THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE SUBSURFACE GEOLOGY OF T. 4 N., R. 4 & 5 E., PONTOTOC COUNTY, OKLAHOMA

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THE SUBSURFACE GEOLOGY OF T. 4 N., R. 4 & 5 E.,

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THE SUBSURFACE GEOLOGY OF T. 4 N., R. 4 & 5 E.,

PONTOTOC COUNTY, OKLAHOMA

CHAPTER I

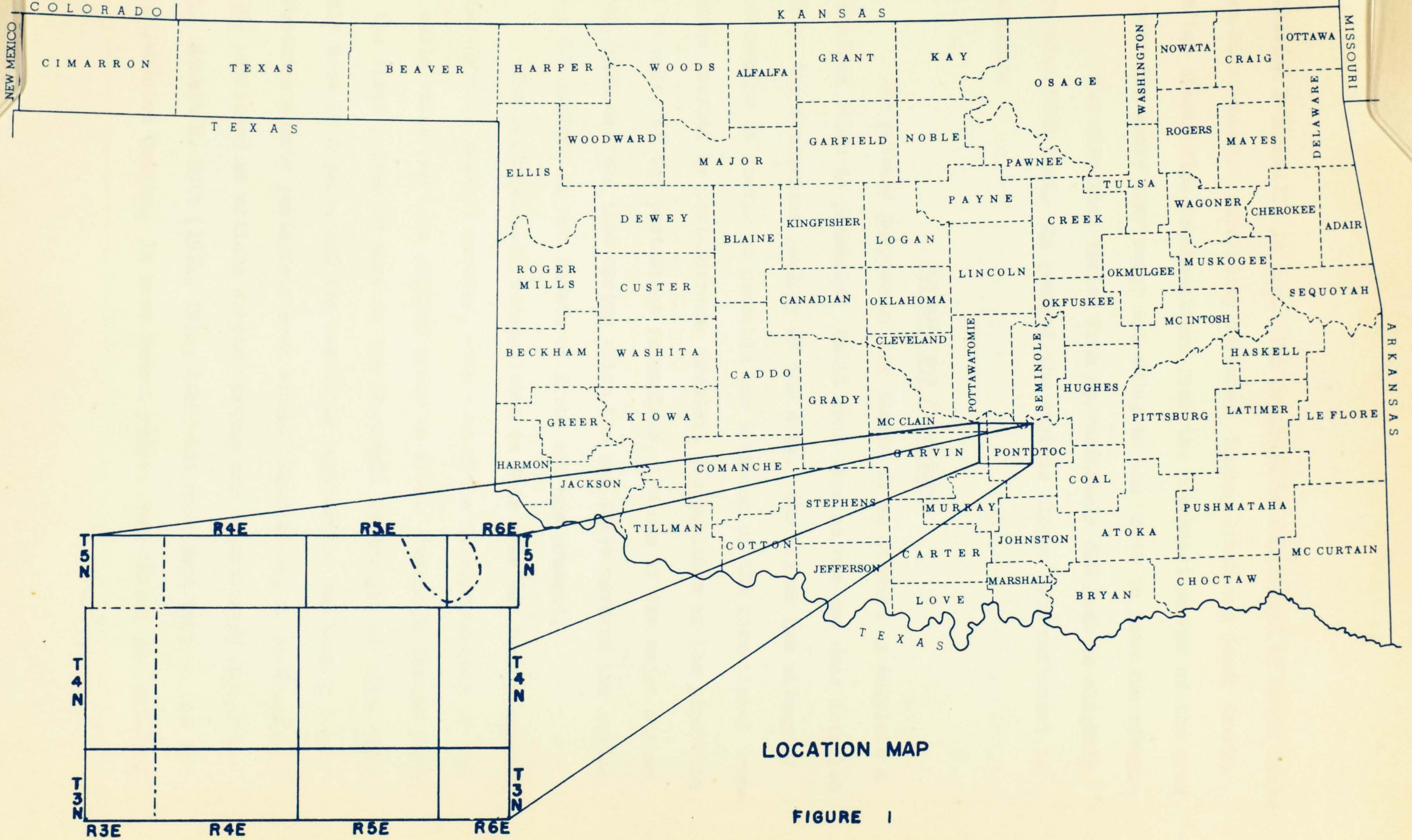
INTRODUCTION

Location

The area included in this discussion is located principally in Pontotoc County, Oklahoma, but includes portions of Garvin, Seminole and McClain counties. The area of primary importance for this thesis is T. 4 N., R. 4 E., and T. 4 N., R. 5 E. For the sake of completeness a strip three miles wide on each side of this rectangle has been included. The thesis area, 216 square miles, is bounded on the north by the center line of T. 5 N., on the east by the center line of R. 6 E., on the south by the center line of T. 3 N., and on the west by the center line of R. 3 E.

Topography and Drainage

This area is situated within the sandstone hills region of Oklahoma. The "hills" are actually dissected, gently dipping cuestas. The escarpments parallel each other in a generally northeast-southwest direction. The valleys are formed by the erosion of shale zones between the more resistant sandstone outcrops which are Permian Asher to Penn-



LOCATION MAP

FIGURE 1

sylvanian Holdenville in age. The drainage is controlled by South Canadian River and two subsidiary streams: Spring Creek and Sandy Creek. The two creeks flow southeastward from the northwest corner of the area to near Ada where they merge and swing to the north to join the river.

The elevation varies from approximately 800 feet to slightly more than 1000 feet. In general the surface slopes from northwest to southeast.

Purpose and Procedure

The primary purpose of the thesis is to present as complete a subsurface study as possible. Until this time no one has done detailed work on the subsurface geology of the area. The writer has attempted to determine as nearly as possible the location of the formational truncations created by post-Morrowan erosion, the position of the pinchouts due to onlap of the post-Atoka formations, the age of the major structural features, the time during which the sea first covered the Hunton arch, and whether or not strata of Krebs age are present.

The geologic work accomplished in this area has been concerned primarily with surface geology, with subsurface interpretations of the few wells which had been drilled prior to 1924. George D. Morgan (1924) was the first person to work on the Stonewall Quadrangle of which this thesis area is a part, and the resulting publication has been a guide to Pontotoc County geologists ever since. Soon after, R. A. Conkling (1930) published an article substantiating and interpreting Morgan's work. Robert H. Dott (1924, 1934, 1941) has done much work in and around Pontotoc County. In more recent years, many theses and articles have been written describing the surface features in and near the area under discussion in this thesis.

The results presented in this paper were obtained primarily through the extensive study of electrical well logs and the microscopic examination of rotary drill samples. Data were obtained also from the Oil Research cards, Corporation Commission logs and Herndon Oil maps. These data do not appear on the maps unless validated from some other source.

CHAPTER II

STRATIGRAPHY

SURFACE ROCKS

Quaternary System

Guertie sandstone.--Recent deposits are restricted to sands and silts dropped along stream channels. The only one of importance is the Guertie sand which was deposited in two irregular bands roughly paralleling the present course of South Canadian River. This suggests that the sand was deposited by an earlier river which flowed in much the same position as the present South Canadian River (Morgan, 1924, p. 143). The sand is composed of varied sizes of smooth, well-rounded quartz grains mixed with yellow silt, creating an overall yellowish appearance. The particles increase in size with depth from sand size (2 mm - 1/16 mm) to pebble size (64 mm - 4 mm).

