# KANSAS GEOLOGICAL SURVEY
## OPEN-FILE REPORT 65-1

United States of America Federal Power Commission,

In the Matter of Area Rate Proceeding (Hugoton-Anadarko Area),

Docket Nos. AR64-1

by

W. Beebe



**KANSAS GEOLOGICAL SURVEY**
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047

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UNITED STATES OF AMERICA
FEDERAL POWER COMMISSION

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| AREA RATE PROCEEDING, ET AL | ) | Docket Nos. |
| (HUGOTON-ANADARKO AREA) | ) | AR64-1, et al |

PREPARED DIRECT
TESTIMONY OF

B. W. BEEBE

Q. Please state your name and business address.

A. B. W. Beebe, P. O. Box 334, Boulder, Colorado.

Q. What is your present occupation?

A. I am an independent geologist and geophysicist and Vice President and Secretary of MM&B Inc., a petroleum exploration company. My principal business is directing exploration for and development of deposits of gas and oil. I do other types of geological and geophysical work on occasion.

Q. Will you please give us a resume of your formal education?

A. I am a graduate of the University of Wichita (now Wichita State University), Wichita, Kansas, 1935, with a Bachelor of Arts degree, major in geology. I was a graduate student in the division of geological sciences at the California Institute of Technology during 1940-41. My graduate studies were interrupted when I was called to active duty as a First Lieutenant, Infantry, O.R.C. in the fall of 1941. I did not return to graduate studies after my release from the service.

Q. Will you please state your professional experience?

A. From 1935 to 1938, I was employed as junior geologist, geologist, and finally assistant to the vice-president of exploration, Shell Petroleum Corporation (now Shell Oil Co.) in Wichita, Kansas, Tulsa, Oklahoma and St. Louis, Missouri. While in St. Louis, I directed and coordinated all of Shell's exploration activities in the Illinois basin. I left Shell to become division geologist for British American Oil Producing Company, serving in north Texas, Kansas and Illinois. In the fall of 1939, I left British American to become associated with Lerke and Whortan consulting geologists in Wichita, Kansas. In 1942, I joined The Bay Petroleum Corporation (now a part of Tenneco Oil Co.), where I organized its exploration department, serving successively as chief geologist, exploration manager, and vice-president, and was in charge of all of that company's land, geological and geophysical activities, development, and reservoir engineering in the Mid-Continent, Texas, Illinois, the Rocky Mountain area, Mississippi, Louisiana, and California. In 1947, I became exploration manager of Anderson-Prichard Oil Corporation, and supervised all of that company's exploration activities and development geology until 1950, when I became a member of Manhart, Millison, and Beebe, petroleum exploration consultants, foreign and domestic. On the dissolution of that partnership in 1955, I joined Keating Drilling Company as director and vice-president in charge of production, and was in charge of exploration, development, engineering and production. I resigned January 1, 1959, to resume practice of geology and geophysics.

Q. What are your professional affiliations?

A. I am a Fellow of the American Association for Advancement of Science and of the Geological Society of America; member of the Society of Exploration Geophysicists, and toured as one of its Distinguished Lecturers during the 1963-64 season, speaking on exploration problems, means of solving them and coordination of exploration activities. I am a member of the Society of Petroleum Engineers of the American Institute of Mining and Metallurgical Engineers and the American Geophysical Union. I am a member of the American Association of Petroleum Geologists, have served as Chairman of its Distinguished Lecture Committee and as its Vice-President, and have been invited to tour as a Distinguished Lecturer in the fall of 1965 under the Association's auspices. I am currently Chairman of its Membership Qualifications Committee. I am a member of the American Gas Association and served as Chairman of the Supply Division of its Committee on Future Requirements and Supply. I am a member of the Society of Independent Professional Earth Scientists and of the American Institute of Professional Geologists. I am Chairman of the Legislative Council of the latter organization. I have also served as Chairman of the Reorganization Committee and am serving as Chairman of the Professional Standards Committee of the American Geological Institute, a federation of all of the major geological societies. I received the first recognition award of the Alumni Association of the University of Wichita. My biography appears in American Men of Science, Leaders in American Science, Who's Who in Science and Engineering, Who's Who in the West, and will be published in the World's Who's Who in Science, now in press. I am also a member of several local and regional geological and geophysical societies.

Q. Have you engaged in writing and editorial activities?

A. Yes, sir. At present I am Special Editor of the forthcoming multivolume symposium of the American Association of Petroleum Geologists, "Natural Gases of North America". I was co-editor of the Association's symposium, "Backbone of the Americas"; was editor of "Covered Wagon Geologist", the autobiography of the late Charles N. Gould; and contributed to "Exploration Geophysics" and "Petroleum Exploration Handbook", both standard texts and references.

Q. Have you engaged in writing and editorial activities with special reference to natural gas?

A. Yes, sir. Since accepting the position of Special Editor of the symposium of the American Association of Petroleum Geologists, "Natural Gases of North America", a massive study of the geography, origin, occurrence, accumulation and entrapment of natural gas, composed of approximately 125 papers, I have done considerable research into various facets of the origin, accumulation, entrapment, exploration for, and development of natural gas deposits. My paper "Natural Gases from a Geologist's Viewpoint", was published in the annual Petroleum Issue of Mines Magazine in 1959. I delivered an invited paper, "Natural Gases of North America", before the Third Annual Meeting of the Southwestern Federation of Geological Societies held in Abilene, Texas, October 12-14, 1960, which was published in the transactions of that meeting; I delivered an invited paper before the annual meeting of the American Association of Petroleum Geologists in Denver, Colorado, April, 1961, entitled, "The Challenge of Exploration for Natural Gas"; and an invited paper before the Mid-Continent Regional Meeting of the American Association of Petroleum Geologists in cooperation with the Mid-Continent Council of Geological Societies in Amarillo, Texas, on October 19, 1961, entitled "Problems in Exploration for Natural Gas"; and have prepared the section on natural gas for the "Earth Science Encyclopedia", to be published by Columbia University.

Q. Have you written articles and technical papers on the Hugoton-Anadarko area?

A. Yes, sir. I delivered a paper in October, 1955, before the annual meeting of the Mid-Continent Federation of Geological Societies, entitled "The Geology of the Northwestern Anadarko Basin". My paper entitled, "Petroleum Geology in the Northwestern Anadarko Basin" was delivered by invitation before the Twentieth International Geological Congress in Mexico City in 1956, and was published in the proceedings of that Congress. In February of 1959, by invitation I addressed the Sixth Geological Symposium at the University of Oklahoma on "Characteristics of Mississippian Production in the Northwestern Anadarko Basin". This paper was published in the proceedings of the Symposium, as well as in Volume 27 of the Tulsa Geological Society Digest. In May, 1964, I delivered an invited paper, "Application of Geological Principles to Exploration for Oil and Gas in Kansas", at the annual meeting of the Kansas Academy of Science, later published in the Transactions of the Academy.

In September, 1956, I led the Thirty-Fifth Anniversary Field Conference of the Oklahoma City Geological Society in the Anadarko Basin, supervised preparation of the road log, preparation and publication of the Guidebook, and wrote several articles for the Guidebook. This conference convened at Guymon, Oklahoma, traveled the northwestern part of the Anadarko Basin, the Sierra Grande Arch, the Apishipa uplift, and other related features, and disbanded on the outcrop of the Glen Eyrie formation, Morrowan in age, in the Rampart range near Colorado Springs, Colorado.

Q. Are you registered or certified?

A. Yes. Geologists are required by statute to register in only one state, Arizona. In lieu of statutory registration, geologists have adopted certification, which serves the same purpose. I am Certified Member No. 156 of the American Institute of Professional Geologists, and hold Certificate No.138 in the Society of Independent Professional Earth Scientists, an organization of independent professional geologists, geophysicists, and petroleum engineers.

Q. Have you ever testified as an expert geologist?

A. Yes, I have testified before the Federal Power Commission, various State regulatory bodies, and in both State and Federal courts.

Q. What testimony are you prepared to give in this hearing?

A. I shall present a simple outline of the physical geography, physiography, and geology of the Hugoton-Anadarko Area, and the relationship of that area, one of the most important gas-producing provinces in the United States, to what is generally known as the Mid-Continent. I shall also discuss some of the important geologic and geophysical problems attendant to exploration and development of that area. I shall show that in the Hugoton-Anadarko Area, the search for important gas reserves is requiring progressively deeper drilling. These gas reserves will be found, for the most part, in stratigraphic traps which can be found only by intensive and risky exploratory drilling.

Q. Was Exhibit 5-1 (BWB-1) prepared by you or under your supervision?

A. Yes. Wherever I use the term "Hugoton-Anadarko Area" in my testimony or exhibit, I am referring to the same Hugoton-Anadarko Area as designated by the Commission for this hearing. The name Hugoton-Anadarko as used in my testimony is in no sense in accordance with standard geological terminology, but is used in a descriptive, geographical sense as used by the Commission.

Q. Are you familiar with the physical geography, physiography, and other related factors in this area?

A. Yes.

Q. Please describe page 1 of your exhibit.

A. This is a map of the Hugoton-Anadarko Area, covering all of the State of Kansas, northwestern Oklahoma and the Panhandles of Oklahoma and Texas all included in the present proceedings, showing the principal physiographic features.

Q. Will you please briefly describe the physical geography and physiographic features of the Hugoton-Anadarko Area?

A. Yes. The surface of this region generally dips eastward and northeastward from its western border (actually from the Rocky Mountains). Highest surface elevation in western Kansas ranges from approximately 3,700 feet in the southwestern part of the state to over 3,900 feet in the northwestern part, and in the Panhandles of Oklahoma and Texas from 4,978 feet at Black Mesa in northwestern Cimarron County, Oklahoma to approximately 4,500 feet in Dallam County, Texas. Lowermost surface elevations range from about 725 feet in northeastern Kansas to about 750 feet in the southeastern part. The lowermost surface elevations in the Oklahoma portion of the area are about 1,100 feet in Caddo County.

Q. Have you prepared maps and/or cross-sections to illustrate the broad aspects of the geology of the Hugoton-Anadarko Area?

A. Yes, I have prepared a columnar section, several maps, and cross-sections for that purpose.

Q. Please explain page 2 of your exhibit entitled, "Generalized Geologic Sections, Paleogic Strata, Hugoton-Anadarko Area".

A. The Hugoton-Anadarko Area, as designated by the Commission, is a large, heterogeneous geologic area. Although, in general, rocks of the same age are present over most of the area, the youngest bedded rocks geologically are present in its western portion and the younger and intermediate rocks are not present in central and eastern Kansas. For example, Tertiary, Cretaceous, Jurassic and Triassic rocks are present over much of the western portion of the area. These rocks are not present in any of the eastern portion, and most of the Tertiary, Cretaceous and Jurassic rocks are confined to the central and western portions of the area. Triassic rocks are found only in the southwestern portion of the region. The Permian-Chase (Wolfcamp) group, which produces gas in the Panhandle-Hugoton field, outcrops along an almost north-south line along the 97th meridian east of Wichita, Kansas, and is not present over eastern Kansas. Many of the other strata of Pennsylvanian age, which are productive in the Anadarko Basin and the Hugoton embayment, outcrop in eastern Kansas. The Lansing and Kansas City limestones outcrop near towns of those names in Kansas, and limestones of Mississippian Osage age outcrop in southeastern Kansas. Rocks of Atokan and Morrowan age do not outcrop at any place in the Hugoton-Anadarko Area.

Not only are rocks of different ages confined to various portions of this geologically heterogeneous area, but there are many changes in facies, which mean changes in the lithology of the rocks. For instance, limestone may change to sandstones or shales, or vice versa. An example of such changes is seen in the upper part of the Missourian section of Pennsylvanian age where the Lansing limestones change to sandstone and shale southward and down dip across the "Shelf" of the Anadarko Basin. These changes in themselves often afford traps for hydrocarbons, and are important in the Hugoton-Anadarko Area.

The columnar section shows the geologic system, era, epoch and group with field and area names for productive sands and gives some indication of the changes in character of the rocks, and the various names by which producing formations are known, their geologic age, and their depth in certain fields. These geologic periods and groups or series of strata will be referred to throughout this testimony.

Q. Please describe page 3 of your exhibit entitled "Tectonic Map, Hugoton-Anadarko Area."

A. This is a map of the entire Hugoton-Anadarko Area showing the many major tectonic elements, that is, major uplifts and basins, and some of the minor structural features that exist in or adjacent to the Hugoton-Anadarko Area. The tectonics of this area are every bit as complex and varied as is the physiography, physical geography and stratigraphy.

Commencing in northeastern Kansas is the Forest City basin which extends into adjacent parts of Nebraska and Missouri. The Forest City basin is a post-Mississippian basin with depths to the pre-Cambrian ranging from less than 2,500 feet to about 4,500 feet.

