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PETROGRAPHIC AND STRATIGRAPHIC ANALYSIS ALONG THE LOWER CRETACEOUS STRATA, IN KIMBLE COUNTY TEXAS

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PETROGRAPHIC AND STRATIGRAPHIC ANALYSIS ALONG THE LOWER CRETACEOUS STRATA, IN KIMBLE COUNTY TEXAS

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PETROGRAPHIC AND STRATIGRAPHIC ANALYSIS ALONG THE LOWER CRETACEOUS STRATA, IN KIMBLE COUNTY TEXAS

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ABSTRACT

The upper Trinity Group is predominantly a carbonate system with minor clastic couplets that were deposited during the Middle Cretaceous in the south Llano Uplift region. The upper Trinity Group was deposited on a southward dipping platform in the Kimble County area. Stratigraphic units of the upper Trinity Group are the Hensel Formation, determined to be supratidal claystones, the Glen Rose Formation, which are mudstones that were deposited in a carbonate lagoon, and the Walnut and Fort Terrett formations, which are wackestones to packstones interpreted to have been deposited on a shallow carbonate shelf.

Nine stratigraphic sections were measured along Interstate 10 and U.S Highway 377 in Kimble County, Texas to analyze the lithostratigraphic, sequence stratigraphic, petrographic, and paleotologic deposition. Three sequences were determined based on disconformites. The Upper Hensel Formation contact with the Lower Glen Rose Formation is based on the uppermost red bed of the Hensel Formation, forming Sequence 1. Sequence 2 begins at the mudstones atop of the Hensel Formation and end at the burrowed mudstone unit, this

sequence represents the Glen Rose Formation. Sequence 3 extends from claystones atop of the burrowed limestone of the Glen Rose Formation and terminates at the disconformable contact with the Fort Terrett Formation, representing the Walnut Formation. Petrographic evidence indicates that marine diagenesis is prevalent. Common bivalves in the area were *Ceratostreon texanum*, which are index fossils for the Walnut Formation and provided substantial evidence for the placement of the Walnut Formation in Kimble County, Texas.

ACKNOWLEDGEMENTS

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INTRODUCTION

The Cretaceous strata in Texas are marked by thick and massive carbonate and clastic sequences that were deposited across the Comanche Shelf. The upper Trinity and lower Edwards record the migration of carbonate and clastic couplets across this shelf. The general facies trend displays a major 2nd order transgression with minor regressions. The transgression allowed for the development of the North American Interior Seaway, which split North America into east and west.

The study area is located along Interstate 10 and US Highway 377 in Kimble County, Texas. Stratigraphic units analyzed are the Hensel Formation, Glen Rose Formation, Walnut Formation, and the Fort Terrett Formation. The Hensel and Glen Rose formations form the upper Trinity Group in Kimble County. The Hensel Formation represents terrestrial to shallow shelf deposits. The dominant lithology of the Hensel Formation are red claystones and grey claystones. Fossils in the Hensel Formation are typically root casts. The Glen Rose Formation is composed of mudstones and marls that suggest a shallow shelf lagoon deposition. Biologic activity is recorded in burrows at the top of the Glen Rose Formation. The Walnut Formation is described as a shallow shelf

lagoon, evidenced by mudstones, marls, and wackestones. *Ceratostreon texanum* is the index bivalve fossil of the Walnut Formation and is used to differentiate the Glen Rose Formation from the Walnut Formation. The Fort Terrett is a massive wackestone to packstone that caps most of the exposed outcrops. Erosional surfaces along the top and bottom mark the divisions of each formation (figure 1).

During the Aptian through Albian age, the west central portion of Texas was under warm shallow seas. This area is known as the Comanche Shelf. The “Glen Rose” sea was calm due to the Devils River Trend and Stuart City Reef restricting marine circulation. These structures aided in the development of the Hensel, Glen Rose, Walnut, and Fort Terrett formations.

Each sequence is represented by one formation. Sequence 1 represents the Hensel Formation. The lower contact is covered; however, the upper contact is along the last red bed. Sequence 2 encompasses the Glen Rose Formation. This sequence begins at the first unit above the red bed and the burrowed mudstone unit at the top of the formation. Sequence 3 consists of the Walnut Formation. It incorporates the claystones above the burrowed unit of the Glen Rose Formation and the units below the Fort Terrett Formation.

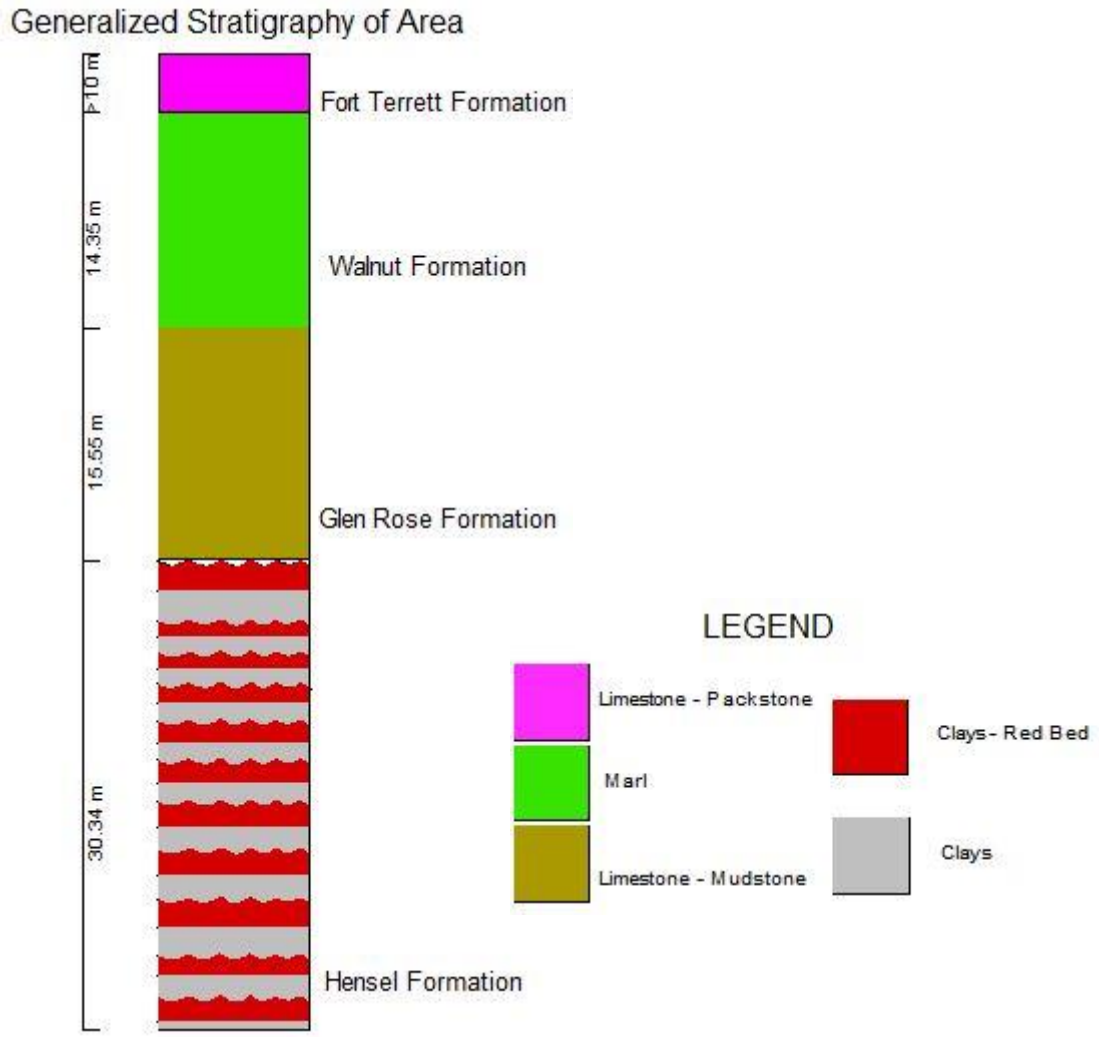

Figure 1 Generalized stratigraphic column for the Lower Cretaceous lithology in Kimble County.

Petrographic samples record microfacies shifts throughout the measured sections. Thin sections show mudstones increasing in fossil content as time progressed, following the model of sea level increasing throughout the Cretaceous. Dominate bioclasts are forams, bivalves, and algae. Thin sections indicate that the study area has undergone several diagenetic stages.

. Payne (1982) indicate that the Hensel Formation in southern Llano Uplift region begins with conglomerate deposition, followed by paleosol development, and ends with an upward fining sequence which is dominantly fine deltaic sands and muds. These lithofacies are indicative of a regression and gradual transgression. The extent of the Hensel Formation is along the southern flanks of the Llano Uplift region. Stricklin (1956), Lozo (1956), and Bergan (2009) model the Glen Rose as a shallow shelf lagoon, which extends from Big Bend, Texas to North Texas. The Glen Rose Formation has been divided into upper and lower based upon the *Corbula martinae* bed. Moore extensively studied the Walnut Formation, and broke it down into several members. Extent of the Walnut Formation in this area has been determined to be from Gillespie County to Tarrant County, Texas. The Fort Terrett Formation was deposited primarily in south central Texas.

The Geologic Atlas Map on the Llano Sheet by Barnes shows that the Hensel Formation and Fort Terrett Formation contact each other (figure 2).

However, other evidence based on sequence stratigraphy and paleontology indicates that the Glen Rose Formation and Walnut Formation are present within the study area.

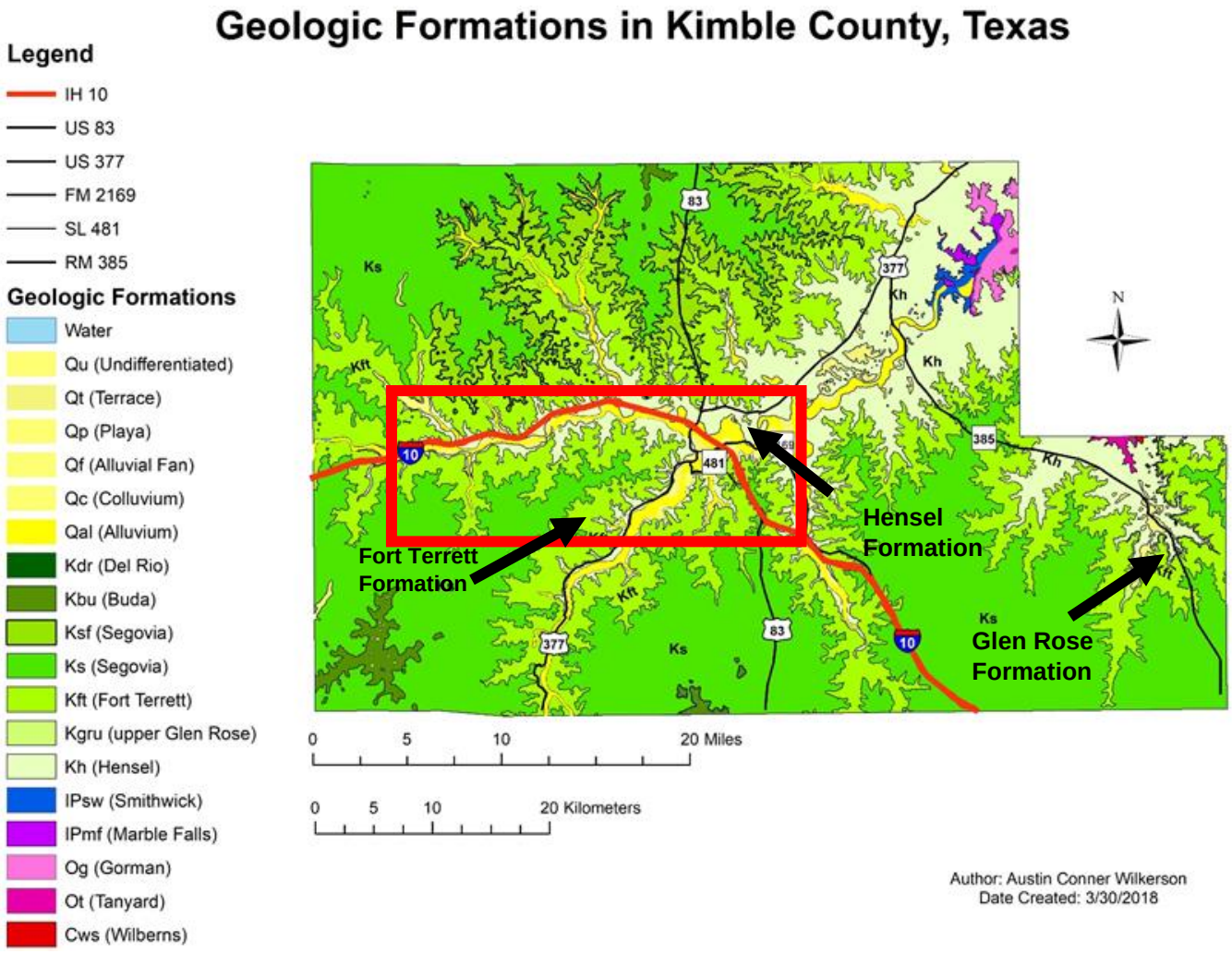

Figure 2. Geologic Atlas of Texas, Llano Sheet, modified from Barnes (1986). In study area boxed in red, the lowermost Cretaceous unit is the Hensel Formation and the uppermost unit is the Fort Terrett Formation. On the East side of Kimble County, there is a presence of the Glen Rose Formation.

CRETACEOUS SETTING IN TEXAS

During the Lower Cretaceous, most of Central Texas was covered by shallow marine waters. The Comanche Shelf was a platform that extended throughout the central portion of Texas. However, it did not extend into the southeastern Gulf Coastal Plain. Lithostratigraphic units can be correlated across the Comanche Shelf. The Maverick and Tyler basins (figure 3), represent shallow marine open basins (Winter, 1962; Fisher and Rodda, 1967). These open basins were divided by the Central Texas Platform (Adkins, 1933). The Stuart City Reef is basinward from the Central Texas Platform, forming the shelf margin (Trabelsi, 1984). The Llano Uplift formed an island during the Cretaceous. Some of the eroding sediment from the Llano islands was carried by the wind, southwest towards the Maverick basin.

The Stuart City Reef was a rudist reef that acted as a wave resistant structure (Winter, 1961). It formed an arch like structure across the southeastern portion of Texas, following a SW-NE strike, and dips slightly to the east. The reef calmed the back reef waters throughout its growth (Winter, 1961).

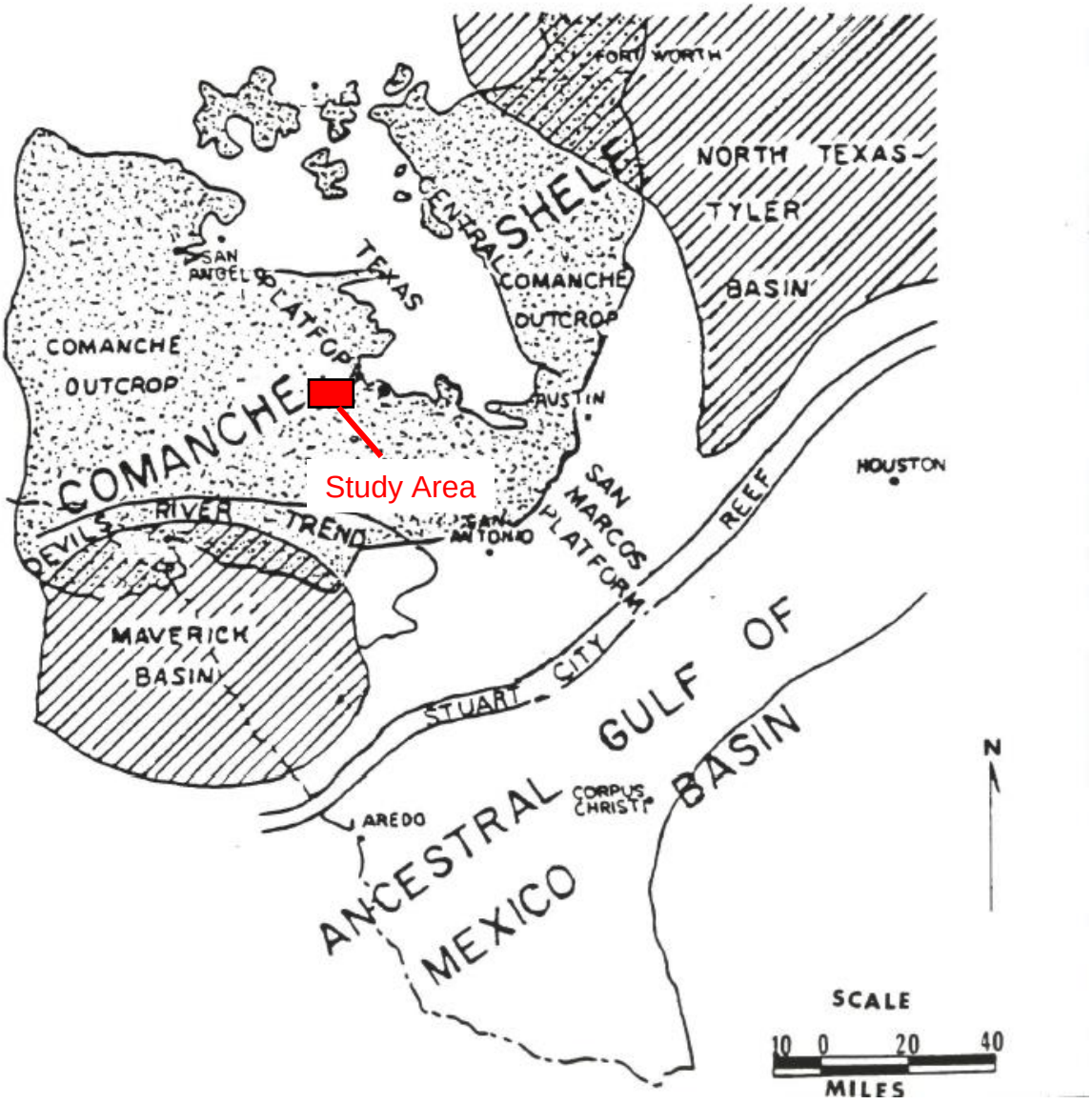

Figure 3. Regional Geologic Elements of Lower Cretaceous in Central Texas (modified from Rose, 1972). Red Box indicates study area.

Formation of the reef may have started during the Aptian (Winter, 1961). The forereef thickens towards the south and thins basinward.

The Devils River Trend is a limestone ridge (wackestone, mudstone, and grainstone) located in southwestern Texas and rimmed the Maverick Basin, which became prominent during the late Albian (Lozo and Smith, 1964). This structure hindered marine circulation around the Llano islands. During Albian time, the Devils River Trend and Stuart City Reef connect (Scot, 1990), which increased the restriction of marine circulation.

The Western Interior Seaway stretched from the present day Gulf of Mexico to the Arctic Ocean, splitting North America into east and west (Parrish, 1984) (figure 4). Circulation patterns of the seaway contributed to the growth of the carbonate factory throughout the Cretaceous. Thick sequences of carbonate deposition were possible because of ideal shallow shelf environments, with low sedimentation rates. The seaway was situated between the tropics of Cancer and Capricorn (30°N and 30°S), allowing for plenty of sunlight, thus allowing organisms to flourish in the photic zone (Parrish, 1984).

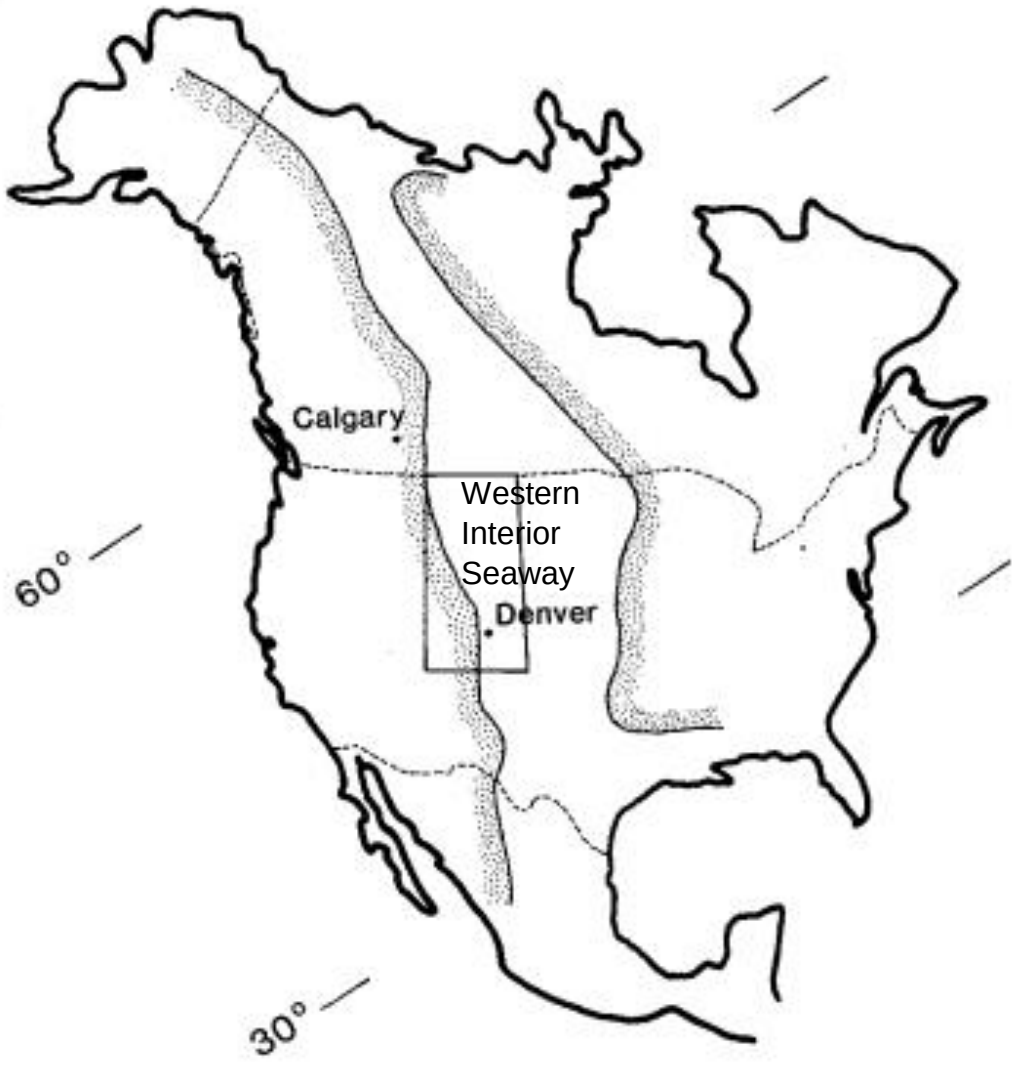

Figure 4. Map of North America split by the Interior Seaway of the Cretaceous, with Latitudes (modified from Parrish, 1984).

ZUNI SEQUENCE

The Mesozoic is divided into two 2nd order sequences, the Absaroka (Pennsylvanian-Middle Jurassic) and the Zuni (Middle Jurassic – Paleocene). The transition between the Absaroka regression and the Zuni transgression overlaps in areas and is hard to differentiate (Bally, 1984). The outcrops present in the study were deposited during the Zuni transgression.

The Zuni transgression coincides with the widening and drifting of the central Atlantic and Gulf of Mexico trailing plate margin (passive margins) (Bally, 1984). Sloss further divided the second order Zuni transgression into three divisions, Zuni I late Early Jurassic- Early Cretaceous Berriasian, Zuni II Early Cretaceous, Valaginian to Early Cenomanian, and Zuni III Late Cretaceous, Cenomanian to Early Paleocene (Bally, 1984).

Vail and others further divided the Zuni sequence; however, the division became complicated because the sequence boundaries were not agreed upon. This was because of the tectonic versus eustatic debate within the concept of sequence stratigraphy (Bally, 1984). The early Sloss and basic models of sequences representing tectonic cycles needed to be refined, and other orders

were added to help explain the smaller parasequences within the Zuni sequence, hence the 3rd order and 4th order cycles (Bally, 1984).

The Zuni sequence shows a subtle onlapping throughout the Western Interior Seaway, which is separated by two separate regressions (Sloss, 1988). These relative sea level falls caused terrestrial deposition, subaerial erosion and subsequent hiatus, hence the three separate Zuni divisions (Miall, 2008). Zuni I shows the siliclastic material being shed off from the west, from orogenic events, which started in the Jurassic and continued through the Tertiary. Syndepositionaly, marine shales and carbonates were deposited throughout the eastern platforms. Gradually, the rate of sedimentation outpaced the subsidence rates. Towards the end of the Cretaceous, tectonic uplift eventually caused relative sea level to fall, subaerially exposing the marine sequences and truncating/erode them. The truncation led to an angular unconformity at the Zuni-Tejas boundary (Miall, 2008).

COW CREEK FORMATION

The Cow Creek Formation was deposited during the Lower Cretaceous, and is dominantly a carbonate unit that represents a transgression over older Pennsylvanian units. Depositional facies include shallow marine and shoals to patch reefs that are composed of corals and sponges (Loucks, 2001). In the southern Llano Uplift region, the lower contact is the Hammett Shale and the upper contact is the Hensel Formation (figure 5). Most of the Cow Creek Formation is in the subsurface; however, outcrops are located in Travis, Hays, and Comal counties.

Siltstones, skeletal packstones to grainstones, and subaerial caliche are the dominate lithologies of the Cow Creek Formation. The caliche represents dune deflation facies, the siltstones indicate a beach facies and the packstones and grainstones represent offshore oyster banks (Owens, 2010).

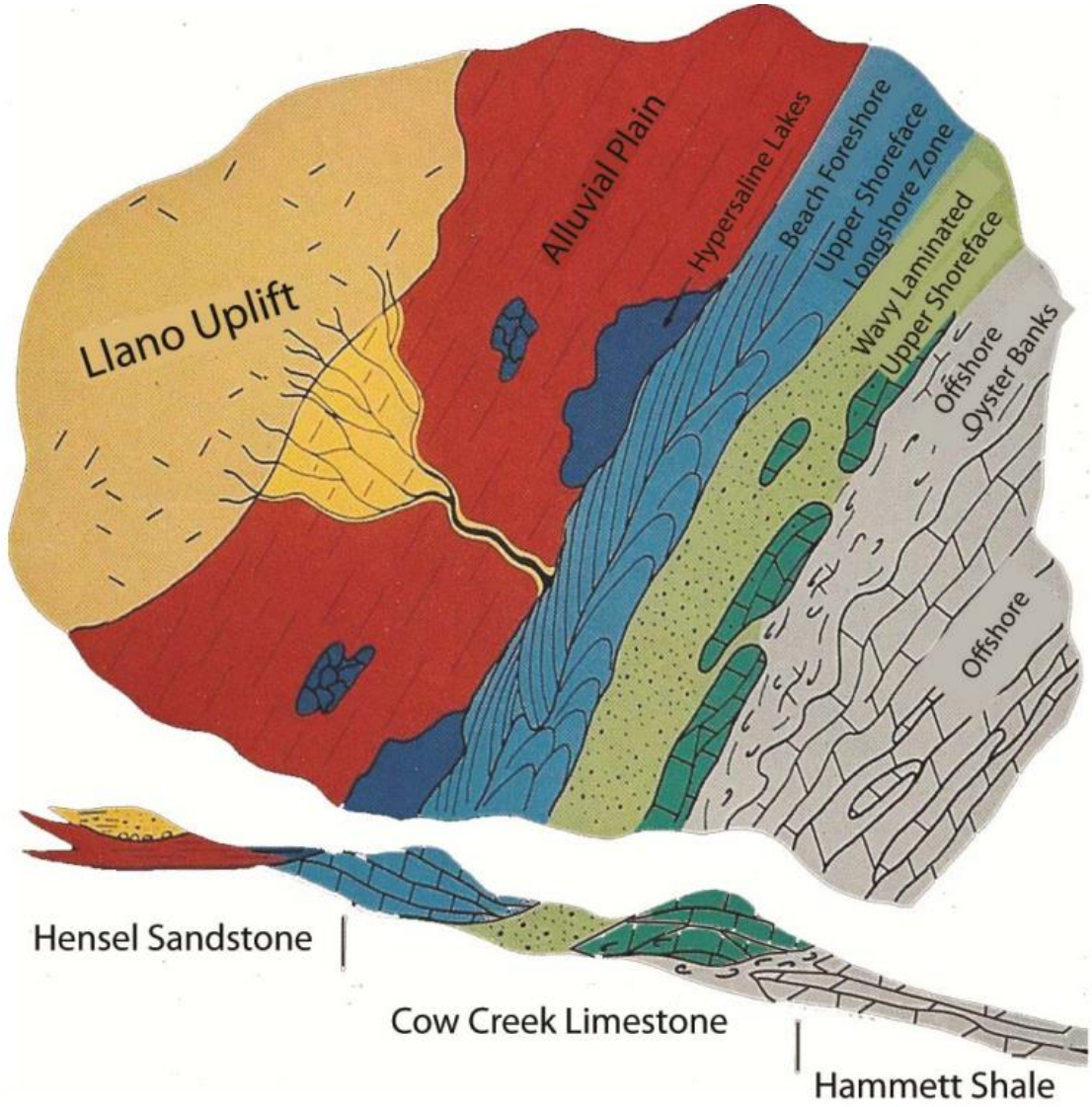

Figure 5. Depositional model for the Cow Creek Formation (from Owens, 2010).

HENSEL FORMATION

The Hensel Formation lies in the middle of the Trinity Group (figure 6). Deposition occurred during the Lower Cretaceous (Aptian), around the Llano Uplift. The Hensel Formation lies around the Llano Uplift (figure 7). Terrestrial sediment deposited in the Hensel Formation came from the Llano Uplift, suggesting paleocurrents came from the north (figure 8) (Jones 1997).

Deposition of the Hensel Formation was the result of subaerial deposition during a marine lowstand. A series of transgressions and regressions on the continental shelf left both marine and nonmarine deposition, resulting in carbonate clastic couplets within the Trinity Group. The clastic component was the Hensel Formation, originating from the up-dip terrigenous deposition during the last and final cycle of the Cretaceous Sea. The Hensel Formation forms a clastic wedge that is bounded unconformably at the base by Paleozoic sedimentary and Precambrian rocks. The top is unconformable with the Edwards Group (Jones 1997).

The Hensel Formation is comprised of three main lithofacies, they include basal conglomerates, middle paleosols, and upper fines. The upper fines

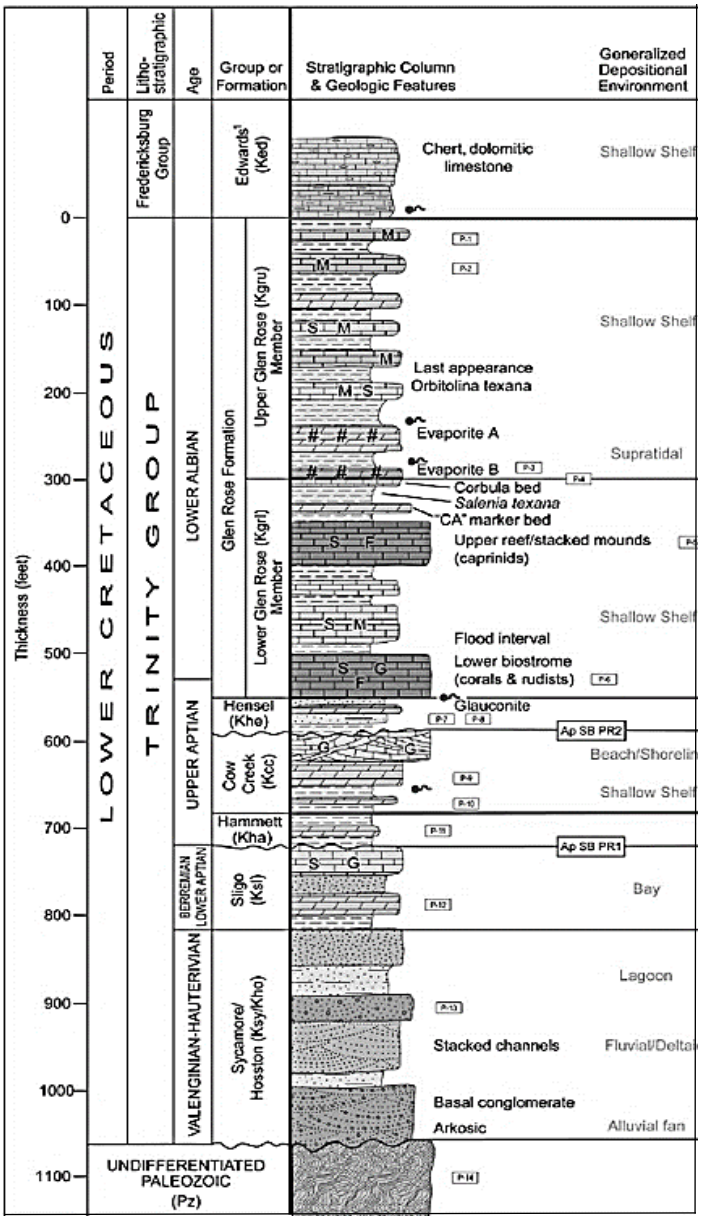

Figure 6. Generalized stratigraphic column for the Lower Cretaceous formations in Central Texas. (from Hunt, 2015).

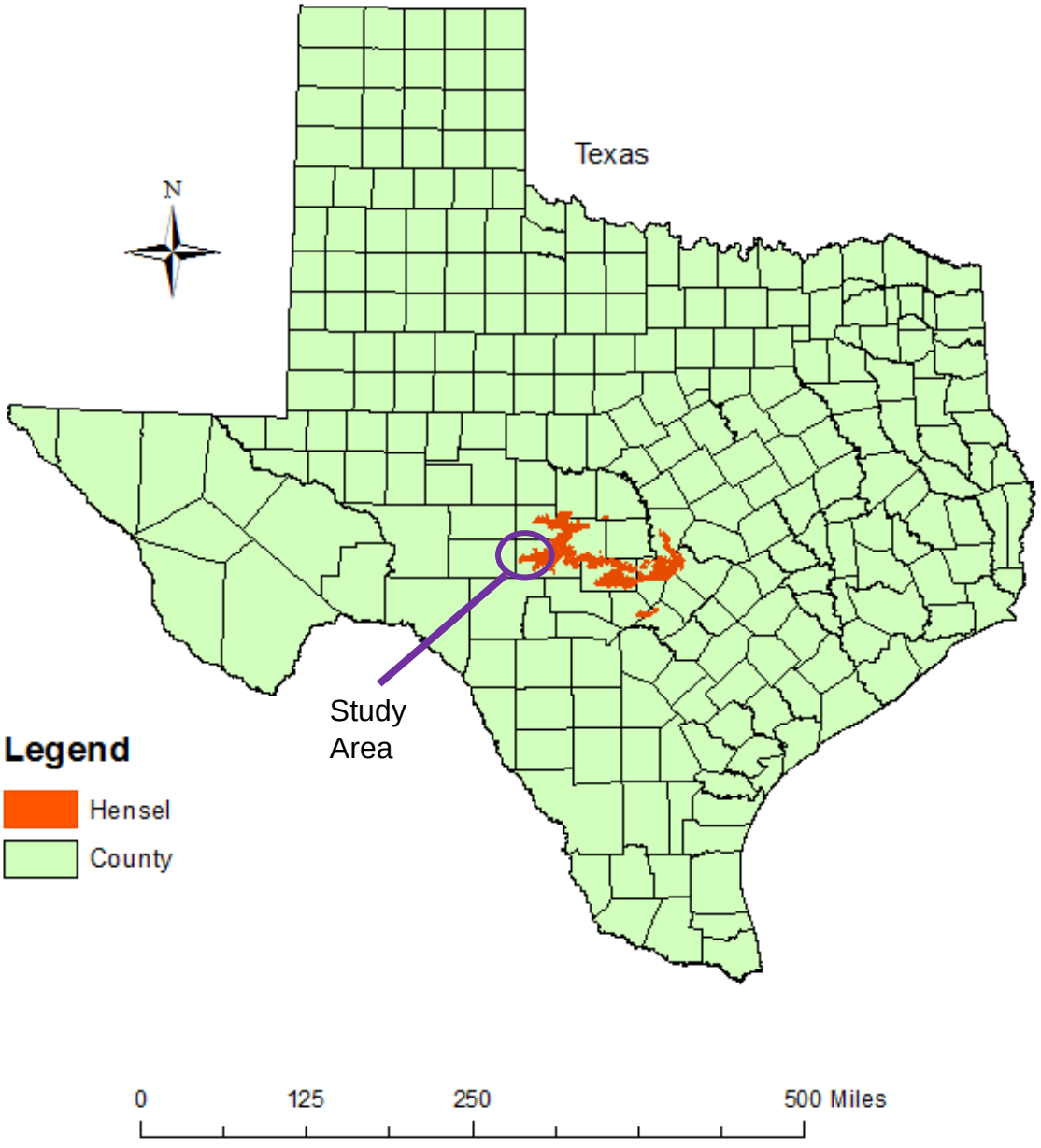

Figure 7. Extent of the Hensel Formation in Central Texas. USGS, TINRIS. Circled in purple is the study area.

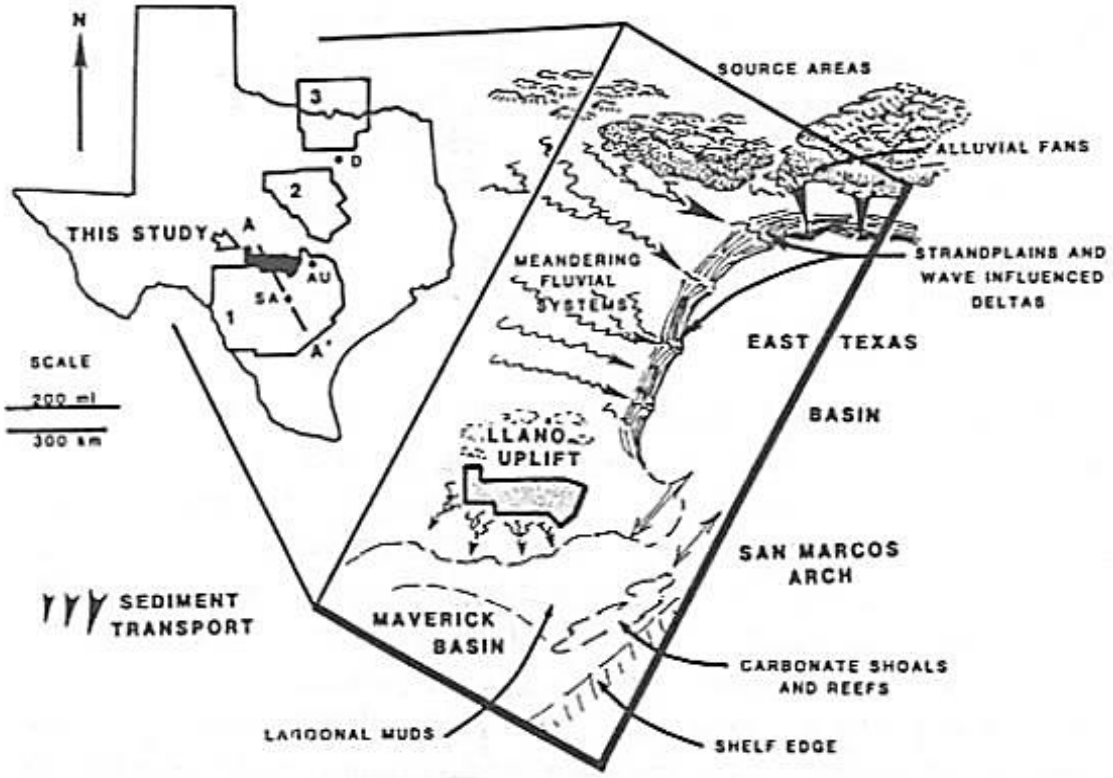

Figure 8. Paleogeographic reconstruction of depositional systems in the Trinity Group (from Payne, 1982).

form the buttes and mesas with up to 35 meters in relief. Capping the buttes and mesas are limestones of the Fredericksburg Group. The red soils are characteristic of the middle paleosols. Along the Llano River and close to the Llano uplift, the basal conglomerates are common. The basal conglomerates indicate high-energy fluvial conditions, located at the apex of the Hensel alluvial fans (Jones, 1997). Conglomerate composition is from boulder to pebble sized material from the Llano Uplift. The finer grained material is a mixed composition of sandstone and mudstone. The sandstones are a result of fluvial channels and the mudstones are a result of lower energy meandered streams that overlie paleosol horizons. Calcareous siltstones and limestones with some terrigenous mudstones formed during the “Glen Rose” sea, which transgressed over the alluvial plains. Each of the three lithofacies is laterally equivalent in age at a given horizon of deposition; however, the limestone beds of the upper fines are not laterally equivalent in age (Jones, 1997).

Basal conglomerates are the lowest lithofacie of the Hensel Formation. Thickness ranges from 0 to 17 meters. The wide range of thickness is due to the topographic surface during deposition. In Gillespie County, the basal conglomerates overlie the Pennsylvanian Marble Falls Limestone and the Smithwick Shale. The irregular surface of the Pennsylvanian formations was from a middle Pennsylvanian orogeny. The basal conglomerates are a series of clastic wedges, which are both vertically stacked and laterally lenticular (Jones, 1997).

Individual horizons of the basal conglomerate range in thickness from 1.2-2 meters. The Basal Conglomerate encompasses course-grained conglomerates, sandstones and paleosols. Paleosols within this lithofacies are less than two meters. Paleosols are also bounded by erosional contacts of the conglomerates (Jones, 1997).

The lower Hensel Formation is defined by the stratigraphic interval between the basal contact of the Paleozoic Marble Falls and Smithwick formations and the conglomeratic horizons that are less than 1.2 meters thick. These are separated, by paleosol intervals that are three meters or thicker. Conglomerate clast ranges are boulders, cobbles, and pebbles. Lithologically, the clasts are limestones that contain sand-sized clasts. Source of the limestone clasts is from the Ordovician Ellenberger Group. Limestone clasts are angular to sub-angular for the Pennsylvanian suite, and rounded to sub-rounded in the Ordovician suite. The igneous suite consists of sub-rounded to rounded “bull quartz” clasts. Structures in the basal conglomerate are poorly preserved. Faint crossbedding appears within some of the larger clasts beds. The conglomerate generally fines upward. Some of the tabular clasts show imbrication, indicating a southwest flow direction in paleocurrents (Jones, 1997).

The middle lithofacies are the paleosols, which are the most consistent units of the Hensel Formation. Isotope ratios of O^{18}/O^{16} and C^{13}/C^{12} indicate that

paleosols were subaerially exposed and climate warmed as time progressed (White, 2009). This lithofacies is recognized by the red, well-developed soil horizons, which are approximately 35 meters thick (115 ft.). Contacts are not based on sharp lithologic or paleontological changes. The upper portion of the paleosol litofacies however, is based on the transition from subaerial calcretes and fluvial sandstones to subaqueous carbonates and red and green mudstones. The calcretes and fluvial sandstones are laterally discontinuous, and the carbonates and mudstones are laterally continuous (Jones, 1997).

Transition is recognized by a thick bed carbonate unit, which is interpreted to be caliche, overlying the paleosol. The main lithologies of this lithofacies are the fluvial sandstones, mudstones, paleosol horizions with calcrete. Sediment from the sandstones originate from the Precambrian crystalline rocks, which consist of quartz and feldspar grains. Minor constituents include, carbonate grains and heavy minerals (Jones, 1997).

The sandstones are immature to sub-immature subarkoses (Folk, 1954). Sandstones are very friable, with calcite cement. The sandstone grades vertically from coarse to fine grained beds. Pebbles are minor constituents and are found in individual beds. Mudstones are the most abundant lithology within the middle lithofacies. They are red in color and dominantly fine-grained silt. Red beds may originate in the Pennsylvanian or Permian red beds that have since been eroded away. Red beds may have originally been illite and chlorite, but now are

smectite, evidenced by high concentrations of feldspar and a lack of kaolin (Amsbury, 1996).

The mudstones are less friable due to both calcite and hematite cements. Sedimentary structures in the mudstone are rare. Calcretes in the mudstone are zones of precipitated, coalesced nodules that are made of micro-spar concretions (Payne, 1982). Tabular geometry of the sandstone indicates a fluvial channel deposit. The sandstone channels widths range from 0.75 meter to 1.6 meters. Some of these channels overlie the red mudstones or other paleosol horizons with an erosional basal contact. Caliche lag deposits may juxtapose this boundary. Some of the calcrete concretions are rhizoconcretions, which branch downward like root structures. Biota within the paleosols are limited due to subaerial exposure, and subsequently have little use for biostratigraphic dating methods. However, fossils include cycad leaves within fine-grained sandstones and vertebrae bones. Cycad preservation within the sandstones indicate an overbank or sheet wash deposit (Jones, 1997).

The upper fines lithofacie have a total thickness of 43 meters, making it the largest of the lithofacies. Here, the fines have distinct and easily identifiable contacts. The upper contact is the Fort Terrett Formation. This contact forms the unconformable boundary between the last friable siltstone or the non-fossiliferous limestone. Intervals of less than 1.5 meters thick of oyster beds are common.

The coquina zones are dominated by bivalves, with some gastropods, which are put into the Edwards Group (Jones, 1997).

The definition of the lower contact of the upper fines lithofacie is the last nodular calcrete zone of the middle paleosols and the first laterally continuous bedded limestone or mudstone. Change in the lithology is due to the shifting from subaerial environments to a subaqueous facie. The change can be seen in the field by identifying the bedding shift from lenticular bodies to consistent lateral continuity. The upper fines have distinct low-energy planar beds that are laterally continuous. Thin limestone beds in the upper part can show steep cross-bed sets, coupled with limestone rip up clast in a bivalve hash matrix. Upper carbonates also contain asymmetrical ripplemarks. At the top of the limestone, beds exhibit trace fossils in the form of horizontal and vertical burrows. The calcareous siltstones of the top portion contain marine foraminifers and ostracods in small quantities. Marine bivalves and bivalve hash are present in only two of the thin limestone beds (Jones, 1997).

Fluvial systems of the Hensel Formation were derived from two types of bedload channels. These channels consisted of caliche matrix and overbank deposits of mudstone and siltstone. Large channels were straight and dominated by very coarse sands and fine gravels. Large trough beds of sand waves indicate high amounts of vegetation growth and deposits of calcrete at the banks. Mud

splays are part of the interfluvial deposits, located proximal to the channels. The thin sands that were deposited during sheet flooding events and were subaerial exposed forming paleosols. Some of the paleosols contain thick calcrete nodules and pipes. Channel facies contain the cross-stratified sediments. Silts and fine sands interfinger in a sheet pattern along the levees. Overbank and interfluvial muds were cemented by calcite. Teepee structures and mudcracks delineate the playas (Payne, 1982) (figure 9).

When transgression in the Southern Llano Uplift area occurred, the alluvial fans were the major sources of sediment supply. The fluvial systems were high gradients, forcing finer sediments to be deposited in areas distal from the uplift. Sediment supply decreased as the transgression continued, due to the area being semi-arid. Paleosols, calichefied mudstones, were extensive and small coastal sabkhas were proximal to the lagoonal grass-flats. At the top of the Hensel Formation, the clastic sediments from the uplift are calcareous, which transition into sandy, lagoonal carbonates of the Fort Terrett Formation (Payne, 1982) (figure 10).

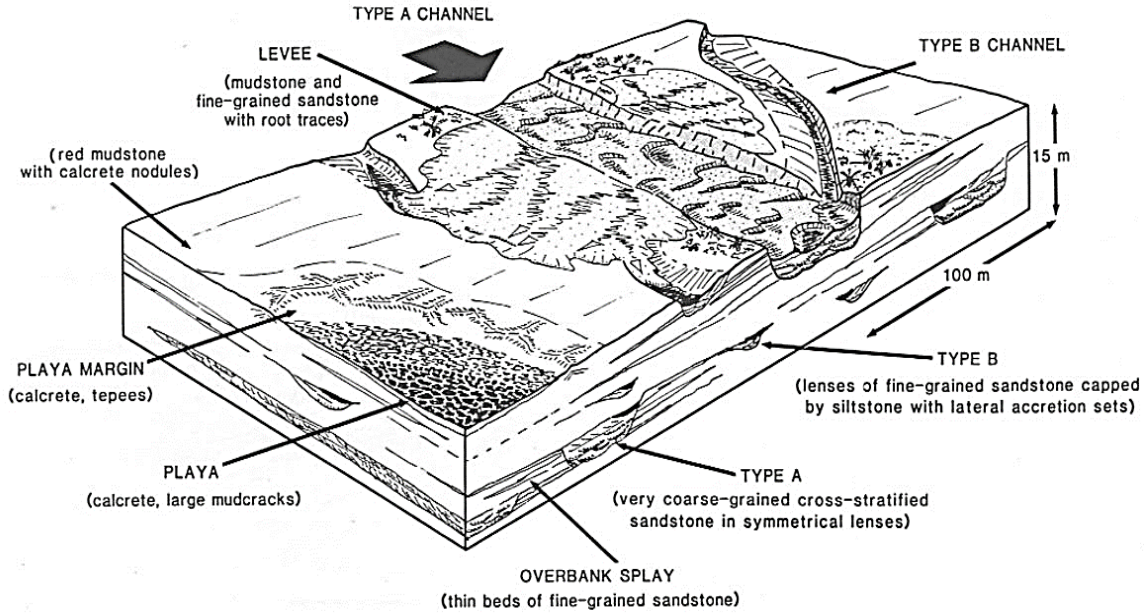

Figure 9. Type A and B channels, with caliche overbank deposits of the Hensel Formation in Gillespie County (from Payne, 1982).

