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OIL AND GAS IN OKLAHOMA

SUBSURFACE STRATIGRAPHY OF WESTERN OKLAHOMA

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FOREWORD

In 1917 the Oklahoma Geological Survey issued Bulletin 19 part 2 entitled, "Petroleum and Natural Gas in Oklahoma." This volume was so popular that the supply was soon exhausted, and for several years copies have not been obtainable.

The present director has seen the need of a revision of this bulletin. On account of lack of appropriations he has not been able to employ sufficient help to compile the data, and has called on some twenty representative geologists throughout the state to aid in the preparation of reports on separate counties. These gentlemen, all busy men, have contributed freely of their time and information in the preparation of these reports.

It will be understood that the facts as set forth in the various reports represent the observation and opinion of the different men. The Oklahoma Geological Survey has every confidence in judgment of the various authors, but at the same time the Survey does not stand sponsor for all statements made or for all conclusions drawn. Reports of this kind are, at best, progress reports, representing the best information obtainable as of the date issued and doubtless new data will cause many changes in our present ideas.

The present chapter has been prepared by Frank C. Greene of Tulsa, Oklahoma. For several years Mr. Greene has been collecting and compiling data on the subsurface of the red beds in western Oklahoma. As early as 1920 he called attention to the presence of a structural trough, since known as the Anadarko Basin, in the southwestern part of the State and suggested that the "Greer" gypsum of Greer County and the adjoining counties might be the Blaine formation.

The Director believes Mr. Greene to be our best authority on the subject on which he has written.

September, 1926

CHAS. N. GOULD
Director

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INTRODUCTION

GENERAL STATEMENT

A study of the logs of holes drilled in western Oklahoma reveals the fact that certain rather definite conclusions can be drawn, and that in general the strata can be correlated with beds exposed at the surface. Several markers are found consistenly over wide areas. Unfortunately, as central Oklahoma and the Arbuckle Mountains are approached, all markers disappear and the driller or geologist finds himself in the midst of a succession of red beds from the surface down to 4,000 or 5,000 feet, perhaps even deeper.

The Blaine gypsums, the Wellington shale and the Panhandle "Big Lime" are replaced by red beds, and in the following discusssion it should be understood that the thicknesses given apply only to formations west of Logan, Canadian and Caddo counties. East of an indefinite line through these counties the divisions of the section described lose their identity.

STRATIGRAPHY

PRE-CAMBRIAN ROCKS

The pre-Cambrian igneous rocks, upon which all the sedimentary strata have been deposited, undoubtedly underlie all of western Oklahoma, but the most important fact—their depth—remains unknown over the entire area with the exception of the Wichita Mountains and their buried extension to the northwest. In the Anadarko Basin along the north side of the Wichita Mountains[1] the depth to igneous rocks is probably very great. The presence of arkosic material in the hole near Canute in Washita County, as well as the regional structure leads to the belief that the depth will be somewhat less in the west-central counties of the western-half of the State. Between these counties and Barton County, Kansas, there is probably a deep trough in which the depth to igneous rocks is very great.

While granite is the predominating type of igneous rock, it is by no means the only one, as has been discussed in the chapter dealing with the general geology of the State, but as far as drilling for oil or gas is concerned, the exact type of igneous rock which is encount-

1. For the purpose of this discussion, the Wichita Mountains should be understood as including the buried extension to the northwest as well as the mountains themselves.

ered is of little importance. What is of importance is to establish the fact that granite or some other type of true igneous rock, unweathered and in its original position, has been reached.

Three intergrading facies of igneous material have been found on the north flanks of the Wichita Mountains: (1) igneous rocks that have been weathered and broken down in place, resting upon and grading down into unweathered materials, (2) transported material in a weathered state, that is, arkose, and (3) more or less mixed with it, large boulders of igneous rocks, transported a greater or lesser distance from the original position, weathered on the exterior but fresh on the interior.

These conditions make it almost impossible to give a definite assertion that any certain well has reached true unweathered igneous rock and has therefore passed the point where production is impossible. However, when the cuttings indicate that a fresh material has been penetrated for 50 or 100 feet without a change, in general, it will be useless to drill farther.

PRE-PENNSYLVANIAN FORMATIONS

In the Wichita Mountains, flanking the uplift on the east end, are some rocks of Cambrian and Ordovician age. These have been described in other papers and will not be discussed further here. They do not appear farther west along either the north or south flanks of the mountains, the Permian resting directly on igneous rocks.

