Stratigraphic and Geochemical Analysis across the Woodbine-Eagle Ford Transition Zone, North Texas

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Introduction and Background

The Early to Middle Cenomanian marks a shift from predominantly oxygenated platform carbonates to sand-rich siliciclastics and then to organic-rich mudstones deposited underneath anoxic-euxinic bottom water conditions in the Gulf Coast. In the proximal portions of the East Texas Basin, this is exhibited by a transition from the Buda Limestone to the coarse Woodbine siliciclastics, and finally to the organic-rich Eagle Ford Shale (Ambrose et al., 2009; Hentz et al., 2014; Denne et al., 2016; Denne and Breyer, 2016). Based on biostratigraphic data, a hiatus is present between the end of Woodbine deposition and the beginning of Eagle Ford deposition (Salvador, 1991; Ambrose et al., 2009; Denne et al., 2016). This hiatus ended with a major transgressive sea level event that flooded much of the North American interior, resulting in the deposition of the organic-rich Eagle Ford sediments from the Middle Cenomanian through the Turonian throughout most of Texas, and the East Texas Basin in particular (Denne and Breyer, 2016; Denne et al., 2016).

Various outcrop and subsurface studies of the Eagle Ford have been conducted to better understand the history of the Eagle Ford throughout Texas, but the use of multiple stratigraphic nomenclature schemes have caused problems for regional correlations (Adams and Carr, 2010). In a study conducted by Denne et al. (2014), it became apparent that the stratigraphic nomenclatures used to describe the Eagle Ford, Woodbine, and Maness Shale are inconsistent and in need of standardization. Many of the microfossil studies originally conducted were outdated and inaccurate, and very few studies fully integrated microfossil, macrofossil, and geochemical data obtained from the Woodbine and Eagle Ford, and the studies that did sometimes reported inaccurate ages (Denne et al., 2016).

For this study, the stratigraphic nomenclature used is based on the nomenclature scheme presented by Denne et al. (2016) in order to gain a better understanding and definition of the Woodbine-Eagle Ford transition zone and their associated formations and members and determine if it was time-transgressive.

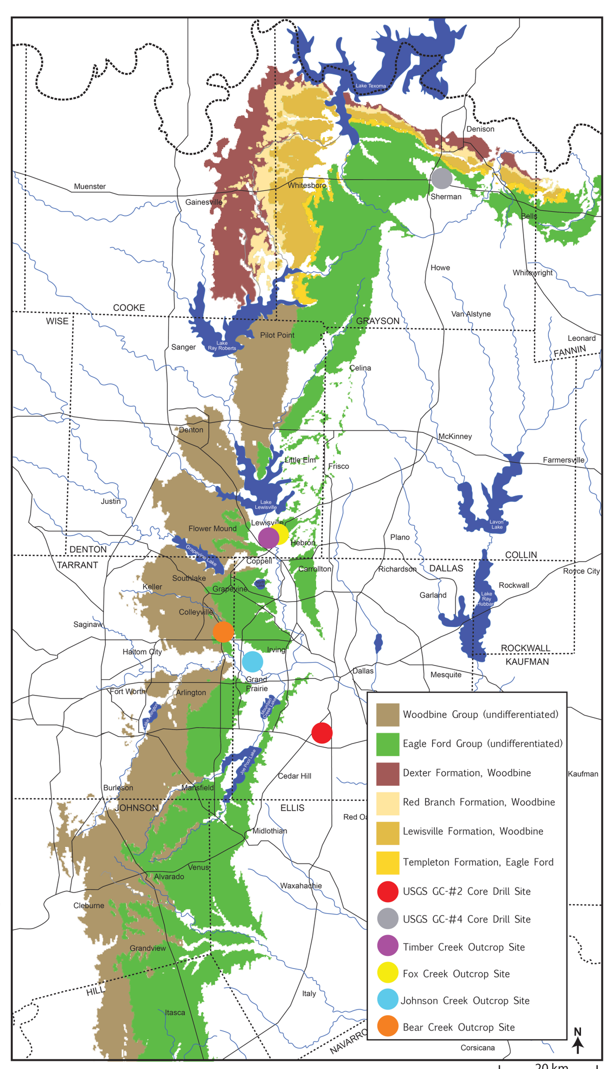

Figure 1: Geologic map of the Woodbine and Eagle Ford outcrops of north Texas with outcrop and drilled core locations. Modified from Henk and Denne (2021).

