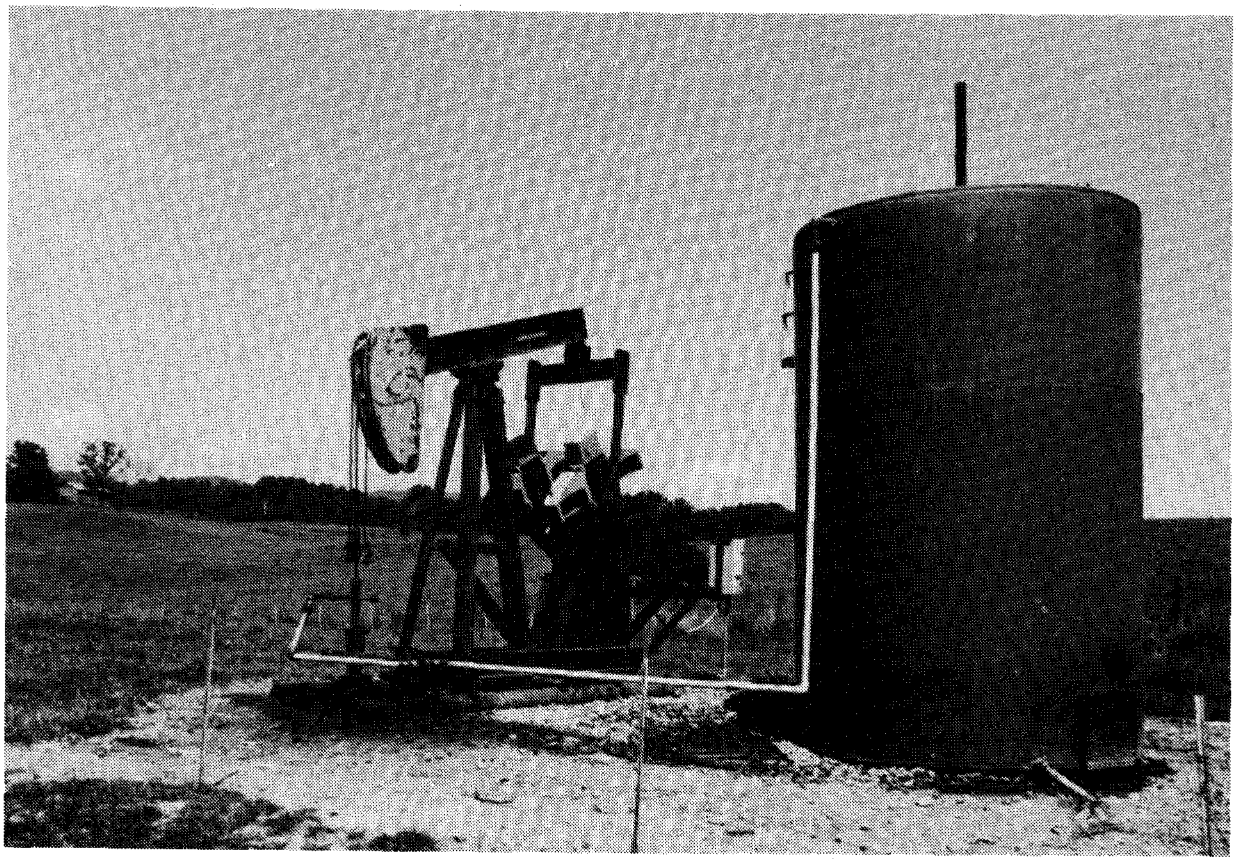
VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 113

OIL AND GAS WELL DATA AND GEOLOGY, LEE COUNTY, VIRGINIA

Jack E. Nolde



COMMONWEALTH OF VIRGINIA

DEPARTMENT OF MINES, MINERALS AND ENERGY
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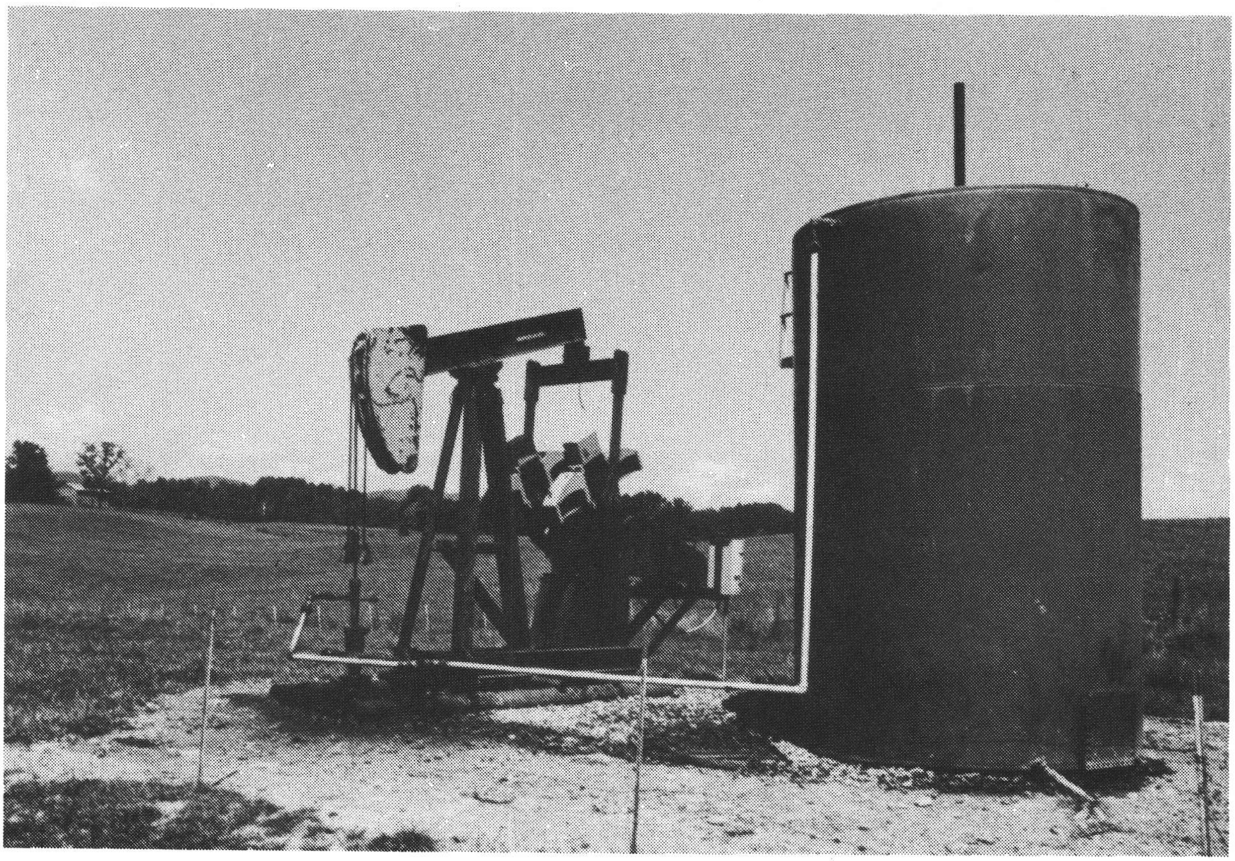

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FRONT COVER: Oil well in the Ben Hur field, Lee County, Virginia (Photograph by Milford Stern, Division of Gas and Oil).

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DEPARTMENT OF MINES, MINERALS AND ENERGY
RICHMOND, VIRGINIA
O. Gene Dishner, Director

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INTRODUCTION

Lee County has an area of 446 square miles and is located in the extreme southwestern portion of Virginia (Figure 1). The county is bordered on the south by Tennessee, on the northwest by Kentucky and on the northeast and east by Wise and Scott counties, Virginia. There are three major oil and gas producing areas in Lee County. The Ben Hur-Fleenortown and Rose Hill oil fields are located in the Valley and Ridge portion of Lee County. Lee County oil production in 1990 totaled 12,017 barrels from 22 wells of 10 companies. Cumulative oil production for the county amounted to 570,189 barrels for 1943 through 1990. There was no reported natural gas production in the county for 1990. Since the discovery of the Ben Hur oil field in 1963, it has dominated Virginia's oil production. Ben Hur accounts for 204,466 barrels (or 65 percent) of the total 313,330 barrels produced in Virginia from 1963 through 1990. Production is principally from fractured Late Ordovician-age Trenton Limestone. Lee County's other producing area is in the Appalachian Plateaus portion. One well produces 1 barrel of oil with 5 barrels of water. But it mainly produces natural gas. The well produces 103 Mcf per day from the Mississippian-age Price Formation and the Greenbrier Limestone. The locations of 196 oil and gas wells are plotted on Plates 1 and 2.

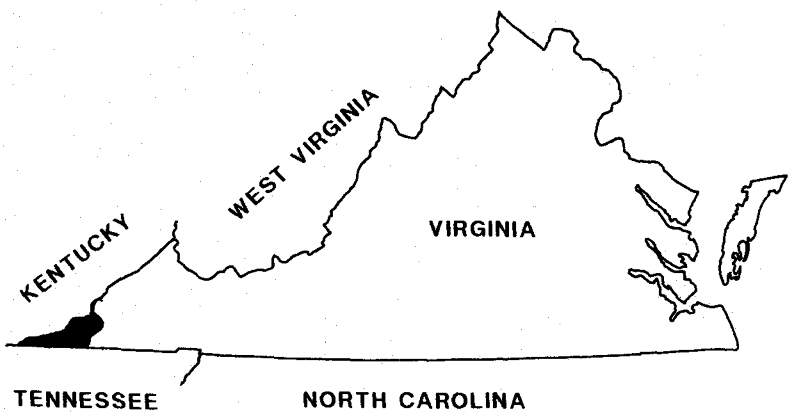

Figure 1. Index map showing location of Lee County, Virginia.

STRATIGRAPHY

The stratigraphic names, rankings, and age assignments used in this report follow usage on the **Correlation of Stratigraphic Units in North America (COSUNA)—Southern Appalachian Region Correlation Chart** by Patchen and others (1985). The descriptions in this section are based on the works cited, upon sample examination, and geophysical logs. Oil and/or natural gas are found in rocks of Cambrian through Mississippian age. A brief description summarized from Miller and Brosge' (1954), Miller and Fuller (1954), and Nolde, Henderson, and Miller (1988) of the principal oil and gas producing formations is as follows:

CAMBRIAN SHALE AND SANDSTONE

Rome Formation

The Rome Formation (Early and Middle Cambrian-age) consists predominantly of grayish-red to pale red, micaceous, shale and siltstone. Minor amounts of grayish-green shale, light-gray, very-fine-grained, thin-bedded dolomite, and pale-red sandy siltstones also are present. A medium- to coarse-grained, glauconitic sandstone about 300 feet thick occurs about 850 feet below the top of the Rome (Miller and Fuller, 1954). The formation has a thickness of about 1600 feet.

