FACTORS AFFECTING U. S. EXPLORATION, DEVELOPMENT AND PRODUCTION 1946–1965

A Report of the
National Petroleum Council

1967

FACTORS AFFECTING U. S. EXPLORATION, DEVELOPMENT AND PRODUCTION 1946–1965

JANUARY 31, 1967

A Report of the
National Petroleum Council
Committee on Factors Affecting
U. S. Exploration, Development and Production 1946–1965

Richard J. Gonzalez, Chairman

NATIONAL PETROLEUM COUNCIL

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January 20, 1967

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Mr. J. C. Donnell II, Chairman
National Petroleum Council
1625 K Street, N. W.
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Dear Mr. Donnell:

On July 18, 1966, Assistant Secretary of the Interior, J. Cordell Moore, addressed a letter to the Chairman of the National Petroleum Council describing a study of the petroleum industry being made by the Department of the Interior and asking for the assistance of the Council in analyzing factors that had affected exploration, development, and production in the United States in the twenty-year period following the end of World War II. This letter defined the scope of the study as follows:

> "It is requested therefore that the Council undertake a study of the petroleum industry exploratory and developmental activities and recovery practices in the United States during the period 1945-65. This study should reveal national and regional trends in: geological/geophysical activity, drilling, secondary recovery, the accumulation of proved reserves and the growth of productive capacity. To the extent practicable, the study may include any comments the Council cares to make on the economic and technological factors which influenced the levels of exploratory and developmental activity, the choice of geographic areas for operations, the relative emphasis on development and stimulated recovery versus exploration for new fields."

In accordance with the recommendation of the Agenda Committee on this request, a Committee on Factors Affecting U. S. Exploration, Development, and Production, 1945-1965, was appointed to make the study. The results of the studies by the Committee are presented in this report. The major points brought out by the study are summarized in the first Part of the report and discussed in greater detail in Part II dealing with Geological and Technological Factors, and Part III dealing with Economic and Policy Factors.

Respectfully submitted,

Richard J. Gonzalez

Richard J. Gonzalez, Chairman
NPC Committee on Factors Affecting
U. S. Exploration, Development,
and Production, 1945-1965

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P A R T I

INTRODUCTION, SUMMARY

AND

CONCLUSION

P A R T I

INTRODUCTION, SUMMARY AND CONCLUSION

A. I N T R O D U C T I O N

A brief look at the record of the petroleum industry of the United States through 1945, of its position at the end of World War II, and of what happened in the twenty-year period ending with 1965 will help provide perspective for the subsequent analysis of factors affecting operations since World War II.

From the discovery of oil in Pennsylvania in 1859 through 1945, cumulative oil production amounted to 31.5 billion barrels of crude oil. At the end of 1945, estimated proved reserves were 23 billion barrels of crude oil and gas liquids and 147 trillion cubic feet of natural gas.

In the twenty-year period 1946-1965, petroleum production in the United States amounted to 53 billion barrels of liquids and about 205 trillion cubic feet of natural gas, or far more than in the previous history of eighty-six years through 1945. Development of new resources not only offset production but also added to known reserves. At the end of 1965, estimated proved reserves were 39.4 billion barrels of liquids and 286.5 trillion cubic feet of gas, representing gains of about 71 percent and 95 percent, respectively, over the levels of 1945.

Production increased between 1945 and 1965 by about 75 percent for petroleum liquids and 260 percent for natural gas. The relation of reserves to annual production remained relatively constant at about 12 to 1 for liquids, but decreased for natural gas from over 30 to 1 down to about 18 to 1.

The preceding summary of achievements in the past twenty years is sufficiently impressive to suggest that there would be little need to undertake an analysis of the factors affecting exploration, development, and production if operations had moved steadily upward. The main reason for study of the postwar period is that the pattern of exploration and development changed significantly after 1956.

Discussion about the decline in operations has centered on the change in wells drilled since the peak in 1956. This change must be evaluated in the light of the previous sharp rise in well completions. In addition, consideration must also be given to the pattern of expenditures and the relation of reserves and productive capacity to demand.

In the period 1945-1956 expenditures for exploration and development tripled to about five billion dollars annually. Well completions and crude oil productive capacity doubled. Demand, reserves, and production of petroleum liquids increased by 60-70 percent in this same period, and imports advanced 300 percent and accounted for 27 percent of the gain in total supply. As a result, unused productive capacity for crude oil increased steadily.

The rate of expansion in the period up to 1956 overshot the requirements of the market for the time being. Consequently, the stage was set for a period of readjustment.

The number of exploratory and development wells drilled in the United States decreased from a peak in 1956 of about 57,000, excluding service wells, to about 39,500 in 1965 and about 36,000 in 1966. Despite this decline, productive capacity and proved reserves continued to increase. However, the rate of annual additions to proved reserves in the five-year period ending with 1965 dropped to less than one percent for petroleum liquids and less than two percent for natural gas, both of which rates were exceeded by the gains in demand and production.

Estimated expenditures for petroleum exploration and development in the United States declined by about 18 percent from 1956 to 1965, considerably less than the decline of 31 percent in number of wells drilled.

In analyzing these fluctuations in petroleum exploration and drilling, it is well to keep in mind that the erratic nature of discoveries makes it difficult and unusual for development of new capacity to be geared closely to growth in demand. Obvious fluctuations in rate of development of new resources throughout the history of the industry emphasize the importance of analyzing the causes of changes in operations as a means of improving understanding of what has happened and what the significance of past developments may be for the future.

Many factors have affected the rate of petroleum exploration, development, and production in the period 1946-1965. They can be classified principally as geological and technological factors reviewed in Part II, and economic and policy factors reviewed in Part III.

The various factors affecting petroleum operations are so interrelated that their influence cannot be measured separately in most cases. Economic conditions often serve to stimulate technology and policy changes. Similarly, technology and policies influence costs and prices.

From the detailed analysis presented in Part II and Part III, the following major factors affecting petroleum exploration, development, and production have been selected for brief comment in this section of the report to provide a general picture as background for study of the details.

B. SUMMARY OF MAJOR FACTORS

Developments in the years right after 1945 reflected an initial reaction from wartime controls. Shortages of materials and manpower, rationing, and price controls during World War II depressed exploration and drilling in the period 1942-1945 and contributed to the postwar boom. Average annual drilling of oil wells dropped from 19,500 in 1940-1941 to 9,000 in 1942-1943 and recovered partially to 13,500 in 1944-1945. Rising demand and the disappearance of unused capacity by 1945 would normally have meant an increase in drilling. Fields found just before and during the shortage of steel were limited by government controls to development on much wider spacing than customary at the time. After World War II, as materials became available, many wells were drilled that would normally have been drilled in the period 1942-1945.

Other geological, technological, economic, and policy factors that affected operations in the period 1946-1965 are set forth below.

GEOLOGICAL FACTORS

1. Decrease in Geological Opportunities in Well Explored Areas

As drilling progressed in the postwar era, many new prospects were found and proved productive, thereby reducing to some extent the remaining opportunities to make profitable discoveries. In Texas, Louisiana, New Mexico, and Wyoming, the number of oil wells drilled in 1946-1965 substantially exceeded their prior completions up to 1945. In California and Kansas, oil wells drilled in the twenty-year period were within 15 percent of their total prior completions. In Illinois and Oklahoma, oil wells drilled in 1946-1965 exceeded 50 percent of their prior total. For these eight states, which accounted for more than 80 percent of the wells drilled in 1946-1965, oil well completions were within eight percent of their prior completions through 1945. In some of the older areas where prospects had already been thoroughly tested by 1945, such as the Appalachian states, drilling was much less than in the period up to 1945 because of limited new opportunities.

Drilling of wells by areas has varied depending on evaluation as to the relative attractiveness of prospects and on the degree of success in finding new reserves. Wherever significant new discoveries have been made, development drilling has responded promptly.

Intensive prior drilling in an area does not necessarily mean that additional prospects will not be found, but does tend to alter the relation of rewards and risks in a discouraging manner in the absence of new technology, for it is natural that what appear to be the best prospects will be tested first.

2. Changing Nature of Geological Opportunity

Many of the most attractive large prospects for new oil and gas appear to be in deeper horizons and in such new areas as the Continental Shelf and Alaska. Costs per well are much higher for these prospects than for the shallow areas that have been the scene of most of the drilling in the United States in the past. Numerous offshore leases have commanded prices of many million dollars, and in addition the costs of wells offshore and in deep horizons is often ten to twenty times as much as for the average onshore well. The financial requirements of such operations affect the number of operators and the number of wells drilled.

In 1963, there were about 3,000 wells drilled over 10,000 feet deep which cost an average of $280,000 and accounted for 36.4 percent of total drilling expenditures. The average cost of these wells was thirteen times that of wells under 5,000 feet. Offshore wells, most of which are also deeper than 10,000 feet, cost an average of $370,000. The striking differences in costs per well and per foot to different depths reported by the latest Joint Association Survey are shown in the following tabulation.

U. S. Well Completions in 1963

Depth Range, Feet	Total Wells	Total Expenditures (Million $)	Avg.Cost Per Well	Average Depth	Avg.Cost Per Foot
0-5,000	28,524	$ 611.7	$ 21,444	2,503	$ 8.57
5,001-10,000	10,342	$ 852.0	$ 82,380	7,125	$11.56
10,001 and over	2,987	$ 839.2	$280,950	12,133	$23.08
Total	41,853	$2,302.9	$ 55,023	4,336	$12.69

TECHNOLOGICAL FACTORS

3. Introduction of Techniques for Stimulating Production by Fracturing

An important technological development contributing to the rise in drilling and in productive capacity was the introduction of fracturing techniques to stimulate the flow of oil and gas from "tight" formations with low permeability. At the level of prices attained in 1950, the new techniques made feasible development of many shallow formations not commercial up to that time. In effect, this method made available a one-time crop of oil previously known to exist or be highly prospective but uneconomic under prior technology. The effect of this change was most noticeable in North Central Texas (Districts 7B and 9), Oklahoma, Arkansas, and Illinois, areas where most of the wells are shallow and most of the drilling is done by smaller operators. The number of wells, both old and new, to which fracturing was applied increased about 20-fold between 1950 and 1955 to a peak of about 46,000 before dropping back to a level around 25,000 annually for the period 1960-1965. More than half of the fracturing jobs up to 1955 were in the shallow areas listed above.

4. Development of Additional Supplies by Fluid Injection

Additional recovery of oil by injection of water and gas in old fields has been a well known method for many years. It has become particularly important during the period under review in both old and new fields. Estimated production from fields with fluid injection, including thermal methods, increased from 700,000 barrels daily in 1946 to 2,700,000 in 1965. The primary and secondary production provided by such fields is estimated to have increased steadily from 15 percent of total production in 1946 to about 34 percent in 1965.

Since additional recovery involves little exploration or development expense, it is attractive for industry to devote research and effort to methods of raising recovery, particularly if the development of new reserves becomes more difficult and expensive. The impact of such efforts on new development depends on the amount and cost of reserve additions by fluid injection and other methods. Various estimates indicate that the effect of technology on recovery and reserves has been substantial.

ECONOMIC FACTORS

5. Changing Growth in Demand

An unusually rapid rate of growth in demand for oil and gas in the period 1945-1955, principally due to success in capturing a larger share of the energy market from coal, was followed by a slower rate of growth in the following decade, particularly for crude oil, as shown by the following tabulation.

U. S. Energy Consumption

	Quadrillion BTU			Percent of Total			Average Annual Growth Rate %	
	1945	1955	1965	1945	1955	1965	1945-55	1955-65
Crude Oil	9.6	16.3	21.6	30.5	40.8	39.6	5.4	2.8
Gas Liquids	0.5	1.2	1.9	1.5	3.0	3.4	9.1	4.7
Natural Gas	4.0	9.2	16.5	12.6	23.1	30.3	8.7	6.0
Coal	16.0	11.7	12.4	50.7	29.3	22.8	-3.1	0.6
Other	1.5	1.5	2.1	4.7	3.8	3.9	0	3.4
Total	31.6	39.9	54.5	100.0	100.0	100.0	2.5	3.1

The share of total energy supplied by crude oil and gas liquids reached a peak of 45.3 percent in 1959 and declined thereafter slowly but steadily to 43 percent in 1965. This reflects the change in the rate of growth in total demand for petroleum liquids from more than five percent per year in the first decade to less than three percent during the period 1955-1965.

6. Rising Importance of Natural Gas

Natural gas produced by the petroleum industry has been a vigorous competitor with liquid fuels throughout the postwar era. By 1965, gas production in the United States exceeded crude oil in energy supplied to the domestic economy. The changes in the principal components of U. S. petroleum energy supply are summarized below.

Petroleum Energy Supply
(Thousand Barrels Daily)

	1945	1955	1965	Change 1945-55	Change 1955-65
U. S. Crude Oil	4,695	6,807	7,804	+ 2,112	+ 997
Gas Liquids	315	772	1,210	+ 457	+ 438
U. S. Natural Gas*	1,977	4,601	8,039	+ 2,624	+ 3,438
Domestic Supply	6,987	12,180	17,053	+ 5,193	+ 4,873
Imports					
Residual Fuel Oil	86	416	944	+ 330	+ 528
Crude Oil and Other	225	832	1,523	+ 607	+ 691
Total	311	1,248	2,467	+ 937	+ 1,219
Total Supply	7,298	13,428	19,520	+ 6,130	+ 6,092

Natural gas and gas liquids accounted for more than one-half of the gain in petroleum supply in both decades, and ran far ahead of both domestic crude oil and imports in the period 1955-1965.

The increasing importance of natural gas relative to crude oil has considerable significance. The rising proportion of

* Expressed as oil equivalent on an energy basis.

petroleum energy requirements supplied by gas, the lower realization on gas than on oil, and the difference in well spacing between oil and gas wells have had the effect of reducing total drilling of new wells in recent years by comparison with earlier periods when oil was relatively more important.

7. Growth in Unused Crude Oil Productive Capacity

In 1945 and 1948, crude oil production in the United States was essentially at capacity. Thereafter, capacity increased faster than production. Table VII, Part III, shows the growth in unused crude oil capacity according to estimates prepared by Committees of the National Petroleum Council. Other estimates are lower, but all indicate a growth in unused capacity up to 1965, which was reflected by the degree of proration in many important producing areas.

The growth in unused capacity was due to factors affecting the estimated rates at which reserves can be produced, as shown by the following tabulation.

Crude Oil Reserves, Production, and Estimated Capacity
(Billion Barrels)

	Proved Reserves Year End	Annual Production	Annual Rate of Capacity	% of Proved Reserves Prod.	Capacity
1945	19.9	1.70	1.70	8.5	8.5
1956	30.4	2.55	3.60*	8.4	11.8
1965	31.3	2.69	4.42*	8.6	14.1

* Capacity based on NPC estimates as of January 1.

The extent of unused capacity led to restrictions on output which lengthened payout periods for new wells and reduced incentives to make new investments. As a result of substantial increases in crude oil output in 1966, unused capacity now exists only in a few areas, primarily Louisiana and Texas, and in these areas allowables for prorated wells have been increased substantially.

8. Greater Competition from Foreign Petroleum

Until 1948, the United States had been a net exporter of petroleum and products for many years. Thereafter, the rapid development of foreign oil at relatively low cost resulted in a rising net import balance. Petroleum imports exceeded exports by 881,000 barrels daily in 1955 and by 2,281,000 in 1965. There also have been increasing imports of gas to compete with both gas and oil in the United States.

The tabulation in Item 6 above shows that imports of residual fuel oil which supplement declining domestic output of that product increased 858,000 barrels daily from 1945 to 1965. During the same period, other petroleum imports increased 1,298,000. In the first postwar decade, the rise in other imports of 607,000 barrels daily was less than a quarter of the gain in domestic output of liquids, but in the period 1955-1965 the slightly larger rise of 691,000 barrels daily was almost 50 percent of the gain in domestic production of liquids.

The substantial participation of imports in meeting the domestic market demand and the effect that they have had and could have on domestic prices tend to limit the profit prospects on domestic investments.

9. Change in Price Conditions

After removal of wartime controls, there was a general increase in prices. Between 1945 and 1955, the wholesale price index for all commodities increased about 60 percent and the average price of crude oil and natural gas more than doubled. After further advances in 1956 and 1957, crude oil prices declined to about $2.88-$2.90 in the period 1959-1965. Natural gas prices continued to increase until 1962, after which they remained relatively constant except for some reductions required by the Federal Power Commission.

The changing behavior of prices relative to cost factors, such as wage rates and payments for oil field materials and machinery, affected the rate of exploration and drilling and contributed to the decline in completion of oil wells after 1956 and of gas wells after 1962.

10. Changing Relation of Expenditures to Gross Revenue

In the first postwar decade, rising production and better prices combined to triple well-head value of U. S. oil and gas by 1955. Economic and technological factors worked together to cause a rise in the portion of revenue from oil and gas production spent on exploration and drilling. Reports of the Joint Association Surveys indicate that this figure changed from 50 percent in 1948 to about 65 percent in 1955-1956. (In addition to outlays for exploration and development, producers must pay for lifting costs, taxes, and capital service charges. At times some operators have total outlays exceeding revenues, in which case they must use outside capital, either borrowed funds or equity capital.)

In the period 1955-1965, as the growth in production slowed down and as prices leveled off or declined, revenues realized by producers increased only about one-third. Concident with the marked change in rate of growth in reveue, the portion of revenue spent on exploration and development dropped back down to 50 percent by 1961-1963.

The change in relation of exploration and development expenditures to revenues indicates the composite view of operators about the attractive prospects for profitable new investments up to 1956 and the less favorable general outlook since then.

11. Changes in the Structure of the Industry

All units in the producing industry, large and small, participated in the expansion in production and expenditures up to 1955. In this period, there was a sharp increase in the proportion of revenue spent on exploration and production, particularly by the group of small operators. Thereafter, as conditions became less favorable for new investments in domestic exploration and production, a large number of mergers and sellouts of companies and properties occurred.

The relative position of independent producers, comprising the smaller operators as a group, has declined steadily during the past ten years. This group has not shared in the growth of crude oil production and accounts for all of the decrease in exploration and development expenditures. For this group of operators whose individual resources generally limit their ability to risk large amounts of capital, the reductions in economic opportunities and the decrease in prospective profitability from new exploration and development expenditures have been relatively greater than indicated by composite national figures.

POLICY FACTORS

12. Wider Spacing of Wells

As allowables per well were restricted progressively, greater pressures developed to participate in prorated markets by drilling wells designed to secure additional allowable. Drilling of this nature was particularly noticeable in Texas, where the average reserves per producing well decreased from 185,000 barrels in 1951 to about 70,000 in 1965.

More recently, court decisions and changed regulatory orders have discouraged close spacing of wells. These changes accelerated a trend which has been operating over the long run toward wider spacing of wells. As a result, fewer wells are drilled now to develop acreage than would have been the case ten years ago or earlier. No data are available as to the effect of this change on the number of wells drilled, but a report of the Interstate Oil Compact Commission on spacing orders indicates that orders for 20 acre spacing or less dropped from 45 percent of the total reported in 1950 and 1955 to less than 20 percent in 1960-1962.

13. Leasing of Federal Lands

Another policy factor affecting exploration and development has been the leasing of Federal lands for oil and gas production. This development has been particularly significant for Louisiana, because of the great interest in the Continental Shelf, and for the Rocky Mountain states, where a large portion of the acreage is held by the Federal government. The rate and terms on which Federal lands are offered for leasing naturally affect expenditures and drilling. Because offshore wells are so much more expensive, they must also have more reserves. Therefore, the wells drilled offshore, which account for only two or three percent of the wells drilled in the United States, add reserves entirely out of proportion to their numbers. Offshore leasing involved unusually large expenditures in 1962 that possibly affected exploration and development expenditures in other areas of the United States afterwards.

14. Federal Regulation of Gas Prices

Since the Supreme Court decision in 1954, the price of gas moving in interstate commerce for resale has been subject to regulation by the Federal Power Commission. The full impact of this regulation was not felt until the 1960's when the Commission adopted area guidelines and began to apply the standard of prices "in-line" with those approved on earlier contracts and to cut some area prices. The peak in drilling of gas wells during the period under review occurred in 1962, seven years after the peak in drilling of oil wells. The fact that approved prices can subsequently be reduced creates an additional unnecessary risk.

15. Federal Limitations on Oil Imports

Government limitations on oil imports were imposed on a voluntary basis in mid-1957 and on a mandatory basis early in 1959.

Under the mandatory oil import program, nonresidual imports into Districts I-IV have been relatively stable in relation to domestic production in that area. District V imports have been increased and decreased in relation to domestic supplies in that District. Residual fuel imports have increased by approximately the amount of the reduction in domestic production of that product.

As previously pointed out, the increase in nonresidual imports during the past decade was almost 50 percent of the gain in domestic production of liquids. In the absence of Federal controls there would have been greater economic pressures for imports to increase much more rapidly.

C. CONCLUSION

The preceding review makes it clear that many diverse factors have affected exploration, development, and production of petroleum in the United States in the period 1946-1965. The way in which these factors worked together explains not only the sharp rise in drilling up to 1956 and the subsequent decline, but also the fluctuations in expenditures and leveling off in rate of development of new resources.

In the first postwar decade, demand was increasing rapidly and development of new resources exceeded output and added materially to proved reserves. In the latest ten-year period, when the growth in demand has slowed down and technology has expanded productive capacity faster than reserves, development of new resources has turned down for crude oil and leveled off for natural gas with the result that the rate of growth has been less for proved reserves than for demand for both oil and gas.

Changes in activities during the period under review can be attributed to changes in the outlook for profitability on new investments to find and develop oil and gas. Improved technology has continued to help industry find, develop, and produce additional resources efficiently and economically. Other factors have worked in the opposite direction, decreasing profit prospects on new investments during the past decade. These include reduced geological opportunities in well explored areas, lower rates of growth in oil and gas consumption and production, rising imports, substantial unused productive capacity, and less attractive prices to producers. In many areas, and particularly for smaller operators not able to risk large sums on individual ventures, economic exploration opportunities have declined.

At the end of 1965, the domestic petroleum industry was in position to meet all demands on it and to expand output by substantial amounts. Also, new development was still offsetting production and adding slightly to known reserves. The substantial outlays being made for exploration and development indicate confidence that additional resources remain to be found and brought into production. The rate at which this happens will depend on the relation of rewards to risks in the future under conditions of keen competition among the principal fuels.

P A R T I I

REPORT OF THE TASK FORCE

ON

GEOLOGICAL AND TECHNOLOGICAL FACTORS

TASK FORCE ON GEOLOGICAL AND TECHNOLOGICAL FACTORS OF THE NATIONAL PETROLEUM COUNCIL'S COMMITTEE ON FACTORS AFFECTING U.S. EXPLORATION, DEVELOPMENT AND PRODUCTION, 1945 TO 1965

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INTRODUCTION

AND

SUMMARY

P A R T I I

GEOLOGICAL AND TECHNOLOGICAL FACTORS AFFECTING

UNITED STATES EXPLORATION, DEVELOPMENT, AND PRODUCTION

1946-1965

I. Introduction

The Subcommittee on Geological and Technological Factors has analyzed activities over the period 1946-1965 for the United States and for each state, with further area breakdowns in Louisiana and Texas. The factors studied and plotted, to the extent data are available, include the following:

Exploration: Seismic crew months; number and average depths of exploratory wells; percent of exploratory wells completed as oil wells and as oil and gas wells.

Development: Number and average depth of development wells; percent of development wells completed as oil wells and as oil and gas wells; drilling expenditures and cost per well and per foot; number of wells stimulated by fracturing treatments.

Production and Reserves: Annual production, annual gross additions to reserves, year-end reserves, and the ratio of reserves to production shown separately for crude oil, gas liquids, and natural gas.

For each state and area, members of the committee have prepared brief comments on major geologic and technical developments affecting activities under review. These comments and the supporting charts are presented in this Appendix by areas (Appalachian, Mid-Continent, Gulf-Southwest, Rocky Mountains, and West Coast) following some introductory remarks pertaining to the entire nation about geological factors and about the technology of exploration, development, and production.

