Mechanical stratigraphy and fault zone deformation in the Austin Chalk in Ten-Mile Creek, Texas

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Abstract

The Austin Chalk is a rhythmically bedded sequence of chalk and marl that represents pelagic to hemipelagic carbonate deposition in the ancestral Gulf of Mexico during the Upper Cretaceous. The Austin Chalk differs from traditional chalk deposits due to its relatively high abundance of clay and volcanic ash. Outcrops of the chalk stretch from north-central Texas to west Texas and surface exposures mirror the subsurface trend of the Ouachita orogen. Deformation of the heavily fractured Austin Chalk is caused by the normal faults associated with the Balcones Fault Zone.

Historically, the Austin Chalk has been exploited as a conventional hydrocarbon reservoir produced from natural porosity and permeability without large hydraulic stimulations. More recently, the Austin Chalk has been explored as a combination fractured and unconventional reservoir, relying on natural porosity and permeability combined with induced hydraulic fracturing to generate new fracture permeability to release hydrocarbons trapped in microscopic pores. In addition to its reservoir properties, much of the city of Dallas is built within the outcrop trend of the chalk. Thus, understanding the properties and deformation features of the Austin Chalk is also important to the construction industry in north-central Texas.

Deformation of the Austin Chalk in Ten-Mile Creek is characteristic of normal faulting seen in platform carbonate sequences. Faults are identified by the presence of slickenlines and fault gouge, and are surrounded by a damage zone defined by synthetic faulting, jointing, and folding. Deformation is concentrated near the fault core and decreases with distance from the fault core. Here, we present a structural analysis of Church of the Nazarene section of Ten-Mile Creek. The mechanical properties of stratigraphic units are quantified using a Schmidt hammer. Fracture parameters, such as fracture density and intensity, are quantified using scanline surveys. Additionally, spectral gamma ray measurements are made in the field using the RS-230 spectrometer.

Introduction and Geologic Background

- Use mechanical stratigraphy and spectral gamma ray properties to constrain stratigraphy of the Austin Chalk in Ten-Mile Creek.
- Gather fracture data and define fracture parameters such as fracture spacing and fracture density for Ten-Mile Creek.
- The Austin Chalk is Upper Cretaceous, ranging from the base of Coniacian to the top of Lower Campanian (Hancock and Walaszczyk, 2004; Gale et al., 2008).
- Stratigraphically, the Austin Chalk lies unconformably above the Eagle Ford Shale, and is overlain by Cretaceous volcanic mounds and the Taylor Group (Figure 1).
- In the DFW area, the Austin Chalk is divided into the lower Atco Member, the marl-rich Bruceville Member, and the upper Hutchins member (Figure 1).
- In addition to clay-rich marl units, the Austin Chalk contains several volcanic ash beds (bentonite).
- The Austin Chalk represents pelagic to hemipelagic deposits that formed in carbonate platform, platform edge, and deep-water shelf settings of the Cretaceous Western Interior Seaway (KWIS) (Dravis, 1980; Hovorka and Nance, 1994) (Figure 2).
- The Austin Chalk is cut by the Balcones Fault Zone, extensional deformation related to the Gulf of Mexico (Figure 3).
- Ten-Mile Creek is located in DeSoto, Dallas County, Texas. There are two sections of Austin Chalk exposed in Ten-Mile Creek, that are informally called the "Church" section and the "Walmart" section (Figure 4).