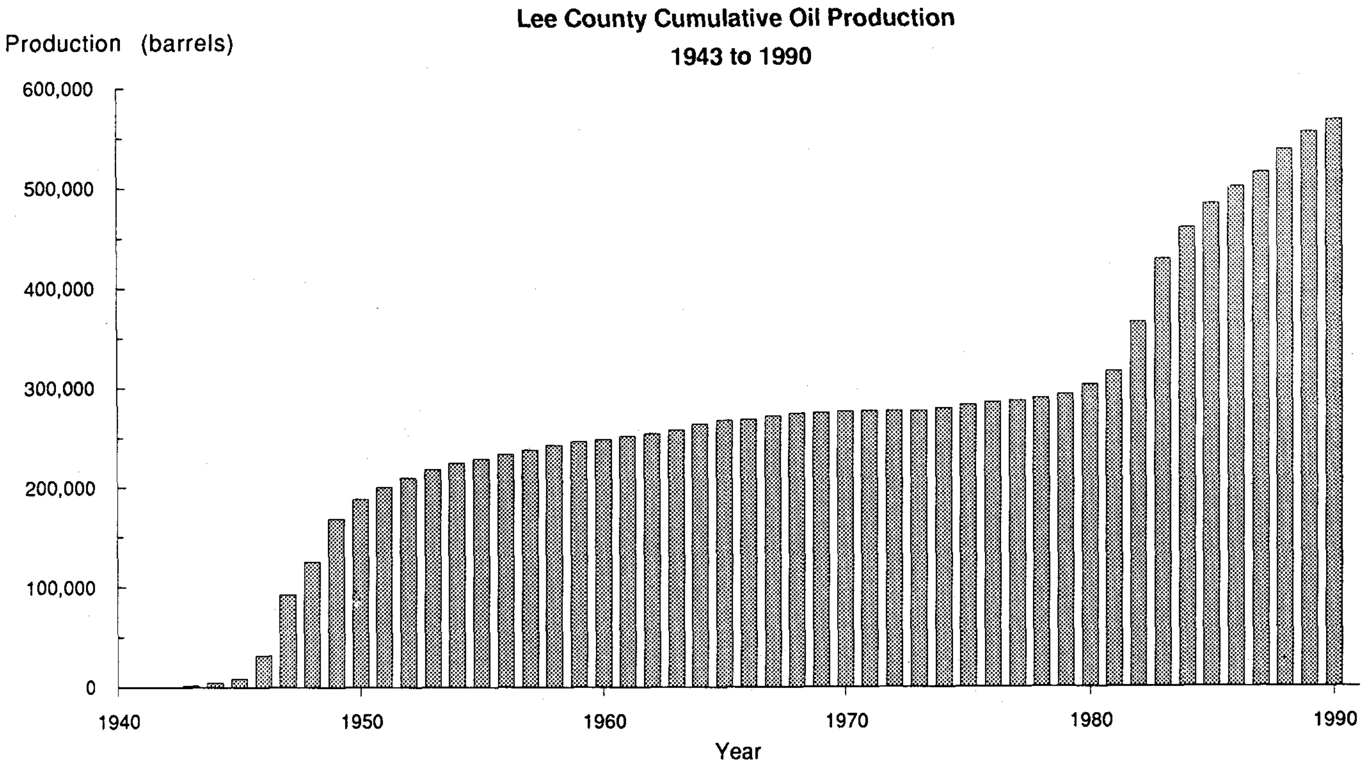

Figure 2. Cumulative Lee County Oil Production, 1943-1990.

Conasauga Shale

The Conasauga Shale is Middle to Late Cambrian-age. Like the Rome Formation, the Conasauga consists of greenish-gray and a little grayish-red shale and siltstone, with many fine- to coarse-crystalline limestone interbeds. The coarse-grained limestones contain abundant glauconite grains. The formation is 500 to 550 feet thick.

CAMBRIAN AND ORDOVICIAN DOLOMITE AND LIMESTONE

Maynardville Formation

The Maynardville Formation (Late Cambrian-age) consists of two members, the Low Hollow Limestone and the Chances Branch Dolomite. The Low Hollow Member is typically light- to dark-gray, fine-grained limestone with clay or silt partings. The limestone differs from limestones of the Conasauga Shale chiefly in having thicker and slightly more irregular partings. The Chances Branch Member is usually in sharp contact with the Low Hollow Member. The lower part of the Chances Branch is a medium-gray, fine-grained dolomite, with some black chert. The upper portion of the member contains light- to dark-gray, fine- to medium-grained, thinly-laminated dolomite; black chert and some dark gray, saccharoidal and vuggy dolomite, similar to that found in the Copper Ridge Dolomite. The thickness of the Maynardville Formation ranges from 250 to 350 feet.

Knox Group

The Knox Group (Late Cambrian to Early Ordovician-age) is a sequence of dolomite with subordinate amounts of interbedded limestone and a few beds of quartzose sandstone. It is comprised of four formations in Lee County, the Copper Ridge Dolomite, Chepultepec Dolomite, Kingsport Dolomite, and Mascot Dolomite. The Cambrian and Ordovician systemic boundary is within the group and is at or near the top of the Copper Ridge Dolomite. Total thickness is typically 2000 feet.

The deepest wells in the county have been completed in the Knox Group. Producing wells penetrated from 647 feet to 2848 feet (beds repeated by faulting) of the Knox Group, and oil and/or gas was produced from the upper one half of the penetrated beds.

Copper Ridge Dolomite: The Copper Ridge (Late Cambrian-age) can be divided into two informal members, lower and upper. The lower member is comprised of dark-gray to dark-brown, medium- to coarse-crystalline, thick-bedded dolomite with a petroliferous odor. Thin beds of white chert occur in the member.

The upper member is a white to light-gray, cryptocrystalline- to coarse-crystalline dolomite in thinner beds than the lower member. Dark gray dolomite is also present locally in the upper member as are thin beds or lenses of white chert. The average thickness of the Copper Ridge Dolomite is 840 feet.

Chepultepec Dolomite: The Chepultepec (Early Ordovician-age) can be divided into two informal members, a lower sandy dolomite and an upper argillaceous dolomite. The sandy dolomite member is comprised of sandy, light-brown, medium- to coarse-crystalline, saccharoidal dolomite; light-gray to light-brown, fine- to medium-crystalline dolomite; and white, medium-grained sandstone.

The argillaceous dolomite member is largely light-gray to grayish-brown argillaceous dolomite with a few pinkish-gray-dolomite beds. Small amounts of light-gray to white chert nodules and beds are present. The Chepultepec Dolomite ranges from 690 to 780 feet in thickness.

Kingsport Dolomite: The Kingsport (Early Ordovician-age) is a light-gray, medium- to coarse-crystalline, saccharoidal dolomite. Some beds contain quartz grains, or flat nodules of light gray chert, or small vugs filled or lined with calcite, dolomite, or quartz. There is some interbedded white, fine-crystalline dolomite, mostly at the top of the formation. The thickness of the Kingsport Dolomite is between 180 and 200 feet in Lee County.

Mascot Dolomite: The Mascot (Early Ordovician-age) is composed of one- to four-foot thick even beds of fine-grained, white dolomite with pink dolomite blebs. Chert nodules are scattered throughout the unit with occasional beds of coarse-crystalline dolomite. Beds of green shale from fractions of an inch to several inches thick separate most of the dolomite beds and are helpful in identifying the Mascot Dolomite in well cuttings. There are a few massive beds of conchoidally fracturing limestone three to four feet thick that are present locally throughout the formation. Thickness ranges from 170 to 460 feet.

ORDOVICIAN LIMESTONE AND SHALE

The undivided Middle and Late Ordovician-age units are, in ascending order: Dot, Poteet, Rob Camp, Martin Creek, Hurricane Bridge, Woodway, Ben Hur, and Hardy Creek limestones. The Dot is Middle Ordovician-age and is primarily thick-bedded, argillaceous dolomite in the lower part and light gray limestone in the upper part. The basal beds of the Dot are slightly to very conglomeratic with chert and dolomite pebbles. The Dot corresponds to the dolomite member and the limestone member of the Murfreesboro Limestone (Miller and Fuller, 1954). The average thickness of the Dot Limestone is 150 feet. The other formations are Late Ordovician-age and principally light-brown to light-gray, cryptocrystalline- to fine-grained limestone. The Poteet and Martin Creek limestone contains abundant chert nodules. The thickness of the interval between the base of the Poteet and the top of the Hardy Creek averages 1150 feet. These formations have not yielded any oil or gas in Virginia.

ORDOVICIAN SHALE AND LIMESTONE

Eggleston Limestone

The Eggleston Limestone (Late Ordovician-age) can be divided into three informal members, lower, middle, and upper. The lower member is entirely greenish-gray, calcareous mudstone with abundant small patches (birdseyes) of white calcite. This member is poorly bedded with crumpling and flowage in the mudstone. The lower member is 36 feet thick at Hagan (Miller and Brosgé, 1954).

The middle member is a gray and brown platy limestone with beds from 1 inch to 12 inches thick. These beds are either cryptocrystalline or fine to coarse crystalline. Only the crystalline beds contain fossils. This member is 57 feet thick at Hagan.

The upper member, 53 feet thick at Hagan, is comprised of zones of platy limestone. Two distinct beds of K-bentonite from less than one-inch up to several feet thick are present in the upper member. The two K-bentonites are about 9 and 51 feet below the top of the Eggleston. Both K-bentonites are underlain by beds of gray chert. Caving below the K-bentonites can be conducive to gas or oil accumulation. Fractures that penetrate the Eggleston can be reservoirs for oil accumulation. The Eggleston Limestone ranges from 135 to 165 feet thick.

Trenton Limestone

The Trenton Limestone (Late Ordovician-age) can be divided into three informal members, lower, middle, and upper. The lower member of the Trenton, approximately 200 feet thick, is composed of gray or mottled-gray and white, coarse-crystalline, fossiliferous limestone, containing mostly brachiopods, bryozoans, and gastropods. Limestone beds are separated by partings or thin beds of dark gray shale. Chert is present in some localities. The middle Trenton, about 275 feet thick, is gray, fine- to medium-crystalline, even-bedded, siliceous limestone. The upper member, 75 feet in thickness, is brown- to brownish-gray, coarse-crystalline, coquinoid limestone. There are typically three bentonite beds within the Trenton. They are approximately 15, 500, and 538 feet below the top. The average thickness of the Trenton Limestone is 550 feet. Fractures that penetrated the Trenton Limestone would favor the accumulation of oil. Oil has been found in all three stratigraphic horizons. There are no sandstones between the base of the Dot Limestone and the top of the Trenton Limestone.

Reedsville Shale

The Reedsville Shale (Late Ordovician-age) consists of alternating beds of greenish-gray, soft shale and two types of Trenton-like limestone. One limestone is a light gray to brownish gray, sandy coquinoid. The other is finely crystalline and medium gray in color. The individual thickness and horizontal and vertical positions of these shale and limestone beds varies between localities in Lee County. The average thickness of the Reedsville is 340 feet.

The sandy limestones and shales of the Reedsville appear to be too dense and too fine grained to hold significant amounts of oil or gas; however, fractures that have reached into the Reedsville Shale might favor the accumulation of oil. Oil is found in the lower half of the formation.

Sequatchie Formation

The Sequatchie Formation (Late Ordovician-age) is grayish-red to green, calcareous, even-laminated mudstone and muddy siltstone with beds of greenish-gray, nodular-bedded, argillaceous limestone in the lower part. The Sequatchie is not favorable for oil and gas accumulation. Thickness of the Sequatchie ranges from 295 to 500 feet.

SILURIAN SANDSTONE

Clinch Sandstone

Miller and Fuller (1954) divided the Clinch Sandstone (Early Silurian-age) into two members, which they named the Hagan Shale Member (lower unit) and the Poor Valley Ridge Member (upper unit). The base of the Hagan Shale is marked by a 15-inch sandstone resting disconformably on the Sequatchie Formation. This is overlain by greenish-gray, fissile shale with numerous platy beds, one to three inches thick, of silty or sandy limestone. The contact between the Hagan Shale and the Poor Valley Ridge is at the base of the lowest thick-bedded, grayish-red to light-gray, fine- to medium-grained sandstone. The Clinch ranges from 300 to 350 feet in thickness. The thick beds in the Clinch appear to be favorable reservoir rocks for oil and gas accumulation. Two samples collected have a porosity of 9.6 percent and 4.1 percent. The sample with 9.6 percent porosity has a permeability of only 0.9 millidarcies along bedding and neglible permeability perpendicular to bedding (Miller, 1948). This apparent lack of permeability may explain the failure to find significant amounts of oil and gas accumulations.

