STRATIGRAPHY OF THE MARBLE FALLS INTERVAL (PENNSYLVANIAN), JACK AND WISE COUNTIES, TEXAS

By

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INTRODUCTION

The Fort Worth basin in north-central Texas is an asymmetric foreland trough that developed along the southern edge of the North American craton during the late Paleozoic (Walper, 1982; Johnson et al., 1988). The basin is bounded by the Bend arch to the west, the Red River arch to the north, the Muenster arch to the northeast, the Ouachita thrust belt to the east and the Llano uplift to the south (Fig. 1). These features developed as the North American plate collided with the South American plate during the Ouachita orogeny (Ng, 1979; Pollastro et al., 2007). Their position and structural orientation strongly influenced the setting in which late Paleozoic strata were deposited (Thompson, 1982). The Marble Falls interval (Pennsylvanian) consists of interfingering carbonate and clastic strata deposited during a regression that spanned the Morrowan and Early Atokan (Thompson, 1982). It lies below the Bend Group (Pennsylvanian) in the northern half of the basin and above the Barnett Shale (Mississippian) throughout much of the basin (Fig. 2).

The recent surge in drilling activity in the Barnett Shale has increased the amount of well control through the Marble Falls interval. In the core area of the Newark East field, Wise County, over two thousand Barnett Shale wells have been drilled, greatly increasing the number of high-resolution logs and the amount of cuttings and core from the Marble Falls interval (IHS Energy, PI/Dwights, 2009). The stratigraphy of the Marble Falls interval is well established in eastern Wise County because of these new data. In western Wise County and Jack County, stratigraphic relationships have not been so clearly resolved. Previously, few wells penetrated the entire Marble Falls interval due to the lack of economic interest in deeper horizons. Wells that did penetrate the Marble Falls commonly stopped after penetrating ~50 ft (~15 m) of the unit, providing no data on the whole interval. At the

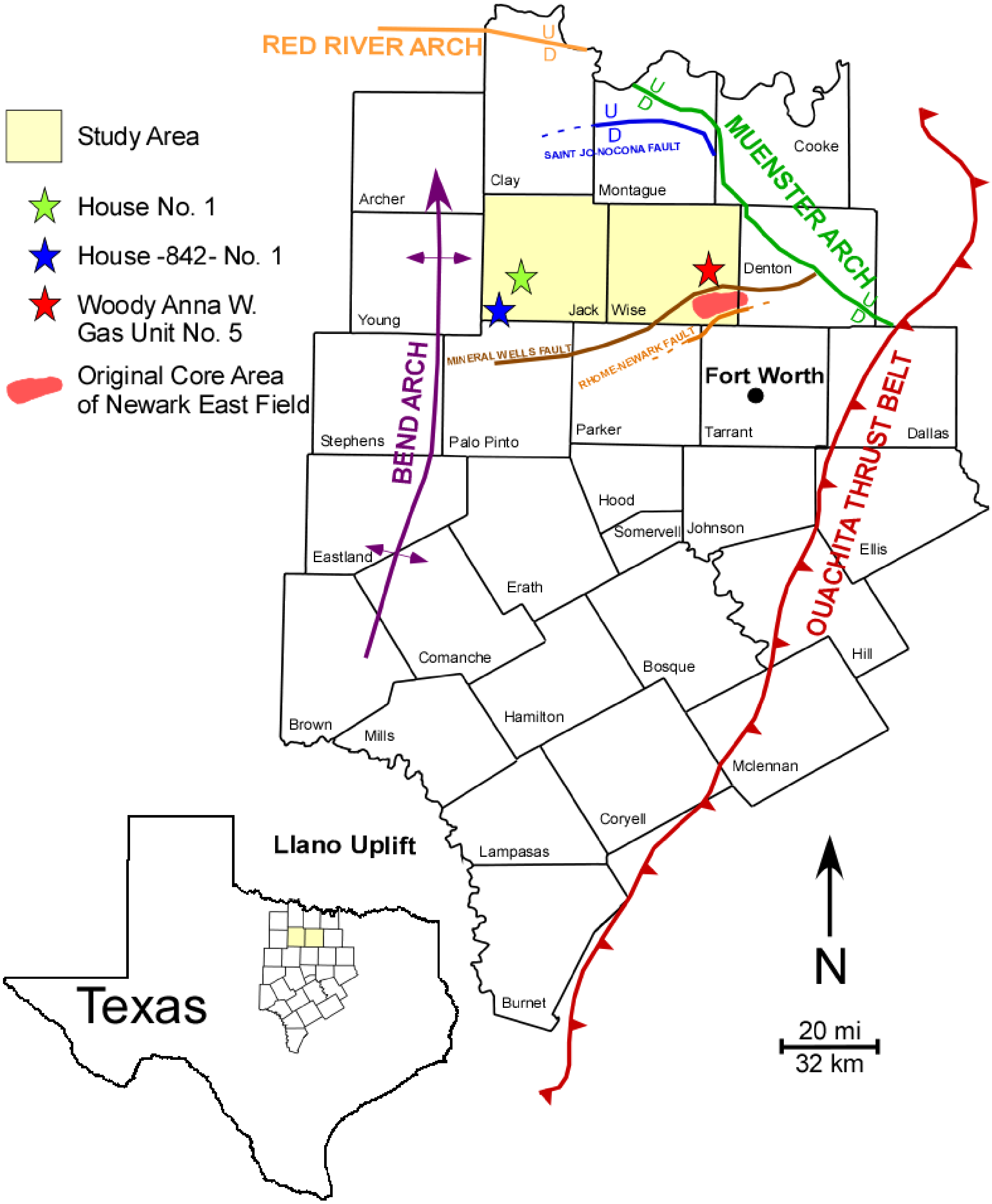

Figure 1. Map of Fort Worth basin showing major structural features, location of key wells, and original core area of the Newark East field. Modified from Loucks and Ruppel (2007) and Steward (2007).

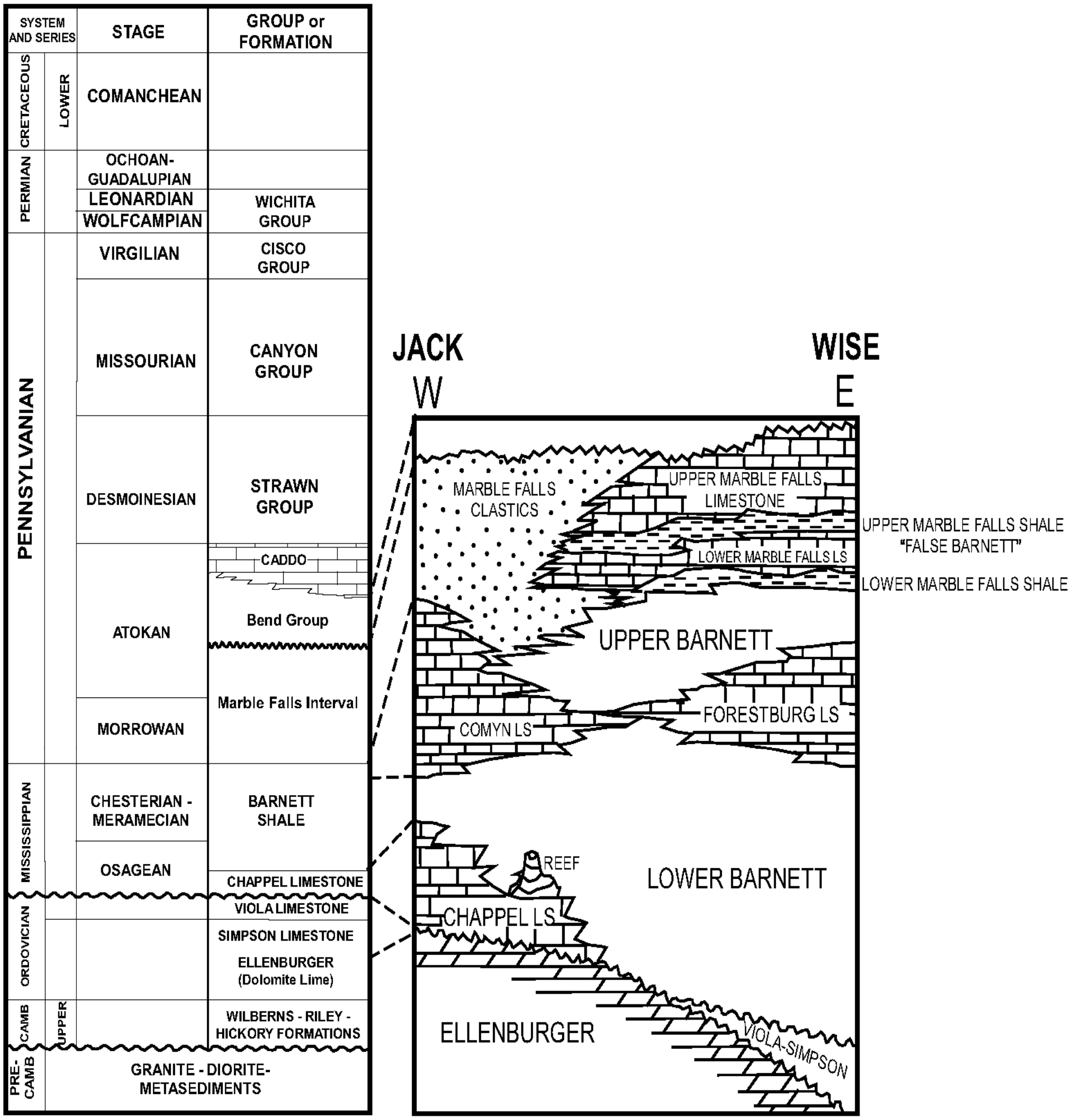

Figure 2. Stratigraphic section for the Fort Worth basin. Modified from Zhao et al. (2007).

present time, however, operators are developing the Barnett Shale in western Wise and Jack Counties, increasing the amount of data through the entire Marble Falls interval. It is the goal of this study to utilize these new data to compare the well-established stratigraphy of the Marble Falls interval in eastern Wise County with the less well-known stratigraphy in western Wise and Jack Counties.

GEOLOGY OF THE FORT WORTH BASIN

Tectonic Setting

The Fort Worth basin in north-central Texas is an asymmetrical shallow trough elongated from north to south that covers approximately 15,000 mi^2 (38,850 km^2) (Pollastro et al., 2007) (Fig. 1). It is one of seven Paleozoic foreland basins that developed along the southern margin of the North American craton during the collision between Laurentia (North American plate) and Gondwana (Afro-South American plate) in the Late Mississippian (Meckel et al., 1992). This collision reactivated several preexisting structural features associated with the Oklahoma aulocogen and generated new features that currently define the extent of the basin (Johnson et al., 1988). The orientation and spatial distribution of these features strongly influenced depositional settings in the Fort Worth basin from Late Mississippian through Late Pennsylvanian.

To the west and south, the basin gradually shallows against the Bend arch and the Llano uplift. The Bend arch to the west is a broad, elongate, north-plunging structure that forms the hinge line between the Midland basin to the west and the Fort Worth basin to the east (Walper, 1977; Flippin, 1982). The arch developed in response to stresses generated during the Ouachita orogeny and from increased sedimentation in the adjacent Midland basin from Late Mississippian through the Permian. During the Permian the arch slowly migrated westward to its present position. The Llano uplift to the south formed as a positive dome-like structure near the southern edge of the North American craton during the Paleozoic (Flippin, 1982; Johnson et al., 1988). It acted as a buttress against the advancing South American plate during the Ouachita orogeny.

The Red River arch to the north and the Muenster arch to the northeast are positive structures that define the northern limit of the basin (Flippin, 1982; Montgomery et al., 2005). Both features were initially formed during the development of the Oklahoma aulocogen but were reactivated during the Ouachita orogeny. They were also prominent sources of the sediment that filled much of the northern half of the Fort Worth basin during the late Paleozoic (Pollastro et al., 2007). The Red River arch strikes west-northwest and consists of a series of discontinuous fault blocks (Thompson, 1982). As these blocks were uplifted, coarse arkosic sediments were eroded off the arch and shed into the basin. The Muenster arch is an uplifted block that strikes northwest–southeast and extends from Denton County, Texas, to Jefferson County, Oklahoma (Henry, 1982; Johnson et al., 1988). It is made up of a series of asymmetrical fault blocks with displacements of approximately 4,500 ft (1,372 m).

The Ouachita thrust belt defines the eastern limit of the basin. It is approximately 1,300 mi (2,092 km) long and stretches from west Texas, around the Llano uplift, through Oklahoma, Arkansas, and into Alabama (Flawn et al., 1961), where it joins with the Appalachian orogenic belt that continues along the east coast of the United States. The fold belt is exposed at the surface in the Marathon uplift in Texas and in the Ouachita Mountains of Oklahoma and Arkansas. A large portion of the fold belt is buried by Cenozoic and Cretaceous sediments, including the portion of the belt that defines the eastern limits of the

Fort Worth basin. Along this portion of the fold belt, tectonic highlands developed from uplifted thrust sheets. These highlands supplied a large portion of the sediment that filled the Fort Worth basin during the Pennsylvanian.

Local folds, major and minor faults, thrust-fold structures, and karst-related collapse features developed within the basin during parts of its history (Pollastro et al., 2007). Some of the more prominent features can be delineated in the subsurface using integrated seismic data and subsurface mapping. One such feature north of the study area in Montague County is the Saint Jo-Nocona fault, which is a high-angle reverse fault that places Ordovician rocks against Mississippian and Lower Pennsylvanian rocks (Henry, 1982). It strikes east-west nearly perpendicular to the Muenster arch before turning parallel to the arch near the town of Nocona in Montague County (Fig. 1). This fault marks the northern limits of Mississippian and Lower Pennsylvanian sediments. The regional Atokan unconformity truncates Mississippian sediments adjacent to this fault, whereas younger sediments are truncated beneath the same unconformity toward the southern part of the basin.

The Mineral Wells and Rhome-Newark faults can be mapped in the subsurface through Palo Pinto, Parker, Wise, and Denton Counties (Fig. 1) (Pollastro et al., 2007; Steward, 2007). The Mineral Wells fault is a northeast-southwest-trending structure that strongly influenced depositional patterns of late Paleozoic sediments and controlled fluid migration in the northern portion of the Fort Worth basin (Montgomery et al., 2005). Its origin, like that of the Saint Jo-Nocona and the Rhome-Newark faults, is not well understood. Seismic data and subsurface mapping suggest that these features are basement faults that formed during the development of the Oklahoma aulocogen and then underwent intermittent movement throughout the Paleozoic, with the most significant movement occurring during the late Paleozoic.

Stratigraphy of the Fort Worth Basin

The fill of the Fort Worth basin consists almost entirely of Paleozoic sediment (Johnson et al., 1988). Nearly 12,000 ft (3,658 m) of Paleozoic strata are present in the deepest part of the basin, adjacent to the Muenster arch. The Paleozoic strata can be subdivided into three groups based on the tectonic history of the basin—Cambrian-Upper Ordovician strata, Middle and Upper Mississippian strata, and Pennsylvanian strata (Montgomery et al., 2005) (Fig. 2).

The Cambrian-Upper Ordovician strata were deposited on a passive continental margin (Montgomery et al., 2005). The Cambrian interval includes the Hickory, Riley, and Wilberns formations, made up of conglomerate, sandstone, shale, and carbonate sequences deposited on top of Precambrian basement rock (Flippin, 1982; Pollastro et al., 2003). The Upper Ordovician section includes dolomite and limestone of the Ellenburger and Simpson Groups and the Viola Limestone. The Simpson and Viola Limestone occur only in the northeast part of the Fort Worth basin adjacent to the Muenster arch. The Ellenburger Group can be found throughout the basin. A major drop in sea level exposed the platform carbonates at the top of the Ellenburger Group for a long period of time during which a karsted surface developed. Erosion associated with this drop in sea level removed Silurian and Devonian strata from the basin (Henry, 1982).

The middle Paleozoic section is composed of Middle and Upper Mississippian platform and basinal strata that were deposited on top of the Upper Ordovician unconformity.

Mississppian rocks were deposited during early phases of the subsidence associated with the advancing Ouachita orogeny (Montgomery et al., 2005; Pollastro et al., 2007). Mississippian strata include the Chappel Limestone and the Barnett Shale as well as the Forestburg limestone (Fig. 2). The Chappel Limestone is a discontinuous, crinoidal, shallow-marine limestone that forms pinnacle reefs up to 300 ft (91 m) high in the western part of the basin (Osterlund, 1984). The Barnett Shale interfingers with and drapes the Chappel Limestone and blankets the lower Paleozoic section. The Barnett has been a major target for oil and gas exploration since the beginning of the twenty-first century. In the Newark East field, the unit is divided informally into three members—an upper shale, lower shale, and a middle limestone. The limestone member is the Forestburg limestone which seperates the upper shale from the lower shale members. The upper and lower shale are undifferentiated where the Forestburg limestone is absent (Montgomery et al., 2005). The upper shale is 60-70 ft (18-21 m) thick and the lower shale ranges from 600 ft (183 m) near the Muenster arch to less than 50 ft (15 m) thick over the Bend arch and the Llano uplift. The Forestburg limestone is an argillaceous lime mudstone (Loucks and Ruppel, 2007), which Bowker (2002, 2003) interpreted as debris-flow deposits shed off the Muenster arch. Loucks and Ruppel (2007) recognized carbonate debris-flow deposits within the Barnett, but interpreted the Forestburg to record deposition from hemipelagic plumes or dilute turbidity currents. Along the Muenster arch, the Forestburg limestone can be up to 200 ft (61 m) thick. Pollastro et al. (2007) interpreted the Forestburg to thin and pinch out to the west on the east side of Jack County and in southern Wise County.

The upper part of the Paleozoic section is composed of Pennsylvanian strata that represent a significant period of subsidence and basin fill related to the Ouachita orogeny

(Montgomery et al., 2005). This section includes the Morrowan-lower Atokan as well as the middle Atokan and Desmoinesian Stages. Dihrberg (1988) and Erlich and Coleman (2005) provide summaries of work on the Marble Falls interval. Previous workers have divided the Marble Falls interval into an upper and lower unit where it is exposed around the Llano uplift. This division is based both on biostratigraphy and lithostratigraphy. The lower unit is assigned to the Morrowan (Early Pennsylvanian), which was deposited during the initial Pennsylvanian transgression as well as during a subsequent regression (Kier et al., 1979; Johnson et al., 1988). These changes in sea level caused facies patterns to vary considerably throughout the basin. The lower unit is a medium- to thick-bedded, dark limestone composed of tubular and phylloid algal mounds overlain by gray-black shale. The upper member is assigned to the Atokan (late Early Pennsylvanian) and consist of interfingering carbonates and clastics that shifted progressively westward in response to a general rise in sea level. This developed a back-stepping carbonate platform to the west that thins onto paleobathymetric highs such as the Llano uplift and the Bend arch. Unconformities are present at the top of both the lower and upper Marble Falls (Erlich and Coleman, 2005). In the northern part of the basin the Marble Falls interval was influenced both by prograding clastic wedges shed from the Red River arch to the northwest and by carbonates prograding from the Muenster arch to the northeast.

The Upper Pennsylvanian section is represented by middle and upper Atokan strata and by the Strawn Group (Desmoinesian). The Atokan strata are highly complex and variable, causing stratigraphic and depositional interpretations to vary significantly (Johnson et al., 1988). These strata consist of mixed carbonate and clastic deposits shed from positive structures created by earlier phases of the Ouachita orogeny (Johnson et al., 1988). The

Strawn Group represents transgressive carbonate bank and westward-prograding fluvial-deltaic environments and is nearly 3,600 ft (1,097 m) thick in the northern part of the basin. The lower Strawn is not well known because of scattered well control but is thought to be similar to the upper Atoka. This implies that margins of the basin were still being uplifted to the north and east during this time. By the time the middle and upper Strawn strata were deposited, basinal subsidence had decreased significantly, allowing high-constructive fluvial-deltaic systems to prograde across the area (Johnson et al., 1988).

In the northwest portion of the Fort Worth basin, nearly 1,500 ft (457 m) of Permian sediments consisting of sandstones and shales are present (Johnson et al., 1988). These clastics were derived from the Ouachita thrust belt, which by then had been eroded down to low-relief hills. These sediments form the Wichita Group and also the upper portion of the Cisco Group (Johnson et al., 1988). Triassic and Jurassic rocks are not found in the basin. Cretaceous sediments are the only sediments in the basin not to have been influenced by the Ouachita orogeny. A major angular unconformity separates Cretaceous rocks from the underlying Pennsylvanian and Permian rocks (Herkommer and Denke, 1982).

PREVIOUS WORK

Studies of the Marble Falls interval have been largely confined to outcrop along the Llano uplift. The first known geologist to have collected fossils from the Marble Falls was Ferdinand Roemer, a German paleontologist who traveled across central Texas from 1845 through 1847 (Dihrberg, 1988). In 1852 he published the first descriptions of four brachiopod species collected from the Marble Falls interval. Based on his findings he determined the Marble Falls interval to have been deposited during the Carboniferous Period.

In 1922 F. B. Plummer and R. C. Moore published the first significant study on the biostratigraphy of the Marble Falls interval. In 1950, Plummer published what is considered to be the most thorough biostratigraphic study of the Marble Falls interval to date, in which he differentiated the strata into a lower and upper unit. The lower unit, which he called the Sloan Formation, was determined to be Morrowan and the upper unit, which he called the Big Saline, was determined to be Atokan, thus placing the Marble Falls interval entirely within the Early Pennsylvanian (Dihrberg, 1988).

In the late 1950's through the early 1970's students working with W. C. Bell at the University of Texas at Austin wrote a series of master's theses and doctoral dissertations that described the lithostratigraphy, biostratigraphy, and depositional history of the Marble Falls interval (Dihrberg, 1988). In 1970, R. R. Gries characterized the macrofossil assemblages found in the Marble Falls interval. She disagreed with Plummer's conclusions that the Marble Falls interval can be differentiated into upper and lower units based on faunal changes. In 1979, P. K. Sutherland and W.L. Manger began a long term biostratigraphic study of the Marble Falls interval and J. R. Groves undertook a preliminary study of the fusilinids at the same time (Dihrberg, 1988). Wiggins (1982) and Johnson (1983) compiled the first lithostratigrapphic and petrographic studies on the Marble Falls interval around the Llano uplift.

Few studies discuss the Marble Falls interval in the subsurface of the Fort Worth basin. Namy (1982) compared the Marble Falls in outcrop with the Marble Falls in the subsurface throughout Brown, Comanche, Hamilton, Lampasas, and Mills Counties in the southern part of the Fort Worth basin. He found the Marble Falls interval in the subsurface to be similar to the Marble Falls in outcrop. Erlich and Coleman (2005) analyzed depositional settings of the Marble Falls interval on the north side of the Llano uplift and extended correlations to well logs in the immediate area. Ng (1974) and Thompson (1982) discussed the Lower to Middle Pennsylvanian section (Morrowan and Atokan) in the northern part of the Fort Worth basin but did not include the Marble Falls interval. More recently, with an increase in drilling for the Barnett Shale, publications by Pollastro et al. (2003), Montgomery et al. (2005), Bowker (2007), Loucks and Ruppel (2007), Pollastro et al. (2007), and Zhao et al. (2007) have included brief discussions on the Marble Falls interval and its relationship to the Barnett Shale. Even though these more recent studies do not thoroughly describe the Marble Falls interval they contain new information about the interval in the northern part of the Fort Worth basin.

METHODS

In this study, the Woody Anna W. Gas Unit No. 5 and the House -842- No. 1 serve as type logs for Wise and Jack Counties, respectively (Figs. 1 and 3). Both carbonate and clastic strata are present in the Marble Falls interval and underlying Mississippian units where these wells are located. Lithologic determinations were made using a combination of gamma ray (GR), photoelectric absorption (PE), neutron-porosity (NPHI), density-porosity (DPHI), and resistivity logs. Limestones were identified as having a GR reading between 15 and 45 API, a PE around 5, a NPHI and DPHI separation less than 10 percent porosity, and a resistivity around 100 ohmms. GR readings equal to or greater than 60 API, a PE between 2.5 and 4, a NPHI and DPHI separation greater than 10 percent porosity, and a resistivity between 10 and 1,100 ohmms were taken to indicate shales. Erratic GR readings between 30 and 100 API, a PE between 2.5 and 6, NPHI and DPHI with little separation to as much as 20

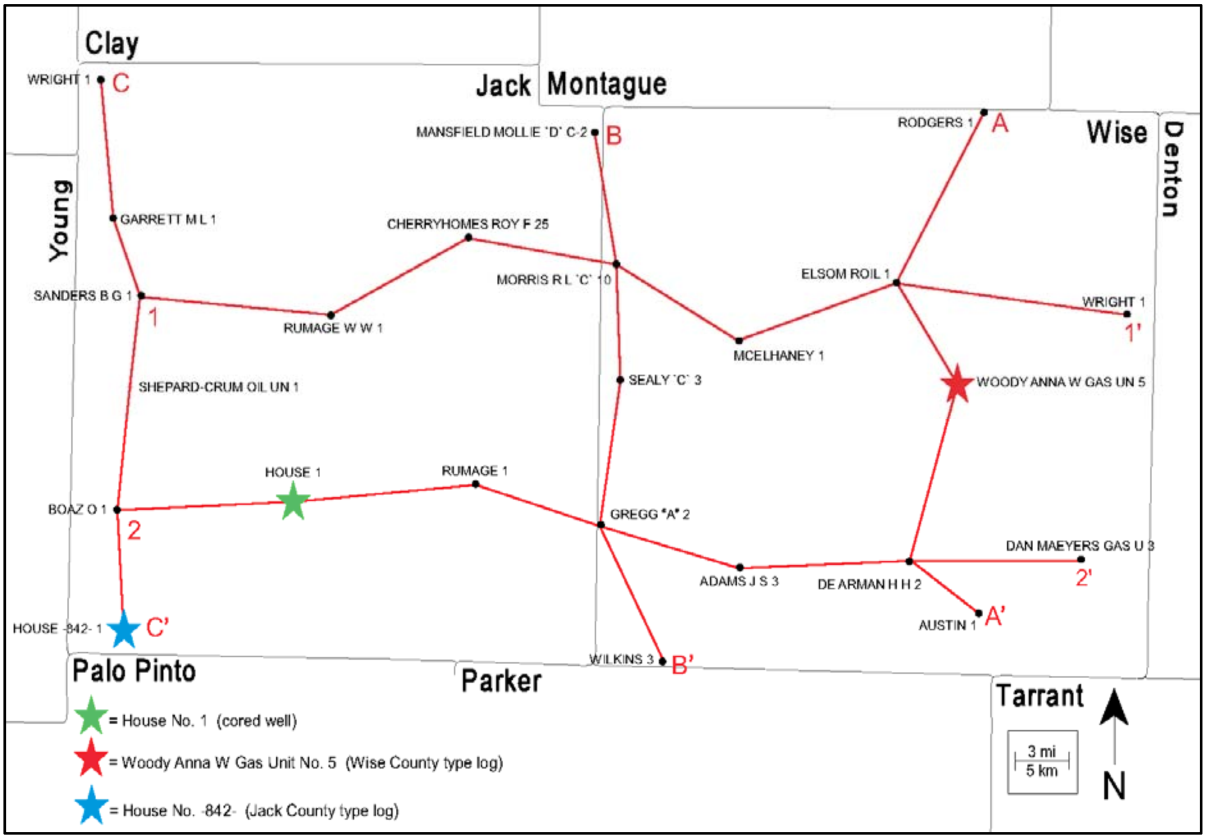

Figure 3. Map of study area showing cross section lines and location of key wells.

percent porosity separation, and a resistivity varying between 10 and 140 ohmms were interpreted as interbedded siltstones and claystones (heterolithics). Calibration with core from the House No.1 well (Figs. 1 and 3) established the validity of this interpretation. More uniform GR readings between 15 and 45 API, a PE between 2.5 and 4, NPHI and DPHI with a consistent separation around 1 to 2 percent porosity, and a resistivity around 100 ohms is taken to represent a more silt-rich rock.