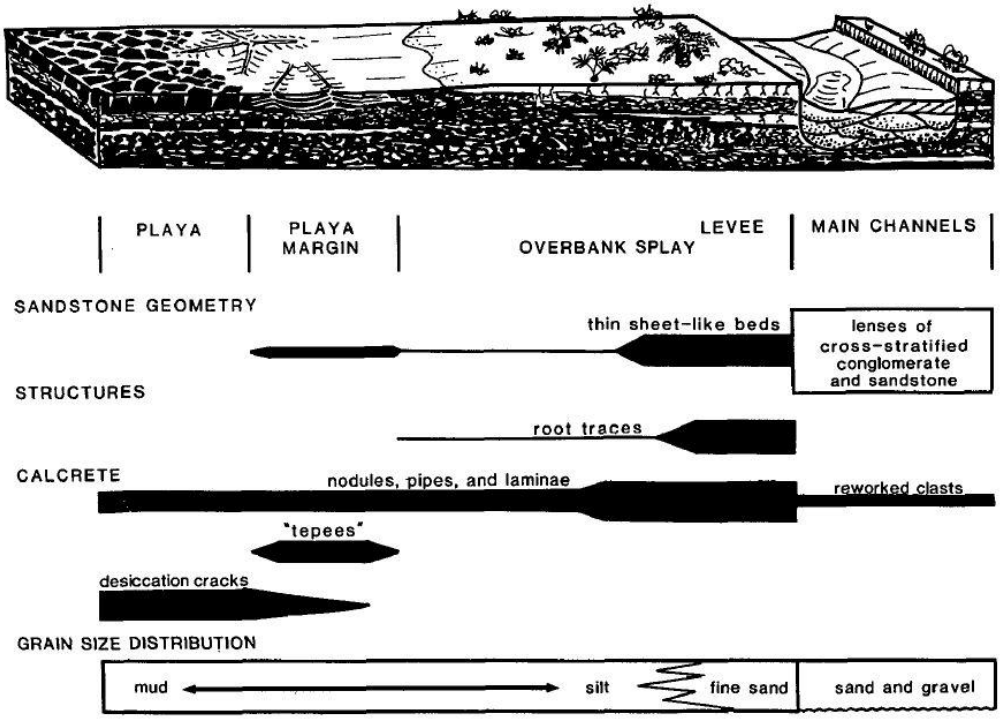

Figure 10. Features and distributions of the matrix and framework at a typical Hensel Formation facies tract (from Payne, 1982).

GLEN ROSE FORMATION

The Glen Rose Formation is Aptian in age and outcrops from Big Bend National Park, to the Dallas-Ft. Worth region of North Texas (figure 11). It overlies the upper Trinity Group and Comanche Series (Bergan, 2009) (figure 12). The Glen Rose Formation is primarily a limestone; however, shales and minor clastic lithologies are present. The dominate depositional environments are the shallow marine to lagoonal facies.

The Glen Rose Formation was deposited on the Central Texas Platform and forms a northwest trend that dips to the east. It marks the last transgression for the Trinity Group. Thickness of the Glen Rose Formation varies from outcrops to subsurface, ranging from 0.7 meters thick outcrops, to 455.6 meters thick in the subsurface (Bergan, 2009).

Glen Rose Formation is often dominated by fossiliferous limestones, composed of bivalves separated by fossiliferous marls. Divisions of the Glen Rose Formation are based on an iron stained bed marker known as the *Corbula martinae* bed; this divides the upper and lower Glen Rose Formation (figure 13).

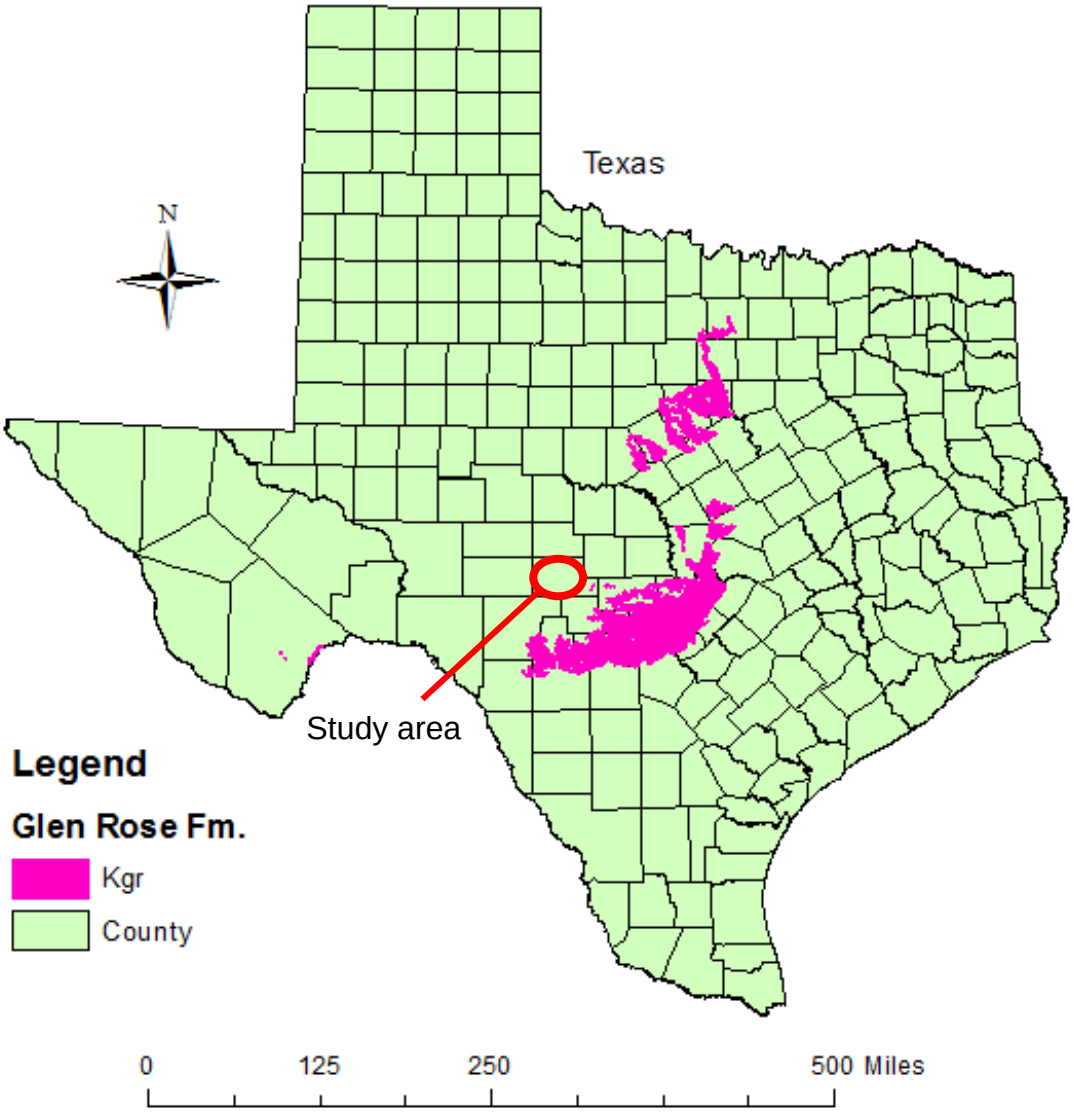

Figure 11. Regional extent of Glen Rose Formation. USGS, TINRIS. Circled in red is the study area.

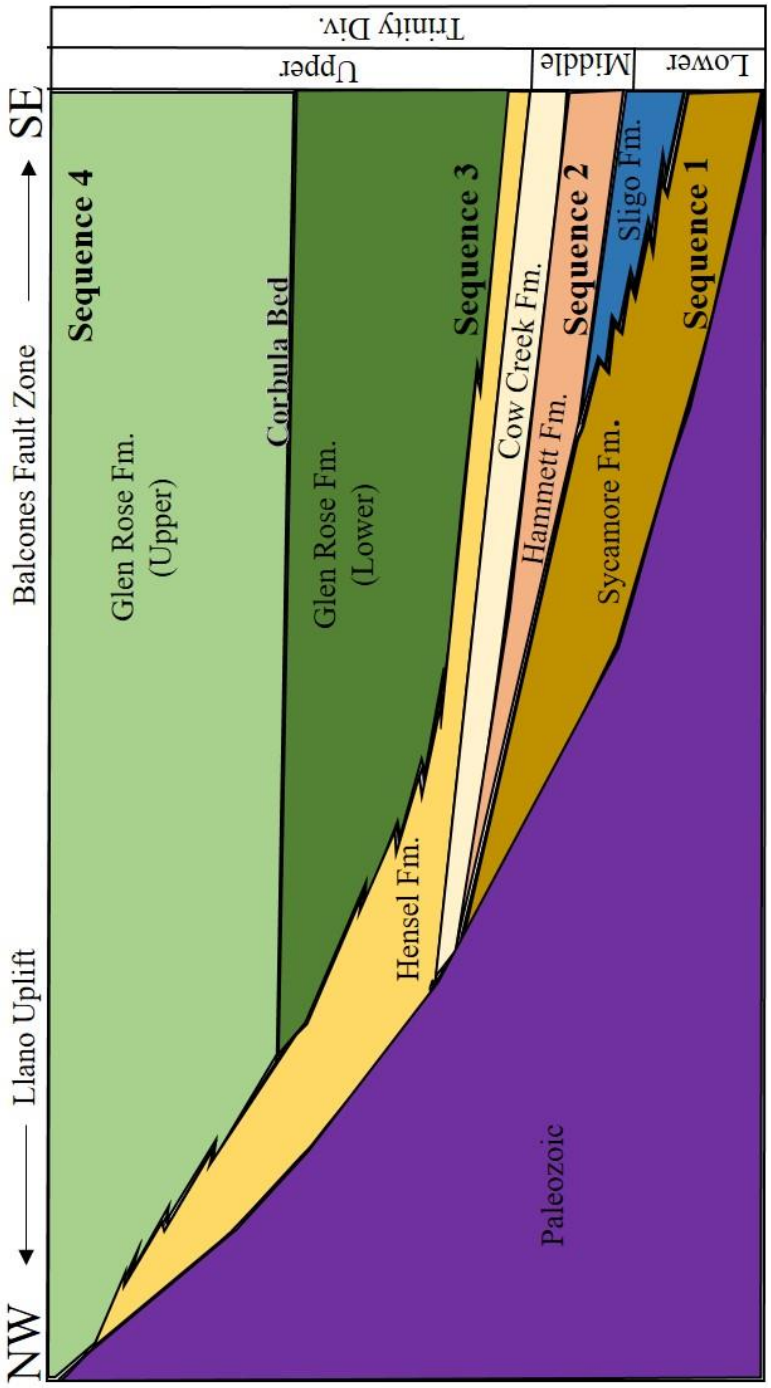

Figure 12. Sequence Model for the Trinity Group (modified from Moore, 1996).

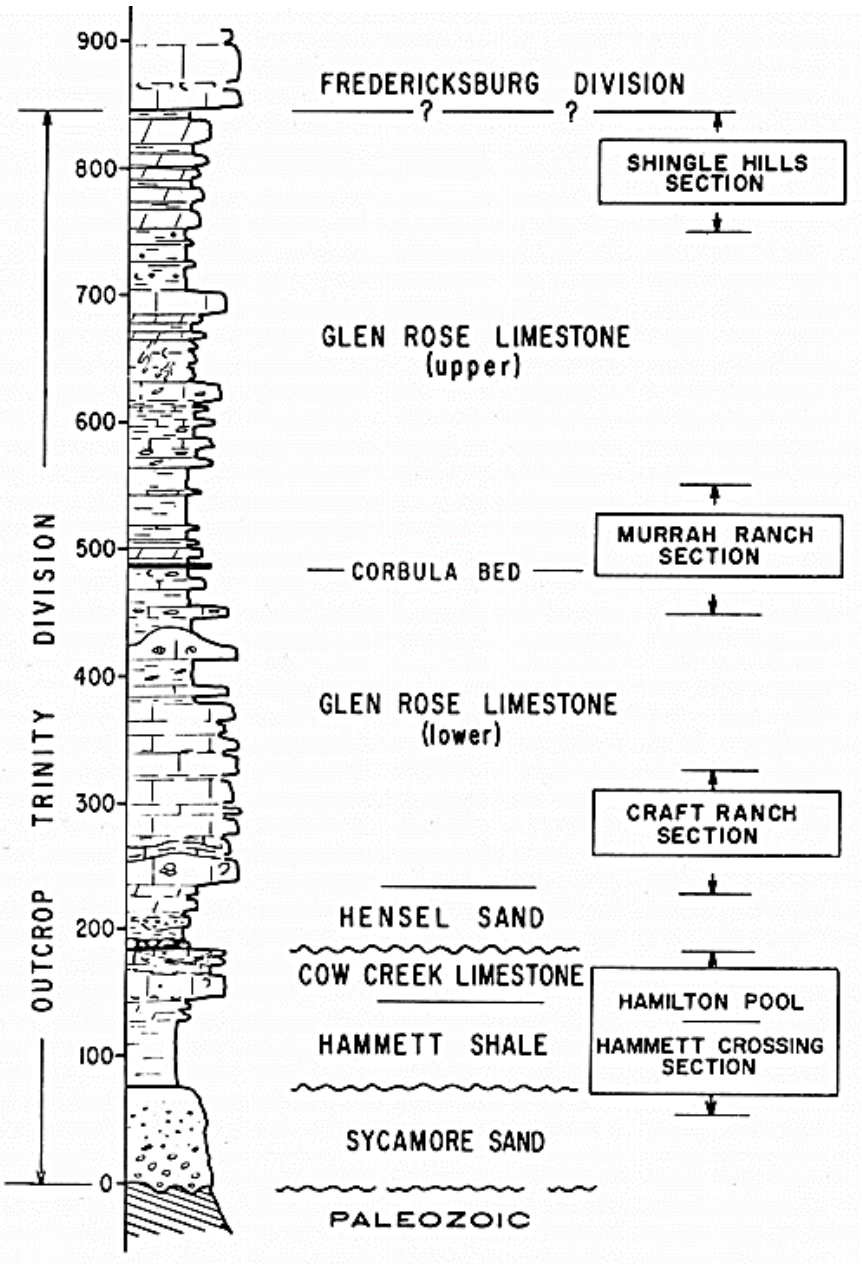

Figure 13. Reference Section, Trinity Division Hays-Travis County Area, Texas. (from Lozo, 1956).

The lower Glen Rose Formation is defined by medium to thick beds of limestone of *Carprinid* pelecypods. Dolomite was produced by secondary dolomitization (Burkholder, 1973). The lower Glen Rose Formation contains both the intertidal to tidal facies. These facies produced mudstone to grainstones (Mancini and Scot, 2006). In South Texas, the lower contact of the Glen Rose Formation is placed at the “lowest (first) persistent limestone ledge” and above the Hensel Formation (Lozo and Stricklin, 1956).

The upper Glen Rose Formation is comprised of several shallowing upward cycles. These cycles grade from subtidal to supratidal facies, and contain mudstone to pack-grain stones. *Corbula martinae* beds overly the dinosaur tracks within the lower Glen Rose Formation. Common dinosaur tracks in the Glen Rose Formation are from the theropod *Grallator gregarious* and *Acrocanthosaurus atokensis* that have been documented throughout Texas (figure 14) (Rogers 2002 and Farlow, 2001). The contact between Glen Rose and Walnut formations is interbedded with dolostone, limestone, and sandstone. The contacts show a sharp change in facies, from restricted tidal flats, to marine lagoons (Mancini and Scot, 2006).

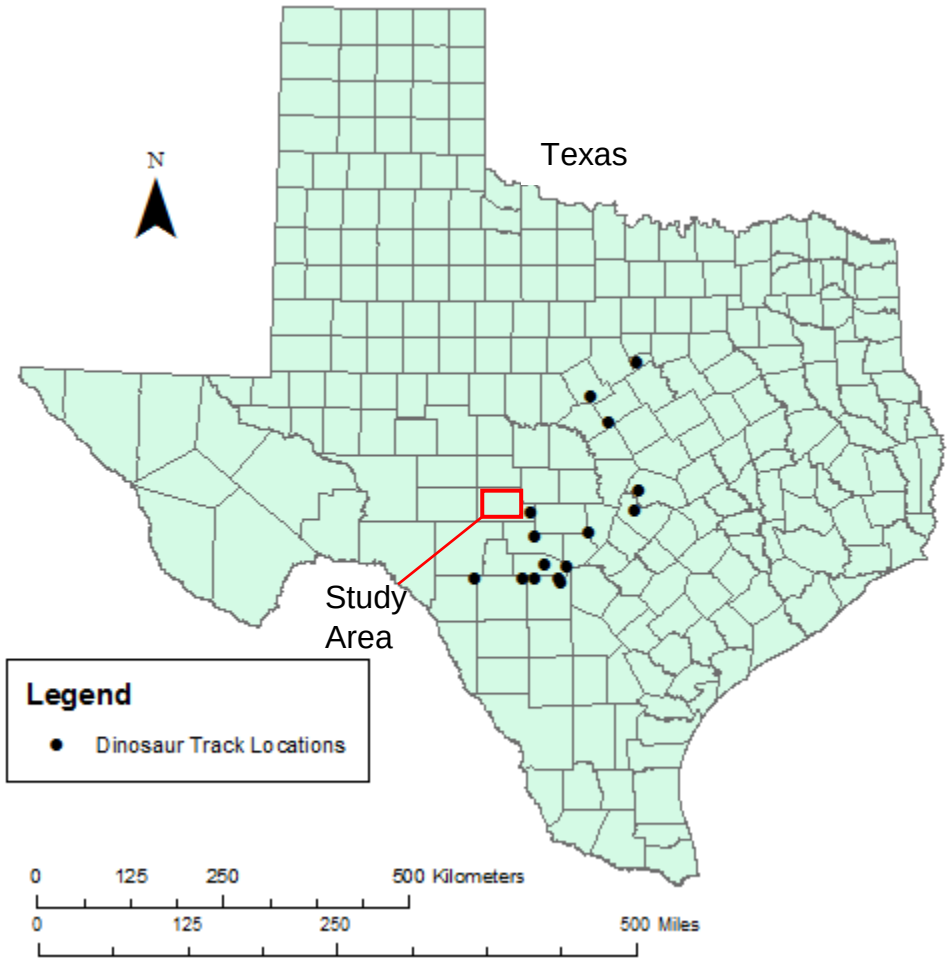

Figure 14. Locations of upper Glen Rose Formation dinosaur footprints in Texas (modified from Langston, 1974). Boxed in red is the study area.

WALNUT FORMATION

The Walnut Formation is Albian in age and is the lowest unit of the Fredericksburg Division. It lies in the middle of the Comanche Series (figure 15). In Central Texas, the Walnut Formation is divided into five members, from oldest to youngest: Bull Creek, Bee Cave, Cedar Park, Keys Valley Marl, and Upper Clay (figure 15). These members can be found in Travis County, Texas. It has a lower disconformable contact with the Glen Rose Formation and disconformable contact with the Paluxy Formation in North Texas and an disconformable contact with Comanche Peak Formation (figure 16). The lower contact with the Glen Rose Formation is typically bored by *Lithophagus* pelecypods (Moore, 1961). Key guide fossils are the oysters *Texigryphea* (figure 18), *Ceratostreon texanum* (figure 17) and the ammonite *Oxytropidoceras* (figure 19).

The Bull Creek Member is the lowest member and contains intraclasts, nodules, shell hash and typically forms wackestones. This member onlaps onto a truncation surface of the Glen Rose Formation, which is bored by pholads. Pholads are burrowing bivalves and are found in the glossifungites ichnofacies.

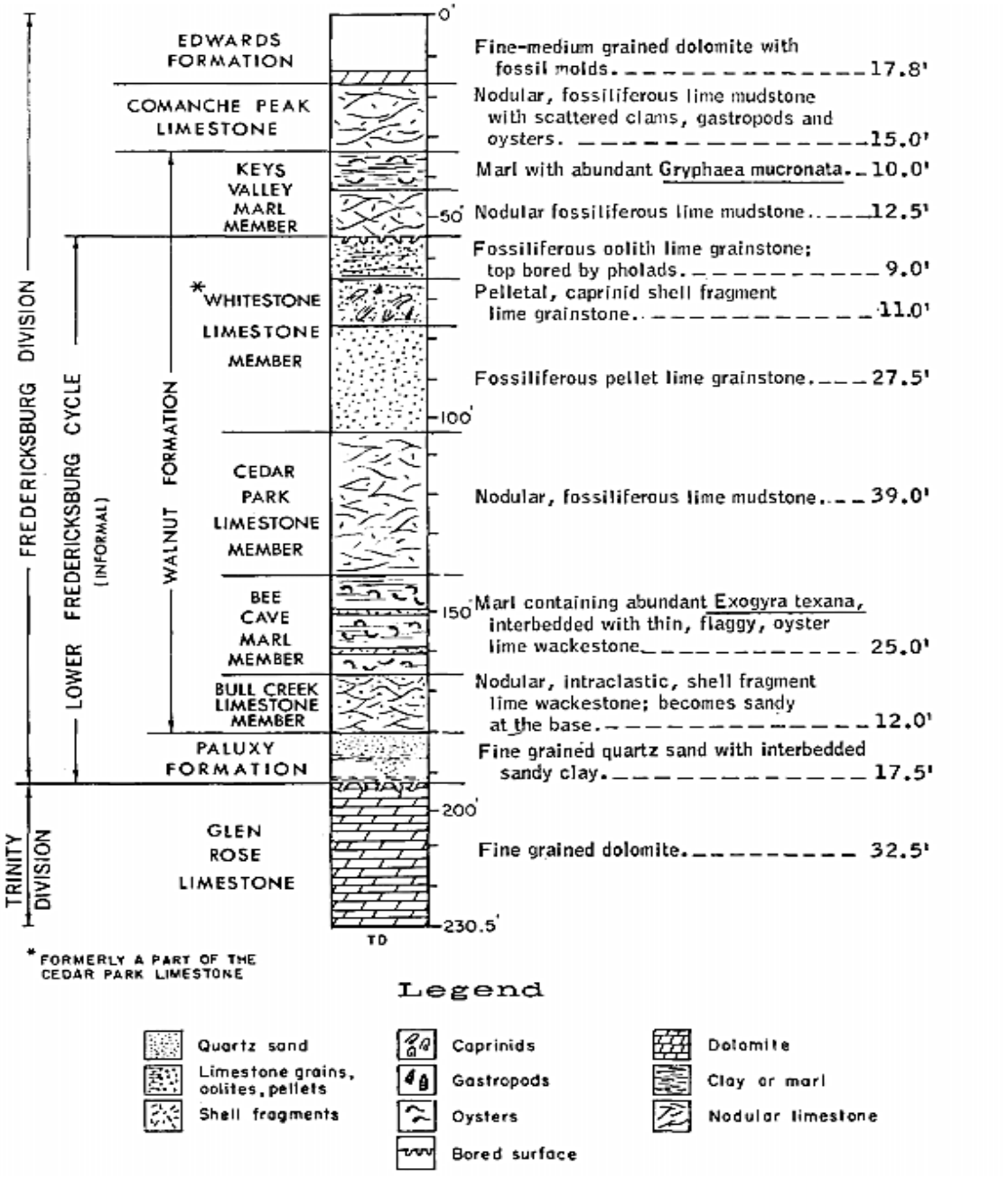

Figure 15. Measured Section of the Lower Fredericksburg Division, with Glen Rose, Paluxy, Walnut and Comanche Peak formations, in Burnet, Texas.

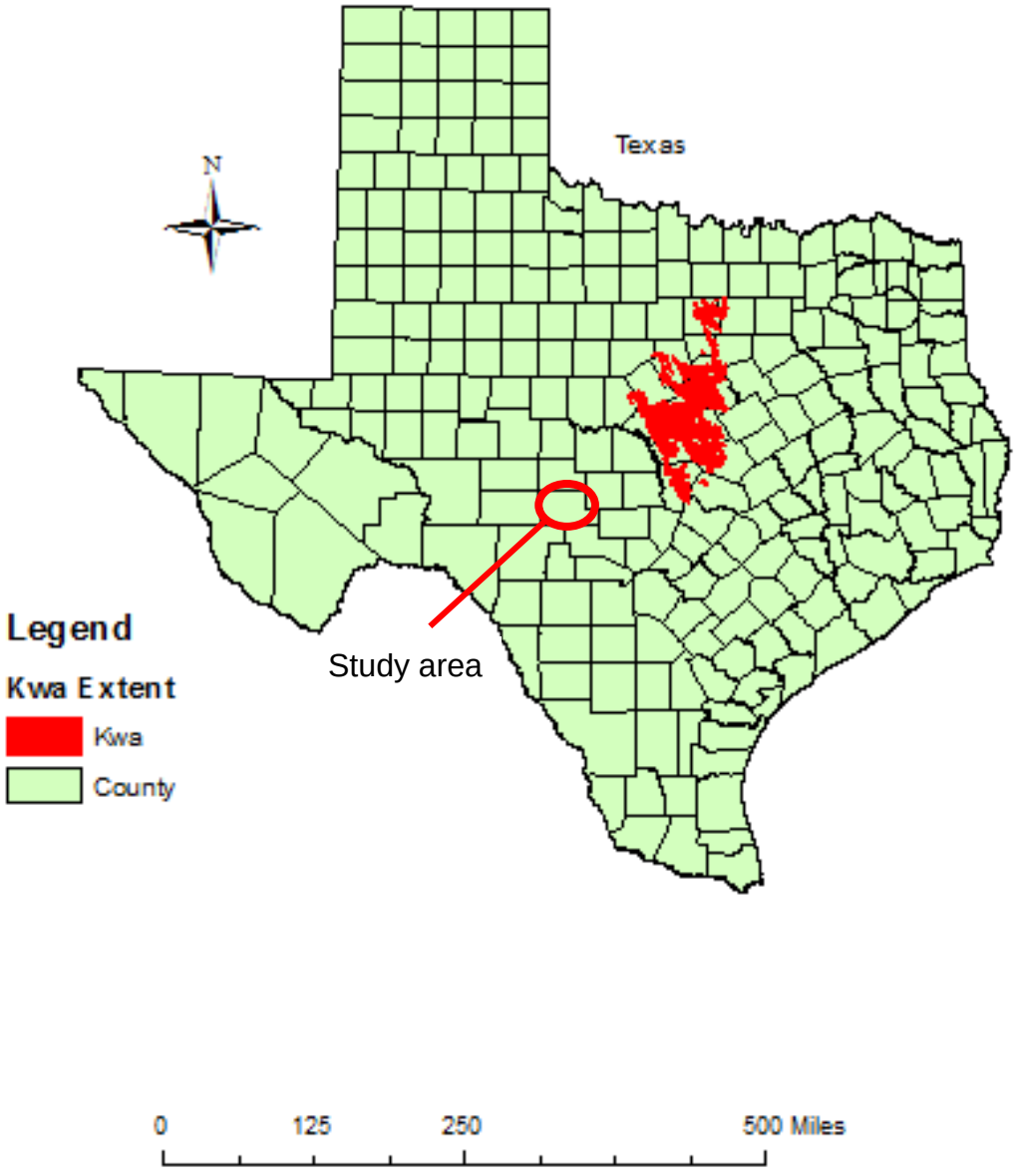

Figure 16. Walnut Fm. extent in Texas. USGS, TINRIS. Circled in red is the study area.

Other notable fauna include *Turritella and Tylostoma.* Depositional facies was probably in a lagoon (Moore, 1961).

The Bee Cave Member is a marl that contains abundant *Ceratostreon texanum, Texigryphea, Holectypus plantus, Enallaster texanus, Porocystis globularis,* and the ammonite zone of *Metengonceras hilli.* In west central Texas, the Bee Cave Member has a discordant contact with the Glen Rose Formation (Moore and Martin, 1966). At the Glen Rose Formation contact, the surface is bored with pholads. It has been interpreted as having been deposited in a lagoon (Moore, 1961) (figure 15).

The Cedar Park Member is a mudstone with minor fossils, nodules, and clastic intraclasts. Fossils include *Ceratostreon texanum, Texigryphea,* and *Toucasia* (Moore, 1961) (figures 17 and 18).

The Keys Valley Marl Member is a fossiliferous micrite. The lower contact is a bored surface from pholads. Along the upper contact, a biostrome of *Texigryphea* is the mapping boundary. Other abundant fossils include *Ceratostreon texanum* and *Enallaster texanus* (Moore, 1961) (figure 17).

The Upper Clay Member is dominated by fossiliferous marl that contain nodules of biomicrite. This unit has been interpreted to have been deposited in a shallow marine shelf (Young, 1962) (figure 15).

Figure 17. *Ceratostreon texanum*. Index fossil for Walnut Fm. Length 9 cm. (Image from Joe Cox, http://www.catnapin.com/Fossil/Bivalve/ffBivalveOstreoida.htm).

Figure 18. *Texigrphea*, numerous species in Edwards Group. This specimen is 6.7 cm in length. (Image from Joe Cox, http://www.catnapin.com/Fossil/Bivalve/ffBivalveOstreoida.htm).

Figure 19. *Oxytropidoceras* found in the Walnut Formation in Hood Count, Texas. Length is 25.4 cm. (Image from Rodney Wise, Ammonites in Hood County. https://www.txfossils.com/nautiloids-hood-county/#).

FORT TERRETT FORMATION

The Fort Terrett Formation is bounded at the bottom by a disconformable contact with the Glen Rose Formation and at the top by a disconformity with the Segovia Formation in South Texas. Extent of the Fort Terrett Formation outcrop is primarily in the west central region of Texas (figure 20). Predominate lithology of the Fort Terrett Formation is limestone, which typically forms the caps on hills in the region. Deposition occurred during the Albian Stage of the Lower Cretaceous.

There are four informal members of the Fort Terrett Formation (Rose, 1972). In ascending order, they are a Basal Nodular Member, Burrowed Member, Dolomitic Member, and Kirschberg Evaporite Member. The bottom of the Fort Terrett Formation contains sand from terrigenous sources, and are outcropped near the Llano Uplift. Throughout the rest of the area, the Basal Nodular Member contains a silty oyster marl that grades upwards to nodular biomicrite with scattered clams and snails. The Burrowed Member contains burrowed limestones that are massive. The dolomitization decreases towards the Llano Uplift.

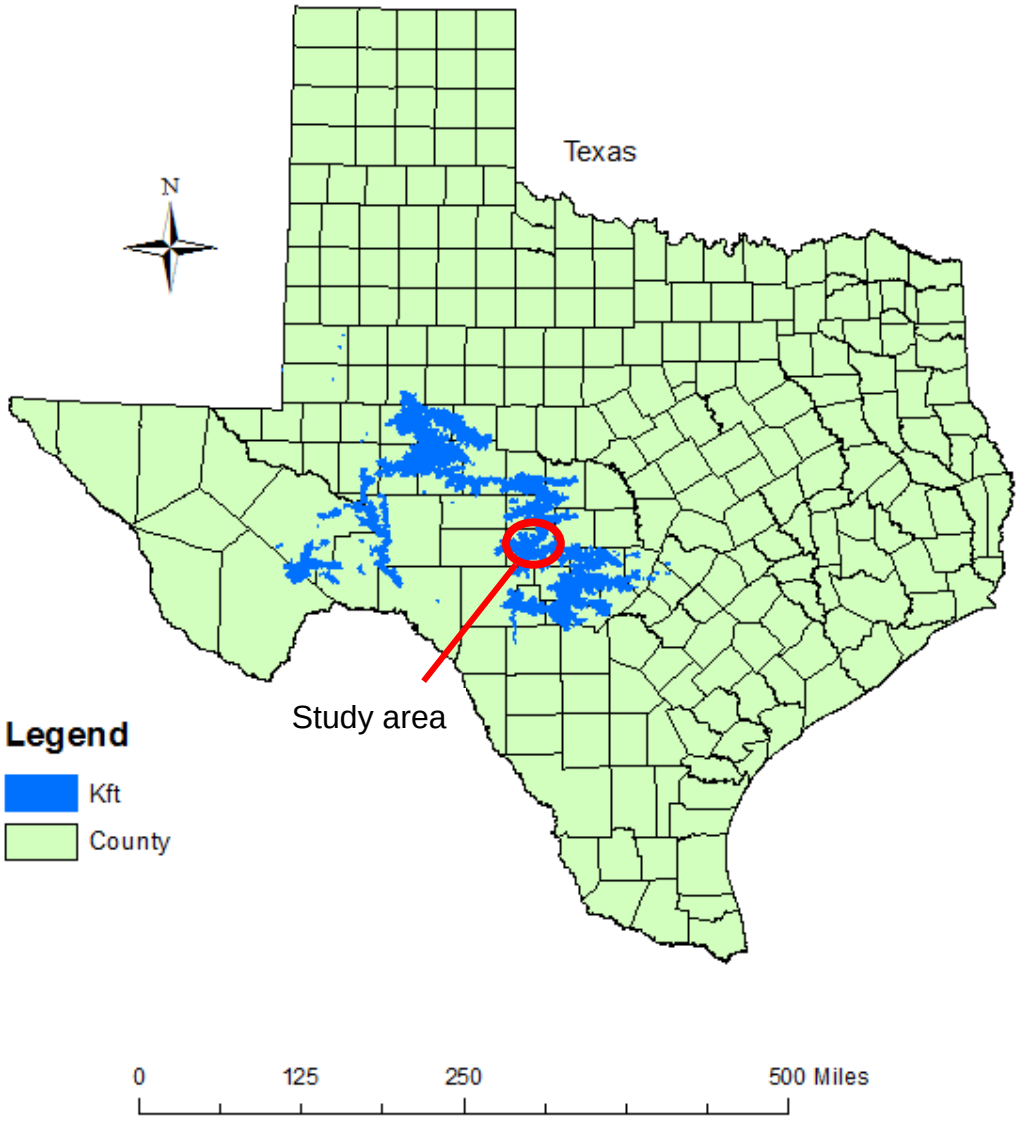

Figure 20. Regional extent of the Fort Terrett Formation in Texas, USGS, TINRIS. Circled in red is the study area.

The upper parts of the Burrowed Member contain thin beds of miliolid and fragments of mollusk biosparite, with some ripples and cross-bedded limestone alternating with dolomite beds. The beds of marl are infrequent and are mostly altered to weathered limestone.

The Burrow Member is between 21 and 27 m thick, but decreases to 17 m near the Llano Uplift. The high porosity and permeability of the burrowed member has led it to become a water-bearing zone within the Edwards Group.

The Dolomitic Member constitutes the next member in the Fort Terrett Formation; it is comprised of massive-thin beds and fine to medium crystalline dolostone. Fine crystalline limestone beds alternate with the dolomite. Common structures within the Dolomitic Member include: stromatolite hard crust, root marks, mud cracks, ripple marks, current streaks, and planar cross-beds. Thickness of the dolomitic member ranges from 12-27 m, and thins towards the Llano Uplift.

The Kirschberg Member is the uppermost part of the Fort Terrett Formation, consisting of thin bedded micrite, milioid grainstone and gray crystalline dolostones. In some areas, the member is in collapse breccias and other areas the beds area not deformed and are flat. Thickness of the Kirschberg Member is between 12 and 24 m. (Trabelsi, 1984).

The Fort Terrett Formation contains a range of facies which included: supertidal and shallow subtidal. There are eighteen depositional cycles have been recognized within the Fort Terrett Formation. Half of the cycles show a progradational sequence of subtidal, to intertidal, to supratidal deposition. The other half of the cycles were subaerially exposed and contained erosional truncation, which destroyed the supratidal zone down to the subtidal deposit 24 meters (Trabelsi, 1984).

The progradational cycles of the Fort Terrett Formation indicate that the deposits were during a slow transgression, followed by a quick rise in eustatic sea level, which are evidenced by the seaward migration of the subtidal, intertidal, and supratidal facies (Trabelsi, 1984). During the regressive cycles, subaerial exposure of the Fort Terrett Formation carbonates allowed for intense meteoric diagenesis. When the next transgression and following still stand occurred, the deposition of the subtidal facies became disconformable along the truncation surface. These disconformities were identified as: 1) oxidized surfaces; 2) pitted or fluted surfaces, (i.e. corrosion surfaces); 3) erosional truncation of beds; 4) sedimentation within the eroded and karstified carbonate surface; and 5) reworked zones that are composed of cobble-sized materials that

were eroded from the bed below the disconformity during the transgressive stage (Trabelsi, 1984).

The collapse breccia zone may indicate climatic change in the upper Fort Terrett Formation. Dissolution of the underlying sulfates of the Kirschberg unit caused the collapse breccia. Major eustatic regressions, extensive subaerial exposure, and changing from arid/semi-arid to subtropical conditions may have caused the conditions for the formation of the collapse breccia, (i.e. the events that led to the formation). Change in climate may indicate global cooling or glacial interval (Trabelsi, 1984).

METHODS

Field observation and sample collection

Fieldwork was conducted between June 2017-August 2017. Nine measured sections were measured using a Jacobs Staff and a steel tape. The Jacobs Staff was used to measure beds over 1 meter and the steel tape was used to measure beds less than 1 meter. Sections measured were along the roadside that had little to no vegetation covering the slope or cliff face. Thin section and hand samples were collected from each unit of the measured sections, along with fossils and unique minerals. The friable samples were collected using a small shovel.

Thin Section Petrography

Twelve representative limestone samples were cut for thin section and sent to Spectrum Petrographics, Inc. in Vancouver, Washington. Samples were impregnated with blue epoxy and stained red with alizarin. The blue epoxy was used to determine porosity and the alizarin stain was used to determine calcite.

Petrographic analysesis was conducted using a LABOMED petrographic microscope. A 300-point count was performed using JMicroVision software. Points were picked at random. Folk's 1959 classification of carbonates was used to classify carbonate rocks.

Digitizing measured sections

Measured sections were digitized using SedLog v.3.1. Measured sections were made into fence diagrams and correlated to determine sequence and depositional models using DesignCad v. 4.8.2. Using ArcMap 10.3.1, a map of the study area was created along with specific spatial references of the measured sections.

Petrologic Classification

Dunham's 1962 classification of limestones was used to classify carbarbonates in the field. Folk's 1959 classification of limestone was used to classify carbonates at the thin section level. Fine grain clastic rocks were classified using Picard's 1972 scheme.

Correlation

Hensel Formation units were correlated by using disconformable surfaces, i.e. red beds and undulating surfaces. The top of the Glen Rose Formation was correlated using the only burrowed unit found. The burrowed unit was used as a

datum because of it being easily recognized in the field. The Walnut Formation was correlated using the burrowed unit as the bottom, and the Fort Terrett Formation as the top, which is also a bounded surface.

Fossil Identification

Bivalve oysters were identified using descriptions from Texas Cretaceous Bivalves and Localities. The genus of the species was determined by the concentric costae and muscle scars. Species was also determined by the relative size of the bivalve.

DATA

Lithostratigraphy

Stratigraphic analyseses of the Hensel, Glen Rose, and Walnut formations consisted of measured sections in the Junction area. Two lithostratigraphic correlations were constructed. The three lithologies present in this study are claystones, limestones, and mudstones. Sedimentary structures present include ripple marks, root cast, and burrows.

The north-south transect was measured along US Highway 377. Six sections were measured over a total distance of 26.15 km along the transect (figure 21). The Hensel, Glen Rose, and Walnut formations were differentiated along both transects. The main lithology along this transect are shales (claystone, mudstone), silty claystones, and limestones (wackestones, packestones). The Hensel Formation in Section 1, 2, and 9 were difficult to correlate except for the uppermost red bed that marks the top and is used to mark the upper contact of the Hensel Formation (figure 21). These paleosol horizons indicate twelve periods of subaerial exposure. The red beds in the Hensel Formation contain root clast that suggest development of a paleosol. The

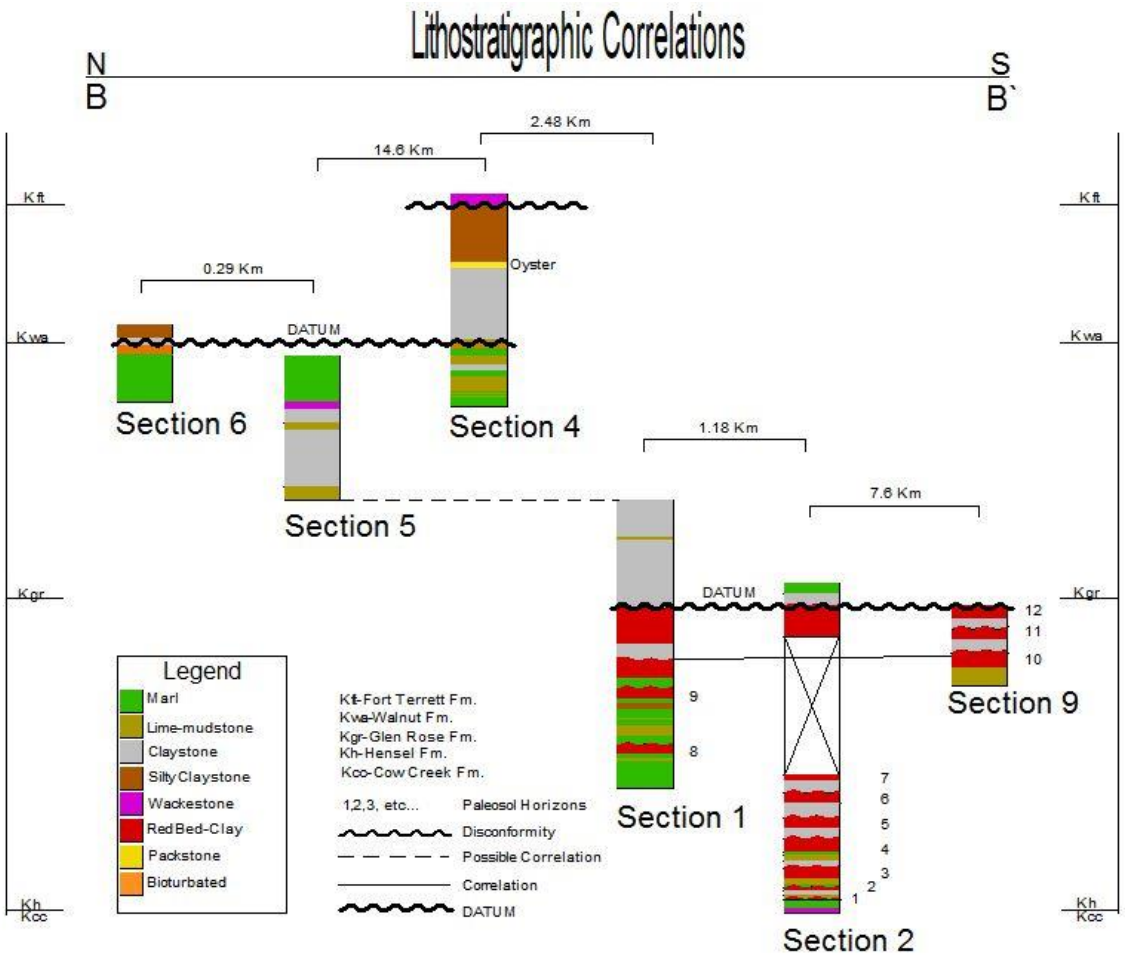

Figure 21. Lithostratigraphic correlation of the North-South transect. The major datums are based on burrows and paleosols. Five formations are detailed and include the Cow Creek, Hensel, Glen Rose, Walnut, and Fort Terrett formations. Twelve paleosols of the Hensel Formation are numbered 1-12.

only limestone (mudstone) in the Hensel Formation was found in Section 9 (figure 23). Thin section analysesis showed that this limestone unit contained silt sized quartz clast and lacks diagnostic sedimentary structures. The Glen Rose Formation is dominated by limestones with silt-sized quartz clasts. The primary sedimentary structures are vertical burrows that are not infilled. The Walnut Formation is dominated by limestones claystone, and mudstones with bivalve fossil allochems.

The west east fence diagram contained five measured sections that were along Interstate 10 (figure 22). The Cow Creek Formation is the lowest unit and only found in Section 2. It contains a limestone (wackestone) fossil hash. Small dissolution pans are common throughout this unit. The lower contact is covered but the upper contact is conformable to the Hensel Formation. The Hensel Formation was correlated by using the upper most paleosol. Eleven of the twelve paleosols were observed and are dominantly shale (claystones). The Glen Rose Formation consists of claystone, mudstone, siltstones (silty claystones) and limestones (packestones, wackestones). Disconformities were present at the top of the Hensel and Glen Rose and Walnut formation contact.

The Hensel Formation in Section 3 contained three subaerial paleosols. Units were difficult to correlate due to the varying amount of paleosols found within each section. The uppermost paleosol found in Section 2 and Section 3

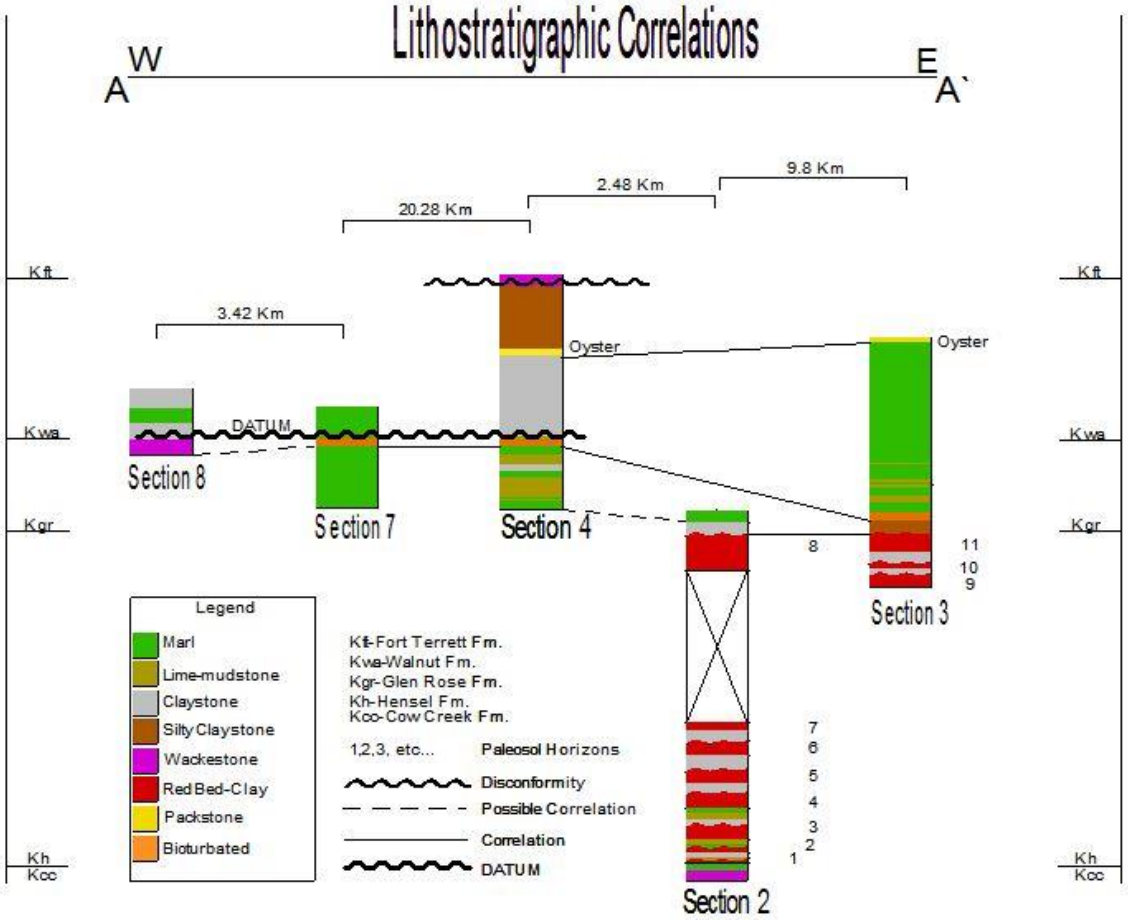

Figure 22. Lithostratigraphic correlation of the lower Cretaceous units in the West-East transec along I-10. The major datums are based on burrows and paleosols. Five formations are found and they are the Cow Creek, Hensel, Glen Rose, Walnut, and Fort Terrett formations. Paleosol units are numbered 1-11. Correlations were based on similar lithology and fossil content

were correlated to each other. The stratigraphic units in the Hensel Formation Section 3 are claystones. A mudstone found in Section 9 contains silt-sized quartz (figure 23)

Two limestones (mudstone) units were found in the Glen Rose Formation. These are outcropped as benches/ledges near the radio and water tower in downtown Junction, Texas, in Section 4. Alternating beds of marl and limestone (mudstone) are found Section 4 in the Glen Rose Formation. These units cannot be correlated because they grade into claystones to the southwest.

A vertically-burrowed limestone (mudstone) marks the top of the Glen Rose Formation. It contains burrows 10-15 cm long. The density of the burrows suggest a period of slow sedimentation, allowing an increase in organic material and burrowing. Thin section analyses from the Glen Rose Formation show silt size quartz clast with a micrite matrix (with minor amounts of marcasite) was present (figure 24). Burrows were not present in Section 5. Thin sections analyses of the samples from section 5 show that the dominant lithology is micrite. Bivalve-rich limestone (wackestone) is present near the top of the Glen Rose Formation and marks the contact with the Walnut Formation. A silty limestone (mudstone) and a burrowed limestone (mudstone) were the only units of the Glen Rose Formation in Section 3. These burrows were the smallest burrows found in the measured sections. The silt-size grains at the top of the

Glen Rose Limestone (mudstone) are composed of quartz clast. The marls and limestones (mudstones), wackestones and claystones are present in Section 4, 7, and 8. Section 7 is a silty mudstone that is characteristic of the other Glen Rose Formation mudstones.

Shales (silty claystones and claystones) are found in the lower Walnut Formation in Section 4 and 6 (figures 24 and 26). A distinctive brown oyster-packstone is located in Section 4. This unit contains *Ceratostreon texanum* an index fossils for the Walnut Formation. *Ceratostreon texanum* is used to divide the Walnut Formation from the Glen Rose Formation. The bivalves and a lack of quartz in figure 36 suggest a shift in clay deposition to carbonate. The thin section shown in figure 25 is classified as bivalve-wackestones using the Dunham 1962 classification. The Walnut Formation extends across Section 3, 4, 7, and 8. The east-west traverse contains limestones (mudstone) interbedded with marls. The limestones in the area are oyster packstones and are present in Section 4. Thin sections of the limestones in Section 3 are mudstones and contain quartz. The limestones (oyster packstones) are interpreted to be oyster mounds to oyster biostromes. The contact between the Walnut and Fort Terrett formations is recognized at slope forming siltstones and the cliff forming limestones (wackestone).

The limestones at the base of the Fort Terrett Formation are wackestone to packstone and forms a grey large cliff. The base of the Fort Terrett Formation is marked by a distinct bed of fossil hash containing bivalves. Study of the lower Fort Terrett Formation is difficult because it forms a vertical cliff.