SILURIAN SHALE AND LIMESTONE

Rose Hill Formation

The name Rose Hill (Early Silurian-age) replaces Clinton of older usage. The Rose Hill is predominantly greenish-gray shale, but contains thin- to medium-beds of grayish-red, fine-grained sandstone and hematite beds up to 2 feet thick. Shale in the lower part of the Rose Hill contains abundant fossils, especially brachiopods and ostracodes. The Rose Hill is 300 to 400 feet thick.

Hancock Formation

In Lee County, the Hancock Formation (Late Silurian-age) consists of medium- to dark-gray, fine-crystalline limestone and brownish-gray dolomite. At the base of the Hancock are a few feet of sandstone or calcareous sandstone containing medium to coarse grains or even small pebbles of quartz. The Hancock changes facies in Lee County, being mostly dolomite in the west and limestone in the east. The Hancock is about 200 feet thick.

DEVONIAN AND MISSISSIPPIAN SHALE AND SANDSTONE

Wildcat Valley Sandstone

The Wildcat Valley Sandstone (Early Devonian-age) consists of pale orange to yellowish-orange, medium- to coarse-grained, porous, friable, quartzose sandstone. Light-gray to light-olive-gray chert with abundant coral and bryozoan fragments and light-olive-gray, finely-laminated fissile shales are present. The average thickness of the Wildcat Valley is 50 feet.

Chattanooga Shale

In Virginia, the Chattanooga Shale (Late Devonian to Early Mississippian-age) is divided into three members, in ascending order, the lower black shale, the middle gray siltstone, and the Big Stone Gap. The lower black shale consists of grayish-black to black, hard, brittle, papery to platy, thickly-laminated shale. The member is equivalent to the Olentangy Shale and the lower part of the Huron Member of the Ohio Shale. In the Appalachian Plateaus area of Lee County the member is 275 feet in thickness.

The middle gray siltstone member consists of medium-gray, hard, platy, thin-bedded siltstone with interbedded olive-gray to dark-gray shale. The member is equivalent to the middle and upper parts of the Huron Member and the Three Lick Bed of the Ohio Shale. The member is 255 feet in thickness.

The Big Stone Gap Member is a grayish-black to black, hard, platy, thin- to medium-laminated shale. In the Appalachian Plateaus area of Lee County the member contains the Berea sandstone (40-feet thick) bed about 100 feet above the base. The Big Stone Gap is equivalent to the Cleveland Member of the Ohio Shale and the Bedford and Sunbury Shales. In the Appalachian Plateaus area of Lee County the member is 215 feet in thickness. The Chattanooga Shale is about 745 feet in thickness in that area.

Price and Maccrady Formations

The lower part of the Early Mississippian-age Price Formation (Weir sand of drillers) is a hard, hackly, thinly-laminated, medium-gray siltstone. The upper part is a medium-gray, very-fine-grained sandstone that is medium bedded, cross laminated, and slightly micaceous. The thickness of the Price is between 200 and 300 feet. Natural gas has been produced from the Price Formation in the Appalachia quadrangle, Lee County, Virginia.

The Maccrady Formation (Late Mississippian-age) consists of grayish-red to grayish-green, thinly laminated, platy parting shale and siltstone. The Maccrady is about 60 feet thick.

MISSISSIPPIAN LIMESTONE

Greenbrier Limestone

The Late Mississippian-age Greenbrier Limestone (Big Lime of drillers) consists of gray to brownish-gray, fine-crystalline, highly-fossiliferous limestone and minor shale. The limestone near the top of the formation is thin bedded, while the remainder of the formation is thick bedded. The shale is gray to reddish gray, silty and calcareous. The Greenbrier ranges from 300 to 500 feet in thickness.

Natural gas and condensate has been produced from the lower third of the Greenbrier Limestone, principally from öolitic beds, in the Appalachia quadrangle. There have been some oil shows.

MISSISSIPPIAN SHALE AND SANDSTONE

Bluefield, Hinton, and Bluestone Formations

The Bluefield Formation averages 280 feet in thickness and consists of dark-gray to medium-gray shales, some of which are fossiliferous and calcareous, and medium-gray, fine-grained sandstone. The limestone of the Bluefield is typically gray to brownish-gray, fine to medium crystalline, silty, and fossiliferous. An 80 feet-thick limestone which occurs about 30 feet above the base of the formation is known as the"Little Lime" by drillers.

The Hinton and Bluestone formations consists of grayish-red sandstone and a few beds of gray and greenish-gray shales. At the base of the Hinton Formation there is the thick-bedded Stony Gap Sandstone Member, that grades upward to soft greenish-gray shale. The Stony Gap sandstone is called the "Middle Maxton" by drillers. The shale contains thin beds of sandstone and limestone. The Tallery Sandstone Member is at the top of the Hinton. The combined thickness of the two formations is about 750 feet.

LOWER PENNSYLVANIAN SANDSTONE AND SHALE

Lee Formation

The Lee Formation consists of three massive sandstone units separated by siltstones and thin coal beds. The sandstone units are quartzose, very hard, light gray to white, and fine to medium grained with basal conglomerates. The lower two sandstones and a shale zone makeup the Middlesboro Member, a series of siltstones and coal beds above comprise the Hensley Member, and the upper sandstone unit is a quartzarenite, the Bee Rock and the Naese Sandstone Members. The Lee averages 1450 feet in thickness.

MIDDLE PENNSYLVANIAN SHALE AND SANDSTONE

Norton, Wise, and Harlan Formations

The Norton, Wise, and Harlan formations are composed largely of siltstone, sandstone, limestone, and coal. The Gladeville Sandstone which separates the Norton and Wise formations is largely a quartzose to feldspathic and micaceous, light gray to white, fine- to medium-grained sandstone about 50 feet thick.

GEOLOGIC STRUCTURE

The Jonesville and Rose Hill districts are located in Powell Valley on the axis of the Powell Valley anticline. The Powell Valley anticline is the major fold of a broad, northeast-plunging anticlinorium which includes the Chesnut Ridge and Sandy Ridge anticlines and Cedars syncline. The Powell Valley anticline on the Pine Mountain thrust block has been thrust approximately 5.8 miles northwest in this area (Bartlett, 1989). Subsurface control across the fensters is sufficient to show that the position of the surface axial trace of the Powell Valley anticline closely parallels the sub-thrust plate fold axis. Sedimentary rocks have been arched upward to form the anitclinorium due to movement along the faults that underlie Powell Valley.

The most prominent of these faults is the Pine Mountain thrust. The Pine Mountain thrust block comprises rocks ranging from Middle Cambrian- to Middle Pennsylvanian-age. The thickness of the thrust block is variable as the Pine Mountain fault has been folded by movement along deeper faults. Although it is known from drillers' reports and a few detailed geologic well logs that the rocks beneath the Pine Mountain fault were not structurally simple. The 8,020-foot No. 1 Bales, Shell Oil Company test in 1965 discovered a deeper major fault, named the Bales thrust (Harris, 1967). The existence of the Bales fault was confirmed in 1976 by the No. 1 Grabeel, Lee Oil Drilling Company, a 7,209-foot cable tool test. Arco's No. 1 Slemp, drilled near Big Stone Gap, further defined the buried structure. It is now apparent that some of the displacement on the Pine Mountain fault west of the Powell Valley axis plus numerous smaller faults within the Bales thrust block are related to the main Bales thrust.

Charles Butts (1927) first recognized the fensters (windows) in the Pine Mountain thrust block. The nearly horizontal Pine

Mountain block has breached in 11 places exposing the Bales block below. Early oil wells were drilled in these fensters into the rocks of the underlying block. Recent drilling has shown that the complex folding, faulting, and fracturing exposed in the fenster areas are also present in the rocks buried beneath the Pine Mountain thrust block. It is the rocks in the Bales block that contain the oil reservoirs that produce in Lee County.

OIL AND GAS FIELDS

From 1910 to 1942, sporadic exploration in Lee County resulted in about 10 wells, not all of which penetrated the Trenton Limestone; most were less than 1500 feet deep. Many were sited near surface oil seeps. The No. 1 McClure, Cedar Valley Oil Company, was drilled between 1910 and 1915 and may have reached a depth of 3300 feet. The well is located about 3 miles west of Jonesville and about three miles south of the Chesnut Ridge anticline. Depth of producing wells range from 1600 to 6400 feet.

ROSE HILL OIL FIELD

Rose Hill oil field is located in the Rose Hill District in western Lee County and along the crest of the Powell Valley anticline (Plate 2). Rose Hill has 103 wells of which 6 are currently producing oil, 7 are shut-in oil or gas wells, 44 are plugged and abdandoned, and 46 are dry holes. Although there had been numerous showings of oil and gas and a little oil production from wells drilled prior to 1940, the real discovery of the Rose Hill oil field was on May 7, 1942, when the B. C. Fugate No. 1 penetrated producing zones in the lower part of the Trenton Limestone at a depth of 1110 feet. The well was on pump from the start. It produced 90 barrels of oil the first day, 56 the second day, and 30 the third. It was then shut in for one year. In the spring of 1943 daily pumping resumed and the well equilibrated to 8 barrels per day of paraffin based oil for five years from the Trenton Limestone. The well was drilled in the Four Mile fenster into the Bales block beneath the Pine Mountain block. The Four Mile fenster is located three miles southeast of Ewing and is one mile long and one half mile wide from northeast to southwest. Approximately 5632 barrels of oil was produced from the Rose Hill field during 1990 from six wells (Figure 3).

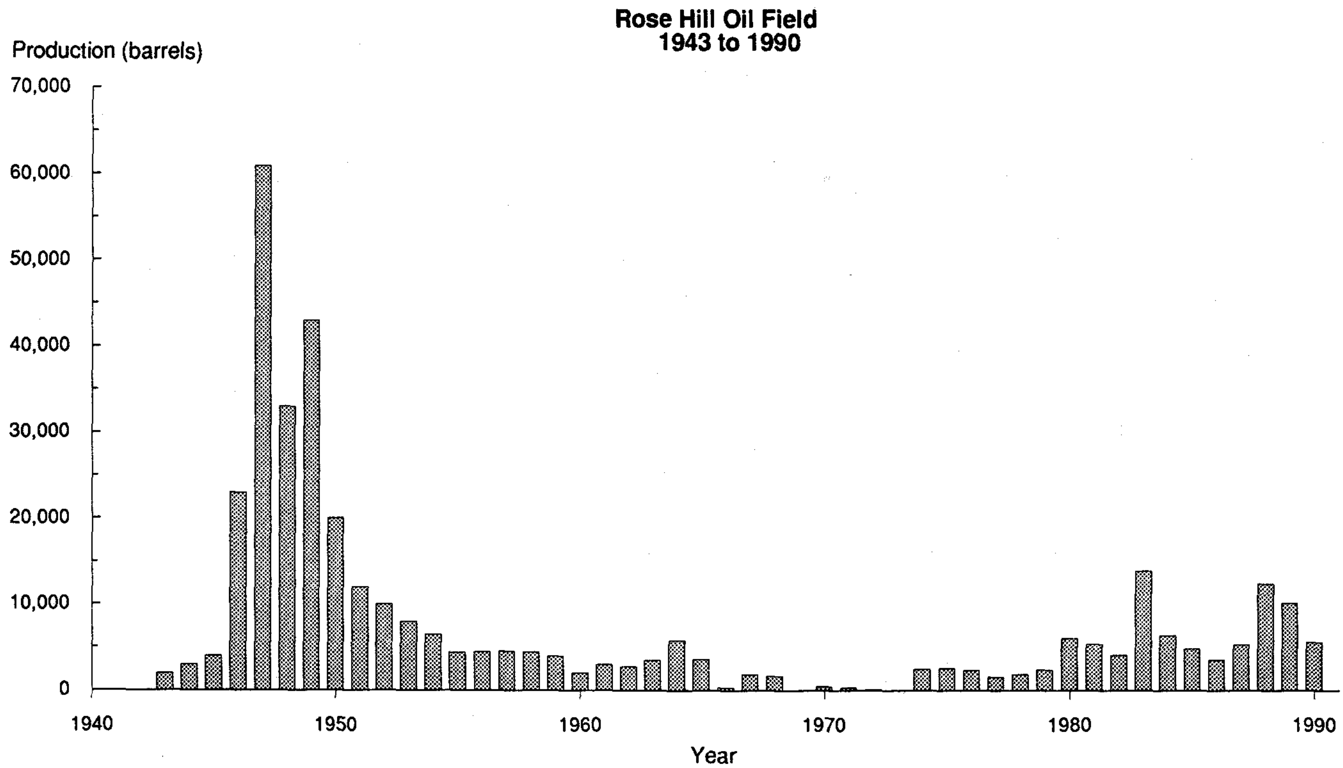

Figure 3. Oil Production from the Rose Hill Oil Field, 1943-1990

BEN HUR-FLEENORTOWN OIL FIELD

The Ben Hur-Fleenortown oil field encompasses an area of about 13.5 square miles and lies along the crest of the Powell Valley anticline (Plate 1). The oil field has 54 wells of which 15 are producing oil, 9 are shut-in oil or gas, 14 are plugged and abandoned oil wells, and 16 are dry holes.