II. Geological Factors

The United States has many provinces containing sedimentary deposits favorable for the accumulation of oil and gas. Some of these provinces, particularly the shallower ones, have been explored intensively for many years. Others, such as Alaska and the Continental Shelf, have been explored only recently, and to a lesser extent than the areas that have been producing for a long time.

After the initial discovery of oil in Pennsylvania in 1859, surface geology was the principal exploratory tool for a long time. Much later, subsurface geology became an additional tool in the search for oil and gas. In the 1920's, the introduction of geophysics added another powerful technique for extending exploration in old areas, as well as in virgin areas. The combination of geology and geophysics led to the discovery of many major fields in the 1930's and subsequently. The frequency and size of discoveries relative to the efforts expended was exceptional in the 1930's, contributing to a rapid expansion of output and to lower prices for crude oil and natural gas.

By the end of 1945, some 1,200,000 wells had been drilled in the United States. Of these, more than 800,000 were oil wells, drilled mostly on close spacing. In the twenty-year period under review, industry drilled an additional 920,000 wells, of which 465,000 were oil wells and 86,000 were gas wells. Because of the wider spacing of oil and gas wells in recent years, and the higher proportion of gas wells that develop much more acreage than oil wells, it seems likely that the total acreage brought into production during the past twenty years may equal or exceed that developed in the prior 86-year history of the industry.

The known reserves of oil and gas have increased greatly since World War II due to discoveries, extensions, and revisions. In the past twenty years ending with 1965, gross additions to reserves have amounted to 69 billion barrels of crude oil and gas liquids and 344 trillion cubic feet of natural gas. These quantities represent more than one-half of the recoverable reserves now estimated to have been discovered to date. This relation would indicate that in the period 1946-1965 discovery and improved recovery have added to the usable petroleum resources of the United States at an annual rate more than four times the average of the prior 86 years. The rate of gross additions to reserves in the past twenty years also exceeds by a substantial margin the average of the prior twenty years, 1926-1945, which corresponds with the early application of geophysics.

Statistics on exploratory drilling were not developed on a consistent basis until about 1944, when the American Association of Petroleum Geologists (AAPG) began issuing annual reports. AAPG reports for 1946-1965 show 127,000 exploratory wells drilled in the search for new fields, of which 14,000 were producers. These new discoveries provided the basis for much development drilling during the period under review. Important extensions and deeper horizons, which are not always classified as discoveries, have also provided drilling opportunities and added to known recoverable reserves of oil and gas.

Each discovery of a new field reduces the number of fields remaining to be found, but may also provide information useful in looking for and locating other prospects to be tested for potential accumulations of petroleum hydrocarbons in commercial quantities. This pattern repeats itself many times in an area until the prospects are thoroughly explored with the technology available, and the rewards anticipated in case of success no longer appear attractive relative to the risks involved. New technology, deeper development, or discovery of a new trend, may renew activity in an area many times before it becomes relatively inactive and an unlikely candidate for important future additions to reserves.

As exploration becomes deeper and more expensive, the number of wells drilled in search of new fields is affected by the exponential increase in well cost with depth. Some operators cannot afford to risk large sums on one venture, and those who are able to do so find it advisable to make careful analysis by other useful exploration methods before starting a well.

In periods when the nature of exploration is changing significantly, as appears to have been the case between the first and second postwar decades, the number of exploratory wells drilled may not provide a good indication of the level of expenditures for exploration or results in terms of new oil and gas. For example, the Joint Association Survey shows average annual exploration expenditures, including overhead, of $2,291 million in the two latest years reported (1962-1963); or almost the same as the average of $2,254 for 1955-1956, although the number of exploratory wells declined by 30 percent between 1955-1956 and 1962-1963. Also, gross additions to reserves of crude oil, gas liquids, and natural gas from discoveries, extensions, and revisions have not changed in accordance with exploratory drilling, as shown by the following comparison of five-year periods.

Annual Average of Exploratory Wells Drilled and Gross Additions to New Reserves

Period	Total Explor. Wells (AAPG)	New Res. Crude Oil Million B.	New Res. Gas Liquids Million B.	New Res. Total Liq. Million M.	New Res. Natural Gas Billion C.F.
1946-50	7,982	2,935	416	3,351	13,393
1951-55	13,107	3,241	529	3,770	16,404
1956-60	13,803	2,808	647	3,455	19,627
1961-65	10,533	2,545	749	3,294	19,277

Analyses of discoveries by size of new reserves made by the American Association of Petroleum Geologists indicate a downward trend in the discovery of major fields. In well-explored areas, as contrasted to the Continental Shelf and Alaska, the contribution of major fields with 100,000,000 barrels or more of crude oil has been disappointing in the past ten years.

The current level of exploration expenditures inidcates expectation of substantial future new discoveries, particularly in newer provinces and deeper horizons. Results will be affected in the future, as they have in the past, by improvements in technology which have made possible the location of more fields and the recovery of greater proportions of the oil in place in known fields.

Within the past decade, exploration efforts have shifted to more obscure trapping mechanisms in deeper sedimentary basins, to offshore areas, and to the interpretation of more complex structural and stratigraphic systems. Exploration of this nature requires heavy predrilling outlays and the ability to meet heavy losses on some wells. Higher costs also limit activity to prospects with sufficient promise to justify risk and to generate acceptable rates of return in case of success. To this extent, more expensive technology may affect the number of ventures undertaken and the number of operators able to take the risks.

III. Exploration Technology

Developments in exploration technology since 1945 have been evolutionary, as has been the case throughout the history of the industry, except for the introduction of geophysics. Consistent refinements to existing techniques have resulted in decided improvements in resolving power and depth penetration of seismic waves, in data processing and in adaptability to new conditions, such as marine operations. Some of the major improvements are set forth briefly in the following paragraph.

Various detector arrays and pattern shooting were developed for improved seismic effectiveness in areas such as West Texas, where high velocity surface formations had historically limited seismic effectiveness. Photogeology greatly accelerated the rate at which reconnaissance surface geology could be conducted. Nonexplosive seismic techniques were developed and proved to be very successful, both onshore and offshore. Perhaps the greatest advance was in the area of data processing. The development and application of magnetic recording, electronic data processing and digital recording resulted in highly sophisticated techniques of filter application, and in interpretation and presentation of geophysical data. The ability to record, store, and process data at high speeds made possible development of such techniques as Common Depth Point recording, which contributed remarkably to the penetration and resolving capabilities of the reflection seismograph. Similar refinements were made in logging techniques, core analyses, and bore hold dip measuring devices. These evolutionary refinements provided more precise measurement of fluid content, rock characteristics, and subsurface dip attitudes.

Refinements and adaptations in exploration were made primarily to improve effectiveness in areas that appeared to offer attractive opportunities. They made it possible for industry to undertake new plays, but their nature was not such as to lead industry into new areas. The majority of the significant technological advances in exploration occurred after 1955, rather than in the first postwar decade when exploration activity was increasing. In a sense, necessity was the mother of intention in this case; for without the improvements that took place, the search for new oil and gas could not have been maintained at the level realized in the past ten years.

IV. Drilling and Production Technology

Technological developments during the 1946-1965 period made a major impact on oil and gas well drilling, development and production. As a result, wells were drilled faster and deeper, vast new geographical areas were opened for exploration and production, productive capacity and reserves of both oil and gas were substantially increased, efficiency was greatly improved, and significant cost savings were accomplished. These developments both improved known tools and techniques and provided breakthroughs into entirely new methods.

Major technological developments in drilling include a better understanding and application of hydraulics in rotary drilling, new types of drilling bits (such as jet, diamond, and chert bits); packed hole drill collars for greater bit weight; improved drilling muds; the use of air and gas as drilling fluids; slim hole drilling; and more flexible and portable drilling rigs. These improvements are reflected in substantial increases in penetration rates, cost savings, and depths reached economically.

According to Joint Industry Association figures, the national average cost per foot of hole drilled between 1953 and 1963 increased only slightly in the face of greater average well depths and increased costs of wages, materials and equipment. Drilling statistics show that the average rate of penetration for a rotary rig has more than doubled in the past 20 years. This, with time reductions in all other drilling and well completion operations, resulted in a large increase in the number of wells each rig is capable of drilling each year.

Changes in Rotary Rig Activity

	Total Wells	Million Feet	Average Depth	Avg. No. Rigs Making Holes	Annual Footage Rate Per Rig
1946	20,500	80	3,900	1,557	51,000
1955	48,400	210	4,300	2,686	78,200
1965	33,000	165	5,000	1,388	118,900

Increased penetration rates have been notable in the deeper hard-rock drilling in West Texas and New Mexico. In one representative area, wells to 11,000 feet that required 100 days in 1950 were drilled in 65 days in 1964, and 9000-foot wells decreased from 60 to 35 days during the same period.

Drilling technology and techniques have made it economically and physically possible to reach progressively greater depths, which increased opportunity for exploration and development into deeper formations. This has resulted in a shift in expenditures to deeper drilling shown by the following table.

NUMBER OF WELLS - TOTAL U.S.*

	0-5,000' Wells	5-10,000' Wells	10-15,000' Wells	15,000' or Over Wells	Total
1953	33,915	12,121	1,860	33	47,929
1959	34,867	11,719	2,757	220	49,563
1963	28,524	10,342	2,723	264	41,853

TOTAL U.S. EXPENDITURES - $\bar{M}$ $*

1953	795.3	1,033.9	474.3	18.0	2,321.5
1959	749.4	1,008.5	748.8	144.3	2,651.1
1963	606.7	852.0	668.7	170.5	2,302.9

AVERAGE COST PER WELL - M $*

1953	23.5	85.3	255.0	546.2	48.4
1959	21.5	86.1	271.6	656.1	53.5
1963	21.4	82.4	245.6	645.8	55.0

PERCENTAGE OF TOTAL EXPENDITURES*

1953	34.3	44.5	20.4	0.8	100.0
1959	28.3	38.0	28.2	5.5	100.0
1963	26.6	37.0	29.0	7.4	100.0

*From Joint Association Survey data.

Before 1945 only two wells had been drilled as deep as 15,000 feet, but over 330 were drilled below this depth in 1965. Depths of 20,000 feet are now becoming common. Notable among these areas is the Delaware Basin of West Texas, where 36 wells have been drilled deeper than 20,000 feet and activity is increasing. The first wildcats in this area required about two years, but similar wells now average about nine months.

Methods for drilling and producing in offshore waters of the United States have been developed entirely since 1946. They have been very important technological factors affecting exploration and production during the twenty-year period. These developments opened over 200,000 square miles for exploration and exploitation. Design and construction of drilling platforms, floating drilling vessels, and production equipment capable of operating in successively deeper waters - and under increasingly severe conditions - has progressed rapidly. Production operations are routinely carried on in waters up to 200 feet deep, and drilling and exploration activities in waters of much greater depth. By 1963, the Joint Association Survey showed almost 13 percent of the total U. S. drilling expenditures were on Louisiana offshore operations alone.

Offshore Louisiana Vs. Total U. S. Drilling

	Wells	Average Depth	Average Cost	Expenditure
Offshore Louisiana	786 (1.8%)	10,393	$370,000	$ 291 Million (13%)
United States	41,853	4,336	55,000	2,303 Million

Offshore wells account for almost 10 percent of the oil and 6 percent of the gas production in the United States, and both are increasing rapidly.

Well stimulation by formation fracturing, developed about 1950, importantly increased oil and gas drilling, productivity and reserves. Many areas previously noncommercial because of low permeability ("tight") reservoirs became profitable to develop, and productivity was greatly increased from many older low-capacity wells. The number of fracture treatments peaked at about 46,000 in 1955, indicating high usage in older wells, and declined to a level of about 25,000 annually for the period 1960-65. In four areas in particular, an appreciable portion of the 50 percent increase in drilling between 1953-58 over 1951-52 can be attributed to fracturing.

Average Annual Oil Well Completions

Area	1951-1952	1953-1958	1953-58 Increase Over 1951-52 Base	1959-1960
Arkansas	226	481	255	377
Illinois	872	1,437	565	892
Oklahoma	3,097	4,442	1,345	2,480
North Texas (9 & 7B)	2,607	3,830	1,223	2,795
	6,802	10,190	3,388	6,544

Formation fracturing techniques were particularly important in stimulating drilling of wells up to 5,000 feet in depth. The surge in development drilling of these less-expensive wells between 1950 and 1956 in the areas tabulated above was in wells up to 2,500 feet in Illinois, and in wells up to 3,750 feet in Arkansas, Oklahoma, and North Texas.

In the large Spraberry area of West Texas containing some 2,600 wells, fracturing, wider well spacing and lower drilling costs together have permitted profitable development of an otherwise uneconomical area. In a study being prepared for the N.P.C. Committee on New Technology, it is estimated over seven billion barrels of oil have been added to reserves of the United States by formation fracturing.

The use of fluid injection and unitization to increase oil recovery, productivity, and reduce operating costs has been of great importance during the twenty-year period. In 1946, fluid injection projects were limited almost entirely to secondary recovery, in which oil was being salvaged from pools that had already been largely depleted by ordinary production methods. During the period, intensive research, coupled with studies of production characteristics in many oil pools, improved understanding of the performance of oil reservoirs. This resulted in the widespread application of methods to increase oil recovery, such as water injection, and enriched and high pressure gas drive. In the past five years thermal methods, utilizing both combustion in the reservoir and the injection of steam, have come into increasing use. The impact of these is noted particularly in the heavy oil areas of California where they account for gains of over 75,000 barrels a day.

The maintenance of pressure by fluid injection early in new pools has combined primary and secondary recovery operations into a single, efficient producing operation. This results in substantially greater recovery of oil (frequently more than doubled) and higher sustained productive capacity. According to studies by the I.O.C.C., oil production from fields under fluid injection (including production from some new fields, as well as secondary production from old fields) accounted for about 34 percent (2.7 million barrels per day) of the total in 1965. This compares with 15 percent in 1946. Reserves added by these methods, from projects now in operation, were estimated at more than 17 billion barrels.

Wider well spacing practices are an outgrowth of engineering study and experience, which has proved that wells efficiently recover oil and gas from wide areas. In many pools with wider spacing, one oil well is now recovering the oil of four to eight wells under spacing patterns of twenty years ago. Better engineered well spacing has discernibly reduced the number of wells drilled and has contributed immeasurably to development efficiency and the conservation of steel and other materials, as well as dollars. In addition to the important cost savings in operation and development of many fields, wider well spacing has increased reserves by permitting the development of fields which would have been marginal or non-profitable under closer spacing practices. Changes in number of wells drilled have been greater for oil than gas, as gas has historically been developed on wider patterns (ten times greater or more) than oil. It is difficult to quantify accurately the effect of changing spacing patterns on the number of wells drilled. However, an indication of the trend is shown by the following summary of spacing orders issued in the United States between 1940 and 1962.

REPORTED OIL SPACING ORDERS ISSUED

	20 Acres or Less	40 Acres	80 Acres	160 Acres or More
1940	25	6	0	0
1950	63	70	8	1
1955	159	136	46	4
1960	76	185	106	16
1961	113	259	207	15
1962	78	248	222	23

REPORTED GAS SPACING ORDERS ISSUED

	160 Acres or Less	320 Acres	640 Acres or More
1940	5	0	0
1950	23	16	18
1955	52	41	50
1960	105	142	190
1961	108	122	129
1962	87	134	172

Source: A Study of Conservation of Oil and Gas Interstate Oil Compact Commission, 1964

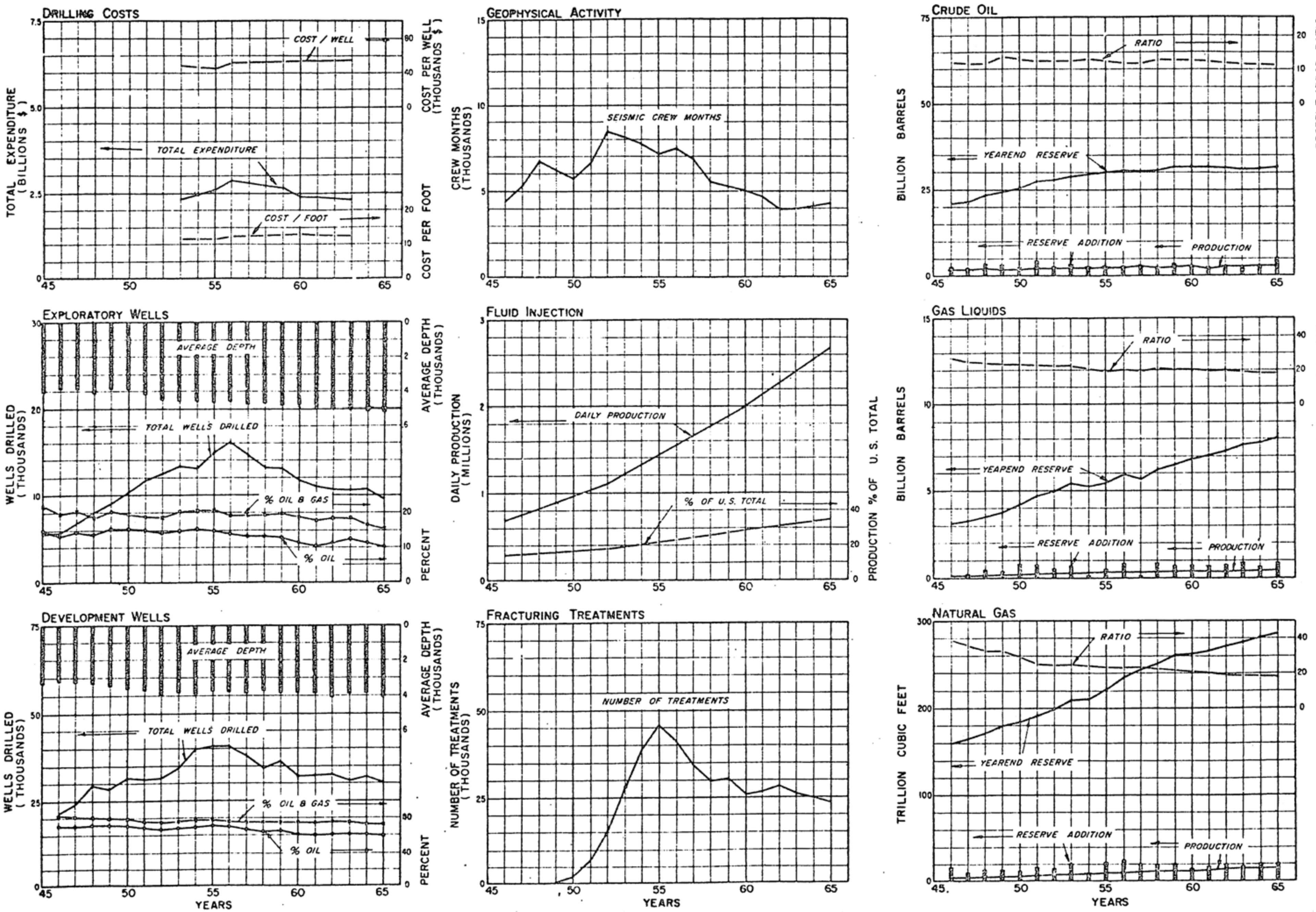
In addition to those mentioned, a large number of other developments in equipment and practices difficult to evaluate individually have, in the aggregate, greatly improved efficiency and effected cost savings. Improvements and new developments in electrical, radioactive, density and sonic logging have provided evaluations of formation productive possibilities which could have at best been determined only by expensive testing a few years ago. Multiple zone completions in a single well bore have also reduced the number of wells required, and in 1965 alone over 3,850 zones were individually completed in some 1,750 bore holes. A high degree of automation of producing operations, ranging from automatic delivery of oil to pipelines to computer-controlled production of entire fields, has come into general application. These all serve to make development and production more attractive in average areas and, in many cases, profitable in marginal areas.

The rapid increase in natural gas markets spurred developments in natural gas transportation and processing, which have resulted in cost savings and increased the competitiveness of natural gas in the energy market.

Notable among these were: metallurgical improvements resulting in large diameter, thin-walled, high-strength pipelines; high volume high-pressure gas compression equipment which efficiently increased pipeline throughput; and improved methods for natural gas storage near consuming areas so that gas was immediately available during periods of high demand. These have stabilized the expense of gas transportation in the face of generally rising costs.

Large volume, underground storage caverns for LPG have enhanced economies in natural gas processing by providing off-season storage. The number of such storage facilities has grown steadily since first developed about 1950, and their capacity is now more than 120 million barrels.

Techniques for the profitable extraction of sulfur from natural gas have permitted development and production of a number of gas fields which, because of high hydrogen sulfide content, could not have been economically produced twenty years ago. The volume of elemental sulfur recovered from such processing exceeded 1,200,000 long tons in 1965.


DRILLING COSTS
TOTAL EXPENDITURE (BILLIONS $)
COST PER WELL (THOUSANDS $)
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
COST PER FOOT
GEOPHYSICAL ACTIVITY
CREW MONTHS (THOUSANDS)
SEISMIC CREW MONTHS
CRUDE OIL
BILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
EXPLORATORY WELLS
WELLS DRILLED (THOUSANDS)
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
FLUID INJECTION
DAILY PRODUCTION (MILLIONS)
DAILY PRODUCTION
% OF U.S. TOTAL
PRODUCTION % OF U. S. TOTAL
GAS LIQUIDS
BILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
DEVELOPMENT WELLS
WELLS DRILLED (THOUSANDS)
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS (THOUSANDS)
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
TRILLION CUBIC FEET
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
YEARS

U. S. TOTAL

PRODUCTION AND YEAR-END RESERVES
OF CRUDE OIL, NATURAL GAS LIQUIDS, AND NATURAL GAS
UNITED STATES 1946-1965

	Crude Oil - Million Barrels				Natural Gas Liquids - Million Bbls.				Natural Gas - Billion Cu. Ft.			
Year	Annual Prod.	Year-End Reserve	Reserve Addition	Reserve/ Prod. Ratio	Annual Prod.	Year-End Reserve	Reserve Addition	Reserve/ Prod. Ratio	Annual Prod.	Year-End Reserve	Reserve Addition	Reserve/ Prod. Ratio
1946	1,734	20,874	2,658	12.0	116	3,163		27.3	4,050	159,704	17,633	39.4
1947	1,857	21,488	2,465	11.6	132	3,254	252	24.6	4,582	165,026	10,921	36.0
1948	2,020	23,280	3,795	11.5	147	3,541	471	24.1	5,148	172,925	13,823	33.6
1949	1,842	24,649	3,188	13.4	157	3,729	387	23.7	5,420	179,402	12,605	33.1
1950	1,974	25,268	2,563	12.8	182	4,268	766	23.5	6,282	184,585	11,984	29.4
1951	2,248	27,468	4,414	12.2	205	4,725	724	23.1	7,457	192,759	15,966	25.8
1952	2,290	27,961	2,749	12.2	224	4,997	557	22.4	8,013	198,632	14,268	24.8
1953	2,357	28,945	3,296	12.3	239	5,438	744	22.8	8,397	210,299	20,342	25.0
1954	2,315	29,561	2,873	12.8	252	5,244	107	20.8	8,743	210,561	9,547	24.1
1955	2,484	30,012	2,871	12.1	281	5,439	515	19.3	9,405	222,483	21,898	23.7
1956	2,617	30,435	2,974	11.6	293	5,902	810	20.2	10,064	236,483	24,716	23.5
1957	2,617	30,300	2,425	11.6	295	5,687	137	19.3	10,680	245,230	20,008	23.0
1958	2,449	30,536	2,608	12.5	295	6,204	858	21.0	11,030	252,762	18,897	22.9
1959	2,575	31,719	3,667	12.3	321	6,522	703	20.3	12,046	261,170	20,621	21.7
1960	2,575	31,613	2,365	12.3	340	6,816	725	20.0	12,771	262,326	13,894	20.5
1961	2,622	31,759	2,658	12.1	362	7,049	695	19.5	13,254	266,274	17,166	20.1
1962	2,676	31,389	2,181	11.7	373	7,312	733	19.6	13,877	272,279	19,483	19.6
1963	2,753	30,970	2,174	11.3	401	7,674	878	19.1	14,747	276,151	18,381	18.7
1964	2,787	30,991	2,665	11.1	420	7,747	609	18.5	15,547	281,251	20,252	18.1
1965	2,849	31,352	3,048	11.0	442	8,024	832	18.2	16,040	286,469	21,319	17.9

RESERVES: Annual bulletins published jointly by American Gas Association, Inc., American Petroleum Institute and Canadian Petroleum Association.