The Bourbon arch separates the Forest City basin from the Cherokee basin lying southward. The Bourbon arch is a broad feature which extends southeastwardly from the Nemaha Granite ridge in central Chase County, Kansas, to southern Bourbon County, Kansas. The Cherokee basin extends into northern Oklahoma and is an early Pennsylvanian Cherokee feature. This is sometimes referred to as the Chautauqua arch.

Westward from the Cherokee and Forest City basins is one of the most prominent and historically important structural features in the Mid-Continent area. The Nemaha Granite ridge, also called the Nemaha anticline, enters Kansas near the 96th meridian in Nemaha County, Kansas, trends southward and southwestward, passing from southeastern Sumner County, Kansas into western Kay County, Oklahoma.

Westward from the Nemaha Granite ridge in north-central Kansas, and extending into the adjoining area of Nebraska, is the Salina basin, containing from four to five thousand feet of sedimentary strata.

Southward from the Salina basin and separated from that basin by a broad Sedgwick saddle is the Sedgwick embayment or Sedgwick basin of the Anadarko basin.

Southwestward from the Salina basin and northwestward from the Sedgwick embayment is the Central Kansas uplift.

The Central Kansas uplift is bounded on its southeastern side by the Sedgwick embayment of the Anadarko basin, which is divided from the Hugoton embayment westward, by the Pratt anticline, a prominent structural feature plunging southwestward from the central Kansas uplift across Pratt and Barber Counties, Kansas into Woods County, Oklahoma, where it is often known as the "Woods County Swell".

Westward from the Pratt anticline in Kansas is the Hugoton embayment of the Anadarko basin. This is a somewhat shallower arm of the Anadarko basin which swings northward into Kansas and lies between the Central Kansas uplift -- Pratt anticline to the east and the Sierra Grande-Las Animas arch of eastern Colorado on the west. The embayment extends northward into adjoining portions of Nebraska and extends westward into southeastern Colorado.

The "Northern Basin shelf" area lies along the Kansas-Oklahoma boundary and extends into the northeastern four counties in the Panhandle of Texas. This region has been the scene of most of the exploration and development drilling for natural gas in the Hugoton-Anadarko Area during the past 12 years. The "Shelf" is a Permo-Pennsylvanian feature and actually occupied different positions from north to south during those periods of geologic time. However, this is a generally accepted geographically descriptive term.

The area southward from the "Shelf" and northward from the Buried Amarillo-Wichita Mountains axis is the Anadarko basin. The deepest part of the basin is belived to lie north of, but near, the Buried Amarillo-Wichita Mountain edge in Caddo and Washita Counties, Oklahoma. Only a few deep test holes have been drilled in this deeper portion of the basin because of high costs of drilling and completing wells.

The Wichita mountains, in which pre-Cambrian rocks outcrop, and its buried northwestern extension are the southern boundary ofthe Anadarko basin in Oklahoma. The Buried Amarillo Mountains which connect with the Wichita Mountains mark the southern limits of the westward extension of the Anadarko basin into Texas. The structure of the Buried Amarillo Mountains is complexly faulted, particularly in its flanks.

The Anadarko basin in the Panhandles of Texas and Oklahoma is partially limited to the westward by the Cimarron uplift which separates the Anadarko basin from the subsidiary Dalhart basin, lying between the Cimmaron uplift and the Sierra Grande arch westward.

Southward from the Buried Amarillo Mountain uplift is the Palo Duro (or Plain View) basin lying between the Buried Amarillo Mountains and the Matador arch southward. Its southeastward extensions are known as the Hollis basin in Oklahoma and the Hardeman basin in Texas.

In summary, therefore, the tectonics of the Hugoton-Anadarko Area are heterogeneous, as are its geography, physiography and stratigraphy. There are at least 15 complex, distinct and separate tectonic elements including uplifts and basins within the Hugoton-Anadarko Area. Depth to pre-Cambrian basement rocks ranges from less than 2,500 feet to an estimated 50,000 feet in the deep trough of the Anadarko basin.

Q. Please describe page 4 of your exhibit entitled "Pre-Cambrian structure of the Hugoton-Anadarko Area."

A. This map shows the structure contoured on the top of the pre-Cambrian basement of the Hugoton-Anadarko Area. All of the major tectonic features heretofore discussed can be recognized on this map, although the map is contoured on a large interval.

Q. Please describe page 5 of your exhibit.

A. This map, as entitled, shows the depth to the top of the pre-Cambrian basement rocks. It differs from the previous map, depicting the structure of the pre-Cambrian, in that on the structure map, all pre-Cambrian points have been reduced to sea level, a common reference plane. However, page 5 shows how much rock one would have to drill to reach the pre-Cambrian in any one place, and is not reduced to a common reference plane. Although the surface of the ground generally dips eastward and northeastward in the Hugoton-Anadarko Area, the surface rises in all directions from estimated depths of approximately 50,000 feet in the trough of the Anadarko basin in Caddo and Washita Counties, Oklahoma to less than 2,000 feet in southeastern Kansas. The pre-Cambrian is actually on the surface at elevations as high as 2,464 feet above sea level at Mt. Scott, the highest point in the Wichita Mountains of Comanche, Kiowa and Greer Counties, Oklahoma.

This map demonstrates the limits of the amount of sediments available for exploration for gas and oil production in any part of the Hugoton-Anadarko Area. This thickness ranges from less than 2,000 feet in the shallowest areas to an estimated 50,000 feet in the trough of the Anadarko basin.

Not all of these sediments, however, are potentially gas and oil productive over all of the region, particularly in its western portion. In the western portion of the area, and in isolated sections further eastward, potential producing strata are covered with a mantle of Recent, Quaternary and Tertiary sands and gravels including Tertiary-Ogallala mortar beds and caliche, rock and debris, all swept from the Rocky Mountains which lie westward. In western Kansas, a section of Cretaceous rocks is also present. In some portions of the westernmost part of the area, there are thin Jurassic and Triassic sediments. The upper Permian is present over all the western portion of the area. Very little of this section from the surface down to near the base of the Permian Leonard series, can be assumed potentially productive. The youngest zone known to have substantial production is the "Red Cave", which is found near the base of the Permian-Leonardian series. It is immediately above the Wolfcampian, the upper part of which is the principal producing zone in the Panhandle-Hugoton field. The "Red Cave" formation is found in depths varying from approximately 1,500 feet to 3,000 feet in the western portion of the Buried Amarillo Mountain uplift, and in the southern portion of the Hugoton embayment and western portion of the Anadarko basin. In some local sections in the western portion of the Hugoton-Anadarko Area, as much as 4,000 feet of section may be considered non-productive.

However, it is evident from this and the previous maps that even by eliminating the probably non-productive strata, there is ample sedimentary section within the hearing area to justify continued exploration for gas and oil. To date, only portions of the area have been explored and in these to varying depths, but rarely below the upper part of the Mississippian in the Anadarko basin. Some portions of the area have been explored only to the lower Permian, and some portions are relatively untested with the drill. Only in southeastern Kansas, along the Namaha Granite ridge, on the Central Kansas uplift and on the Buried Amarillo Mountains has the entire sedimentary section been adequately explored. The section from the upper portion of the Mississippian to the pre-Cambrian is relatively unexplored over most of the Anadarko basin, the Hugoton embayment and the Salina basin, for example. These will be discussed in more detail hereinafter.

Q. Mr. Beebe, please discuss the modes of occurrence and accumulation of gas and oil in the Area.

A. Gas and oil occur in both structural and stratigraphic traps. A structural trap is one which depends on deformation of the rocks for trapping oil and gas. A stratigraphic trap is formed by lateral variations of the reservoir character and does not require deformation of the rock units for entrapment. The lateral variations in continuity can be a result of changes in lithology or a break in continuity without faulting. We speak very loosely of structural traps and stratigraphic traps. However, the many so-called stratigraphic traps are a combination of both structural and stratigraphic features. The Hugoton-Anadarko area differs from many other regions because of the larger number of stratigraphic traps which have been found,a result of numerous inconformities, stratigraphic and lithologic facies changes in the sedimentary section. The Hugoton-Anadarko Area contains examples of all three classifications, structural, stratigraphic, and a combination of both. An example of a primarily structural occurrence may be found at the North Custer City field on the deep north flank of the Anadarko basin.

Examples of primarily stratigraphic occurrences are the Glick, the Cedarvale, the Liberal Light, the Catesbey-Chaney, the Putnam, and the Laverne-Mocane fields.

The North Gotebo field, a complicated occurrence on the complex north flank of the Wichita Mountains, is an example of a combination of structural and stratigraphic conditions. In summary, almost every type of structural and stratigraphic trap and the many possible combinations thereof have been found in the Hugoton-Anadarko Area, some containing gas and oil. The widest variety of stratigraphic traps has been found in portions of the hearing area, particularly the "Shelf" of the Anadarko basin.

Because of the nature of these stratigraphic traps, the "exploration" is not finished when a trap is located, since the lateral extent and character of the trap can only be revealed by development drilling, a much more hazardous operation than development of structural traps.

Also, since the stratigraphic trap is not caused by warping of strata, finding them overlying one another is most unusual.

Q. Do you expect that future exploration in the Hugoton-Anadarko Area will be largely directed to search for stratigraphic traps?

A. Yes.

Q. Have you prepared maps or diagrams to illustrate the importance of stratigraphic traps in the Anadarko basin?

A. Yes, sir, pages 6, 7, 8, 9, 10 and 11 of my exhibit were prepared for this purpose.

Q. Please explain these pages.

A. These pages consist of two maps and four cross-sections. The maps depict the character and distribution of the rocks on the old erosional surface beneath the two major unconformities so important to the area. These maps represent a bird's eye of the surface below the unconformity if the overlying rocks were stripped away.

The first map of the younger unconformity surface, entitled "Generalized Pre-Pennsylvanian Paleogeology of the Hugoton Anadarko Area", shows the distribution of the Mississippian and older formations where the former has been completely removed by erosion on the higher areas.

The second map, entitled: "Generalized Pre-Woodford-Chattanooga-Kinderhook Paleogeology of the Hugoton-Anadarko Area, exhibit page 7, shows the character and distribution of rocks of Hunton age and older beneath this unconformity. The two unconformities intersect on the flanks of uplifts.

The features shown on these maps are of the greatest importance in the Anadarko basin. Many of the stratigraphic traps producing gas and oil result from secondary porosity induced by weathering of the erosional surface. The wedge edges of truncated strata may either broaden or narrow as they wrap around the major uplifts. These are likely places to prospect for stratigraphic traps.

The unconformities are also important for the development of stratigraphic traps resulting from onlap or offlap of sediments and their erratic distribution on the unconformity surface. Porous permeable beds wedge out against the unconformity.

The four cross-sections, two north-south and two east-west, exhibit pages 8, 9, 10, and 11 give depth to the paleogeologic maps, show location and depth to the unconformities, the truncated, weathered wedge edges below and the wedging out of younger sediments above.

In addition, the cross-sections show to a degree the varying character of the sediments in four parts of the area and the influence of tectonic features, structure and sedimentation. Page 8 of the exhibit traverses the western portion of the area from north to south through the Hugoton embayment, crosses the Buried Amarillo Mountains, the Palo Duro basin and ends on the Matador arch. Rocks in the northern part of the Hugoton embayment are primarily carbonates which thicken and become more clastic and contain sandstones southward and finally become highly arkosic near the Buried Amarillo Mountains, thin markedly over the Mountains with many units absent and then thicken southward into the Palo Duro basin. The contrast in character of the basins is quite evident.

The second north-south section, page 9 of the exhibit, commences near the wedge edge of the Mississippian in Reno County, Kansas, crosses the Anadarko basin "Shelf", its trough and ends on the north flank of the Wichita Mountains. Lithology of the Pennsylvanian rocks changes southward from carbonates and fine clastics to coarser clastics with sandstone, with facies changes which afford still a third set of conditions conducive to the formation of stratigraphic traps. The basin shelf and its trough are easily seen.

Page 10 of the exhibit is an east-west section through the Forest City basins across the Nemaha Granite ridge, through the Salina basin across the Central Kansas uplift and into the Hugoton embayment, showing the two unconformities, the change westward in the Pennsylvanian from carbonates, shales and sandstones to a section of mostly carbonates. In contrast the second east-west section, page 11 of the exhibit, from the Nemaha Granite ridge in Garfield County, northern Oklahoma, to the Sierra Grande arch in Colfax County, New Mexico, shows the much more clastic nature of this section along the "Shelf" of the north flank of the Anadarko basin and the arkosic character of the Pennsylvanian near the Sierra Grande arch. Facies changes and the lenticular nature of some of the Pennsylvanian sediments are well illustrated.

These six pages vividly portray the causative factors for the various types of stratigraphic traps found in the Anadarko basin.