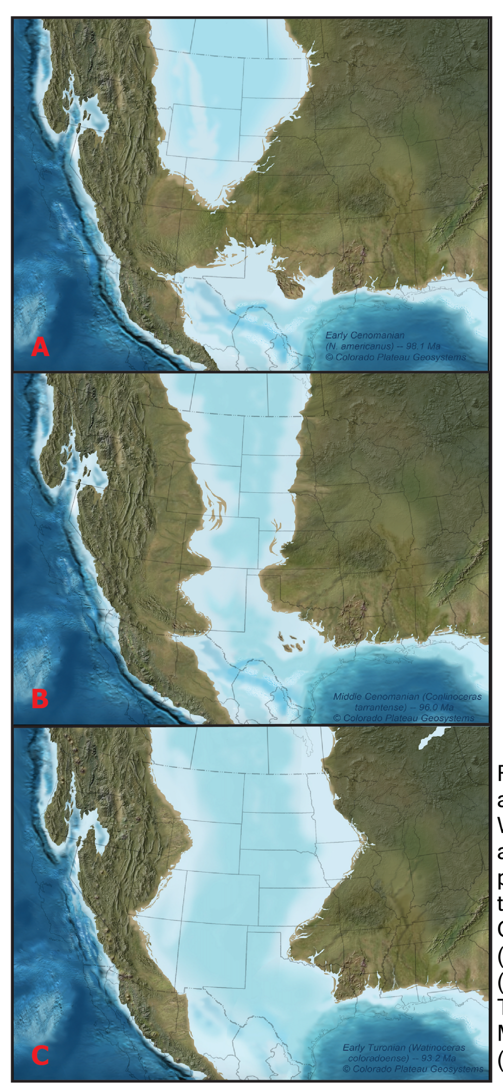

Figure 2: Development and evolution of the Western Interior Seaway and Gulf Coast paleogeography through the (A) Early Cenomanian (98.1 Ma), (B) Middle Cenomanian (96 Ma), and (C) Early Turonian (93.2 Ma). Modified from Blakey (2014).

Methods

- X-ray diffraction (XRD), inductively coupled plasma-mass spectrometry (ICP-MS), and core gamma log data on the GC-2 and GC-4 cores provided by the USGS
- Biostratigraphy data on the GC-2 provided by Denne
- GC-2 and GC-4 core descriptions
- Field work at Metroplex outcrops include: cleaning off the outcrop to show a fresh face, measuring and describing the section, collecting gamma ray data with a hand-held gamma-ray spectrometer, and collecting samples for further analysis
- Handheld X-ray fluorescence (XRF) analyses on outcrop samples and GC-2 and GC-4 cores
- Thin section analysis on selected samples from outcrop sections
- U-Pb zircon analysis of bentonites found at outcrop locations