The Ben Hur oil field was discovered on November 1, 1963 following the publication of Miller and Brosgé's (1954) report on the Jonesville district, which described the Sulphur Springs fenster. The discovery well was the No. 1 Roy Bledsoe operated by Merrill Natural Resources (J. W. Miloncus). The well was drilled to a total depth of 2207 feet. There were three oil shows within the Trenton at 1606 feet, 1640 feet, and 2189 feet. Initial oil production was 25 barrels per day. The Trenton was perforated and acidized with 10,000 gallons of HCl at a depth of 1595 to 1643 feet (upper Trenton). Final oil production after stimulation was 7 barrels per day. The well was plugged and abandoned in 1989. Ben Hur currently has 28 wells, with 6 producing oil, 6 shut-in oil or gas, 7 plugged and abandoned oil or gas, and 9 dry holes. The field produces from the Trenton, Eggleston, and Knox.

In late 1981, Ben Hur Oil Company moved about 2 miles west of the Ben Hur field near the Big Fleenortown fenster and found a strong Trenton oil producer at the No. 1 James Dean. The No. 1 James Dean was completed on March 28, 1982 to a total depth of 2550 feet. The well had gas shows at 2020 and 2190 feet. Initial oil production was 65 barrels per hour. The well was acidized from 2287 to 2532 feet. Main production is from 2216 to 2287 feet (lower Trenton). This discovery opened the Fleenortown oil field. The boundaries of the Ben Hur and Fleenortown field has subsequently overlapped, forming the Ben Hur-Fleenortown field. Approximately 6279 barrels of oil was produced from the Ben Hur-Fleenortown field from 15 wells during 1990 (Figure 4).

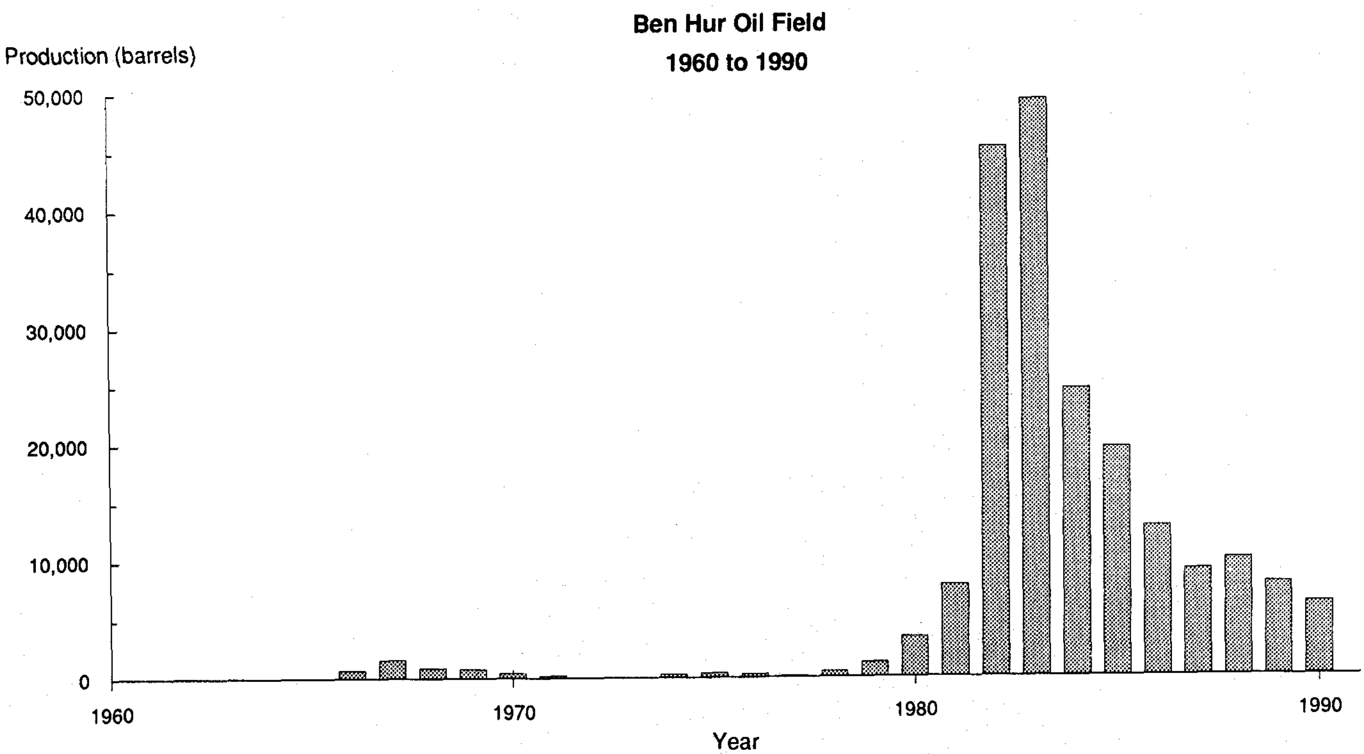

Figure 4. Oil Production from the Ben Hur-Fleenortown Oil Field, 1960-1990.

APPALACHIAN PLATEAUS AREA

Two wells have been completed in the Appalachian Plateaus area, the ANR Production Company, 10,010 and the Gulf Oil Corporation, No.1 Ronnie Montgomery. The ANR 10,010 well was drilled as an outpost extension test of the Roaring Fork gas field. The well was drilled to a total depth of 5836 feet. Formation at total depth is the Wildcat Valley Sandstone. The well was completed on May 9, 1983 as a gas producer with shows in the Price Formation at 4871 to 4991 feet and a show of gas and oil in the Greenbrier Limestone from 4567 to 4719 feet. Final open flow after stimulation of the Price Formation was 103 MCF per day. The well also produces one barrel of oil and five barrels of water per day from the Greenbrier Limestone.

The No. 1 Ronnie Montgomery well was drilled as a new field wildcat and completed as a dry hole on October 21, 1984. The well was drilled to a total depth of 5560 feet. Formation at total depth is the Sequatchie. The well had shows of oil and gas in the Greenbrier limestone (3780-3800 feet) and the Price Formation (3993-4002 feet) and had shows of gas in the Clinch Sandstone from 5376 to 5428 feet.

SOURCE AND MIGRATION OF OIL AND GAS

Commercial quantities of oil and gas have been produced from Ordovician, Devonian, Mississippian, and Pennsylvanian strata. Rock units that are possible source beds include shales and limestones in the Rome Formation, Conasauga Shale, Reedsville Shale, and the Chattanooga Shale. These rocks seem to contain the requisite kinds and amounts of organic matter and in general to have undergone sufficient burial as to release oil or gas in commercial quantities.

Depth, duration of burial and the geothermal gradient are the most important factors that control diagenesis of organic matter. In recent years, attention has been directed toward the use of conodont color alteration as an index of organic thermal maturity (Epstein, 1975; Epstein and others, 1974). Epstein and others (1977) and Harris and others (1978) have compiled maps showing Conodont Alteration Index (CAI) isograds for limestones of the Ordovician, Silurian through Middle Devonian, and Upper Devonian through Pennylvanian intervals in parts of the Appalachian basin. CAI mapping in Lee County reveals that CAI in Ordovician limestone and in Devonian and Mississippian conodonts range between 1.5 and 2.5, CAI isograds follow the pattern of folding, and CAI isograds in footwall rocks exposed in fensters are lower CAI than in overlying hangingwall rocks. Therefore the thermal maturity pattern, as indicated by CAI mapping, was almost entirely established prior to thrusting.

There is an important relationship between the CAI isograds and past and present oil and gas production in the Appalachian basin. Major commercial production of oil is limited to areas of CAI of 2 or less and production of gas is limited to upward to a CAI of 4.5. Therefore in Lee County the CAI averages 2 thus confirming the organic thermal maturity for oil and gas production.

Maturation of hydrocarbons and the timing of oil and gas generation are believed to depend primarily on the time-temperature history of the sediment. The appropriate time-temperature history of Paleozoic source rocks in Lee County can be determined by combining the model burial history with the geothermal gradient to predict the time-temperature index of maturity - the TTI (Lopatin, 1971; Waples, 1980). Rock units having TTI values of 1 to 15 signify zone of wet gas generation, 15 to 160 the zone of oil generation, and 1500 is the wet gas deadline. The reconstructed burial history for the Paleozoic rocks in Lee County is presented in Figure 5.

Based on the burial history, one can estimate the timing for hydrocarbon generation by using burial history models (Waples, 1980). A simplified burial history model was constructed for Lee County. Basic assumptions made were, 1) a constant surface temperature 50° F (10° C) and 2) a geothermal gradient of 1.9° F/100 ft (35° C/ km) for lower Paleozoic rocks and 2.5° F/100 ft (45° C/ km) for upper Paleozoic rocks.

In general the shales in the Rome Formation entered the zone of oil generation about 420 million years ago during Early Silurian-time and remained until about the beginning of the Pennsylvanian-time (330 million years ago). Shale in the Reedsville Formation entered the zone of oil generation about 317 million years ago during late Early Pennsylvanian and still remains within the zone. The Chattanooga Shale entered the zone about 293 million years ago (late Late Pennsylvanian) and has remained within the zone of oil generation.

CONTROL OF OIL AND GAS PRODUCTION

Oil and gas have been recovered at several horizons within the Trenton Limestone, but our study has indicated that more of the recent production is obtained from the upper portion.

Primary, intergranular, porosity is important in the various Mississippian sandstone and siltstone units, including the Berea, Price, sandstones in the Bluefield Formation, Stony Gap Sandstone, and other sandstones of the Lee and Wise formations. Discontinuous zones of oolitic or skeletal limestone in the Greenbrier also contains intergranular porosity.

Secondary porosity, including fractures, dolomitization vugs are of special importance. Organic-rich shale in the Chattanooga is both a source and a reservoir for gas and have extremely low matrix permeabilities to gas. The shales and siltstones of lower organic-richness may act as resevoirs for gas that is generated in adjacent source rocks. Because the Chattanooga has low matrix permeability, gas production is related to the presence of fractures and folds which were caused by emplacement of the Pine Mountain fault. The Chattanooga Shale is a gas reservoir largely because of fracture porosity. Local production from the upper part of the Knox and from the Trenton also relates largely to presence of fractures. Vuggy porosity resulting from dolomitization has created small reservoirs in the Knox and Greenbrier.