Using these lithologic determinations, tops were selected and correlated throughout the study area. Digital and raster logs (1,451 in all) were used for correlation. Out of the logs that were used, 212 were digital logs and 1,239 were raster images. Tops from the log database were used to make three north-south stratigraphic cross sections and two west-east stratigraphic cross sections (Fig. 3). The datum for the stratigraphic cross sections is the top of the lower Barnett Shale, which is the most continuous and laterally extensive horizon within the study area.

Structure and isopach maps were created based on correlations made within the study area. A structure map was generated on the base of the lower Barnett Shale and on top of the Marble Falls interval. Isopach maps of the upper limestone, upper shale, lower limestone, lower shale, and clastic portion in the Marble Falls interval, as defined below, were also made. All maps were contoured by hand and digitized in Petra®. Isopach maps were then color filled to emphasize lithologic trends.

Once a stratigraphic framework was established, 279 ft (85 m) of core were examined from the House No. 1 well in south-central Jack County to characterize the clastic portion in the Marble Falls interval. The House No. 1 was drilled to a measured depth of 4,932 ft (1,503 m). Conventional core was taken from a depth of 4,932 ft (1,503 m) to 5,339 ft (1,627 m), recovering the lower part of the Bend Group, most of the Marble Falls interval, and a portion of the Comyn Limestone. After coring was complete, the House No. 1 was drilled to a total depth of 5,758 ft (1,755 m), penetrating 90 ft (27 m) into the Ellenburger Group. Color, composition, grain size, sedimentary structures (including trace fossils), and fractures were observed in the core using a binocular microscope.

Fifty-eight thin sections were made from the core and analyzed using a standard petrographic microscope. Thin sections were stained for calcite using alizarin red-S.

RESULTS

Stratigraphy

Logs from the Woody Anna W. Gas Unit No. 5 in Wise County serve as the type log for the eastern portion of the study area (Figs. 3 and 4). The sharp contact at 7,011 ft (2,137 m) between a thick limestone and the overlying clastics was taken to mark the regional unconformity at top of the Marble Falls interval. The contact at 7,942 ft (2,421 m) between high GR shales and the underlying carbonates was taken to mark the regional unconformity developed on the underlying Ordovician carbonates. Nine stratigraphic intervals and two marker horizons were identified between the top of the Marble Falls limestone and the top of the Ordovician carbonates.

The Marble Falls interval can be subdivided into four units in eastern Wise County–an upper limestone, an upper shale, a lower limestone, and a lower shale. The upper shale is equivalent to the shale referred to as the “false Barnett” by operators in the area. A pronounced increase in GR and resistivity readings at the base of the lower shale marks the contact with the underlying Barnett Shale. A 250 ft (76 m) thick section of limestone within the Barnett divides the shale into upper and lower members. This limestone is equivalent to the Forestburg limestone of Henry (1982). Steed (2009) divided the Forestburg limestone into three units–an upper limestone, middle shale, and lower limestone. In this study, the Forestburg is divided even further into four units–an upper limestone, upper shale, lower limestone, and lower shale.

The shales within the Forestburg limestone have gamma readings of less than 105 API units. Below the Forestburg limestone is a shale section characterized by high gamma ray and resistivity readings. GR readings within this shale generally exceed 105 API units

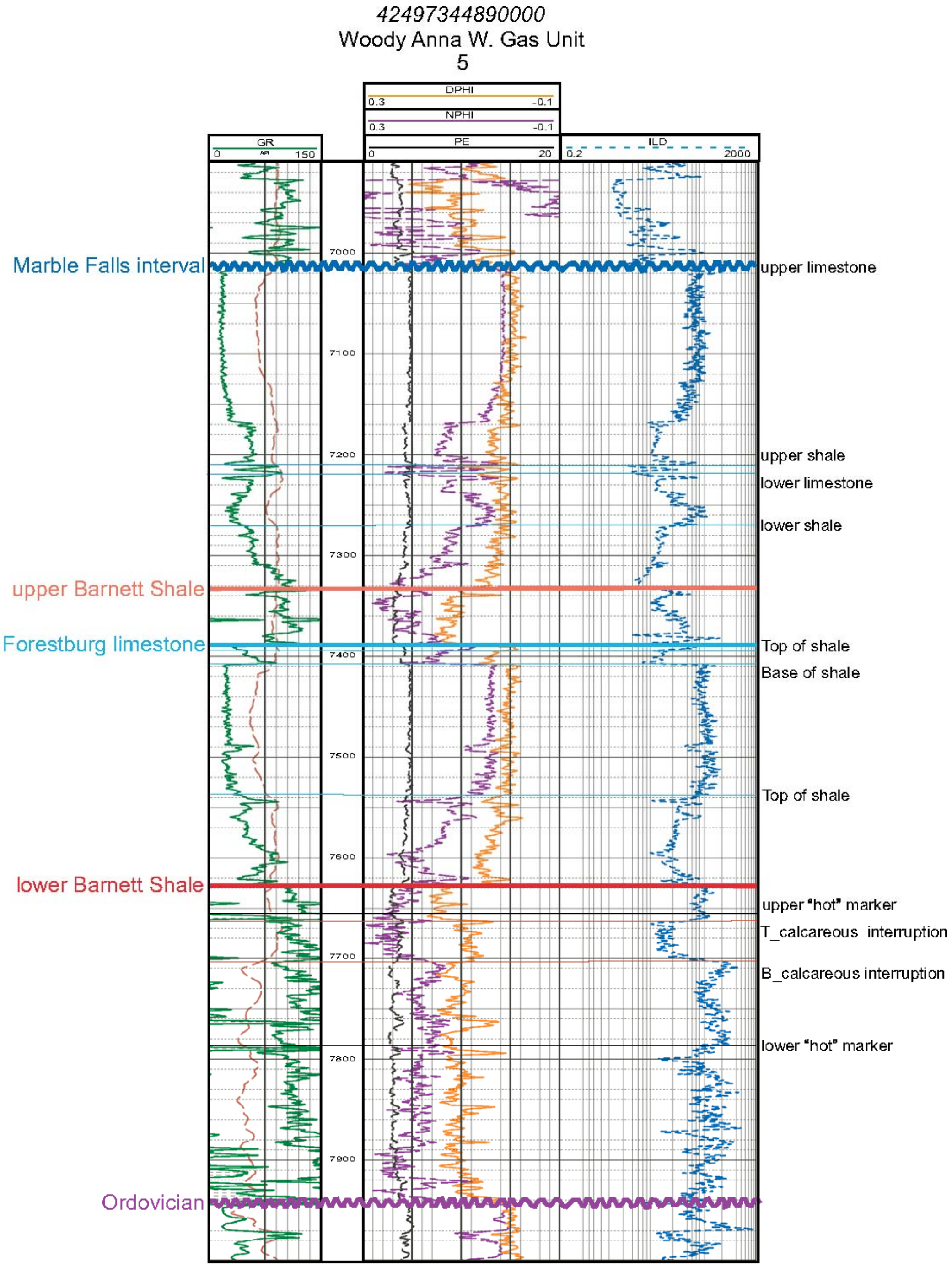

Figure 4. Type log for Wise County showing tops (horizons) and intervals correlated throughout the study area.

(Fig. 4). This interval is the lower Barnett Shale of Bowker (2003). Two “hot” markers with GR readings above 225 API units and a slightly less resistive interval are present within the lower Barnett. The upper and lower hot markers correspond, respectively, to gamma ray spikes 4 and 3 that Steed (2009) correlated throughout the northern portion of the Fort Worth basin. The less resistive interval corresponds to the “calcareous interruption” in the Barnett Shale that Henry (1982) defined in Montague County.

Logs from the House -842- No. 1 in Jack County serve as the type log for the western portion of the study area (Figs. 3 and 5). The sharp contact at 4,573 ft (1,394 m) between the blocky log signature of the underlying clastics and the erratic log signature of the overlying shales, sands, and conglomerates was taken to mark the regional unconformity at the top of the Marble Falls interval. The contact at 5,116 ft (1,559 m) between the highly resistive limestone and the underlying, less resistive, dolostone is taken to mark the regional unconformity developed on the underlying Ordovician carbonates. Three stratigraphic units and two marker horizons were identified between the top of the Marble Falls clastics and the top of the Ordovician carbonates. The Marble Falls is made up of a clastic unit that is not further subdivided. The GR signature within this interval is mostly erratic but becomes more uniform up-slope toward the shallower part of the basin as the lithology changes from interbedded siltstone and claystone to a more uniformly silt-rich lithology. A pronounced decrease in GR, NPHI, and DPHI, along with an increase in PE marks the contact of the clastic interval with the underlying Comyn Limestone.

Below the Comyn Limestone is a shale section characterized by high GR and resistivity readings. GR readings within the shale generally exceed 105 API units (Fig. 5). This interval is the lower Barnett Shale of Bowker (2003). Two “hot” markers with GR readings

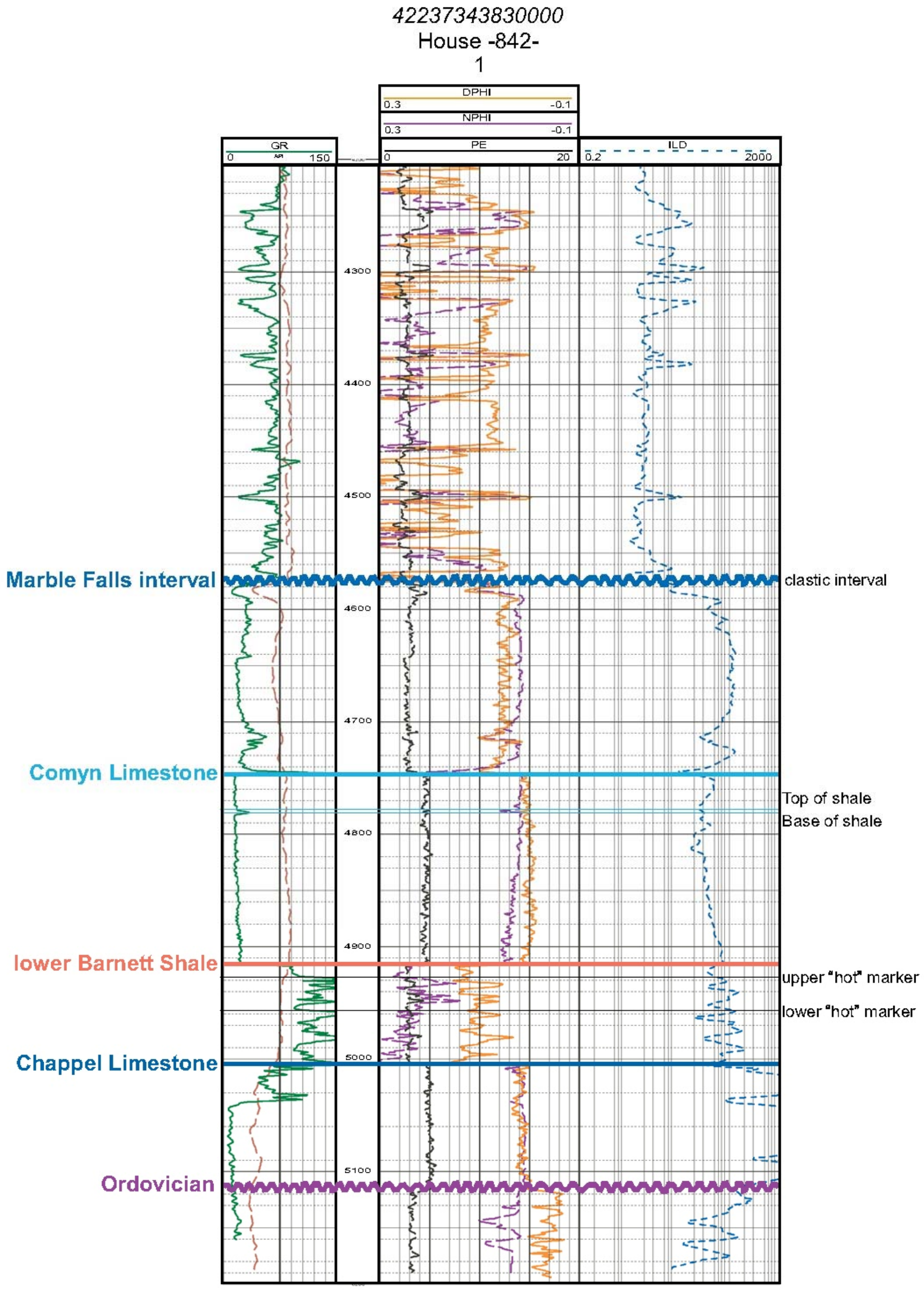

Figure 5. Type log for Jack County showing tops (horizons) and intervals correlated throughout the study area.

over 200 API units were identified within the lower Barnett Shale. The upper and lower "hot" markers correspond to the upper and lower "hot" markers identified in Wise County. A 100 ft (30 m) section of Chappel Limestone occurs between the Barnett Shale and the underlyng dolomite of the Ellenburger Group.

Cross Sections

The upper limestone, upper shale and lower limestone of the Marble Falls interval extend uninterrupted from north to south in eastern Wise County (Figs. 3 and 6, plate I). The lower shale unit pinches out in the very southern portion of the county where it is interpreted to interfinger with the lower limestone. Mississippian units below the Marble Falls interval are generally thick to the north and thin to the south. In contrast with this general trend, the lower limestone unit of the Forestburg limestone thickens in central Wise County before thinning and pinching out to the south. The upper and lower shale members of the Barnett extend uninterrupted from north to south along with the upper limestone and upper shale unit of the Forestburg limestone. The "calcareous interruption" of Henry (1982) in Montague County correlates to the south in to Wise County where it terminates in the southern portion of the county.

In the northern portion of the study area, all of the units within the Marble Falls interval, the upper shale member of the Barnett, and the Forestburg limestone terminate in the eastern portion of Jack County (Figs. 3 and 7, plate II). These units are interpreted to interfinger with over 400 ft (122 m) of clastic sediments. The Comyn Limestone terminates in the western portion of Jack County and interfingers with the same thick clastic section.

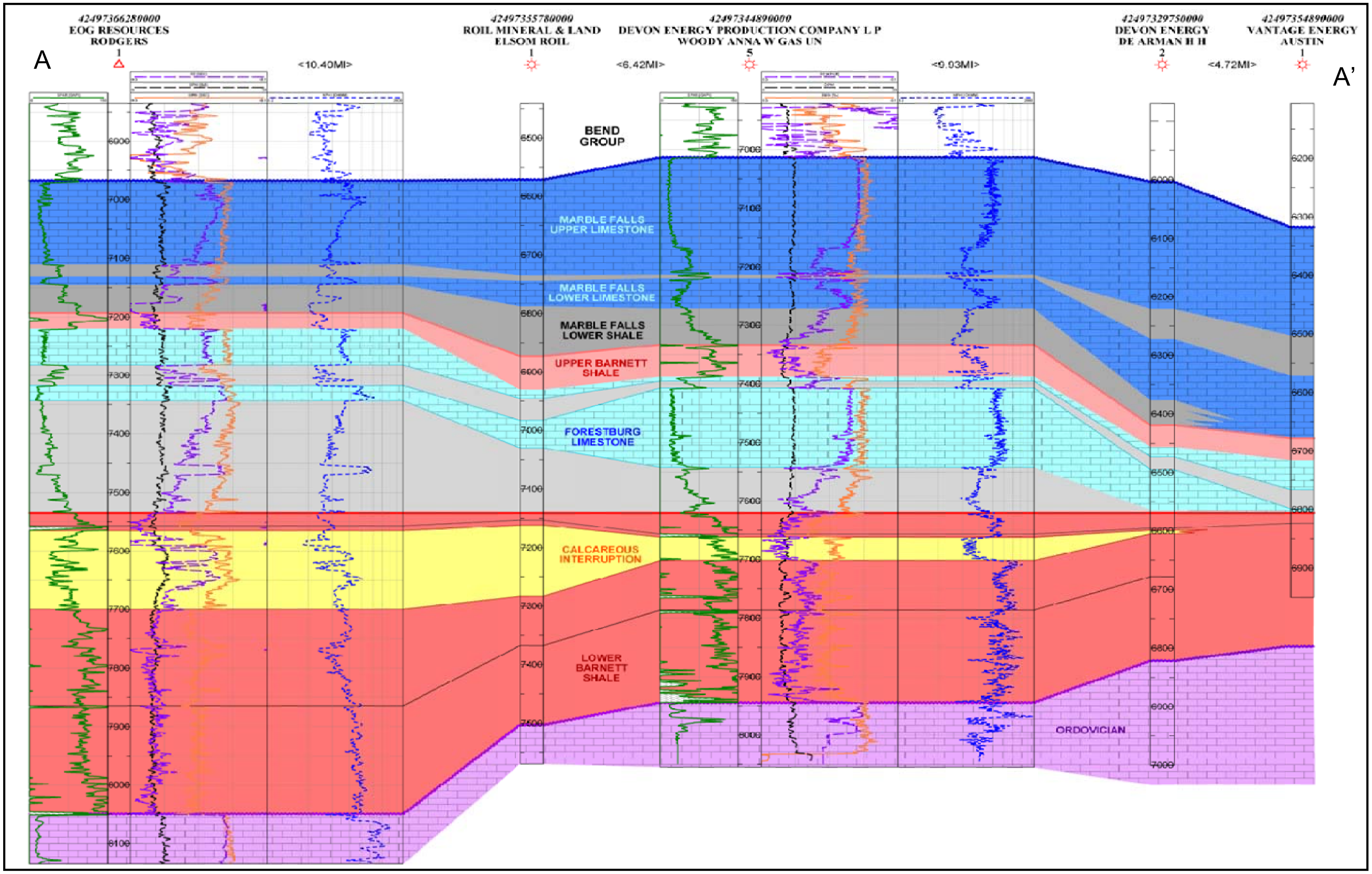

Figure 6. Stratigraphic cross section A-A'. Datum is top of lower Barnett Shale. For location of cross section see Figure 3.

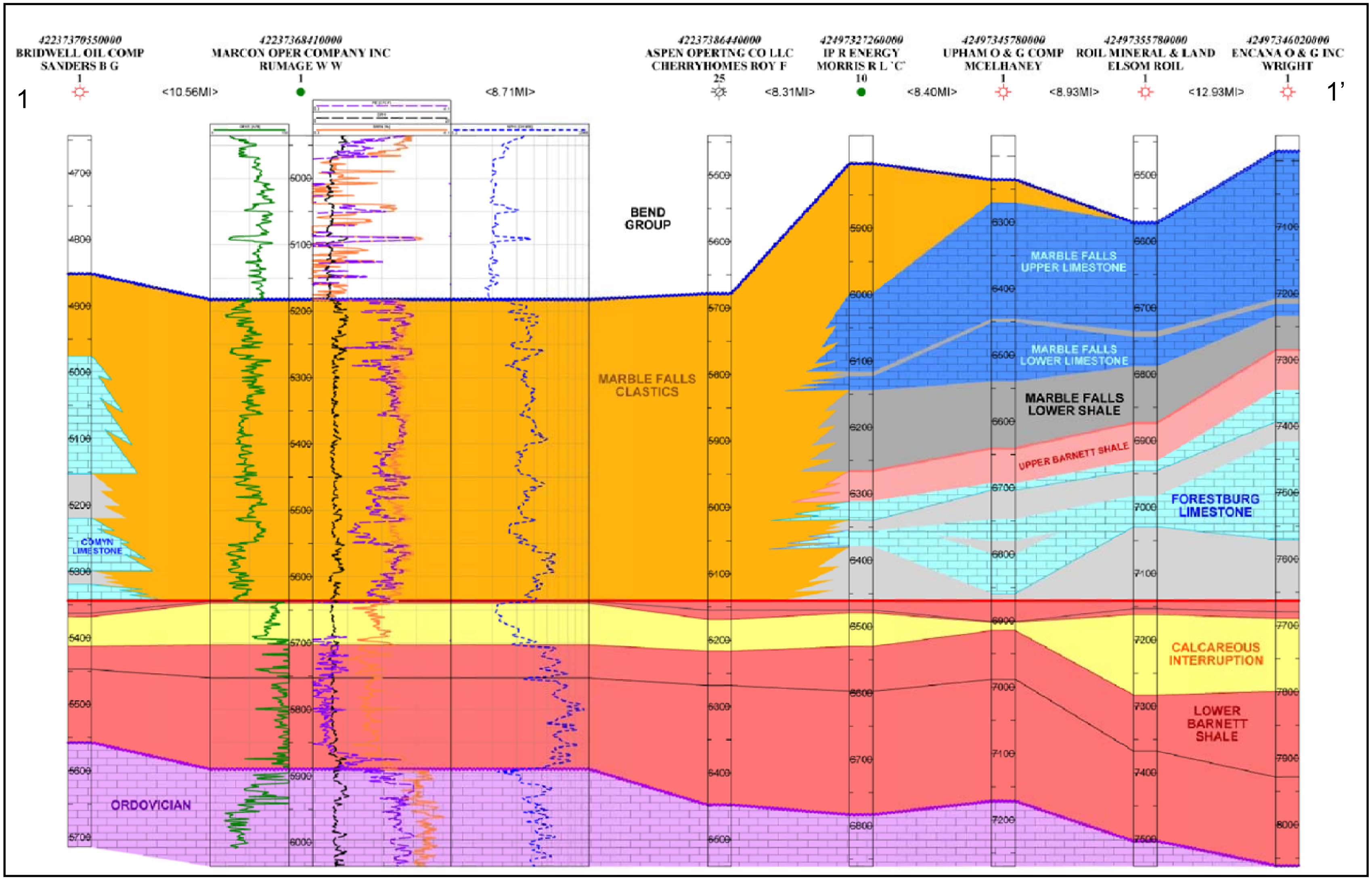

Figure 7. Stratigraphic cross section 1-1'. Datum is top of lower Barnett Shale. For location of cross section see Figure 3.

The lower shale member of the Barnett and the “calcareous interruption” extend uninterrupted from eastern Wise County to western Jack County. The “calcareous interruption” appears to become finer grained to the west and south away from the Red River arch and Muenster arch.

In the southern portion of the study area, all of the units within the Marble Falls interval and the upper Barnett Shale terminate in the western portion of Wise County (Figs. 3 and 8, plate III). The upper limestone and upper shale units of the Marble Falls interval terminate further to the east than the lower limestone, lower shale, and upper Barnett Shale. All of these units are interpreted to interfinger with the clastic interval of the Marble Falls. The Forestburg limestone and Comyn Limestone units are continuous from east to west and could not be differentiated (see discussion). The lower Barnett Shale is also continuous across the sudy area, but thins to the west above the Chappel Limestone. The “calcareous interruption” interval of Henry (1982) is thin in the southeast portion of Wise County and terminates in the western portion of Wise County.

The clastic interval and the lower Barnett Shale are the only two units that continue uninterrupted from north to south along the Jack and Wise County boundary (Figs. 3 and 9, plate IV). The upper limestone of the Marble Falls interval thickens to the south before interfingering with the clastic interval in southwestern Wise County. The upper shale of the Marble Falls interval occurs only in the central portion of the counties. It interfingers with the upper and lower limestone units to the north and the clastic interval to the south. The lower limestone occurs as a thin unit in the northern portion of Jack and Wise counties and thickens to the south before interfingering with the clastic interval. The upper Barnett Shale extends uninterrupted to the south. To the north it pinches out and is interpreted to

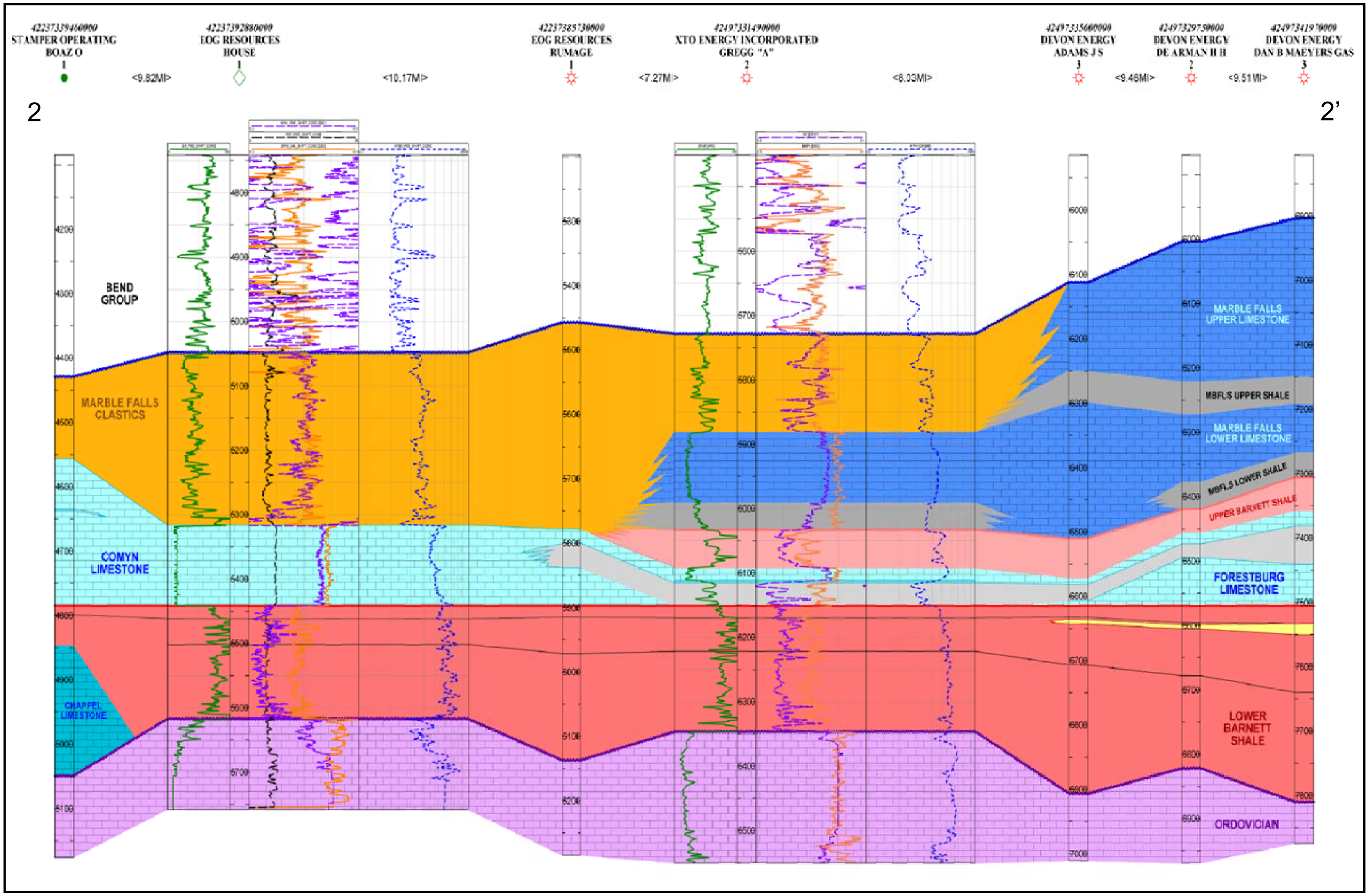

Figure 8. Stratigraphic cross section 2-2’. Datum is top of lower Barnett Shale. For location of cross section see Figure 3.

