Shale Shaker

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Oklahoma 2011 Drilling Highlights,

The Geology and Deep Structure of the Oklahoma Ouachita Mountains – The SOPC 1-22 Weyerhaeuser Well,

And much more.

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Shale Shaker

Shale Shaker Staff

OCGS Executive Committee

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About the Cover

Michael Root creates the covers of the *Shale Shaker*. The cover for this Issue utilizes an image supplied by Michelle Dodd, Coordinator of Photography for Chesapeake Energy Corporation and is one of many contained within Chesapeake's Visual Resource Center.

The cover ties nicely with this Issue's technical subject matter: "Oklahoma 2011 Drilling Highlights," by Dan T. Boyd, of the Oklahoma Geological Survey; and "The Geology and Deep Structure of the Oklahoma Ouachita Mountains – The SOPC 1-22 Weyerhaeuser Well," by Michael D. Allison, North Texas Sample Log Service, William H. Willis II, Manager - Southern Minerals, Weyerhaeuser Company, and Neil H. Suneson, of the Oklahoma Geological Survey.

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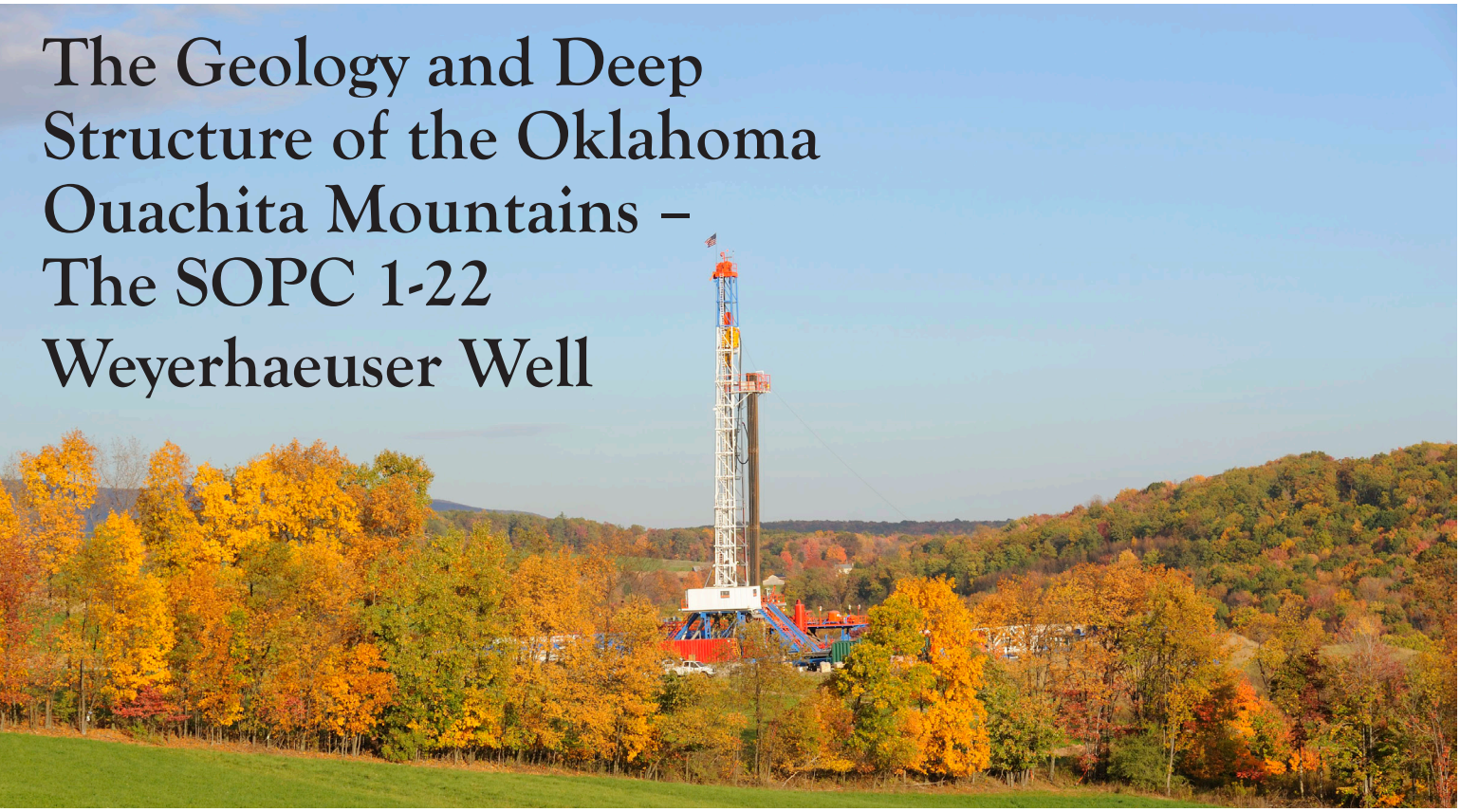
The Geology and Deep Structure of the Oklahoma Ouachita Mountains – The SOPC 1-22 Weyerhaeuser Well



Introduction

Thanks to the generosity of Weyerhaeuser Company and the cooperation of consulting geologist Michael D. Allison, the Oklahoma Geological Survey (OGS) recently released a formerly proprietary report on one of the most important wells ever drilled in the Ouachita Mountains of Oklahoma – the Standard Oil Production Company (SOPC) 1-22 Weyerhaeuser. Spudded on April 9, 1987 and located on the crest of the Broken Bow Uplift more than 50 mi south of the thrust front of the Ouachita tectonic belt (Figure 1), the 1-22 Weyerhaeuser TD'd at almost 19,000 ft and fortunately, Weyerhaeuser elected to thoroughly study all the cuttings from surface to TD and all the cores that were cut. Equally important, Weyerhaeuser chose Mike Allison – a wellsite geologist with vast experience in the petrography of lower and middle Paleozoic strata in southeast Oklahoma – to log the well. The well is important for a number of reasons, but none more so than it drilled through the basal decollement of the fold-and-thrust belt into foreland facies strata at about 11,750 ft and again at 13,400 ft. This well is therefore critical for all modern tectonic interpretations of the Ouachita Mountains (e.g., Arbenz, 2008).