South of the Wichita Mountains along Red River and to the south in Texas, Ordovician rocks have been found in wells. In western Kay, eastern Grant, and eastern Garfield counties, Ordovician beds have been penetrated by the drill on buried uplifts. In the area north of the Wichita Mountains and west of the counties mentioned little is known of the pre-Pennsylvanian beds except that they extend, of course, beyond the farthest west points where they outcrop, but are probably absent over much of the area according to the interpretation of the few paleogeographic data available. It seems probable, however, that a more or less narrow basin extends silghtly north of west from Grant and the adjacent counties. The deep well near Canute, Oklahoma, (sec. 21, T. 11 N., R. 19 W.) entered granite wash at 5,070 feet. The Clark County, Kansas, well (sec. 20, T. 32 S., R. 21 W.) was still in sedimentary rocks at 5,679 feet. The Cheyenne Bottoms well in Barton County, Kansas (sec. 22, T. 18 S., 13 W.) entered granite-schist at 3,602 feet. Wells near Syracuse, Kansas, and in eastern Colorado have penetrated a thick succession of sedementary rocks, while in northwestern Kansas the few available data indicates a relatively thin Paleozoic section.

PENNSYLVANIAN AND PERMIAN FORMATIONS

The Red Beds in Central Oklahoma

Both the vertical and horizontal boundaries of this set of red beds are so indefinite that they can scarcely be described. In Grady, McLain, Cleveland and the adjoining counties, the drill penetrates a great succession of red shale and sand, the base of which has not been reached so far as is known to the writer. There are, of course, some beds of light-colored shale and some thin limestones, but they are in the minority. The upper part of this mass of red material belongs to the Cimarron group, and as the light-colored material that normally occurs below that group farther west is absent in the counties mentioned, the dividing line can not be drawn between red beds of Cimarron age and older beds.

These older red beds are known to include material extending from the Kansas City formation into the Marion or Wellington formation.

From the center of this mass of red beds below the Cimarron, the individual beds change color to the east, north, and west, the red beds and accompanying sandstones give place to light-colored shales and limestones. The thinning to the east, however, is greatly accentuated by the regional rise of the strata to the east and the accompanying truncation by erosion.

From the Canadian River to the Arkansas River, through Seminole, Okfuskee and Creek counties, the eastern boundary of the red beds is nearly, but not quite, a true stratigraphic plane with a strike comparable to that of the beds below that outcrop to the east. The boundary approximately corresponds with the base of the Vamoosa formation of Morgan[2] and of the Tiger Creek sandstone of Fath[3]. It is also very close to the top of the Glenn formation.

South of the Canadian River, formations as low as the Boggy shale, and possibly older, contain beds of red material, although they are not mentioned in any descriptions of these formations that have been seen by the writer. This red material is not known to extend any considerable distance north of the Canadian River either on the outcrop or in well logs, and the beds below the stratigraphic plane mentioned, are mostly devoid of red material.

North of the Arkansas River the red color gives place to blue or gray with certain exceptions. Some red layers, as for example that below the Oread limestone, extend across Kansas and Missouri into Iowa and Nebraska. The higher red layers in general extend farther north and maintain their thickness for a greater distance than lower beds do. This gives rise to the condition well known to all who have colored and compared graphic logs from central Oklahoma and southern Kansas. The Oklahoma logs show a practically unbroken succession of red material and sandstones and those from Kansas, shales and limestones, with relatively few red layers and sandstones.

The base of the main mass of red material dips to the west at the same rate as the underlying formations, 40 to 100 feet per mile. In McLain, Cleveland, Oklahoma, and adjoining counties the base reaches its lowest point and the mass attains its greatest thickness. However,

2. Morgan, Geo. D., Geology of the Stonewall Quadrangle, Oklahoma: Bureau of Geology, Bull. 2, 1924.
3. Fath, A. E., Structure of the northern part of the Bristow Quadrangle, Creek County, Oklahoma: U. S. Geol. Survey, Bull. 661, pp. 69-99, 1917.

as the light-colored material of the Wellington is absent in most of this area, it is impossible to distinguish in well logs the Enid formation from the lower red beds.

The few deep wells that have been drilled through the red beds west of the deepest part of the basin indicate that the lens of red material terminates rather abruptly at a line extending from Anadarko to Medford. West of this line and below the base of the Enid formation, layers of red material more than 20 or 30 feet thick are rare and few wells log more than 2 or 3 red layers.

In western Oklahoma two zones of red material belonging to this terrane are found. The lower seems to be the western representative of the Chase formation and is found in the 600 foot sand-arkose-shale series below the "Big Lime" and above the Foraker limestone. The upper is the western extension of the Marion or Wellington formation. As already mentioned the amount of red material in either of them is small.