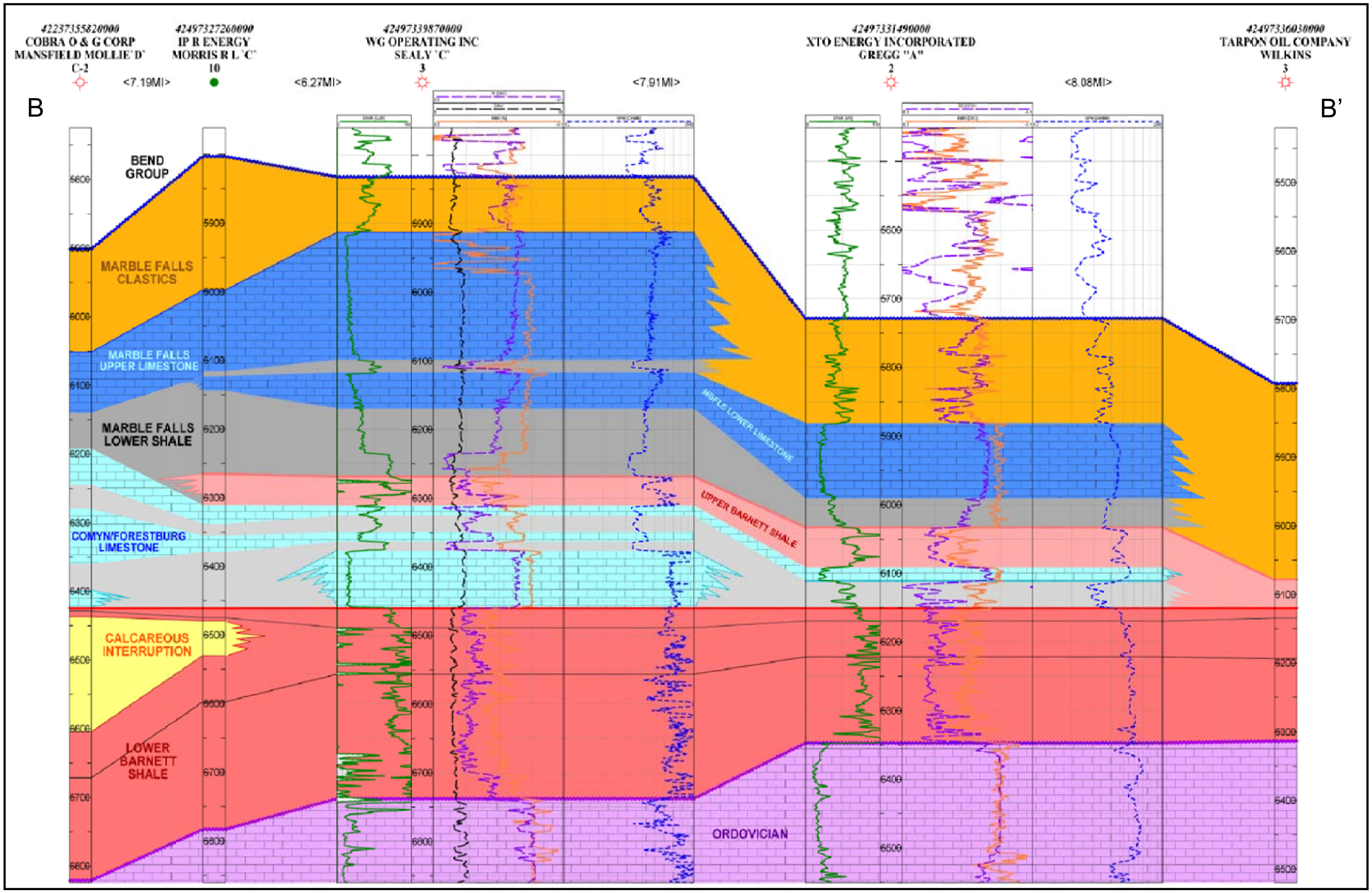

Figure 9. Stratigraphic cross section B-B'. Datum is top of lower Barnett Shale. For location of cross section see Figure 3.

interfinger with the lower shale of the Marble Falls interval. The limestone and shale units of the Forestburg limestone and the Comyn Limestone are not differentiated. The units are continuous to discontinuous from north to south and interfinger with the upper Barnett Shale to the south. The “calcareous interruption” is thick to the north and quickly thins to the south before pinching out and interfingering with the lower Barnett Shale.

The Comyn Limestone and the lower Barnett Shale are the only two units that extend uninterrupted from north to south in western Jack County (Figs. 3 and 10, plate V). The regional unconformity at the top of the Marble Falls truncates the clastic interval. The “calcareous interruption” is thick to the north and thins to the south where it pinches out and interfingers with the lower Barnett Shale where the Chappel Limestone begins.

Structure Maps

The contour pattern at the base of the lower Barnett Shale indicates an east-northeast deepening trend in the basin (Fig. 11). The shallow contours to the west reflect the positive structure of the Bend arch, while the deeper eastern contours reflect greater subsidence along the Ouachita thrust belt. Two conspicuous structures are shown by the contours within the study area. In southern Wise County, a structural nose plunging to the northeast trends perpendicular to the Muenster arch. This contour pattern reveals the structure of the Mineral Wells fault. In western Jack County, the basin shallows against an isolated structural high informally known as the “Sewell” high (Osterlund, 1984). Carbonate deposition took place on this high when and where seas were shallow. Contour lines are broadly spaced in central Wise County and northern Jack County. Contour lines become more closely spaced in the western, southern, and eastern parts of the study area.

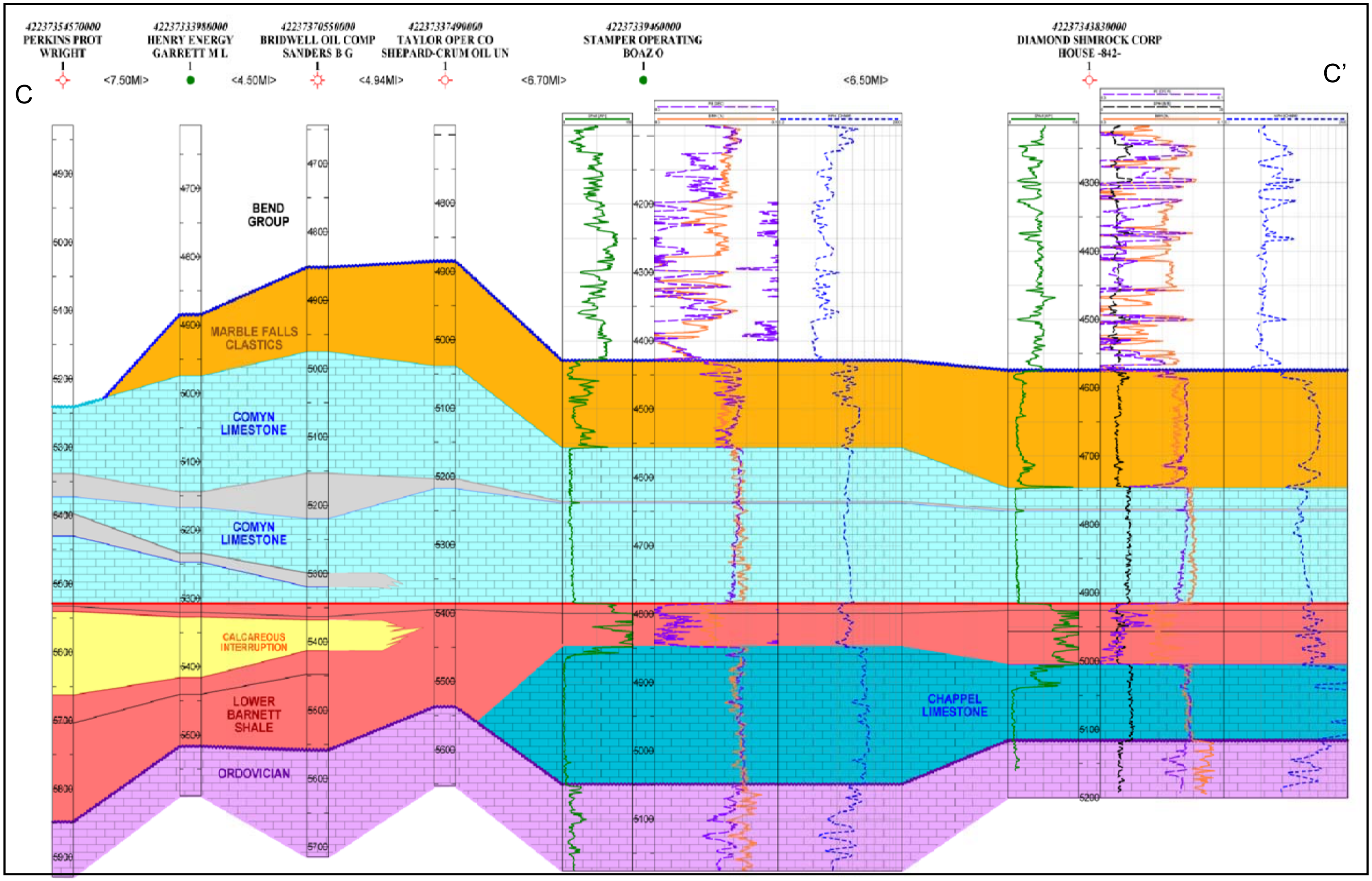

Figure 10. Stratigraphic cross section C-C’. Datum is top of lower Barnett Shale. For location of cross section see Figure 3.

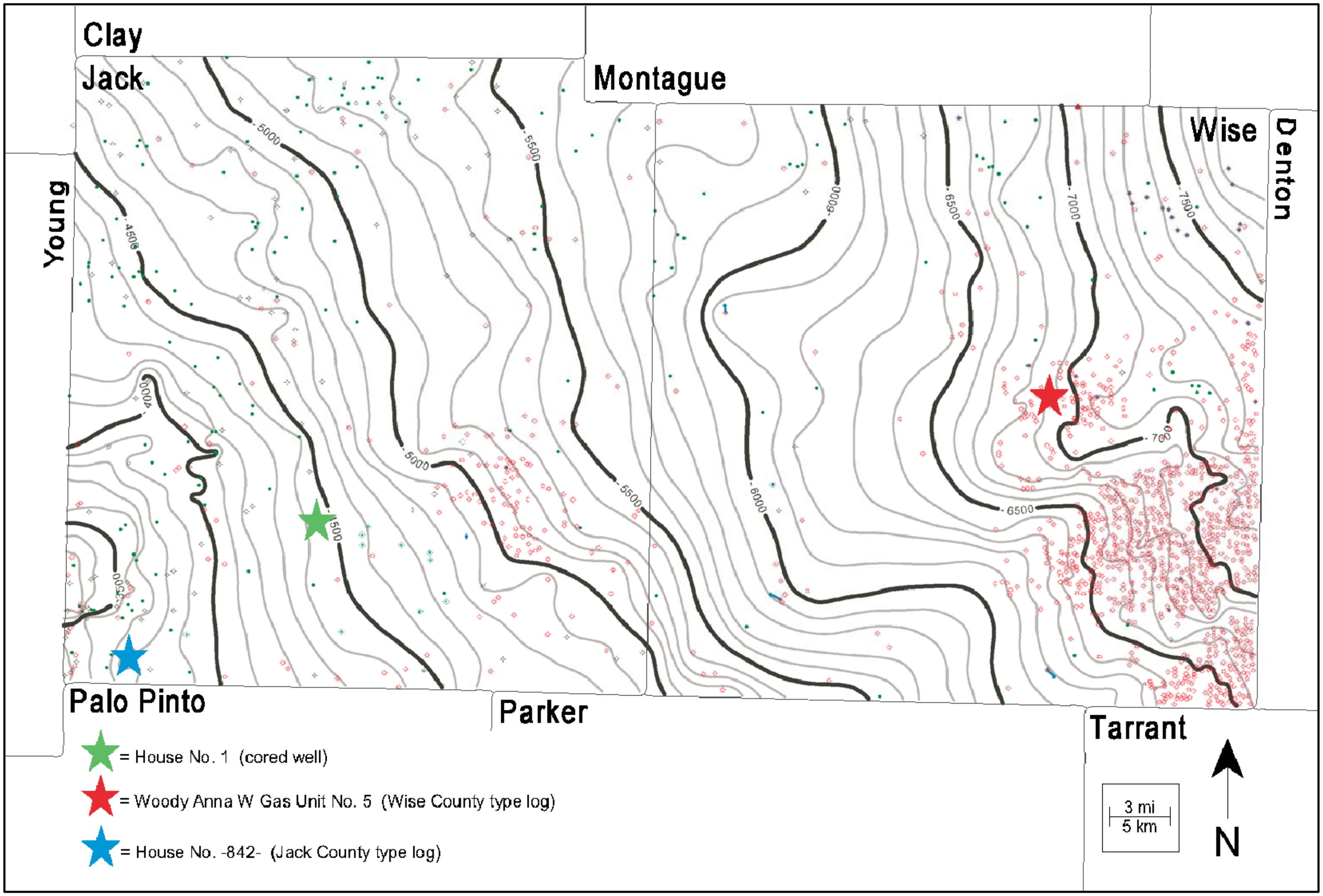

Figure 11. Structure contour map on base of Barnett Shale. Wells used for correlation indicated by red and green symbols. Contour interval, 100 feet.

The structure on top of the Marble Falls interval closely resembles the structure on the base of the lower Barnett Shale (Fig. 12). This suggests that there was no differential structural movement during deposition. Both the Mineral Wells fault and the “Sewell” high are apparent. The Mineral Wells fault shows the same northeast-plunging nose that turns slightly to the east at the boundary between Wise and Denton Counties. The continuity from the base of the lower Barnett Shale to the top of the Marble Falls interval suggests that the fault developed after deposition of the lower Atoka. The contour lines showing the “Sewell” high at the top of the Marble Falls interval are more spread apart than the contour lines on the lower Barnett Shale.

Isopach Maps

A pronounced thick is present on the isopach map for the upper limestone in the Marble Falls in south-central and east-central Wise County (Fig. 13). The thick trends slightly north of due west. The upper limestone is more than 260 ft (79 m) thick on the eastern border of Wise County. It pinches out abruptly in eastern Jack County, where the limestone interfingers with the clastic interval in the Marble Falls (Figs. 7 and 8). The unit also thins rather sharply to the south into Parker County. The decrease in thickness is more gradual to the north and a strong reentrant is present in northeastern Wise County. The lower limestone in the Marble Falls interval is thinner than the upper one, reaching a maximum thickness of only some 200 ft (61 m) (Fig. 14). A pronounced northwest-southeast-trending thick is present in east central Jack County and southwestern Wise County. The thickness drops off sharply to the southwest where the limestone interfingers with clastic strata (Fig. 7).

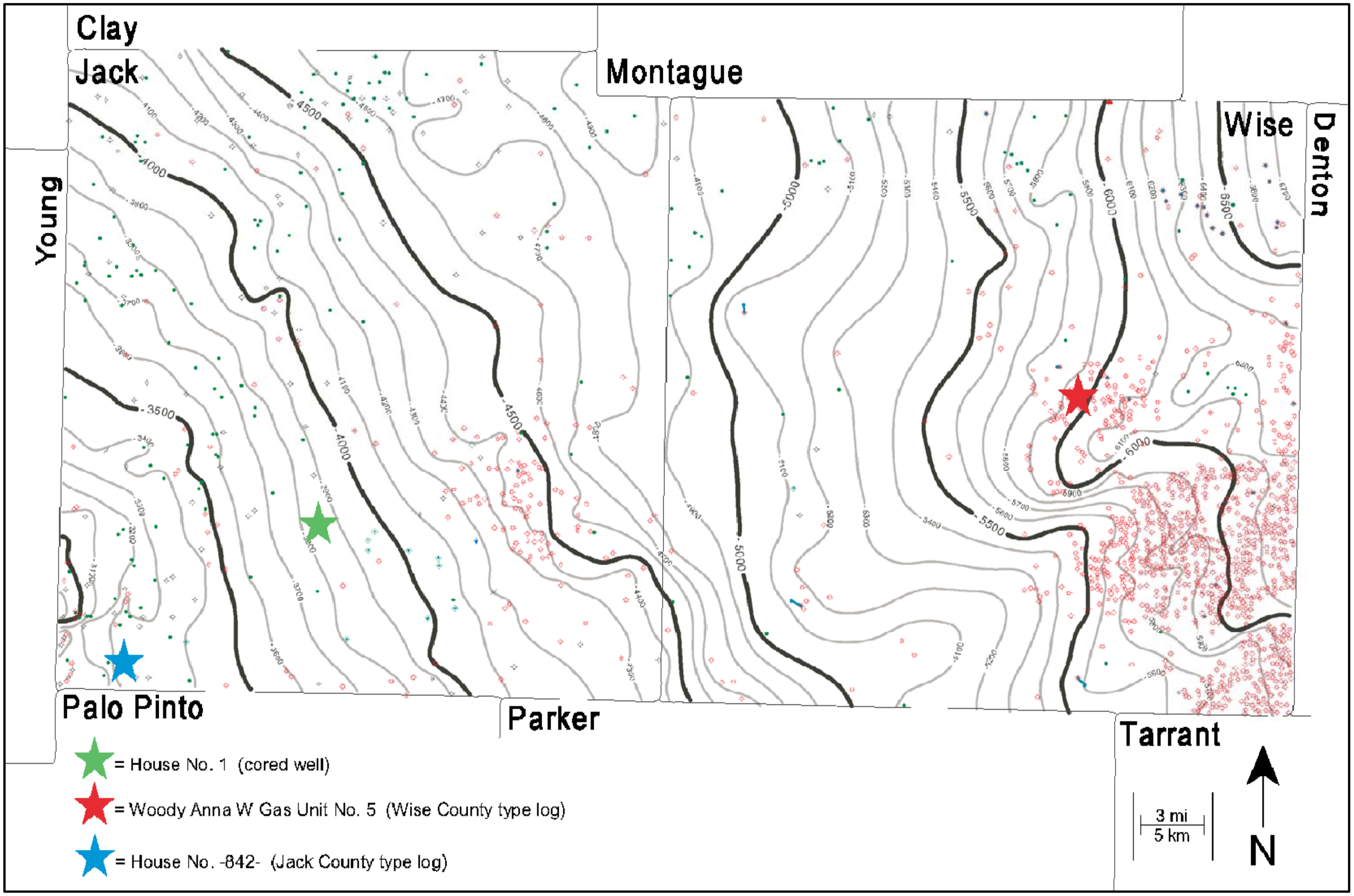

Figure 12. Structure contour map on top of Marble Falls interval. Wells used for correlation indicated by red and green symbols. Contour interval, 100 feet.

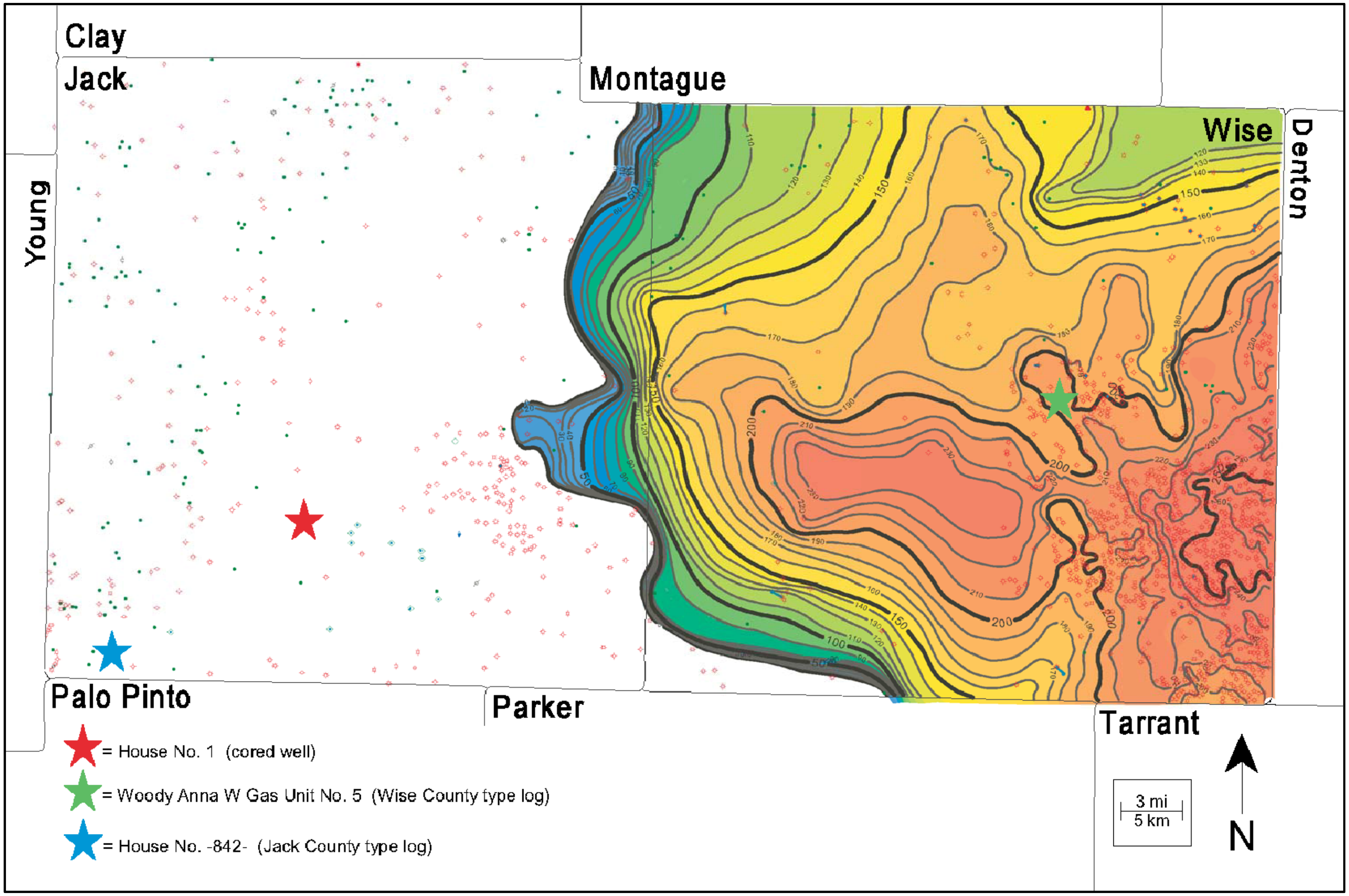

Figure 13. Isopach map of upper limestone in the Marble Falls interval. Wells used for correlation indicated by red and green symbols. Contour interval, 10 feet.

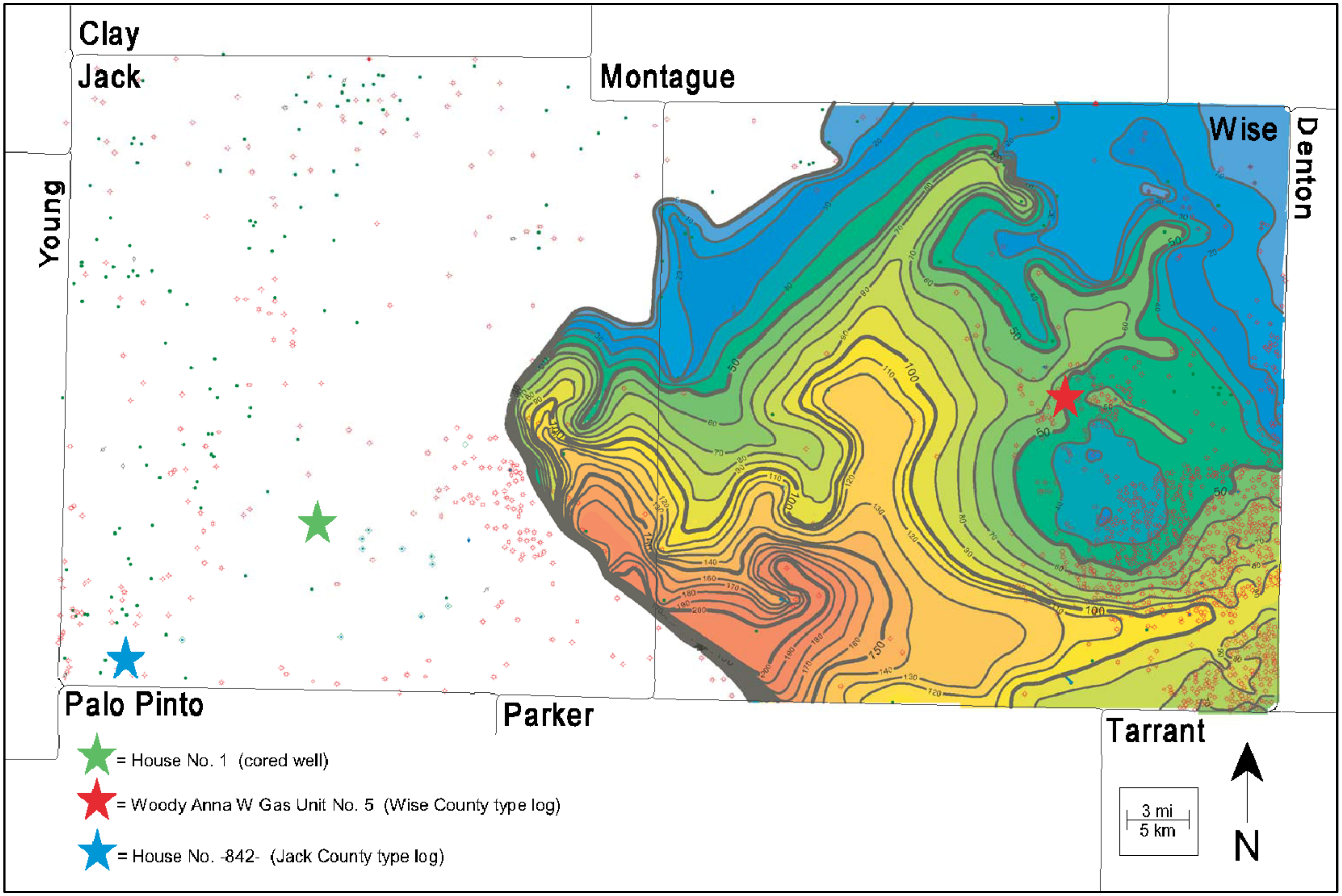

Figure 14. Isopach map of lower limestone in the Marble Falls interval. Wells used for correlation indicated by red and green symbols. Contour interval, 10 feet.

Three finger-like thicks separated by pronounced thin areas extend to the northeast from the main body of the limestone.

The upper shale in the Marble Falls interval separates the upper and lower limestone. Its isopach map resembles that of the lower limestone, with a pronounced northwest-southeast-trending thick in east-central Jack County and southern Wise County (Fig. 15). It too ends abruptly to the southwest where the shale interfingers with interbedded siltstones and claystones in the Marble Falls clastic interval (Fig. 7). The maximum thickness of the shale is 70 ft (21 m) in southern Wise County. It thins from there both to the north and west. The lower shale lies immediately beneath the lower limestone. It reaches a maximum thickness of more than 130 ft (40 m) in northwestern Wise County, where the upper shale is thin or absent (Fig. 16). The shale pinches out abruptly to the west and south where it interfingers with the clastic interval in the Marble Falls (Fig. 7).

The isopach map for the clastic interval in the Marble Falls shows a pronounced thick extending approximately north-south in central Jack County (Fig. 17). The clastics reach a thickness of almost 500 ft (152 m) in the central portion of the county. The clastics thin abruptly along the contact with the upper and lower limestone. A thin wedge of clastic material extends across the top of the upper limestone in western Wise County (Figs. 7 and 17). The clastic interval also thins to the west over the top of the Comyn Limestone (Figs. 7 and 17). The clastic interval is thickest where the limestones and shales in the Marble Falls interval are thinnest.