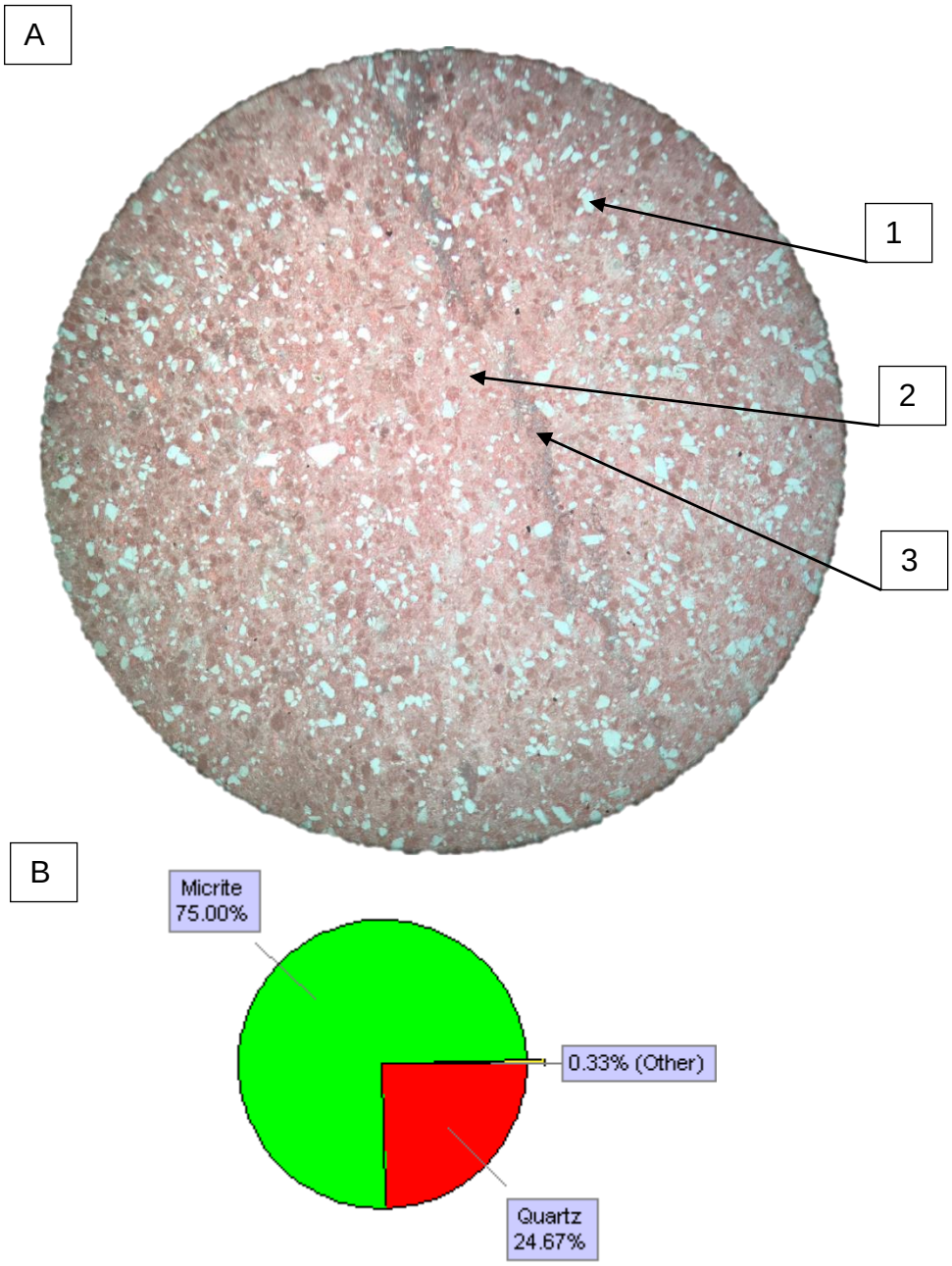

Figure 23. A) Thin section of the Hensel Formation. Magnification is 4x, with field of view is 1 cm. 1- Angular quartz grain. 2- Stained micrite. 3- Blue stained intergranular porosity. B) Pie chart showing percentage of micrite, quartz and other (porosity). A total of 300 grains were counted. This thin section is a micrite.

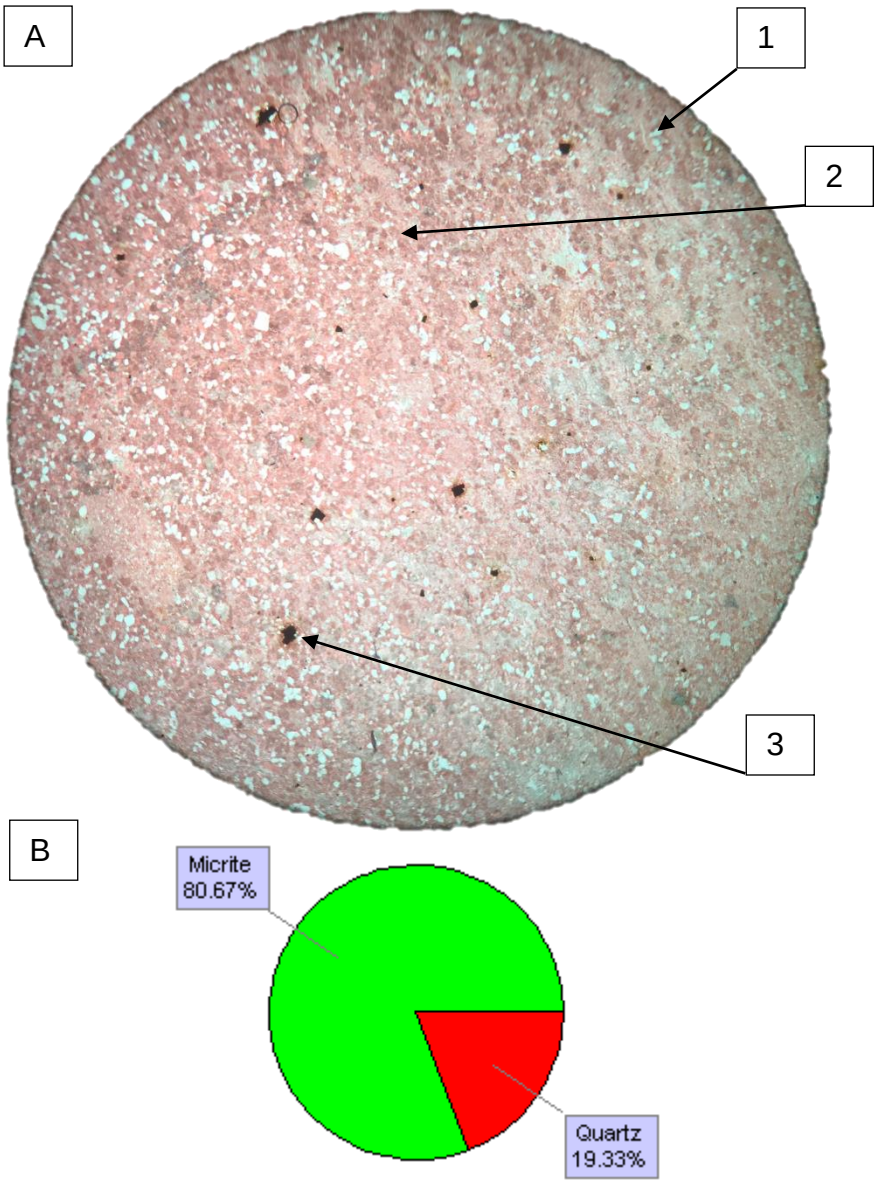

Figure 24. A) Thin section from Glen Rose Formation. Magnification is 4x, with field of view is 1 cm. 1- Quartz silt grain. 2- Stained micrite. 3- Marcasite. B) Pie chart showing percentage of micrite, quartz and marcasite. A total of 300 grains were counted. This thin section is classified as a silty micrite.

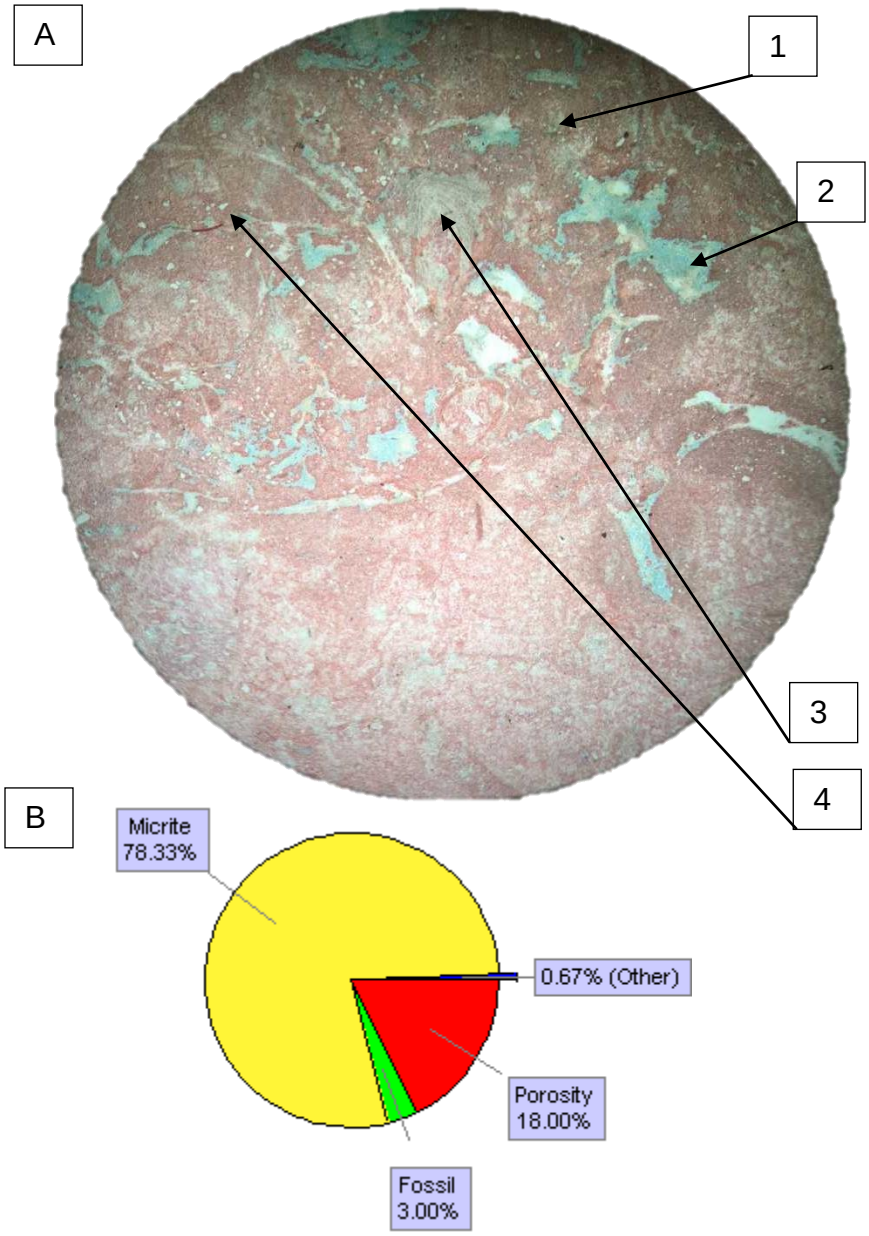

Figure 25. A) Thin section from Walnut Formation. Magnification is 4x, with field of view is 1 cm. 1- Stained micrite. 2- Intergranular porosity. 3- Bivalve Fossil. 4- Quartz silt grain. B) Pie chart showing percentage of micrite, quartz, porosity and fossils. A total of 300 grains were counted. This thin section is classified as a biomicrite.

Figure 26. Section 1 Outcrop. Hensel Fm. in yellow green. Glen Rose Fm. in light green. Numbers 1-5 indicate the paleosol beds.

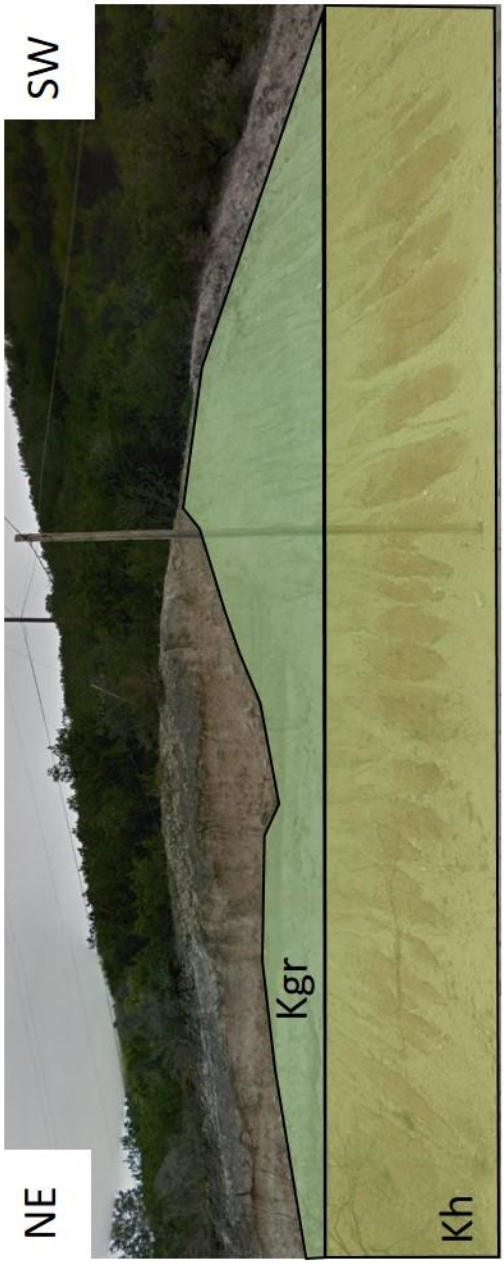

Figure 27. Section 2 outcrop. Hensel Fm. yellow green. Glen Rose Fm. light green. A thick red bed lies marks the top of the Hensel Formation.

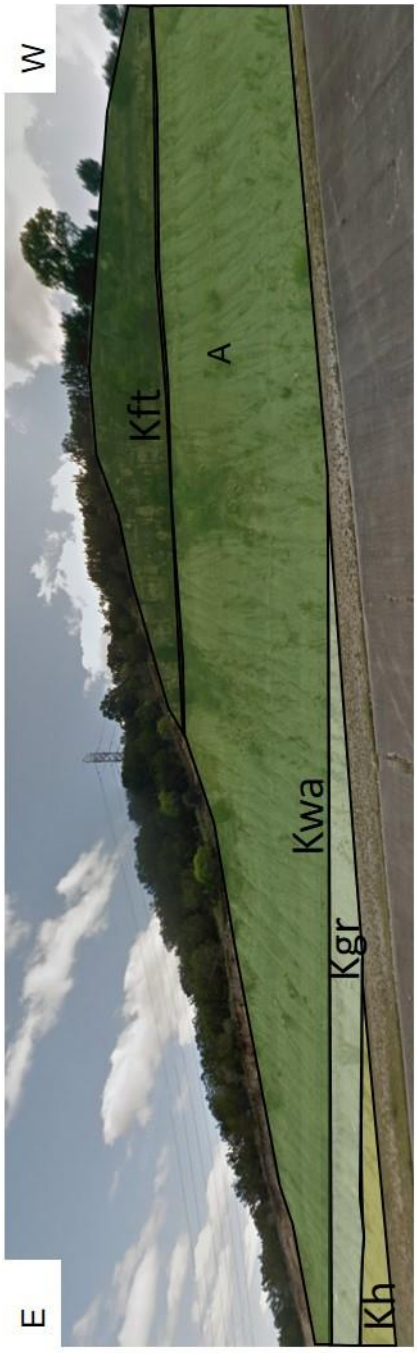

Figure 28. Section 3 outcrop. Hensel Fm. yellow green. Glen Rose Fm. light green. Walnut Fm. medium green. Fort Terrett Fm. dark green. The boundary of the Glen Rose and Walnut formations is the burrowed unit. A) Correlative limestone (wakestone) for study area

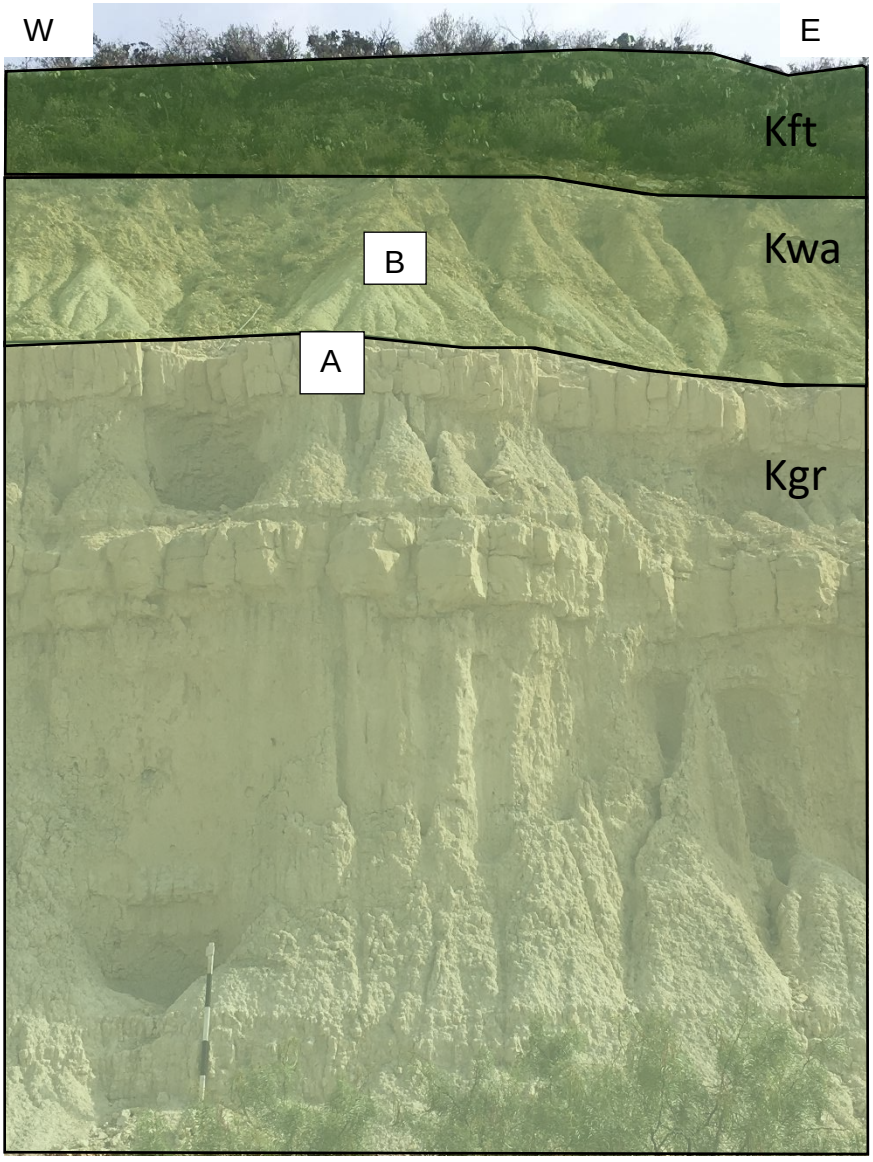

Figure 29. Section 4 outcrop. Glen Rose Fm. light green. Walnut Fm. medium green. Fort Terrett Fm. dark green. A) Limestone (mudstone) bed containing burrows. B) Limestone (oyster packstone) bed.

Figure 30. Section 5 outcrop. Glen Rose Fm.

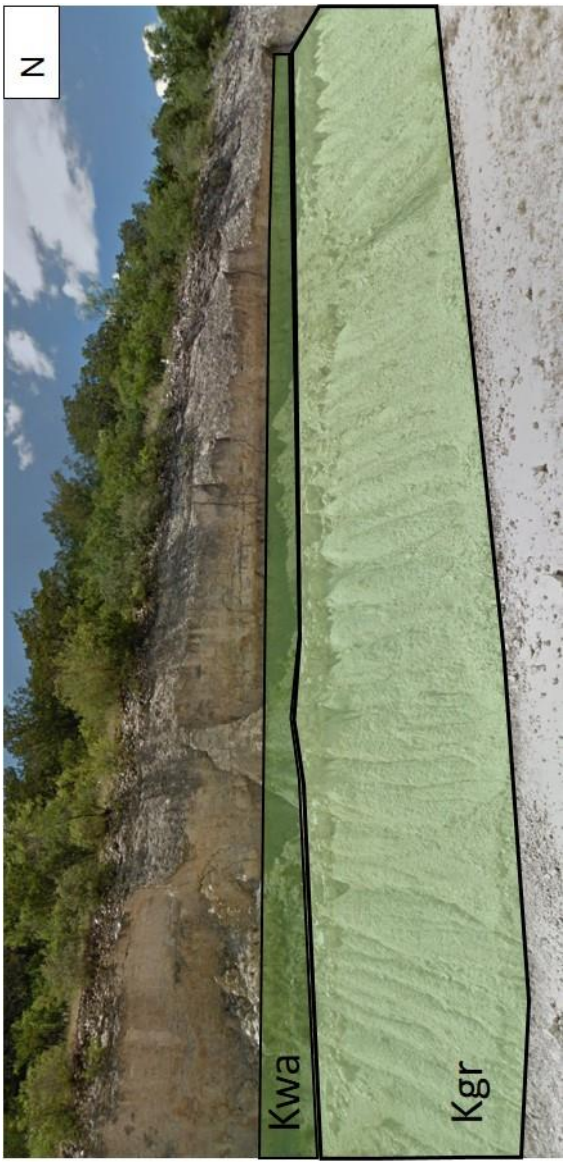

Figure 31. Section 6 outcrop. Glen Rose Fm. light green. Walnut Fm. medium green. Burrows are located at the Glen Rose and Walnut formation contact.

Figure 32. Section 7 outcrop. Glen Rose Fm. light green. Walnut Fm. medium green. Burrows are located at the Glen Rose and Walnut formation contact.

Figure 33. Section 8 outcrop. Glen Rose Fm.

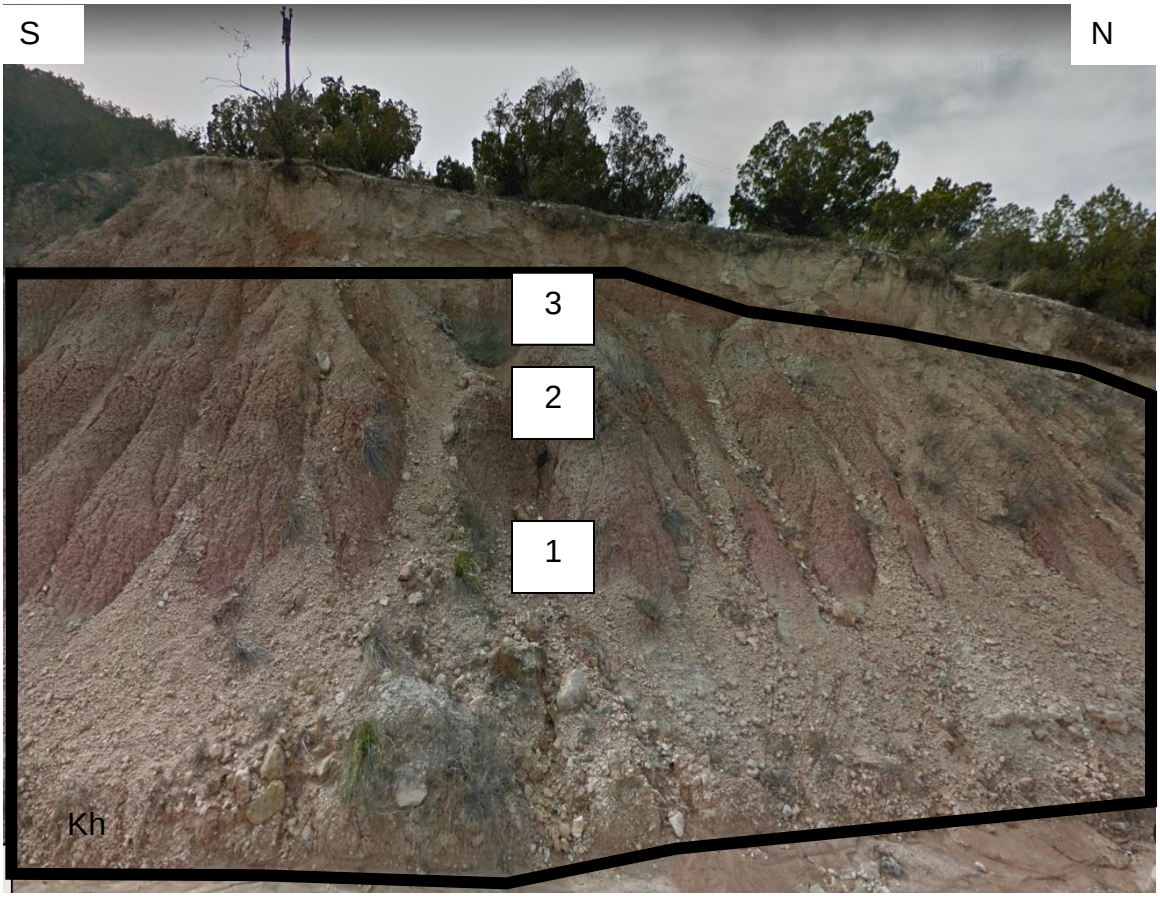

Figure 34. Section 9 outcrop. Hensel Fm. Numbers 1-3 represent paleosol units. Each of the paleosol units correspond to a parasequence.

Diagenesis

The diagenesis within the study area was based on thin section analyses from the Hensel, Glen Rose, and Walnut formations. These units primarily underwent through the early and late stages of diagenesis.

The Hensel Formation diagenetic model began with the deposition of carbonate mud in a shallow shelf marine environment. Next, was the development of micritic envelopes around the matrix. Dolomitization of the unit occurred next, based on the presence of unstained rhombohedrons. Dedolomitization of the unit was next, based on the lack of dolomite rhombohedrons and micritization of the dolomite rhombohedrons. The last event was the development of minor interparticle porosity and fracture porosity with iron oxide staining.

The Glen Rose Formation diagenetic model began with the deposition of carbonate mud with iron sulfide minerals in a shallow shelf anoxic marine environment. Next, was the development of micritic envelopes. Next was an early stage of dolomitization based on the presence of unstained rhombohedrons that do not cut across the calcite matrix. There was also an early stage dedolomitization due to the rhombohedrons being micritized in the center of the crystal. Next, there was late stage dolomitization based on the dolomite

rhombohedrons containing dolomitic overgrowths. Finally, there was a late phase of teleogenetic dissolution, which forms fracture porosity.

The Walnut Formation diagenetic model began with the deposition of carbonate mud with a fluvial source of quartz. Next, was the development of micritic envelopes. Allochems were then recrystallized from aragonite to calcite. There was an early stage of dolomitization based the rhombohedrons that do not cut across the calcite matrix. There was also an early stage of dedolmitization based on micritization of the dolomite rhombohedrons. Next, was a late stage dolomitization, based on the dolomite rhobohedrons containing dolomitic overgrowths. This dolomitization was followed by a late stage dedolomitization, which was based on micritization of the dolomitic overgrowths. The last event was marked by the development of fracture, interparticle, vuggy, and moldic porosity from meteoric waters in the vadose zone. Some of the porosity was partially infilled by evaporates.

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Fossils

Fossils in the study area are dominantly oysters found in the Walnut Formation and burrows from the Glen Rose Formation (figure 35). *Ceratostreon texanum* (figure 36) and *Ceratostreon weatherfordense* are the most common oysters. *C. texanum* and *C. weatherfordense* first appear in the Walnut Formation (Denison et al, 2003). *C. weatherfordense,* is similar to the larger *C. texanum* but these specimens are more elongate with less costae. Some *C. weatherfordense* specimens have pronounced keels, and others are relatively less pronounced. The *C. texanum* specimens have less ornate costae that spiral towards the depressed beak. Both species have one muscle scar that is on the posterior adductor and no hinge teeth (Offeman, 1982)

In the Glen Rose Formation, large *Exogyra sp.* samples were found. *Exogyra sp.* are large and triangular. They contain many growth layers that are concentric but irregular. The beaks size ranges from hidden to small and rounded (figure 42-44).

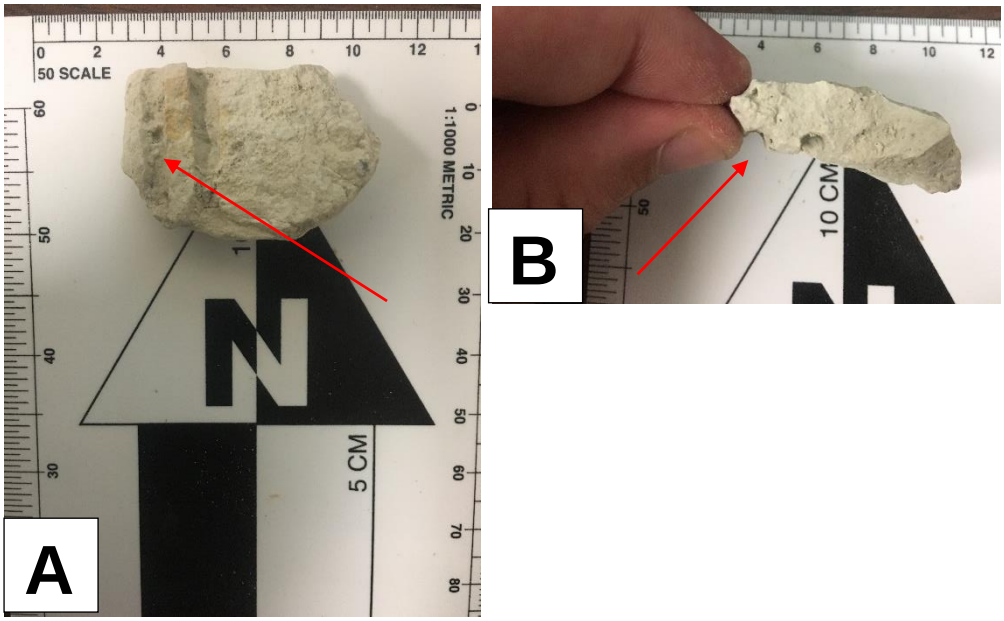

Figure 35. Section 3. A) Cross Section of burrows. B) Top view of burrows Arrows indicate burrows.

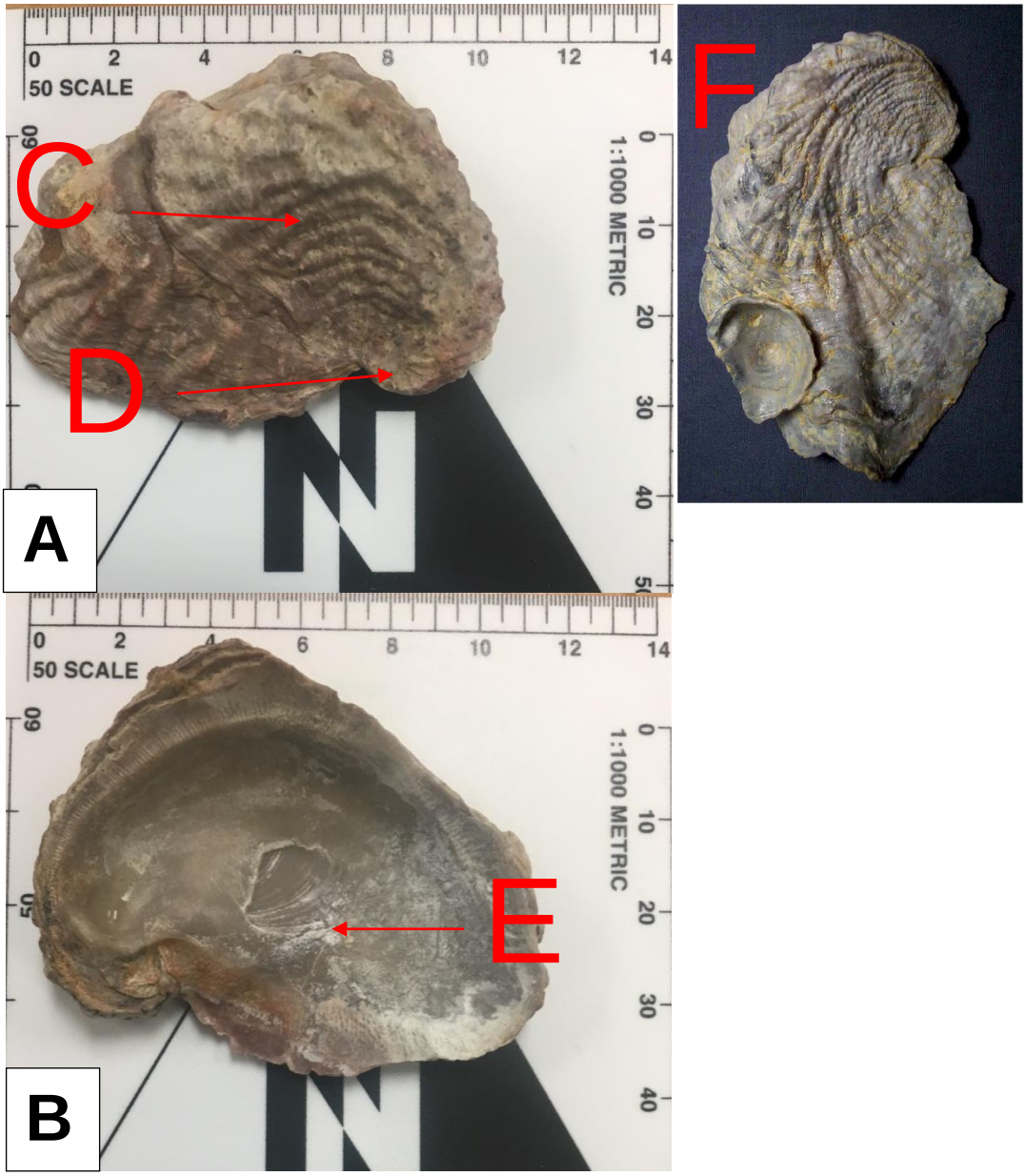

Figure 36. Left Valve of *Ceratostreon texanum*. Found in Section 4 Walnut Fm. Albian Age. A) Dorsal view of the left valve. B) Ventral view of the left valve. C) Unequal costae that spiral toward the beak. D) Depressed Beak. E) 1 muscle scar. F) C. texanum found in the Walnut Fm. in Hood County, sample is 9cm in length.

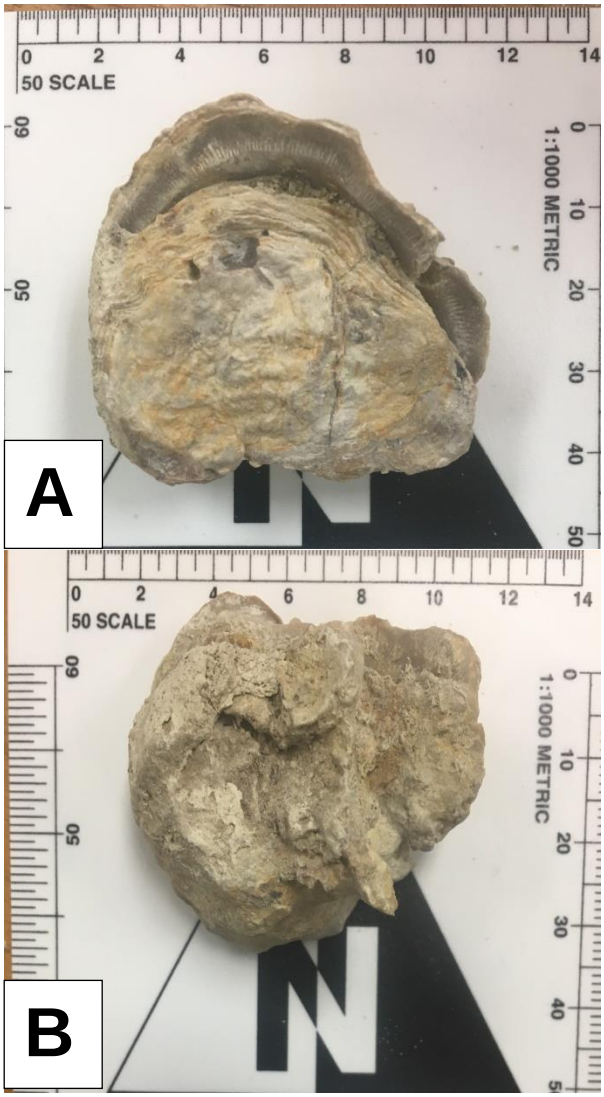

Figure 37. Right valve of oyster found in Section 4, Walnut Fm. Albian age. A) Ventral view of right valve. B) Dorsal view of an oyster that has overgrowths. Identification of the bivalve could not be determined.

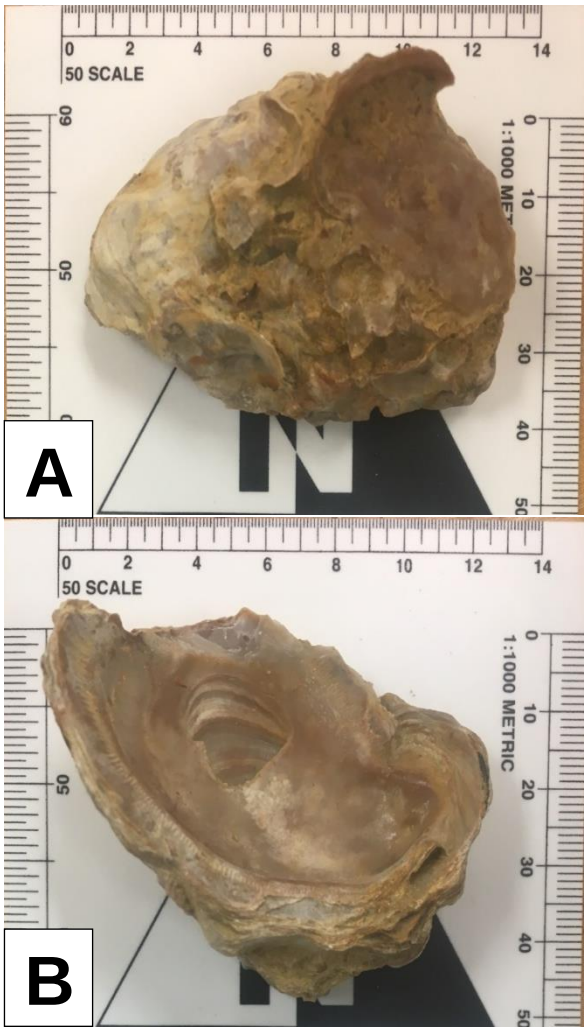

Figure 38. Oyster fossil with dorsal oyster growth. Found in Section 4, Walnut Fm. Albian age. A) Dorsal view of the shell. B) Ventral view of shell. Identification of the bivalve could not be determined.

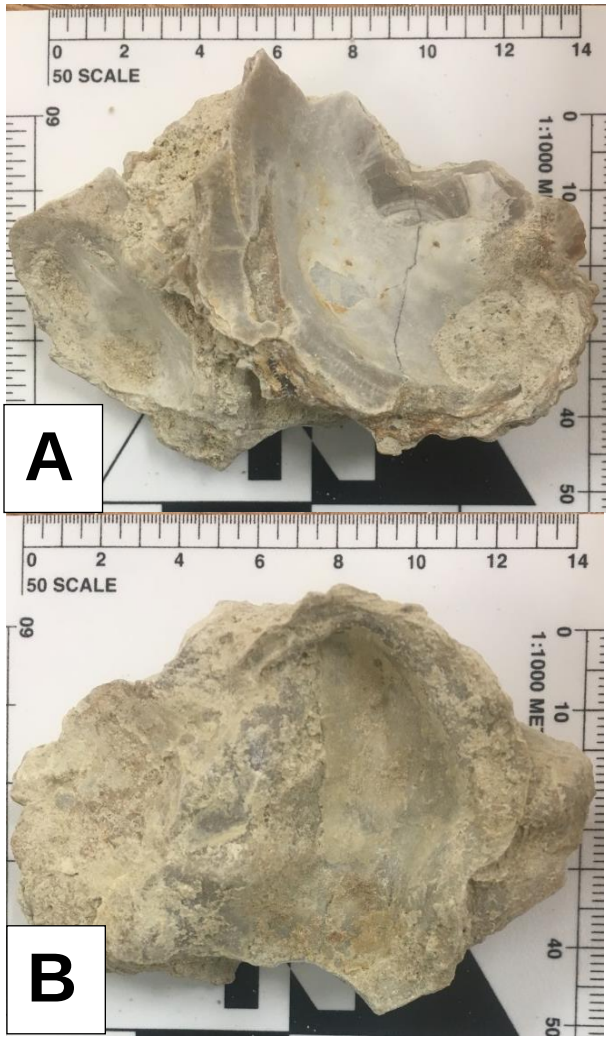

Figure 39. Aggregate oysters found in section 4, Walnut Fm. Albian age. A) Two separate oysters bounded together. B) Opposite of oysters bounded together. Identification of the bivalve could not be determined.

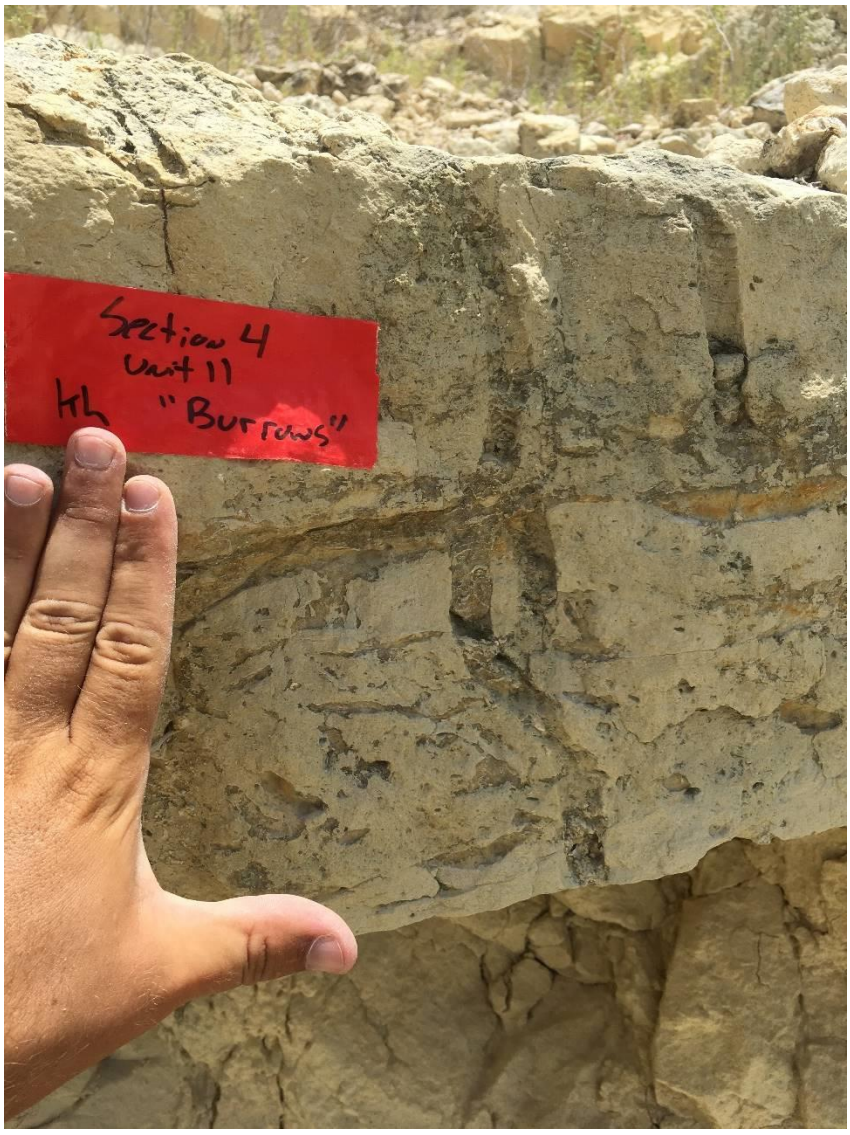

Figure 40. Section 4. Burrows in limestone (mudstone) from Glen Rose Fm. Unit 11. Burrows are vertical and horizontal.

Figure 41. A) Section 6 burrows found in limestone (mudstone).

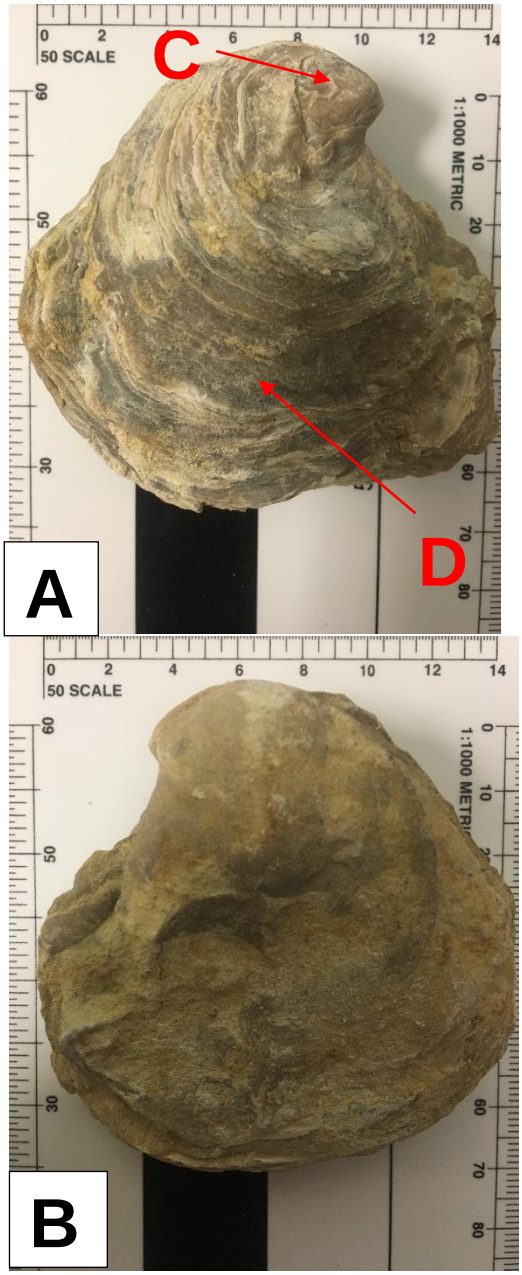

Figure 42. *Exogyra sp.* found in Section 8 Glen Rose Fm. Aptian age A) Dorsal view of left valve, B) Ventral view of left valve, C) Beak, D) Concentric ornamentation

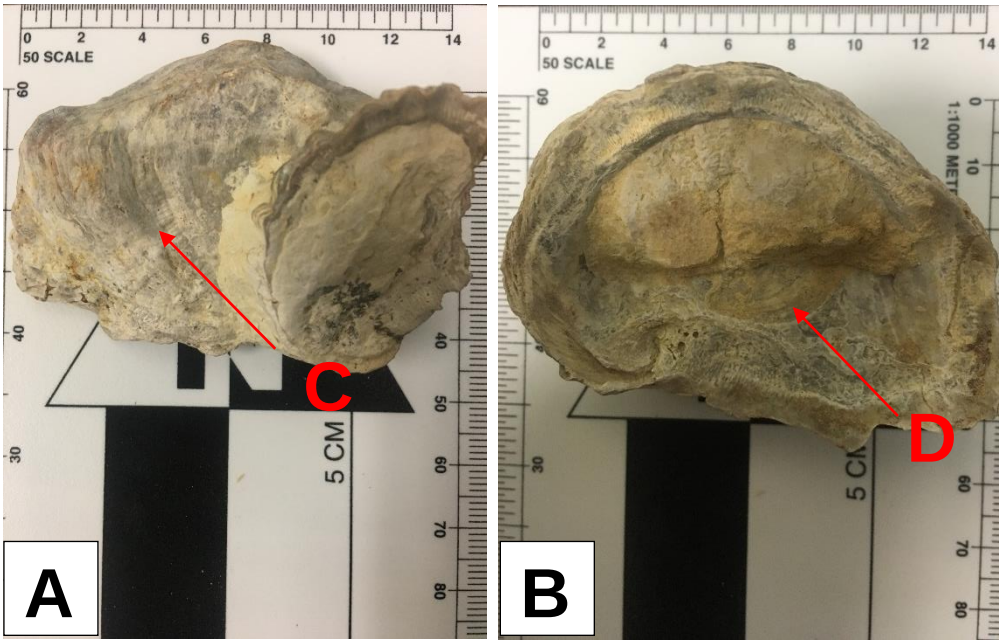

Figure 43. *Exogyra sp.* from Section 8 Glen Rose Fm. Aptian age A) Dorsal view of left valve, B) Ventral view of left valve, C) Concentric ornamentation, D) Muscle scar. Identification of the bivalve could not be determined.

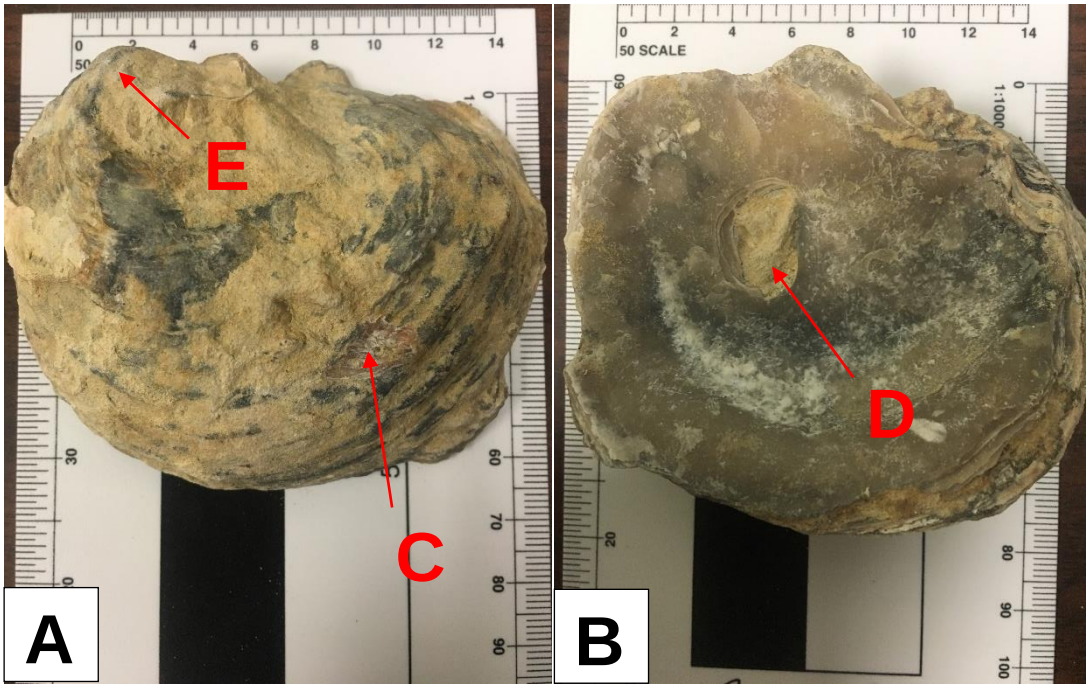

Figure 44. *Exogyra sp.* from Section 8. Glen Rose Fm. A) Dorsal view of left valve, B) Ventral view of left valve, C) Concentric ornamentation, D) Muscle scar, E) Beak

Depositional Environments and Facies

The Comanche Shelf was located in Central Texas (figure 3). The Stuart City Reef that began during the Albian protected the shelf. This reef restricted marine waters in the Llano region based on high concentration of sulfide minerals and low fossil content. Sulfide minerals were present at outcrops where the Glen Rose Formation was present. Silt-sized quartz was windblown onto the shelf, indicated by the presence of metamorphosed quartz. These quartz grains were present in the Hensel Formation and may have been sourced from metamorphic rocks on the Llano islands.