Q. Have most of the wells drilled in the Anadarko basin penetrated and tested the older Mississippian and pre-Mississippian rocks?

A. No, sir. The general practice in this basin has been to drill wells to the upper 100 feet of the Mississippian formations and drill no deeper.

Q. What is the reason for this?

A. It is not because of the lack of possibilities of gas and oil at greater depths but because of the considerably increased cost of drilling through the hard abrasive cherty Mississippian section and the underlying rocks and testing these older beds. Possible loss of circulation of drilling fluids is an ever present hazard and adds to costs. Furthermore, we do not know very much about the characteristics of the older Mississippian and subjacent strata over much of the Anadarko basin and Hugoton embayment because it has been penetrated in so few widely scattered test wells. This fact increases risk in drilling, which coupled with increased costs deters drilling through the Mississippian.

Q. Are gas and oil easy to detect in formations such as the Mississippian, during the drilling process?

A. No sir, they are not. If the formation is composed primarily of chert rubble, as is often the case of the Mississippian Osage regolith, showings of gas and oil are often very difficult to find. Gas cannot be seen and often the odor cannot be perceived in drill cuttings without mechanical aids. An experienced wellsite geologist will often drill stem test a porous formation simply on suspicion if gas detecting devices are not on location. Even with gas detectors, the use of oil or distillate in the mud, a common practice, or an unusual section of carbonaceous or bituminous shales may make it difficult to interpret the readings of the gas detector.

The necessity for frequent drill stem testing, the use of the gas detectors and suites of several different types of logs, increases the cost of exploration drilling in the Anadarko basin.

Q. Are you familiar with gas and oil production in the Hugoton-Anadarko Area?

A. I am.

Q. Have you prepared a map of gas and oil fields of the Hugoton-Anadarko area?

A. Yes.

Q. Please describe page 12 of your exhibit.

A. This is a map of all of the gas and oil fields in the Hugoton-Anadarko Area. The nonassociated gas fields are shown in red, except for the Hugoton-Panhandle field, which is outlined in red, and the Greenwood field, which is in a red pattern, to differentiate them from the deeper production which has been found within these field areas. The oil fields are shown in green. Combination fields, in my definition, are those oil fields marketing gas. These are shown with a red triangle within the green of the field. Combination fields producing great quantities of both gas and oil do not occur as frequently nor are they as important in the Hugoton-

Anadarko Area as in other parts of the county.

Most of the gas fields in eastern Kansas have long been abandoned, and this area is no longer a major source of gas. The Kansas Corporation Commission, Oil and Gas Division, reported production from only 23 fields in 1963, mostly small amounts and marketed locally. Except for the Forest City basin, this area has been virtually drilled out and offers very little promise for additional gas discoveries.

The great bulk of the natural gas production, as can be seen from the map, lies in southwestern Kansas, northwestern Oklahoma and the Panhandles of Oklahoma and Texas. The now combined Panhandle-Hugoton field, one of the largest known single accumulations of gas in the world, contributes a substantial portion to the current production. However, this field is now about half depleted and reserve additions in the hearing area have not replaced production. The Panhandle-Hugoton field produces dry gas from Permian upper Wolfcamp (Chase) limestones and dolomites. The Panhandle sector of the field also produces from the "Red Cave" and Wichita formations above the Wolfcamp and from arkoses called granite wash below the Wolfcamp limestones and dolomites.

The exploration for natural gas alone was relatively slow in the Anadarko basin until the early 1950's because of lack of incentive. The period 1950-1960, however, brought increased incentives and resulted in exploration of the "Shelf" portion of the Anadarko basin and portions of the Hugoton embayment to the upper Mississippian at depths generally less than 8,000 feet. A number of gas fields, many small, and few large, were discovered or developed during this period.

Q. Please describe pages 13 and 15 of your exhibit.

A. Page 13 of my exhibit shows the number of fields discovered per year in the Hugoton-Anadarko Area and is supported by the schedule on page 14. Page 15 of my exhibit shows the number of fields discovered per year in what I define as the Anadarko-Dalhart basins and is supported by the schedule shown on page 16. As shown previously in my exhibit, the Anadarko-Dalhart basins are areas of predominate gas production and are a separate geological entity.

The earliest period of exploration shown on pages 13 and 15 is the period of exploration primarily by surface geological methods. This period started with the discovery of the Eldorado field in Kansas in the year 1915 and extended until approximately 1930. However, large areas of the surface are not suitable for surface geological exploration. Therefore, about 1921 the core drill was introduced as a supplement to surface geological mapping. Although both methods continue to be used to some extent, both the surface and core drill reached the limit of their economic usefulness as primary exploratory methods by about 1930. As can be seen from page 13 of my exhibit, surface and core drill methods were moderately successful in the hearing area; however as shown on page 15 of my exhibit, they were largely ineffectual in the Anadarko-Dalhart basins. About 1927 the reflection seismograph was introduced. The use of the seismograph has extended with certain refinements to the present and is today the primary method of locating structural traps but has only limited usefulness in searching for stratigraphic traps. As can be seen from page 13 of my exhibit, the seismograph was responsible for finding a number of fields during the late 1930's and middle 1940's. However, as shown on page 15 of my exhibit, the seismograph was largely ineffectual as a finding method during these periods in the Anadarko-Dalhart basins. The salt-mud log and improved gas detecting devices were developed after World War II and were introduced into the hearing area in the early 1950's. The introduction of these devices and the increased economic incentives to search for gas led to increased discoveries starting in the early 1950's, peaking in 1959 as can be seen on page 13 of my exhibit. An inspection of page 15 of my exhibit will reveal that a substantial amount of the increased discoveries in the hearing area were due to discoveries in the Anadarko-Dalhart basins. These discoveries were primarily gas fields and were primarily stratigraphic occurrences.

In examining the history of exploration as shown on pages 13 and 15 of my exhibit, it can be seen that different exploration techniques have been introduced periodically since 1915. However, despite continued and extensive research which has been devoted to the development of new and radically different exploration techniques, no such technique has been developed since the reflection seismograph; and, in my opinion, none will be developed in the foreseeable future. As I have pointed out heretofore, future supplies of gas in the hearing area will be primarily stratigraphic occurrences which may be found to a large extent only by drilling. Therefore, increased incentive is needed for the industry to undertake the increased expense and risk of exploring for these stratigraphic occurrences of gas.

Q. How does a geologist go about finding gas and oil in these extremely complex variable traps, particularly stratigraphic, which you have described in the Hugoton-Anadarko Area?

A. It is not easy. Structural traps are by far the easiest to find in most of the regions of the world, and many have been found in the Hugoton-Anadarko Area by the various techniques used to map local structure. It is likely that there are additional structural traps remaining to be found in this area. However, we are approaching the limits of usefulness of present geophysical methods and equipment in our attempts to locate such traps. Unless and until new methods and equipment for locating structural traps are developed, our principal reliance in this area will be upon the discovery of stratigraphic traps.

Subsurface studies are frequently made in an attempt to locate environments where stratigraphic traps may be found. There are a variety of regional maps which can be constructed to show distribution, character and extent of certain porous and permeable formations and their regional structural attitude. However, one of the most unfortunate aspects of subsurface studies directed at location of stratigraphic traps is that they are in so few instances definitive; an actual drill site can seldom be specified. These studies show only a generally favorable area, and then how to find the gas and oil accumulations in this favorable belt becomes a frustrating and expensive problem to solve by drilling. Because so many stratigraphic traps are associated in some way with structural noses, terraces, re-entrants, etc., structural methods are of some assistance, but the only way to locate a true stratigraphic trap, unless there is a definite trend which can be projected, is simply by drilling. This becomes an extremely costly method of exploration.

An example of the hazards of development drilling of stratigraphic traps in the Anadarko basin may be found in the 42 township area in Ellis, Dewey and Woodward Counties, Oklahoma. To the end of 1964, a number of individual reservoirs were discovered. Of 207 wells drilled to these discoveries, 121 were producers and 86 were dry holes. In other words, over 40 percent of the development wells drilled were dry. The development of stratigraphic traps in the Anadarko basin is often nearly as hazardous as finding them.

Nor do most stratigraphic traps often offer the multi-zone possibilities for production more common in areas where structural traps predominate, such as the Gulf Coast.

Although the industry also has carried on extensive research to develop better methods to find stratigraphic entrapments which might contain gas and oil, nevertheless I see no method in the foreseeable future. The results of research and experiments to date and even the use of the computer have simply been a refinement of existing techniques.

Q. Mr. Beebe, please state your appraisal of the various tectonic and structural elements and the stratigraphy and lithology of the area from the standpoint of the discovery of gas and oil.

A. The geology of this heterogenous Hugoton-Anadarko Area has some similarities in that it all lies in what has sometimes been called the Western Interior Coal basin.

The Cherokee basin--Chautauqua arch, the Nemaha Granite ridge, part of the Sedgwick embayment, Central Kansas uplift, Pratt anticline, and the Buried Amarillo Mountain province, are provinces which have been for the most part, "drilled out" or thoroughly explored with conventional techniques. The portions of these areas which are not now producing have failed to yield to conventional methods of exploration. Future discoveries probably will be small in both area and reserves. In general, major companies have almost abandoned these provinces for exploration.

The most promising area, of course, is the

Anadarko-Dalhart basins and the tributary Hugoton embayment in which gas is the primary objective. The Hugoton embayment contains the Hugoton Field, the Greenwood and many other fields of southwestern Kansas. The Laverne-Mocane and Camrick fields and the many deeper fields north of the Panhandle field in Texas in general lie along the Northern Basin "Shelf", or in, or on the edge of, the Hugoton embayment.

The entire Anadarko-Dalhart basins area offers potential for the discovery of oil and gas, particularly gas, provided there is sufficient economic incentive to the explorer and developer. Because of the peculiar surface and nearsurface conditions, conventional methods of exploration have met with grave difficulties in most of this area.

The Hugoton field is a stratigraphic trap caused by an updip change in facies from the porous permeable limestones and dolomites of the Permian Chase (upper Wolfcamp) to impermeable red shale and siltstone along its western limits. Loss of permeability is also a limiting factor northward. The Chase beds dip under water to form the eastern boundary of the field. Southward it merges into the Panhandle gas field, where gas accumulation is controlled by structure of the Buried Amarillo Mountain. The original reservoir pressure of the Hugoton field was only about one-half that normally expected at comparable depths.

The reservoirs underlying the Hugoton field area are not similar to the Chase. Exploration of the pre-Chase beds have been underway for years. Gas and oil discoveries have been made underlying the Chase production. Production has been found in at least 10 different Permo-Pennsylvanian and Mississippian pay zones. However, many exploratory test wells to pre-Chase formations have been dry. Although several of the discoveries are of some importance, none is remotely comparable to the Hugoton Chase field. There can be no doubt that the pre-Chase production within the confines of the Hugoton Chase field will consist of individual fields, and that the entrapments will be both structural and stratigraphic.

This simply means that the area of the Hugoton field, 5,800 square miles, must be re-explored, primarily by drilling. The pre-Chase possibilities will not be exhausted until the Arbuckle-Ellenberger has been adequately explored. Exploration will require years of hazardous exploratory drilling, and will be expensive. Discovery of stratigraphic accumulations of gas and oil by exploratory drilling of 5,000 to 8,000 holes costing from $40,000 to $120,000, depending on depth and local conditions, is one of the most expensive methods of exploration.

Although the Sedgwick embayment and part of the northern "Shelf" area of the Anadarko basin have been explored by the drill to the upper Mississippian in many places and discovery possibilities are therefore limited in these zones; nevertheless the lower Mississippian and pre-Mississippian have not been tested sufficiently over much of this region. Furthermore, the Hugoton embayment of western Kansas, except for the Hugoton Chase field, is virtually untested.

However, the greatest opportunities for additional discoveries in the Anadarko basin lie in that virtually untested portion basinward from the Shelf. Recent and significant discoveries have been made at Gageby Creek and Mobeetie, Wheeler County, Texas, and at North Custer City, Custer County, Oklahoma.

I believe that there are possibilities of production from formations ranging from Permian beds to basal Pennsylvanian strata at depths ranging up to approximately 25,000 feet in the downdip Anadarko basin. There are potentially productive formations available in the eroded and weathered upper Mississippian formations lying below the pre-Pennsylvania unconformity. Productive possibilities in the older and pre-Mississippian beds in the basin await developmentof adequate evaluation exploration techniques and methods. These beds have been virtually untested; only 25 test holes have been drilled to the Arbuckle-Ellenberger in the entire deeper part of the Anadarko Basin.