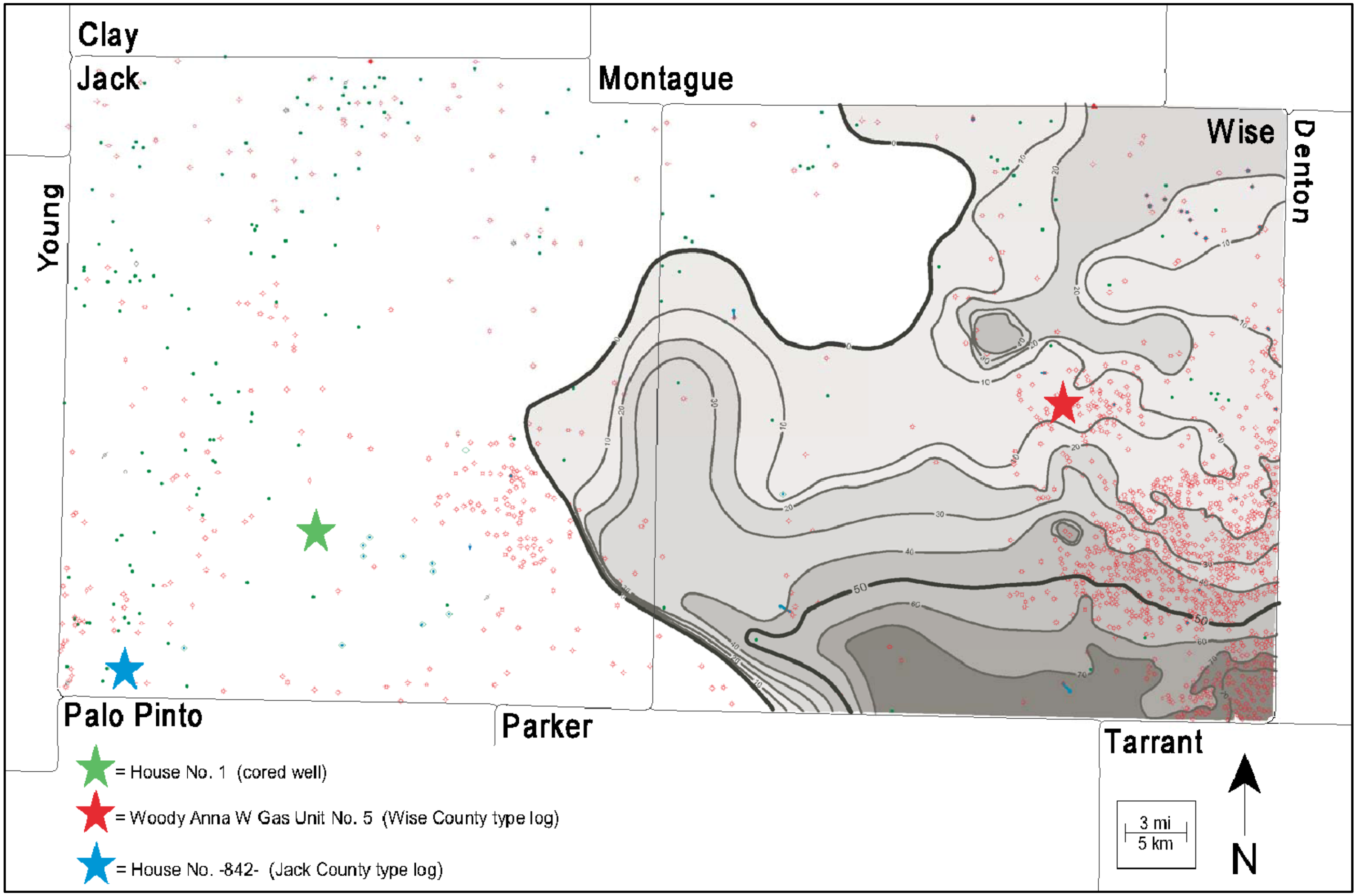

Figure 15. Isopach map of upper shale in the Marble Falls interval. Wells used for correlation indicated by red and green symbols. Contour interval, 10 feet.

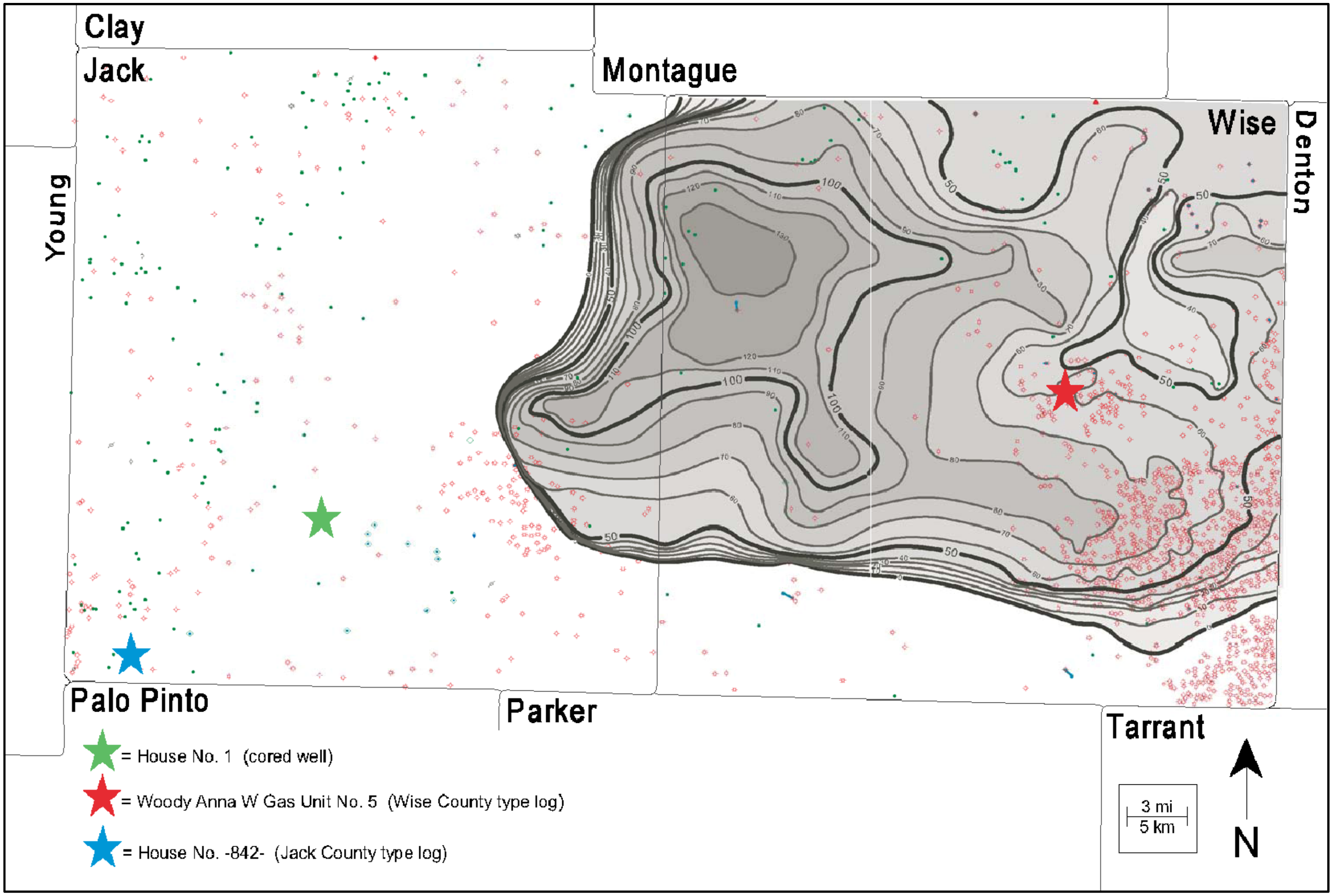

Figure 16. Isopach map of lower shale in the Marble Falls interval. Wells used for correlation indicated by red and green symbols. Contour interval, 10 feet.

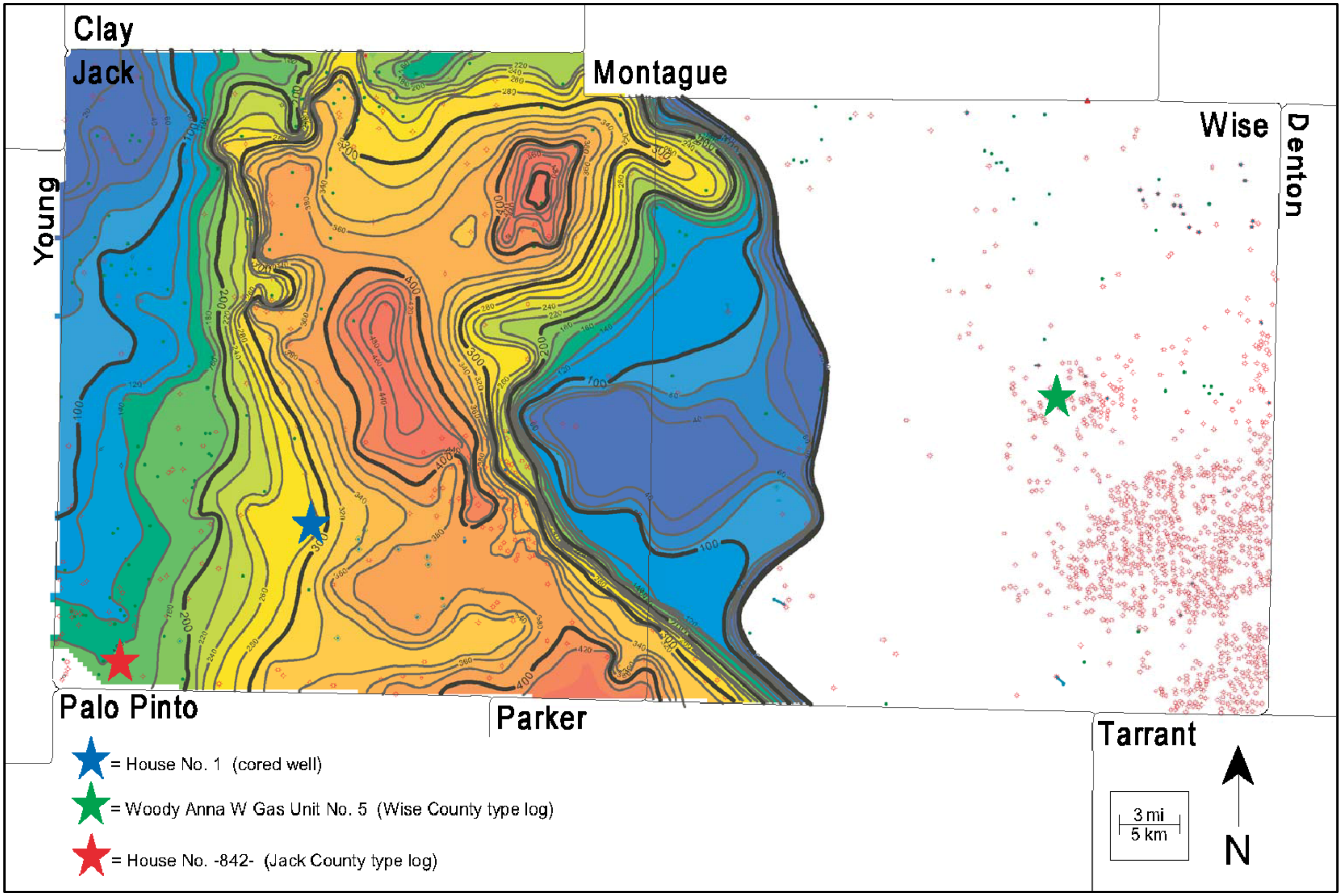

Figure 17. Isopach map of clastic interval in the Marble Falls interval. Wells used for correlation indicated by red and green symbols. Contour interval, 20 feet.

CORE ANALYSIS

Four lithologies are present in the core recovered from the House No. 1 well in Jack County (Table 1). The most common lithology, comprising approximately 70% of the core, is a light gray to gray spiculitic siltstone (Figs. 18A and 19). Silt-sized sponge spicules (some of which have been altered to either chert or calcite) quartz grains, glauconite, dolomite, muscovite, and authigenic pyrite are present. The second most common lithology, comprising approximately 30% of the core, is a dark gray to black laminated mudstone to claystone (Figs. 18B and 20). Clay-sized particles of argillaceous material predominate. Varying, but subordinate, amounts of silt-sized quartz, glauconite, dolomite, muscovite, and phosphatic material are also present. The remaining two lithologies are a light gray spiculitic crinoidal siltstone (Figs. 18C and 21) and a micritic limestone (Figs. 18D and 22). The spiculitic crinoidal siltstone occurs only at one level near the top of the Marble Falls within the core and comprises only 2% of the core. It is a poorly sorted mixture of siliceous sponge spicules, dolomite crystals, and glauconite forming a matrix of sand- to gravel-sized crinioid fragments. The micritic limestone occurs only at the base of the core and comprises approximately 3% of the cored interval. Micrite and dolomite crystals are the primary constituents within the micritic limestone (Fig. 22).

Seven facies are present in the core (Table 1). Six of the facies (A-F) are defined primarily by the relative abundance of siltstone to mudstone or claystone in the cored interval and secondarily by the composition of the silt fraction and the degree of bioturbation. These facies are composed of varying mixtures of lithologies L1 through L3 that mainly reflect changes in energy levels at the site of deposition. Micritic limestone (L4) with thin interbeds of euhedral dolomite crystals in dark clay comprises the seventh facies (G).

LITHOLOGY	**DESCRIPTION**
L1	Spiculitic siltstone
L2	Laminated mudstone to claystone
L3	Crinoidal siltstone
L4	Micritic limestone
FACIES	**DESCRIPTION**
A	• Spiculitic siltstone with thin interbeds of dark claystone • Siltstone/claystone ratio > 9:1 • Siltstone is highly bioturbated
B	• Spiculitic crinoidal siltstone with interbeds of black claystone • Siltstone/claystone ratio ≈ 1:1 • Siltstone is highly bioturbated
C	• Spiculitic siltstone with thin interbeds of black mudstone • Siltstone/claystone ratio ≈ 8:1 • Silst is highly bioturbated
D	• Quartz-rich siltstone interbedded with dark gray claystone • Siltstone/claystone ratio > 9:1 • Spicules less abundant • Silt is highly bioturbated
E	• Black claystone with thin interbeds of siltstone • Siltstone/claystone ratio ≈ 1:8 • Siltstone is moderately bioturbated
F	• Black claystone with rare event beds • Siltstone/claystone ratio > 1:9 • Siltstone is not bioturbated
G	• Micritic limestone with thin interbeds of dolomitic claystone • Siltstone/claystone ratio > 9:1 • Bioturbation is not present

Table 1. List of lithologies and facies in House No. 1 well.

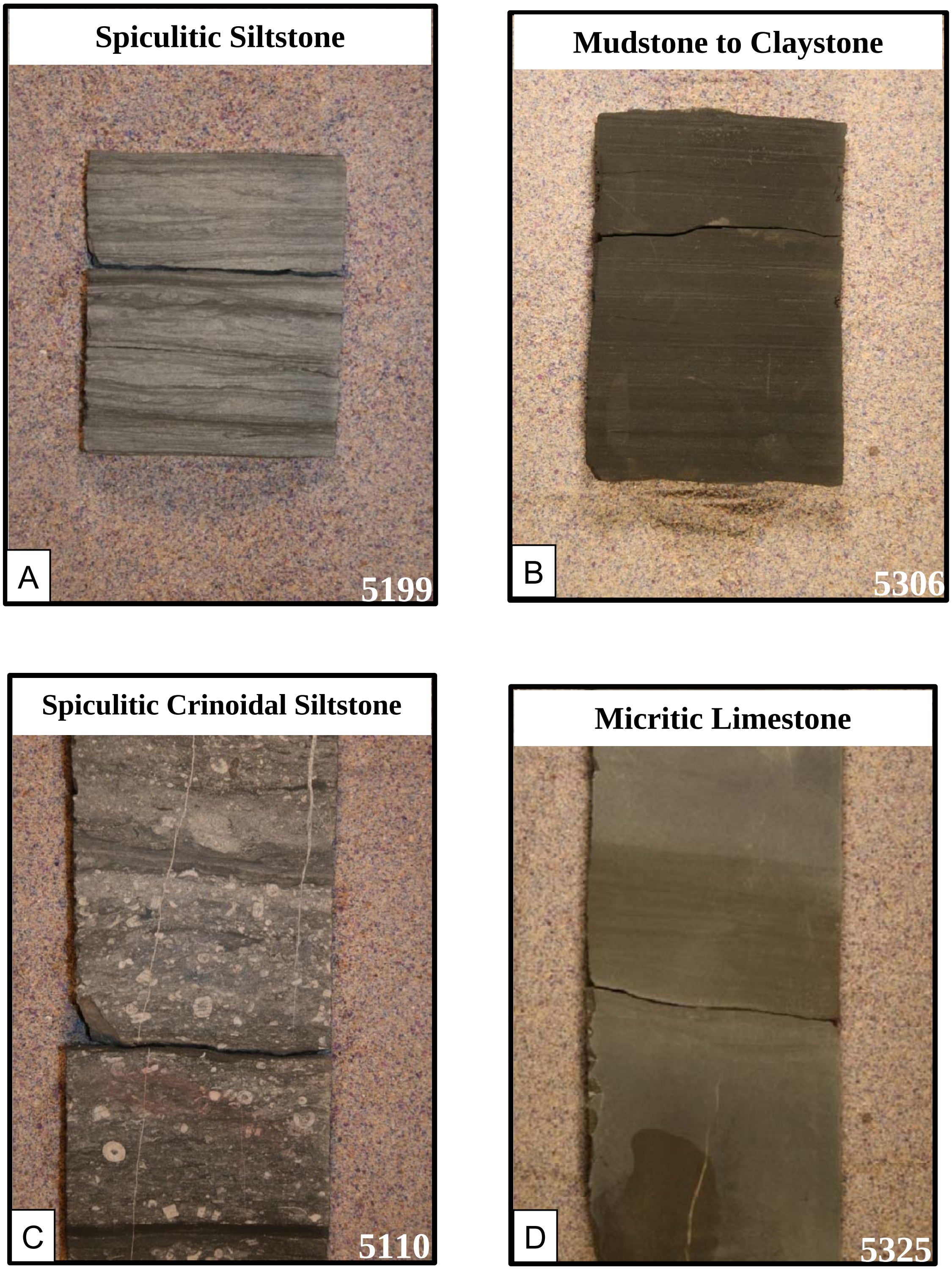

Figure 18. Core photos of lithologies present in the House No. 1 well. In this and following core photographs, white numbers in lower right corner indicate depth (in ft.) at which core was taken. Core is 8 cm wide.

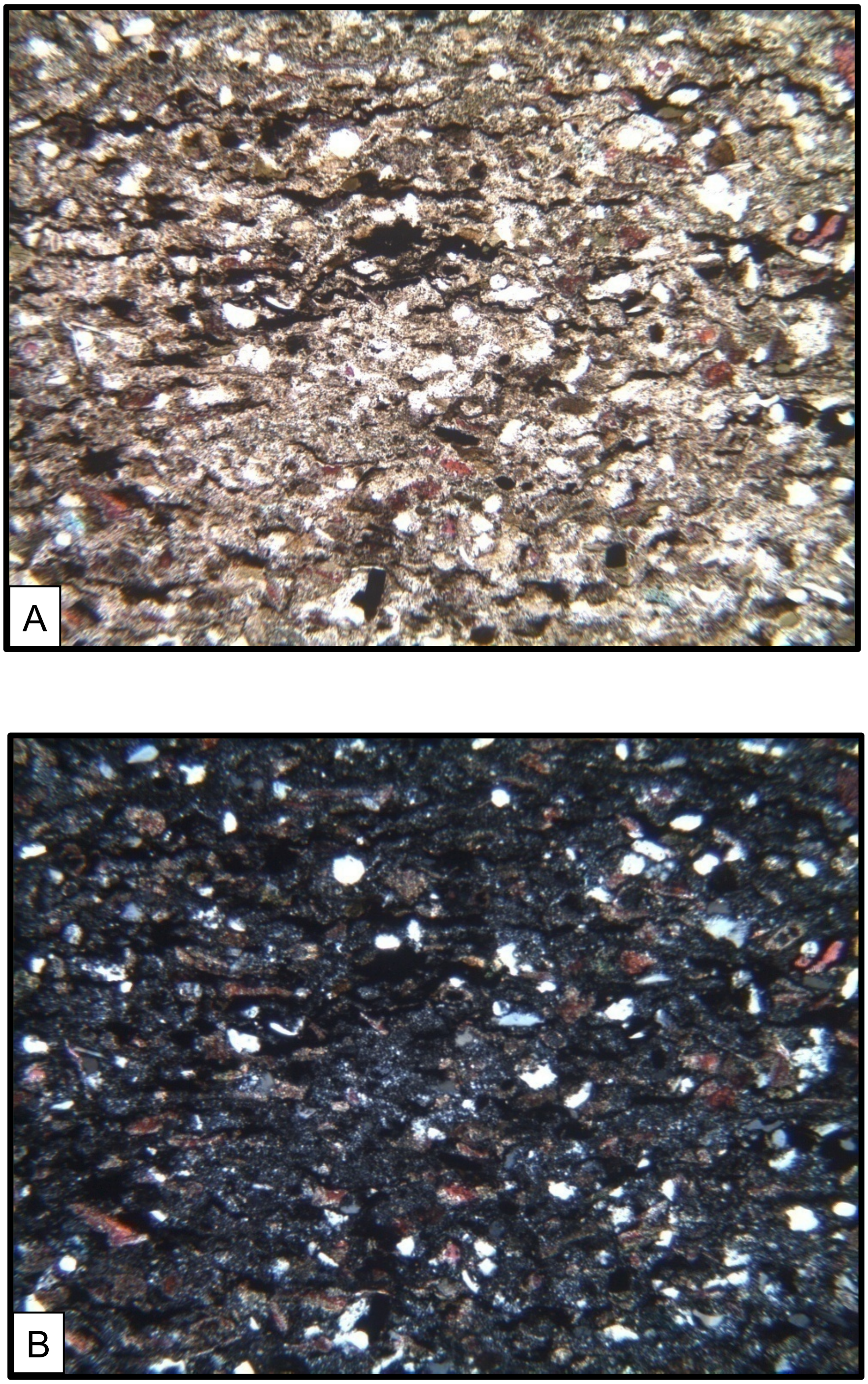

Figure 19. Photomicrographs of light gray spiculitic siltstone. Photomicrograph A is in plane-polarized light and photomicrograph B is the same photomicrograph in cross-polarized light. Field of view (FOV) is 2.4 mm across. Depth in core is 5,077.2 feet.

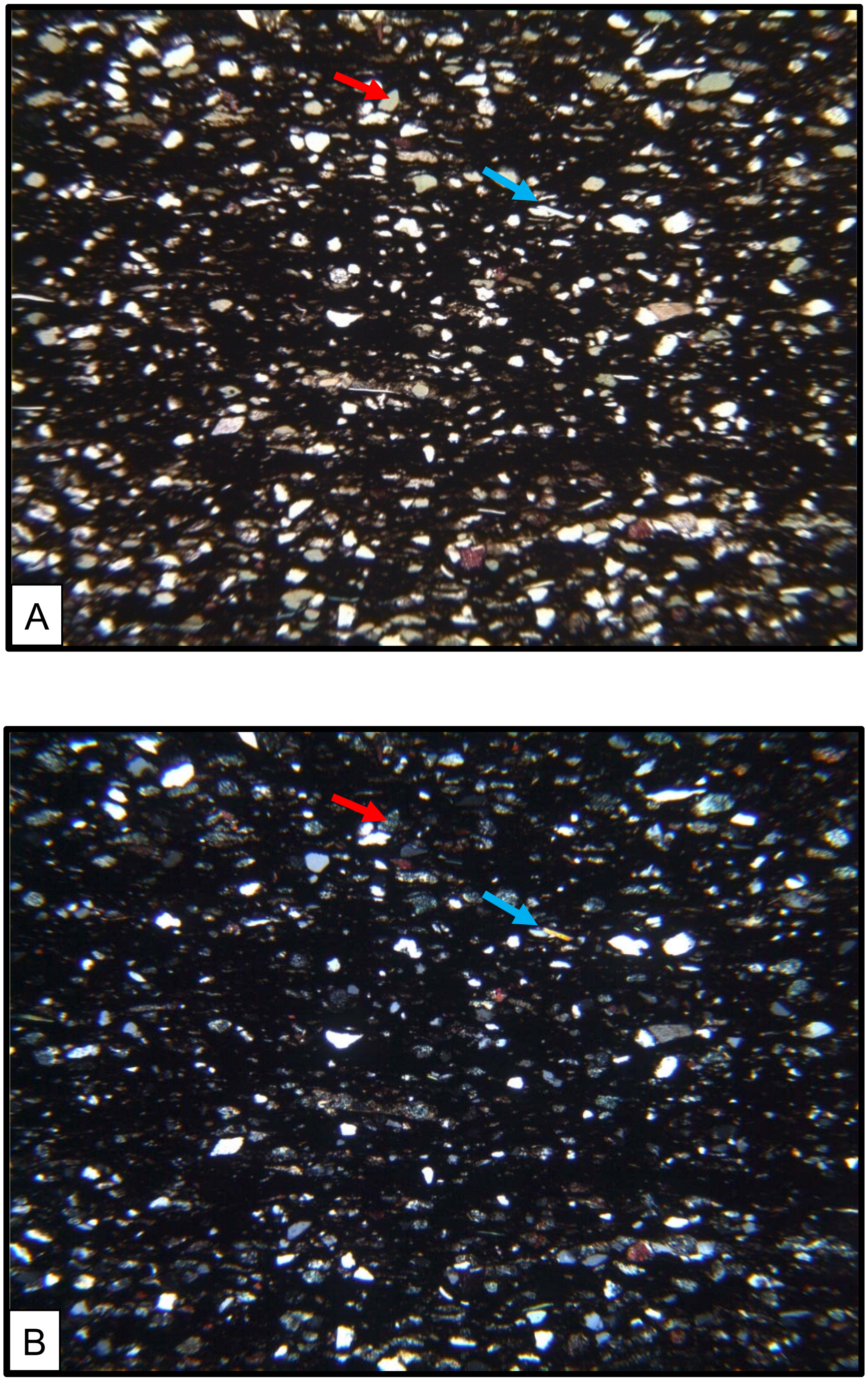

Figure 20. Photomicrographs of black mudstone. Photomicrograph A is in plane-polarized light and photomicrograph B is the same photomicrograph in cross-polarized light. Red arrow indicates glauconite grain. Blue arrow indicates muscovite grain. FOV is 2.4 mm across. Depth in core is 5,162.6 feet.