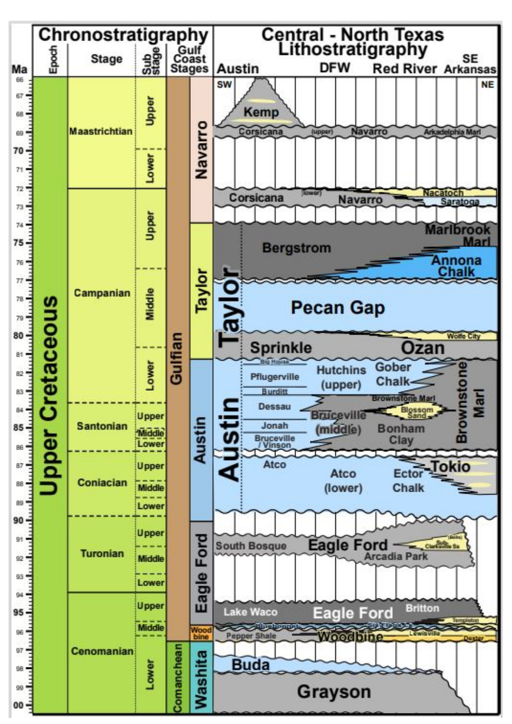


Figure 1. Upper Cretaceous stratigraphic units in southern and eastern Texas (Denne, 2021, unpublished).

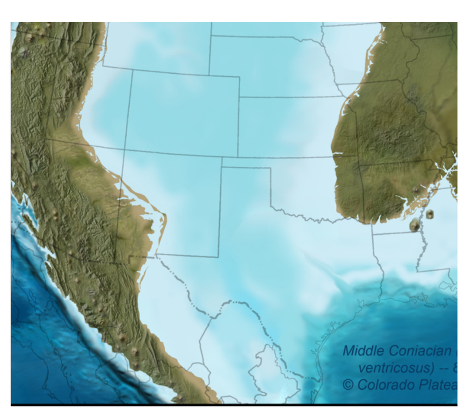


Figure 2. Middle Coniacian paleogeography of Texas and the Midcontinent (Blakey, 2005).

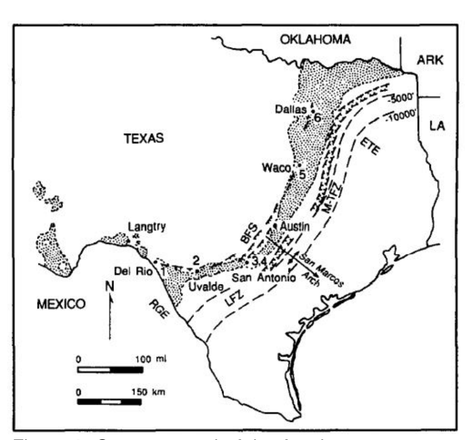


Figure 3. Outcrop trend of the Austin Chalk (shaded) and Balconies fault zone (dashed line BFS) (Corbett, et al., 1987).

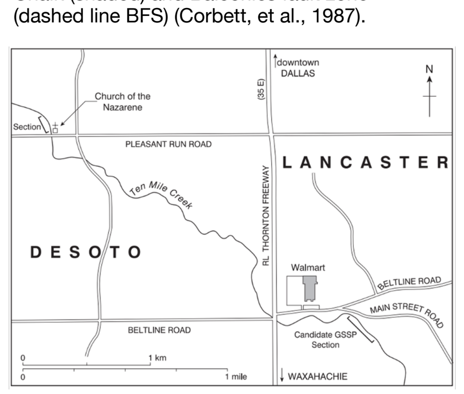


Figure 4. Map of Ten-Mile Creek outcrop locations (Gale et al. 2007).

Methods

Spectral Gamma-ray analysis

- The RS-230 spectrometer is a portable, hand-held radiation spectrometer survey instrument used in the geophysical industry.
- Measurements are taken in 6 inch increments throughout the measured section.
- The spectral gamma ray tool provides potassium (in %), uranium (in ppm), and Thorium (in ppm).

Figure 5. RS-230 hand held spectrometer

Mechanical analysis

- Mechanical properties of the measured section will be characterized using a Schmidt hammer.
- The Schmidt hammer is a rebound hammer that provides a non-destructive method of measuring rebound hardness in the field.
- Rebound values are recorded on a paper scroll within the tool, and may be related to rock properties such as hardness, unconfined compressive strength, and Young's modulus (Aydin and Bass, 2005).