This paper summarizes some of the contents of the OGS report (Open-File Report OF 1-2012). The entire report consists of the following (asterisk denotes those parts that are included in this paper):

* Introduction – Neil H. Suneson
* Letter of Introduction – Michael D. Allison
* Letter of Introduction – William H. Willis

* Revised Preliminary Report (August 18, 1987) on SOPC 1-22 Weyerhaeuser (31 p.) – Revised by Michael D. Allison, January 2012

Final Report (October 17, 1987) on SOPC 1-22 Weyerhaeuser (46 p.) – Michael D. Allison
Geologic Evaluation, inc. shows, logs run, core intervals, drill stem test, formation tops.
General Statement
Thin Section Evaluation
Core Thin Section Evaluation
Geological Evaluation
Introduction
Sample Study
Geological Sequence Penetrated
Correlation of Ouachita Facies
Correlation of Foreland Facies (inc. Hunt #1 Neely)
Primary Tectonic Stages
Metamorphism
Reservoir and Source Potential

*References Cited

261 Photomicrographs of cuttings, 90 ft to 18,940 ft (*example, Figure 2, this report)

Core photographs and photomicrographs

45 from Core #1, 12,137 ft to 12,149 ft

22 from Core #2, 12,149 ft to 12,209 ft

43 from Core #3, 14,252 ft to 14,301 ft (*example, Figures 3A and 3B, this report)

19 from Core #4, 17,089 ft to 17,106 ft

19 Photomicrographs from the Hunt No. 1 Neely well, 12,850 ft to 18,700 ft

17 Photomicrographs of Arbuckle Group samples from various wells in Grayson County, Texas. (Well names and locations proprietary)

Sample Log of SOPC 1-22 Weyerhaeuser, North Texas Sample Log Service – Michael D. Allison (*part, Figure 4, this report)

History of Geologic Investigations

Prior to drilling the SOPC 1-22 Weyerhaeuser well on the crest of the Broken Bow Uplift in 1987, very little was known about the deep structure of the Ouachita Mountains. Most authors, including those who had published classic papers on Ouachita geology (e.g., Honess, 1923; Miser, 1929; Flawn and others, 1961), did not address the extent that overthrusting may have played in Ouachita tectonics. Although a major role for thrust faulting was not universally accepted (see, for example, the public and acrimonious 1957 – 1958 debate between Tom Hendricks and Peter Misch in the American Association of Petroleum Geologists Bulletin, summarized by Suneson (2008)), most geologists agreed that the Ouachitas were a fold-***and-thrust*** belt. But the extent of overthrusting and the amount of shortening the orogenic belt had undergone remained controversial.

Key to the argument was the recognition that early and middle Paleozoic shelf strata present in the subsurface of the Arkoma Basin (Cambro-Ordovician Arbuckle Group through Mississippian Caney Shale) were equivalent to basinal strata in the Ouachita Mountains (Cambro-Ordovician Collier Shale through Mississippian Stanley Group) (Ham, 1959) and that the basinal strata had been thrust to the north or northwest over the shelf strata. How far south the shelf strata extended and lay buried beneath the thrust sheets of basinal strata would allow a minimum amount of shortening to be determined. More control would be possible if the early and middle Paleozoic shelf edge could be identified in the subsurface.

Geophysical studies and a couple of deep wells gave geologists a clue as to how far south the shelf strata extended. In early 1981, the Consortium for Continental Reflection Profiling (COCORP) completed a seismic-reflection survey across the Ouachita Mountains in western Arkansas (Figure 1). Two interpretations of the data by Nelson and others (1982, fig. 3) and Lillie and others (1983, fig. 5) show shelf strata extending to just south of the crest of the Benton Uplift beneath a major decollement separating the shelf strata from the overlying early and middle Paleozoic basinal strata exposed in the uplift. In 1967, Shell spudded the No. 1

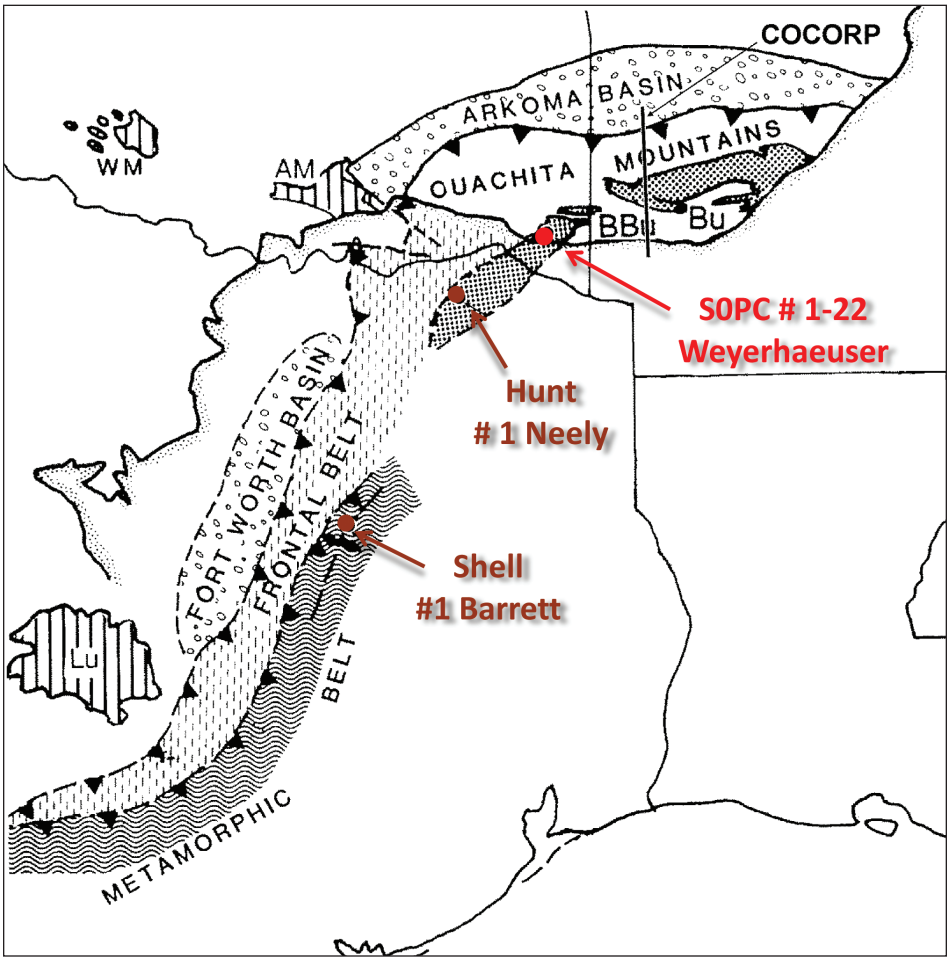


Figure 1. Generalized tectonic map of Ouachita tectonic belt (modified from Viele and Thomas, 1989). Bu – Benton Uplift; BBu – Broken Bow Uplift; AM – Arbuckle Mountains; WM – Wichita Mountains; Lu – Llano Uplift.