Hensel Formation

Payne (1982) divided the Hensel Formation in to three parts: basal conglomerate, middle paleosols, and upper fines. The basal conglomerate is a conglomerate that contains clast from the Llano Uplift; this was not observed in study area. The paleosols are comprised of alternating red beds and clay-rich limestones and claystones (figure 52). The upper fines are comprised of fine-grained clastics, but were not observed in the study area. The lack of conglomerate may indicate that the conglomerate was never deposited in Kimble County, as indicated by the Cow Creek contact with the middle paleosols. The lack of the upper fines division maybe due to erosion or non-deposition.

The Hensel Formation in Junction, Texas is marked by eleven cycles of red beds and clay-rich limestone to claystone. Some of the red beds have horizontal and vertical patterns of white caliche material, which are interpreted as root structures with in a paleosol (figure 52). The clay-rich limestones and claystones are void of sedimentary structures and fossils, with the exception of one bed of symmetrical ripples.

The cycles of paleosols coupled with clay-rich limestone and claystones indicate that this part of the Hensel Formation was deposited in a shallow marine depositional environment. The paleosols record subaerial exposure and regressive seas on a shallow shelf. The clay-rich limestones and claystones record transgressions on a shallow shelf, intertidal lagoons, or tidal flat. The cycles probably indicate a higher order sequence, which record a transgression. The significance of the paleosols is that they indicate the maximum flooding surface.

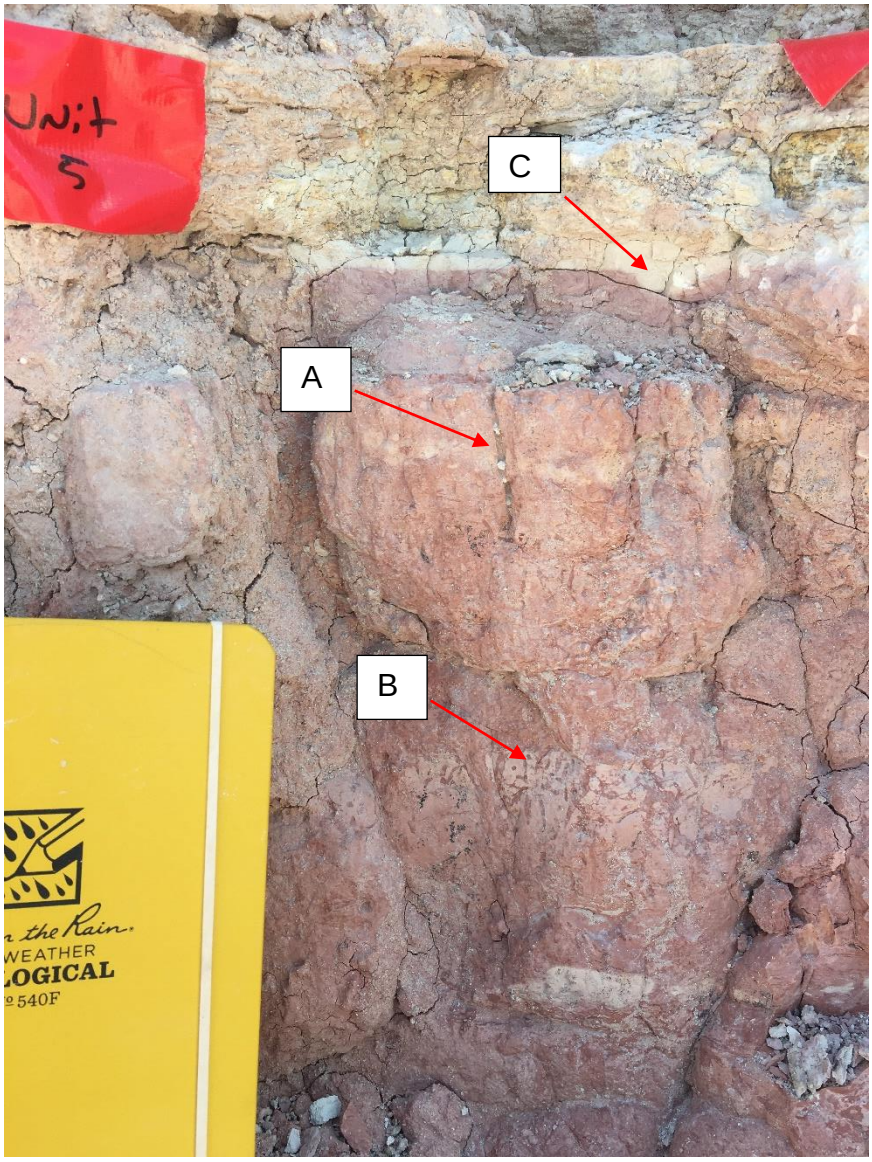

Figure 45. Section 1 Hensel Fm. Unit 5. A) Paleosol with horizontal white clay lens. B) Paleosol with vertical root structures. C) Disconformable surface.

Glen Rose Formation

Limestones ranging from mudstones to packstones dominate the Glen Rose Formation as a whole. The Glen Rose Formation is divided into an upper and lower unit based on the *Corbula martinae* bed, but only the upper Glen Rose is present in the study area. Clays mixed with the limestone units may have been derived from the Llano Uplift shedding siliciclastic sediments to the southwest as sea level dropped (Moore 1996). The clay-sized sediments may have inhibited marine biodiveristy, as suggested by a lack of fossils in the formation.

Gray clay-rich limestones and mudstones dominate the Glen Rose Formation in Kimble County. A thin mudstone unit shows one bed of symmetrical ripples, indicating a tidal flat (figure 46). The mudstones have a variety minor allochems that include whole bivalves, possible leaf imprints, and bivalve hash.

The transition from the Hensel Formation red beds to clay-rich limestones and mudstones indicate a rise in relative sea level. The lower part of the Glen Rose Formation is clay-rich while the top contains less clay. This indicates either a loss of the source of the clay, or a gradual increase of energy to winnow the clays out. Bivalves that are whole are not common and suggest that the shallow marine shelf around Kimble County was not favorable for their development of the biohems or reefs.

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Figure 46. A) Section 5 Glen Rose Fm. Unit 4 symmetrical ripple marks in limestone-mudstone.

Walnut Formation

The Walnut Formation is a limestone that is divided into four members. These members are based on changes in lithology and fossil content. The major marker for the Walnut Formation is the bivalve *C. texanum* and the ammonite *M. hilli.*

Thin limestones beds and silty shale dominate the Walnut Formation in Kimble County. The limestones are bivalve-wackestones and bivalve-packstones. Wackestones and packstones indicate higher energy environments that favor bivalve biostromes as indicated by a planar bed geometry. Bivalves are generally whole, but in some beds, the bivalves are broken in pieces.

These biostromes were built laterally rather than vertically. This may indicate that sea level stabilized enough to allow the bivalves to grow laterlly across that facies interval. The higher energy suggest shallow shelf that is more open than in lagoonal facies. Preservation of whole bivalve fossils indicate rapid burial. Some of the bivalves were bored into, indicating the oyster population was dense in some areas.

Fort Terrett Formation

The Fort Terrett Formation is marked by well-cemented limestones (wackestones to packstones). Fossils are diverse in outcrop, with gastropods and bivalves dominating the fauna. Fossils are broken, suggesting a higher energy environment. The depositional environment is interpreted as a shallow marine shelf based on high fossil diversity, little clastic material, and massive limestone beds.

Sequence Correlation

Three disconformities were identified in the study area. The first disconformity is located between the Hensel and Glen Rose formations. A disconformity is present between the uppermost paleosol of the Hensel Formation and the overlying marl of the Glen Rose Formation. This disconformity marks a clear break in the deposition and the sequence boundary. The second disconformity lies between the burrowed limestones (mudstone) of the Glen Rose Formation and the silty claystones of the Walnut Formation. The third disconformity is between the silty claystones of the Walnut Formation and the limestones (wackestone) of the Fort Terrett Formation. This contact contains large truncations of the bedding in the Walnut Formation. Twelve parasequences are recorded within the Hensel Formation on the basis of repeating palesol units.

East-West Transect

The west to east transect includes Section 2, Section 3, Section 4, Section 7, and Section 8 (figure 47). Three sequences were differentiated, using a burrowed unit as a datum. The bottom of Sequence 1 is the lowest point measured within the Hensel Formation. The uppermost red bed forms the top of the Hensel Formation. Sequence 2 comprises of the Glen Rose Formation that

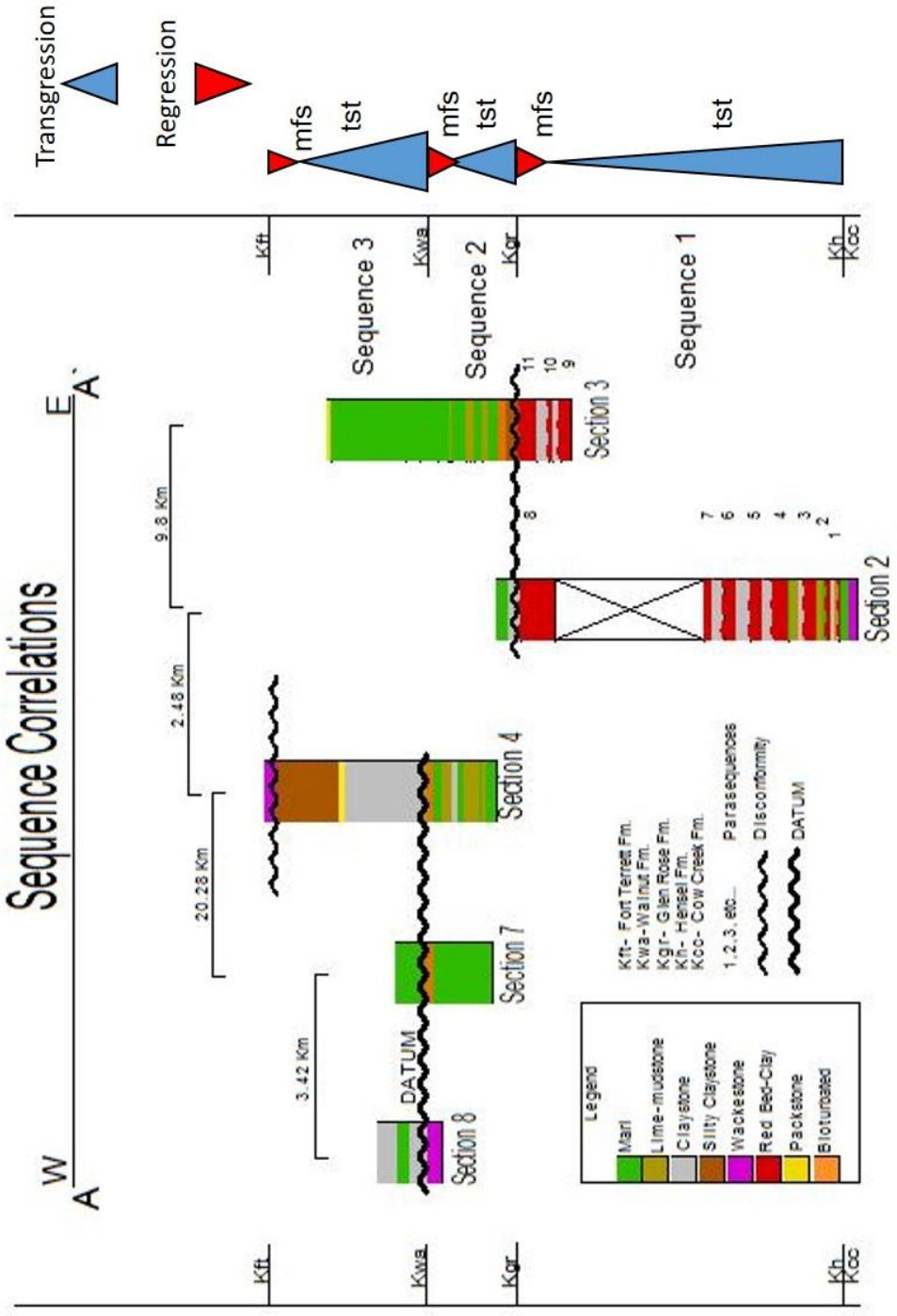
begins at the contact of the red bed and marl and ends at the burrowed unit. Sequence 3 begins above the burrowed unit and ends at the Fort Terrett Formation contact.

Sequence 1 is placed at the disconformity at the top of the paleosol and suggest a regression of the sea at the end of the Hensel Formation deposition. The eleven paleosols indicate parasequence produced by minor fluctuations in sea level. The gray marls indicate a transgressive systems tract, and the paleosols indicate a maximum flooding surface.

Sequence 2 represents the Glen Rose Formation transgressing. It ended with a regression that produced the burrowed unit. The burrowed unit represents a slow deposition that allowed the developed of burrows by *Lithophagus.* There are five minor cycles within this sequence. There are five parasequences within the Glen Rose sequence. These are small and are marked by the vertical sequence of lime-mudstones, marl, claystones. The marls and claystones indicate a transgressive systems tract and the bored limestone (mudstone) indicate a maximum flooding surface.

Sequence 3 is placed at channels cut into the Glen Rose Formation that are filled with clay of the Walnut Formation. The Walnut Formation consist of marl, packstone and silty claystone. Correlating beds based on lithology is not

practical. The limestones (packstone) and marls indicate a transgressive systems tract and the silty claystones indicate a maximum flooding surface



. Figure 47. West-East Transect of Correlations. Three Sequences are identified using bounding surfaces.

North-South Transect

The north to south transect includes Section 6, Section 5, Section 4, Section 1, Section 2, and Section 9 (figure 48). Three sequences are recognized using the burrowed unit as a datum. The bottom of Sequence 1 is the lowest point measured within the Hensel Formation and the top of the sequence is the last red bed observed. Sequence 2 comprises of the Glen Rose Formation that begins at the top contact of the red bed and ends at the burrowed unit. Sequence 3 is the Walnut Formation and begins at the top of the burrowed unit and ends at the Fort Terrett Formation contact.

Sequence 1 is represented by a claystone and contains a number of parasequences. These parasequences are recognized by the presence of red paleosol horizons and indicate that sea level rose and fell twelve times producing alternating claystone to marl lithologies. The gray marls indicate a transgressive systems tract and the paleosols (red beds) indicate a maximum flooding surface.

Sequence 2 is represented by limestones of the Glen Rose Formation. The upper most unit of the Glen Rose Limestone has been extensively burrowed. The burrowed unit suggest a hiatus or limited exposure due to small undulations and burrows from *Lithophagus.* These small cycles are indicated by the migration of lime-mudstones, marl, claystones. The marls and claystones suggest a

transgressive systems tract and the bored limestone (mudstone) suggesting a maximum flooding surface.

Sequence 3 is recognized on the basis of containing fine claystones and marls that coarsen up relative to the top of the contact. The limestones (packstone) and marls indicate a transgressive systems tract and the silty claystones at the contact of the Walnut and Fort Terrett and contain a maximum flooding surface.

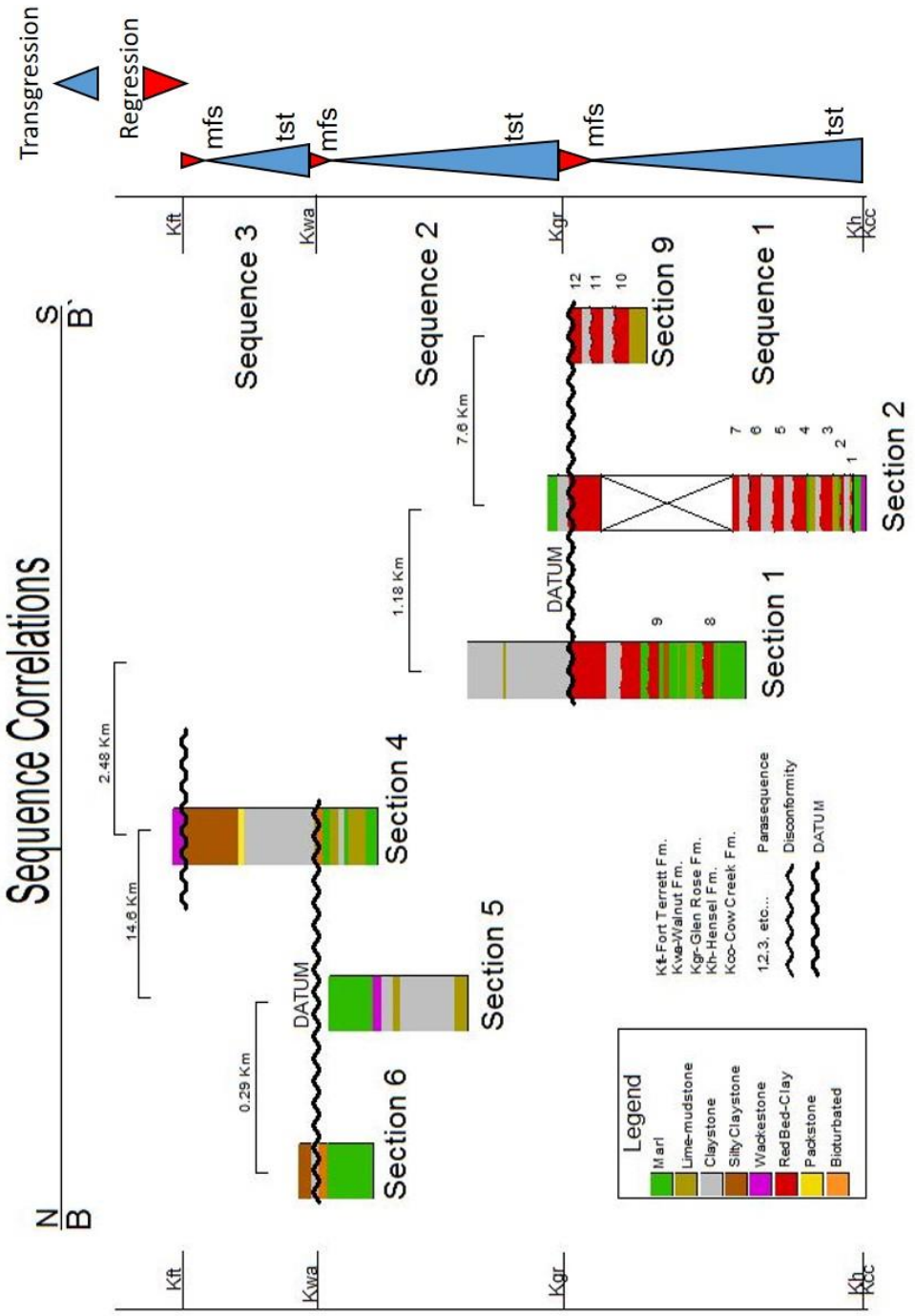


Figure 48. North-South transect of correlations. Three sequences are identified using bounding surfaces.

DISCUSSION

Within Kimble County, the Lower Cretaceous Trinity and Fredericksburg groups contains the Hensel, Glen Rose, Walnut and Fort Terrett formations, which can be divided into three sequences based on the presence of disconformities. These disconformites were recognized by Virgil Barnes in the Geologic Atlas of Texas, Llano Sheet 1986 and by Moore (1995) in his model of the Lower Cretaceous stratigraphy (figure 49-50). The Atlas of Texas map shows a small upper Glen Rose Formation mapped in western part of Kimble County, in the Geologic Atlas. Moore's (1995) sequence model shows the lower Walnut Formation thinning towards the west in the Fredericksburg region and pinching out east of Kimble County. However, the paleontological evidence of *Cerastreon texanum* suggests that the Walnut Formation is present in Kimble County and is in contact with the Glen Rose Formation below and with the Fort Terrett Formation above.

The Cow Creek Formation in Kimble County lies below the Hensel Formation. The only locality the Cow Creek Formation was seen in the study

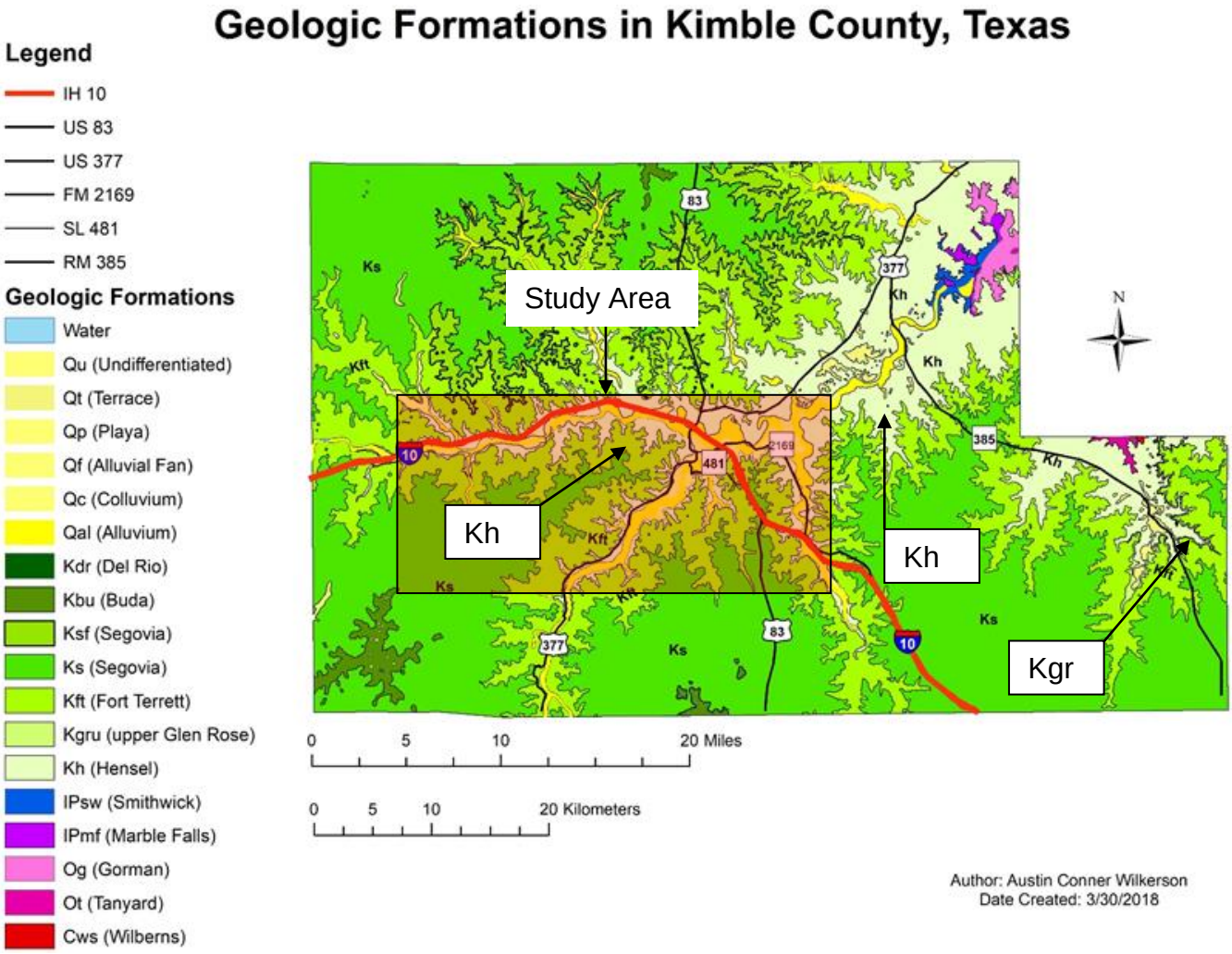


Figure 49. Geologic Atlas of Texas, modified from Barnes 1986, Llano Sheet. Hensel Fm. (Kh) (yellow-green) is mapped as a contact with Fort Terrett (Kft) (light green). The exception to this is a small outcrop in the southwest portion of the map, where the Upper Glen Rose Fm. (dark green) (Kgr) contact the Fort Terrett (Kft). Boxed in red is the study area.

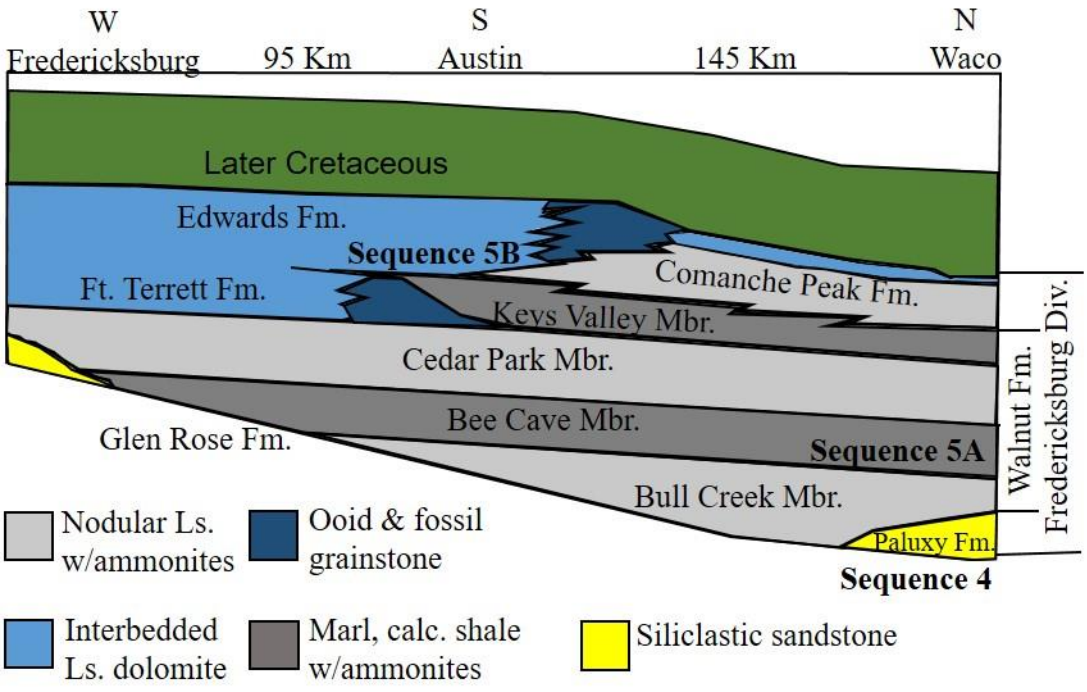


Figure 50. Moore's (1995) sequence models of the Fredericksburg Division (modified). Sequence 5A fits with Sequence 3 in this paper.

area is at Section 2, where the North Llano River has removed the younger overburden. The Cow Creek Formation in Kimble County is a wackestone to packstone with bivalve hash as described by Owens (2010). The current stratigraphic section for central Texas indicates that the Cow Creek Formation is below the Hensel Formation.

The Hensel Formation in Kimble County is an alternating series of red beds and gray claystones, with a localized limestone (mudstone) lens. Fossils within the formation are root casts, that are present in some units but are not found in every unit in the study area. Diagnostic characteristics of the paleoenvironment are the root structures, indicating subaerial exposure along a tidal flat and white calcrete beds that suggest development of a soil profile. This evidence takes in account of the oxygen isotope studies, which supports identifying the Hensel Formation supratidal marine deposit (White 2009).

The Glen Rose Formation in Kimble County change from limestones and mudstones to claystones. The absence of macrofossils in the study area indicate a stressed marine environment. Most of the measured Glen Rose Formation units lack sedimentary structures, which suggest calm environments. The top of the Glen Rose Formation is burrowed. The absence of structures indicate a restricted marine shelf (figure 51).

The Walnut Formation in Kimble County contains silty mudstone to wackestones and packstone. In thin sections, the fine-grained sediments indicate an increase in energy on the shelf. This higher energy allowed bivalves to flourish and is evidence for a more open marine shelf system (figure 51).

The stratigraphic and paleontological data obtained in the field suggested that the carbonate contacts are more than just Hensel Formation and Fort Terrett Formation but share a disconformable contact with each other, as indicated by truncated surfaces. The second piece of evidence is the lack of upper fines facies in the Upper Hensel Formation. The third piece of evidence is the presence of *C. texanum.* The *C. texanum* indicates that the Walnut Formation is between the Glen Rose and Fort Terrett formations.

The lower contact of the Glen Rose Formation, in Kimble County overlies the Hensel Formation. The contact was placed above the uppermost observed red bed, which was interpreted as a paleosol of the Hensel Formation. The paleosol (red bed) indicates subaerial exposure and the end of the regression.

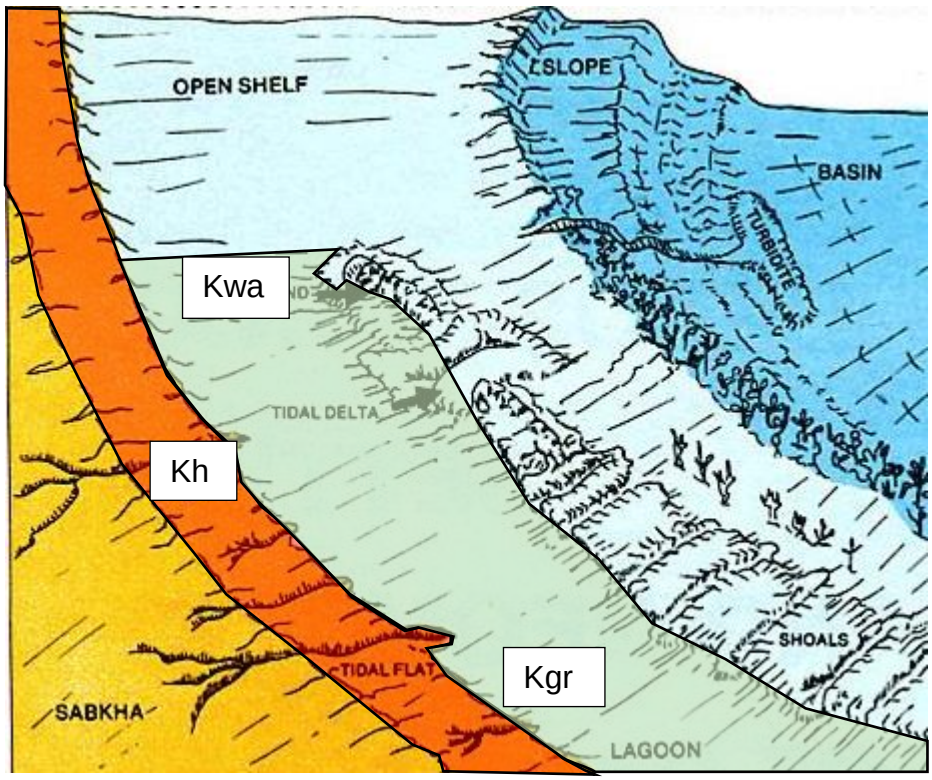


Figure 51. Depositional model for the Lower Cretaceous carbonate ramp. Hensel Fm. (Kh) model in orange, Glen Rose Fm. (Kgr) and Walnut Fm. (Kwa) in light green. SEPM (2013)

The Hensel and Glen Rose formation share a contact because: 1) there are no more paleosols (red beds) that suggest regressions and subaerial exposure; and 2) thick units of gray to white marl along with thin beds of mudstone indicate shallow shelf marine/lagoonal facies, which is characteristic of the Glen Rose Formation. The terrestrial facies in the Hensel Formation should grade into fine sands from deltaic facies, such as those outcrops in Gillespie County; however, no evidence supports this model in Kimble County. The lack of marine fossils in the Glen Rose Formation and Hensel Formation suggest anoxic marine waters that were inhospitable to most marine fauna (figure 51).

The Upper Glen Rose Formation can be correlated to other similar outcrops in Bell County to Uvalde County due to the extensive and recognizable burrows within the limestone (mudstone) (Moore, 1961). A small disconformity in the lime-mudstone indicates that this bed was exposed or went into hiatus for a short time. This bed is light brown to tan and its burrows range from 2-26 cm in length and can be correlated throughout the study area. The burrowed bed represents the top of the Glen Rose Formation and the top of the Glen Rose sequence (Moore, 1995). This bed marks the contact of the Glen Rose Formation and Walnut Formation in the Austin area. In the study area, lithophagus bivalves may have formed the burrows.

The upper contact of the Glen Rose Formation is overlain by silty mudstone that contains abundant bivalve oysters of the Walnut Formation. These bivalve oysters were identified as *Ceratostreon texanum,* which are common and key fossils in the Walnut Formation. The presence of *C. texanum* indicate a bioherm of bivalves, because it is the only fossil found at this portion of the Walnut Formation. The depositional environment is interpreted to be shallow marine or lagoon. The Walnut Formation is divided into a sequence because both the upper and lower contacts are truncated. The upper contact is the Fort Terrett Formation, identifiable due to the dominant dark gray limestone cliff that caps all the mesas in the study area.

Expansion of Moore's (1995) model to include Kimble County allows for correlation of specific members within the Walnut Formation (figure 52). The Cedar Park Member is the only member of the Walnut Formation that contacts the Fort Terrett Formation in central Texas. However, lithologically the Cedar Park Member is defined as a nodular limestone and is not observed in Kimble County. *C. texanum* is a common fossil within the Cedar Park Member, which was found in abundance at outcrop; however, another common fossil for the member is *Texigryphea mucronata* but was not observed.

Evidence that supports the extension of Moore's (1995) model to Kimble County includes 1) the first appearance of *C. texanum,* 2) the burrowed unit

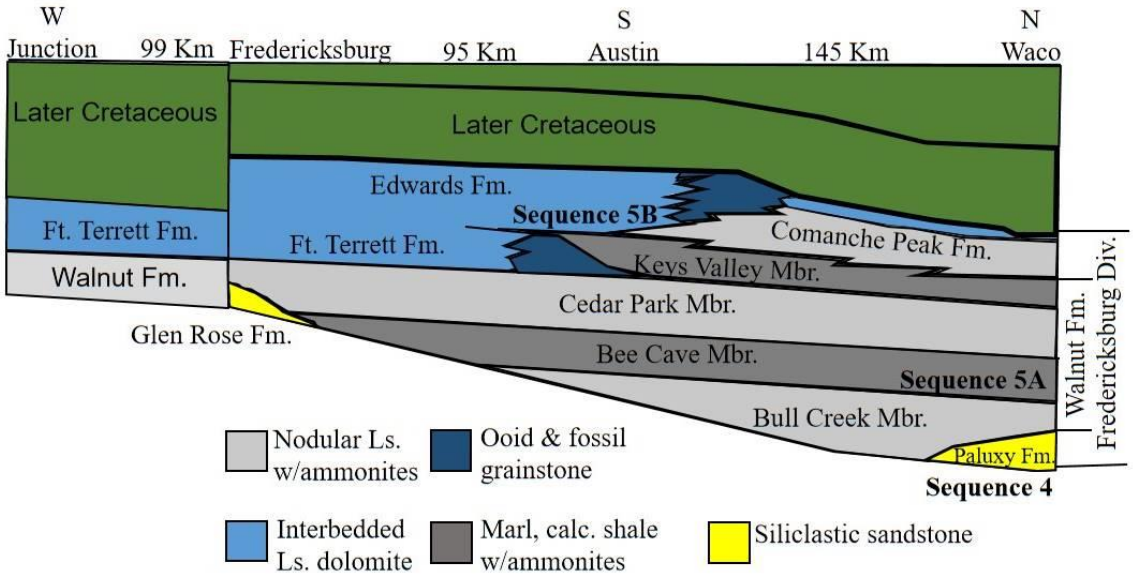


Figure 52. Sequence model of the Cretaceous strata. Model includes the expansion of Moore's 1995 model. Sequence 5a correlates with Sequence 3 in study area.

topping the Glen Rose Formation and 3) the lower unconformable contact of the Fort Terrett Formation. Moore's 1995 Sequence 5a is equivalent to the sequence 3 proposed. However, determining the actual member of the Walnut Formation was not concluded. Key index fossils needed to identify the Walnut Formation precisely are the ammonites *Metengonceras hilli, Oxytropidoceras* and the bivalve *T. mucronata.*

CONCLUSION

The stratigraphic relationship of the Lower Cretaceous units exposed in Kimble County Texas in ascending order is the Cow Creek, Hensel, Glen Rose, Walnut and Fort Terrett formations. The Cow Creek, Glen Rose and Fort Terrett are predominately mudstones and wackestones whereas the Hensel Formation is comprised of claystones and the Walnut Formation as silty mudstones and wackestones.

Each of the three sequences represent a formation. The Hensel Formation represents Sequence 1. The Glen Rose Formation represents Sequence 2. The Walnut Formation represents Sequence 3. Transition from one sequence to another is abrupt. The Hensel and Glen Rose formations are separated by a disconformity, the Glen Rose-Walnut formation contact is defined by a burrowed horizon in mudstone, and the Walnut-Fort Terrett formations contact by disconformity.

Ceratostreon texanum are bivalve fossils that first appear in the Walnut Formation (Denison et al, 2003) and are common in outcrops in the study area.

There is a lack of faunal diversity in the Walnut Fomation with *C. texanum* being the principle fossil found.

Carbonate petrography of the Hensel, Glen Rose, and Walnut formations suggest that these units were depositional environment is a shallow shelf marine to lagoon with aeolian influence from the Llano islands. Early marine diagenesis is indicated by the recrystallization of micrite to microspar. Dissolution of the Walnut and upper Glen Rose formation units was caused by meteoric fluids.

Presence of root clasts, intraclasts, red beds, and disconformable surfaces indicate that the red beds in the Hensel Formation were produced by soil forming processes to form paleosols.

This study shows that the Walnut Formation and Glen Rose Formation are mappable units within the study area. The modernization of the stratigraphic framework from the study area has potential to reevaluate formations present in outcrop towards the south and west.

FUTURE WORKS

Four additional studies would be, 1) A full section is located at Section 9, ranging from Hensel to Fort Terrett formations. The object of the future work would be to gain access to this section which is on private property and measure and study the units to correlate them to the other sections in the study. 2) 87Sr/86Sr data of *C. texanum* in the study area. This data would be used to correlate the 87Sr/86Sr data from Denison and others (2003) and can be used to determine the dates of the Walnut Formation in the study area. 3) Conduct an Scanning Electron Microscope (SEM) study of the limestones for Hensel, Glen Rose, and Walnut formations. It would be used to determine microfossils and identify clays in the marl and claystone units. SEM data would give a clearer view of the diagenesis of the units present and help for trace mineral analyses as well as microfossil identification. 4) Collect ammonites from the stratigraphic units present and determine ammonite biostratigraphy for the units in the study area to determine the ammonite zone. Obtaining a *Metengonoceras hilli* or *Oxytropidoceras* sample would confirm the presence of the Walnut Formation.

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Appendix I

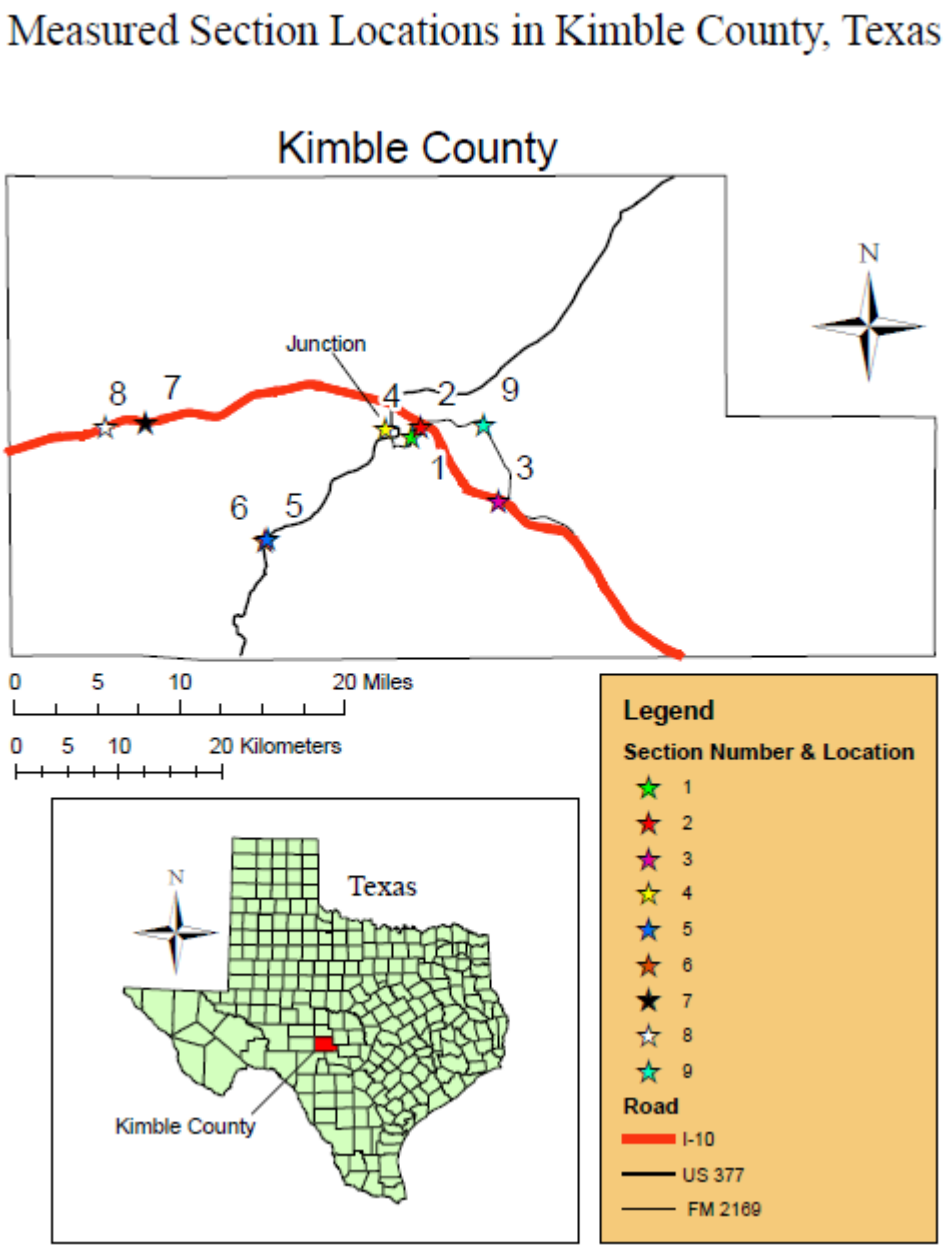

Figure 53. Reference Map of Study Area. Study area was in Kimble County, Texas. Nine measured sections are located on this map.

Table 1. GPS locations of the nine Measured Sections in Kimble County, Texas.

GPS Locations of Measured Sections		
Section Number	Latitude	Longitude
1	30.4832	-99.7596
2	30.4919	-99.7528
3	30.4261	-99.6842
4	30.4898	-99.7831
5	30.3932	-99.8874
6	30.3912	-99.8942
7	30.4954	-99.9943
8	30.4907	-100.0296
9	30.4943	-99.6971
*GCS N. America 1983		

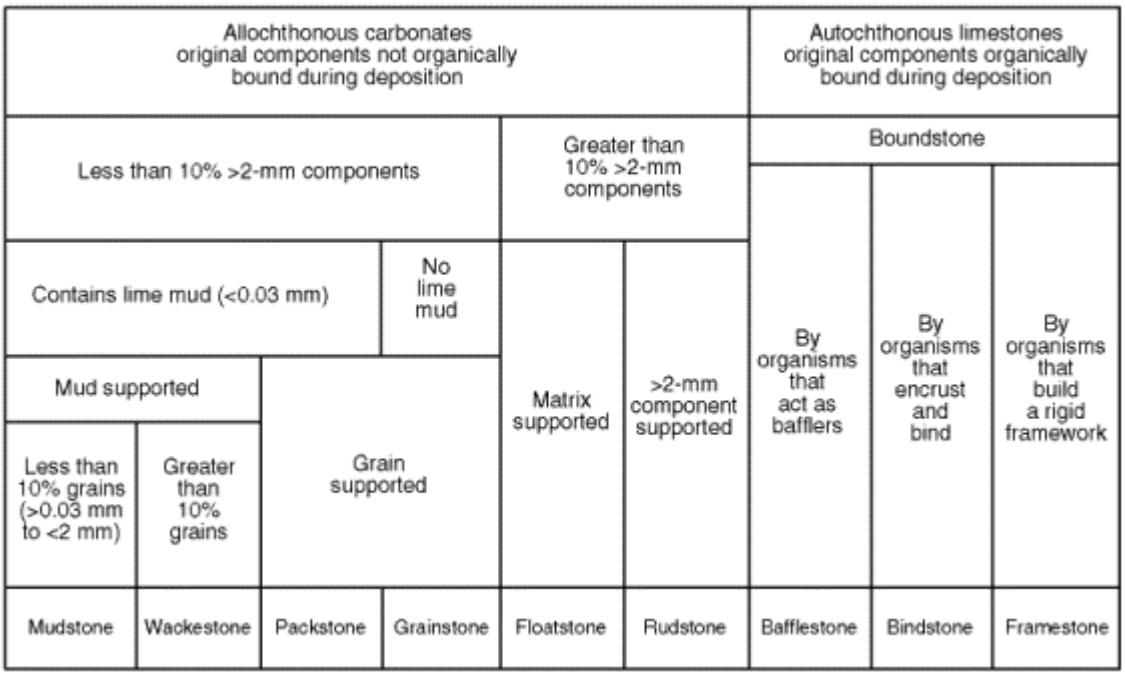

Figure 54. Dunham's Carbonate Classification 1962.

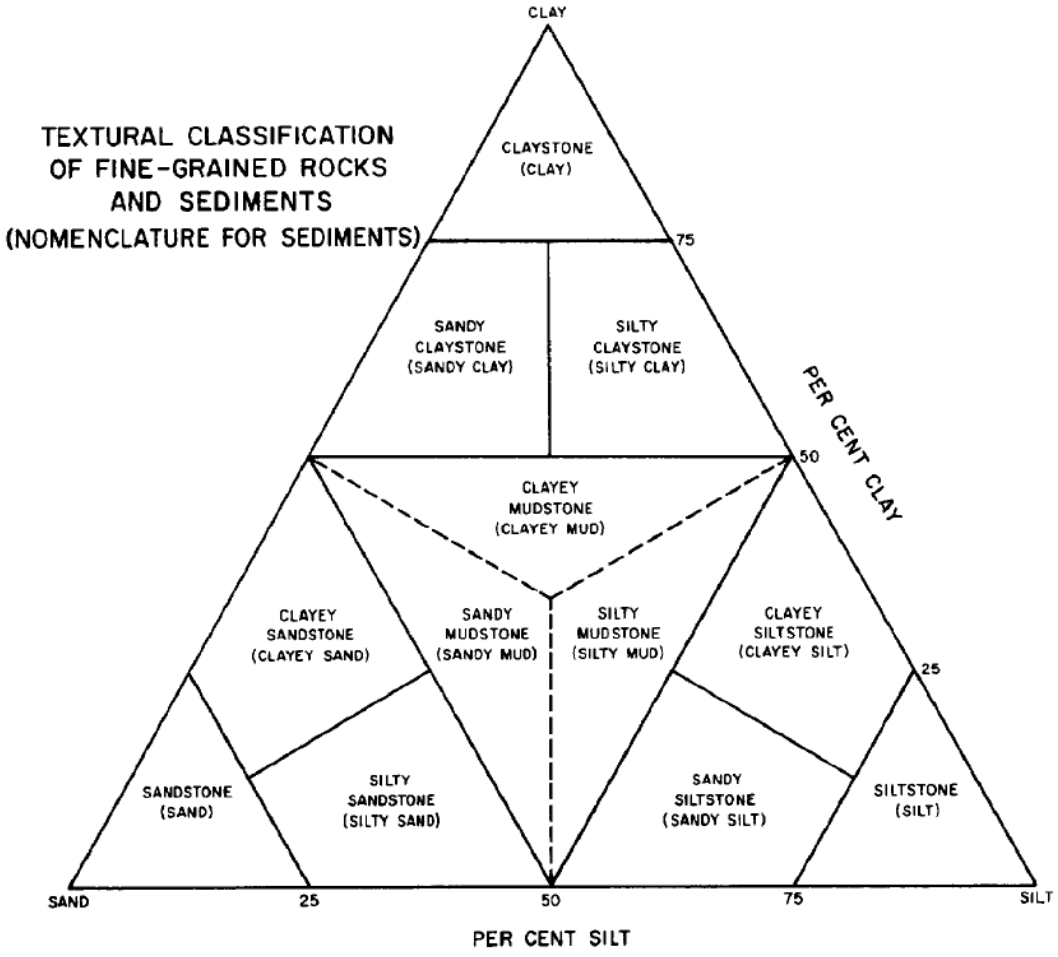

Figure 55. Picard's 1971 Classification of Fine-Grained Rocks and Sediment.

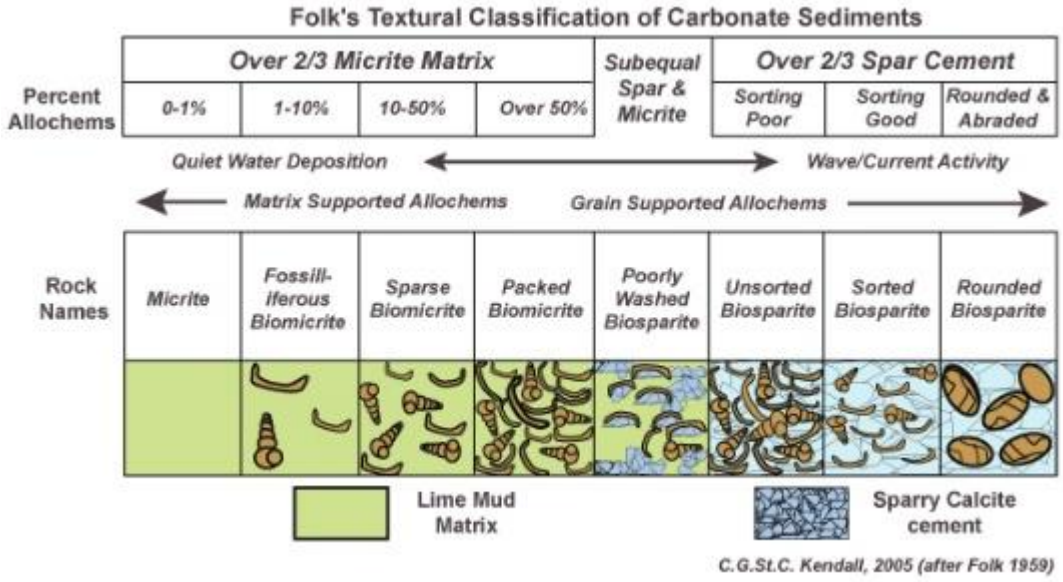

Figure 56. Folk's 1959 classification of carbonates. This model was used for thin section classification.