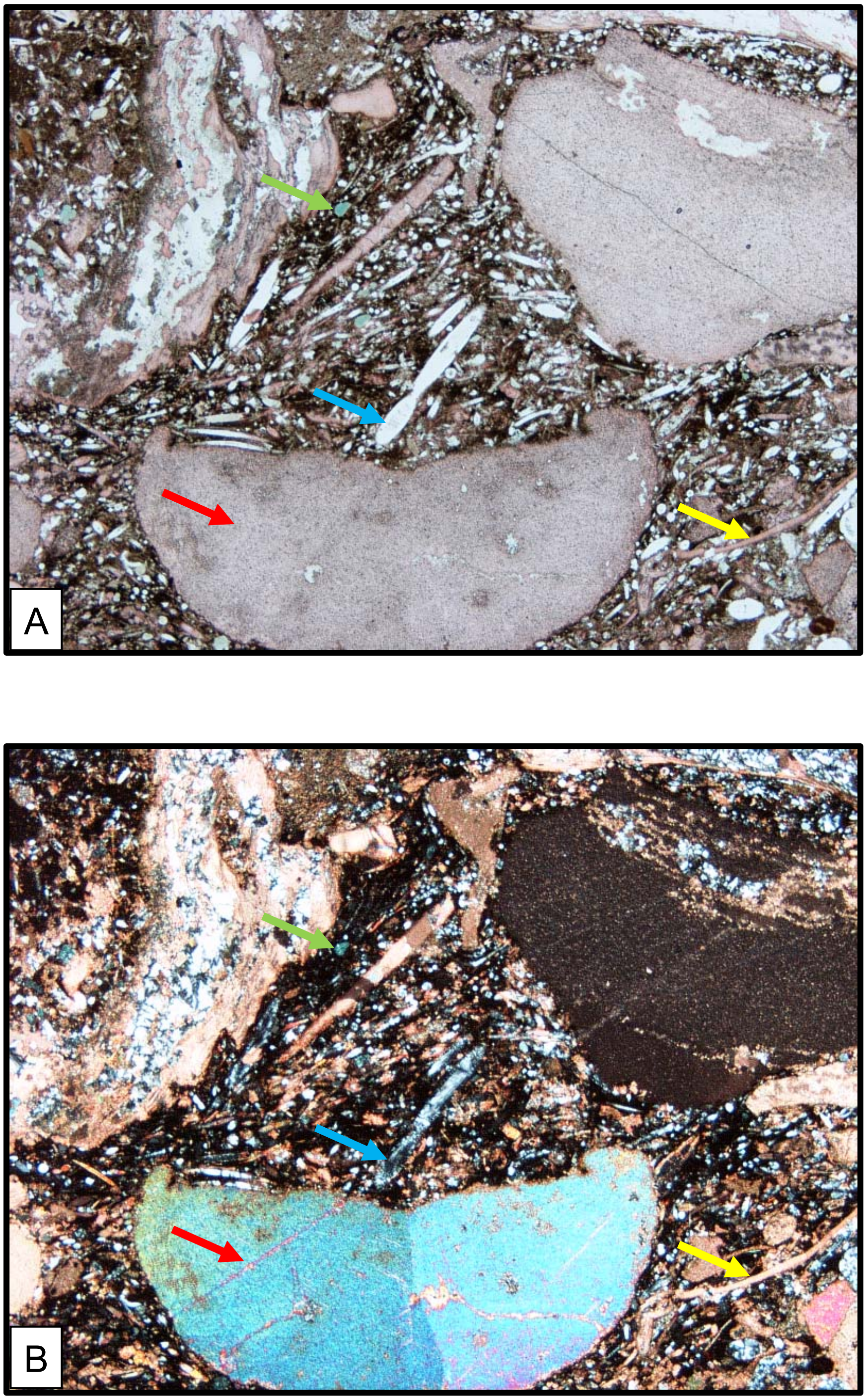

Figure 21. Photomicrographs of light gray spiculitic crinoidal siltstone showing crinoid fragments (red arrow), siliceous sponge spicules (blue arrow), shell fragments (yellow arrow), and glauconite grains (green arrow). Photomicrograph A is in plane-polarized light and photomicrograph B is the same photomicrograph in cross-polarized light. FOV is 8.5 mm across. Depth in core is 5,110.6 feet.

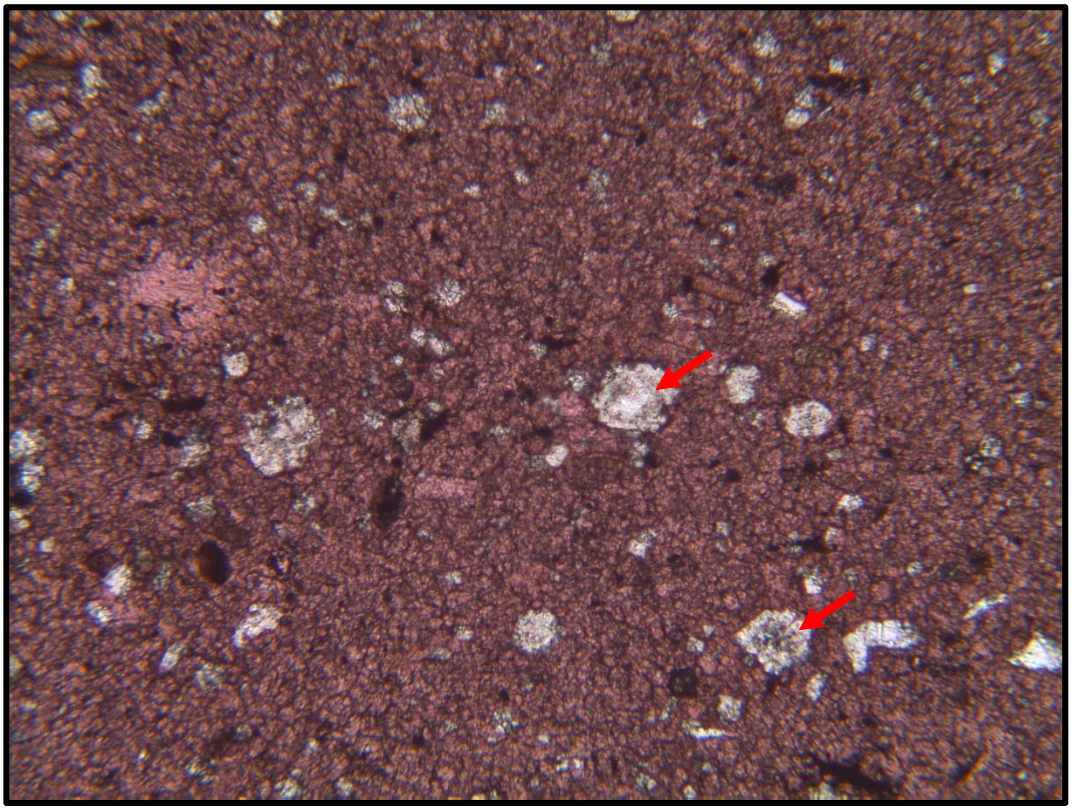

Figure 22. Photomicrograph of subhedral dolomite within the light gray micritic limestone. Calcite is pink due to alizarin red-S stain. Red arrows indicate dolomite grains. FOV is 0.1 mm across. Depth in core is 5,338.7 feet.

Facies A

Facies A is a light gray, laminated spiculitic siltstone with thin interbeds of dark gray to black laminated claystone (Fig. 23A) (Table 1). The siltstone comprises over 90% of the facies and is commonly highly bioturbated (Fig. 23B). The siltstone reacts strongly with dilute HCl indicating a significant content of calcium carbonate. The claystone reacts less strongly with HCl. The laminae within the siltstone are generally continuous across the core, planar and parallel, but may be discontinuous, wavy, and nonparallel. Laminae within the claystone are mostly continuous across the core, planar, and parallel. Discrete burrows are present in the siltstone. Sediment within the burrows contains less argillaceous material and is therefore lighter in color than the host material (Fig. 24). Facies A has a total thickness of 45 ft (14 m) and makes up 16% of the cored interval (Table 2). The facies is found only at the top of the Marble Falls interval at depths of 5,060 ft to 5,105 ft (Fig. 25).

Facies B

Facies B consists of spiculitic crinoidal siltstone with thin interbeds of black claystone (Table 1). Crinoid fragments mostly occur in the light gray siltstone of facies B (Fig. 26A). The siltstone comprises approximately 50% of the facies and is highly bioturbated (Fig. 26B). Silt intervals are 0.2-17 in (0.5-42 cm) thick and strongly react with HCl; the claystone reacts less strongly with HCl. Laminae within the claystone are continuous across the core, planar to wavy, and parallel. At one silt- and claystone boundary (red outline in Fig. 26A) a rare dolomite lithoclast occurs that has been partially replaced by chert on one end (Fig. 27). Facies B has a total thickness of 14 ft (4 m) and makes up only 5% of the cored interval (Table 2). It occurs only near the top of the Marble Falls interval

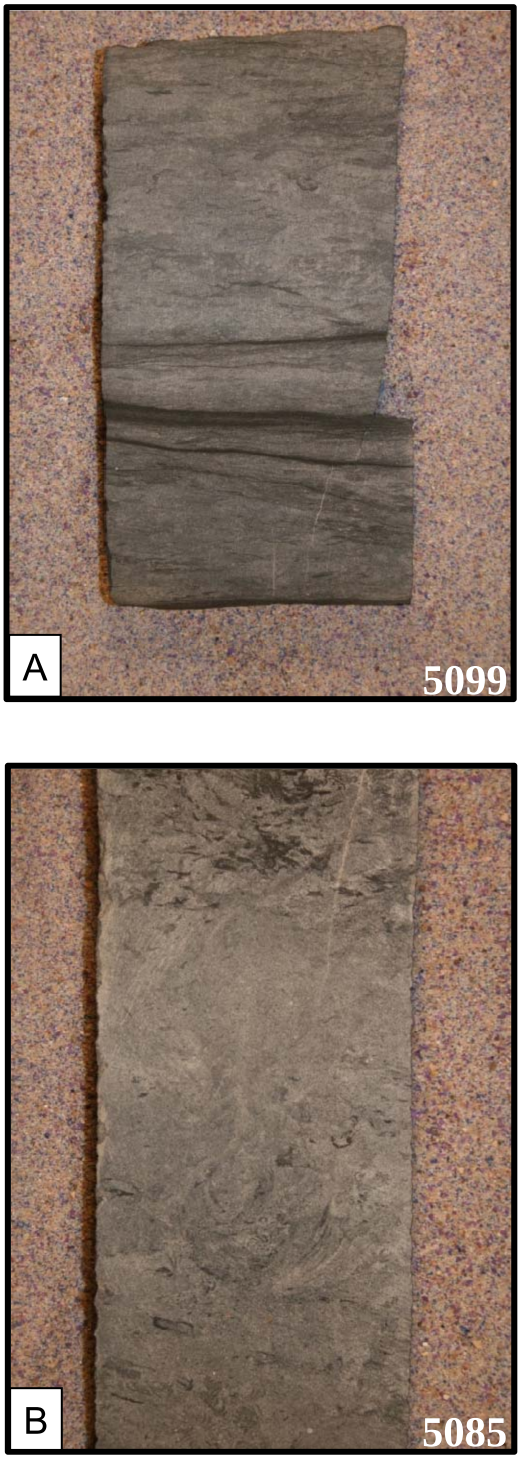

Figure 23. Core photos of facies A. Photo A shows light gray laminated spiculitic siltstone with thin interbeds of dark gray to black laminated claystone. Photo B shows light gray highly bioturbated siltstone. Core is 8 cm wide.

Figure 24. Photomicrograph of burrow in facies A. Lamination (yellow line) in matrix is bent around burrow. Vertical fracture cutting burrow is completely healed mostly by calcite and some dolomite. Plane-polarized light. FOV is 29 mm across. Depth in core is 5,064.5 feet.

FACIES	OCCURRENCE	AVERAGE THICKNESS	TOTAL THICKNESS	% OF CORE
A	1	45’	45’	16%
B	1	14’	14’	5%
C	6	22’	134.5’	48%
D	1	18’	18’	6%
E	4	6’	21’	8%
F	2	10.6’	21.5’	8%
G	1	22’	22’	8%

Table 2. Occurrence, average thickness, total thickness, and relative abundance of each facies.

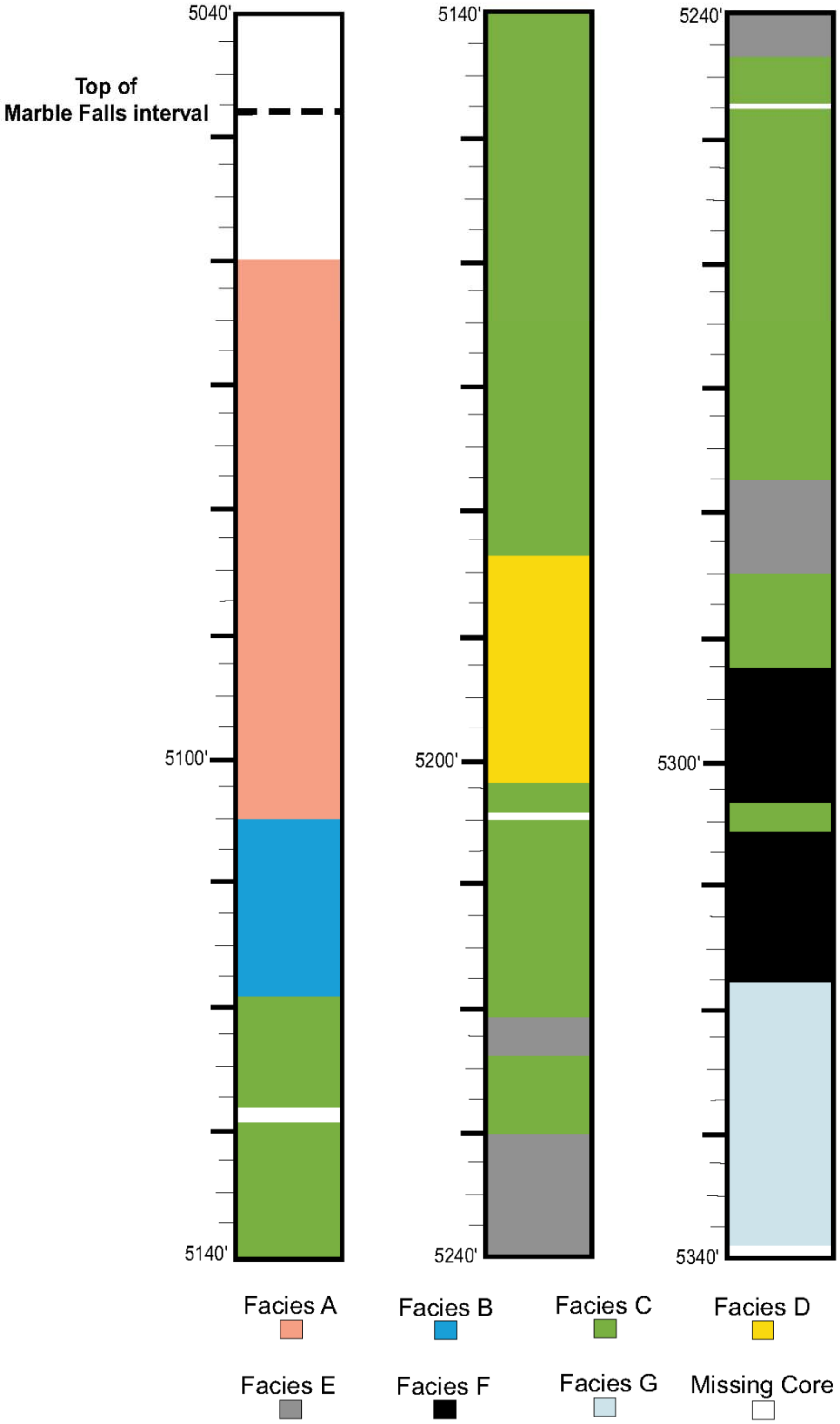

Figure 25. Stratigraphic distribution of facies.

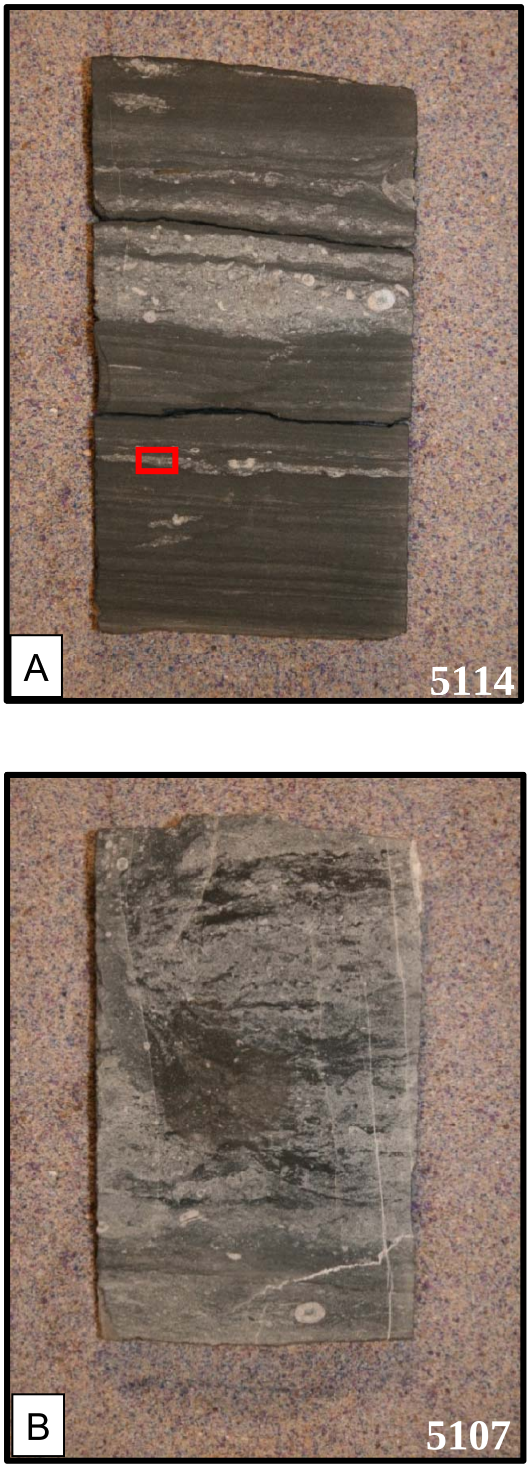

Figure 26. Core photos of facies B. Photo A shows claystone with thin interbeds of light gray spiculitic crinoidal siltstone. Photo B shows highly bioturbated light gray spiculitic crinoidal siltstone. Red outline indicates point at which Figure 27 was taken. Core is 8 cm wide.

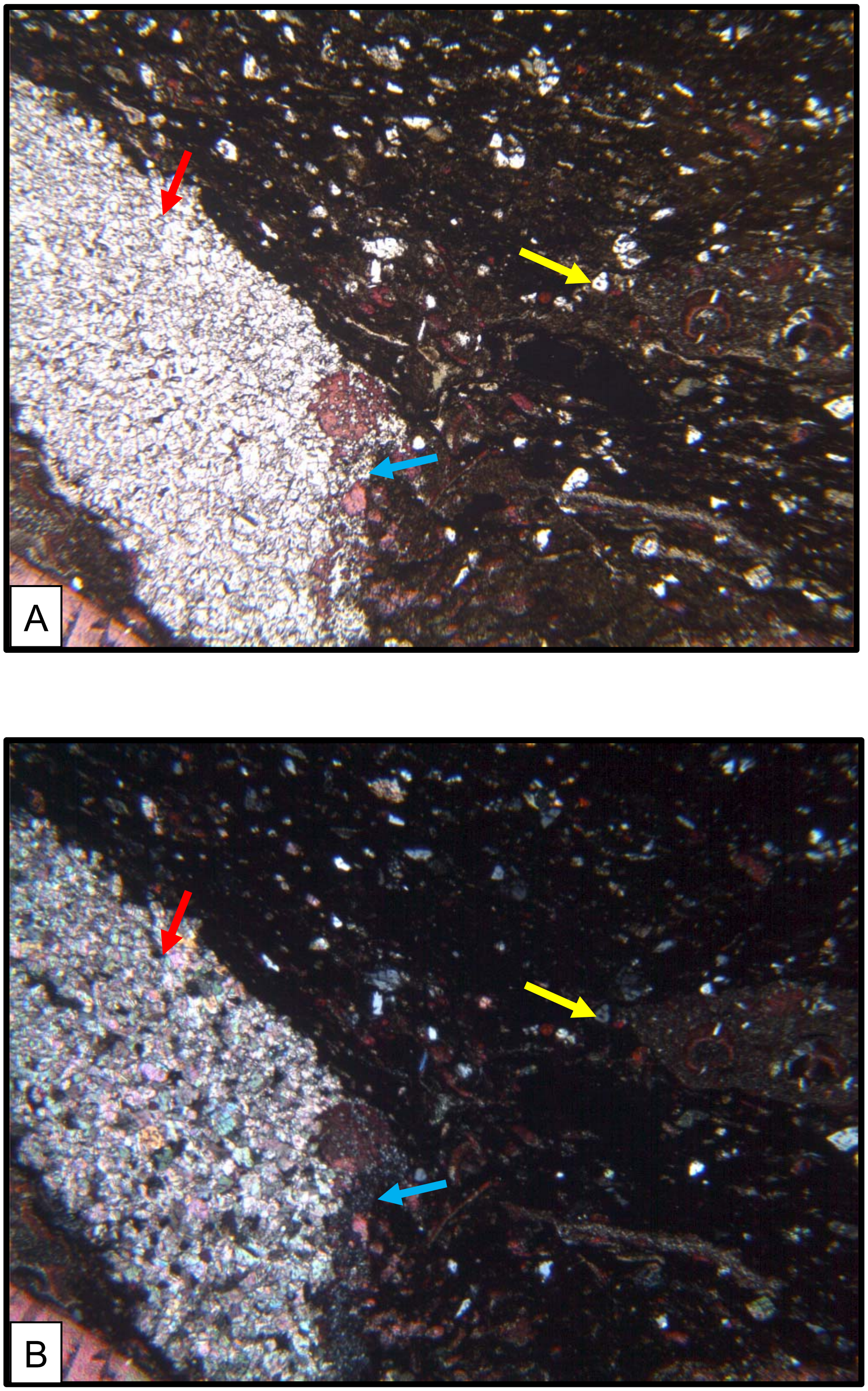

Figure 27. Photomicrograph of dolomite lithoclast (red arrow) surrounded by silt and argillaceous material within the claystone of facies B. Photomicrograph A is in plane-polarized light and photomicrograph B is the same photomicrograph in cross-polarized light. One end of the lithoclast has been altered to chert (blue arrow). The yellow arrow indicates an individual dolomite grain. FOV is 2.4 mm across. Depth in core is 5,113 feet.

(Fig. 25) at a depth of 5,105 to 5,119 ft (1,556 to 1,560 m) and has a gradational boundary with facies A.

Facies C

Facies C consists of light gray, spiculitic siltstone with thin interbeds of black mudstone (Table 1). The siltstone comprises over 80% of the facies and is highly bioturbated (Fig. 28A). The siltstone reacts strongly with HCl, but the mudstone does not react. The laminae within the siltstone are generally discontinuous across the core, wavy and parallel, but may be continuous, planar, and parallel. Laminations within the mudstone are mostly continuous across the core, planar and parallel, but may be discontinuous, wavy, and nonparallel (Fig. 28B). The siltstone contains both siliceous and calcareous cement (Fig. 29) that are finely interbedded within one foot intervals. Facies C is the most common facies in the core (Fig. 25). It occurs at six different depths, has a total thickness of 134.5 ft (41 m), and makes up 48% of the core (Table 2). Its boundary with other facies is gradational.

Facies D

Facies D consists of light gray siltstone and dark gray claystone (Table 1). The siltstone comprises 80% of the facies and is highly bioturbated (Fig. 30A). The siltstone reacts strongly with HCl, whereas the claystone reacts less strongly. The laminae within the siltstone are mostly discontinuous across the core, wavy and nonparallel, but may be continuous, planar, and parallel (Fig. 30B). Minor ripple cross lamination is present. Laminae within the claystone are generally continuous across the core, planar and parallel, but may be discontinuous, wavy, and nonparallel. Subangular detrital quartz is the most

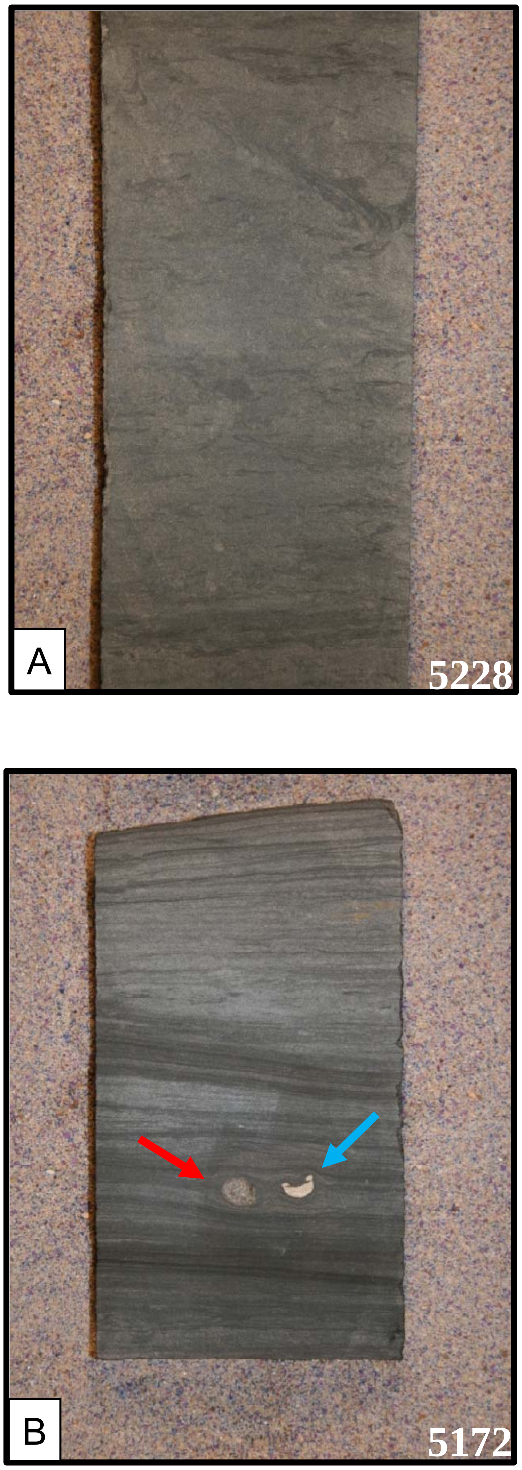

Figure 28. Core photos of facies C. Photo A shows highly bioturbated light gray spiculitic siltstone. Photo B shows laminae within the siltstone and mudstone. Also note bryozoan (red arrow) and echinoderm (blue arrow) shell fragments in facies C. Core is 8 cm wide.

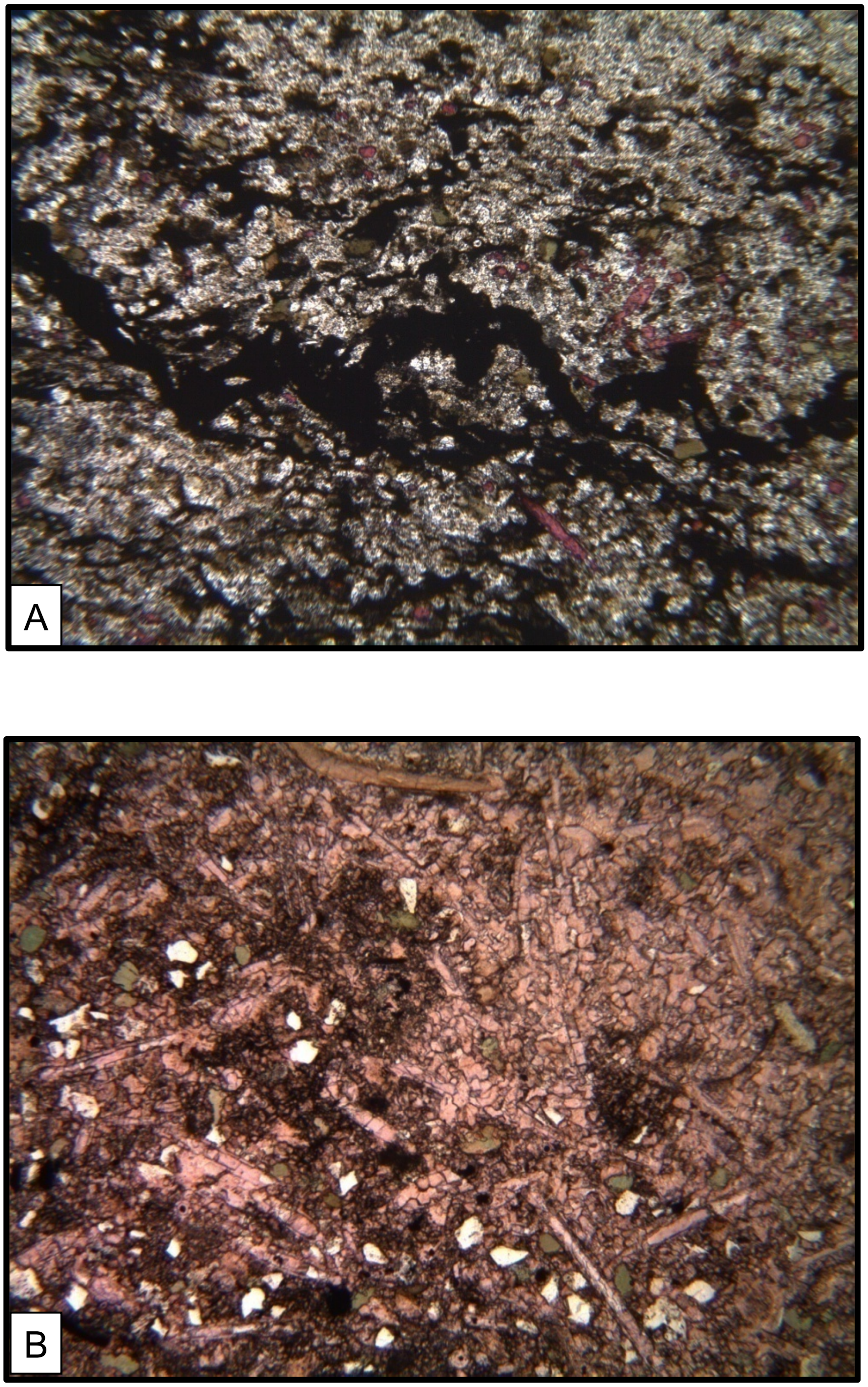

Figure 29. Photomicrographs showing siliceous and calcareous siltstone within facies C. Photomicrograph A is in plane-polarized light and shows siliceous siltstone. 5,266.7 feet. Photomicrograph B is in plane-polarized light and shows calcareous siltstone. FOV is 2.4 mm across. Depth in core is 5,139.6 feet.