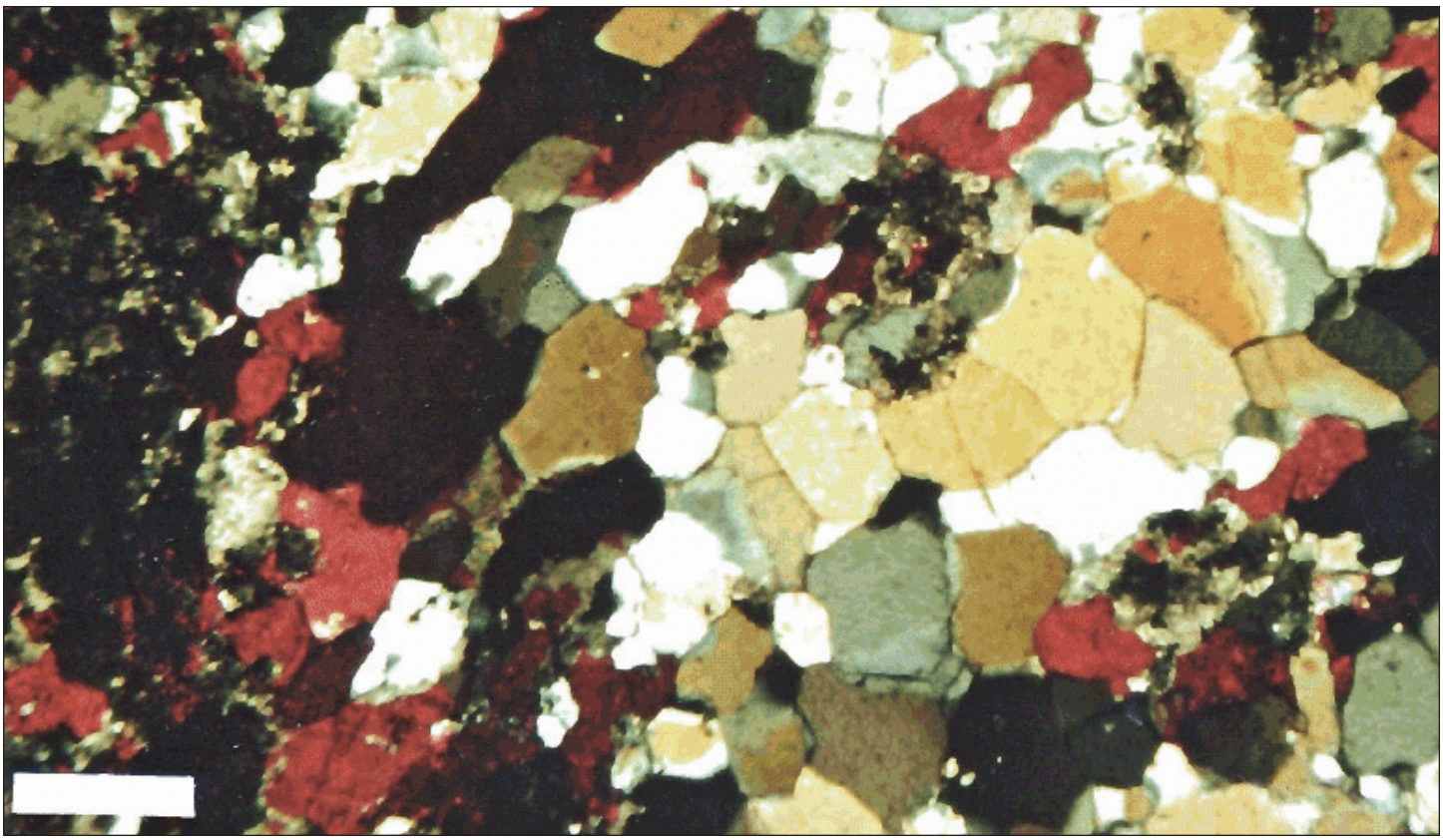


Figure 2. Graphitic dolomitic quartzite. Note the calcite replacement of quartz and the sutured contacts between the quartz grains. Cambrian (?) Arbuckle Group, 15,220-30'. Bar represents 1/4 mm.

Barrett well in Hill County, Texas (Figure 1), on trend with the (now entirely subsurface) Ouachita tectonic belt as mapped by Flawn and others (1961). The well drilled what is now interpreted as an allocthonous section of Ouachita facies basinal strata separated from underlying Cambrian(?) to Devonian(?) metamorphosed carbonates by a major decollement (Rozendal and Erskine, 1971; Nicholas and Waddell, 1989). The Hassie Hunt Trust No. 1 Neely well was spudded in May 4, 1974 and completed February 15, 1975 in Lamar County, Texas (Figure 1), on trend with and about 50 mi southwest of the southern extent of the exposed part of the Broken Bow Uplift. It drilled a similar sequence to the Barrett well, with deformed shelf-facies carbonates in the bottom of the well (Nicholas and Waddell, 1989). Both wells and the geophysics showed that basinal Ouachita strata had been thrust over shelfal strata.

Starting in 1982, SOHIO (later SOPC) agreed to explore for oil and gas on 824,000 acres of Weyerhaeuser land in the Ouachita Mountains of southeast Oklahoma. At the time only ten wells deeper than 10,000 ft had been drilled in an area encompassing more than 87 townships (slightly over two million acres) south of the Windingstair Fault in Oklahoma, and none had penetrated the basal thrust fault of the Ouachita fold-and-thrust belt. The exploration program included a wide variety of studies and included seismic exploration and the drilling of six wells. The results of some of SOHIO's exploration efforts have been published or released (e.g., Leander and Legg, 1988; Titus and Cole, 1996) and the completion reports and logs of the wells are in the public domain (Oklahoma Corporation Commission). However, Mike Allison's detailed studies are the "crown jewel" of the program and were never released, until now.

The OGS is proud to have partnered with Mike Allison and Weyerhaeuser Company in releasing the detailed geological studies of the 1-22 Weyerhaeuser well. As pointed out by Mr. Allison in his introductory letter, a better understanding of the tectonics of the Benton – Broken Bow Uplift and, indeed, the entire Ouachita orogenic belt, will be based on data such as those released in this report. He adds that oil and gas are successfully produced from several fields within the Ouachitas and that "surely these are not the only productive locations along this 1,300-mile trend." Mr. William H. Willis, Manager – Southern Minerals with Weyerhaeuser Company, seconds Mr. Allison's statement and hopes "that this report finds utility in both the oil/gas industry and the academic community."

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Letter of Introduction
September 13, 2011

From May 8 to July 29, 1987, as a consulting geologist, I was involved as a well site geologist on the Standard Oil Production Co., Weyerhaeuser #1-22, 800' FNL, 2,300' FEL, Section 22, T5S, R24E, McCurtain County, Oklahoma; approximately 6.5 miles NW of Broken Bow, Oklahoma. The well was spudded on April 19 on Lower Ordovician Crystal Mountain Sandstone and the well's location is along the crest of the Benton-Broken Bow Uplift. The well was drilled in 111 days and reached a total depth of 19,000', bottoming in Cambrian Arbuckle. Following the completion of drilling a geologic and petrographic analysis report on the well was prepared and presented to Weyerhaeuser as well as Standard Oil Production Co.; formerly Sohio.

During 1987, as a consulting geologist and owner of the Allison Oil and Gas Co., Inc. and the North Texas Sample Log Service, I was afforded the opportunity of performing the well site geologic study of the Weyerhaeuser 1-22. For me this study has become the most unique well study of my career, primarily due to who the client was.

As a corporate petroleum geologist I was trained in sample identification and during my graduate program as a carbonate petrologist. Combined with a microphotographic capability I was able to document observations. Academically I earned a M.S. degree from West Texas State University, now West Texas A & M University, Canyon, Texas in 1979. My primary studies were under Dr. George Asquith, currently Professor Emeritus, Texas Tech University, Lubbock, Texas. It was during these studies that my petrographic analysis "thin section" techniques were acquired. Though petrographic analysis is uniquely adapted to carbonate studies these techniques are also useful for the evaluation of other rock types. It was these professional and academic capabilities that allowed my office to be selected to perform this study.