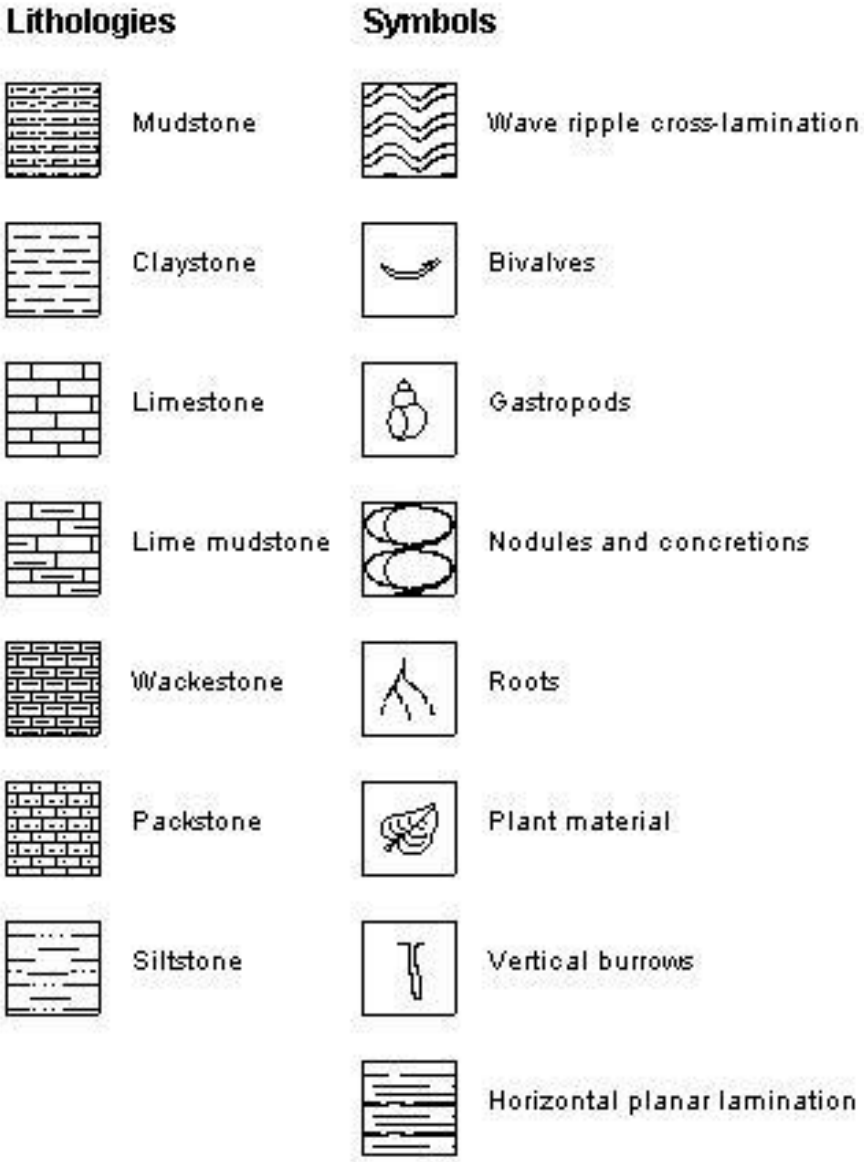

Figure 57. Legend for Measured Sections 1-9.

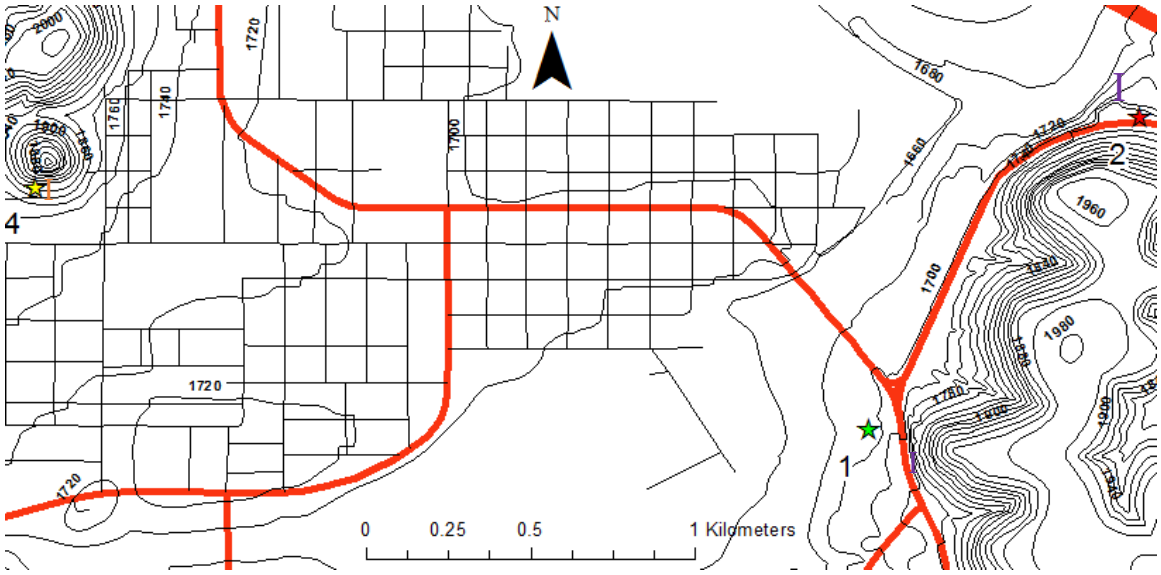

Figure 58. Section 1, Section 2, and Section 3 location.

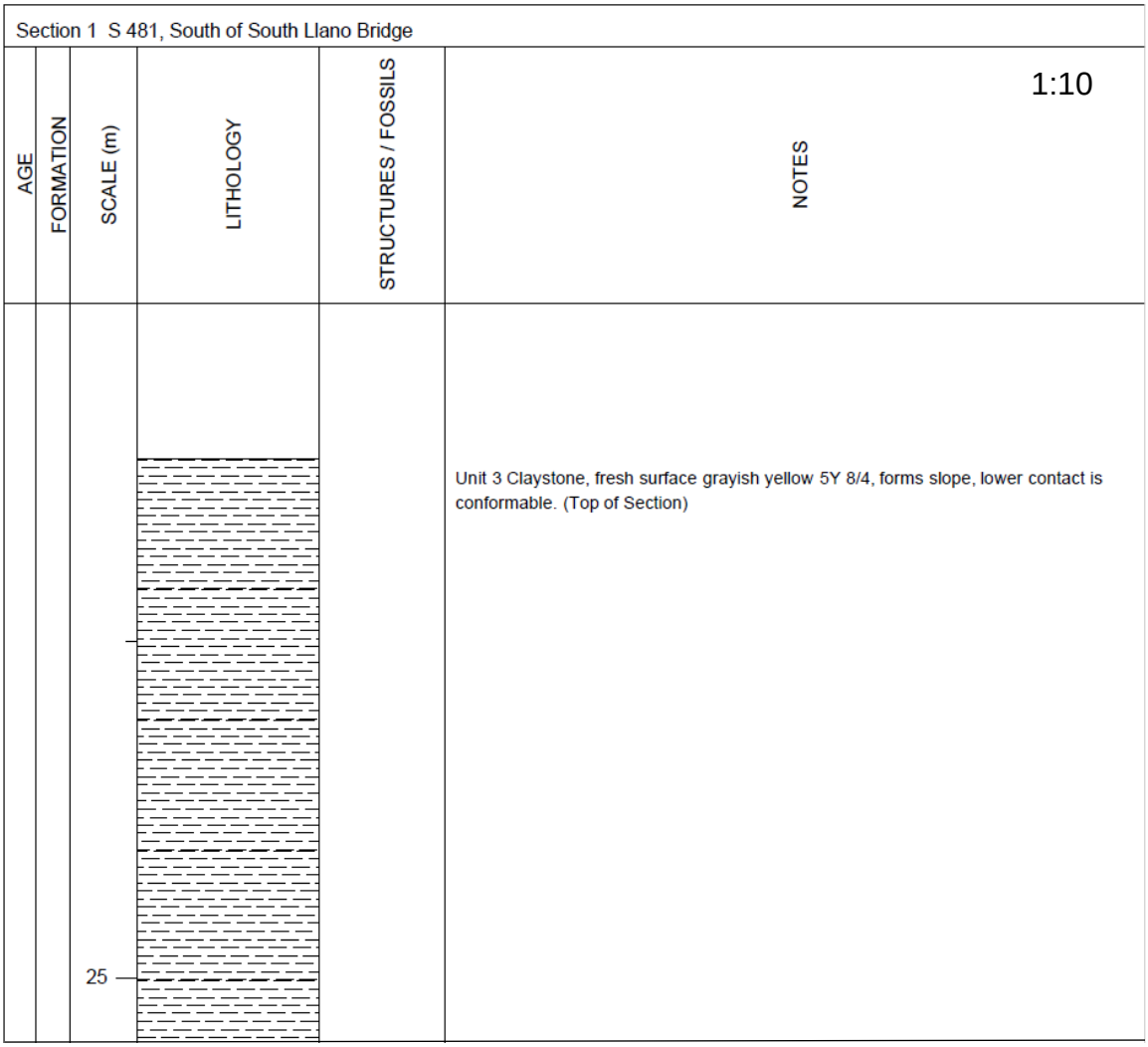

Figure 59. Section 1, part 1. 24.75 meters – 25.75 meters. Glen Rose Fm. Unit 3. Lat: N 30.48327778 Long: 99.75969889 W

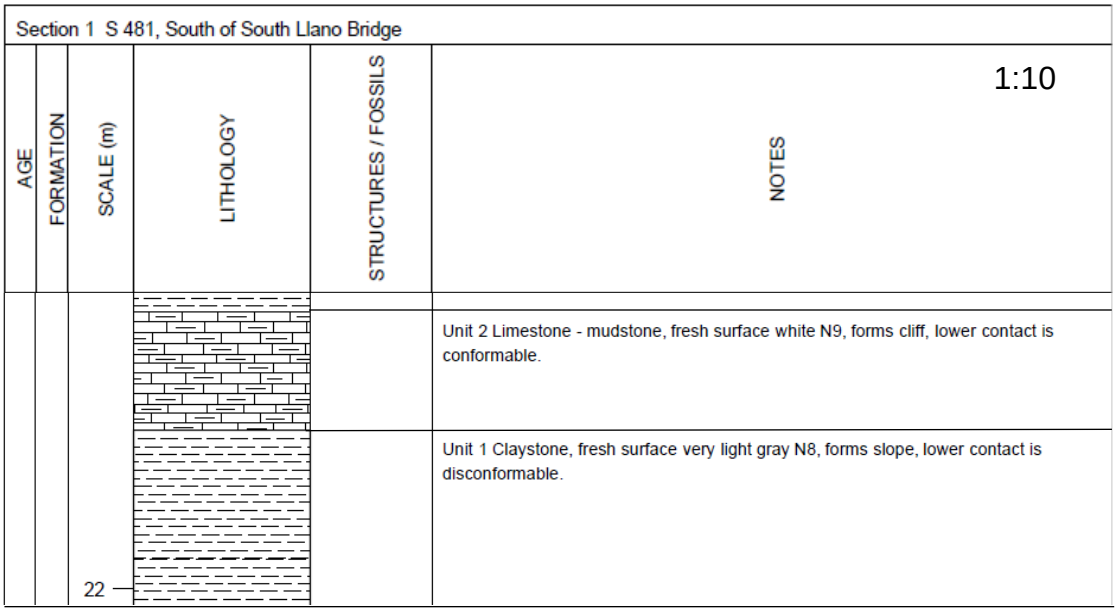

Figure 60. Section 1, part 2. 22-22.25 meters. Glen Rose Units 1-2. Lat: N 30.48327778 Long: 99.75969889 W

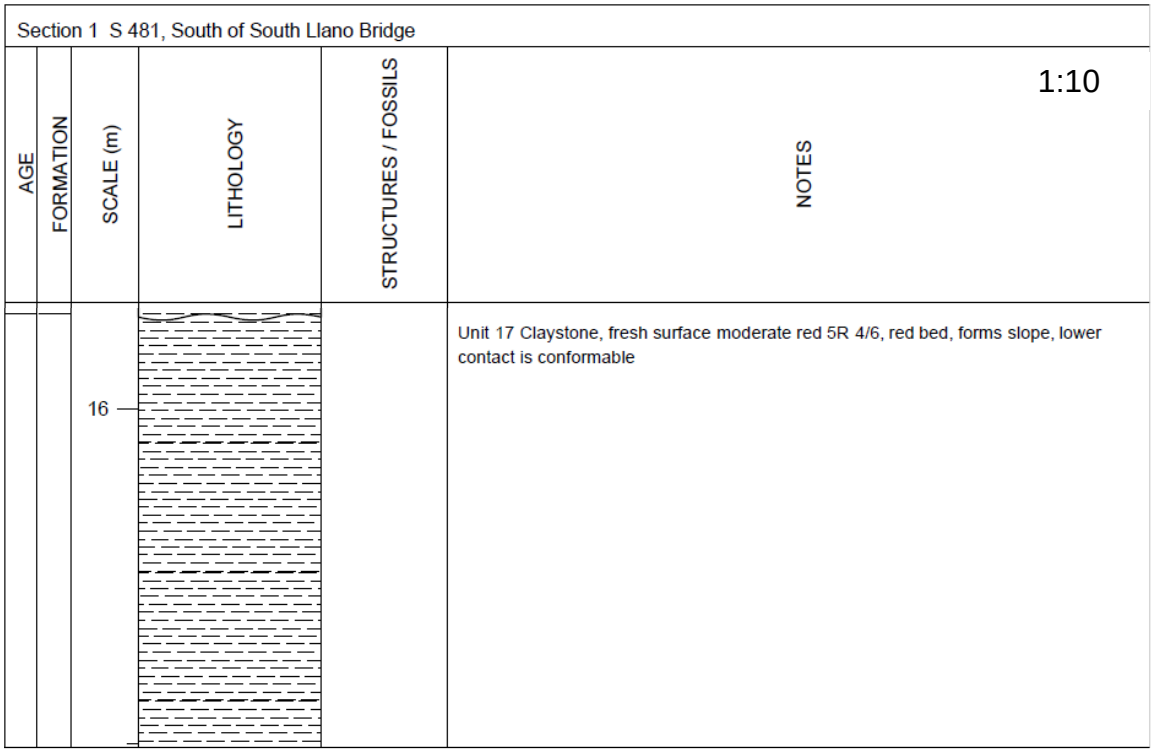

Figure 61. Section 1, part 3. 15.5 meters – 16.25 meters. Hensel Fm. Unit 17. Lat: N 30.48327778 Long: 99.75969889 W

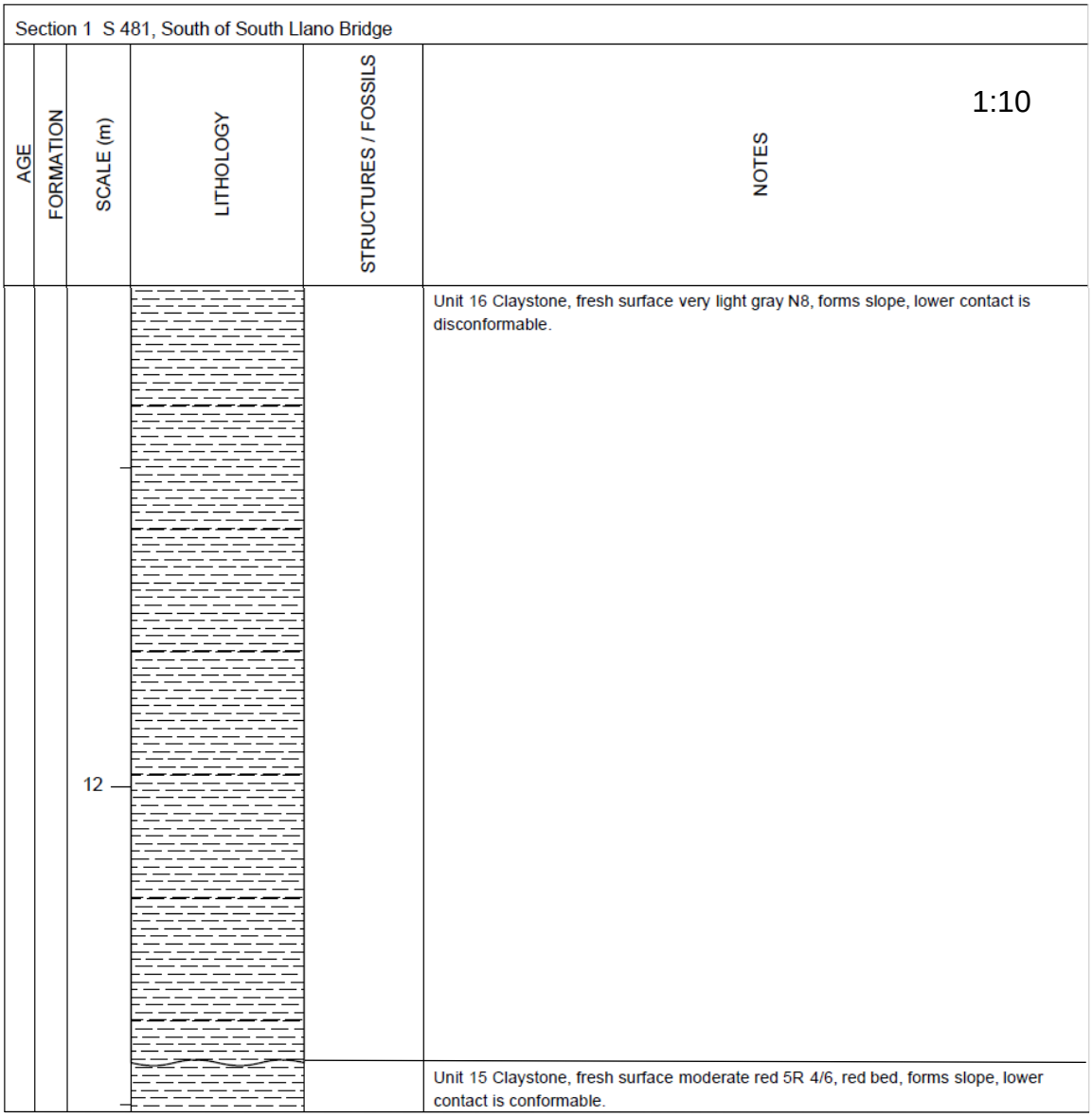

Figure 62. Section 1, part 4. 11.5 meters - 13 meters. Hensel Fm. Unit 15-16. Lat: N 30.48327778 Long: 99.75969889 W

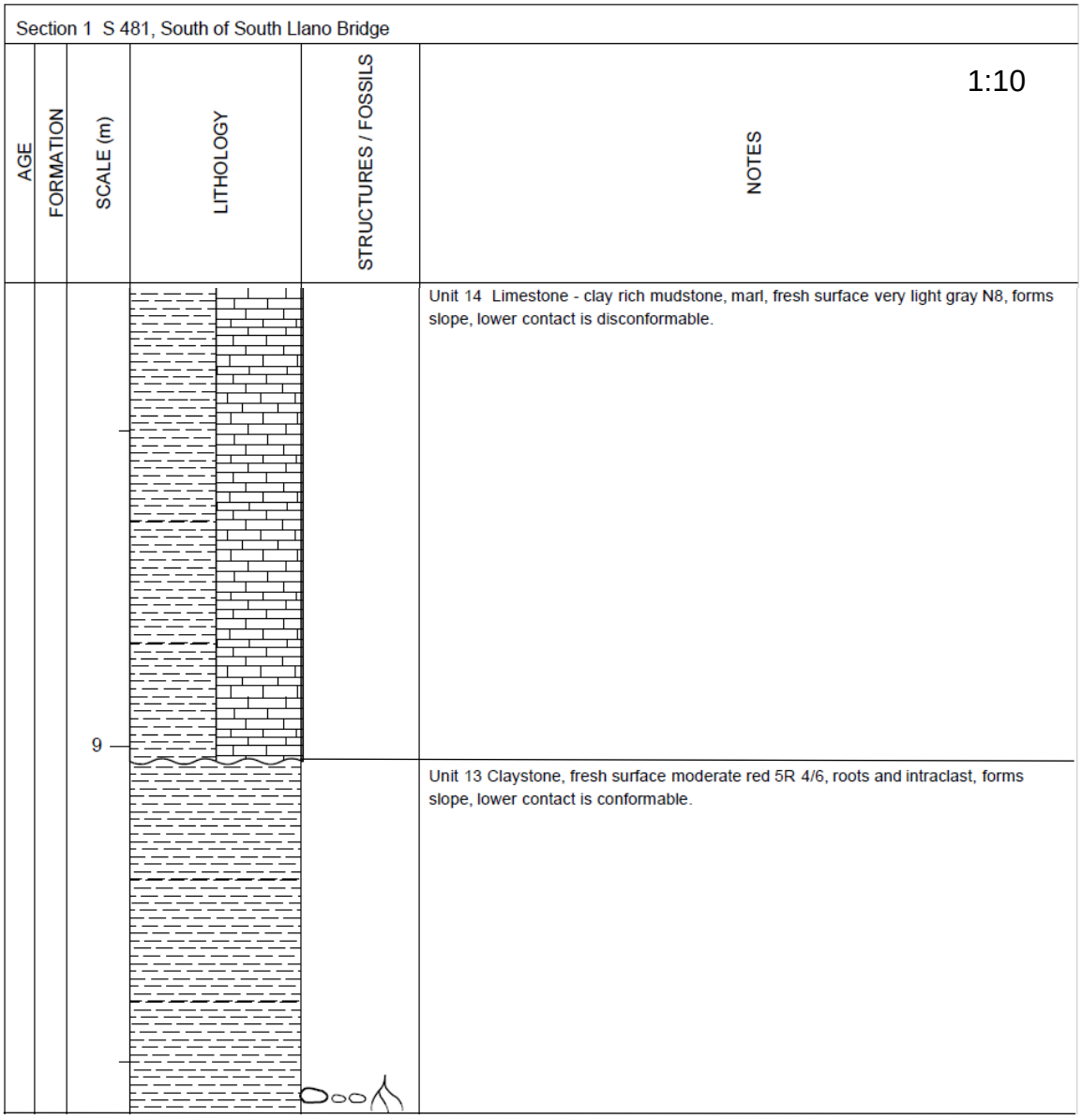

Figure 63. Section 1, part 5. 8.5 meters - 10 meters. Hensel Fm. Units 13 -14. Lat: N 30.48327778 Long: 99.75969889 W

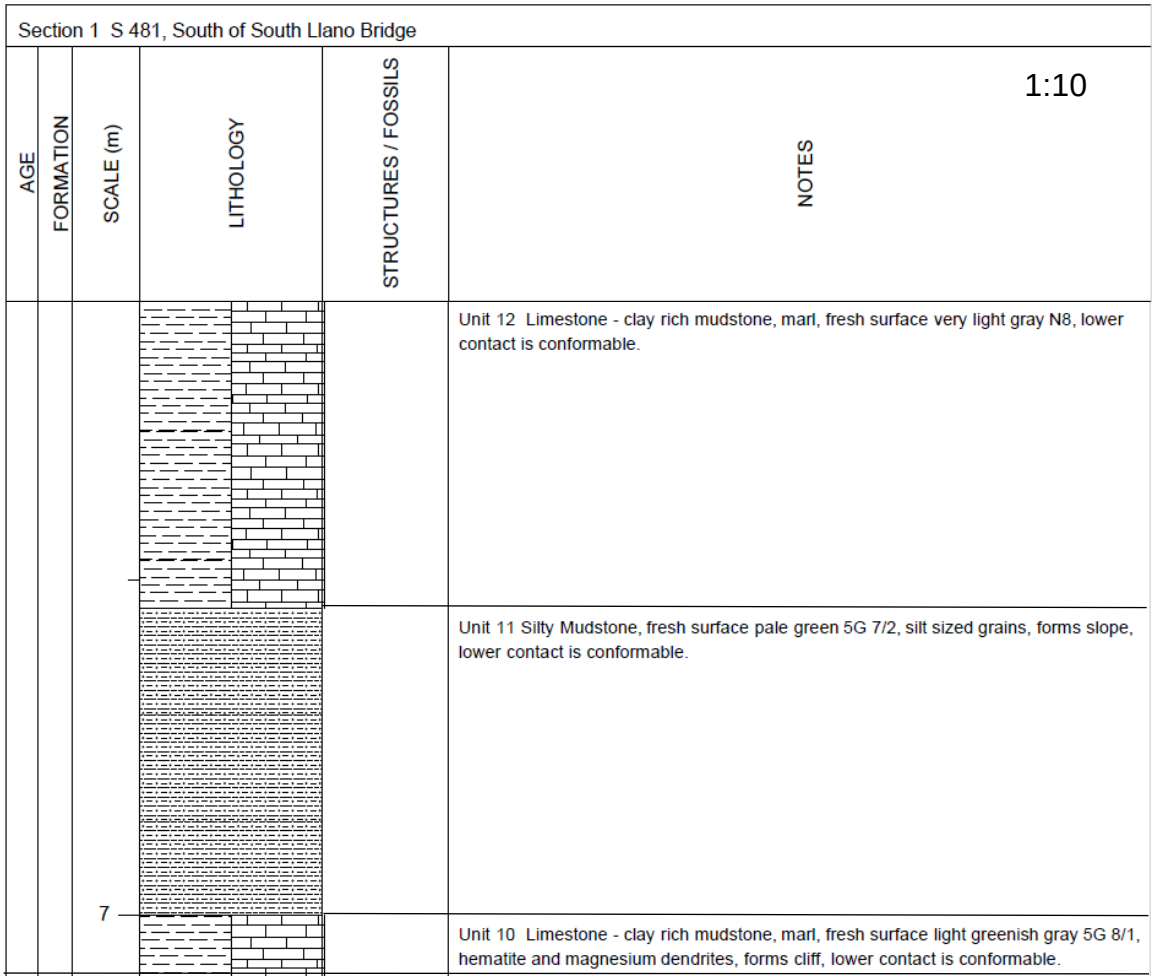

Figure 64. Section 1, part 6. 5 meters - 7 meters. Hensel Fm. Units 10-12. Lat: N 30.48327778 Long: 99.75969889 W

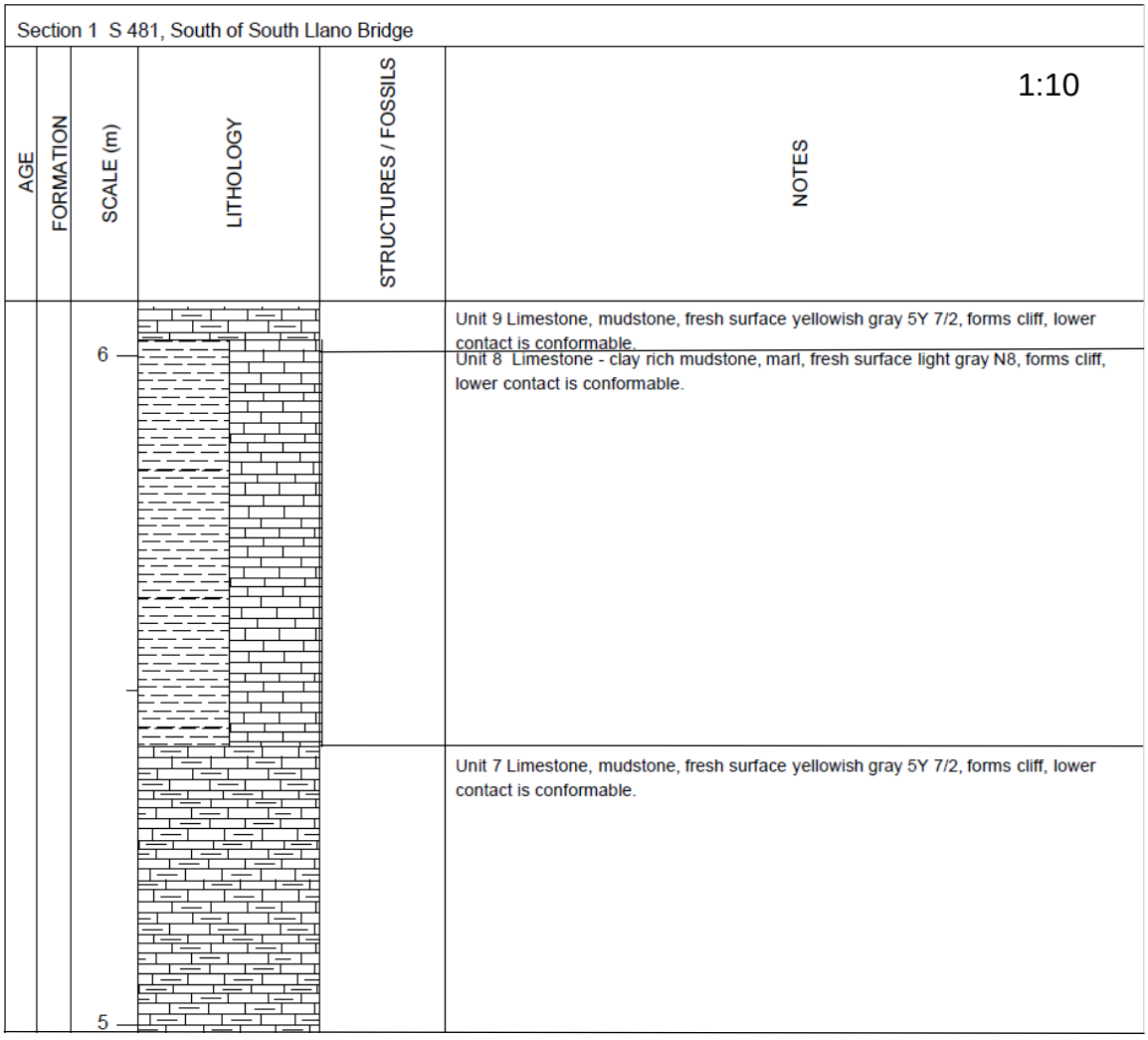

Figure 65. Section 1, part 7. 5 meters - 6 meters. Hensel Fm. Units 7-9. Lat: N 30.48327778 Long: 99.75969889 W

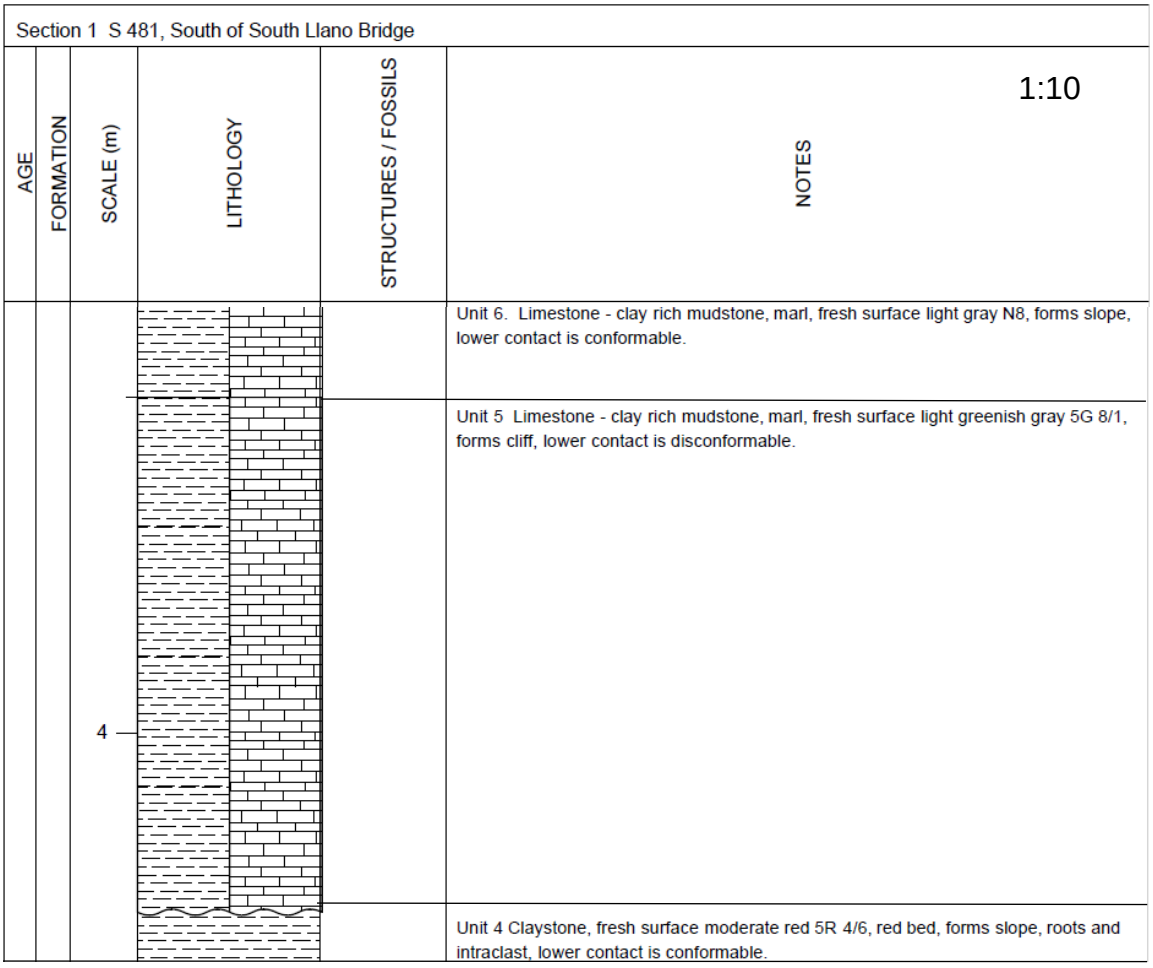

Figure 66. Section 1, part 8. 3.5 meters – 4.75 meters. Hensel Fm. Units 4-6. Lat: N 30.48327778 Long: 99.75969889 W

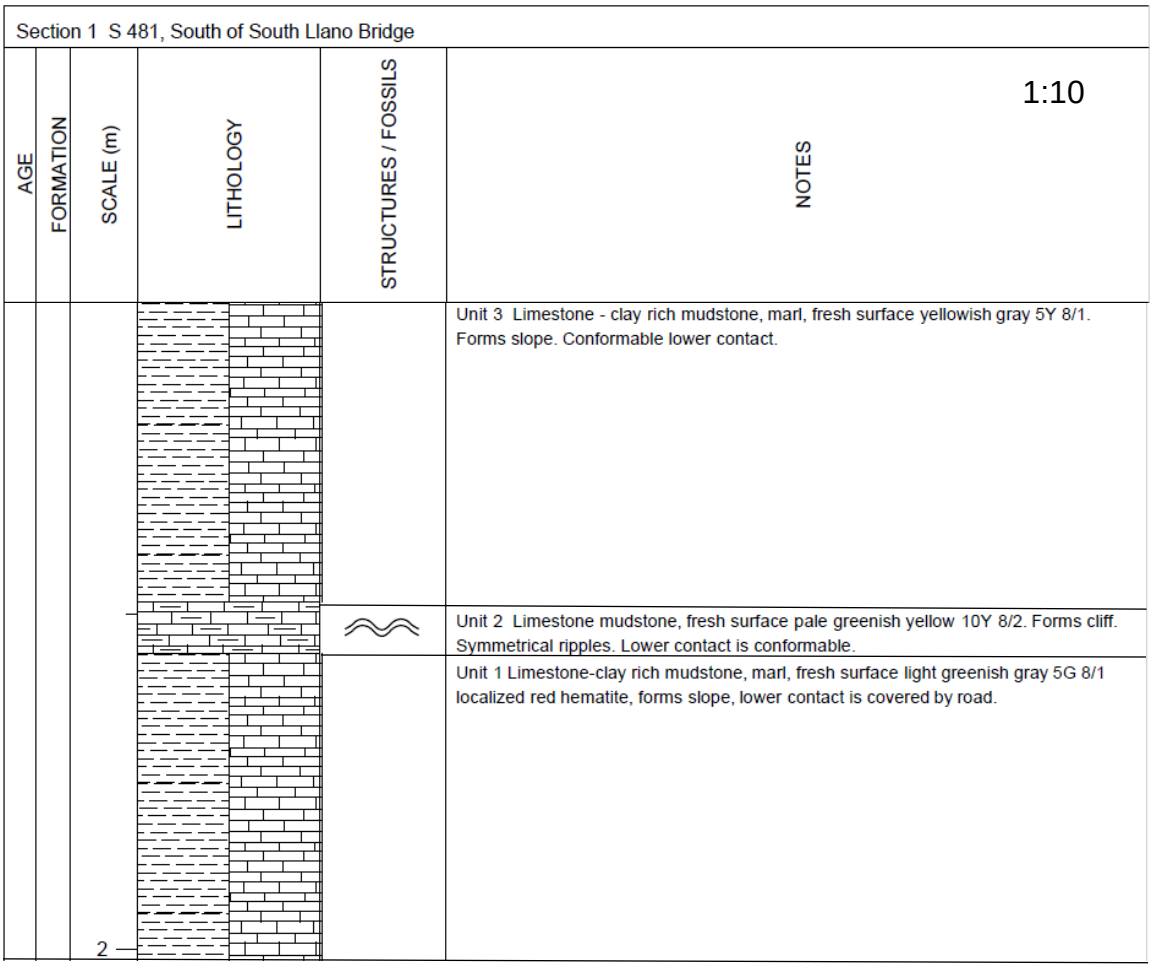

Figure 67. Section 1, part 8. 2 meters – 3 meters. Hensel Fm. Units 1-3. Lat: N 30.48327778 Long: 99.75969889 W

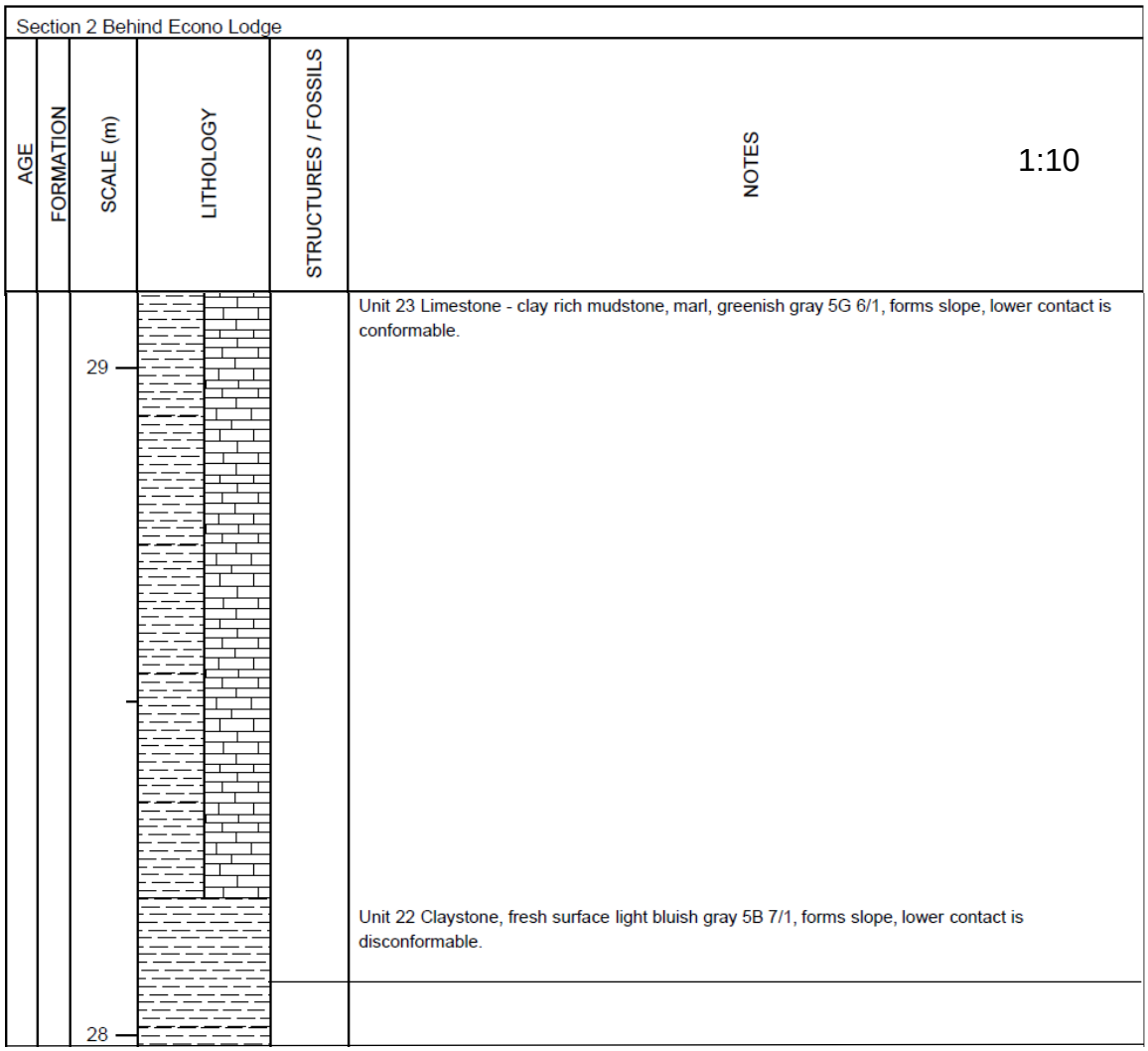

Figure 68. Section 2, part 1. 28 meters - 29 meters. Hensel Fm. Unit 22-23. Lat: N 30.4919 Long: 99.75281 W

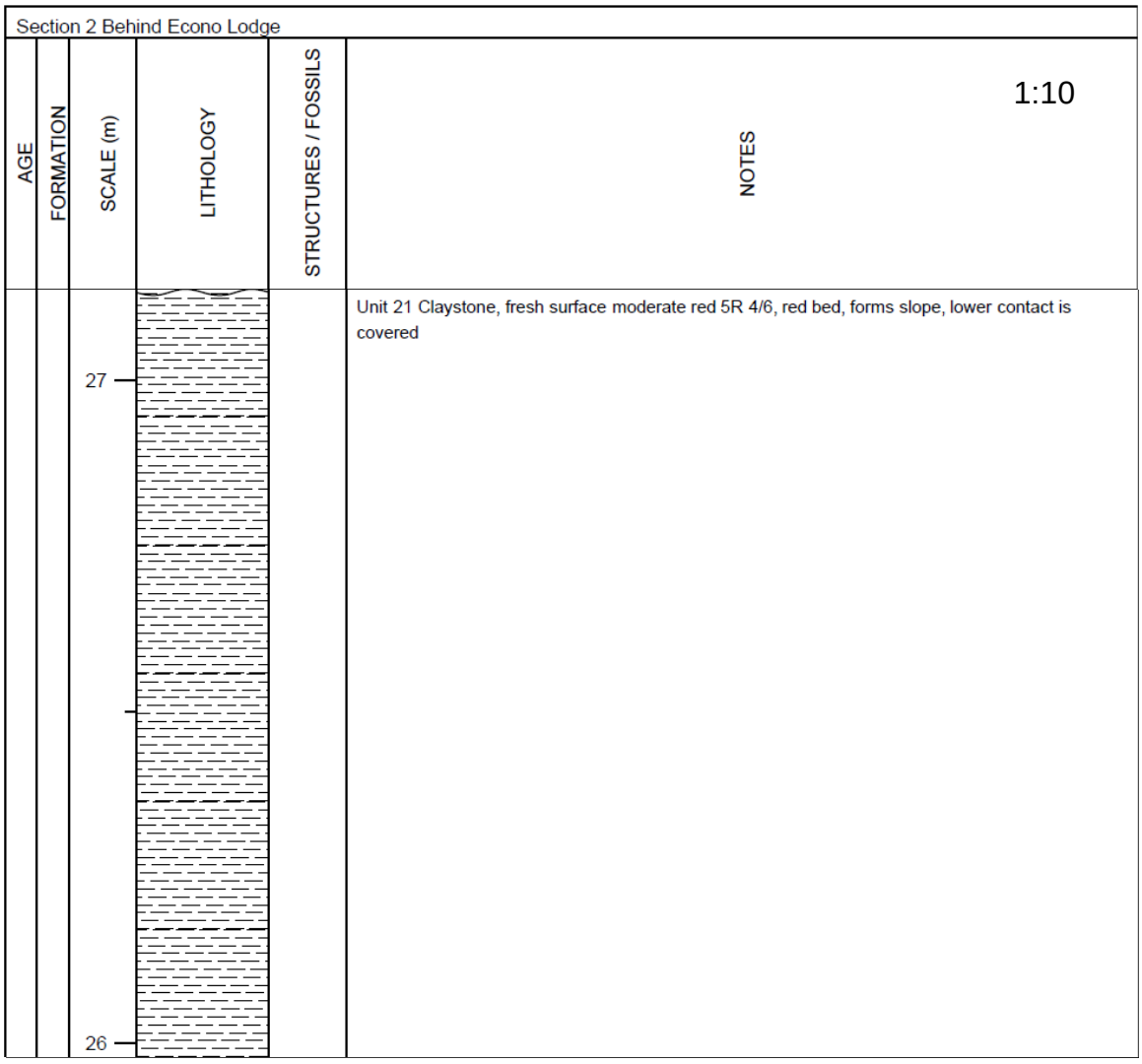

Figure 69. Section 2, part 2. 26 meters - 27 meters. Hensel Fm. Unit 21. Lat: N 30.4919 Long: 99.75281 W

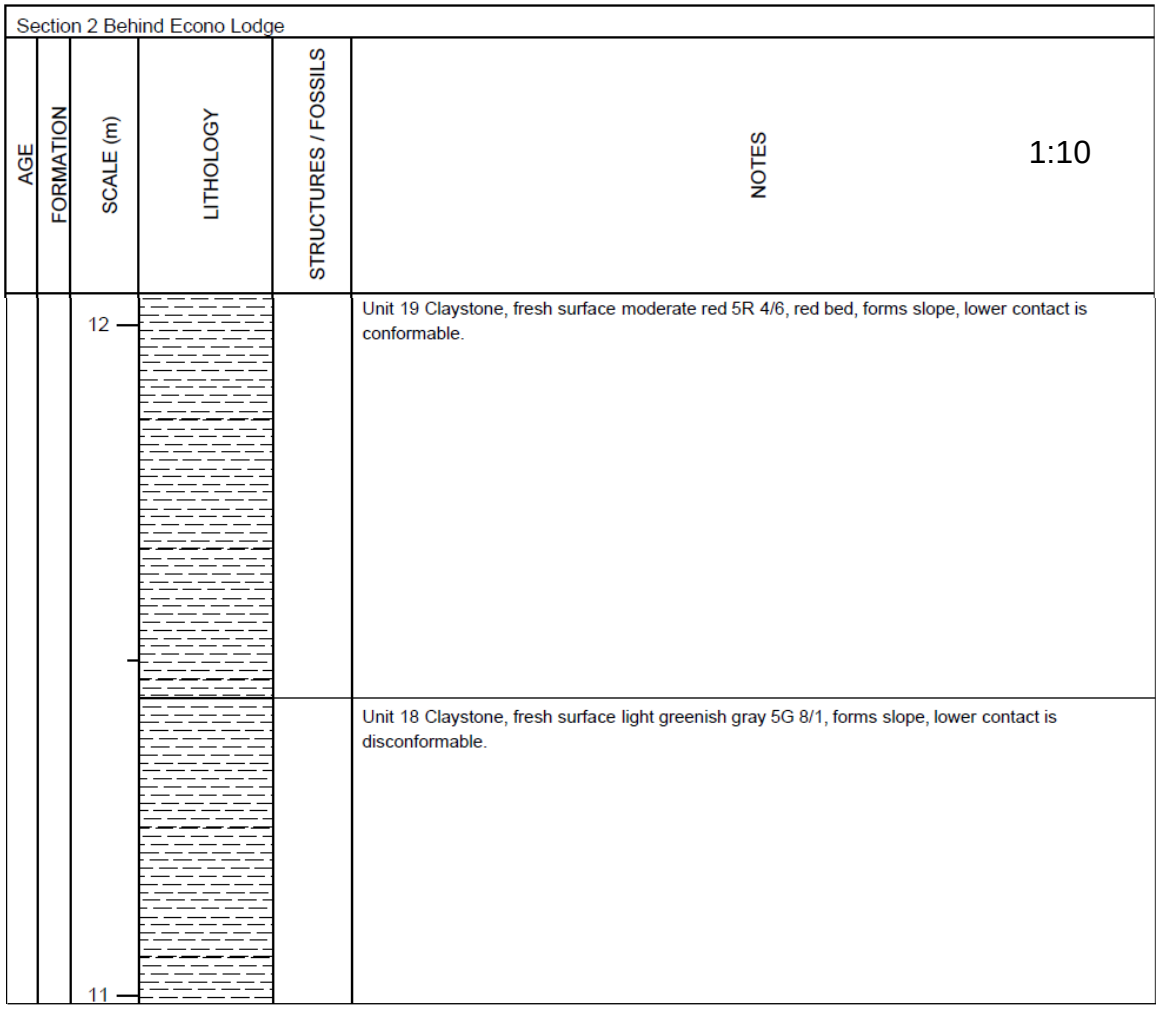

Figure 70. Section 2, part 3. 11 meters - 12 meters. Hensel Fm. Units 18-19. Lat: N 30.4919 Long: 99.75281 W

