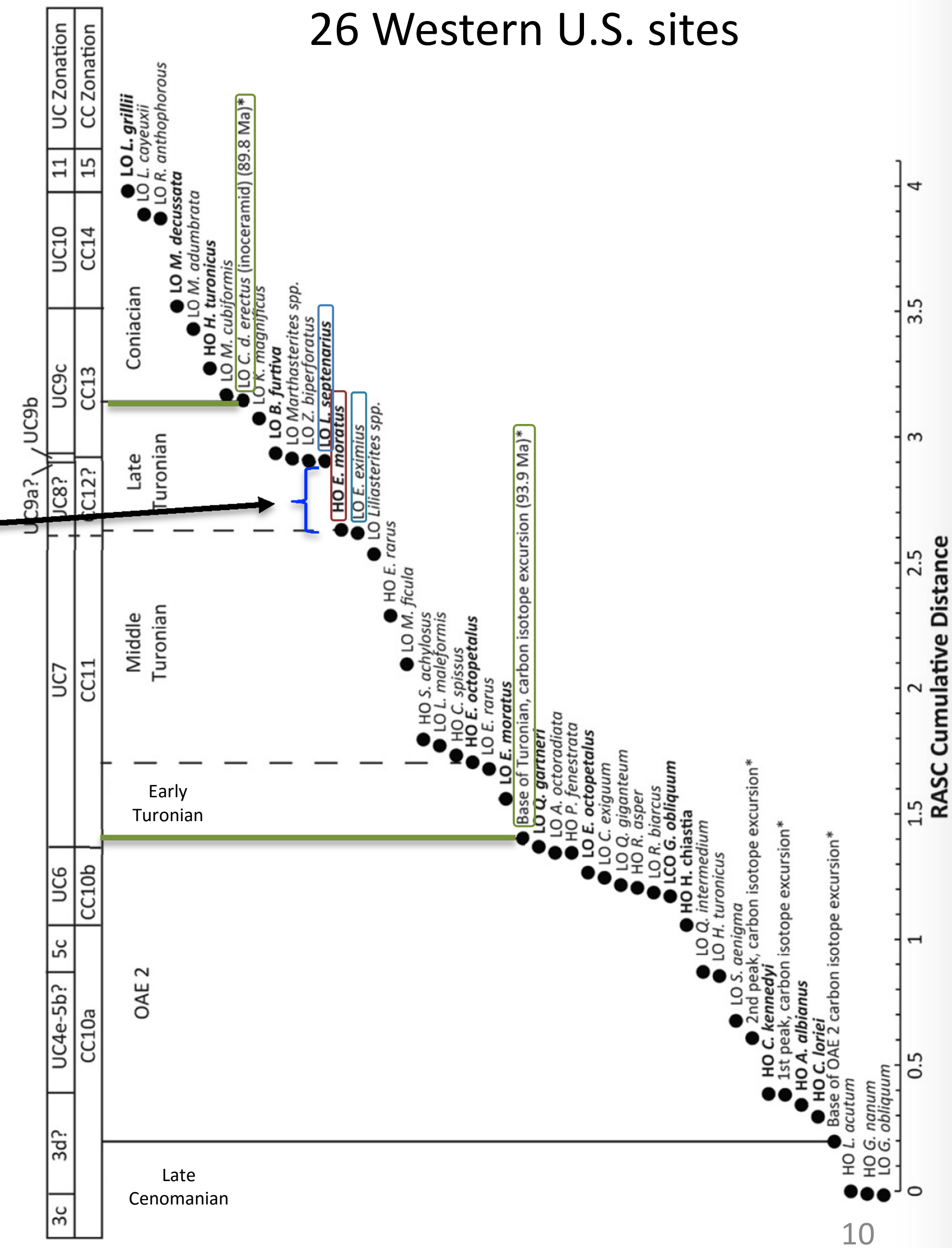
<u>Using 26 Western Interior Seaway sections</u>, RASC methodology shows the most consistent order of events in geologic time.

This order of events is consistent with our observations in the Eagle Ford/Austin for both *E. moratus* and *E. eximius*

This order does not match other authors and consultants work

Some range contractions occur with RASC (Corbett et al., 2014, citing Hammer and Harper, 2006) but this <u>doesn't explain the inconsistency among biostratigraphers working the Eagle Ford</u>

Statistically derived order of events from 26 Western U.S. sites

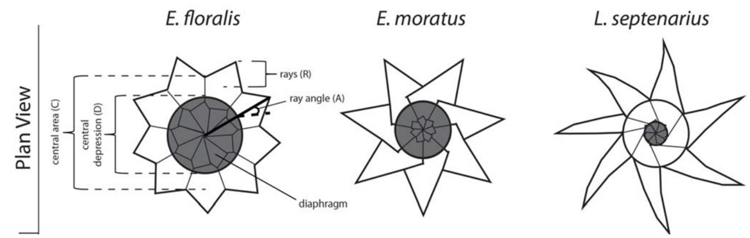


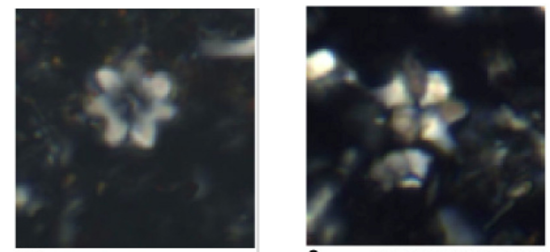
Modified from Corbett et al. (2014)

2c Example of a key lineage causing problems

Eprolithus to *Lithastrinus* lineage

- Lineage with *Eprolithus* and *Lithastrinus* genera have multiple, distinguishing, morphologic characteristics
- Despite taxonomic descriptions, paleontologist often disagree as to which characteristics “define” a taxon.
- Paleontologists can unfortunately identify this lineage differently based on biases of experience prior mentoring
- Preservation can also play a significant role in consistently identifying these features!





13 *E. eptapetalus* 29R-2, 22 8 *L. septenarius* 29R-1, 18

Corbett and Watkins (2014)

Some key features are:

- Length or rays/arms
- Width of rays/arms
- Angle between rays/arms
- Width of central area
- Elevation of central area
- Overlap of rays/arms

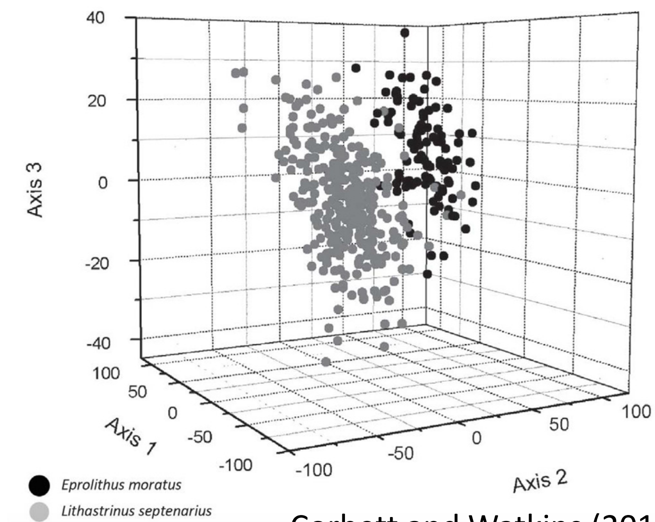
2d Proposed method for consistency of Eprolithus

- One key of the morphologic criteria helps with poorly preserved specimens.