As stated above, who the client was is what made this study so unique. Rather than the operator, whose perspective is based on the term of the lease and the period that the well is being drilled, the client for this project was Weyerhaeuser, also known as the "farmer and/or land owner." In that the client was the land/minerals owner the scope and objectives were profoundly different. As was expressed to me at the onset of this project, Weyerhaeuser's perspectives are multiple decades if not centuries. What they wanted from my office was not only the data which I could provide during a "standard" well site study but also a complete geologic analysis documenting the well data, no matter how redundant. It was also expressed that they wanted the study to cover the entire drilled section. Also, they requested that all thin sections be delivered to the Hot Springs, Arkansas office. With this complete data set studies would be possible by scientists in the future.

Well site work began on May 8, 1987, at which point the well was drilling at approximately 7,700'. In addition to beginning sample identification at that depth, samples were acquired from the upper part of the hole and were also studied.

During the study a sample log was prepared from surface to total depth. Also, 265 thin sections and 406 microphotographs were prepared to document the sample log observations. The attached Oklahoma Geological Survey "Open-File Report" is the report which was prepared to document these observations.

Profound gratitude is expressed to Weyerhaeuser for allowing the release of the report. Also, special thanks go to Mr. William Willis of Weyerhaeuser, who was my supervisor during the project and continuous supporter for the release of this report. Without Mr. Willis these data would be, for all time, filed away in a corporate filing cabinet. Also, Dr. Neil Suneson of the Oklahoma Geological Survey has graciously offered to provide a cover letter to this Open-File Report. His insights within the introduction to this report are what place this report in perspective and without his remarks any importance it may have would be muted.

Lastly, though Mr. Willis and I had worked for several years to allow the release of this report, it was Dr. Randy Keller of the Oklahoma Geological Survey who was able to "make it happen." Though Dr. Keller and Dr. Suneson had never seen the report, they believed that scientific data existed and that any research data along the crest of the Benton-Broken Bow Uplift could be profoundly important for a better understanding of the Ouachita facies in southeastern Oklahoma.

It is hoped that these data may prove useful for better understanding of the Benton-Broken Bow Uplift, the core of the Ouachita facies complex and ultimately the potential for oil and gas exploration within the 1,300 mile thrust system. Oil and gas have been discovered and successfully produced at Isom Springs Field, Marshall County, Oklahoma and Pinon Field, Pecos County, Texas, as well as other locations. Surely these are not the only productive locations along this 1,300 mile trend. Hopefully this report may assist in additional production along the trend.

Respectfully submitted

M.D. Allison

Letter of Introduction

Mineral Resources Department

Weyerhaeuser
The future is growing™

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October 27, 2011

Frederick Weyerhaeuser was a teenager when he emigrated from Germany to the US in the 1850's. He began work counting lumber but eventually acquired a large block of timberlands in Minnesota. In the late 1890's he recognized a good opportunity to move his operations to Washington State so he sold all his Minnesota land and minerals. Later he learned he had sold a good portion of the developing Mesabi iron range which is the iron resource that essentially made US Steel. As a consequence, all Weyerhaeuser youngsters have been and are still counseled that it is OK to sell land…just not the minerals! This principle is still alive and well today within Weyerhaeuser Company who owns a 7,100,000 net acre mineral estate and a 5,300,000 surface acre estate. Minerals are considered a core asset and are managed by a dedicated group of industry professionals who employ both long term and short term strategies as needs and opportunities dictate. We deal primarily in energy products, construction aggregates and industrial minerals.

In late 1982 Weyerhaeuser and SOHIO (later Standard Oil Production Company) entered into a 5 year agreement to explore for oil/gas on Weyerhaeuser's land in Oklahoma (824,000 acres). In late 1983, a similar agreement was negotiated for a portion of Weyerhaeuser's land in Arkansas (592,000 acres). The combined agreement area was entirely within the Ouachita Overthrust province. A large database was amassed and an extensive evaluation of the agreement area was conducted. Methods used included drilling 6 wells, seismic, surface geological mapping, surface gamma ray surveys, aerial photo analysis, petrography, palynology, geochemistry, induced polarization, gravity, magnetotellurics, aeromagnetics, etc. SOHIO assembled a very talented core team of professionals who stayed intact for the duration of the agreement and words cannot convey the fabulous work they did. I too was there for the duration as AR/OK Senior Geologist – Weyerhaeuser Company which was both an honor and a pleasure. My previous experience as a prospect generator with Stephens Production Company and Davis Oil Company was wonderful but quite unlike managing, understanding and re-interpreting all the frontier data generated by SOHIO as well as legacy data already possessed by Weyerhaeuser. Unfortunately, no commercial discovery was made despite a yeoman effort and expense somewhere north of $50,000,000. However, there is no doubt that others will continue stand on the shoulders of those that preceded them in the quest for more commercial hydrocarbons from the Ouachitas.

The SOPC #1-22 Weyerhaeuser spud on April 7, 1987 and everyone involved recognized that it was going to be a very important well. Weyerhaeuser wanted the best well site geologist available who had experience with the Ouachita and Foreland facies we expected to penetrate. We were pleased to have contracted with Mike Allison who independently produced the exceptionally nice report we are now gifting to the Oklahoma Geological Survey.

One might wonder why Weyerhaeuser waited 24 years to release this report. Strategies were debated numerous times and we were divided between the short term and long term approaches as described above…..so we just landed somewhere in the middle! It is a pleasure to do so now and it is my hope that this report finds utility in both the oil/gas industry and the academic community.

Sincerely,

William Willis
Manager—Southern Minerals
Weyerhaeuser Company

Revised Preliminary Report

M.D. Allison
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August 18, 1987

COMPANY:	Standard Oil Production Co.
WELL NAME:	Weyerhaeuser #1-22
LOCATION:	800' FNL & 2300' FEL of section 22, T5S, R24E, McCurtain County Oklahoma. Approximately 6.5 miles northwest of Broken Bow
ELEVATION:	G.L.: 625', D.F.: 656', K.B.: 658'
TOTAL DEPTH:	18,987' (strap) 19,000' (geolograph)
COMMENCED:	4-9-87
COMPLETED:	7-29-87
STATUS:	D & A
NOTE:	Geosearch Logging Inc., P.O. Box 3697, Edmond, Oklahoma 73083 provided a mud logging trailer and evaluated the well from surface to T.D.
DRILLING CONTRACTOR:	Noble Drilling Rig #T-133

GEOLOGIC EVALUATION:

Introduction:

The Standard Oil Production Company, Weyerhaeuser 1-22, sec. 22, T5S, R24E, McCurtain County, Oklahoma is probably the most geologically significant well ever drilled along the 1,300 mile Ouachita foldbelt. What makes this well significant are a combination of where the well was drilled, what formations were penetrated and the tectonic events which can be documented.