The deposits range in thickness from ten feet to sixty feet, and in width from a few feet to nearly two miles. The dip is slight (four feet to five feet per mile) and appears to conform to the existing surface at the time of deposition.

Permian System

Wolfcampian Series

Pontotoc Terrane

The strata composing the Pontotoc terrane are generally arkosic, particularly so in the lower portion and lessening upwards. The material making up these deposits was derived mainly from the Arbuckle area as evidenced by the recognizable limestone fragments incorporated. The Pontotoc terrane includes the Vanoss, Stratford and Konawa, including Asher, formations and is 1200 to 1500 feet thick in this area where present. The name Pontotoc terrane was given to these three formations by Morgan (1924, p. 132) because of their lithologic similarity.

Asher formation.--The red beds of the Asher formation crop out in the northwestern corner of the thesis area. The formation is composed of thick coarse red sandstone from 200 feet to 250 feet thick. Morgan (1924, p. 142) assigned the Asher formation to the Permian system on the basis of color and stratigraphic position. Green (1936, p. 1454) has stated that Asher is a local facies of the Konawa formation.

Konawa formation.--The Konawa formation is composed primarily of red shales, but red sandstone beds are not uncommon. One chert conglomerate has been observed, but there are no important limestones.(Morgan, 1927, p. 141). The formation is approximately 500 feet thick with a dip of one degree to the northwest.

Stratford formation.--This formation is composed of shale, limestone and sandstone with shale predominating. In the lower part is the Hart limestone member which is composed of alternating limestone, sandstone and shale. The thick shale section above the Hart contains a few sandstones, some of which are arkosic. East of the town of Stratford the shales have a gumbo-like character (Morgan, 1924, p. 139). The thickness is 400 feet in this area. The dip of this formation is one degree northwest.

Pennsylvanian System

Virgilian Series

Vanoss formation.--The Vanoss formation is composed of arkosic material incorporated into thin alternating strata of conglomerate, limestone, shale and sandstone. The few limestones are very argillaceous, grading into shales both north and south of the town of Center. In the upper part of the formation the sandstone diminishes greatly in favor of the shale. These upper shales are light colored, gray or brown, with minor amounts of red. The top of the formation is immediately beneath the Hart limestone bed of the Stratford formation. The thickness varies from 250 feet to 650 feet. The Vanoss and all formations older than it and younger than Wapanucka dip consistently about one degree toward the northwest.

Ada formation.--This formation is made up predominantly of coarse sandstones and conglomerates. Many of the sands and conglomerates contain asphalt, so much in fact that near Ada it is quarried for use as a paving material. The source of the asphalt is not known as the adjacent shales are all light colored and do not appear to be likely source beds (Morgan, 1924, p. 128). The base of the formation is marked by a thin, persistent black limestone. The amount of clastic material decreases toward the north which results in a corresponding decrease in thickness to about sixty feet instead of the normal 100 feet.

Vamoosa formation.--The Vamoosa formation is mostly chert conglomerates, coarse red-brown sandstones and red shales, with thirty feet of dark homogeneous shale in the lower part (Conkling, 1930, p. 125). The particles become finer and lighter in color toward the top. The Vamoosa conglomerates resemble the conglomerates of the Stratford and Vanoss formations, but are not arkosic. The Vamoosa contains a greater thickness of chert conglomerate than any other formation in the area. The formation is approximately 260 feet thick.

SUBSURFACE ROCKS

Pennsylvanian System

Missourian Series

Ochelata group

Formations of this group, namely the Hilltop formation, are absent. This is apparently the result of non-deposition during the Arbuckle uplift.

Skiatook group

The formations of this group as well as the Holdenville formation, crop out within the bounds of this thesis area, but they are of primary interest as subsurface strata.

Belle City limestone.--The Belle City limestone is composed of two limestone beds with an intervening shale zone. The upper member is generally the thicker and more massive of the two. Its thickness ranges from one to fifteen feet as compared to one to five feet for the lower. The upper lime is white or light gray; the lower is commonly buff to brown. Stylolites and solution cavities along joint planes are common in the upper member. The shale is approximately twelve feet thick and is found in most colors except red. The Belle City limestone is a relatively pure limestone and is the youngest example of such in the area.

Francis formation.--This unit is primarily shale with minor amounts of sandstone, cherty limestone and limestone conglomerate. Immediately below the Belle City limestone are two thick sections in which sandstone and chert conglomerate predominate. Under these is a thick section of slightly calcareous shale which makes up the main body of the Francis formation. Next is a twenty foot sandstone and conglomerate section underlain by thirty feet of black shale. Near the base of the Francis and at the top of the Seminole formation is a named, mappable limestone member, the DeNay limestone. It is a somewhat crinoidal limestone about one foot thick. South of Ada it is composed almost entirely of crinoid stems, but to the north the fossils decrease and the member assumes a bright yellow color (Morgan, 1924, p. 114). The Francis formation is found to have a thickness of 290 feet.*

Seminole formation.--Directly below the DeNay limestone member of the Francis formation is the Seminole formation, a fine brown sandstone grading downward into a conglomerate composed of laminated or stratified chert with a few quartz pebbles and sand grains. The conglomerate is cemented with a matrix of fine brown ferruginous sand grains. The thickness is 180 feet.

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*All thicknesses in this section, Sursurface Rocks, are maximums.

Des Moinesian Series

Marmaton group

Holdenville formation.--The Holdenville formation is predominantly shale with minor sandstone strata and two limestone members. The sands are poorly developed and are extremely shaley. The formation is 150 feet thick.

The most important of the two limestones is the Sasakwa limestone which is found thirty to forty feet below the base of the Seminole formation. This limestone is persistent throughout the entire area of this work (Plate No. IV). In most places it is a ten foot pure limestone. In others it becomes very sandy and seems to thicken accordingly. The Sasakwa appears to be the first formation to have been deposited over the Hunton arch.

The Homer limestone, according to Morgan (1924, p. 104), occurs seventy feet below the Sasakwa. It appears that in subsurface this interval varies from ten feet to forty feet and that the member is much less persistent, becoming a limey shale in many scattered areas.

Wewoka formation.--The Wewoka formation is principally a sandstone but with intervening shale lentils. The sandstone members locally grade into both limestone and chert conglomerate. The upper conglomerates contain recognizable fragments of Viola and Hunton limestone which probably came from the Hunton arch. The formation has a thickness of 210 feet.

Wetumka formation.--The Wetumka formation is predominantly a soft dark shale overlying the Calvin formation. There are a few sandstone strata above and below the shale, creating difficulty in accurately determining its limits. The formation has a thickness of 140 feet.

Calvin formation.--The Calvin formation is the youngest prolific oil producer in this region. It is commonly a gray-brown, coarse sandstone in ten to fifteen foot lentils interbedded with similar thicknesses of hard shale. The sands decrease in particle size downward in the formation so that the lower part becomes entirely shale. The thickness is 100 feet.

Senora formation.--The Senora is also an excellent oil reservoir. The upper part of the formation is thin reddish-brown sandstone and shales of similar thickness with the shale predominating. In the basal member sandstones are more abundant. Also in the lower member is a sandy limestone stratum. This is very thin and occurs locally. The thickness is 160 feet.

Stuart shale.--The Stuart shale is a relatively thin section of soft shales and sandstone occurring in dark hues of green, black and blue. The shales are found near the top and bottom. A fifty foot sandstone member grades into the shales above and below (Dannenberg, 1952, p. 68). The thickness is 90 feet.