PRODUCTION: Bureau of Mines, U. S. Department of the Interior. (Condensate production is included with crude oil. Natural gas production is "marketed" production).

EXPLORATORY ACTIVITY IN UNITED STATES
1946-1965

YEAR	EXPLORATORY WELLS DRILLED OIL	GAS	DRY	TOTAL	% PRODUCTIVE OIL	OIL & GAS	TOTAL FOOTAGE (THSDS.)	AVERAGE DEPTH	SEISMIC CREW MONTHS
1946	762	375	4,622	5,759	13.2	19.7	22,338	3,879	4,379
1947	982	396	5,397	6,775	14.5	20.3	26,393	3,896	5,278
1948	1,098	365	6,550	8,013	13.7	18.3	32,751	4,087	6,694
1949	1,406	424	7,228	9,058	15.5	20.2	34,798	3,842	6,203
1950	1,583	431	8,292	10,306	15.4	19.6	40,175	3,898	5,714
1951	1,763	454	9,539	11,756	15.0	18.9	49,344	4,197	6,571
1952	1,776	559	10,090	12,425	14.3	18.8	55,615	4,476	8,399
1953	1,981	699	10,633	13,313	14.9	20.2	60,664	4,557	8,113
1954	1,985	726	10,389	13,100	15.2	20.7	59,601	4,550	7,773
1955	2,236	874	11,832	14,942	15.0	20.8	69,206	4,632	7,157
1956	2,267	822	13,118	16,207	14.0	19.1	74,337	4,587	7,433
1957	1,945	865	11,904	14,714	13.2	19.1	69,181	4,702	6,877
1958	1,745	822	10,632	13,199	13.2	19.4	61,484	4,658	5,543
1959	1,702	912	10,577	13,191	12.9	19.8	63,253	4,795	5,267
1960	1,321	868	9,515	16,704	11.3	18.7	55,831	4,770	5,060
1961	1,157	813	9,022	10,992	10.5	17.9	54,442	4,953	4,693
1962	1,211	771	8,815	10,797	11.2	18.3	53,616	4,966	3,915
1963	1,314	664	8,686	10,664	12.3	18.5	53,485	5,015	3,966
1964	1,219	577	8,951	10,747	11.3	16.7	55,497	5,163	4,102
1965	946	515	8,005	9,466	10.0	15.4	49,204	5,198	4,247

Exploratory Drilling: American Association of Petroleum Geologists bulletins, years 1945-1960. F. H. Lahee, "Statistics of Exploratory Drilling in the U.S." ("Exploratory Wells" include outposts, new-pool wildcats, deeper-pool tests, shallower-pool tests, and new-pool wildcats).

Geophysical Activity: "Seismic Crew Months" from International Oil Scouts Association reviews and/or Society of Exploration Geophysicists reports.

DRILLING COSTS, PRODUCTION FROM FLUID INJECTION PROJECTS, AND NUMBER OF FRACTURING TREATMENTS IN UNITED STATES 1946-1965

	Drilling Costs			Fluid Injection Projects		Number of Fracturing Treatments
Year	Total Expenditure (Millions)	Per Well	Per Foot	Daily Oil Production	Percent of U. S. Total	
1946				684,900	14.4	
1947						
1948						
1949						190
1950						2,246
1951						6,966
1952				1,115,000	17.8	15,518
1953	$ 2,322	$ 48,304	$ 11.76			28,178
1954						38,868
1955	2,600	46,500	11.55			45,632
1956	2,868	50,200	12.35			41,353
1957						34,202
1958						29,799
1959	2,651	53,500	12.90			30,444
1960	2,424	54,934	13.01	2,007,900	28.5	25,874
1961	2,398	54,518	12.85			26,873
1962						28,406
1963	2,303	55,023	12.69			26,022
1964						24,958
1965				2,684,900	34.4	23,415

Fluid Injection Projects:

1. E. G. Dahlgren, "Magnitude of Secondary Recovery Operations in the U.S.," A.P.I. Secondary Recovery Operations in the U.S. (Second Edition, 1960).
2. E. G. Dahlgren, A. E. Sweeney and Dr. Paul Torrey, "Estimated Annual Production from Fluid Injection Projects," I.O.C.A. A Study of Conservation of Oil and Gas in the U.S., 1964.
3. Dr. Paul D. Torrey, I.O.C.C. "Evaluation of U. S. Oil Resources" as of 1-1-62 and 1-1-66.

Drilling Costs: Joint Association Surveys of Industry Drilling Costs.

Fracturing Treatments: Pan American Petroleum Corporation.

DEVELOPMENT DRILLING IN UNITED STATES
1946-1965

YEAR	WELLS DRILLED: OIL	WELLS DRILLED: GAS	WELLS DRILLED: DRY	WELLS DRILLED: TOTAL	% PRODUCTIVE: OIL	% PRODUCTIVE: OIL & GAS	TOTAL FOOTAGE (THSDS.)	AVERAGE DEPTH
1946	15,089	2,715	3,428	21,232	71.1	83.9	74,728	3,184
1947	17,009	2,909	4,125	24,043	70.7	82.8	87,629	3,329
1948	21,487	2,532	5,476	29,495	72.8	81.4	104,642	3,304
1949	20,636	2,463	5,499	28,598	72.2	80.8	103,318	3,446
1950	22,847	2,412	6,465	31,724	72.0	79.6	119,092	3,612
1951	21,690	2,576	7,114	31,380	69.1	77.3	122,978	3,754
1952	21,690	2,696	7,547	31,933	67.9	76.3	131,641	3,940
1953	23,781	3,107	7,816	34,704	68.5	77.5	138,177	3,842
1954	27,788	3,251	8,779	39,818	69.8	78.0	159,409	3,904
1955	29,331	2,739	8,910	40,980	71.6	78.3	157,068	3,763
1956	28,891	3,293	8,720	40,904	70.6	77.3	159,582	3,804
1957	25,531	3,735	8,797	38,063	67.1	76.9	152,739	3,904
1958	22,392	3,977	8,190	34,559	64.8	76.3	135,893	3,784
1959	23,677	4,104	8,524	36,305	65.2	76.5	145,002	3,846
1960	19,805	4,390	8,059	32,314	61.5	75.1	134,867	3,848
1961	19,944	4,851	8,084	32,879	60.7	75.5	137,679	3,828
1962	20,038	5,077	7,867	32,982	60.8	76.2	144,954	4,097
1963	18,974	4,087	7,661	30,722	61.8	75.1	130,861	3,967
1964	19,401	4,278	8,537	32,216	60.2	73.5	134,404	3,897
1965	17,815	4,209	8,011	30,035	59.3	73.3	132,229	4,138

Development Drilling: "Total Wells Drilled" from The Oil and Gas Journal, less A.A.P.G. exploratory wells and service wells.

United States Drilling and Production
Statistical Charts
1945-1965

Sources of data are as follows, except when otherwise noted on the charts:

DRILLING COSTS: Joint Association Surveys of Industry Drilling Costs.

EXPLORATORY DRILLING: American Association of Petroleum Geologists bulletins, years 1945-1960. F. H. Lahee, "Statistics of Exploratory Drilling in the U.S." ("Exploratory wells" include outposts, new-pool wildcats, deeper-pool tests, shallower-pool tests, and new-field wildcats).

DEVELOPMENT DRILLING: "Total wells drilled" from The Oil and Gas Journal, less service wells and A.A.P.G. exploratory wells.

GEOPHYSICAL ACTIVITY: "Seismic crew months" from International Oil Scouts Association reviews and/or Society of Exploration Geophysicists reports.

FLUID INJECTION PROJECTS:

1. E. G. Dahlgren, "Magnitude of Secondary Recovery Operations in the U.S.," A.P.I. Secondary Recovery Operations in the U.S. (Second Edition, 1950).
2. E. G. Dahlgren, A. E. Sweeney and Dr. Paul Torrey, "Estimated Annual Production from Fluid Injection Projects," I.O.C.C. A Study of Conservation of Oil and Gas in the U.S., 1964.
3. Dr. Paul D. Torrey, I.O.C.C. "Evaluation of U.S. Oil Resources" as of 1-1-62 and 1-1-66.

FRACTURING TREATMENTS: Pan American Petroleum Corporation.

RESERVES: Annual bulletins published jointly by American Gas Association, Inc., American Petroleum Institute and Canadian Petroleum Association.

PRODUCTION: Bureau of Mines, U.S. Department of the Interior. (Condensate production is included with crude oil. Natural gas production is "marketed" production).

APPALACHIAN

AREA

NEW YORK

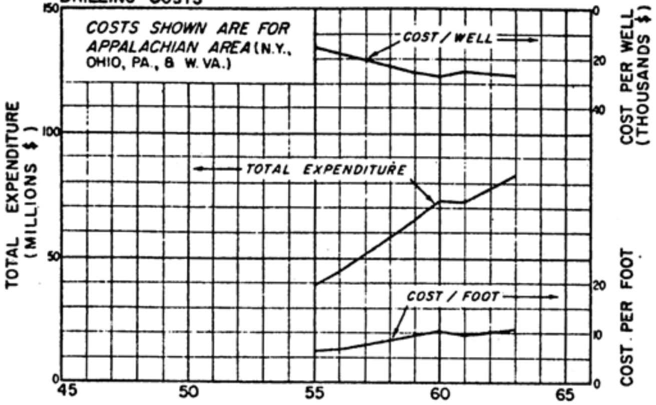
Exploration activity was generally on a very low level throughout the period of 1945 to 1960. Success in the application of formation fracturing technology to Medina gas sands resulted in increased exploratory well activity in 1960 when 61 wells were drilled. 1961 saw the peak in exploratory wells at 67, which declined to 50 in 1965. The oil reserves were under waterflood operation and showed a steady decline from 81 million barrels in 1945 to 11 million barrels in 1965. Daily production decreased from 13,000 barrels in 1945 to 5,000 barrels in 1958 and has held at that level through 1965 due to waterflood projects.

The production of oil in New York is highly dependent upon secondary recovery operations. In some respects, the New York fields are similar to those of Pennsylvania, however, the sands are less continuous and more variable in lithology. Some areas are exceptionally prolific, while others are of average productivity or of marginal quality. Waterflooding is used almost exclusively in New York as the reservoirs are not adaptable to air or gas repressuring.

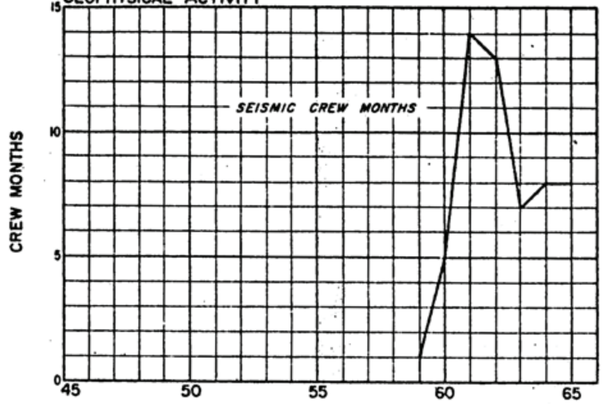
The oil fields of New York were rapidly approaching depletion when waterflooding was initiated. New York is an outstanding example of maintaining oil production by secondary recovery operations.

Gas reserves have increased as a result of the Medina gas sand activity, but gas production has remained constant at 10 to 15-million cubic feet per day.

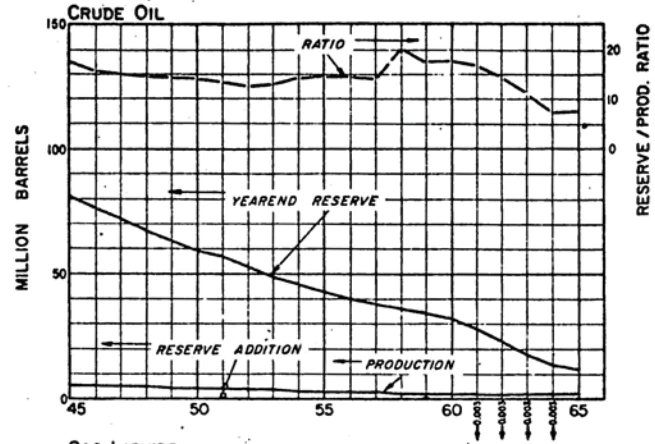
Drilling Costs



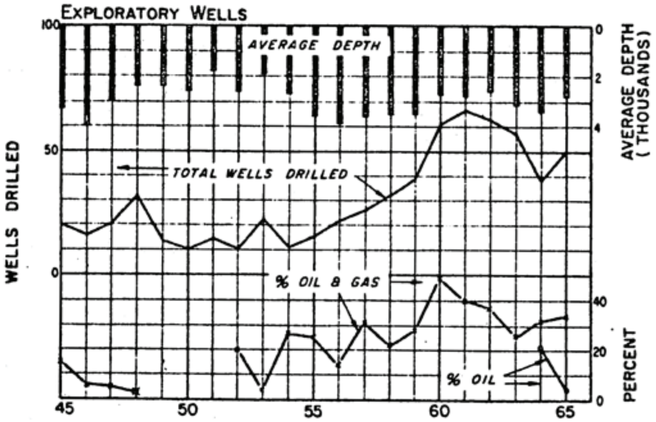
Geophysical Activity



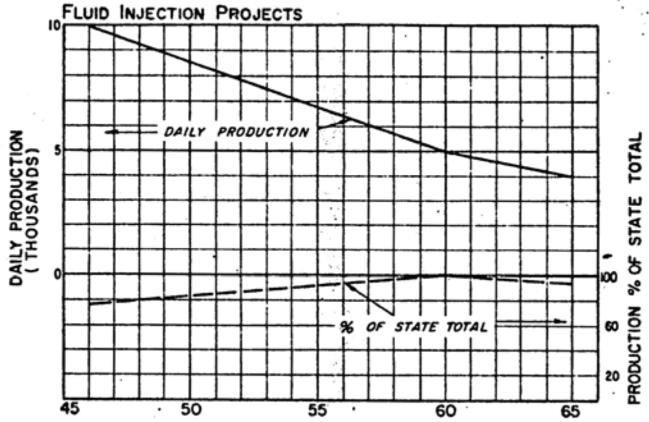
Crude Oil



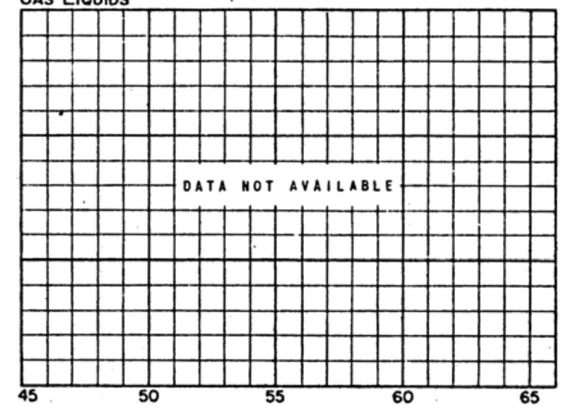
Exploratory Wells



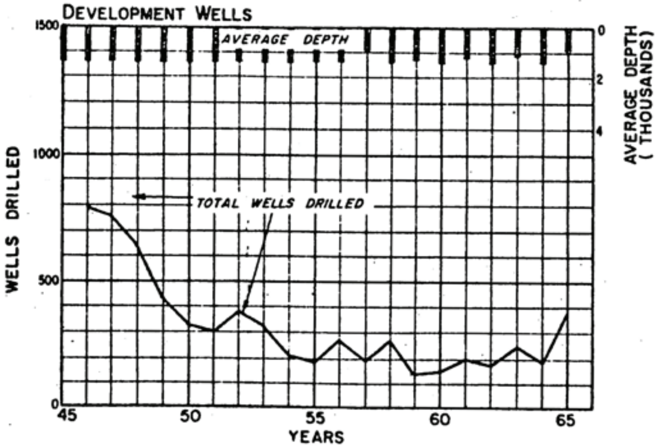
Fluid Injection Projects



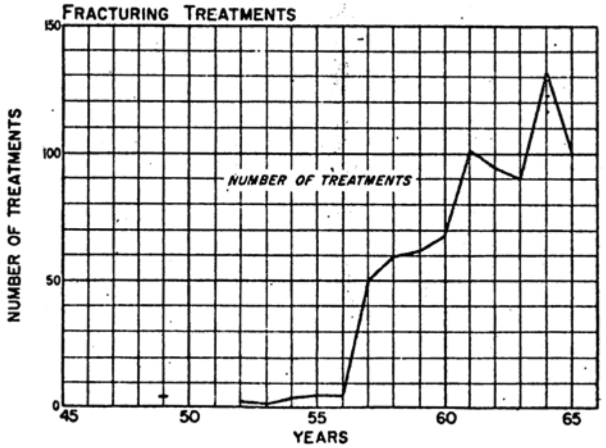
Gas Liquids



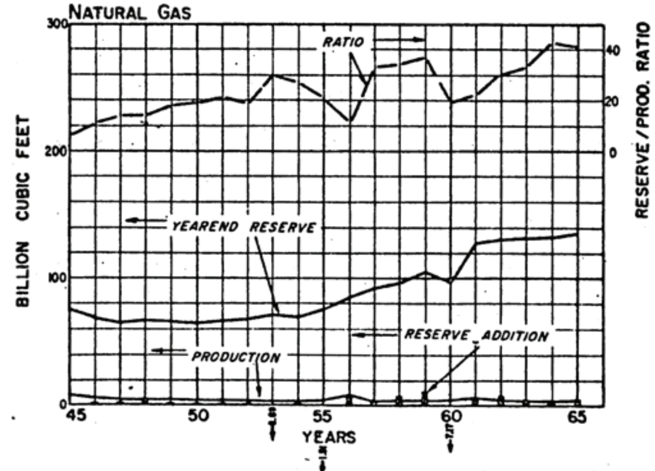
Development Wells



Fracturing Treatments



Natural Gas



NEW YORK

PENNSYLVANIA

Prior to 1945 the industry in Pennsylvania had already turned its attention to deeper sediments in the Middle Devonian and older zones. These are gas targets and have been the main support for exploration throughout this period. Results have not been particularly gratifying. Field discoveries at Leidy Oriskany Field in 1951 and at Driftwood Pool in 1954 resulted in sharp but short-lived peaks in the gas production curve and a gentle rise in gas reserves. The application of formation fracturing technology resulted in a slight reserve increase between 1958 and 1960 and a small increase in gas production.

The early '60s saw the buildup of new interest in deep gas possibilities in Pennsylvania. Several companies commenced seismic and leasing programs in the area. However, by the close of the period under consideration, this new interest had diminished. Geophysical and leasing activity were down in 1965. This new interest did result in increased exploratory well activity, but failure to significantly increase gas reserves has served to dampen exploration activity.

Pennsylvania entered 1945 with its major oil production under control of waterfloods and other methods of secondary recovery. Oil production exhibited a continuous decline from 1945 to 1965. Oil reserves have declined overall. The sharp peaks are attributed to improved secondary recovery technology or new and/or expanded secondary projects coming on stream. These projects are very sensitive to economic as well as technological factors.

The Bradford Field which first started to respond to water injection around 1927 and reached its peak in 1937, is still today the major contributor to Pennsylvania's crude oil production. It is estimated that perhaps an additional 100 million barrels of oil will be produced from the Bradford Field during the next twenty years. A number of properties in the Bradford Field, which were developed for flooding as late as 1937, have been subsequently redrilled and reworked successfully for a second crop of flood oil.

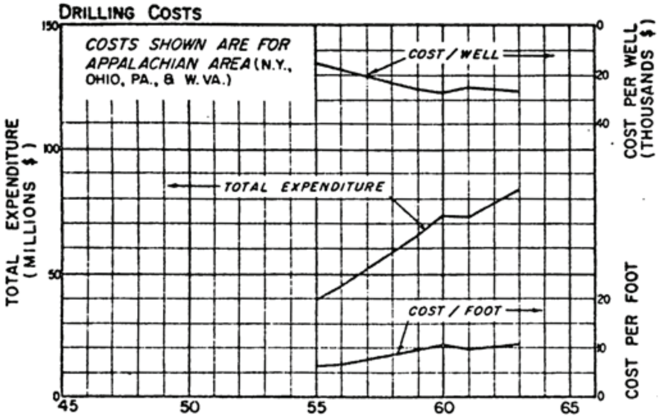
Waterflooding was first developed in Pennsylvania and although waterflooding techniques were first initiated on a trial and error basis, all of the improved developments that are standard procedure today were pioneered by the independent Pennsylvania oil producers who, in competition with each other, were trying to find easier, better and more efficient and economical methods of producing oil by waterflooding. It is difficult to relate any specifics of reserves or production to the many technological advancements resulting from the solution of waterflooding problems. Mentioning just a few, however, would have to include the treatment of injection water, channeling and selective plugging, and corrosion.

(Pennsylvania)

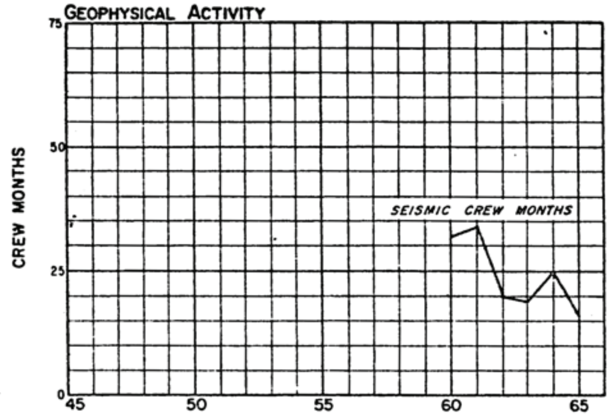
Projects using the application of heat have been and are currently being conducted in the State of Pennsylvania. Three projects employing the fire flood method have been attempted with no success, but they provided valuable information on the applicability of a combustion process to similar reservoirs containing oil of low viscosity. Currently, five or six steam injection floods are in operation in northern Pennsylvania but no information on the results is available at this time.

Fracturing in Pennsylvania was not widely applied until 1954 and has been confined mainly to the Bradford, Oriskany and White Medina sands. Most Oriskany treatments were failures, however, over fifty percent of all gas wells fraced showed a threefold increase in open flow capacity. Some 71% of the Bradford sand wells were successfully treated at the time of their completion as waterflood wells. The number of fracturing treatments has increased rapidly since 1954.