Corbett and Watkins (2014) *"By careful focusing through the specimens it is possible to determine whether the rays protrude completely between the proximal and distal sides or form a smoother rounded wall around the diaphragm with protrusions restricted to the proximal and distal ends of the wall elements."*

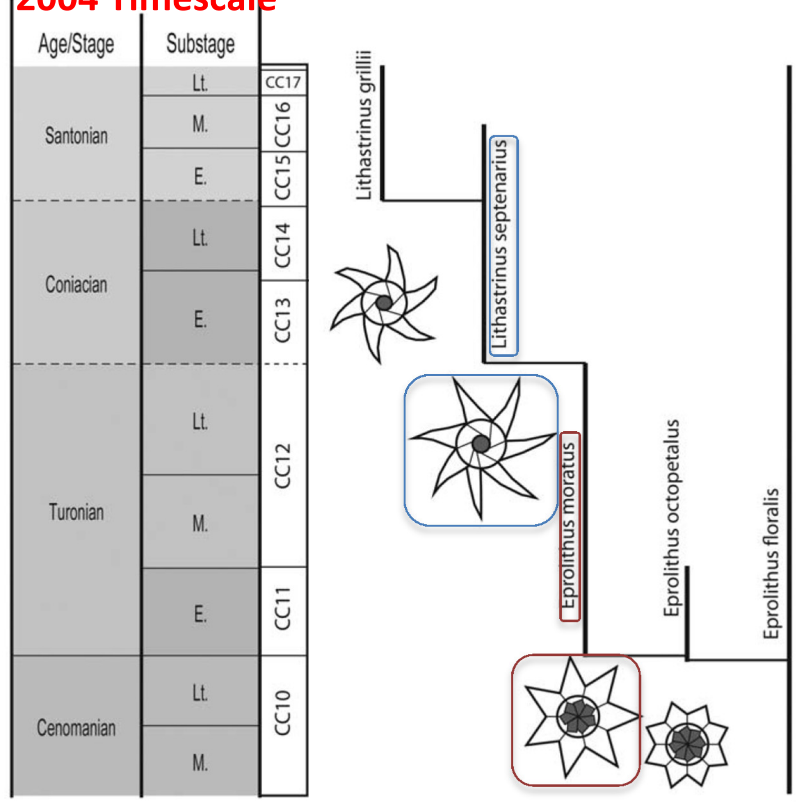
- In practice – Focus up and down on the specimen to observe visible rotation on the elements of a Lithastrinus, but no rotation on Eprolithus.

- **This approach provides for a clear separation of populations in this lineage.**



Corbett and Watkins (2014)

2004 Timescale

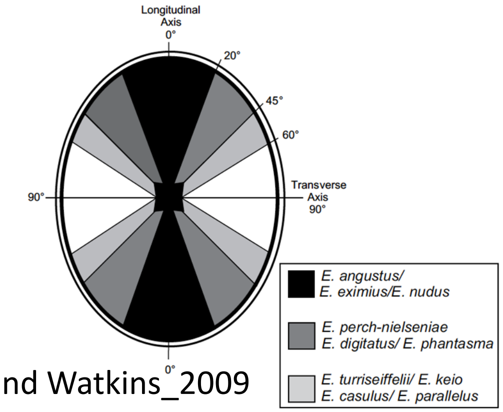


After Corbett and Watkins (2014)

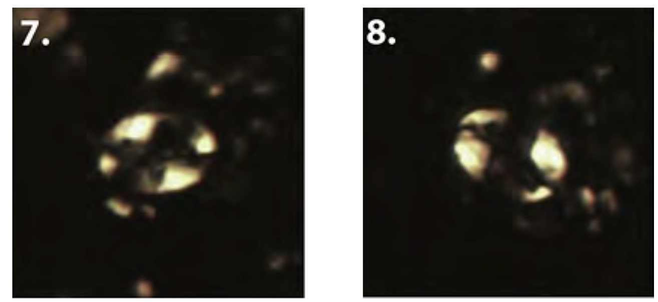
2e Another problematic marker taxa

- ***E. eximius* is a key Eagle Ford zonal marker**
- Shamrock in 2009 published criteria for subdividing this lineage
- “Lumping (grouping together) versus splitting” results in different events in time for this key marker
- Splitting out similar forms will shorten the lower range of *E. eximius*
- Some biostratigraphers have adopted these splits and others have not
- Summary figures with an *E. eximius* datum, rarely show whether the paleontologist split out similar forms in his/her species abundance charts

Eiffellithus eximius and related taxa



Shamrock and Watkins_2009



E. eximius of Eldrett et al. (2015)
Iona 1 core

Corbett et al. (2014)
Swift Fasken A1H

2f Recommendation to use these taxonomic splits

Eiffellithus eximius and related taxa

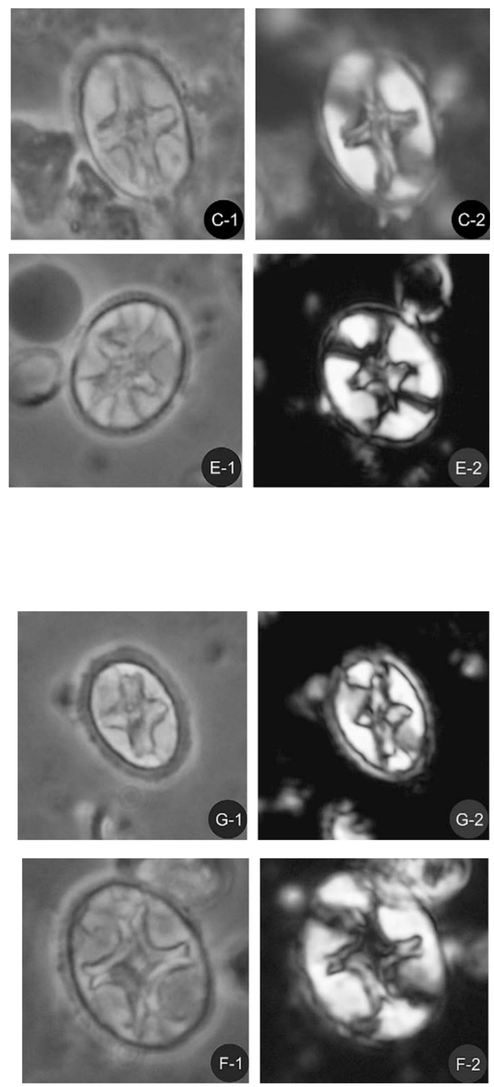
Including forms with >20^0 rotation extends the range older and out of the upper Turonian, Langtry unit

Eiffellithus eximius
(sensu strictu)