Thurman sandstone.--The Thurman sandstone is composed primarily of yellow to brown fine sand particles. One exception is at the base where several thin limestone conglomerates can be found. The pebbles comprising these are rounded and water worn and are generally chert and limestone. Some of the limestone particles appear to be from the pink crinoidal member of the Chimneyhill formation of the Hunton group (Morgan, 1924, p. 84). In the upper sandy part are found many thin brownish shale beds. The thickness is 100 feet.

Krebs group

Boggy formation.—This formation is composed of sandstone, shales and limestone with the clastics greatly predominating. The clastic material increases in size toward the south becoming conglomeratic south of this area. As a result of a pinchout by onlap the Boggy is present only in the southernmost part of the mapped area and rests unconformably on the Wapanucka formation. The sequence present is the uppermost part of the formation and consists of white to gray, chalky well-rounded sandstone with a calcareous cement, gray-green, black and red shales and fifteen feet of brown shaley limestone in two beds separated by five feet of sand. Its thickness here is 210 feet, as opposed to a possible 1200 to 1500 feet in the vicinity of Franks, Oklahoma (Morgan, 1924, p. 78).

The remainder of this group, the Savanna, Hartshorne and McAlester formations are not present within the bounds of the mapped area since the seas at these times had not advanced far enough to reach the area.

Atokan Series

The Atokan series is absent in this area because during Atoka time the seas were still receding and the shoreline was many miles to the southeast of this area.

Morrowan Series

Wapanucka formation.—The Wapanucka formation is divided into two distinct members. The upper is a fifty foot bed of pisolitic limestone. It is generally brownish to light gray in color, medium to coarsely crystalline. The Wapanucka limestone was exposed to erosion at the end of Morrowan time; consequently, it thins eastward toward its pinchout line (Plate No. I). Since it was exposed and weathered, it is porous and quite friable. The lower member is a 200 foot section of black shale containing several thin limey sandstones and sandy limestone beds. The Wapanucka formation and all older units dip toward the northeast at slightly less than one degree.

Union Valley formation.--The Union Valley formation is also divided into two distinct members. The upper member is a finely crystalline, shaley limestone which varies in color from buff to white or bluish-white and is forty feet thick. Glauconite is found locally in the lower part of the limestone. The lower member is a 240 foot thick bed of fine grained, angular sandstone. It is sometimes called the Cromwell sand with which it has been correlated. The sand has several thin gray shale beds and locally contains glauconite. For the most part the Union Valley sand is very porous and contains salt water.

Springeran Series

Springer formation.--The Springer formation is a dark gray limey shale. Its most distinctive characters are a splintery fracture, greasy appearance and minor amounts of pyrite. In the Ardmore basin there are several sand zones. In this thesis locale the sands are not developed, leaving an almost homogeneous shale from top to bottom. The one exception to this is a thin zone of siderite concretions in the lower part (Dannenberg, 1952, p. 8). The formation is 440 feet thick.

Mississippain System

Chesterian Series

Caney shale.--The Caney is a hard shale, extremely calcareous. It is much the same color as the Springer shale except that the Caney shale breaks into blocky pieces and has a gritty appearance making it easily distinguished from the Springer shale. Several thin siliceous finely crystalline buff limestones are included in this section. The Caney shale is 180 feet thick.

Maramecian Series

Mayes shale.--The Mayes shale is a calcareous shale and limestone zone which is equivalent to the Sycamore limestone of the Arbuckle Mountains (Dott, 1948). The limestone is similar in outward appearances to the shale, gray in color and extremely gritty to the touch. The limestone is predominantly in the lower part, but thin lime streaks are scattered throughout. Pyrite is abundant and glauconite occurs in small amounts. The Mayes is 150 feet in thickness.

Kinderhookian Series

Woodford shale.--The Woodford shale is a dark brown to black siliceous shale. Black chert is found in thin beds throughout, but is more abundant in the lower portion. The shale breaks into blocky pieces closely resembling the Caney except that the Woodford has a smoother texture. Characterizing the Woodford shale is the chert, pyrite and abundant plant spores and conodonts (Boyd, 1938, p. 156). The lower, cherty member of the formation rests unconformably on the rocks of the

Hunton group or on the Sylvan shale if the Hunton is not present. The structure conforms to the Hunton arch and the thickness is 320 feet.

Silurian and Devonian Systems

Hunton group

This group is divided into five limestone formations only four of which are present over much of this area. These are the Bois d'arc, Haragan, Henryhouse and Chimneyhill limestone. The fifth or uppermost, the Frisco limestone, appears to have been eroded away except in T. 5 N., R. 6 E. The group varies in thickness from zero, on the Hunton arch and other high areas, to 290 feet in T. 5 N., R. 6 E.

Helderbergian Series

Bois d'arc limestone.--The Bois d'arc limestone may be as thick as 80 feet in this area and is present only where the total thickness of Hunton is more than 180 feet. It has been exposed to erosion over this entire area, and for the most part is absent. The limestone is off-white to gray in color, medium to coarsely crystalline, and contains much white chert throughout the section.

Haragan-Henryhouse limestone.--The Devonian Haragan and Silurian Henryhouse are difficult to distinguish between lithologically and would be impossible to separate without the aid of fossils. After the Haragan was laid down, there was cessation of deposition without uplift or erosion. When the Henryhouse was deposited, environmental conditions had not changed, causing the similarity in the units. Both formations are composed mainly of soft shaley marlstone, dolomitic limestone and shale. The limestone is finely crystalline and dirty to off-white in color. The shale is limey, dark gray color and gritty to the touch. The two formations have a total thickness of 150 feet.

Niagaran Series

Chimneyhill limestone.--The Chimneyhill limestone is divided into three distinct members, all of which are fifteen to twenty feet thick and easily identified. The highest is finely crystalline light gray to white with large pink calcite crystals. This member is denoted the Pink Crinoidal member. The second is the Glauconitic member. The color and crystallinity are similar to that of the overlying member. Its particular characteristic is the inclusion of many pinhead sized glauconite particles and a few pyrite crystals. The lowest is the Oolitic member, which is coarsely crystalline, off-white to gray in color and is generally porous. The presence of abundant oolites is ubiquitous in the lowest member.

Ordovician System

Cincinnatian Series

Sylvan shale.--The Sylvan shale is a characteristically satiny green shale. It is fine-textured and breaks into thin plates. A buff dolomite section is near the base. The thickness is nearly constant at 120 feet.

Fernvale limestone.--The Fernvale limestone is coarsely crystalline off-white to gray, with some sand and chert near the base. The formation averages forty-five feet in thickness according to Wengerd (1948, p. 2221) and rests unconformably on the underlying Viola limestone.

Champlainian Series

Viola limestone.--The Viola limestone, unlike the Fernvale is finely crystalline gray to white, massive and dolomitic. It contains little or no sand but has abundant banded gray-white chert. The total thickness of the Fernvale and Viola combined is a fairly constant 290 feet with the exception of places where the Viola group was exposed to the erosion which created the post-Morrowan unconformity. The Viola is one of the best oil producing strata in the area.

