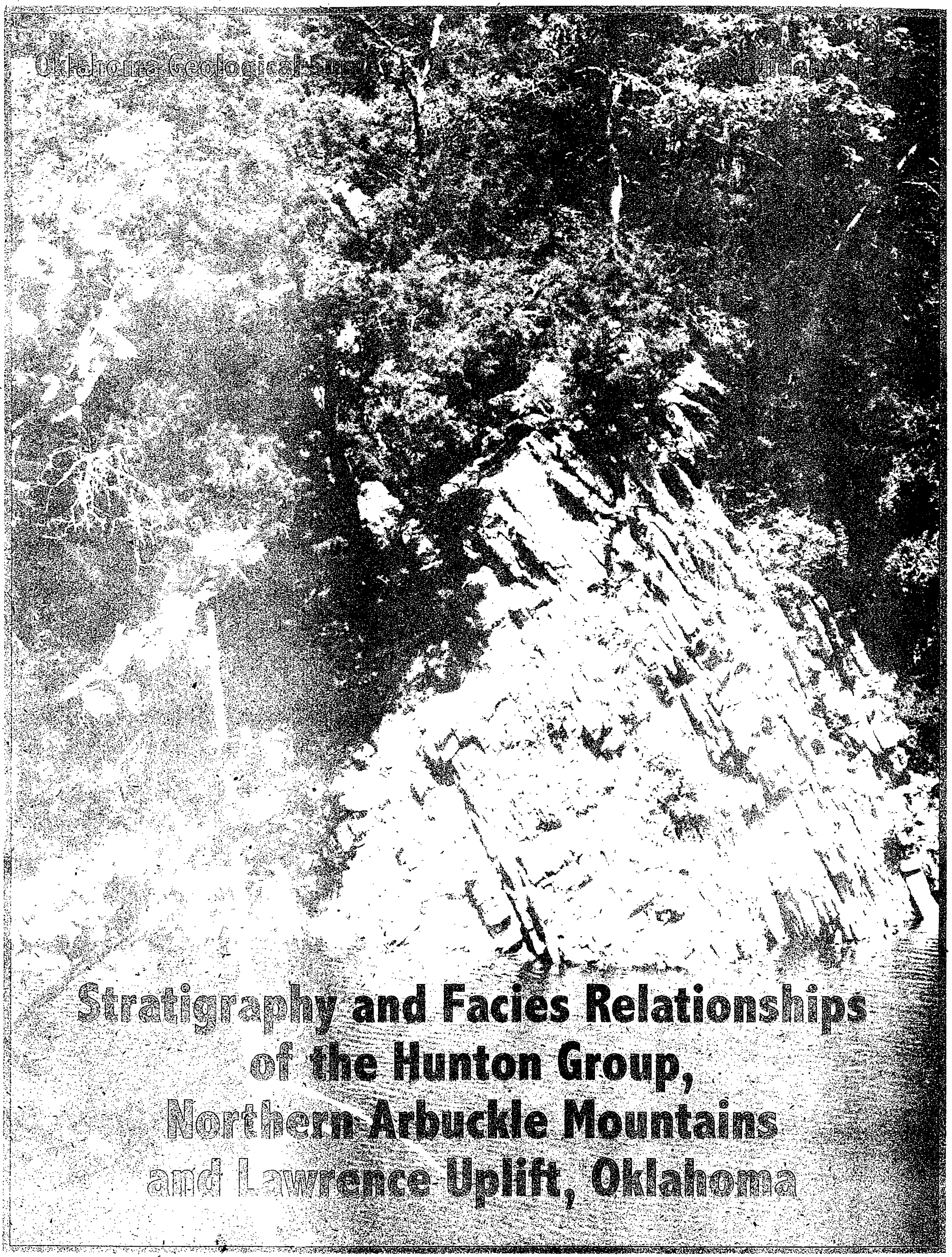
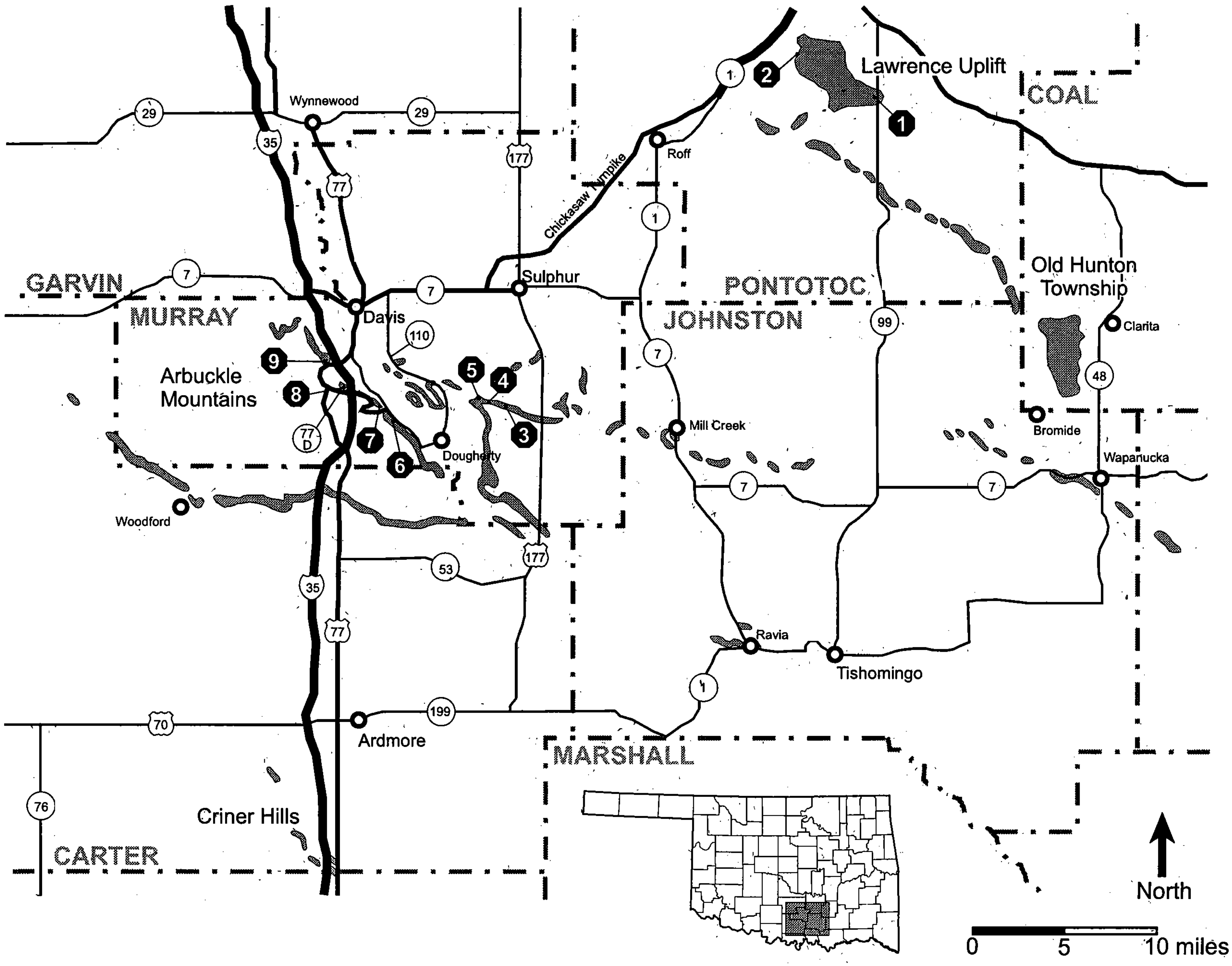
Oklahoma Geological Survey Guidebook



Stratigraphy and Facies Relationships of the Hunton Group, Northern Arbuckle Mountains and Lawrence Uplift, Oklahoma

Map of Field-Trip Stops



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Guidebook 33

Stratigraphy and Facies Relationships of the Hunton Group, Northern Arbuckle Mountains and Lawrence Uplift, Oklahoma

Thomas M. Stanley

Prepared for a one-day field trip, this volume is one in a continuing series that provides information and technical assistance to Oklahoma's oil and gas operators.

The Hunton Group field trip has been offered in conjunction with a one-day workshop on the Hunton Group play. The workshop information is covered in a companion publication, **Hunton Play in Oklahoma (Including Northeast Texas Panhandle)**, *by Kurt Rottmann, E. A. Beaumont, R. A. Northcutt, Zuhair Al-Shaieb, Jim Puckette, and Paul Blubaugh (OGS Special Publication 2000-2).*

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Front Cover

Steeply dipping beds of the Cravatt and Fittstown Members, Bois d'Arc Formation, exposed on west side of small cove and just below the main camp facilities at the Goddard Youth Camp at Stop 3. Beds strike S. 85° E. and dip 45° to the north.

Photograph by Thomas M. Stanley

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PREFACE

The purpose for this guidebook is to expose the reader to the basics of Hunton Group stratigraphy and lithofacies analysis as they are exemplified at the surface in the Arbuckle Mountains. An attempt to bridge the gap between subsurface mapping and log correlations with these surface outcrops is also made. The guidebook is divided into two parts: Part I, general stratigraphy and lithofacies of the Hunton Group as they are expressed throughout the Arbuckle region; and Part II, descriptions of the nine field-trip stops of the northern outcrop belt and Lawrence uplift. Stops will concentrate on all aspects of Hunton facies, but particularly those that form good hydrocarbon reservoirs in the subsurface. At each stop, surface gamma-ray profiles of the outcrops have been made and compared to subsurface log signatures. Interpretations of carbonate depositional environments are emphasized in both parts of this guidebook, with the understanding that a correct interpretation of facies and depositional environment is essential for predicting potential hydrocarbon reservoirs.

Much of this guidebook could not have been written without the superlative work done by previous investigators, particularly Thomas W. Amsden (1957; 1958a,b; 1960; 1967; 1975; and 1980), who alone contributed the bulk of our present understanding of the Silurian–Devonian of the southern Midcontinent. Also to be acknowledged are Al-Shaieb and others (1993a,b; 2000) and Al-Shaieb and Puckette (2000), who evaluated surface and subsurface Hunton Group rocks in the context of modern carbonate facies analysis, as well as Amsden and Barrick (1988), Barrick and others (1990), and Barrick and Klapper (1992), who provided important information on the conodont biostratigraphy. Other work on Hunton surface and subsurface stratigraphy, reservoir characterization and development, and general geology is summarized in the recent publication by Kurt Rottmann (2000), prepared for the Hunton play workshop co-sponsored by the Oklahoma Geological Survey (OGS) and Petroleum Technology Transfer Council.

For their assistance in producing this guidebook, I thank Christie Cooper, OGS managing editor, and her staff (particularly Bill Rose and Frances Young, technical editors). I also thank Jim Anderson and Laurie Lollis, OGS cartographers, for their help in constructing figures and field-trip displays. I am grateful to Dr. David Newell for his early review of the manuscript. Lastly, I wish to thank Wayne Edgar, John Roach, and Gary Fielding for granting permission to view Hunton Group outcrops on their properties.

THOMAS M. STANLEY
Field-Trip Leader

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PART I

General Stratigraphy and Lithofacies of the Hunton Group

INTRODUCTION AND SCOPE

Since the Hunton Group was first named by Taff (1902), this thin suite of carbonate rocks has played a significant role in Oklahoma's oil and gas industry. The Hunton Group and equivalent rocks occur in most geologic provinces of Oklahoma and represent a major exploration target in all sedimentary basins found in the subsurface (Northcutt, 2000). For example, Hunton reservoirs have been developed in 62% of the counties in Oklahoma (i.e., 48 out of 77 counties), and since 1977, cumulative production from these reservoirs has exceeded 157,118,000 barrels of oil and 46,759,666,000 cubic feet of gas (Northcutt, 2000).

The purpose of this guidebook is to introduce the reader to the basics of Hunton Group stratigraphy and lithofacies that occur in the main outcrop belt of the Arbuckle Mountains (Fig. 1), and allow for the extrapolation of these surface exposures into the deeper parts of the Anadarko basin. This will be achieved by interpreting vertical and lateral facies relations between nine Hunton Group exposures (Fig. 1) and comparing these detailed descriptions to their corresponding gamma-ray profiles. The gamma-ray profiles can then be used as standards for future subsurface mapping of Hunton-equivalent rocks using wireline logs.

An attempt was also made to consolidate the important published literature that has been done on the Hunton Group since it was first described. Consequently, this guidebook may be used as a single source for future work on the Hunton rocks. Finally, this report represents a primer that will introduce investigators to the principles of carbonate deposition and facies analysis, and will attempt to apply those same concepts to the Hunton Group.

The Hunton Group was originally named the *Hunton limestone* by Taff (1902; 1904, p. 29–31) from rocks exposed in the area of the Old Hunton Township in Coal County, Oklahoma (Amsden, 1960). Subsequent to Taff's studies, the Hunton limestone underwent a number of nomenclature changes and revisions, first by Reeds (1911, 1927), then by Maxwell (1931, 1936), and finally by Amsden (1957; 1958a,b; 1960). The lithostratigraphic and biostratigraphic framework was finalized by Amsden (1967, 1980), at which time the Hunton limestone was elevated to group status. Currently the Hunton Group consists of seven formations and five members spanning the Upper Ordovician through Lower Devonian stratigraphic section in south-central and northeastern Oklahoma (Fig. 2).

In ascending order, the main lithostratigraphic units of the Hunton Group include the Keel Formation, which includes the basal Ideal Quarry Member, the Cochrane Formation, and the Clarita Formation; the Clarita can be further subdivided into the lower Prices Falls Member and the upper Fitzhugh Member (Fig. 2). These three formations are grouped into a larger lithostratigraphic division called the Chimneyhill Subgroup (Amsden, 1967). Continuing up the Hunton column, members of the Chimneyhill Subgroup are unconformably overlain by the Henryhouse Formation, which is itself unconformably overlain by the Haragan Formation, and then the Bois d'Arc Formation. The Bois d'Arc Formation can be further subdivided into the lower Cravatt Member and the upper Fittstown Member. Finally, the Frisco Formation, which represents a lithologically distinct suite of carbonate rocks, caps the Hunton Group in the northeastern region of the Arbuckle Mountains (Fig. 2; Pl. 1, in envelope). The whole Hunton Group package is unconformably bounded at the top by the Upper Devonian–Lower Mississippian Woodford Shale and bounded below by the Upper Ordovician Sylvan Shale (Fig. 2; Pl. 1).

Besides the Arbuckle Mountains, Hunton-equivalent rocks also crop out in the Ozark uplift of northeastern Oklahoma and include strata extending from the Upper Ordovician Pettit Formation through the Lower Devonian Sallisaw Formation (Fig. 2). The Ozark section typically represents a more shallow-water, upper-shelf, shoal-type mixed carbonate and dolomite sequence that differs from the predominantly subtidal shelf carbonates found in the Arbuckle Mountains (Amsden, 1960, 1961, 1978; Amsden and Rowland, 1965; Amsden and Barrick, 1988). For the purposes of this field trip, only the Arbuckle section will be discussed in any detail.

The Late Ordovician–Early Devonian Hunton Group formed across a stable, shallow epicontinental shelf during a time of relative tectonic quiescence (Fig. 3). During this period of history, warm, shallow seas covered most of North America and propagated the deposition of shoal and moderately deep-water carbonate sediment across most of the cratonic shelf. Reef-type buildups developed around the perimeter of the Michigan basin, which was also the site of extensive evapo-

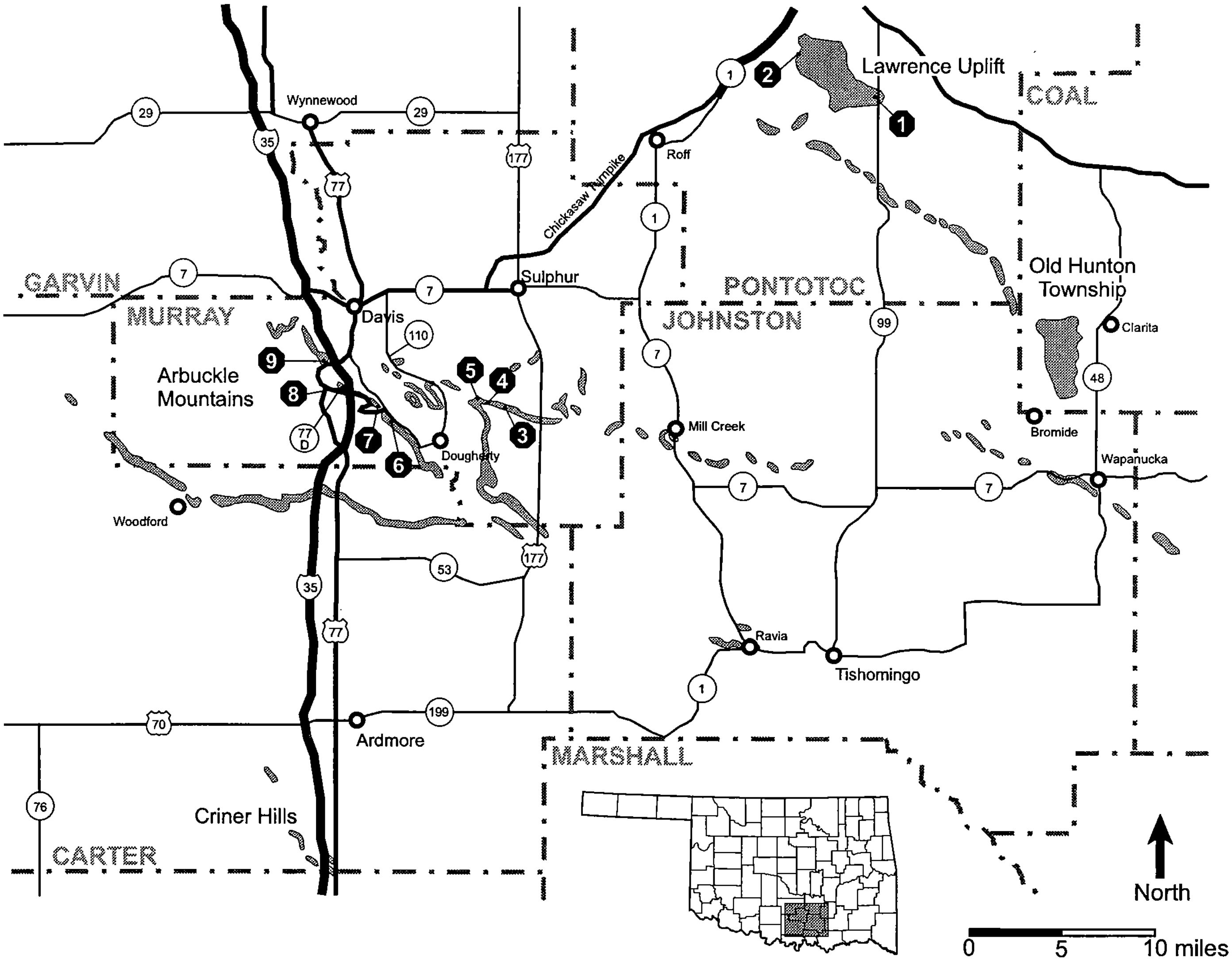


Figure 1. Location map of field-trip stops and measured sections. Shaded areas represent Hunton Group outcrops.

rite deposition during the Silurian Period. The Transcontinental arch, northwest of present-day Oklahoma, represented the only positive topographic feature on the North American cratonic interior. Extensive highlands, however, were developing to the east, southeast, and north of North America, which were the results of the Late Ordovician Taconian and Middle–Late Silurian Caledonian orogenies. Deeper water shale and chert were deposited in fore-arc basins adjacent to subduction zones south (Ouachita basin) and southeast of paleo–North America, as well as off the present-day Pacific coast (Dott and Batten, 1976) (Fig. 3).

CARBONATE ROCKS – A PRIMER

Most carbonate rocks form from the chemical and biochemical precipitation of calcium carbonate within marine environments that are limited to shallow, clear, warm waters (Wilson, 1975). As such, all modern carbonate deposits form within a narrow climatic zone of tropical to subtropical waters situated between 30° north and south latitudes (Wilson, 1975, p. 2, fig. I-1). Based on concepts of uniformitarianism, it stands to reason that most ancient carbonate deposits also developed within this narrow tropical zone.

The bulk of carbonate components, or grains, are biochemically derived from the accumulation of dead calcite- or aragonite-secreting invertebrate fauna. Calcareous flora, such as algae, are also important participants in the development of carbonate rocks, because they produce much of the fine-grained lime mud found in most carbonate sediment and rock. Other carbonate components may be derived from the feeding activity of invertebrate organisms where sediment is ingested and passed through the gut of the animal to produce grapestone and peloid-textured lime sediment. Still other types of carbonate rock form from the cementation of living sessile organisms (i.e., corals, stromato-

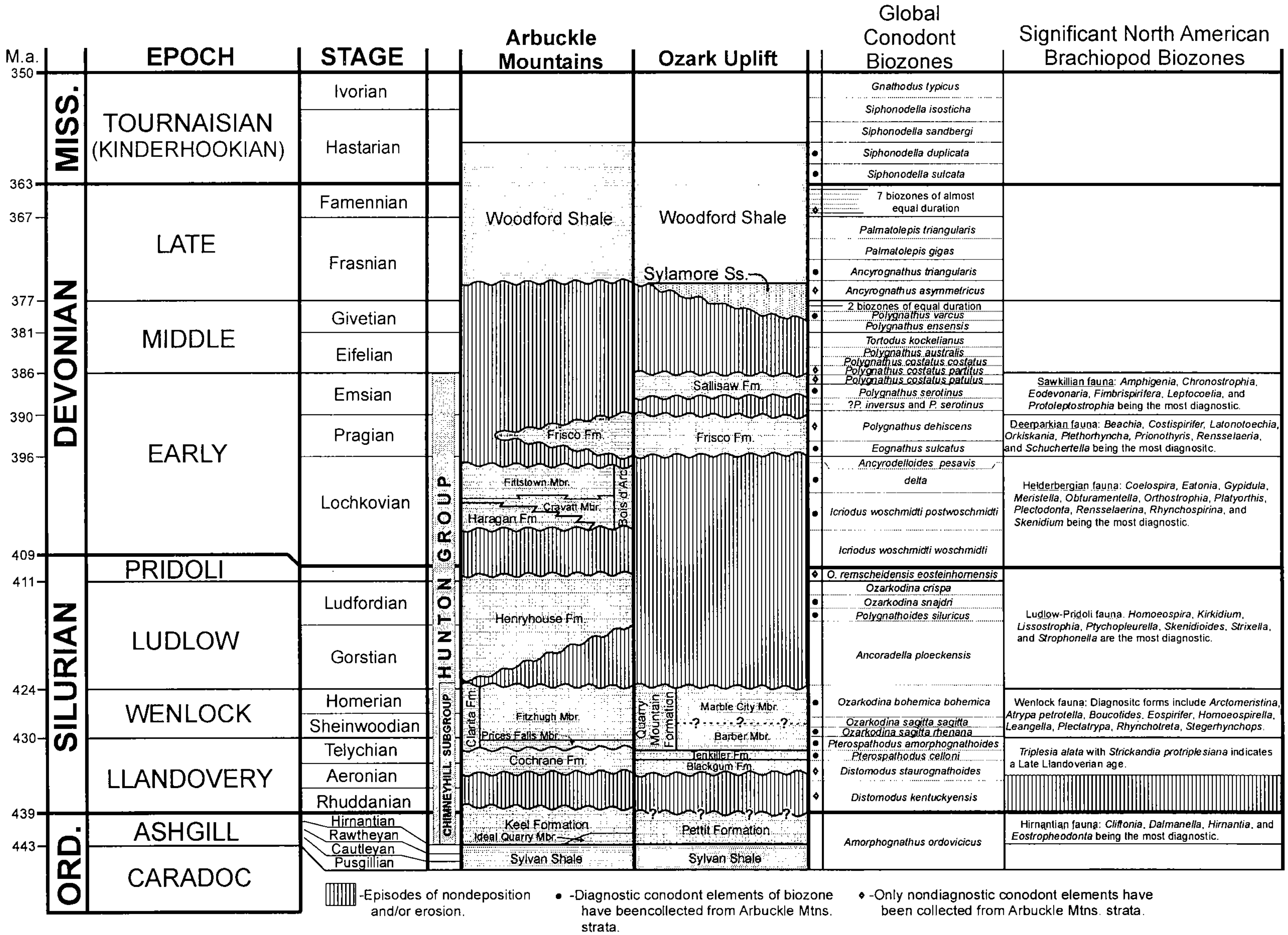


Figure 2. Lithostratigraphic chart illustrating units constituting the Hunton Group and other associated units that crop out in the Arbuckle Mountains and Criner Hills area of south-central Oklahoma, as well as time-equivalent strata exposed in the Ozark uplift in northeastern Oklahoma. Vertical thickness of individual formations and members based on the presence or absence of conodont assemblages. Small column to left of conodont biozones indicates completeness of the assemblage collected from Hunton units of the Arbuckle Mountains region. Also shown are the important brachiopod-assemblage zones from these units established by Amsden (1958a,b; 1960; 1967) and Amsden and Barrick (1988). Data on type and completeness of Hunton conodont assemblages from Amsden and Barrick (1986, 1988), Barrick and others (1990), Barrick and Klapper (1992), and Johnson and Klapper (1992). Nomenclature and standard duration of the Late Ordovician through Early Mississippian Periods, their subdivisions, and their standard conodont biozones are from Harland and others (1990).

poroids, or rudist bivalves) to produce reef boundstones. Under special circumstances, calcium carbonate is chemically precipitated directly from seawater in littoral zones to produce ooids and oolitic sediment.

All of the components discussed above represent different grain types that are commonly found within carbonate rocks. Grain type, size variation, and the way in which grains are organized within carbonate rocks constitute but one important physical component needed to accurately classify and interpret limestone depositional environments. Accurate interpretations of carbonate facies will ultimately determine the size and location of potential hydrocarbon reservoirs. For example, ooids form specifically in shoaling, intertidal environments, and because of their open-packed fabric, oolitic limestones contain considerable intergranular porosity and permeability. Both of these factors are necessary to create a good hydrocarbon reservoir, and

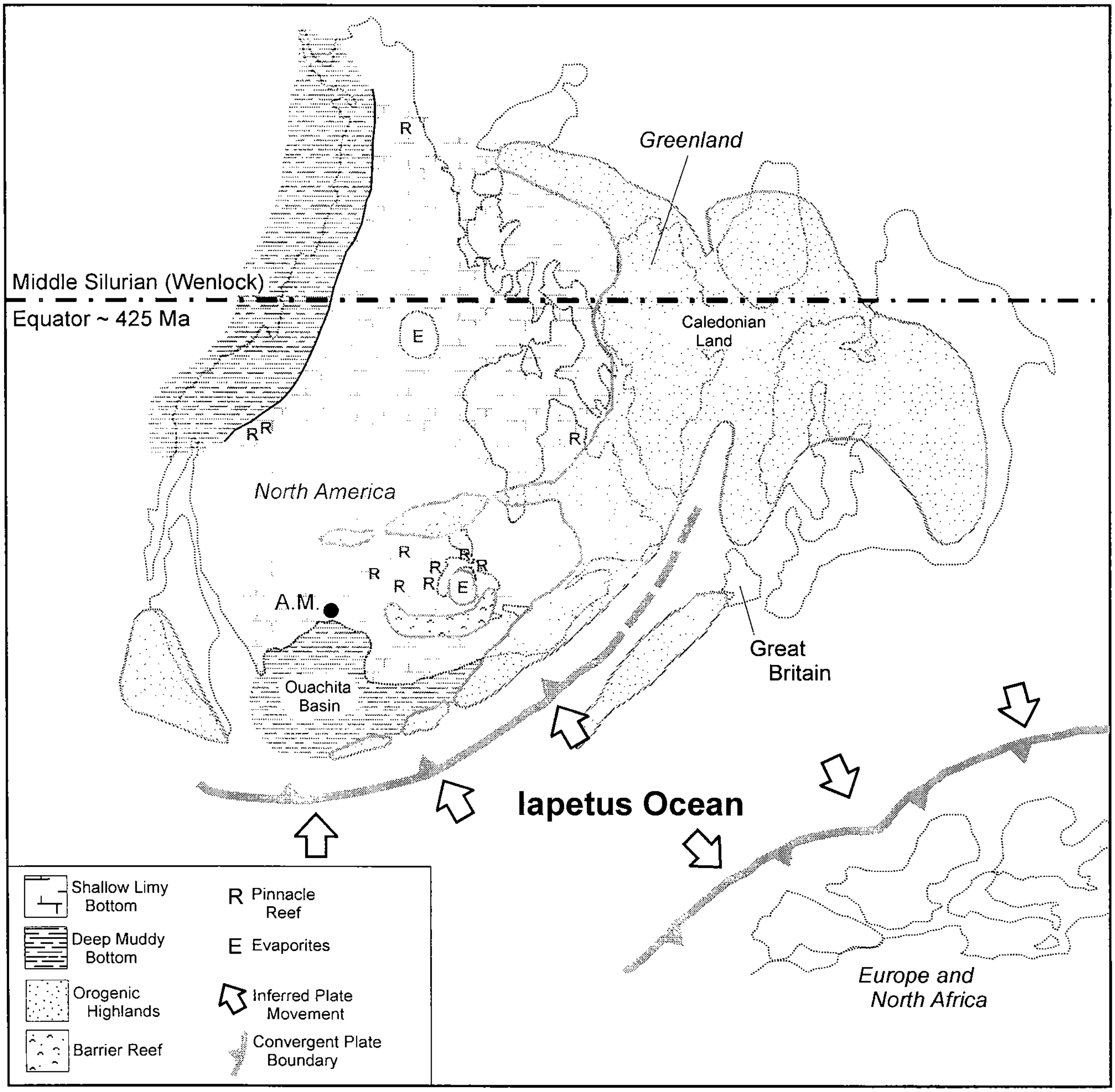


Figure 3. Paleogeographic situation of the North American craton during Clarita deposition (middle Silurian, Wenlock), but model can be applied to most periods of Hunton deposition from the Late Ordovician through the Early Devonian. During this specific time the North American craton was submerged under a shallow sea and was the site of extensive carbonate deposition. Deeper marine, terrigenous clastic deposition was occurring just off the craton in what is now called the Ouachita basin. Point labeled *A.M.* gives the approximate position of the Arbuckle Mountains during the Wenlock Epoch. Base paleogeographic map is from Scotese (1997). Sedimentary-facies interpretations based on data from Lowe (1975), Dott and Batten (1976, p. 252, fig. 13.12), and Medlock and Fritz (1993, p. 157, fig. 13).

TABLE 1. – Classification of Carbonate Rocks According to Depositional Texture[a]

<table>
<tr><td colspan="6">Depositional Texture Recognized</td><td rowspan="6">Depositional Texture Not Recognized</td></tr>
<tr><td colspan="6">Original components were not bound together during deposition</td></tr>
<tr><td colspan="4">Less than 10% >2mm components</td><td colspan="2">Greater than 10% >2mm components</td></tr>
<tr><td colspan="3">Contains mud
(particles of clay and fine silt size)</td><td>Lacks mud</td><td rowspan="3">Matrix supported</td><td rowspan="3">Component supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td colspan="2">Grain-supported</td></tr>
<tr><td>Less than 10% grains</td><td>More than 10% grains</td><td></td><td></td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Floatstone</td><td>Rudstone</td><td>Crystalline Carbonates</td></tr>
</table>

[a]Modified from Dunham (1962, table 1), with further amplification by Embry and Klovan (1971, fig. 2).

it stands to reason that understanding how and where these specific carbonate facies develop will only improve hydrocarbon-exploration efforts.

Along these lines, the presence of lime mud is also an important physical component of carbonate sediment and rock, because it normally inhibits the development of porosity. Lime mud, or micrite, forms predominantly from the disaggregation of calcareous algae. It also can form from the burrowing and boring activities of some fauna and flora in a process called micritization, where preexisting calcareous shell material is broken down into a fine powder.

The amount of micrite found in sediment is directly dependent on the strength and pervasiveness of current activity under which the sediment was formed. Typically, high-energy environments, such as those within intertidal zones, are the sites of coarse-grained sediment that contains little micrite. Within these littoral zones, persistent current activity will wash the fine silt and clay fractions farther out to sea, leaving just the coarser grain fraction behind. Conversely, low-energy environments, such as subtidal open shelves, are the loci for fine-grained-carbonate deposition. Given that coarser grained carbonate sediment has a greater percentage of its rock volume resulting in porosity relative to fine-grained sediment, it is logical to explore for potential hydrocarbon reservoirs in carbonates developed under high-energy conditions. As an example, known Hunton reservoirs in the Anadarko basin are hosted in grain-supported fabrics, or in dolomitized Hunton carbonates that formed within littoral zones (Amsden, 1975; Al-Shaieb and others, 1993a, 2000; Beaumont, 2000; Rottmann, 2000b).

Probably the easiest and most useful carbonate-facies classification scheme, and the one used to classify Hunton carbonates in this guidebook, was advanced by Dunham (1962). The classification is useful because it is based on the depositional texture of the sediment prior to lithification and diagenesis. Consequently, the classification is helpful in interpreting the original depositional environment under which the limestone was formed. This is done by determining the type of fabric in conjunction with the amount of micrite contained in the rock (Table 1).

If depositional texture can be recognized, limestone fabrics may be either grain supported (grainstones, packstones, rudstones) or mud supported (mudstones, wackestones, or floatstones) (Table 1). If the limestone contains no micrite, it is called a grainstone and is commonly derived from sediment that was deposited in high-energy environments. All other rock types in Dunham's (1962) classification contain appreciable amounts of lime mud and so are more indicative of low-energy environments. The other textural terms, such as wackestone or mudstone, are differentiated on the basis of the percentage of grains present, whereas a packstone is a grain-supported limestone that contains some lime mud (Table 1). Floatstone and rudstone are special textural terms that denote carbonate fabrics that typically developed around some types of biohermal buildups (i.e., Waulsortian facies) or as downslope accumulations of reef talus material (Embry and Klovan, 1971; Wilson, 1975). Consequently, floatstones and rudstones contain large grain components in comparison with the other textural terms.

Given that the manufacture of marine carbonates is highly dependent on the physical and chemical conditions under which they formed, carbonate facies can be used to interpret ancient depositional environments. Two major factors that affect carbonate production are (1) water energy and (2) depth.

Current activity is beneficial because it controls the level of oxygenation and water circulation and mixing, and it carries nutrients to sessile, suspension-feeding organisms (corals, brachiopods, bryozoans, and crinoids) that make up the bulk of coarse-grained carbon-

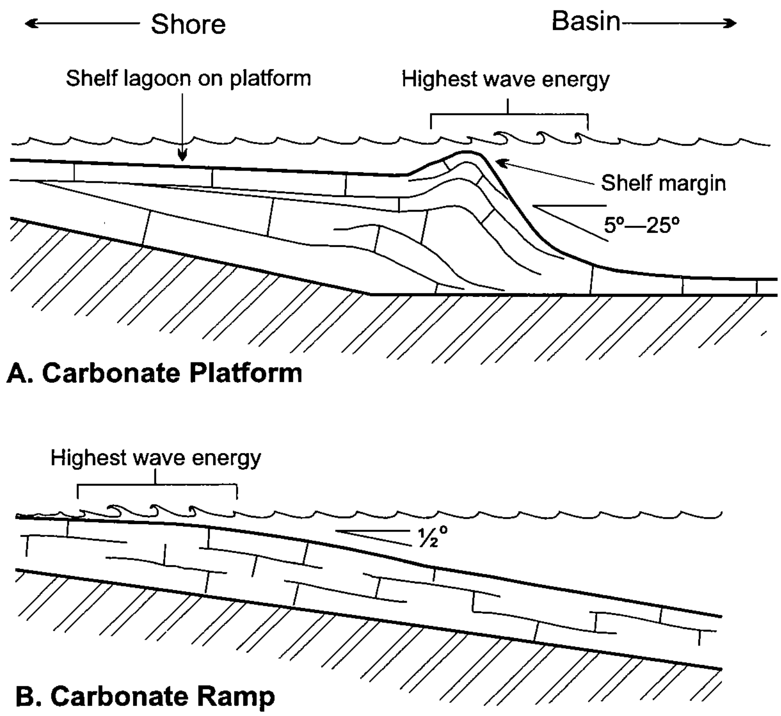


Figure 4. Comparison of shelf profiles of differing regional carbonate buildups. *A*—Typical carbonate-platform style with a near-horizontal top and an abrupt shelf margin with steep paleoslopes where high-energy sediment is deposited. *B*—Carbonate-ramp style that builds up from positive areas and down gentle regional paleoslopes that have no obvious break between shelf and basin. Note that in ramp buildups, the high-energy zone occurs relatively close to shore, and the facies patterns tend to be wide and irregular in comparison with a carbonate platform. No vertical or horizontal scale is implied. Diagram modified from Wilson (1975, fig. II-2).

ate sediment. Current activity is also important because it removes fine-grained terrigenous and lime detritus that would ordinarily interfere with the respiration and feeding of carbonate-producing organisms.

Depth is important because it indirectly influences current energy (i.e., deeper water usually results in weaker currents) and directly controls the amount of light reaching the sea floor. Deeper water generally equates to darker conditions, which not only have an adverse effect on primary producers (algae, phytoplankton) but also affect algal-dependent hermatypic organisms, such as modern reef-building corals (Wilson, 1975).

Owing to these specific major, and many minor, conditions, thick accumulations of carbonate sediment primarily occur in shallow water (within a 100-ft depth; Fig. 4A). This is contrary to conditions necessary for the accumulation of thick terrigenous clastic deposits, which require preexisting depressions, sinks, or basins that can accommodate increased clastic influx. By their very nature, thick carbonate deposits indicate paleohighs rather than -lows, and shallow shelves rather than deep basins. Accommodation space necessary for thick carbonate deposits are created during the contemporaneous activity of either a rapid increase in sea level or shelf subsidence, or both, coupled with the simultaneous increase in carbonate production. Most times, however, carbonate production will outpace subsidence and flooding, and results in a basinward migration of carbonate shelf facies. In a tectonically active region, the thickest accumulations of carbonate sediment are usually at, or just shoreward of, the shelf margin (Wilson, 1975; Beaumont, 2000) (Fig. 4A).

For more information concerning the origin, interpretation, and significance of carbonate rocks, the reader is referred to excellent texts by Wilson (1975), Blatt and others (1980), Leeder (1982), and Scholle and others (1983), and to a summary paper written for the Hunton workshop by Beaumont (2000).

ORDOVICIAN–DEVONIAN CARBONATE-RAMP MODEL

The Late Ordovician–Early Devonian Hunton Group was deposited across a shallow cratonic shelf that exhibited a very slow rate of subsidence (Adler, 1971; Feinstein, 1981; Al-Shaieb and others, 1993a, 2000). As such, the regional development of the Hunton Group is associated with a ramp-style carbonate buildup (Fritz and Medlock, 1993). This type of regional framework differs in the types and configurations of facies that normally develop near platform margins (e.g., the lower Paleozoic reefal buildups of central Nevada and western and southeastern Canada).

Differences between the two regional styles are illustrated in Figure 4. As stated earlier, the thickest accumulation of carbonate rocks in the platform model occurs at or near the shelf margin. Within the platform model, the margin represents the locus for both high-energy sedimentation and maximum carbonate productivity. Owing to the steep shelf slope (some with basin inclines nearing 25°–35° of repose), facies zones on the basinward side of the shelf margin are narrow and more easily differentiated from adjacent zones. On the shoreward side of the shoal margin, a broad, quiet-water, restricted marine zone usually develops (Wilson, 1975) (Fig. 4A). In carbonate ramps, no obvious break in the shelf slope occurs, so the accumulation of sediment remains equal (relative to thickness and sedimentation rate) across the entire shelf (Fig. 4B). Also, the high-energy zone occurs closer to shore, and facies zones tend to be wider, more irregular, and poorly differentiated from each other because of the gentle slope that develops basinward (Wilson, 1975; Fritz and Medlock, 1993).

Some ancient examples of carbonate ramps include Mississippian carbonate facies developed adjacent to the central Montana high, and the middle Cretaceous Glen Rose and Fredricksburg sequences developed

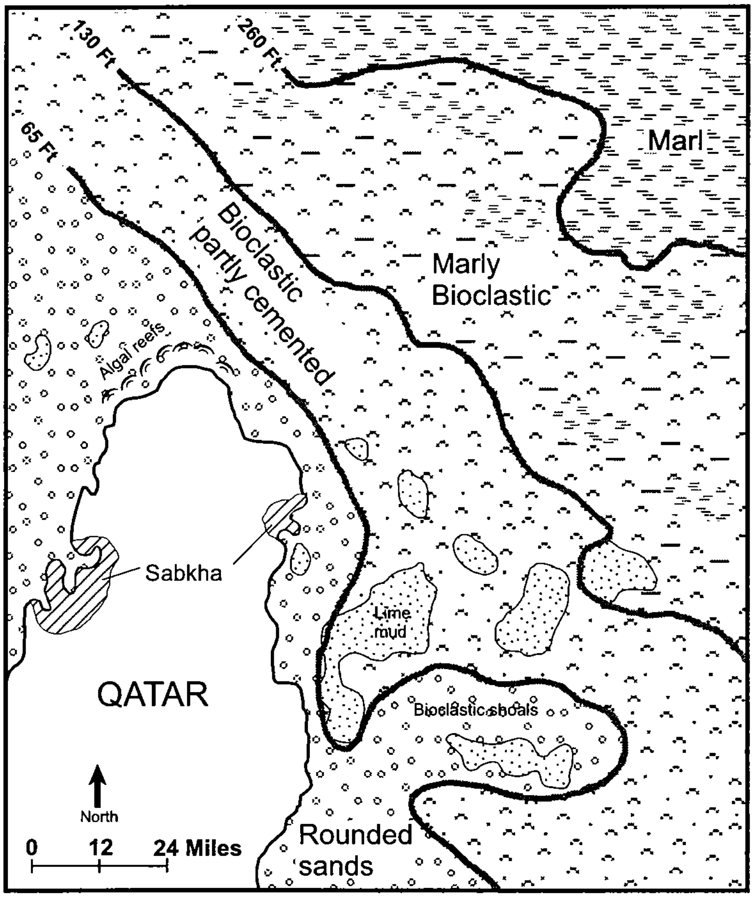


Figure 5. Modern analog of the Hunton-style carbonate ramp, showing the correlation between bathymetry and facies type off the coast of Qatar, Persian Gulf. Note progressive facies change from shoal-water lime sands to shaly lime muds (marls) going into deeper water. Although facies change loosely follows bathymetry, there is a degree of intergradation between juxtaposed facies zones. Diagram from Wilson (1975, fig. II-10), and from Wilson and Jordan (1983).

along the Llano uplift in central Texas (Wilson, 1975).

Modern analogs of the carbonate-ramp model are rare because of widespread active tectonism, coupled with low sea-level stands, which are more common today than in other times of Earth's history. Greater tectonism appears to foster platform styles over ramp development, because it creates greater rates of basin subsidence and a greater degree of regional differentiation between shelf and basin. Low sea levels also work against the development of broad, epicontinental seas, which are necessary for ramp development. One area that exhibits conditions ideal for the development of a carbonate ramp is the region off the Qatar Peninsula in the Persian Gulf (Wilson, 1975; Wilson and Jordan, 1983) (Fig. 5).

At Qatar, the high-energy zone is proximal to the landmass and is characterized by the deposition of rounded, bioclastic and oolitic, shoal-type sands. Moving farther offshore, carbonate sediments become increasingly fine grained and argillaceous to the point at which true marls are encountered (Wilson, 1975; Wilson and Jordan, 1983) (Fig. 5). As with most carbonate sediments, these major facies belts around the Qatar Peninsula develop subparallel to bathymetric contours, although a good deal of diffusion and gradation exists between each facies zone. The gradual nature of the facies zones is primarily due to the gentle depositional slope that trends northeast off the Qatar coast at 2.5 ft per mi (0.3° of slope).

This lateral facies progression from shallow, high-energy bioclastic sands to deep, low-energy lime muds and marls around Qatar is applicable to the vertical facies relationships observed in Hunton outcrops. Based on the Qatar model and field observations of Hunton facies relationships, coupled with other published models from previous subsurface investigations of Hunton stratigraphy (Al-Shaieb and others, 1993a, 2000), the rocks of the Hunton Group have been classified into five standard facies belts for purposes of this field trip (Fig. 6; Table 2). Field criteria used to identify the five facies zones are outlined in Table 2 and are based primarily on the predominant depositional texture found in each facies, the amount of argillaceous material associated with each facies, the types and preservational conditions of associated fossils, and the presence or absence of chert.

Facies Zone 1

This facies does not occur at the surface, but has been described from cores intersecting Hunton-equivalent rocks in the Anadarko basin (Al-Shaieb and others, 1993a, 2000; Friedman, 1993; Fritz and Medlock, 1993; Howery, 1993; Olson, 1993) (Fig. 6; Table 2). The zone represents high intertidal and supratidal restricted-marine deposition that develops shoreward of the high-energy, intertidal zone of facies 2. In the modern ramp model of Qatar, this zone is analogous to the shallow sabkha deposits that fringe isolated bays and inlets along the peninsula (Fig. 5).

Facies Zone 2

This is the high-energy depositional belt formed along the carbonate ramp (Fig. 6; Table 2). The facies develops within the intertidal zone and is dominated by rocks having grain-supported textures, with very little associated lime mud. Ooids and rounded bioclasts are the dominant grain types. At Qatar, this facies belt is analogous to the rounded bioclastic sands found at depths of less than 65 ft of water (Fig. 5).