The Weyerhaeuser 1-22 was drilled along the crest of the Benton-Broken Bow uplift, spudded in the Ordovician Crystal Mountain Sandstone and quickly penetrated into the Cambrian Collier Formation, the oldest Ouachita facies formation observed in the Ouachita Mountains. This well is located on the "type section" for Ouachita facies deposits in Oklahoma and is in one of the most heavily studied portions of the Ouachita foldbelt. The Ouachita facies rocks penetrated by this well should

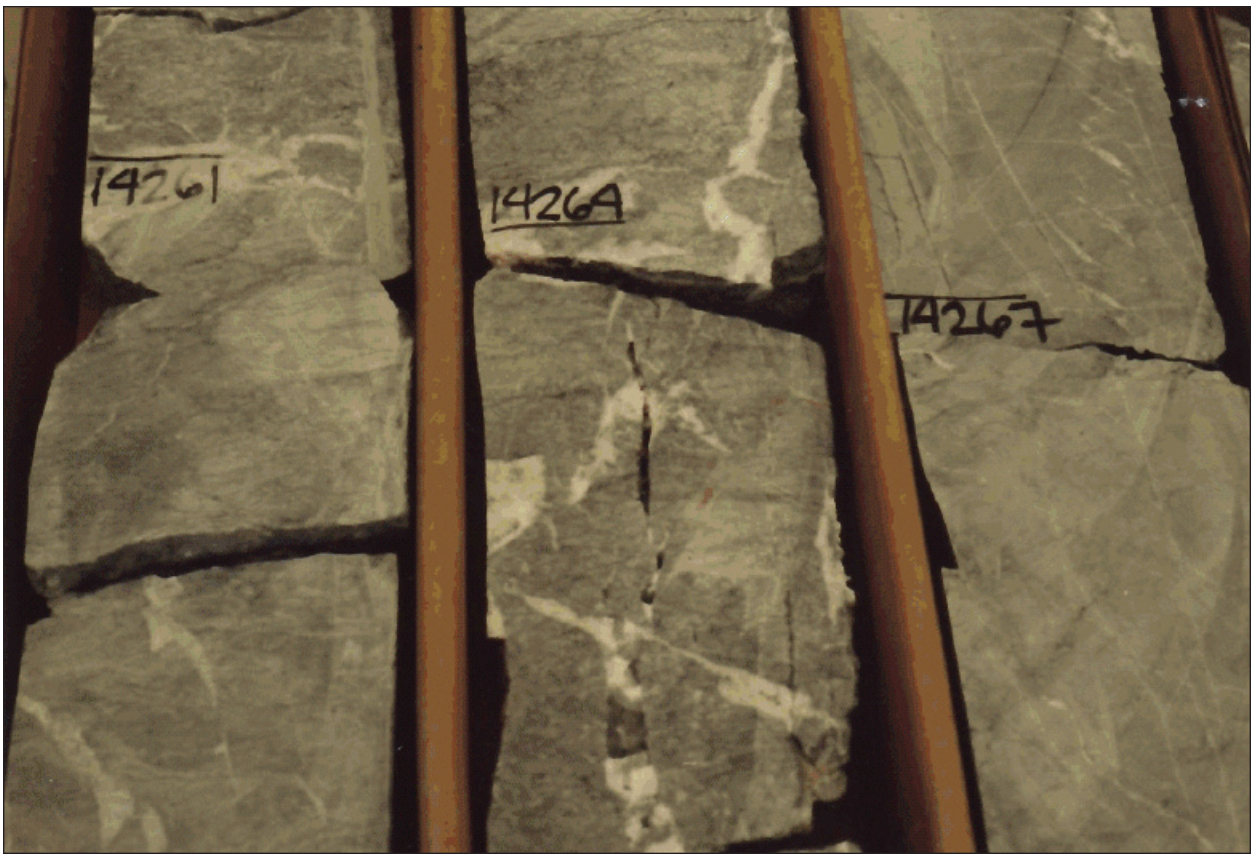

Figure 3a. Core #3 (slab). Note that at 14,264' there numerous large, open fractures with partial quartz and calcite filling while at 14,261' and 14,267' only minor fracturing is observed. The samples at 14,264' are coarse- to medium-crystalline metadolomite while at the other depths the samples are very fine crystalline metadolomite.

Figure 3b. Core #3 (uncut) from 14,280-81'. Note large open porosity in quartz- and calcite-filled fracture zone.

therefore be readily recognized by comparison with outcrop samples. Any new unidentified intervals would therefore, in all probability, be new or previously unrecognized formations. This is important because Honess (1923) or Miser and Purdue (1929) were only able to recognize approximately 200 ft. of Collier and at no time were they able to determine its base or identify what may be below.

It has long been known that the Ouachita facies rocks represent a large thrust sheet which moved north by major tectonic forces. This thrust sheet in Arkansas and southeastern Oklahoma was thrust over a continental foreland facies of lower to middle Paleozoic rocks. In that this well is drilled through the main thrust and into the overridden foreland facies helps to understand the tectonics of the region and to give some understanding of the magnitude of this middle Paleozoic tectonic event.

Lastly, as one moves east of the Arbuckle Mountains exposure of the foreland facies rocks this sequence quickly passes under the leading edge of the Ouachita foldbelt. In that very few wells have been drilled through the Ouachita thrust sheet into the foreland facies, a general ignorance exists about what depositional or stratigraphic changes may have occurred as one proceeds to the east-southeast. It has been hypothesized by some that the depositional basin for the Ouachita facies rocks was in an east-southeast direction from the Arbuckle Mountains outcrop (Figure 5). In that a sequence of approximately 7,000' of foreland facies, lower Paleozoic, rocks were penetrated, a better understanding of this depositional transition from the foreland facies depositional environment into the Ouachita facies depositional environment has been made possible.

Geologic Sequence Penetrated:

In attempting to identify the various rock units penetrated the most difficult problem to overcome is the amount of metamorphic alteration observed. With very rare exceptions all samples observed are greenschist facies metamorphics. Also, either due to non-deposition or destruction no recognizable fossil evidence is observed.

Taking into consideration the above mentioned difficulties, the following formation tops, in feet, are recognized:

0-176'	Ordovician Crystal Mountain Sandstone
176-5,150'	Cambrian Collier Formation
5,150-11,750'	Ordovician Womble Formation
11,750-12,870'	Cambrian(?) Arbuckle Group
12,870-13,396'	Ordovician Womble Formation
13,396-13,700'	Ordovician West Spring Creek(?) Formation
13,700-14,332'	Ordovician Kindblade(?) Formation
14,332-15,040'	Ordovician Cool Creek(?) Formation
15,040-18,987'	Cambrian(?) Arbuckle Group

The Crystal Mountain Sandstone, Collier Formation and Womble Formation are Ouachita facies sediments while the Arbuckle Group rocks are of the foreland facies. A model has been prepared which portrays these formations and presents the tectonic conditions which are believed to have created this linear sequence (Figure 6).