Simpson group

The Simpson group is a thick sequence of sandstones, shales, limestones and dolomites divided into five named formations. It varies in thickness from 900 to 2600 feet in southern Oklahoma. The great variance in thickness is explained by Taff (1903, p. 3) as being the result of the "local absence of the basal portion of the formation". The uppermost, or Bromide, formation consists mainly of limestone, sandy limestone and thin dolomite beds. The second, or the Tulip Creek formation, is predominantly sandy dolomite, coarse sand and green gray shale. The third formation is the McLish which is divided into two parts. The upper is a series of alternating beds of massive dense limestone, dolomite and platy beds of green shale. The lower half is a thick bed of soft, well sorted, sub-rounded, white sandstone which is sometimes called the Wilcox and has been correlated with the "second Wilcox" sand of the Seminole area (Boyd, 1938, p. 1568). The fourth formation is the Oil Creek, which like the rest of the Simpson, is composed of sandstone, limestone, dolomite and shale. A mottled gray, coarsely crystalline fossiliferous limestone is the topmost marker in the Oil

Creek. The Joins formation is the lowest formation and is poorly developed or absent in many localities. Where present, it is interbedded dolomite, dolomitic sandstone, limestone and sandstone, darker in color than the strata above.

Canadian Series

Arbuckle group

Only rarely has the Arbuckle group been penetrated by the drill and then only to shallow depth, so that little is known of the actual lithology in this locale. In adjacent areas it is sandstone and dolomitic limestone near the top grading downward into more pure limestone and dolomite.

Composite Log of Rocks Penetrated

Because no one electric well log penetrated the entire section of strata, a log composed of typical electrical characteristics was made from portions of several well logs which the writer believes to be most representative for each stratigraphic unit. In conjunction with the log is a general geologic section for the area.

CHAPTER III

STRUCTURE

Regional Structure

This area is located in a region of deformation caused by three periods of uplift. It lies on the east flank of the Hunton arch, northwest of the hingeline of the McAlester basin, and northeastward from the Arbuckle anticline. The regional dip is in two directions with beds of pre-Atoka age dipping northeastward at more than one degree, and all younger formations dipping approximately one degree northwestward.

The region is affected primarily by two major tectonic features. The Hunton arch is a broad generally northward plunging anticlinal structure with the strata dipping gently to the east and west. The Arbuckle anticline was formed much later and plunges west-northwest forming an acute angle with the Hunton arch. The anticline is not located within this thesis area, but has affected it by a general tilting of all formations younger than Wapanucka toward the northwest, and by decreasing the dip of the pre-Atoka formations. The sediments of pre-Atoka age on the east flank of the Hunton arch dip moderately northeast toward the hingeline of the McAlester basin. The basin is, according to Weeks' (1951, pp. 71-74) classification, an asymmetrical basin sloping southeastward until it abutts against the Ouachita Mountains, the borderline of the basin.

DESCRIPTION OF MAPS

Structural Contour Map on the Top of the Viola Limestone

The Viola limestone has been severely faulted and folded over the entire area. It dips generally northeastward at approximately one degree, but there are many anomalies due to the smaller features.

In the east half of T. 4 N., R. 3 E., and the extreme western portion of T. 4 N., R. 4 E., the Viola has been completely removed from the crest of the Hunton arch leaving upper Simpson formations in contact with the overlying Pennsylvanian beds. A similar situation exists in Sec. 22, T. 4 N., R. 4 E., with the Viola having been removed from a small structural high leaving Simpson as a small inlier. The dome has more than 100 feet of closure as indicated when both the Simpson and the Viola are contoured. Nine wells have produced from the upper Simpson.

Faulting has been intensive throughout most of the area. The zone of severest faulting is in the lower sections of T. 5 N., R. 4, 5, and 6 E., and the upper half of T. 4 N., R. 4, 5, and 6 E. This zone includes three east-west faults which approximately parallel each other and traverse nearly the entire length of the mapped area. The two northernmost faults form a deep graben. The second and third faults each raise the Viola approximately 500 feet on their southern block, to a high central band of the map. The fourth major fault is in the southeast corner of the area. The fault is nearly vertical with the upthrown block to the north also helping to create the high central portion. Several small faults appear which have little or no affect on the overall structure. These are located in Sec. 24, 25 and 28, T. 4 N., R. 5 E., Sec. 15, 22 and 27, T. 4 N., R. 5 E., and Sec. 35 and 36, T. 4 N., R. 4 E. Also there are several spur faults splitting from the major faults.

Many anticlinal features appear on this map. The dome in Sec. 22, T. 4 N., R. 4 E., has been previously mentioned. Largest and most important economically is the southeast Bebee anticline in Sec. 3, 4 and 10, T. 4 N., R. 5 E. It is bounded on the northeast and southwest by faults with more than 200 feet of closures between them. It has thirty-six producing wells at the present time. The dome was probably created in Devonian time resulting in the removal of the Hunton limestone by erosion (Plate No. III). Sec. 19, T. 4 N., R. 5 E., contains a small irregular anticline of more than 100 feet of closure. Two wells produce from this dome. In Sec. 29 and 30, T. 4 N., R. 5 E., is a dome of less than 100 feet of closure. The area of maximum closure is small, less than one-fourth of a square mile; however, fourteen wells have produced oil. In Sec. 35, T. 4 N., R. 4 E., and plunging southwestward, is a faulted anticline with more than 300 feet of closure against the fault. The anticline has no production at this time.

Sec. 7, T. 4 N., R. 6 E., appears to contain a slight structural nose closing against a fault. At the present time, there are no wells to substantiate this. In T. 4 N., R. 4 E., the Viola contours indicate the sharply plunging nose of the Hunton arch.

The contours in T. 5 N., R. 4 and 5 and 6 E., are very irregular and indicate many highs and lows most of which have little effect on the production.

Isopachous Map of the Hunton Limestone

Nearly the entire western half of the map is void of the Hunton. This is the high central portion of the Hunton arch, which has been exposed to two periods of uplift and erosion. The limestone ranges in thickness from zero feet in several localities to more than 260 feet in T. 4 N., R. 6 E. The variation in thickness is due primarily to erosion, with depositional differences being secondary. Several small structural features are indicated by a thin section or complete absence of the Hunton limestone.

T. 4 N., R. 5 E., appears to have been subjected to intensive erosion. Sec. 2, 3, 4, 9 and 10 indicate folding similar to that of the Viola. Sec. 29 and 30, T. 4 N., R. 5 E., has a large thinned area around the South Center field in much the same position as the Viola high.

In Sec. 20, 23 and 36, there is an elongate area of thinning which did not appear on any other map as a structural feature of any kind. Conkling (1930, p. 129) described a surface anticline in this exact position and named it the Bebee anticline.

In T. 4 N., R. 3, 4, 5 and 6 E., there is the same irregularity that was found in the Viola limestone. Where the Viola is high the Hunton is relatively thin and where the Viola is low, the Hunton is thicker. The Hunton limestone is generally thicker in the northern and eastern parts of the area.

Possible faulting is indicated on this map by a close grouping and paralleling of contour lines. The faulting is in much the same position as on the Viola map, as would be expected. Only the faults which affect the thickness of the Hunton are included. These are northwest-southeast striking faults near the Bebee anticline in T. 4 and 5 N., R. 5 E., and a northeast-southwest fault in T. 4 N., R. 5 E.