Because of the indefinite character of this terrane, there is little to be said about its thickness. Where the maximum thickness occurs, it can not be separated from the overlying Cimarron red beds. In the Grady-McClain-Cleveland County region, the thickness is believed to be in excess of 2,500 feet.

As has been mentioned, this series of red beds includes two groups of beds, separated in the Enid-Perry region by non-red material. The lower group is to be correlated with the beds between the Chanute shale of the Kansas City formation and the top of the Chase formation, both inclusive. The upper is the Marion or Wellington formation.

Gould[4] gave the name Chandler (formation on map, district in discussion) to the lower part of these red beds.

They are approximately equivalent to the Vamoosa, Ada and Pontotoc of Morgan[5] which have a combined thickness of 1,500 to 1,900 feet.

PONTOTOC (?) TERRANE

The oldest beds in western Oklahoma of which there is any extensive knoweldge are assigned to the rather indefinite Pontotoc (?) terrane. It appears probable that the arkosic beds along the north side of the Wichita Mountains occupy a slightly higher position in the geologic column than those along the north side of the Arbuckle Mountains. This statement is based on the fact that the top of the arkosic beds of the Wichita Mountains correlates with younger beds more accurately than does the top of the Pontotoc beds of the Arbuckle Mountains. They are deposits of arkose, arkosic sands, sands, sandy shales and argillaceous shales, variable in color, representing the material eroded from the Wichita Mountains as they were gradually uplifted during late Pennsylvanian and early Permian times and carried off-

4. Gould, Chas. N., Geology and water resources of Oklahoma: U. S. Geol. Survey, Water-Supply Paper 148, 1905.
5. Morgan, Geo. D., Geology of the Stonewall Quadrangle, Oklahoma: Bureau of Geology, Bull. 2, 1924.

shore and deposited. Just as the Pontotoc beds north of the Arbuckle Mountains grade northward into non-arkosic sands, shales and limestones, so do the buried Pontotoc (?) beds north of the Wichita Mountains pass into the limestones and shales found in the trough between Canute, Oklahoma, and Barton County, Kansas.

Along the Wichita Mountains the arkosic beds rest upon the igneous rocks from which they were derived. Along the Arbuckle Mountains older Pennsylvanian and other Paleozoic beds have been found below the Pontotoc, but whether or not this condition prevails north of the Wichita Mountains is unknown.

The Pontotoc (?) beds are the principal oil sands of the Sayre, Oklahoma and Wheeler and Carson counties, Texas fields and are usually termed by the driller "granite wash."

LIMESTONES AND SHALES OF NORTHWESTERN OKLAHOMA

As already mentioned, the Pontotoc (?) grades northward into light-colored shales, limestones, sandstones and red beds, the proportion of the first two mentioned increasing to the north. It is almost certain that there are limestones and shales older than those that are the time equivalent of the Pontotoc (?) terrane, present in an increasing thickness toward the trough at or near the Kansas-Oklahoma State line. These older Pennsylvanian beds also increase in thickness from west to east and in Kay and Grant counties, wells can be correlated with beds older than the Pontotoc that outcrop in eastern Oklahoma.

In western Kay, Grant, Alfalfa, and Garfield counties, the 600 feet, more or less, of strata above the Foraker limestone, form a set of beds distinguished from those above and below. Included in these beds are sandstones, sandy limestones and red beds in far greater abundance than in the strata immediately over and under them. Resting on the Foraker limestone is a red bed marking the base of this zone, and while this is not the lowest red layer in the section, the other lower red beds are thin and scattered.

The correlation of the arkosic beds north of the Wichita Mountains with the 600 foot zone described above is made because of the red and arenaceous material. It is realized that the Pontotoc (?) of the Arbuckle Mountains region includes the southern representatives of much lower beds than the Foraker, but it is believed that the Pontotoc (?) of the Arbuckle region is much thicker than that of the Wichita Mountain region.

THE PANHANDLE "BIG LIME"

This name is used temporarily until a suitable geographic name is proposed for these beds. It is possible that the Panhandle "Big Lime" is represented by some part of the Marion, probably above the Herrington limestone. On the other hand it is possible that it has no surface outcrop in Kansas or Oklahoma. As far as Oklahoma is concerned, the term "limestone" is a misnomer because gypsum, anhydrite, dolomite, and salt constitute most of the formation.