Results

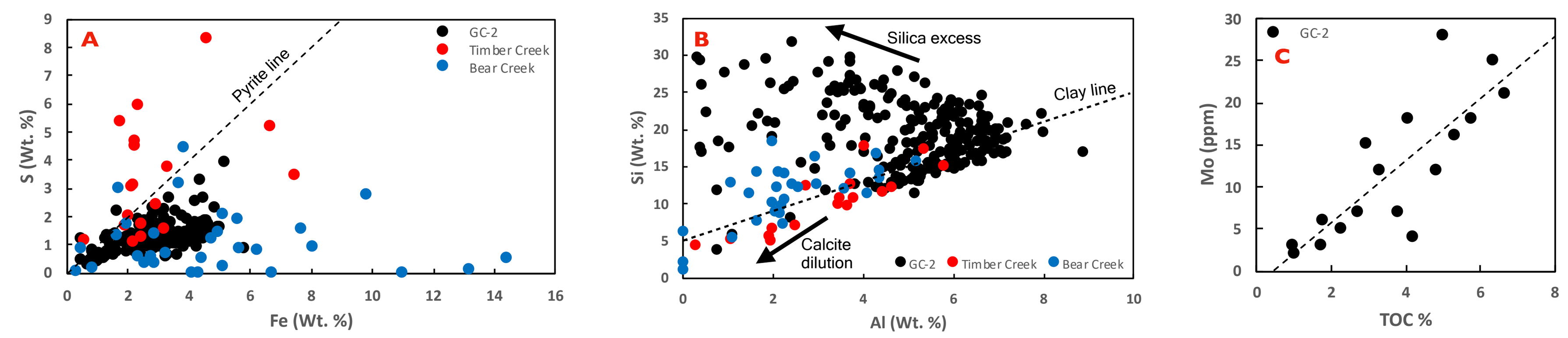

Figure 3: Geochemical relationships of the Woodbine-Eagle Ford transition zone from the USGS GC-2 core and outcrops at Timber and Bear Creek. (A) S-Fe relationship from XRF data. (B) Si-Al relationship from XRF data showing the distribution of Si and Al into clay and quartz, and the dilution of silicates by calcite. (C) Mo-TOC relationship in the USGS GC-2 core from ICP-MS data demonstrating an increase in Mo when TOC increases. The black line represents the best-fit linear regression of the data.

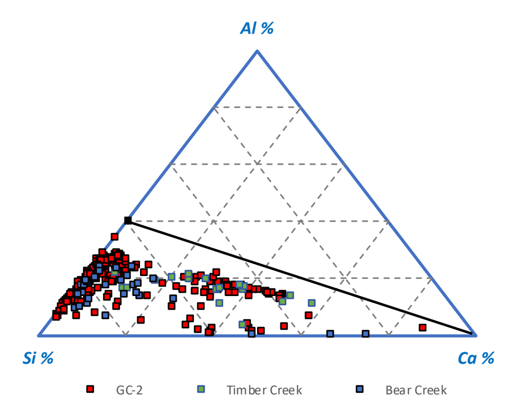

Figure 4: A ternary plot of XRF data showing the relative relationship of Al, Si, and Ca percentages from the USGS GC-2 core and the Timber and Bear Creek outcrops, assumed to reflect bulk mineralogical changes in clay, quartz, and calcite. The black square marks the "average shale" location on the diagram (Rowe et al., 2012), and the black line represents the trajectory by which a low-Ca average shale would be diluted by calcite.