The well, according to mapping by Honess (1923, pl. 1), is spudded in the Crystal Mountain in close proximity to the contact with the underlying Collier Formation. The base of the Crystal Mountain and top of Collier is 176' (KB). The interval below the Crystal Mountain Sandstone closely resembles the Collier as described by Honess. It consists of graphitic phyl-

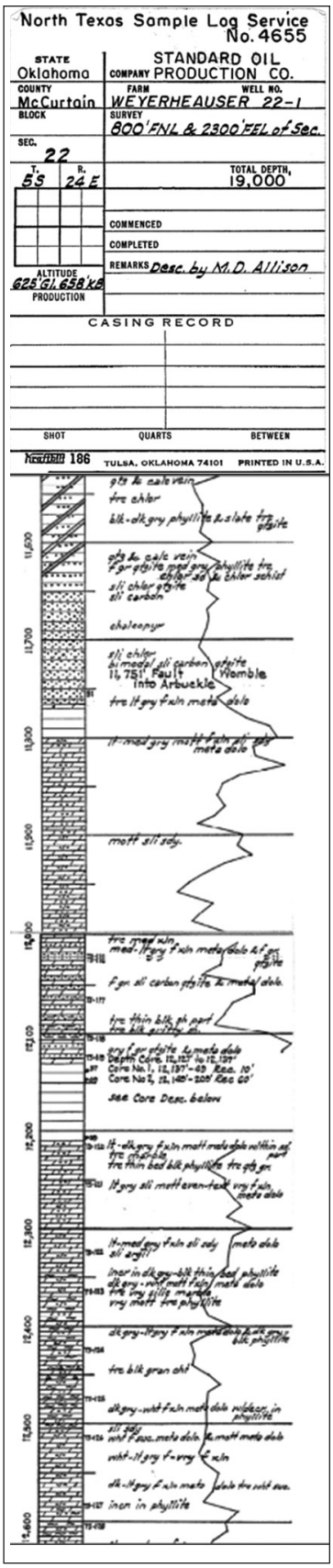

Figure 4. Sample log from 11,600 ft to 12,600 ft from SOPC 1-22 Weyerhaeuser. This part of the log cuts a fault separating Womble Shale (Ordovician) above from Arbuckle Group (Cambrian) below.

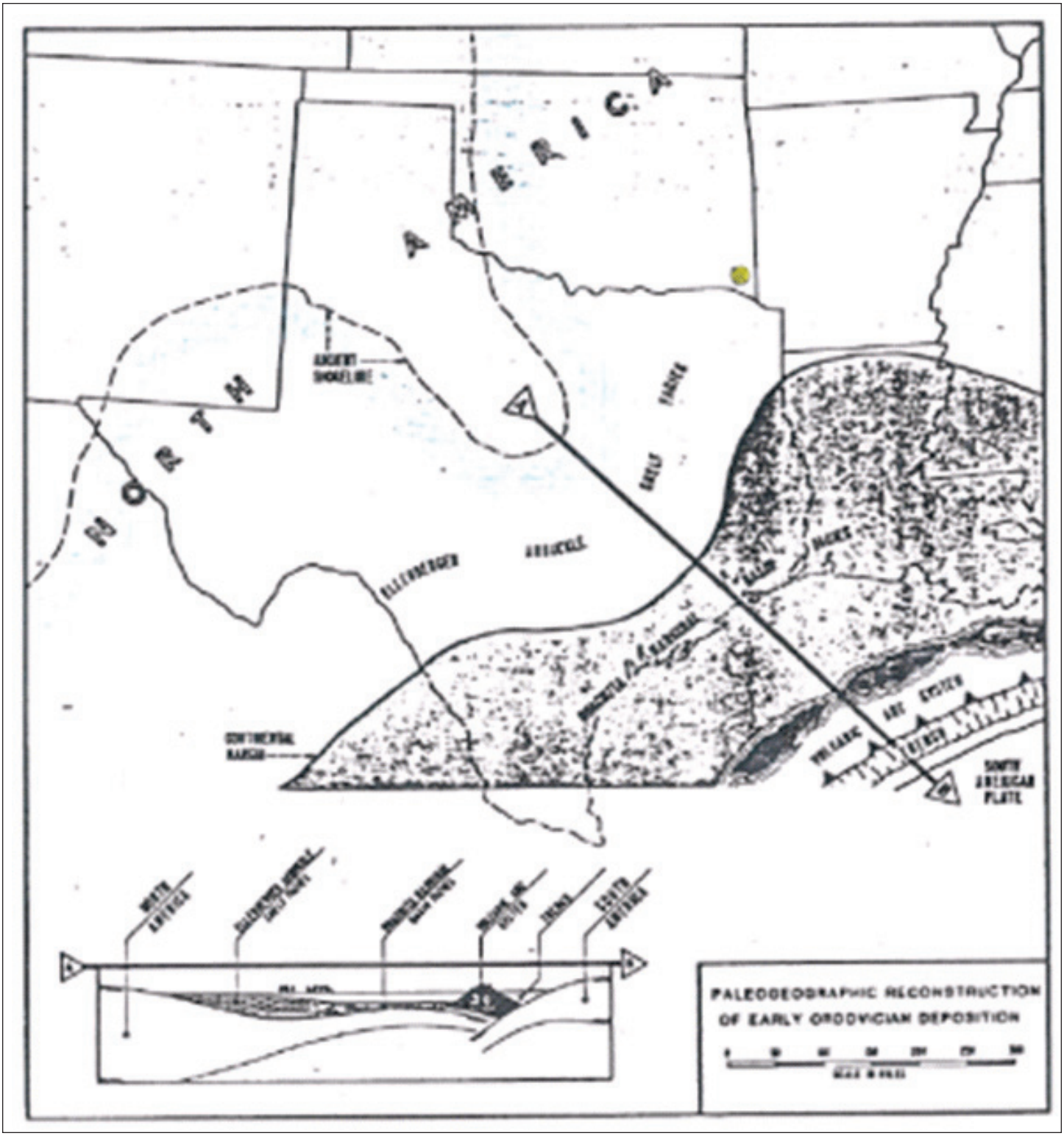

Figure 5. Location of Standard Oil Production Co., Weyerhaeuser #1-22 in respect to a reconstruction of Early Ordovician depositonal regions (Walper, 1982).