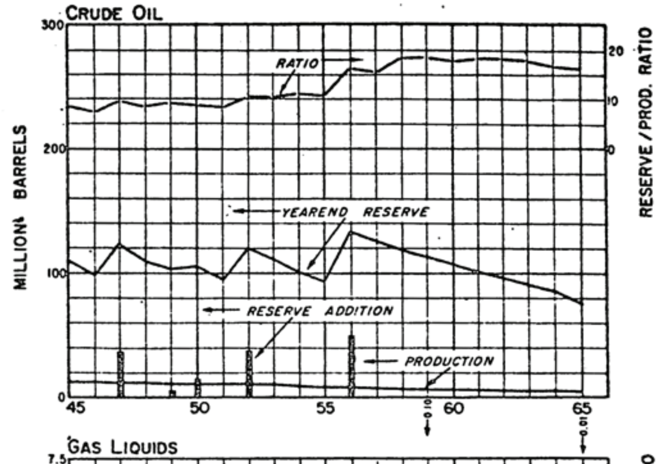
Drilling Costs



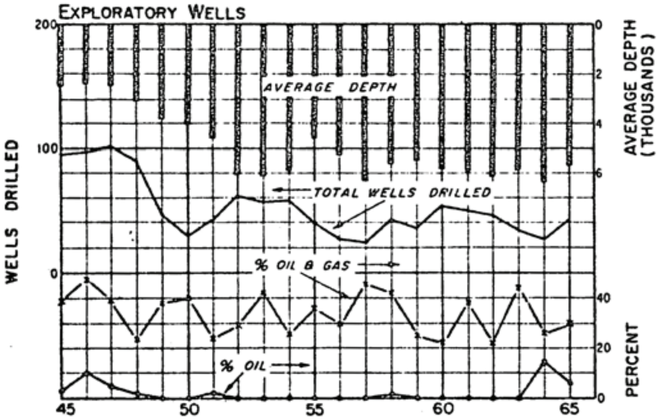
Geophysical Activity



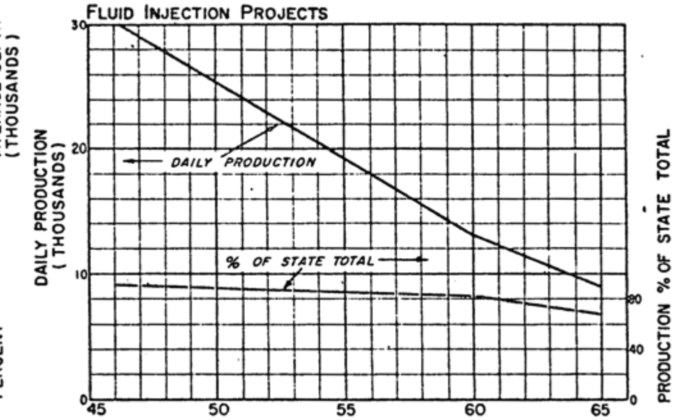
Crude Oil



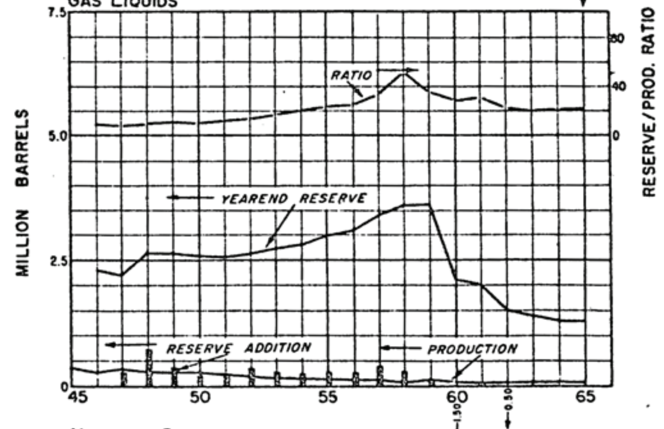
Exploratory Wells



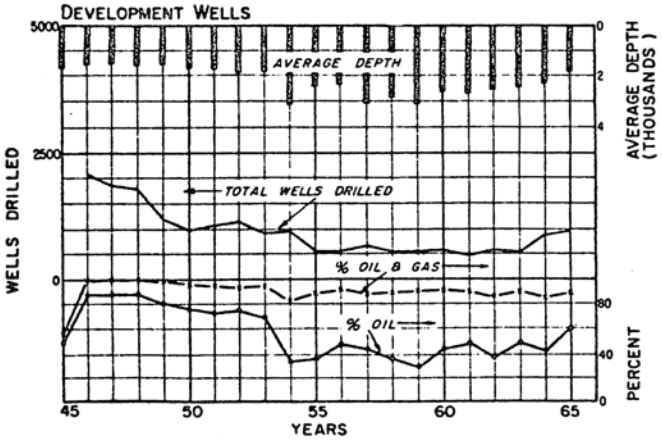
Fluid Injection Projects



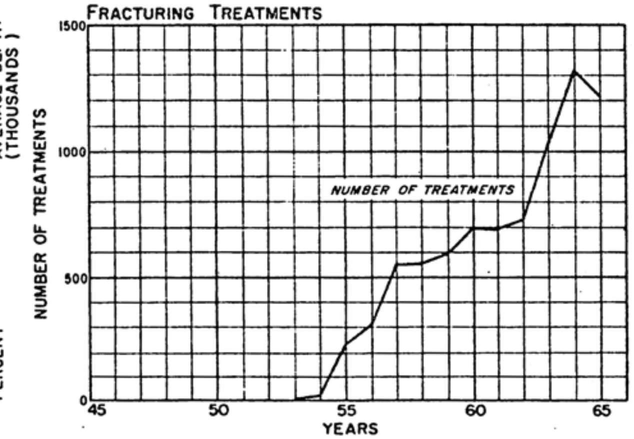
Gas Liquids



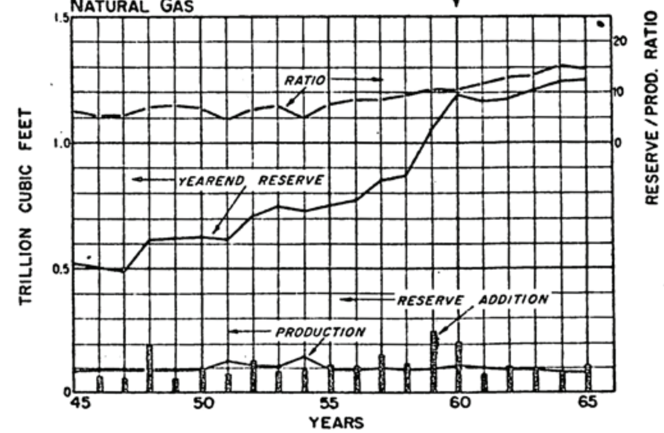
Development Wells



Fracturing Treatments



Natural Gas



PENNSYLVANIA

WEST VIRGINIA

Crude oil did not play a significant role in West Virginia for the period of 1945-65. At the beginning of the period, 1945, crude production was at the stripper stage from secondary recovery operations commenced in prior years. An average well produced at the rate of .48 barrels per day, reserves approached 50 million barrels and production was only 6,000 to 8,000 barrels per day between 1945 and 1965. Oil, therefore, had only a minimal effect on exploration and production in West Virginia.

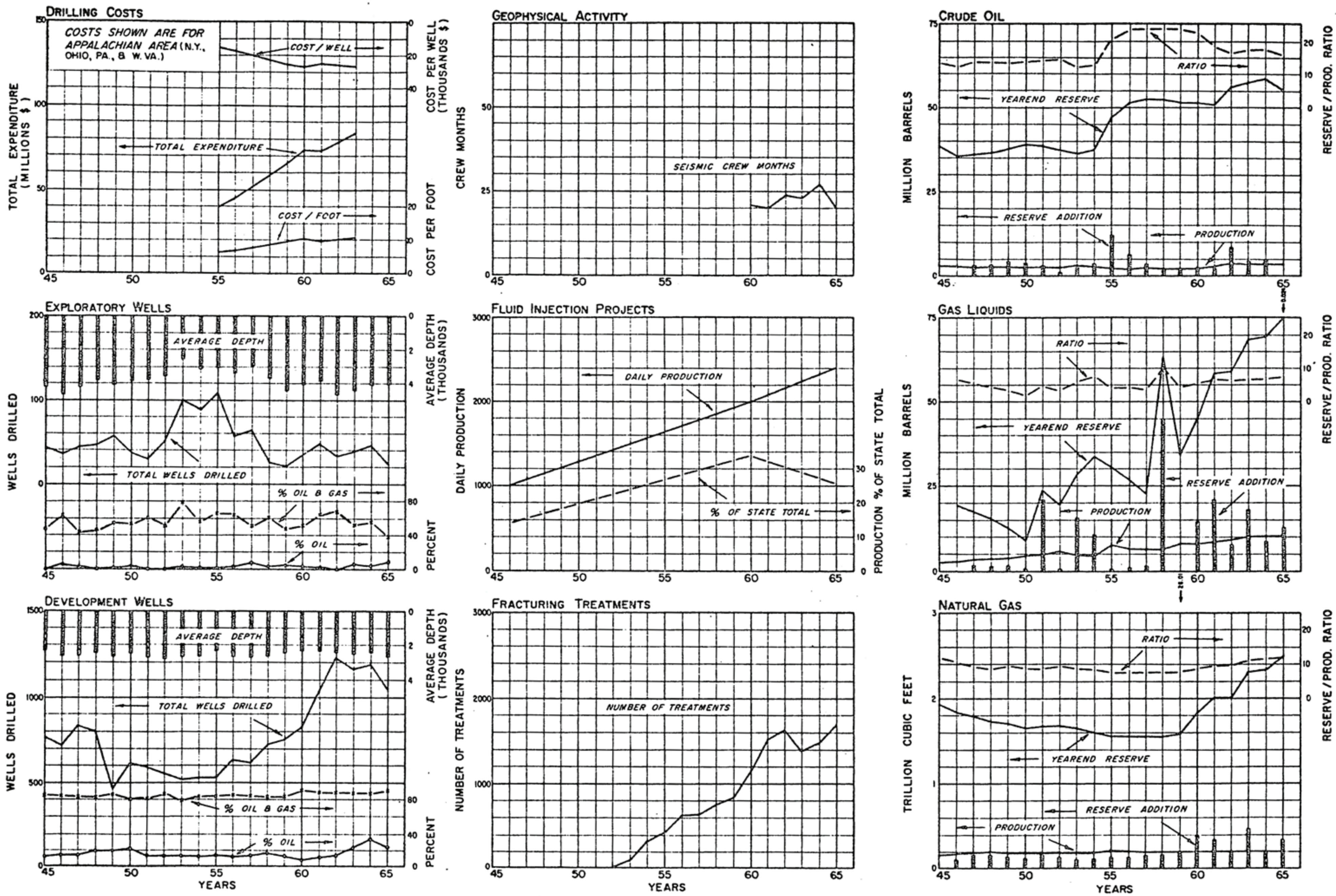
Exploration was at a very low level throughout 1945 to 1965. Increases in exploratory well activity in 1953-55 resulted from gas discoveries at Terra Alta and Gladys fields. However, exploratory well activity fell again in 1957 and showed only a slight increase in later years after the benefits of formation fracturing technology had been demonstrated.

Gas reserves declined until 1959. Formation fracturing applied to numerous old wells resulted in reserves increasing from 1959 through 1965. Gas production held at the 500 million cubic feet per day level throughout the period. Improvement in liquid recovery from gas streams resulted in increasing liquid production throughout the period under study.

Fracturing in West Virginia did not gain widespread use until early 1953. Today, some thirteen years later, fracturing has become an integral part of the completion program. Its need is so apparent that without it the activity in West Virginia would have been considerably curtailed. The most recent significant gas development has been the Newburg formation centered in Kanawha County. Many of the wells produce under one million cubic feet per day and produce several million after fracturing. Such response has increased development and is encouraging exploration of a large area through the central part of the State.

Formations being fractured extensively are the Injun, Oriskany, and Berea sands. Most fracturing during the past five years has been associated with gas production. However, many wells in the Big Injun oil sand and other oil sands in central West Virginia have become economic by fracturing.

During the past twenty years, there have been a small number of secondary recovery projects attempted in West Virginia, but with little over-all economic success. Two steam pilots employing the huff-and-puff method have been attempted without success.



WEST VIRGINIA

MID-CONTINENT

AREA

ARKANSAS

Arkansas entered the postwar years with exploratory drilling at a minimum and geophysical activity at a relatively high plateau, which continued until 1952 before declining. Much of the State's crude oil production (40%) was already the result of secondary recovery.

Exploratory drilling increased in 1947 to double the effort of 1945 and remained at that level of just over 120 wells per year through 1954. This exploratory well program did not discover new, large fields, but did extend existing fields and help increase crude reserves to their high for the twenty-year period. Secondary recovery was the principal cause of this reserve increase. Geophysical effort declined abruptly in 1953 and continued a downward trend throughout the rest of the period.

Commencing in 1955, exploratory drilling activity increased because of success in new pays and extensions. In south Arkansas, a total of fourteen new oil pays, one gas-condensate pay, and fourteen new extensions around the Schuler, El Dorado, Lisbon and Magnolia Giant Fields were discovered. Significant new discoveries were also made at McKinney Bayou and Willisville, while in northern Arkansas the discovery of the Gragg Field gave some momentum to exploration. This increased activity continued, and in 1957 exploratory drilling reached a peak. In south Arkansas, ten new fields were discovered, and the advent of sand fracturing led to the drilling of many wells in shallow areas.

The year 1958 saw a decline in all drilling activity and in the number of fracturing treatments; however, in north Arkansas the greatest number of Pennsylvanian discoveries in the history of the Arkansas Valley were recorded. Commencing in 1960, gas became the primary target for explorers. Deep Pennsylvanian discoveries in southeastern Oklahoma spread to Arkansas, followed by Mississippian targets in 1961. Northern Arkansas became a major gas province and gas reserves increased 64% between 1960 and 1965. The first Hunton-Siluro-Devonian gas was found in 1962, when selectivity of prospects yielded a success ratio of 28% for wildcats and 70% for field wells.

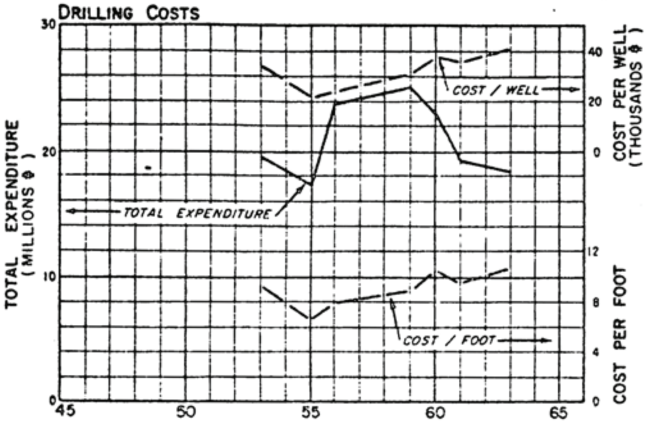
The end of this report period (1965) saw exploratory drilling on the decline, gas becoming the primary target, and selectivity of exploratory prospects a necessity because of the deeper targets.

The area of technology contributing most to the State's production has been fluid injection projects conducted in some of the old, major fields. Throughout the report period, some 45% of the State's annual production has been from fluid injection projects. These projects produced an estimated 12,800,000 barrels in 1965, which is 49.2% of the State's annual production for that year.

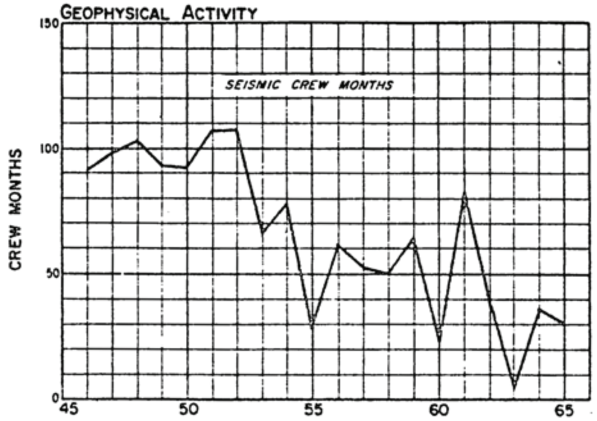
(Arkansas)

The impact of fracturing in Arkansas is readily apparent. The peak period of treatments occurred in 1958 and coincided with shallow Nacotoch and Buckrange developments in southern Arkansas. Although reserves were not significantly increased, a notable increase in capacity was created as a result of the drilling program associated with the fracturing program.

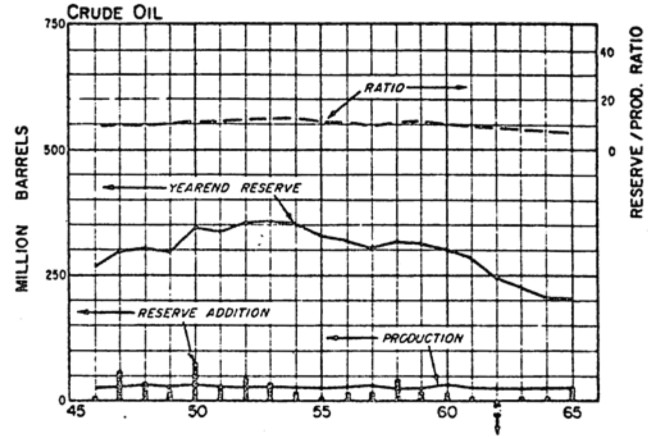
DRILLING COSTS



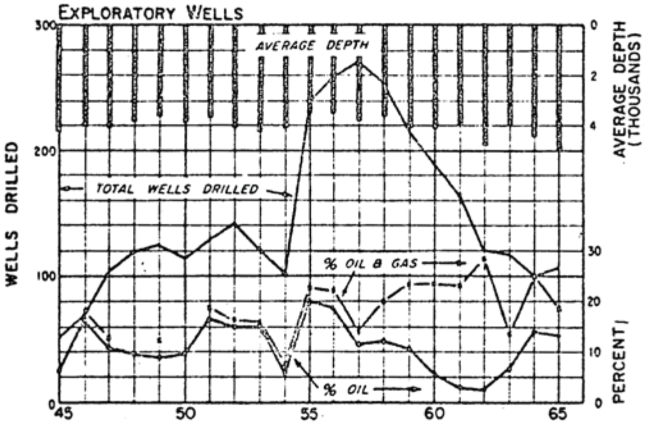
GEOPHYSICAL ACTIVITY



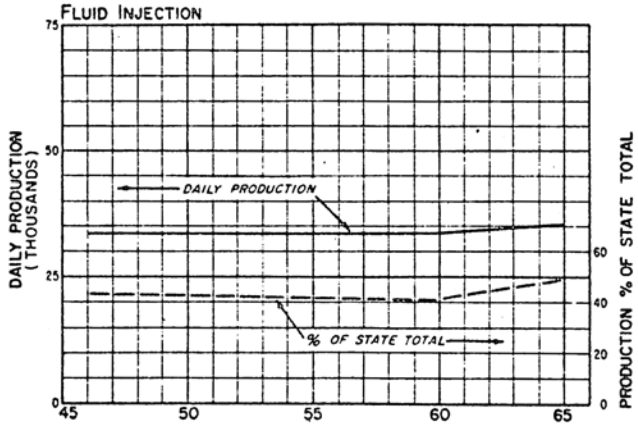
CRUDE OIL



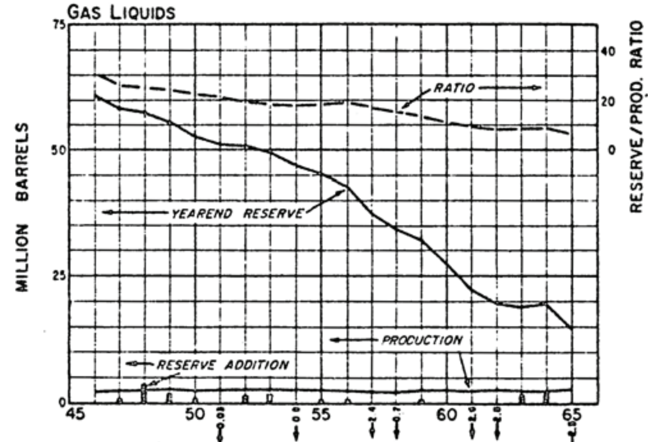
EXPLORATORY WELLS



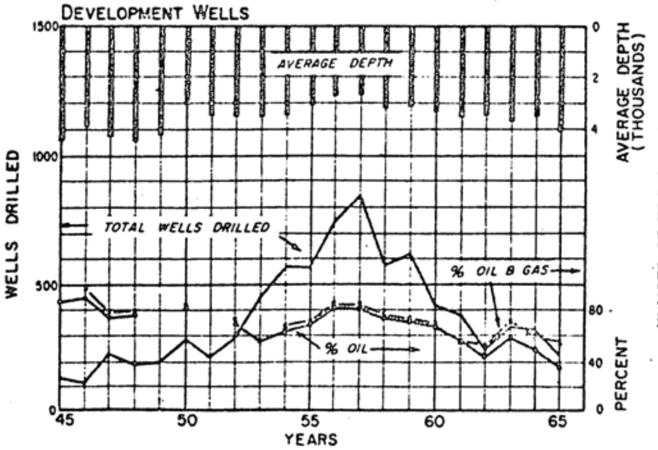
FLUID INJECTION



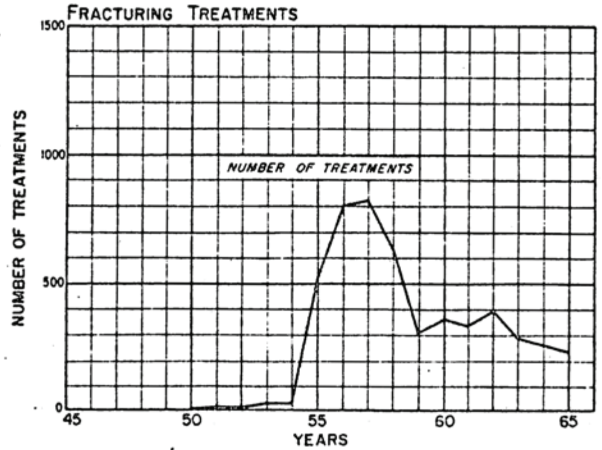
GAS LIQUIDS



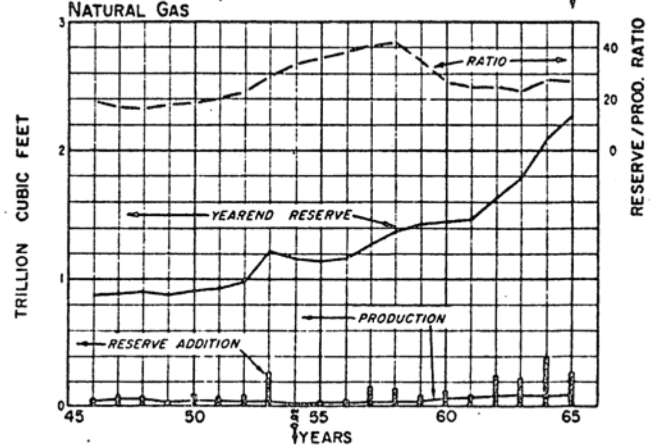
DEVELOPMENT WELLS



FRACTURING TREATMENTS



NATURAL GAS



ARKANSAS

ILLINOIS

At the beginning of 1946 Illinois was witnessing the initial success of new technology in secondary recovery methods on producing rates. A serious decline in production commencing prior to 1941 was partially arrested in 1943 by secondary recovery operations. As it became evident that the reservoirs were responding very well to improved secondary recovery methods and with the release of war time restrictions, exploratory and development drilling program was expanded beginning in 1945 and reached a peak in 1950-51. The exploratory well program did not discover large fields, but did extend existing fields and uncovered new pays in old fields. Geophysical effort, both seismic and gravity, also increased during this period but failed to make a significant contribution to finding new fields. Geophysical effort subsided in 1953-54 and did not increase again for the period under consideration.

Oil reserves increased from 350 million barrels in 1945 to 650 million barrels in 1951 as a result of secondary recovery projects and exploratory drilling. When reviewing the technological advances which have influenced the reserve and production history of Illinois, waterflooding must be considered as the foremost factor. Production from waterflood projects has increased from 13 million barrels in 1946 to 120,000 in 1965, and currently is 70% of the state total. Highlighting the more successful floods are Louden, Salem, and Clay City Consolidated. These three fields, alone, were responsible for over 35 percent of the state's production in 1964.

Although it is difficult to know exactly when trial flooding began, the first pressure flood was initiated in 1942. For twenty consecutive years, waterflooding increased oil production and it was not until 1962 that a decrease in waterflood oil became apparent from the previous year.

Producing formations associated with waterflooding are predominantly well consolidated sandstones of the Pennsylvanian and Mississippian systems. With the exception of the Aux Vases sand, most sands are of moderate permeability and porosity. Limestones of the Mississippian and the Oolitic McClosky limestone have been successfully flooded. With improved technology, waterflooding has been even more successful in the Illinois Basin. Failures are mostly associated with the older projects. Experience has reduced the percentage and in recent years, where properties have been carefully selected and properly engineered, the number of unsuccessful floods has been low.