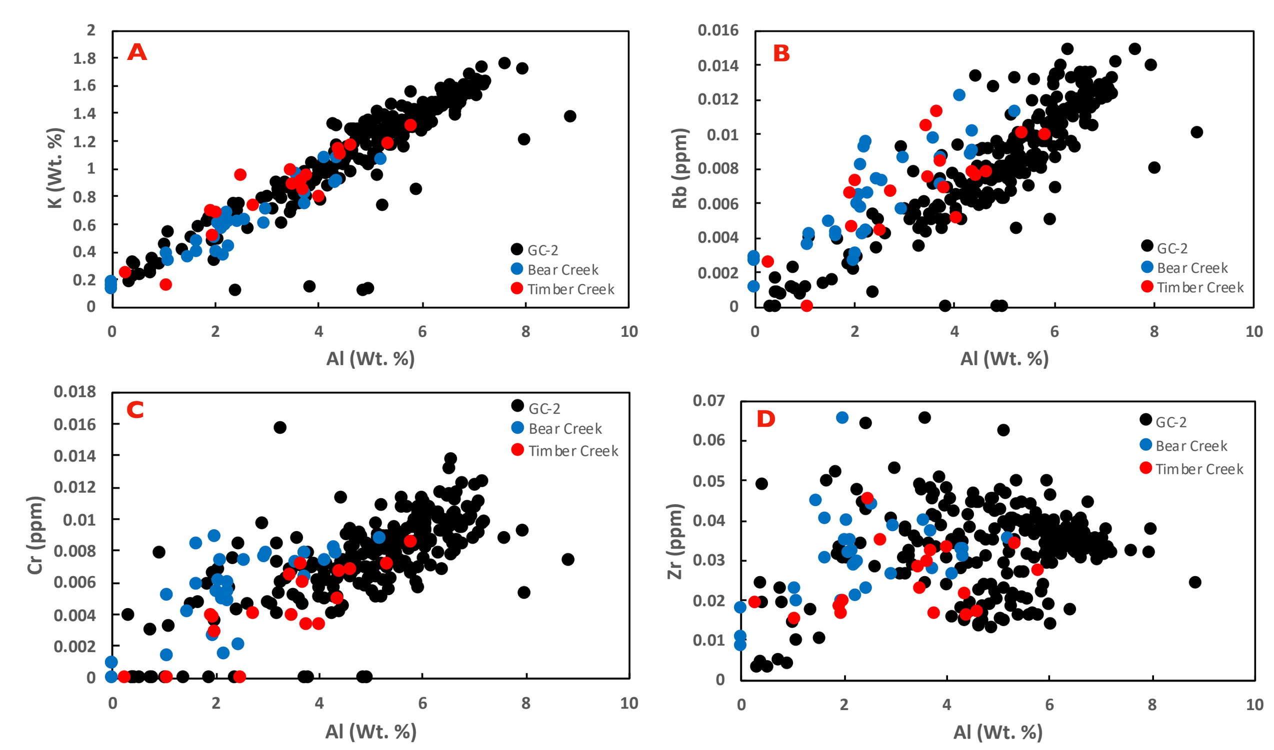

Figure 5: Cross-plots of aluminum against common elements associated with shale facies from XRF data of the USGS GC-2 core and Timber and Bear Creek outcrops. (A) Potassium; (B) Rubidium; (C) Chromium; (D) Zirconium. Aluminum is on the X-axis for every graph. Values increase upwards and to the right.

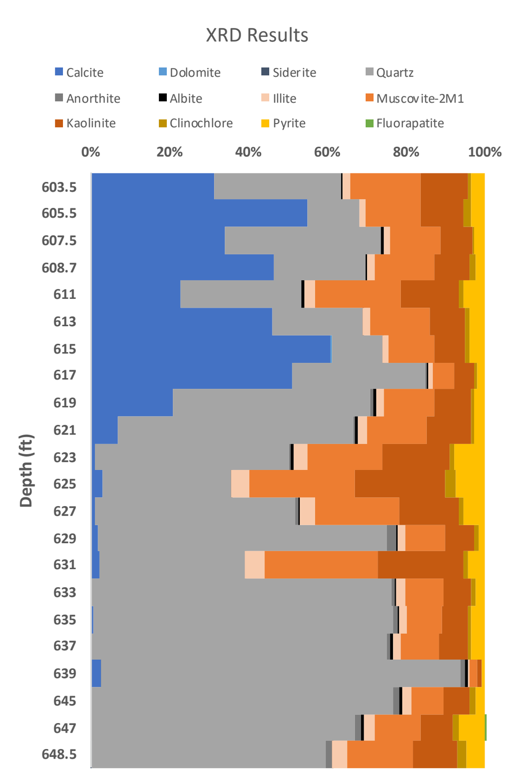

Figure 6: XRD results of the Woodbine-Eagle Ford transition zone in the USGS GC-2 core provided by the USGS.