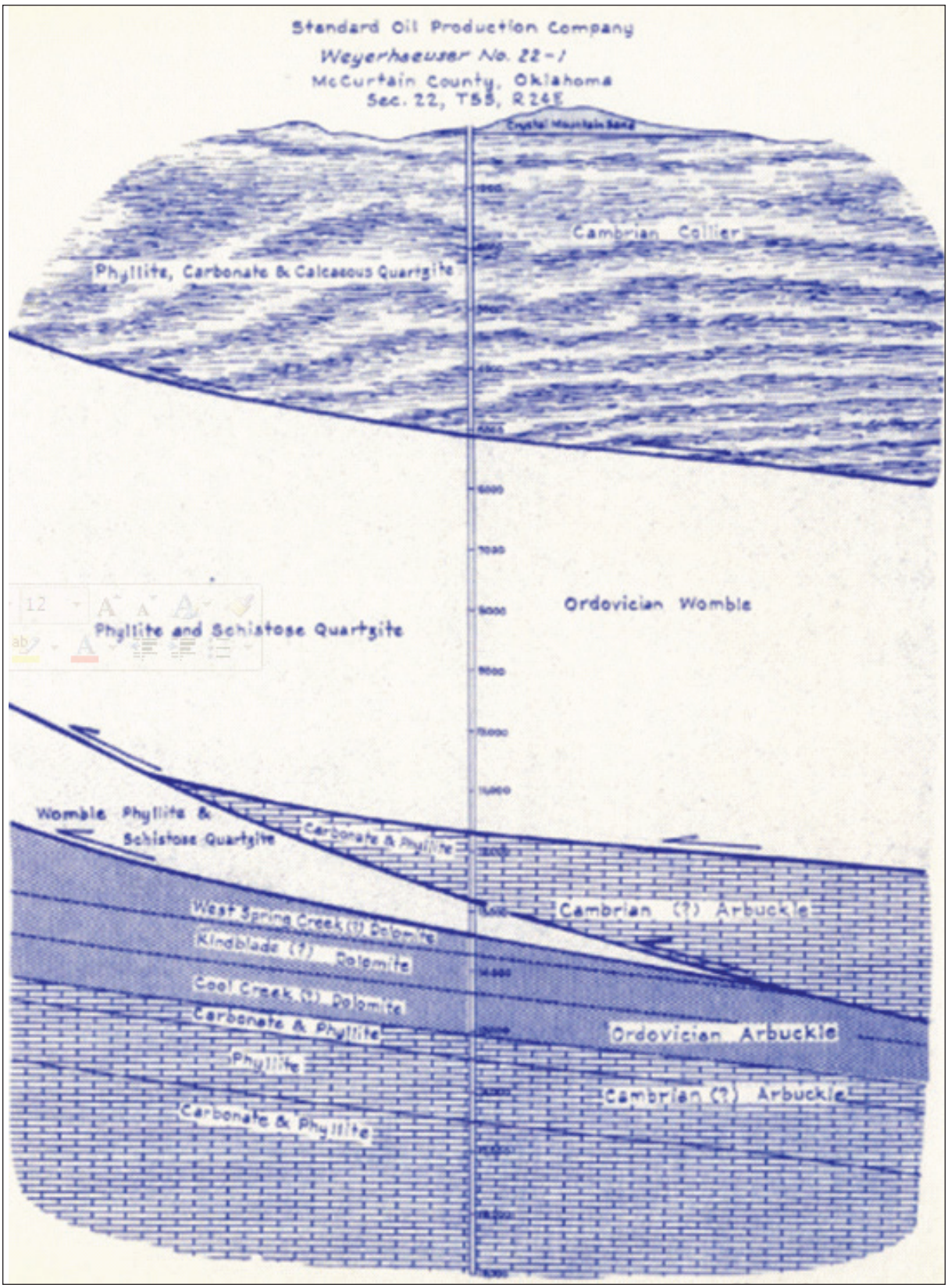

Figure 6. Structure and stratigraphy of the SOPC #1-22 Weyerhaeuser well.

lite, graphitic dolomitic calcareous quartzite, graphitic sandy dolomitic marble and calcareous meta-dolomite. The Collier is found to be from 176-5,150'. The Crystal Mountain and Collier interval is a separate thrust sheet which has been thrusted over the Ordovician Womble Formation.

The interval from 5,150' to 11,750' is a very uniform section consisting of chloritic slightly feldspathic micaceous quartzite, light gray sandy phyllite and mica schist. Numerous quartz veins containing vermicular chlorite are also observed. This interval contains very strong similarities to the Womble Formation with the exception of identifiable graptolite fossils.

At 11,750' the main thrust between the overlying Ouachita facies thrust sheet and the overridden foreland facies is observed. The foreland facies below the thrust is an Arbuckle sequence of very fine to fine crystalline meta-dolomite, sandy meta-dolomite, phyllite and quartzite. This interval strongly resembles the subsurface Arbuckle of Grayson County, Texas, and the Arbuckle Mountains outcrop of south central Oklahoma, with the exception of the presence of a shale fraction. This Arbuckle section is of apparent Cambrian age. The reason for this interpretation will be more readily explained during the discussion of the interval below 15,040'.

At 12,870' a reverse fault is noted and a repeat section of Womble is recognized. Petrographically and lithologically this interval of the Womble most closely resembles the lower portion of the Womble interval which is observed between 11,000' and 11,700'. This repeated Womble interval is noted from 12,870-13,396'.

At 13,396' the main thrust from Ouachita facies to foreland facies is repeated and once again an Arbuckle interval is noted. This Arbuckle interval begins in the Ordovician West Spring Creek(?) which is from 13,396-13,700'. Below the West Spring Creek(?) is the Kindblade(?) Formation from 13,700-14,332'. The Kindblade is a very fine to fine crystalline meta-dolomite and sandy cherty meta-dolomite. The primary geologic changes from the interval above are a coarser and more bimodal crystal size, decrease in quartz and chert grains, very ragged crystal boundaries which aren't previously recognized and the general harder or resistant nature of the rock. Below the Kindblade(?) is found a cream to tan calcareous very sandy meta-dolomite which is believed to be the Cool Creek(?) Formation. The Cool Creek is from 14,332-15,040'. The basal Ordovician McKenzie Hill Formation isn't recognized.

In work by Ham (1955) the following are observed: 1) the West Spring Creek is generally a thin bedded fine crystalline dolomite with thin sandstones in the upper half while the lower half consists of thick bedded limestone or dolomite and thin sandstone lenses and chert. 2) The Kindblade is the least sandy and cherty of the Arbuckle formations. 3) The Cool Creek Formation is the most sandy, cherty and siliceous of all the Arbuckle formations. What was not stated by Ham (1955) but needs elaborating is that in southern Oklahoma the entire Ordovician portion of the Arbuckle section is very uniform throughout. Unless one has a large enough section to evaluate or usable fossils are recognized it becomes very difficult to tell exactly where one is in the section.

In comparing the interval from 13,396' to 15,040' the same general trend, as described by Ham (1955), is recognized and is the primary reason for these conjectures. To date no fossils have been recognized which might assist in correlation.

Below 15,040' a very argillaceous interval is recognized. From 15,040-15,480' the rocks are sandy argillaceous meta-dolomite, phyllite, sandy marble and quartzite. Between 15,480' and 18,150' are phyllite, quartzite, meta-dolomite and marble. The 18,150' to 18,987' (TD) section is dolomitic phyllite, sandy marble and meta-dolomite with a decrease in phyllite and quartzite with depth. Below 18,600' phyllite has dropped out and below 18,750' quartzite is absent.

In comparing the interval 15,040-15,700' in the Weyerhaeuser 1-22 with the interval 18,070-18,400' in the Hassie Hunt, Neely #1, Lamar County, Texas a very similar section is observed. Utilizing sample and electric log data from the two wells, in the Neely #1 at 18,070' a sharp increase in phyllite is observed followed by a dramatic resistivity break at 18,330'. In the Weyerhaeuser 1-22 a similar observance of phyllite is noted at 15,040' with a resistivity break at 15,480'. Denison (1975), in the Neely #1, interpreted this interval below 18,070' as Cambrian Arbuckle.