Facies Zone 3

This belt forms intermediate to the intertidal high-energy conditions of zone 2, and the subtidal low-energy conditions of facies 4 and 5. As such, this zone

TABLE 2. – Description of Facies Zones Associated with Standard Carbonate-Ramp Model Developed During Ordovician–Devonian of Oklahoma

Facies Zone 1: Restricted Circulation on Marine Ramp

This facies includes fine sediment in very shallow lagoons, shelves, and restricted supratidal tidal flats that have restricted circulation or potentially hypersaline conditions. Coarser sediment may occur proximal to zone 2 or consist of pelleted sediment. Areas of subaerial exposure and/or meteoric diagenesis may occur.

- *Location and width*—Shoreward of zone 2, high intertidal to supratidal; proximal to accumulated lime-mud buildups that could restrict open circulation. Facies may be narrow or wide depending on width of zone 2 or extent of pre-Woodford erosion.
- *Energy*—Low energy, restricted marine.
- *Prevailing rock types*—Predominantly mud-supported carbonates with dolomite; grain-supported textures rare except for pelleted sediments.
- *Grain type and depositional texture*—Pelleted or unfossiliferous muds most common, some whole fossils and some cryptal algal and fenestral fabrics are found (Al-Shaieb and others, 1993a).
- *Terrigenous clastics*—Some, derived from windblown shoreward sources.
- *Biota*—Restricted-marine fauna and flora, mostly gastropods, ostracodes, and encrusting algae.
- *Occurrence*—Facies does not occur in surface exposures in the Arbuckle Mountains but has been described from cores intersecting lithofacies equivalent to various members of the Chimneyhill Subgroup and *Kirkidium* beds of the Anadarko basin (Al-Shaieb and others, 1993a; Friedman, 1993; Fritz and Medlock, 1993; Howery, 1993; Olson, 1993).

Facies Zone 2: Washed Littoral Sands

Facies takes the form of shoals, beaches, and intertidal or offshore tidal bars. Represents water that ranges in depth from subaerial exposure to as much as 50 ft. Sand washed nearly clean of mud and consists of ooids or rounded bioclastic debris. Salinity and oxygenation of marine waters variable, owing to periodic exposure.

- *Location and width*—Intertidal zone, well above normal wave base; the width of the facies varies, depending on duration and extent of marine regression.
- *Energy*—High energy, normal marine.
- *Prevailing rock types*—Grainstones and sorted packstones.
- *Grain type and depositional texture*—Oolitic or bioclastic grain-supported textures predominate. Fabrics are well-sorted open packing, and rounded. There is some algal coating of grains.
- *Terrigenous clastics*—Rare.
- *Biota*—Highly fragmented; normal, but monotypic marine fauna; predominantly crinoid debris with some brachiopod-shell material. Encrusting algae may be present.
- *Occurrence*—Surface exposures include some intervals in the intermound and capping rock of the Frisco Formation, oolitic facies of the Keel Formation, Fittstown Member of the Bois d'Arc Formation, and most of the Cochrane Formation; subsurface occurrences include the *Kirkidium* biofacies of the Anadarko basin.

Facies Zone 3: Downslope Bioclastic Sand and Mud Facies

This facies forms downslope of high-energy zone, below effective wave base but not below storm wave base. Represents material deposit on gentle incline that is periodically washed. Sediment is highly variable in size, shape, and texture; generally consists of unsorted bioclastic packstone and wackestone, with minor grainstone. Salinity and oxygenation normal.

- *Location and width*—Immediate subtidal zone; below effective wave base but not below storm wave base. Facies usually narrow; exceptions include some facies of the Frisco Formation.
- *Energy*—Moderate energy, with intermittent storm-surge currents. Currents are enough to wash most, but not all, clay-size particles out of sediment.
- *Prevailing rock types*—Variable types, mostly unsorted skeletal packstone and wackestone, some whole-fossil wackestone (lower parts of zone) and skeletal grainstone (upper parts of zone).
- *Grain type and depositional texture*—Variable mixture of lime mud and bioclastic sand, some reworked oolites from zone 2. Grain-supported textures predominate; skeletal grains generally fragmented in varying shapes and sizes.
- *Terrigenous clastics*—Rare.
- *Biota*—Diverse, normal-marine fauna and flora; mainly baffler and encruster types, such as crinoids, fenestrate bryozoans, and encrusting algae. Shelly fauna common but mostly fragmentary.
- *Occurrence*—Most lithofacies of the Frisco Formation (including the mound and intermound facies), some intervals of the Fittstown Member of the Bois d'Arc Formation, the *Kirkidium* beds of the Anadarko basin, the Ideal Quarry Member of the Keel Formation, and parts of the Cochrane Formation.

Facies Zone 4: Mid-Level Shelf Facies

This facies forms in intermediate depths along the carbonate ramp in water that may extend down to 150–250 ft, well below effective and storm wave base. Strata consist of thin carbonate beds with minor interbeds or partings of clayey and/or siliceous material. Resembles deeper water basin sediments (zone 5) but is less argillaceous. Oxygen levels still support a diverse, normal-marine fauna.

- *Location and width*—Zone starts below storm wave base, forms across wide areas of the carbonate shelf.
- *Energy*—Generally low current energy, enough to keep oxygen levels and circulation normal.
- *Prevailing rock types*—Whole-fossil wackestones and mudstones dominate, skeletal wackestones present; cherty in some places.
- *Grain type and depositional texture*—Mostly whole fossils set within lime-mud matrix. Skeletal or fragmentary bioclasts may occur in upper parts, which were washed down from zone 3.
- *Terrigenous clastics*—Common as terrigenous detritus in carbonates, some as shale partings; chert may be common.
- *Biota*—Diverse, normal-marine, benthic, and epibenthic fauna. Dominated by brachiopods and crinoids; trilobites, gastropods, and ostracodes also occur.
- *Occurrence*—Facies represented by most of the Haragan Formation and the Cravatt Member of the Bois d'Arc Formation. It is also represented by the Fitzhugh Member of the Clarita Formation and the upper parts of the Henryhouse and Cochrane Formations.

(continued on next page)

TABLE 2. – *(Continued)*

Facies Zone 5: Deep Shelf Facies

Facies forms in water 200+ ft deep. Oxygenation becomes variable, which affects the abundance and location of benthic marine fauna. Strata consist of thin- to thick-bedded argillaceous carbonates, with some well-segregated shale intervals. Fine-grained terrigenous clastics derived from the Ouachita clastic province.

- *Location and width*—Occupies a wide zone along the farthest offshore position of the carbonate ramp.
- *Energy*—Low energy with very little circulation.
- *Prevailing rock types*—Well-bedded argillaceous mudstone, that is locally very fossiliferous.
- *Grain type and depositional texture*—Whole fossils (rarely fragmented) set in lime-mud matrix. Pelleting and burrowing of sediment common.
- *Terrigenous clastics*—Shale commonly interbedded with argillaceous carbonates in well-segregated layers.
- *Biota*—Fairly diverse marine fauna dominated by brachiopods, whose distribution may be irregular owing to areas of limited oxygenation along the marine benthos.
- *Occurrence*—Facies best represented by the Henryhouse Formation and the Prices Falls Member of the Clarita Formation. Lower stratigraphic intervals of the Haragan Formation also may fall within this zone.

contains a mixture of grain-supported and mud-supported textures (although true grainstones and pure mudstones are rare), and include grains composed almost exclusively of fragmented (but not rounded) fossil material (Fig. 6; Table 2). This facies belt gets little continuous current activity but is occasionally reworked by storm currents. The mud-mound facies of the Frisco Formation most likely developed in the lower parts of this facies belt.

Facies Zone 4

Facies zones 4 and 5 represent the subtidal open-shelf portion of the carbonate-ramp model. Both of these facies zones are texturally characterized by whole, unabraded fossils set in a mud-supported fabric (Fig. 6; Table 2). Zone 4 differs from zone 5 in having less terrigenous detritus, and chert is commonly interbedded with the fossiliferous mudstones (see discussion under General Stratigraphy—Bois d'Arc Formation, below). In addition, because zone 4 reflects more normal-marine conditions (i.e., better oxygenated and circulated waters, less fine-grained clastics to disrupt filter-feeding organisms), this facies tends to be more fossiliferous than zone 5 carbonates. At the Qatar Peninsula,

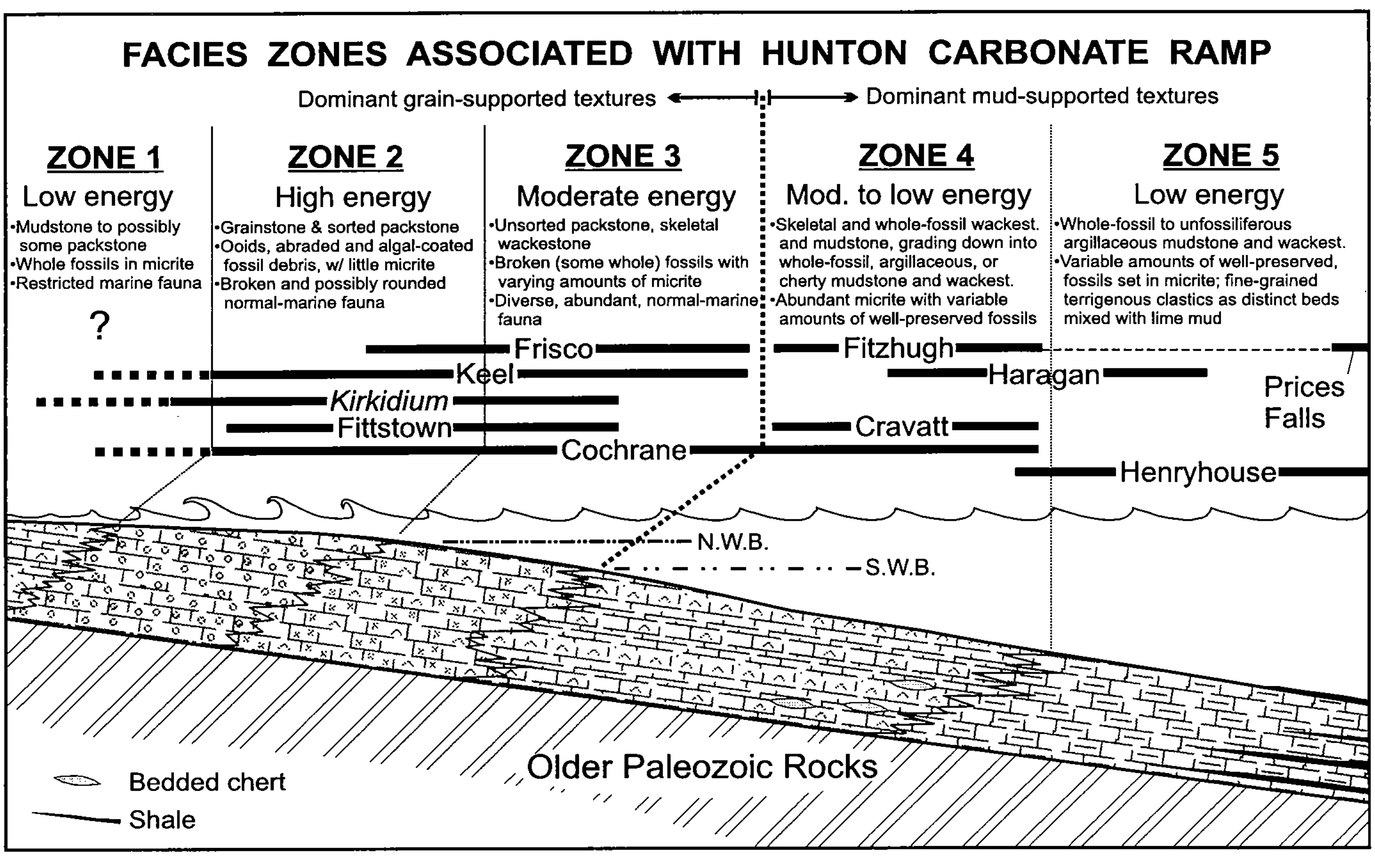


Figure 6. Idealized standard facies model of the Hunton Group, based on a carbonate-ramp model of deposition. Illustrated are the main facies zones, their diagnostic depositional textures, and the bathymetric positions the major units of the Hunton would have hypothetically formed under this depositional scheme. *N.W.B.* and *S.W.B.* represent normal wave base and storm wave base, respectively. Only rocks formed under facies zones 2 through 5 occur in the outcrop belt around the Arbuckle Mountains. No vertical or horizontal scale is implied. Detailed descriptions of each standard facies zone are also given in Table 2.

this facies belt is analogous to the marly bioclastic muds found at depths of 130–260 ft (Fig. 5).

Facies Zone 5

This facies is similar to facies zone 4, but associated carbonate rocks are much more argillaceous, and some are associated with distinct, segregated beds of fine-grained terrigenous sediment (Fig. 6; Table 2). Rocks of this facies also tend to be sparsely fossiliferous in comparison with zone 4 carbonates. Consequently, this facies is interpreted to have occupied the most basinward and deepest water carbonate belt developed off the shelf ramp during the period of Ordovician–Devonian deposition in Oklahoma. Zone 5 most likely is analogous to the offshore marl facies of Qatar (Fig. 5).

CARBONATE CYCLES AND SEQUENCE STRATIGRAPHY

As with other epicontinental sedimentary packages, the Hunton Group contains many examples of cyclic sedimentation that detail numerous periods of sea-level fluctuation across the shallow Ordovician–Devonian shelf. One such cyclic sequence was reported by Al-Shaieb and Puckette (2000) and Al-Shaieb and others (2000) and is termed the Henryhouse–Haragan–Bois d'Arc carbonate sequence (HHB type I sequence). This sequence more or less represents a single, continuous shoaling-upward cycle that is unconformably bounded by a pre-Henryhouse erosional event below, and a pre-Woodford event above. The "grand HHB cycle" also contains a number of minor shallowing-upward parasequences and indicates that a subsequent number of smaller transgressive–regressive cycles occurred during the Silurian–Devonian prior to completion of the HHB "grand" cycle (Al-Shaieb and Puckette, 2000; Al-Shaieb and others, 2000).

Wilson (1975, p. 49–51) outlined several types of shoaling-upward cycles found in carbonate sequences throughout geologic history. The most common, and the one most applicable to the Hunton Group sequence is the upward-shoaling (fill-in) carbonate cycle, which is illustrated in Figure 7 (Wilson, 1975; Wilson and Jordan, 1983).

In this example, the shallow, epicontinental shelf is flooded by a rapid transgression, which is rarely preserved in the stratigraphic record. Following the transgression, the flooded shelf begins to fill with normal-marine sediments. This continues until the cycle culminates in a shoal phase and eventually into evaporite deposition and exposure.

The carbonate–evaporite fill-in cycle typifies most shallow, epicontinental shelf sedimentation, in that the resulting cycle after shelf flooding is asymmetric, characterized by a thin transgressive and a thick regressive record (Coogan, 1972; Wilson, 1975; Heckel, 1977, 1989; Wilson and Jordan, 1983). Invariably, the regressive portion of the cycle grades upward into a shoal-water phase, and eventual exposure, before the next cycle begins.

Carbonate cycles are noticeable in almost every formation of the Hunton Group. The only exception appears to be the Cochrane Formation (reasons for this lone exception are detailed under the section General Stratigraphy—Cochrane Formation, below). The Henryhouse–Haragan–Bois d'Arc cycle has already been mentioned (Al-Shaieb and Puckette, 2000; Al-Shaieb and others, 2000). The cycle starts with a thin interval of very argillaceous mudstone and graptolitic clayshale at the base of the Henryhouse Formation. This basal Henryhouse interval is best interpreted as a condensed section representing the maximum extent of marine transgression. Note that this basal section (transgressive part of the HHB cycle) is relatively thin in comparison to the regressive sequence that includes the rest of the Henryhouse, the Haragan, and the Bois d'Arc Formations (labeled *Thy* in Fig. 8). The whole cycle ends with a shoal phase represented by the clean, well-sorted grainstones of the Fittstown Member of the Bois d'Arc Formation.

As noted earlier, the HHB sequence can be broken up into two major transgressive–regressive events, coupled with numerous, smaller parasequence events. The Henryhouse Formation would compose a complete regressive fill-in, although the shoal phase, repre-

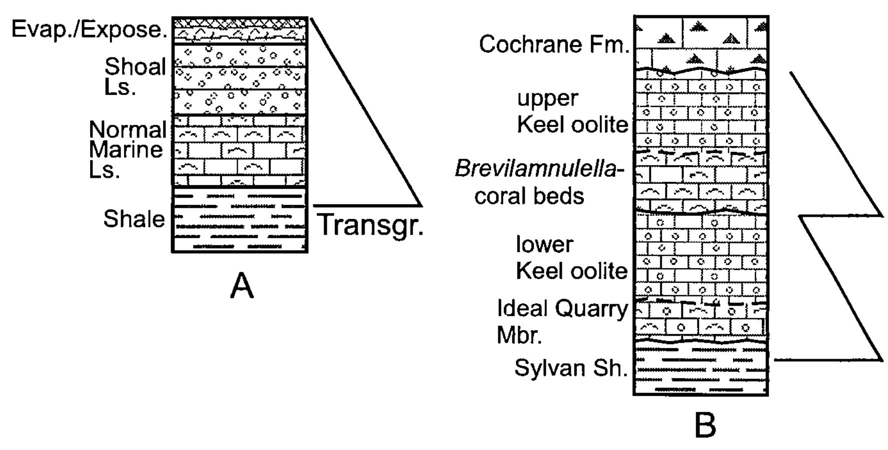


Figure 7. Common pattern of cyclic sedimentation in carbonates. *A*—Typical upward-shoaling, carbonate–evaporite fill-in model. Bulk of preserved sedimentological record is one of slow, sustained regression, which follows a rapid transgression. Diagram modified from Wilson (1975, fig. II-25). *B*—General stratigraphic section of the Keel Formation, measured from Holnam Quarry in Pontotoc County, Oklahoma (Amsden and Barrick, 1986, p. 13, text-fig. 12). Note strong correspondence of facies change in the Keel with that shown in the standard cycle at left. This upward-shoaling (fill-in) cycle can be applied to most members of the Hunton Group. See Appendix for explanation of lithologic symbols.

sented by the *Kirkidium* biofacies (Amsden, 1980), does not crop out in the Arbuckle Mountains. The Haragan–Bois d'Arc couplet constitutes the second major fill-in cycle of the HHB sequence. As with the basal Henryhouse graptolite shale beds (which signify maximum transgression), the basal Haragan Formation also contains shaly carbonate beds similar to those of the Henryhouse interval (albeit thinner and less shaly) (*Tha* in Fig. 8). The increased influx of terrigenous clastics at the start of Haragan deposition is well exemplified at Stops 8 and 9 (Part II, this guidebook). At these stops, the upper Henryhouse beds have a clean carbonate texture and indicate deposition in shallower water in comparison with the lower Henryhouse. The cycle then repeats, as shaly carbonates at the base of the Haragan Formation indicate that another major transgression occurred near the start of the Devonian (see Stop 8, Figs. 45–48, and Stop 9, Figs. 49, 50, Part II, this guidebook).

Minor parasequence boundaries in the HHB cycle are denoted by scattered, atypical clean carbonate beds intercalated with more typical argillaceous car-

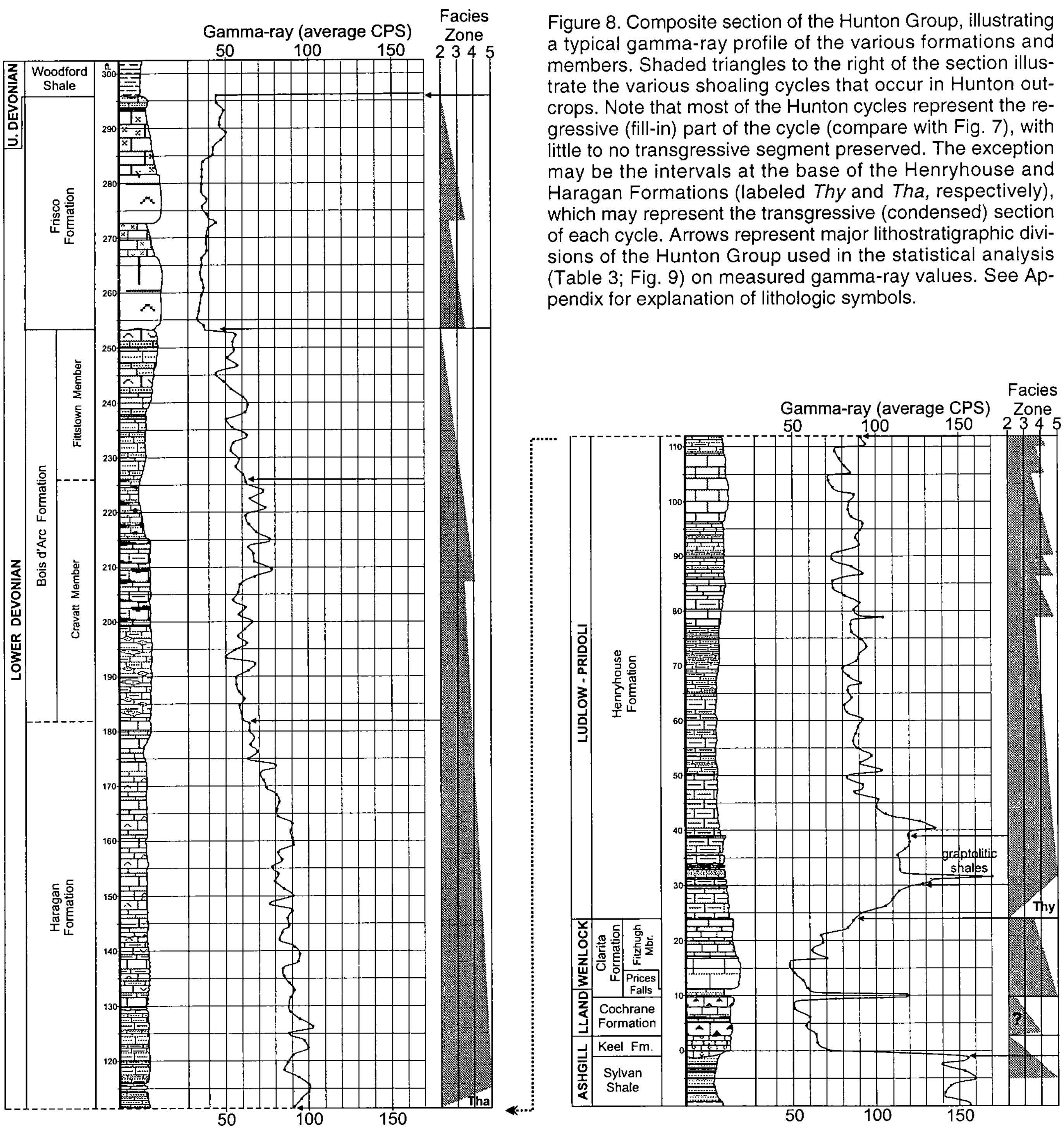


Figure 8. Composite section of the Hunton Group, illustrating a typical gamma-ray profile of the various formations and members. Shaded triangles to the right of the section illustrate the various shoaling cycles that occur in Hunton outcrops. Note that most of the Hunton cycles represent the regressive (fill-in) part of the cycle (compare with Fig. 7), with little to no transgressive segment preserved. The exception may be the intervals at the base of the Henryhouse and Haragan Formations (labeled *Thy* and *Tha*, respectively), which may represent the transgressive (condensed) section of each cycle. Arrows represent major lithostratigraphic divisions of the Hunton Group used in the statistical analysis (Table 3; Fig. 9) on measured gamma-ray values. See Appendix for explanation of lithologic symbols.

bonates of the Henryhouse and Haragan Formations (Fig. 8). Usually, on wireline logs, a noticeable gamma-ray low accompanies these cleaner carbonate beds and can be used to identify upper parasequence boundaries (Al-Shaieb and Puckette, 2000, p. 135, fig. 8; Al-Shaieb and others, 2000, p. 41, fig. 33).

A more obvious carbonate fill-in cycle is represented by the basal Sylvan Shale–Ideal Quarry Member–Keel oolite couplet (Fig. 7). The initial transgression most likely started in the Sylvan Shale, while basin fill-in progressed through the normal-marine phase (represented by the Ideal Quarry Member) and ends at the shoal-water phase represented by the Keel oolite facies. At the Holnam Quarry (see Stop 2, Part II, this guidebook) the Keel cycle is complicated by an additional fill-in carbonate cycle above the lower Keel oolite (Fig. 7). In this second cycle, the normal-marine phase is represented by what Amsden and Barrick (1986) termed the *Brevilamnulella*–coral beds (a skeletal packstone) (Fig. 7). The shoal phase of this second cycle is represented by the upper Keel oolite.

Another such cycle can be interpreted from the Clarita Formation, with the condensed transgressive section represented by the Prices Falls Member. The details of this cycle are explained under the section General Stratigraphy—Clarita Formation, below.

The individual Hunton cycles are bounded above and below by a major unconformity, thus grouping each suite as a sedimentologically related package of rocks, but which are genetically unrelated to the shoal cycles above and below (Fig. 2).

GAMMA-RAY PROFILES AND SUBSURFACE CORRELATION

Accompanying each measured section in this guidebook is a companion figure illustrating the gamma-ray profile of each exposure. Each profile was constructed using a Scintrex gamma-ray spectrometer/scintillometer that measures gamma-ray radiation in counts per second (CPS) and subsequently records average counts per second calculated over a 10-second interval. Each recording station was spaced at 16-in. intervals up the exposed section, and five successive, 10-second averages were taken at each station. The five values were then averaged together in the laboratory, and the average counts per second were plotted on section grids (see Part II, this guidebook). In all, 734 individual station averages were calculated to produce the nine individual gamma-ray profiles. The most complete lithostratigraphic sections and their gamma-ray profiles were then used to construct the composite Hunton section shown in Figure 8.

A casual observation of Figure 8 shows that a few Hunton units exhibit very strong and unique gamma-ray signatures. The most obvious are the combined low gamma-ray values measured from the formations within the Chimneyhill Subgroup. This sequence of clean carbonates stands out in stark contrast to the high gamma-ray readings measured from the underlying Sylvan Shale and overlying argillaceous beds of the Henryhouse Formation. Within this low gamma-ray signature of the Chimneyhill limestones, the highly argillaceous lime mudstones and clayshales of the Prices Falls Member give high gamma-ray readings that can easily be detected from wireline logs (see gamma-ray profiles of Hunton Group exposures at Stop 7 [Fig. 42], Stop 8 [Fig. 46], and Stop 9 [Fig. 50], Part II, this guidebook).

The graptolite-bearing shales and argillaceous limestones of the basal Henryhouse also produce a unique gamma-ray profile, particularly in contrast with the Chimneyhill Subgroup, below (Fig. 8) (see also gamma-ray profiles of Hunton Group exposures at Stop 7 [Fig. 42], Stop 8 [Fig. 46], and Stop 9 [Fig. 50], Part II, this guidebook). This basal interval of the Henryhouse has already been used with great effect in subsurface correlations of Hunton rocks in the Anadarko basin (Rottmann, 2000c, figs. 117, 118).

The Frisco Formation also appears to exhibit a unique gamma-ray profile, particularly when viewed in contrast with the underlying Bois d'Arc Formation and the overlying Woodford Shale, which repeatedly gave gamma-ray readings >400 CPS (Fig. 8). Unlike other Hunton units, the Frisco gives off very low readings that are relatively unvarying.

The units between the Frisco Formation and the basal graptolite shales of the Henryhouse are far less distinct from each other on first appearance (Fig. 8). All of these middle units (i.e., Henryhouse, Haragan, and Bois d'Arc) exhibit variable gamma-ray readings in the moderate to high range (70–100 average CPS). The variability in gamma-ray values is most likely due to the varying degrees of argillaceous limestones found throughout this section. However, there appears to be a sustained trend of decreasing gamma-ray values, starting at the basal Henryhouse through the Bois d'Arc Formation, which probably corresponds with a gradual shallowing sea at the time of deposition (Fig. 8) (see also gamma-ray profiles of Hunton Group exposures at Stop 3 [Fig. 22], Stop 4 [Fig. 27], and Stop 5 [Fig. 33], Part II, this guidebook). Given the apparent graphical differences in gamma-ray signatures between each of these major units, it may be possible to correlate them with a great degree of accuracy in the subsurface using only wireline logs.

One way to assess the validity of using only gamma-ray data from well logs for such subsurface correlations would be through statistical analysis. A one-way, model I ANOVA was performed on the 734 calculated gamma-ray averages for the nine sections. The data were divided into seven major lithostratigraphic intervals of the Hunton Group: (1) the Chimneyhill Subgroup minus the Prices Falls Member; (2) the graptolitic shales and argillaceous limestones at the base of the Henryhouse Formation; (3) the remaining beds of the Henryhouse (including units above and below the interval with graptolitic shales); (4) the Haragan Formation; (5) the Cravatt and (6) Fittstown Members of the Bois d'Arc

Formation; and (7) the Frisco Formation. The different formations of the Chimneyhill Subgroup were not segregated in the test because their gamma-ray values were not noticeably different from one another; statistically, they appear as a single unit. The two members of the Bois d'Arc Formation were treated as individual units primarily because of their different lithologies (a cherty mudstone versus a clean grainstone). For purposes of correlation, the Bois d'Arc was also segregated to test whether gamma-ray values for the Cravatt Member are statistically different from those for the Haragan or Henryhouse Formation, the two units most likely to be in direct contact with the Bois d'Arc. In order to conform to the assumptions of statistical testing (i.e., that the data must be independent, must be normally distributed, and must show homogeneity of variance), the data were transformed into their natural logarithms (ln-transformed) prior to testing. The results of the tests are given in Table 3 and plotted in Figure 9. Statistical terms are defined in Table 3.

The ANOVA results indicate that statistically significant differences are evident between the gamma-ray values for some, or all, of the major lithostratigraphic units (Table 3A). A GT2 method for making multiple unplanned group comparisons was performed to identify pairs of lithostratigraphic units with statistically significant differences between their gamma-ray values (Table 3B). The GT2 test compares the mean difference between gamma-ray values for a pair of lithostratigraphic units to a minimum significant difference (MSD) between the values. The mean difference is statistically significant if it exceeds the MSD for the pair. The GT2 test results (Table 3B) indicate that, with few exceptions, the gamma-ray values for the major lithostratigraphic units in the Hunton Group are unique; the mean differences between gamma-ray values for most pairs of lithostratigraphic units are statistically significant. The only exceptions are for the Henryhouse–Haragan and the Chimneyhill–Fittstown comparisons.

TABLE 3. – Results of Model I ANOVA of 734 Gamma-Ray Averages Collected from Major Lithostratigraphic Units of Hunton Group[a]

A. ANOVA results of ln-transformed gamma-ray values. The large F-value is highly significant and indicates that means of gamma-ray values from some of the major units statistically differ from each other.

	DF	SS	MS	F-value	*p*
Major units	6	38.423	6.404	248.404***	**<0.0001**
Residual	727	18.742	0.026		

B. Results of GT2 method for multiple unplanned comparisons of the ln-mean gamma-ray values, given a 1% experimentwise error rate. Values in the upper diagonal represent the minimum significant difference (MSD) that must be exceeded between any two means being tested. Values in the lower diagonal are ln-mean differences between the groups being compared. The test indicates that all gamma-ray signatures, except for the Henryhouse-Haragan (Hh-Hr) and Chimneyhill-Fittstown (Ch-Ft) pairs are statistically different (values with asterisks). The two bolded values represent the two mean comparisons that did not show a statistical difference.

	Hh	Hr	Fr	Ch	Gr	Ft	Cr
Hh	—	0.058	0.108	0.067	0.122	0.098	0.066
Hr	**0.049**	—	0.109	0.068	0.123	0.098	0.067
Fr	0.781*	0.731*	—	0.114	0.153	0.134	0.113
Ch	0.392*	0.342*	0.389*	—	0.127	0.104	0.074
Gr	0.375*	0.425*	1.156*	0.767*	—	0.146	0.126
Ft	0.402*	0.352*	0.379*	**0.009**	0.777*	—	0.103
Cr	0.297*	0.247*	0.484*	0.095*	0.672*	0.105*	—

C. Table of back-transformed gamma-ray values for each of the major units tested. Provided are the back-transformed values of the lower 99% confidence limit (l 99%), the mean (μ), the upper 99% confidence limit (u 99%), and the number of observations from each unit (n). These values are also illustrated in Figure 9.

	l 99%	μ	u 99%	n
Henryhouse Formation	83.01	85.37	87.79	206
Haragan Formation	78.88	81.29	83.76	188
Frisco Formation	36.45	39.13	42.01	33
Chimneyhill Subgroup	55.53	57.68	59.92	117
Graptolitic shales	114.66	124.34	134.83	25
Fittstown Member	53.68	57.17	60.88	42
Cravatt Member	61.19	63.50	65.89	123

[a]Henryhouse Formation (Hh) minus basal graptolitic shale interval; Haragan Formation (Hr); Frisco Formation (Fr); Chimneyhill Subgroup (Ch) minus Prices Falls Member; basal graptolitic shale (Gr) interval of Henryhouse; and Fittstown (Ft) and Cravatt (Cr) members of Bois d'Arc Formation. The model I ANOVA was performed using StatView v. 4.0 statistical package (Haycock and others, 1992). Procedures for using the GT2 method can be found in Sokal and Rohlf (1981, p. 248).

Definitions of statistical terms: **ANOVA**—acronym for "analysis of variance"; **GT2 method**—a statistical method for unplanned comparisons of sample means between groups having vastly different sample sizes; **F-value**—a ratio derived when dividing the mean-square (MS) of the major groups by the MS of the residual; **DF**—degree of freedom, a value important in determining what the standard F-value should be; **SS**—sum of squares, the value calculated by taking the sum of all squared, mean deviates of each observation; **MS**—mean-square, the value calculated by dividing the SS by the DF from each variance source; ***p***—the probability statistic, or the probability that the differences in magnitude between the standard and calculated F-values are a natural, random occurrence (not significant); **residual**—measures the amount of variance from individual observations within each major group (rather that amount of variance from comparison between the different groups); **ln-mean**—the mean (average) of the natural log-transformed observations; **experimentwise**—the acceptable amount of type I or type II error; **back-transformed**—because of the initial log transformation of the observations to achieve a normal distribution, the mean and 99% confident limits are transformed back into their original unit values (counts per second).

Figure 9 plots the values listed in Table 3C, which are back-transformed gamma-ray values for each of the seven lithostratigraphic units being tested. Note that in Figure 9 the 99% confidence bars for the Henryhouse–Haragan and Chimneyhill–Fittstown pairs overlap. The differences in the gamma-ray values for the units in these pairs are not statistically significant; thus, their gamma-ray values could not be used to distinguish them on a well log, which confirms the GT2 comparison results.

These tests indicate that most of these Hunton lithostratigraphic units can be differentiated from each other solely on the basis of their gamma-ray values, and, indeed, well logs have been used to correlate Hunton units in the subsurface (Rottmann, 2000b,c). Problems will arise if attempts are made to differentiate Henryhouse and Haragan strata, or if Fittstown beds rest directly on Chimneyhill strata. In these cases, the subsurface stratigrapher will not be able to satisfactorily identify the different units. All other Hunton lithostratigraphic couplings, however, should be resolvable through the use of gamma-ray values.

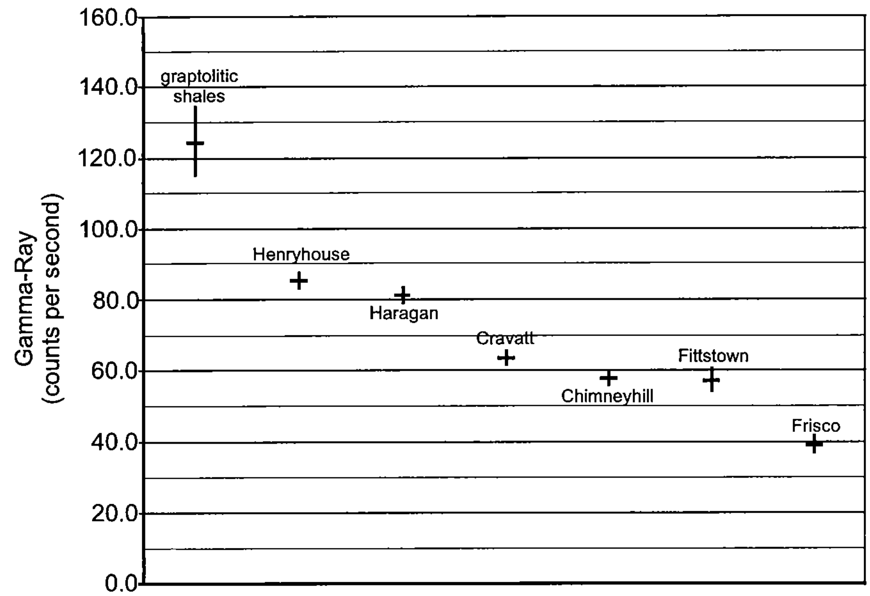


Figure 9. Plot of back-transformed average gamma-ray values (from Table 3C) for the major stratigraphic units tested. Horizontal lines mark the mean gamma-ray values; upper 99% confidence limits are at the tops of the vertical lines; lower 99% confidence limits are at the bottoms of the vertical lines. The differences in mean gamma-ray values for units in pairs with overlapping confidence limits (Henryhouse and Haragan Formations, and Chimneyhill Subgroup units and Fittstown Member of Bois d'Arc Formation) are not statistically significant.

Besides differentiating various Hunton units, the gamma-ray signatures could also be useful in identifying which lithostratigraphic intervals are the major reservoirs in various oil and gas fields. For example, it would be beneficial to know whether the Chimneyhill Subgroup, the upper Bois d'Arc, or the Frisco Formation is the main producer in any given field. Such information could increase the efficiency of exploration programs and facilitate better evaluation of potential exploration targets beyond the primary field. It could also save the expense of drilling targets in areas where the producing interval is missing.

GENERAL STRATIGRAPHY OF HUNTON GROUP

Chimneyhill Subgroup

The Chimneyhill Formation was first named by Reeds (1911) from Hunton exposures found along Chimneyhill Creek (currently known as South Fork of Jack Fork Creek), Pontotoc County, Oklahoma (Amsden, 1957, 1960). After Reeds' work, Amsden (1967) elevated the Chimneyhill Formation to subgroup rank, while elevating Reeds' (1911) members to formation rank. In ascending order, the main lithostratigraphic divisions of the Chimneyhill Subgroup include (1) the Keel Formation, with the basal Ideal Quarry Member; (2) the Cochrane Formation; and (3) the Clarita Formation, with the basal Prices Falls Member and the upper Fitzhugh Member (Figs. 2, 8).

The Chimneyhill Subgroup represents a resistant sequence that contrasts sharply with the softer, recessive-weathering units of the Sylvan shales below and the Henryhouse–Haragan argillaceous mudstones above. This contrast is also obvious in gamma-ray profiles from wireline logs, as was noted in the section above, and in Figure 8. The contrast between these three lithotopes is so pronounced in the field that the Chimneyhill Subgroup represents one of the best exposed and most easily mappable rock sequences found in the Arbuckle Mountains.

Keel Formation

Nomenclature History

The Keel Member was described from uppermost Ordovician carbonate rocks exposed in the eastern highwall of the Lawrence Quarry, operated at that time by the Ideal Cement Co. in Pontotoc County, Oklahoma (Amsden, 1960). The Keel was subsequently elevated from member to formation rank when the Chimneyhill Formation was elevated to subgroup status by Amsden (1967). Where it is fully exposed, the Keel Formation is subdivisible into the basal Ideal Quarry Member and an upper unnamed oolite member.

Lithofacies, Ideal Quarry Member

This member is a brown-weathering, unsorted pelmatozoan (or skeletal) packstone to grainstone (depending on the amount of lime mud present). Although the limestone contains a diverse, normal-marine faunal assemblage, crinoid plates, ossicles, and short stems make up the bulk of the enclosed fossils. Generally, fossil material accounts for >50% of the limestone and is usually set within a coarse sparite matrix. The lime-mud content varies from zero to 9% of total rock volume of the unit (Amsden, 1960, 1967; Amsden and Barrick, 1986). Chert, ooids, and algal-coated grains are also present in varying amounts. The Ideal Quarry ooids superficially resemble Keel-type ooids. On closer examination, however, the two types differ considerably in appearance, as Ideal Quarry ooids grow from coating of algae around a fossil nucleus (Amsden, 1960). As such, these ooids tend to have irregular, oblong, or subspherical shapes that usually have wrinkled, exterior surfaces.

Without close examination of the ooids, however, the most obvious difference between the Ideal Quarry Member and the overlying Keel-type oolite facies appears to be the brown-weathering color of the former. Typical Keel oolite facies rarely, if ever, weathers a dark color. This feature is particularly noticeable at the Price Falls section (Stop 7, Part II, this guidebook).

Lithofacies, Unnamed Oolite Member

This lithofacies is typical of the Keel Formation and consists of a light gray oolitic grainstone to an oolitic skeletal packstone. Ooids represent 30–60% of rock volume and exhibit well-developed concentric and radial internal structures indicative of those formed in littoral marine zones (Amsden, 1960; Amsden and Barrick, 1986). Besides ooids, pelmatozoan fragments also occur. All grains are usually set within a medium to coarse sparite matrix. Lime mud, although present in some intervals, makes up <3% total rock volume of this facies (Amsden and Barrick, 1986).

The oolite facies is variably developed at the base and at the top of an unnamed laminated Keel mudstone. This second lithofacies consists of a yellow-brown-weathering, laminated skeletal wackestone to mudstone, which has developed locally between these upper and lower oolitic facies. Within this laminated facies, fossil components are represented by a sparse, but locally diverse, restricted marine assemblage that can constitute 10–50% of total rock volume (Amsden and Barrick, 1986). Lime mud makes up the remaining sedimentological contribution to the laminated facies. This laminated-mudstone facies is not to be confused with the *Brevilamnulella*–coral beds that occur at the type locality. The *Brevilamnulella*–coral beds are interpreted as similar in origin to the Ideal Quarry Member (Amsden and Barrick, 1986) (Fig. 7) (see also Holnam Quarry measured section [Stop 2] and corresponding graphic columnar section [Fig. 18], Part II, this guidebook).

From previous reports (Amsden, 1960; Amsden and Barrick, 1986), the laminated-limestone facies appears to have developed only in some areas of southeastern Pontotoc County and in northeastern Johnston County. Some sections farther west of these areas do exhibit partial development of a laminated facies (see also U.S. Highway 77 measured section [Stop 9] and corresponding graphic columnar section, unit 3 [Fig. 49], Part II, this guidebook) and suggest that the laminated facies is not as geographically restricted to the area of the Lawrence uplift as was once thought.

Distribution and Thickness

In the outcrop belt around the Arbuckle Mountains, the Keel Formation reaches its maximum thickness (10–15 ft) in a northwest trend extending from the Old Hunton Township near Clarita to the region of the Lawrence uplift (Amsden, 1960) (Pl. 1, in envelope). In most areas of the Arbuckle Mountains, the thickness of the Keel Formation is only 1–3 ft.

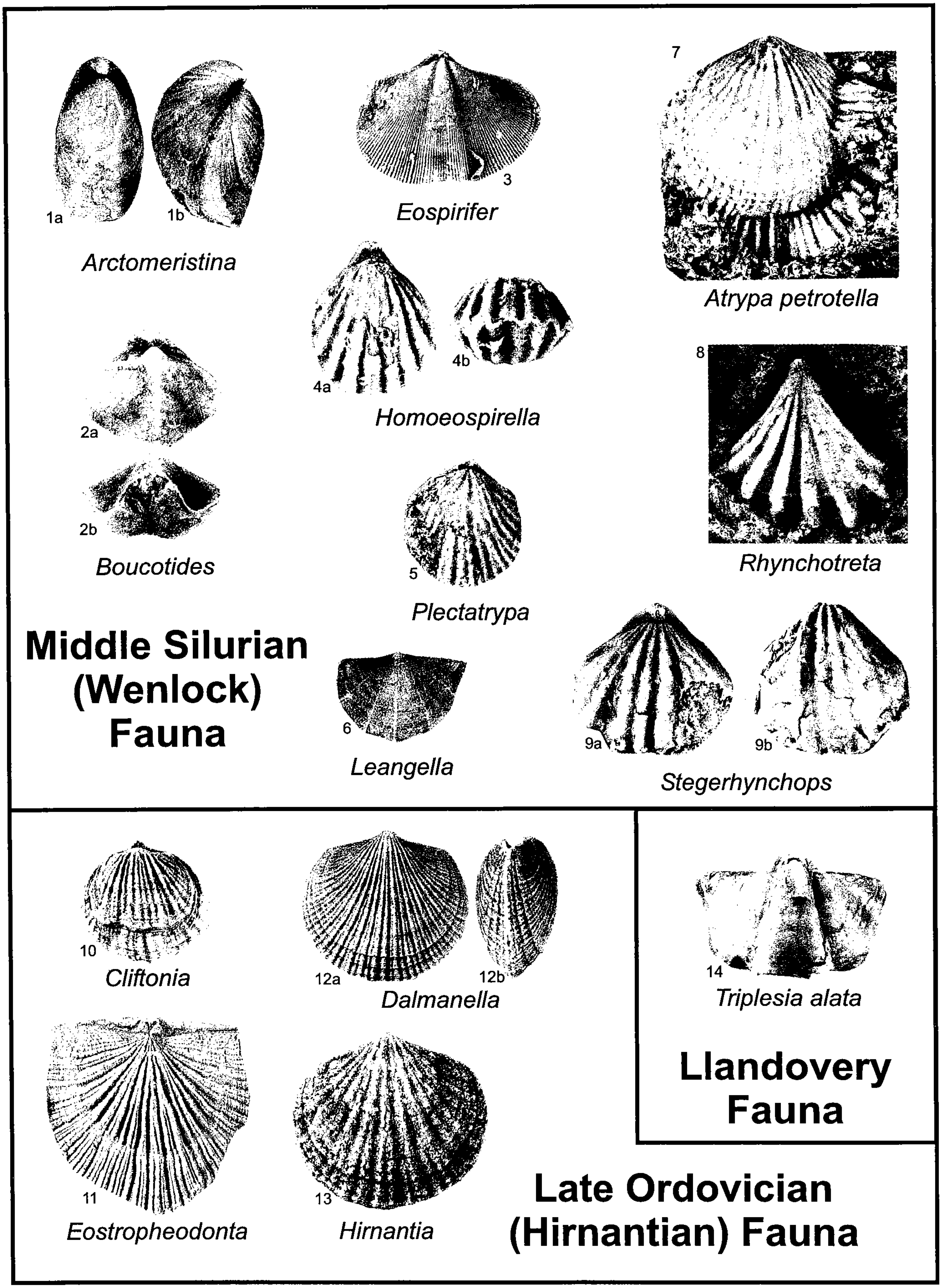
The Arbuckle region was greatly affected by a period of pre-Cochrane nondeposition and erosion. Consequently, the Keel Formation is missing in the central Arbuckle outcrop belt along a northwest line extending from Ravia through Davis, Oklahoma (Fig. 1; Pl. 1).