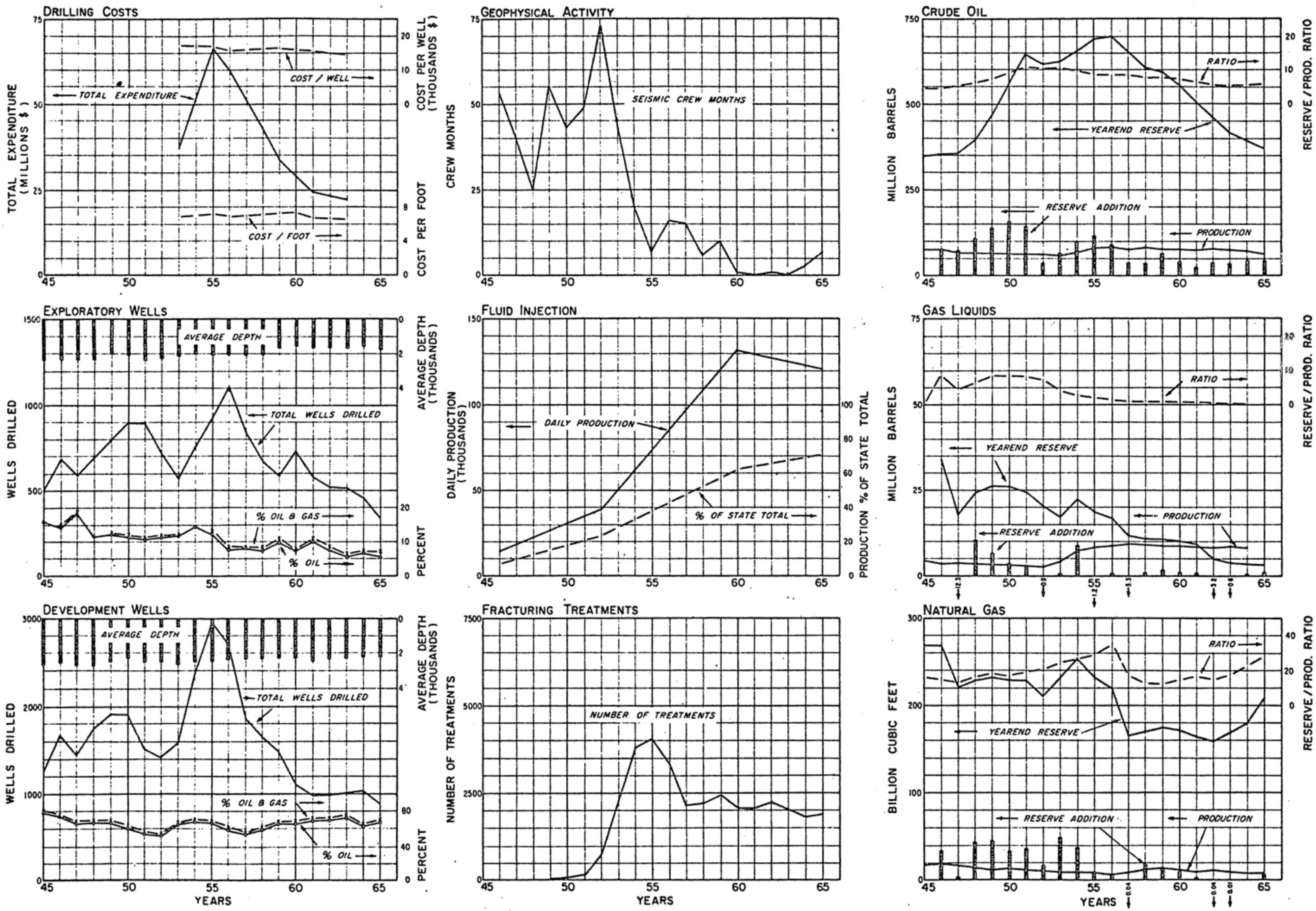
Although, as of today, secondary recovery methods using water injection are still the most important factor in the Illinois oil industry, experimental laboratory research work and field trials relating to tertiary recovery have been under way since 1961.

The initial effect of the development and introduction of formation fracturing technology in 1952 was a reduction in drilling, both development and exploratory wells. This reduction in drilling lasted until 1954 as operators applied available funds to fracturing old wells rather than drilling new wells. Spectacular results were exhibited in producing rates with the application of formation fracturing. This technique was widely accepted and fracturing jobs were numerous.

Commencing in 1954 drilling activity, both development and exploratory, again began to increase as the inventory of old wells for fracturing was depleted. This new wave of drilling climaxed in 1956 with 1103 exploratory wells. New geological horizons in the Aux Vases and Walterburg sands were opened up as a result of fracturing. Industry responded to this new technology and reserves rose to the highest level for this period -- some 700 million barrels. Production also hit its highest point for the period. Expansion of secondary recovery projects also contributed to the increase in reserves and producing rates.

The first successful attempt of fracturing the Aux Vases sand where it was fine grained took place in 1953. Once it was realized that the Aux Vases could be successfully fractured into commercial wells, about eighty percent of the Aux Vases completions near Fairfield were fractured. The popularity increased to a point where more than fifty percent of all wells completed were fractured. Fracturing through 1961 was a major factor, with waterflooding, in maintaining the state's production rate.

Crude oil reserves showed an appreciable increase in the late forties and maintained itself until 1959, when the current decline in reserves began. A reserve peak was reached in 1955-56 which corresponds to the time of maximum drilling during this report period. Supplementing this was the impetus of waterflooding during the entire period of 1949 through 1959. Illinois is an excellent example of how the effects of technological advancement can be directly observed in increased reserves and production.


DRILLING COSTS
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
TOTAL EXPENDITURE
COST / WELL
COST / FOOT
GEOPHYSICAL ACTIVITY
CREW MONTHS
SEISMIC CREW MONTHS
CRUDE OIL
MILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
EXPLORATORY WELLS
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
FLUID INJECTION
DAILY PRODUCTION (THOUSANDS)
PRODUCTION % OF STATE TOTAL
DAILY PRODUCTION
% OF STATE TOTAL
GAS LIQUIDS
MILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
DEVELOPMENT WELLS
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
NUMBER OF TREATMENTS
NATURAL GAS
BILLION CUBIC FEET
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
YEARS

ILLINOIS

INDIANA

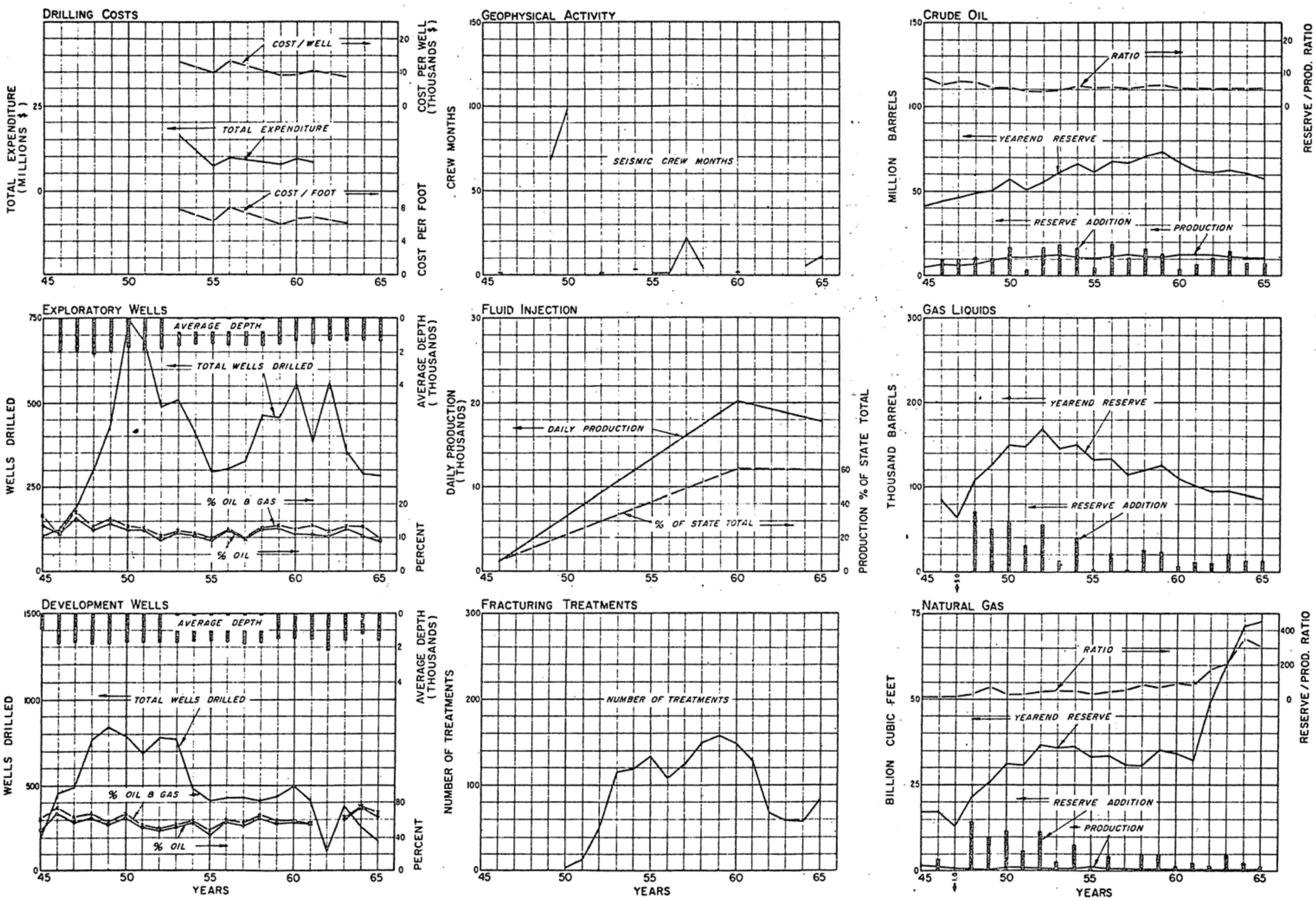
Indiana entered the postwar years with a backlog of exploratory prospects and the economic climate was right to take advantage of these opportunities. Shallow, inexpensive wells (around 1,500 foot depth), oil potential and good crude oil prices provided the initial incentive. Early, favorable results in finding production from multiple Mississippian zones and Devonian reefs provided the driving force that caused exploratory well activity to increase from 105 wells in 1945 to a peak of 743 wells in 1950. Oil production peaked in 1953 at 35,000 barrels per day from 13,000 barrels per day in 1945, and reserves showed a similar rise. Geophysical activity and leasing were also at high levels during this period.

After 1950 exploratory well activity began to fall off as fewer opportunities were available, reaching a low of 292 wells in 1955, however, exploratory and development drilling again increased in 1958-1960 in recognition of new opportunities in rocks of the shallow Chester series. Since 1962 exploratory well activity has declined.

Geophysics has not played a significant role since 1949-1950 in the Indiana area. Shallow, stratigraphic pools do not lend themselves to definition by known geophysical means.

Indiana's production has been maintained at approximately 32,000 barrels per day since 1955 by secondary recovery operations. Oil reserves reached a maximum in 1959 and have since continuously declined as exploration failed to add new, large productive areas. Of the 585 total wells drilled in 1964, 240 were associated with secondary recovery projects, which indicates the impetus of secondary recovery operations on the industry in Indiana. Most of these secondary recovery wells were in the Mississippian and Pennsylvanian reservoirs in the southwestern part of the state. Waterflood operations have been increased each year for the past fifteen years, and one hundred fields have now been partially or wholly subjected to waterflooding. The production decline from older projects is being partially offset from newer floods. Secondary recovery oil is making an increasing contribution to the State's total output. In 1965 waterflood projects produced 18 million barrels which was 60% of the State's total.

Formation fracturing did not have a significant impact on Indiana production as it did in other states except for extensive fracturing of initial completions in the Aux Vases and Tar Spring formations. Since 1962 there has been a drop in the number of fracturing treatments in Indiana, which is related to fewer wells being drilled.



DRILLING COSTS
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
GEOPHYSICAL ACTIVITY
SEISMIC CREW MONTHS
CREW MONTHS
CRUDE OIL
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
MILLION BARRELS
RESERVE / PROD. RATIO
EXPLORATORY WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
FLUID INJECTION
DAILY PRODUCTION
% OF STATE TOTAL
DAILY PRODUCTION (THOUSANDS)
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
YEAREND RESERVE
RESERVE ADDITION
THOUSAND BARRELS
DEVELOPMENT WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
BILLION CUBIC FEET
RESERVE / PROD. RATIO
YEARS

INDIANA

KANSAS

Exploratory activity was at a low level at the beginning of the period. It quickened after 1946, mainly in the Hugoton field and Central Kansas Uplift.

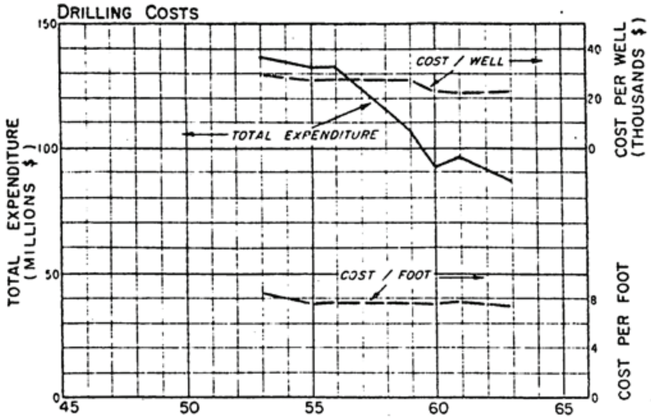
Activity remained at a relatively high level until 1960 when it began a decline that has continued to the present time. Development in the Greenwood field area in 1961 and 1962 provided some additional exploration incentive with temporary effect.

Fracturing techniques have been of particular importance in the large Hugoton gas field and have provided opportunity for additional drilling in many parts of the State, particularly in the period 1953-1956. The development of logging tools for salt sections and improved porosity tools also contributed to activity.

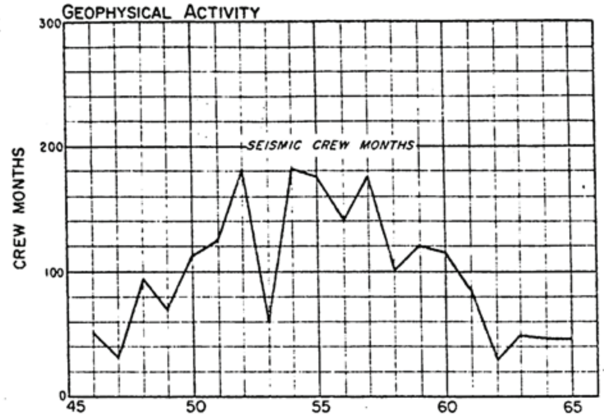
Fluid injection has been active and by the end of 1965 there were 1,039 active projects, accounting for 17 percent of the State's production.

Large reserves of oil are known to exist in the shallow, thin Pennsylvanian sands of southeastern Kansas. From 1956 through 1965, nine steam and seven in-situ projects had been attempted in sands ranging from 100 to 860 feet deep. Few, if any, of these were profitable, and most of the projects have been terminated.

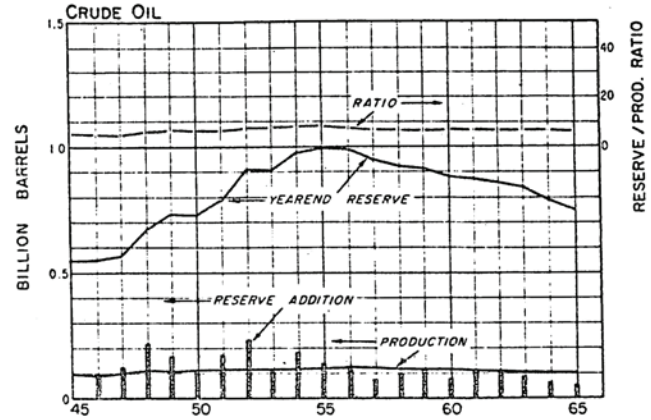
Drilling Costs



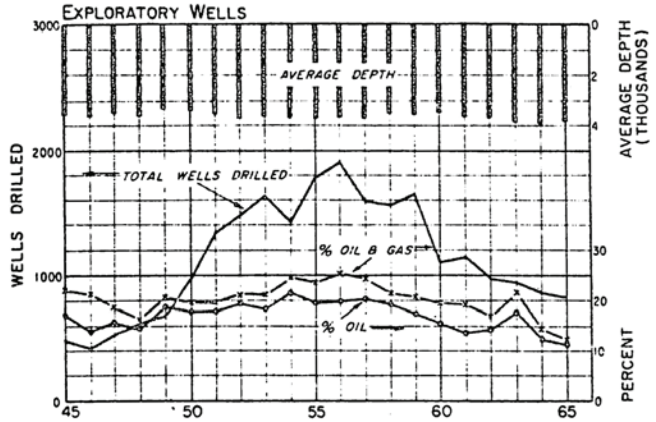
Geophysical Activity



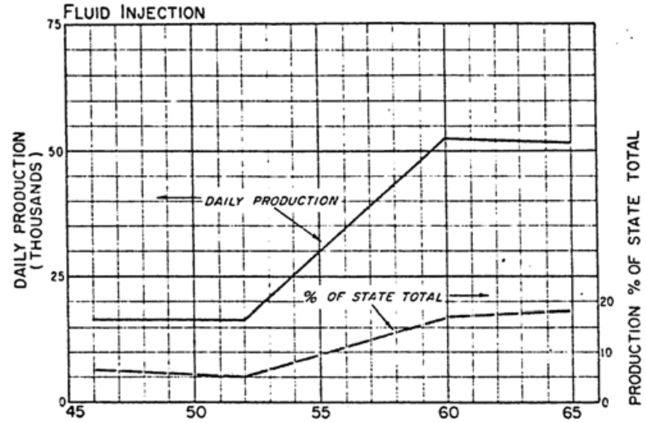
Crude Oil



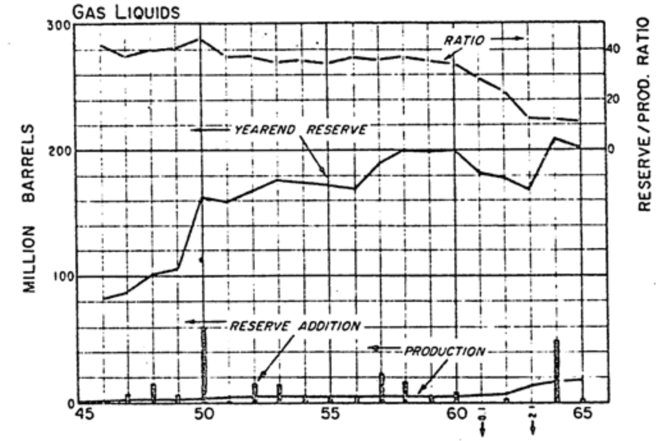
Exploratory Wells



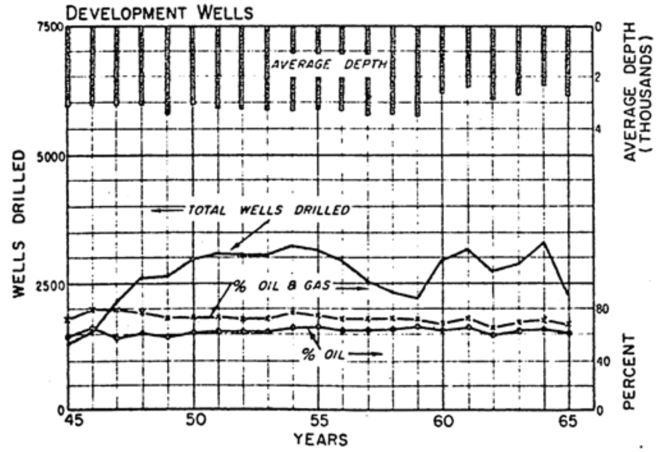
Fluid Injection



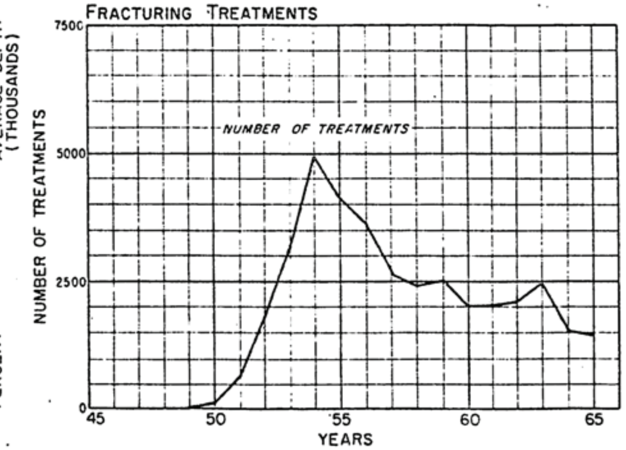
Gas Liquids



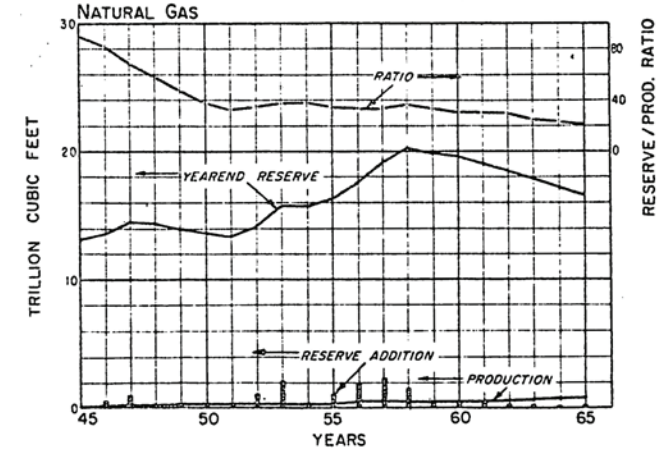
Development Wells



Fracturing Treatments



Natural Gas



KANSAS

KENTUCKY

Kentucky entered the postwar years with exploratory well activity at a low level, oil production declining, and reserves at their lowest level for the total period of 1945-65.

These conditions continued until 1948-49. The year 1950 saw expansion into new areas of geologic opportunity. Previously, the area south of the Shawnee-Rough Creek Fault system was thought to be unfavorable for exploration. A revision of this concept resulted in an increase in exploratory wells and leasing activity. Several discoveries from Chester sands and the McClosky limestone resulted from this move and contributed to a high level of exploration through 1956.

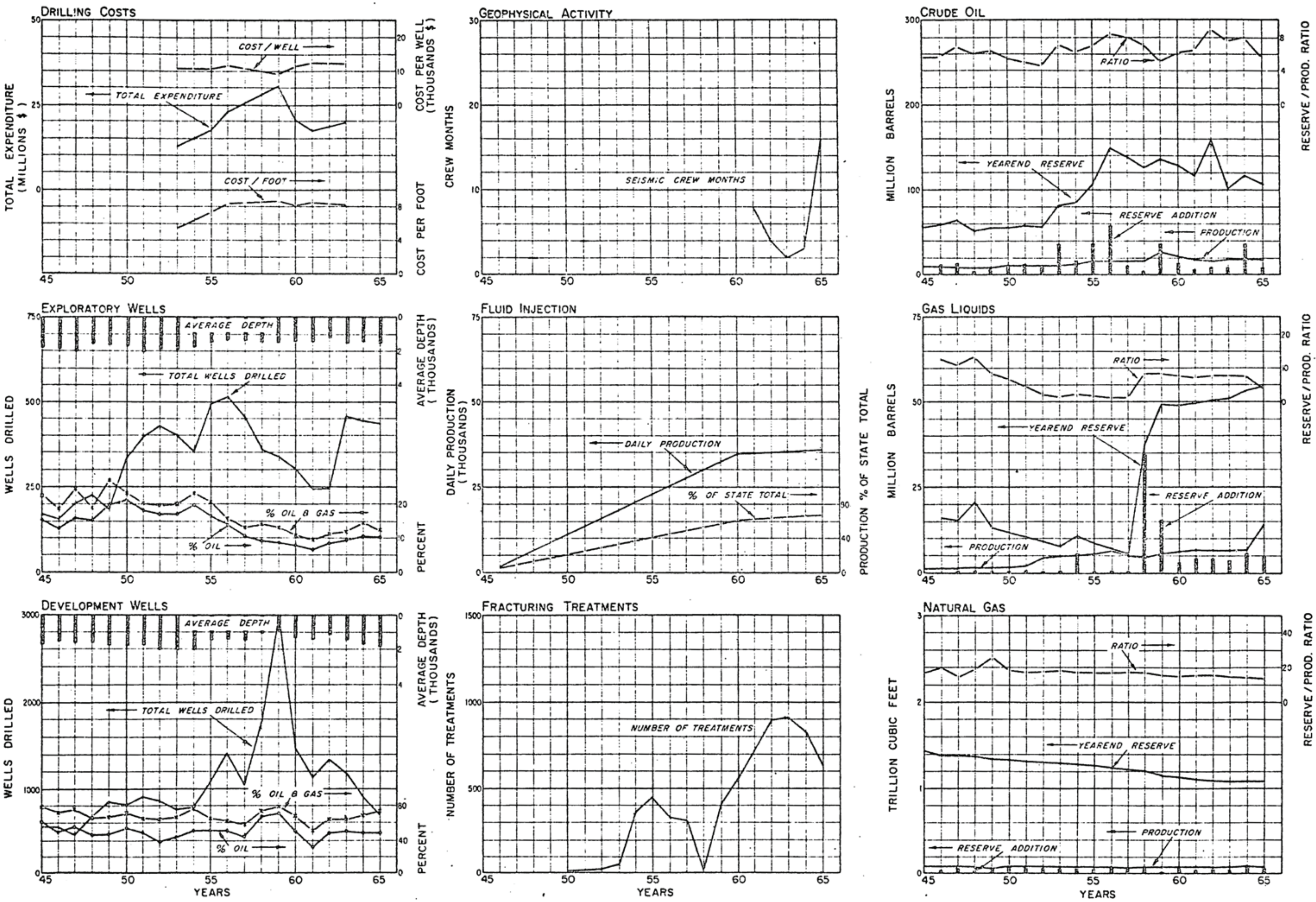
Shallow Chester Pool discoveries in Muhlenberg and Christian Counties made 1956 a peak year. This level was maintained through 1959 as a result of discoveries in Green County. 1963 was strongly influenced by a discovery in Harrison County. Geophysics has played only a minor role in exploration in Kentucky. An increase in seismic activity in 1961 was preparatory to drilling a series of pre-Cambrian tests and the increase in 1965 resulted from evaluation work conducted prior to the sale of oil and gas rights under the Camp Breckinridge Military Reservation.