Eiffellithus angustus

Eiffellithus perch-nielseniae

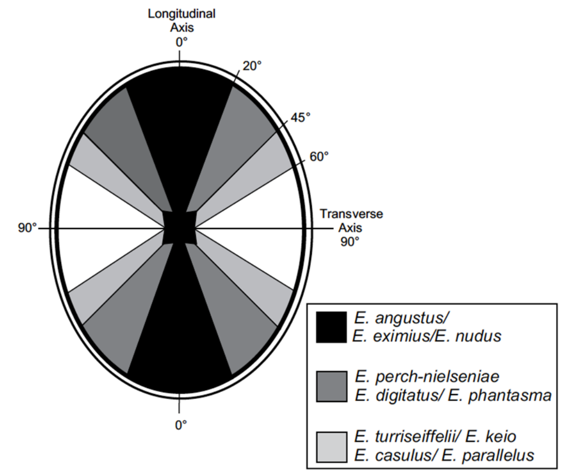
Eiffellithus digitatus

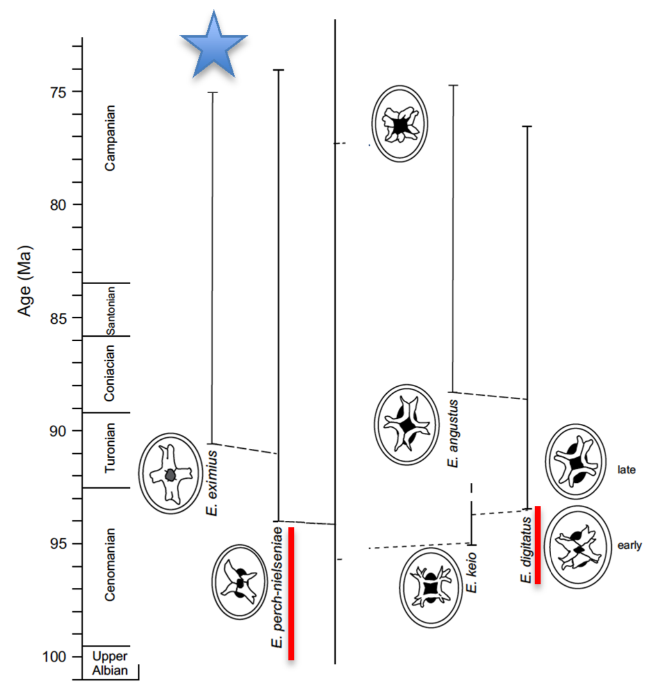


0-20^0

20^0-40^0

Some assign all forms into E. eximius

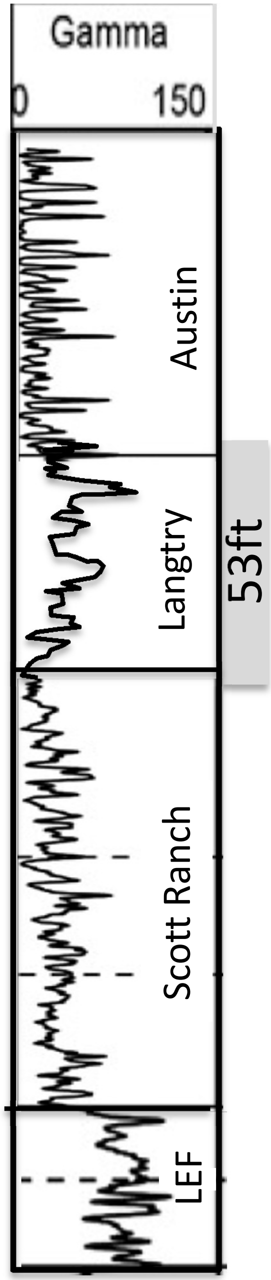




All images from Shamrock and Watkins (2009)

3a - Example 1 – Observations in Webb Co., reference well

Swift Fasken A1



			key markers used for correlation									not used		
log derived lithology (Corbett, 2014)	**Sample Depth (ft)**	**Sample Depth (m)**	Eprolithus octopetalus	Chiastozygus spissus	Eiffellithus eximius (sensu strictu)	Eiffellithus eximius (>20 deg)	Lithastrinus septenarius	Eprolithus moratus (E. eptapetalus)	Miravetesina ficula	Aspidolithus parcus expansus	Micula decussata	Lucianorhabdus maleformis	Marthasterites furcatus	Zeugrhabdotus biperforatus
limstn - Austin	9297.2	2833.81	0	0	0	1	1	0	0	0	10	1	0	0
limstn - Austin	9304.9	2836.17	0	0	0	0	0	0	0	0	1	0	0	0
limstn - Austin	9314	2838.94	0	0	1	1	0	0	0	0	1	0	0	0
limstn - Austin	9326.2	2842.65	0	0	0	0	0	0	0	0	2	0	0	0
limstn - Austin	9335.9	2845.62	0	0	1	0	0	0	0	0	1	0	0	0
limstn - Austin	9346.8	2848.92	0	0	0	1	0	0	0	0	0	0	0	0
limstn - Austin	9356.8	2852.00	0	0	0	1	0	0	0	0	1	0	0	0
limstn - Austin	9365.7	2854.69	0	0	0	0	0	0	0	0	1	0	0	0
limstn - Austin	9375.2	2857.59	0	0	1	1	0	0	0	0	2	0	0	0
limstn - Austin	9380.6	2859.24	0	0	0	0	0	0	0	0	2	1	0	0
limstn - Austin	9385.8	2860.84	0	0	1	1	0	0	0	0	1	1	0	0
limstn - Austin	9395.3	2863.71	0	0	1	1	0	0	0	0	2	0	1	0
limstn - Austin	9407.4	2867.42	0	0	0	1	0	0	0	0	0	0	0	0
mixed - transitional	9412.00	2868.81												
mixed - transitional	9418.6	2870.82	0	0	0	3	0	0	0	0	0	0	0	0
mixed - transitional	9420.2	2871.31	0	0	2	2	0	0	1	0	0	1	0	0
mixed - transitional	9425.3	2872.87	0	0	2	1	0	0	0	0	0	2	0	0
mixed - transitional	9428	2873.69	0	0	0	0	0	0	0	0	0	0	0	0
mixed - transitional	9429.7	2874.20	0	0	0	1	2	0	0	0	0	0	0	0
mixed - transitional	9438	2876.74	0	0	0	1	0	2	0	0	0	0	0	0
mixed - transitional	9447.4	2879.61	0	0	0	0	0	0	0	0	0	0	0	0
mixed - transitional	9459	2883.14	0	0	0	0	0	2	0	0	0	0	0	0
mixed - transitional	9465.00	2884.97												
calc/mdstn -Eagle Ford	9467.9	2885.86	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9479.5	2889.39	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9482.9	2890.42	0	0	0	1	0	1	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9489	2892.28	0	1	0	0	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9499.00	2895.33	0	1	0	0	0	1	0	0	0	1	0	0
calc/mdstn -Eagle Ford	9509	2898.38	0	1	0	2	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9519.5	2901.58	1	0	0	1	0	1	0	0	0	1	0	0
calc/mdstn -Eagle Ford	9524.2	2903.01	1	0	0	2	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9555.2	2912.46	1	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9564.9	2915.42	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9578.5	2919.56	0	1	0	2	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9582.7	2920.84	1	2	0	2	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9589	2922.76	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9599.5	2925.96	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9603.9	2927.30	0	2	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9606.7	2928.15	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9610	2929.16	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9620.5	2932.36	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9624.2	2933.49	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	9645.2	2939.89	0	0	0	0	0	0	0	0	0	0	0	0

Base *M. decussata* position indicates possible missing section in basal Austin

Either missing section or significant taxonomic turnover in Langtry unit

FO *M. decussata*

FO A. parcus expansa (B. furtiva) – not observed

FCO *M. ficula*,

FCO *E. eximius* (<20^0) - high

LCO *E. moratus* (*E. eptapetalus*)

FCO *L. septenarius*

LCO *C. spissus*

LO *E. octopetalus*

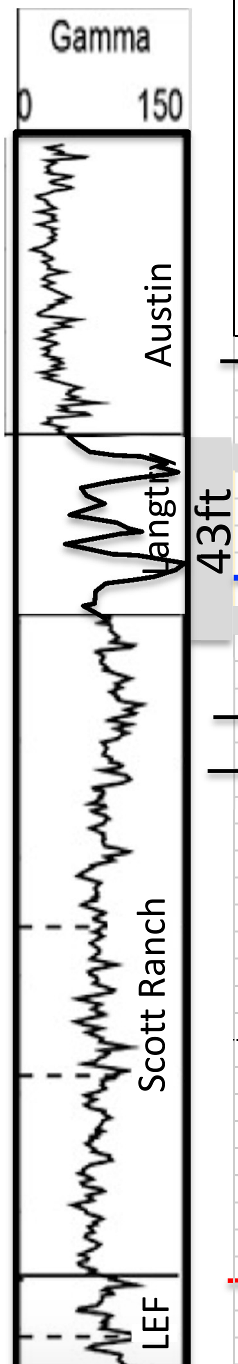
FO *E. eximius* (>20^0)?