Stratigraphy and Age

In Oklahoma the Keel Formation is correlative with the Pettit Formation in the southern part of the Ozark uplift (Amsden and Rowland, 1965; Amsden and Barrick, 1986). This assessment, however, is based solely on lithologic and stratigraphic similarities between the two units, because the Pettit Formation lacks fossils for biostratigraphic correlation (Amsden, 1980; Amsden and Barrick, 1986).

The Keel Formation is unconformably bounded, at least in the area of the outcrop belt; however, the Keel–Sylvan contact may be conformable in the deeper parts of the Anadarko basin of Oklahoma and the Texas Panhandle. In this area the Sylvan grades upward into an unbroken series of calcareous and dolomitic shales and argillaceous limestones across the contact with the Hunton (Amsden, 1980). Also, previous reports on the Sylvan–Hunton transition (Amsden, 1957, 1960, 1975, 1980; Amsden and Barrick, 1986) stated that there is no clear-cut evidence of an unconformity at the base of the Keel, even in the outcrop belt. An unconformity has always been assumed, however, based on the abrupt change in lithology across the contact (Amsden, 1960). The section at Stop 9 (Part II, Fig. 49, this guidebook) appears to show a channeled lower contact of the basal Keel oolite into the underlying Sylvan Shale, suggesting that some post-Sylvan–pre-Hunton erosion has taken place.

The age assessment of most of the Keel Formation is Late Ordovician (Ashgill, Hirnantian) on the basis of diagnostic brachiopod assemblages (Amsden and Barrick, 1986; Barrick and others, 1990) (Figs. 2, 10). Conodonts are not diagnostic for any particular Upper Ordovician zone, but they do support the Hirnantian as-


1a
1b
Arctomeristina
3
Eospirifer
7
Atrypa petrotella
2a
2b
Boucotides
4a
4b
Homoeospirella
8
Rhynchotreta
5
Plectatrypa
Middle Silurian
(Wenlock)
Fauna
6
Leangella
9a
9b
Stegerhynchops
10
Cliftonia
12a
12b
Dalmanella
14
Triplesia alata
Llandovery
Fauna
11
Eostropheodonta
13
Hirnantia
Late Ordovician
(Hirnantian) Fauna

sessment. Samples collected from the upper oolite facies of the Keel in Pontotoc County, however, do contain diagnostic elements of the *Distomodus* sp. conodont assemblage (Fig. 2), and indicate that, locally, the upper 1 ft of the Keel is Early Silurian (Llandovery) in age (Amsden and Barrick, 1986).

Facies Interpretation

The Keel Formation represents a shoaling-upward carbonate package that was formed just below, to within, the littoral zone of the Late Ordovician sea. Shoaling conditions are represented by well-developed oolite facies, which formed under constant wave or tidal action in very warm, shallow marine waters (Wilson, 1975; Inden and Moore, 1983). The lack of appreciable amounts of lime mud suggests constant washing of the oolite sediment by currents, which would then carry the fine-grained fraction farther offshore. The lack of cross-bedding, and an oolitic fabric that is underpacked, however, suggest that this facies developed in the lower part of the littoral zone and not as an upper beach face or tidal bar that would occasionally be subaerially exposed. It may be that, given the low-lying topography along the Ordovician–Silurian benthos, wave or tidal energy was enough to form ooids but not enough to create extensive beach-face- or barrier-island-type carbonate-sand deposits (Irwin, 1965; Wilson, 1975). Given their higher lime-mud content, the Ideal Quarry Member and the *Brevilamnulella*–coral beds suggest a slightly deeper water and lower energy environment of deposition than that of the oolite facies.

The Ideal Quarry Member, being an unsorted bioclastic packstone, probably formed at, or just below, normal wave base. Some ooids and algal-coated grains, which formed higher in shoal-water facies zone 2, likely were transported into the subtidal parts of the shelf, where most of the Ideal Quarry facies formed. A similar situation is occurring in the Persian Gulf, as low-lying topography causes intergradation of distinct carbonate facies zones along the shallow shelf (Wilson, 1975) (Figs. 5, 6).

The preponderance of mud in the laminated-limestone facies suggests an origin even farther offshore than that of either the Keel oolite or the Ideal Quarry Member.

Taken as a whole, the Sylvan–Ideal Quarry–Keel oolite sequence represents the typical carbonate–evaporite (fill-in) cycle of Wilson (1975, p. 50). This cycle consists of a lower terrigenous phase (Sylvan Shale), a middle normal-marine phase (Ideal Quarry Member and/or laminated-limestone facies), an upper shoaling phase (traditional Keel oolite), and a final evaporite or exposure phase (represented by the upper Keel unconformity) (Fig. 7). The shelf-carbonate cycle records a regressive sequence following an initial, rapid transgression that is rarely preserved (Wilson, 1975). Given the repetition of various facies up-section, a deepening of the shelf from shoaling conditions probably occurred more than once during Keel deposition (Fig. 7). The initial flooding of the southern Midcontinent shelf was probably triggered by the end of Late Ashgill (Rawtheyan) continental glaciation (Amsden and Barrick, 1986; Brenchley, 1990). Following a late Rawtheyan–early Hirnantian low-level sea stand, which coincided with maximum growth of the Gondwana ice sheet, flooding of the continental shelves occurred toward the end of the Hirnantian (Brenchley, 1990). This rapid flooding was followed by steady progradation and fill-in of the inundated area by normal-marine and shoal-type carbonates of the Keel and other Late Ordovician oolitic limestones of the Midcontinent (Amsden and Barrick, 1986).

Cochrane Formation

Nomenclature History

The Cochrane was named and described by Maxwell (1936) from rocks exposed along Chimneyhill Creek (now Jack Fork Creek) in Pontotoc County, Oklahoma (Amsden, 1960). As with the Keel Formation, the Cochrane was elevated to formation status by Amsden (1967).

Lithofacies

The Cochrane Formation represents one of the more variable units of the Hunton Group. In most sections, the Cochrane is a poorly sorted to well-sorted glauconitic grainstone. This grades laterally and vertically into a skeletal packstone or wackestone in some sections. Chert is also a component of the formation and occurs as bedding laminae or nodules. Some nodular chert exhibits a distinct brecciated texture (Stop 9, Part II, this guidebook), which might be an original depositional texture or might indicate that the Cochrane was subaerially exposed at some point in its history (Amsden, 1960). One of the unique lithologic characteristics of the Cochrane is its irregular bedding, which appears to distinguish it from the other members of the Hunton

Figure 10 *(facing page)*. 1–9, diagnostic middle Silurian (Wenlock) brachiopod genera collected from the Clarita and Quarry Mountain Formations; 10–13, diagnostic Hirnantian brachiopod genera (Late Ordovician) found in the Keel Formation; 14, diagnostic late Llandovery brachiopod genus found in the Cochrane and Blackgum Formations. *1, Arctomeristina, a,b,* brachial and lateral views, ×1; *2, Boucotides, a,b,* brachial and anterior views, ×2; *3, Eospirifer,* brachial valve, ×2; *4, Homoeospirella, a,b,* brachial and anterior views, ×4; *5, Plectatrypa,* brachial valve, ×2; *6, Leangella,* pedicle valve, ×5; *7, Atrypa petrotella,* pedicle valve, ×3; *8, Rhynchotreta,* brachial valve, ×4; *9, Stegerhynchops, a,b,* brachial and pedicle views, ×3; *10, Cliftonia,* brachial valve, ×2; *11, Eostropheodonta,* brachial valve, ×2; *12, Dalmanella, a,b,* pedicle and lateral views, ×2; *13, Hirnantia,* brachial valve, ×6; *14, Triplesia alata,* brachial valve, ×1. Figures 10.1–9 reproduced from Amsden (1978); Figures 10.10, 12–13 reproduced from Amsden (1974); Figure 10.11 reproduced from Moore (1965); Figure 10.14 reproduced from Amsden and Barrick (1988).

Group (Amsden, 1960). Glauconite is also a common feature of the Cochrane Formation, although it is not exclusive to the Cochrane. From previous reports (Amsden, 1957, 1960), glauconite is commonly observed in the grainstone facies of the Cochrane but is rare in Cochrane facies with appreciable amounts of lime mud. The significance of this is explained below.

The Cochrane contains a rather diverse, normal-marine assemblage that is difficult to liberate from the surrounding matrix. Where collection is possible, the enclosed fauna consists of several species each of brachiopods, bryozoans, trilobites, and gastropods (Maxwell, 1936; Amsden, 1960; Amsden and Barrick, 1988).

Significance of Glauconite

Glauconite is conspicuous in the Cochrane Formation, although it makes up only 0.5–2.0% of total rock volume (Amsden, 1960). It usually occurs as small, distinct grains scattered throughout the unit, but it can also represent irregularly shaped filling of hollow fossils (ostracodes, gastropods) or replacement of sponge spicules (Amsden, 1960). At one locality (Price Falls section, Stop 7, Part II, this guidebook), glauconite is so well concentrated in the basal half of the Cochrane Formation that it forms distinct bedding laminae.

Glauconite is a complex clay mineral composed of a mixture of potassium and iron cations set in a mica-type structural lattice. In modern marine environments, it forms by the alteration of organic matter, mica, or other clay minerals at depths of 30–2,000 m (Blatt and others, 1980, p. 602). Glauconite commonly occurs associated with phosphate, where many pelletal and nodular occurrences of phosphate also have high concentrations of glauconite (Leeder, 1982, p. 32). As with occurrences of phosphate, the presence of glauconite in modern sediment and in ancient marine rocks invariably implies low rates of sedimentation (Wilson, 1975; Leeder, 1982). Low rates usually translate to longer residence times of sedimentary particles on the sea floor, and subsequently a greater degree of current washing of the finer grained fraction out of those sediments. Consequently, one should expect a strong association between glauconite and carbonate rocks with predominantly grain-supported textures. This is the case, as Hunton units containing conspicuous amounts of glauconite (i.e., the Cochrane Formation and the Fittstown Member of the Bois d'Arc Formation) are usually grainstones.

The Prices Falls Member of the Clarita Formation also contains appreciable amounts of glauconite. Unlike the grainstone facies of the Cochrane, however, the Prices Falls is composed of a mixture of fine-grained lime mud and/or terrigenous clastics. Although, texturally, the Prices Falls mudstones are distinct from the Cochrane grainstones, the member most likely represents a condensed section formed under a period of deepening water and slow rates of sedimentation (see Clarita Formation—Facies Interpretation, below).

Distribution and Thickness

Throughout most of the Arbuckle Mountains, the Cochrane Formation attains a thickness of 3–8 ft. Thicker sections occur south of Clarita, Oklahoma (Pl. 1, in envelope, section J1), and in exposures north of Woodford, Oklahoma (Pl. 1, section Ca1). At both localities the Cochrane Formation attains a maximum thickness of 57 and 28 ft, respectively.

The Cochrane is missing in only a few areas in the Arbuckle Mountains. The most extensive area is a northeast-trending belt northwest of Ravia, Oklahoma (Pl. 1, section J15), where all of the Hunton Group has been removed by extensive pre-Woodford erosion. The Cochrane is assumed to be missing in a small area north of Ravia (Pl. 1, section J9) and also in the area just south of Davis, Oklahoma (Amsden, 1960).

Stratigraphy and Age

Amsden (1971) collected the brachiopod *Triplesia alata* in association with *Stricklandia protriplesiana* from the Cochrane Formation, and also from the upper 10 ft of the Blackgum Formation in the Ozark uplift (Amsden and Rowland, 1965) (Fig. 10). This assigns a late Llandovery age to both formations (Fig. 2).

Further age refinement can be done by using enclosed conodont assemblages. Elements of the *Distomodus staurognathoides* zone are found at many localities, including *D. staurognathoides* proper (Barrick and others, 1990). The range zone conodont *Pleurospathodus celloni* was also collected from the upper few feet of the Cochrane and also from the Tenkiller Formation of the Ozark uplift (Amsden and Barrick, 1988; Barrick and others, 1990). The conodonts support a late Llandovery age for the Cochrane, but not latest Llandovery (Harland and others, 1990) (Fig. 2).

By virtue of similar faunas, the base of the Cochrane Formation in the Arbuckle Mountains is correlative with the Blackgum Formation, whereas the upper part of the Cochrane is correlative with the Tenkiller Formation.

Facies Interpretation

The variable lithologies found in the Cochrane suggest a more complex depositional history than for other units of the Hunton Group. Grainstone and packstone textures indicate that shoaling or near-shoaling conditions occurred at some time during Cochrane deposition (Fig. 6; Table 2). Wackestone and mudstone, along with the presence of chert, however, suggest a deeper water origin for these textures (Fig. 6; Table 2). The presence of normal-marine fossils indicates that much of the Cochrane was deposited under well-oxygenated waters.

As mentioned previously, the presence of glauconite indicates that there may have been substantial periods of repeated transgressions and regressions, creating many episodes of erosion and nondeposition across the Early Silurian sea floor. These diastems, coupled with brief intervals of erosion, probably added to the variable lithology and irregularly bedded character of the Cochrane Formation.

Clarita Formation

Nomenclature History

The Clarita Formation is named for the town of Clarita in Coal County, Oklahoma (Amsden, 1957). The type locality, however, is the same as for the Chimneyhill Subgroup—exposures along the South Fork of Jack Fork Creek, Pontotoc County, Oklahoma.

The formation consists of two members: the basal Prices Falls Member, named for Price Falls in Murray County, Oklahoma (Amsden, 1967), and the upper Fitzhugh Member, named for the town of Fitzhugh, Oklahoma, near the type section of the Clarita Formation in Pontotoc County (Amsden, 1960).

Lithofacies, Prices Falls Member

The Prices Falls Member is a distinct, 1–2-ft-thick interval of well-laminated, dark gray or brown clayshale that grades into a tan- or brown-weathering, highly argillaceous carbonate mudstone. Typically, thicker sections of the Prices Falls are composed of terrigenous clastic material, whereas thinner sections are usually argillaceous limestone. Glauconite is present sporadically in either the clayshale or carbonate lithology.

The member is poorly exposed at most stratigraphic sections in the Arbuckle Mountains, where it is usually represented by a recessed, covered interval sandwiched between the more resistant Cochrane Formation and overlying Fitzhugh Member.

Lithofacies, Fitzhugh Member

In the Arbuckle Mountains proper, the Fitzhugh is everywhere a light gray, skeletal to whole-fossil mudstone to a wackestone (locally). Amsden and others (1980) described three facies that commonly occur in the Fitzhugh. The more usual of these facies are mud dominated and include the arthropod micrite facies and the ostracode silty-marlstone facies. A third facies described by Amsden and others (1980) is a crinoid sparite facies, which is present only in the northeastern part of the Hunton Group outcrop belt, trending along a line between the Lawrence uplift and the Old Hunton Township. According to descriptions by Amsden and others (1980), this sparite facies is classified as a grainstone under Dunham's (1962) terminology (see Table 1).

Most of the mudstone and wackestone textures described in field-trip stops fall into the arthropod micrite facies of Amsden and others (1980). More argillaceous intervals described from the Fitzhugh, such as at the top of the member at the U.S. Highway 77 section (Stop 9, unit 10, Part II, this guidebook) and the middle argillaceous zone at the Goddard Youth Camp section (Stop 3, unit 6, Part II, this guidebook), would fall under the ostracode silty-marlstone facies of Amsden and others (1980, p. 6, text-fig. 4). These argillaceous-mudstone facies probably represent deposition in slightly deeper water than the typical Fitzhugh mudstones.

Overall, the Fitzhugh Member is a uniformly thin, wavy-bedded limestone that appears massive on fresh surfaces. At most localities, micrite composes 39–75% of total rock volume. Fossils are sparse, but where present they consist mostly of crinoid plates and short columns and other related pelmatozoan debris. In the more argillaceous intervals, very few macrofossils have been found (Amsden and others, 1980, p. 9, text-fig. 7).

Distribution and Thickness

The Clarita Formation is present in most outcrops of the Arbuckle Mountains except for an east–west-trending region between the towns of Ravia and Mill Creek (in the west) to Wapanucka and Bromide (in the east) (Fig. 1; Pl. 1, in envelope).

The Clarita reaches its greatest thickness in a northwest-trending outcrop belt, starting at the Old Hunton Township and ending at the Lawrence uplift, where it attains a thickness of 40 to 45 ft, respectively. Across much of the southern outcrop belt of the Arbuckles, the thickness of the formation remains fairly consistent, varying only from 12 to 15 ft at most localities (Amsden, 1960, p. 63, fig. 19).

Stratigraphy and Age

The Clarita Formation is correlative with the Quarry Mountain Formation in the Ozark uplift. The Quarry Mountain consists of the basal Barber Member and the upper Marble City Member (Fig. 2). The Marble City Member is a crinoid–bryozoan grainstone, which closely resembles the crinoid sparite facies of the Fitzhugh in the northern part of the Arbuckle Mountains (Amsden, 1978; Amsden and others, 1980). The Barber Member of the Quarry Mountain Formation is a dolomite that offers little lithostratigraphic comparison to the Fitzhugh or Prices Falls Member of the Arbuckles. Conversely, the micritic facies that dominates the Fitzhugh Member in the southern outcrop belt of the Arbuckles has not been observed in Silurian outcrops in the Ozark uplift (Amsden, 1978; Amsden and others, 1980).

The preponderance of micrite and argillaceous micrite in the Upper Silurian sections in the Arbuckles is probably due to their proximity to the Ouachita clastic province along the outer parts of the Late Silurian shelf (Fig. 3). Here, the shelf was deeper and susceptible to a steady supply of fine-grained terrigenous clastics from the Ouachita province in comparison with the shallower water, high-energy parts of the shelf near the Ozarks (Amsden and others, 1980).

The Prices Falls Member contains no macrofossils. Conodonts collected from the member include diagnostic elements of the *Pterospathodus amorphognathoides* biozone, which is latest Llandovery to possibly earliest Wenlock (Amsden and Barrick, 1988; Barrick and others, 1990). This zone also incorporates the lower beds of the overlying Fitzhugh Member (Fig. 2).

The Prices Falls–Cochrane contact is thought to be erosional (Amsden, 1960). This assessment is based on a number of observations: (1) at some localities the contact cuts across bedding of the Cochrane Formation at an oblique angle; (2) the very thin nature of the Cochrane Formation at some localities (especially at Stop 7, Price Falls section, Part II, this guidebook) indicates considerable pre-Clarita erosion; and (3) the contrasting nature of the lithologies between the argillaceous Prices Falls Member and the grain-supported textures of the Cochrane Formation, which suggests an abrupt change in depositional history. There is no break, however, in the conodont biozones between the Prices Falls and Cochrane, indicating that the duration of post-Cochrane–pre-Clarita erosion was less than the duration of a conodont biozone. This is in stark contrast to the chronostratigraphic gap represented by the Henryhouse–Haragan contact, which encompasses considerably more time but shows little evidence of erosion (see discussion under Henryhouse Formation, below).

Brachiopods collected from the crinoid sparite facies of the Fitzhugh, and from the upper beds of the Quarry Mountain Formation, are all Wenlock in age (Amsden, 1978; Amsden and others, 1980) (Fig. 10).

Diagnostic elements of the *Ozarkodina sagitta rhenana* biozone were collected near the base of the Fitzhugh, just above the collections made from the *Pterospathodus amorphognathoides* biozone. Elements of the *O. bohemica bohemica* biozone were also collected from the upper part of the Fitzhugh (Barrick and others, 1990) (Fig. 2). This would place the top of the Clarita precisely at the Wenlock–Ludlow boundary; however, it may be that the uppermost beds of the Fitzhugh contain conodont elements of earliest Ludlow age (Amsden and Barrick, 1988).

No conodonts have been reported from the Quarry Mountain Formation, but owing to similar brachiopod faunas, the Quarry Mountain probably represents the same time span (latest Llandovery–earliest Ludlow) as the Clarita Formation.

Facies Interpretation

The whole Clarita depositional package represents a regressive fill-in cycle of Wilson (1975) that is similar to the Sylvan–Keel carbonate evaporite cycle (see discussion under Keel Formation—Facies Interpretation, above) (Fig. 7). For the Clarita, the clastic phase is represented by the lithofacies of the Prices Falls Member, whereas the shoaling phase is represented by the crinoid sparite facies common throughout the northern Arbuckle outcrop belt.

The initial transgression across the Upper Silurian shelf was rapid and resulted in deposition of the Prices Falls Member in the outermost part of zone 5 of the carbonate-ramp model (Fig. 6; Table 2). The member represents a condensed section that marks the maximum point of transgression of the Wenlock seas prior to the start of basin fill-in. As such, the sedimentation rate during Prices Falls deposition was probably low. This interpretation is augmented by the thin but regionally extensive argillaceous-mudstone/clayshale facies of the Prices Falls, coupled with the presence of abundant glauconite (see discussion under Cochrane Formation—Lithofacies, above).

The Fitzhugh Member represents the regressive fill-in part of the cycle. The micritic facies probably formed along a stable subtidal shelf within zone 4 of the ramp model (Fig. 6; Table 2). Shoaling conditions continued into zones 2 and 3 during Fitzhugh deposition and are represented by the crinoid sparite facies in the northern Arbuckle outcrop belt. On the basis of the limited distribution of the crinoid sparite facies, these shoaling conditions either were never attained in the southern outcrop belt of the Arbuckles, or this particular facies was removed from the area by pre-Henryhouse erosion. The second possibility seems unlikely, however, given the consistency of conodont biozones and the lack of a distinct lithologic break in southern exposures of the Fitzhugh Member.

The nature of the Clarita carbonate cycle is more complex than a continual regressive fill-in following a single transgressive event. Exposures in the northern outcrop belt exhibit intercalation between the high-energy crinoid-sparite facies, and the low-energy micrite facies, which suggests that a number of smaller transgressive–regressive cycles occurred throughout Fitzhugh deposition (see Amsden and others, 1980, p. 6, text-fig. 4). In the southern outcrop area, the grainstone–mudstone couplet is replaced with a mudstone–argillaceous-mudstone couplet. The argillaceous mudstones, representing the ostracode-silty-marlstone facies of Amsden and others (1980), characterize deposition in the lower part of zone 4, or the upper part of zone 5, of the ramp model. The cleaner carbonate mudstones, representing Amsden and others' (1980) arthropod-micrite facies, were most likely deposited in the upper regions of zone 4 (Fig. 6; Table 2).

Henryhouse Formation

Nomenclature History

The Henryhouse was named and described by Reeds (1911) from rocks exposed along Henryhouse Creek, north of Woodford in Carter County, Oklahoma. Reeds mistakenly named these rocks the *Henryhouse shale*, which was later changed to the *Henryhouse Formation* by Maxwell (1936), as very little shale occurs in this part of the Silurian section (Amsden, 1957).

Amsden (1957) loosely treated the Henryhouse and the overlying Haragan Formation as a single lithologic unit termed the *Hunton marlstone*. Reasons for this initial grouping are readily apparent, because there is little lithologic distinction between the two units. Faunally, however, the Henryhouse Formation has a distinct Late Silurian character, whereas the Haragan Formation is Early Devonian (Amsden, 1957, 1960) (Fig. 2). In fact, the only reliable method that can differentiate the Henryhouse and Haragan stratigraphically is by examining their contrasting fossil fauna (Amsden, 1960). These lithologic similarities, coupled with faunal differences, are astonishing when one considers that an extensive erosional unconformity separates the two formations in the Arbuckle Mountains.

Lithofacies

With few exceptions, the Henryhouse Formation consists of a whole-fossil (to unfossiliferous) argillaceous mudstone to locally occurring wackestone. Some narrow intervals within the Henryhouse of the Lawrence uplift exhibit packstone textures, but these are rare (Amsden, 1960; Amsden and Barrick, 1988).

Insoluble residues, consisting of silt- to clay-size quartz detritus, vary from 10% to 35% of total rock volume of the Henryhouse, whereas average clay "contaminants" are near 20% of rock volume (Amsden, 1960, p. 68, fig. 20). For these reasons I hesitate to use the term *marlstone* in describing the limestones of the Henryhouse and Haragan Formations and prefer to use a modifier (i.e., argillaceous) in conjunction with a depositional texture. The term *marl* is most often used to describe carbonate-rich clay and silt in which the carbonate component accounts for less than 55–60% of rock volume (Wilson, 1975; Blatt and others, 1980). The Hunton "marlstones" do not fall under this definition.

The distribution of fine-grained clastics in the Henryhouse is variable stratigraphically and geographically. Generally, the base of the Henryhouse has the greatest concentration of terrigenous material, as individual beds of shale can be segregated from the argillaceous limestones in this part of the section. A good example of these interbedded shales and argillaceous limestones can be seen at Stop 7 (unit 9), at Stop 8 (unit 9), and at Stop 9 (unit 12) (see Part II, this guidebook). As one continues up-section, there is a gradual decrease in fine-grained clastics to the point at which the upper Henryhouse limestones begin to take on a "cleaner" carbonate texture. These clean carbonates are better indurated, exhibit a greater degree of conchoidal fracture, and produce a more distinct ring when struck in comparison with the more argillaceous limestones of the lower Henryhouse.

On a regional scale, the degree of clastic contaminants in the Henryhouse lessens to the northwest in the Anadarko basin. Here, the typical Henryhouse "marlstone" is gradually replaced by a clean bioclastic sparite termed the *Kirkidium* biofacies by Amsden (1975). The significance of these stratigraphic and geographic trends in decreasing clastics is explained under the Facies Interpretation section of the Henryhouse, below.

The Henryhouse contains a diverse and well-preserved fossil fauna. Fossil concentrations are variable across the outcrop belt, as the Henryhouse tends to be the most fossiliferous (and the lithostratigraphically thickest) in the area of the Lawrence uplift (Amsden, 1960). It is also in this area that the amount of terrigenous clastics decreases noticeably, and some Henryhouse beds exhibit a packstone depositional texture (Amsden, 1981). Rarely, however, do fossils exceed 25% of total rock volume in most exposures of the Henryhouse Formation. The fossil fauna is dominated by brachiopods, with a proportionate amount of crinoid debris. Other macrofossils include corals, bryozoans, gastropods, trilobites, and even graptolites (Amsden, 1960).

Distribution and Thickness

The extent of Henryhouse coverage mimics the underlying Clarita Formation. For example, the Henryhouse is absent in a northeast–southwest-trending zone that extends from Ravia and Clarita in the east to Mill Creek in the west (Amsden, 1960, p. 82, fig. 27) (Fig. 1; Pl. 1, in envelope).

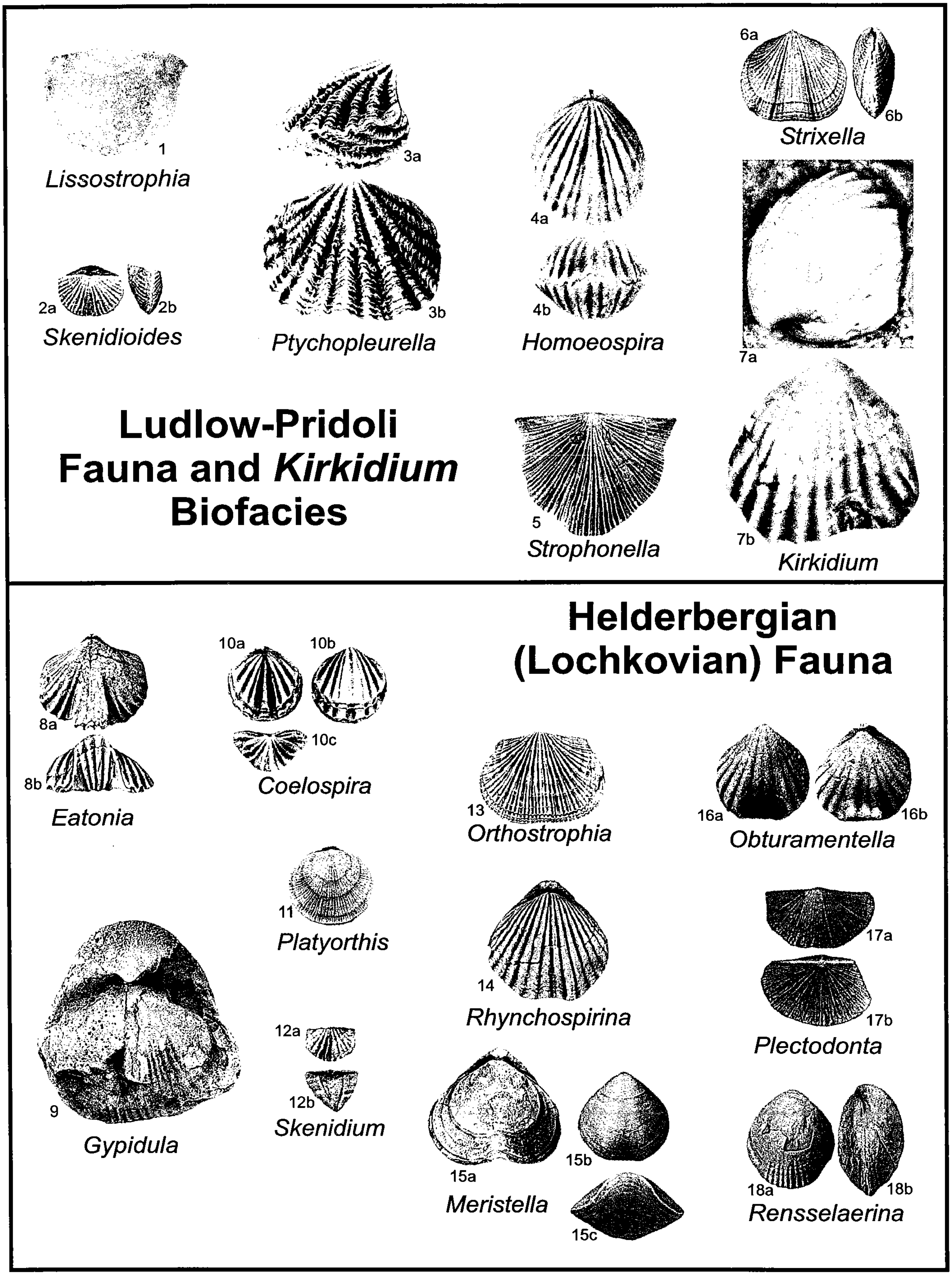
In outcrop, the Henryhouse reaches its thickest extent of 250 ft around the Lawrence uplift and in the westernmost part of the outcrop belt (Pl. 1, section Ca9). From these extremes, the formation gradually thins to zero toward the southeastern part of the Arbuckle Mountains.

Stratigraphy and Age

Brachiopods collected from the Henryhouse are of Late Silurian age, typed as a Ludlow–Pridoli brachiopod fauna (Amsden, 1960; Amsden and Barrick, 1988) (Fig. 2; Fig. 11). Other macrofossils, such as trilobites, crinoids, and corals, support a Ludlow–Pridoli assessment. Graptolites collected from the basal Henryhouse shales, however, suggest a late rather than an early Ludlow age for this interval (Jaeger, 1967; Amsden, 1967), which is contrary to findings based on conodonts (see below).

Henryhouse conodont assemblages show less abundance and diversity than previous Hunton units, which has caused some problems in typing local Silurian assemblages to global conodont biostratigraphic zones (Fig. 2). At a few localities the base of the formation contains conodonts belonging to the *Kockelella* fauna, which shows similarities to conodont assemblages collected in the upper part of the Clarita Formation (Barrick and others, 1990; Barrick and Klapper, 1992). It is unclear whether these elements of the *Kockelella* zone are correlative with the *Ancoradella ploeckensis* global biozone (Fig. 2); however, on the basis of their similarities to the Clarita assemblages, these lower Henryhouse beds are probably early Ludlow in age rather than late Ludlow on the basis of contained graptolites (Jaeger, 1967) (Fig. 2).

Many described sections of the Henryhouse do not contain this lower conodont assemblage. Instead, basal units directly above the Clarita Formation contain ele-


Ludlow-Pridoli Fauna and Kirkidium Biofacies
1 Lissostrophia
2a 2b Skenidioides
3a 3b Ptychopleurella
4a 4b Homoeospira
5 Strophonella
6a 6b Strixella
7a 7b Kirkidium
Helderbergian (Lochkovian) Fauna
8a 8b Eatonia
9 Gypidula
10a 10b 10c Coelospira
11 Platyorthis
12a 12b Skenidium
13 Orthostrophia
14 Rhynchospirina
15a 15b 15c Meristella
16a 16b Obturamentella
17a 17b Plectodonta
18a 18b Rensselaerina

ments of the *Ozarkodina snajdri* biozone (late Ludlow), and have no intervening *Kockelella* or *Polygnathoides siluricus* conodont elements. It appears that more complete Henryhouse sections are restricted to the southern outcrop belt, such as at Stop 9 (Part II, this guidebook), which shows *Kockelella* conodont fauna gradually replaced by *P. siluricus*, which is then replaced by *O. snajdri* zone elements (Barrick and others, 1990; Barrick and Klapper, 1992). In the more northerly areas, however, these gradual biozone replacements do not occur. Instead, successively younger Henryhouse beds sit directly on members of the Chimneyhill Subgroup. For example, in the area of the Lawrence uplift, samples collected from the basal 26 ft of the Henryhouse contain conodonts identified as *Ozarkodina remscheidensis eosteinhornensis* (Barrick and Klapper, 1992). Although *O. r. eosteinhornensis* is a long-ranging subspecies that extends down into the upper Ludlow (*O. crispa* biozone), its presence in the Henryhouse probably indicates an uppermost Silurian (Pridoli) age for these beds (Barrick and Klapper, 1992) (Fig. 2).

What can be said about the lower Henryhouse contact is that it is time-transgressive from southwest to northeast, as basal beds tend to be younger toward the Lawrence uplift. Whether this time transgression is a real artifact of deposition, or only reflects extensive periods of early–middle Ludlow erosion and nondeposition, is uncertain. There is, however, no lithologic evidence to suggest that erosion occurred during deposition of the basal Henryhouse.

The Henryhouse has no time-equivalent units in the Ozark area; however, northwestward into the Anadarko basin, the typical argillaceous mudstones of the Arbuckle Henryhouse grade into skeletal grainstones of the *Kirkidium* beds (Amsden, 1975, 1981) (Fig. 11). Conodonts are rare from the *Kirkidium* beds, owing to extensive dolomitization throughout the Anadarko basin. Some nondiagnostic elements of the *Kockelella* fauna have been sampled from cores, along with diagnostic conodont elements of the *Polygnathoides siluricus* biozone (Barrick and others, 1990). This suggests that the *Kirkidium* biofacies is at least as old as middle Ludlow and possibly as old as early Ludlow.

Figure 11 *(facing page)*. 1–7, diagnostic Ludlow–Pridoli brachiopod genera (Late Silurian) collected from the Henryhouse Formation; 8–18, diagnostic Helderbergian brachiopod genera (Early Devonian, Lochkovian) collected from the Haragan Formation. *1, Lissostrophia*, pedicle valve, ×5; *2, Skenidioides, a,b,* brachial and lateral views, ×1; *3, Ptychopleurella, a,b,* lateral and pedicle views, ×3; *4, Homoeospira, a,b,* brachial and anterior views, ×3; *5, Strophonella*, pedicle valve, ×1; *6, Strixella, a,b,* pedicle and lateral views, ×2; *7, Kirkidium, a,b,* lateral and brachial views, ×1; *8, Eatonia, a,b,* brachial and anterior views, ×1; *9, Gypidula*, brachial valve, ×1; *10, Coelospira, a–c,* brachial, pedicle, and posterior views, ×1; *11, Platyorthis*, brachial valve, ×1; *12, Skenidium, a,b,* brachial and posterior views, ×3; *13, Orthostrophia*, pedicle valve, ×1; *14, Rhynchospirina*, brachial valve, ×2; *15, Meristella, a–c,* brachial, pedicle, and anterior views, ×1; *16, Obturamentella, a,b,* pedicle and brachial views, ×2; *17, Plectodonta, a,b,* pedicle and brachial views, ×3; *18, Rensselaerina, a,b,* pedicle and lateral views, ×1. Figure 11.1 reproduced from Amsden (1978); Figures 11.2, 5–6, 8–10, 12–18 reproduced from Amsden (1958a); Figure 11.3 reproduced from Moore (1965); Figure 11.4 reproduced from Amsden (1974); Figure 11.7 reproduced from Amsden and Barrick (1988); Figure 11.11 reproduced from Amsden (1958b).

Facies Interpretation

Overall, the Henryhouse Formation represents deposition in deep water (well below storm wave base) along the Late Silurian shelf. The evidence for this interpretation is based on the abundant terrigenous detritus that is associated with the Henryhouse carbonates, coupled with the unbroken and unabraded macrofossils that are found in the formation. Additional evidence comes from the presence of graptolite-bearing clayshales commonly found near the base of many Henryhouse sections in the Arbuckle Mountains. The presence of a graptolite fauna is usually indicative of deep-water deposition. Abundant clay "contamination" in dominantly carbonate rock also indicates quiet-water deposition under deep-water conditions (Wilson, 1975). Consequently, most of the Henryhouse Formation appears to have formed within zone 5 of the carbonate-ramp model (Fig. 6; Table 2), with the basal interbedded lime-mudstone–clayshale lithofacies having formed in the farthest offshore parts of that zone.

The Henryhouse Formation also represents a carbonate-shelf cycle as outlined by Wilson (1975, chapter X) (see section on Carbonate Cycles and Sequence Stratigraphy, above) and is part of a more extensive carbonate cycle that includes the Haragan through Bois d'Arc Formations. Taken together, these units represent a long-standing regressive fill-in cycle that started with rapid transgression in the lower Ludlow (basal Henryhouse) and culminated in a capping shoal grainstone in the upper Lochkovian, Early Devonian (Fittstown Member).

The initial transgression across the Late Silurian shelf was extensive. This interpretation is based on the presence of the interbedded lime-mud–clayshale lithofacies in cores and wireline logs as far north as the Anadarko basin of Canadian County, Oklahoma (Rottmann, 2000a). Quiet, deep-water deposition continued in the Anadarko basin for some time, possibly into the middle Ludlow on the basis of conodonts (see discussion under Stratigraphy and Age for the Henryhouse, above). Some shallowing of the seas across the whole Silurian ramp is suggested by a loss of distinct clayshale beds and by the subtle change in carbonate depositional textures (from argillaceous mudstones to cleaner mudstones) in the upper parts of the Henryhouse section (see description of Stops 7 through 9 in Part II of this guidebook). If the presence of terrigenous detritus is even mildly proportional to water depth, these upper mudstones represent shallower water deposition (deposition in the lower part of zone 4) in comparison with the lower Henryhouse lime mudstones (Fig. 6; Table 2).

Farther to the northwest in the Anadarko basin, actual shoaling conditions were reached, as evidenced by *Kirkidium* grainstones in cores (Amsden, 1975). Carbonate shoals never fully developed in the Arbuckle Mountains except for some minor packstone beds found locally in sections in the Lawrence uplift.

Haragan Formation

Nomenclature History

The Haragan Formation was named and described by Reeds (1911) from exposures along Haragan Creek (also named by Reeds) just north of White Mound, Murray County, Oklahoma (Amsden, 1957, 1960). As with the Henryhouse, Reeds (1911) used the deceptive term *Haragan shales* to describe these rocks. This was subsequently changed to the Haragan Formation by Maxwell (1936).

Lithofacies

Lithologically, rocks of the Haragan Formation are nearly identical to those of the Henryhouse Formation and are composed of whole-fossil argillaceous mudstones and wackestones. On average, the Haragan carbonates are less argillaceous and more fossiliferous than those of the Henryhouse. For example, terrigenous detritus may reach Henryhouse proportions of 10–30%, but the Haragan averages only 16% argillaceous material in comparison with the Henryhouse's average of 20% (Amsden, 1960, p. 77, fig. 7). Along with the decrease in argillaceous material, the Haragan Formation tends to contain more beds that have wackestone to packstone depositional textures in comparison with the average mudstone lithofacies of the Henryhouse.

Fossils are common in almost all Haragan exposures and are of a distinct Early Devonian character. All are well preserved and show little abrasion or breakage. The amount of fossils varies considerably, but most localities contain 15–20% fossils to total rock volume (usually the Henryhouse contains <10% fossils). Some zones, however, have yielded >50 % fossils, but these zones are not regionally extensive (Amsden, 1957, 1960). Brachiopods and various types of crinoid debris dominate the faunal assemblages. Other macrofossils include gastropods, bryozoans, trilobites, and rugose and tabulate corals (Amsden, 1960). In some sections (Stops 4, 8, and 9; see Part II of this guidebook), the crinoid bulb *Scyphocrinites* forms a thin but conspicuous zone near the base of the formation.

These distinctions in fossil content and insoluble residue, however, are too subtle to be of much use lithostratigraphically in distinguishing the two formations. Instead, the age difference of their respective macrofaunas (Late Silurian for Henryhouse, Early Devonian for Haragan) is the only reliable criterion in truly segregating Haragan carbonates from those of the Henryhouse (Amsden, 1957, 1958a,b, 1960; Amsden and Barrick, 1988) (Fig. 11).

Besides the inherent difficulties in differentiating the Haragan from the Henryhouse, the Haragan also shows a gradational contact with the overlying Cravatt Member of the Bois d'Arc Formation. The differentiation of these two units depends not on their respective faunas but on the presence or absence of chert (Amsden, 1957, 1960). The Haragan contains little to no chert, whereas the Cravatt contains conspicuous amounts of bedded chert.

Distribution and Thickness

The Haragan Formation shows a similar distribution pattern to that of the underlying Henryhouse Formation (see Pl. 1, in envelope). In outcrop, the Haragan attains a maximum thickness of 228 ft in the Old Hunton Township near Clarita, Oklahoma. Another maximum of nearly 110 ft occurs near White Mound, just southeast of Dougherty, Oklahoma. In most other areas in the outcrop belt, the Haragan averages only ~75 ft in thickness (Amsden, 1960, p. 98, fig. 32).

Much of the variability in thickness of the Haragan is related to vertical and lateral gradation with the overlying Bois d'Arc Formation. In many places where the Haragan is thick, the overlying Cravatt Member is thin, and vice versa (compare Amsden, 1960, figs. 32, 39).

Stratigraphy and Age

There are no Haragan-equivalent units in the Ozark uplift or in the far northwestern parts of the Anadarko basin (Amsden, 1975). Some areas in the central Anadarko basin of Kingfisher and Logan Counties, however, may have a thin remnant of Haragan–Bois d'Arc beds preserved (Rottmann, 2000a).

Brachiopods collected from sections in the Arbuckle Mountains belong to a Helderbergian fauna, which is Early Devonian (Lochkovian) in age. This contrasts markedly with the obvious Late Silurian brachiopod fauna of the Henryhouse Formation (Amsden, 1957, 1958a, 1960) (Figs. 2, 11). This age assessment also encompasses units of the overlying Bois d'Arc Formation, which contain the same macrofauna as the Haragan, although in slightly different proportions (Amsden, 1958a,b; Amsden and Barrick, 1988).

Conodont elements collected from the lowest occurring definitive biozone of the Haragan belong to the *Icriodus woschmidti postwoschmidti* zone of the lower, but not lowest, Lochkovian (Barrick and others, 1990; Barrick and Klapper, 1992) (Fig. 2). The overlying Cravatt Member also contains diagnostic elements of the *I. w. postwoschmidti* biozone, which should be expected, given the lateral and vertical gradational nature of the Haragan–Cravatt contact.