Pre-Atoka Paleogeologic Map

This map depicts, as well as available control allows, how this surface would appear at the present time if the over-lying strata were removed. The formation lines generally follow the configuration of the Hunton arch nosing as would be expected, with the strikes changing from generally north to northwest in the northern portion of the map. Since the central core of the arch is at the extreme western side of the map, the formations younger than Ordovician Simpson dip to the north and east across this area. The dip of the individual strata whose truncated edges make up the unconformity is slightly greater than one degree while the unconformity surface itself slopes toward the northwest at less than one degree. All formations from Simpson to Pennsylvanian Wapanucka are exposed within this area.

The contour lines are of little value for distinguishing the pre-Atoka structures and erosional features from the post-Atoka structure because all are reflected on this surface.

Isochore Map of the Interval Between the Pre-Atoka Unconformity Surface And the Top of the Sasakwa Limestone

This map depicts the topography of the unconformity surface as it appeared at end of Sasakwa time, by elimination of the deformation of the surface caused by the later Arbuckle orogeny. The thin areas represent topographic highs while the thick areas are the lows. In only a few cases does the topography correspond to the subcrop pattern.

In T. 4 N., R. 4 E., the 300 feet contour line approximates the Viola Sylvan contact, and in T. 4 N., R. 5 E., and T. 4 N., R. 6 E., a broad valley widens northeastward much the same as the Springer and the Union Valley formations do. Most of the lower structural features are either not reflected in the topography or appear as broad flattenings. Two exceptions to this are the small domes in T. 4 N., R. 4 E., and T. 3 N., R. 4 E., which are within the Viola subcrop belt.

Structural Contour Map on the Top of the Sasakwa Limestone

Comparatively little structure affects the Sasakwa limestone. It dips in a northwesterly direction with an average dip of one degree. The important oil producing structural features on older beds in T. 4 N., R. 4 E., and T. 4 N., R. 5 E., are reflected only as terraces. The elongate anticline in the southern portion of T. 4 N., R. 4 E., can be identified, but there is little or no closure.

Two faults cut the Sasakwa. One is located in T. 4 N., R. 4 E. The other is in T. 5 N., R. 5 E., and both appear to cut the entire section from Viola to Sasakwa.

In the southern and eastern portions of the map, the Sasakwa was too near the surface to make accurate correlations from the electric logs; consequently, that section of the map was not contoured. From the last point contoured, the unit continues to rise until it crops out in Sec. 9 and 17, T. 3 N., R. 6 E.

DESCRIPTION OF CROSS-SECTIONS

Cross Section A - A'

This is an east-west cross section along the northern boundery of T. 4 N., R. 3 E., R. 4 N., R. 5 E., T. 4 N., R. 5 E., and the southern portion of T. 5 N., R. 6 E.

The Pennsylvanian formations dip generally westward; variation in rate of dip cause several terraces, but no pronounced structural features. The strata thin in direction of dip.

The unconformity surface is quite irregular showing the effects of faulting, folding and erosion. In general it is low to the west, rising over the Hunton arch and continuing to rise to a point between wells No. 7 and No. 8 where it begins to decline toward the McAlester basin.

The regional dip of the pre-Pennsylvanian beds is opposite to that of the younger formations and gentler. However, the gentleness of regional dip of the older formations is misleading, because of the intense deformation of the area. Consequently the dip changes not only angle, but direction many times. Associated with the folding are many faults. Two of the most important are on either side of well No. 5 forming what appears to be a deep graben. This is somewhat misleading since the line of section crosses the same fault twice on both sides of well No. 5. However, the graben is actually there and may be seen on the north-south cross section C - C'. The fault cutting the Pennsylvanian beds does not intersect strata older than Springer on this line of section because of its angle of dip.

Between wells No. 6 and No. 7 are two faults which converge just southwest of the line of section. The fault between well No. 7 and No. 8 appears to have left an eroded fault scarp against which the Thurman and Stuart formations pinched out.

Cross Section B - B'

This is an east-west cross section which is located in the south-central parts of T. 4 N., R. 4 E., and T. 4 N., R. 5 E.

All formations younger than Wapanucka in this cross section dip consistently westward with little or no structure shown. The Francis formation and the Seminole formation indicate a marked thickening down dip. The unconformity surface shows a general inclination similar to the overlying strata. However, many irregularities are present, such as the Simpson outlier in Sec. 22, T. 4 N., R. 4 E. Also, the Viola "valley" between it and the main Simpson core of the eroded Hunton arch is indicated by wells No. 1, No. 2 and No. 3 of this cross section. This illustration shows the approximate positions where the middle Pennsylvanian beds pinch out. The western extremity of the Hunton group can be seen as well as its general thickening eastward.

Cross Section C - C'

This line of section is from north to south in a relatively straight line and follows closely the dividing line between T. 4 N., R. 4 E., and T. 4 N., R. 5 E. The cross section intersects both the severely faulted area in the north half of T. 4 N., R. 5 E., and the large fault in T. 3 N., R. 5 E.

The Pennsylvanian section appears to thicken northward as it comes off the unfaulted block in the center of the cross sections, giving the impression that the sediments were draped over the high. The No. 8 well has penetrated 210 feet of Boggy and a normal sequence of Thurman sandstone and Stuart shale. These three strata pinchout because of onlap before reaching well No. 7 in Sec. 30, T. 4 N., R. 5 E. As drawn the strata appear to pinchout down dip. This is the result of the Arbuckle orogeny having tilted both the rock units and the unconformity surface.

The No. 3 well, the J. J. Fleet Roberts #1 was drilled in a deep graben formed by the two northernmost faults in T. 4 N., R. 5 E. The area of the graben was probably high at the end of Devonian time, as suggested by the fact that the Hunton limestone is extremely thin. On to the south, the faults raise the Viola from depths of 1900 feet to 550 feet to form the central high area. The No. 8 well, the Sanders Oil Company Grase #1, was drilled on the down-thrown side of a fault which has more than 1500 feet of displacement.

CHAPTER IV

GEOLOGIC HISTORY

The Ordovician Arbuckle limestone is the oldest unit drilled in this area and has been penetrated to depths of only a few hundred feet. This thick limestone sequence is assumed to be present throughout most of Oklahoma (Cronenwett, 1956, p. 7). There are no major depositional breaks in the complete section. Morgan (1924, p. 18) has stated that there were "slight warping movements initiated in the Arbuckle Mountain area in the late Cambrian or early Ordovician period." At the end of Arbuckle time there was a general withdrawal of the seas exposing a vast area of Arbuckle limestone to erosion.

The Simpson seas advanced depositing a great thickness of alternating sandstone, limestone and shale. Cronenwett (1956, p. 38) states that:

> Simpson strata of Southern Oklahoma, however, indicate that this was an area of continued subsidence and in this direction these platform sediments may be observed in gradual transition to a more basinal type deposit.

The lowest formation, the Joins, was not deposited in this thesis area which remained relatively high during Joins time. The remaining formations are all stratigraphically high enough to be present. A hiatus of slight duration at the end of McLish time caused the McLish formation to be thinner than normal here.

Minor warping and oscillation continued through Simpson time and the remainder of the Ordovician period (Decker & Merritt, 1931, p. 16). However, the movement was of such small magnitude that it scarcely affected the deposition of the Viola limestone and Sylvan shale. They are both extremely consistent in thickness with the exception of localities where they were subjected to later erosion.