During the drilling of the Weyerhaeuser 1-22 the interval below 15,040' was originally interpreted to be a thrust fault followed by a repeated section of the Ouachita facies Cambrian Collier Formation. In comparing the samples and thin sections from the Collier interval observed from 1,000-5,000' and the interval below 15,040' very strong similarities are observed and in many cases the samples can not be differentiated. In that the Arbuckle Group is known to transition across the Ordovician-Cambrian contact and a strong correlation of this deep Arbuckle section with the Collier Formation exists, it is interpreted that the interval below 15,040' is, in all probability, Cambrian in age.

In evaluating the outcrop area of the Ozarks region of northeastern Oklahoma and southern Missouri, the Cambrian section consists of the LaMotte Sandstone at the base, followed, in ascending order, by the Bonneterre, Davis, Derby-Doerun, Potosi and Eminence formations (McCracken, 1964). In contrast to the Cambrian section of southern Oklahoma which contains no shales of significance, the Davis Formation in the St. Francois Mountains of southern Missouri contains well developed shales. The Bonneterre through Derby-Doerun are characterized by McCracken (1964) as "a gray, silty, earthy

to fine grained, sandy zone throughout." The presence of this Cambrian section in northern Arkansas and southern Missouri does provide some evidence for the potential of shale deposition in the Cambrian as one moves east of the Arbuckle Mountains outcrops of south central Oklahoma.

In an attempt to speculate on the thickness of the Cambrian Period deposits in the vicinity of the Weyerhaeuser 1-22 a comparison has been made with several outcrop sections from the Arbuckle and Ozark mountains. The thickest section noted is in the Arbuckle Mountains and was determined to be 2,100' thick. This Cambrian section is at the Joins Ranch outcrop (sec. 3&4, T1S, R1W), and was found to rest unconformably on Cambrian rhyolite and Precambrian granite. At this location the lower 450' is the Reagan Sandstone (Ham, 1955).

If the Cambrian section in this well was topped at 15,040' and no sections are repeated, then nearly 4,000' of Cambrian has been penetrated. In that the location of the Weyerhaeuser 1-22 is in a basinward direction from the Joins Ranch outcrop of south central Oklahoma, this increase in thickness would be consistent with what would be expected. What is not known is if the basal Reagan Sandstone which is noted in southern Oklahoma or the La-Motte Sandstone of Missouri would continue to exist as one transgresses toward the deep basin depositional environment. Therefore, to speculate upon how deep one would have to drill to reach basement rocks would only be conjecture, particularly without having seen a basal sand unit at total depth.

To further complicate the matter, in the Arbuckle Mountains the ratio of Ordovician to Cambrian deposits for the Pre-Simpson is roughly 70/30. In the Ozark region this ratio for the equivalent section is 80/20. If the interpretation for the formation tops are correct, then in this well approximately 1,600' of Ordovician was penetrated in comparison with 4,000' of Cambrian, a ratio of roughly 30/70. This is reversed from what would be expected. Therefore, if the correlations are correct, then a repeated Cambrian section exists or a much greater rate of deposition occurred during Cambrian time as one transgresses toward the deep basin and toward the hypothesized Collier depositional area. Due to the above mentioned inconsistencies and the very thick Cambrian section already penetrated, it is hypothesized that the basement igneous deposits could be encountered at any time.

The basement rocks in the Arbuckle Mountains consist of the Cambrian Carlton Rhyolite Group and Precambrian mesozone granites (Ham, 1973). The Carlton Rhyolite Group has a known drilled thickness of 5,000' of rhyolite above 1,050' of Cambrian basalts and tuffs (Ham, 1973). Below these Cambrian igneous extrusives are the Precambrian Blue River Gneiss, Tishomingo Granite and an unnamed granodiorite (Ham et al., 1964). These igneous intrusive have a drilled thickness of nearly 11,000'.

At this point the most useful tool for speculating the depth to basement would be seismic records from the area. If a basal Cambrian sand exists above the Cambrian rhyolites and tuffs or Precambrian granites it may be recognizable. Also, there may be a possibility that a reflector would exist at the top of Precambrian unconformity. If seismic is unavailable or proves to be of no value, it is the author's opinion that there would be no more than 4,000' of additional Cambrian sediments prior to encountering the Cambrian or Precambrian basement.

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Biographical Sketch

M.D. Allison is a consulting geologist in Gainesville, Texas. He received his B.S. (1970) and M.S. (1979) degrees in Geology from West Texas State University, now West Texas A & M University in Canyon, Texas. He is an owner and President of the Allison Oil & Gas Co., Inc. and the North Texas Sample Log Service. Prior to this he worked at Derrick Petroleum Company, Inc., Gainesville, Texas as chief research geologist and as a Geophysicist at Amoco Production Company in Denver, Colorado. His primary work is in sample and petrographic analysis studies with the primary focus on lower Paleozoic rocks. He co-authored a paper with R.W. Allen on the Simpson-Arbuckle contact in northwestern Oklahoma County, Oklahoma in 1997, Oklahoma Geological Survey, Circular 99. He has also had other papers published. He is a member of AAPG, DPA, EMD and has been a member of the House of Delegates of AAPG since 1993. He is a recipient of the 2011 Meritorious Service Award from the Mid-Continent Section of AAPG of which he is a member, and he has served as Treasurer, Secretary and Vice President of the Mid-Continent Section. He is currently serving as president of the Ardmore Geological Society.

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Biographical Sketch

Mr. Willis currently serves as Southern Minerals Manager for Weyerhaeuser Company in Hot Springs, AR. In this role, he manages mineral businesses on a 3.4 million acre surface estate and a 3.7 million net acre mineral estate in eleven southern states. He is responsible for establishing strategy and financial management of the Company's hard mineral business and for supporting the energy products businesses (oil/gas, geothermal, wind). Prior to joining Weyerhaeuser, Mr. Willis held a variety of positions with oil and gas exploration companies, including Davis Oil Company (Tulsa, OK) and Stephens Production Company (Ft. Smith, AR). Mr. Willis holds B.S and M.S. degrees in Geology from the University of Arkansas (Fayetteville). He is a Registered Arkansas Geologist and serves on the Arkansas Geological Survey as Vice Chair. He serves as an honorary member of the University of Arkansas (Fayetteville) Geosciences External Advisory Board. Mr. Willis is a member of AAPG, SMME and other professional organizations.

The Geology and Deep Structure of the Oklahoma Ouachita Mountains – The SOPC 1-22 Weyerhaeuser Well, cont.

Neil Suneson
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Biographical Sketch

Neil Suneson has worked for the Oklahoma Geological Survey since 1986. His first major project with the Survey was mapping part of the frontal belt of the Ouachita Mountains and the very southern part of the Arkoma Basin, and many of his current interests focus on that part of Oklahoma. Prior to coming to Oklahoma he worked for Chevron USA as a development geologist in the San Joaquin Basin. He graduated from Amherst College in 1972, received his M.S. in geology from Arizona State University in 1976, and Ph.D. in geology from the University of California – Santa Barbara in 1980.

Note: Figures 4, 5, and 6 use the graphics from the senior author's original work from the late 1980's. These original documents were used and not redrafted in order to preserve their historical significance. *The Editor.*

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