The *Icriodus woschmidti postwoschmidti* biozone is correlative with the *eurekaensis* biozone in the Devonian stratotype section of Nevada and represents the second lowest conodont zone of the Lochkovian (Barrick and others, 1990; Barrick and Klapper, 1992; Johnson and Klapper, 1992, p. 128, fig. 1). This indicates that, even with a complete stratigraphic section, there is a hiatus of at least one conodont zone (the *I. w. woschmidti* global biozone) between the Haragan and Henryhouse Formations (Fig. 2).

Regardless of how much absolute time is missing from the record, the scant lithologic evidence of an unconformity along the contact is astonishing. In some sections (such as sections J11 and C1 on Pl. 1, in envelope), however, the Haragan rests directly on top of the Cochrane Formation, suggesting that a considerable amount of post-Henryhouse–pre-Haragan erosion occurred prior to Haragan deposition. This is in stark contrast to the Cochrane–Clarita contact, which is clearly an erosional unconformity in outcrop but which shows no discontinuity in successive conodont zones across the contact (see section on Clarita Formation—Stratigraphy and Age, above). What is even more astonishing is that the environmental conditions on either side of the Silurian–Devonian boundary were identical, or at least were similar enough to create nearly identical lithofacies in both the Haragan and Henryhouse.

Facies Interpretation

As with the Henryhouse Formation, the argillaceous limestones of the Haragan suggest deposition under deep, quiet-water conditions. Given the decrease in argillaceous material and conditions more favorable to abundant marine fauna (in comparison with the Henryhouse), the Haragan Formation probably formed under slightly shallower conditions than its Late Silurian counterpart (upper zone 5 to lower zone 4 of the carbonate-ramp model; Fig. 6; Table 2).

Taken as a whole, the Haragan–Bois d'Arc carbonate package represents a long-standing, regressive fill-in, comparable to Wilson's (1975) carbonate–evaporite model. From the initial transgression at the base of the Haragan, there is a gradual decrease in argillaceous material up-section (Haragan through Cravatt Member), indicating continual shallowing conditions. This shallowing culminates in the formation of grainstone–packstone shoals represented by the Fittstown Member. It is likely that the underlying Henryhouse Formation is part of this same regressive cycle in which the basal interbedded lime-mud–clayshale lithofacies represents the maximum point of transgression. A similar, but not identical, deep-water phase is evident in some localities at the base of the Haragan (Stops 8 and 9, units 16 and 22, respectively, Part II, this guidebook) and indicate that, following the Silurian–Devonian hiatus, flooding and deepening of the Oklahoma shelf occurred. Similar deep-water facies may also be present at the Goddard Youth Camp section (Stop 3, unit 12, Part II), although the section is too incomplete to make a more definitive comparison with these other transgressive facies. Once this initial transgression occurred, it appears that the regressive progradation of the Devonian shelf continued uninterrupted during the remainder of Haragan and Bois d'Arc deposition.

Bois d'Arc Formation

Nomenclature History

The Bois d'Arc Formation was named after the creek of the same name in Pontotoc County, Oklahoma; however, a type locality was never designated by Reeds (1911). Later, Amsden (1957) designated the type section to be exposures along Jack Fork Creek (formerly Chimneyhill Creek) in Pontotoc County, Oklahoma (Amsden, 1960).

The Bois d'Arc consists of two members. At first, the basal cherty mudstones were named the Cravatt by Maxwell (1936) and placed in the Haragan Formation, whereas the upper grainstone facies were retained as the Bois d'Arc. Amsden (1957, 1958b), reorganized this portion of the section by shifting Maxwell's (1936) Cravatt "formation" back into the Bois d'Arc, giving it member status and naming the upper grainstone facies the Fittstown Member. The type locality of both members was established by Amsden (1957) at exposures along the South Fork of Jack Fork Creek, Pontotoc County, Oklahoma. The Cravatt Member derives its name from Katy Cravatt, who owned the land that included Maxwell's (1936) sections. The Fittstown Member was named for the town of Fittstown, Pontotoc County, Oklahoma (Amsden, 1957).

Lithofacies, Cravatt Member

The Cravatt Member consists of slightly argillaceous, cherty mudstones and wackestones. Except for the ubiquitous occurrences of nodular and bedded chert, the Cravatt looks similar to upper beds of the Haragan Formation.

Although the Cravatt is argillaceous, it contains less terrigenous detritus than either the Henryhouse or Haragan Formation. The proportion of insoluble residues ranges from 3% to 22% and averages ~11% of total rock volume (Amsden, 1960, p. 107, fig. 36). This decrease in clay and quartz detritus between the Cravatt and Haragan, however, is too subtle a difference to be of any lithostratigraphic use. Instead, the base of the Cravatt is defined by the first occurrence of chert (Amsden, 1957, 1958b, 1960).

Two basic types of chert occur: (1) a porous, brown-weathering, nodular variety that is often referred to as tripolitic chert; and (2) a denser, glassy, and bedded type referred to as vitreous chert (Amsden, 1957, 1958b, 1960). Usually the tripolitic variety is restricted to the lower intervals of the Cravatt, whereas the vitreous type is more common in the middle and upper parts of the section (see Stops 3 through 5, Part II, this guidebook).

Fossils collected from the Cravatt are similar to those of the Haragan Formation in that the individual taxonomic components are virtually the same (although their relative proportions may differ). The Cravatt fossils are also well preserved, but some exhibit breakage and abrasion, unlike the Haragan fossils.

Lithofacies, Fittstown Member

This member is a distinct, thin, even-bedded, well-sorted skeletal grainstone with local interbeds of well-sorted packstone and skeletal wackestone. The mud-textured carbonates, however, are usually restricted to the lower half of the member, but where they occur intercalated with the grainstones, the bedding of the Fittstown is wavy to irregular and exhibits a noticeable pinch-and-swell appearance across the outcrop (Amsden, 1957, 1960).

Insoluble residue is much reduced in the grainstone facies, as quartz detritus only averages near 4% total rock volume. Argillaceous limestones (similar to the Cravatt or Haragan type) are rare to nonexistent in the Fittstown. Even the more mud-supported textures are clean carbonates, having little detrital-clay contamination. The Fittstown grainstones are cemented by a medium to coarse sparite cement that accounts for 16–19% of total rock volume (Amsden, 1960).

Glauconite is also a common constituent of the grainstone facies, but little of it is found in the mud-bearing carbonate intervals.

Fossil material constitutes 80–85% of total rock volume in the grainstones (Amsden, 1960). It is almost all highly fragmented and exhibits a great deal of abrasion. Crinoid debris makes up the bulk of the material, followed by brachiopods, some trilobites, bryozoans, and rarely rugose corals (Amsden, 1960). Fossils from mud-textured beds (particularly the wackestones) make up a well-preserved fauna that is similar in taxonomic composition to that of the Cravatt Member.

Distribution and Thickness

Owing to the gradational nature of the Haragan–Bois d'Arc contact, the areal geometry of the Bois d'Arc is highly dependent on the areal distribution of the Haragan (see Pl. 1, in envelope). Generally, the Bois d'Arc reaches its thickest extent in areas where the Haragan is relatively thin, and vice versa.

The maximum thickness of the Bois d'Arc is ~200 ft near Mill Creek, Oklahoma (Pl. 1, section J11; Fig. 1). The formation attains a thickness of 190 ft just south of Bromide, Oklahoma (Pl. 1, section J6; Fig. 1). The Bois d'Arc is absent in a zone extending across much of the south-central Arbuckles and extending into the Criner Hills (Fig. 1; Pl. 1), where it has been stripped away by pre-Woodford erosion. On average, the Bois d'Arc attains a thickness of 80 ft at most localities.

Stratigraphy and Age

In all respects, the Haragan–Cravatt–Fittstown sequence represents a lateral and vertical gradational series, with the Fittstown representing the end member of the regressive fill-in model of Wilson (1975) (Fig. 7). In this interpretation, the Cravatt Member represents an intermediate lithofacies between the deeper water Haragan argillaceous-mudstone facies and the shallow-water Fittstown grainstone facies (Amsden, 1958b, 1960; Amsden and Barrick, 1988). As would be expected from this gradational lithostratigraphic relationship, the major macrofaunal components of the Bois d'Arc are similar to those of the underlying Haragan Formation. As such, the Bois d'Arc Formation contains a typical Helderbergian brachiopod fauna of Early Devonian (Lochkovian) age (Amsden, 1958b, 1960; Amsden and Barrick, 1988) (Figs. 2, 11).

Conodonts are scarce throughout the Bois d'Arc, and where elements have been collected they are not diagnostic of any specific conodont zone. What has been stated, however, is that most conodont elements from the Cravatt Member exhibit a Haragan "flavor" (Barrick and others, 1990). Toward the top of the Cravatt and the base of the Fittstown, *Icriodus woschmidti postwoschmidti* has been collected (Barrick and others, 1990; Barrick and Klapper, 1992). This indicates that the Cravatt and the basal Fittstown are time-equivalent to the Haragan Formation, at least on the duration of a conodont biozone. Toward the top of the Fittstown, elements of the *delta* zone (late but not latest Lochkovian) were identified (Barrick and Klapper, 1992; Johnson and Klapper, 1992) (Fig. 2). No diagnostic elements belonging to the *Ancyrodelloides pesavis* biozone (latest Lochkovian) have been collected from any member of the Bois d'Arc Formation.

No Bois d'Arc–equivalent strata have been identified in areas of the Ozark uplift or in the subsurface of the Anadarko basin (Amsden, 1975).

Facies Interpretation

The continual decrease in argillaceous material, starting in the upper Haragan and continuing into the Cravatt Member, coupled with the increase in grain-supported textures in the Fittstown, suggest a gradual shoaling of the Early Devonian seas across the Oklahoma shelf.

A decrease in argillaceous material, and a well-preserved but sporadically fragmentary fossil fauna, suggest that the Cravatt Member was deposited in slightly shallower, higher energy water than the Haragan Formation. More than likely, Cravatt facies were deposited exclusively in zone 4 of the carbonate-ramp model, with some local occurrences of lower zone 3 packstones that were washed basinward (Fig. 6; Table 2).

The occurrence of chert in carbonate rocks in general, and in the Cravatt Member specifically, is still something of an enigma. Most marine water is undersaturated with respect to dissolved silica; consequently, most primary chert found in marine rocks originated from the concentration of siliceous organisms like diatoms and radiolarians (Blatt and others, 1980). It is unclear whether the chert of the Cravatt Member is due to organic activity or is secondarily derived by geochemical alteration and/or diagenesis. Amsden (1960) did note an intergradation between the different types of chert found in the Cravatt Member. This progression usually grades from spongy silica to porous, tripolitic chert to vitreous chert. Amsden (1960) also noted that many of the porous, tripolitic-chert nodules have a vitreous-chert core. All of this suggests that the Cravatt chert had a single origin and that the tripolitic type was formed from alteration of the vitreous type.

Wilson (1975, p. 355) noted that most cherty carbonates are commonly found in facies formed in deep-water, open-shelf environments with minimal clastic influx. These facies fall in Wilson's (1975) belt 3 of his carbonate model, which is comparable to the outer zone 4 of my carbonate-ramp model (Fig. 6; Table 2).

The sorted to unsorted grainstones of the Fittstown Member represent the climax in shoaling. Prior to sparite cementation, these deposits probably represented crinoidal sands that formed under the high-energy conditions of zone 2 (Fig. 6; Table 2). The sporadic intercalated packstone and wackestone beds probably formed in the upper parts of zone 3.

Frisco Formation

Nomenclature History

Reeds (1911) originally included the Frisco beds with his Bois d'Arc Formation, but later he (Reeds, 1927) removed these strata, stating that they were lithologically distinct from the Bois d'Arc grainstones, and established the Frisco Formation (Amsden, 1960). Reeds (1927) took the name *Frisco* from the town of that name in Pontotoc County, Oklahoma, but he never designated a type section. Later, Amsden (1957) designated the type section of the Frisco Formation at exposures along Bois d'Arc Creek in Pontotoc County (see Stop 1, Part II, this guidebook).

Lithofacies

The Frisco Formation consists of two distinct lithofacies. The first is a mud-supported, crinoid–bryozoan floatstone to wackestone interpreted as developing as mud accumulations within bryozoan–crinoid thickets (Table 1; Fig. 12). The second lithofacies comprises grain-supported, intermound, and capping-bed facies, formed from the reworking and washing of the mound facies by currents (Medlock, 1984; Fritz and Medlock, 1992).

The mound facies normally have an irregular geometry composed of multiple, coalescing, conical-shaped piles of poorly sorted carbonate sediment, with each individual mound varying from 10 to 20 ft thick (Al-Shaieb and others, 1993b, p. 203). The interiors of the mounds have well-preserved crinoid and bryozoan fragments, all supported by a lime-mud matrix. In textural terms, this facies is classified as a floatstone to a whole-fossil or skeletal wackestone (Table 1).

Both the intermound and capping-rock lithofacies consist of crinoid-rich, poorly sorted to well-sorted packstones, grainstones, and even rudstones (depending on the sizes of component grains) (Table 1). Com-

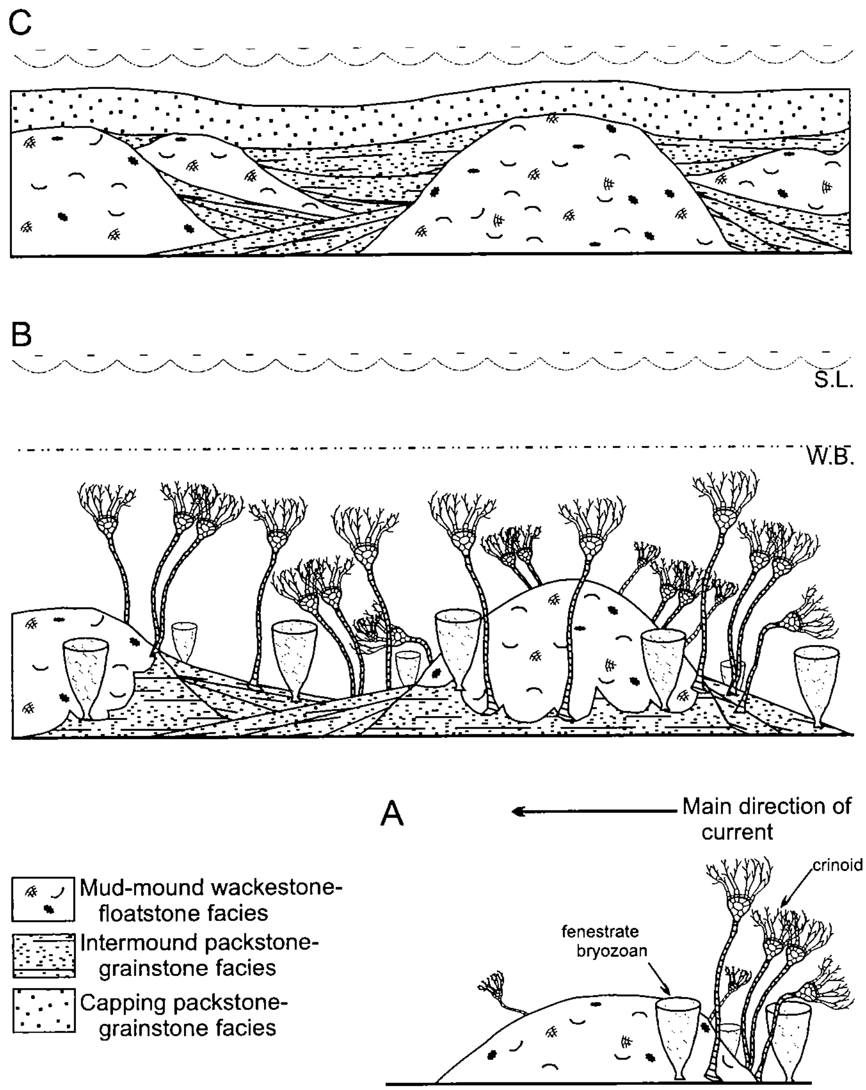


Figure 12. Diagram illustrating hypothetical development of the Frisco mud-mound, intermound, and capping facies, through: *A*—Progressive colonization of current-induced pile of lime mud on lee side of crinoid–bryozoan thickets. *B*—Rising sea level allows lime mud to accumulate below wave base (*W.B.*) and in center of thicket, while intermound beds develop coarse debris from outer edges of thicket, where most fine mud is washed out. *C*—Lowering of sea level (*S.L.*) brings mound and intermound facies into intertidal zone, where they become reworked by waves, forming the coarser grained capping facies. Diagram based on Wilson (1975, fig. V-15) and Fritz and Medlock (1993, fig. 18).

positionally, the intermound and capping lithofacies are the same, though the grain components of the cap rock appear poorer sorted (almost graded) in comparison with those of the intermound lithofacies.

Distribution and Thickness

Owing to extensive post-Frisco–pre-Woodford erosion, the Frisco Formation has a limited distribution that encompasses only the northern outcrop belt of the Arbuckle Mountains (Fig. 1; Pl. 1, in envelope). Throughout most of this trend, the Frisco attains no more than 15 ft in thickness. The thickest occurrence of the Frisco in outcrop is on the eastern edge of the Lawrence uplift, where it is about 40–45 ft thick at the type section along Bois d'Arc Creek (see Stop 1, Part II, this guidebook).

Outcrops of the Frisco Formation have also been described from the Ozark uplift (Amsden, 1961; Amsden and Barrick, 1988). The formation also has a far more extensive distribution in the subsurface, which includes the central, eastern, and near-western parts of the Anadarko basin (Amsden, 1975; Rottmann, 2000a).

Stratigraphy and Age

Articulate brachiopods collected from the Frisco Formation in the Arbuckle Mountains were assigned a middle Early Devonian (Pragian) age by Amsden and Ventress (1963) (Fig. 13).

Only a fragmentary conodont fauna has been collected, but elements of *Dvorakia* sp. and *Icriodus* sp. are common (Barrick and others, 1990). The Frisco *Icriodus* may be related to *I. claudiae*, which makes its first appearance in the *Eognathus sulcatus* biozone (earliest Pragian) and ranges up into the *kindlei* zone (or the *Polygnathus dehiscens* global biozone correlation) in Nevada (Barrick and others, 1990; Barrick and Klapper, 1992). All of this supports a Pragian, or at least an early Pragian, age for the Frisco Formation (Fig. 2).

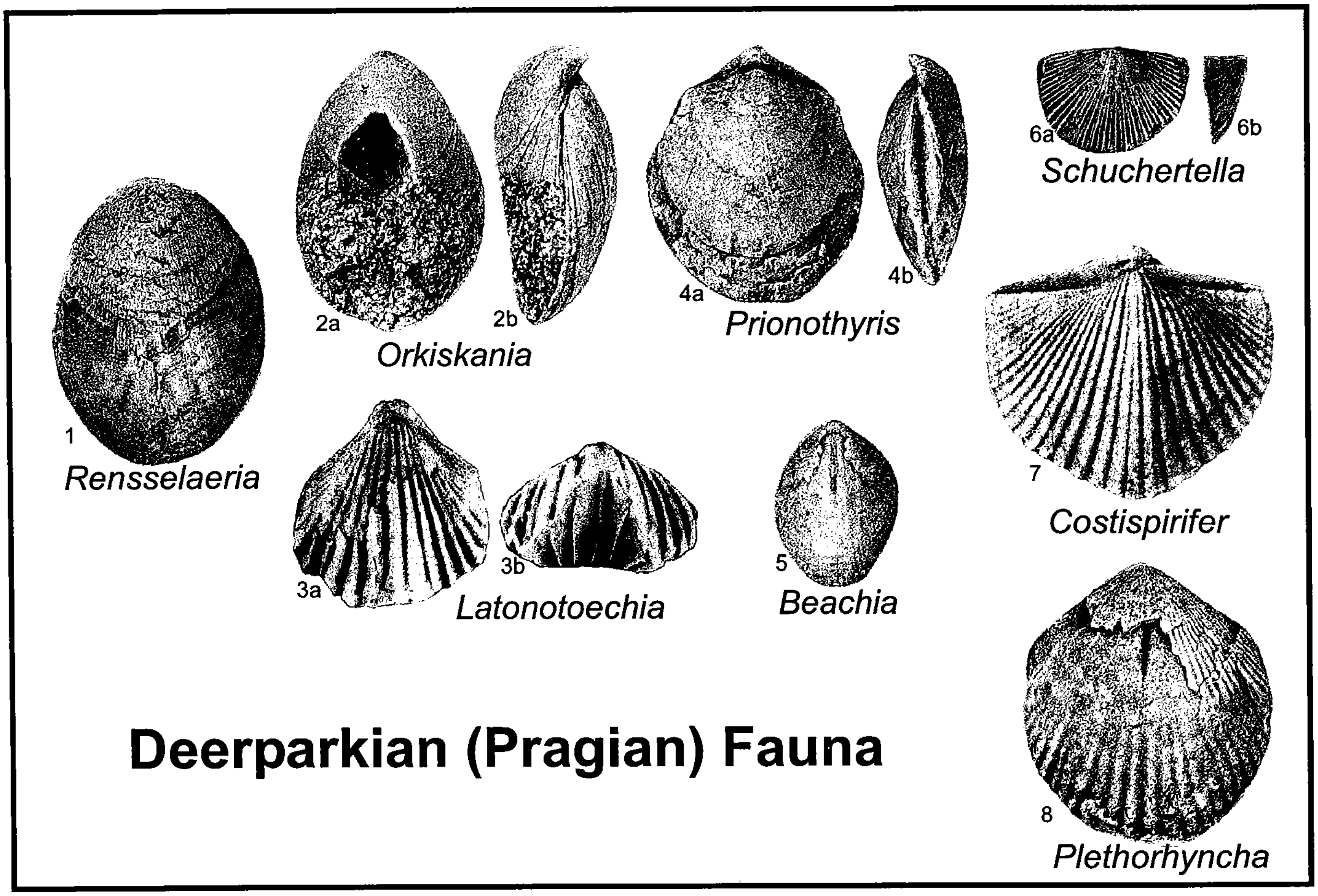


Figure 13. Diagnostic Deerparkian brachiopod genera (Early Devonian, Pragian) collected from the Frisco Formation. *1, Rensselaeria*, pedicle valve, ×1; *2, Orkiskania, a,b,* pedicle and lateral views, ×2; *3, Latonotoechia, a,b,* brachial and anterior views, ×1; *4, Prionothyris, a,b,* brachial and lateral views, ×1; *5, Beachia*, pedicle valve, ×1; *6, Schuchertella, a,b,* brachial and lateral views, ×2; *7, Costispirifer*, brachial valve, ×1; *8, Plethorhyncha*, brachial valve, ×1. Figures 13.1, 2, 4–6, and 8 reproduced from Amsden and Ventress (1963); Figures 13.3 and 7 reproduced from Moore (1965).

Facies Interpretation

The Frisco mud-mound facies are distinct from other Hunton facies in that their genesis deviates from the standard ramp model (Fig. 6; Table 2). The mound facies formed from the actual gregarious activities of organisms (in this case, crinoids and bryozoans) that produced a local accumulation of carbonate sediment that had local positive relief along the Devonian benthos (Medlock, 1984; Fritz and Medlock, 1993). The mound and accompanying intermound facies appear to be precursors of the Waulsortian-mound facies that would soon dominate the North American and European shelves during the Mississippian Period (Wilson, 1975, chapter V). As such, the typical Waulsortian mound can be used as a standard facies model for the Frisco mounds and associated facies (Fig. 12). Much of the interpretation of the Frisco mounds that follows is also derived from detailed studies done by Medlock (1984), and in summaries given in Fritz and Medlock (1993, p. 174, fig. 18) and Al-Shaieb and others (1993b, p. 204, fig. 15).

Lime mud makes up the bulk of the mound facies, and supports whole or fragmentary fossil material. Usually the mounds would accumulate on the leeward current side of crinoid and bryozoan thickets, or form from the actual baffling of sediment by these organisms (Wilson, 1975) (Fig. 12A). On the basis of their poorly sorted character and conical shape, the mud mounds probably accumulated below wave base in moderate- to low-energy environments (Wilson, 1975, p. 165). Most likely, this accumulation occurred in the lower part of zone 3 of the ramp model (Fig. 6; Table 2).

Coarser bioclastic debris may have drifted outside of the protection of the surrounding crinoid–bryozoan thickets. Exposed to mild prevailing currents, this bioclastic material was washed of the fine-mud fraction, leaving only the coarser bioclastic material behind to form the intermound packstone–grainstone facies (Wilson, 1975, p. 167) (Fig. 12B).

At some point in the accumulation of the Frisco mound and intermound facies, sea level must have dropped to a point that exposed these sediments to the constant wave action of the littoral zone. The net effect was a washing and reworking of the mound and intermound sediments by increased current activity, thus forming the capping grainstone facies that blankets these older Frisco facies (Medlock, 1984; Fritz and Medlock, 1993) (Fig. 12C).

PART II

Stop Descriptions

STOP 1

Bois d'Arc Creek Measured Section

Bois d'Arc Creek was designated the type section of the Frisco Formation by Amsden (1957, p. 47). Although a full Hunton section was described along Bois d'Arc Creek by Amsden (1960, appendix 1, sections P8 and P11), only the Frisco Formation and the upper beds of the Fittstown Member are incorporated into this guidebook. (For the location of Stop 1, see Figure 1 and the field-trip road log in Table 4.)

The Frisco Formation (Figs. 14, 15) is unique among other Hunton formations in that it represents localized development of carbonate sediment that had positive relief on an otherwise irregular, post-Fittstown erosional surface (Medlock, 1984; Fritz and Medlock, 1993). This style of carbonate buildup seen in the Frisco is typical of the Waulsortian-mound facies, which is commonly found in Mississippian deposits of North America and Europe (Wilson, 1975).

MEASURED SECTION, STOP 1
Type Locality of Frisco Formation
Bois d'Arc Creek Measured Section

Location: *Section starts at a road cut on west side of OK-99 (units 5–7), just south of the Bois d'Arc Creek overpass, and continues down along the north side of the creek (units 1–3); in the SE¼SE¼NE¼ sec. 11, T. 2 N., R. 6 E., Pontotoc County, Oklahoma (Ahloso, Oklahoma, 7.5′ quadrangle).*

Thickness (feet)

HUNTON GROUP (total measured thickness, 49.0 ft)

FRISCO FORMATION (total thickness, 45.2 ft)

7. Moderate- to well-sorted crinoidal grainstone, bluish white (5B9/1) to white (N9), weathering to medium gray (N5) or medium light gray (N6); weak to moderately indurated; beds thin to medium, planar, 3.0–8.0 in. thick, with thinner beds more common toward top of exposure. Fossil material is highly fragmented and appears to be composed exclusively of crinoid debris. Upper contact is unknown 2.3
6. Poorly sorted packstone and rudstone, with minor crinoidal grainstone (Fig. 17); grayish orange (10YR7/4), weathering medium light gray (N6)

Three general components are associated with the Frisco Waulsortian buildup—the mound facies, the intermound facies, and the capping-rock facies (Al-Shaieb and others, 1993b) (see Fig. 12, and the section

Stop 1
Bois d'Arc Creek Measured Section

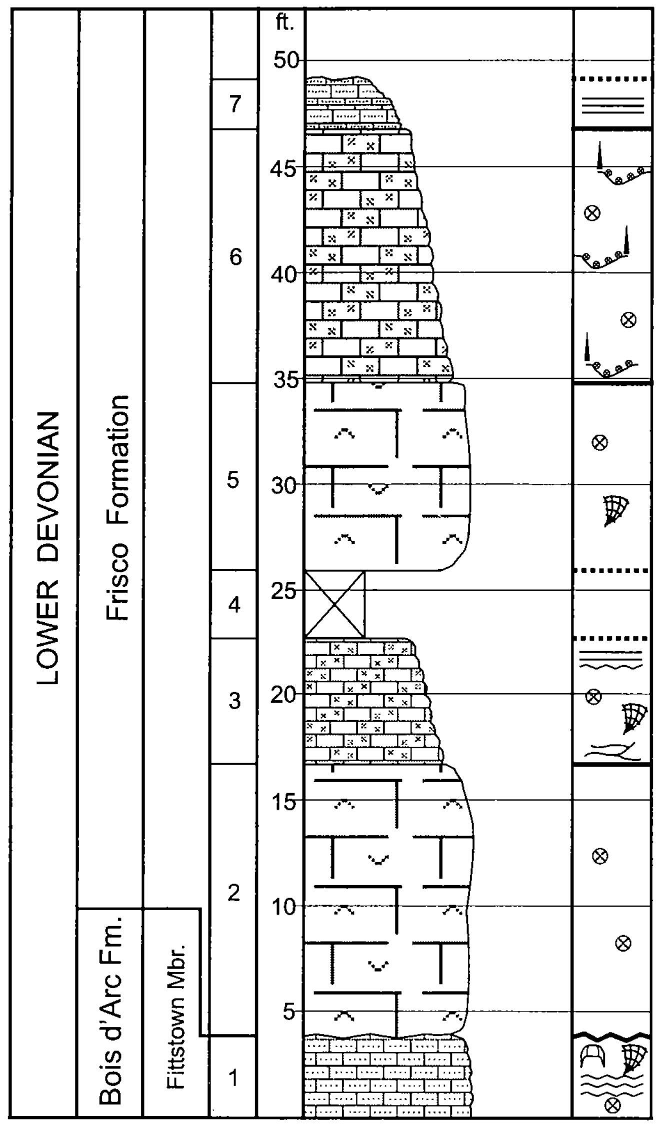


Figure 14. Graphic columnar section of exposed parts of the Frisco and Bois d'Arc Formations in Bois d'Arc Creek at Stop 1 (Bois d'Arc Creek section). Explanation of symbols found in Appendix.

TABLE 4. – Road Log for Hunton Group Field Trip

Interval	Cumulative mileage	Road Log and Description
0.0	0.0	Leave parking lot of Holiday Inn, Ada, by turning right (east) onto OK-3.
0.4	0.4	Intersection with Broadway Avenue; continue east on OK-3.
1.8	2.2	Intersection with OK-3W/OK-19.
5.2	7.4	Exit OK-3 onto OK-99; take OK-99 south in the direction of Fittstown.
2.5	9.9	Clear Boggy Creek.
1.3	11.2	Jack Fork Creek.
1.8	13.0	***Stop 1*** – Type section of the Frisco Formation along Bois d'Arc Creek. Mud-mound geometry, intermound, and capping facies. Contact with Fittstown Member of the Bois d'Arc Formation.
—	—	Leave Stop 1 by going back north on OK-99.
2.5	15.5	Turn west (left) onto asphalt section-line road.
2.0	17.5	Encounter T-intersection; continue north on asphalt road.
0.5	18.0	Turn west (left) onto asphalt half-section road.
1.3	19.3	Asphalt half-section road changes to gravel.
0.3	19.6	Outcrop of Chimneyhill Subgroup in North Fork Creek.
0.4	20.0	Curve in road; continue north.
0.5	20.5	Curve in road; continue west.
0.7	21.2	Outcrop of Henryhouse Formation on south side of road.
0.2	21.4	Hill and curve in road; continue north.
0.6	22.0	Intersection with OK-1; turn south (left).
1.6	23.6	***Stop 2*** – Turn left into the Holnam Quarry. Type section of the Keel Formation and Ideal Quarry Member. Contact between Sylvan Shale and Chimneyhill Subgroup well exposed. Cochrane Formation also present in pit wall.
—	—	Leave Holnam Quarry and go west on OK-1 toward Sulphur.
8.0	31.6	Entering the town of Roff; continue south on OK-1.
9.2	40.8	Intersection with OK-7; continue west on OK-7 toward the town of Sulphur.
6.4	47.2	Encounter T-intersection with US-177 in Sulphur; continue south on US-177.
0.3	47.5	Intersection with OK-7 west; continue south through Chickasaw National Recreation Area on US-177.
1.4	48.9	Intersection with OK-110.
4.5	53.4	Buckhorn Creek.
1.5	54.9	Turn west onto Goddard Youth Camp Road.
2.8	57.7	***Stop 3*** – Goddard Youth Camp. Good exposures of fossiliferous Haragan Formation, and Bois d'Arc Formation; contact between Haragan Formation and Cravatt Member; compare differences between facies of Haragan Formation, and Cravatt and Fittstown Members of Bois d'Arc Formation.
—	—	Leave Stop 3 and continue west along Goddard Youth Camp Road.
1.4	59.1	Entrance for Life Style Center of America.
0.4	59.5	***Stop 4*** – Optional; park on north side of road and walk west along south side of prominent ridge with good exposures of Bois d'Arc Formation. Typical surface expressions of Chimneyhill Subgroup, Henryhouse and Haragan argillaceous mudstones, and lower part of Bois d'Arc Formation.
—	—	Leave Stop 4 and proceed west along Goddard Youth Camp Road.
1.1	60.6	Encounter T-intersection with OK-110; turn north (right).
0.2	60.8	Intersection with Lakeview Road; proceed east to Lake of the Arbuckles dam.
0.8	61.6	***Lunch Site*** – Cullen Cofer Overlook. Rocks exposed at this site are conglomerates of lower facies of Upper Pennsylvanian Vanoss Group (Ham and McKinley, 1954).
—	—	Leave lunch site and return to OK-110.
0.8	62.4	Intersection with OK-110; proceed south to Goddard Youth Camp Road.
0.2	62.6	Turn east (left) onto Goddard Youth Camp Road.
0.5	63.1	***Stop 5*** – Hunton anticline; walk south along narrow blacktop road leading into quarry. Good exposure of the Haragan through Bois d'Arc Formations. Gradational contact between Cravatt and Fittstown Members of Bois d'Arc Formation.
—	—	Leave Stop 5 and proceed west back to OK-110.

(continued on next page)

TABLE 4. – *(Continued)*

Interval	Cumulative mileage	Road Log and Description
0.5	63.6	Intersection with OK-110; proceed south toward town of Dougherty.
2.8	66.4	Town of Dougherty; continue south across railroad tracks.
0.7	67.1	Washita River.
0.2	67.3	Bend in road; continue to follow county blacktop northwest. Washita River should be on your right.
2.6	69.9	***Stop 6*** – Optional; proceed southwest along shallow creek. Exposures of Cravatt Member of Bois d'Arc Formation, lower Henryhouse Formation, and Chimneyhill Subgroup on either side of creek. Typical surface expression of these units in the Arbuckle Mountains south of Washita River.
—	—	Leave Stop 6 and continue northwest on county blacktop.
0.5	70.4	Turn west and proceed onto OK-77D.
0.1	70.5	***Stop 7*** – Type section of Prices Falls Member of Clarita Formation. Good exposure of Chimneyhill Subgroup as Ideal Quarry Member and Keel oolite are well represented. An unusually thin interval of Cochrane Formation is also present, which underscores the extent of post-Cochrane–pre-Clarita erosion.
—	—	Leave Stop 7; continue west along OK-77D.
0.1	70.6	Sharp corner at Falls Creek Assembly; turn right (north) and continue on OK-77D over Arbuckle Mountains.
1.4	72.0	Sharp corner; scenic turnout on right.
1.0	73.0	***Stop 8*** – Woodford Shale, Henryhouse Formation and Haragan Formation are present. Good exposure of Woodford–Hunton contact; base of Woodford contains atypical brown-carbonate facies.
—	—	Leave Stop 8 and continue north along OK-77D.
0.2	73.2	T-intersection; turn left (west) toward intersection with US-77.
0.2	73.4	***Stop 9*** – US-77 road cut. Exposure of Sylvan Shale, Hunton Group, and Woodford Shale. Only Ideal Quarry Member of Keel Formation and Bois d'Arc Formation are absent.
—	—	End of field trip; return to the Holiday Inn at Ada via US-77 to Davis; Davis to Sulphur on OK-7; and Sulphur to Ada along OK-7 to OK-1.
45.6	119.0	Back at the Holiday Inn.

to medium gray (N5). Beds thick to massive, and where defined, 2–4 ft thick; some lower bedding surfaces concave (channeled?), having a lag deposit of large, intact crinoid stems. Crinoid lag conspicuous at base of unit, and at 5.7 ft and 9.7 ft above base. Internal bedding appears graded in some intervals. Bedding thickness decreases to medium, as interbedded grainstones become more numerous in upper one-third of unit. Upper contact is sharp and planar to slightly wavy 12.0

5. Coarse, poorly sorted floatstone to wackestone; pale olive (10Y6/2) to pale yellowish brown (10YR6/2), weathering to medium light gray (N6) to medium gray (N5). Unit is a massive interval of lime mud supporting large crinoid plates and stems; some fenestrate bryozoans occur, but seen only as moldic preservation. Upper 2–3 ft of interval contains smaller crinoid debris and is best termed a wackestone rather than a floatstone. Upper contact appears sharp and planar 8.8

4. Covered interval; probably represents continuation of unit 3 .... 3.3

Note: The lower units of the Frisco and upper units of the Bois d'Arc Formations (units 1–3) were measured from exposures on the north side of Bois d'Arc Creek.

3. Poor to moderately sorted skeletal packstone (Fig. 16); very pale orange (10YR8/2) to bluish white (5B9/1), weathering to medium gray (N5) to medium dark gray (N4), with dusky yellow (5Y6/4) staining along internal laminae. Bedding distinct and better developed than in units above and below; irregular, thin bedding to laminated bedding in basal two-thirds, grading upward into a wavy to planar, thin-bedded character in upper one-third of unit; bed thickness varies from 0.5 in. at base to 3.0 in. toward top, and averages 1.0 in. thick overall. Fossil material coarse, well preserved, and dominated by crinoid debris in basal half, but an equal mix of crinoid and bryozoan fragments and better sorting of fossils in upper half. Upper contact covered 6.0

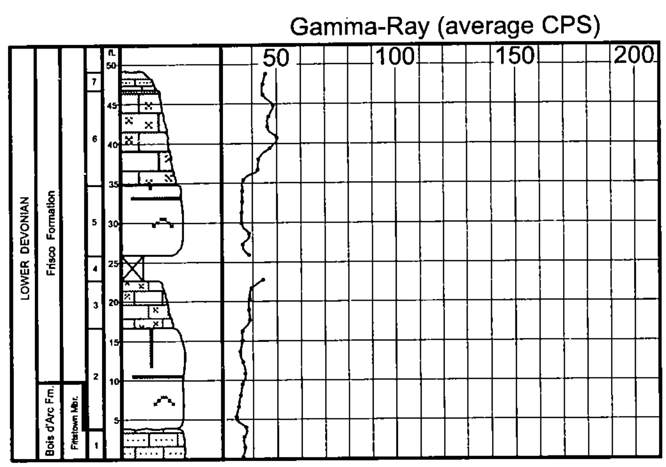


Figure 15. Gamma-ray profile of the Frisco Formation and the Fittstown Member, exposed in Bois d'Arc Creek at Stop 1. Note low, uniform gamma-ray values for mound facies.

2. Skeletal wackestone to mudstone, with scattered patches of floatstone (Fig. 16); pale olive (10Y6/2) to pale yellowish brown (10YR6/2), weathering medium gray (N5) to medium light gray (N6). Predominantly a wackestone with abundant crinoid debris, but sporadically grading laterally and vertically into mudstone textures; upper 3 ft of unit with floatstone texture and an increase in bryozoan fragments. Overall, unit appears structureless but is really composed of a coalescing and stacked series of 2–3-ft-thick, structureless lenticular pods, each pod having a 2.0–4.0-in.-thick, weakly laminated zone at top; the laminated zones appear to contain coarser fossil fragments than the structureless pods; each pod might extend 10–20 ft along outcrop. Upper contact looks sharp and planar 12.8

BOIS D'ARC FORMATION (total thickness measured, 3.8 ft)

Fittstown Member

1. Skeletal grainstone, very pale orange (10YR8/2) to grayish pink (5R8/2), weathering medium gray (N5) and grayish blue green (5BG5/2) near base of exposure, and yellowish gray (5Y7/2) toward top. Beds are thin and very wavy (pinch and swell common along outcrop); 1.0–6.0 in. thick, averaging ~2.5 in. thick. Well-sorted grainstone texture dominates, although upper few beds show packstone texture. Unidentifiable crinoid and brachiopod-shell fragments common; trilobite cephalon and bryozoan fragments are more abundant in upper beds. Upper contact sharp but undulatory, as Frisco beds noticeably truncate upper Fittstown beds .... 3.8+

Total thickness of section 49.0+

Figure 16. Units 2 and 3, Bois d'Arc Creek section (Stop 1). Photo taken from bridge overpass. Unit 2 is mound facies and is typically massive in appearance. Unit 3 is the intermound facies and exhibits better defined bedding. Contact between the two units has a slight dip of 3° to the right.

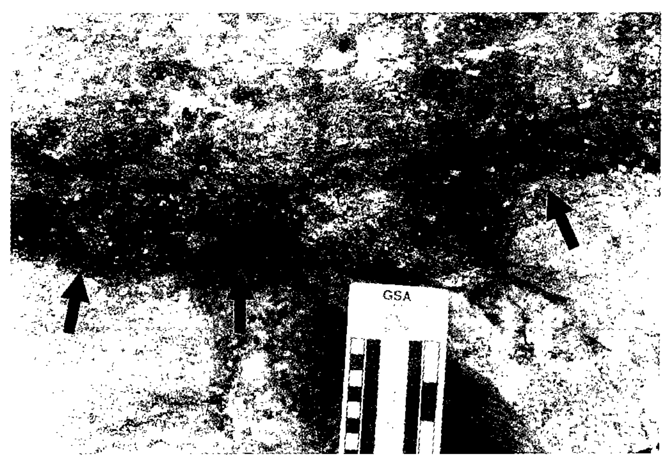


Figure 17. Crinoid lag along base of concave (channeled?) bedding surface (arrows) near the base of unit 6, Bois d'Arc Creek section (Stop 1). Scale in inches and centimeters.

on Frisco Formation—Facies Interpretation, in Part I). Each of these facies will be examined at this site. The mound facies (Fig. 14, units 2, 5; Fig. 16) consists of massive beds of lime-mud-supported, well-preserved crinoid plates and stems. Some bryozoan material occurs, but this is usually present in the upper parts of the mound and the intermound facies. The mound facies can best be seen on the north side of Bois d'Arc Creek, where it unconformably rests on wavy grainstone beds of the Fittstown Member. If the creek level is low, the Frisco–Bois d'Arc contact can be viewed ~100 ft upstream of the Oklahoma Highway 99 overpass. The contact is striking, as the thin, wavy-bedded grainstones of the Fittstown can easily be differentiated from the massively bedded lower Frisco mound facies.

In contrast with the mound facies, the intermound facies (Fig. 14, unit 3; Fig. 16), can best be described as a floatstone having well-developed bedding. Fossil components are usually large, poorly sorted, and well preserved, and are composed of nearly an equal mix of crinoid stems and plates and bryozoan material (although the bryozoans typically are characterized by moldic preservation).

The capping facies (Fig. 14, units 6, 7; Fig. 17) is similar to the intermound facies, although bedding is less noticeable in the former. The capping facies is also coarser and less sorted than the intermound type and contains noticeably more crinoid material relative to other fossil components. Some lower bedding surfaces in the capping facies are distinctly concave upward, appearing almost channeled, and have what can only be described as a coarse, crinoid lag along the "channel" bottoms (Fig. 17). Beds above these lag deposits are graded and fine upward. Lime mud remains an important constituent in the lower beds of the capping facies; however, there is a noticeable decrease in mud content in the upper one-third of unit 6, whereas unit 7, which represents a true shoal-water grainstone, has no lime mud.

The processes under which the capping facies formed appear to have been reworking of older mound and intermound sediments by periodic storm surges or eustatic sea-level changes, which would first scour older sediment, leaving a coarse fossil lag. Finer grained components were washed out of this coarse lag and deposited farther offshore. As storms or tidal currents waned, progressively finer grained sediment was deposited, producing the graded bedding.

The gamma-ray signature of the Frisco Formation is also unique in comparison with other units of the Hunton (see Figs. 8, 15). Gamma-ray values are low and relatively uniform in comparison with more argillaceous carbonates, such as those beds in the Haragan or Henryhouse Formation. This is particularly evident for the mound facies, whose average count-per-second signature ranges in the upper thirties (Fig. 15). The intermound and capping facies also reflect uniform gamma-ray signatures but which are slightly higher than readings from the mound facies.

STOP 2

Holnam Quarry Measured Section

Holnam's Lawrence Quarry was originally owned by the Ideal Portland Cement Co. and was designated the type locality of the Keel Formation and the Ideal Quarry Member by Amsden (1957, 1960). Excellent exposures of the lower Chimneyhill Subgroup (Keel and basal Cochrane Formations) and the Sylvan Shale can be seen capping the easternmost highwall of the Holnam pit (Figs. 18–20).

The Ideal Quarry Member (Fig. 18, unit 3; Fig. 20) is variably developed along the base of the Keel limestone, as the thickness of the unit varies from a minimum of zero to a maximum of ~2 ft. Lithologically, the member is an irregularly laminated skeletal packstone to grainstone. Fossils are common and usually are in the form of short crinoid stems and unidentifiable plates.