On the north flanks of the Wichita Mountains and throughout western Oklahoma, in every hole drilled sufficietly deep, the Panhandle "Big Lime" rests on the arkosic material or the 600 foot zone of material correlated with it, either directly or with a little intervening shale.

The thickness of the "Big Lime" is variable. It lenses out to the east and increases toward the center of the Anadarko Basin. In much of northwestern Oklahoma it averages about 300 feet and probably attains a maximum thickness of 500 or 600 feet. It is also probable that it is absent in the central and western parts of the Oklahoma Panhandle.

It is somewhat difficult to make generalizations on the thickness as the upper part of the "Big Lime" is shaly and frequently is logged as containing salt—a feature of the overlying shale. It is the principal oil-bearing formation in Hutchinson County, Texas.

WELLINGTON SHALE

Throughout western Oklahoma the Wellington shale constitutes one of the chief, if not the principal, marker in subsurface stratigraphy. Its gray, blue or black hue contrasts so strongly with the red of the overlying Enid that it is conspicuous in all carefully kept logs. It contains much salt in northwestern Oklahoma and southern Kansas. In the eastern part of the Wellington area, the salt beds are thin and near the base of the formation, interspersed with thin anhydrites (logged as limes) and a little red and brown shale. Farther west the salt beds are thicker and also higher in the formation.

It is a question whether these salt beds have been dissolved away along the eastern margin of the Wellington or whether they were not deposited there. If they were deposited and dissolved away, as seems probable, the reason is at hand for some of the irregularities in the stratigraphy.

In the Anadarko Basin very little salt is reported, but most logs show a great many thin lime shells, probably anhydrite in most cases. Salt is absent also in the central and western parts of the Oklahoma Panhandle.

The thickness of the Wellington ranges from 200 to 500 feet and averages about 300 feet. In general it thins to the east. Over the buried extension of the Wichita Mountains it seems to be absent in places.

ENID FORMATION

The Enid formation includes an almost unbroken succession of red material from the top of the Wellington non-red shale to the base of the Blaine gypsums. In well logs four divisions may be distinguished, although all the divisions are not recognizable in all areas. Where present in its entirety the thickness of the Enid ranges from 1,200 to 2,200 feet, the variation taking place in all the members.

The lowest member is a zone of red shale and sandstone 100 to 300 feet in thickness, probably the Harper sandstone member. Above this is 100 to 300 feet of blue shale, with minor amounts of red shale and in the Woods and Harper counties area large amounts of rock salt. From this occurrence it is believed that this is the Salt Plains shale member.

This blue shale member makes a good marker over all of western Oklahoma, and it is present in many logs in west-central Kansas. It is probably present even where not logged and has escaped notice through cavings of the other red material.

From the top of this member to the base of the Blaine gypsum there are one or two members, depending on the locality. In most of west-central Oklahoma the interval is nearly all red shale, but in the Harper and Woods counties area there is a second zone of rock salt, of which the writer has seen no mention in the literature, in the uppermost 100 to 300 feet of the Enid. The presence of this salt bed explains the occurrence of several salt plains just below the escarpment of the Blaine gypsum.

The upper one or two members of the Enid comprise two-thirds or three-fourths of the whole, and because of this fact they have a wide range in thickness, 800 to possibly 1,600 feet.

Aside from the rock salt, the upper part of the Enid is mostly logged as red shale (red rocks or red mud), but a few sandstones are reported, and it is often found that the sandy beds line up fairly well.

BLAINE FORMATION

The Blaine formation is a zone of anhydrites and red shales, with a few thin dolomites. In many cases the relatively hard anhydrite beds are logged as limestones. Upon exposure the anhydrite in places becomes gypsum. The formation is 100 to 200 feet in thickness and appears in the log of practically every well that has penetrated its horizon. As a rule, it marks the base of a series of thick sands, and, as already mentioned, very little sandy material is found for a long distance below it.

THE WOODWARD AND HIGHER FORMATIONS

As very few wells have been drilled in that part of Oklahoma where any considerable thickness of material is present above the Whitehorse sandstone, a study of well logs adds little information. Usually some red shale is logged immediately above the Blaine and the remainder of the log shows a succession of red rock and water sand which varies from well to well.