possible complete section of Scott Ranch portion of Upper Eagle Ford

Unpublished data from Corbett (2012)
log not scaled to nanno data

3b - Example 2 – Observations in 2nd Webb Co. well

Lewis Chamberlain State



log derived lithology (Corbett)	Sample Depth (ft)	Sample Depth (m)	key markers used for correlation									not used		
			Eprolithus octopetalus	Chiastozygus spissus	Eiffellithus eximius (sensu strictu)	Eiffellithus eximius (>20 deg)	Lithastrinus septenarius	Eprolithus moratus (E. eptapetalus)	Miravetesina ficula	Aspidolithus parcus expansus	Micula decussata (below event)	Lucianorhabdus maleformis	Marthasterites furcatus	Zeugrhabdotus biperforatus
limstn - Austin	11850.40	3612.05	0	0	1	0	0	0	?	1	0	0	0	0
limstn - Austin	11861.50	3615.43	0	0	0	0	0	0	1	0	0	0	0	0
limstn - Austin	11869.50	3617.87	0	0	1	0	2	0	0	0	0	0	0	0
limstn - Austin	11879.20	3620.82	?	0	1	0	2	?	1	0	0	0	0	0
mixed - transitional	11890.00	3624.12												
mixed - transitional	11890.10	3624.15	0	0	1	2	4	0	0	0	0	0	50	0
mixed - transitional	11899.80	3627.10	0	0	1	0	1	?	1	0	0	0	1	0
mixed - transitional	11910.90	3630.49	0	0	2	4	2	0	1	0	0	0	3	0
mixed - transitional	11920.50	3633.41	0	0	1	4	30	1	1	0	0	0	25	0
mixed - transitional	11930.00	3636.31	0	0	0	2	0	1	0	0	0	1	0	0
mixed - transitional	11933.00	3637.22												
calc/mdstn -Eagle Ford	11940.50	3639.51	0	0	0	3	0	2	1	0	0	1	0	0
calc/mdstn -Eagle Ford	11951.60	3642.89	0	0	0	0	0	1	0	0	0	0	0	0
calc/mdstn -Eagle Ford	11959.80	3645.39	0	0	0	0	0	1	0	0	0	0	0	0
calc/mdstn -Eagle Ford	11970.40	3648.62	1	1	0	1	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	11980.50	3651.70	0	0	0	1	0	1	0	0	0	0	0	0
calc/mdstn -Eagle Ford	11992.10	3655.24	0	0	0	0	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12001.50	3658.10	?	0	0	0	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12011.20	3661.06	0	3	0	0	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12020.50	3663.89	0	0	0	0	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12030.80	3667.03	0	0	0	0	0	2	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12041.50	3670.29	0	2	0	0	0	3	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12050.30	3672.98	1	0	0	0	0	1	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12060.20	3675.99	0	0	0	0	0	?	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12071.80	3679.53	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12080.50	3682.18	1	0	0	0	0	1	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12090.80	3685.32	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12101.50	3688.58	?	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12111.10	3691.51	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12120.60	3694.40	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12130.80	3697.51	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12140.40	3700.44	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12151.60	3703.85	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12160.70	3706.63	0	0	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12171.30	3709.86	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12181.50	3712.97	0	1	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12190.70	3715.77	0	3	0	0	0	0	0	0	0	0	0	0
calc/mdstn -Eagle Ford	12201.50	3719.06	0	1	0	0	0	0	0	0	0	0	0	0

Paleo section starts below *M. decussata* at uppermost Turonian nanno event

Either missing section or significant taxonomic turnover in Langtry unit

FO *A. parcus expansa* (*B. furtiva*)

FCO *M. ficula*,
LCO *E. moratus* (*E. eptapetalus*)
FCO *L. septenarius*
FCO *E. eximius* (<20^0)

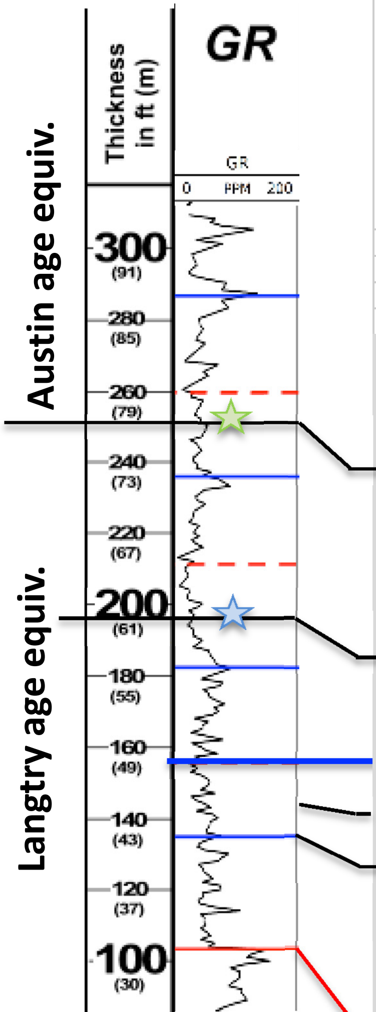
LO *E. octopetalus*
LCO *C. spissus*

FO *E. eximius* (>20^0)

Unpublished data from Pospichal (2011); courtesy of Lewis and University of Nebraska; log not scaled to nanno data

3c - Example – Expanded Langtry section shows separation of events

Hot Springs Outcrop, Big Bend National Park



Key nannos - Hot Springs section, Big Bend National Park						key markers used for correlation										not used		
	log derived lithology (Wehner)	Sample Deptl	Sample Deptl	Sample Depth revei	Total Abundance	Eprolithus octopetalus	Chiastozygus spissus	Eiffellithus eximius (sensu strictu)	Eiffellithus aff.eximius (>2 deg.)	Lithastrinus septenarius	Eprolithus eptapetalus (moratus)	Miravetesina ficula	Aspidolithus parcus expansus	Micula decussata		Lucianorhabdus maleformis	Marthasterites furcatus	Zeugrhabdotus biperforatus
	Austin?	306			no paleo collected													
	Austin?				no paleo collected													
	Austin?				no paleo collected													
	Austin?	300	91.4	0.0	no paleo collected													
	transitional	290	88.4	3.0														
	transitional	289.0	88.1	3.4	54	0	0	0	0	0	0	0	1	0		0	0	0
	transitional	280.0	85.3	6.1	80	0	0	1	2	0	0	1	0	0		0	0	0
	transitional	271.0	82.6	8.8	34	0	0	0	0	0	0	0	0	0		0	0	0
	transitional	255.0	77.7	13.7	827	0	0	5	4	2	0	3	1	0		0	0	0
	transitional	244.0	74.4	17.1	880	0	0	12	0	2	?	0	0	0		0	1	0
	transitional	236.0	71.9	19.5	1181	0	0	5	1	?	0	0	0	0		1	1	0
	transitional	219.0	66.8	24.7	237	0	0	1	0	0	0	1	0	0		0	0	0
	transitional	217.0	66.1	25.3	30	0	0	1	0	0	0	1	0	0		0	0	0
	transitional	214.0	65.2	26.2	935	0	0	1	1	0	0	1	0	0		0	0	0
	transitional	206.0	62.8	28.7	84	0	0	0	1	0	0	1	0	0		0	0	0
190ft	transitional	194.0	59.1	32.3	578	0	0	1	0	0	0	1	0	0		0	0	0
	transitional	183.0	55.8	35.7	562	0	0	2	1	0	0	0	0	0		0	0	0
	transitional	168.0	51.2	40.2	948	0	0	1	0	0	1	0	0	0		0	0	0
	transitional	164.0	50.0	41.5	255	0	0	0	2	0	0	0	0	0		0	0	0
	transitional	160.0	48.8	42.7	489	0	0	1	0	0	0	0	0	0		0	0	0
	transitional	156.0	47.5	43.9	451	0	0	1	0	0	1	0	0	0		0	0	0
	transitional	147.0	44.8	46.6	647	0	0	2	1	?	4	0	0	0		0	1	0
	transitional	138.0	42.1	49.4	1235	0	0	1	2	0	1	0	0	0		0	0	0
	transitional	134.0	40.8	50.6	1303	0	0	1	0	0	1	0	0	0		0	0	0
	transitional	122.0	37.2	54.3	77	0	0	0	1	0	0	0	0	0		0	0	0
	transitional	119.0	36.3	55.2	8	0	0	0	0	0	0	0	0	0		0	0	0
	transitional	109.0	33.2	58.2	15	0	0	0	0	0	0	0	0	0		0	0	0
	transitional	107.0	32.6	58.8	1009	0	1	0	0	0	0	0	0	0		0	0	0
	transitional	100.0	30.5	61.0	1339	0	0	2	4	?	0	2	0	0		1	0	0
	transitional																	
	L. Eagle Ford	96.0	29.3	62.2	532	0	1	0	0	0	0	0	0	0		0	0	0
	L. Eagle Ford	86.0	26.2	65.2	471	0	0	0	0	0	0	0	0	0		0	0	0