Despite the number of Permian and Pennsylvanian producing zones of the "Shelf" area, it cannot be assumed that such conditions will continue to prevail in the down-dip basin to the extent they are found on the "Shelf" and vicinity. Entrapment of hydrocarbons on the "Shelf" took place because it offered ideal geological conditions for such changes. Although changes in facies have been found in the downdip areas, it would be unwarranted assumption and a costly mistake to assume that conditions known to pre-vail on the "Shelf" existed downdip. Furthermore, although there are some extensive fields on the "Shelf", many fields are small in size and frequently uneconomic. Experience in the Anadarko basin to date shows that stratigraphic accumulations of oil and gas are the most likely to be found. Significant structural anomalies simply do not appear to be present over large portions of the basin. To explore the deeper part of the Anadarko basin for strati-graphic traps will require additional economic incentive because of the greater incremental cost as wells are drilled to greater depth.

Exploration of this area will be difficult and costly. So few holes have been drilled through the entire section that little is known about much of the subsurface geology. Furthermore, conventional exploration tools are not always adequate for mapping structure in this area. Reflection seismograph work has scored some successes but has failed miserably in many other cases. Many different techniques have been used, some of which have been quite effective locally, but none of which has been found universally applicable to the problems. Core drill markers are much too deep for economic exploration by that method over much of the area, and, of course, both core drilling and seismograph are designed to find only structural traps. There appears to be no valid reason why additional gas production cannot be found in beds ranging in age from the Wolfcamp to the Arbuckle-Ellenberger in the Anadarko basin but exploration will be difficult and expensive.

In summary, the Anadarko basin and the tributary Sedgwick and Hugoton embayments offer the greatest promise for future gas discovery. Most of the current gas production and areas remaining to be explored are in that basin. The Dalhart basin is actually a part of the Anadarko basin and is considered favorable because gas production has been found in the Kerrick Field of Dallam County, Texas. The Anadarko and Dalhart basins should be thought of as one feature with the best possibilities for future gas production. The Palo Duro basin, has had disappointing history but since it is located south of the Panhandle gas and oil field, and north of the fields of the Matador arch, both producing from the Permo-Pennsylvanian, has potential. The basin to date has not responded to conventional exploration methods and techniques.

The prospects of the Salina basin, are virtually unknown. It is difficult to explore but production of oil has been found on its southeastern flank in a sedimentary section productive in nearby provinces. I judge its potential for natural gas at best to be mediocre to poor, and speculative. The Forest City basin is another relatively untested area. However, geological conditions are such that larger structures, if present, would have been found by now. It has been carefully explored for these features. Both its stratigraphic potential and its gas potential are unknown, but conditions requisite for large stratigraphic traps are questionable. Both gas and oil have been found in the few small fields found to date.

The Cimarron uplift offers little promise of future discoveries of importance because of its limited area. As has been pointed out the remainder of the hearing area has been thoroughly explored and significant gas discoveries are not expected.

Q. Have you prepared graphs and schedules to show the results of exploratory drilling in the Hugoton-Anadarko area and for any part of this area?

A. Yes, sir, I have prepared a series of graphs and supporting schedules for exploratory drilling in the Hugoton-Anadarko area, and similar graphs and supporting schedules for the Anadarko-Dalhart basins, which, in my opinion, are the known potential gas producing portions of the area. The latter area includes the southwestern portion of Kansas, most of northwestern Oklahoma, except for two counties, which to date have been primarily oil productive, the Oklahoma Panhandle, and those counties or portions of counties lying in the Anadarko-Dalhart basins north of the Buried Amarillo Mountains. The source of the information on the graphs and the supporting schedules is from the annual yearbooks of the International Oil Scouts Association. These yearbooks report exploratory drilling in the various states by scouting districts and counties. It is not feasible to attempt to break the data into units smaller than counties in most instances.

These summaries of exploratory drilling are not lists of new field wildcats only, but also include new pool wildcats, extensions, and shallower and deeper pool tests. The Committee on Statistics of Exploratory Drilling of the American Association of Petroleum Geologists makes the above breakdown by those classes but unfortunately that breakdown is not made in the Oil Scouts Yearbook. The statistics therefore indicate a higher success ratio than would be indicated for new field wildcats, which according to the latest report, that of 1964, from the A.A.P.G. Committee of Statistics of Exploratory Drilling, is 10.57%.

The graphs and schedules prepared portray trends in exploratory drilling in the Hugoton-Anadarko area, and in the Anadarko-Dalhart basins. These graphs, with supporting schedules, were prepared to show these trends and may be found on pages 17 to 36 of my exhibit.

Q. Will you please explain these graphs and supporting schedules?

A. The graphs and supporting schedules on pages 17 to 20 compare the numbers of exploratory wells drilled during the years 1950-1963 in the Hugoton-Anadarko area with those in the Anadarko-Dalhart basins. Shown on each graph are the totals of exploratory wells, dry holes, oil wells, and gas wells. On the basis of these statistical data alone it could be concluded that the entire hearing area as a whole is primarily an oil productive province, where more oil wells are drilled each year than gas wells. However, it must be emphasized that the hearing area includes the Central Kansas uplift and Eastern Kansas, both oil producing provinces with little or no significant gas production.

The reverse is true in the Anadarko-Dalhart basins which are primarily gas productive.

The graph on page 17 also shows that in the hearing area the peak of exploratory drilling occurred in 1956, and that drilling has declined significantly since that time.

By comparison, exploratory drilling in the Anadarko-Dalhart basins did not reach a peak until 1959, and has declined since that time.

The graphs on pages 21 and 23 compare the total footage drilled in exploratory wells in these areas during this same period, and show that the maximum footage was drilled in the hearing area in 1956 and that it has declined since that time. However, a secondary peak was reached in 1959, at the time the maximum number of wells was drilled in the Anadarko-Dalhart basins. However, the maximum footage was not drilled in the Anadarko-Dalhart basins until 1961, and has suffered a severe decline since that date.

The graphs on pages 25 and 27, with supporting schedules, express the number of all exploratory wells in percentages of oil wells, gas wells, and dry holes, and also the percentage of successful exploratory wells, both gas and oil, in both the hearing area and the Anadarko-Dalhart basins during 1950-1963. Again, it is evident that oil activity predominates in the entire hearing area, but that in the

Anadarko-Dalhart basins, gas is more important.

Oil is relatively unimportant in the Anadarko-Dalhart basins; considerably less important than the percentage of successful wells, number of successful wells, or footage of successful wells would indicate. Most of the oil fields are unimportant. Of a total of 489 fields in the Anadarko-Dalhart basins reporting oil production in 1963, according to the International Oil Scouts Yearbook, only 76, or 15-1/2% reported production of 100,000 barrels or more during that year. Such a field produces only 274 barrels daily and is not an important source of oil.

The graphs on pages 29 and 31, with supporting schedules, express in percentages the exploratory footage drilled in all wells, dry holes, oil producers and gas producers and the percentages of footage of oil and gas producers in both areas during 1950-1963.

The graphs on pages 33 and 35, with supporting schedules, show the average depth of all exploratory wells; oil wells, gas wells and dry holes in the hearing area and the Anadarko-Dalhart basins from 1950-1963. The marked increase in the percentage of gas footage in the hearing area is primarily a result of increased drilling in the Anadarko-Dalhart basins. The greater average depth of gas wells and its increase since 1950 is evident on page 33. The increase in depth of wells is even more obvious on page 35, the Anadarko-Dalhart basins.

Q. Mr. Beebe, will you summarize your testimony.

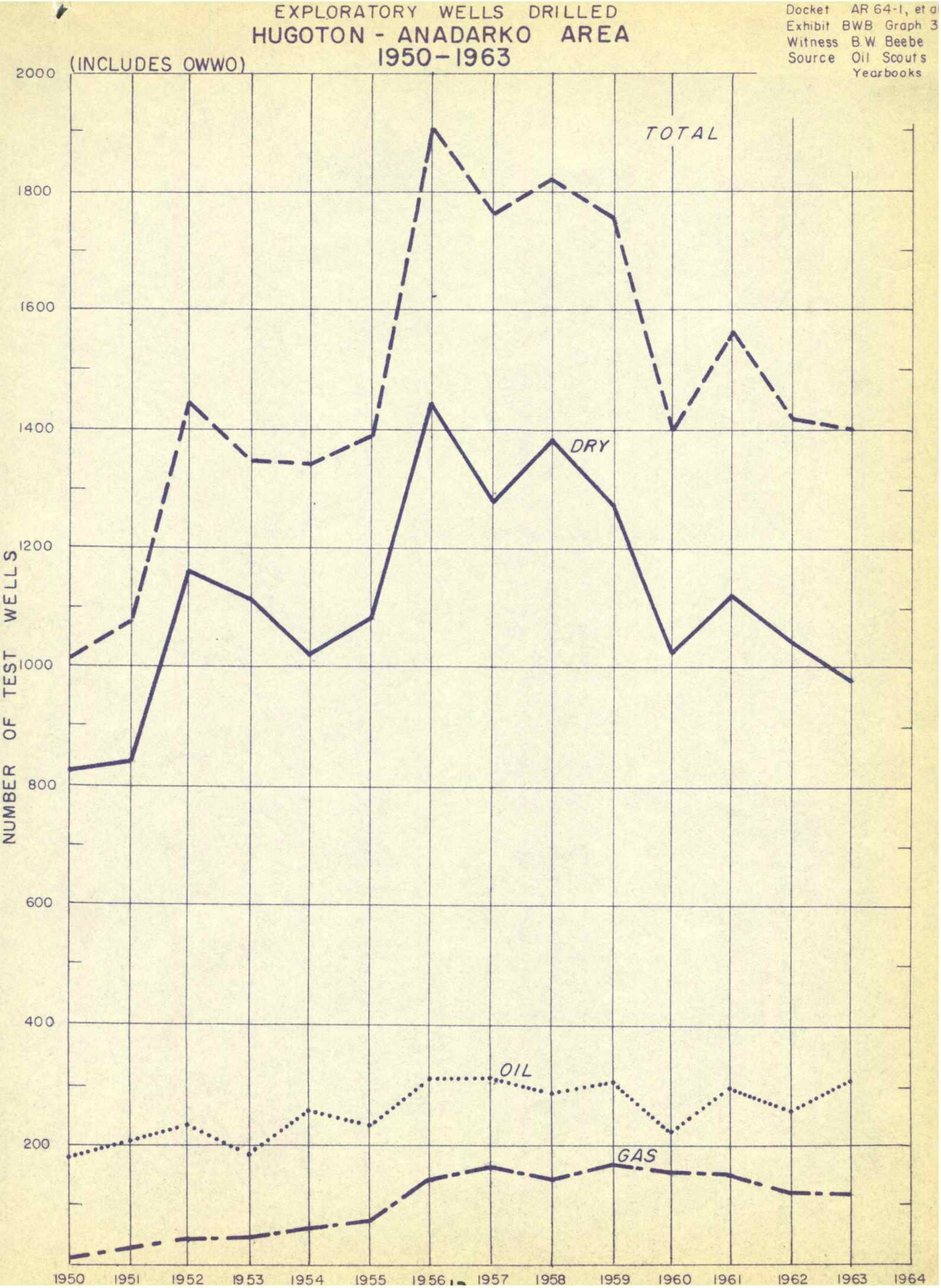
A. The Hugoton-Anadarko Area is a large, heterogeneous region containing a number of geological provinces producing gas and oil found under a variety of conditions. Its exploration history spans the entire period of the oil and gas industry during which exploration methods evolved from "creekology" through surface geology, core drilling, geophysics, to subsurface geology. Exploration generally spread westward from eastern Kansas with primary emphasis on oil. Because of the lack of incentive, the discovery and extended development of the large Hugoton-Panhandle field and the recognition of the Anadarko-Dalhart basins portion of the Hearing Area as predominantly potentially gas productive, undoubtedly exploration was retarded in the deeper areas.

Overall, the Hearing Area has been, and is, a contracting region for exploration. Southeastern Kansas, the Buried Amarillo Mountains, the Nemaha Granite ridge, the Pratt anticline, the Cimarron and Central Kansas uplifts are mature producing provinces explored extensively to basement rocks. Future exploration in these areas will consist only of the search for small traps to be found by more intensive exploratory drilling. These areas, except for the Buried Amarillo Mountains, have proved to be predominantly oil productive and hold little promise for additional gas discoveries of importance.

The future successful exploration for gas of the Hugoton-Anadarko Hearing Area, clearly demonstrated by its past history, lies in the Anadarko-Dalhart basin, including the Hugoton and Sedgwick embayments. By this I do not mean that past trends in oil vs. gas production, oil vs. gas exploratory drilling, success ratios, or other historical data compiled on the entire Hearing Area will be a reflection of the future. The deeper part of the Anadarko basin, the Dalhart sub-basin and much of the Hugoton embayment will be primary objectives for future exploration within the Hearing Area. Knowledge is sufficient to indicate that the search will be primarily directed to location of stratigraphic traps with gas as the predominant product.