STRUCTURE

The outstanding structural features of western Oklahoma are the Anadarko Basin and the broad shallow syncline extending north from it. There is a steep northerly dip along the north side of the Wichita

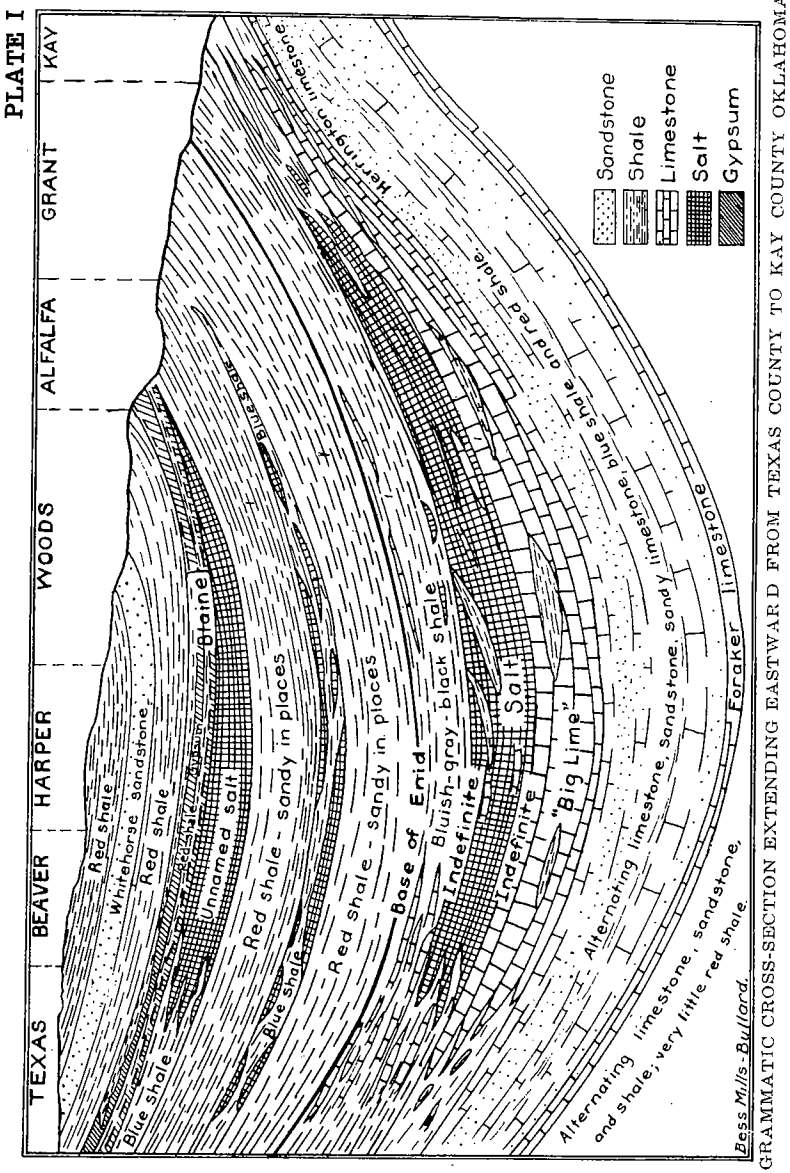
Mountains, a gentle southwest dip and southeast dip from the north into the Anadarko Basin. These features are shown in the accompanying map and cross-section. (Plate I and Plate II). The structure map is offered as a preliminary attempt, and will be modified as new wells are drilled and more accurate elevations are obtained. (See insert).

CONCLUSION

From the standpoint of the oil operator it is desirable that all wells be drilled into the granite wash, testing both the "Big Lime" and the granite wash where they are present. In the northern counties, sands below the Foraker limestone are to be expected, although to date most of the gas and the fair showings of oil have been found in the 600 foot zone above the Foraker limestone which, as already mentioned, is logged as containing much sandy material.

It is believed that the gas in the Oklahoma Panhandle comes from this zone.

PLATE I



DIAGRAMMATIC CROSS-SECTION EXTENDING EASTWARD FROM TEXAS COUNTY TO KAY COUNTY OKLAHOMA

WHAT THE MAP SHOWS

The base of the Permian red beds (Harper sandstone, a basal member of the Enid formation in northwestern Oklahoma) constitutes one of the best markers of western Oklahoma. The contouring on the map is necessarily preliminary for in some counties only one or two wells have been drilled sufficiently deep to penetrate the Wellington shale below the red beds.

The main structural feature shown on the map is the Anadarko Basin. The second structural feature in importance, is the broad shallow syncline trending northward from the Anadarko Basin, which is a result of the southwest dip in the north-central counties and the southeast dip in the northwestern counties.

When the surface elevation of a drilling well is known, the depth to the base of the Permian red beds can be computed by the use of this map.

CORRECTION

Contours in Anadarko Basin denote distance below sea level, and should read minus (—).

Contours in the Oklahoma and Texas panhandles should read plus (+)