The Keel oolite facies (Fig. 18, units 4, 5; Fig. 20) is also well developed in the quarry wall and, where mapped, consists of a lower and an upper oolite interval (Amsden and Barrick, 1986) (Fig. 7). Separating the two oolite facies is another, variably developed skeletal packstone called the *Brevilamnulella*–coral beds by Amsden and Barrick (1986) (Fig. 18, unit 5; Fig. 7). This facies is texturally similar to that of the Ideal Quarry Member, which suggests that both units formed under similar environmental conditions. Owing to the gradational nature of the upper contact, it is difficult to segregate the *Brevilamnulella*–coral packstone facies from the rest of the upper Keel oolite. Locally, whole *Streptelasma* horn corals can be seen in the lower part of

Stop 2
Holnam Quarry Measured Section

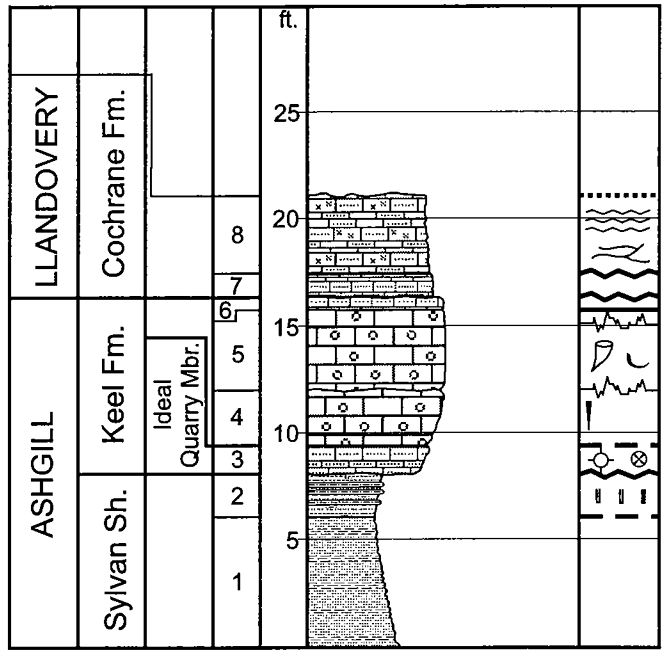


Figure 18. Graphic columnar section of basal Chimneyhill Subgroup exposed along the eastern highwall at the Holnam quarry (Stop 2). Explanation of symbols found in Appendix.

MEASURED SECTION, STOP 2
Type Locality of Keel Formation, and Sylvan Shale Contact
Holnam Quarry Measured Section

Location: Good exposures of the basal Chimneyhill Subgroup and its contact with the Sylvan Shale occur all along the eastern highwall of the Holnam pit, which is ~6 mi southwest of Ada, Oklahoma. Specifically, this section was measured from highwall exposures in the W½SE¼NE¼ sec. 36, T. 3 N., R. 5 E., Pontotoc County, Oklahoma (Ahloso, Oklahoma, 7.5′ quadrangle).

Thickness (feet)

CHIMNEYHILL SUBGROUP
(total exposed thickness, 13.5 ft)

COCHRANE FORMATION (total exposed thickness, 4.7 ft)

8. Skeletal grainstone, with some packstone in upper part of exposure; medium gray (N5) to medium light gray (N6) near base, weathering a pale brown (5YR5/2); bedding thin, very wavy, with pinch-and-swell structure across outcrop; beds are 1.0–4.0 in. thick, averaging ~2.0 in. thick. A nodular-chert zone occurs 2.0 in. above base of unit. Glauconite common throughout, occurring as irregular masses and as individual spherical grains. Fossils consist predominantly of fragmented crinoid plates, columns, and unidentifiable brachiopod-shell material. Upper contact is unknown 3.6

7. Interbedded skeletal grainstone and bedded chert; very light gray (N8), weathering light brown (5YR 5/6) to very pale orange (10YR8/2); chert typically very light gray (N8) to white (N9), weathered and fresh. Beds thin, wavy, 1.0–5.0 in. thick; chert beds show strong pinch-and-swell structure and usually pinch out altogether beyond 6–7 ft along strike. Glauconite grains are present but meager. Fossil material is dominated by brachiopod fragments relative to crinoid debris. Upper contact is sharp but wavy 1.1

KEEL FORMATION (total thickness, 8.8 ft)

6. Skeletal grainstone with minor chert nodules; light gray (N7), weathering light brown (5YR5/6). Unit distinct from rest of Keel Formation; composed of one to two distinct beds, whereas rest of Keel appears massive, and a noticeable decrease in proportion of ooids is evident relative to basal Keel. Beds are 3.0–6.0 in. thick and slightly wavy. Chert in small nodules appears to show internal brecciation. Fossil material unidentifiable but probably consists of brachiopod fragments. Upper contact is sharp but slightly wavy 0.6

5. Oolitic grainstone, bluish white (5B9/1), weathering to light brown (5YR5/6) to pale greenish yellow (10Y8/2). Bedding appears thick to massive, with stylolite contacts noticeable on weathered faces. Ooids well rounded and well sorted (average ~⅛ in. diameter); compose about 45–60% of interval and exhibit a close-packed structure throughout (although only moderately packed in upper 1 ft of interval). Most intergranular space occupied by a fine-grained sparite. Fossils occur but are highly fragmentary and appear to be predominantly crinoidal in composition; some well-preserved horn corals (*Streptelasma* sp.) occur sporadically in the basal 2 ft of unit. Upper contact is sharp and planar; however, some stylolites are noticeable on weathered surfaces 4.3

4. Oolitic grainstone, very light gray (N8) to pale greenish yellow (10Y8/2), weathering pale yellowish orange (10YR8/6). Bedding thick to massive (stylolite contact 28.0 in. above unit base). Ooids exhibit great variability in size and shape compared with unit above; open packed structure common, and inverse graded bedding evident; some algal-coated grains intermixed with traditional ooids evident in upper 2–3 ft. Medium to coarse sparite cement occurs. Fossil material common but mostly unidentifiable. Upper contact is sharp but wavy to stylolitic 2.6

Ideal Quarry Member

3. Skeletal grainstone to packstone; moderate greenish yellow (10Y7/4), weathers light brown (5YR 6/4). A faint, discontinuous bedding lamination is evident, appearing to average ~0.25 in. thick. Grainstone and packstone textures poorly to moderately sorted, with grains mostly composed of crinoid plates and columns having moderate to coarse grain size; some subrounded algal liths occur. Besides crinoid debris, other fossil material is unidentifiable. Upper contact is gradational over 1 to 2 in. 1.3

SYLVAN SHALE (measured thickness, 8.0 ft)

2. Interlaminated clayshale and siltstone; dark yellowish orange (10YR6/6) fresh and weathered. Clayshale is well laminated, very silty, and slightly calcareous, with laminae averaging no more than 0.10 in. thick; siltstone is discontinuously laminated, is very calcareous (almost a true marlstone), with bedding laminae 0.12–0.25 in. thick. Some burrow mottling evident on interlaminae surfaces, but no other macrofossils evident. Upper contact is sharp but wavy 2.0

1. Clayshale, light gray (N7) at base of exposure, grading to yellowish gray (5Y7/2) toward top; weathering light gray (N7) near base to very pale orange (10YR8/2) near top. Clayshale is slightly silty and calcareous, and blocky laminated. Silt and calcite content decreases toward base of exposure. Upper contact is gradational 6.0

Total thickness of section 21.5+

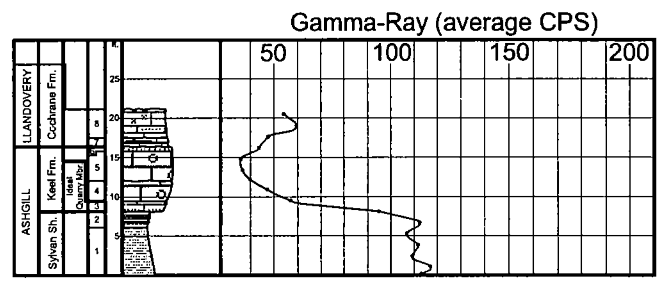


Figure 19. Gamma-ray profile of the sequence from the Sylvan Shale through the lower Cochrane Formation, exposed at the Holnam quarry (Stop 2).

Figure 20. Photo taken along the eastern highwall at the Holnam quarry (Stop 2), showing contact between the Sylvan Shale (recessive interval) and the basal part of the Chimneyhill Subgroup (ledge-forming interval). Dark arrows point to the contact between the upper and lower Keel oolite (units 4 and 5). Light arrows point to the Keel–Cochrane contact. Photo reproduced from Amsden and Barrick (1986).

unit 5 (Fig. 18), which is the only clue as to the presence of the packstone facies.

Capping the Keel Formation is an unusual nodular-chert-bearing grainstone facies that is not as oolitic as the rest of the Keel (Fig. 18, unit 6) and which in some respects resembles the overlying beds of the Cochrane Formation. The differences between the Cochrane and unit 6 of the Keel are the obvious lack of glauconite in the latter unit and the obvious lack of oolite in the Cochrane. Unit 6 is also important because the Early Silurian conodont *Noixodontus girardeauensis* was collected from similar facies at Amsden's (1960, appendix 1) section P9 (Amsden and Barrick, 1986). The occurrence of *N. girardeauensis* in the upper few inches of the Keel expanded the range of the formation to include the Late Ordovician (Hirnantian) through the Early Silurian (Rhuddanian) (Fig. 2).

As for the Cochrane, only a partial section of this formation is preserved along the east highwall (Figs. 16, 20). Lithologically it is similar to other occurrences in the Arbuckle Mountains region, and consists of a wavy to irregularly bedded glauconitic grainstone with abundant sparite cement. Atypical of the Cochrane, however, is a thin unit of interbedded chert and glauconitic grainstone at the base of the formation (Fig. 18, unit 7). This bedded chert is rarely seen at the other measured sections on this field trip, but because this facies occurs low in the formation its absence may just be due to poor exposure rather than to depositional or erosional artifacts.

The gamma-ray profile (Fig. 19) is typical of the Sylvan–Hunton transition in that high, somewhat variable gamma-ray readings of the Sylvan abruptly give way to low, uniform measurements of the Chimneyhill Subgroup (see also the gamma-ray profile for the Hunton Group exposure at Stop 9 [Fig. 50]). This contrast between the Sylvan and Chimneyhill Subgroup is also easily observed from wireline logs, which makes the Sylvan–Hunton contact one of the easiest to map in the subsurface.

For more information about the Holnam Quarry and its operations, contact John Roach, quarry supervisor.

STOP 3

Goddard Youth Camp Measured Section

A nearly complete section of the Hunton Group can be found on either side of a small cove just below the main camp facilities. Only the top of the Henryhouse and the lower part of the Haragan are missing, as the contact between the two formations is covered by Goddard Youth Camp Road. This section corresponds to Amsden's (1960, appendix 1) section M10. It should be noted that in most copies of Amsden's (1960, appendix 1, p. 247) work, this site is incorrectly located at R. 2 E., whereas the correct coordinates should read R. 3 E., Murray County, Oklahoma. For purposes of this field trip, only the Bois d'Arc–Haragan part of the Goddard section will be examined in detail. Structurally, beds in this part of the Arbuckle Mountains dip to the north at 45° and strike S. 85° E.

The contact between the Haragan Formation and the overlying Bois d'Arc Formation is well exposed on top of an east–west-trending ridge on the east side of the cove. Here, one can see the transitional nature between the two formations, as weakly argillaceous mudstones of the Haragan grade into weakly argillaceous mudstones of the basal Cravatt Member of the Bois d'Arc Formation (Figs. 21, 22). The only lithologic difference between the two units is brown chert in the lower beds of the Cravatt Member (Amsden, 1958b, 1960). Faunally, as well, the upper beds of the Haragan Formation and the Cravatt Member are virtually identical (see Fig. 2 for lithostratigraphic relationship). The lithologic and paleontological similarities between the two limestones are so acute that Amsden (1960) considered the Cravatt Member to be only a facies of the Haragan Formation.

MEASURED SECTION, STOP 3
Haragan–Bois d'Arc Contact
Goddard Youth Camp Measured Section

Location: *The Bois d'Arc Formation (units 17–20) were described from exposures on the west side of narrow cove in the NW¼SW¼SW¼SE¼ sec. 33; the Haragan Formation (units 10–15) were described from exposures on the east side of narrow cove in the N½SE¼SW¼SW¼SE¼ sec. 33; and the Chimneyhill Subgroup (units 2–8) were described from exposures on the south side of Goddard Youth Camp Road in the S½ SE¼SW¼SW¼SE¼ sec. 33, T. 1 S., R. 3 E., Murray County, Oklahoma (Sulphur South, Oklahoma, 7.5′ quadrangle).*

	Thickness (feet)
HUNTON GROUP (total thickness, 241.0 ft)	
BOIS D'ARC FORMATION (total thickness, 73.9 ft)	
Fittstown Member	
21. Covered interval, some of which may represent Woodford Shale	5.0+
20. Interbedded glauconitic grainstone and skeletal wackestone. Grainstones are a bluish white (5B 9/1), and wackestones typically a grayish orange (10YR7/4); both weather to a pale brown (5YR 5/2) to a grayish olive (10Y4/2) stain along bedding. Grainstone intervals wavy, thin to medium bedded, 5.0–11.0 in. thick. Wackestone beds common in basal one-third to half of unit, typically wavy, medium bedded, 7.0–12.0 in. thick. Some vitreous-type chert lenses and thin partings occur in the wackestones. Glauconite grains are conspicuous in grainstone intervals, inconspicuous in mud-supported intervals. Fossils mostly fragmented, consisting predominantly	

of crinoid debris in grainstone intervals, and brachiopod-shell material and crinoid debris in wackestones. Upper contact is covered 18.2

19. Glauconitic grainstone, bluish white (5B9/1), weathering to medium dark gray (N4) to pale brown (5YR5/2); beds thin, wavy, 1.0–6.0 in. thick, averaging 2.0 in. thick, with thicker bedded material more common in basal 4.0 ft of unit; glauconite common throughout as small grains to rarely small, irregular masses; some sparite cement, but unit is weakly indurated overall. Fossils highly fragmented, dominated by crinoid debris; however, some well-preserved trilobite cephalons occur in lower half of unit. Upper contact is sharp and planar..................... 11.6

Cravatt Member

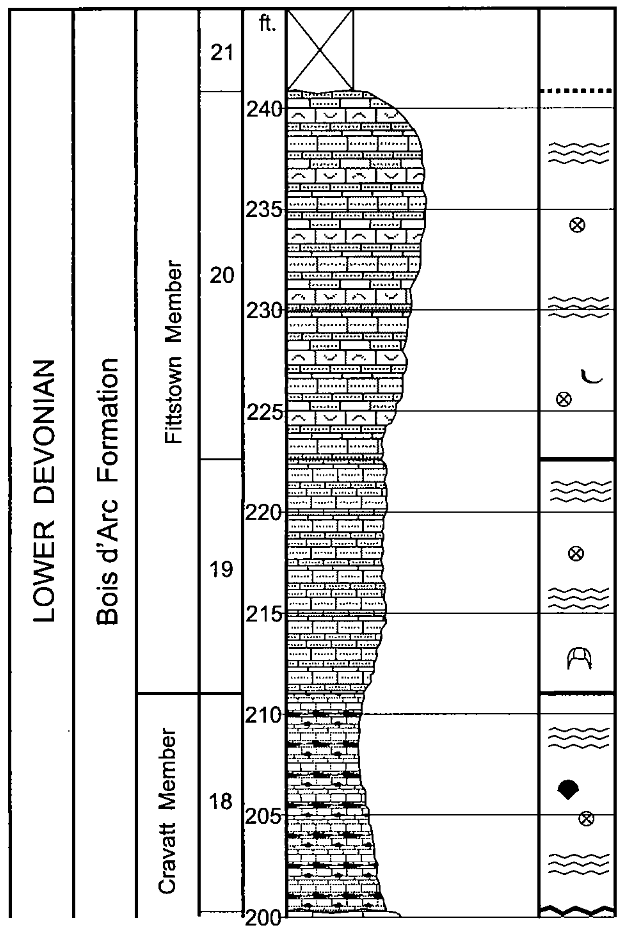
18. Whole-fossil mudstone and wackestone, interbedded with laminated, very argillaceous mudstone. Unit is pale yellowish brown (10YR6/2) to yellowish gray (5Y7/2) and weathers to pale brown (5YR5/2) to medium dark gray (N4); laminated intervals are dark yellowish orange (10YR 6/6) that weather to grayish olive (10Y4/2). Beds in mudstone and wackestone intervals slightly wavy, 7.0–11.0 in. thick, with little argillaceous material; laminated argillaceous intervals no more than 1.0 ft thick (average 8.5 in. thick) occur every 3.0 to 5.0 ft up-section. Vitreous-type chert beds and fossils common in thicker bedded intervals in comparison with thinner bedded intervals. Brachiopods are the dominant faunal element, followed by crinoid debris. Upper contact is sharp and planar, and occurs at first grainstone bed of Fittstown Member......... 10.8

17. Interbedded argillaceous mudstone and vitreous chert, yellowish gray (5Y7/2), weathering to medium light gray (N6) with moderate greenish yellow (10Y7/4) splotches; beds thin to medium, slightly wavy, 2.0–8.0 in. thick; a decrease in argillaceous material occurs up-section. Chert is vitreous and pale greenish yellow (10Y8/2) weathered and fresh; beds discontinuous across outcrop, with slight pinch-and-swell appearance; in general, chert extends only 1.0–5.0 ft laterally along outcrop, averaging 4.0 in. thick. Fossils rare, except for some crinoidal material in upper few feet of unit. Upper contact appears very wavy to almost erosional and is augmented by a laminated argillaceous mudstone at the base of unit 18 .... 16.0

16. Interbedded argillaceous mudstone and tripolitic chert (Fig. 23), yellowish gray (5Y7/2), weathering to medium light gray (N6) with moderate greenish yellow (10Y7/4) staining; chert is light brown (5YR6/4), weathering to dark yellowish brown (10YR4/2). Mudstone in this interval is similar to that in unit 17, above; this unit differs, owing to presence of tripolitic chert (according to Amsden's [1960] terminology), which appears more porous and nodular than vitreous-type chert. Chert nodules average 3.0 in. thick and extend no more than 7.0–8.0 in. laterally along outcrop; mostly found in lower two-thirds of unit. Mudstones alternate between indurated intervals and less indurated, argillaceous intervals 2.0–4.0 ft thick; beds wavy, thin, 1.0–6.0 in. thick. No fossils evident. Upper contact is gradational, and depends on the first occurrence of vitreous-type chert 17.3

Stop 3

Goddard Youth Camp Measured Section *(continued)*



HARAGAN FORMATION (total exposed thickness, 69.5 ft)

15. Skeletal mudstone (Fig. 23), pale yellowish brown (10YR6/2), weathering to very pale orange (10YR 8/2) to medium gray (N5), with pale yellowish orange (10YR8/6) staining along fractures; beds wavy (becoming only slightly wavy near top), thin to laminated near base, 0.25–1.0 in. thick, averaging 0.5 in. thick, and becoming thin to medium in upper, transitional 20 in. of unit as beds are 3.0–12.0 in. thick. As a whole, unit is less argillaceous and exhibits a better carbonate texture than other units of the Haragan Formation. Fossils sparse, dominated by well-preserved crinoid columns, whereas rare, whole brachiopods occur in upper half. Upper contact with Bois d'Arc gradational, and depends on the first occurrence of chert 6.6

14. Very argillaceous mudstone (Fig. 24), moderate orange pink (5YR8/4), weathering to grayish

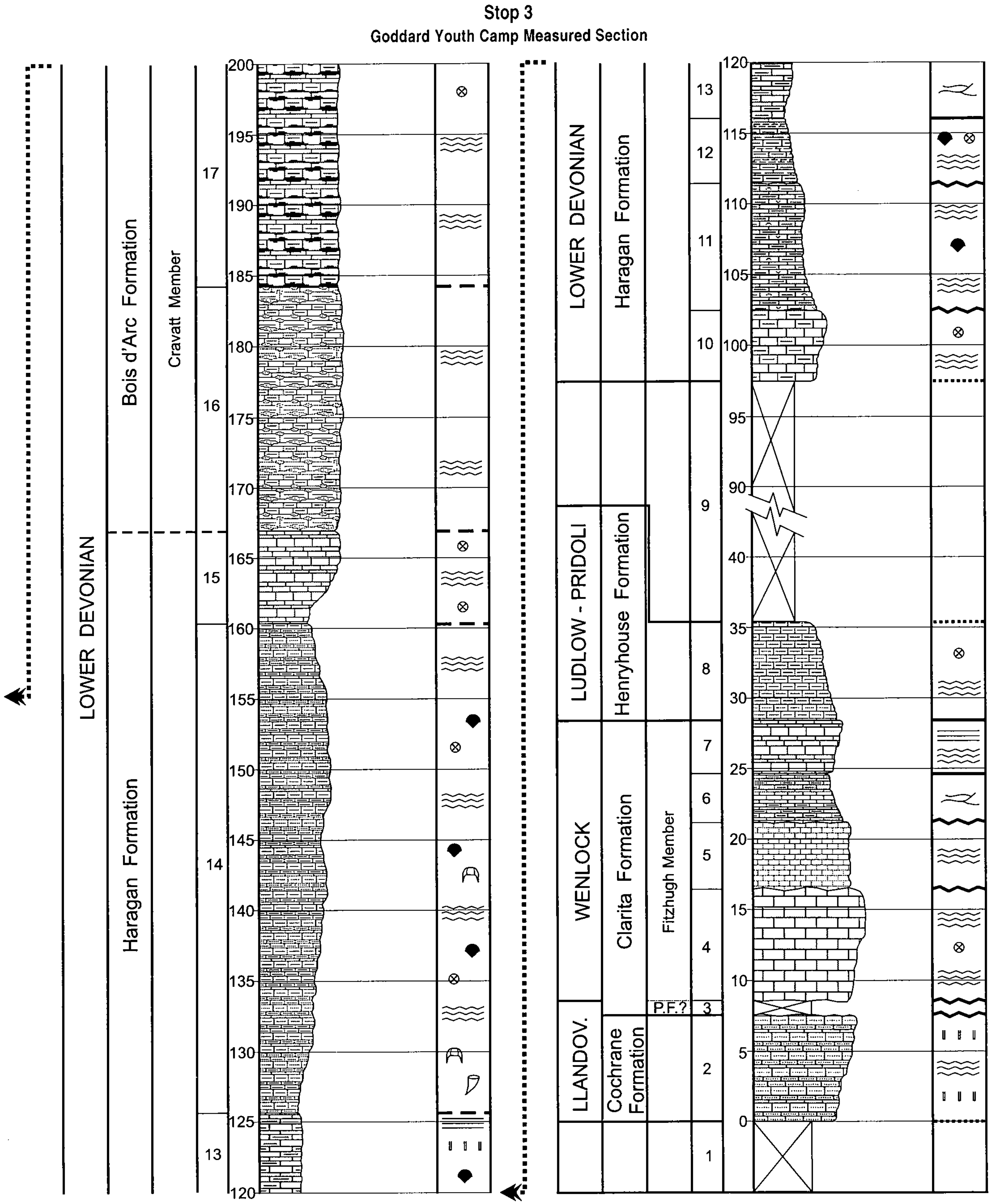


Figure 21 *(above and facing page)*. Graphic columnar section of exposed parts of the Hunton Group at Stop 3 (Goddard Youth Camp section). Explanation of symbols found in Appendix.

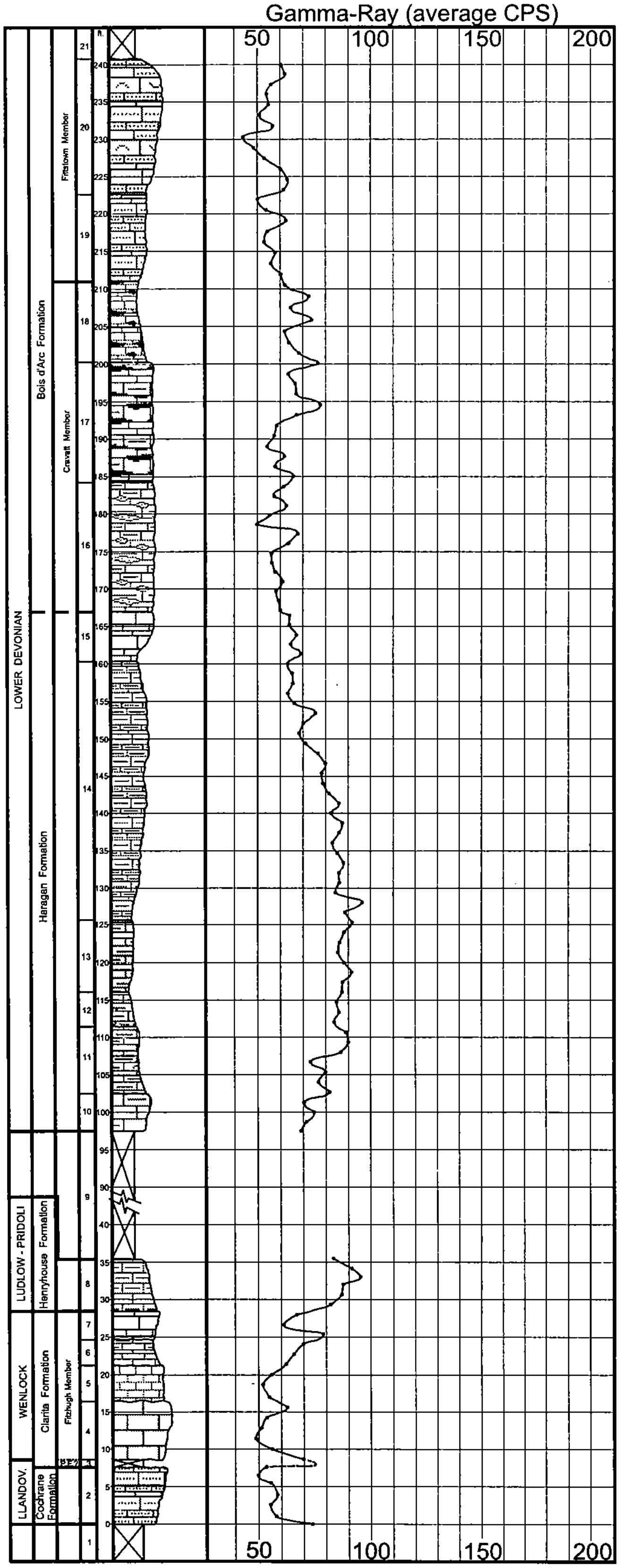


Figure 22. Gamma-ray profile of the Hunton Group exposed at the Goddard Youth Camp (Stop 3). Note gradual decrease in gamma-ray values going up the Haragan section, indicating a decrease in argillaceous material, which implies a gradual decrease in water depth throughout its deposition.

This gradational nature is well exemplified at this site. The uppermost transitional Haragan beds (Fig. 21, unit 15; Fig. 23) are less argillaceous and better indurated than the typical argillaceous mudstones cropping out below, and in hand sample they look similar to the lower mudstones of the Cravatt Member (Fig. 21, unit 16; Fig. 23). The presence of chert in the overlying Cravatt beds is the only definitive way to distinguish the two units.

The chert in the lower beds of the Cravatt is what Amsden (1960) described as a porous, tripolitic variety. It is usually less dense, more nodular, and weathers brown, in comparison with the bluish-weathering, denser, bedded vitreous chert common in the upper parts of the member. This vitreous chert can be viewed in beds cropping out farther up the ridge. As with the Haragan–Cravatt contact, the contact between Cravatt beds with tripolitic versus vitreous chert is highly gradational (Fig. 21, units 16, 17). Amsden (1960) not only noted extreme intergradation between the different members of the Bois d'Arc but also between the different varieties of chert in the Cravatt Member. For example, many specimens of tripolitic chert have a vitreous core, implying that the porous, tripolitic variety may be the result of weathering of the vitreous chert. Unfortunately, the best place to observe the transition between the different varieties of chert, as well as the contact between the Cravatt and Fittstown Members, is on the west side of the inlet.

On the east side of the cove, beds of the Fittstown Member can be seen along the north flank of the ridge

yellow (5Y8/4) to dark yellowish orange (10YR 6/6); beds in basal 13.3 ft thin and wavy, 1.0–2.0 in. thick, decreasing to 0.5–1.0 in. thick and becoming almost wavy laminated in uppermost 8.0 ft of interval. Abundant argillaceous material throughout. Well-preserved, whole fossils common throughout; composed of a diverse marine assemblage dominated by spiriferid brachiopods; also abundant crinoid debris (short stems and ossicles), small rugose corals, encrusting bryozoans, and trilobite fragments (usually only thoraxes and pygidia). Upper 8.0 ft of unit badly weathered owing to ground-water leaching (thin veins and stringers of leached calcite occur at base of weathered zone). Upper contact looks gradational 34.7

13. Very argillaceous mudstone and rarely wackestone, moderate orange pink (5YR8/4) to moderate greenish yellow (10Y7/4), weathering to grayish yellow (5Y8/4) to grayish orange (10YR 7/4); unit slightly more indurated than ones directly above and below; bedding laminated, very wavy to almost irregular at base, 0.25–1.0 in. thick, becoming more planar bedded in upper 16.0 in. of unit; thin shale (or very argillaceous mudstone) partings in lower half. Well-preserved, whole fossils common in basal half to two-thirds of unit; fauna dominated by small spiriferid brachiopods; burrow mottling com-

Figure 23. Contact (dashed line) between the Haragan Formation and the Cravatt Member of the Bois d'Arc Formation, Goddard Youth Camp section (Stop 3). Note nodular chert in the basal bed of the Cravatt and the absence of chert in upper beds of the Haragan. Scale in inches and centimeters.

(Fig. 21, unit 19). On fresh surfaces these Fittstown beds are a distinct light-colored (appearing almost white), glauconitic, skeletal grainstone that is easily differentiated from the brown-weathering mudstones and wackestones of the underlying Cravatt Member.

Besides the Bois d'Arc Formation, the upper part of the Haragan Formation is well represented at this site. Here, one can see the typical weathering and bedding

mon in upper one-third of unit. Upper contact is gradational over 1.0 to 1.5 ft 9.7

12. Very argillaceous mudstone and minor wackestone, interbedded with very calcareous shale, yellowish gray (5Y7/2), weathering to dark greenish yellow (10Y6/6); dark yellowish orange (10YR 6/6) staining along bedding; poorly exposed, weakly indurated; beds in more indurated zones wavy laminated, 0.25–0.5 in. thick; recessive shale intervals commonly 2.0–3.0 in. thick. Rare skeletal wackestone beds composed mostly of crinoid debris occur in middle of unit. Whole fossils readily weather free of matrix, consisting of brachiopods and crinoid debris. Upper contact sharp and planar 4.6

11. Very argillaceous mudstone and wackestone, pale yellowish brown (10YR6/2), weathering to pale yellowish orange (10YR8/6), grayish orange (10YR 7/4), or very pale orange (10YR8/2); beds wavy, thin to laminated, 0.5–1.0 in. thick, with scattered partings of more argillaceous mudstone; unit becomes more argillaceous and thinner bedded toward top. Fossils readily weather free of matrix; all are well preserved and composed predominantly of spiriferid and rhynchonellid brachiopods. Upper contact is sharp but wavy 8.9

10. Argillaceous skeletal mudstone, pale yellowish orange (10YR8/6), weathering to dark yellowish brown (10YR4/2) to grayish orange pink (5YR 7/2); unit well indurated and much more resistant to weathering than units above. Beds thin to medium, very wavy, appearing to pinch and swell across outcrop, 1.0–5.0 in. thick but averaging ~2.0 in. thick. Fossils consist mostly of crinoid debris, with some small spiriferid brachiopods. Upper contact is sharp but wavy; lower contact is covered 5.0

9. Covered interval. Includes lower Haragan and most of Henryhouse 62.1

HENRYHOUSE FORMATION (total exposed thickness, 7.0 ft)

8. Argillaceous mudstone, grayish orange (10YR7/4) fresh and weathered; unit poorly exposed; beds planar, thin to medium, 3.0–9.0 in. thick (thin beds more common in basal part of exposure). Fossils rare, consisting exclusively of crinoid plates and ossicles. Upper contact is covered ... 7.0

***Note:** Amsden (1960, appendix 1, p. 249) originally measured 28 ft of Henryhouse Formation at this locality.*

CHIMNEYHILL SUBGROUP (total thickness, 28.5 ft)

CLARITA FORMATION (total thickness, 20.9 ft)

Fitzhugh Member

7. Skeletal mudstone, yellowish gray (5Y7/2), weathering to medium dark gray (N4); unit is dense, well indurated; minor argillaceous material occurs in upper 1.0 ft; beds wavy laminated at base, grading into planar-thin toward top, generally 0.5–4.0 in. thick. Scattered crinoid fragments only fossils observed. Upper contact appears sharp and planar 3.8

6. Argillaceous mudstone, color variable, ranging from pale yellowish brown (10YR6/2) at base to grayish orange (10YR7/4) at top, weathering to grayish pink (5R8/2) at base to pale red (10R6/2) at top; unit looks atypical of Fitzhugh but is similar in texture to some Haragan or Cravatt beds; beds irregular to very wavy, laminated to thin, averaging 0.5 in. thick at base to 1.5 in. thick toward top; some recessive weathering (~3.0 in. thick), very argillaceous mudstone intervals occur in middle of unit. No fossils evident. Upper contact sharp, planar, and augmented by distinct, 8.0-in.-thick, very argillaceous mudstone bed 3.5

***Note:** This unit probably corresponds to Amsden and others' (1980) ostracode silty marlstone biofacies of the Fitzhugh Member.*

5. Skeletal mudstone (Fig. 25), yellowish gray (5Y 7/2), weathering to medium dark gray (N4); beds thin and wavy, remaining a consistent 2.0 in. thick throughout. Some crinoid fragments occur. Upper contact is sharp but wavy 4.8

4. Skeletal mudstone, yellowish gray (5Y7/2), weathering to very pale orange (10YR8/2) to medium dark gray (N4); similar to unit 5 above except for beds, which are slightly wavy, medium to thick, 5.0–12.0 in., with thinner bedded material more common at top. Some crinoid material sparsely scattered throughout. Upper contact is sharp but wavy 7.8

Prices Falls Member(?)

3. Covered interval, which probably represents Prices Falls Member 1.0

COCHRANE FORMATION (total thickness, 7.6 ft)

2. Glauconitic grainstone intercalated with mudstone, yellowish gray (5Y7/2), weathering to medium gray (N5) to pale brown (5YR5/2); unit mostly a sparry grainstone, but some pods and lenses of mudstone occurring throughout formation, which weathers to dark yellowish orange (10YR6/6); beds wavy, thin to medium, 2.0–8.0 in. thick, averaging 5.0 in. thick; thinner beds more common at base of unit. Some lower bedding surfaces have large, horizontal ?*Thallasonoides* burrows, which give bedding its wavy to irregular appearance; however, some bedding surfaces appear as if channeled. Glauconite occurs throughout unit as small, individual grains. Unidentifiable fossil debris abundant, most likely crinoidal. Upper contact is sharp but wavy; lower contact is covered 7.6
1. Covered interval, which probably represents Sylvan Shale .... 5.0+

Total thickness of section 241.0+

characteristics of the argillaceous mudstones and wackestones that compose most of the Haragan (Fig. 24). A close examination of these beds shows that the Haragan is richly fossiliferous, and the fossils easily weather free of the surrounding matrix. These weathering characteristics are obvious in the lower part of the exposed section, where the enclosed fossils are easily liberated from the shaly intervals of lime mudstone (Fig. 21, units 11, 12).

Besides the fossils, also note the extreme argillaceous nature of these Haragan limestones (Fig. 24) and consider how the abundance of terrigenous clastics would affect reservoir development. The large volume

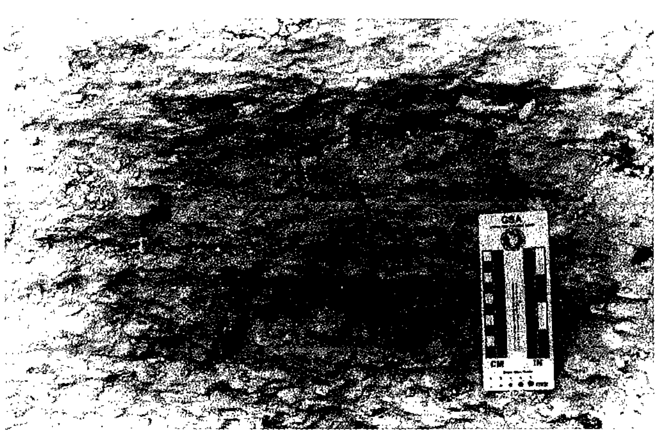


Figure 24. Unit 14 of the Haragan Formation at the Goddard Youth Camp section (Stop 3), showing wavy to irregularly laminated bedding of the argillaceous, whole-fossil mudstones and wackestones. Scale in inches and centimeters.

Figure 25. Unit 5, Goddard Youth Camp section (Stop 3), showing typical wavy, thin-bedded Fitzhugh mudstones. Scale in inches and centimeters.

of clay- and silt-size terrigenous detritus in these beds (as well as in the underlying Henryhouse) invariably inhibits development of good porosity and permeability, and underscores the reason why neither argillaceous facies has a history as an effective hydrocarbon reservoir. Only in some parts of the Anadarko basin, where sufficient dolomitization has created secondary porosity in the *Kirkidium* grainstones and packstones of the Henryhouse, do reservoirs develop in this part of the Hunton section.

The presence of abundant argillaceous material in the Haragan is also reflected in the gamma-ray profile of this section (Fig. 22). Note that gamma-ray values measured throughout the argillaceous Haragan mudstones range in the high seventies to eighties. The cleaner limestones of the Bois d'Arc Formation and Chimneyhill Subgroup produce a much lower gamma-ray signal that varies only between 50 and 60 CPS (Fig. 22).

The rest of the Hunton Group (Fig. 21, units 2–8) are exposed on the south side of Goddard Youth Camp Road. Anyone wishing to examine this section in more detail should contact Mr. Wayne Edgar, owner and operator of the Goddard Youth Camp.

STOP 4 – Optional

Bois d'Arc Ridge Measured Section

This section is nearly identical to that of the Goddard Youth Camp. It is included because it illustrates the typical outcrop expression of the different members of the Hunton Group and provides easier access to the Chimneyhill Subgroup.

What one should notice first in this area is the prominent east–west-trending ridge that extends along the south side of Goddard Youth Camp Road. The north side of the ridge is composed exclusively of units of the Bois d'Arc Formation, with unit 20 of the Cravatt Member exposed on the east end of the ridge and unit 24 of the Fittstown Member exposed on the west end (Figs. 26–28). Most of these beds in the Cravatt Member contain well-preserved fossil assemblages that can easily be seen at the tops of exposed bedding surfaces.

The rest of the Hunton Group crops out on the south side of the ridge. As one walks to the west, the area opens into a meadow that is floored with spotty outcrops of Henryhouse and Haragan beds (Fig. 29). Continue walking west for about 1,000 ft until a broad sad-

MEASURED SECTION, STOP 4
Surface Expression of Hunton Group
Bois d'Arc Ridge Measured Section

***Location:** Excellent exposures of the Bois d'Arc Formation (units 20–24) can be viewed along a prominent ridge on south side of Goddard Youth Camp Road in the N½NE¼SE¼ sec. 31; the rest of the Hunton Group can be found on the south side of Bois d'Arc ridge. The best exposures of the Chimneyhill Subgroup (units 2–6) occur in the SE¼NW¼NE¼SE¼ sec. 31. Spotty occurrences of the Henryhouse Formation (units 7–11) are best seen in the SW¼NW¼NE¼SE¼ sec. 31. The Haragan Formation and the basal part of the Cravatt Member of the Bois d'Arc Formation (units 15–20) can be seen in the SW¼ NE¼NW¼SE¼ sec. 31, T. 1 S., R. 3 E., Murray County, Oklahoma (Dougherty, Oklahoma, 7.5′ quadrangle).*

Thickness (feet)

HUNTON GROUP (total thickness, 258.9+ ft)

BOIS D'ARC FORMATION (total thickness, 55.9+ ft)

Fittstown Member

25. Covered interval, some of which may represent Woodford Shale .... 5.0+

24. Skeletal grainstone, with minor packstone interbeds (Fig. 28); interval poorly exposed and badly weathered; very light gray (N8), weathering to grayish green (10G4/2). Beds thin to medium, generally planar but becoming wavy in middle part of section, 3.0–9.0 in. thick but averaging ~6.0 in. thick; some packstone textures occur in basal half of unit. Small glauconite grains occur throughout but are most abundant in basal half. Fragments of crinoid material common, along with other unidentifiable shell debris. Upper contact is covered 5.9

23. Whole-fossil wackestone, greenish gray (5G6/1), weathering to grayish yellow (5Y8/4); interval has good carbonate texture; beds thin to medium, slightly wavy, 3.0–6.0 in. thick, averaging ~5.0 in. thick. Well-preserved, whole fossils common on exposed bedding surfaces; crinoid stems particularly abundant, along with *Meristella* sp. as monospecific assemblages. Upper contact sharp but wavy, and placed at first occurrence of grainstone texture from unit above 4.2

Cravatt Member

22. Slightly argillaceous mudstone and wackestone with minor chert interbeds; yellowish gray (5Y 7/2), weathering medium gray (N5), with dark yellowish brown (10YR4/2) staining on bedding surfaces; chert, weathering to pale yellowish orange (10YR8/6), is more common in basal and upper one-third of unit. Beds variable, laminated to medium; laminated material very wavy, more common in basal one-third, averaging ~0.25 in. thick; thicker beds only slightly wavy, 2.0–6.0 in. thick, averaging ~4.0 in. thick. Where present, chert beds inconspicuous, lenticular, extending no more than several feet along strike. Well-preserved, whole fossils common along exposed bedding surfaces; monotypic zones of *Howellella* sp. and *Meristella* sp. occur 16.2 and 18.7 ft above base of unit, respectively. Upper contact is gradational and based on first occurrence of silt-free carbonate 21.5

21. Interbedded argillaceous mudstone and vitreous chert; yellowish gray (5Y7/2), weathering medium gray (N5). Beds thin to medium, slightly wavy, 3.0–8.0 in. thick. Gradual decrease in argillaceous content up-section. Chert is vitreous, very pale blue (5B8/2) to pale pink (5RP8/2) fresh and weathered; beds appear continuous across outcrop, averaging 3.0 in. thick, with only slight pinch and swell. Crinoidal material common along bedding planes. Upper contact appears sharp but very wavy and is based on first occurrence of wavy laminated beds of unit above 10.8

20. Interbedded argillaceous mudstone and tripolitic chert, yellowish gray (5Y7/2), weathering to medium light gray (N6); chert is light brown (5YR 6/4) to grayish orange pink (5YR7/2) fresh and weathered. Mudstone beds 1.0–5.0 in. thick, with thinner bedded material more common in basal half. Chert throughout interval; beds very wavy, discontinuous, averaging 3.0 in. thick; extend no more than 2–3 ft laterally along outcrop. Few fossils evident. Upper contact is gradational and based on first occurrence of vitreous-type chert beds 13.5

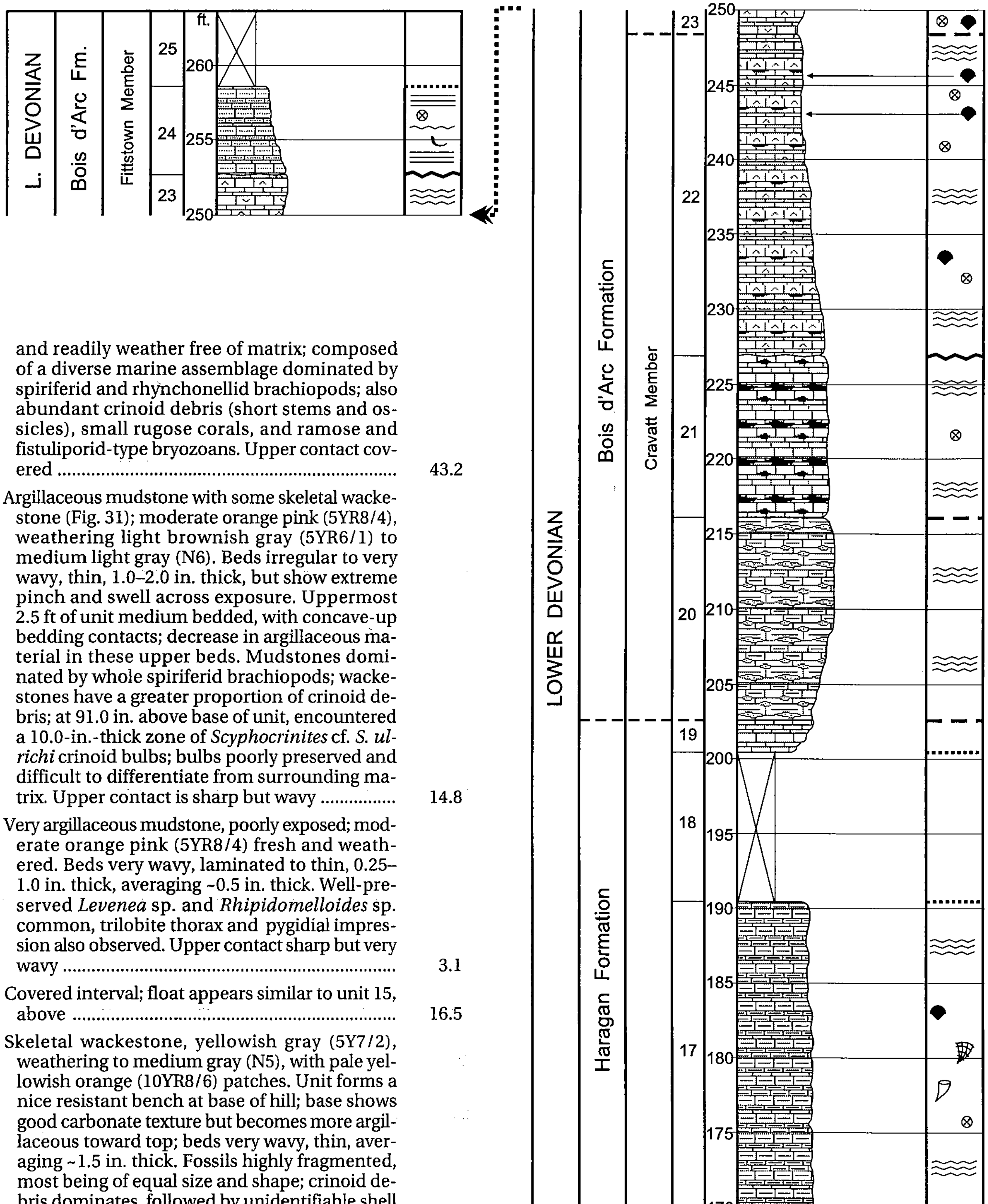
HARAGAN FORMATION (total thickness, 96.5+ ft)