Figure 6. Schmidt hammer

Fracture analysis

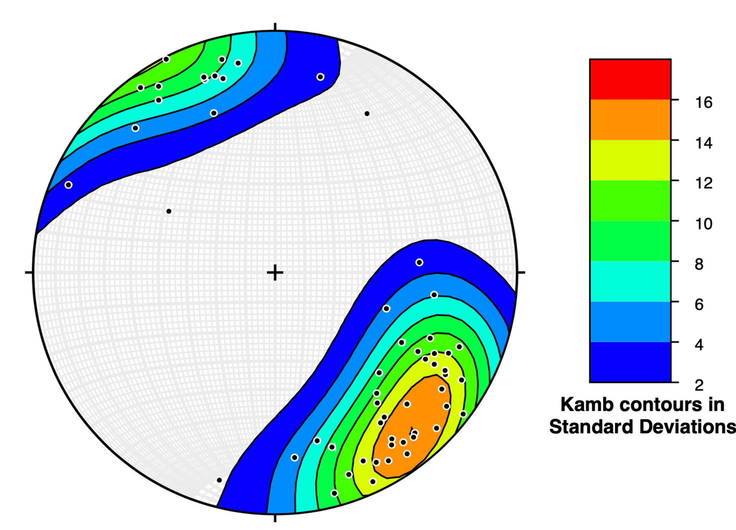
- Fracture data is gathered in the field using a linear scanline method described by Priest and Hudson (1980).
- Orientation of fractures are measured with a brunton compass.
- Linear scanlines allow for the estimation of fracture parameters such as linear fracture spacing and linear fracture density.

Figure 7. Linear scanline on chalk bed in Ten-Mile Creek.

Results

- 60.5 feet of Austin Chalk is exposed at the Church section of Ten-Mile Creek.
- Deformation is concentrated near the fault zone, folding and fracturing decreases as one moves up through the section (Figure 8).
- Interlimb angles of folds in the church section vary from gentle (>120˚) to open (120˚-70˚) near the fault zone.
- Fractures measured in Ten-Mile Creek are classified as bedding confined, bedding terminated, or through-going (Figure 9).
- Many fractures "step over" to another fracture after they terminate (Figure 10).
- Some fractures occur as conjugate sets dipping in opposite directions (Figure 12).
- Poles to fracture planes are plotted and contoured on stereonets.
- Data from linear scanline #1 suggests there are two distinct fracture sets. This is consistent with field observations. One fracture set is subvertical, while another fracture set occurs with more moderate dip (50˚-75˚).
- Data from linear scanline #2 is more clustered than #1, suggesting only a single fracture set occurs within this layer. Almost all fractures measured along this scanline are subvertical (joints).

Linear Scanline #1



Linear Scanline #2

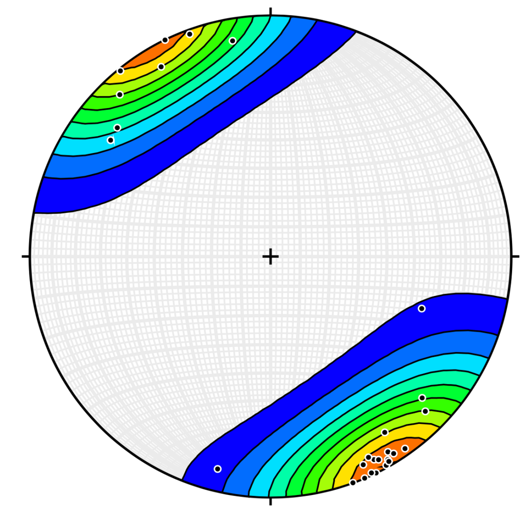


Figure 8.

Figure 9. An example of a through-going fracture.

Figure 10. An example of a fracture that steps over.

Figure 11. An example of branching fractures.

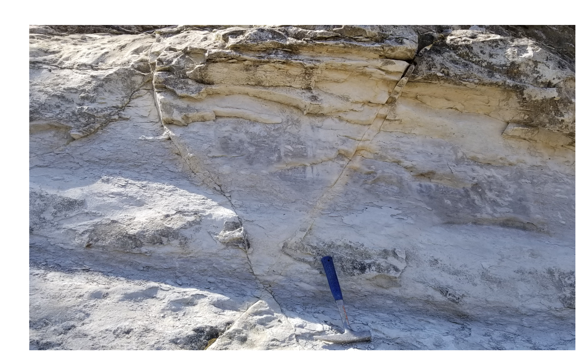


Figure 12. An example of a set of conjugate fractures.