The Hunton group was laid down conformably on the Sylvan shale. The lower two formations are of Silurian age and the upper three are Devonian. The depositional environment remained unchanged during the transition from Silurian to Devonian causing the Henryhouse and Haragan formations to be lithologically similar. The two latest formations, the Bois d'arc and the Frisco limestone were laid conformably on the Haragan. At the end of Frisco time this region received its first major uplift. Although small in magnitude, as compared with future warpings, it still greatly affected the Devonian and older formations. In the area of this thesis at least three structural features and several faults were formed (Plate No. III). The Hunton arch, which is located in the eastern half of T. 3 N., R. 5 E., and the western half of T. 4 N., R. 4 E., is the most important. The arch was not formed entirely until early Pennsylvanian time, but Devonian uplift created minor arching and an accompanying zone of weakness which culminated in the later fold. In Sec. 34, T. 5 N., R. 4 E., and Sec. 1 and Sec. 2 of T. 4 N., R. 4 E., Mississippian Woodford shale rests directly on Ordovician Sylvan shale. This coupled with the fact that the Hunton formation thickens consistently from west to east tends to substantiate the fact that some arching took place at this time.

The Mississippian period began with the subsidence of the land area and the subsequent deposition of the Woodford shale. Rau & Ackley (1939, p. 233) have stated that "the Woodford was laid down in a quiet sea as evidenced by the preservation of such delicate fossils as conodonts and plant spores." As a result of a general subsidence of the entire area, the Hunton arch did not remain as a positive area. Thus the Woodford shale was deposited at a nearly constant thickness over the entire region. The slight thinning over the high areas was probably due to a draping effect.

Directly above the Woodford are the black limey shales of the Mayes and Caney formations. Dannenburg (1952, p. 8) suggests that the McAlester-Coal basin had begun to subside by this time, because these two formations thicken to the east or basinward. The Mississippian period came to a close with a partial emergence of the land, leaving isolated bodies of water (Dott, 1927, p. 12). These relic seas, according to Harlton (1938, p. 859) resulted in swampy conditions causing the sideritic layers and concretions common to the Springer shales.

At the end of Springeran time the land to the northeast of the future location of the Ouachita Mountains began to subside allowing the Morrowan seas to enraoch from the southeast. Barker (1953, p. 188) states that the "Union Valley sandstone bed marks a near shore deposit of the sea." Immediately overlying the Union Valley formation is the Wapanucka formation, which includes shale in lower sections and limestone above. That Morrowan formations are characterized by sandstone, shale and limestone alternation within a short vertical range is explained by Wallis (1915, p. 75) who states, "such sedimentation would indicate repeated and rapid changes of level in the near by land mass with alternate deposition of terrigenous and clear water sediments".

At the close of Morrowan time there occurred an extremely important uplift. In this thesis area, the Hunton arch was formed along the previously mentioned Devonian zone of weakness. Many of the smaller anticlines and faults were created at this time (Plate No. I). Dott (1934, p. 585) has dated the Hunton arch as having occurred from the same movements that caused "the folds which go to make up the Wichita-Red River Mountains and include the Criner Hills, Healdton Hills, Wichita Mountains, Amarillo buried Mountains and the Red River uplift." With the rising of the Hunton arch, the seas receded eastward into the then subsiding McAlester basin, causing the Atoka sediments to have an offlap relationship with the underlying Wapanucka limestone. The entire area was left above water level exposing it to a great period of intensive erosion as seen on Plate No. III.

During Krebs time the seas advanced slowly westward on the erosion surface and deposited the Hartshorne, McAlester, Savanna and Boggy formation by progressive overlap in a semicircular pattern to the south, east and north of the area mapped. The Boggy, being youngest, has the greatest areal extent and is the only one of the formations which reaches this area. The uppermost 210 feet is all that is present.

Morgan (1924, p. 7) has shown that a slight oscillation of the Hunton arch area occurred near the end of Boggy time causing the sea to retreat into the McAlester basin. The sea again advanced to deposit the coarse Thurman sandstone and the quiet water deposits of Stuart shale and the Senora formation. This was followed by another slight uplifting and the deposition of the Calvin sandstone possibly as an offlap deposit (Dott, 1927, p. 14).

Until this time the Hunton arch had remained as a positive area with all the deposition thus far on its east flank. The Calvin, being youngest, enroached farthest. It thins to a feather edge just west of the west line of R. 5 E. (Plates No. XI and XII). According to Dott (1927, p. 14) the connection with the sea through the McAlester basin on the east side of the Hunton arch was broken at the end of Calvin time several miles to the south of the area mapped. The Wetumka and Wewoka formations were deposited progressively higher on the east flank of the arch. The Sasakwa limestone member is the oldest formation to overlie the arch and be unaffected by the older structural features in this area. During late Marmaton time connection was made with the sea on the west flank of the Hunton arch (Dott, 1927, p. 15). Since the McAlester basin was still an embayment, the arch was left as a peninsula with water on three sides. This being the situation, the Sasakwa limestone should pinchout on top of the structure somewhere to the south of this area of study.

Continuous deposition followed until the end of Belle City time when the first indications of the Arbuckle orogeny occurred (Dott, 1924, p. 17). By the end of Missourian time the orogeny was at its peak, and came to an end in mid-Virgilian Vamoosa time (Dott, 1927, p. 20). The effects of the orogeny in this thesis area were the development of numerous faults and a general tilting of the entire area toward the northwest (Plates III, V, VII). During the orogeny there was a break in deposition and minor erosion until Vamoosa time, which is middle Virgilian in age (Dott, 1927, Table I, p. 11).

The Vamoosa and the remaining formations, the Ada and Morgan's (1924, p. 132) Permo-Pennsylvanian Pontotoc terrane were laid down as coarse detrital deposits of material derived from the Arbuckle uplift and the remaining exposed portion of the Hunton arch.

Immediately above the Pontotoc terrane is the Permian Asher formation. Morgan (1924, p. 19) has stated, "all Permian formation of the Stonewall Quadrangle have been slightly folded indicating movement in the area during or subsequent to that period." Then followed a great period of erosion and non-deposition until recent time when the Guertie sand was laid down as a river deposit.

CHAPTER V

ECONOMIC CONSIDERATIONS

History of Production

Much of the early exploration and development of the area covered by this work would be impossible to set forth except for the excellent records of W. A. Delaney, pioneer wildcatter and producer in Pontotoc County. Early day logging methods and requirements for logging by the Corporation Commission were quite primitive and very grateful acknowledgment should be made to Delaney for his help in this historical background (Paine, B., personal communication).

T. 4 N., R. 6 E.

The first production of any nature in this area or, for that matter, in Pontotoc County was discovered by Skelly and Sankey in 1916. The discovery well in Sec. 31, T. 4 N., R. 6 E., produced commercial gas from 1005 feet to 1015 feet. Subsequent drilling resulted in the discovery of gas in several lenticular sands all within 1100 feet of the surface. Total productive area was not in excess of 500 acres. The first gas production was utilized by the Ideal Cement Company, which has continued in operation to the present date and is the principal consumer of natural gas from all Pontotoc, Coal and Hughes County gas fields. All of the wells in the discovery field in this township have been exhausted and plugged and abandoned.

Closely following the Skelly and Sankey discovery in 1916, W. B. Skirvin drilled a well in Sec. 17, T. 4 N., R. 6 E., which produced commercial gas from approximately 1700 feet. Although local geologists are somewhat at variance as to classification of the producing sand, it is most generally referred to as Union Valley. During the course of a subsequent drilling, which lasted over a period of several years, gas production was secured in Sec. 8, 9, 16 and 17 from this same horizon. This field has proven to be the most prolific producer of gas in all of Pontotoc County. Although the field has been exhausted as to the original gas, the entire structure has been purchased by Southwest Natural Gas Company and is used by them as a seasonal storage reservoir.