Oil production and reserves have increased since the beginning of the period. Although discoveries have caused sharp, short-lived peaks in reserves and production, the overall pattern shows an increase. As in other states, formation fracturing has played a significant part. Fracturing in eastern Kentucky has been mainly confined to the Weir sand, with some fracturing of the Berea, Injun, Big Lime and other formations. The number of fracturing treatments peaked in 1962 and 1963. Although detailed production data is not available, an estimated 70 percent of the wells fraced showed a good increase in productivity. Wells in the Weir sand, without any substantial production possibilities, have been converted to commercial producers.

Secondary recovery operations have also been a factor in maintaining Kentucky's reserve and production positions. Gas injection started in 1940, and due to the unsystematic manner in which the projects were conducted, the results were not too encouraging. Subsequent gas repressuring, using techniques learned from earlier failures, pointed the way to better planned projects which, in the late forties and early fifties, began to yield satisfactory production. Besides the Weir sand, air and gas repressuring in the Big Sinking and Irvine-Furnace corniferous lime fields of east central Kentucky have been highly successful, although the scarcity of gas for repressuring limited the magnitude of these successes.

In 1948, water injection was commenced in the Oil Springs area (Weir sandstone) in east central Kentucky. Expansion of the project resulted in a 1954 peak in production. Waterflooding was also initiated in the Big Sinking field in 1949 with large production increases.

The first repressuring project was started in western Kentucky in 1935. The first waterflood was begun in April 1941, with controlled flooding commencing in 1946. Although the great majority of waterfloods in western Kentucky deal with sandstone, in more recent years there has been an increasing interest in the flooding of oolitic limestone. Considerable success has been attained in flooding limestones where other conditions are favorable.


DRILLING COSTS
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
GEOPHYSICAL ACTIVITY
SEISMIC CREW MONTHS
CREW MONTHS
CRUDE OIL
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
MILLION BARRELS
RESERVE / PROD. RATIO
EXPLORATORY WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
FLUID INJECTION
DAILY PRODUCTION
% OF STATE TOTAL
DAILY PRODUCTION (THOUSANDS)
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
MILLION BARRELS
RESERVE / PROD. RATIO
DEVELOPMENT WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
RATIO
YEAREND RESERVE
PRODUCTION
RESERVE ADDITION
TRILLION CUBIC FEET
RESERVE / PROD. RATIO
YEARS

KENTUCKY

MICHIGAN

Exploratory drilling activity showed an increase in 1945 of 25% over 1944, after release from wartime restrictions and shortages. The level of geophysical activity was very low in 1945, because core drilling was then the principal method of preliminary exploration in Michigan. However, core drilling was down to 203 core holes from a peak of 376 in 1943. Annual oil production was declining at the rate of approximately 1,500,000 barrels per year, a trend that had begun prior to 1945. Gas production in 1945 showed an increase of 2-billion cubic feet over 1944 as a result of shut-in gas fields coming on production. Oil reserves had leveled out at approximately 60-million barrels as annual production approximated annual reserve additions. Gas reserves began to increase as a result of the economic incentives provided by new markets for gas.

The period from 1945 to 1958 is one of over-all decline except for a short burst of activity by gravity crews climaxing in 1953. Exploratory wells drilled decreased from 356 in 1945 to 145 in 1957. Daily oil production declined 22,000 barrels per day, while gas production fell 35-million cubic feet per day. Oil reserves were drawn down from 65 million barrels in 1945 to 45 million barrels in 1958 as production consistently exceeded new discoveries and the older fields were depleted.

Gas reserves showed a slow but steady increase, reaching 350 billion cubic feet in 1956. The introduction of gravity in 1952-53-54 was an effort to reverse the down-trend by bringing in technology new to the area. The immediate results were not encouraging. The gravity work fell off sharply after 1954 and the downtrend in all parameters continued unabated until 1957-58.

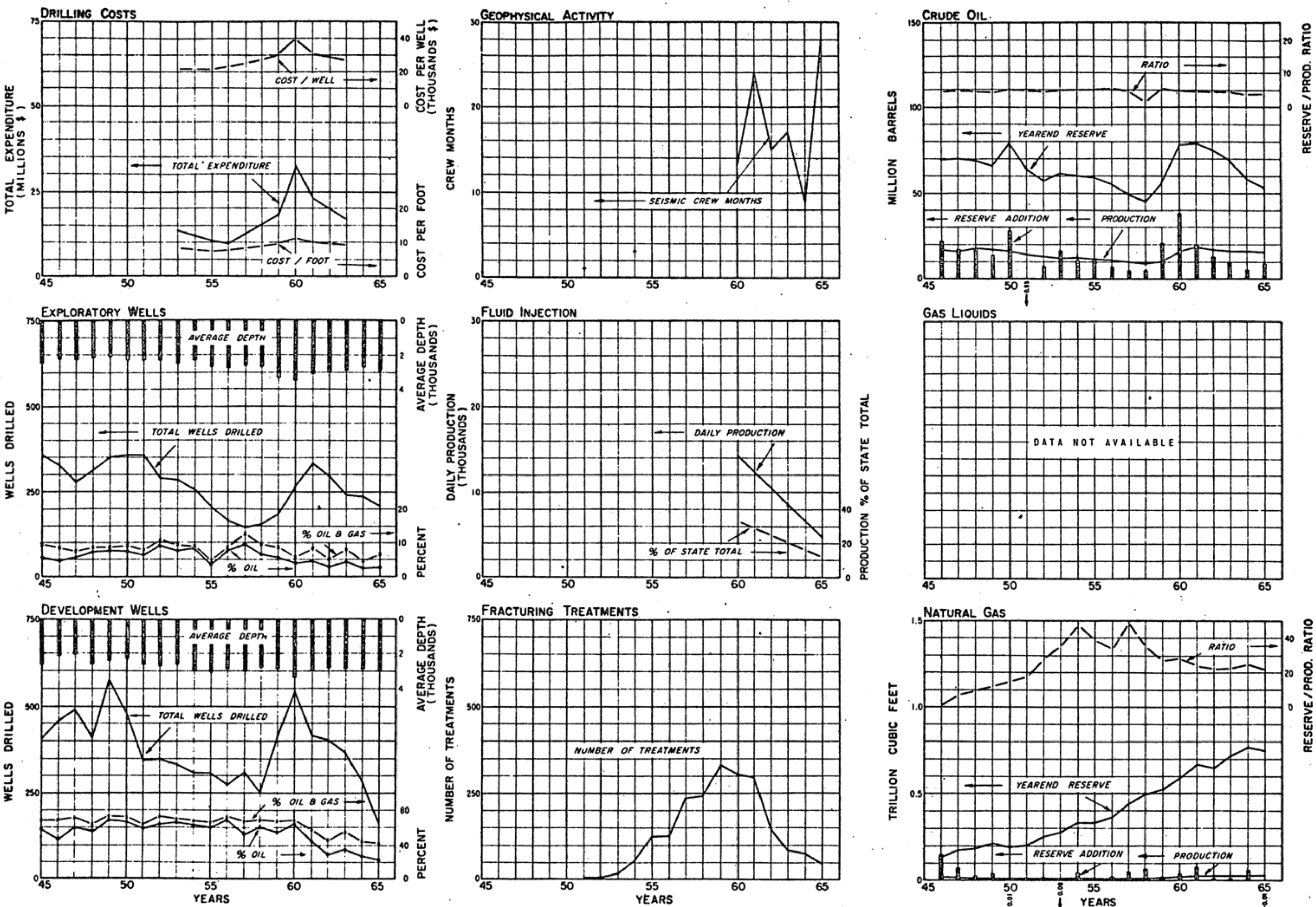
The discovery of oil and gas at Scipio in 1957 followed by several Niagaran reef gas fields in 1959-61 in the "Thumb" area provided areas of renewed geologic opportunity and a resulting increase in exploration activity. Exploratory wells increased from 145 in 1957 to 332 in 1961. Daily oil production rose from 25,000 barrels per day to 51,000 barrels per day. Gas production increased approximately 75 million cubic feet per day. Geophysical activity, particularly gravity, rose quickly to a sharp peak in 1961 as the search for reefs and features similar to Albion-Scipio intensified. Gravity and seismic activity decreased after 1961, peaking again in 1965 as the search for gas-bearing reefs in the southeastern portion of the state was intensified.

Exploratory well activity peaked in 1961 at 332 wells. Failure in locating other fields similar to Albion-Scipio resulted in a decrease of wildcat wells to 208 in 1965, decrease in oil production from 51,000 barrels per day in 1961 to 40,000 barrels per day in 1965 and a decrease in reserves from 79 million barrels to 52 million barrels.

(Michigan)

Gas reserves and production generally show increases each year throughout the period 1957-1965. The gas reefs have additional utility as gas storage reservoirs.

Throughout the period of this report, development activity has been limited to a few fields


DRILLING COSTS
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST / WELL
TOTAL EXPENDITURE
COST PER FOOT
COST / FOOT
GEOPHYSICAL ACTIVITY
CREW MONTHS
SEISMIC CREW MONTHS
CRUDE OIL
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
MILLION BARRELS
RESERVE / PROD. RATIO
EXPLORATORY WELLS
AVERAGE DEPTH
AVERAGE DEPTH (THOUSANDS)
TOTAL WELLS DRILLED
WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
FLUID INJECTION
DAILY PRODUCTION (THOUSANDS)
DAILY PRODUCTION
% OF STATE TOTAL
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
DATA NOT AVAILABLE
DEVELOPMENT WELLS
AVERAGE DEPTH
AVERAGE DEPTH (THOUSANDS)
TOTAL WELLS DRILLED
WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
TRILLION CUBIC FEET
RESERVE / PROD. RATIO
YEARS

MICHIGAN

OHIO

Ohio entered the period under study at a very reduced level of exploration activity. Total well completions were down from preceding years, there was no leasing of large blocks, major companies had practically withdrawn from the State's activity. No new oil pools were discovered and gas completions were down due to high costs and lack of discoveries.

The discovery and development of Canton Gas field in 1946-48 resulted in an upswing in development drilling, but did not affect exploratory well activity which continued to decline. Gas production rose sharply as a result of the Canton Gas field discovery, but fell to approximately 100 million cubic feet per day between 1948 and 1951 as Canton field declined. Gas production leveled off at or near 100 million cubic feet per day and continued at that rate through 1965. Oil production and reserves declined until 1951.

The years 1959-60 saw the beginning of interest by operators in deeper sediments. In 1960 one oil discovery and one gas discovery focused interest on the Cambro-Ordovician sediments and resulted in an increase in exploratory well activity. This play received its greatest push in 1963 with the Trempealau discovery in Morrow County. As a result of this discovery, exploratory well activity jumped from 207 wells in 1963 to 753 in 1964. Oil reserves rose to a new high of 100 million barrels in 1965, oil production increased 27,000 barrels per day by 1964, and then began to decline in 1965 as the initial flush producing rates dropped off.

Geophysical crew activity rose from almost zero to 260 crew months in 1964 and then dropped sharply in 1965 which also saw a decline in exploratory wells and total well completions. The inability to significantly extend the Trempealau play has had a dampening effect on exploration.

The widespread acceptance of hydraulic fracturing has had a significant effect on Ohio's oil reserves and oil production. The initiation of fracturing in 1951 was the main factor related to the increase in reserves from 1952 through 1959. The formations involved were the Berea and Clinton sands and results show that 68 percent of the Berea gas wells fraced were considered successful. Of the Berea oil wells fraced, statistics indicate that 40 percent were considered successful. Of 325 Clinton wells, 79 percent of which were oil producers, fracturing was successful in 94 percent of the applications. For the most part, the fracture treatments were of the jelled water type.

The magnitude of the increased production in Ohio, which is the result of fracturing, ranges from 2 to 100 times the natural production. This increase in production on marginal wells is great enough to make producing wells out of those that previously would have been abandoned. As a general statement, fracturing results show a higher production after completion than does the nitro shooting. In the cable tool operations, used predominantly in Ohio, fracturing also saves time in well completion work. Some 5,700 fracturing jobs were performed in the State between 1952 and 1959. Oil reserves increased from 27 million barrels in 1952 to 73 million barrels in 1959, and production increased 7,000 barrels per day in the same period.

Gas sands did not respond to fracturing as did the oil sands. Therefore, a large increase in gas reserves and production similar to the increase in oil did not take place.

Beginning in 1956 total well completions declined as opportunities to employ fracturing technology in new wells diminished. However, oil reserves and production continued to increase to 1958-59 due to the application of fracturing technology to older wells. After 1958-59, oil reserves and production leveled out or declined slightly as the initial response to fracturing began to fade.

The first official waterflood in Ohio occurred in 1939 and was initiated in the Berea sandstone at Chatham Township, Medina County. It has been very successful and is still operating today. Other attempts at waterflooding the Berea and other formations prior to 1950 resulted in only poor to moderate success. Few of the early floods were based on technical advice and most were of a hit or miss nature.

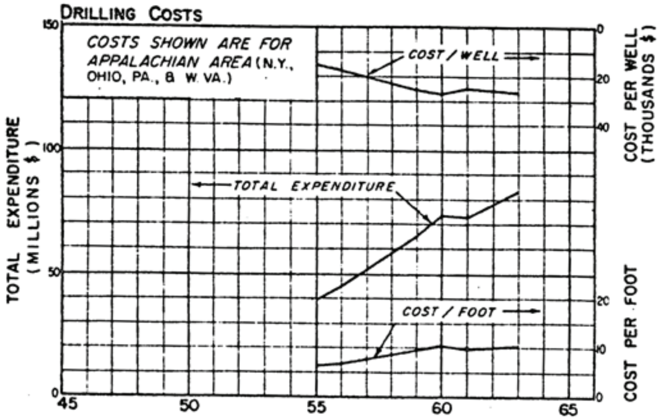
By 1950 there were ten active shallow sand repressuring projects in Ohio, located in Monroe, Morgan and Washington Counties. The formations involved included the Cow Run, Macksburg, Injun and Keener zones. Also active in the late forties and early fifties were a Berea sandstone repressuring operation in Carroll County and five Clinton sandstone projects in Perry and Hocking Counties. Repressuring of the Clinton sandstone had previously occurred some time prior to 1950, but the attempts were unsuccessful and the projects subsequently abandoned.

Since 1950 little has been published on secondary recovery in Ohio. As late as 1962 there were supposedly 14 active repressuring (recycling) operations in the Clinton sandstone. The most common method used in the recycling program is that of recycling the produced natural gas, but there is seldom any make-up gas added; accordingly, little, if any, repressuring is actually taking place. In one operation, however, the operator is using inert exhaust gas for recycling.

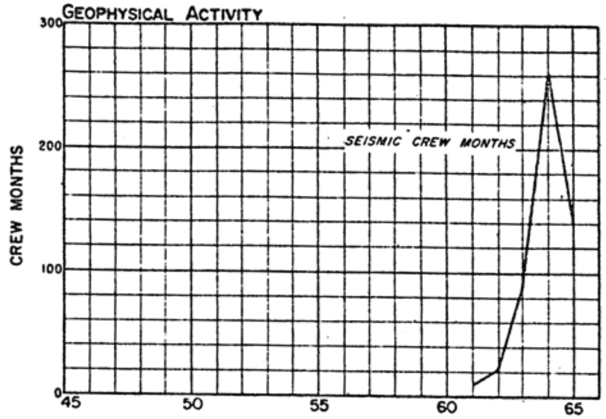
As late as 1962 there were 17 active waterflood operations in Ohio. For the most part, these floods were confined to the Berea, Keener and Clinton formations. Some of these floods are now thought to be abandoned.

In summation, successful secondary recovery of oil in Ohio has been mainly confined to repressuring by air or gas, including recycling, and to a few well engineered Berea sandstone waterfloods. Attempts at waterflooding other Berea areas and productive zones have been disappointing, probably because of lack of information and proper engineering techniques.

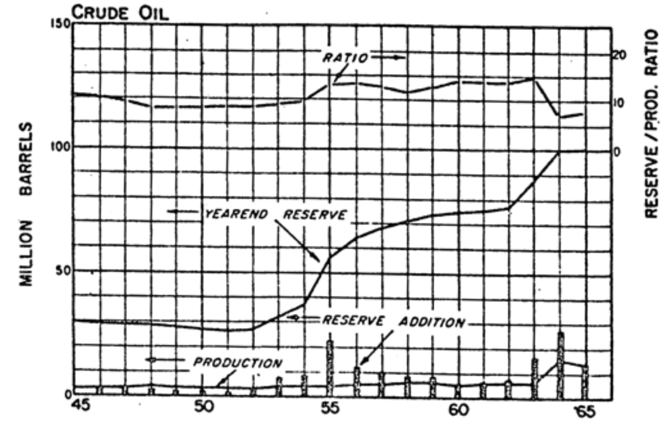
Drilling Costs



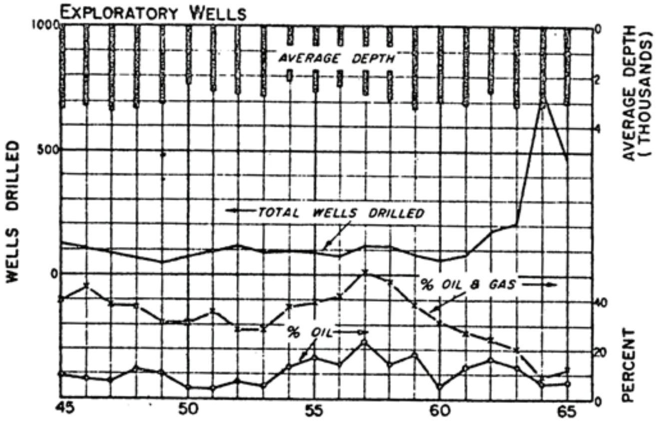
Geophysical Activity



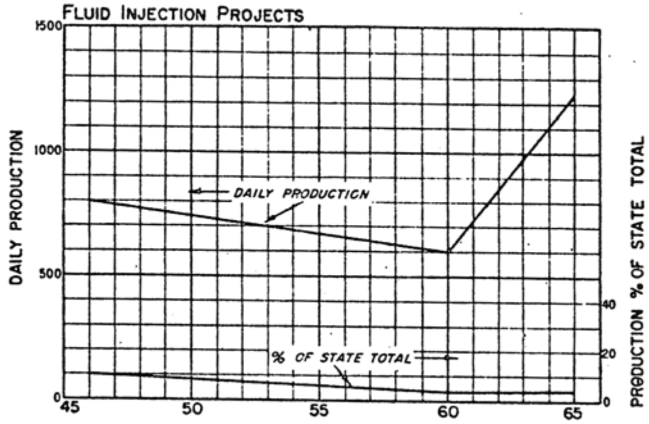
Crude Oil



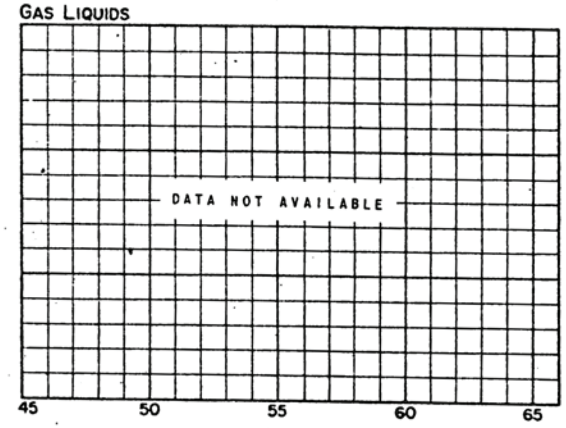
Exploratory Wells



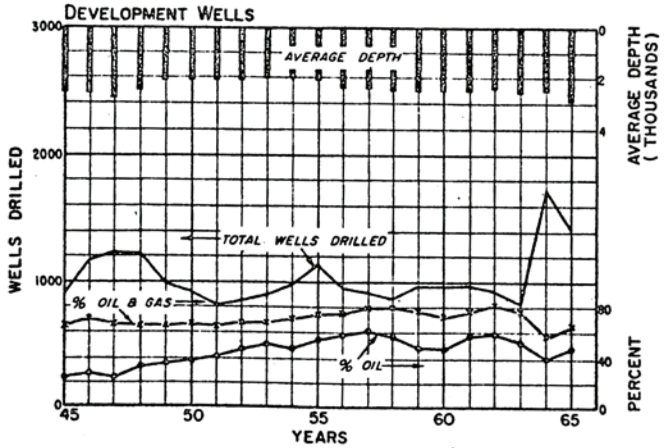
Fluid Injection Projects



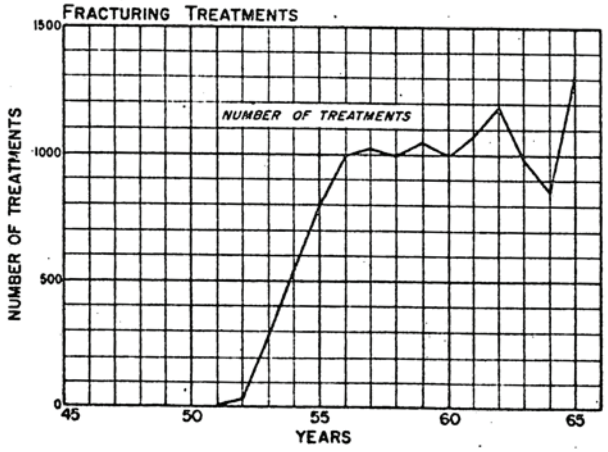
Gas Liquids



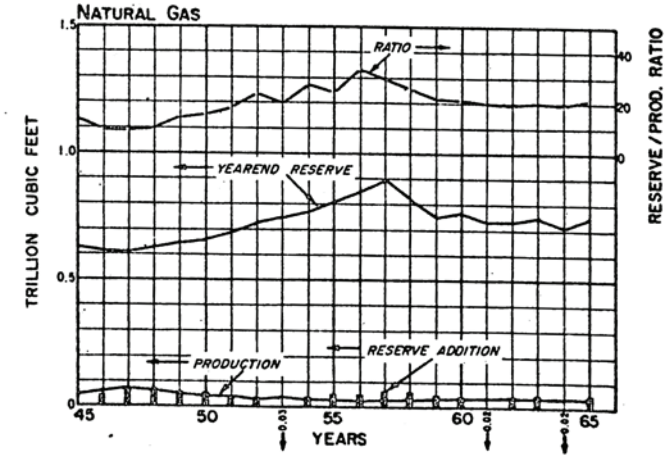
Development Wells



Fracturing Treatments



Natural Gas



OHIO

OKLAHOMA

The discovery of Southwest Antioch in 1946 caused extensive exploration and development of the Golden Trend area through 1950, and the discovery of Sholem Alechem in 1947 started concurrent development in the Sho-Vel-Tum area. Although a few wells penetrated the deep formations, in general the time required to drill the hard, lower formations was prohibitive. From 1945 to 1950, in the range of several months was required to reach 9,000 feet in the Stephens County area. A 1965 rig, using modern drilling technology, could reach 9,000 feet in 14 days in the same area. This ratio of improvement would not necessarily apply to other areas, but does indicate the significance of drilling improvements that have encouraged development of deep geologic provinces.