FO *A. parcus expansa*
(B. furtiva)

FCO *M. ficula*

LCO *E. moratus* (*E. eptapetalus*

FCO *L. septenarius*

FCO *E. eximius* (<20^0)

A. parca expansa occurs in Austin lithology at all other sites east and south of Big Bend

Expanded upper Turonian of Langtry equiv. sediments

Expanded Langtry equiv. sediments overlie major unconformity

Unpublished data from J. Pospichal (2014); courtesy of Texas A&M; log not scaled to nanno data

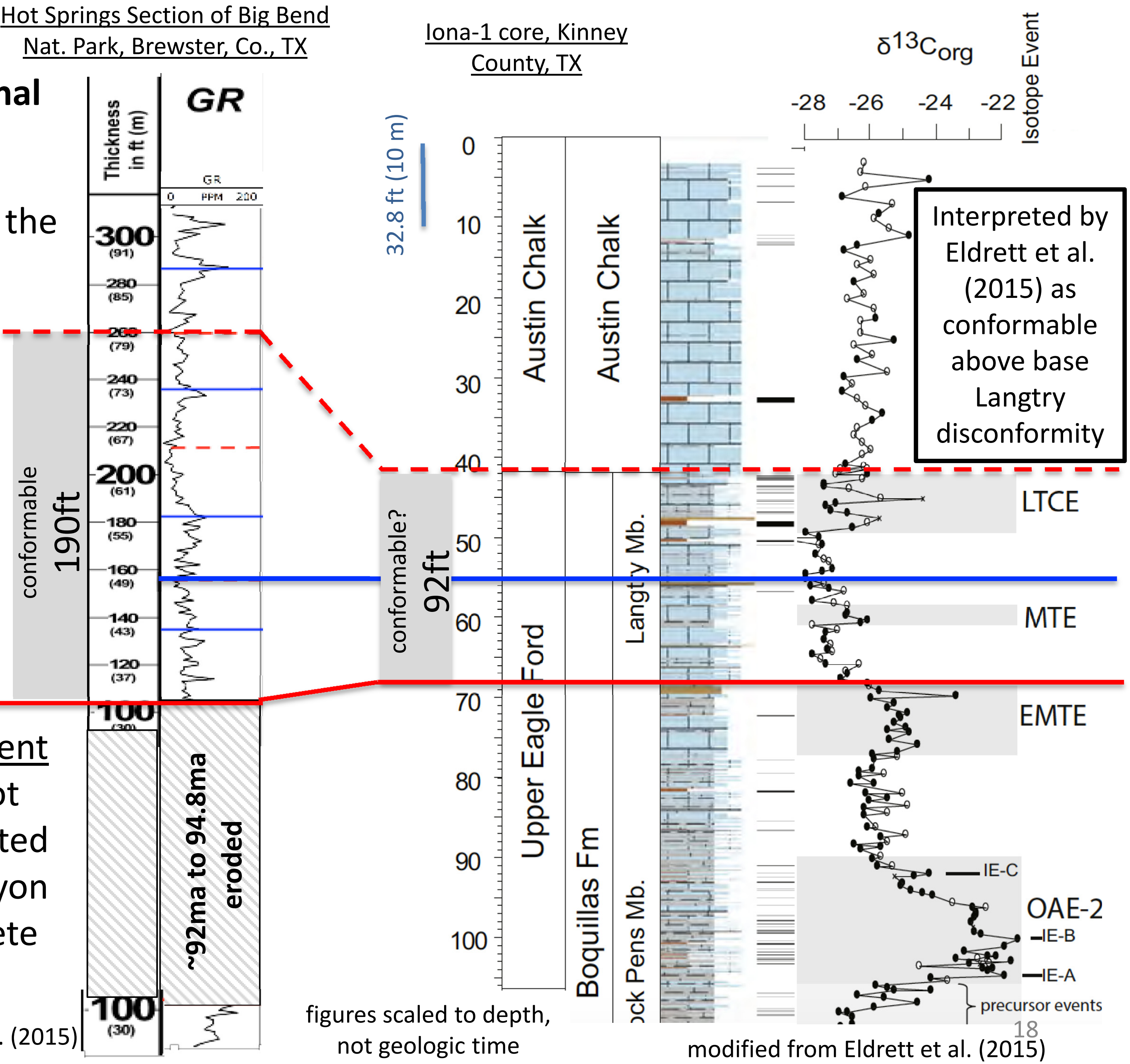
4a Comparison of two most conformable sections of Langtry equiv. rocks

Tectonic and depositional implications

facies change seaward of the Comanche platform

rapid subsidence in Langtry equivalent sections with associated accumulation rates estimated at ~140ft/my

early Laramide uplift event removes section at Hot Springs that was deposited as nearby as Lozier Canyon area and nearly complete in Maverick Basin