Other witnesses will present evidence on the current status of proven reserves in the area, existing markets for gas, and future requirements for gas which could be served from this area. Recognition of good prospects for replacing the depleting reserves of existing fields by new discoveries cannot defer to some future date the exploration that must precede these new discoveries. Studies of the relationships between exploration activity and the drilling of prospects which I have made reveal a time lag of four to five years between the maximum exploration effort and exploratory drilling, and more years elapse before a discovery can be completely developed. Prospects must be found, leased, thoroughly explored, drill sites selected and titles cleared, before exploratory wells can be drilled. Obviously, there must be a greater hope of reward for successful search if the recently declining exploration effort is to be reversed and expanded to a scale sufficient to meet demands and if the monies necessary to reverse the alarming downward trends now prevalent in the industry are to become available. A substantial acceleration of drilling activity is required if the Hugoton-Anadarko Area is to supply its present customers in the future.

## INDEX



EXPLORATORY WELLS DRILLED
HUGOTON - ANADARKO AREA
1950-1963
(INCLUDES OWWO)
Docket AR 64-1, et al
Exhibit BWB Graph 3
Witness B.W. Beebe
Source Oil Scouts Yearbooks
NUMBER OF TEST WELLS
2000
1800
1600
1400
1200
1000
800
600
400
200
TOTAL
DRY
OIL
GAS
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964

EXPLORATORY WELLS DRILLED
HUGOTON-ANADARKO AREA 1950-1963
(Includes OWWO)

| Year | Total Exploratory Wells | Exploratory Wells Resulting In | | |
|---|---|---|---|---|
| | | Gas Completions | Oil Completions | Dry Holes |
| 1950 | 1,013 | 10 | 179 | 824 |
| 1951 | 1,077 | 28 | 208 | 841 |
| 1952 | 1,440 | 45 | 234 | 1,161 |
| 1953 | 1,343 | 44 | 187 | 1,112 |
| 1954 | 1,340 | 61 | 258 | 1,021 |
| 1955 | 1,389 | 74 | 234 | 1,081 |
| 1956 | 1,903 | 143 | 312 | 1,448 |
| 1957 | 1,760 | 165 | 314 | 1,281 |
| 1958 | 1,819 | 143 | 289 | 1,387 |
| 1959 | 1,754 | 172 | 308 | 1,274 |
| 1960 | 1,402 | 155 | 224 | 1,023 |
| 1961 | 1,566 | 150 | 297 | 1,119 |
| 1962 | 1,420 | 120 | 259 | 1,041 |
| 1963 | 1,401 | 117 | 309 | 975 |
| Totals | 20,627 | 1,427 | 3,612 | 15,588 |

SOURCE: Oil Scouts Yearbooks

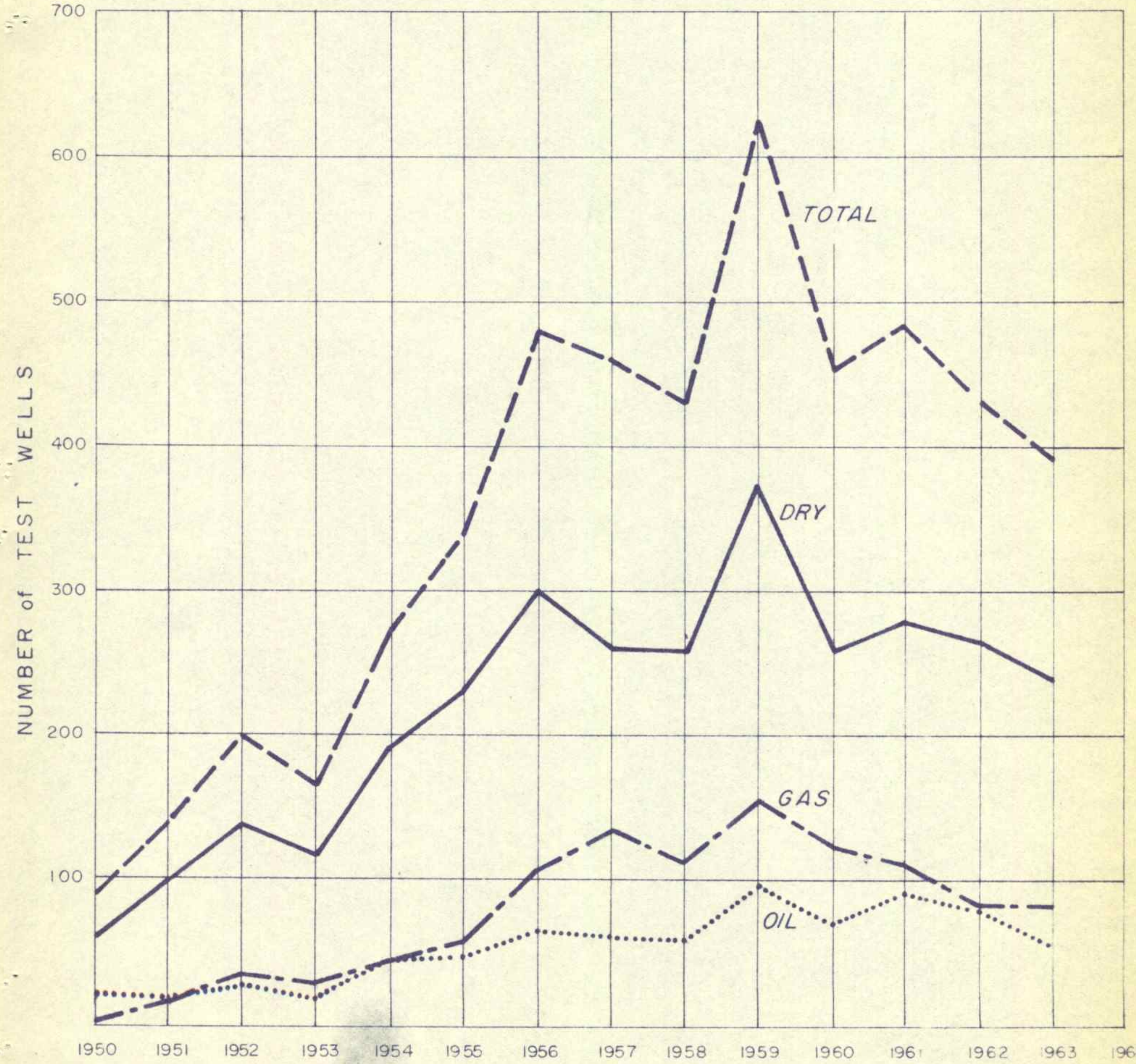
Docket No. AR 64-1, et al
Exhibit BWB Schedule 3
Witness: B. W. Beebe

# EXPLORATORY WELLS DRILLED

# ANADARKO - DALHART BASINS

## 1950 - 1963

(INCLUDES OWWO)




Source – Oil Scouts Yearbooks

Docket AR 64 - 1 et al

Exhibit BWB Graph 4

Witness B. W. Beebe

EXPLORATORY WELLS DRILLED
* ANADARKO-DALHART BASINS 1950-1963
(Includes OWWO)

| Year | Total Exploratory Wells | Exploratory Wells Resulting In | | |
|---|---|---|---|---|
| | | Gas Completions | Oil Completions | Dry Holes |
| 1950 | 90 | 6 | 23 | 61 |
| 1951 | 140 | 18 | 21 | 101 |
| 1952 | 197 | 35 | 26 | 136 |
| 1953 | 166 | 30 | 17 | 119 |
| 1954 | 273 | 45 | 45 | 183 |
| 1955 | 341 | 59 | 48 | 234 |
| 1956 | 478 | 110 | 66 | 302 |
| 1957 | 459 | 136 | 62 | 261 |
| 1958 | 432 | 115 | 60 | 257 |
| 1959 | 626 | 157 | 96 | 373 |
| 1960 | 454 | 125 | 71 | 258 |
| 1961 | 484 | 116 | 89 | 279 |
| 1962 | 430 | 83 | 80 | 267 |
| 1963 | 383 | 84 | 57 | 242 |
| Totals | 4,953 | 1,119 | 761 | 3,073 |

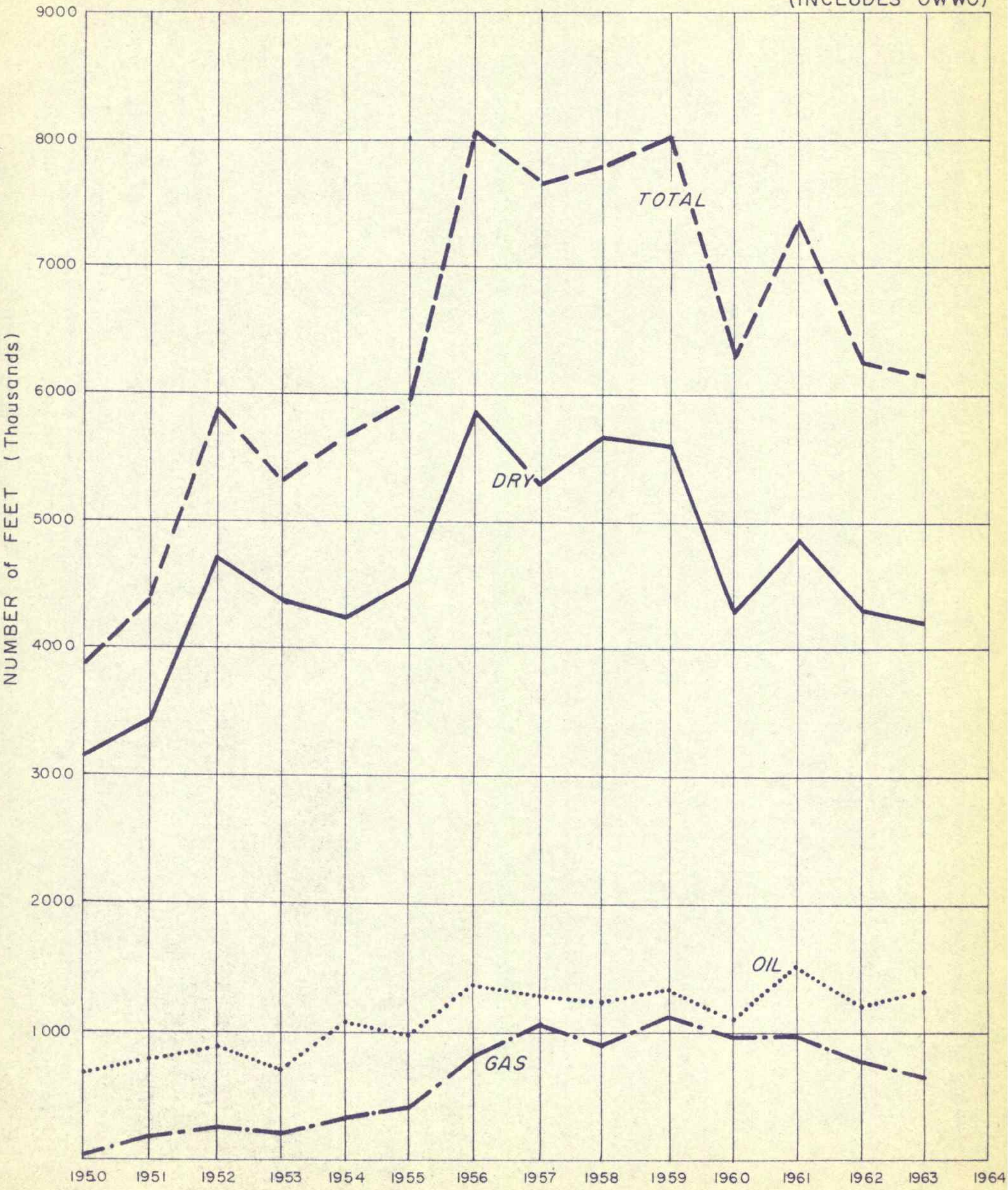
* Anadarko-Dalhart Basin Area consists of the following counties in the Hugoton-Anadarko area:
KANSAS: Barber, Clark, Comanche, Edwards, Finney, Ford, Grant, Gray, Greeley, Hamilton, Haskell, Kearny, Kiowa, Meade, Morton, Scott, Seward, Stanton, Stevens, and Wichita.
OKLAHOMA: Alfalfa, Beaver, Beckham, Blaine, Caddo, Canadian, Cimarron, Custer, Dewey, Ellis, Grady, Grant, Harper, Major, Roger Mills, Stephens (T2N-Rgs 4 & 5W), Texas, Washita, Woods, and Woodward.
TEXAS: Carson, Dallam, Gray, Hansford, Hartley, Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Roberts, Sherman, and Wheeler.