Figure 7: Sand lenses located at the base of the Timber Creek outcrop.

Figure 8: Oyster bed capping the top of the Bear Creek outcrop.

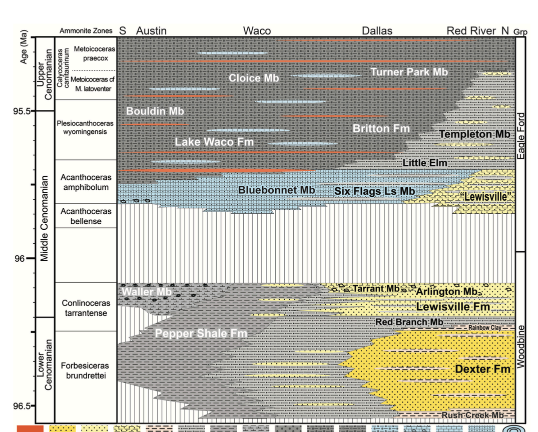

Figure 9: Wheeler diagram of the Woodbine and lower Eagle Ford outcrop belt in central and north Texas with ammonite zones and lithology. From Denne et al., 2016.

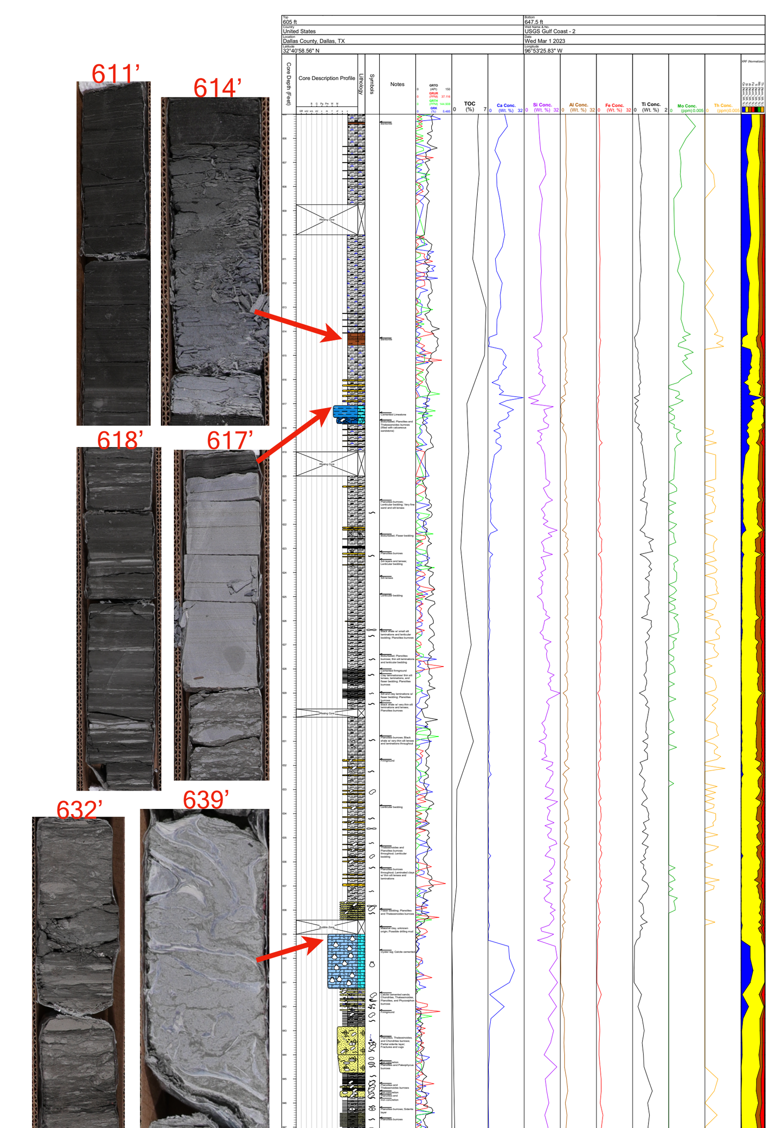

Figure 10: Core description of the USGS GC-2 core with gamma ray and TOC data provided by the USGS and handheld XRF data. Core photos are included of the oyster lag, bioclastic limestone, and bentonite bed. Other core photos depict the transition to anoxic conditions.