T. 5 N., R. 5 E.

The discovery well which was the forerunner of what has been one of the most prolific producing fields in eastern Oklahoma, was drilled by R. I. Carter, B. A. LaSalle and George Nance in Sec. 28, T. 5 N., R. 5 E., in 1921. Production was from an unconformity sand at 1800 feet. The well was a small producer and failed to cause any continued drilling campaign at the time. In the following year George Nance and R. I. Carter drilled a wildcat on the Frank Haggard farm in Sec. 3, T. 4 N., R. 5 E., which produced some oil from the Hunton limestone. The well was not produced commercially but is of some historical significance in that it was the first Hunton limestone oil produced in the state. Modern methods of completion with acid would probably have resulted in a good commercial well here.

Real drilling activity in this field did not commence until 1927 when B. A. LaSalle drilled the first well in the area to produce from the Viola limestone at approximately 2600 feet. First production was from a Trentonian chert which has proven to be the most uniform and prolific producer in the area. Since this discovery drilling of the area has been fairly continuous to the present date resulting in uncovering additional reserves in the Wewoka sand, Calvin sand, Senora sand, Hunton limestone, Viola (Fernvale) and Viola (Trenton). At least one well in the field has also produced from the Simpson dolomite. At present the greater Bebee field is producing or has produced from some of these strata in most of T. 5 N., R. 5 E., and in part of T. 5 N., R. 4 E.

T. 5 N., R. 6 E.

First production in this township was secured at a wildcat well drilled by Gillette and Kroeger on the Oliver farm in Sec. 36, T. 5 N., R. 6 E., in 1917. By present day standards the well would not be considered commercial and was in some respects a mal-completion having been drilled with cable tools and a string of defective pipe. Some sporadic drilling continued in the area for a number of years, but it was not until 1927 that any real drilling campaign took place. At that time a well drilled by the late T. B. Slick encountered gusher type production from the Hunton limestone at approximately 2800 feet. The well was somewhat freakish in that four offsets were drilled and all were dry. The discovery well, however, continued to produce for a number of years and resulted in a total production reputed to be 190,000 barrels. From 1927 to the present time drilling has continued so that the area has produced in every section of the township with the exception of Sec. 5 and Sec. 6. Principal producing horizons are Calvin sand, Senora sand and Thurman sand.

T. 4 N., R. 5 E.

This township has been the scene of considerable wildcatting since 1923 when the original thesis of George Morgan was published, covering the entire Stonewall Quadrangle. This work is still considered by local explorers to be the most valuable single contribution to the development of the Pontotoc country.

Among the many surface features mapped by Morgan was an anticline which extended from Sec. 24, T. 5 N., R. 4 E., to Sec. 28, T. 4 N., R. 5 E. First test on this feature was drilled by J. B. Umpleby and C. J. Wrightsman. The well produced flowing sulphur water from sand found at 2745 feet total depth. Since this original test a number of tests have been drilled on this enormous structure and each of them has secured nothing but sulphur water in the Ordovician formations. Sands in these formations usually show evidence of having been previously saturated with hydro-carbons, but all have been replaced by waters.

One area in this general region gave some promise of commercial production when Bert D. Paine drilled a discovery well in SW NW Sec. 29, T. 4 N., R. 5 E., in 1952. Initial production was from a Viola dolomite at 1450 feet. Upon acidizing the well made 450 barrels of oil per day. Some fifteen additional wells were drilled. Production declined rapidly, however, and all wells have been abandoned as commercial failures.

Within recent years Paine Stapleton et al have secured commercial gas and oil production from Pennsylvanian sands in Sec. 27, 28 and 33, T. 4 N., R. 5 E. Principal source of gas is from the Calvin sand found at approximately 1050 feet. Seven wells have been drilled in this area and are now producing.

T. 4 N., R. 4 E.

First commercial production in this township was discovered by W. H. Pine in SW SE Sec. 22 in 1954. The producing zone has been classified as the first Bromide sand. The discovery well produced initially at the rate of ninety barrels of thirty-seven gravity oil per day. The producing area, as developed to date, is small covering approximately 160 acres, all in Sec. 22.

T. 3 N., R. 4 E.

A one well discovery was made in this township in 1922 by Oscar Gilbert and George Clark. The discovery well was drilled in SE SE NW Sec. 28. Production was found at 866 to 872 feet from a Pennsylvanian sand. Initial production was rated at 200 barrels per day of sixteen degree gravity oil. At the time of discovery and in subsequent years approximately twelve additional exploration wells in this area have been drilled and all were failures.

Future Possibilities

A large part of this area has been tested for oil with a fair percentage of production. Many locations which could possibly prove productive remain untried.

One of the most likely places for oil or gas appears to be along the feather edge of the Union Valley sandstone. This sand is a known prolific producer in other parts of the state and produces some gas in this area (Sec. 31, T. 5 N., R. 6 E., Sec. 26, T. 4 N., R. 5 E., Sec. 4, T. 3 N., R. 5 E.). The sand itself is generally porous and is saturated with salt water down dip. A structural high in conjunction with the pinchout line such as in Sec. 7 and Sec. 18, T. 4 N., R. 6 E., would seem to be an ideal location.

In certain cases the Hunton is a good producer in this area. It seems that when the Viola is low and the Hunton thicker than 160 feet oil may be found. This situation exists in Sec. 17, 19 and 20 of T. 5 N., R. 5 E., where the Hunton has produced for many years. This same situation exists in Sec. 13 and 24, T. 5 N., R. 4 E. There are a few producing wells there, but it appears that the locale has not been fully explored.

A small faulted anticline in Sec. 34 and 35, T. 4 N., R. 5 E., and Sec. 2, 3, 4 and 9 of T. 3 N., R. 4 E., is very apparent in the Viola formation. The structure was exposed to erosion after the post-Morrowan uplift which should have created the secondary porosity necessary for petroleum accumulation in limestones. The north end of the structure is also the highest structural elevation of the Viola in this area even though the Viola group has been thinned greatly by the erosion.

A large percentage of the present production comes from stratigraphic and small structural traps in the Thurman, Senora and Calvin formations. It is not likely that all of these have been found, particularly the stratigraphic traps. Due to the closeness of the two major uplifts the clastic material was poured in rapidly with little chance for consistency in reworking and sorting which could cause traps from facies and porosity changes.

These possibilities plus others not so apparent would indicate that there is more oil to be found in this area.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The following statements summarize facts known about the general area prior to the beginning of this thesis:

1. The structure is the result of three major periods of orogeny each creating erosional surfaces to a greater or lesser extent.

2. The rock units have a two-fold dip. Formations older than Atoka dip northeastward at less than one degree, while all formations younger than Wapanucka dip northeastward at one degree.

3. The erosional surface caused by the Devonian uplift removed or thinned the Hunton limestone in many areas.

4. The second period of orogeny began at the end of Morrowan time and resulted in the formation of the Hunton arch. The rock units were tilted and truncated by the erosional surface.

5. During and after the formation of the Hunton arch, the seas receded into the McAlester basin depositing offlapping sediments of Atoka age.

6. All formations younger than Wewoka crop out on the surface in this area.

7. The third period of orogeny began in mid-Missourian time (Belle City) and culminated in mid-Virgilian time (Vamoosa).

8. The entire area of this thesis was tilted as a block toward

the northwest during the third period of orogeny. Few structural features were formed here.