SOURCE: Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Schedule 4
Witness: B. W. Beebe

# EXPLORATORY FOOTAGE
# HUGOTON-ANADARKO AREA
# 1950-1963

(INCLUDES OWWO)




Source - Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Graph 5
Witness B. W. Beebe

EXPLORATORY FOOTAGE
HUGOTON-ANADARKO AREA 1950-1963
(Includes OWWO)
(Figures to nearest hundred)

| Year | Total Exploratory Footage | Exploratory Footage Resulting In | | |
|---|---|---|---|---|
| | | Gas Completions | Oil Completions | Dry Holes |
| 1950 | 3,881,500 | 36,400 | 682,200 | 3,162,900 |
| 1951 | 4,384,300 | 170,300 | 781,800 | 3,432,200 |
| 1952 | 5,889,800 | 263,700 | 893,500 | 4,732,600 |
| 1953 | 5,334,100 | 229,800 | 729,900 | 4,374,400 |
| 1954 | 5,667,100 | 344,300 | 1,077,000 | 4,245,800 |
| 1955 | 5,948,600 | 427,600 | 982,200 | 4,538,800 |
| 1956 | 8,066,100 | 820,800 | 1,369,100 | 5,876,200 |
| 1957 | 7.647,400 | 1,057,500 | 1,274,400 | 5,315,500 |
| 1958 | 7,776,300 | 890,900 | 1,229,700 | 5,655,700 |
| 1959 | 8,028,000 | 1,120,900 | 1,321,500 | 5,585,600 |
| 1960 | 6,278,500 | 968,400 | 1,019,500 | 4,290,600 |
| 1961 | 7,351,500 | 972,500 | 1,512,400 | 4,866,600 |
| 1962 | 6,244,700 | 767,300 | 1,180,900 | 4,296,500 |
| 1963 | 6,142,000 | 645,300 | 1,309,800 | 4,186,900 |
| Totals | 88,639,900 | 8,715,700 | 15,363,900 | 64,560,300 |

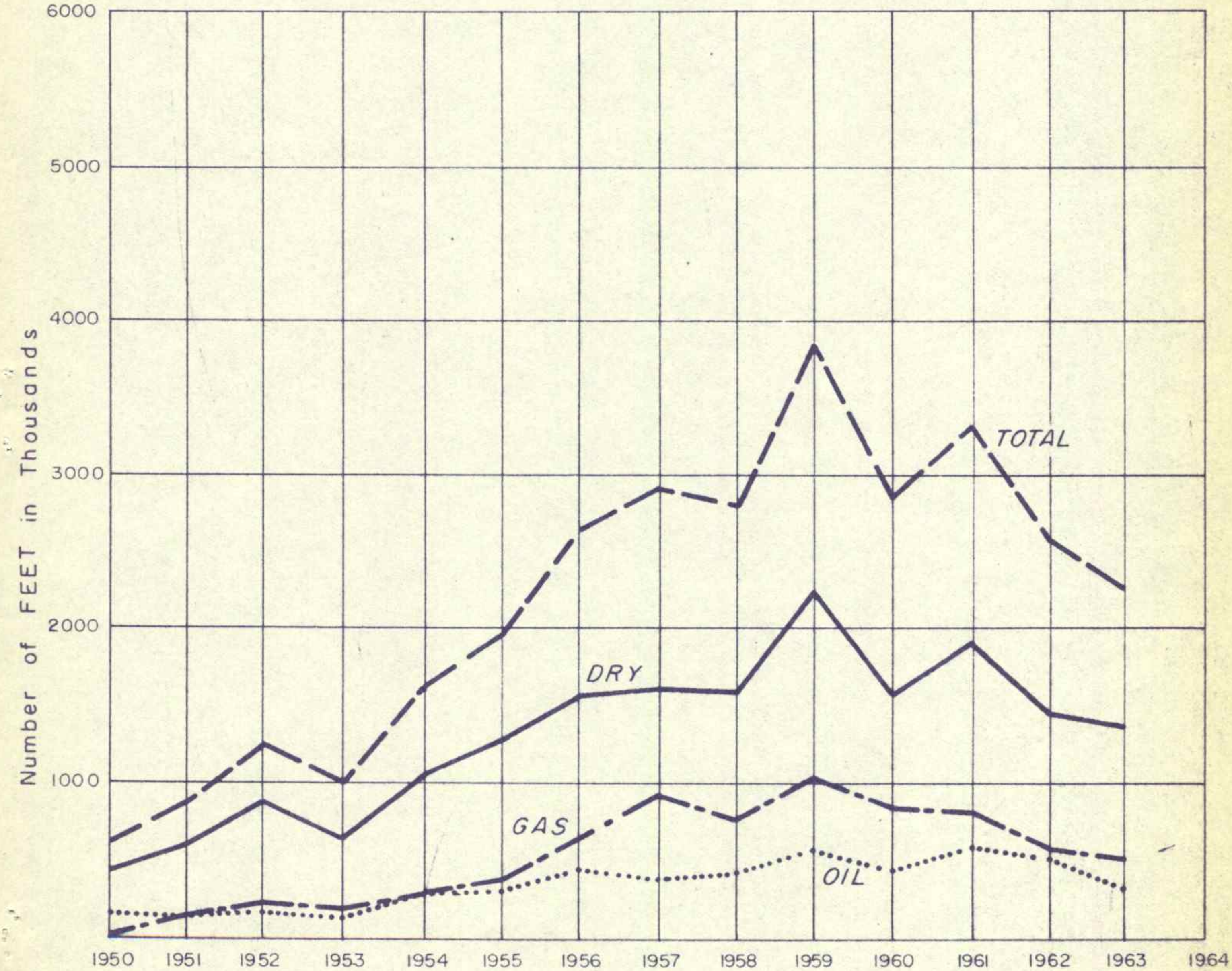
SOURCE: Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Schedule 5
Witness: B. W. Beebe

# EXPLORATORY FOOTAGE

# ANADARKO - DALHART BASINS
# 1950 – 1963

(INCLUDES OWWO)




Source - Oil Scouts Yearbooks

Docket No. 64-1 et al
Exhibit BWB Graph 6
Witness B.W. Beebe

EXPLORATORY FOOTAGE
ANADARKO-DALHART BASINS 1950-1963
(Includes OWWO)
(Figures to nearest hundred)

| Year | Total Exploratory Footage | Exploratory Footage Resulting In: Gas Completions | Oil Completions | Dry Holes |
|---|---|---|---|---|
| 1950 | 601,100 | 20,000 | 141,300 | 439,800 |
| 1951 | 875,700 | 130,200 | 128,500 | 617,000 |
| 1952 | 1,252,400 | 226,000 | 151,100 | 875,300 |
| 1953 | 1,037,000 | 177,900 | 105,300 | 753,800 |
| 1954 | 1,643,800 | 279,400 | 290,400 | 1,074,000 |
| 1955 | 1,978,100 | 362,000 | 311,400 | 1,304,700 |
| 1956 | 2,658,200 | 648,000 | 440,200 | 1,570,000 |
| 1957 | 2,926,700 | 927,900 | 380,200 | 1,618,600 |
| 1958 | 2,811,300 | 792,000 | 418,300 | 1,601,000 |
| 1959 | 3,885,700 | 1,055,000 | 575,000 | 2,255,700 |
| 1960 | 2,867,900 | 848,200 | 458,500 | 1,561,200 |
| 1961 | 3,332,200 | 818,500 | 596,400 | 1,917,300 |
| 1962 | 2,596,700 | 596,200 | 524,800 | 1,475,700 |
| 1963 | 2,264,300 | 539,100 | 329,700 | 1,395,500 |
| Totals | 30,731,100 | 7,420,400 | 4,851,100 | 18,459,600 |

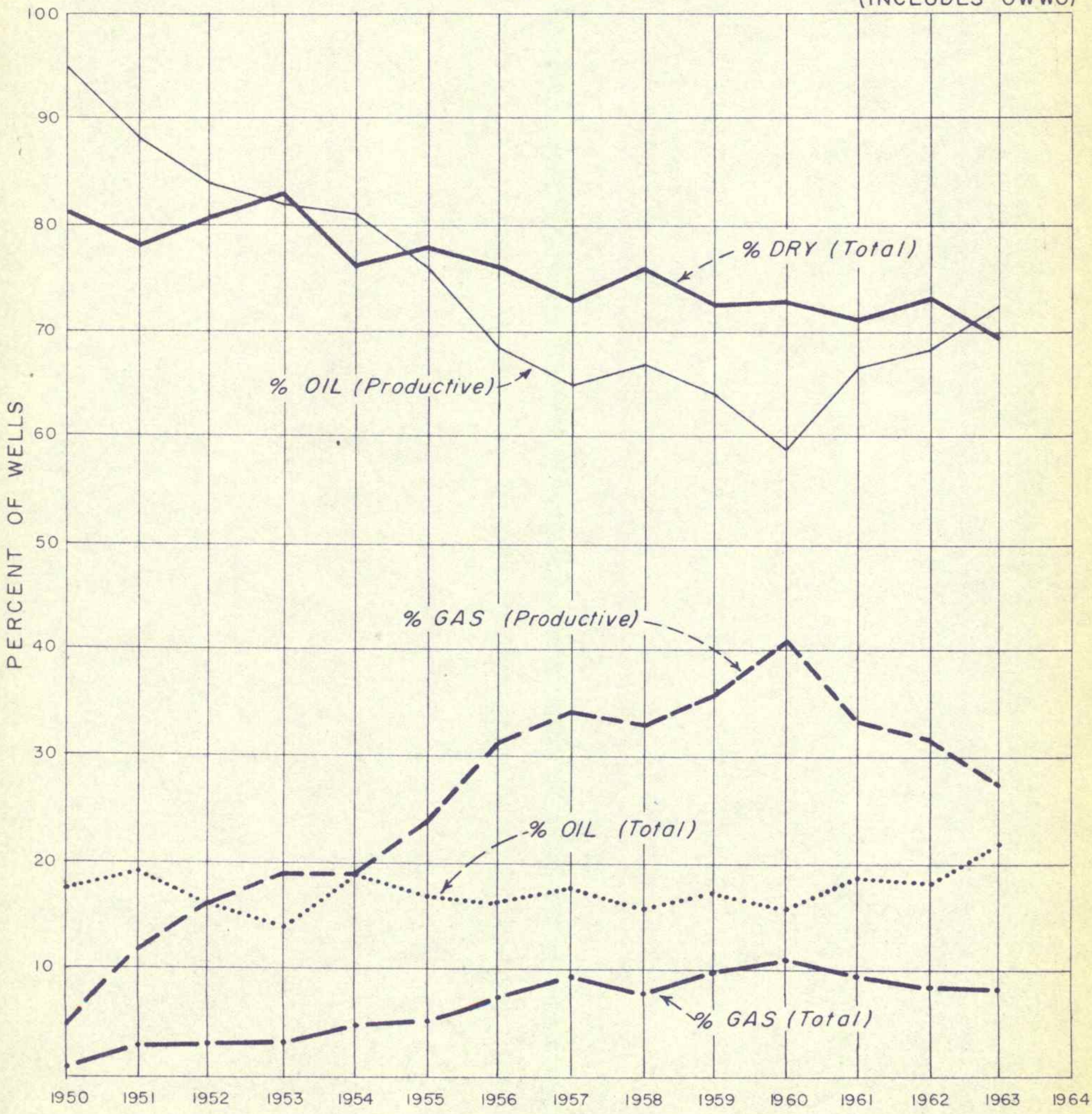
SOURCE: Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Schedule 6
Witness: B. W. Beebe

# COMPARISON IN PERCENTAGES OF RESULTS OF EXPLORATORY DRILLING WITH DIVISION OF SUCCESSFUL WELLS

# HUGOTON-ANADARKO AREA 1950-1963

(INCLUDES OWWO)




Source - Oil Scouts Yearbooks

Docket AR 64-1, et al

Exhibit BWB Graph 7

Witness B. W. Beebe

COMPARISON IN PERCENTAGES OF RESULTS OF EXPLORATORY

DRILLING WITH DIVISION OF SUCCESSFUL WELLS

HUGOTON-ANADARKO AREA

| | Results of Exploratory Drilling | | | Division of Successful Wells | |
|---|---|---|---|---|---|
| Year | Gas | Oil | Dry | Gas | Oil |
| 1950 | 1.0% | 17.7% | 81.3% | 5.3% | 94.7% |
| 1951 | 2.6% | 19.3% | 78.1% | 11.9% | 88.1% |
| 1952 | 3.1% | 16.3% | 80.6% | 16.1% | 83.9% |
| 1953 | 3.3% | 13.9% | 82.8% | 19.0% | 81.9% |
| 1954 | 4.5% | 19.3% | 76.2% | 19.0% | 81.0% |
| 1955 | 5.4% | 16.8% | 77.8% | 24.0% | 76.0% |
| 1956 | 7.5% | 16.4% | 76.1% | 31.4% | 68.6% |
| 1957 | 9.4% | 17.8% | 72.8% | 34.4% | 65.6% |
| 1958 | 7.9% | 15.9% | 76.2% | 33.1% | 66.9% |
| 1959 | 9.8% | 17.6% | 72.6% | 35.8% | 64.2% |
| 1960 | 11.0% | 16.0% | 73.0% | 40.9% | 59.1% |
| 1961 | 9.6% | 19.0% | 71.4% | 33.6% | 66.4% |
| 1962 | 8.5% | 18.2% | 73.3% | 31.7% | 68.3% |
| 1963 | 8.3% | 22.1% | 69.6% | 27.5% | 72.5% |