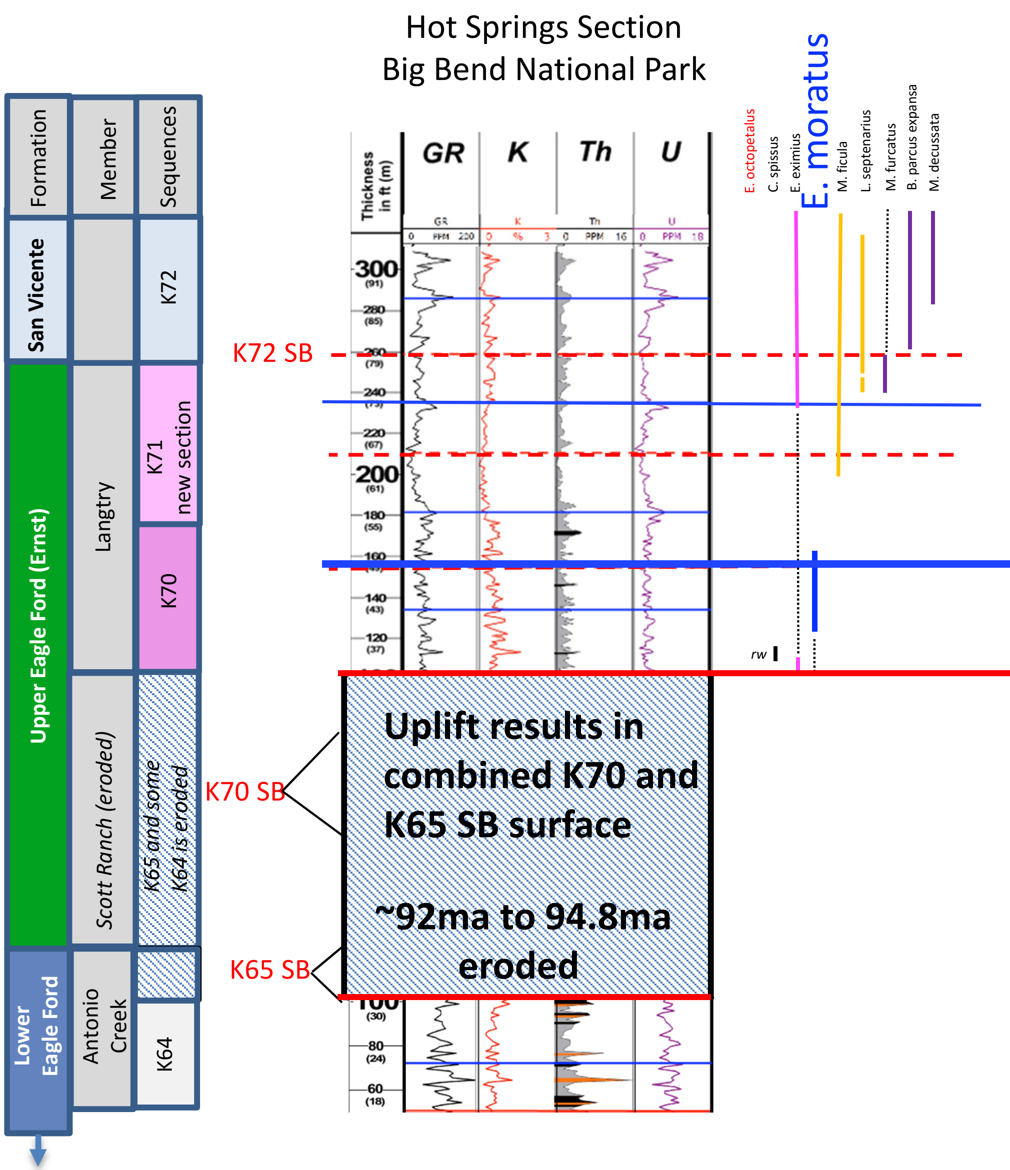
modified from Wehner et al. (2015)

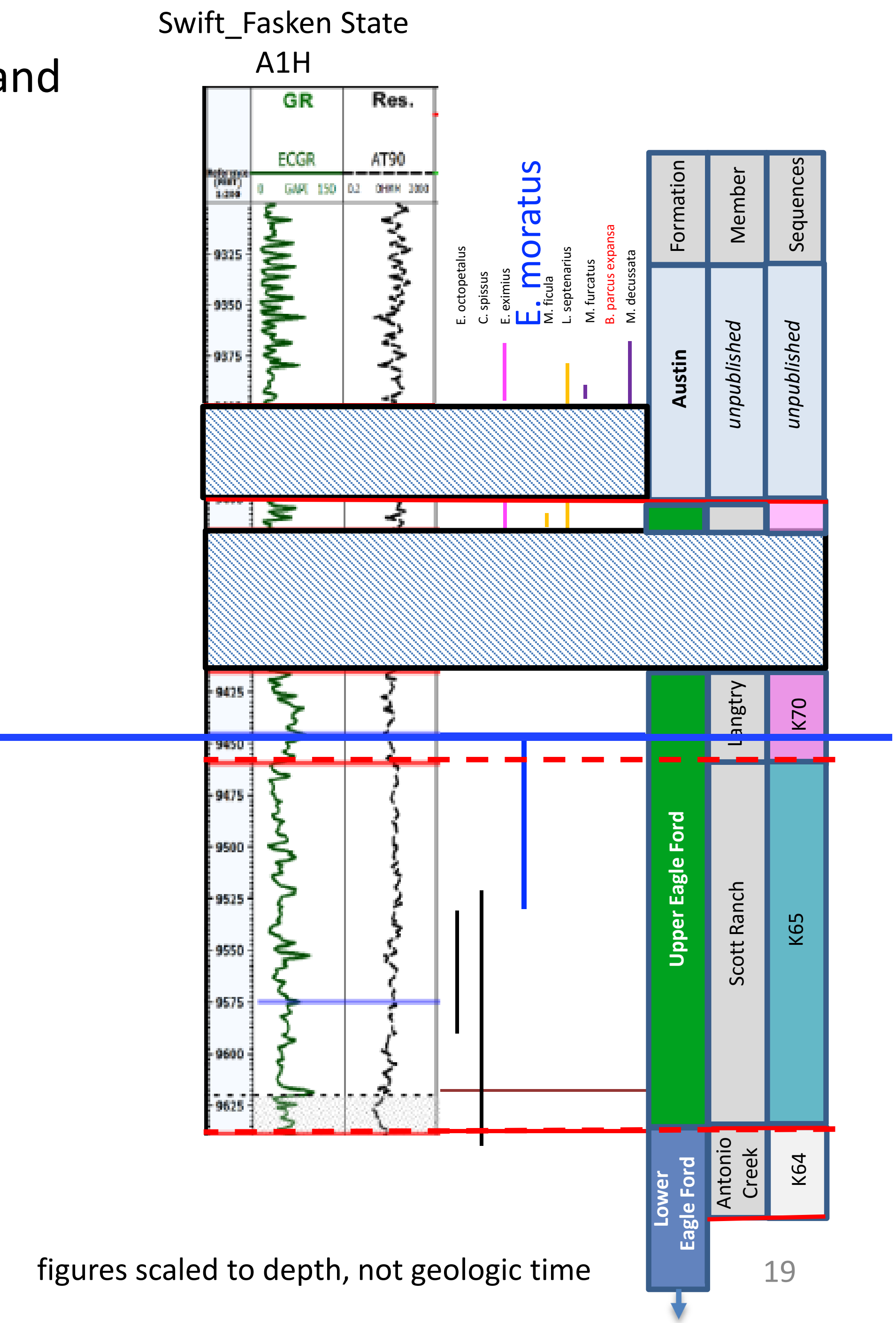
figures scaled to depth, not geologic time

modified from Eldrett et al. (2015)

4b Timing of erosional events are regionally different from Hot Springs to Webb, Co

Several key erosional events present in Maverick and Webb Co., in Langtry and Lower Austin sections