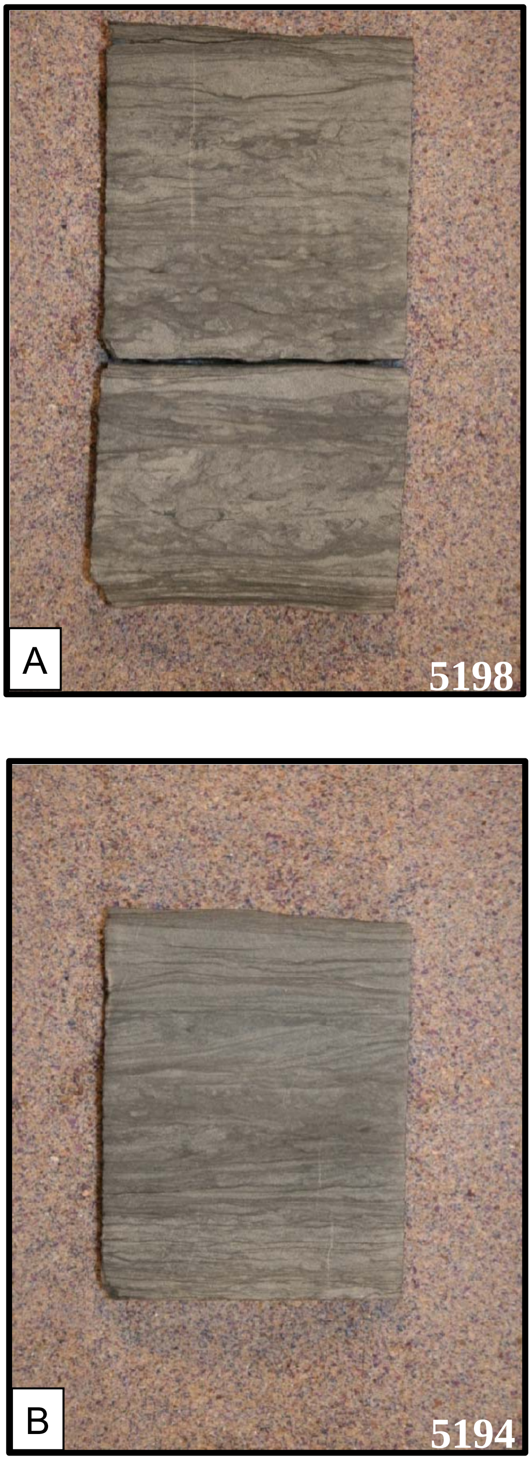

Figure 30. Core photos of facies D. Photo A shows highly bioturbated light gray siltstone. Photo B shows laminae within light gray siltstone. Core is 8 cm wide.

common grain type within the siltstone (Fig. 31). Few Partially collapsed agglutinated forams are also present. Facies D has a total thickness of 18 ft (5 m) and makes up 6% of the core (Table 2). The facies occurs only in the middle of the Marble Falls interval at a depth of 5,184 to 5,202 ft (Fig. 25).

Facies E

Facies E consists of black claystone with light gray interbeds of siltstone (Table 1). The claystone comprises over 80% of the facies (Fig. 32A). The claystone does not react with HCl. The siltstone reacts strongly with HCl and is slightly bioturbated (Fig. 32B). The laminae within the claystone are mostly discontinuous across the core, planar and nonparallel, but may be continuous, planar, and parallel. Laminae within the siltstone are mostly continuous across the core, planar and parallel, but may be discontinuous, wavy, and nonparallel. Argillaceous material with thin silt laminae dominates this facies (Fig. 33). Facies E has a total thickness of 21 ft (7 m) and makes up 8% of the core (Table 2). It occurs at four levels in the lower portion of the Marble Falls interval at a depth of 5,221 to 5,285 ft (Fig. 25).

Facies F

Facies F consists of black claystone with rare event beds of dark gray mudstone (Table 1). Compacted shell fragments and nautiloids are present (Fig. 34A). Facies F strongly reacts with dilute HCl toward the top of the facies but reacts only slightly toward the base of the facies. It is mostly massive, but does show faint, continuous, planar laminae (Fig. 34B). Dark gray interbeds of mud contain shell fragments and other fine-grained material

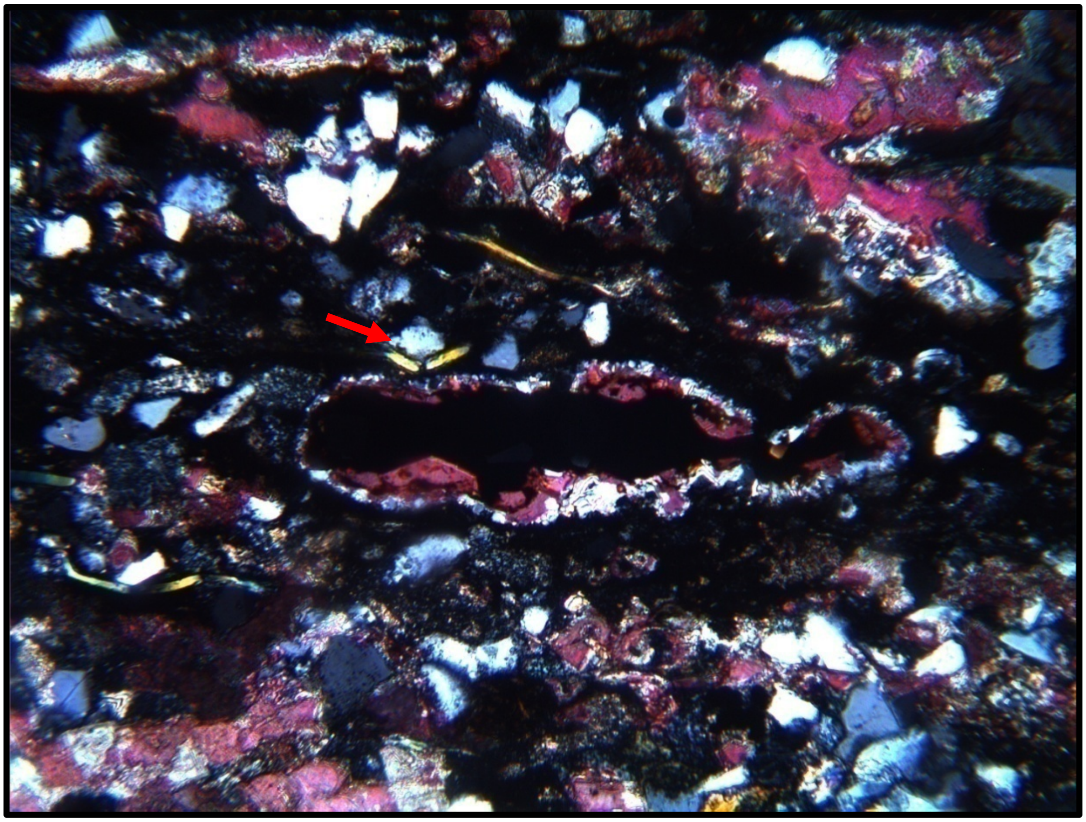

Figure 31. Photomicrograph showing abundant quartz surrounding a partially collapsed agglutinated foram within facies D. Note the calcite growth inside the foram. Also note the muscovite grain broken in two against the overlying quartz grain (red arrow). Cross-polarized light. FOV is 0.1 mm across. Depth in core is 5,195.6 feet.

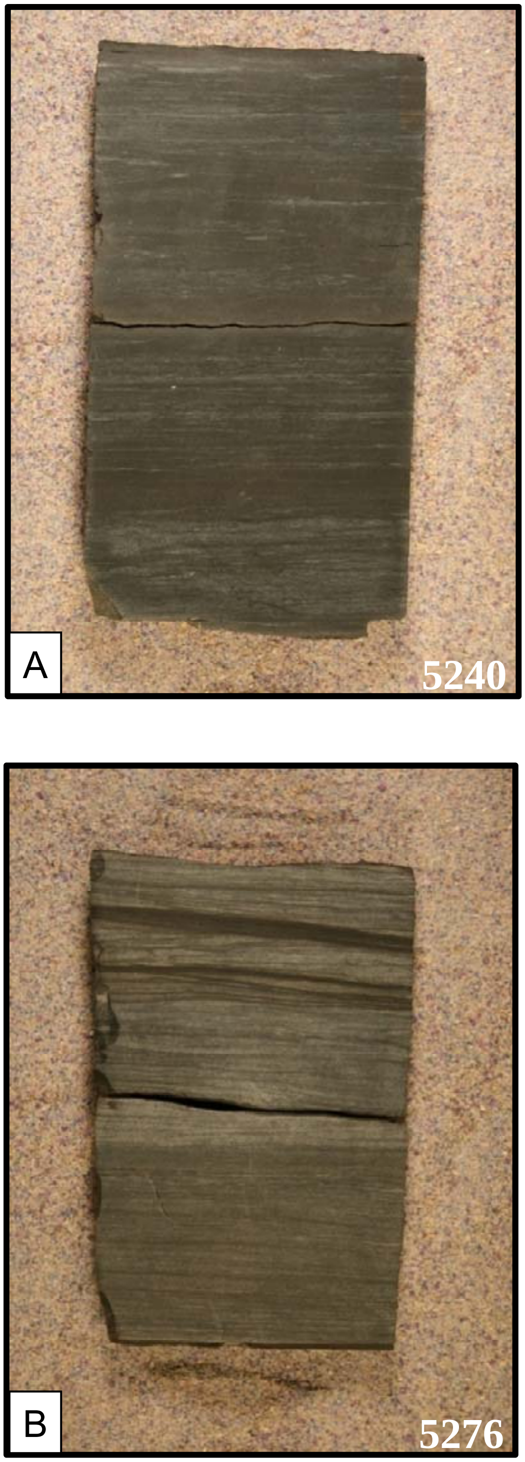

Figure 32. Core photos of facies E. Photo A shows black claystone. Photo B shows slightly bioturbated light gray siltstone. Core is 8 cm wide.

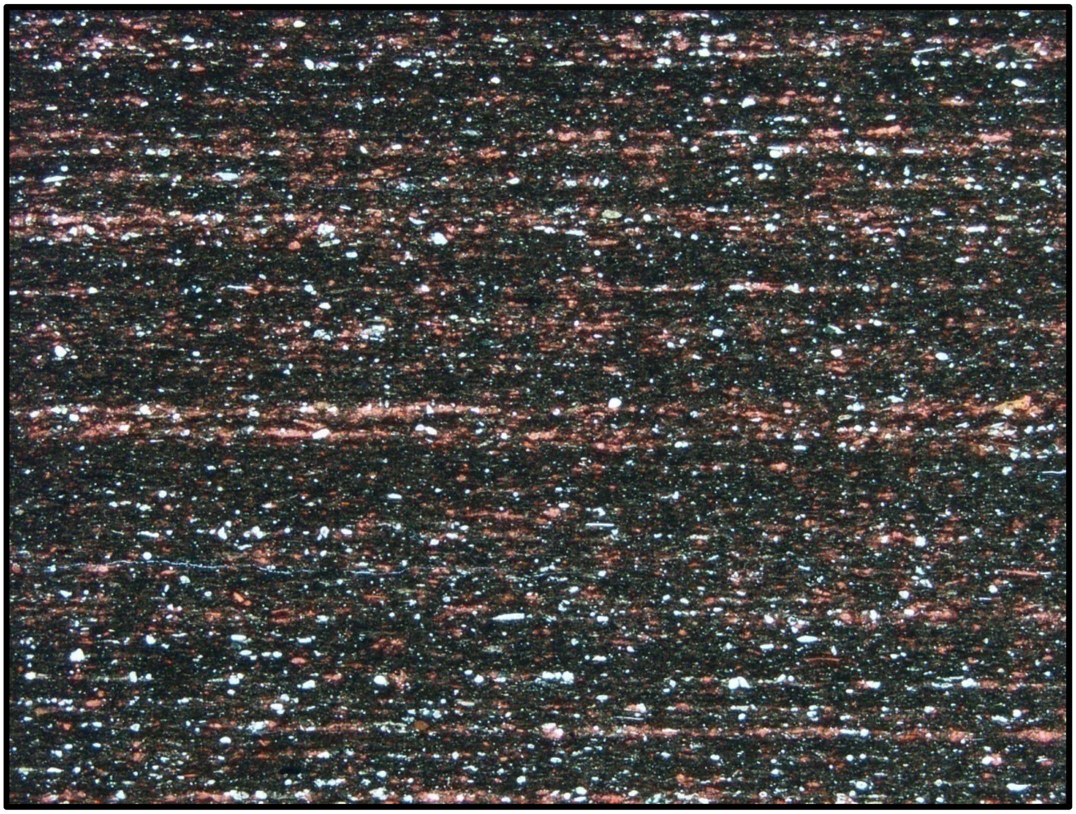

Figure 33. Photomicrograph of distinct laminae within facies E. Plane-polarized light. FOV is 10.25 mm across. Depth in core is 5,281.4 feet.

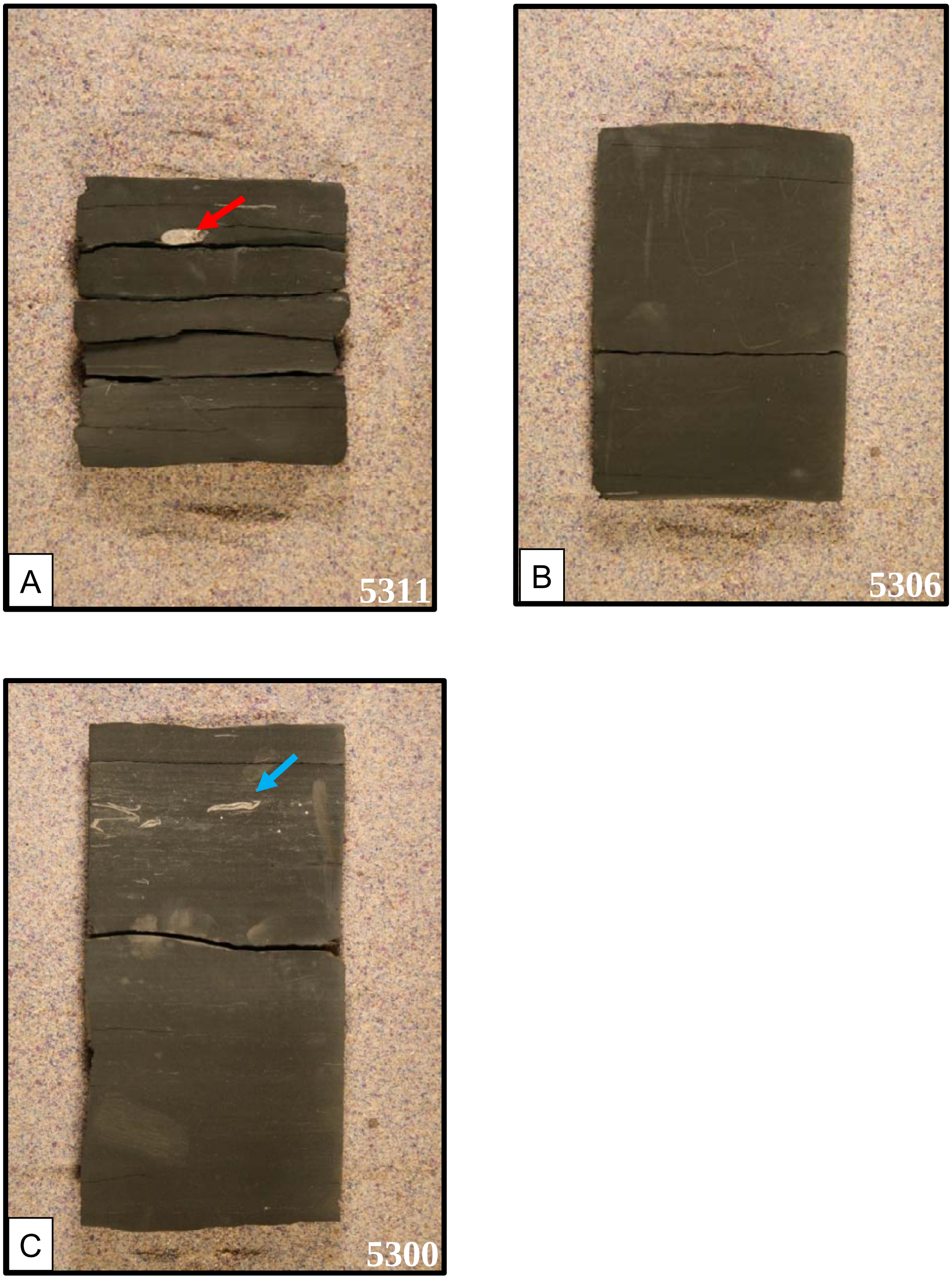

Figure 34. Core photos of facies F. Red arrow indicates nautoloid fragment. Blue arrow indicate shell fragments in an event bed. Core is 8 cm wide.

(Fig. 34C). These beds are 0.2 to 1.0 in (0.5 to 2.5 cm) thick and are mostly gradational at their top and base. In some places, the contact at the base is sharp and scoured, whereas the top remains gradational. Compaction is evidenced by elongate shell fragments partially replaced by calcite bent around silt-sized, well-rounded glauconite grains (Fig. 35). Facies F has a total thickness of 21.5 ft (7 m) and makes up 8% of the core (Table 2). It occurs twice in the lower portions of the core (Fig. 25). The base of facies F shows parting and has gradational contacts with the overlying facies C and the underlying facies G.

Facies G

Facies G is a light gray micritic limestone with interbeds of dolomitic claystone (Fig. 36A) (Table 1). The micritic limestone comprises approximately 90% of the facies. The dolomitic claystone interbeds occur every 2.4 to 14 in (6.35 to 35.6 cm) and are 0.6 to 3.0 in (1.5 to 7.5 cm) thick (Fig. 36B). Both the micritic limestone and the claystone strongly react with HCl. The limestone is mostly massive, but may show faint continuous, planar, parallel laminae. It is mostly micrite with euhedral to subhedral dolomite rhombs. Laminations in the interbedded claystone are generally continuous across the core, curved, and parallel to nonparallel, but may be continuous, planar, and parallel. The claystone is well sorted and is comprised of euhedral crystals of dolomite (Fig. 37). Calcite and argillaceous material occur in small amounts. Facies G is 22 ft (8 m) thick and occurs only at the base of the core at a depth of 5,317 to 5,339 ft (1,621 to 1,627 m) (Fig. 18), making up the final 8% of the core (Table 2).

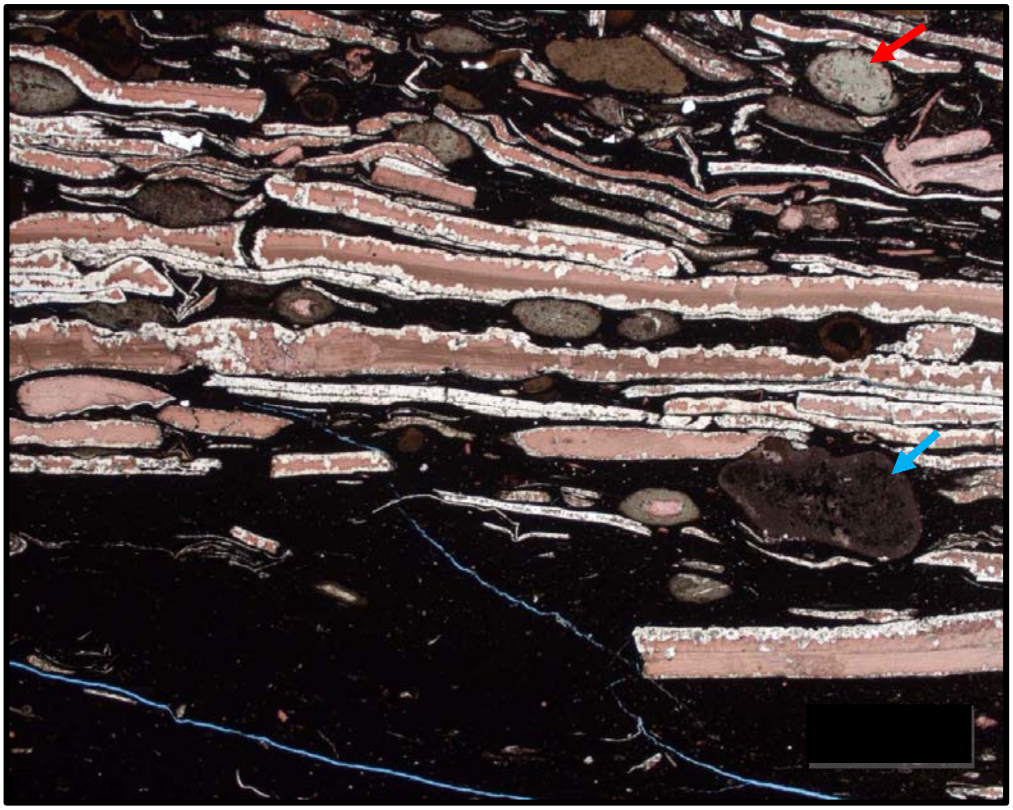

Figure 35. Photomicrograph of shell fragments within facies F. Glauconite grains (red arrow) and phosphatic grains (blue arrow) are also present. Plane-polarized light. FOV is 5.7 mm across. Depth in core is 5,317.4 feet.

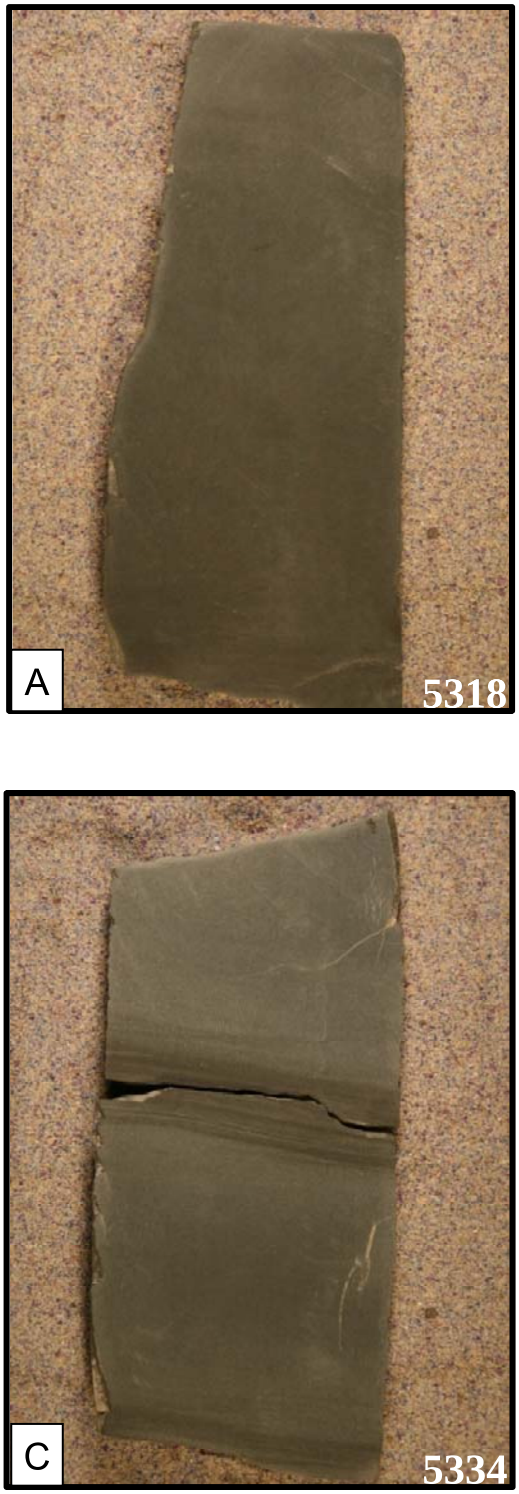

Figure 36. Core photos of facies G. Photo A shows massive micritic limestone. Photo B shows the micritic limestone with interbedded dolomitic claystone. Core is 8 cm wide.

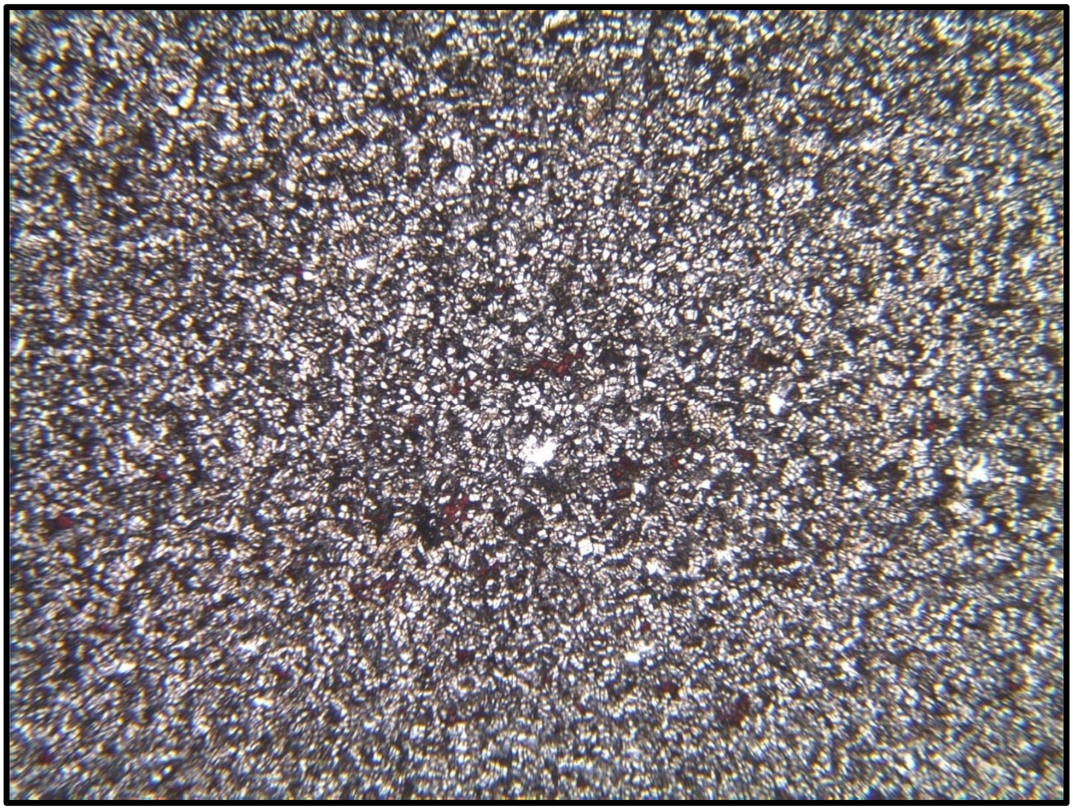

Figure 37. Photomicrograph of dolomite crystals within facies G. FOV is 2.4 mm across. Depth in core is 5,323.5 feet.