9. A depositional break with minor erosion occurred between Belle City time and Vamoosa time.

10. Formations of Vamoosa age and younger derived the material from Arbuckle anticline area.

The work done in this thesis includes: Structural maps on the top of the Viola and Sasakwa limestones, a paleogeologic map of the pre-Atoka unconformity surface, an isopachous map of the Hunton group, an isochore map of the interval between the Sasakwa limestone and the pre-Atoka unconformity surface, two east-west cross sections and one north-south cross section. From this study the following conclusions can be drawn for the thesis area.

1. The area of study is located on the eastern flank of the Hunton arch, northwestward from the hinge line of the McAlester basin and northeastward from the Arbuckle anticline.

2. The Hunton arch was begun in the first period of orogeny (Devonian time). The result was probably only very slight arching but sufficient to create a zone of weakness allowing the later movement to raise the arch to its maximum height in this area.

3. The formations exposed on the pre-Atoka unconformity surface were from Ordovician Arbuckle to Pennsylvanian Wapanucka progressing up section from west to east. Their distribution is shown on the paleogeologic map.

4. The majority of the faults in this area is apparently associated with the uplift of the Hunton arch.

5. At the beginning of Krebs time, the sea began to advance from the east until by lower Holdenville time it had reached the crest of the Hunton arch. The updip limits of the onlapping post-Atoka formations are shown in cross-sections.

6. The only formation of Krebs ages present in this area is the upper 210 feet of the Boggy formation, which is present in the southeastern corner of the mapped area.

7. Structural features formed prior to Atoka time are reflected in middle and upper Pennsylvanian formations only as terraces.

8. The dip of the pre-Atoka formations was made gentler and changed from west to northwest by the Arbuckle orogeny.

BIBLIOGRAPHY

Barker, James C. "Geology of a Portion of the Lawrence Uplift, Pontotoc County, Oklahoma," Tulsa Geol. Soc. Digest, Vol. 19, 1951, pp. 69-51.

Boyd, Baxter W. "Jesse Pool, Pontotoc and Coal Counties, Oklahoma," Amer. Assoc. Petr. Geol. Bull., Vol. 22, 1938, pp. 1560-1578.

Conkling, R. A. "Oil and Gas in Oklahoma, Pontotoc County," Okla. Geol. Survey Bull., Vol. 3, 1930, pp. 109-131.

Cronenwett, Charles E. "A Subsurface Study of the Simpson Group in East Central Oklahoma," (Unpublished Masters Thesis), Univ. of Okla. 1956.

Dannenberg, Roy B. "The Subsurface Geology of Coal County, Oklahoma," Shale Shaker, Vol. 2, 1952, pp. 61-19.

Decker, Charles E. and Merritt, Clifford A. "The Stratigraphy and Physical Characteristics of the Simpson Group," Okla. Geol. Survey Bull., No. 55, 1931, pp. 16 and map.

Dott, Robert H. "Notes on Pennsylvanian Paleogeography with Special Reference to South Central Oklahoma," Okla. Geol. Survey Bull., No. 40, 1927.

... "Overthrusting of the Arbuckle Mountains, Oklahoma," Amer. Assoc. Petr. Geol. Bull., Vol. 18, 1934, pp. 567-602.

... "The Geology of Garvin County, Oklahoma," Okla. Geol. Survey Bull., No. 40, 1927, pp. 1-31.

... "Regional Stratigraphy of the Mid-Continent," Amer. Assoc. Petr. Geol. Bull., Vol. 25, 1941, pp. 1669-1670.

... "General Geologic Section of Oklahoma Oil Producing Areas," (Norman, Oklahoma:) Okla. Geol. Survey, 1944, Rev. 1948, Reprinted from the National Oil Scouts & Landman Yearbook, Vol. XVIII, 1948.

Green, Darsie A. "Permian and Pennsylvanian Sediments Exposed in Central and West-Central Oklahoma," Amer. Assoc. Petr. Geol. Bull., Vol. 20, 1936, pp. 1454-1455.

Harlton, Bruce C. "Stratigraphy of the Oklahoma Salient of the Ouachita Mountains," Amer. Assoc. Petr. Geol. Bull., Vol. 22, 1938, pp. 852-914.

Hill, John. Geologist for Samedan Oil Corp., Ardmore, Okla., Personal communication.

Hyatt, Don L. "Preliminary Report on the Fitts Pool, Pontotoc County, Oklahoma," Amer. Assoc. Petr. Geol. Bull., Vol. 20, 1936, pp. 951-974.

Huffman, George C. and Barker, James C. "Mississippian Problems in the Lawrence Uplift, Pontotoc County, Oklahoma," Amer. Acad. Sci. Proc., Vol. 31, 1951, pp. 78-80.

Kuhleman, M. H. "Mississippian and lower Pennsylvanian Stratigraphy of a portion of the Stonewall and Atoka Quadrangles, Oklahoma," (Unpublished masters thesis) Univ. of Oklahoma, 1948.

Levorsen, A. I. "Geology of Seminole County, Oklahoma," Okla. Geol. Survey Bull., No. 20, Vol. 3, 1930, pp. 289-351.

Morgan, George D. Geology of the Stonewall Quadrangle, (Norman, Oklahoma:) Bureau of Geology, 1927.

... The Boggy Unconformity and Overlaps in Southern Oklahoma, (Norman, Oklahoma:) Bureau of Geology, 1924.

Paine, Bert D. Ada, Oklahoma, Personal communication.

Paschal, E. A. "Major Tectonic Provinces of Southern Oklahoma their Relation to Oil and Gas Fields," Amer. Assoc. Petr. Geol. Bull., Vol. 25, 1941, p. 1.

Powers, Sidney. "Age of the Folding of the Oklahoma Mountains," Geol. Soc. Amer. Bull., Vol. 39, 1928, pp. 1031-72.

Rau, H. L. & Ackley, K. A. "Geology and Development of the Keokuk Pool, Seminole and Pottawatomie Counties, Oklahoma," Amer. Assoc. Petr. Geol. Bull., Vol. 23, 1939, p. 233.

Taff, Joseph A. "Tishomingo Folio," U. S. Geol. Survey, Geol. Atlas, (No. 98), 1903, p. 1-8.

Wallis, Franklin B. "The Geology and Economic Value of the Wapanucka Limestone of Oklahoma," Okla. Geol. Survey Bull., No. 23, 1955, pp. 1-102.

Wallman, D. C. "Southern Okla. in Major Tectonic Provinces of Oklahoma," Shale, Shaker, Vol. 2, No. 4, 1951, pp. 4-18.

Weeks, L. C. "Sedimentary Basins and Oil Occurrences," World Oil, Vol. 132, 1951, pp. 71-74.

Wengerd, Sherman A. "Fernvale and Viola Limestone of South-Central Oklahoma," Amer. Assoc. Petr. Geol. Bull., Vol. 32, 1948, pp. 2183-2253.

U. S. Geol. Survey Map, "Topographic Map Stonewall Quadrangle," 1901.

Weeks, L. C. "Sedimentary Basins and Oil Occurrences," World Oil, Vol. 132, 1951, pp. 71-74.

...n A. "Fe... ...ne of South-Central Okla-
...Amer... ...Vol. 32, 1948, pp. 2183-

...l Quadrangle," 1901.