In well cuttings and on porosity logs the limestones in the Trenton lack sufficient porosity and permeability to be classed as

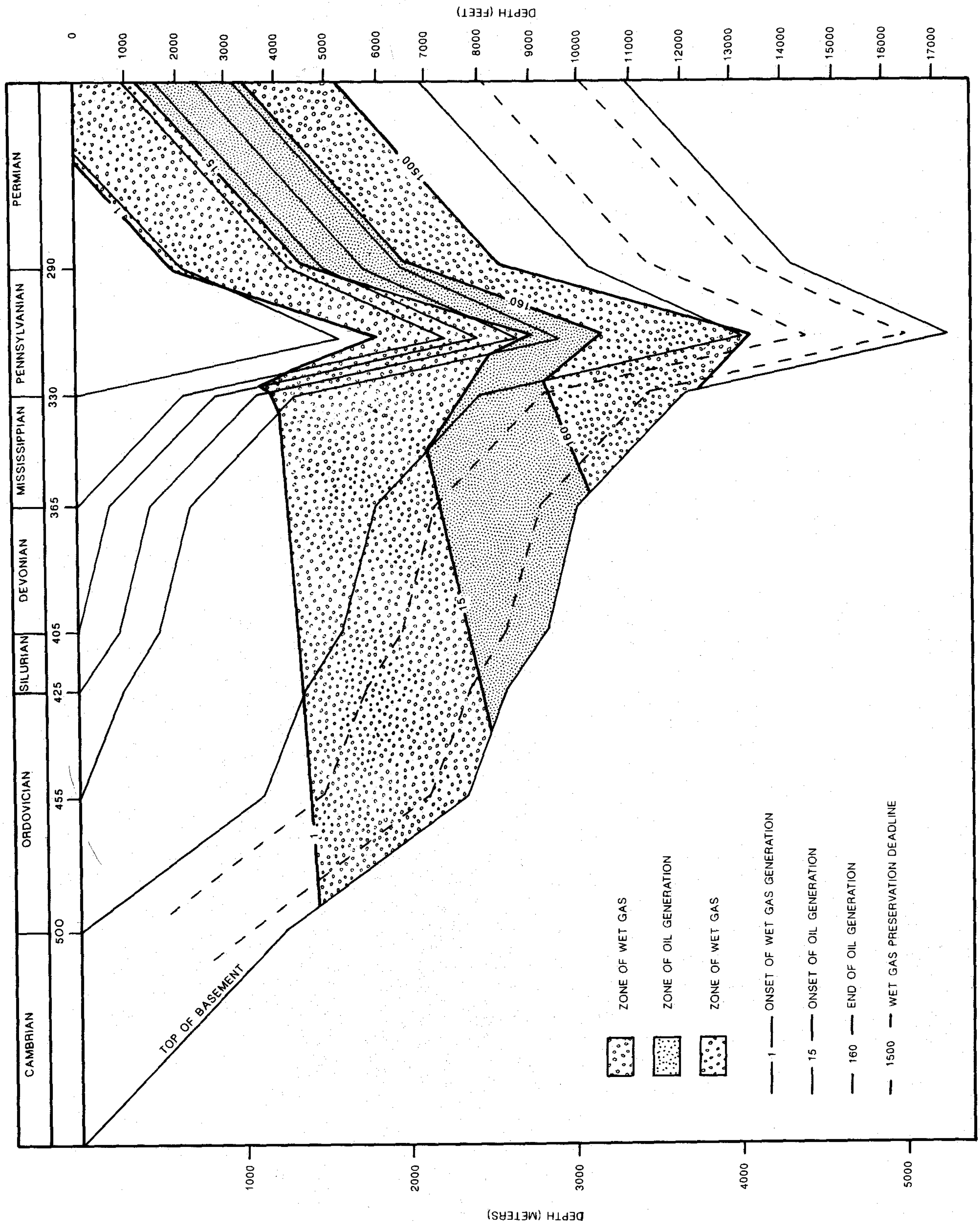

Figure 5. Time-Temperature model for the Paleozoic rocks in Lee County.

reservoir rock. Original pore space has been filled in by calcite deposition during diagenesis partially aided by deep burial and structural stress. Therefore, the open-space within the Trenton that contains the oil is not original pore space and must be due to fractures formed during emplacement of the Pine Mountain fault. These fractures apparently are extensive and interlocking to allow oil migration. The horizons of accumulation may be variable due to the presence of interbedded impermeable shale beds.

During the folding of the Powell Valley anticline, fracture systems developed in a parallel to diagonal direction to its northeast-southwest axis. Drilling in recent years has shown there is more oil production from wells drilled within 100 feet of a surface fracture trace. Beyond 100 feet, oil production decreases. Deeper drilling has also resulted in more productive wells.

In 1981, T. M. Gathright studied the relationship of oil production and occurrence to fracture patterns as recognized from Landsat imagery and aerial photography. He concluded that the methods proved potentially useful for gross site evaluations but that the technique needs to be refined for individual sites. It should also be noted that the fracture patterns developed in the Pine Mountain block may not be identical to the patterns developed in the Bales block. Approximately 90 fracture measurements (Bartlett, 1985, 1989) taken at bedrock outcrops in the Sulphur Springs window (Ben Hur field) as well as a limited number of fracture orientations from downhole fracture identification logs indicate there is no dominant fracture system in the Bales thrust block. The closely spaced fractures indicate that proper secondary treatment should enhance oil recovery.

The same forces which created the Pine Mountain and Bales thrusts also created regional and local fracture sets in this competent but relatively brittle unit. These fractures are now known to be erratic in quantity and quality but are at least locally interlocking to allow oil migration in the quantities produced by many Trenton wells.

Theoretically, fractures may be expected to be more common in the upper portion and basal portion of a thick competent unit such as the Trenton Limestone. The Table presents an analysis of the recorded fractures from twenty wells in Lee County. Using an arbitrary 100-foot interval from the top of the Trenton, the table shows the percentage of fractures quantitatively noted on the fracture identification logs. Although the sample is small, there is a clear indication of fracture concentrations in the upper and lower 200-foot intervals of the Trenton Limestone.

Table 1. Distribution of fractures in the Trenton Limestone.

	Trenton Limestone Interval (feet)					
Well	0-100	101-200	201-300	301-400	401-500	501-600
1	17.6	25.2	15.6	8.8	20.6	12.2
2	17.8	23.6	2.4	11.9	13.3	31.0
3	16.9	17.3	15.1	7.6	18.2	24.9
4	17.2	21.3	5.6	10.1	19.4	26.4
5	20.6	16.7	6.6	8.3	12.9	34.9
6	24.3	18.3	13.3	10.4	14.6	19.1
7	27.6	12.6	9.8	10.3	14.3	25.4
8	18.9	14.3	8.6	8.4	20.7	29.1
9	21.4	21.2	5.6	12.0	15.9	23.9
10	17.7	13.2	8.5	10.1	16.3	34.2
11	16.6	18.7	13.1	7.1	21.2	23.3
12	21.4	14.3	8.7	8.3	14.2	33.1
13	26.3	15.6	9.3	11.2	13.8	23.8
14	25.2	23.3	7.6	9.0	14.6	20.0
15	18.2	16.7	5.3	9.8	21.1	28.9
16	19.1	18.7	13.2	7.2	20.6	21.2
17	20.9	17.3	8.1	8.9	19.4	25.4
18	26.4	19.2	12.3	12.1	14.3	15.7
19	27.7	21.6	5.9	9.9	13.1	21.8
20	30.2	14.3	8.7	10.1	19.8	16.9
Average	21.6	18.2	9.2	9.5	16.9	24.6

OIL AND GAS PRODUCTION AND POTENTIAL

Oil from the Trenton Limestone is mostly an amber color and high volatile with API gravity ranging from 43° to 48°. Tests on Trenton oil from one well recorded marked changes in viscosity with temperature variations. At 90°F the viscosity was 2.72 centipoise, and at 50°F the oil thickened to 8.62 centipoise, reflecting in part the precipitation of paraffin (Bartlett, 1985). The oil has a high paraffin content, which tends to collect on pumps and rods and may plug off production if not treated by solvents on a regular basis. Connate water is produced, mostly in small quantities in a few wells, but no oil-water interface has been defined in any of the fields.

Production records for Lee County prior to 1954 are fragmentary. From 1943 to 1990, record show approximately 361,275 barrels of oil have been produced from the Rose Hill field, and from 1963 to 1990 the Ben Hur field has yielded approximately 207,514 barrels of oil. Total production for the county has amounted to 570,189 barrels through 1990 (Figure 3).

The Trenton wells commonly produce small quantities of natural gas with the oil production. In 1983, Stonewall Gas Co. encountered an apparently commercial flow of gas at their No. 1 Cope about one mile east of the Rose Hill oil field (Bartlett, 1985). After several hours of uncontrolled flow, the well tested at 4,500 MCF per day. Since no offsets have been drilled, it is not known whether this represents a sizable gas field or a gas cap on a new Trenton oil pool.

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COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES

PUBLICATION 113, PLATE 1
GEOLOGIC MAP AND OIL AND GAS WELL DATA
FOR EASTERN LEE COUNTY, VIRGINIA

GEOLOGIC MAP AND OIL AND GAS WELL DATA FOR EASTERN LEE COUNTY, VIRGINIA

JACK E. NOLDE

1992

MAP NUMBER	OPERATOR	LANDOWNER	ELEVATION (FEET)	TOTAL DEPTH (FEET)	RESULT	PRODUCING FORMATION
	APPALACHIA QUADRANGLE (61A)					
9-01	ANR Production Co.	Penn Virginia 10010	2336.3	5836	Gas Well-SI	Price, Greenbrier Ls
	BEN HUR QUADRANGLE (30A)					
2-01	J. W. Miloncus	Browning Wynn No. 1	1975.0	2000	Dry Hole	
2-02	Wilshire Oil Co. of Texas	Grace Cobb No. 1	1520.0	2572	Dry Hole	
2-03	David Law	J. V. Graham No. 1	1500.0	2781	Oil Well-PA	Trenton Ls
2-04	Trans State Oil Co.	J. V. Graham No. 2	1500.0	3115	Dry Hole	
2-05	Wilshire Oil Co. of Texas	J. V. Graham No. 3	1710.0	2725	Dry Hole	
2-06	Robert F. Spear	Roy Bledsoe 102	1910.0	2379	Dry Hole	
2-07	Mountain Empire Oil & Gas Co.	Roy Bledsoe No. 3	1910.0	1650	Oil Well-For	Trenton Ls
2-08	Penn Virginia Resources Corp.	Leslie Terry Est. 106	1948.5	2363	Oil Well-SI	Trenton Ls
2-09	Penn Virginia Resources Corp.	Leslie Terry Est. 107	2012.0	2520	Dry Hole	
2-10	Penn Virginia Resources Corp.	Leslie Terry Est. 108	1971.8	1810	Oil Well	Trenton Ls
2-11	Penn Virginia Resources Corp.	Ralph C. Howard No. 1	1786.0	2240	Oil Well	Trenton Ls
2-12	Penn Virginia Resources Corp.	C. Daugherty 110	1770.0		Gas Well-SI	
2-13	OMNI Petroleum Co.	James Bledsoe No. 1	1764.0	2764	Oil Well-PA	Trenton Ls
2-14	Penn Virginia Resources Corp.	F. S. Howard No. 1	1674.0	2482	Oil Well-SI	Trenton Ls
2-15	Eastern States Exploration	C. B. Waddell No. 1	1740.3	2850	Oil Well-PA	Clinch Ss
2-16	Eastern States Exploration	R. P. Waddell No. 1	1740.7	2850	Oil Well-PA	
2-17	Raintree Oil Co.	Pete Williams No. 1	1690.0	2280	Dry Hole	
2-18	Penn Virginia Resources Corp.	Castle Daughtery 104	1640.0	2657	Oil Well-SI	Trenton Ls
2-19	Ahora Oil Co.	James V. Graham 1	1601.9	2508	Oil Well-PA	
2-20	Penn Virginia Resources Corp.	Roy E. Roberts 8709	1870.2	5110	Gas Well-SI	Eggleston Ls, Dot Ls
3-01	Merrill Natural Resources	Roy Bledsoe No. 1	1855.0	2207	Oil Well-PA	Trenton Ls
3-02	Ben Hur Oil & Gas Co.	Ewing Bledsoe No. 1	1904.5	1947	Oil Well-PA	
3-03	Ben Hur Oil Co.	James Dean No. 1	1831.5	2550	Oil Well	Trenton Ls
3-04	Ben Hur Oil Co.	Frank Seabolt No.1	1795.1	2450	Oil Well	Trenton Ls
3-05	Ben Hur Oil Co.	Clarence Strouth 1-B	1745.8	2797	Oil Well	Trenton Ls
3-06	Ben Hur Oil Co.	Allen Cody No. 1	1685.5	2246	Oil Well	Trenton Ls
3-07	Stonewall Gas Co.	Edgar Hines No. 1	1698.0	2358	Oil Well	Trenton Ls
3-08	Ben Hur Oil Co.	Sam Williams No. 1	1746.7	2800	Dry Hole	
4-01	David Law	Dewey Livesay No. 1	1790.0	800	Dry Hole	
4-02	Ben Hur Oil Co.	H. M. Williams No. 1	1636.0	2550	Oil Well	Reedsville Sh
4-03	Hydrocarbon Development	Hobert Matlock No. 1	1768.0	1600	Dry Hole	
5-01	APACO Petroleum Co.	Joe Sutton No. 1	1596.2	1948	Dry Hole	
6-01	Virginia Oil & Gas Expl.	Dana Wolliver No. 1	1403.7	1380	Dry Hole	
	BIG STONE GAP QUADRANGLE (61D)					
4-01	Penn Virginia Resources Corp.	Guy Reasor 8712	1706.5	3027	Gas Well-SI	
9-01	ARCO Exploration Co.	W. Campbell Slemp 1	1646.0	13252	Dry Hole	
	HUBBARD SPRINGS QUADRANGLE (30B)					
1-01	BMW Resources	Moore, Hall, & Hines 1	1778.3	3675	Oil Well-PA	Eggleston Ls
1-02	Eastern States Exploration	Harrison Wilder No. 1	1768.3	2750	Dry Hole	
3-01	B & T Drilling Co.	William & Alice Ely 4	1640.0	2800	Dry Hole	
4-01	K. R. Wilson	C. Phipps No. 1	1585.0	1902	Dry Hole	
4-02	Stonewall Gas Co.	Chester Surgener No. 1	1740.0	3796	Dry Hole	
4-03	Stonewall Gas Co.	W. M. Gobble No. 1	1760.0	5199	Dry Hole	
5-01	Cedar Valley Oil Co.	D. C. McClure No. 1	1353.0		Dry Hole	
6-01	APACO Petroleum Co.	Aubra P. Dean No. 1	1720.0	2664	Oil Well	Trenton Ls
6-02	APACO Petroleum Co.	Aubra P. & Sue Dean 2	1680.0	2236	Oil Well	Reedsville Sh
6-03	APACO Petroleum Co.	Gale Slemp No. 1	1490.0	2412	Oil Well	Reedsville Sh
6-04	APACO Petroleum Co.	Aubra Dean No. 3	1660.0	1975	Oil Well-SI	Trenton Ls
6-05	APACO Petroleum Co.	Aubra Dean No. 4	1765.0	2480	Oil Well	Trenton Ls
6-06	APACO Petroleum Co.	Dale Smith No. 1	1541.0	1812	Oil Well	Reedsville Sh
6-07	Eastern States Exploration	Dale Eldridge No. 1	1637.5	2200	Oil Well	Trenton Ls
6-08	Raintree Oil Co.	Gladys Ely No. 1	1603.0	1820	Oil Well-PA	Trenton Ls
6-09	Raintree Oil Co.	Gladys Ely No. 2	1588.0	1630	Oil Well-PA	Trenton Ls
6-10	Raintree Oil Co.	Samuel Livesay No. 1	1811.0	2880	Oil Well-PA	Trenton Ls
6-11	Raintree Oil Co.	Gladys Ely No. 3	1564.0	1860	Oil Well-PA	Trenton Ls
6-12	Raintree Oil Co.	Gladys Ely No. 10	1658.6	1830	Oil Well-PA	Trenton Ls
6-13	Stonewall Gas Co.	Denver Browning No. 1	1688.1	3120	Oil Well-PA	Trenton Ls
6-14	Stonewall Gas Co.	George Lee No. 1	1770.0	5620	Dry Hole	
6-15	Grover Witt	Dewey Grizzle No. 1	1580.3	1550	Oil Well-SI	Trenton Ls
6-16	Newton Steele	Grace Young No. 1	1703.0	3150	Dry Hole	
6-17	Newton Steele	Eppie Collins No. 2	1742.0	600	Dry Hole	
6-18	Newton Steele	Grace Young No. 2	1725.0	3150	Oil Well-For	Trenton Ls
6-19	Southern Exploration	Gladys Ely No. 9	1782.0	1820	Oil Well	Trenton Ls
6-20	Adkison Drilling	Lee No. 2	1688.0	2569	Dry Hole	
8-01	C. E. Deaton	M. H. Snodgrass No. 1	1280.0	1706	Dry Hole	
8-02	Morgan Gold Hydrocarbons	David E. Gibson No. 1	1255.0	2015	Dry Hole	
	PENNINGTON GAP QUADRANGLE (62D)					
6-01	Gulf Oil Exploration	R. Montgomery No. 1	1695.5	5560	Gas Well-PA	

						61B	61A
				62C	62D	61C	61D
32B	32A	31B	31A	30B	30A	29B	29A
32C	32D	31C	31D	30C	30D	29C	

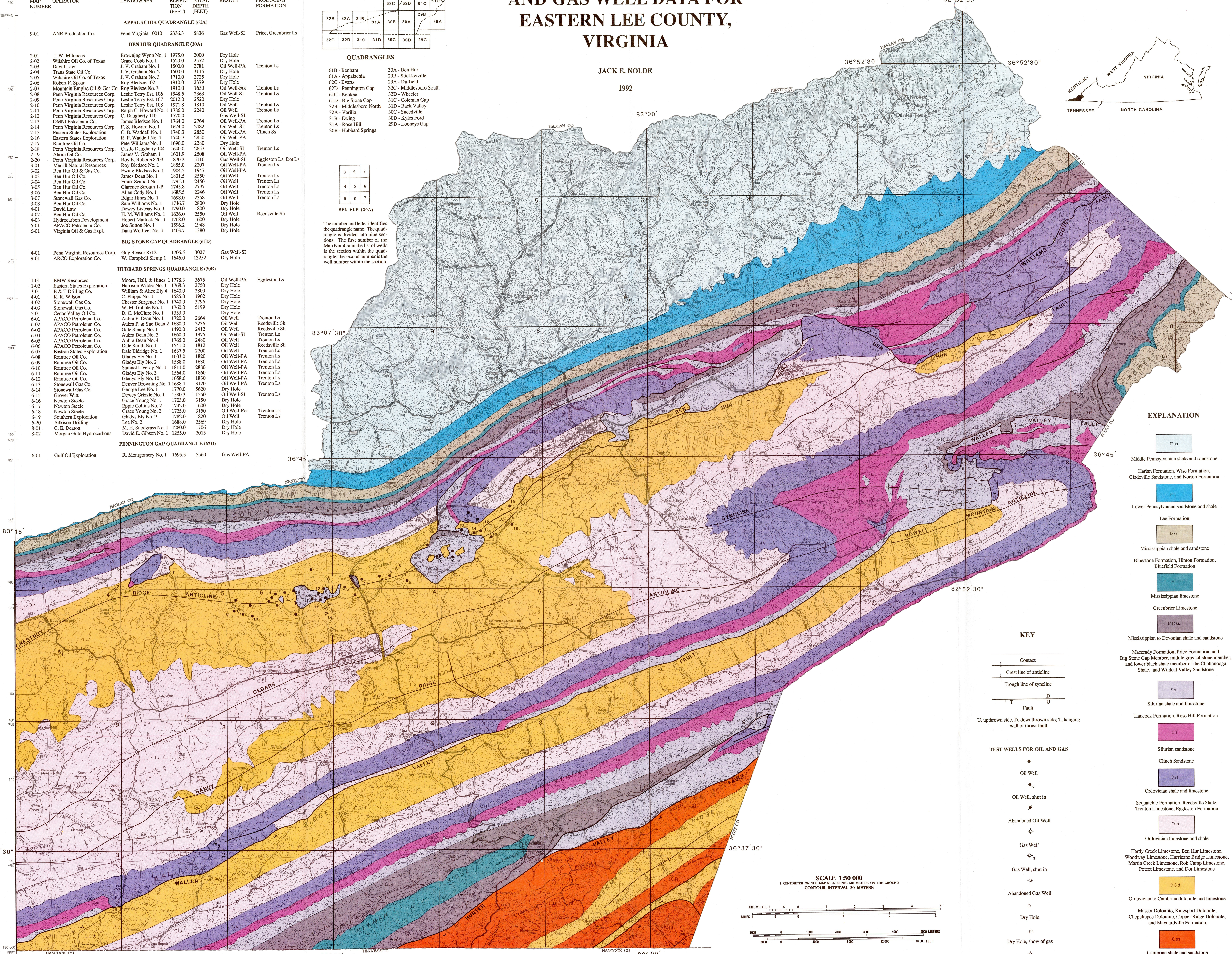
QUADRANGLES

61B - Benham	30A - Ben Hur
61A - Appalachia	29B - Stickleyville
62C - Evarts	29A - Duffield
62D - Pennington Gap	32C - Middlesboro South
61C - Keokee	32D - Wheeler
61D - Big Stone Gap	31C - Coleman Gap
32B - Middlesboro North	31D - Back Valley
32A - Varilla	30C - Sneedville
31B - Ewing	30D - Kyles Ford
31A - Rose Hill	29D - Looneys Gap
30B - Hubbard Springs	

3	2	1
4	5	6
9	8	7

BEN HUR (30A)

The number and letter identifies the quadrangle name. The quadrangle is divided into nine sections. The first number of the Map Number in the list of wells is the section within the quadrangle; the second number is the well number within the section.