19. Mudstone, slightly argillaceous; pale yellowish brown (10YR6/2), weathering very pale orange (10YR8/2) to medium light gray (N6); beds planar to slightly wavy, medium, 7.0–9.0 in. thick. Except for absence of chert, unit appears similar to basal mudstones of Cravatt Member. No fossils evident. Upper contact gradational, and depends on the first occurrence of chert at the base of Bois d'Arc Formation 2.2

18. Covered interval 10.0

17. Very argillaceous mudstone and wackestone (Fig. 31), moderate orange pink (5YR8/4), weathering grayish yellow (5Y8/4) to dark yellowish orange (10YR6/6). Beds in basal one-third thin, wavy, 1.0–2.0 in. thick; beds in upper two-thirds laminated to thin, 0.5–1.0 in. thick. Gradual decrease in argillaceous material toward top of unit. Well-preserved, whole fossils common

Stop 4
Bois d'Arc Ridge Measured Section *(continued)*



and readily weather free of matrix; composed of a diverse marine assemblage dominated by spiriferid and rhynchonellid brachiopods; also abundant crinoid debris (short stems and ossicles), small rugose corals, and ramose and fistuliporid-type bryozoans. Upper contact covered 43.2

16. Argillaceous mudstone with some skeletal wackestone (Fig. 31); moderate orange pink (5YR8/4), weathering light brownish gray (5YR6/1) to medium light gray (N6). Beds irregular to very wavy, thin, 1.0–2.0 in. thick, but show extreme pinch and swell across exposure. Uppermost 2.5 ft of unit medium bedded, with concave-up bedding contacts; decrease in argillaceous material in these upper beds. Mudstones dominated by whole spiriferid brachiopods; wackestones have a greater proportion of crinoid debris; at 91.0 in. above base of unit, encountered a 10.0-in.-thick zone of *Scyphocrinites* cf. *S. ulrichi* crinoid bulbs; bulbs poorly preserved and difficult to differentiate from surrounding matrix. Upper contact is sharp but wavy 14.8

15. Very argillaceous mudstone, poorly exposed; moderate orange pink (5YR8/4) fresh and weathered. Beds very wavy, laminated to thin, 0.25–1.0 in. thick, averaging ~0.5 in. thick. Well-preserved *Levenea* sp. and *Rhipidomelloides* sp. common, trilobite thorax and pygidial impression also observed. Upper contact sharp but very wavy 3.1

14. Covered interval; float appears similar to unit 15, above 16.5

13. Skeletal wackestone, yellowish gray (5Y7/2), weathering to medium gray (N5), with pale yellowish orange (10YR8/6) patches. Unit forms a nice resistant bench at base of hill; base shows good carbonate texture but becomes more argillaceous toward top; beds very wavy, thin, averaging ~1.5 in. thick. Fossils highly fragmented, most being of equal size and shape; crinoid debris dominates, followed by unidentifiable shell material. Upper contact covered 6.7

12. Covered interval. Includes lower Haragan and upper Henryhouse Formations 30.7

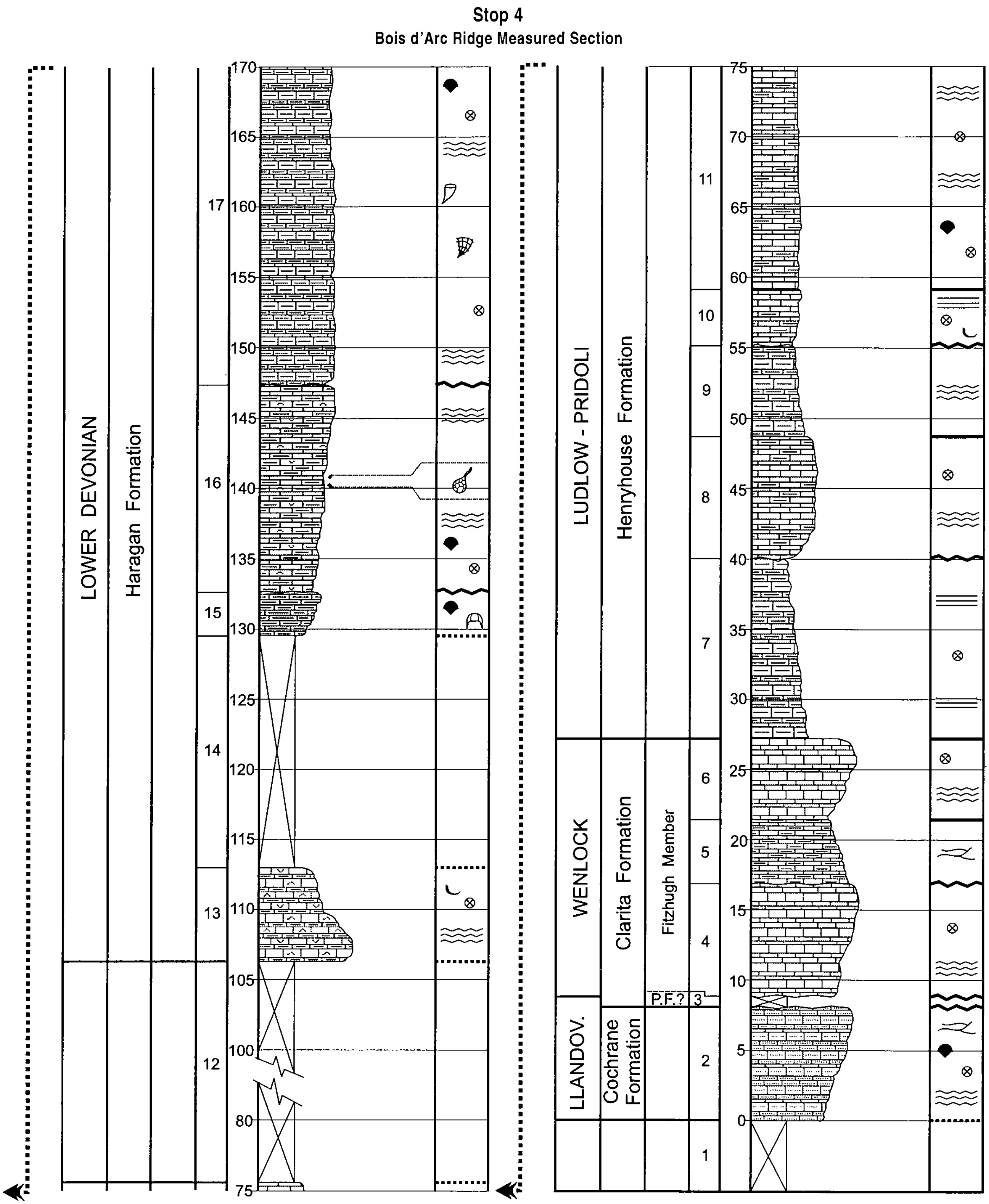


Figure 26 *(above and facing page)*. Graphic columnar section of the Hunton Group exposed at, and on the south side of, a prominent ridge along Goddard Youth Camp Road (Bois d'Arc ridge section, Stop 4). Explanation of symbols found in Appendix.

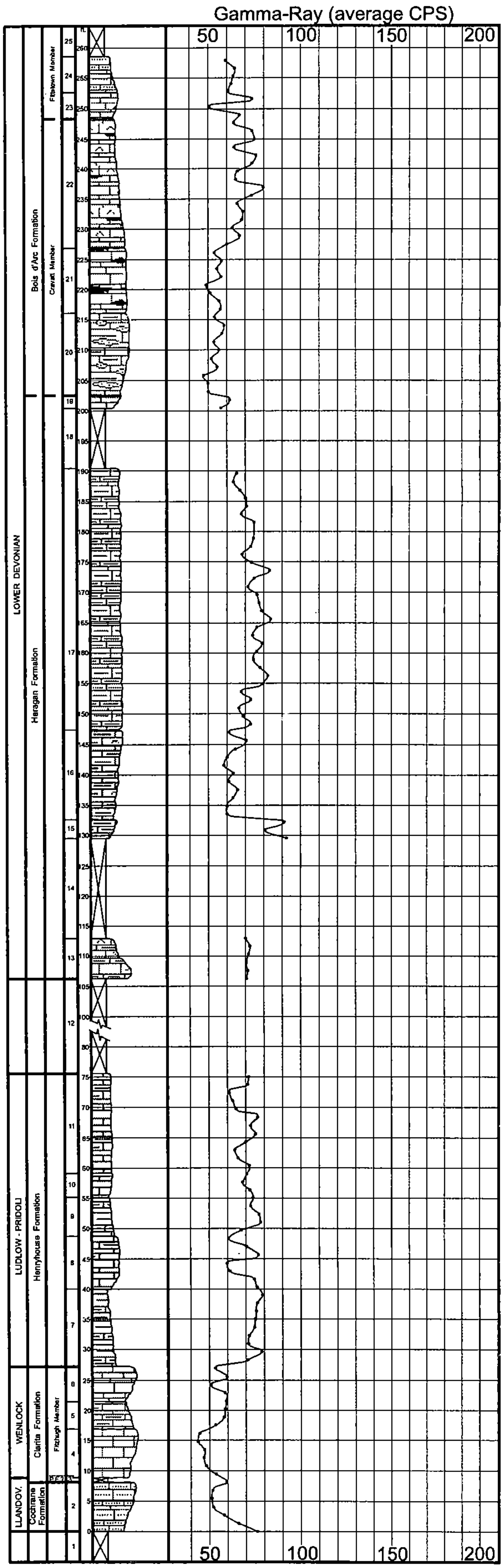


Figure 27 *(left)*. Gamma-ray profile of the Hunton Group exposed on the south side of the prominent ridge at Stop 4 (Bois d'Arc ridge section). See text for additional information.

HENRYHOUSE FORMATION (total thickness, 48.5+ ft)

11. Slightly argillaceous mudstone, yellowish gray (5Y7/2), weathering medium light gray (N6), with dark yellowish brown (10YR4/2) staining along bedding; more argillaceous beds weathering to grayish orange (10YR7/4). Beds wavy, thin, 1.0–4.0 in. thick, averaging ~3.0 in. thick; more argillaceous intervals tend to be thicker bedded, averaging ~5.0 in. thick. Fossil fragments scattered throughout, consisting of crinoid plates and ossicles, along with some small, unidentifiable brachiopods. Upper contact is covered..... 16.5

10. Slightly argillaceous mudstone (Fig. 30); unit a distinct pale reddish brown (10R5/4) fresh and weathered. Beds planar to slightly wavy, thin to medium, 3.0–6.0 in. thick, averaging ~5.0 in. thick. Mudstone very dense, weakly argillaceous in lower half. Fossils present, consisting of small bits of crinoid and brachiopod fragments. Upper contact is sharp and planar, augmented by distinct color change into next unit 4.0

9. Argillaceous mudstone; grayish orange (10YR 7/4), weathering medium light gray (N6), poorly exposed owing to recessive weathering. Beds thin, slightly wavy, 1.0–3.0 in. thick, averaging close to 1.5 in. thick. Fossils sparse, only scattered crinoid fragments observed. Upper contact is sharp but wavy; exhibits distinct color difference from overlying unit 6.4

8. Slightly argillaceous mudstone; looks similar to unit 11, above. Yellowish gray (5Y7/2) to grayish orange (10YR7/4), weathering medium light gray (N6). Beds wavy, thin, 1.0–3.0 in. thick, averaging ~1.5 in. thick; typically, argillaceous beds alternate with nonargillaceous ones and tend to have wavier bedding contacts. Unit is more resistant to weathering than ones above and below. Fossil fragments scattered throughout, consisting mainly of crinoid plates and ossicles. Upper contact is sharp and planar 8.7

7. Argillaceous mudstone, poorly exposed; grayish orange (10YR7/4), weathering medium light gray (N6) to pale yellowish brown (10YR6/2). Beds appear planar, thin, 1.0–3.0 in. thick, but averaging ~2.5 in. thick. Fossils sparse, represented only by crinoid fragments. Upper contact is sharp and wavy 12.9

CHIMNEYHILL SUBGROUP (total thickness, 27.3 ft)

CLARITA FORMATION (total thickness, 19.2 ft)

Fitzhugh Member

6. Fossiliferous mudstone, yellowish gray (5Y7/2), weathering medium dark gray (N4); unit is well indurated, with minor argillaceous zones in basal 16.0 in. and upper 24.0 in. of unit. Beds wavy, thin to medium, 1.0–10.0 in. thick, with thinner bedded material more common in argillaceous zones. Fossils present, represented by sparse

crinoid plates or small stems. Upper contact appears sharp and planar 5.8

5. Argillaceous mudstone; unit is poorly exposed along outcrop; pale yellowish brown (10YR6/2), weathering grayish pink (5R8/2), with pale red (10R6/2) staining along bedding planes. Beds irregular to very wavy, thin, averaging ~2.0 in. thick. No fossils evident. Upper contact is sharp and planar 4.6

Note: This unit corresponds to Amsden and others' (1980) ostracode silty marlstone biofacies of the Fitzhugh Member.

4. Mudstone, yellowish gray (5Y7/2), weathering very pale orange (10YR8/2) to medium dark gray (N4). Beds slightly wavy to planar, thin to medium, 1.0–8.0 in. thick, with thinner bedded material more common in base and upper one-third of interval. Some crinoid material scattered throughout. Upper contact is sharp but wavy 8.0

Prices Falls Member(?)

3. Covered interval, which probably represents Prices Falls Member 0.8

COCHRANE FORMATION (total thickness, 8.1 ft)

2. Glauconitic grainstone, yellowish gray (5Y7/2), weathering medium gray (N5) to pale brown (5YR5/2). Beds wavy, medium to thick, 6.0–20.0 in. thick, decreasing to 4.0–6.0 in. thick in upper 2 ft; scattered mudstone partings occur along bedding in upper part of unit. Glauconite occurs throughout as small, individual grains. Sparite cement coarse, giving limestone a recrystallized texture. Unidentifiable fossil debris abundant, most likely crinoidal, but some whole brachiopods do occur. Upper contact is sharp but wavy; lower contact is covered 8.1

1. Covered interval, which probably represents Sylvan Shale .... 5.0+

Total thickness of section 258.9+

dle is crossed. On the left (south) is a prominent tree line that parallels the open glade and which approximately corresponds with the top of the Chimneyhill Subgroup.

At this locality the Chimneyhill Subgroup consists only of the Cochrane and Clarita Formations. Thus, the Cochrane Formation rests directly on the Sylvan Shale in this area of the Arbuckle Mountains (Amsden, 1960). Owing to the well-indurated nature of its members, the Chimneyhill Subgroup forms a prominent ledge sandwiched between the recessively weathering Sylvan Shale and the softer weathering, argillaceous beds of the Henryhouse Formation (Fig. 30). The gamma-ray profile reflects this weathering dynamic, as the units in the Chimneyhill Subgroup have low, uniform gamma-ray values in comparison with the high and more variable gamma-ray values measured from the overlying Henryhouse Formation (compare the gamma-ray values at Stop 7, Fig. 42). The exception to this trend is the Prices Falls Member of the Clarita Formation and an argillaceous unit within the Fitzhugh Member of the Clarita (Fig. 22, unit 6; Fig. 26, unit 5). Both of these units exhibit higher than normal gamma-ray readings in comparison with the other members of the Chimneyhill. The reason for these differences is invariably due to the amount of argillaceous material that is found in each of these anomalous units. Overall, most members of the Chimneyhill Subgroup have little argillaceous material and thus emit lower gamma-ray values. The Henryhouse and Haragan Formations also contain abundant terrigenous detritus and therefore emit higher gamma-ray values. There are exceptions, as some clean limestone intervals in the Henryhouse and Haragan exhibit

Figure 28. Unit 24, Bois d'Arc ridge section (Stop 4), showing typical thin to medium, planar beds of Fittstown grainstones. Hammer for scale is ~2 ft long and rests on top of unit 23.

Figure 29. South side of Bois d'Arc ridge (Stop 4), shot from the Haragan–Bois d'Arc contact, showing typical spotty outcroppings of the Haragan and Henryhouse Formations. Tree line at base of slope approximates top of the Chimneyhill Subgroup.

Figure 30. Spotty outcropping of the Henryhouse Formation, Bois d'Arc ridge section (Stop 4). Resistant bed at left is base of unit 10. Tree line at right approximates the top of the Chimneyhill Subgroup. Stratigraphic top is to the left.

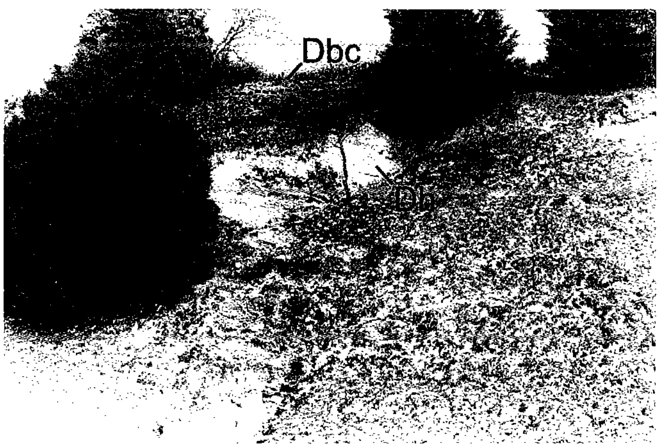


Figure 31. Typical weathering character of the Haragan Formation (*Dh*), Bois d'Arc ridge section (Stop 4). *Dh* points to unit 17 of the Haragan. Resistant beds to the right of pine tree in foreground correspond to the base of unit 16. Dashed line at top approximates the Cravatt Member (*Dbc*)–Haragan contact.

gamma-ray values similar to those of the Chimneyhill (e.g., units 8, 11, and 16 at this section) (Figs. 26, 27). Units of the Bois d'Arc Formation contain intermediate levels of argillaceous material. As one would expect, the corresponding gamma-ray values of the Bois d'Arc are intermediate to the values measured from the clean Chimneyhill limestones and from the argillaceous Haragan mudstones. This trait is also exemplified in Figure 27.

Increased argillaceous material in the Hunton limestones also affects the surface expression and weathering patterns of the group. Note the continuous exposure of the clean Chimneyhill limestones in comparison to the spotty nature of the argillaceous Henryhouse and Haragan outcrops (Figs. 30, 31). Traversing north from the top of the Chimneyhill, scattered beds of more resistant Henryhouse and Haragan lithologies can be seen interspersed between more extensive, covered intervals that represent less resistant argillaceous Henryhouse–Haragan units (Figs. 29, 30). This pattern continues up the ridge until the more resistant, weakly argillaceous beds of the Bois d'Arc Formation are encountered (Fig. 31).

Throughout this area, Hunton beds dip to the north from 25° to 45° and strike N. 70°–76° E. The section does not appear to have been faulted, although faults have been mapped in this area (see Stop 5—Hunton Anticline Quarry Measured Section, below).

STOP 5

Hunton Anticline Quarry Measured Section

The Hunton anticline quarry was first opened during the building of the Lake in the Arbuckles dam (Al-Shaieb and others, 1993b) (Figs. 32, 33). In the quarry face, a broad, west–northwest-plunging anticline can be observed within the upper part of the Hunton Group section. The quarry section starts at the top of the Haragan Formation and continues upward to the Fittstown–Woodford Shale contact (Fig. 34). Also in the quarry wall, there is an obvious reverse fault that extends almost parallel to the fold axis and which cuts across the south limb of the fold. The amount of displacement along this fault is only a few tens of feet, but it is enough to expose upper Haragan beds along the base of the south wall of the quarry.

Unlike at previous localities, the Haragan Formation appears lithologically distinct from the overlying beds of the Cravatt Member of the Bois d'Arc Formation (Figs. 32, 33, 35). In the quarry wall the Haragan is a brown-stained argillaceous mudstone that contrasts nicely with the grayish-weathering, cherty, slightly argillaceous beds of the Cravatt Member. Note a series of laminated to thin, very argillaceous beds that occur near the Haragan–Cravatt contact (Fig. 32, units 2, 4; Fig. 35). These laminated, shaly breaks are rarely seen in outcrops or road cuts but are common in the fresh exposure of the quarry wall (e.g., units 7, 12, and 14 of the Cravatt Member). Their presence indicates that the Bois d'Arc Formation has a more complicated history of sea-level change than was previously interpreted from surface outcrops.

Even with its more complicated depositional history, the Cravatt Member at this site retains the same overall sequence of units observed at previous stops. The usual progression starts with a basal tripolitic-cherty limestone (Fig. 32, units 5, 6). This is followed by

Stop 5
Hunton Anticline Quarry Measured Section

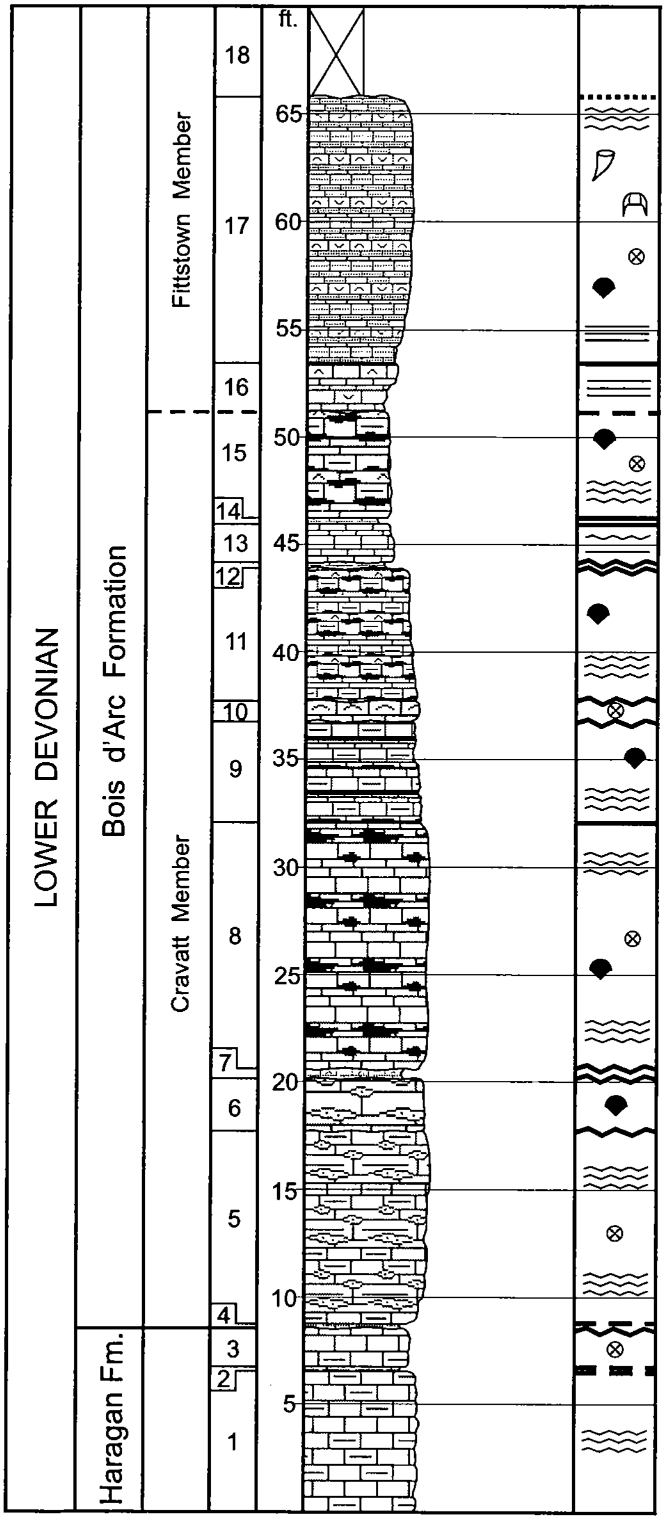


Figure 32. Graphic columnar section of exposed parts of the upper Hunton Group (upper Haragan through Bois d'Arc Formations) at Stop 5 (Hunton anticline quarry section). Explanation of symbols found in Appendix.

MEASURED SECTION, STOP 5
Bois d'Arc Formation
Hunton Anticline Quarry Measured Section

Location: The quarry is along the S line of the SE¼SE¼NW¼ sec. 31, T. 1 S., R. 3 E., Murray County, Oklahoma (Dougherty, Oklahoma, 7.5′ quadrangle).

	Thickness (feet)
HUNTON GROUP (total exposed thickness, 65.7 ft)	
BOIS D'ARC FORMATION (total thickness, 57.2 ft)	
Fittstown Member	
18. Covered interval; may contain some Woodford Shale	5.0+
17. Glauconitic, well-sorted skeletal grainstone (Fig. 38), interbedded with some whole-fossil wackestone and packstone. Grainstones are very light gray (N8) to bluish white (5B9/1), weathering grayish green (10G4/2), with medium dark gray (N4) stain along outcrop face; wackestone and packstone a yellowish gray (5Y7/2), weathering same as grainstones. Beds planar at base, becoming wavy near top, mostly medium to thick, 6.0–12.0 in. thick; usually grainstones more evenly but thicker bedded, averaging 10.0 in. near base and grading to 7.0 in. to top; wackestones and packstones average ~6.0 in. thick. Gradual decrease in wackestone beds in upper half of unit. Glauconite common in grainstones and occurs as irregular masses and small individual grains; rare in wackestones. Minor chert occurs as small nodules and thin partings in grainstone. Whole-fossil brachiopods and well-preserved crinoid stems common in wackestones; grainstones typically composed of unidentifiable fossil fragments, although a well-preserved rugose coral and trilobite thorax were observed in upper half of interval. Upper contact is covered ...	12.4
16. Whole-fossil wackestone and skeletal packstone, yellowish gray (5Y7/2), weathering medium dark gray (N4); lithology same as wackestone–packstone beds in unit above; essentially, unit has good carbonate texture with very little argillaceous material; beds planar, thin to medium, 3.0–6.0 in. thick. Whole-fossil brachiopods and crinoid stems common along bedding surfaces of wackestones; packstones typically composed of large brachiopod fragments and short crinoid stems and ossicles. Upper contact is sharp, planar, and placed at first grainstone bed from unit above	2.2

Note: The Fittstown Member is best exposed along main access road just below present level of quarry floor.

Cravatt Member

15. Whole-fossil wackestone and mudstone interbedded with thin, vitreous chert (Fig. 37); greenish gray (5GY6/1), weathering medium bluish gray (5B5/1), with grayish yellow (5Y8/4) stains along bedding contacts (corresponds with increased argillaceous material at contacts). Beds wavy, medium, 4.0–6.0 in. thick. Mudstones tend to be thicker bedded than wackestones. Well-pre-

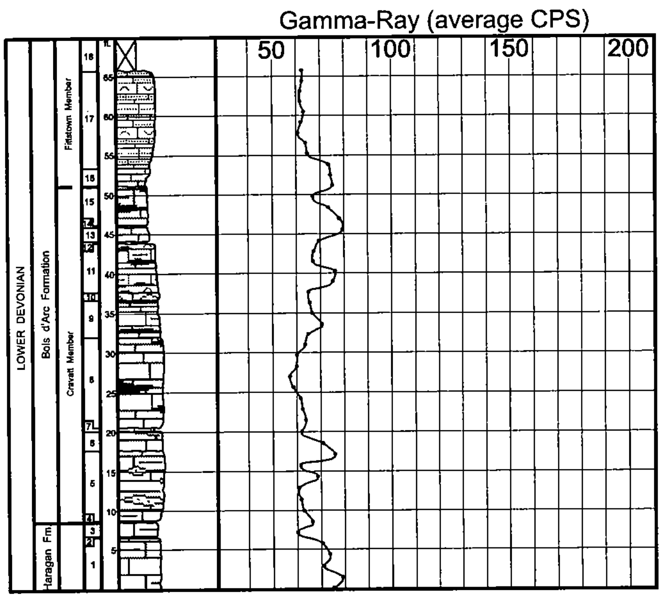


Figure 33. Gamma-ray profile of section exposed at the Hunton anticline quarry (Stop 5). See text for additional information.

served brachiopods and crinoid stems common throughout, particularly noticeable along bedding surfaces. Some laminated, skeletal-packstone intervals are interbedded with thin, vitreous chert beds. Upper contact appears wavy, most likely gradational; picked where limestone beds having good carbonate texture are encountered and no obvious chert occurs 5.3

14. Very argillaceous mudstone, pale yellowish orange (10YR8/6) fresh and weathered; bedding very wavy, laminated. Unit noticeably recessive. No fossils evident. Upper contact is sharp and planar 0.2

13. Whole-fossil mudstone (Fig. 37), pale olive (10Y 6/2), weathering light gray (N7) to light bluish gray (5B7/1). Beds planar medium to wavy laminated, 0.5–3.0 in. thick; laminated material tends to be more argillaceous than medium-bedded mudstones and are more common at top of unit. Well-preserved brachiopods, ramose and fenestrate bryozoans, and crinoid stems common along bedding contacts. Upper contact is sharp and planar 1.8

12. Very argillaceous mudstone, similar to unit 14 above, poorly exposed and recessive; color dusky yellow (5Y6/4) fresh and weathered; bedding very wavy laminated. Some glauconite(?) grains occur. No fossils evident. Upper contact sharp but very wavy 0.2

11. Slightly argillaceous mudstone and wackestone interbedded with chert; pale olive (10Y6/2) to yellowish gray (5Y7/2), weathering light bluish gray (5B7/1) to light gray (N7) to very light gray (N8) at top. Chert weathers to pale yellowish orange (10YR8/6). Beds wavy, thin to medium, some wavy laminated in upper half of unit, 0.25–3.0 in. thick. Laminated intervals tend to be more argillaceous and contain less chert. Whole brachiopods common on bedding surfaces. Upper contact is sharp but wavy 6.2

10. Crinoidal wackestone, grayish orange pink (5YR 7/2), weathering light gray (N7). Consists of a single bed containing variably sized crinoid fragments (mostly short stems and ossicles, but some plates also occur); less argillaceous than other limestones of the Cravatt. Upper contact is sharp but very wavy and is augmented by a 0.10-in.-thick shaly parting 0.92

9. Argillaceous mudstone and chert (Fig. 36), grayish orange pink (5YR7/2), weathering light gray (N7), with grayish yellow (5Y8/4) and medium dark gray (N4) stains along bedding surfaces and bedding faces, respectively. Beds thin to medium, very wavy with pinch-and-swell structure, 2.0–5.0 in. thick, averaging 3.0 in. thick. Argillaceous material common, especially along bedding contacts. Vitreous chert light gray (N7), weathering pale greenish yellow (10Y8/2); chert bedding discontinuous, 1.0–2.0 in. thick. Large, well-preserved brachiopods (?*Meristella* sp.), and crinoid ossicles and large stems common along tops of beds, with little fossil material in bed interiors. Upper contact sharp but very wavy 4.7

8. Whole-fossil mudstone and vitreous chert, grayish orange pink (5YR7/2), weathering light gray (N7), with medium dark gray (N4) and grayish yellow (5Y8/4) staining along bedding contacts. Beds very wavy, medium, 5.0–7.0 in. thick, with shaly partings between some beds in upper half. Interval less argillaceous than units 7 and 9. Vitreous chert weathers light bluish gray (5B7/1) to grayish blue (5PB5/2); beds normally 1.0–2.0 in. thick and extend ~2 ft along quarry face, but may be 3.0 in. thick and extend up to 10 ft along face. Fossils dominated by large brachiopods, commonly at tops of beds, but crinoid stems also occur. Upper contact sharp and planar, augmented by a 0.25-in. shaly-limestone break 11.4

7. Laminated argillaceous wackestone, very light gray (N8), weathering moderate orange pink (5YR8/4), with grayish black (N2) stains. Unit varies from an indurated, irregularly laminated, whole-fossil wackestone in middle to a weakly indurated, planar laminated wackestone in basal 0.5 in. and upper 2.0 in. of exposure. Fossils consist of small brachiopods and bryozoans. Upper contact is sharp but wavy; coincident with a 0.10-in.-thick, dark yellowish orange (10YR6/6) clay-shale parting... 0.4

6. Argillaceous mudstone and nodular chert; light bluish gray (5B7/1), weathering medium bluish gray (5B5/1); chert weathers to light brown (5YR 5/6). Unit consists of two massive beds of the same approximate thickness. Tripolitic chert nodular and inconspicuous. Well-preserved brachiopods common. Upper contact is sharp but wavy 2.4

5. Argillaceous mudstone and tripolitic chert (Fig. 35), very pale orange (10YR8/2) to light gray (N7), light bluish gray (5B7/1) toward top, weathering

medium light gray (N6) to medium bluish gray (5B5/1). Chert weathers a pale greenish yellow (10Y8/2) to light brown (5YR5/6). Beds wavy, medium to thick, 4.0–16.0 in. thick, averaging ~10.0 in. thick; each bed separated by an irregularly laminated, 0.1–0.25-in.-thick shaly-limestone break. Chert beds lenticular, 1.0–2.0 in. thick and extending only 1–1.5 ft along quarry face. Fossils sparse, consisting primarily of crinoid ossicles and small stems; rare brachiopods. Upper contact sharp but wavy 8.9

4. Very argillaceous mudstone, grayish yellow (5Y 8/4) fresh and weathered. Bedding irregularly laminated, with partings no more than 0.10 in. thick; where weathered, unit appears similar to shale. Horizontal burrows (?*Planolites*) common along laminae surfaces. Fragments of lingulid(?) brachiopods also occur, suggesting deposition in a high-energy environment. Upper contact gradational 0.2

HARAGAN FORMATION (total exposed thickness, 8.5 ft)

3. Argillaceous mudstone (Fig. 35), light gray (N7), weathering medium dark gray (N4) to moderate brown (5YR3/4). Unit a single bed. Fossils common, consisting mostly of crinoid debris along with some brachiopod fragments. Upper contact appears sharp but wavy; technically gradational, depending on first occurrence of chert in Cravatt Member 1.8

2. Very argillaceous wackestone, moderate brown (5YR3/4) fresh and weathered; beds very wavy laminated, 0.25 in. thick on average but with strong pinch-and-swell structure along quarry face. Abundant crinoid plates and small stems, and small spiriferid brachiopods. Upper contact gradational 0.2

1. Argillaceous mudstone, yellowish gray (5Y7/2) near base, light gray (N7) near top, weathering moderate brown (5YR3/4) to medium gray (N5); some laminated intervals weather grayish orange (10YR7/4). Beds wavy, thin, 1.0–3.0 in. thick; irregularly laminated zones of very argillaceous mudstones occur every 16 to 17 in. up-section; laminated intervals are no more than 2.0 in. thick and pinch out a short distance along quarry wall. Fossils rare. Upper contact gradational, lower contact not exposed in quarry 6.5

Total thickness of section 65.7

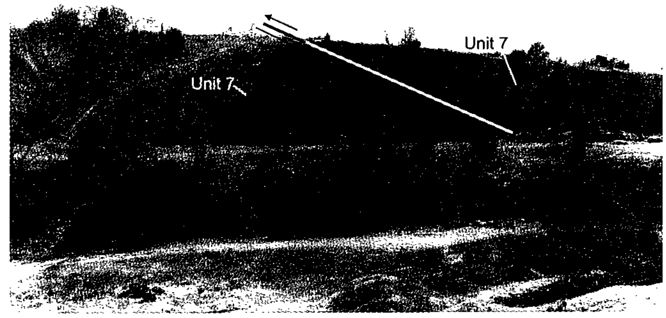


Figure 34. Overview of Hunton anticline quarry section (Stop 5), looking to the southeast. View shows a reverse-faulted anticline (arrows illustrate relative movement along fault), with fault offsetting the southern limb of fold. Marker bed, unit 7 of the Cravatt Member, also labeled to illustrate amount of offset along fault.

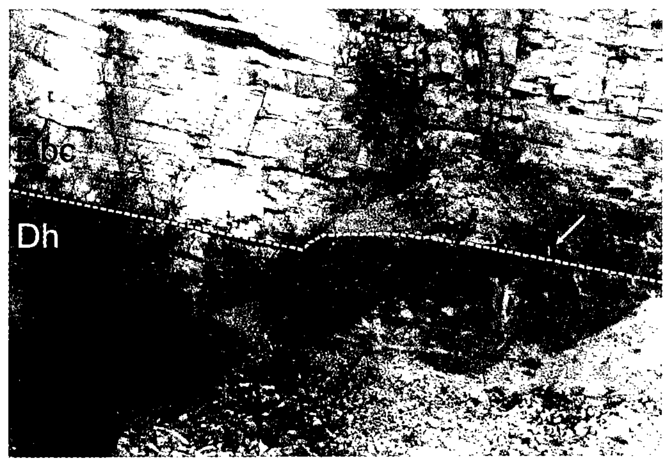


Figure 35. Contact between the Haragan Formation (*Dh*) and Cravatt Member (*Dbc*), exposed along the south quarry wall, Hunton anticline quarry section (Stop 5). Arrow at right points to hammer for scale (~2 ft long).

a vitreous-cherty limestone (Fig. 32, units 8, 9; Fig. 36) and ends with a wavy-laminated limestone and chert interval (Fig. 32, units 12–15; Fig. 37). These upper units of the Cravatt Member (units 11–15) are highly fossiliferous, but unlike the Haragan fossils they do not readily weather free of the surrounding matrix. The Cravatt fossils are more frequently seen along the tops of bedding surfaces exposed on the northern and western parts of the quarry floor.

The transition between the Cravatt and Fittstown Members of the Bois d'Arc can best be seen along the quarry access road just north, and below, the current level of the quarry floor (Fig. 38). Here, wackestones and mudstones of the Cravatt grade upward into packstones and glauconitic grainstones of the Fittstown. Unlike the contact at the Goddard section, which was sharp, the Cravatt–Fittstown contact here can best be described as intercalated, or even gradational. This was noted by Amsden (1960) at many sections, who showed that Cravatt mud-supported limestones commonly grade upward into Fittstown grain-supported limestones through a considerable stratigraphic thickness. Amsden (1960, p. 120) went on to note a strong vertical as well as lateral gradation between the two members. This can also be said of the paleontological data, as both brachiopod and conodont assemblages are iden-

Figure 36. Unit 9, Hunton anticline quarry section (Stop 5), showing bedding character of vitreous chert (darker beds) in Cravatt mudstones (lighter beds). Scale in inches and centimeters.

Figure 37. Units 11–15, Hunton anticline quarry section (Stop 5), showing thin, laminated nature of units 12 and 14, and interbedded mudstone and chert of unit 15. Scale just below unit 12, in inches and centimeters.

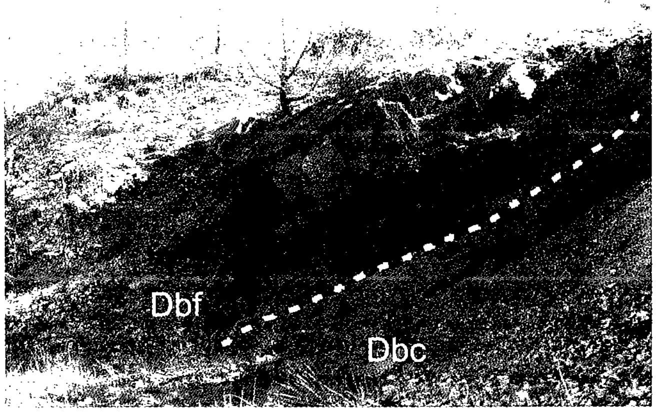


Figure 38. Cravatt (*Dbc*)–Fittstown (*Dbf*) gradational contact (dashed line), Hunton anticline quarry section (Stop 5). Beds dip to the north.

tical for much of these units. There is some evidence from conodont biostratigraphy, however, that at least the upper beds of the Fittstown are slightly younger than the Cravatt (Barrick and Klapper, 1992; Johnson and Klapper, 1992). Currently, the Cravatt–Fittstown contact is placed at the point where beds begin to have a good limestone texture and contain no obvious argillaceous material or distinct chert beds (Fig. 38). This criterion was recommended by Amsden (1960, p. 102) in determining the contact.

The Woodford Shale is well exposed on the north side of the quarry and can be viewed on either side of the access road. Unfortunately, the actual Woodford–Hunton contact is obscured.

The gamma-ray profile is similar to other Haragan–Bois d'Arc transitional sequences (compare Figs. 22, 27, and 33). Average gamma-ray counts for the Haragan are high, ranging up in the seventies. These values gradually decline in the lower Cravatt Member, which has average counts in the upper sixties. Where the clean grainstones of the upper Fittstown are encountered, the average gamma-ray count appears to stabilize near 60 CPS and marks a nice contrast with the more argillaceous beds of the upper Cravatt (Fig. 33).

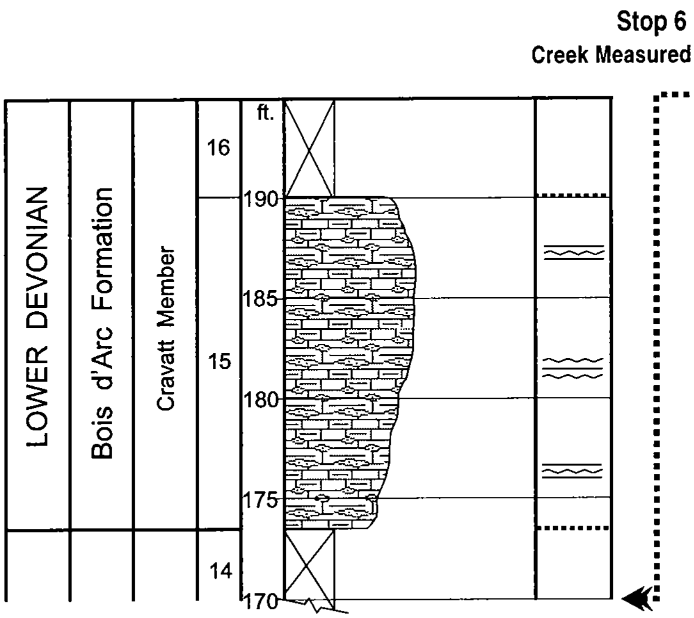
STOP 6 – Optional

Creek Measured Section

Almost all exposures on the west side of the Washita River exhibit some degree of structural deformation. For example, Hunton beds at this site are overturned and dip steeply to the west. This deformation is probably related to the Washita Valley fault system located only half a mile to the southwest, where faulting has overturned much of the Paleozoic section (from the Ordovician Oil Creek Formation through the Mississippian Sycamore Limestone) in this region of the Arbuckle Mountains (Ham and McKinley, 1954). In general, Hunton beds are overturned to the west at an average dip of 77°, and they strike N. 25° W.

This is a short section of the Hunton Group, where the upper Henryhouse and Haragan Formations are not well exposed (Figs. 39, 40). The section is included because of the contrast in the basal formations of the Chimneyhill Subgroup here and at the next section (Stop 7), which is only half a mile to the northwest.

At this site, the basal Keel Formation is thin, poorly exposed, and represented only by the (probable) Ideal Quarry Member. At the next site (Stop 7, Price Falls measured section, below), the Keel–Ideal Quarry sequence is >7 ft thick. The disparity in thickness between the two sites, coupled with the absence of the



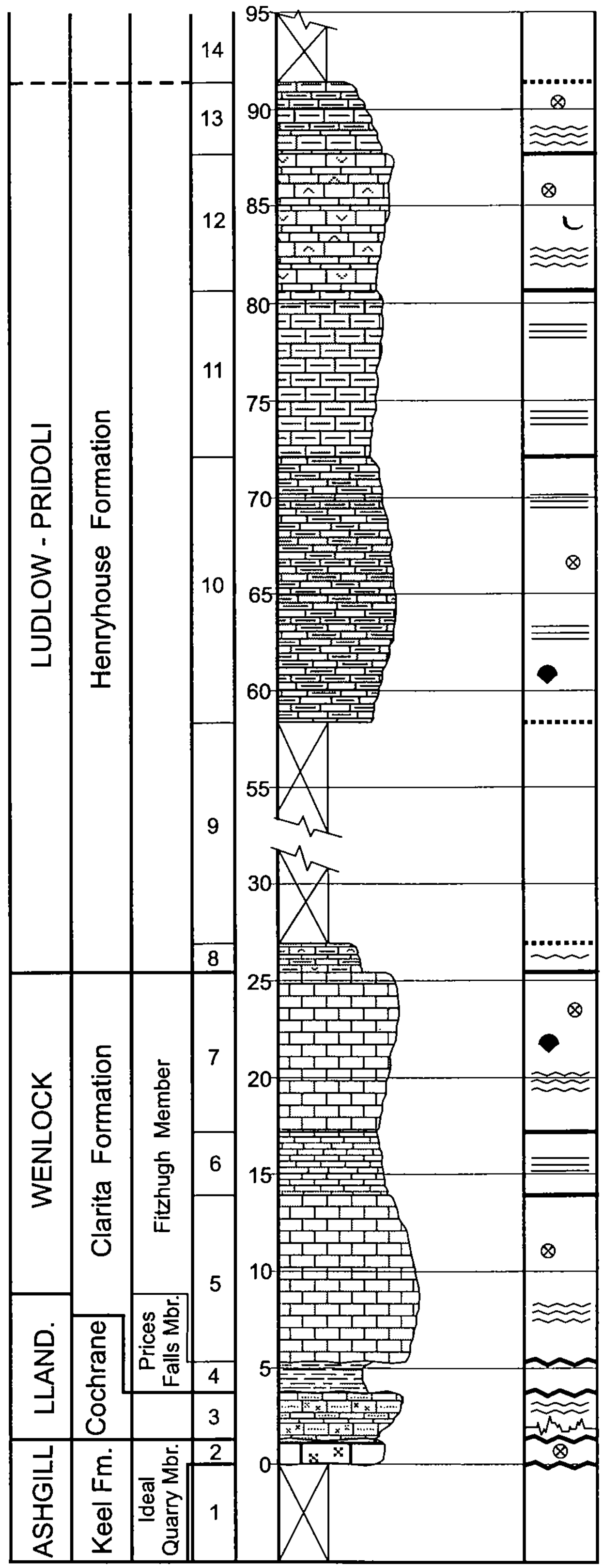


Figure 39. Graphic columnar section of exposed parts of the Hunton Group at Stop 6 (Creek section). Explanation of symbols found in Appendix.