In 1956 exploration started in new areas of geologic opportunity and brought about extensive development of the Anadarko Basin of northwestern Oklahoma (1956-1960) and, to a lesser extent, the Arkoma Basin in southeastern Oklahoma (1962-1963). Gas drilling has not been used extensively, but has been applied to good advantage in the Arkoma Basin to increase penetration rates and avoid drilling mud damage of the producing formations.

The most significant areas of exploration at greater depths were the deep Ordovician fields of southern Oklahoma. Activity in Carter-Knox (1958-1959) and Chitwood (1961-1962) were not particularly significant as to the number of rigs operating, but exploration investments (well cost) were extremely high.

Faster drilling, better logging tools, fracturing and wide spacing combined to bring about development in the marginal areas of Garfield, Grant, Kingfisher and Major Counties, starting in 1960. In the five year period of development, 2,900 wells were drilled, which was 15 percent of Oklahoma's total drilling.

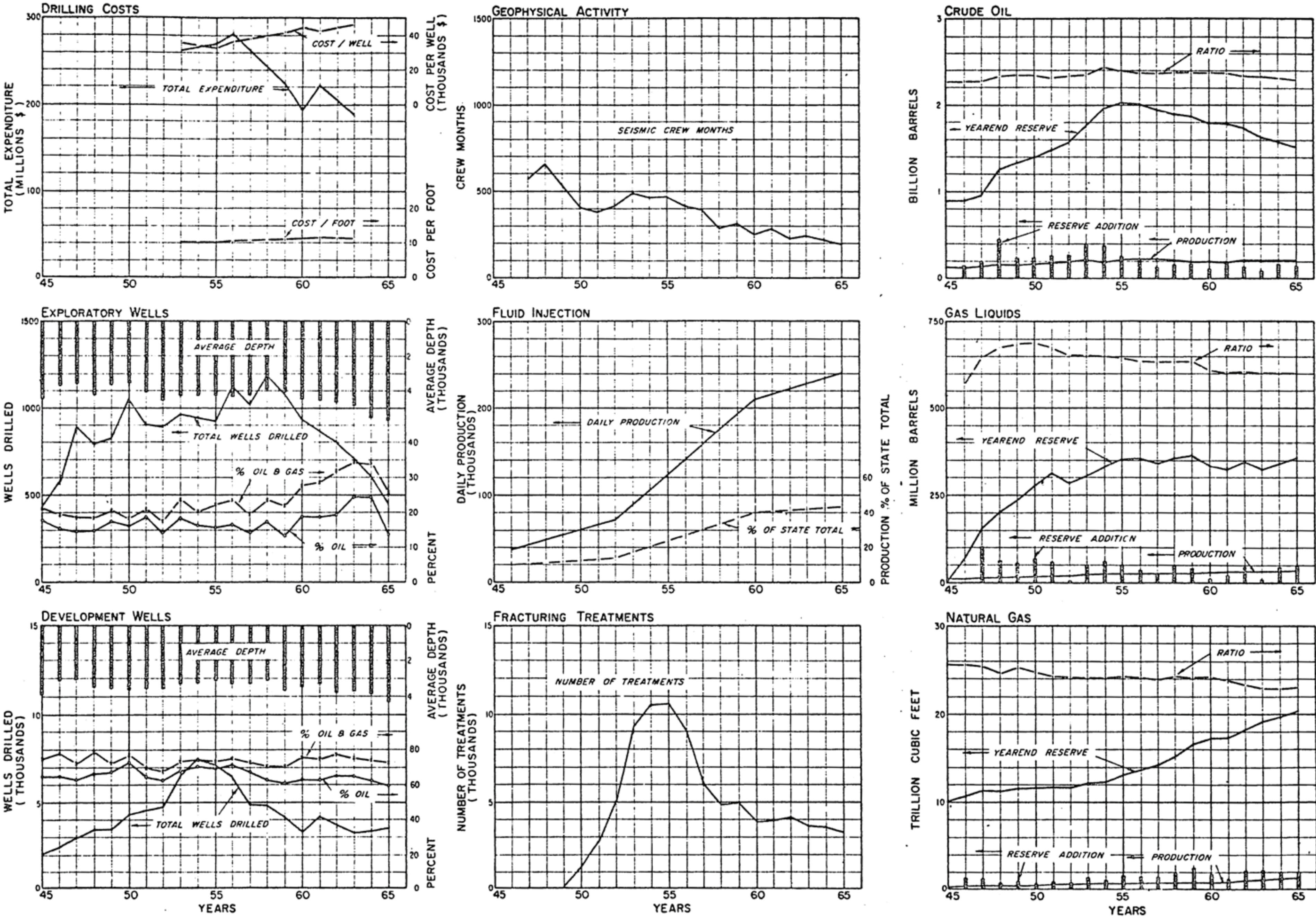
Development of electrical logging equipment for use in areas of salt deposits stimulated exploratory efforts in northwestern Oklahoma. Better porosity tools contributed to a considerable amount of development in areas of low porosity reservoirs - particularly carbonate reservoirs. Salt section logging equipment became available in 1950 and the improved porosity tools were available in 1956.

Fracturing was applied, beginning in 1949, to stimulate old and new wells. It increased in use with experience and technological improvements until, during 1954, some 4,900 treatments were performed. Development drilling was also stimulated and Oklahoma's crude oil reserve reached its all-time peak the following year.

Oklahoma was a proving ground for fluid injection processes dating back to 1936 and 43 percent of 1965 production came from these projects. Some 1,226 projects of all kinds were active during the year. A compulsory unitization law was enacted in 1947 and has provided significant support for such operations.

(Oklahoma)

There has been a well-defined trend in Oklahoma toward wider spacing of wells in oil reservoirs. In the 1950-55 period, approximately 60 percent of the spacing orders provided twenty or less acres per well, whereas this category declined to 20% in 1965. In the 1950-55 period, there were less than 10 percent 80-acre spacings, and this category increased to 33 percent in 1965. Oil well spacing has extended to 160 acres for many fields in the last five years.



DRILLING COSTS
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
COST PER FOOT
GEOPHYSICAL ACTIVITY
CREW MONTHS
SEISMIC CREW MONTHS
CRUDE OIL
BILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
EXPLORATORY WELLS
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
FLUID INJECTION
DAILY PRODUCTION (THOUSANDS)
DAILY PRODUCTION
% OF STATE TOTAL
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
MILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
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PRODUCTION
DEVELOPMENT WELLS
WELLS DRILLED (THOUSANDS)
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
% OIL & GAS
% OIL
TOTAL WELLS DRILLED
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS (THOUSANDS)
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
TRILLION CUBIC FEET
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
YEARS

OKLAHOMA

TENNESSEE

There were no significant exploratory successes in Tennessee during the period 1945-65. Production is limited to shallow horizons and has been established in only seven counties in Northern Tennessee. Oil was first discovered in 1916, and oil production peaked in 1927. Small spurts of exploratory drilling activity in 1948, 1952 and 1959-62 resulted in small discoveries; but production today is approximately the same as it was in 1945, as reserve additions have barely offset withdrawals during the past twenty years.

No plot of data for Tennessee is included because of the limited amount of Exploration and Production activity.

GULF-SOUTHWEST

AREA

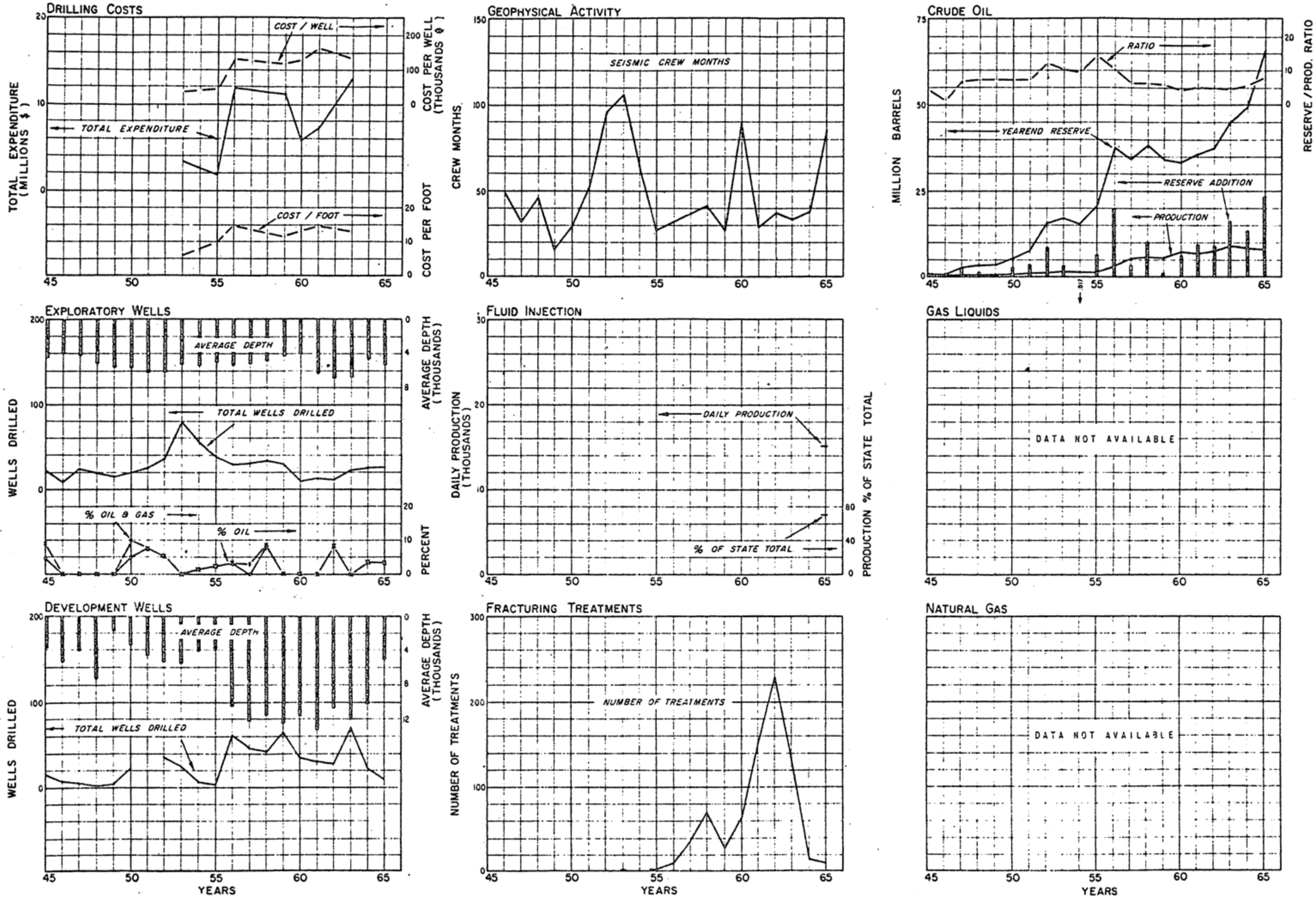
ALABAMA

Alabama first became an oil producing state in 1944 with the discovery of the Gilbertown Field in Choctaw County. The small amount of activity in Alabama during the early years of the period under study was the result of this shallow discovery. Additional small discoveries were made during the period 1945-1965, but nothing of any significance. The small discoveries did stimulate seismic activity for a short period between 1951 and 1955.

Alabama's largest and most significant discovery occurred in 1955, when the Citronelle Field was opened in Mobile County. Within two years, a total of 97 wells had produced 5.5 million barrels of oil. The field was unitized and a water injection program started in 1961. Favorable response encouraged further drilling in marginal areas and the field now has over 400 wells. These extensions account for essentially all of Alabama's development drilling during the period 1955-65.

Fluid injection into this complex reservoir covers some 30 tight sands found at depths of 10,000-12,000 feet. It is expected to increase the ultimate oil recovery from 40 to 120 million barrels.

Geophysical activity increased in 1965 as a result of success in neighboring Mississippi in the deeper Smackover, but this has not led to significant drilling activity.


DRILLING COSTS
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
GEOPHYSICAL ACTIVITY
CREW MONTHS
SEISMIC CREW MONTHS
CRUDE OIL
MILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
EXPLORATORY WELLS
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
FLUID INJECTION
DAILY PRODUCTION (THOUSANDS)
PRODUCTION % OF STATE TOTAL
DAILY PRODUCTION
% OF STATE TOTAL
GAS LIQUIDS
DATA NOT AVAILABLE
DEVELOPMENT WELLS
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
DATA NOT AVAILABLE
YEARS

ALABAMA

FLORIDA

Oil was first discovered in Florida in 1943 at the Sunniland Field, Collier County, in the Lower Cretaceous Glen Rose formation. This discovery caused exploratory activity to be at a relatively high level at the start of the 1945-65 period, compared to pre-Sunniland years. However, it was not until 1954 and the discovery of the Forty-Mile Bend Field, Dade County, that this increased effort resulted in production. The Forty-Mile Bend Field was abandoned in 1956 after producing only 33,000 barrels of oil and exploratory drilling declined to a plateau of less than ten wells per year. This low level of drilling held through 1965.

The only other significant discovery in Florida occurred in 1964, when oil production was established at the Sunoco-Felda Field in Hendry County. The producing horizon was the Lower Cretaceous Sunniland (Glen Rose).

Most of the exploratory activity has been confined to the southwest part of the state. The discoveries have been relatively deep (over 11,000 feet), and expensive.

No plot of data for Florida is included because of the limited amount of Exploration and Production activity.

LOUISIANA

Drilling activity in Louisiana was at a minimum in 1945. A steady increase in exploratory activity has occurred since that time. Geophysical activity was at a relatively high level in 1945 and this continued until 1956, after which there was a decline until 1963.

In north Louisiana a modest backlog of drilling prospects existed for the Wilcox at the beginning of the report period. Exploratory activity peaked in 1951 with the discovery of eight new Wilcox fields. Interest in the Cotton Valley (Jurassic) increased in 1951 with the discovery of gas in the Sentell Field in Caddo Parish. The discovery of the Springhill Field in Webster Parish during 1952 was an important development. By the end of 1952, a total of 51 producers had been drilled and six rigs were still drilling for the Tokio (Upper Cretaceous) pay. Drilling activity continued its increase through 1963, due primarily to the development of the Wilcox Trend and the Saratoga-Annona Chalk area.

In south Louisiana in 1945, exploratory drilling was relatively low, however, it continued to show a steady increase followed by a marked rise in 1954 attributable to the offshore Tidelands decision in 1953. A relatively high rate of geophysical activity from 1945 to 1955 provided prospects for the overall marked drilling increase in 1954 and 1955. As a result of the Tidelands decision, exploratory activity offshore almost doubled in 1954 compared to 1953.

In 1955 the reflection seismograph can be credited with the discovery of 56 of the 57 fields found in south Louisiana. Miocene objectives were the primary target of exploration efforts, with the Oliocene running second. Some of the more important offshore discoveries in 1955 were at Eugene Island, Block 128; Grand Isle, Block 47; and West Delta, Block 59. Exploratory effort continued at a high rate offshore for the remainder of the period studied, while activity onshore fluctuated to a minor degree. In 1959, offshore leasing in the Federal-State disputed area was resumed, and was followed by increased exploratory drilling activity in 1963 and 1964. The high rate of exploratory activity in all portions of south Louisiana was the direct result of industry responding to new exploration opportunities.

The application of Paleontology and Lithofacies techniques in the Tertiary sediments and advances in geophysical technology paced the expansion in offshore exploration.

Crude oil reserves for the State of Louisiana increased 250% between 1945 and 1965, while gas reserves increased a little over 200%, mainly as a result of the success in the offshore areas. During 1965, Louisiana produced 20.9% of the United States' crude oil, and has 16.7% of the remaining United States crude oil reserves.

Improved drilling technology as applied to the deep drilling in south Louisiana and the development of drilling techniques have been a large factor in the growth of Louisiana as a major producing area. The shift to deep drilling is observed beginning in 1956, with a sharp decline in the total number of wells drilled within the state, but the maintenance of a steadily inclining development footage rate.

The development of the offshore Louisiana reserves evolved from drilling operations from shell base and pilings in 20 feet of water during the 1949 to 1952 period to the current jack-leg platforms, sophisticated barges, and elaborate floating vessels. These newer innovations were introduced in quantity about 1960. The availability of the improved deep water (200-300 feet) drilling equipment has allowed operations in progressively deeper water and the timely development of a limited number of fields in water exceeding 200 feet.

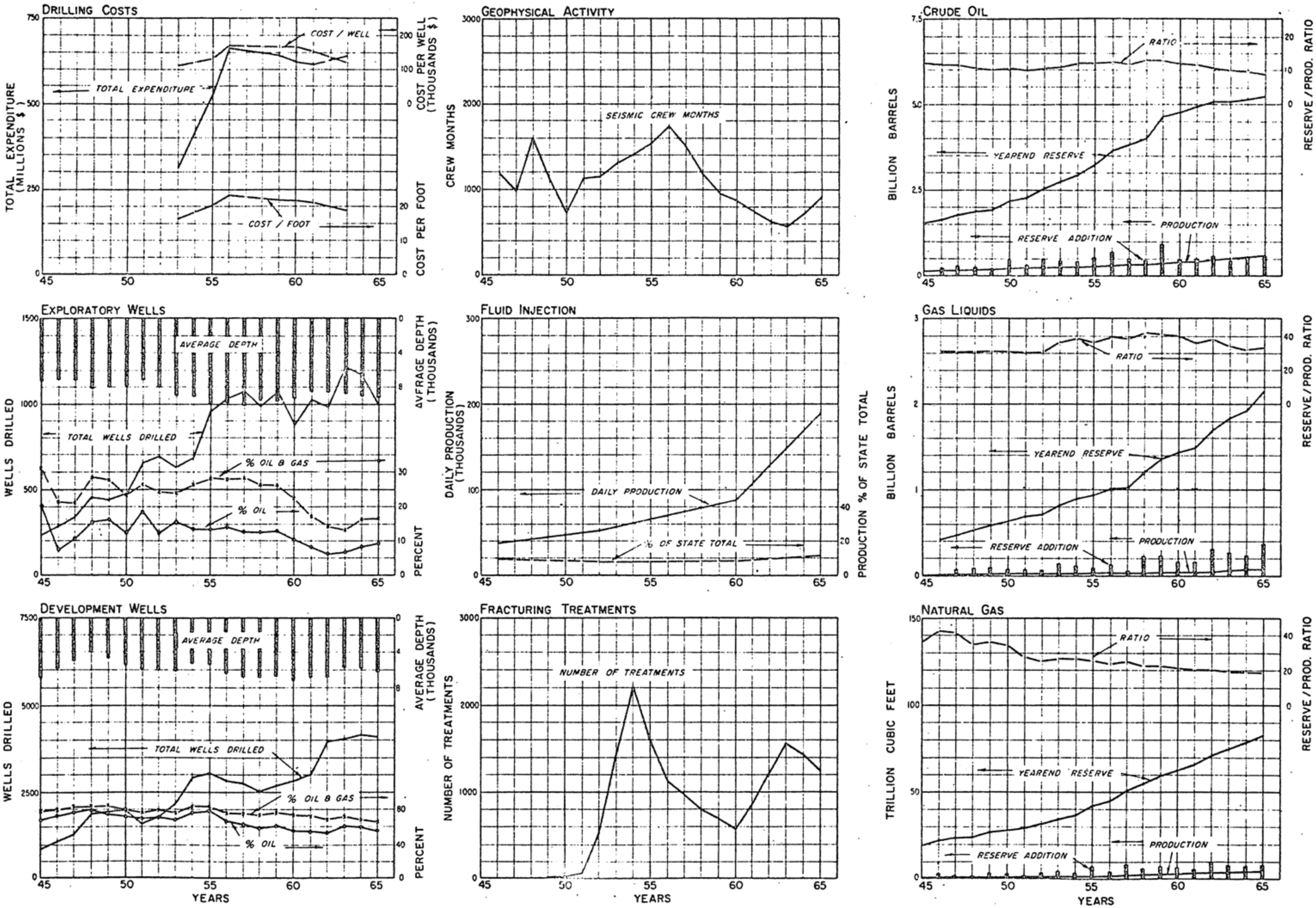
In the emergence of Louisiana as a major contributor of domestic production, the role of fluid injection projects cannot be ignored. This technology has steadily increased production and reserves over the past 20 years. Though not as pronounced in comparison with the improved drilling technology, it has been estimated that fluid injection projects have supplied 8 to 10 percent of the State's total annual production over the years. The current year, 1965, indicates that 69.5 million barrels, or 11.7 percent of the State's production, may be attributed to secondary recovery and pressure maintenance projects.

Since 1950 gas has been injected in steeply dipping fault blocks along the Louisiana coast to displace oil to downdip well bores. This attic recovery process has applied to over 200 projects with a high degree of success.

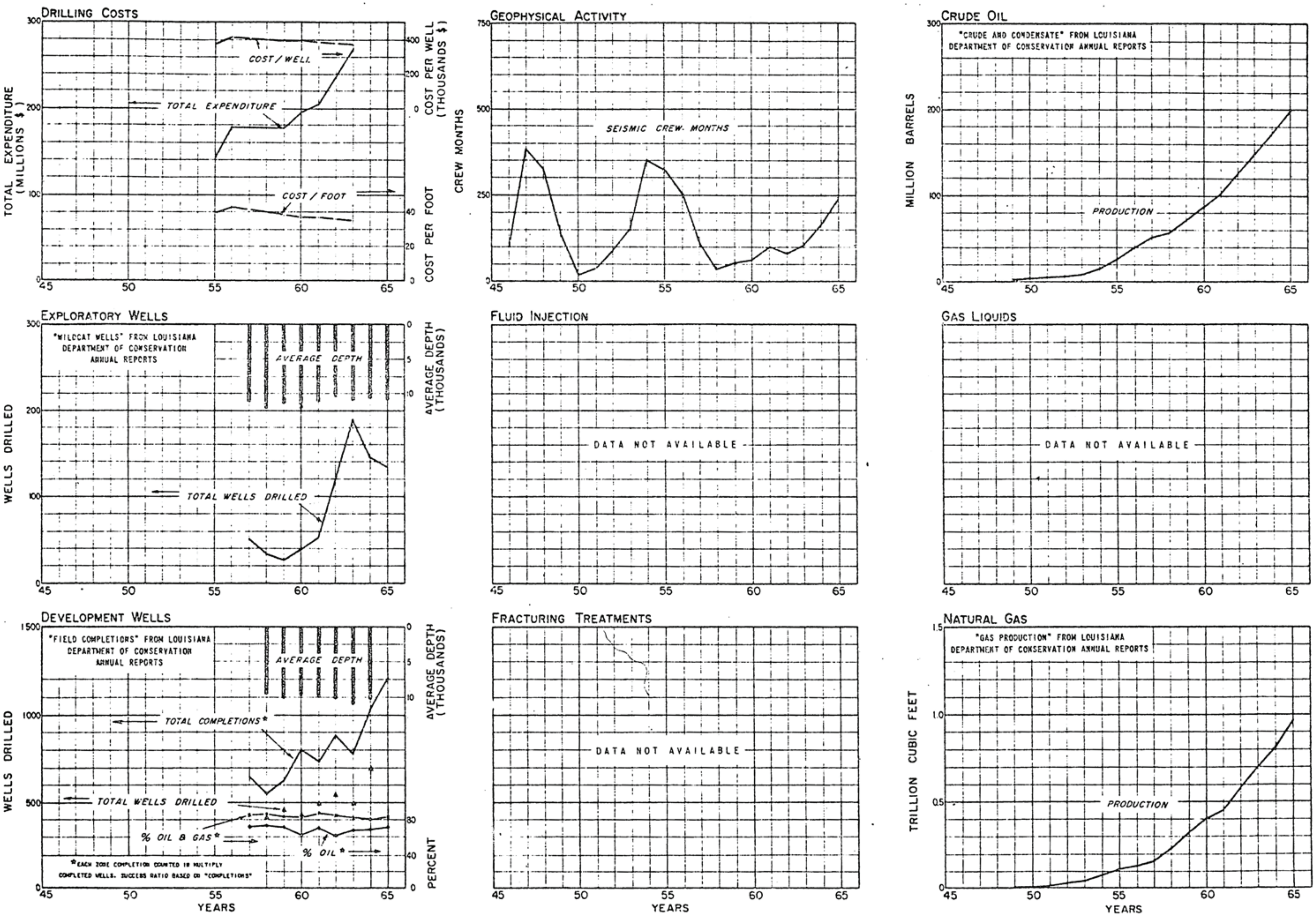
Exclusion of sand from well bores has been a major operating problem in the Gulf Coast. Screens, gravel packing and other mechanical means of control have gradually been replaced by various forms of plastic consolidation. Although these methods are still undergoing technical improvement, a high degree of success is reported for present applications.