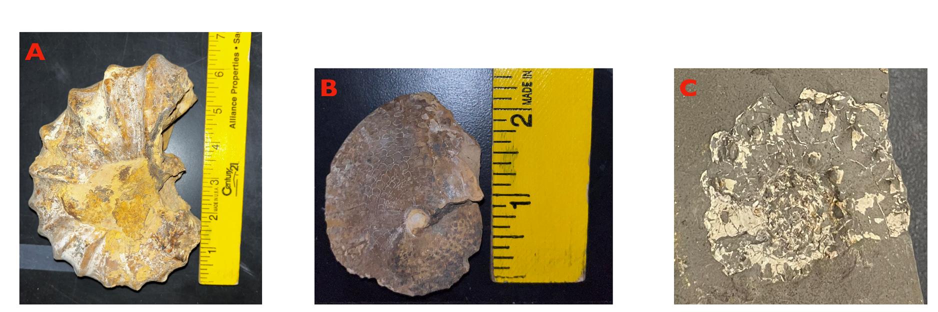

Figure 11: Ammonites found from outcrop sections located in the Metroplex. (A) *Paraconlinoceras barcusi* of the *Conlinoceras tarrantense* Zone found in the upper section of the Bear Creek outcrop, (B) *Metengonoceras dumbli* found in the upper section of the Bear Creek outcrop, and (C) *Paraconlinoceras barcusi* of the *Conlinoceras tarrantense* Zone found in the lower section of the Timber Creek outcrop.

Discussion & Future Work

- Sections represent a 7.6 m interval of gradually deepening tidally-dominated, bioturbated, heterolithic deposits of the Tarrant Member (Woodbine) to organic-rich (2-4% TOC), prodeltaic mudstones with interbedded tempestites, overlain by a 0.5 m thick bioclastic, quartz-rich limestone (Six Flags Limestone)
- Overlying laminated mudstones and thick bentonites of the Britton Formation (Eagle Ford) contain higher abundances of organic matter (4-7% TOC), redox proxies, nannofossils and foraminifera, and calcite than the underlying mudstones in the section
- Tarrant Member was deposited in a tidally influenced, estuarine or shallow marine environment and the Britton Formation would have been deposited within a relatively deep, anoxic shelf environment
- Ammonites found at outcrop indicate tidally-dominated deposits are older than 96.1 Ma, and the bioclastic limestone was deposited from 95.8-95.7 Ma
- Proximal locations received a more continuous sediment supply during the initial transgression, whereas more distal locations were sediment starved, resulting in deposition of the Six Flags and Bluebonnet limestones, which were not identified in the Lewisville outcrops and the GC-4 core
- A trip to the USGS Core Research Center in Denver, CO is planned to analyze and interpret the more proximal GC-4 core
- Thin section analysis will be conducted with the intent of identifying sedimentary structures, as well as determine the composition and lithology of each outcrop section
- U-Pb radiometric dating of zircon grains from bentonites found at outcrop locations in Lewisville and Austin, TX will be conducted to determine the age of these bentonites, possibly proving that these are the same bentonites and act as regional bed-markers that can be correlated from north to south Texas