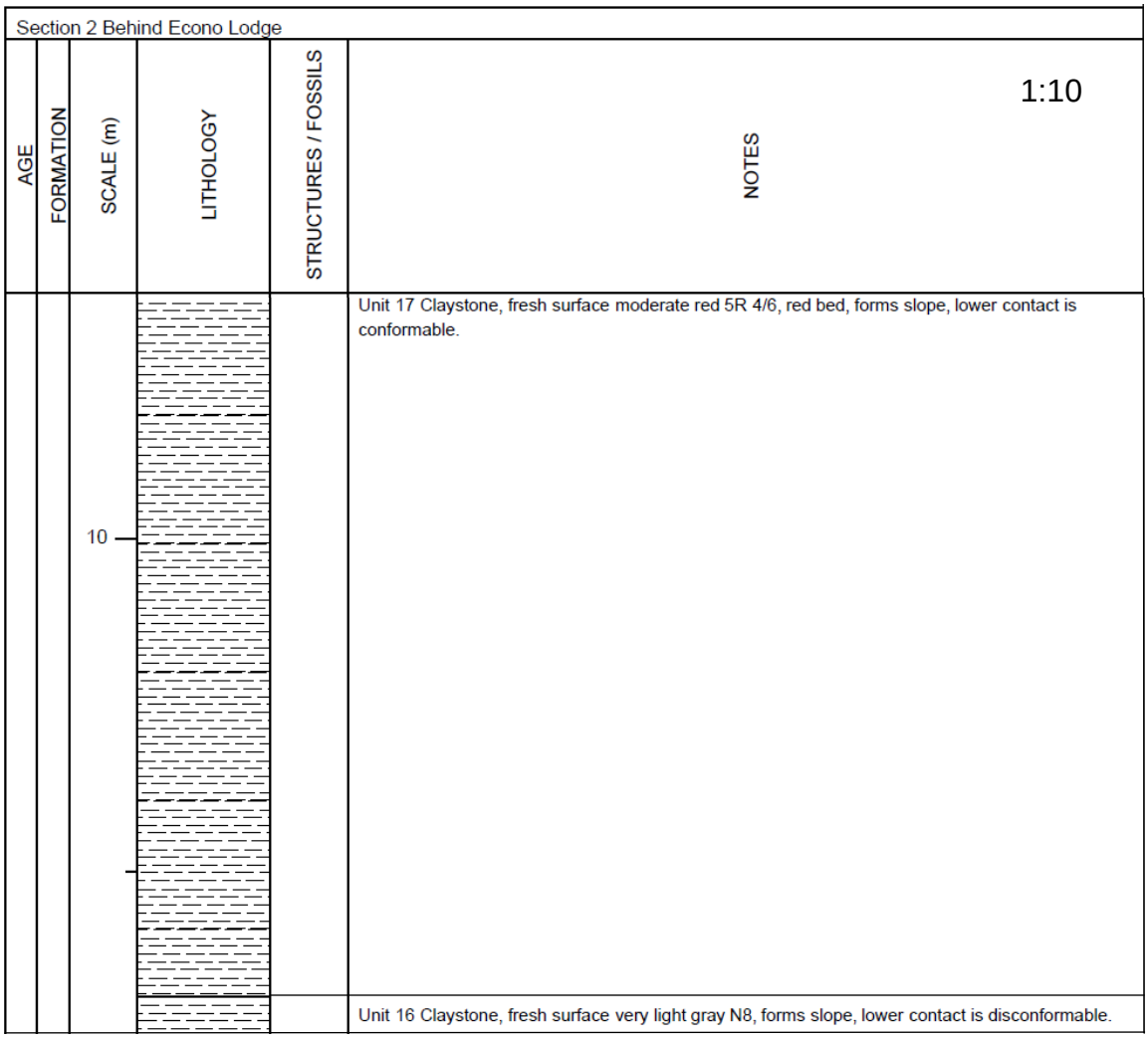

Figure 71. Section 2, part 4. 10 meters - 12 meters. Hensel Fm. Units 16-17. Lat: N 30.4919 Long: 99.75281 W

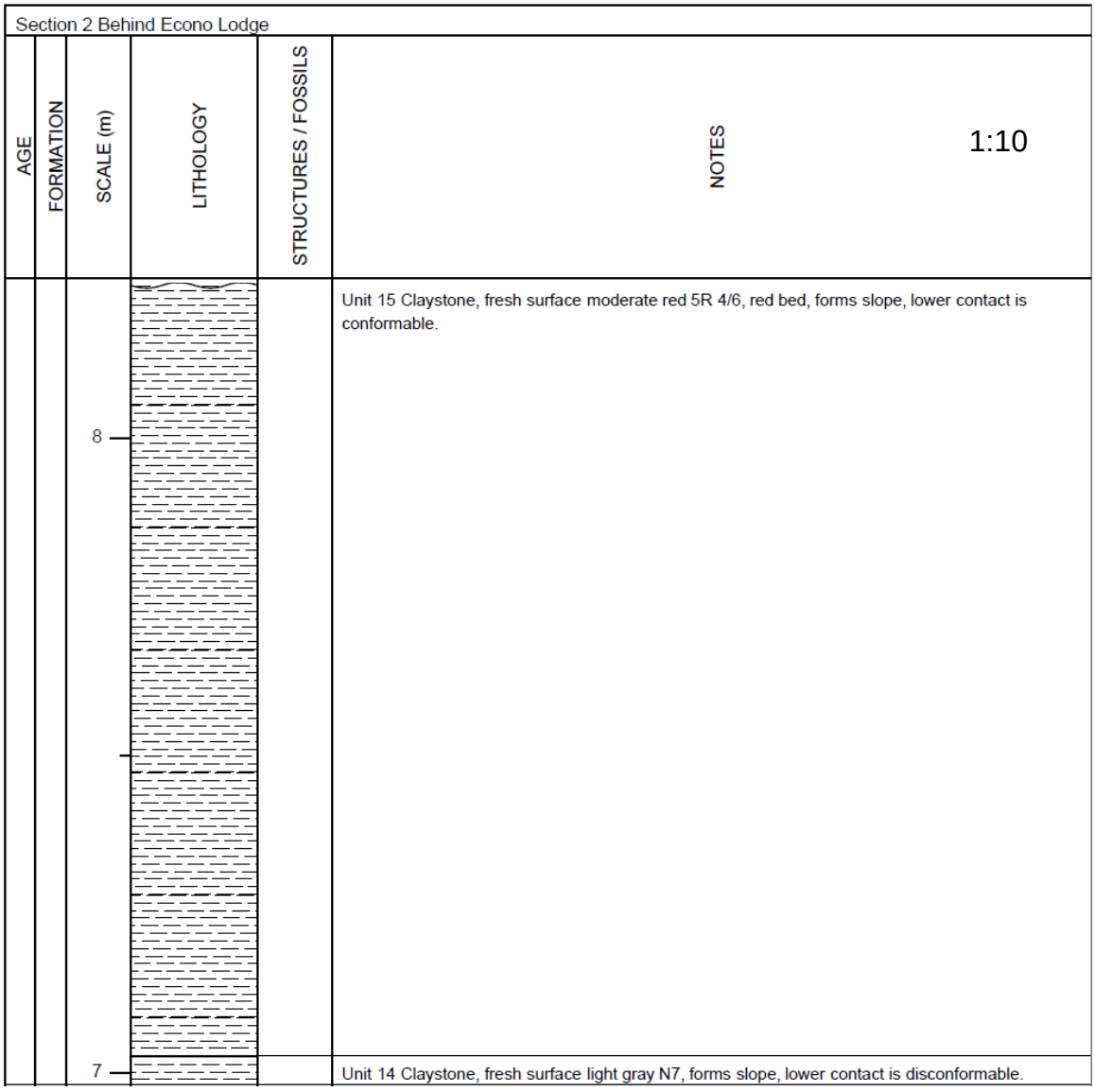

Figure 72. Section 2, part 5. 7 meters - 9 meters. Hensel Fm. Units 14-15. Lat: N 30.4919 Long: 99.75281 W

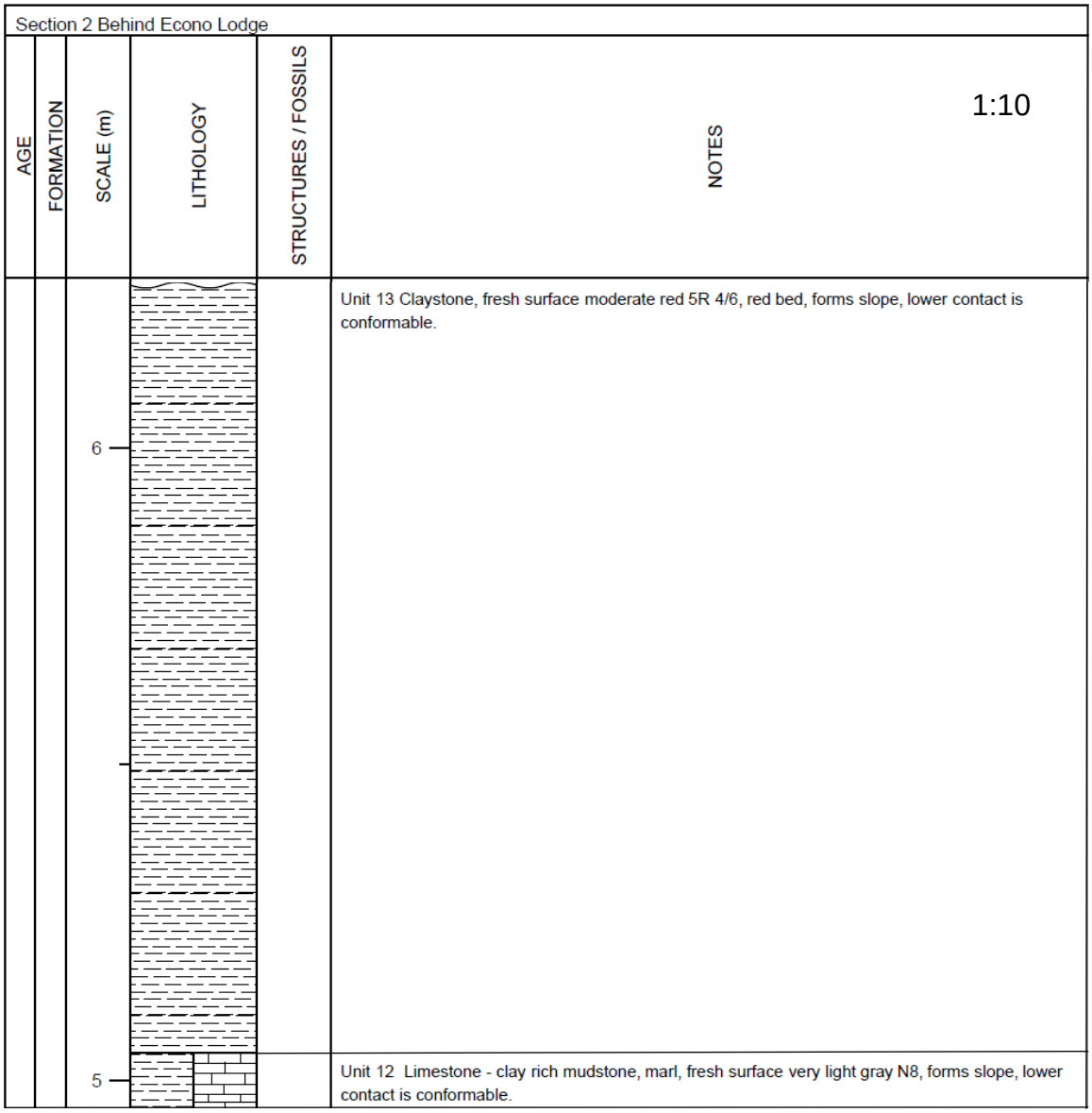

Figure 73. Section 2, part 6. 5 meters - 6 meters. Hensel Fm. Units 12-13. Lat: N 30.4919 Long: 99.75281 W

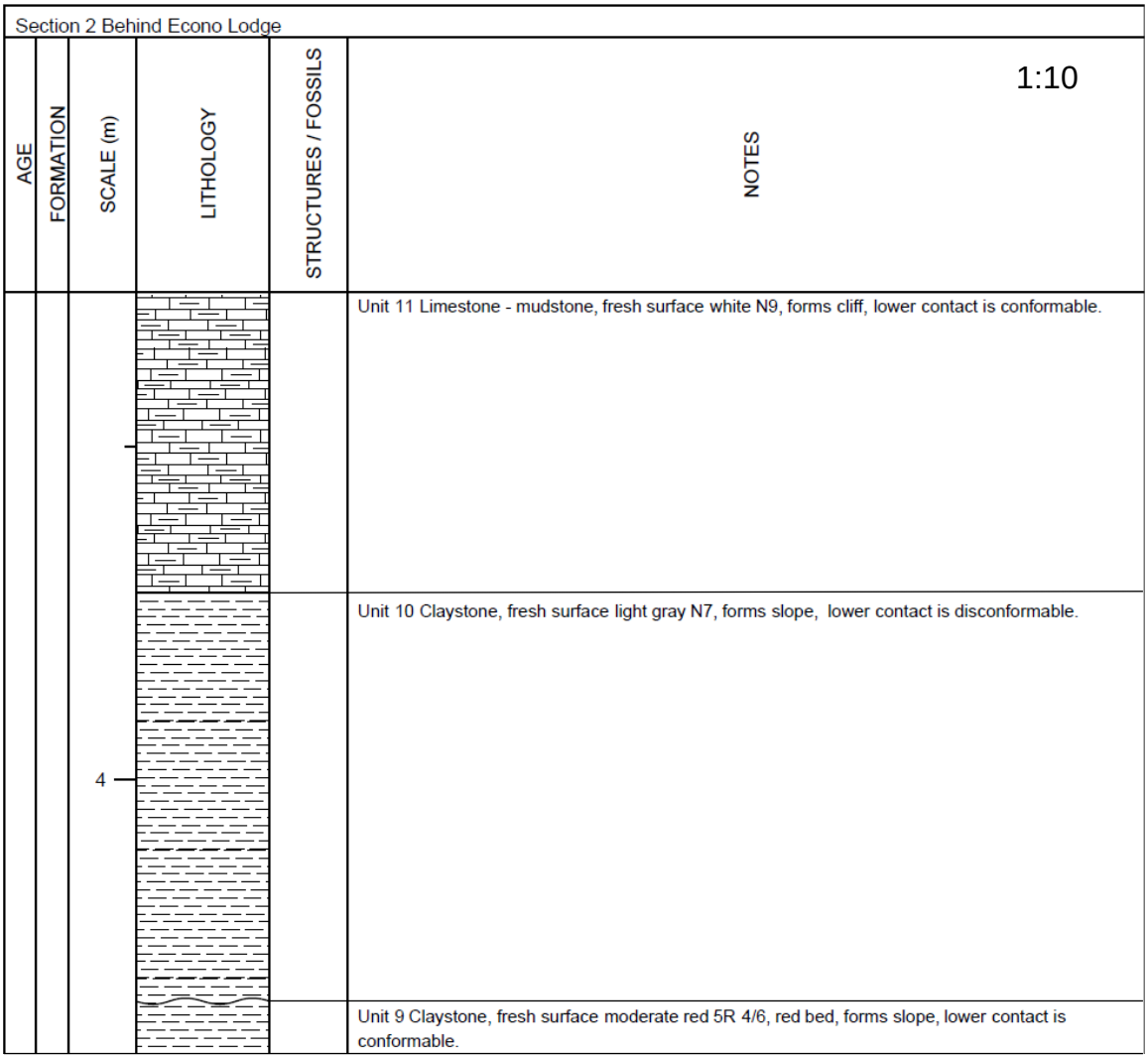

Figure 74. Section 2, part 7. 3.5 meters – 4.5 meters. Hensel Fm. Units 5-9.Lat: N 30.4919 Long: 99.75281 W

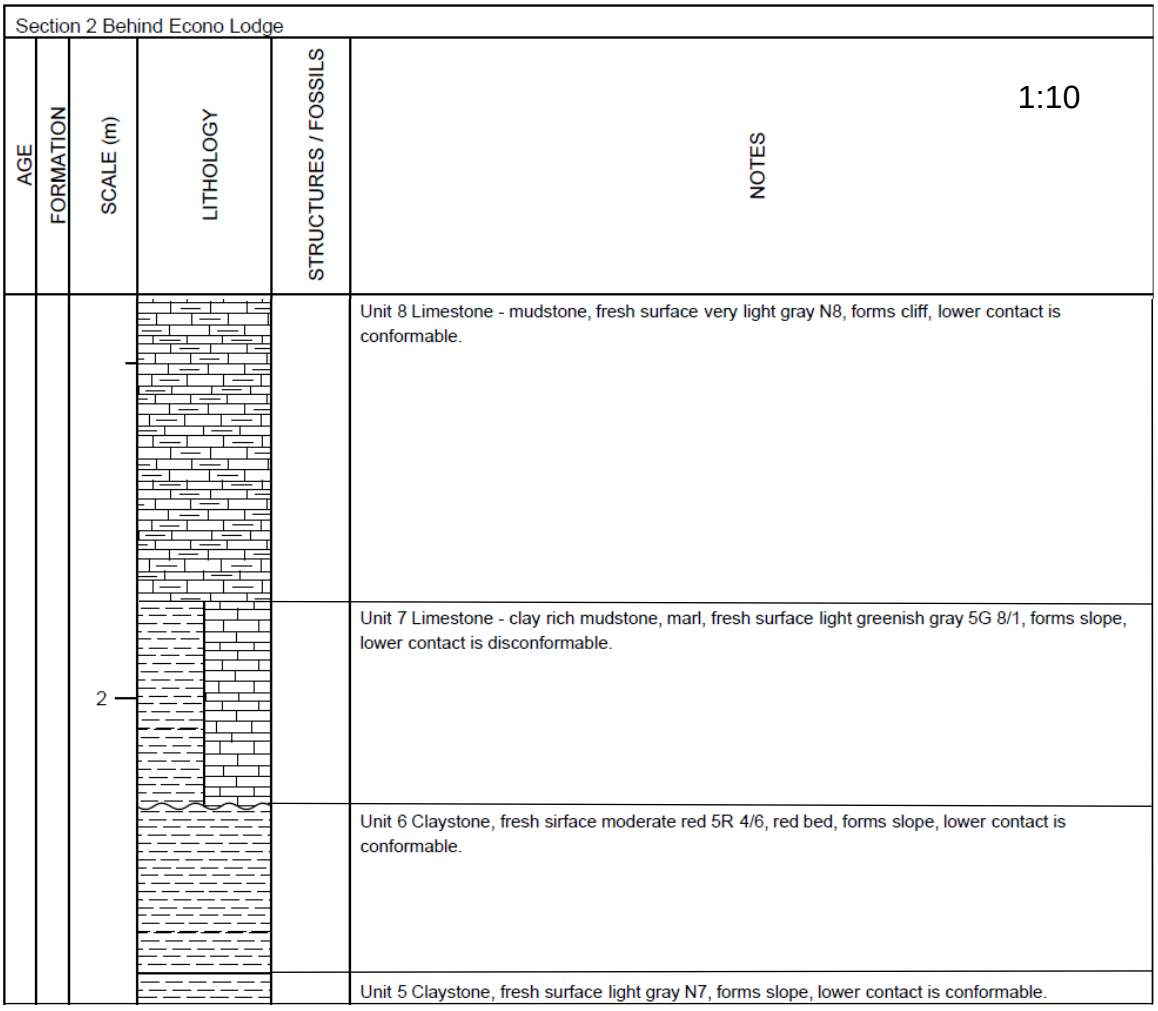

Figure 75. Section 2, part 8. 1.5 meters – 2.5 meters. Hensel Fm. Units 5-8. Lat: N 30.4919 Long: 99.75281 W

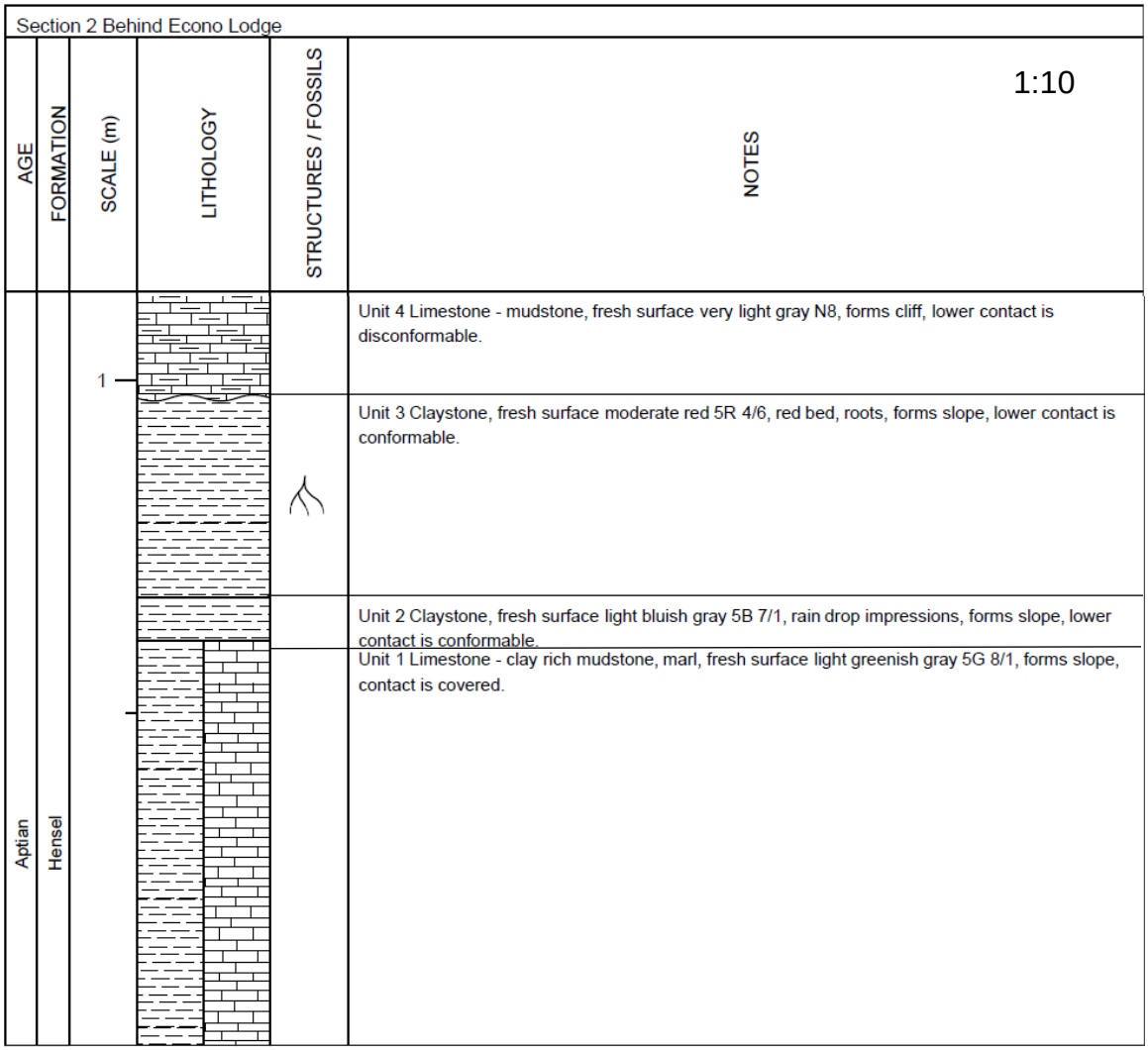

Figure 76. Section 2, part 9. 0 meters – 1.5 meters. Hensel Fm. Units 1-4. Lat: N 30.4919 Long: 99.75281 W

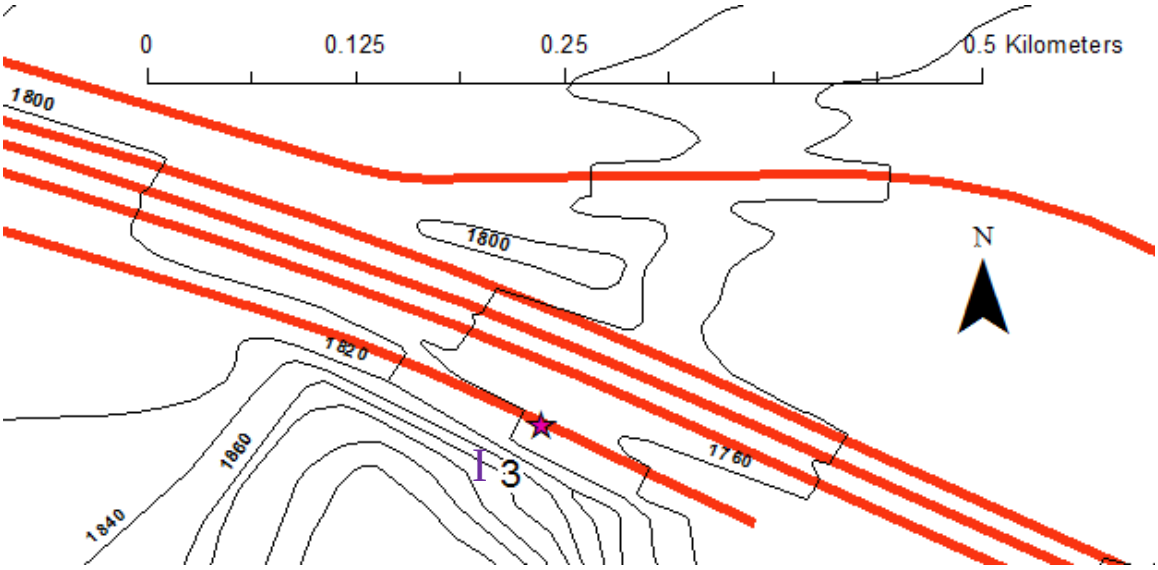

Figure 77. Section 3 location.

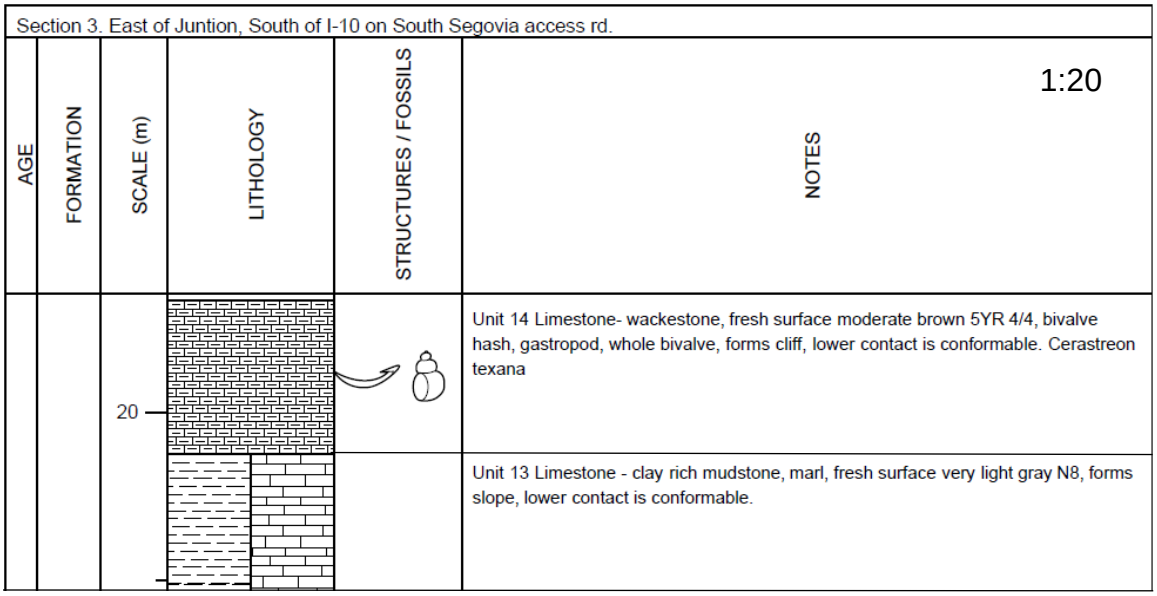

Figure 78. Section 3 part 1. 19.5 meters - 20 meters. Walnut Formation. Unit 13, 14. Lat: N 30.4261 Long: 99.6842 W

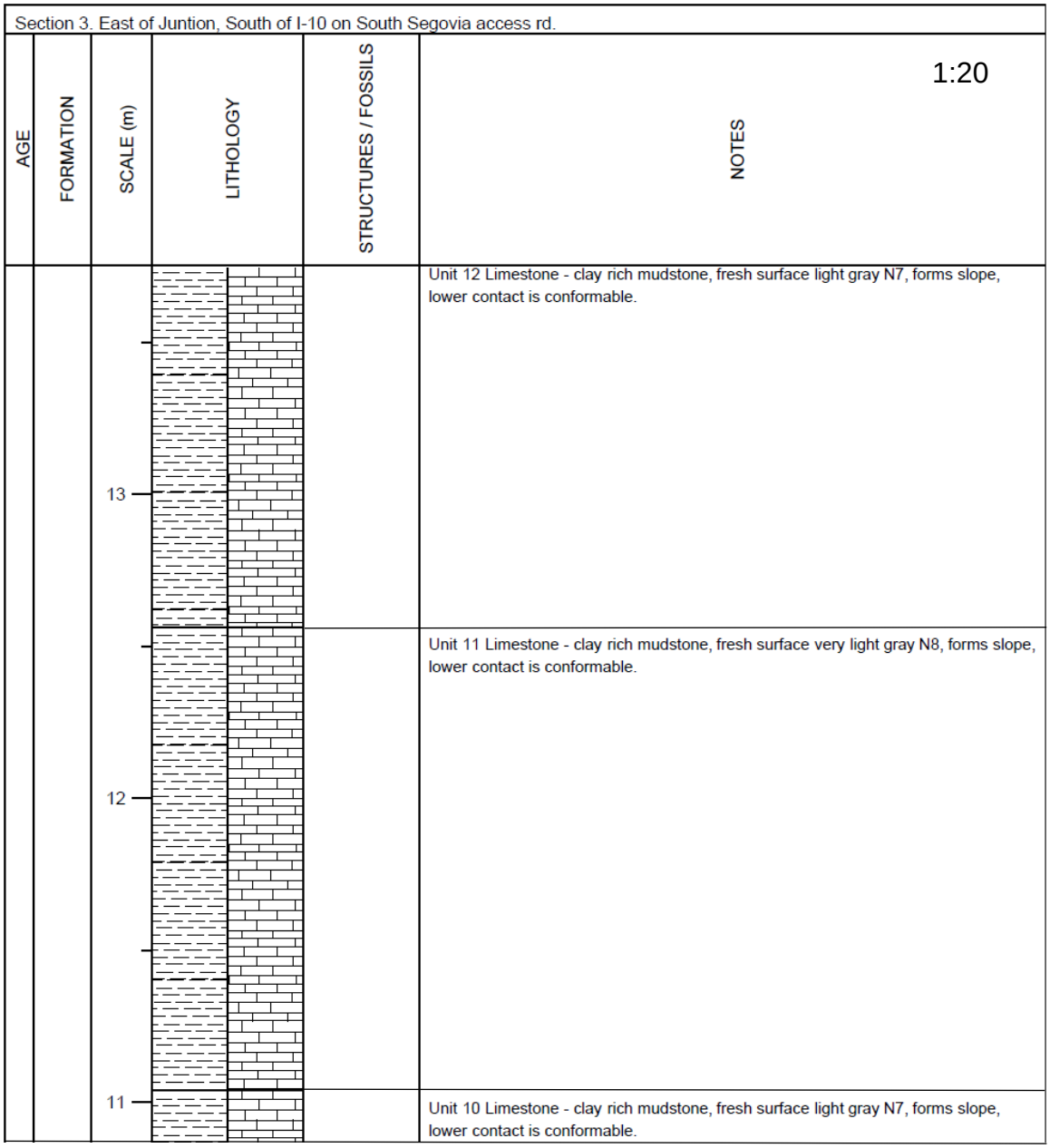

Figure 79. Section 3, part 2. 11 meter - 14 meter. Walnut Fm. Units 10-11. Lat: N 30.4261 Long: 99.6842 W

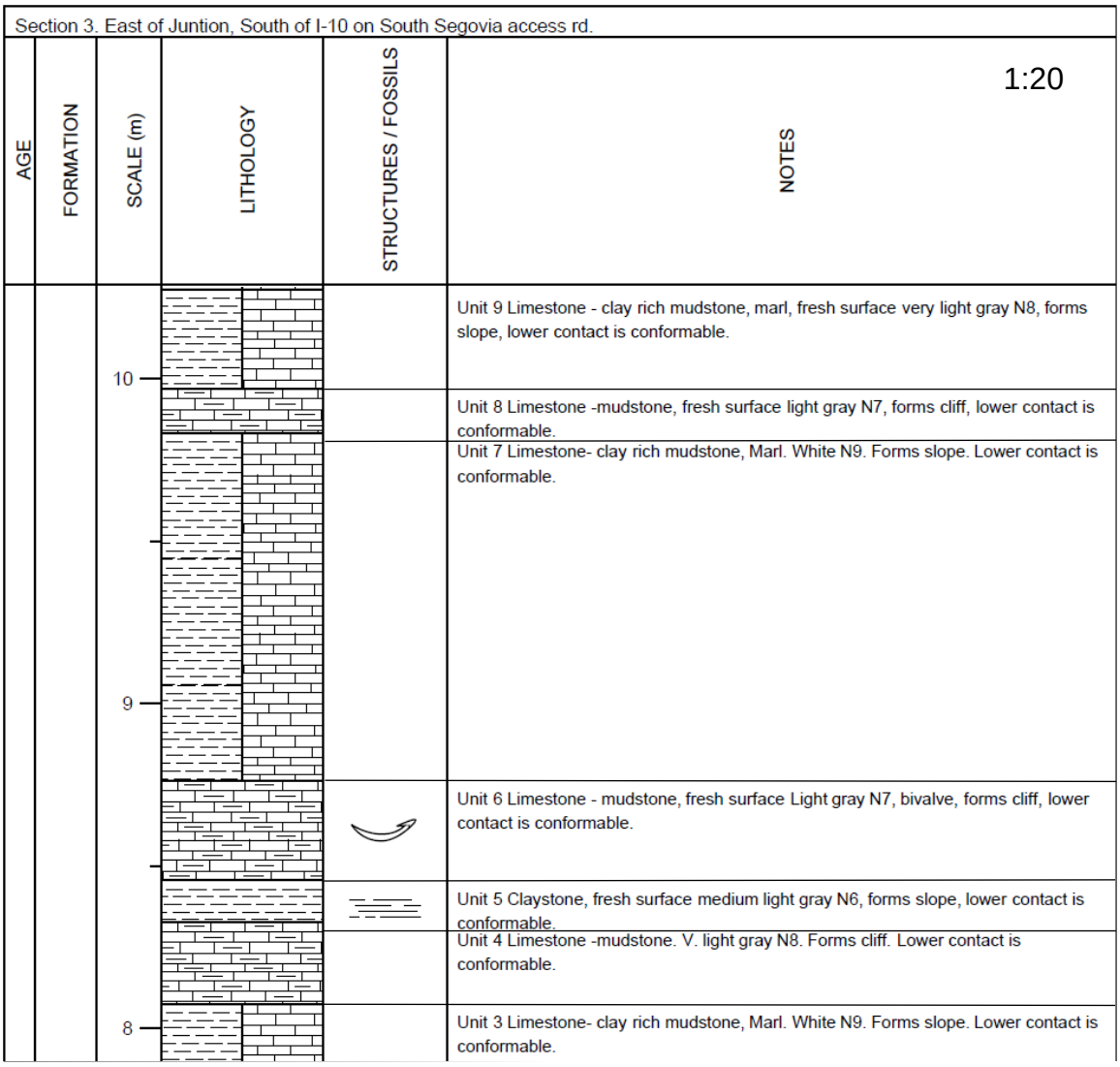

Figure 80. Section 3, part 3. 8 meters - 10 meters. Walnut Fm. Units 10-12. Lat: N 30.4261 Long: 99.6842 W

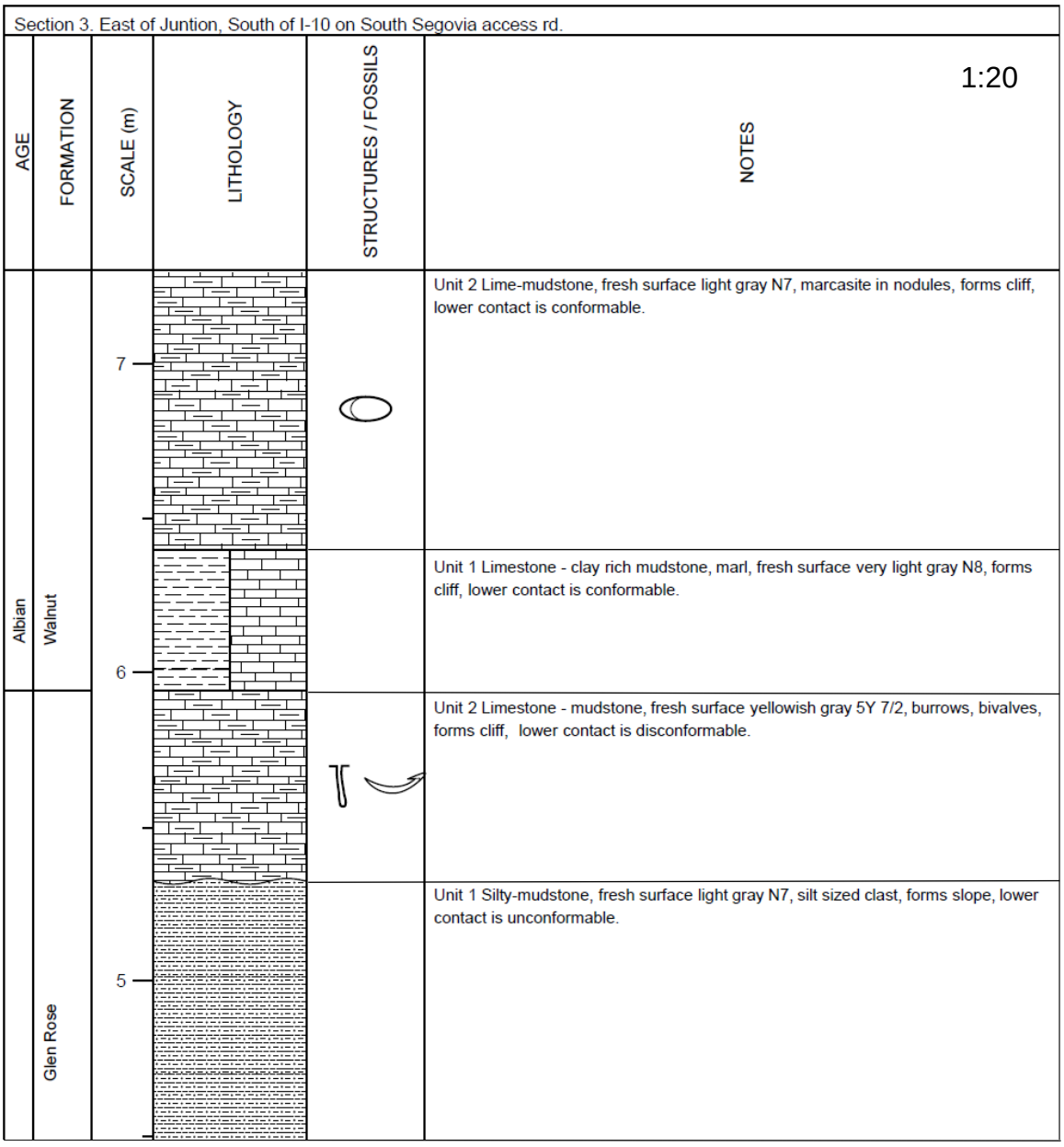

Figure 81. Section 3, part 4. 4.5 meters - 7 meters. Walnut Fm. Unit 1-2. Glen Rose Fm. Unit 1-2. Lat: N 30.4261 Long: 99.6842 W

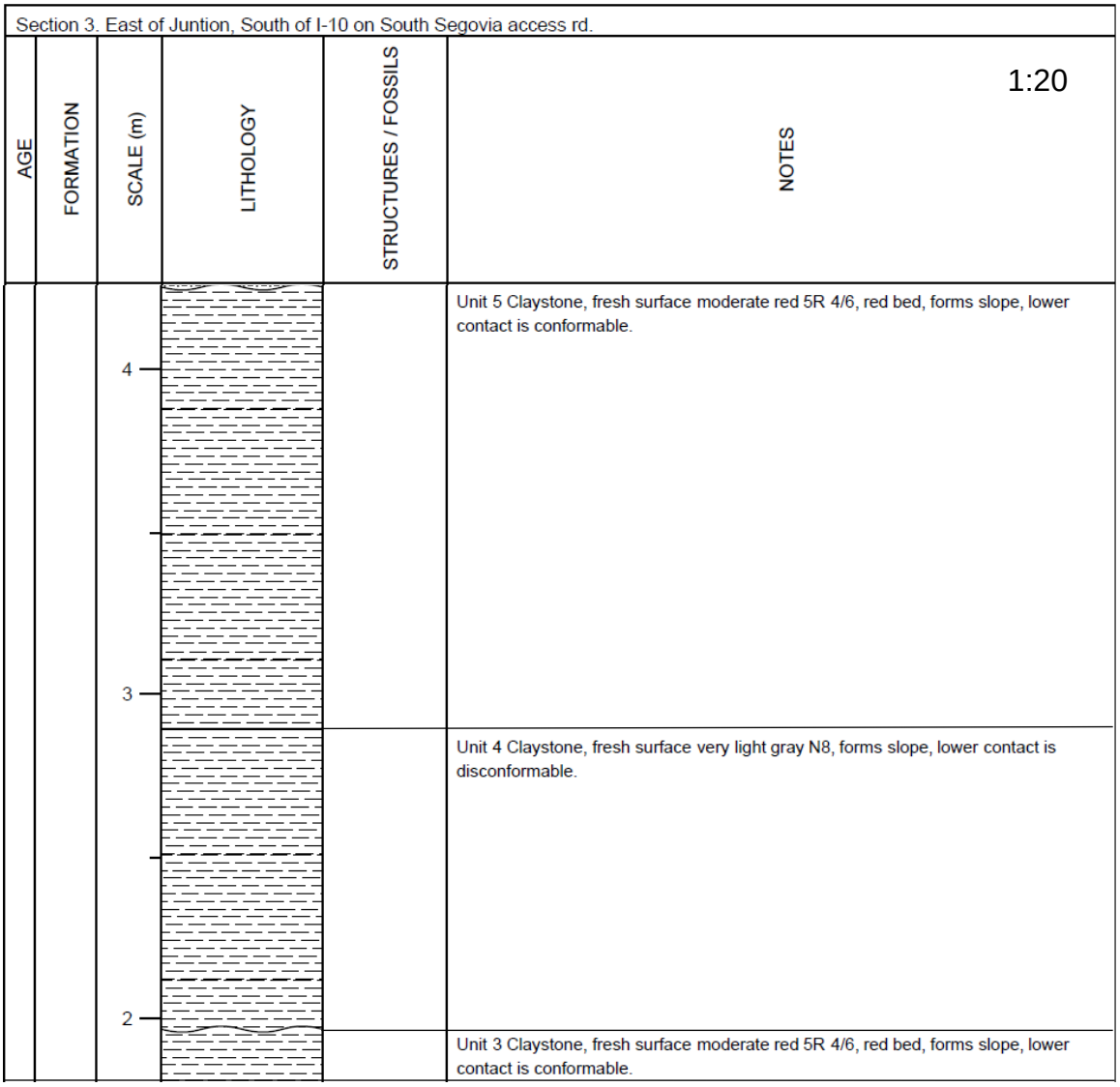

Figure 82. Section 3, part 5. 2 meters – 4.5 meters. Hensel Fm. Unit 3-5. Lat: N 30.4261 Long: 99.6842 W

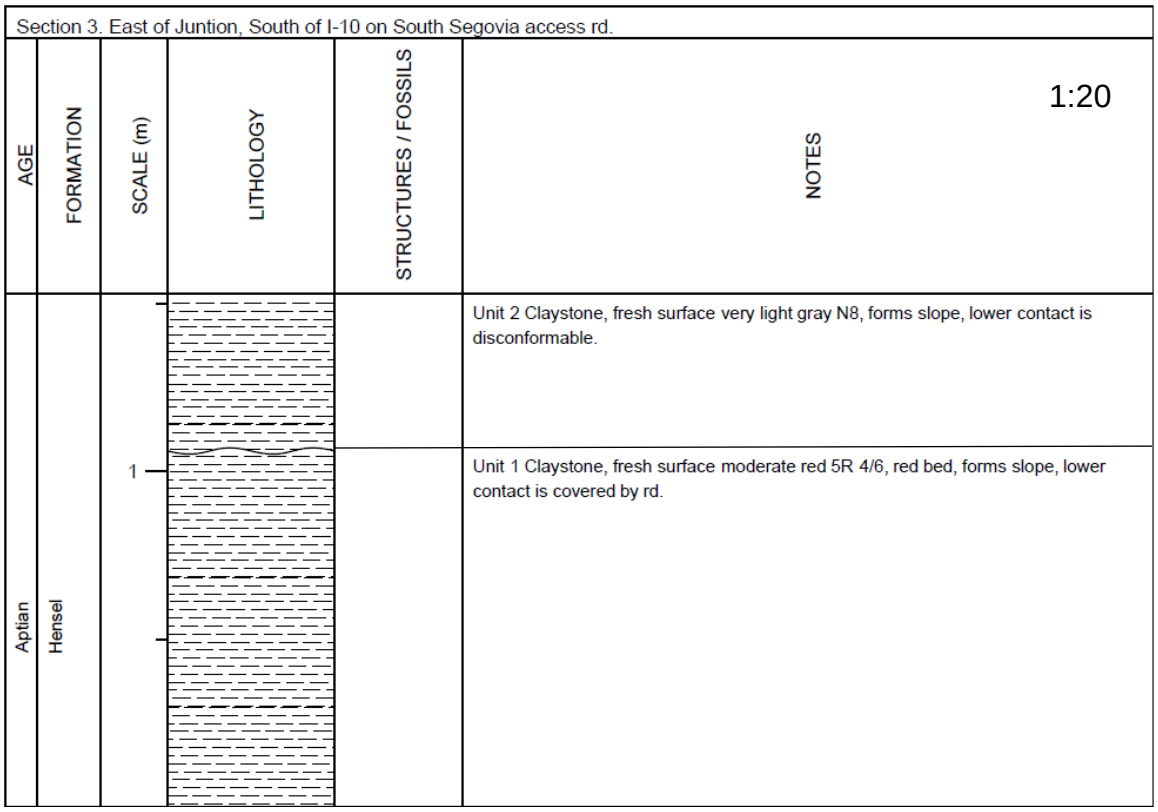

Figure 83. Section 3, part 6. 0 meters – 1.5 meters. Hensel Fm. Unit 1-2. Lat: N 30.4261 Long: 99.6842 W

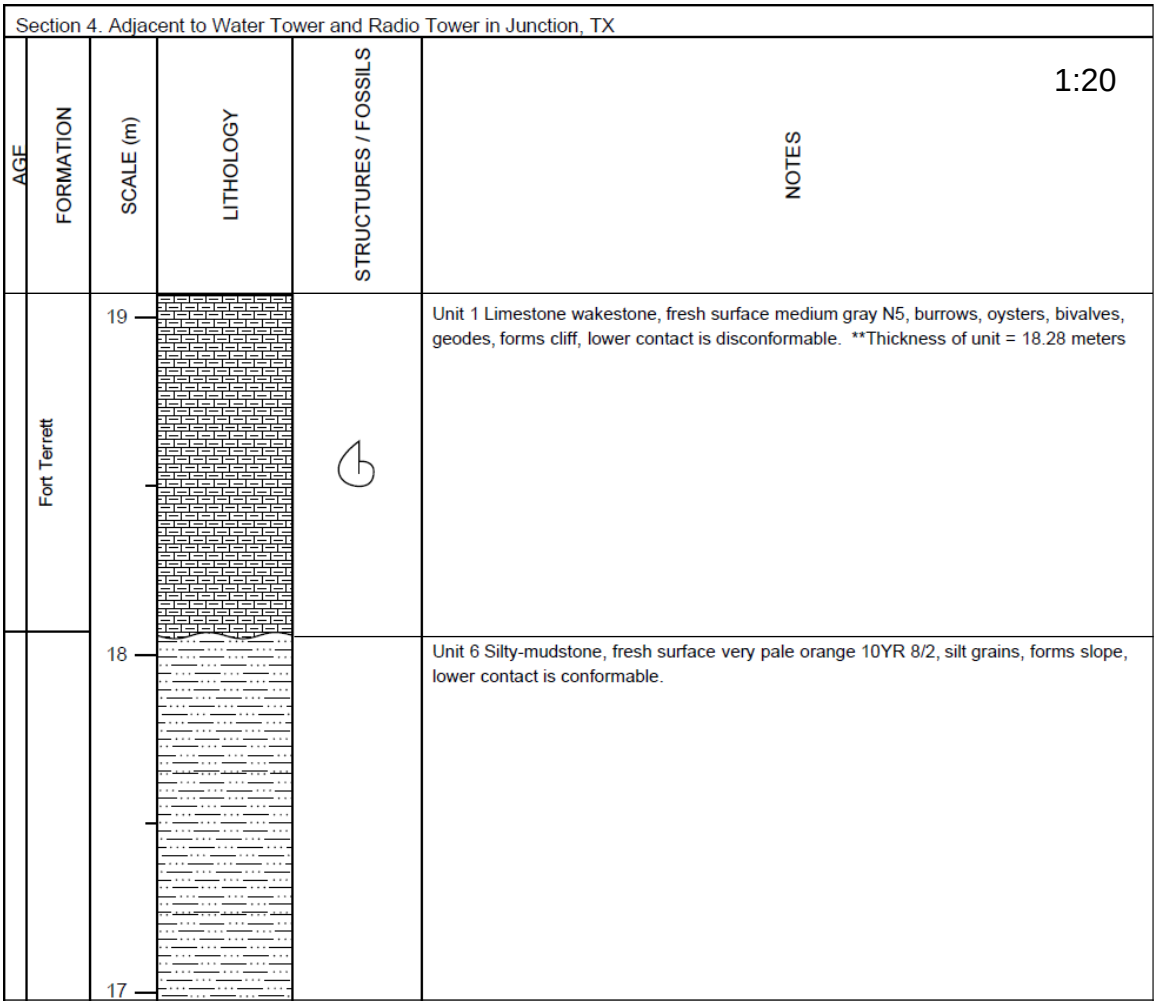

Figure 84. Section 4, part 1. 17 meters to 19 meters. Shows Walnut Fm. Unit 6 and Fort Terrett Fm. Unit 1. Lat: N 30.48982 Long: 99.78313