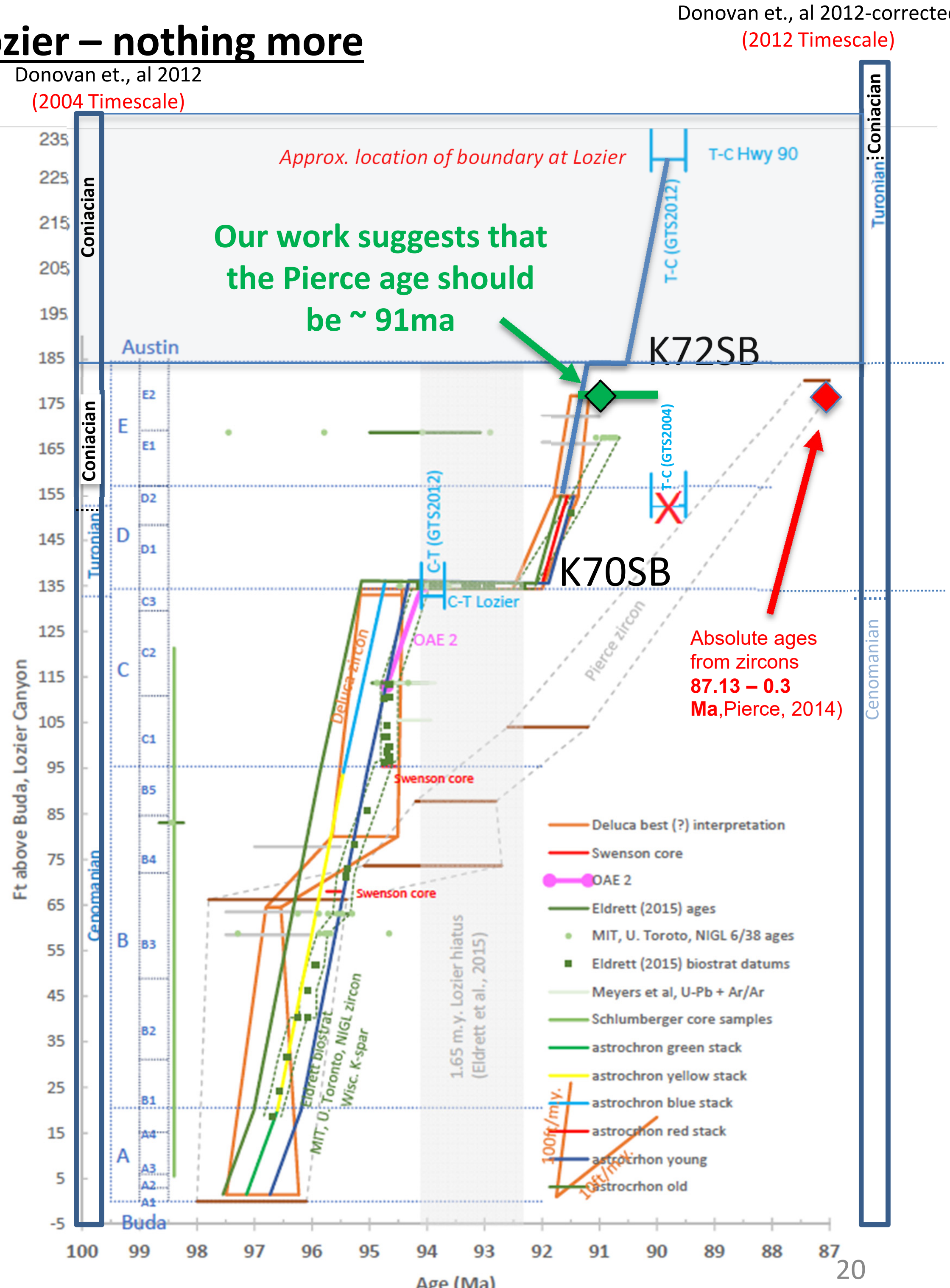




figures scaled to depth, not geologic time

4c - Simple correction for timescale at Lozier – nothing more

- Donovan and Staerker (2010) and Donovan et al. (2012) used the 2004 timescale as reference for the base Coniacian – subsequent use needs to correct for this (see boundary bars to right).
- After correction, base Coniacian in West Texas moves ~50ft higher into the Austin section
- Based on the biostrat work presented, the range for possible age of top Langtry at Lozier Canyon would be from 91.4 Ma to 89.95 Ma, with the **best fit being approximately 91 Ma**
- See Lowery et al. (2014) and Corbett et al, (2014) for more discussion and biostrat descriptions



Modified from Deluca (2016)

5 - Summary:

- Nannofossil community needs to be more consistent in how key markers are used
- Suggested "best practice" for taxonomic consistency is provided for the two most problematic taxa used for correlation (*E. moratus/L. septenarius* lineage and *E. eximius*)
- Nannofossil events that are most frequently observed are assigned ages and a recommendation to abandon the usage of some traditional markers is provided
- Wells in western and southern Webb, Co., have some of the uppermost Turonian eroded along the contact of the uppermost Eagle Ford (Langtry member) and the Austin Chalk
- At the Hot Springs section in Big Bend, a significant erosional event removed much of the middle Turonian, all of the lower Turonian, and likely some of the uppermost Cenomanian (event that spans from ~92Ma to 94.8Ma)
- Following the episode of erosion, the Hot Springs section accumulated a thick section of upper Turonian
- The differences in thickness and completeness of geologic section in the region suggest a <u>more tectonically active environment during the latest Turonian to earliest Coniacian that has previously been proposed</u>

Acknowledgments

We wish to thank the companies who contributed data for scientific evaluation and eventual release of this information into the public domain.

Specific thanks go to Swift Energy, Lewis Energy, and BP America for student sponsorship and release of the data and interpretations from the Fasken A1H and Chamberlain State cores.

We appreciate Texas A&M Geology for the release of the biostratigraphic data from the Hot Springs Trail section of Big Bend National Park.

In the spirit of learning, James Eldrett at Shell provided his insights and use of the nannofossil data from the Iona Research core for comparison with the other data used in this study.

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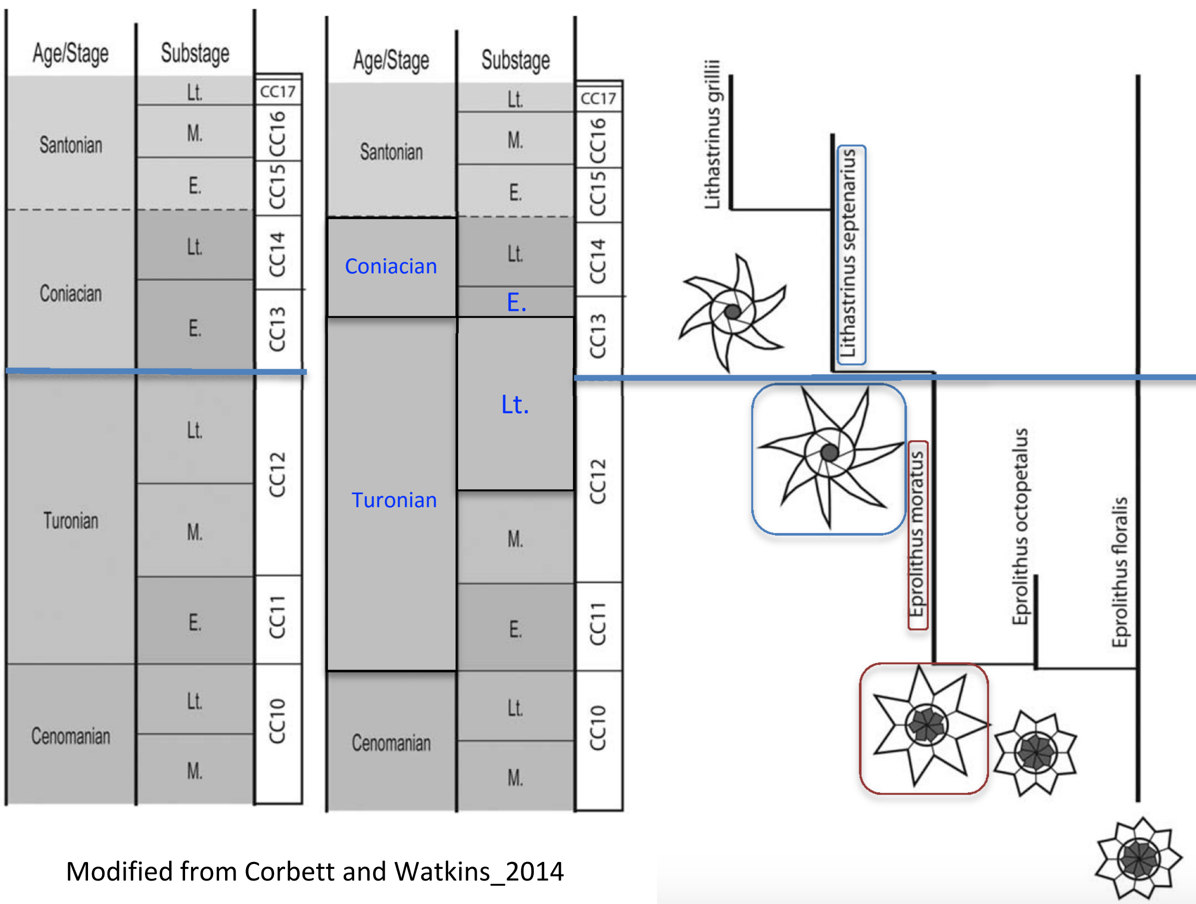
Extra slides