Discussion and Further Research

- Perform spectral gamma-ray analysis, mechanical analysis, and fracture analysis on the section of Austin Chalk exposed at the Walmart section of Ten-Mile Creek (Figure 13).
- Correct linear fracture parameters for orientation bias as shown in Zeeb et al. (2013).
- Explore the possibility of circular scanline techniques described by Mauldon et al. (2000).
- Circular scanlines provide a more realistic model for a three dimensional fracture network compared to the linear scanline method (Zeeb et al., 2013).
- Explore relationships between the mechanical properties of rock strata and fracture parameters, such as mean fracture spacing and mean fracture density.
- Examine relationship between layer thickness, mechanical properties, and fracture spacing.
- Explore relationships between mechanical stratigraphy and spectral gamma-ray properties of the Austin Chalk.

Figure 13.

References

Blakey, R., 2005, Paleogeography and geologic evolution of North America; images that track the ancient landscapes of North America.

Denne, R. A., 2018, Plankton: Encyclopedia of Petroleum Geoscience

Dravis, J. J., 1980, Sedimentology and diagenesis of the upper cretaceous Austin chalk formation, south Texas and northern Mexico: University Microfilms International

Gale, A. S., Kennedy, W. J., Lees, J. A., Petrizzo, M. R., Walaszczyk, I., 2007, An integrated study (inoceramid bivalves, ammonites, calcareous nannofossils, planktonic foraminifera, stable carbon isotopes) of the Ten Mile Creek section, Lancaster, Dallas County, north Texas, a candidate Global boundary Stratotype Section and Point for the base of the Santonian Stage: Acta Geologica Polonica, vol. 57, no. 2, pg. 113 – 160

Gale, A. S., Hancock, J. M., Kennedy, W. J., Petrizzo, M. R., Lees, J. A., Walaszczyk, I., Wray, D. S., 2008, An integrated study (geochemistry, stable oxygen and carbon isotopes, nannofossils, planktonic foraminifera, inoceramid bivalves, ammonites and crinoids) of the Waxahachie Dam Spillway section, north Texas: a possible boundary stratotype for the base of the Campanian Stage: Cretaceous Research, 29, pg. 131 – 167

Hancock, J. M., Walaszczyk, I., 2004, Mid-Turonian to Coniacian changes of sea level around Dallas, Texas: Cretaceous Research, vol. 25, pg. 459 – 471

Hovorka, S. D., Nance, H. S., 1994, Dynamic Depositional and Early Diagenetic Processes in a Deep-Water Shelf Setting, Upper Cretaceous Austin Chalk, North Texas: Transactions of the Gulf Coast Association of Geological Societies, vol. XLIV, pg. 269 – 276

Loucks, R. G., Larson, T. E., Zheng, C. Y. C., Zahm, C. K., Ko, L. T., Sivil, J. E., Sheng, P., Ruppel, S. C., Ambrose, W. A., 2020, Geologic characterization of the type cored section for the Upper Cretaceous Austin Chalk Group in southern Texas: A combination fractured and unconventional reservoir: AAPG Bulletin, v. 104, no. 10, pg. 2209 – 2245

Mauldon, M., M. B., Dunne, Rohrbaugh Jr., M. B., 2000, Circular scanlines and circular windows: new tools for characterizing the geometry of fracture traces: Journal of Structural Geology, vol.23, pg. 247 –258

Norton, G. H., 1965, Surface Geology of Dallas County, The Geology of Dallas County: Dallas Geological Society, plate 1 Radiation Solutions Inc., 2019,

Priest, S. D., Hudson, J. A., 1981, Estimation of Discontinuity Spacing and Trace Length Using Scanline Surveys: International Journal of Rock Mechanics, Mining Science, and Geomechanics, vol. 18, pg. 183 –197

RS-125/230 User Manual: Radiation Solutions Inc.

Zeeb, C., Gomez-Rivas, E., Bons, P. D., Blum, P., 2013, Evaluation of sampling methods for fracture network characterization using outcrops: AAPG Bulletin, vol. 97, no. 9