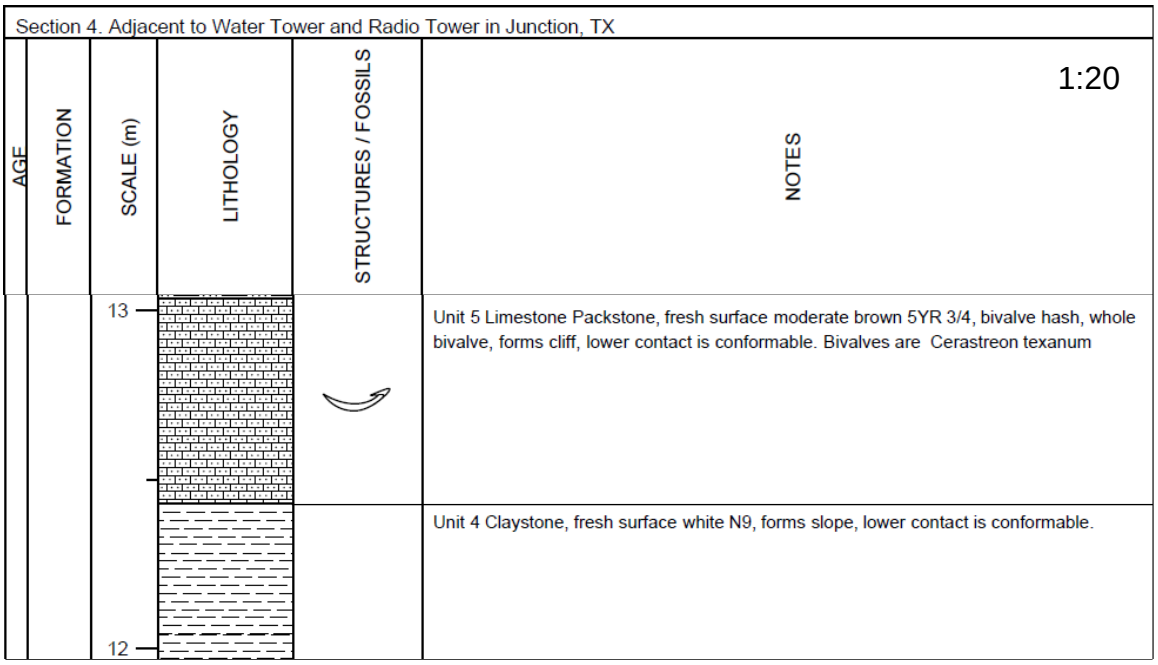

Figure 85. Section 4, part 2. 12 meters to 13 meters. Shows Walnut Units 4-5 Lat: N 30.48982 Long: 99.78313

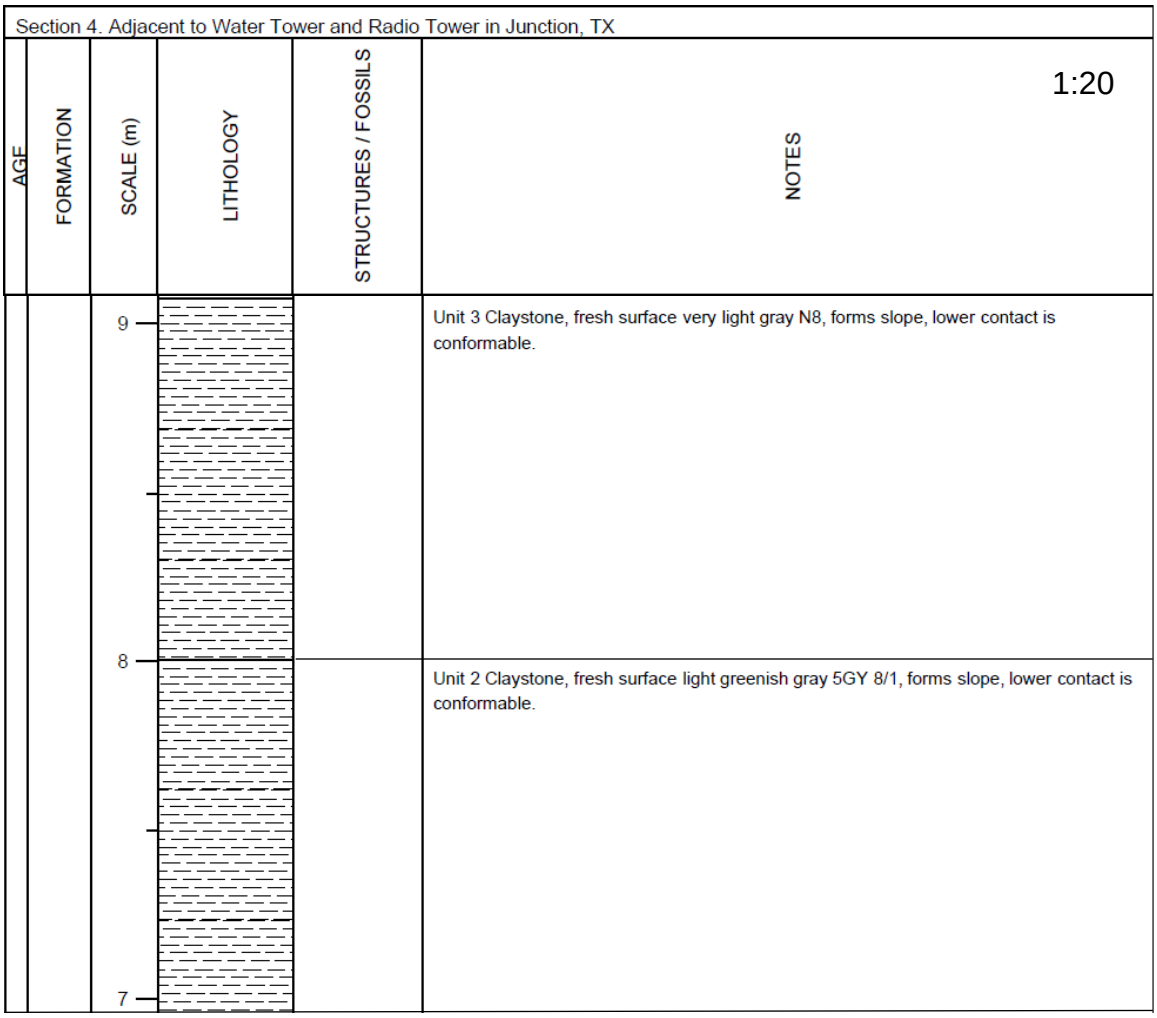

Figure 86. Section 4, part 3. 7 meters to 9 meters. Walnut Fm. Unit 2-3. Lat: N 30.48982 Long: 99.78313

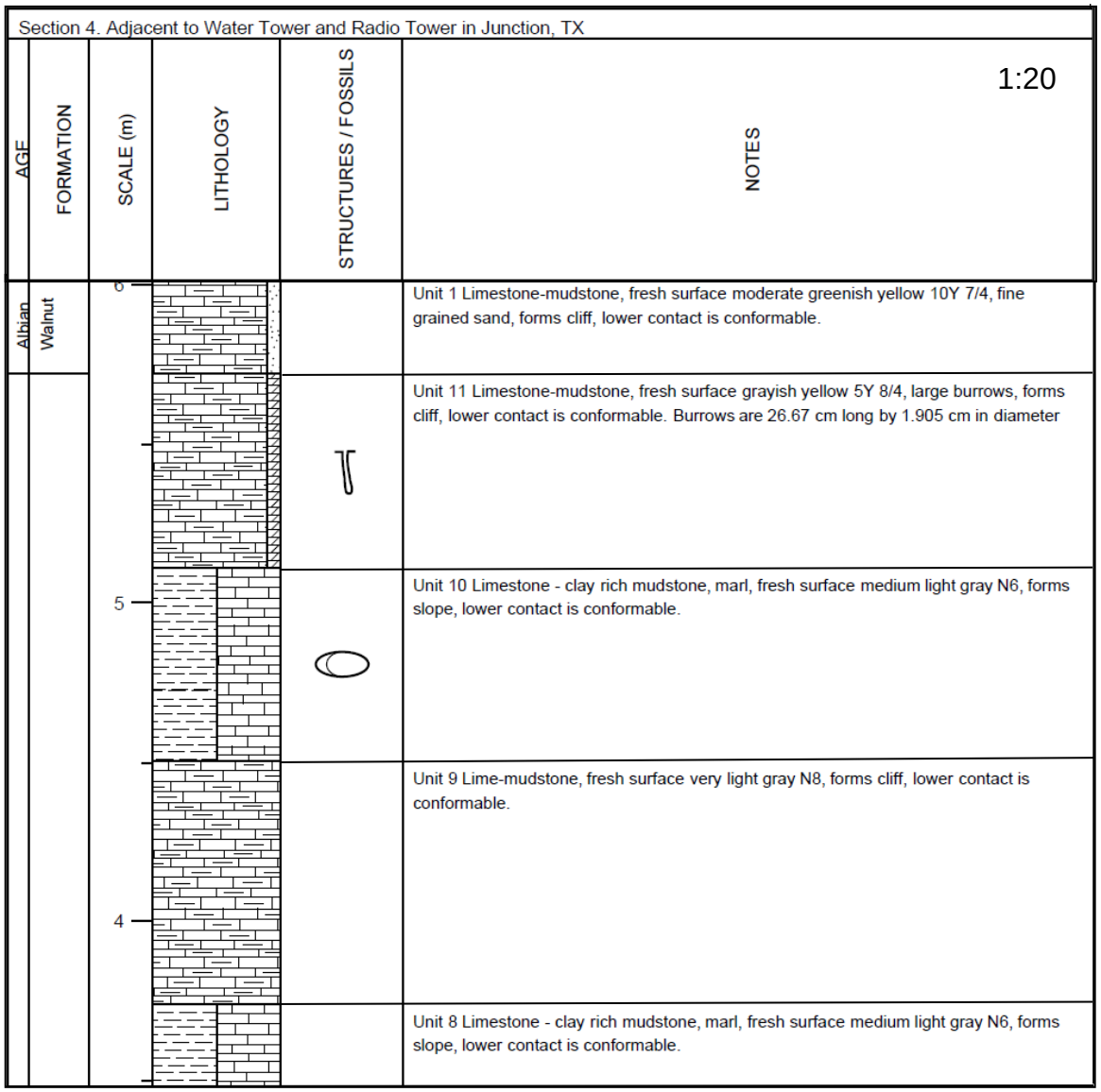

Figure 87. Section 4 part 4. 3.5 meters - 6 meters. Glen Rose Fm. Units 8-11, Walnut Fm. Unit 1.Lat: N 30.48982 Long: 99.78313

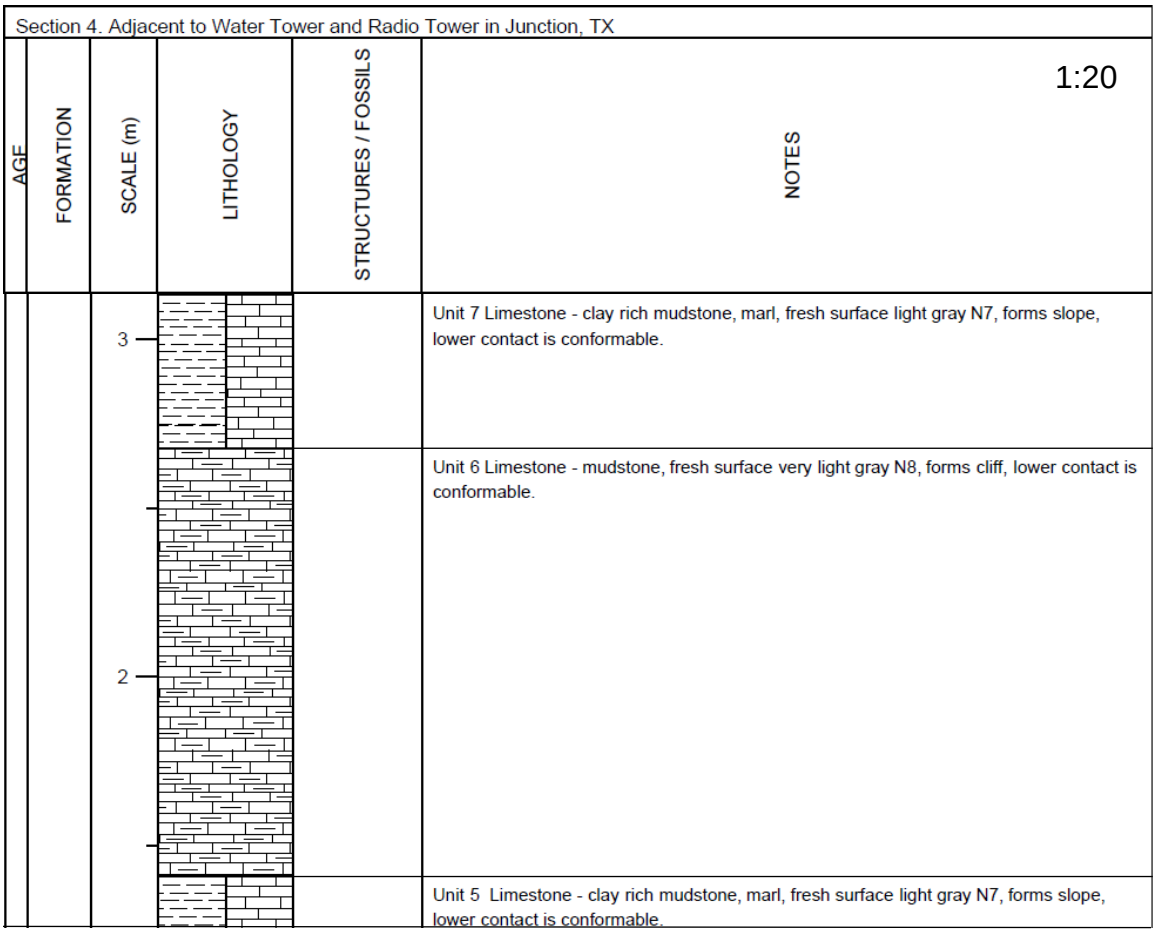

Figure 88. Section 4 part 4. 1.5 meters - 3 meters. Glen Rose Fm. Units 5-7. Lat: N 30.48982 Long: 99.78313

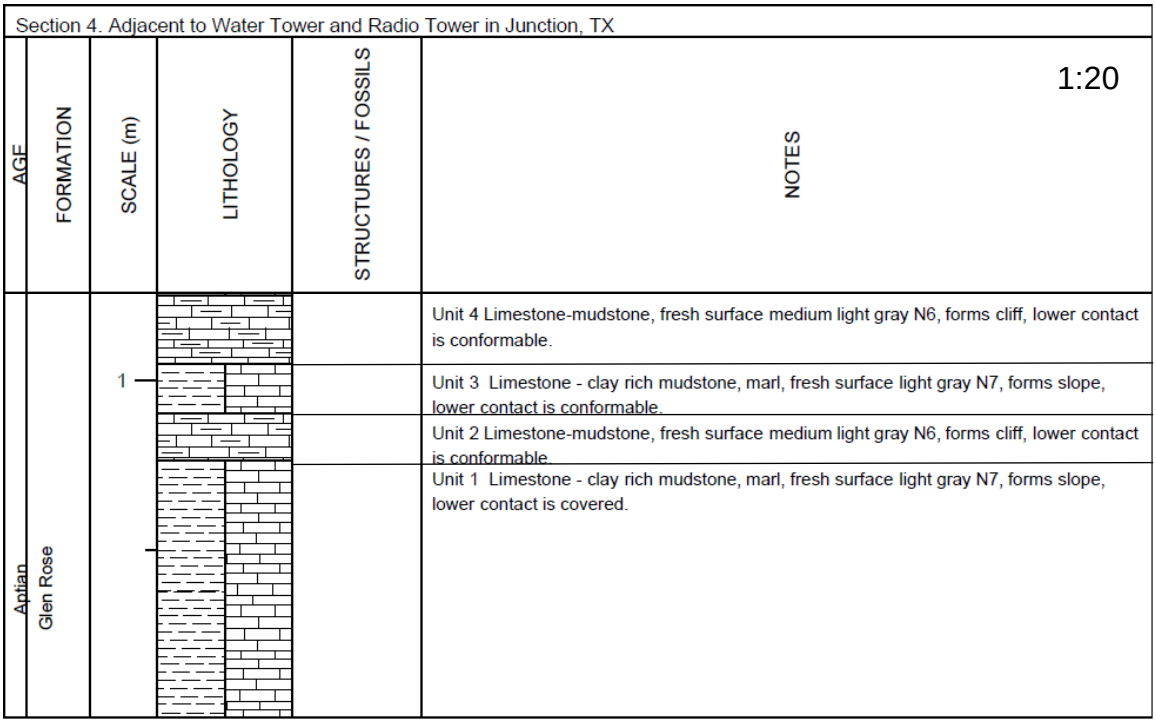

Figure 89. Section 4 part 4. 0 meters – 1.5 meters. Glen Rose Fm. Units 1-4, Lat: N 30.48982 Long: 99.78313

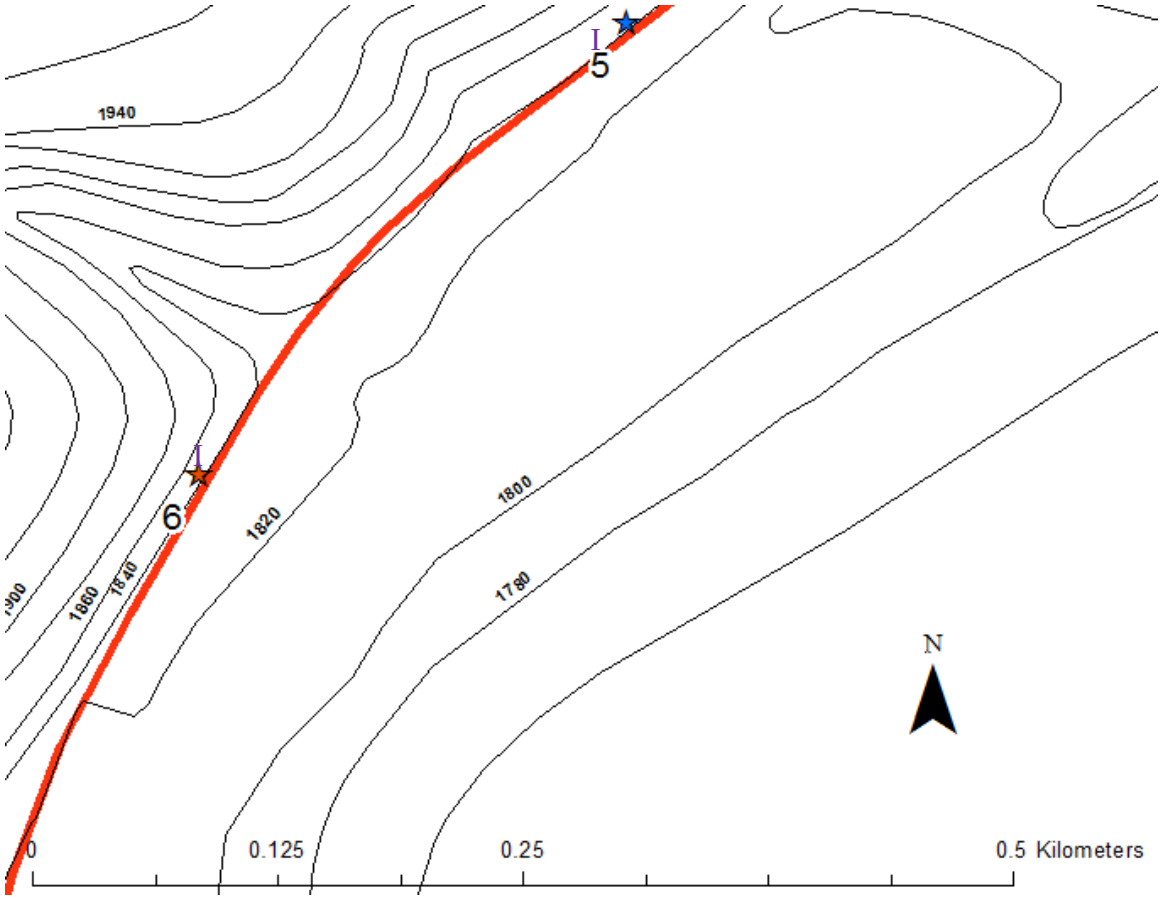

Figure 90. Section 5 and Section 6 locations.

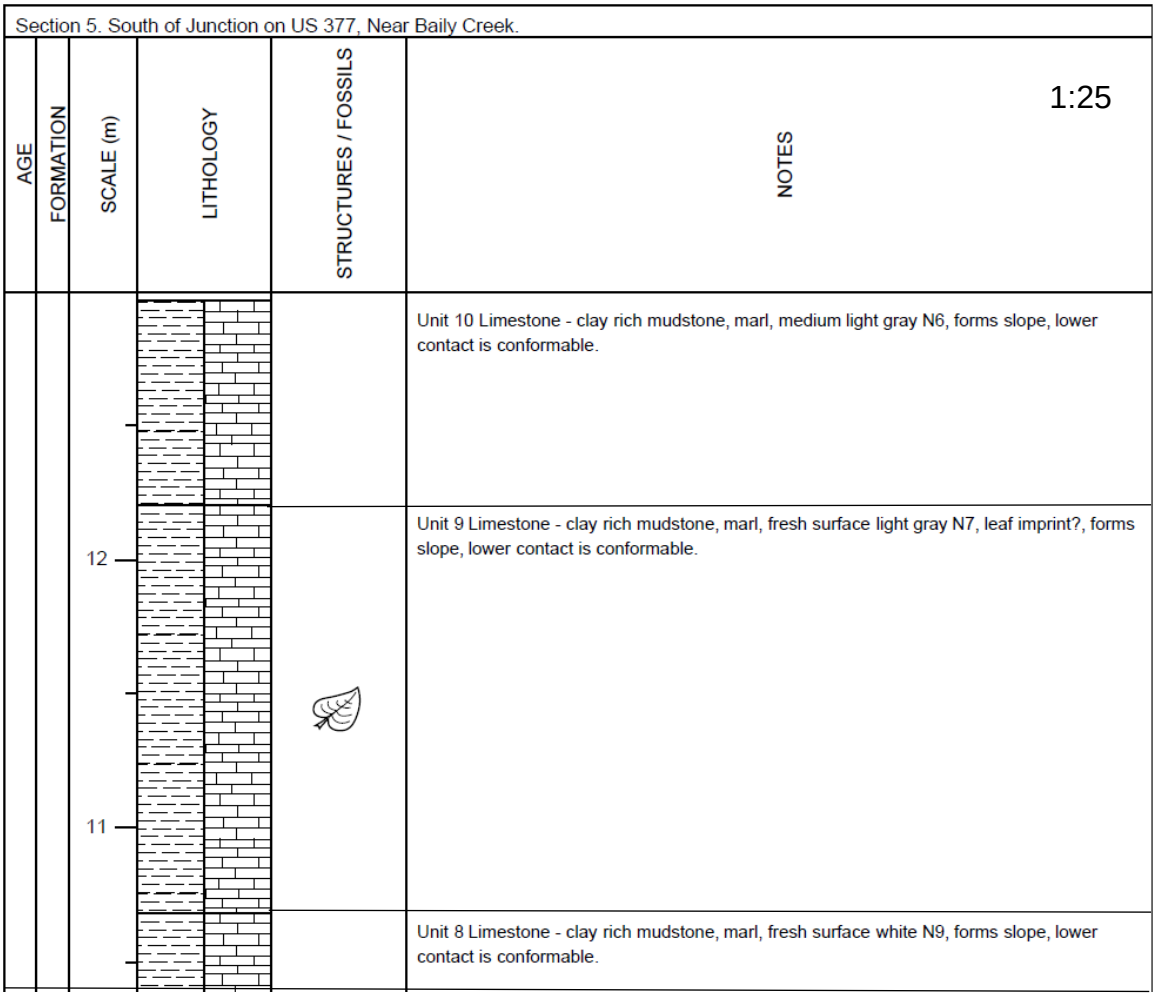

Figure 91. Section 5 part 1. 10.5 meters – 13 meters. Glen Rose Fm. Units 8-10. Lat: N 30.39325 Long: 99.88742 W

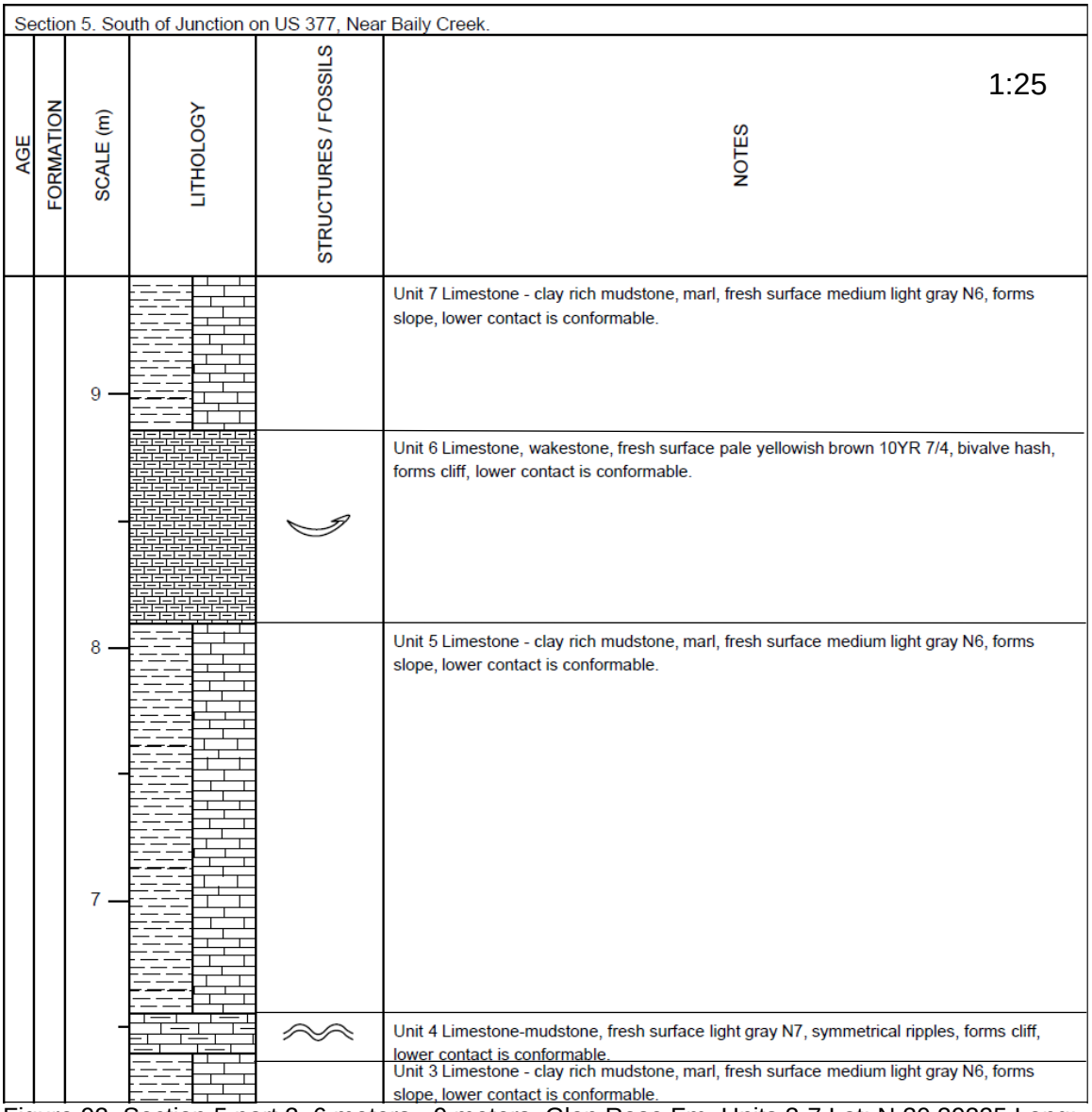

Figure 92. Section 5 part 2. 6 meters - 9 meters. Glen Rose Fm. Units 3-7.Lat: N 30.39325 Long: 99.88742 W

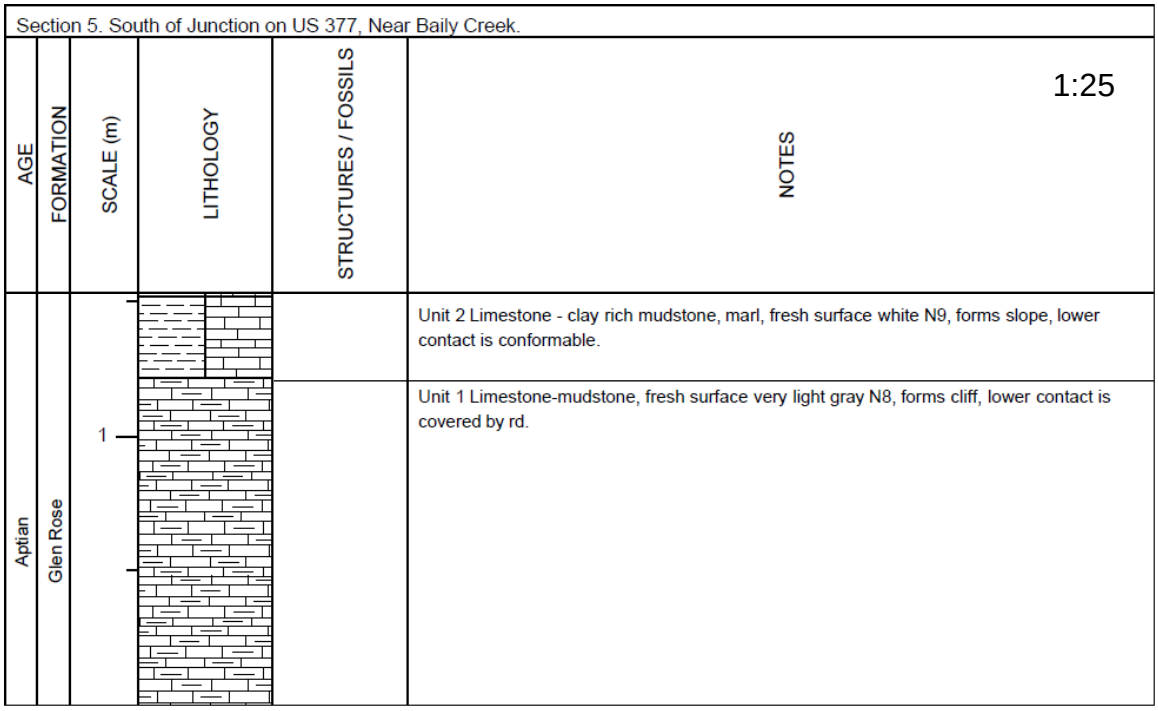

Figure 93. Section 5 part 3. 0 meters - 2 meters. Glen Rose Fm. Units 1-2. Lat: N 30.39325 Long: 99.88742 W

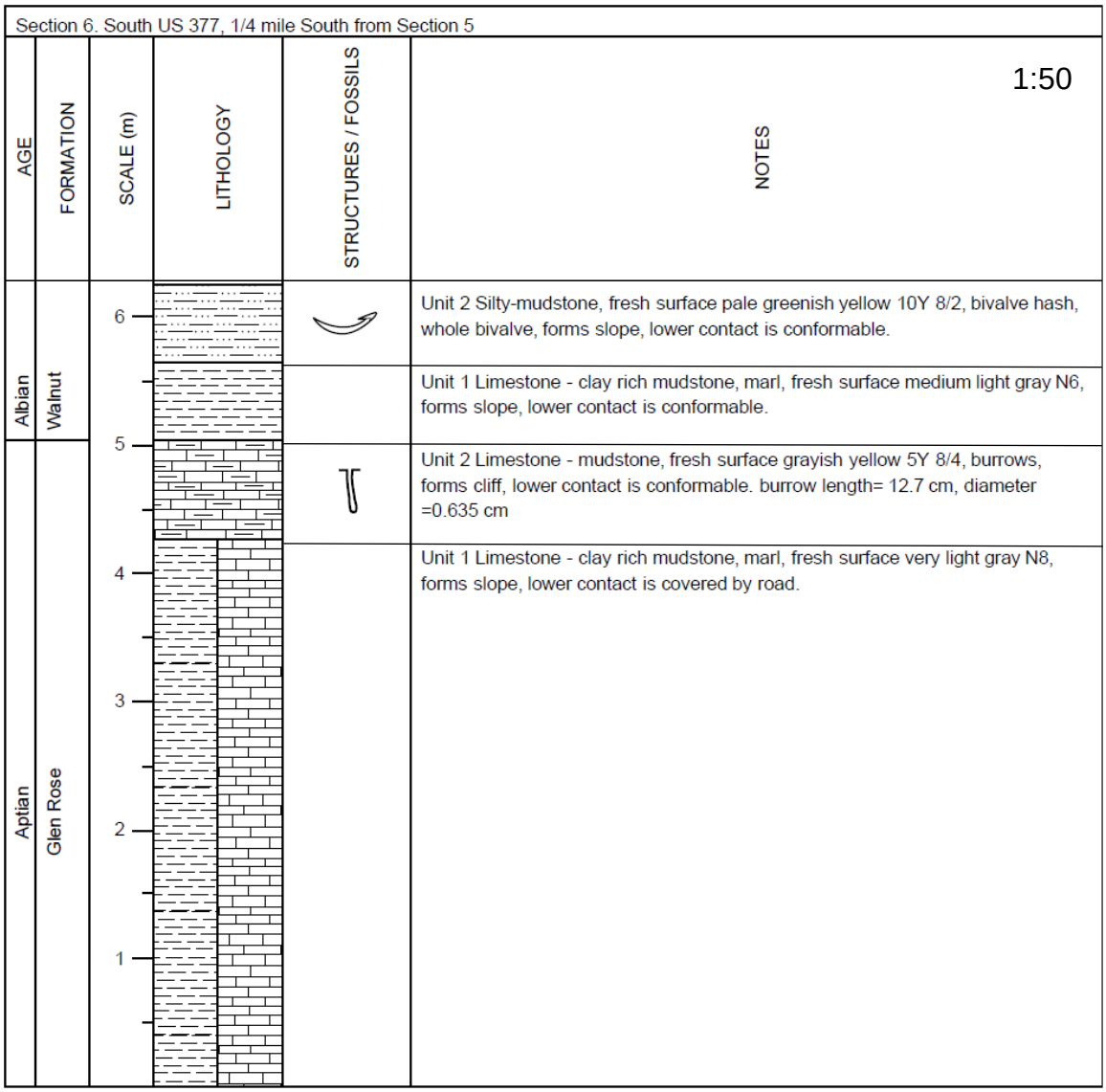

Figure 94. Section 6. 0 meters – 6 meters Glen Rose Fm. Unit 1-2. and Walnut Fm. Unit 1-2. Lat: N 30.39121 Long: 99.88942 W

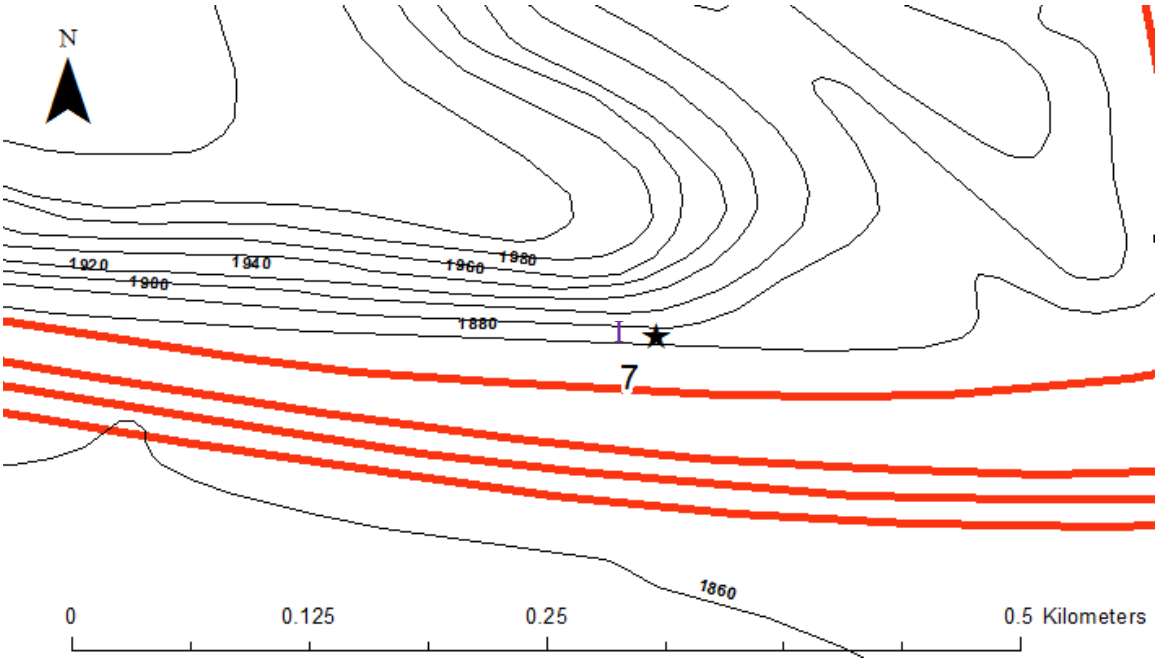

Figure 95. Section 7 location.

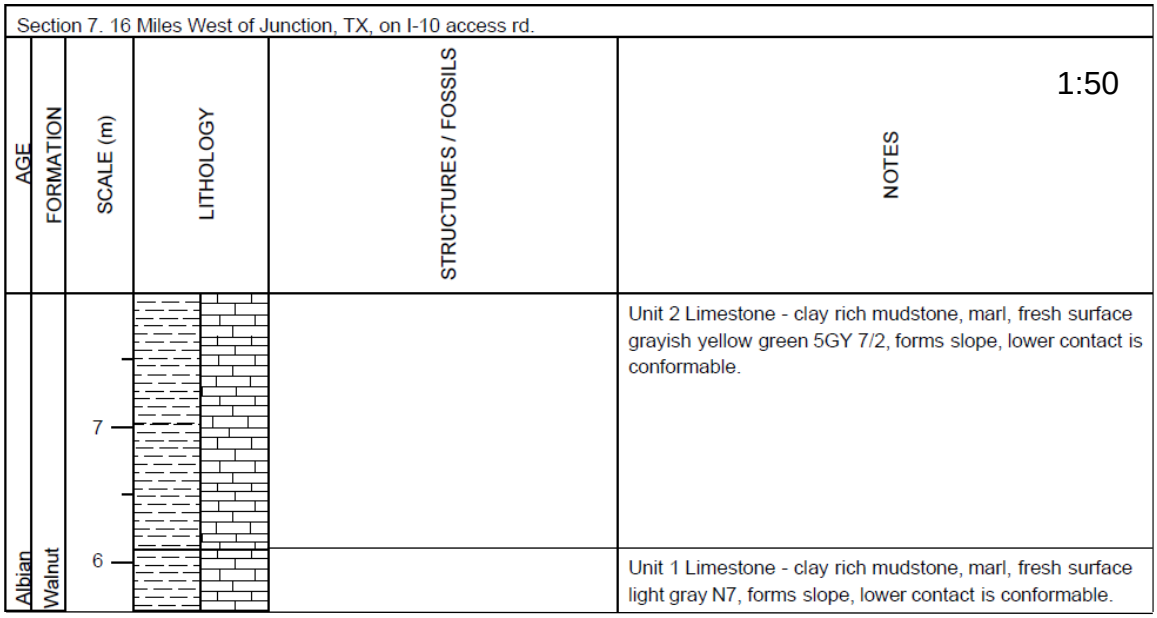

Figure 96. Section 7. 5.5 meters – 8 meters. Walnut Fm. Unit 1-2. Lat: N 30.4954 Long: 99.9943 W

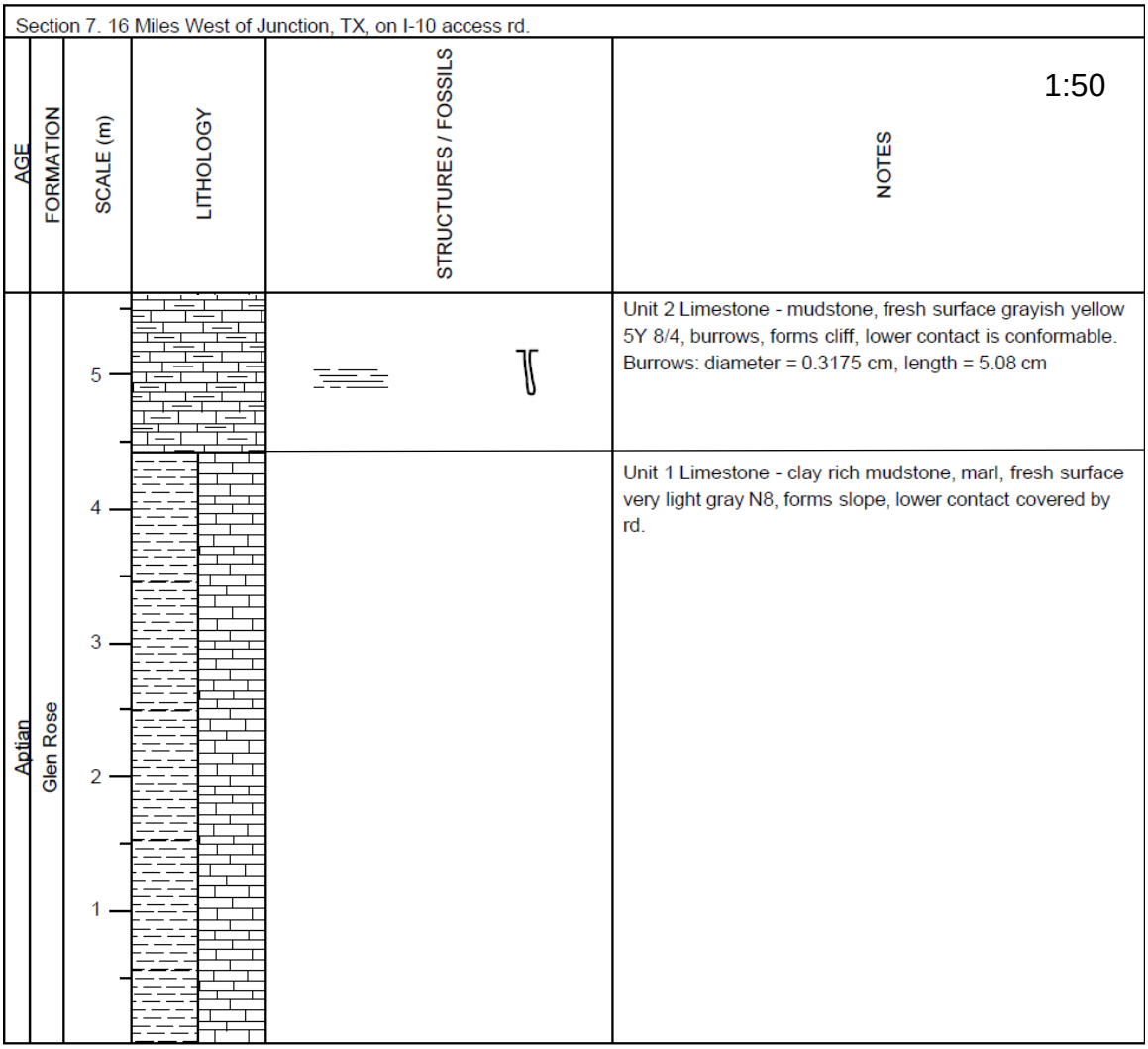

Figure 97. Section 7. 0 meters – 5.5 meters. Glen Rose Fm. Unit 1-2. Lat: N 30.4954 Long: 99.9943 W

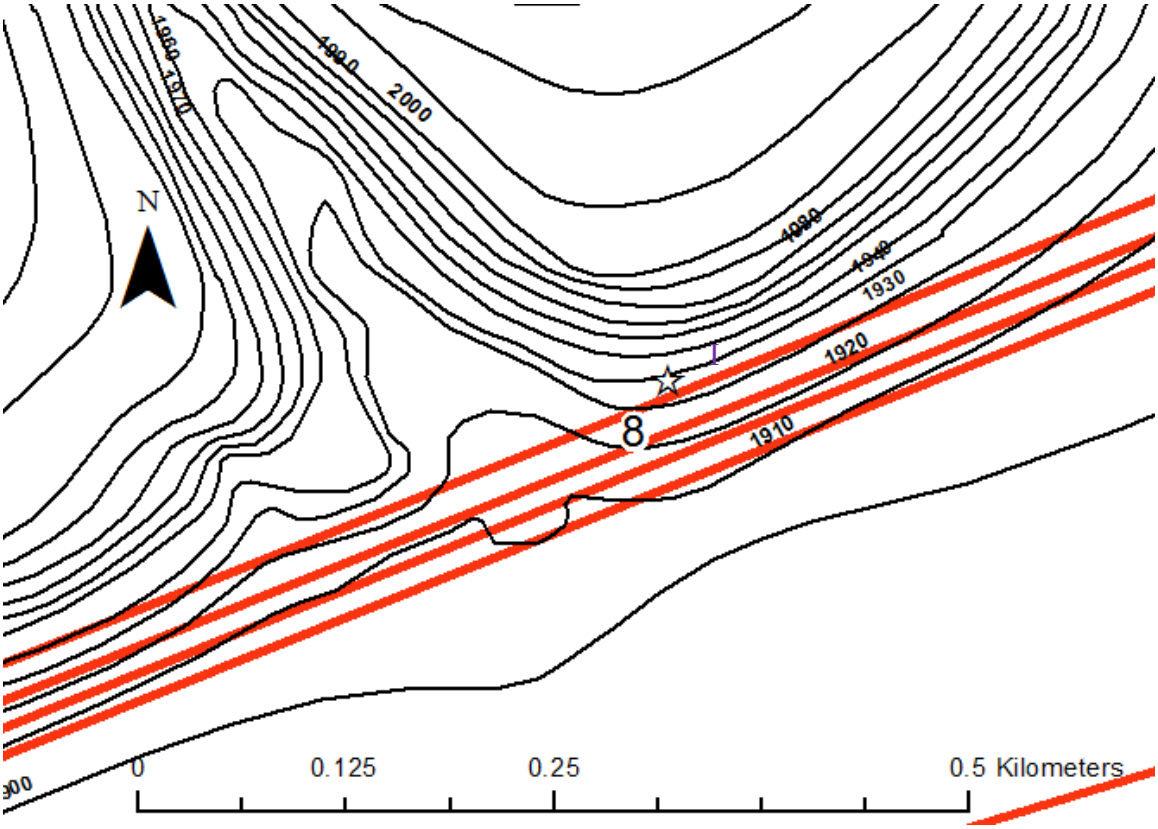

Figure 98. Section 8 location.