EXPLANATION

Pss — Middle Pennsylvanian shale and sandstone
Harlan Formation, Wise Formation, Gladeville Sandstone, and Norton Formation

Ps — Lower Pennsylvanian sandstone and shale
Lee Formation

Mss — Mississippian shale and sandstone
Bluestone Formation, Hinton Formation, Bluefield Formation

Ml — Mississippian limestone
Greenbrier Limestone

MDss — Mississippian to Devonian shale and sandstone
Maccrady Formation, Price Formation, and Big Stone Gap Member, middle gray siltstone member, and lower black shale member of the Chattanooga Shale, and Wildcat Valley Sandstone

Ssl — Silurian shale and limestone
Hancock Formation, Rose Hill Formation

Ss — Silurian sandstone
Clinch Sandstone

Osl — Ordovician shale and limestone
Sequatchie Formation, Reedsville Shale, Trenton Limestone, Eggleston Formation

Ols — Ordovician limestone and shale
Hardy Creek Limestone, Ben Hur Limestone, Woodway Limestone, Hurricane Bridge Limestone, Martin Creek Limestone, Rob Camp Limestone, Poteet Limestone, and Dot Limestone

OЄdl — Ordovician to Cambrian dolomite and limestone
Mascot Dolomite, Kingsport Dolomite, Chepultepec Dolomite, Copper Ridge Dolomite, and Maynardville Formation,

Єss — Cambrian shale and sandstone
Conasauga Shale, and Rome Formation

KEY

Contact

Crest line of anticline

Trough line of syncline

Fault

U, upthrown side, D, downthrown side; T, hanging wall of thrust fault

TEST WELLS FOR OIL AND GAS

Oil Well

Oil Well, shut in

Abandoned Oil Well

Gas Well

Gas Well, shut in

Abandoned Gas Well

Dry Hole

Dry Hole, show of gas

Dry Hole, show of oil

SCALE 1:50 000
1 CENTIMETER ON THE MAP REPRESENTS 500 METERS ON THE GROUND
CONTOUR INTERVAL 20 METERS

KILOMETERS 1 .5 0 1 2 3 4 5
MILES 1 .5 0 1 2 3
1000 0 1000 2000 3000 4000 5000 METERS
2000 0 4000 8000 12 000 16 000 FEET

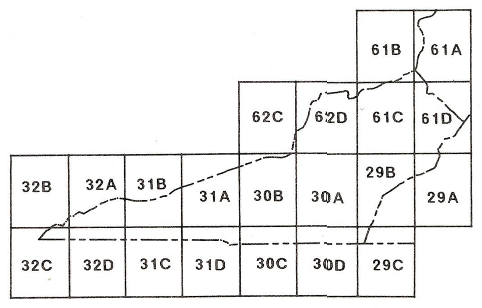
Base map: Department of the Interior
U.S. Geological Survey
Reston, VA - 1983

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES

GEOLOGIC MAP AND OIL AND GAS WELL DATA FOR WESTERN LEE COUNTY, VIRGINIA

JACK E. NOLDE

1992



QUADRANGLES

61B - Benham	30A - Ben Hur
61A - Appalachia	29B - Stickleyville
62C - Evarts	29A - Duffield
62D - Pennington Gap	32C - Middlesboro South
61C - Keokee	32D - Wheeler
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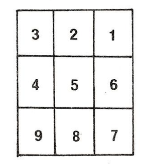
31A - Rose Hill	29D - Looneys Gap
30B - Hubbard Springs	



BEN HUR (30A)

The number and letter identifies the quadrangle name. The quadrangle is divided into nine sections. The first number of the Map Number in the list of wells is the section within the quadrangle; the second number is the well number within the section.

MAP NUMBER	OPERATOR	LANDOWNER	ELEVATION (FEET)	TOTAL DEPTH (FEET)	RESULT	PRODUCING FORMATION
		BACK VALLEY QUADRANGLE (31D)				
2-01	K. R. Wilson	O. Cavins No. 1	1500.0	2001	Dry Hole	
3-01	Shell Oil Co.	L. S. Bales No. 1	1380.0	8020	Dry Hole	
3-02	Hughes and Irving	Hidden Hollow No. 1	1430.0	1950	Dry Hole	
3-03	Spear Oil Co.	Max Parkey S-801	1595.0	1339	Dry Hole	
3-04	Penn Virginia Resources Corp.	Joe Turner 8840	1712.0	3200	Gas Well-SI	Woodway Ls
		COLEMAN GAP QUADRANGLE (31C)				
1-01	Rouge Oil Co.	Fugate Est. No. B-3	1539.0	2037	Oil Well-PA	
1-02	Fitch, Seal & Sliney	Bob Lemons No. 2	1466.0	1222	Oil Well	Trenton Ls
1-03	Rouge Oil Co.	Fugate Est. No. 1	1534.0	1610	Oil Well-PA	Eggleston Ls
1-04	H and R Oil Co.	B. C. Fugate No. 1	1450.0	1494	Oil Well-PA	Trenton Ls
1-05	R. Y. Walker	B. C. Fugate No. 2	1512.0	2003	Dry Hole	
1-06	Virginia Lee Oil Co.	B. C. Fugate No. 3	1451.0	1773	Oil Well-PA	Trenton Ls
1-07	Stacy et al.	Patton Ely Est. No. 1	1552.0	2900	Dry Hole	
1-08	Rouge Oil Co.	Logan Snodgrass No. 1	1467.0	1832	Dry Hole	
1-09	Rouge Oil Co.	W. T. Jenkins No. 1	1711.0	215	Dry Hole	
1-10	Rouge Oil Co.	Fugate Est. No. 4	1494.0	1526	Oil Well-PA	
1-11	Rouge Oil Co.	Fugate Est. No. 3	1481.0	1320	Oil Well-PA	
1-12	Rouge Oil Co.	Fugate Est. No. B-2	1533.0	1769	Oil Well-PA	
1-13	Rouge Oil Co.	Fugate Est. No. 2	1477.0	1215	Oil Well-PA	
1-14	Rouge Oil Co.	B. C. Fugate No. 2A	1475.0	1986	Dry Hole	
1-15	Rouge Oil Co.	G. C. Dean No. 1	1494.0	1766	Oil Well-PA	
1-16	Rouge Oil Co.	Cleve Dean No. 2	1640.0	2300	Dry Hole	
1-17	Rouge Oil Co.	Cleve Dean No. 1	1698.0	209	Dry Hole	
1-18	Rouge Oil Co.	L. E. Bales No. 2	1750.0	2152	Dry Hole	
1-19	Rouge Oil Co.	L. E. Bales No. 1	1532.0	1767	Oil Well-PA	
1-20	Rouge Oil Co.	Bob Lemons No.1	1438.0	1445	Dry Hole	
1-21	H and R Oil Co.	Clifford Yeary Est. 1	1390.0	3130	Dry Hole	
1-22	Rouge Oil Co.	Bob Lemons No. 3	1531.0	1590	Dry Hole	
1-23	Dunningan, Malloy, Stacy	Glenn Yeary Est. 1	1614.0	2835	Dry Hole	
1-24	Ewing Oil Co.	L. E. Bales Est. 2	1750.0	2167	Dry Hole	
1-25	T. B. Smith	Clarence Dean No. 1	1515.0	2085	Dry Hole	
1-26	Rouge Oil Co.	Stacey Nelson No. 1	1538.0	1575	Oil Well-PA	Trenton Ls
1-27	R. Y. Walker et al.	B. C. Fugate No. 1	1447.0	1115	Oil Well-PA	Trenton Ls
1-28	Rouge Oil Co.	Andy Ely No. 1	1543.0	2166	Oil Well-PA	Trenton Ls
1-29	Rouge Oil Co.	Joe Dean No. 1	1573.0	1666	Oil Well-PA	Trenton Ls
1-30	Trans State Oil Limited	Josh Dean No. 2	1475.0	2007	Dry Hole	
1-31	Eastern States Exploration	Elbert Harris No. 1	1590.0	1573	Oil Well-PA	
1-32	Robert F. Spear	L. Snodgrass Heirs 101	1500.0	2135	Gas Well-PA	Woodway Ls
1-33	Robert F. Spear	L. Snodgrass Heirs 103	1520.0	1853	Oil Well-PA	Eggleston Ls
1-34	Lee Oil Drilling Co.	L. T. & P. Harris 1	1570.0	1762	Dry Hole	
1-35	Moore and Witt	Logan Snodgrass No. 4	1530.7	1890	Oil Well-PA	Eggleston Ls
1-36	Eastern States Exploration	Edwards & Riggs No. 1	1500.0	2425	Oil Well-PA	Trenton Ls
1-37	BMW Resources	Herbert Turner No. 1	1653.4	1708	Oil Well-PA	Trenton Ls
1-38	BMW Resources	Herbert Turner No. 2	1535.0	3650	Dry Hole	
1-39	Penn Virginia Resources Corp.	Lowe & Wolliver 101	1540.0	4200	Gas Well-SI	
1-40	Rouge Oil Co.	B. C. Fugate No. 2B	1475.0	1908	Dry Hole	
2-01	Virginia Lee Oil Co.	E. M. Brooks No. 1	1452.0	4079	Gas Well-PA	Hancock
2-02	Rouge Oil Co.	Henley Sutton No. 1	1509.0	4000	Dry Hole	
2-03	Rouge Oil Co.	W. C. Martin Heirs 1	1600.0	4072	Dry Hole	
		EWING QUADRANGLE (31B)				
7-01	Rouge Oil Co.	Myrtle Campbell No. 1	1522.0	1260	Oil Well-PA	
7-02	Dr. Adam Stacy	Sibbie Ramsey No. 1	1530.0	2100	Oil Well-PA	Reedsville Sh
7-03	Rouge Oil Co.	Joe Chadwell Est. 1	1393.0	2015	Dry Hole	
7-04	Grover Witt	Ben Campbell No. 2	1403.0	1400	Oil Well-PA	Clinch Ss
7-05	M. L. McGinnis	F. B. Fugate Est. 1	1550.0	2000	Dry Hole	
7-06	State Oil and Gas Co.	Charles Marcum No. 1	1365.0	1718	Oil Well-PA	
7-07	Blackberry Oil Co.	Glenn Yeary No. 2	1566.4	2319	Dry Hole	
7-08	Rowlett and Adkinson Oil Co.	Curtis Rowlett No. 1	1625.0	2551	Oil Well-PA	Clinch Ss
7-09	Witt Oil and Drilling Co.	Ben Campbell No. 3	1448.0	1990	Dry Hole	
7-10	Stonewall Gas Co.	Pauline Seal No. 1	1590.0	2213	Oil Well-PA	Trenton Ls
7-11	Edds & Moore	Harris Edds No. 1	1603.0		Oil Well-PA	
7-12	Robert Spear	R. V. Chadwell No. 1	1670.0		Dry Hole	
9-01	Johnson and Gilmore	B. Parkey Est. No. 1	1460.0	2650	Dry Hole	