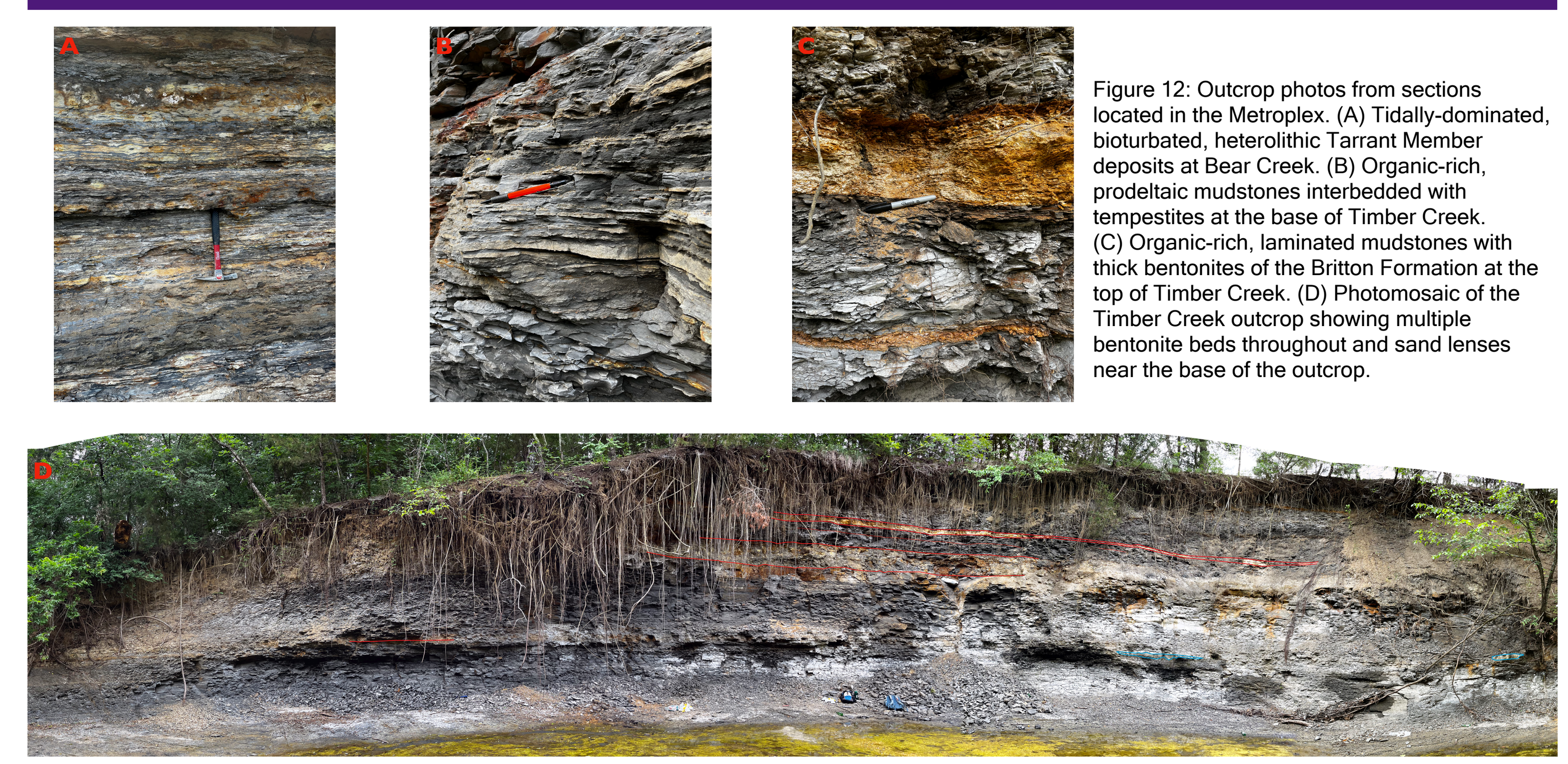

Figure 12: Outcrop photos from sections located in the Metroplex. (A) Tidally-dominated, bioturbated, heterolithic Tarrant Member deposits at Bear Creek. (B) Organic-rich, prodeltaic mudstones interbedded with tempestites at the base of Timber Creek. (C) Organic-rich, laminated mudstones with thick bentonites of the Britton Formation at the top of Timber Creek. (D) Photomosaic of the Timber Creek outcrop showing multiple bentonite beds throughout and sand lenses near the base of the outcrop.