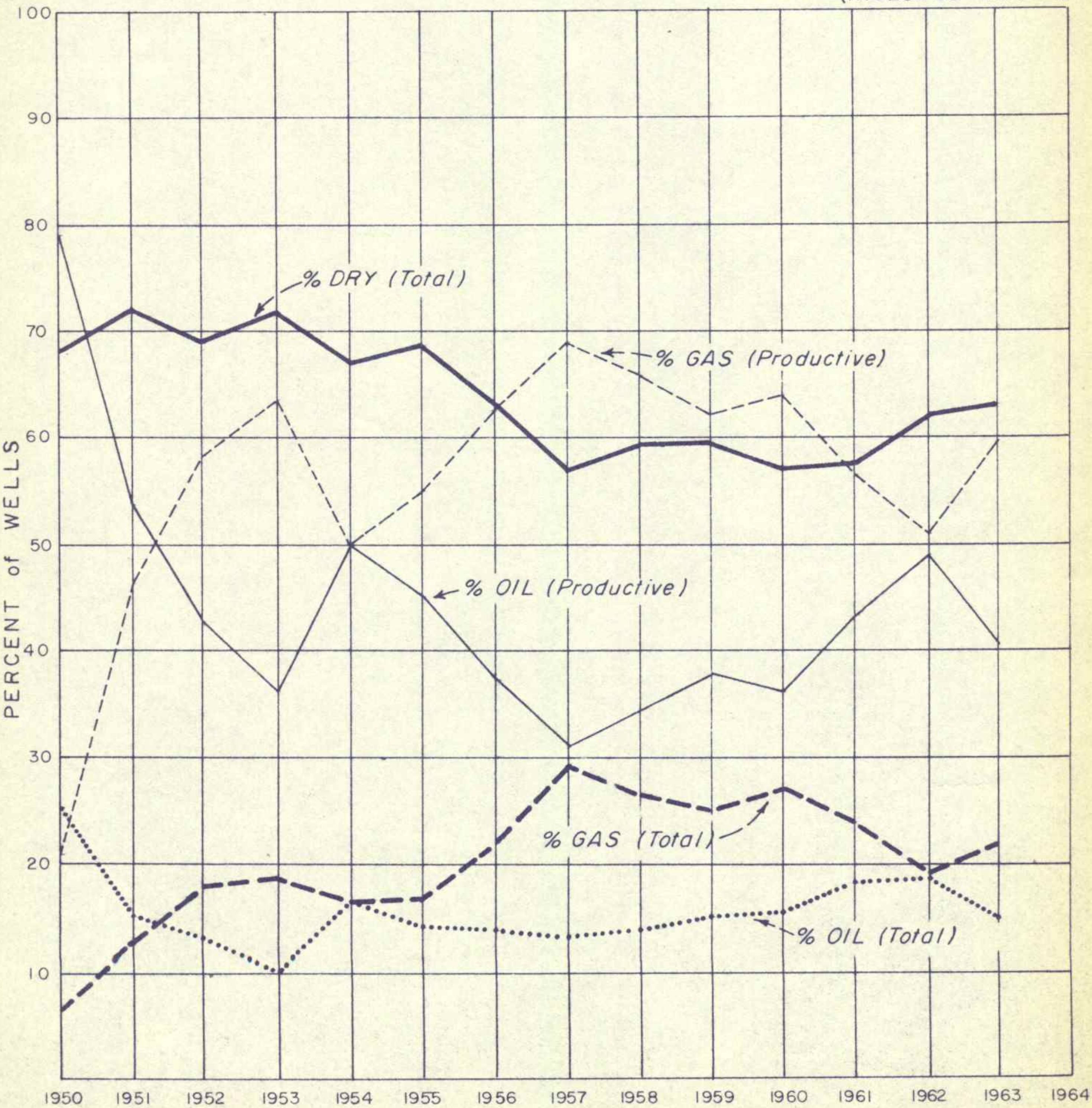
SOURCE: International Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Schedule 7
Witness: B. W. Beebe

# COMPARISON IN PERCENTAGES OF RESULTS OF EXPLORATORY DRILLING WITH DIVISION OF SUCCESSFUL WELLS

# ANADARKO-DALHART BASINS 1950-1963

(INCLUDES OWWOs)




Source - Oil Scouts Yearbooks

Docket AR 64 - I, et al

Exhibit BWB Graph 8

Witness B.W. Beebe

COMPARISON IN PERCENTAGES OF RESULTS OF EXPLORATORY

DRILLING WITH DIVISION OF SUCCESSFUL WELLS
ANADARKO=DALHART BASINS
(Includes OWWO)

| | Results of Exploratory Drilling | | | Division of Successful Wells | |
|---|---|---|---|---|---|
| Year | Gas | Oil | Dry | Gas | Oil |
| 1950 | 6.7% | 25.5% | 67.8% | 20.7% | 79.3% |
| 1951 | 12.9% | 15.0% | 72.1% | 46.2% | 53.8% |
| 1952 | 18.1% | 13.2% | 69.0% | 58.4% | 42.6% |
| 1953 | 18.7% | 10.2% | 71.7% | 63.8% | 36.2% |
| 1954 | 16.5% | 16.5% | 67.0% | 50.0% | 50.0% |
| 1955 | 16.7% | 14.1% | 68.6% | 55.1% | 44.9% |
| 1956 | 22.3% | 13.8% | 63.2% | 62.5% | 37.5% |
| 1957 | 29.5% | 13.5% | 56.9% | 68.7% | 31.3% |
| 1958 | 26.6% | 13.9% | 59.5% | 65.7% | 34.3% |
| 1959 | 25.1% | 15.3% | 59.6% | 62.1% | 37.9% |
| 1960 | 27.5% | 15.7% | 56.8% | 63.8% | 36.2% |
| 1961 | 23.9% | 18.4% | 57.7% | 56.6% | 43.4% |
| 1962 | 19.3% | 18.6% | 62.1% | 50.9% | 49.1% |
| 1963 | 21.9% | 14.9% | 63.2% | 59.6% | 40.4% |

SOURCE: International Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Schedule 8
Witness: B. W. Beebe

COMPARISON IN PERCENTAGE OF RESULTS OF EXPLORATORY
DRILLING FOOTAGE WITH DIVISION OF SUCCESSFUL WELL FOOTAGE
HUGOTON-ANADARKO AREA
(Includes OWWO)

| | Results of Exploratory Drilling Footage | | | Division of Successful Well Footage | |
|---|---|---|---|---|---|
| Year | Gas | Oil | Dry | Gas | Oil |
| 1950 | .9% | 17.6% | 81.5% | 5.1% | 94.9% |
| 1951 | 3.9% | 17.8% | 78.3% | 17.9% | 82.1% |
| 1952 | 4.5% | 15.1% | 80.4% | 22.8% | 77.2% |
| 1953 | 4.3% | 13.7% | 82.0% | 23.9% | 76.1% |
| 1954 | 6.1% | 19.0% | 74.9% | 24.2% | 75.8% |
| 1955 | 7.2% | 16.5% | 76.3% | 30.3% | 69.7% |
| 1956 | 10.2% | 17.0% | 72.8% | 37.5% | 62.5% |
| 1957 | 13.8% | 16.7% | 69.5% | 45.3% | 54.7% |
| 1958 | 11.5% | 15.8% | 72.7% | 42.0% | 58.0% |
| 1959 | 14.0% | 16.5% | 69.5% | 45.9% | 54.1% |
| 1960 | 15.4% | 16.3% | 68.3% | 48.7% | 51.3% |
| 1961 | 13.2% | 20.6% | 66.2% | 39.1% | 60.9% |
| 1962 | 12.2% | 18.9% | 68.9% | 39.4% | 60.6% |
| 1963 | 10.5% | 21.3% | 68.2% | 33.0% | 67.0% |

SOURCE: International Oil Scouts Yearbooks

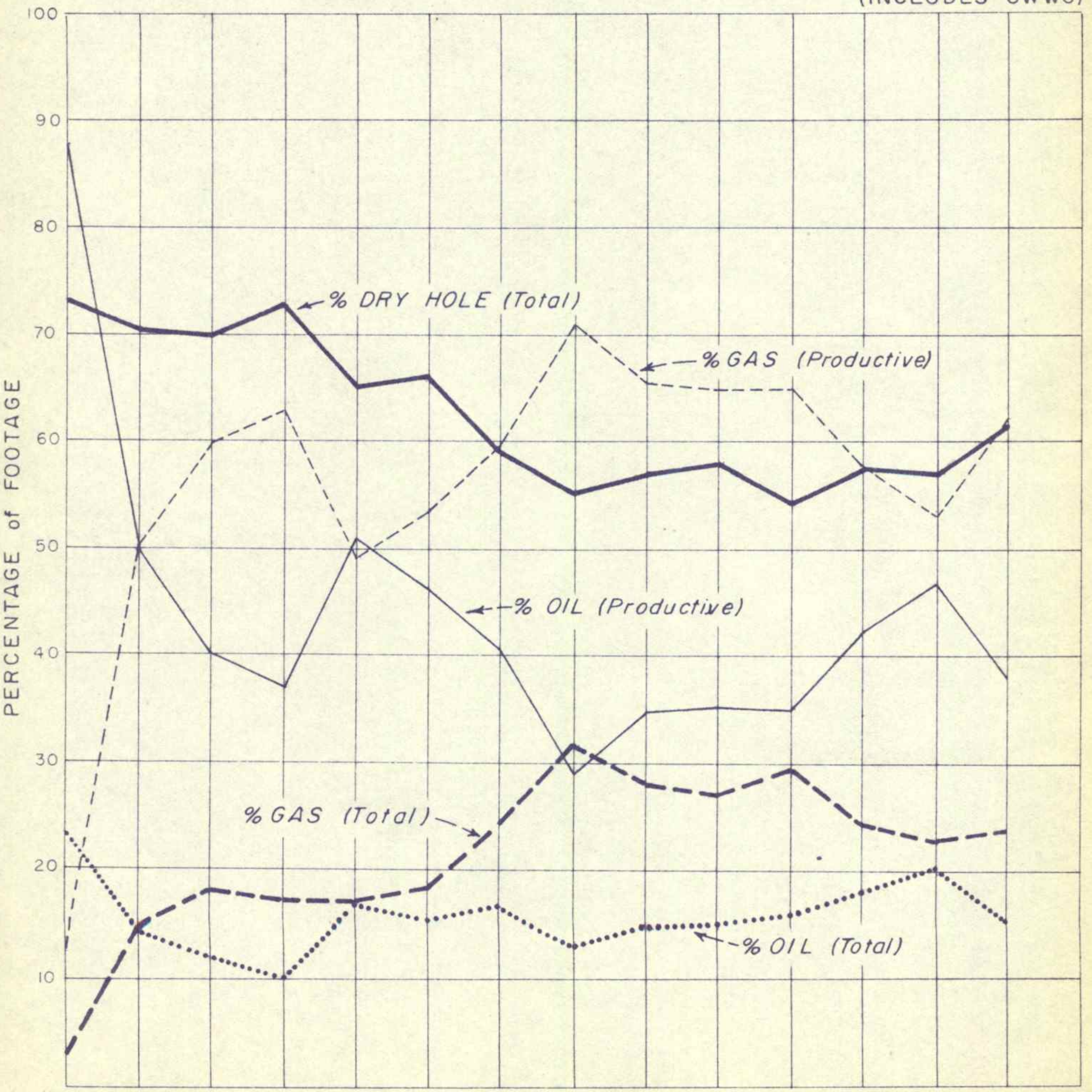
Docket No. AR 64-1, et al
Exhibit BWB Schedule 9
Witness: B. W. Beebe

# COMPARISON IN PERCENTAGES OF RESULTS of EXPLORATORY DRILLING FOOTAGE WITH DIVISION of SUCCESSFUL WELL FOOTAGE

## ANADARKO-DALHART BASINS

## 1950-1963

(INCLUDES OWWO)