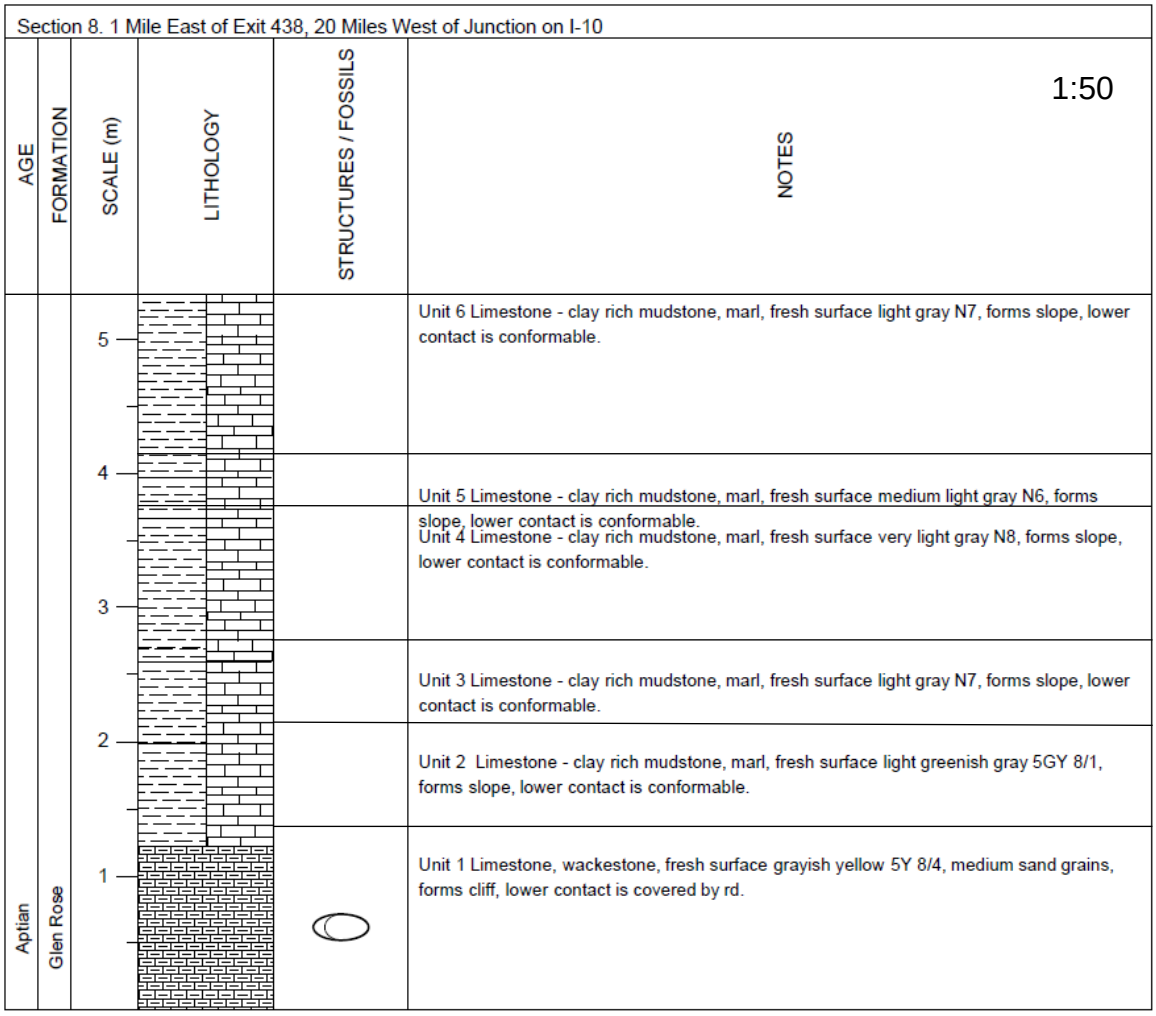

Figure 99. Section 8. Glen Rose Fm. 0 meters – 5.5 meters. Units 1-6. Lat: N 30.4907 Long: 100.0296 W

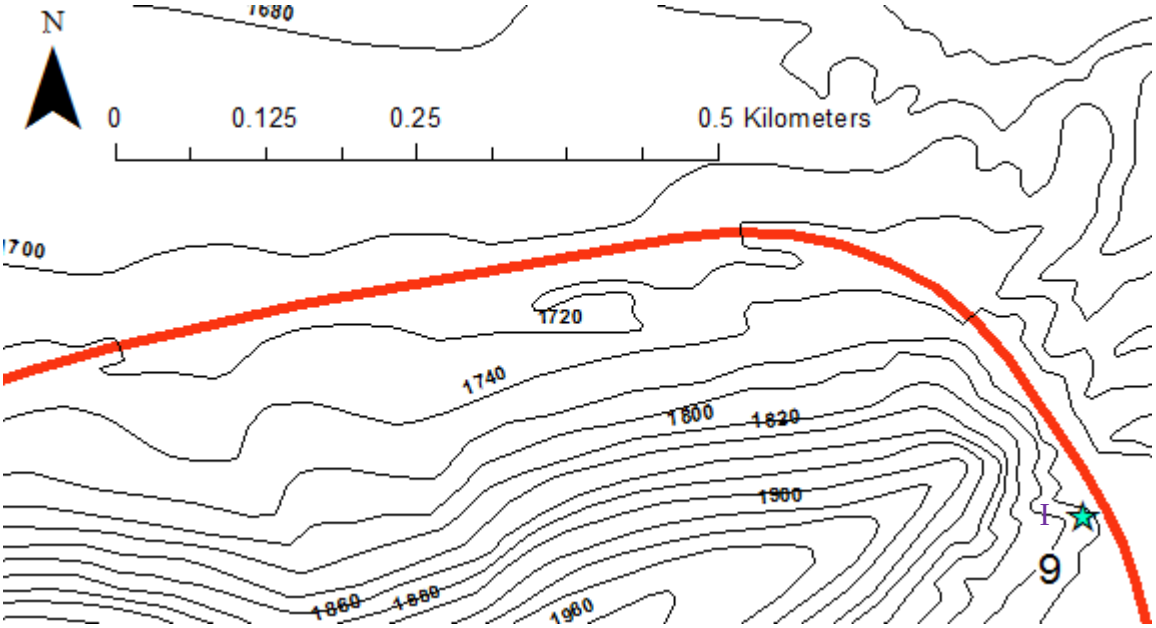

Figure 100. Section 9 location

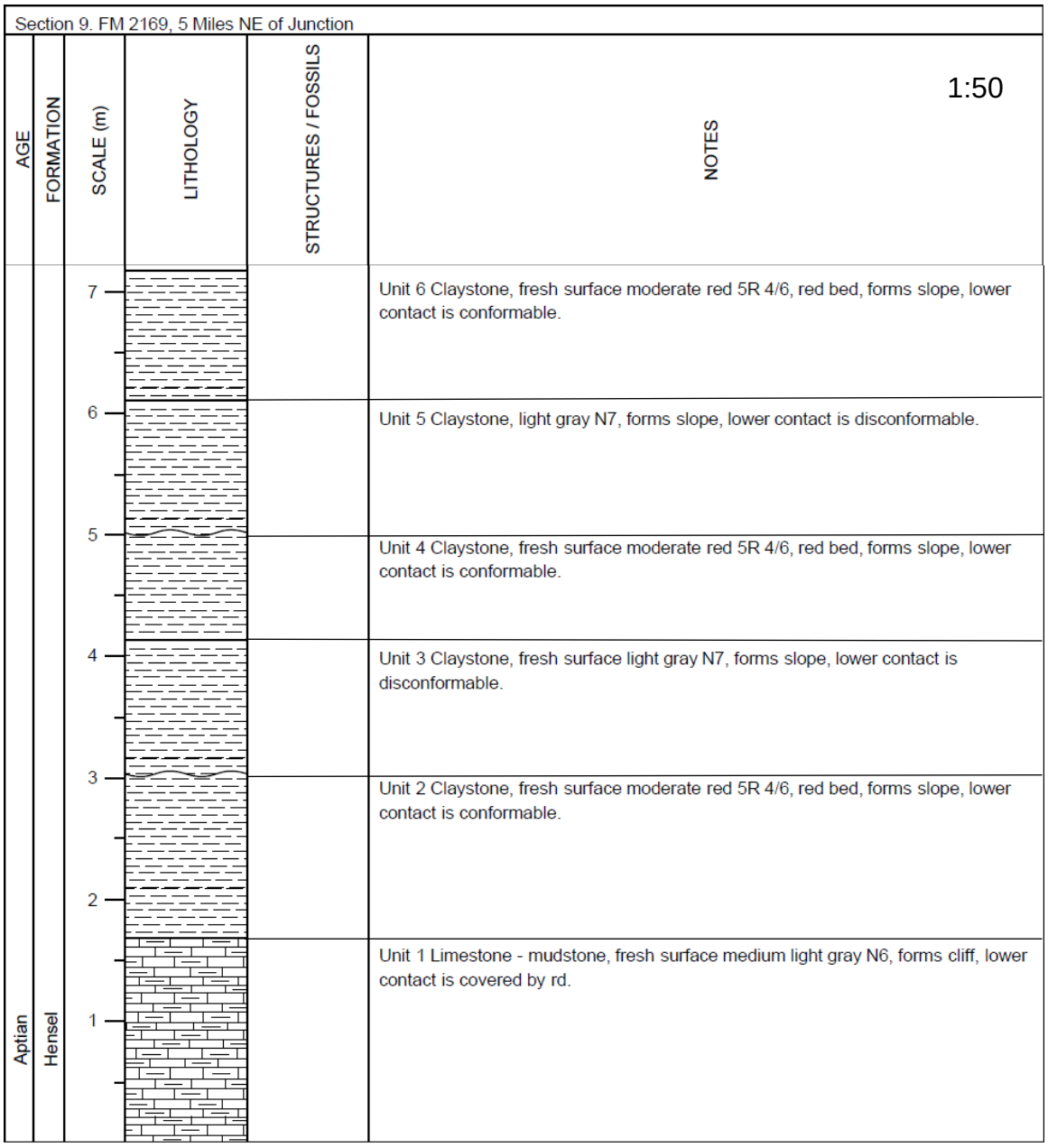

Figure 101. Section 9. Hensel Fm. 0 meters – 7 meters. Units 1-6. Lat: N 30.4943 Long: 99.6971 W

Sample A09-001-Section 3-Walnut Fm.-Unit-6

Dominate bioclast grains are bivalve, green algae, pisoid, and calpionellid. Other allochems include calcite, marcasite, quartz, and glauconite. Sorting is moderate. Cavity structures are fenestral, frature, and vuggy. Porosity is intergranular (figure 102).

Sample A09-002-Section 3-Walnut Fm.-Unit 14

The dominate bioclast grains are bivalve. Other allochems are marcasite and quartz. Quartz grains range from silt-to sand size grains. Sorting is moderate. Cement is calcite. Porosity is intergranular and fracture. Folk classification is a silty fossiliferous micrite (figure 103).

Sample A09-003-Section 4- Glen Rose Fm.-Unit 2

Dominate bioclast grains are bivalves, green algae, milloid, and calcispheres. Other allochems are glauconite, marcasite, quartz, and calcite. Quartz is silt to sand sized. Sorting is moderate. Cavity structures are fenestral and channel. Evidence for compaction is a stylolite that cuts through entire sample. Porosity is fenestral. Folk classification is fossiliferous micrite (figure 104).

Sample A09-004-Section 4- Glen Rose Fm.-Unit 4

Dominate grains are quartz, marcasite, and calcite. Quartz grains are silt size and rounding is subrounded - subangular. Sorting is moderate. Cavity structure is channel. Cement is silica. Evidence for compaction is stylolites. Contains intergranular porosity. Folk classification is micrite. Depositional facies is interpreted as lagoon (figure 105).

Sample A09-005- Section 4- Glen Rose Fm.-Unit 6

Dominate bioclast are forams (milloid, trochoids), bivalve, green algae, calpionellids, pisoids, and calcispheres. Other allochems are quartz, calcite, glaconite, feldspar, and marcasite. Quartz grains are silt size, rounded to subrounded. Sorting is moderate. Cavity structures are vugs. Porosity is intergranular. Folk classification is fossiliferous micrite. Depositional facies is lagoonal (figure 106).

Sample A09-006- Section 4- Walnut Fm.-Unit 1

Dominate bioclasts are forams (milloid), peloids, green algae, and calpionellids. Other allochems are quartz, marcasite, calcite, feldspar. Quartz grains are silt size, and are rounded to subrounded. Sorting is moderate. Cavity structures are fenestral. Porosity is intergranular. Folk classification is silty fossiliferous micrite. Depositional facies is shallow shelf (figure 107).

Sample A09-007- Section 4- Walnut Fm.-Unit 5

The bioclast grains are bivalves. Other allochems are quartz, marcasite, and calcite. Quartz grains are silt size and are rounded to subrounded. Sorting is moderately well. A bivalve shell is replaced by hematite. Evidence for compaction is that some shells are broken and quartz grains are pressed into the shells (figure A-108).

Sample A09-008- Section 5- Glen Rose Fm.-Unit 1

Dominate bioclast grains are peloids and green algae. Other allochems are quartz, marcasite and calcite. Quartz grains are silt size and rounded to subangular. Sorting is well sorting. Porosity is absent. Folk classification is micrite. The depositional environment is lagoonal (figure 109).

Sample A09-009- Section 5- Glen Rose Fm.-Unit 4

Dominate bioclast are forams (milloids), green algae, and calcisphere. Other allochems are quartz, marcasite, glauconite, and calcite. Quartz grains are silt sized and rounded to subangular. Sorting is moderately well. Porosity is intergranular. Folk classification is fossiliferous micrite. Depositional environment is lagoon (figure 110).

Sample A09-010- Section 5- Glen Rose Fm.-Unit 6

Dominate bioclast are bivalves and forams (milloids). Other allochems are quartz, and calcite. Quartz grains are silt sized and are rounded to subrounded. Sorting is moderate. Cavity structures are vuggy and channel. Porosity is intergranular, fracture, and shelter. Folk classification is packed biomicrite. Depositional environment is shallow marine (figure 111).

Sample A09-011- Section 7- Glen Rose Fm.-Unit 2

Dominate allochems are quartz, calcite, glauconite, and marcasite. Quartz grains are silt sized and rounded to subrounded. Sorting is very well. Cavity structures are vuggy, fenestral, and channel. Porosity is inergranular and shelter. Folk classification is dismicrite. Depositional environment is lagoon (figure 112).

Sample A09-012- Section 9- Hensel Fm.-Unit 1

Dominate bioclast are forams (Trochoid, Milloid), green algae, bivalves, and calcisphere. Other allochems are quartz, feldspar, calcite, and marcasite. Quartz grains are silt sized and rounded to subrounded. Sorting is moderate. Cavity structures are channel and fenestral. Porosity is intergranular. Folk classification is fossiliferous micrite. Depositional environment is shallow shelf (figure 113)

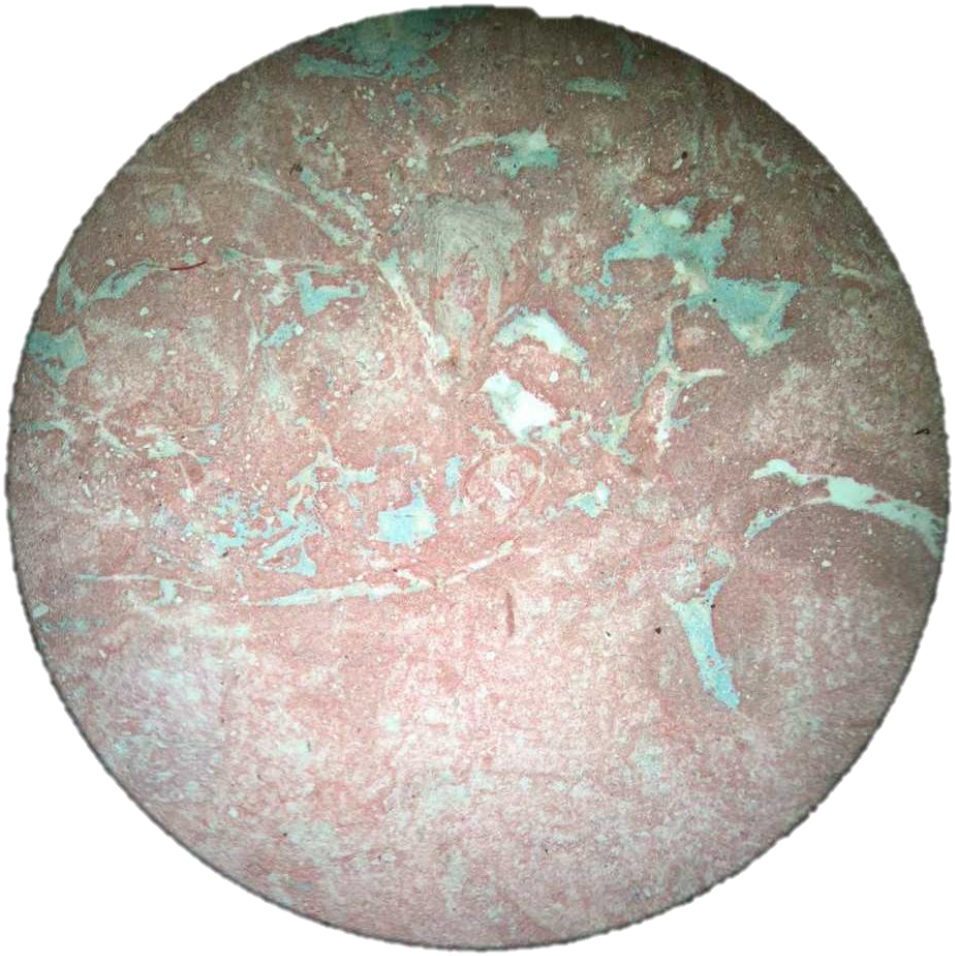

Figure 102. Sample A9-001 Section 3 Walnut Formation Unit 6. Magnification is 4x, with field of view is 1 cm. Thin section in plain light of fossiliferous biomicrite (Folk), mudstone (Dunham). B) A pie chart of a 300-point count indicates that the thin section is 78% micrite, 4% fossil, 18% porosity.

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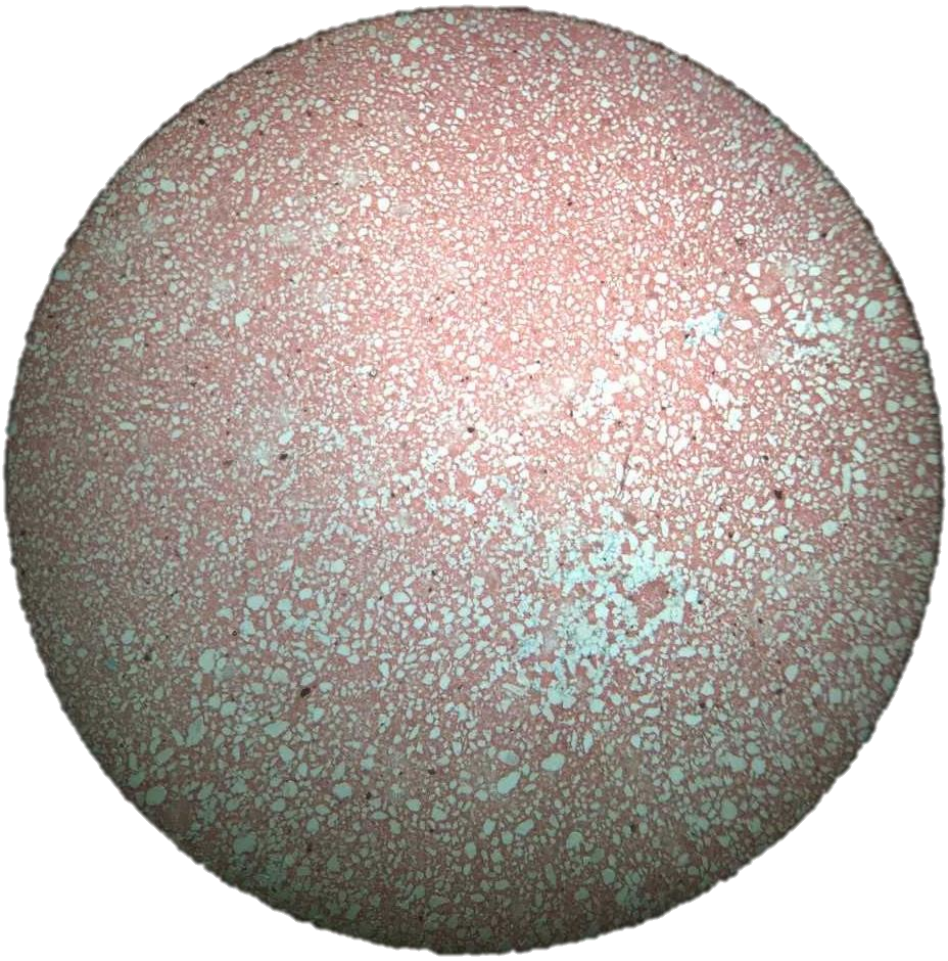

Figure 103. Sample A09-002 Section 3 Walnut Formation Unit 14. Magnification is 4x, with field of view is 1 cm. Plain light of quartz rich micrite (Folk), mudstone (Dunham). A 300-point pie chart of the thin section, 62.67% is micrite and 32.67% is quartz

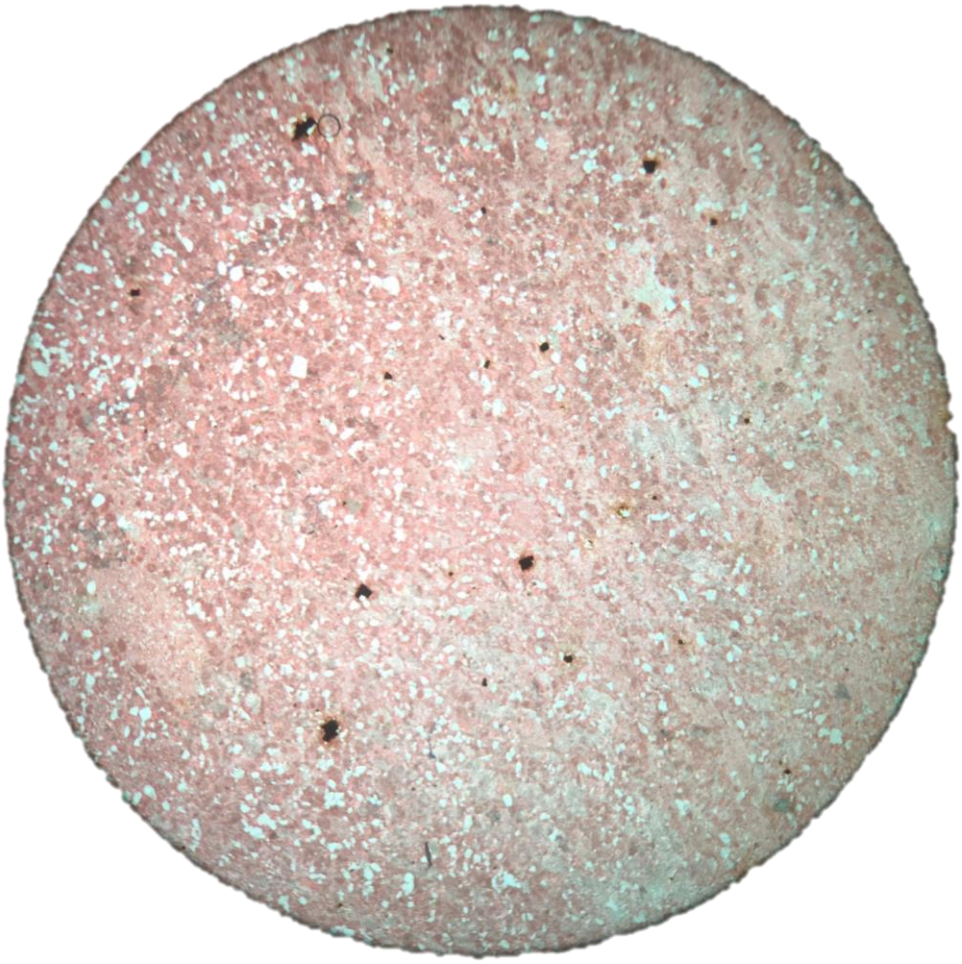

Figure 104. Sample A09-003 Section 4 Glen Rose Formation Unit 4. Magnification is 4x, with field of view is 1 cm. Thin section in plain light of fossiliferous micrite. Mudstone (Dunham). A 300-point pie chart of the thin section, 80.67% micrite, 19.33% quartz.

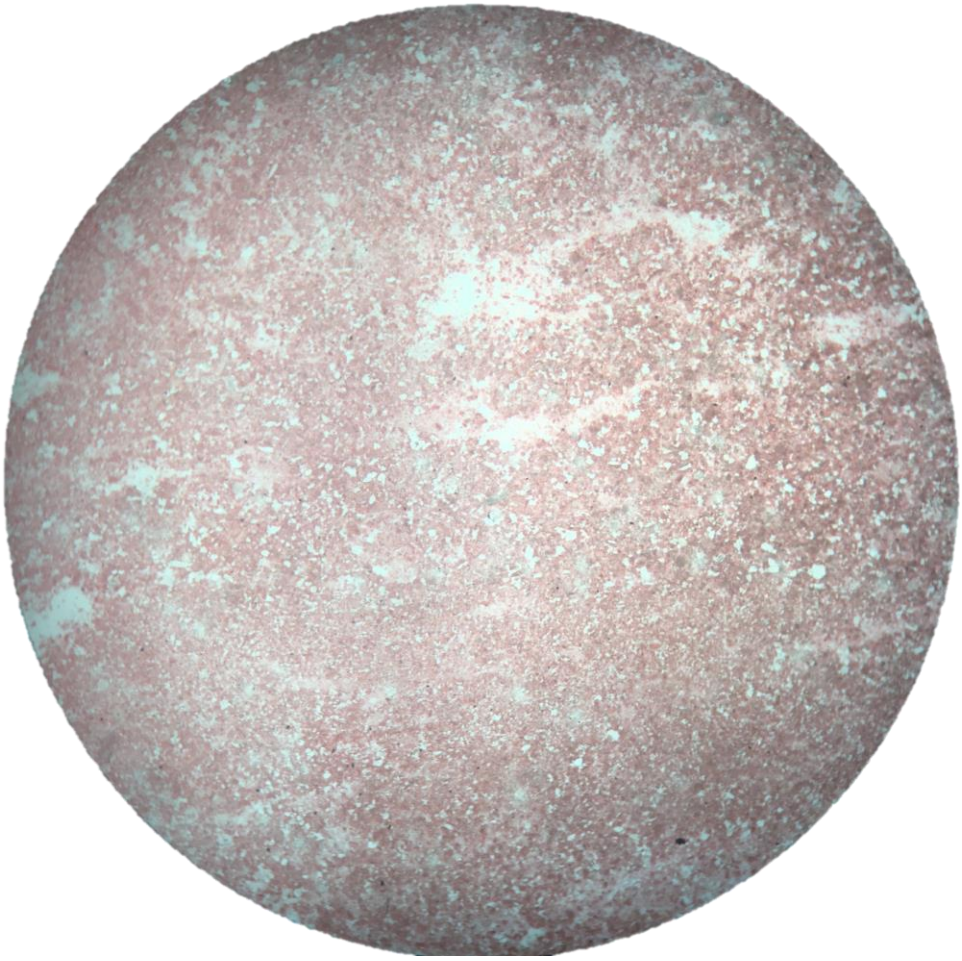

Figure 105. Sample A09-004 Section 4 Glen Rose Formation Unit 4. Magnification is 4x, with field of view is 1 cm. Plain light thin section of micrite (Folk) mudstone (Dunham). A 300-point pie chart of thin section, 79.38% micrite, 12.95 % quartz, 7.67% porosity (porosity not stained blue).

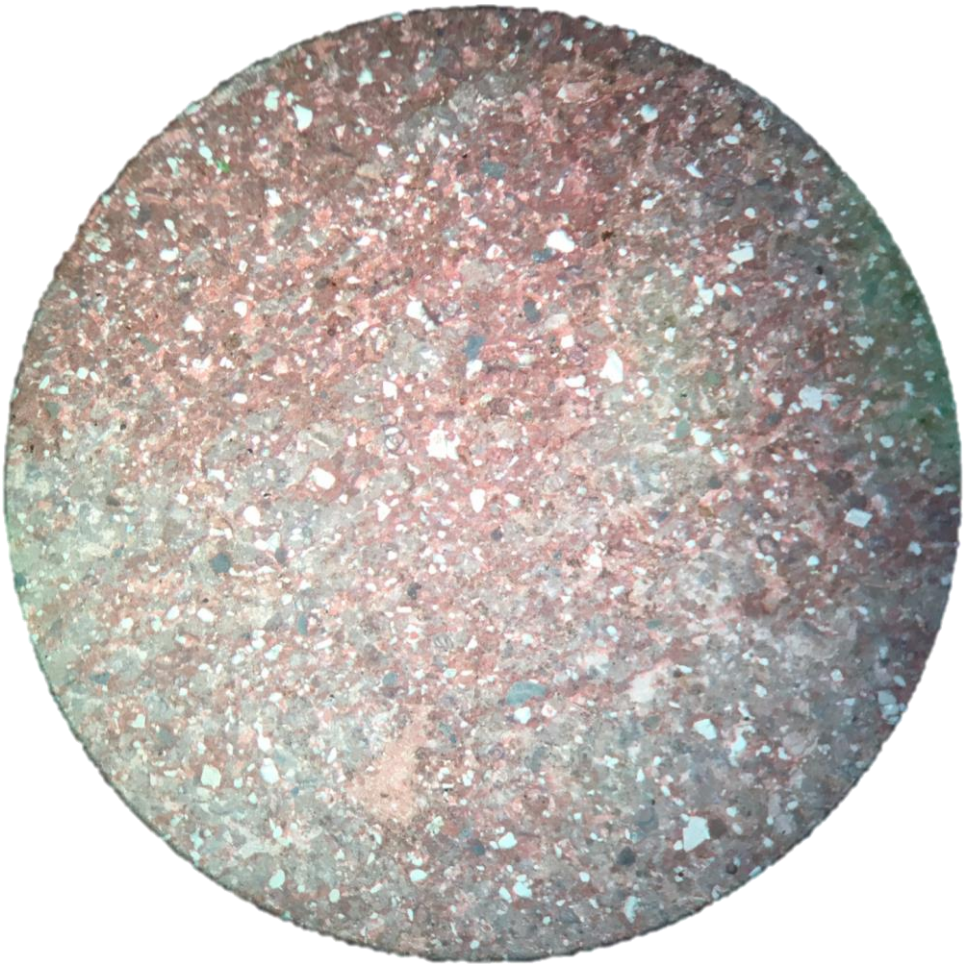

Figure 106. Sample A09-005 Section 4 Glen Rose Formation Unit 6. Magnification is 4x, with field of view is 1 cm. A) Plain light thin section of fossiliferous micrite (Folk) mudstone (Dunham). A 300-point count pie chart of the section, 81.33% micrite, 18.67% quartz.

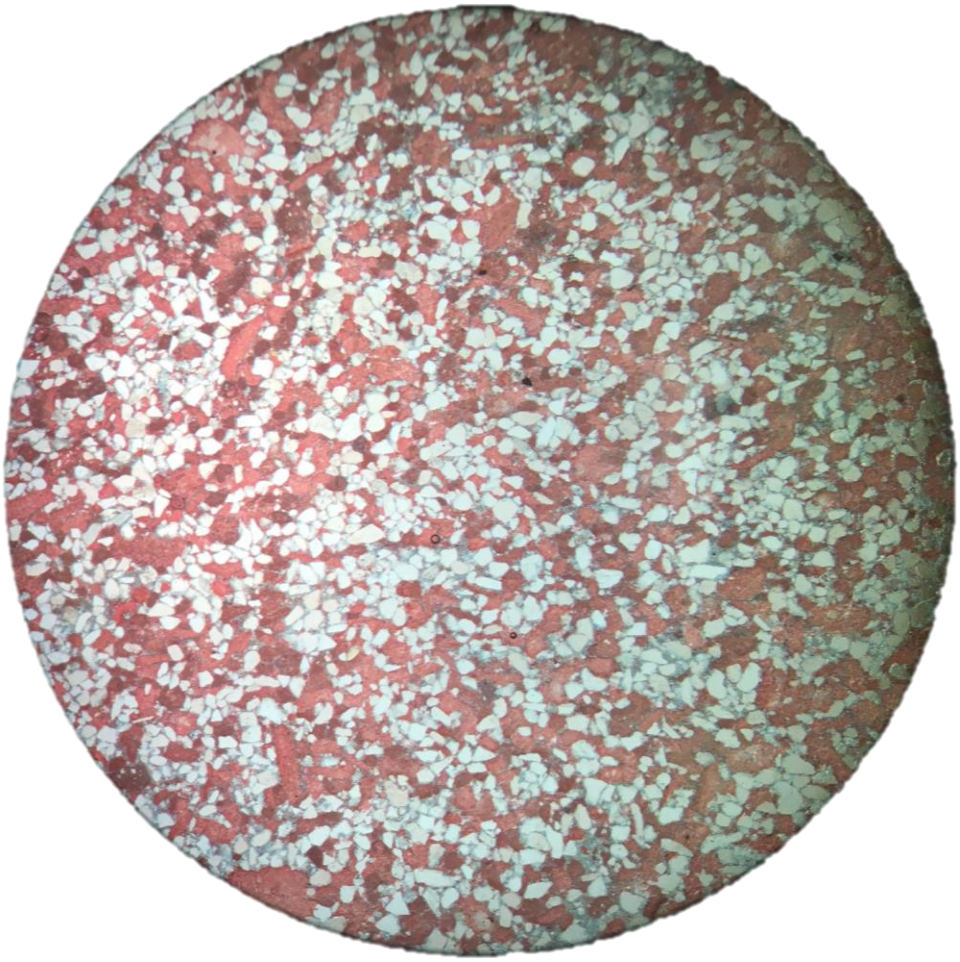

Figure 107. Sample A09-006 Section 4 Walnut Formation Unit 1. Magnification is 4x, with field of view is 1 cm. A) Thin section in plain light of fossiliferous micrite (Folk) mudstone (Dunham). A 300-point count pie chart of the section, 61.67% quartz, 38.33% micrite,

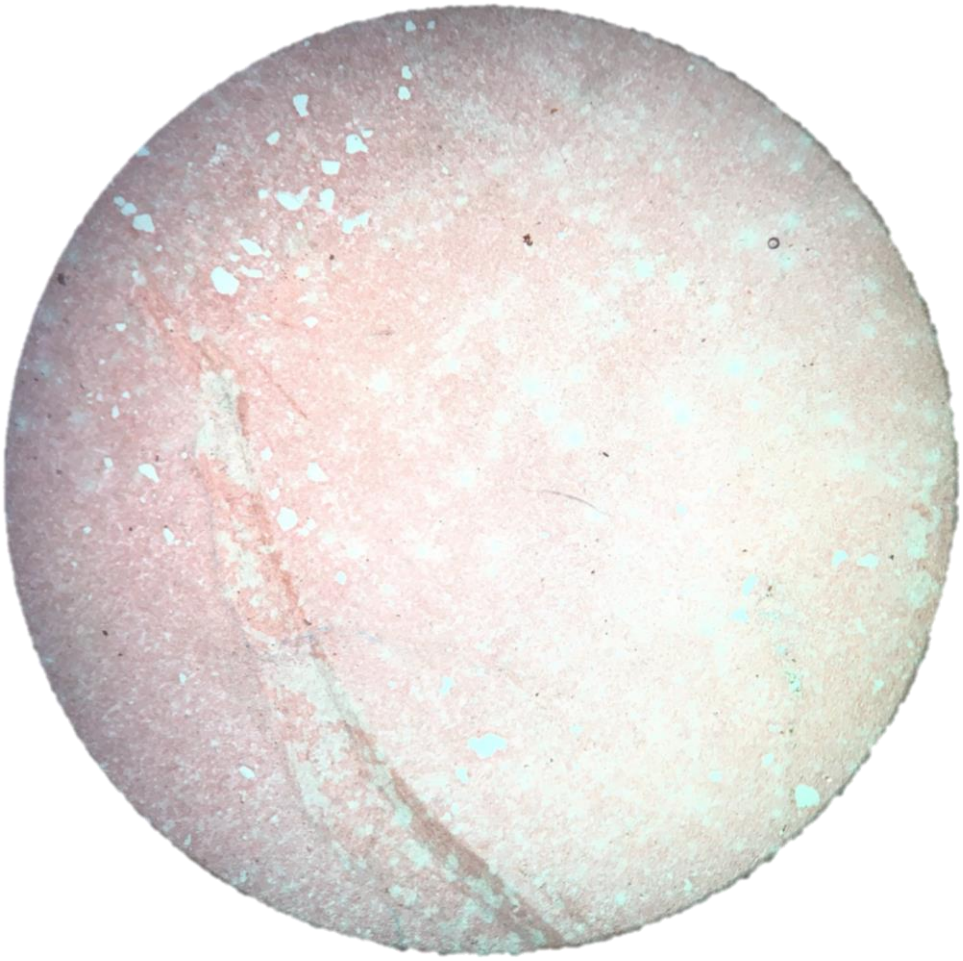

Figure 108. Sample A09-007 Section 4 Walnut Formation Unit 5. Magnification is 4x, with field of view is 1 cm. Plain light thin section of packed micrite (Folk) mudstone (Dunham). A 300 point count pie chart of the section, 85.33% micrite, 10.57% bivalve, 4% other (quartz, porosity).

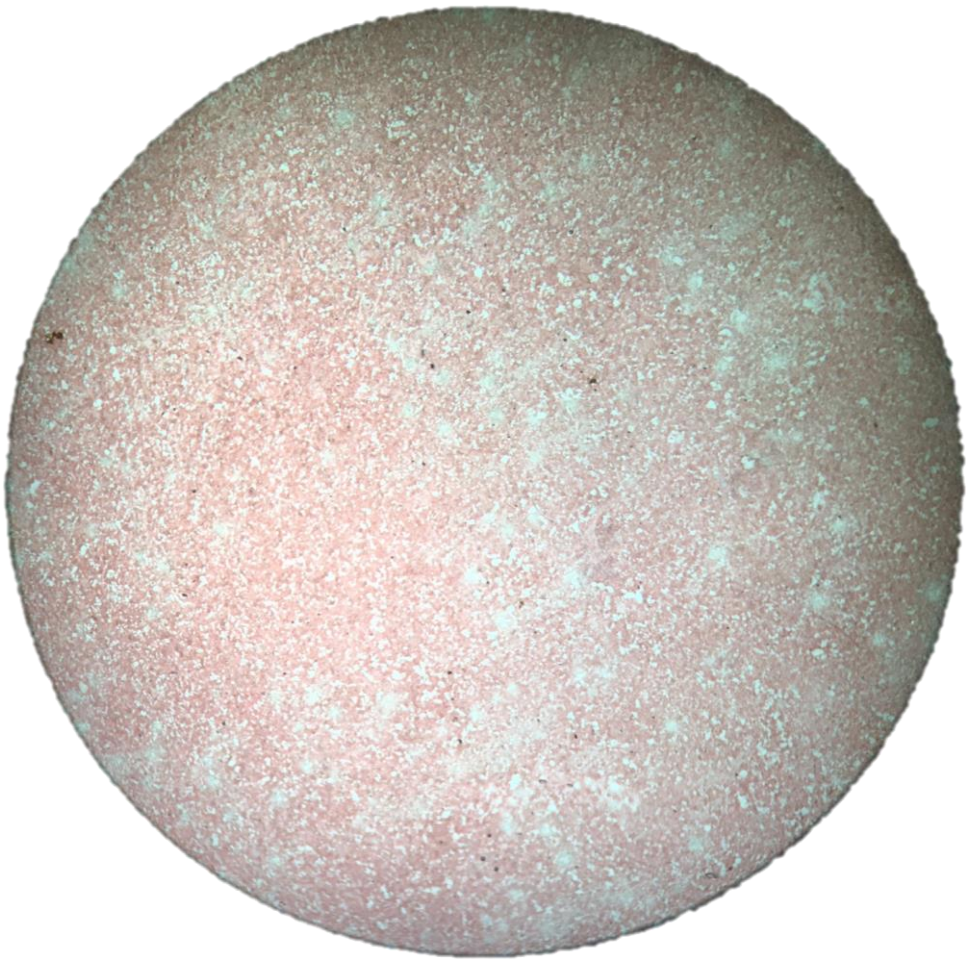

Figure 109. Sample A09-008 Section 5 Glen Rose Formation Unit 1. Magnification is 4x, with field of view is 1 cm. Plain light thin section of micrite (Folk) mudstone (Dunham). A 300-point pie chart of thin section, 73% micrite, 26% quartz 1% porosity.

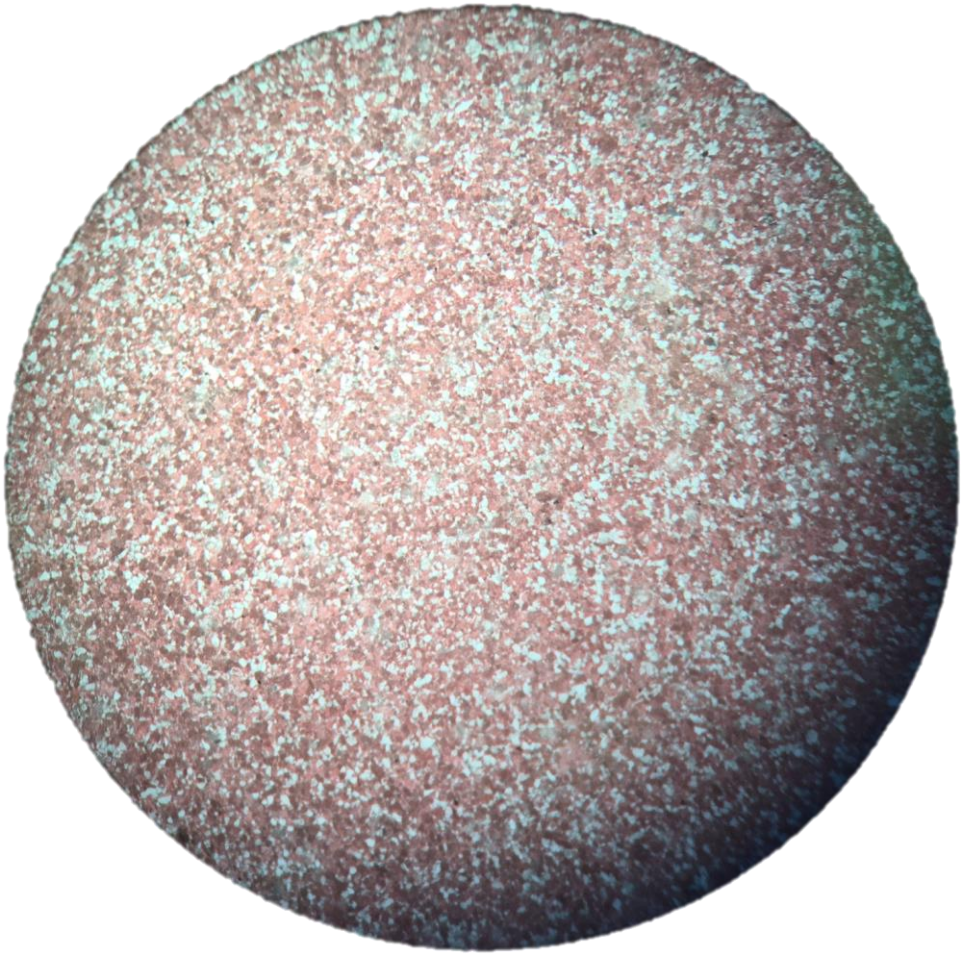

Figure 110. Sample A09-009 Section 5 Glen Rose Formation Unit 4. Magnification is 4x, with field of view is 1 cm. Plain light thin section of micrite (Folk) mudstone (Dunham). A 300-point count chart of thin section, 65.33% micrite, 34.67% quartz

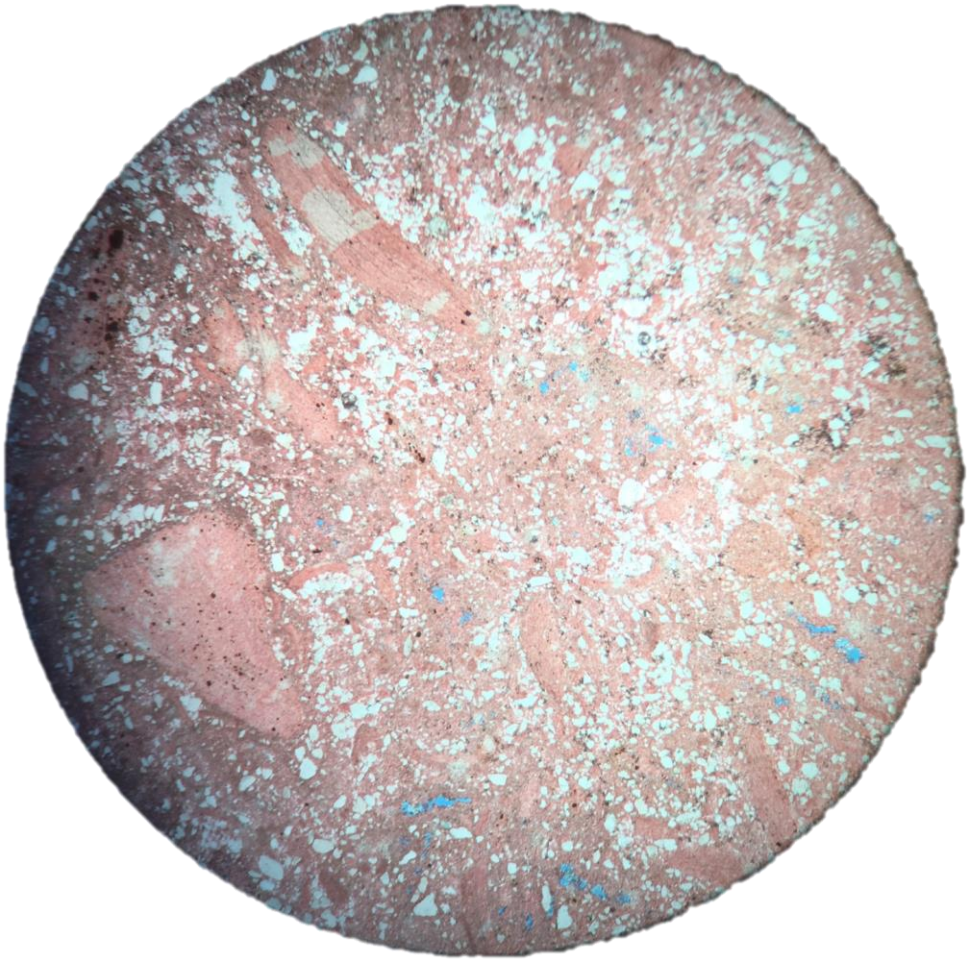

Figure 111. Sample A09-010 Section 5 Glen Rose Formation Unit 6. Magnification is 4x, with field of view is 1 cm. Plain light thin section of packed micrite (Folk) bivalve-wackestone (Dunham). A 300-point count graph of thin section, 50% micrite, 39.67% quartz, 8.67% bivalve.

Figure 112. Sample A09-011 Section 6 Glen Rose Formation Unit 2 Magnification is 4x with field of view is 1 cm. Plain light thin section of micrite (Folk) mudstone (Dunham). A 300-point count graph thin section, 60% micrite, 30% quartz, 10% porosity.

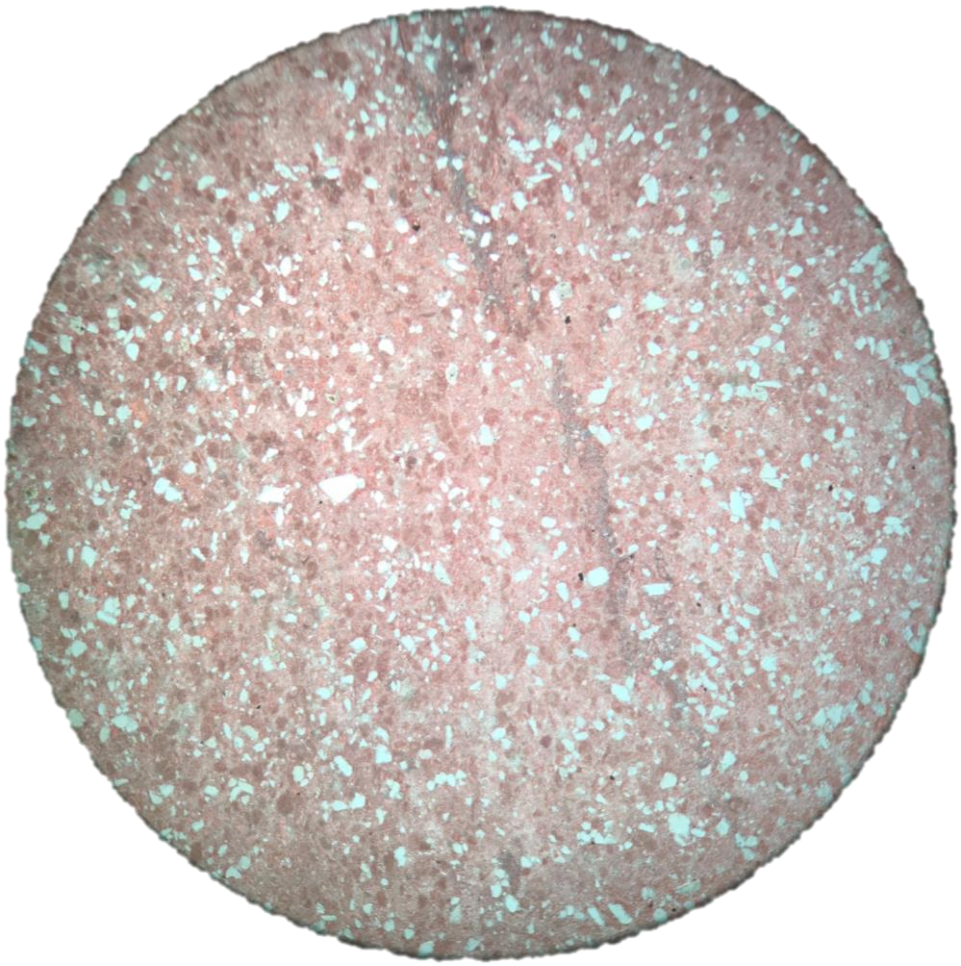

Figure 113. Sample A09-012 Section 9 Hensel Formation Unit 1 Magnification is 4x, with field of view is 1 cm. Plain light thin section of micrite (Folk) mudstone (Dunham). A 300-point count graph of thin section, 75% micrite, 24.67% quartz, 0.33% other (porosity, feldspar).

Section 1. Oyster Fossils

Seventeen oysters were collected at this locality. Fossils were complete but disarticulated. Two species are identified as *Ceratostreon texanum, and Ceratostreon weatherfordense.* The smaller of the species, *C. weatherfordense,* is similar to the larger *C. texanum* but these specimens are more elongate with less costae. Some *C. weatherfordense* specimens have pronounced keels, and others are relatively less pronounced. The *C. texanum* specimens have less ornate costae that spiral towards the depressed beak. Both species have one muscle scar that is on the posterior adductor, and no hinge teeth (Offeman, 1982).

Section 3. Oyster Fossils and Burrows

Thirty-two fossil samples were collected at this locality. Most samples are covered in oyster overgrowths and/or covered in lime-mudstone inhibiting proper classification. Four specimens are identified as *Ceratostreon texanum.* Three of the *C. texanum* are relatively flat and oval while one specimen is elongate and slightly concentric. All four of these samples have spiraled depressed beaks with radiating costae. The muscle scar is present in three of the specimen, the other specimen persevered its internal organs and hiding the internal structures. No teeth were located on the specimens. Two brachiopod specimens were acquired as well, one specimen has nine concentric costae on the exterior, and the other

specimen has no costae. Both samples have large beaks. Interior structures are covered in lime-mudstone. Specimens were not identified further (Offeman, 1982).

Burrows are small with only 2.54 cm in length and 5 mm in diameter. No infilling of the burrows (figure 35). This unit was not extensively burrowed.

Section 4. Oyster Fossils and Burrows

Fifty-six identifiable oysters were found and analyzed at this locality. Fossils were complete but disarticulated, some contained cast preservation (steinkerns) of their organs. Twenty-six of these specimens are identified as *Ceratostreon texanum* (figure 36-40). The largest sample was measured at 10.5 cm at length, and 9 cm at height. These oysters have growth lines that form distinctive ornate ridges on the external shell that swirl to the depressed beak. The shells are oval to slightly crescentic. The ventral margin and the hinge area can be seen in all samples, as well as one muscle scar in the middle of the interior of the shell. Cast of oysters indicate a rapid burial with little bioturbation. Oyster aggregate indicate oysters were living in crowded conditions (Offeman, 1982). Burrows are 26.67 cm long and 1.9 cm in diameter. Inside of the burrows are not infilled (figure 30). This unit was not extensively burrowed.

Section 7 Burrows

Burrows are small, 5.08 cm long and 31 mm in diameter. These burrows are infilled with mud. This unit is extensively burrowed.

Section 8 Oyster Fossils

Forty -six specimens were collected at this locality. Nineteen are *Ceratostreon texanum,* ten *are Ceratostreon weatherfordense,* three *Exogyra sp.,* fourteen unknown*. C. texanum* contains two groups, five of which have distinct keels, but are smaller in size, and the other group is relatively flat and slightly more oval. The *C. texanum* have costae that radiate in a swirl pattern toward the beak. Each of these specimens have one muscle scar and no teeth. *C. - weatherfordense* are considerably smaller, about half the size of *C. texanum.* The exterior and interior of the *C. weatherfordense* is similar to *C. texanum*.

The three *Exogyra sp.* are large and triangular. They contain many growth layers that are concentric but irregular. The beaks size ranges from hidden to small and rounded (figure 42-44).

The unknown fossils contain holes from pholads and are covered in lime-mudstone. External shells have little diagnostic features on them; however, most of the interior shells reveal one muscle scar (Offeman, 1982).

VITA

Austin Conner Wilkerson graduated from Granbury High School, Granbury Texas in May 2010. He then attended Tarleton State University, Stephenville Texas, where he obtained a Bachelor of Science Degree in Geoscience with a minor in History on May 2015. In August 2015, he entered Stephen F. Austin University, and received the degree of Masters of Science in Geology with a minor in Spatial Science in May 2018.

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Style used: Geological Society of America

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