Conclusions

- The Woodbine-Eagle Ford contact was found to be transitional in nature, going from sandy estuarine, prodeltaic mudstones, to laminated, organic-rich mudstones over a 7.6 m interval.
- Relative ages based on the ammonites in the outcrops indicate that the bottom-waters became anoxic-euxinic at approximately 95.8 Ma, nearly 1.5 My later than more distal, basinal locations, confirming that the initiation of bottom-water anoxia in the greater East Texas Basin was time-transgressive.

References

Ambrose WA, Hentz TF, Bonnaffe F, Loucks RG, Brown LF Jr, Wang FP, Potter EC. 2009. Sequence stratigraphic controls on complex reservoir architecture of highstand fluvial deltaic and lowstand valley-fill deposits in the Upper Cretaceous (Cenomanian) Woodbine Group, East Texas field: Regional and local perspectives. American Association of Petroleum Geologists Bulletin 93:231-269.
Adams RL, Carr JP. 2010. Regional depositional systems of the Woodbine, Eagle Ford, and Tuscaloosa of the U.S. Gulf Coast: Transactions of the Gulf Coast Association of Geological Societies, v. 60, p. 3-27.
Denne RA, Hinote RE, Breyer JA, Kosanke TH, Lees JA, Engelhardt-Moore N, Spaw JM, Tur N. 2014. The Cenomanian-Turonian Eagle Ford Group of South Texas: Insights on timing and paleoceanographic conditions from geochemistry and micropaleontologic analyses. Palaeogeography, Palaeoclimatology, Palaeoecology 413:2-28.
Denne RA, Breyer JA, Callender AD, Hinote RE, Kariminia M, Kosanke TH, Kita Z, Lees JA, Rowe H, Spaw JM, Tur N. 2016. Biostratigraphic and geochemical constraints on the stratigraphy and depositional environments of the Eagle Ford and Woodbine Groups of Texas. In Breyer JA (Editor). The Eagle Ford Shale: A Renaissance in U.S. Oil Production, Memoir 110: American Association of Petroleum Geologists, Tulsa, Oklahoma. p. 1-86.
Denne, RA, and Breyer JA. 2016. Regional depositional episodes of the Cenomanian-Turonian Eagle Ford and Woodbine Groups of Texas, In Breyer JA (Editor). The Eagle Ford Shale: A Renaissance in U.S. Oil Production, Memoir 110: American Association of Petroleum Geologists, Tulsa, Oklahoma. p. 87-133.
Henk, B, and Denne, RA. 2021. Reevaluation of Upper Woodbine Depositional Environments in the Outcrops of the Type Area, North-Central Texas: SEG / AAPG International Meeting for Applied Geoscience & Energy, Program with Abstracts, Denver, CO.
Hentz, TF, Ambrose WA, Smith DC. 2014, Eaglebine play of the southwestern East Texas Basin: Stratigraphic and depositional framework of the Upper Cretaceous (Cenomanian-Turonian) Woodbine and Eagle Ford Groups: American Association of Petroleum Geologists Bulletin 98: 2551-2580.
Rowe H, Hughes N, and Robinson K. 2012. The quantification and application of handheld energy-dispersive x-ray fluorescence (ED-XRF) in mudrock chemostratigraphy and geochemistry: Chemical Geology, v. 324-325, p. 122-131.
Salvador A. 1991. Origin and development of the Gulf of Mexico Basin, in A. Salvador, ed., The Gulf of Mexico Basin: Geological Society of America, Decade of North American Geology, v. J, p. 389-444.