MEASURED SECTION, STOP 6
Chimneyhill Subgroup
Creek Measured Section

Location: Most of this section was measured along the north side of a northeast-trending drainage ~0.5 mi southeast of Price Falls in the NE¼SE¼SW¼ sec. 33, T. 1 S., R. 2 E., Murray County, Oklahoma (Dougherty, Oklahoma, 7.5′ quadrangle).

Thickness (feet)

HUNTON GROUP (total thickness, 190.2+ ft)

BOIS D'ARC FORMATION (total thickness, 16.6+ ft)

Cravatt Member

16. Covered interval; may contain some Woodford Shale .... 5.0+
15. Interbedded argillaceous mudstone and nodular tripolitic chert; grayish orange (10YR7/4), weathering medium light gray (N6); chert weathering to light brown (5YR5/6). Beds planar to slightly wavy, mostly thin, 1.0–3.0 in. thick, averaging ~1.0 in. thick; some beds 8.0–9.0 in. thick in middle of interval. Tripolitic chert mostly nodular, but some discontinuously bedded intervals occur in the basal 3–5 ft of unit. No fossil material evident. Upper and lower contacts covered...... 16.6
14. Covered interval; mostly represents Haragan Formation, but may include basal beds of the Cravatt Member and upper beds of Henryhouse Formation 82.2

HENRYHOUSE FORMATION (total thickness, 66.2 ft)

13. Argillaceous mudstone, grayish yellow (5Y8/4), weathering pale olive (10Y6/2). Beds wavy, thin to medium, 2.0–6.0 in. thick, averaging ~3.5 in. thick. Fossils rare except for local patches of cri-

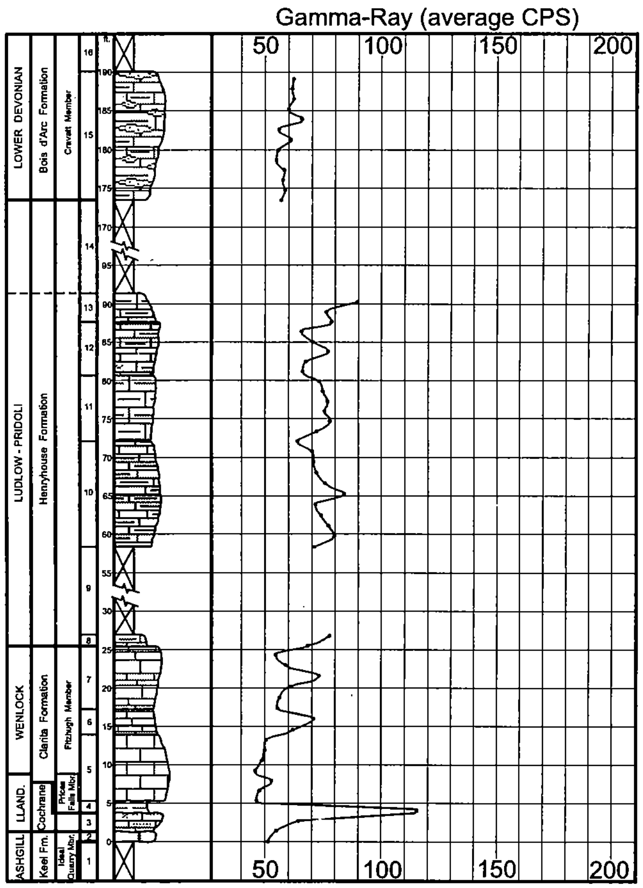


Figure 40. Gamma-ray profile of Hunton Group exposed at the Creek section (Stop 6). Note strong gamma-ray value of the Prices Falls Member in comparison with the rest of the Chimneyhill Subgroup. See caption for Figure 42 (Stop 7) for additional comments.

Keel Formation at previous localities (Stops 3, 4), is strong lithologic evidence for a post-Keel–pre-Cochrane erosional event (Fig. 2).

The Cochrane Formation also shows strong variability between these two sections. Here, the Cochrane is just over 2 ft thick, whereas at the next site (Stop 7) the Cochrane averages only 3 in. thick (compare the graphic columnar section for Stop 6 [Fig. 39] with the one for Stop 7 [Fig. 41]). At previous sites (Stops 3, 4), the Cochrane Formation averages ~8 ft in thickness. As with the Keel, this is strong lithologic evidence that the Cochrane underwent extensive erosion prior to deposition of the overlying Clarita Formation. The magnitude of the erosional event appears to increase going west, starting at the Goddard Youth Camp. Biostratigraphically, however, there is very little evidence to suggest that a post-Cochrane–pre-Clarita erosional event has occurred (Fig. 2).

Another aspect of this section is the unique gamma-ray profile of the Chimneyhill Subgroup, particularly the Prices Falls Member of the Clarita Formation (Figs. 39, 40). Here, and at the next section, the Prices Falls Member is a blocky laminated clayshale. In other areas, such as at Stops 8 and 9, the Prices Falls is a laminated, very argillaceous limestone. Whichever lithology predominates, the gamma-ray signature of the member is usually very high and contrasts markedly with the surrounding low gamma-ray values measured from the rest of the Chimneyhill limestones (compare the gamma-ray profiles for exposures at Stop 6 [Fig 40], Stop 7 [Fig. 42], Stop 8 [Fig. 46], and Stop 9 [Fig. 50]). It seems apparent that the Prices Falls would represent a good marker horizon that can be used in subsurface mapping through the use of wireline logs.

noid debris along bedding surfaces in upper half of unit. Upper contact is covered 3.8

12. Skeletal mudstone to wackestone, with minor argillaceous mudstone; yellowish gray (5Y7/2) near base, grading upward into pale red (5R6/2), weathering grayish yellow green (5GY7/2) to pale olive (10Y6/2). Good carbonate-textured skeletal mudstone dominates basal part, whereas distinct wackestone textures common near top; interbeds of argillaceous mudstone occur sporadically in lower two-thirds of unit. Beds planar to slightly wavy, laminated to thin, 0.25–2.0 in. thick, averaging ~1.0 in. thick. Fossils dominated by crinoid debris, although some unidentifiable shell fragments also occur in wackestone beds. Upper contact is sharp and planar 7.0

11. Argillaceous mudstone, grayish yellow (5Y8/4), weathering pale olive (10Y6/2). Beds planar medium, 6.0–9.0 in. thick, with thicker beds more common in upper half of unit. Fossils rare. Upper contact sharp and planar 8.6

10. Argillaceous mudstone, similar to unit 11 above, but noticeably thinner bedded; grayish yellow (5Y8/4), weathering pale olive (10Y6/2). Beds planar, thin to laminated, 0.5–1.0 in. thick, with laminated material more common in upper two-thirds of unit. Fossils rare, consisting mostly of crinoid debris, but some small brachiopods do occur in lower half. Upper contact is sharp and planar 13.8

9. Covered interval 31.5

8. Argillaceous mudstone and wackestone, poorly exposed and badly weathered; grayish orange (10YR7/4) fresh and weathered. Beds wavy, thin, averaging ~2.0 in. thick. Whole-fossil brachiopods common, along with short crinoid stems. Upper contact covered 1.5

CHIMNEYHILL SUBGROUP (total thickness, 25.2 ft)

CLARITA FORMATION (total thickness, 21.6 ft)

Fitzhugh Member

7. Skeletal mudstone, yellowish gray (5Y7/2), weathering grayish orange (10YR7/4) to light olive gray (5Y6/1). Beds thin, slightly wavy, averaging ~3.0 in. thick. Unit slightly argillaceous in upper 2 ft. Fossil material consists mainly of crinoid debris, with some brachiopod-shell fragments. Upper contact is sharp but wavy 8.2

6. Mudstone, yellowish gray (5Y7/2), weathering grayish orange (10YR7/4). Beds planar, laminated to thin, 0.5–2.0 in. thick, with laminated beds alternating with thicker bedded material. No fossils evident. Upper contact is sharp and planar 3.2
5. Skeletal mudstone, similar to unit 7 above; moderate orange pink (5YR8/4), weathering medium gray (N5). Overall unit is dense, well indurated, and appears structureless; on weathered surfaces, however, beds actually thin, wavy, 1.0–3.0 in. thick, averaging ~1.5 in. thick. Crinoid fragments common, consisting of short stems and ossicles; whole brachiopods rare. Upper contact is sharp and planar 8.6

Note: The remainder of the Chimneyhill Subgroup was measured on the south side of shallow drainage.

Prices Falls Member

4. Silty clayshale, poorly exposed and badly weathered; moderate brown (5YR3/4) fresh and weathered. Bedding appears discontinuously laminated, almost blocky. Silt content remains constant throughout. No glauconite or fossils evident. Upper contact is sharp but wavy 1.6

COCHRANE FORMATION (total thickness, 2.4 ft)

3. Glauconitic grainstone(?) and packstone(?); depositional texture difficult to see in hand sample owing to diagenetic sparite cement and severe weathering; grayish orange pink (5YR7/2), weathering light olive gray (5Y5/2) to pale olive (10Y6/2). Unit appears to have been a crinoidal grainstone to possibly a packstone that contains a lot of diagenetic sparite. Beds medium, very wavy to irregular, 5.0–10.0 in. thick, averaging 6.0 in. thick; thicker bedded material more common in upper half of unit; bedding contacts in lower 3.0 in. look stylolitic. Glauconite conspicuous, occurring as small, irregularly shaped masses scattered throughout interval. Upper contact is sharp but wavy 2.4

KEEL FORMATION (total thickness, 1.2 ft)

Ideal Quarry Member(?)

2. Crinoidal packstone to grainstone(?); unit usually submerged below creek level and has undergone severe weathering; lack of glauconite and differences in weathering characteristics indicate bed is not part of the Cochrane Formation but possibly represents the Ideal Quarry Member. Unit pale olive (10Y6/2) to pale yellowish brown (10YR6/2), weathering yellowish gray (5Y7/2) to pale greenish yellow (10Y8/2); contains mud partings that weather dark yellow orange (10YR6/6); consists virtually of a single bed with irregular mudstone partings internally. No ooids present, but crinoid material common. Coarse sparite cement throughout. Upper contact sharp and very wavy; lower contact is covered 1.2
1. Covered interval, which probably represents Sylvan Shale .... 5.0+

Total thickness of section 190.2+

STOP 7

Prices Falls Measured Section

This locality was originally designated as type by Amsden (1967) for the Prices Falls Member of the Clarita Formation. This site also pertains to Amsden's (1960, appendix 1, p. 251) section 12A and includes the Chimneyhill Subgroup and basal Henryhouse Formation. Also present, but not reported by Amsden (1960), are exposures of the Cravatt Member of the Bois d'Arc Formation and the Woodford Shale. Both of these lithostratigraphic units are well exposed near the Oklahoma Highway 77D junction to Falls Creek Assembly.

As with the last section, the Haragan Formation does not crop out at this locality. The main lithologic differences and similarities between this section and the one exposed at Stop 6 have already been commented upon under the latter's description (see Stop 6—Creek Measured Section), so only a cursory review will be given. Beds at this locality are not overturned but dip steeply to the east between 77° to near vertical, and strike N. 30°–50° W.

The Keel Formation, including the Ideal Quarry Member, is well developed at this locality and has a combined thickness of >8 ft (Figs. 41, 42, units 2, 3; Fig. 43). Differences between the two units are slight. Generally, the Ideal Quarry Member weathers to a dark brown color and contains fewer ooids than the typical Keel oolite facies. In addition, many of the "ooids" in the Ideal Quarry Member are really algal-liths or calcispheres, which are small versions of oncolites. Whether the rounded grains formed from algal coating on broken bioclasts, or are the result of direct calcite precipitation, their presence is usually indicative of similar environments of deposition—namely, intertidal, shoaling conditions.

The Cochrane Formation is unusually thin at this section, averaging only 3 in. in thickness (Fig. 44). The bed is unquestionably Cochrane, because it lacks the oolitic texture of the upper Keel, and it contains abundant glauconite. Interestingly, some ooids of the underlying Keel are planed off along the contact with the Cochrane Formation (Amsden, 1960), again highlighting the extent of the erosional unconformity that exists between these two formations.

The Prices Falls Member of the Clarita Formation reaches its thickest extent in outcrop at this section and is representative of a true shale (Fig. 44). In most other sections described by Amsden (1957, 1960, 1967), and visited on this field trip, the Prices Falls is a recessively weathering, very argillaceous limestone. Given its very argillaceous nature, and subsequently strong gamma-ray signature, the Prices Falls Member represents an ideal marker horizon on wireline logs (Fig. 42). At this section the shale of the Prices Falls is extraordinarily "hot," emitting values of 140–190 CPS (Fig. 42).

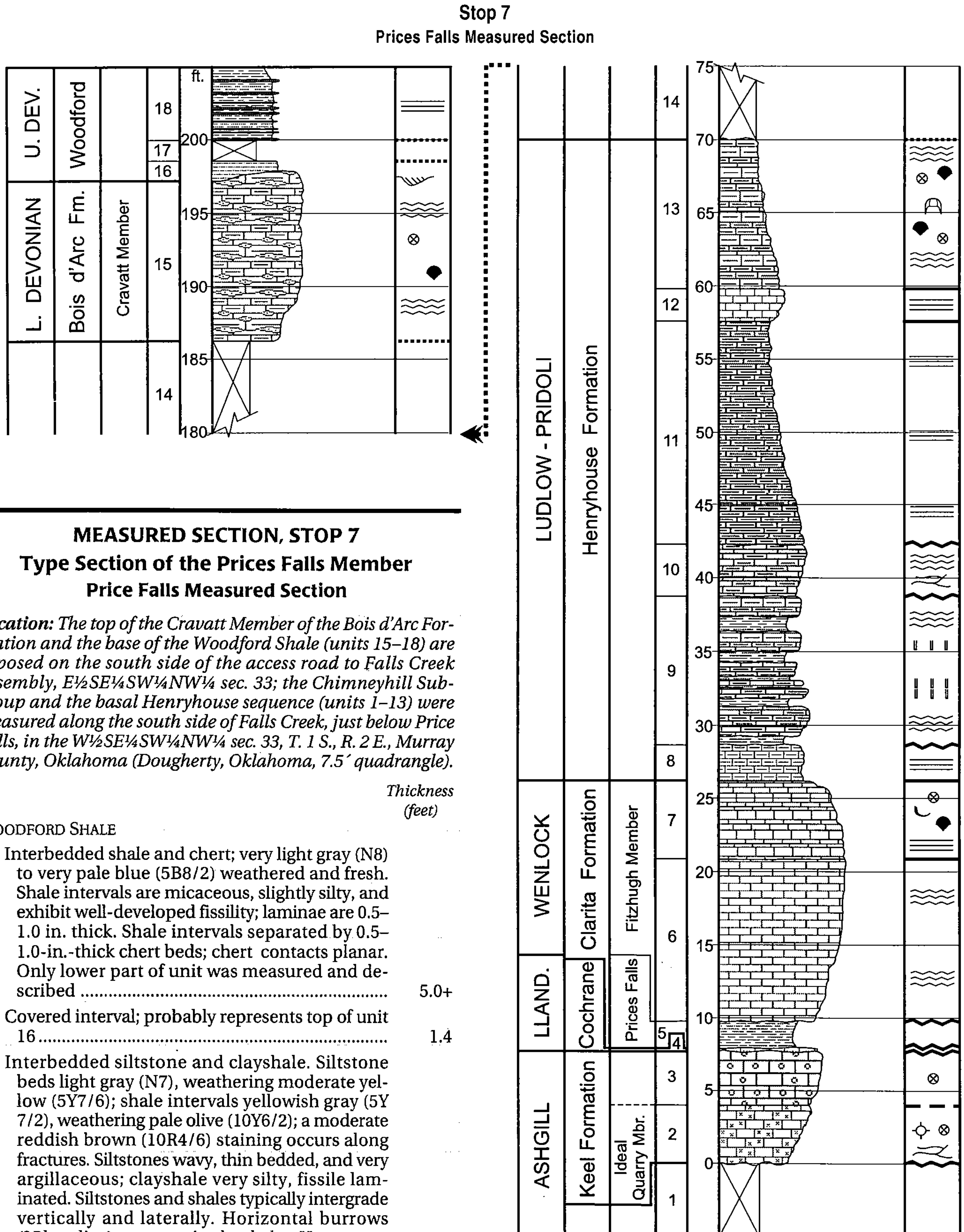


Figure 41. Graphic columnar section of exposed parts of the Hunton Group at Stop 7 (Price Falls section). Explanation of symbols found in Appendix.

MEASURED SECTION, STOP 7
Type Section of the Prices Falls Member
Price Falls Measured Section

Location: The top of the Cravatt Member of the Bois d'Arc Formation and the base of the Woodford Shale (units 15–18) are exposed on the south side of the access road to Falls Creek Assembly, E½SE¼SW¼NW¼ sec. 33; the Chimneyhill Subgroup and the basal Henryhouse sequence (units 1–13) were measured along the south side of Falls Creek, just below Price Falls, in the W½SE¼SW¼NW¼ sec. 33, T. 1 S., R. 2 E., Murray County, Oklahoma (Dougherty, Oklahoma, 7.5′ quadrangle).

Thickness (feet)

WOODFORD SHALE

18. Interbedded shale and chert; very light gray (N8) to very pale blue (5B8/2) weathered and fresh. Shale intervals are micaceous, slightly silty, and exhibit well-developed fissility; laminae are 0.5–1.0 in. thick. Shale intervals separated by 0.5–1.0-in.-thick chert beds; chert contacts planar. Only lower part of unit was measured and described .... 5.0+
17. Covered interval; probably represents top of unit 16 .... 1.4
16. Interbedded siltstone and clayshale. Siltstone beds light gray (N7), weathering moderate yellow (5Y7/6); shale intervals yellowish gray (5Y 7/2), weathering pale olive (10Y6/2); a moderate reddish brown (10R4/6) staining occurs along fractures. Siltstones wavy, thin bedded, and very argillaceous; clayshale very silty, fissile laminated. Siltstones and shales typically intergrade vertically and laterally. Horizontal burrows (?*Planolites*) common in clayshales. Upper contact is covered; lower contact with Hunton Group appears channeled by as much as 8 in. Maximum thickness of unit 1.3

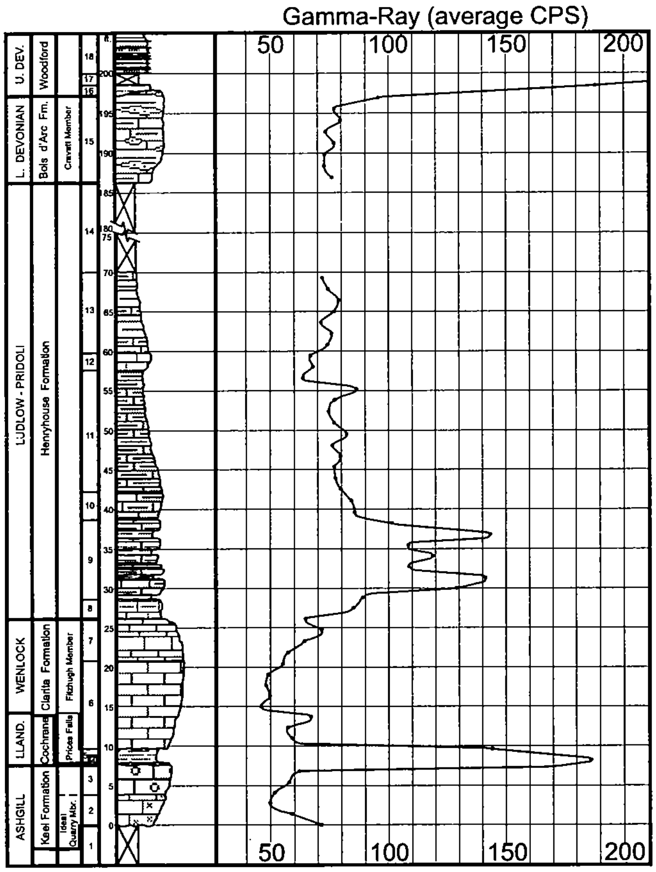


Figure 42. Gamma-ray profile of Hunton Group exposed at Price Falls (Stop 7). Note strong gamma-ray values measured from the shale of the Prices Falls Member, as well as the high values from the basal graptolite shales of the Henryhouse Formation. Both intervals represent transgressive, condensed parts of the carbonate-shoal (fill-in) cycle.

Figure 43. Near-vertical Keel Formation, Price Falls section (Stop 7). Light-colored arrows approximate the Ideal Quarry Member (left)–Keel oolite (right) contact. Scale in inches and centimeters.

HUNTON GROUP (total thickness, 198.2 ft)

BOIS D'ARC FORMATION (total thickness, 11.6 ft)

Cravatt Member

15. Whole-fossil mudstone and minor tripolitic chert; pale greenish yellow (10Y8/2) to very pale orange (10YR8/2); weathers dark yellowish brown (10YR4/2), with very pale orange (10YR8/2) staining along bedding. Predominantly thin to medium bedded, with laminated bedding common in upper 2 ft of exposure; overall, beds are 0.5–8.0 in. thick, averaging ~5.0 in. thick, and are wavy. Chert inconspicuous in upper half of unit; usually occurs as small nodules, but some discontinuous, irregular beds present in lower half. Whole-fossil brachiopods and some crinoid debris occur sporadically in lower two-thirds of unit. Upper contact is sharp but concave (channeled?) 11.6
14. Covered interval; mostly represents Haragan Formation but may include basal beds of Cravatt Member and upper beds of Henryhouse Formation 116.3

HENRYHOUSE FORMATION (total exposed thickness, 44.2 ft)

13. Argillaceous, whole-fossil mudstone, yellowish gray (5Y7/2), weathering pale yellowish brown (10YR6/2) and dark yellowish brown (10YR4/2). Beds wavy, thin to medium, 1.0–7.0 in. thick, becoming irregularly bedded in upper one-third of unit. Large, well-preserved brachiopods common as well as short crinoid stems and ossicles; trilobite pygidium in middle of unit. Upper contact is covered 10.7
12. Skeletal mudstone, grayish orange (10YR7/4), weathering dark yellowish brown (10YR4/2), with pale yellowish brown (10YR6/2) stains along bedding. Unit shows good carbonate texture, with little argillaceous material. Beds planar, thin, averaging ~1.0 in. thick. Some small crinoid fragments occur. Upper contact sharp and planar 2.2
11. Argillaceous mudstone, very pale orange (10YR 8/2), weathering olive gray (5Y4/1) to yellowish gray (5Y7/2), with light olive gray (5Y5/2) stains along bedding surfaces and fractures. Beds are planar, thin, and appear to be a consistent 1.0 in. thick; however, some 3.0–4.0-in.-thick laminated intervals occur in lower one-third of unit. No fossils evident. Upper contact is sharp and planar 15.3
10. Argillaceous mudstone, similar to unit above except for bedding. Unit very pale orange (10YR 8/2), weathering olive gray (5Y4/1). Beds wavy to irregular, thin to medium, 2.0–4.0 in. thick, averaging ~2.5 in. thick. Fossils rare. Upper contact sharp but wavy 3.5
9. Interbedded argillaceous mudstones and laminated clayshales. Mudstones pale olive (10Y6/2), weathering grayish orange (10YR7/4), pale brown (5YR5/2), and light brown (5YR6/4); occur either as single beds or as series of beds separated by intervals of clayshale. Clayshales moderate yellowish brown (10YR5/4) fresh and weathered, usually occur as a recessive interval between

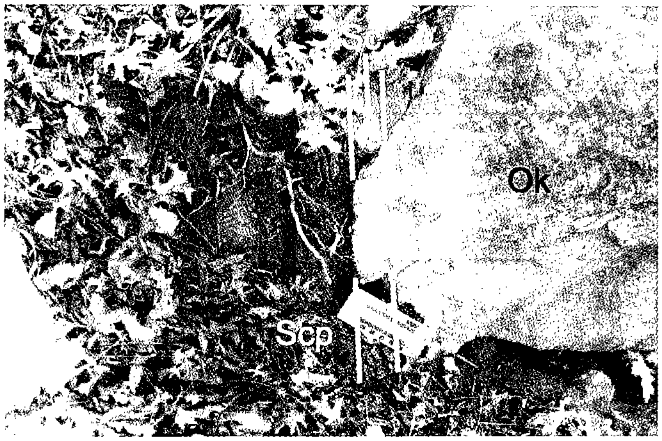


Figure 44. Near-vertical sequence, starting with Keel oolite (*Ok*) at right and ending with Prices Falls Member (*Scp*) at left, Prices Falls section (Stop 7). Note thin bed of Cochrane Formation (*Sc*) at center. Scale in inches and centimeters.

more resistant mudstones. Individual beds and bedding intervals can be arranged in the following ascending order: (1) basal 7.0 in. of laminated clayshale and very argillaceous mudstone; (2) 24.0 in. of thin-bedded argillaceous mudstone, with interval divided into seven distinct beds; (3) 6.0 in. of blocky laminated clayshale; (4) a single 8.0-in. bed of argillaceous mudstone, with lower bedding surface consisting of horizontal burrows (?*Thallasonoides*); (5) 2.0-in.-thick interval of laminated clayshale; (6) a single 4.0-in. bed of argillaceous mudstone with horizontal burrows along lower bedding contact; (7) 2.0 in. of laminated clayshale; (8) 11.0 in. of thin-bedded argillaceous mudstone, interval equally divided into three distinct beds; (9) 12.0 in. of well-laminated clayshale; (10) 18.0 in. of thin-bedded argillaceous mudstone with shale partings between three distinct beds; (11) 10.0 in. of blocky laminated clayshale; and (12) 17.0 in. of argillaceous mudstone, divided into two distinct beds separated by a 0.25-in. shale parting. Upper contact is sharp but wavy 10.1

***Note:** Interval likely correlates with unit 9, Stop 8 (Fig. 45), and unit 12, Stop 9 (Fig. 49), where this facies is better exposed. Amsden (1960) reports graptolites collected from some of these shale beds.*

8. Very argillaceous mudstone, very pale orange (10YR 8/2), weathering olive gray (5Y4/1). Beds planar, thin to medium, 2.0–5.0 in. thick. Looks similar to upper part of Fitzhugh Member of Clarita Formation but is definitely more argillaceous and recessively weathered than typical Fitzhugh. Some crinoid debris occurs. Upper contact is sharp and slightly wavy 2.4

CHIMNEYHILL SUBGROUP (total thickness, 26.1 ft)

CLARITA FORMATION (total thickness, 18.2 ft)

Fitzhugh Member

7. Skeletal mudstone, yellowish gray (5Y7/2), weathering grayish orange pink (5YR7/2) to pale olive (10Y6/2); unit exhibits slight increase in argillaceous material and more variable bedding compared with the one below. Bedding planar, thin to medium, 3.0–7.0 in. thick. Fossils common, consisting predominantly of brachiopod-shell fragments with some small, whole brachiopods; crinoid debris also occurs. Upper contact is sharp and planar 5.3

6. Mudstone, grayish orange pink (5YR7/2) to yellowish gray (5Y7/2), weathering grayish green (5G5/2) to medium gray (N5); pale greenish yellow (10Y8/2) staining occurs as local patches. Beds appear massive but on weathered surfaces are distinctly thin and wavy, 1.0–5.0 in. thick, averaging ~2.0 in. thick. Some argillaceous intervals only a few inches thick occur locally in basal 3.4 ft of unit. Fossils inconspicuous, consisting mostly of crinoid debris with some unidentifiable shell fragments. Upper contact is sharp and planar 11.1

Prices Falls Member

5. Silty clayshale (Fig. 44), moderate brown (5YR 3/4) to dark yellowish brown (10YR4/2) fresh and weathered; becoming light olive gray (5Y 5/2) along upper and lower unit contacts. Shale is very silty, weakly calcareous, blocky (discontinuously) laminated. Glauconite occurs as small, distinct grains; conspicuous in lower half of interval, less so in upper half. No fossils evident. Upper contact is sharp but wavy 1.8

COCHRANE FORMATION (total thickness, 0.2 ft)

4. Glauconitic skeletal grainstone (Fig. 44), grayish orange pink (5YR7/2), weathering moderate orange pink (5YR8/4); grades laterally to pale yellowish brown (10YR6/2); some internal-bedding laminae appear pale yellowish orange (10YR8/6). Unit either represented by single thin bed or laterally grades into interlaminated skeletal grainstone and glauconite (with some laminae composed entirely of glauconite grains). Overall, unit is a skeletal grainstone, with a coarse sparite matrix and scattered grains of glauconite throughout. Fossils unidentifiable owing to coarse sparite. Upper contact sharp, very wavy, causing fluctuations in unit thickness along strike; contact definitely erosional. Maximum thickness 0.2

KEEL FORMATION (total thickness, 7.7 ft)

3. Oolitic grainstone (Fig. 43), yellowish gray (5Y8/1) to very pale blue (5B8/2), weathering grayish orange (10YR7/4) to pale olive (10Y6/2); turning very pale orange (10YR8/2) near upper contact. Unit massive; basal 2.4 ft consists of loosely packed ooids, and some crinoid fragments, set in a coarse sparite matrix; grades upward into a more closely packed oolite, and sparite grainstone. Some crinoid fragments occur in lower part, rare in upper part. Upper contact sharp but wavy; thickness variable owing to gradational lower contact. Maximum thickness 3.8

Ideal Quarry Member

2. Skeletal packstone (Fig. 43), grayish orange (10YR 7/4), becoming yellowish gray (5Y7/2) toward

top, weathering dark yellowish brown (10YR 4/2) to pale yellowish brown 10YR6/2); similar to unit above, except weathers dark brown and contains more lime mud. Bedding irregularly laminated in basal 7.0 in. of unit, with bedding laminae 0.25–0.5 in. thick; grades upward into a more massive-appearing skeletal packstone, which is thin to medium bedded on weathered surfaces. Ooids and rounded calcispheres common throughout. A thin, moderate reddish brown (10R4/6) concretion zone occurs 11.0 in. below top of unit. Fossils consist of abundant crinoid stems and plates; some whole-fossil brachiopods occur in basal laminated part. Upper contact is gradational and corresponds with change in weathering color; lower contact covered 3.9

1. Covered interval, which probably represents Sylvan Shale .... 5.0+

Total thickness of section 210.9+

Another interval that may be of some use in subsurface correlation is the graptolite-bearing shales near the base of the Henryhouse (Fig. 41, unit 9). These interbedded shales and argillaceous limestones actually represent the thin, transgressive part of the "grand" HHB carbonate cycle (Al-Shaieb and Puckette, 2000; Al-Shaieb and others, 2000) (see section on Carbonate Cycles and Sequence Stratigraphy, and Fig. 8, in Part I). In the terminology of sequence stratigraphy, this interval represents a condensed section that marks the maximum point of transgression of the Late Silurian sea. Note that the gamma-ray values are distinct and contrast markedly with the low values measured from the Fitzhugh Member and with the lower values measured from the overlying argillaceous limestone beds of the upper Henryhouse (also see section on Gamma-Ray Profiles and Subsurface Correlation, in Part I).

STOP 8

Oklahoma Highway 77D Measured Section

A nearly full section of the Hunton Group can be found at this site, but only the Hunton–Woodford transition on the north side of Oklahoma Highway 77D will be examined in detail (Figs. 45, 46). This section pertains to Amsden's (1960, appendix 1, p. 239) section M5. As with most exposures in this area of the Arbuckle Mountains, the beds are near vertical to slightly overturned, owing to the influence of the Washita fault system less than 0.5 mi to the southwest. Beds at this section are overturned, dipping to the southwest at 80° and striking N. 62° W.

MEASURED SECTION, STOP 8
Woodford Shale–Hunton Group Contact
Oklahoma Highway 77D Measured Section

Location: *The interval from the Woodford Shale through the upper part of the Henryhouse Formation (units 10–27) was measured along the north and south sides of OK-77D, in the NE¼NE¼SW¼NE¼ sec. 30; the basal part of the Henryhouse (units 8, 9) and the uppermost part of the Chimneyhill Subgroup (units 6, 7) were measured on the south side of OK-77D in the SW¼NW¼SE¼NE¼ sec. 30; the remaining units of the Chimneyhill Subgroup (units 2–7) were measured on the west side of OK-77D in the NW¼SE¼SE¼NE¼ sec. 30, T. 1 S., R. 2 E., Murray County, Oklahoma (Turner Falls, Oklahoma, 7.5′ quadrangle).*

Thickness (feet)

WOODFORD SHALE

27. Interbedded shale and chert, very light gray (N8) to very pale blue (5B8/2) weathered and fresh. Shale intervals are slightly silty and exhibit well-developed fissility; laminae 0.5–1.0 in. thick. Shale intervals separated by 0.5–1.0-in.-thick chert beds; chert bedding contacts planar to slightly wavy owing to abundant phosphate nodules. Upper part of unit was not measured .... 5.0+
26. Fissile shale, dark gray (N3) to light olive gray (5Y5/2) weathered and fresh; shale silty, exhibiting well-developed fissility. Interval contains abundant woody material; a poorly preserved orthid brachiopod was collected at base. Upper contact is sharp and planar 0.80
25. Cherty sandstone, light brownish gray (5YR6/1) weathered and fresh; sandstone is fine grained, quartz rich, and indurated, with minor amounts of clay and silt in matrix; thin chert stringers as discontinuous lenses or pods. Upper contact is sharp and planar 0.33
24. Silty sandstone, moderate blue green (5BG4/6) weathered and fresh. Similar to unit 25, above, but contains a higher silt and clay content in matrix and is much more friable; bedding appears laminated. Chert lenses in basal 2.0–3.0 in. of unit. Upper contact is erosional, as unit 25 may be channeled down by as much as 3.0 in. into unit 24. Maximum thickness 0.46
23. Calcareous siltstone, yellowish gray (5Y7/2) to grayish yellow (5Y8/4) weathered and fresh; siltstone well laminated, with bedding laminae 0.10–0.25 in. thick; calcareous throughout but increasingly calcareous toward base as unit grades down into an argillaceous carbonate mudstone. Upper contact gradational 2.5
22. Calcareous chert (Fig. 47), labeled as "Woodford brown? carbonate" by Amsden (1960, p. 240); dark yellowish orange (10YR6/6) weathered and fresh, with grayish brown (5YR3/2) staining on fractures and bedding planes; massive, well-indurated bed, consisting of zones of chert mixed with carbonate and clastic(?) material. Laminated argillaceous mudstone interlaminated with chert common in upper one-third of unit; massive chert in middle one-third of unit, with

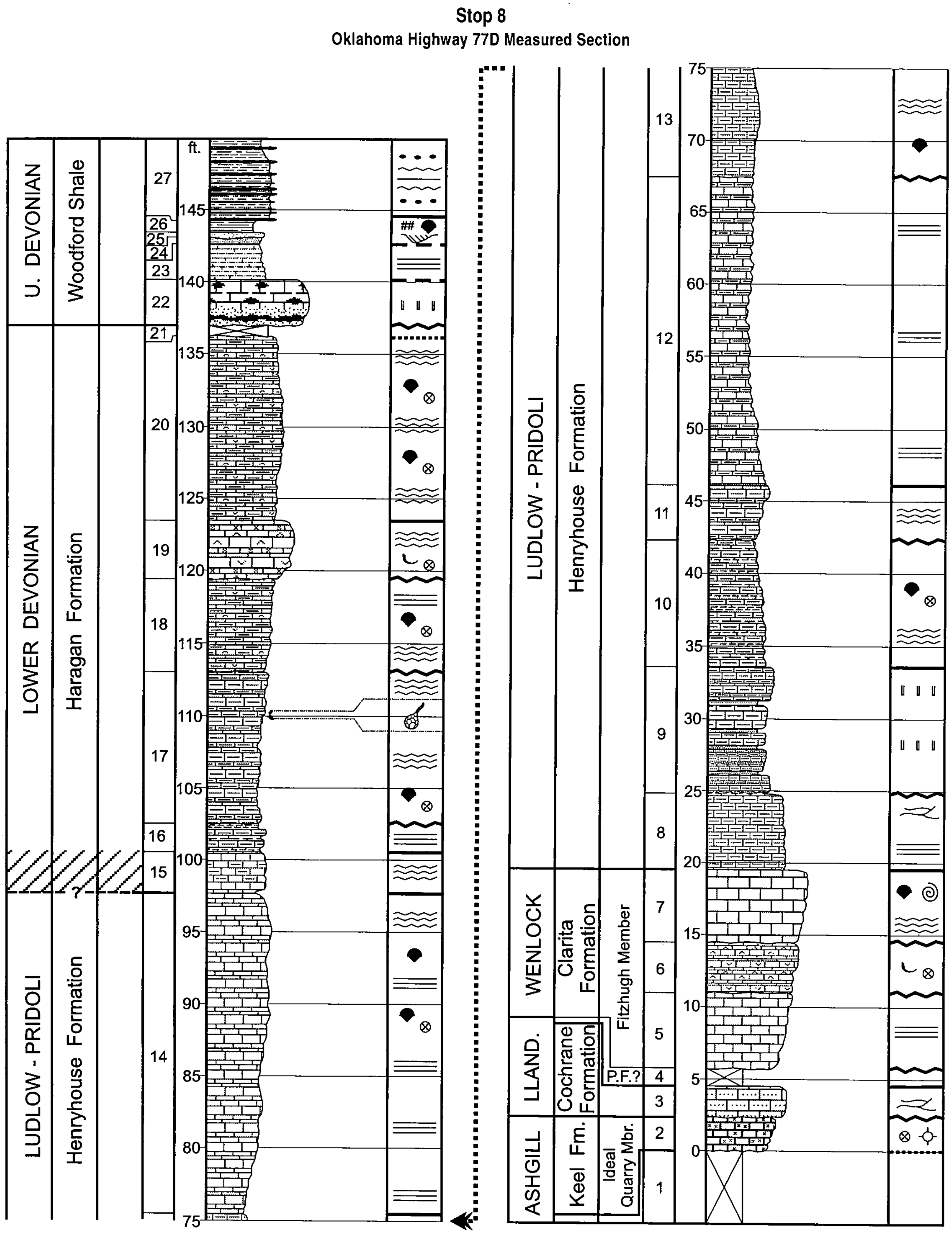


Figure 45. Graphic columnar section of exposed parts of Hunton Group at Stop 8 (Oklahoma Highway 77D section). Explanation of symbols found in Appendix.

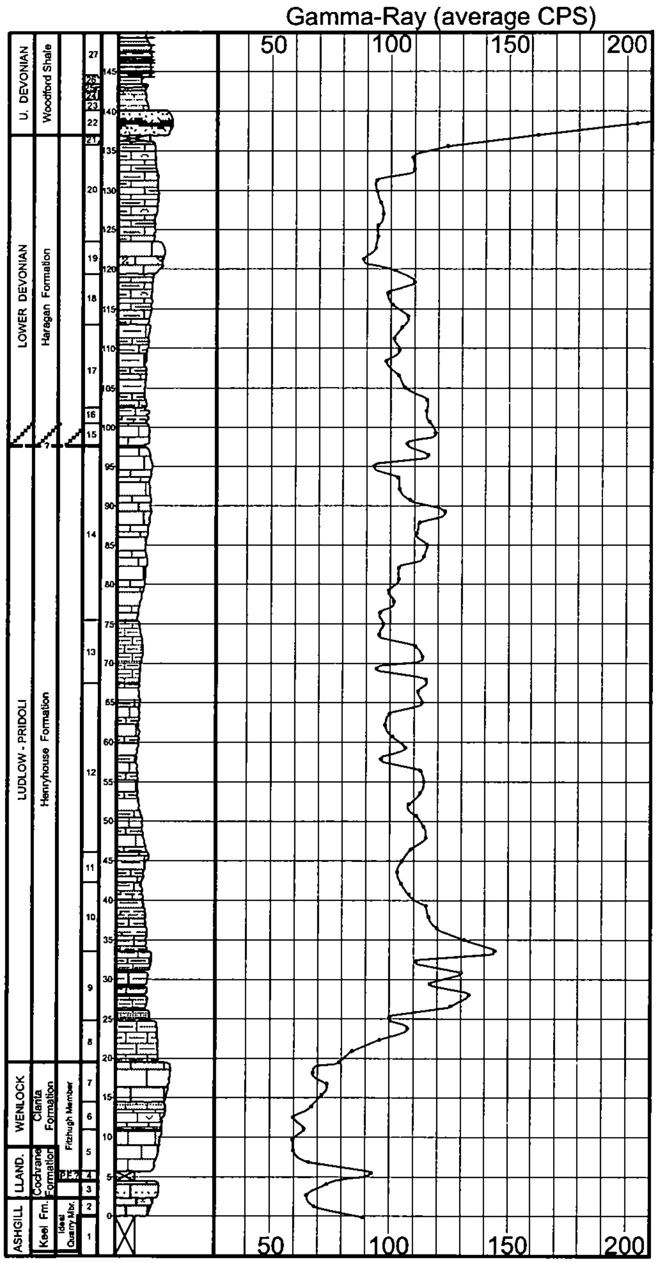


Figure 46. Gamma-ray profile of Hunton Group exposed along north and south sides of OK-77D (Stop 8). See text for additional information.

fracturing and shearing of chert common; basal one-third consists of a very fine grained siliceous sandstone (or siltstone) interbedded with chert laminae. Horizontal and vertical burrows common along base of unit. Upper contact gradational over 6.0 in.; lower contact with Hunton Group appears sharp but slightly wavy 3.2

HUNTON GROUP (total thickness, 136.8 ft)

HARAGAN FORMATION (total thickness, 39.4 ft)

21. Covered and rubble zone, consisting of blocks and fragments of Haragan limestone 0.75

20. Argillaceous mudstone and wackestone, grayish orange (10YR7/4), weathering to very pale orange (10YR8/2) to light gray (N7); pale yellowish orange (10YR8/6) stain along bedding contacts. Wackestone texture and argillaceous content increase toward top of interval; bedding contacts also show increase in argillaceous material; beds thin to laminated, 0.5–3.0 in. thick, averaging 1.0 in. thick; average bed thickness decreases to 0.5 in. toward base of interval; decreased bedding thickness toward base corresponds with increased mudstone texture. Whole, unabraded fossils common throughout unit, typically concentrated along bedding contacts; fossils dominated by spiriferid brachiopods, and crinoid ossicles and short stems. Upper contact is covered 12.8

19. Skeletal wackestone to packstone, grayish orange (10YR7/4), weathering to grayish olive (10Y4/2) to grayish brown (5YR3/2) along bedding planes. Bedding wavy, thin to medium, with thinner bedding more common in middle of unit; bed thickness 0.5–7.0 in. Very little argillaceous material evident except in basal 5.0–10.0 in. of unit. Most fossils consist of abraded crinoid and brachiopod debris; some whole brachiopods (mainly *Meristella* sp. and other spiriferid brachiopods) occur but are not obvious. Upper contact is sharp and planar 4.1

18. Argillaceous mudstone and wackestone similar to unit 20, above; grayish orange (10YR7/4), weathering to very pale orange (10YR8/2), with pale yellowish orange (10YR8/6) stain along bedding contacts. Bedding thin to laminated, planar to slightly wavy, with wavy bedding contacts occurring more toward base of unit. Whole, unabraded fossils common but concentrated along bedding contacts rather than in bed interiors; fossils dominated by various species of brachiopods and by crinoid ossicles, plates, and short stems. Upper contact is sharp but wavy .. 6.4

17. Argillaceous mudstone with minor argillaceous, skeletal wackestone; grayish orange (10YR7/4), weathering to very pale orange (10YR8/2) to light gray (N7). Unit slightly more argillaceous and recessive than previous carbonate units. Beds medium to thin, 2.0–7.0 in. thick, slightly wavy. Whole, unabraded fossils represented by numerous species of brachiopods; disarticulated crinoid material also occurs along bedding planes; crinoid bulbs, *Scyphocrinites* cf. *S. ulrichi* (Fig. 48), are common in a 15.0-in.-thick zone starting 32.0 in. below top of unit. Upper contact appears sharp but wavy 10.5

Note: Rest of Haragan Formation was described from exposures on the south side of OK-77D.