Source - Oil Scouts Yearbooks

Docket AR 64-1, et al
Exhibit BWB Graph 10
Witness B. W. Beebe

COMPARISON IN PERCENTAGE OF RESULTS OF EXPLORATORY
DRILLING FOOTAGE WITH DIVISION OF SUCCESSFUL WELL FOOTAGE
ANADARKO-DALHART BASINS
(Includes OWWO)

| | Results of Exploratory Drilling Footage | | | Division of Successful Well Footage | |
|---|---|---|---|---|---|
| Year | Gas | Oil | Dry | Gas | Oil |
| 1950 | 3.3% | 23.5% | 73.2% | 12.4% | 87.6% |
| 1951 | 14.9% | 14.7% | 70.4% | 50.3% | 49.7% |
| 1952 | 18.0% | 12.1% | 69.9% | 59.9% | 40.1% |
| 1953 | 17.2% | 10.1% | 72.7% | 62.8% | 37.2% |
| 1954 | 17.0% | 17.7% | 65.3% | 49.0% | 51.0% |
| 1955 | 18.3% | 15.7% | 66.0% | 53.8% | 46.2% |
| 1956 | 24.4% | 16.6% | 59.0% | 59.5% | 40.5% |
| 1957 | 31.7% | 13.0% | 55.3% | 70.9% | 29.1% |
| 1958 | 28.2% | 14.9% | 56.9% | 65.4% | 34.6% |
| 1959 | 27.2% | 14.8% | 58.0% | 64.7% | 35.3% |
| 1960 | 29.6% | 16.0% | 54.4% | 64.9% | 35.1% |
| 1961 | 24.6% | 17.9% | 57.5% | 57.8% | 42.2% |
| 1962 | 22.9% | 20.2% | 56.9% | 53.2% | 46.8% |
| 1963 | 23.8% | 14.6% | 61.6% | 62.1% | 37.9% |

SOURCE: International Oil Scouts Yearbooks

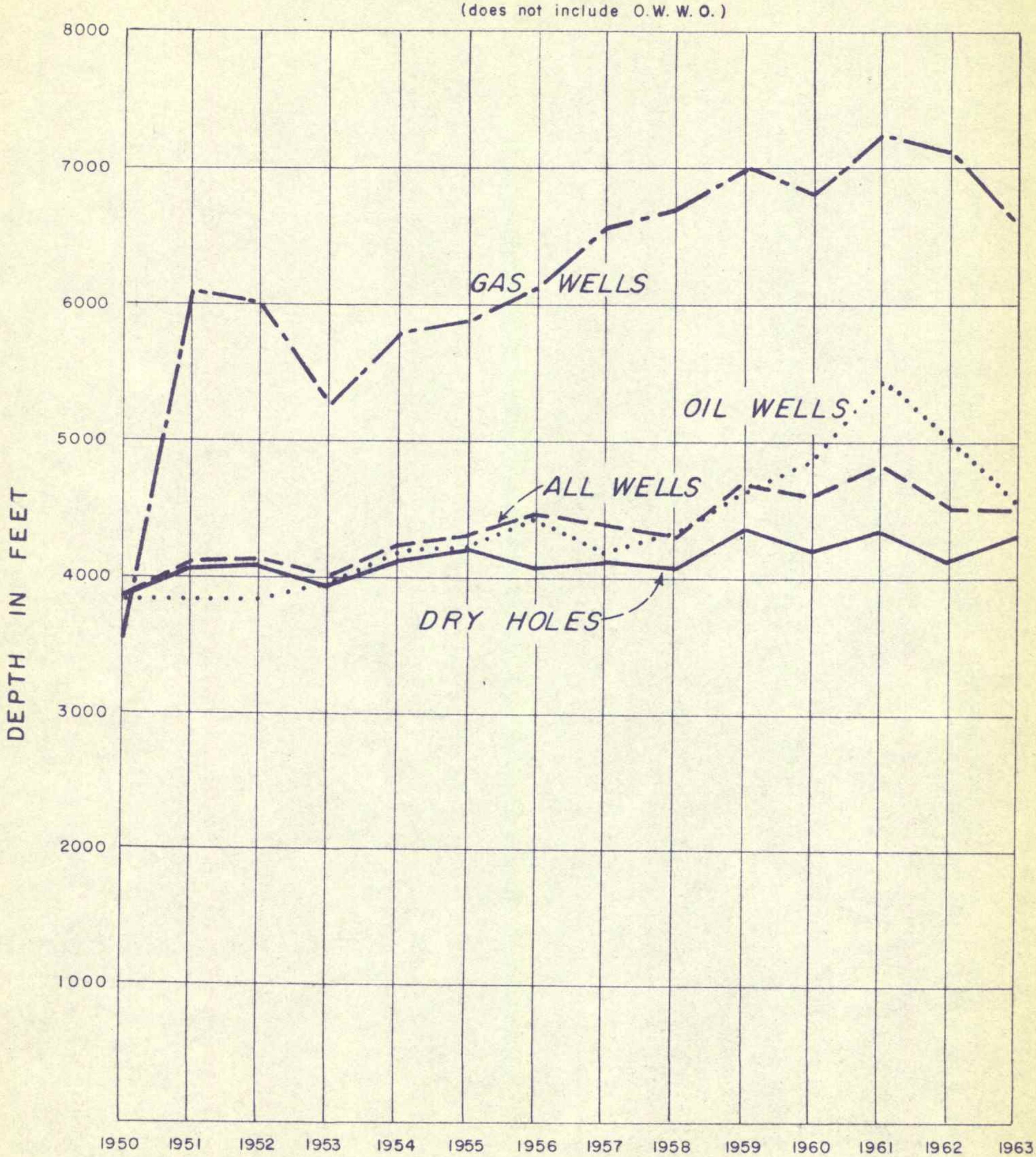
Docket No. AR 64-1, et al
Exhibit BWB Schedule 10
Witness: B. W. Beebe

AVERAGE DEPTH OF EXPLORATORY WELLS

# HUGOTON-ANADARKO AREA

## 1950 - 1963

(does not include O.W.W.O.)




Source: Oil Scouts Yearbooks

Docket No. AR 64-1 et al

Exhibit BWB Graph 11

Witness: B.W. Beebe

AVERAGE DEPTHS OF EXPLORATORY WELLS
HUGOTON-ANADARKO AREA 1950-1963
(Does not include OWWO)

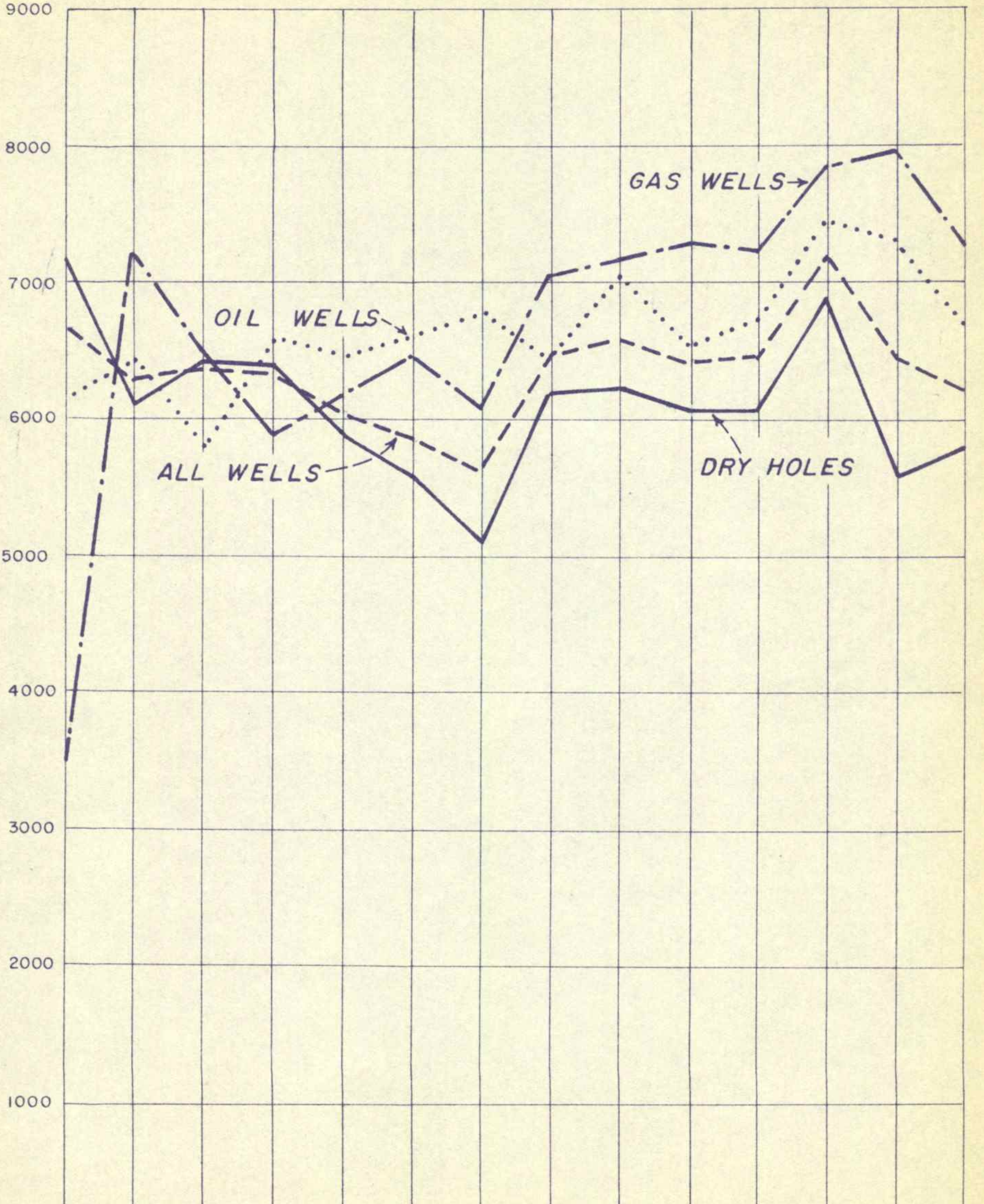
| Year | Total Exploratory Wells | Gas Completions | Oil Completions | Dry Holes |
|---|---|---|---|---|
| 1950 | 3,831 | 3,640 | 3,811 | 3,838 |
| 1951 | 4,082 | 6,082 | 3,814 | 4,081 |
| 1952 | 4,099 | 5,993 | 3,835 | 4,080 |
| 1953 | 3,980 | 5,223 | 3,945 | 3,937 |
| 1954 | 4,236 | 5,738 | 4,191 | 4,158 |
| 1955 | 4,292 | 5,858 | 4,215 | 4,203 |
| 1956 | 4,459 | 6,125 | 4,445 | 4,058 |
| 1957 | 4,378 | 6,592 | 4,178 | 4,149 |
| 1958 | 4,318 | 6,689 | 4,321 | 4,089 |
| 1959 | 4,673 | 7,003 | 4,637 | 4,388 |
| 1960 | 4,574 | 6,805 | 4,876 | 4,202 |
| 1961 | 4,820 | 7,257 | 5,475 | 4,365 |
| 1962 | 4,518 | 7,122 | 5,004 | 4,139 |
| 1963 | 4,517 | 6,571 | 4,541 | 4,303 |

SOURCE: Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Schedule 11
Witness: B. W. Beebe

# AVERAGE DEPTH EXPLORATORY WELLS
# ANADARKO-DALHART BASINS
# 1950-1963

(does not include O. W. W. O.)




Source: Oil Scouts Yearbooks

Docket No. AR 64-1 et al
Exhibit BWB Graph 12
Witness B.W. Beebe

AVERAGE DEPTHS OF EXPLORATORY WELLS
ANADARKO-DALHART BASINS 1950-1963
(Does not include OWWO)

| Year | Total Exploratory Wells | Gas Completions | Oil Completions | Dry Holes |
|---|---|---|---|---|
| 1950 | 6,679 | 3,333 | 6,143 | 7,209 |
| 1951 | 6,300 | 7,233 | 6,425 | 6,109 |
| 1952 | 6,357 | 6,457 | 5,811 | 6,436 |
| 1953 | 6,334 | 5,900 | 6,581 | 6,404 |
| 1954 | 6,021 | 6,209 | 6,453 | 5,869 |
| 1955 | 5,887 | 6,464 | 6,625 | 5,599 |
| 1956 | 5,620 | 6,113 | 6,772 | 5,119 |
| 1957 | 6,493 | 7,060 | 6,444 | 6,202 |
| 1958 | 6,591 | 7,189 | 7,051 | 6,230 |
| 1959 | 6,442 | 7,273 | 6,534 | 6,064 |
| 1960 | 6,484 | 7,232 | 6,743 | 6,075 |
| 1961 | 7,213 | 7,870 | 7,455 | 6,897 |
| 1962 | 6,479 | 7,949 | 7,318 | 5,585 |
| 1963 | 6,214 | 7,268 | 6,735 | 5,791 |

SOURCE: Oil Scouts Yearbooks

Docket No. AR 64-1, et al
Exhibit BWB Schedule 12
Witness: B. W. Beebe