Fractures

Fractures were observed in facies A, B, C and G. Most fractures are vertical and are completely healed by calcite and dolomite. Fractures in facies A, B, and C occur primarily in intervals rich in silica.

Facies A is dominated by open fractures that are 0.4 in (10 mm) wide and partially healed by calcite and dolomite (Fig. 38A). Other, narrower, < 0.039 to 0.2 in (1 mm to 4 mm) wide fractures occur throughout facies A and are completely healed by calcite and dolomite (Fig. 38B). Fractures in facies B are 0.4 to 1 in (1 mm to 9 mm) wide and are completely healed by calcite and dolomite (Fig. 38C). Fractures in facies C are completely healed by calcite and dolomite and occur throughout the facies. Almost all of the fractures in facies C terminate at silt- and claystone boundaries (Fig. 38D). Fractures in facies G are both vertical and sub-horizontal and can extend up to 9 in (228 mm) (Fig. 39). Some fractures are only partially healed, but most are completely healed by calcite and dolomite.

DISCUSSION

In eastern Wise County, four stratigraphic units are present in the Marble Falls interval—an upper limestone, upper shale, lower limestone, and lower shale (Fig. 6). These units terminate to the west at or near the Jack and Wise County boundary (Figs. 13, 14, 15, and 16), where the strata are interpreted to interfinger with a thick section of heterolithics that extend to the west (Figs. 7, 8, and 17). In this study core was available only for the heterolithic interval. However, the depositional setting for the limestone and shale units in Wise County can be interpreted from knowledge of the regional geology, their lithology as

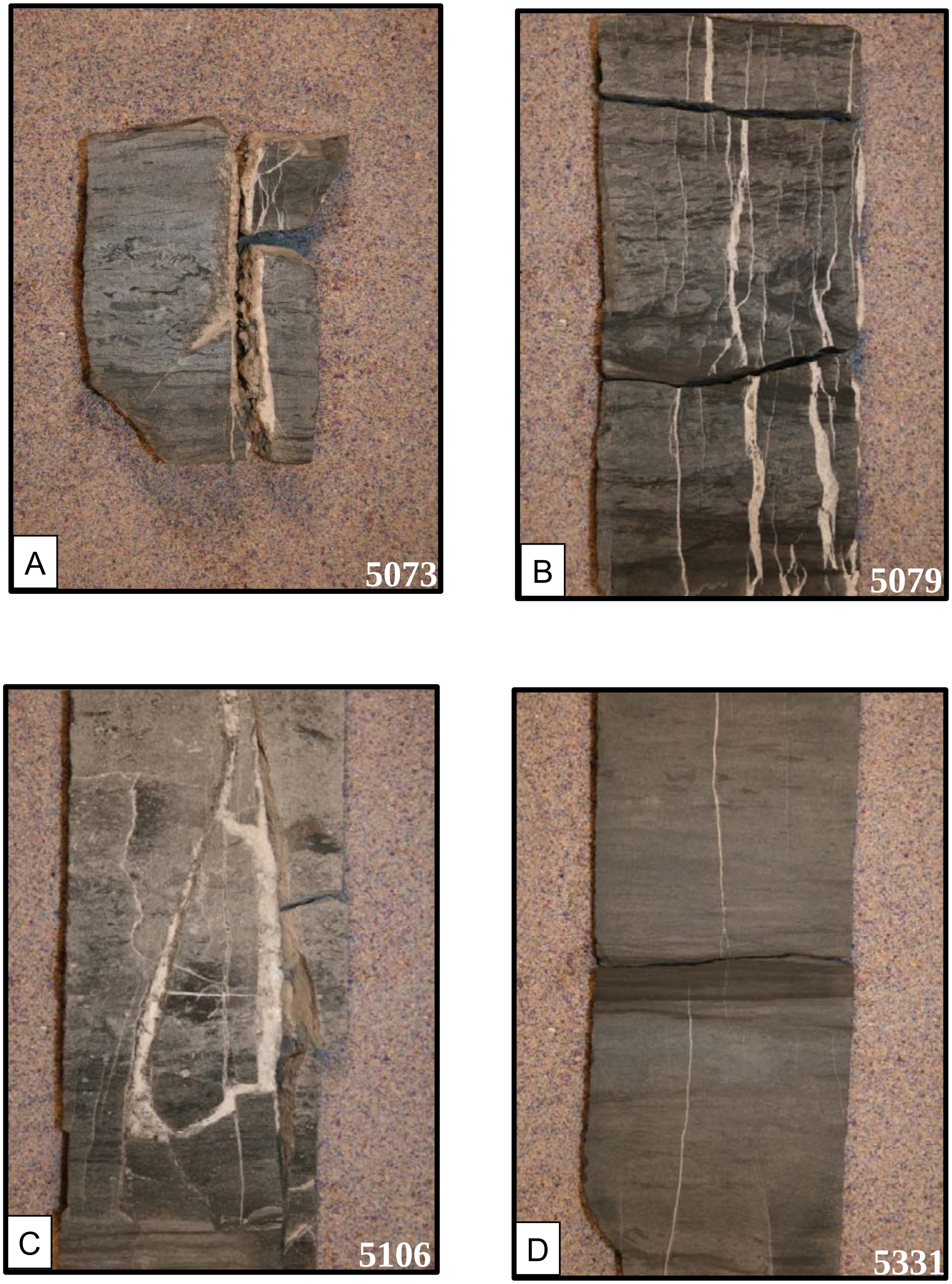

Figure 38. Core photos of fractures in Marble Falls clastic interval. Photo A and B are of facies A. Photo C is of facies B. Photo D is of facies G. Core is 8 cm wide.

Figure 39. Core photo of fracture in facies G. Core is 8 cm wide.

interpreted from well logs and log curve shapes, and the thickness, geometry, and orientation of the units as seen on isopach maps.

The Barnett Shale was deposited in deep-water in slope and basinal settings (Loucks and Ruppel, 2007). The upper shale member of the Barnett in Newark East field interfingers to the west with heterolithic lithologies in the lower part of the Marble Falls interval, which must, by Walther's Law, have been deposited either higher on the slope or in a shelf setting. The Marble Falls interval in Wise County was deposited in progressively shallower water settings as the basin filled. Log curve shapes in the Marble Falls interval reveal the gradual filling of the basin. The lower shale coarsens upward and grades into the lower limestone. This limestone grades upward into shale as an influx of mud suppressed deposition of carbonate sediment. The mud then gives way to a thick limestone sequence that shallows upward until it is truncated by the regional unconformity at the top of the Marble Falls. This transition records the passage from the deep anoxic environment in which the Barnett Shale was deposited to the shallower water, well-oxygenated conditions in which the upper limestone in the Marble Falls was deposited. The Marble Falls is overlain by coarse clastics of the Bend Group.

In Jack County, the heterolithic interval in the Marble Falls lies conformably on and interfingers with the underlying Barnett Shale (Kier et al, 1979; Henry, 1982). The lower part of the heterolithic section cored in the House No. 1 well in Jack County correlates with the upper shale member of the Barnett in Newark East field in Wise County (Figs. 7 and 8). Heterolithic facies comprise the entire Marble Falls interval in the House No 1 well, from the top of the Comyn Limestone to the base of the Bend Group. The lower part of the heterolithic interval must have been deposited in outer shelf or upper slope environments because to the east (basinward) it interfingers with the lower slope and basinal deposits that comprise the Barnett Shale. However, most of the heterolithic section in the House well interfingers with shales and limestones in the Marble Falls that are interpreted based on log curve shapes to be shallower water deposits that record the in-filling of the basin. This seeming discrepancy can be resolved by looking at the distribution of facies within the heterolithic interval.

The primary depositional facies in the Barnett Shale is a siliceous mudstone (Loucks and Ruppel, 2007). The mudstone may be laminated or nonlaminated. Bioturbation is extremely rare. Sponge spicules are the most common sand- and silt-sized grains in the Barnett (Bunting, 2007). Other grains include shell fragments, quartz grains, glauconite and phosphatic material. Similar grain types are present in the siltstones, mudstones and claystones that comprise the heterolithic interval of the Marble Falls in the core from the House well. Black, laminated mudstone to claystone (L2) is the major component of facies E and F which occur in the lower portion of the cored interval. Facies F consists almost entirely of black claystone. It was most likely deposited in deep anoxic waters like the Barnett. The dark color and absence of bioturbation in thin siltstone beds within the claystone suggest anoxic bottom waters without a burrowing infauna. This facies has the most basinal aspect of all the rock in the heterolithic section. It is found only at the base of the core immediately above facies G (Fig. 25), which I correlate with the Comyn Limestone. This unit closely resembles the Forestburg limestone that comprises the middle member of the Barnett Shale in Newark East field. Loucks and Ruppel (2007) interpret the Forestburg as a deep-water limestone deposited from hemipelagic mud plumes or dilute turbidity currents.

Most of the heterolithic interval consists of spiculitic siltstone with thin interbeds of black mudstone (facies C). Siltstone is much more common than mudstone (Table 1) and the siltstone is highly bioturbated. The high degree of bioturbation indicates the presence of a flourishing infauna which would require aerated sediment and oxygenated bottom waters. By this time either the basin had became less restricted and/or shallower. Facies C has a "shallower water" aspect than facies F. The abundance of siltstone and the degree of bioturbation in facies C suggest higher energy levels and oxygenated bottom waters. While not direct indicators of water depth, both of these conditions are more typical of "shallower" rather than "deeper" water settings. Facies E is intermediate between facies F and C. It is interbedded with facies C in the lower half of the cored interval, but is not present in the upper part of the core. Like facies F, facies E consists mainly of black claystone, but contains thin interbeds of siltstone that are moderately bioturbated.

Like facies C, facies D consists almost entirely of highly bioturbated siltstone. However the composition of the siltstones in facies D is quite different. Quartz is conspicuous among the silt-sized grains and sponge spicules are much less abundant. Ripple lamination is more well developed in facies D than in facies C. The reason for the influx of quartz at this time in the filling of the basin remains problematic. Some change in provenance must be responsible, but the nature of that change is unknown. The change was only temporary because a thick section of spiculitic siltstones underlies and overlies the one occurrence of facies D. Low energy facies (E and F) with a "deeper" water aspect do not occur above this point in the core.

Facies B lies above facies C and has approximately equal amounts of siltstone and claystone. Even though dark mud was again being deposited, the interbedded siltstones are highly bioturbated. The character of the source area has changed too, because crinoid fragments are common among the sand- and silt-sized grains. Stands of crinoids must have been growing on the bottom in the immediate area or else higher on the slope or shelf. Layers of spiculitic crinoidal siltstone become more common toward the top of the single interval of facies B in the core. These coarser grained layers may have been deposited from storm surges moving sediment down the slope from more proximal settings, perhaps the Sewell high on the Chappel shelf to the west. This high may have been the source of the large dolomite lithoclast observed within this facies (Fig. 27). Facies A is found at the top of the core below the regional unconformity at the top of the Marble falls interval (Fig. 25). Whatever conditions had allowed for the deposition of the crinoidal siltstones and black claystones of facies B had now vanished. Facies A has a high energy, "shallow" water aspect. Highly bioturbated, rippled siltstones (L1) are much more common than dark mudstones and claystones (L2).

Correlations made in this study suggest that the Comyn Limestone and the Forestburg limestone are the same lithostratigraphic unit, but include sediments derived from two different sources (Figs. 8, 9, and 40). These units lie below the upper shale member of the Barnett in Wise County and beneath the heterolithics of the Marble Falls interval in Jack County. Cross sections in western Jack County show the Comyn thickening to the west. Cross sections in central Wise County show the Forestburg thickening to the east. Both limestones thin toward the border between the two counties and cannot be differentiated with the available well control.

Bowker (2002, 2003) and Montgomery et al. (2005) suggest the Forestburg was deposited from carbonate debris flows coming off the Muenster arch. The Forestburg thickens to the east because the source area was to the east, not because accommodation space was necessarily greater. The westward thickening trend and eastward dipping beds indicated by FMI logs suggest that the Comyn Limestone was sourced by the Chappel shelf on top of the Bend arch to the west. Separate sources suggest that the Comyn Limestone and the Forestburg limestone either onlap or interfinger with each other along the boundary between Jack and Wise Counties (Fig. 40).

A provenance in southern Oklahoma has been suggested for some sediment in the Fort Worth basin (Bowker, 2007). Henry (1982) mapped a "calcareous interruption" interval within the lower Barnett Shale in Montague County but was unable to carry his correlations in to Wise County because of sparse well control and poor log quality. Since then, both the quality of logs and the number of logs available for correlation has increased throughout Jack and Wise Counties. This new data allowed the "calcareous interruption" interval to be correlated more extensively throughout these counties. This interval proved essential to define and correlate to prevent associating the Marble Falls interval with the underlying Mississippian sediments. It becomes limier to the east-northeast and thickens to the north, which are similar trends that Henry (1982) observed.

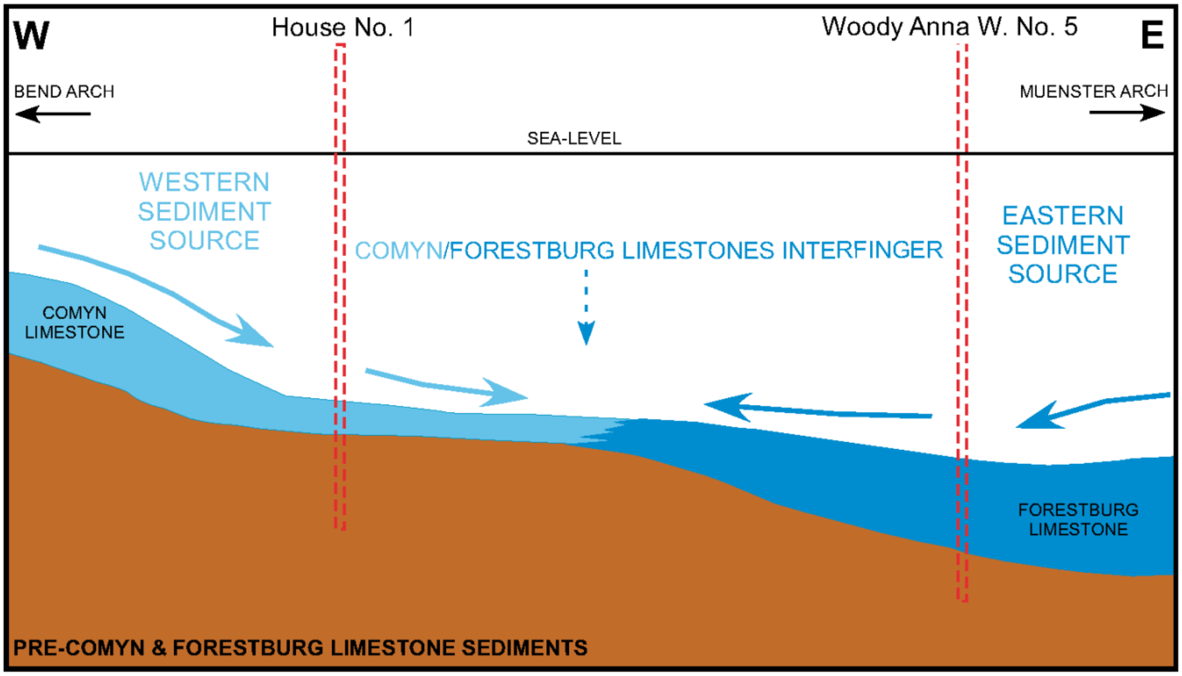

Figure 40. Depositional model of Comyn Limestone and Forestburg limestone. No scale implied.

CONCLUSIONS

The Marble Falls interval in the northern portion of the Fort Worth basin is comprised of five stratigraphic units. Four units, an upper limestone, upper shale, lower limestone, and lower shale, are present in the eastern half of Wise County (Figs. 4, 13, 14, 15, and 16). These units interfinger to the west with a heterolithic unit comprised of siltstones, mudstones and claystones in Jack County (Figs. 5 and 17). These units formed from authochthonous carbonate sediment produced in shallow epeiric seas and from siliciciclastic (and perhaps carbonate) debris eroded off rising positive structures such as the Bend arch, Red River arch, Muenster arch, and the Ouachita thrust belt during the Ouachita orogeny.

Four lithologies are present in core taken from the House No. 1 well in southwest Jack County. Three of the lithologies (L1-L3) are found in the heterolithic deposits. These are a spiculitic siltstone (L1), laminated mudstone to claystone (L2), and spiculitic crinoidal siltstone (L3) (Table 1). The laminated spiculitic silstone comprises 70% of the cored interval. A fourth lithology (L4) occurs below the heterolithic interval. It is a micritic limestone considered to be part of the Comyn Limestone.

Seven facies are present in the core (Table 1). Six of the facies (A-F) are defined primarily by the relative abundance of siltstone to mudstone or claystone in the cored interval and secondarily by the composition of the silt fraction and the degree of bioturbation. These facies are composed of varying mixtures of lithologies L1 through L3 that mainly reflect changes in energy levels at the site of deposition. Micritic limestone (L4) with thin interbeds of dolomitic clay comprises the seventh facies (facies G). The vertical distribution of these facies suggests that the Marble Falls interval was deposited during an overall regression.

Log curve shapes through the limestone and shale units identified in Wise County also infer an overall regression during deposition of the Marble Falls. The log curve shapes for the lower shale unit provide evidence for a coarsening upward sequence that grade into the lower limestone unit (Fig. 4). The log curve shapes for the lower limestone unit show a fining upward sequence that grade into the upper shale unit. This shale unit then grades upward into a clean limestone that was probably deposited in shallow water. The regional unconformity that occurs at the top of the Marble Falls interval marks a period of subaerial exposure and erosion.

Previous workers have assigned the Comyn Limestone in western Jack County and the surrounding areas to the early Atokan and considered it to be more closely related to the overlying Marble Falls (Pennsylvanian) than to the underlying Mississippian sediments. The Comyn is lithologically similar to the Forestburg limestone (Mississippian) to the east and log correlations made in this study implies that the Comyn and the Forestburg are the same lithostratigraphic unit. This suggests that the Comyn was deposited during the later part of the Mississippian and should not be associated with the overlying Marble Falls interval.

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APPENDICES

Appendix 1: Cross Section Well Data

Appendix 2: Core Photos

Appendix 1

Cross Section

Well Data

API	WELL NAME	OPERATOR	COUNTY	ELEV_KB	MBFLS INTERVAL (TVD)	MBFLS UPPER LIMESTONE (TVD)	MBFLS UPPER SHALE (TVD)	MBFLS LOWER LIMESTONE (TVD)	MBFLS LOWER SHALE (TVD)	LOWER BARNETT SHALE (TVD)	BASE OF LOWER BARNETT SHALE (TVD)
42237354570000	WRIGHT 1	PERKINS PROTHRO CO	JACK	1065	~	~	~	~	~	5529	5848
42237333980000	GARRETT M L 1	HENRY ENERGY CORPORA	JACK	1102	4885	~	~	~	~	5308	5517
42237370550000	SANDERS B G 1	BRIDWELL OIL COMPANY	JACK	1154	4852	~	~	~	~	5344	5558
42237337490000	SHEPARD-CRUM OIL UN	TAYLOR OPER CO	JACK	1334	4885	~	~	~	~	5386	5537
42237339460000	BOAZ O 1	STAMPER OPERATING CO	JACK	1212	4429	~	~	~	~	4785	4847
42237343830000	HOUSE -842- 1	DIAMOND SHMROCK CORP	JACK	1176	4574	~	~	~	~	4916	5005
42497331490000	GREGG "A" 2	XTO ENERGY INCORPORA	WISE	983.5	5729	~	~	5881	5990	6151	6347
42237392880000	HOUSE 1	EOG RESOURCES	JACK	1188	5047	~	~	~	~	5440	5616
42237385730000	RUMAGE 1	EOG RESOURCES	JACK	1031	5457	~	~	~	~	5897	6137
42497335600000	ADAMS J S 3	DEVON ENERGY PRODUCT	WISE	870	6112	6112	6249	6299	~	6615	6906
42497329750000	DE ARMAN H H 2	DEVON ENERGY	WISE	781	6003	6001	6220	6272	6376	6569	6822
42497341970000	DAN B MAEYERS GAS U	DEVON ENERGY PRODUCT	WISE	926	6904	6901	7149	7192	7267	7505	7809
42237355820000	MANSFIELD MOLLIE`D`	COBRA OIL & GAS CORP	JACK	1145	5901	6052	~	~	6140	6424	6821
42497327260000	MORRIS R L `C` 10	I P R ENERGY PARTNER	WISE	1004	5803	5998	6116	6124	6144	6461	6783
42497336030000	WILKINS 3	TARPON OIL COMPANY	WISE	1240	5793	~	~	~	~	6120	6314
42237368410000	RUMAGE W W 1	MARCON OPERATING COM	JACK	976	5182	~	~	~	~	5636	5890
42237386440000	CHERRYHOMES ROY F 25	ASPEN OPERTNG CO LLC	JACK	1049	5678	~	~	~	~	6140	6448
42497355780000	ELSOM ROIL 1	ROIL MINERAL & LAND	WISE	942	6572	6572	6735	6745	6787	7141	7503
42497346020000	WRIGHT 1	ENCANA OIL & GAS (US	WISE	750	6986	6986	7207	7216	7233	7663	8062
42497366280000	RODGERS 1	EOG RESOURCES	WISE	951	6967	6967	7108	7131	7144	7534	8047
42497344890000	WOODY ANNA W GAS UN 5	DEVON ENERGY PRODUCT	WISE	1090	7013	7013	7213	7220	7271	7620	7944
42497354890000	AUSTIN 1	VANTAGE ENERGY LLC	WISE	676	6318	6318	6502	6572	~	6806	~
42497339870000	SEALY `C` 3	WG OPERATING INC	WISE	891	5832	5913	6098	6117	6169	6460	6738

Data on wells used in cross sections: API number, Well Name, Operator, County in which the well was drilled, KB (Kelly Bushing), top of MBFLS interval in True Vertical Depth (Marble Falls interval), top of MBFLS upper limestone in TVD (Marble Falls upper limestone), top of MBFLS upper shale in TVD (Marble Falls upper shale), top of MBFLS lower limestone in TVD (Marble Falls lower limestone), top of MBFLS lower shale in TVD (Marble Falls lower shale), lower Barnett Shale in TVD, and base of lower Barnett Shale in TVD.

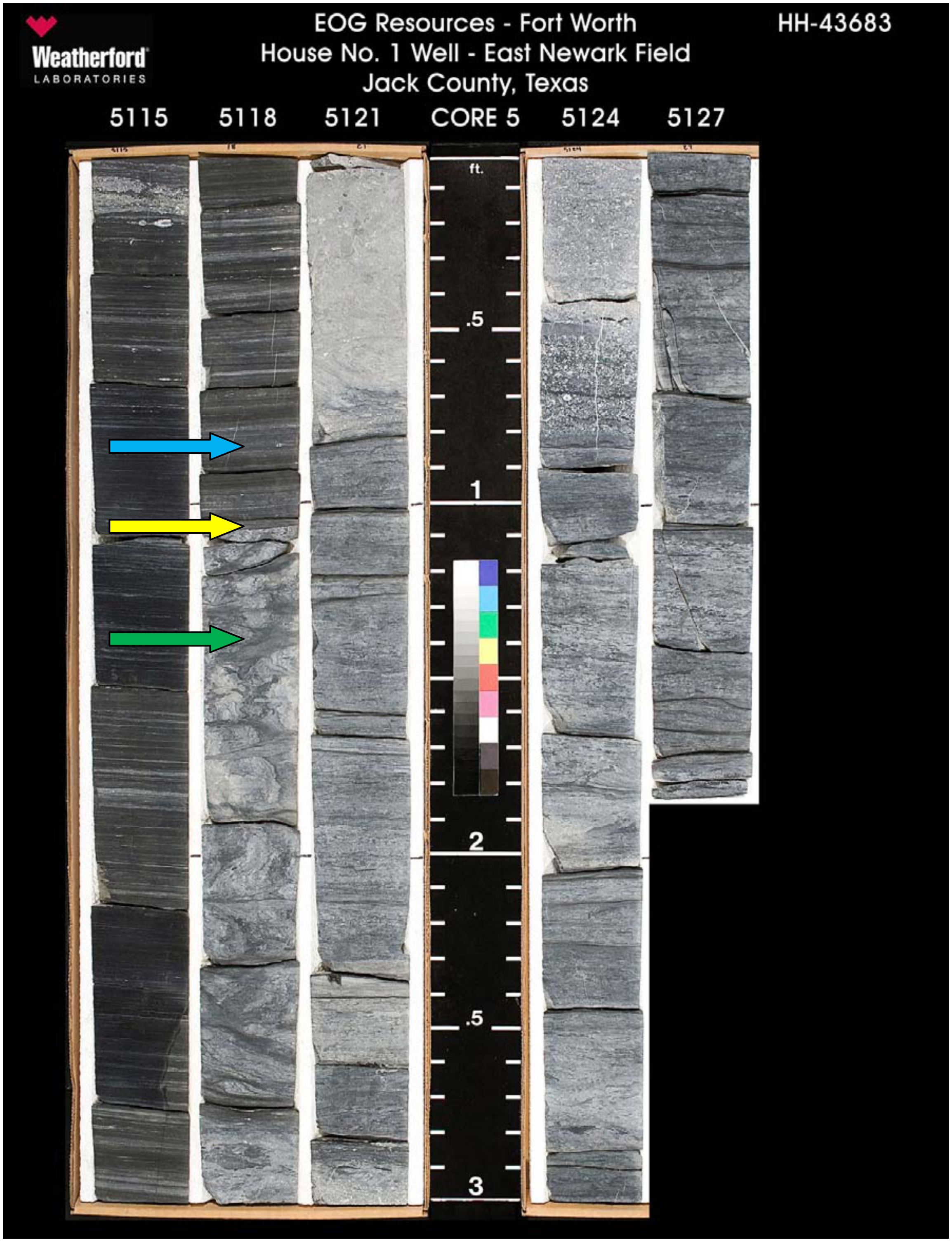
Appendix 2

Core Photos

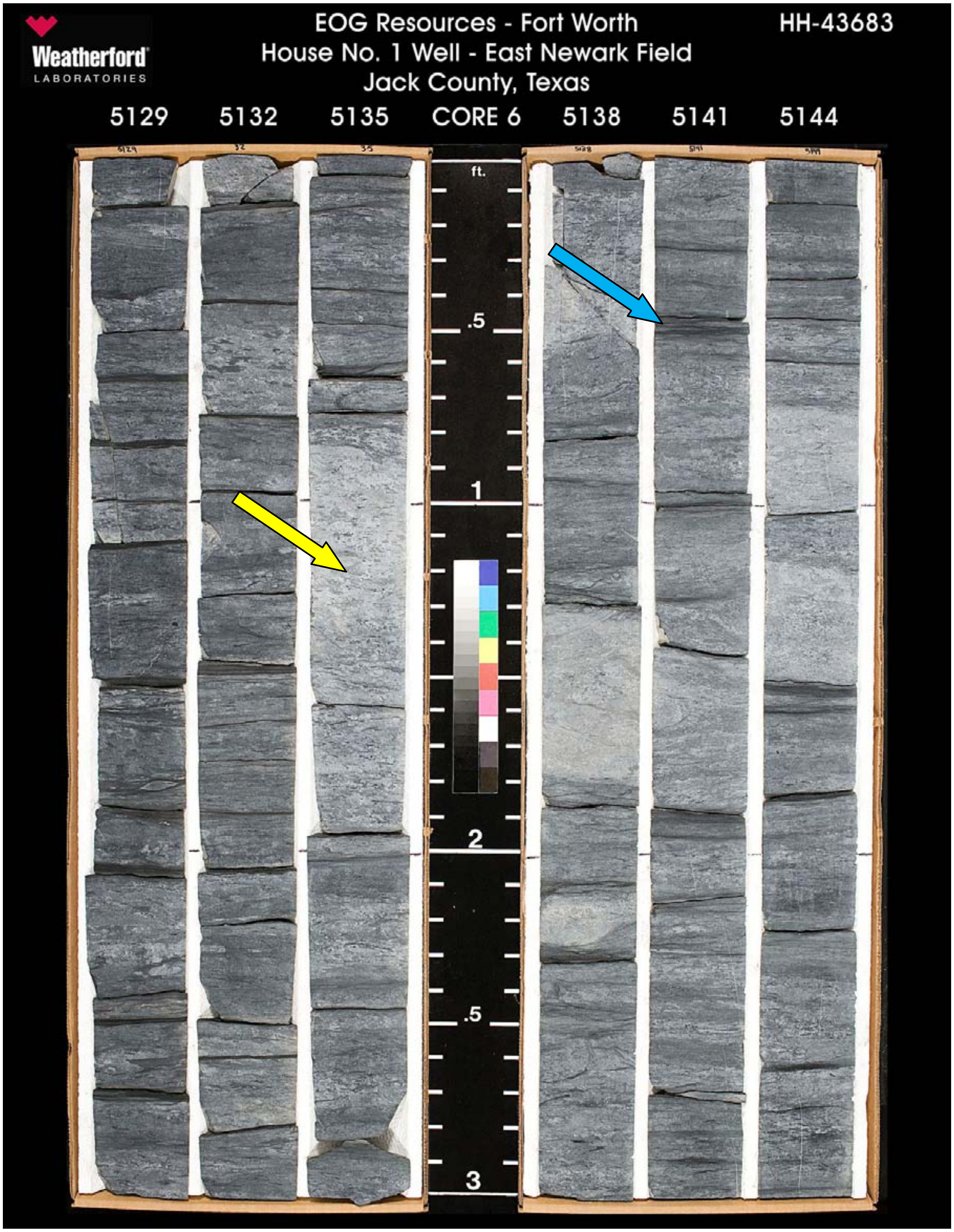
5060 - 5079 ft. Facies A. Note the partially to completely healed, vertical fractures within the highly bioturbated siltstone (yellow arrow).