16. Argillaceous mudstone, grayish orange (10YR 7/4), weathering to moderate orange pink (5YR 8/4) to grayish yellow (5Y8/4); bedding slightly wavy, becoming planar toward base, medium bedded to laminated, with laminated intervals being more recessive, discontinuous across outcrop, and containing a greater amount of argillaceous material; thicker mudstone beds aver-

age 7.0 in. thick. No fossils were evident. Upper contact is sharp but wavy 2.0

15. Mudstone, slightly argillaceous, grayish orange (10YR7/4), weathering to moderate orange pink (5YR8/4) to grayish yellow (5Y8/4). Beds slightly wavy, thin to medium, 2.0–5.0 in. thick, with thicker beds more common at base of interval. Some whole, unabraded fossil brachiopods present. Upper contact is sharp and planar 2.8

Note: The base of unit 15 may correspond with the base of the Haragan Formation, according to the change in bedding character and carbonate texture. Amsden (1960) is ambiguous on the precise location of the Haragan–Henryhouse contact at this locality, measuring 40 ft of missing section across the critical interval. The current placement of the contact is justified because the basal Haragan at this stop lithostratigraphically matches the basal Haragan at Stop 9, which has better biostratigraphic control across the Silurian–Devonian boundary (Amsden, 1960; Barrick and Klapper, 1992).

HENRYHOUSE FORMATION (total thickness, 78.1 ft)

14. Whole-fossil mudstone, yellowish gray (5Y7/2) to grayish orange (10YR7/4), weathering to pale brown (5YR5/2), grayish blue green (5BG5/2), or medium light gray (N6); pyrolusite dendrites common along bedding surfaces. Beds are planar to slightly wavy toward top, medium to thin, 1.0–8.0 in. thick, averaging 6.0 in. thick, with thicker, planar beds more common in basal two-thirds of unit. Whole, unabraded fossils common, appearing more abundant in upper one-third. Upper contact is sharp and planar 22.2

13. Argillaceous mudstone, grayish orange (10YR7/4), weathering to a moderate orange pink (5YR8/4); beds thin and wavy, averaging 2.0 in. thick. Whole fossils present but sparse, and exhibit little abrasion. Upper contact is sharp and planar 8.0

12. Interbedded mudstone and argillaceous mudstone, grayish orange (10YR7/4), weathering to yellowish gray (5Y7/2); unit consists of alternating beds of indurated mudstone and weakly indurated, recessive argillaceous mudstone. More indurated beds 1.0–9.0 in. thick increase in abundance in upper one-fourth to one-third of interval. Non-indurated intervals contain more argillaceous material on average and have laminated to thin beds 0.25–2.0 in. thick. No fossils evident. Upper contact sharp but slightly wavy 21.3

11. Argillaceous mudstone, grayish orange (10YR 7/4), weathering to yellowish gray (5Y7/2). Similar in texture to unit 13; however, this unit is not as recessive and has thicker bedding. Beds slightly wavy, thin to medium, 2.0–6.0 in. thick, averaging 4.0 in. thick. Fossils rare. Upper contact is sharp and planar 3.8

10. Very argillaceous mudstone, very pale orange (10YR8/2) to grayish yellow (5Y8/4) weathered and fresh, becoming medium dark gray (N4) on bedding surfaces. Unit consists of alternating intervals of slightly indurated argillaceous mudstones interbedded with discontinuous zones of friable, very argillaceous to shaly mudstones. Overall, bedding is irregular, wavy laminated to thin bedded, with individual beds 0.25–1.0 in. thick. Unbroken and unabraded brachiopods common, along with fairly long crinoid stems and plates, some beds almost a wackestone in texture. Upper contact is sharp but wavy 8.8

Note: The rest of the Henryhouse Formation was described from a small drainage just east of the I-35 overpass in the SW¼NW¼SE¼NE¼ sec. 30, T. 1 S., R. 2 E., Murray County.

9. Interbedded argillaceous mudstones and laminated clayshales, lithostratigraphically the same as unit 12 at Stop 9. Overall, mudstones are grayish orange (10YR7/4) and weather light brown (5YR5/6) and to dark yellowish brown (10YR 4/2) along bedding planes; occur as single beds or as series of beds separated by intervals of poorly exposed clayshale. Where adequately exposed, clayshales are light brownish gray (5YR 6/1) or light olive gray (5Y6/1) weathered and fresh. Individual beds and bedding intervals can be arranged in the following ascending order: (1) 0.5 in. of shale, or a very recessive, very argillaceous mudstone parting; (2) 15.0 in. of laminated to thin-bedded argillaceous mudstone, beds 0.5–2.0 in. thick; (3) 3 in. of poorly exposed clayshale; (4) 18.0 in. of irregularly to wavy-laminated argillaceous mudstone; (5) 3.0 in. of poorly exposed, fissile clayshale; (6) 10.0 in. of argillaceous mudstone, with gradational upper contact; (7) 3.5 in. of blocky laminated, silty clayshale; (8) 19.0 in. of argillaceous mudstone with no bedding evident; (9) 3.5 in. of blocky laminated, silty clayshale; and (10) 29.0 in. of medium- to thin-bedded argillaceous mudstone, beds 1.0–8.0 in. thick, with thinner beds toward base; a 5.0-in.-thick, resistant argillaceous-mudstone bed occurs at top. Some burrow mottling in mudstone beds. Upper contact is sharp and planar 8.7

8. Argillaceous mudstone, grayish orange (10YR 7/4), weathering to yellowish gray (5Y7/2). Beds thin to medium, slightly irregular in upper half, becoming planar in lower half, 2.0–9.0 in. thick, averaging ~5.0 in. thick. No fossils evident. Upper contact is sharp but wavy 5.3

Note: The Chimneyhill Subgroup was described along west side of OK-77D in the NW¼SE¼SE¼NE¼ sec. 30, T. 1 S., R. 2 E., Murray County.

CHIMNEYHILL SUBGROUP (total thickness, 19.3 ft)

CLARITA FORMATION (total thickness, 14.9 ft)

Fitzhugh Member

7. Whole-fossil mudstone, moderate orange pink (5YR8/4), weathering to medium gray (N5); medium to thick bedded, slightly wavy, with beds 12.0–14.0 in. thick. Bedding planes with characteristic "tear-pants" weathering. Unit becomes increasingly argillaceous and thicker bedded toward Henryhouse contact. Fossil brachiopods and crinoid debris common, gastropods rare; fossils more common in upper half of unit. Upper contact is sharp and planar 5.0

6. Skeletal wackestone, grayish orange (10YR7/4), weathering to yellowish gray (5Y7/2) or light olive gray (5Y6/1). Beds wavy, thin to medium, 1.0–6.0 in. thick, averaging ~3.0 in. thick. Some fossiliferous mudstone beds occur in middle of unit. Fossils typically fragmentary (though some whole brachiopods do occur) and are dominated by crinoid plates and ossicles. Upper contact is sharp but wavy 3.5
5. Whole-fossil mudstone, moderate orange pink (5YR8/4), weathering to medium gray (N5); looks similar to unit 7, above, although contains less argillaceous material. Beds planar, medium, 4.0–8.0 in. thick, with thicker beds more common at top and base of unit. A few whole spiriferid brachiopods and crinoid debris present. Upper contact is sharp but wavy 5.2

Prices Falls Member(?)

4. Covered interval, which probably represents Prices Falls Member 1.2

COCHRANE FORMATION (total thickness, 2.2 ft)

3. Unsorted pelmatozoan grainstone; very light gray (N8) to light brown (5YR6/4), weathering to medium dark gray (N4). Mostly coarse crinoid debris set within coarse sparite matrix. Minor glauconite occurs as small grains in upper part of unit, conspicuously absent in lower part. Beds irregular and discontinuous across outcrop; 6.0–8.0 in. thick in upper half of unit, grading down to 2.0–3.0 in. thick in lower half. Upper contact appears to have been sharp and planar 2.2

KEEL FORMATION (total thickness, 2.2 ft)

Ideal Quarry Member

2. Unsorted skeletal packstone to grainstone(?), poorly exposed; light brown (5YR6/4) weathered and fresh. Bedding appears thin to laminated. Fossils consist of highly fragmentary crinoid debris and shell material; algal coating of fossil material common, giving appearance of ooids. Upper contact is sharp but very wavy 2.2
1. Covered interval, which probably represents Sylvan Shale .... 5.0+

Total thickness of section 154.1+

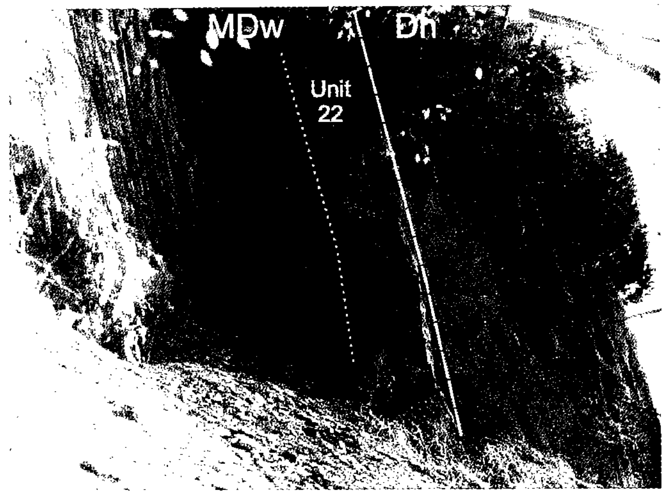


Figure 47. Contact (thick dashed line) between Haragan Formation (*Dh*) and Woodford Shale (*MDw*), OK-77D section (Stop 8). Top of Amsden's (1960) brown Woodford(?) carbonate (unit 22) highlighted by thin dotted line. Beds are slightly overturned to the southeast (right).

This section is unusual in that Amsden (1960) described his brown Woodford(?) carbonate at the base of the Woodford Shale (Fig. 45, unit 22; Fig. 47). The Woodford brown carbonate appears to have limited distribution in the Arbuckle Mountains, as Amsden (1960, p. 135) has mapped it only here, and at a site near Oil Creek, Johnston County, Oklahoma (Pl. 1, in envelope, section J15). At Oil Creek the brown carbonate rests directly on the Sylvan Shale and was interpreted as altered Chimneyhill limestone. At this section, the unit is definitely part of the Woodford Shale and rests along the unconformable surface at the top of the Haragan Formation (Figs. 45, 47). Lithologically, the unit is a massive bed of cherty carbonate that grades downward into cherty, fine-grained sandstone to siltstone at its base. Whether this bed can be correlated with the supposedly altered "Chimneyhill" interval near Oil Creek is still debatable, but it stands to reason that the brown carbonate at this locality is of Woodford age and not related to any member of the Chimneyhill Subgroup.

Except for the absence of the Bois d'Arc Formation, the Hunton Group is represented by an almost complete stratigraphic section. Here, and at the next locality (Stop 9—U.S. Highway 77 measured section) the Bois d'Arc has been removed by extensive post-Hunton–pre-Woodford erosion.

The placement of the Haragan–Henryhouse contact is tenuous at this site. Amsden (1960, p. 241) is ambiguous as to its precise position, for at the time this section was measured nearly 40 ft of the section, which included the critical interval of the Haragan–Henryhouse transition beds, was covered. Today, the contact is well exposed; however, the Henryhouse is fossil poor, so the uppermost Henryhouse bed of definite Silurian age cannot be precisely ascertained. A similar situation was encountered by Amsden (1960) at the next section (Stop 9, Fig. 49), where a 4-ft interval of undeterminable age is sandwiched between beds of known Late Silurian age (Henryhouse) below and known Early Devonian age (Haragan) above. At the present site, the Henryhouse–Haragan contact was placed on criteria of similar lithostratigraphic sequences with those seen at Stop 9. It appears there is a sudden increase in argillaceous material going from definite Henryhouse beds to definite Haragan beds at Stop 9, and just above this transition is a thin interval with the crinoid bulb *Scyphocrinites* (Fig. 48; compare Figs. 45 and 49, units 17 and 23, respectively). Based on these criteria, the Henryhouse–Haragan contact most likely occurs at the base (or possibly at the top) of unit 15 (Fig. 45).

Figure 48. Unit 17, OK-77D section (Stop 8), showing zone of *Scyphocrinites* cf. *S. ulrichi* bulbs (arrows) in thin-bedded argillaceous mudstones. Photo taken of near-vertical beds along south side of OK-77D. Stratigraphic top is to left. Scale in inches and centimeters.

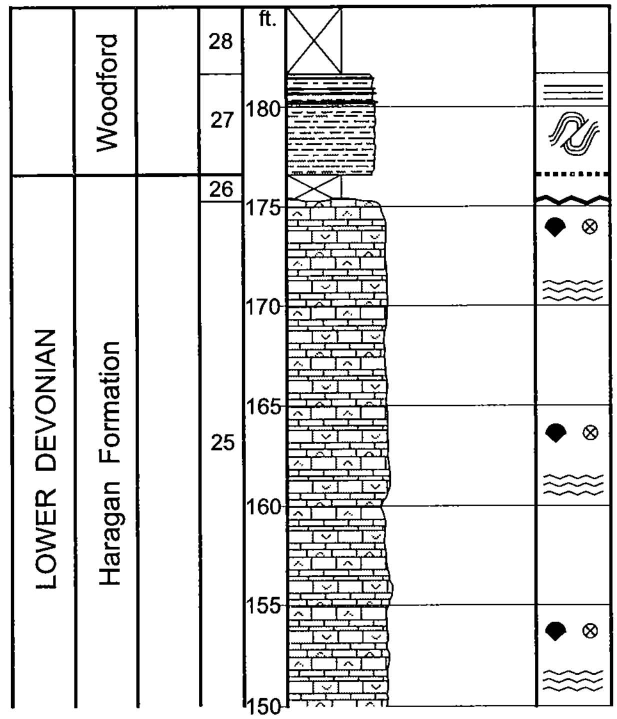
STOP 9

U.S. Highway 77 Measured Section

Except for the absence of the Bois d'Arc Formation, this section is one of the most complete of the Hunton Group in the Arbuckle Mountain region (Figs. 49–51). As with the last stop, Hunton beds are near vertical in attitude and thus afford an excellent opportunity to view the whole section at a glance. This includes an excellent exposure of the Sylvan–Hunton contact on the south end of the outcrop (Fig. 52), and a well-exposed cut through the Hunton–Woodford contact on the north end. Unlike the last section, however, there is no brown Woodford(?) carbonate, as interbedded micaceous

Stop 9

U.S. Highway 77 Measured Section *(continued)*



MEASURED SECTION, STOP 9
Sylvan Shale and Hunton Group
U.S. Highway 77 Measured Section

Location: Section was measured from a road cut in the W½ SE¼NE¼NW¼ sec. 30, T. 1 S., R. 2 E., on west side of U.S. Highway 77, ~0.25 mi south of intersection with I-35, Murray County, Oklahoma (Turner Falls, Oklahoma, 7.5′ quadrangle).

Thickness (feet)

WOODFORD SHALE

28. Covered interval within Woodford Shale .... 5.0+

27. Interbedded silty shale and chert. Interval is poorly exposed and deeply weathered, with overturned beds that contain numerous small folds; unit consists of fissile, slightly silty calcareous shale, interbedded with siltstone laminae and chert. Shale is grayish orange pink (5YR7/2), papery textured, and has continuous bedding laminae that average <0.06 in. thick. Siltstones are very pale orange (10YR8/2) and slightly more resistant to weathering than shales, and are more common in basal 20.0 in. of unit. Chert occurs as dark yellowish orange (10YR6/6) planar beds; beds average 0.5 in. thick, except for one prominent 2.0-in.-thick bed starting 40.0 in. above base of unit. Upper part of Woodford is covered 5.0

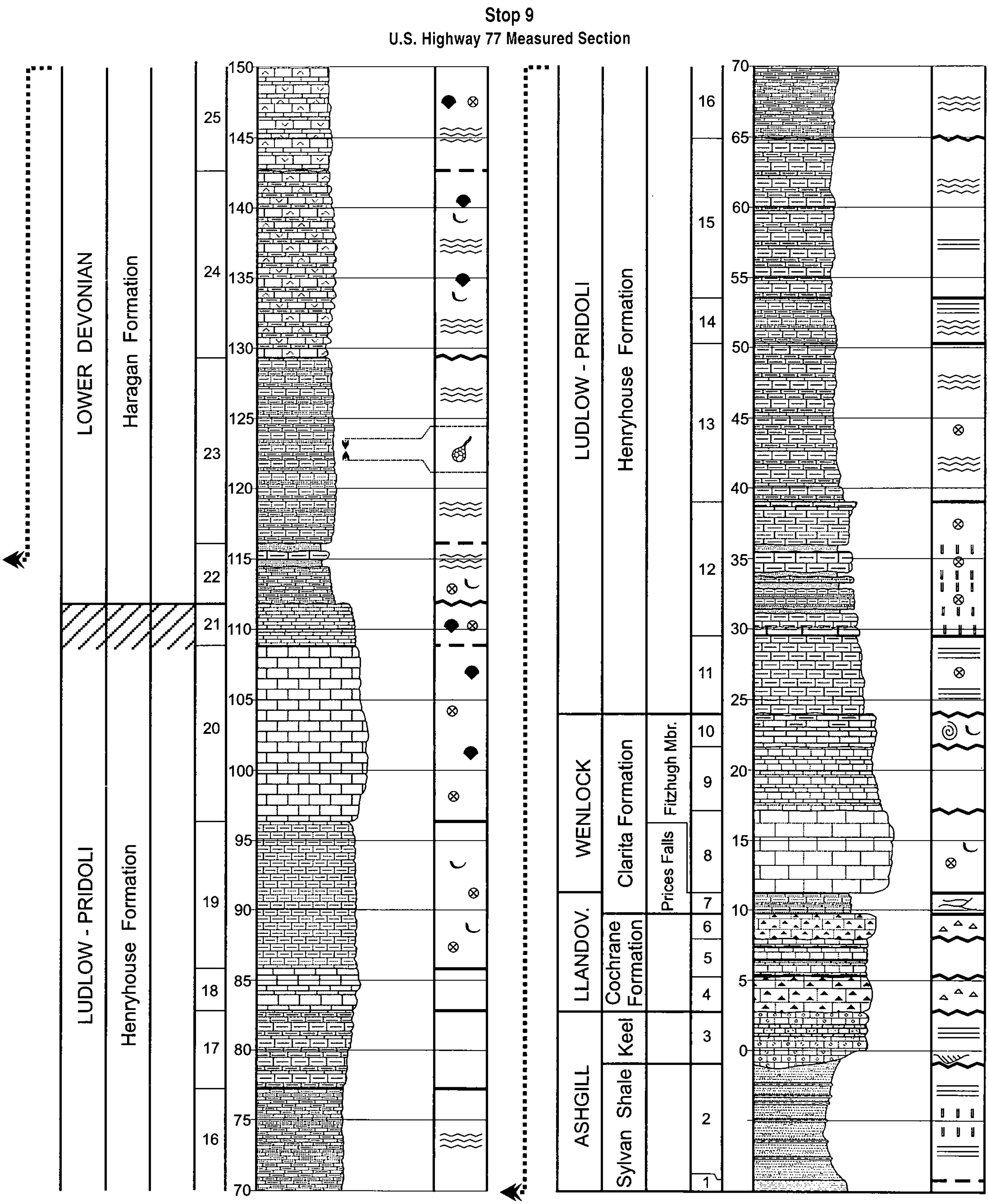


Figure 49 *(above and facing page)*. Graphic columnar section of exposed parts of the Hunton Group at Stop 9 (U.S. Highway 77 section). Explanation of symbols found in Appendix.

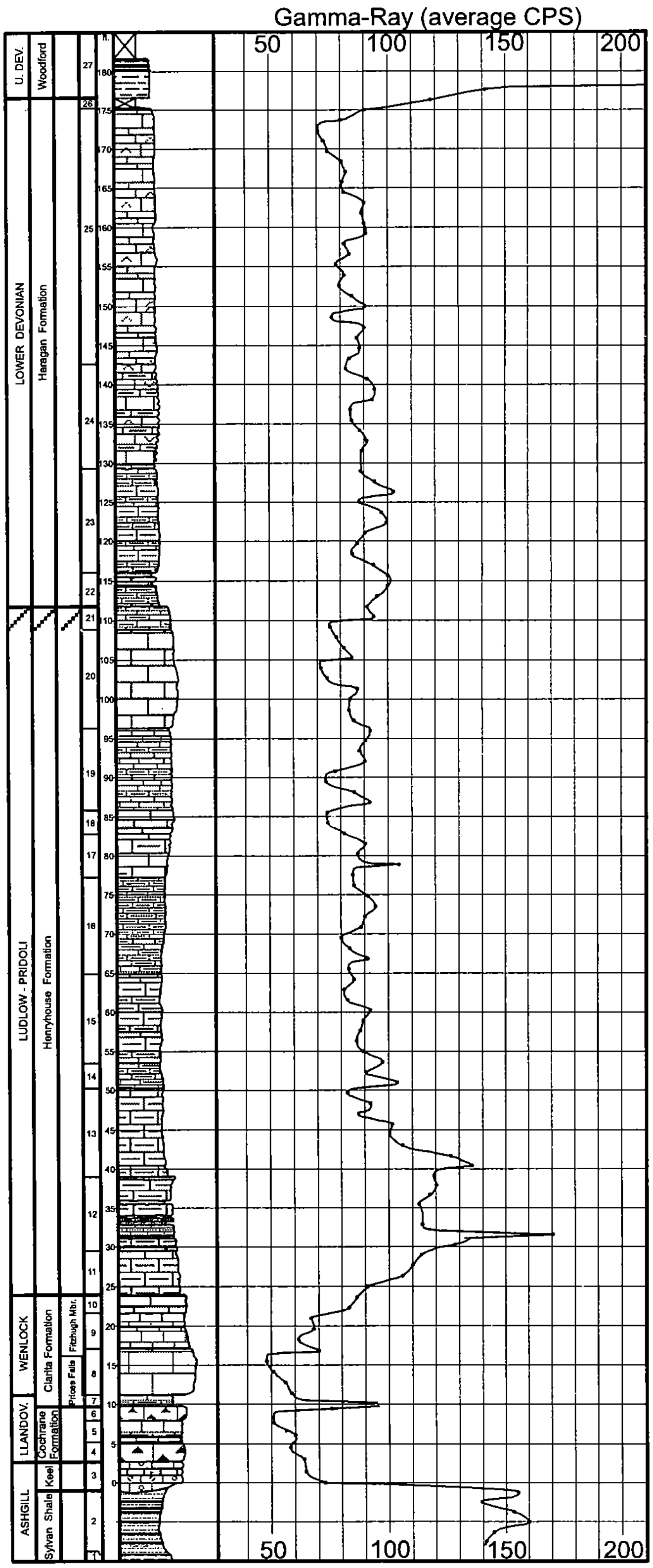


Figure 50. Gamma-ray profile of Hunton Group exposed along north side of US-77 (Stop 9). See text for additional information.

shales and thin chert beds typical of the Woodford Shale rest directly on top of the Haragan Formation. In general, beds dip steeply to the north at approximately 83° and strike N. 80° W., although some of the upper beds of the Haragan and the Woodford Shale are overturned.

One interesting feature of this section is the apparent channeling of the basal Keel Formation into the underlying Sylvan Shale (Fig. 52). This channeling can be seen toward the top of the exposure, where an additional 16 in. of Keel oolite appears to cut into the upper laminated shales of the Sylvan (Fig. 49, unit 2). Previous reports on the Sylvan–Hunton transition (Amsden, 1957, 1960, 1975, 1980; Amsden and Barrick, 1986) stated that no clear-cut evidence of an unconformity is seen at the base of the Keel, although one has been inferred to exist in Arbuckle outcrops. The contact at this locality does suggest that some pre-Hunton erosion probably occurred in this part of the Arbuckle Mountains.

HUNTON GROUP (total thickness, 176.8 ft)

HARAGAN FORMATION (total thickness, 64.7 ft)

26. Rubble zone consisting of blocks and fragments of Haragan limestone, and Woodford shale and chert 1.3

25. Whole-fossil wackestone and mudstone, moderate orange pink (5YR8/4), weathers yellowish gray (5Y7/2). Well-indurated and dense, with sparse argillaceous mudstone and wackestone laminae along bedding. Beds thin, wavy, 0.5–1.0 in. thick; bedding contacts slightly recessive owing to increased argillaceous material. Fossils dominated by whole brachiopods that appear unabraded and articulated; crinoid debris also occurs. Upper contact is obscured by rubble zone 32.6

24. Whole-fossil wackestone interbedded with skeletal, argillaceous mudstones. Wackestone texture similar to unit 25, above; however, beds wavy, medium to thick, 13.0–20.0 in. thick, with thicker wackestone beds more common in basal part of unit. Wackestones interbedded with more recessive, pale yellowish orange (10YR8/6) argillaceous-mudstone intervals. Argillaceous mudstones wavy, thin bedded, 0.5–3 in. thick. Decrease in argillaceous content toward top of unit. Fossil content same as unit 25, although argillaceous mudstones contain fragmentary, rather than unabraded, remains. Upper contact is gradational over 6.0 to 12.0 in. and is marked by a decrease in argillaceous material 13.3

23. Argillaceous mudstone, pale yellowish orange (10YR8/6), weathered and fresh. Thin, irregular to very wavy beds, 0.25–2.0 in. thick, averaging 0.5 in. thick. Irregularly laminated, very argillaceous mudstone to very calcareous shale partings occur along bedding surfaces in basal half of unit, whereas upper half of unit becomes less

Figure 51. Overview of US-77 section (Stop 9), looking west. Major lithostratigraphic contacts are labeled: Sylvan Shale–Hunton Group contact (*Os/OSDh*); Prices Falls Member, base of Clarita Formation (*Scp*); Clarita–Henryhouse contact (*Sc/Sh*); Henryhouse–Haragan contact (*Sh/Dh*); and Hunton Group–Woodford Shale contact (*OSDh/MDw*).

argillaceous and evenly bedded. Whole, unabraded fossils represented by numerous species of brachiopods are common; disarticulated crinoid material also present; crinoid bulbs, *Scyphocrinites* cf. *S. ulrichi*, are common in a 20.0-in.-thick zone starting 70.0 in. below top of unit. Upper contact appears sharp but wavy 13.3

22. Argillaceous mudstone interbedded with very calcareous shale (Fig. 54), pale yellowish orange (10YR8/6), weathering to pale brown (5YR5/2) along bedding and fractures. Unit can be subdivided into four distinct intervals that more or less intergrade: (1) A basal 31.0-in.-thick zone of thin-bedded to laminated, soft-weathering argillaceous mudstone; beds wavy to irregular, 0.25 in. thick at base, increasing to 2.0 in. thick toward top; fossils common, consisting of fragmentary brachiopods and crinoids. (2) A 6.0-in.-thick irregularly laminated very argillaceous mudstone to very calcareous shale, with few fossils observed. (3) A single, 7.0-in.-thick, unfossiliferous argillaceous-mudstone bed. (4) An uppermost 7.0-in.-thick section of irregularly laminated very argillaceous mudstone to very calcareous shale. Upper contact of unit is gradational over a distance of 4.0–6.0 in. 4.2

***Note:** The base of unit 22 also corresponds with the base of the Haragan Formation, according to Amsden (1960). In contrast with the Henryhouse, the Haragan Formation is much more argillaceous, fossiliferous, and recessive at this stratigraphic position.*

HENRYHOUSE FORMATION (total thickness, 88.2 ft)

21. Whole-fossil mudstone (Fig. 54), grading upward into argillaceous mudstone, yellowish gray (5Y 7/2), weathering to medium gray (N5) to pale greenish yellow (10Y8/2). Beds even, thin to medium, 1.0–6.0 in. thick, becoming more irregular owing to increase in argillaceous material in upper 12.0–18.0 in. of unit. Rare brachiopods in lower half of unit. Upper contact appears sharp but wavy 3.0

20. Mudstone (Fig. 54), yellowish gray (5Y7/2), weathering medium gray (N5) along bedding and fractures. Interval more indurated and thicker bedded than one above. Beds 6.0–12.0 in. thick, with thicker beds more common toward base of unit. Fossils sparse, consisting of whole brachiopods mixed with some crinoid plates and ossicles. Some argillaceous-limestone beds occur interstratified with less-argillaceous-limestone beds. Upper contact is gradational over several inches and is marked by an increase in argillaceous material and a decrease in bed thickness 12.5

19. Argillaceous mudstone, grayish orange (10YR 7/4), weathering light brown (5YR6/4); fairly well indurated but still recessive in comparison with surrounding units with a more characteristic carbonate texture. Beds even, thin to medium, 0.5–5.0 in. thick, averaging 3.0 in. thick. Thinner bedded material tends to be more common in basal 4.0 ft of unit, whereas argillaceous material and bed thickness increase toward top. Fossil material sparse, consisting of fragmentary shell material and crinoid debris. Calcite veining prominent throughout. Upper contact is sharp and planar 10.5

18. Mudstone, yellowish gray (5Y7/2), weathering to medium gray (N5) to pale greenish yellow (10Y 8/2); beds medium, 5.0–10.0 in. thick, with thicker beds (averaging 9.0 in.) common at base and thinner beds (averaging 6.0 in.) more common toward top of unit. Argillaceous material also shows a slight increase toward top. Fossils rare. Upper contact sharp and planar 3.0

17. Argillaceous mudstone, grayish orange (10YR 7/4), weathering to light brown (5YR5/6); beds thin to medium, 3.0–10.0 in. thick. Unit less argillaceous than other argillaceous-limestone units of the Henryhouse. No fossils evident. Upper contact sharp and planar 5.6

16. Argillaceous mudstone, grayish orange (10YR 7/4), weathering to dark yellowish brown (10YR 4/2) to yellowish gray (5Y7/2) along fractures and bedding surfaces; beds thin and even, averaging a uniform 1.0-in. thickness throughout; bedding contacts are slightly recessive, with a lighter weathering hue owing to an increase in argillaceous material; recessive zones range from 0.10 to 0.25 in. about the bedding contact. The unique weathering character gives the unit a banded appearance between the dark brown and light gray color of the weathered limestones. Fossils rare. Upper contact sharp and planar ... 12.7

15. Argillaceous mudstone, similar to unit above except for thicker, more variable bedding; grayish orange (10YR7/4) weathered and fresh; bedding character medium, planar (near base) to wavy (near top), beds 4.0–7.0 in. thick; some 0.5–1.0-in. argillaceous partings along bedding contacts in upper half of unit; partings coincide with an increase in wavy rather than planar bedding. Upper contact sharp but wavy 11.2

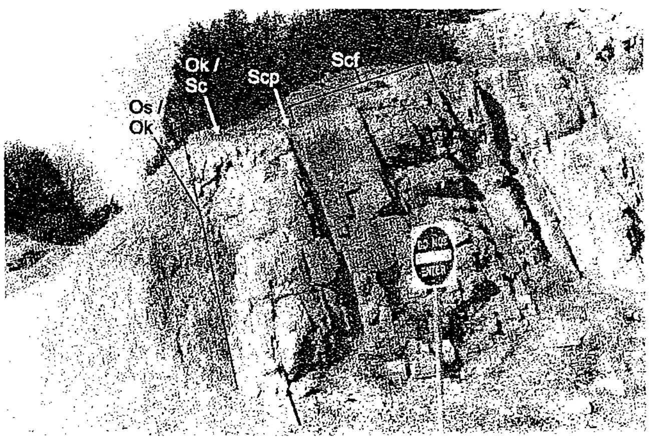


Figure 52. Chimneyhill Subgroup, US-77 section (Stop 9), showing channeled lower contact of the Keel oolite into the Sylvan Shale (*Os/Ok*). Also shown are the Keel–Cochrane contact (*Ok/Sc*), and the Prices Falls (*Scp*) and Fitzhugh (*Scf*) Members of the Clarita Formation. Massive-looking interval in the basal Fitzhugh corresponds to unit 8, and bedded Fitzhugh is unit 9. Rest of exposure to the right is the basal Henryhouse.

The Cochrane Formation is also atypical at this locality (Fig. 52). Whereas at other sections the Cochrane has a distinct grain-supported texture, here the Cochrane is mud supported and contains an overabundance of chert. Glauconite occurs, but it is sparse and found only in the upper and lower units (Fig. 49, units 4, 6) and is conspicuously absent in the middle unit (Fig. 49, unit 5).

Both the Henryhouse and Haragan Formations are well exposed, and the lithologic transitions that occur within and between the two can easily be examined. For example, a general shoaling trend can be discerned in the Henryhouse. This shoaling trend is repeated in the Haragan. First, the basal argillaceous mudstones and shales of the Henryhouse (Fig. 49, unit 12; Fig. 53) are well exposed at this site and represent the maximum point of transgression of the Late Silurian seas (see section on Carbonate Cycles and Sequence Stratigraphy, and Fig. 8, in Part I). This sequence is also easily identified by its high gamma-ray signature that contrasts well with the lower values of the Chimneyhill

14. Argillaceous mudstone, fresh and weathering color same as unit 15; beds thin, planar to slightly wavy; 0.5–1.0 in. thick. Texture similar to unit 16 except for absence of argillaceous partings along bedding contacts. Upper contact sharp and planar 3.2

13. Argillaceous mudstone, grayish orange (10YR 7/4), weathering to light brown (5YR5/6) to dark yellowish brown (10YR4/2); medium bedded, wavy although some thinner beds occur; 4.0–11.0 in. thick, but average ~9.0 in. thick. On fresh surfaces, internal bedding laminations evident; weathered surfaces typically have a light and dark banded appearance similar to unit 16. Fossils rare, mostly composed of crinoid fragments. Upper contact sharp and planar 11.2

12. Interbedded argillaceous mudstones and laminated clayshales (Fig. 53). Mudstones grayish orange (10YR7/4), weathering light brown (5YR 5/6) to dark yellowish brown (10YR4/2); occurring either as single beds or a series of beds separated by intervals of clayshale; crinoid plates and individual ossicles present in some beds. Clayshales are medium gray (N5) that weather to light brownish gray (5YR6/1) to light olive gray (5Y6/1), and have streaks of grayish orange (10YR7/4) along laminations; clayshale is silty and very calcareous, with discontinuous, blocky laminated bedding; no body fossils evident, although graptolites have been reported from clayshale intervals (Al-Shaieb and others, 1993b); mottling from horizontal burrows (?*Chondrites*) common. Individual beds and bedding intervals can be arranged in the following ascending order: (1) basal 7.5 in., burrow-mottled argillaceous mudstone; (2) 0.5-in.-thick, wavy, very argillaceous mudstone parting; (3) two 6.-in.-thick argillaceous mudstone beds, similar to bed 1 except for absence of burrow mottling; (4) 4.0-in.-thick blocky laminated clayshale with wavy upper and lower contacts; (5) 17.5-in.-thick, thin-bedded argillaceous mudstone with beds 0.1–0.5 in. thick; (6) 5.5-in.-thick blocky laminated clayshale with wavy upper and lower contacts; (7) 5.5-in.-thick argillaceous mudstone; (8) 4.0-in.-thick blocky laminated clayshale with gradational lower contact with bed 7 and wavy upper contact with bed 9; (9) 18.0-in.-thick interval of argillaceous mudstone composed of two equal-size beds; (10) 5.5-in. thick blocky laminated clayshale with wavy upper and lower contacts; and (11) 37.0-in.-thick, slightly recessive, massive to thick-bedded argillaceous mudstone, with a 5.0-in. thick resistant argillaceous-mudstone bed at top. Upper contact of unit sharp and planar 9.8

11. Argillaceous mudstone, grayish orange (10YR7/4) fresh and weathered; beds medium, 6.0–9.0 in. thick, appearance fairly planar and uniform (although beds at base of unit are thinner on average). Crinoid plates and ossicles present. Upper contact is sharp and planar, denoted by a bedding and weathering color change 5.5

CHIMNEYHILL SUBGROUP (total thickness, 23.9 ft)

CLARITA FORMATION (total thickness, 14.1 ft)

Fitzhugh Member

10. Mudstone, grayish orange (10YR7/4), weathering to yellowish gray (5Y7/2) to light olive gray (5Y 6/1); beds medium, 4.0–9.0 in. thick. Unit is increasingly argillaceous toward Henryhouse contact. Fossil fragments consist of brachiopods, gastropods, and crinoids. Upper contact is sharp but undulatory; coincides with a 0.1-in. shale

Figure 53. Unit 12 of the Henryhouse Formation, US-77 section (Stop 9), showing interbedded graptolite-bearing clayshales, and argillaceous mudstones. Interval represents point of maximum transgression of the Late Silurian seas. Stratigraphic top is to the right. Scale in inches and centimeters.

(or argillaceous-mudstone break) and a distinct color change from unit 11 of Henryhouse Formation 2.3

9. Mudstone (Fig. 52), moderate orange pink (5YR 8/4), weathering to medium gray (N5); medium to thin bedded, with very argillaceous mudstone laminae occurring along bedding contacts; beds 1.0–8.0 in. thick, averaging 6.0 in. No fossils evident. Upper contact looks sharp but wavy 4.4
8. Fossiliferous mudstone (Fig. 52), moderate orange pink (5YR8/4), weathering to medium gray (N5), grayish blue green (5BG5/2), or yellowish gray (5Y7/2) along some bedding surfaces; unit is massive to thick bedded, consisting of three to four distinct beds, each averaging 24.0 in. thick; bedding surfaces with distinct "tearpants" weathering. Fossil material common, consisting of crinoid debris with minor brachiopod-shell fragments. Upper contact is sharp but wavy 5.9

Prices Falls Member

7. Argillaceous mudstone (Fig. 52), grayish orange (10YR7/4) fresh and weathered. Unit recessive and poorly exposed; bedding appears irregularly laminated, with individual laminae 0.25–0.50 in. thick. Argillaceous material and glauconite more common in upper half of interval, and limy material and crinoid debris much more common in lower half. Upper contact is sharp and planar 1.5

COCHRANE FORMATION (total thickness, 7.0 ft)

6. Cherty mudstone, medium gray (N5), weathering light gray (N7); planar, medium bedded, with individual beds 5.0–10.0 in. thick. Chert and mudstone appear brecciated, possibly as a result of karst development; chert usually very light gray (N8). Glauconite grains common; minor crinoid fragments present. Upper contact is sharp and planar 1.8
5. Bedded chert and mudstone, medium gray (N5), weathering to light gray (N7) or pale green (10G 6/2); beds thin to medium, 2.0–6.0 in. thick, separated by 0.5–1.0-in.-thick discontinuous laminae or lenses of very light gray (N8) chert. No glauconite evident; crinoid fragments rare. Upper contact is sharp but wavy 2.7
4. Cherty mudstone, moderate orange pink (5YR 8/4) to medium gray (N5), weathering to light gray (N7), pale green (10G6/2), or very pale orange (10YR8/2); unit consists of a single massive bed of fossiliferous mudstone with irregular pods or breccia blocks of chert; chert typically grayish yellow (5Y8/4) to very light gray (N8); breccia texture exhibited by mudstone and chert may indicate paleokarst development. Glauconite grains common throughout. Fossil material consists of crinoid plates and individual ossicles; whole crinoid stems rare. Upper contact is sharp but wavy 2.5

KEEL FORMATION (total thickness, 2.8 ft)

3. Intercalated oolitic packstone–grainstone and laminated crinoidal wackestone–packstone. Oolitic facies medium light gray (N6) to light bluish gray (5B7/1), weathering to bluish white (5B9/1) to light gray (N7), with some oxide zones on fractures weathering to grayish orange (10YR 7/4); this facies is loosely concentrated in the basal 17.5–33.5 in. and upper 7.0 in. of unit; ooids are loosely packed and are uniform in size and shape; grain interstitial space occupied predominantly by sparite, but some lime mud also occurs. Crinoidal facies is pale yellowish brown (10YR6/2) to light brownish gray (5YR6/1), weathering to pale brown (5YR5/2) to medium gray (N5); facies common in a zone 7.0–15.5 in. from top of unit, although it also occurs as irregular patches within the oolitic facies; whole or partial crinoid columns common, set within a laminated mud matrix and/or calcite spar; some "clasts" of oolitic limestone also occur. As a whole, beds are 3.0–7.0 in. thick, with a single 16.0-in. bed at top. Upper contact is sharp but wavy. Thickness is variable owing to channeled lower contact (Fig. 52): where measured 2.8

SYLVAN SHALE

2. Clayshale (Fig. 52), pale yellowish brown (10YR 6/2) to pale greenish yellow (10Y8/2), weathering to very pale orange (10YR8/2); shale continuously laminated, silty and calcareous, interbedded with 0.10–0.20-in.-thick siltstone to very fine grained sandstone laminae. Coarser clastics slightly more resistant in comparison to clayshale; individual shale laminae 0.05–0.10 in. thick; burrow mottling common on bedding surfaces. Upper contact sharp but channeled by overlying Keel Formation by as much as 16 in.. 7.7
1. Clayshale, similar in most respects to unit 2; however, this unit consists of thicker and more discontinuous laminae, and shale is not as silty, containing fewer coarse-clastic interbeds. Upper contact is gradational .... ~50

Total thickness of section 244.5+

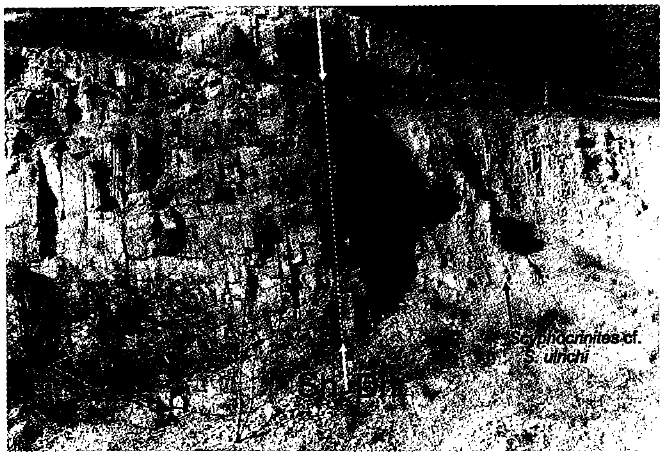


Figure 54. Closeup of Henryhouse (*Sh*)–Haragan (*Dh*) contact (thin dotted line), US-77 section (Stop 9). Note recessive nature of argillaceous mudstones at the base of the Haragan in comparison with the more resistant mudstones of the upper Henryhouse. Zone with the crinoid bulb *Scyphocrinites* cf. *S. ulrichi* marked by dark arrow.

Subgroup and upper beds of the Henryhouse (Fig. 50). Above this point, the regressive, fill-in part of the HHB cycle commenced, resulting in deposition of the rest of the Henryhouse argillaceous mudstones (Fig. 49, units 13–21). Toward the top of the Henryhouse (Fig. 49, units 17–21; Fig. 54), there appears to be an overall decrease in argillaceous material in these beds, suggesting that the Silurian seas were shallowing and that this part of the Henryhouse section was shifting up the carbonate ramp into zone 4 facies (Fig. 6; Table 2). This shallowing trend in the Henryhouse is somewhat evident on the gamma-ray profile (Fig. 50). Note that there is a gentle trend of decreasing gamma-ray values when moving from the top of unit 12 to the top of unit 21. This probably indicates a gradual decrease in argillaceous material (i.e., a gradual shallowing of the Late Silurian seas) as one moves up the section.

A similar transgressive–regressive trend occurs in the overlying Haragan Formation (Figs. 8, 50). At the base of the Haragan, a thin sequence of very argillaceous to shaly mudstones (Fig. 54) occurs, which are analogous to the condensed section at the base of the Henryhouse (compare units 12 and 21 in Fig. 49). The gamma-ray signature also shows a sharp increase in average counts per second through this zone (Fig. 50). Continuing up the Haragan section, there is a continual decrease in argillaceous material (similar to that observed in the upper Henryhouse), suggesting that these limestones were forming in progressively shallower water, away from any source of clastic material.

Unfortunately, the carbonate (fill-in) cycle is incomplete at this section, owing to the missing Bois d'Arc facies; however, one could infer that the cycle would have continued through to the top of the Fittstown shoal-water grainstones.

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APPENDIX
Explanation of Symbols Used in Guidebook

LITHOLOGY

- Mudstone
- Wackestone
- Packstone
- Oolitic grainstone
- Skeletal grainstone
- Argillaceous mudstone/wackestone
- Limestone w/ tripolitic chert
- Limestone w/ vitreous chert
- Limestone w/ brecciated chert (?)
- Silty shale
- Fissile shale
- Calcareous shale
- Sandstone
- Covered interval

BEDDING

- Thick/massive bedding
- Thin/uniform bedding
- Medium-thin bedding

Section continued on next column or page

SEDIMENTARY FEATURES

- Unit contact, planar
- Unit contact, wavy
- Unit contact, gradational
- Unit contact, covered/unknown
- Planar bedding
- Wavy bedding
- Irregular bedding
- Stylolitic bedding
- Channeling
- Channeling with crinoid lag
- Fining-upward sequence
- Brecciation
- Micro-folding and faulting
- Phosphate nodules
- Brachiopods
- Crinoid bulb
- Trilobite
- Gastropods
- Coral
- Bryozoan
- Crinoid debris
- Shell fragments
- Algae-coated grains
- Plant fragments
- Burrows and burrow mottling