Extra – Eprolithus Lineage Referenced to Geologic Time Scales

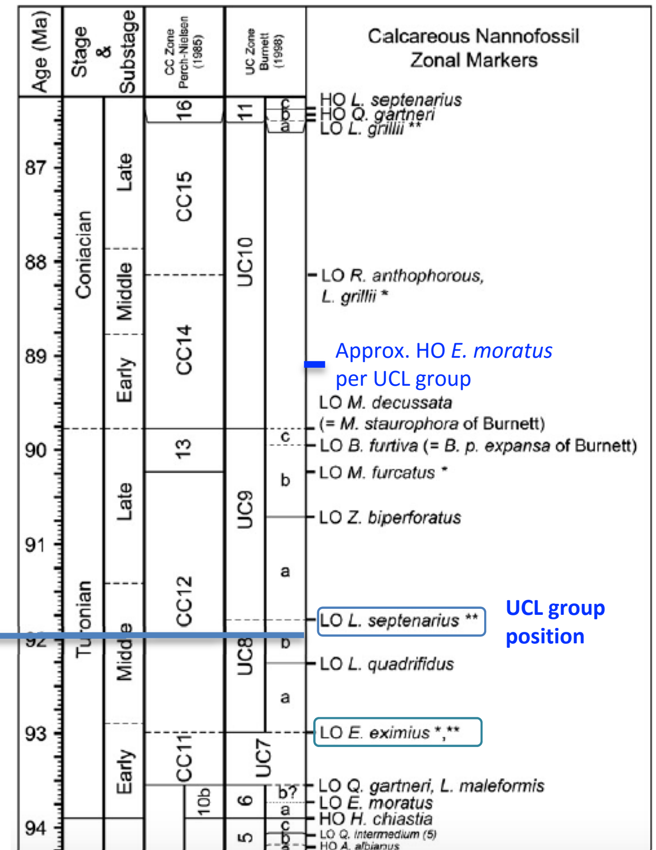
- Notice that difference in placement of LO (FAD) of L. septenarius and HO E. moratus
- The key events that we've adopted (FSU, UNL) are not suitable for the UCL zonation and are different morphovariants

Original referenced to 2004 Timescale

Corrected to 2012 Timescale



Modified from Corbett and Watkins_2014



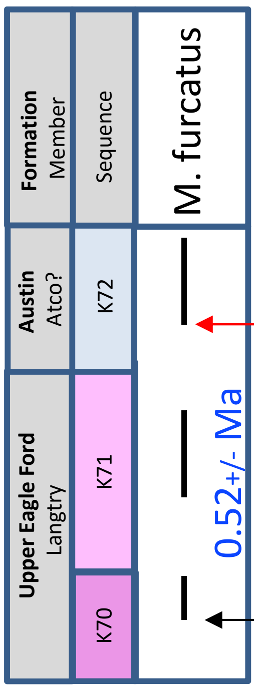
Modified from Corbett et al.,_2014

Placement of zones and bioevents in geologic time is based on updated timescale of Ogg and Hinnov (2012).

Extra – Generalized stratigraphic position of Marthasterites furcatus

In the region, the FO (FAD) typically occurs down in the Langtry Member

General Occurrence observed in Region



FO? in Eldrett (2015)
89.72 Ma

FAD (FO) Corbett and Watkins (2014)
90.24 Ma

Eldrett - "In the Iona-1 core, the FO of *M. furcatus* occurs at the Coniacian-Turonian boundary based on the numerical age assignment" (up in the Austin, using the age they chose to assign it)

"FO of *Marthasterites* spp. fragments occurs deeper in the section, at 28.48 m".

Eldrett - "This event is debated as a reliable age diagnostic event, as the global stratigraphic location of the FO of M. furcatus has been demonstrated as diachronous, ranging from the early Turonian through early Coniacian (Crux,1982; Burnett, 1998; Burnett and Whitham, 1999; Lees, 2002; Wiese et al. 2004), which led Lees (2008) to preclude it from being a useful marker-species over any great distance."

Although species is shows inconsistent occurrences, other Eagle Ford regional data indicates that it ranges as deep stratigraphically as the middle part of the Langtry, which would likely be 0.5-1.0 Ma older than where Eldrett et., al (2015) have chosen to assign it an age.

- Lozier (Corbett and Watkins, 2014)
- Hot Springs (this study)
- Swift Fasken A1 core (Corbett and Watkins, 2014)
- Chamberlain State core (Corbett and Watkins, 2014)
- Bouldin Creek (Jiang, 1989)
- Wagon Mound – Juana Lopez Member (Sikora and Howe 2004)

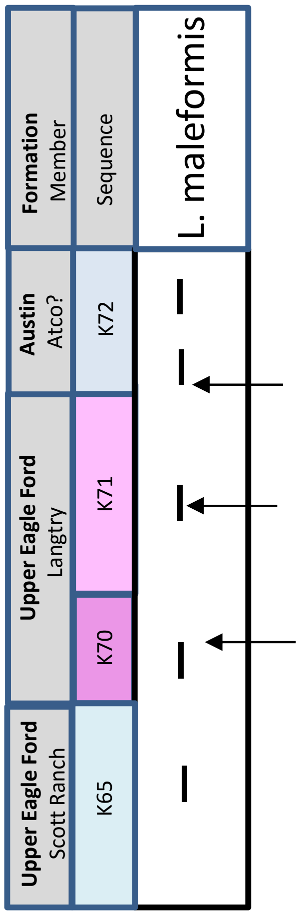
Problem fossil number 2: *Lucianorhabdus maleformis* is either too rare and inconsistent part of assemblage to be used as confident age marker

In the Iona-1 core, this event is interpreted to occur In the Austin at the contact with the Langtry

A questionable and isolated specimen of L. maleformis was observed deeper, down in the Langtry

Other regional data indicates that it occurs as deep stratigraphically as the middle part of the Upper Eagle Ford, which would likely be 0.5-1.0 Ma older than where Eldrett et., al (2015) have chosen to assign it an age.

General Occurrence observed in Region



FO as event N16 (too high/too young)
90.23 Ma - Eldrett (2015)

Eldrett et al. (2015) observed as questionable specimen

FAD Corbett et al. (2014)
~93.55 Ma

FO (FAD) observed in Upper Eagle Ford, Scott Ranch Member
- Swift Fasken A1 core (Corbett et., al, 2014)
- Chamberlain State core (Corbett et., al, 2014)

FO (FAD) observed in Langtry
- Lozier (Corbett et., al, 2014)
- ACC core (Corbett and Watkins, 2014; unpublished data)
- Bouldin Creek (EF – South Bosque; Jiang, 1989)