5079 - 5097 ft. Facies A. Note bioturbated siltstone interbedded with laminated claystone (yellow arrow). Also note completely healed vertical fractures.

5097 - 5115 ft. Facies A and B. Note gradational contact (yellow arrow) between facies A (blue arrow) and facies B (green arrow). Also note interbeded crinoidal siltstone in black laminated claystone with fracturing.

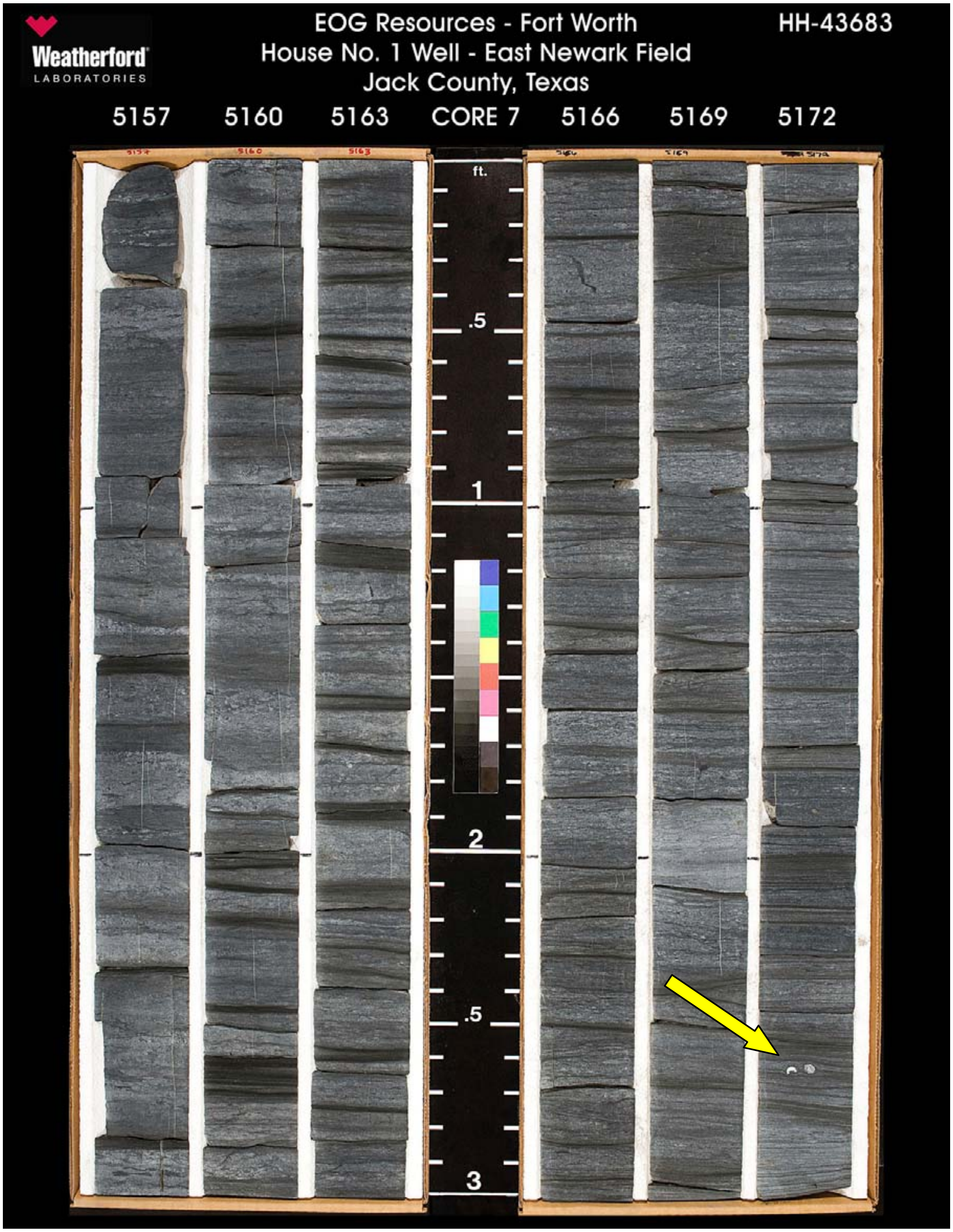


5115 - 5128 ft. Facies B and C. Note sharp contact (yellow arrow) between the interbedded silt and clay of facies B (blue arrow) and a highly bioturbated siltstone of facies C (green arrow).



5129 - 5147 ft. Facies C. Note highly bioturbated siltstone (yellow arrow) with interbedded planar to wavy laminated claystone (blue arrow).

5147 - 5157 ft. Facies C. Note highly bioturbated siltstone (yellow arrow) with interbedded planar to wavy laminated claystone (blue arrow). Also note completely healed vertical fractures.

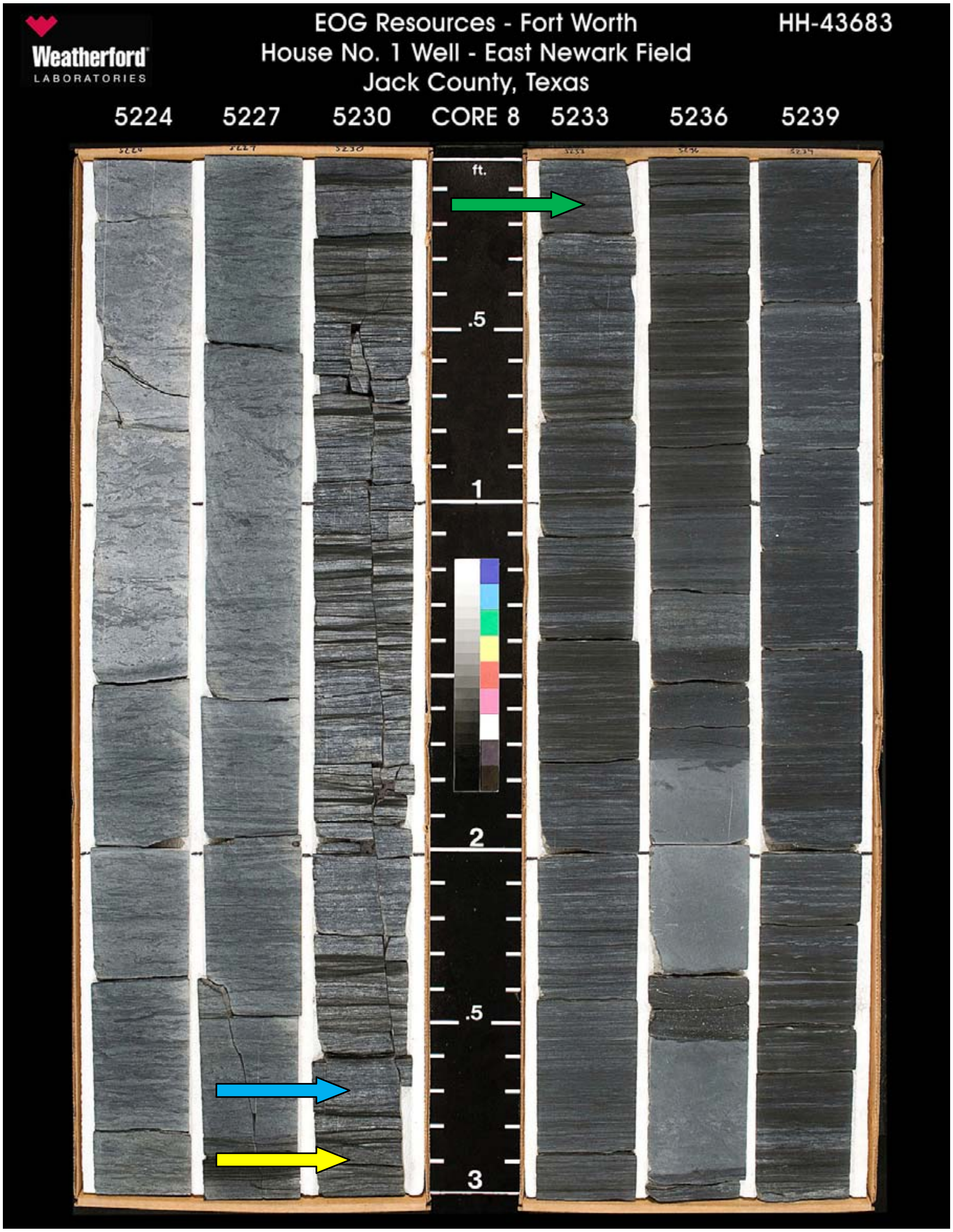


5157 - 5175 ft. Facies C. Note highly bioturbated siltstone with interbedded planar to wavy claystone. Yellow arrow points to bryozoan (left) and echinoderm (right).

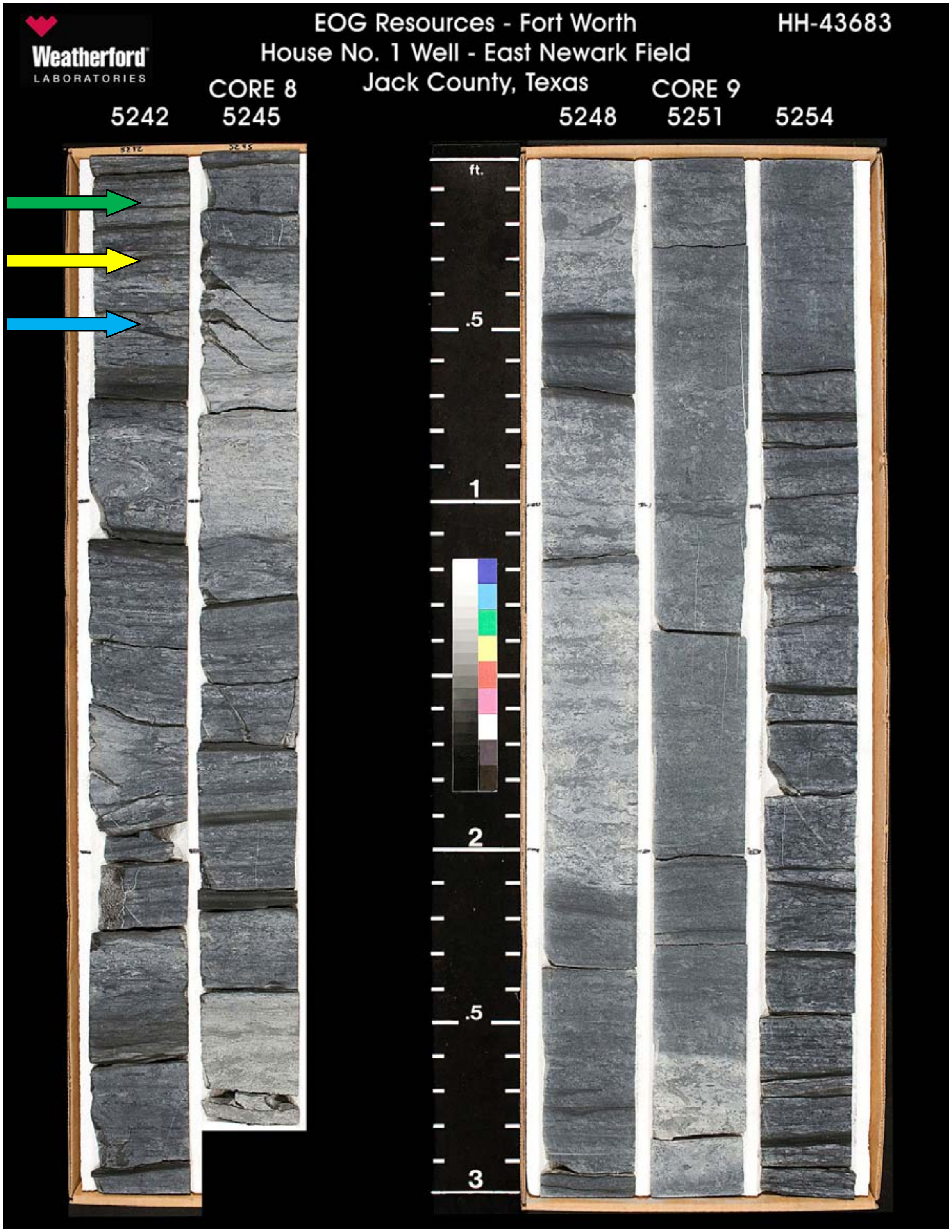
5175 - 5193 ft. Facies C and facies D. Note sharp contact (yellow arrow) between facies C (blue arrow) and D (green arrow). Also note wavy laminae of facies D.

5193 - 5211 ft. Facies D and C. Note sharp contact (yellow arrow) between facies D (green arrow) and C (blue arrow).

5211 - 5224 ft. Facies C and E. Note thin, laminated claystone interval of facies E (yellow arrow) interbedded with facies C.

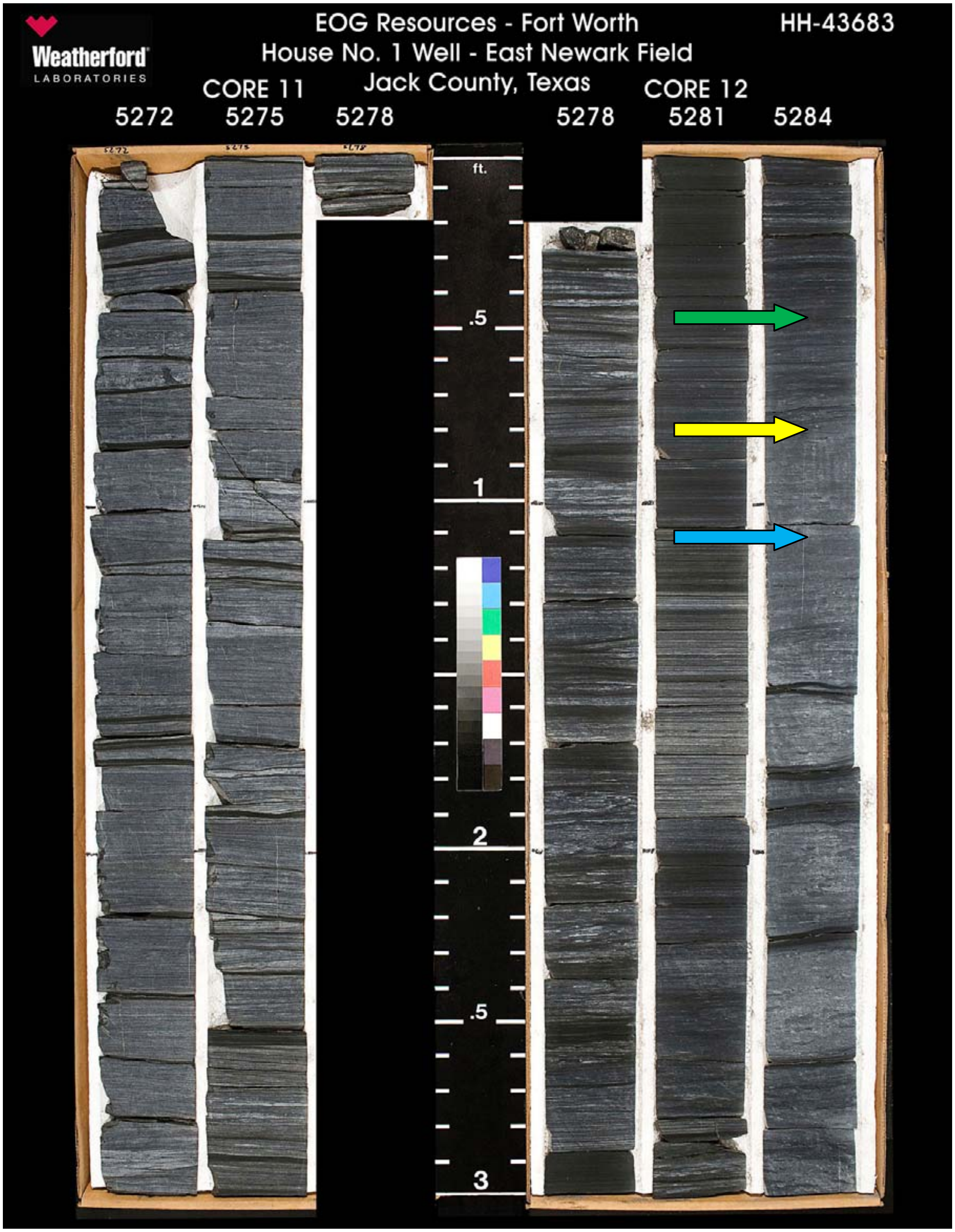


5224 - 5242 ft. Facies C and D. Note gradational contact (yellow arrow) between facies C (blue arrow) and E (green arrow).



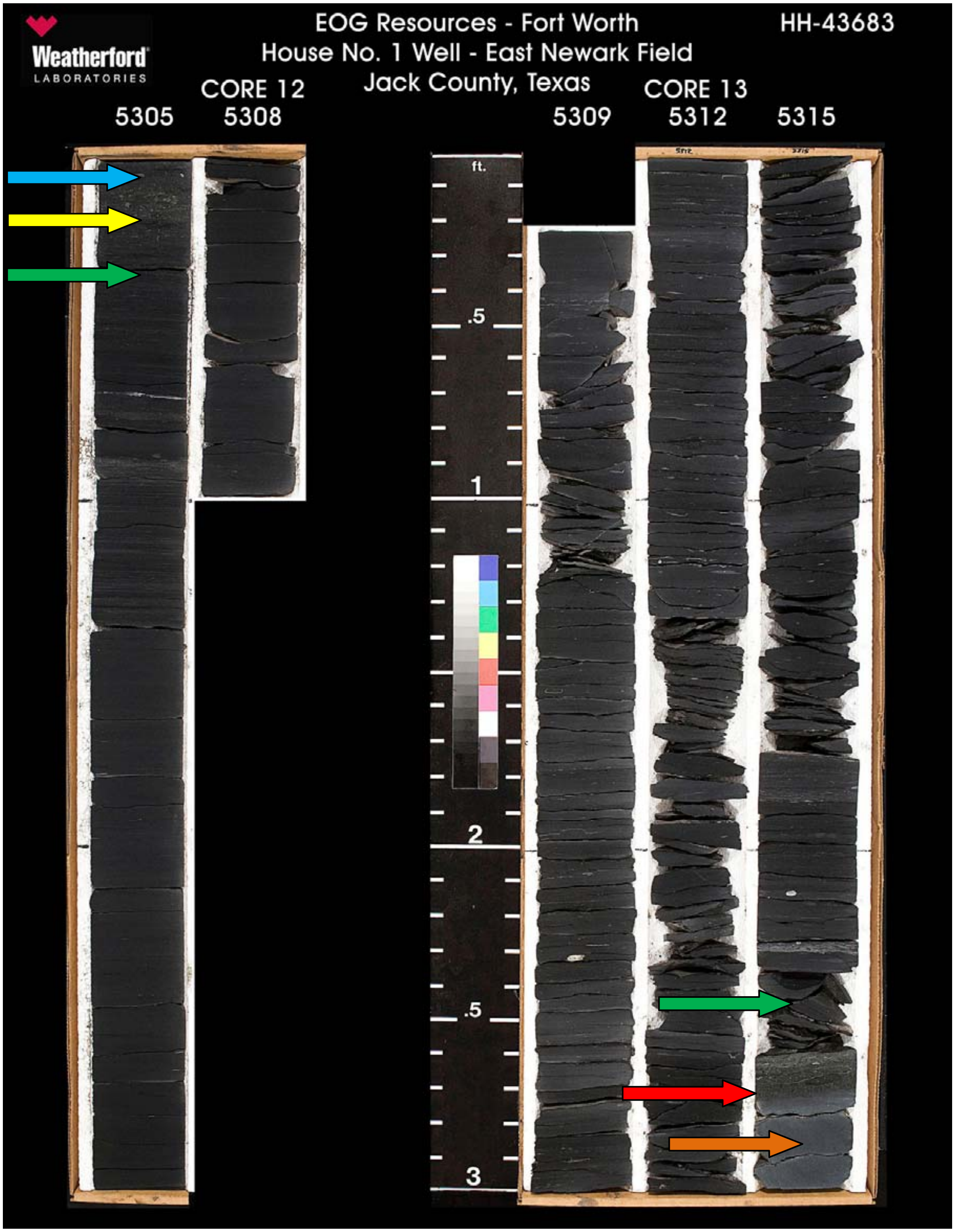
5242 - 5257 ft. Facies C and D. Note gradational contact (yellow arrow) between facies E (green arrow) and C (blue arrow).

5257 - 5269 ft. Facies C. Note pyrite (yellow arrows).



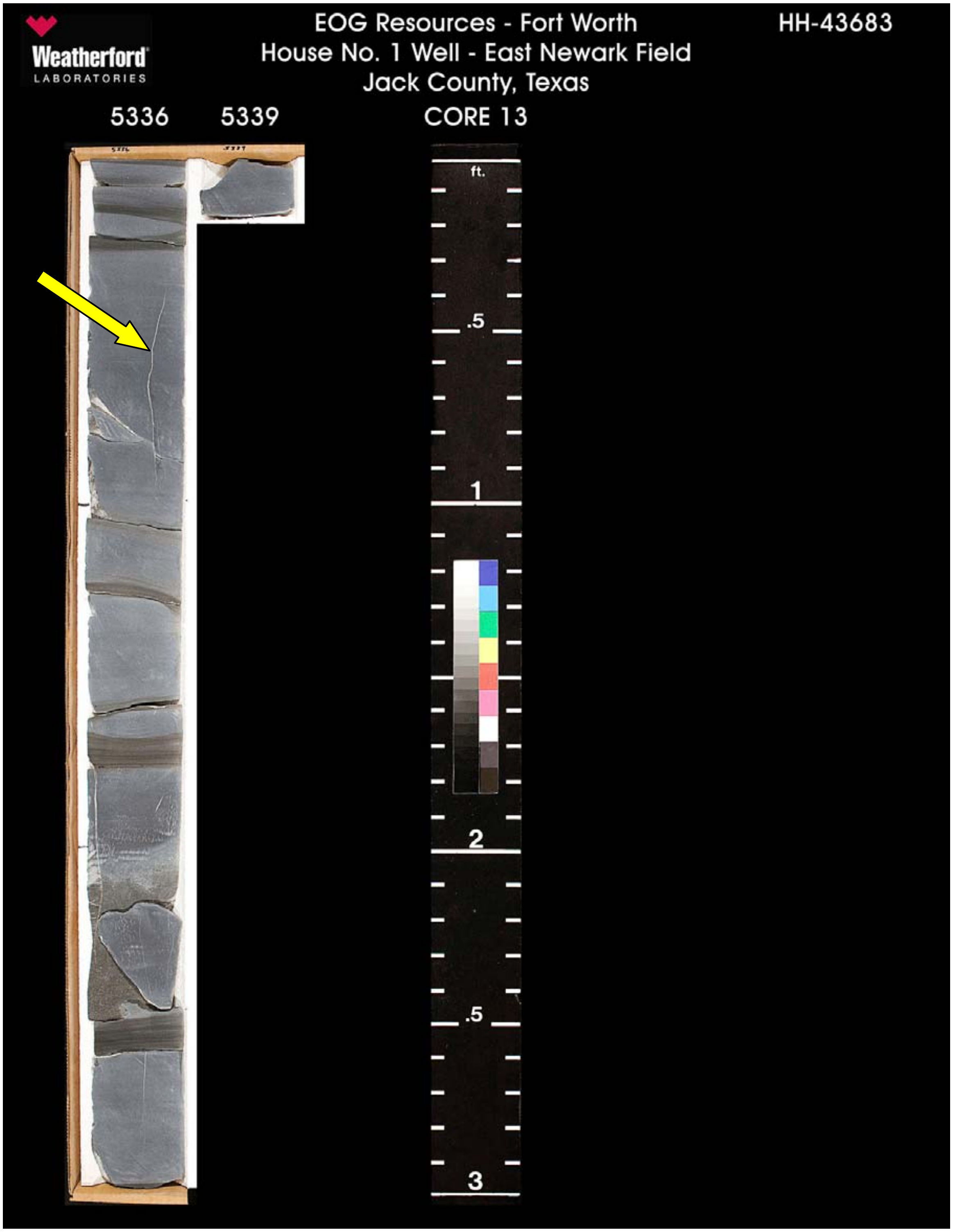
5272 - 5287 ft. Facies C and E. Note gradational contact (yellow arrow) between facies E (green arrow) and C (blue arrow).

5287 - 5305 ft. Facies C and F. Note gradational contacts (yellow arrows) between facies C (blue arrows) and F (green arrow).



5305 - 5318 ft. Facies C, F, and G. Note gradational contact (yellow arrow) between facies C (blue arrow) and F (green arrows), and sharp contact (red arrow) between facies F and G (orange arrow).

5318 - 5336 ft. Facies G. Note interbedded dolomitic claystone and micritic limestone. Also note discontinuous vertical fractures (yellow arrow).



5336 - 5339 ft. Facies G. Note interbedded dolomitic claystone and micritic limestone. Also note discontinuous vertical fractures (yellow arrow).

VITA

Personal Background	Klinton Marcus Farrar Fort Worth, Texas Born July 20, 1984, Fort Worth, TX Son of Marcus and Kay Farrar Married to Melanie F. Farrar, August 11, 2007
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ABSTRACT

STRATIGRAPHY OF THE MARBLE FALLS INTERVAL (PENNSYLVANIAN), JACK AND WISE COUNTIES, TEXAS

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Five informal stratigraphic units can be recognized on well logs through the Marble Falls interval in the northern Fort Worth basin. Four of the units—an upper limestone, upper shale, lower limestone, and lower shale—are present in the eastern half of Wise County. These units interfinger to the west in Jack County with a heterolithic unit comprised of siltstones, mudstones and claystones. Facies recognized in core through the heterolithic unit and log curve shapes in the limestones and shales reveal shallowing-upward sequences formed as the basin filled. The basin fill contains authochthonous carbonate sediment produced in shallow epeiric seas and siliciciclastic (and perhaps carbonate) debris eroded off rising positive structures such as the Bend arch, Red River arch, Muenster arch, and the Ouachita thrust belt during the Ouachita orogeny. Revised correlations based on additional well control suggest the Comyn Limestone and the Forestburg limestone are the same lithostratigraphic unit.