MAP NUMBER	OPERATOR	LANDOWNER	ELEVATION (FEET)	TOTAL DEPTH (FEET)	RESULT	PRODUCING FORMATION
		ROSE HILL QUADRANGLE (31A)				
4-01	K. R. Wilson	E. C. H. Rosenbaum 1	1440.0	1466	Dry Hole	
4-02	Penn Virginia Resources Corp.	Betty Stickley 8829	1590.1	2641	Oil Well	Trenton Ls
5-01	Herbert Gardiner	Candy Cawood No. 1	1700.0	150	Oil Well-PA	
5-02	Lee Oil Drilling Co.	Don Grabeel No. 1	1573.0	7209	Oil Well-PA	Moccasin
5-03	Stonewall Gas Co.	Starling Cope No. 1	1686.0	2537	Gas Well-SI	Trenton Ls
5-04	Penn Virginia Resources Corp.	Beryl Owens 8713	1736.6	2364	Oil Well	Trenton Ls
5-05	Penn Virginia Resources Corp.	Claude C. Davis 8810	1705.5	4041	Gas Well-SI	Mascot Dol
6-01	R. R. Murray	Anthony Ely Est. No. 1	1330.0	2532	Dry Hole	
6-02	Penn Virginia Resources Corp.	Chance & Montgo. 102	1664.5	5572	Gas Well-SI	Hurricane Bridge-Martin Creek Lss
8-01	Robert Vorhees	Mill Davis No. 1	1620.0	4406	Dry Hole	
8-02	Stonewall Gas Co.	Steve Hensley No. 1	1692.0	4312	Oil Well-SI	Mascot-Kingsport Dol
8-03	Penn Virginia Resources Corp.	Jewell Davis 8828	1745.1	5064	Dry Hole	
9-01	Dr. Adam Stacy	Abney & Edds No. 1	1450.0	1770	Oil Well-PA	
9-02	Dr. Adam Stacy	Charles Frye No. 1	1520.0	1745	Oil Well-PA	Trenton Ls
9-03	G. D. Lee	G. D. Lee No. 1	1400.0	2254	Oil Well-PA	
9-04	Rouge Oil Co.	James Ray No. 2	1330.0	1470	Oil Well-PA	Trenton Ls
9-05	Rouge Oil Co.	M. E. McCurry No. 1	1380.0	2318	Oil Well-PA	Trenton Ls
9-06	Rouge Oil Co.	C. E. Hobbs No. 1	1347.0	1850	Dry Hole	
9-07	Rouge Oil Co.	James Ray No. 1	1330.0	1477	Oil Well-PA	Trenton Ls
9-08	K. R. Wilson	Sensebaugh Heirs 1	1588.0	2002	Dry Hole	
9-09	James Webb	Beatty Heirs No. 1	1330.0	1798	Dry Hole	
9-10	Stacy and Cardwell	A. Shackleford No. 1	1550.0	2780	Dry Hole	
9-11	Cardwell and Stacy	Abney Heirs No. 1	1430.0	1798	Oil Well-PA	Trenton Ls
9-12	J. C. Sheaffer et al.	Gilbert Lee No. 3	1410.0	1869	Dry Hole	
9-13	Fred Shaner et al.	Owens No. 1	1660.0	2325	Dry Hole	
9-14	Rouge Oil Co.	W. S. Riley No. 1	1500.0	355	Dry Hole	
9-15	Rouge Oil Co.	J. R. Osborn No. 1	1340.0		Oil Well-PA	Trenton Ls
9-16	Rouge Oil Co.	H. B. Nolan No. 1	1376.0	2373	Dry Hole	
9-17	Rouge Oil Co.	R. L. Bales No. 1	1348.0	1867	Oil Well-PA	Trenton Ls
9-18	Mountain Empire Oil & Gas Co.	Pritchard Est. No. 1	1460.0	467	Dry Hole	
9-19	Lon Montgomery	Lon Montgomery No. 1	1455.0	2400	Dry Hole	
9-20	Rouge Oil Co.	Lee Marcum No. 1	1570.0		Dry Hole	
9-21	Ingram or Holcombe	Ingram No. 1	1570.0	1870	Dry Hole	
9-22	Rouge Oil Co.	C. B. Hobbs No. 1	1430.0	1850	Oil Well-PA	Trenton Ls
9-23	H and R Oil Co.	Grant Smith Est. No. 1	1605.0	2188	Dry Hole	
9-24	H and R Oil Co.	Dewey Lee No. 1	1440.0	2156	Oil Well-PA	Trenton Ls
9-25	W. B. Fulton	Lee Martin No. 1	1415.0	1498	Dry Hole	
9-26	L. E. Bales et al.	Gilbert Lee No. 2	1420.0	1410	Oil Well-PA	Trenton Ls
9-27	L. E. Bales et al.	Gilbert Lee No. 1	1420.0	303	Oil Well-PA	
9-28	Jack Asher	Jack Asher No. 1	1410.0	900	Dry Hole	
9-29	American Trading Products Co.	Gilbert Lee No. 4	1395.0	2108	Dry Hole	
9-30	Ewing Oil Co.	Manford Lee No. 6	1420.0		Dry Hole	
9-31	J. W. Miloncus	Ryland Ramsey No. 3	1547.0	2114	Dry Hole	
9-32	Rouge Oil Co.	C. E. Hobbs No. 2	1400.0	2200	Oil Well-PA	
9-33	Trans State Oil Co.	Ike & Mary K. Bacon 2	1390.0	1791	Oil Well-PA	Trenton Ls
9-34	Eastern States Exploration	Ryland Ramsey No. 2		1748	Oil Well-PA	
9-35	Lee Oil Drilling Co.	Wolfe-Snodgrass Unit 1	1461.0	2166	Oil Well-PA	Trenton Ls
9-36	Lee Oil Drilling Co.	W. & J. Burgan 1	1655.0	3998	Oil Well-PA	Rob Camp Ls
9-37	Nininger Oil Co.	Glen Marcum No. 1	1450.2	1900	Dry Hole	
9-38	Mountain Empire Gas & Oil Co.	Ike Bacon No. 1	1348.6	1893	Dry Hole	
9-39	Spear Oil Co.	Ryland Ramsey No. 4	1555.0	1985	Dry Hole	
9-40	Spear Oil Co.	Ryland Ramsey No. 5	1484.3	1885	Oil Well-PA	Trenton Ls
9-41	Muenster Drilling Co.	Elmer Ray No. 1	1570.0	1770	Oil Well-PA	Trenton Ls
9-42	Longview Oil Co.	Ike & Mary K. Bacon 3	1412.0	1900	Oil Well-PA	Trenton Ls
9-43	Pride Oil Co.	R. Wilson Est. No. 1	1627.8	2072	Oil Well	Clinch Ss
9-44	Merrill Natural Resources	Wayne Burgan No. 1	1390.0	1975	Dry Hole	
9-45	BMW Resources	Ewell Frye No. 1	1648.6	2790	Oil Well-PA	Trenton Ls
9-46	Stonewall Gas Co.	Donald Long No. 1	1585.0	1995	Oil Well	Trenton Ls
9-47	Stonewall Gas Co.	Morgan Hensley No. 1	1670.2	2150	Oil Well	Trenton Ls
9-48	Eastern State Exploration	Ryland Ramsey No. 6	1458.3	3852	Oil Well-PA	Mascot Dol
9-49	Stonewall Gas Co.	E. Hargraves No. 1	1500.0	1936	Dry Hole	
9-50	Penn Virginia Resources Corp.	Morgan Hensley 8836	1735.0	6425	Gas Well-SI	
9-51	Tennessee Land & Exploration	Rinehart-Ray No. 1R	1502.0	2009	Dry Hole	
9-52	Sovereign Petroleum Co.	Lucy Trent No. 1	1650.0	3852	Oil Well-SI	Kingsport Dol
9-53	Penn Virginia Resources Corp.	Jackie W. Engle 8708	1636.8	3800	Gas Well-SI	
9-54	Penn Virginia Resources Corp.	J. & M. Gillis 8827	1519.5	4400	Dry Hole	
9-55	Penn Virginia Resources Corp.	Clebert Surber 8830	1456.0	3692	Dry Hole	

EXPLANATION

Pss
Middle Pennsylvanian shale and sandstone
Harlan Formation, Wise Formation, Gladeville Sandstone, and Norton Formation

Ps
Lower Pennsylvanian sandstone and shale
Lee Formation

Mss
Mississippian shale and sandstone
Bluestone Formation, Hinton Formation, Bluefield Formation

Ml
Mississippian limestone
Greenbrier Limestone

MDss
Mississippian to Devonian shale and sandstone
Maccrady Formation, Price Formation, and Big Stone Gap Member, middle gray siltstone member, and lower black shale member of the Chattanooga Shale, and Wildcat Valley Sandstone

Ssl
Silurian shale and limestone
Hancock Formation, Rose Hill Formation

Ss
Silurian sandstone
Clinch Sandstone

Osl
Ordovician shale and limestone
Sequatchie Formation, Reedsville Shale, Trenton Limestone, Eggleston Formation

Ols
Ordovician limestone and shale
Hardy Creek Limestone, Ben Hur Limestone, Woodway Limestone, Hurricane Bridge Limestone, Martin Creek Limestone, Rob Camp Limestone, Poteet Limestone, and Dot Limestone

OCdl
Ordovician to Cambrian dolomite and limestone
Mascot Dolomite, Kingsport Dolomite, Chepultepec Dolomite, Copper Ridge Dolomite, and Maynardville Formation,

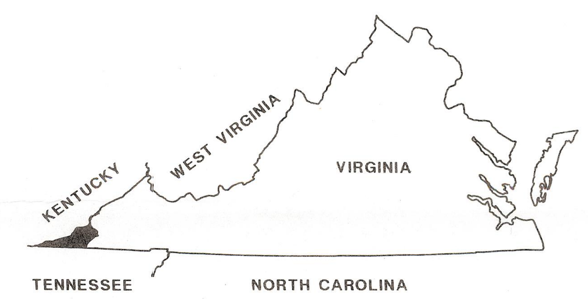
Css
Cambrian shale and sandstone
Conasauga Shale, and Rome Formation

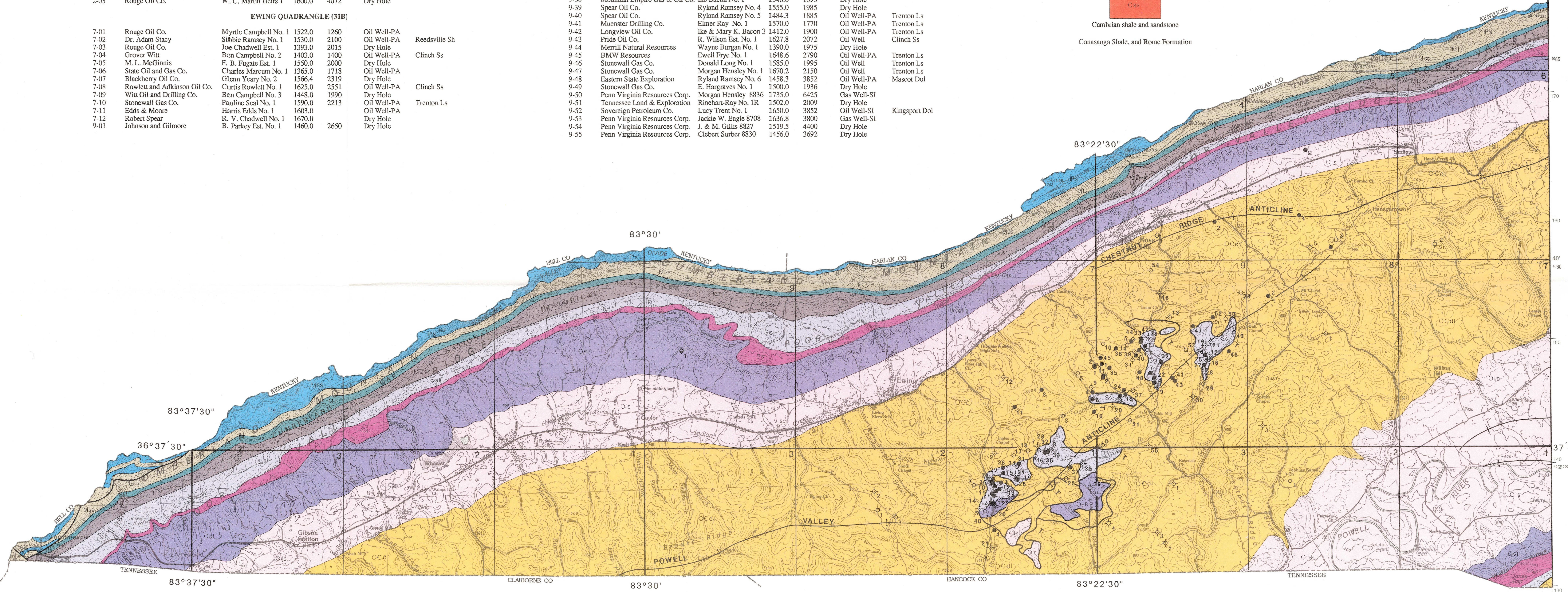
KEY

Contact
Crest line of anticline
Trough line of syncline
Fault
U, upthrown side, D, downthrown side; T, hanging wall of thrust fault

TEST WELLS FOR OIL AND GAS

Oil Well
Oil Well, shut in
Abandoned Oil Well
Gas Well
Gas Well, shut in
Abandoned Gas Well
Dry Hole
Dry Hole, show of gas
Dry Hole, show of oil





Base map: Department of the Interior
U.S. Geological Survey
Reston, VA - 1983

SCALE 1:50 000
1 CENTIMETER ON THE MAP REPRESENTS 500 METERS ON THE GROUND
CONTOUR INTERVAL 20 METERS