Multiple completion of wells predates this study, but improvements in technology have greatly extended these applications. The first general application included two tubing strings isolated with a packer in a single casing. In the late 1950's it became common practice to cement two or more casings in a single borehole and complete each in a single horizon or as a dual completion. Multiple completion technology has made a significant contribution in Louisiana where most fields have multiple reservoir sands.

The effect of fracturing technology cannot be fully evaluated because it was developed concurrently with other technological advances, however, it is felt that the fracing process has been a major factor in maintaining the oil production rate of north Louisiana. The two peaks of fracture application, 1954 and 1963, coincide with peak drilling periods of this particular area.



LOUISIANA TOTAL



LOUISIANA OFFSHORE

MISSISSIPPI

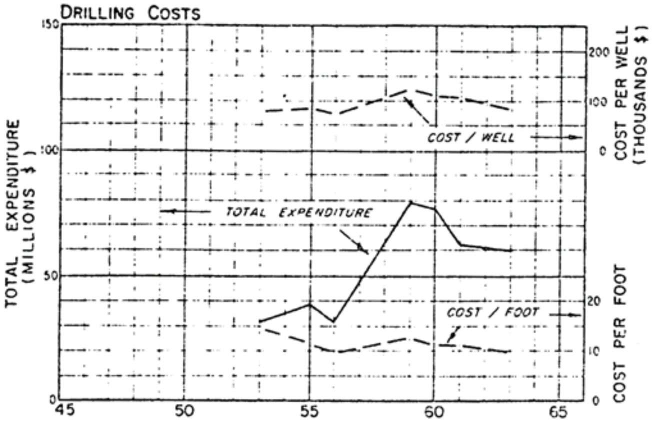
Mississippi began the postwar period with a low level of exploratory drilling. Geophysical activity in 1945 was at a relatively high level, but declined to its low for the report period in 1951. The drilling of all wells remained relatively constant for the period 1945 through 1958.

In 1959, total drilling activity reached an all-time high, and increased 34% over 1958 as a result of successful drilling programs for Upper Cretaceous (Lower Tuscaloosa) and field development for Lower Cretaceous pays. This same trend continued into 1960, when 19 oil fields and 3 gas fields were discovered. A total of 133 development oil wells were completed in the McComb area, which was the most active. The Tuscaloosa play experienced a decline, while the Tertiary (Wilcox Trend) became more active as independent and small companies promoted this shallow play. The most significant discovery in 1963 was the first Smackover production in the state in the Bienville Forest Field. Continued interest in Wilcox production caused exploratory drilling in 1964 to increase by 39.7% over 1963; however, the success ratio was less. The continued pursuit of Wilcox stratigraphic accumulations maintained exploratory activity at a relatively high rate for the remainder of the period.

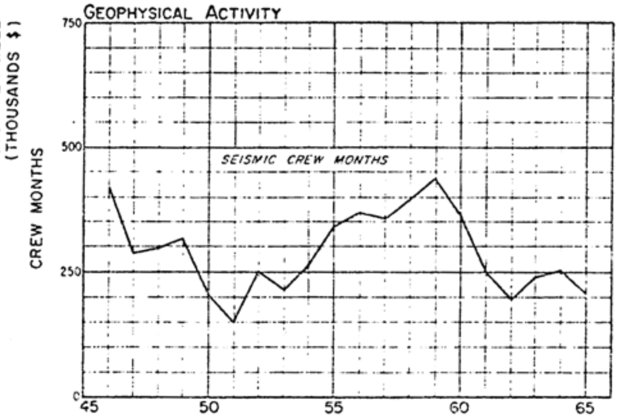
A correlation between increased drilling in 1959 and the number of fracturing treatments can also be observed in Mississippi. Both oil and gas reserves remained at a constant level throughout most of the period, with new reserve additions essentially replacing production.

Fluid injection projects are becoming of increasing significance in Mississippi. It is estimated that 10,700,000 barrels of oil were produced in 1965 from fluid injection projects representing 19.2% of the state's total crude production.

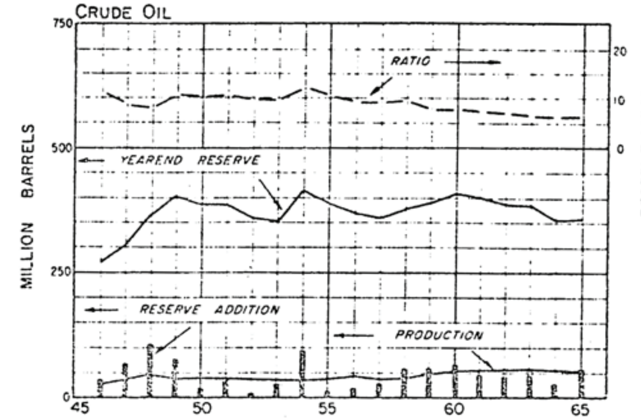
Drilling Costs



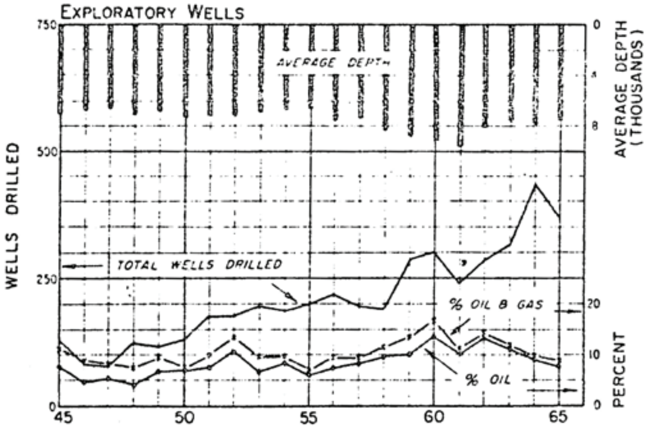
Geophysical Activity



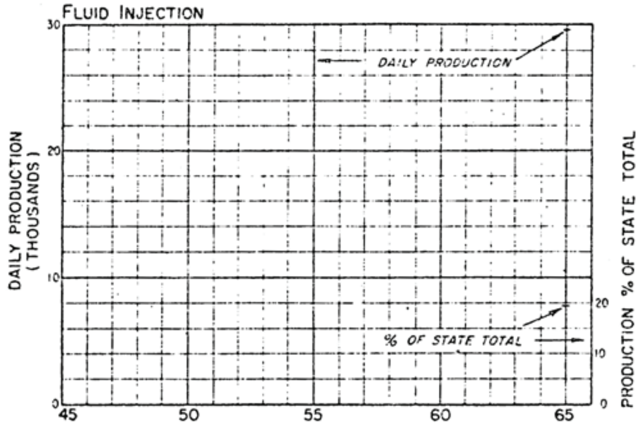
Crude Oil



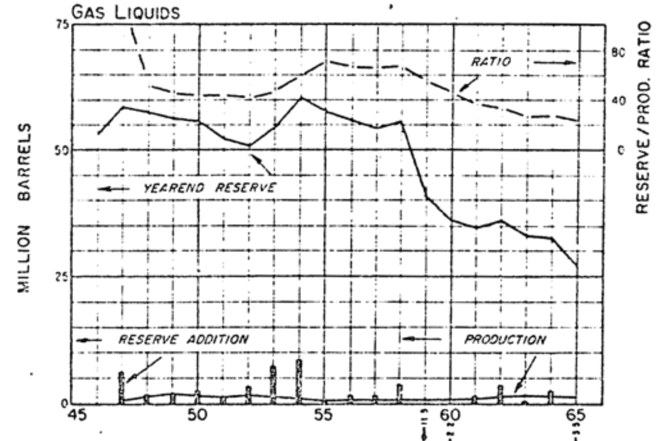
Exploratory Wells



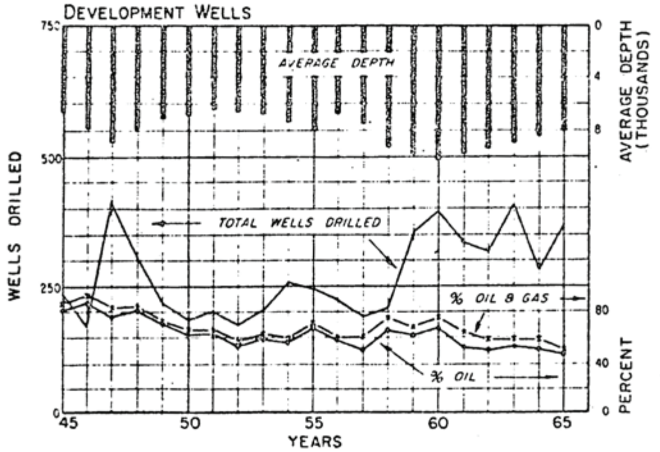
Fluid Injection



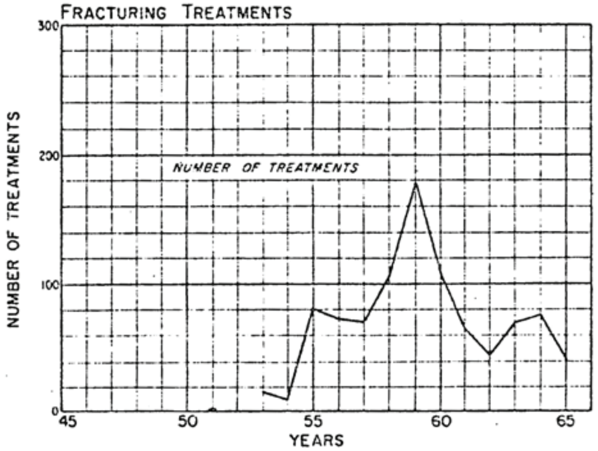
Gas Liquids



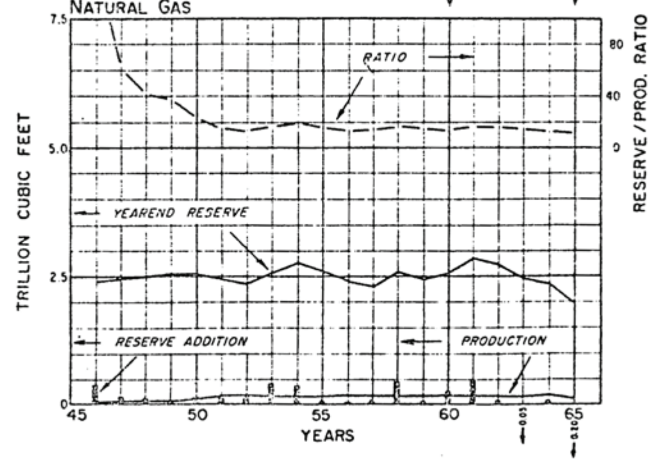
Development Wells



Fracturing Treatments



Natural Gas



MISSISSIPPI

NEW MEXICO

Exploratory activity was at a low level in New Mexico at the beginning of the period under study. Drilling was largely directed to the exploration and development of the shallow Permian formation, but within a few years significant discoveries in the deeper Devonian were being made.

Development drilling began a prolonged rise in 1951 and reached a peak in 1957. Active fracturing operations, beginning in 1953, substantially increased the producing capacity of gas wells in that shallow (above 3,000 feet) "basin sands" in a large area extending from the Monument field southwest into Texas and resulted in drilling many additional wells within the proven area and in major extensions. With the increase in productive capacity, gas transmission lines were extended into the area which resulted in an upsurge in drilling that was responsible for a substantial part of the total wells drilled, which increased from some 400 wells per year in the late 1940's and early 1950's to over 800 in 1955 and maintained nearly that rate through 1960.

The increase in drilling rate resulting from new and improved equipment and drilling practice was a major factor in the increased development, expecially in creating extensions of the producing area. The lower cost of wells permitted development of many areas that would not have been economical to develop with the drilling equipment and practices of 1945.

Although 40 acre spacing was the predominate pattern for southeast New Mexico, 80 acre oil well spacing was approved for deeper drilling in 1950 on the basis of technical information and reservoir knowledge. Continuing development of the pools added to sound basis of information and an increasing number of pools have since been developed on wide spacing.

The impact of technology on the time to drill wells in southeast New Mexico is outstanding, especially deep wells. Wells completed in 1950-1951 below 11,000 feet which required about 100 days were being drilled in an average of 65 days by 1963-1964. Drilling time for a 9,000-10,000 foot well decreased from 60 days to 35 days in the same period. The more important technological developments were the button bits, jet bits, improved drilling muds, and larger and longer drill collar strings which were used to drill with much higher weights on the bit.

The initiation of fluid injection projects in southeast New Mexico has been extremely active for the past seven years. The four active projects at the beginning of 1959 had increased to 137 projects by the beginning of 1966.

Eighteen of these were in northwest New Mexico, leaving some 119 projects in the southeast area. All but two of these are water injection projects. For the entire State, 18 percent of some 57,000 barrels per day are from injection projects and some 43,000 barrels per day are from the southeast area. A major factor in the recent upsurge has been the development of technology that permitted sound evaluation of a given project before making the large initial investment with insufficient assurance of its probable success.

In northwest New Mexico, exploration and development of the Lower Permian (1956 and 1957) and exploration of the Pennsylvanian carbonates (1959 and 1960) provided the most outstanding periods of exploratory effort. The development of the Mesa Verde gas discovery in the San Juan Basin started in 1952 and peaked in 1958 at 937 wells. Development of the Pictured Cliffs and Dakota gas fields has contributed significantly to the number of development wells drilled since 1958 in the San Juan Basin.

The approval of a 24-inch gas line from the area to the Pacific Coast in mid-1950, giving an assured market for the gas, resulted in an intense development of a large area that had several widely scattered gas wells. There were 33 gas wells drilled in 1950 and development reached a peak in 1953 of 546 new gas wells, then declined.

Although the two main producing sands of the San Juan Basin are both of satisfactory thickness, the productivity in many wells was low. Fracturing with oil and sand gave substantial increases in producing capacity. Introduction of water-sand fracturing in larger quantities provided still more incentive to extend development into areas of low natural productivity, and substantially contributed to a second peak of development of 536 gas wells in 1957. The increased capacity to produce, the added development which was encouraged, together with a greater assurance of the indicated reserves, all resulted in a substantial increase in market through the additional large transmission lines to the Pacific Coast, to the northwest through the Salt Lake City area and to the northeast into Colorado.

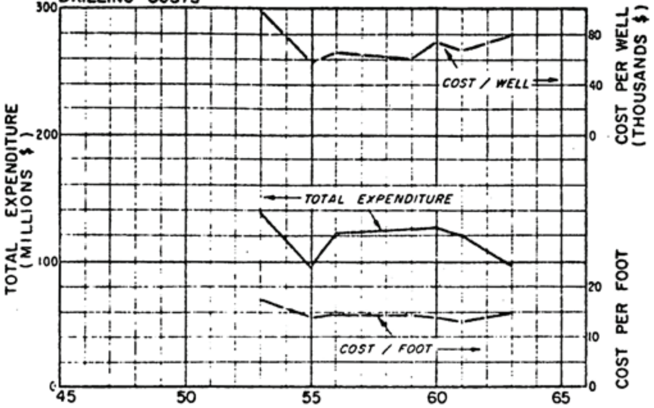
The decreased cost of drilling resulting from technological development has also been a major contribution to the development. The higher rates of drilling were primarily a result of improved bits, especially jet bits, improved drilling fluids, and the ability to carry greater weight on the bit. Air-gas circulating fluid greatly reduced the drilling days, and was most effective in the deeper wells. Introduction of foaming agents permitting air-gas drilling through greater underground water flows extended the area in which the method could be used.

Oil production in northwest New Mexico did not become of significant importance until 1956. The producing zones are of low permeability and production rates are normally small except in some wells of the better pools. By 1956 the benefits of fluid injection early in the life of a pool were becoming generally recognized and now over two-thirds of the oil production in northwest New Mexico is from pools under fluid injection.

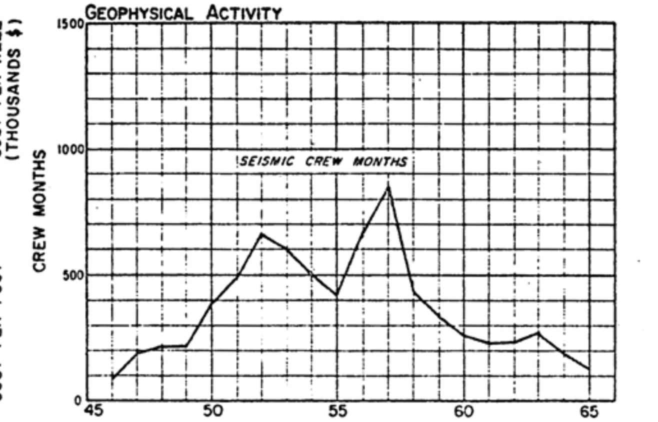
Spacing for oil wells in northwest New Mexico is generally 80 acres, although the earliest of the recent development was on 40 acre spacing. Bisti, the first of these (1955), was initially at 40 acres, but a later major extension was developed on 80 acre spacing. Several pools have been developed on 160 acre spacing.

Spacing for gas wells, with few exceptions, is 320 acres. A few of the earliest wells were on 160 acres and at the time development commenced, 320 acre spacing was considered wide. Time and engineering technology have now proven 640 acre spacing, and it is probable that similar development undertaken now would not be on a denser pattern. These wider spacings have been a major factor in extending the development for both oil and gas in northwest New Mexico.

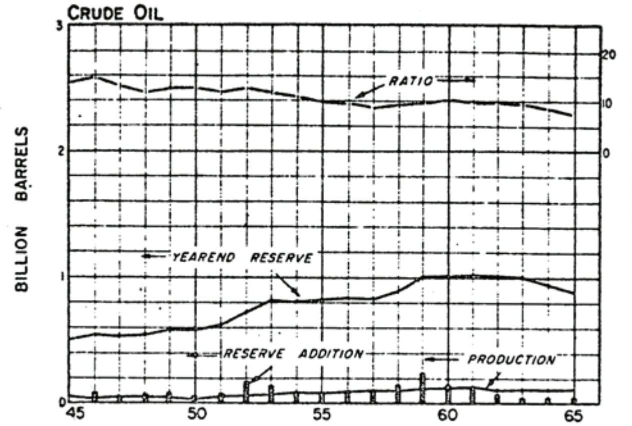
Drilling Costs



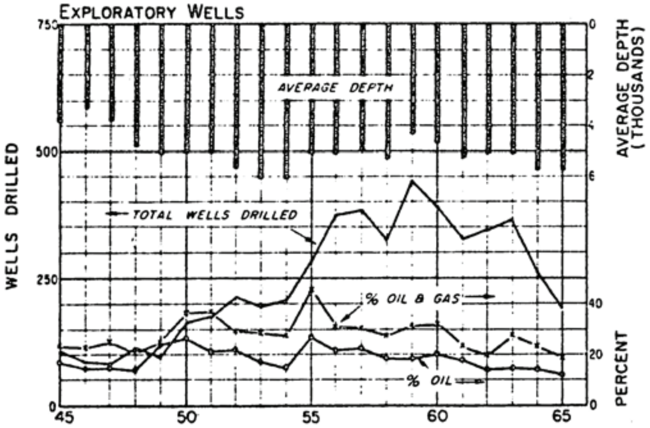
Geophysical Activity



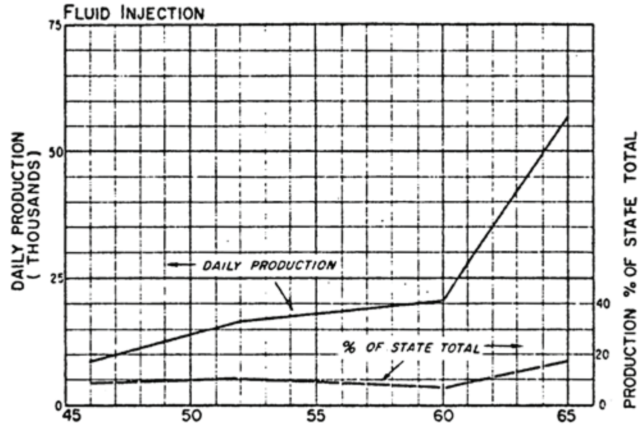
Crude Oil



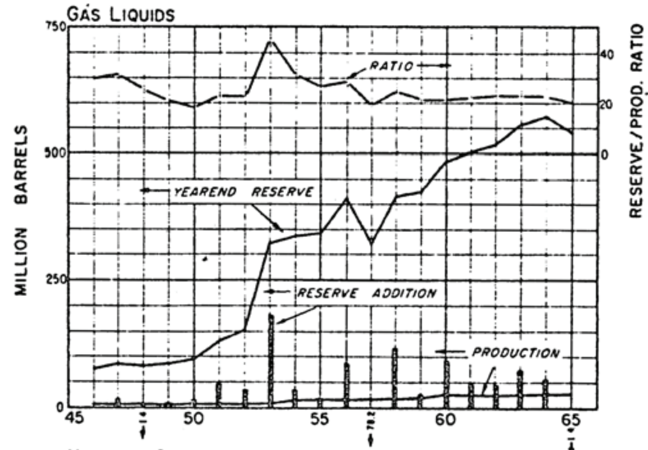
Exploratory Wells



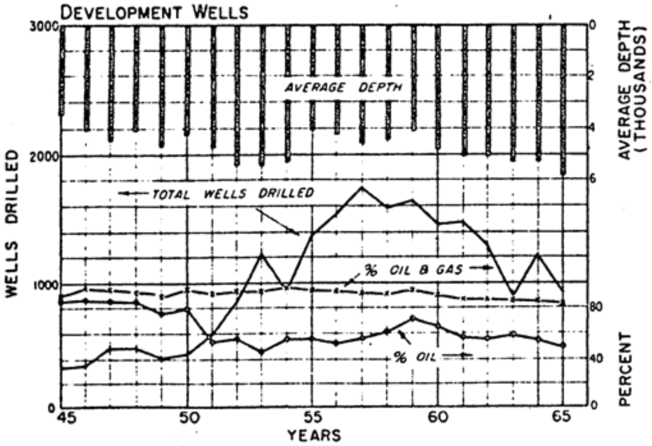
Fluid Injection



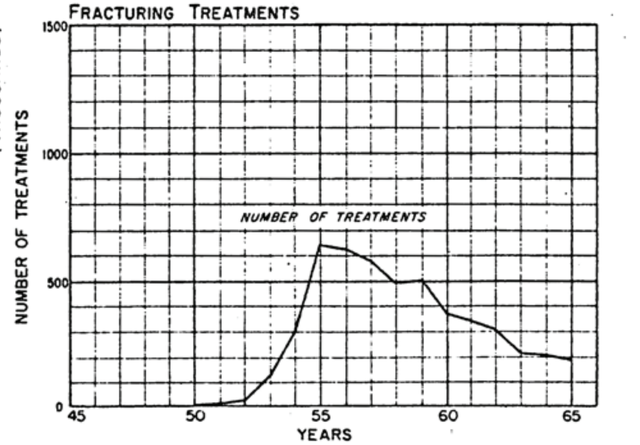
Gas Liquids



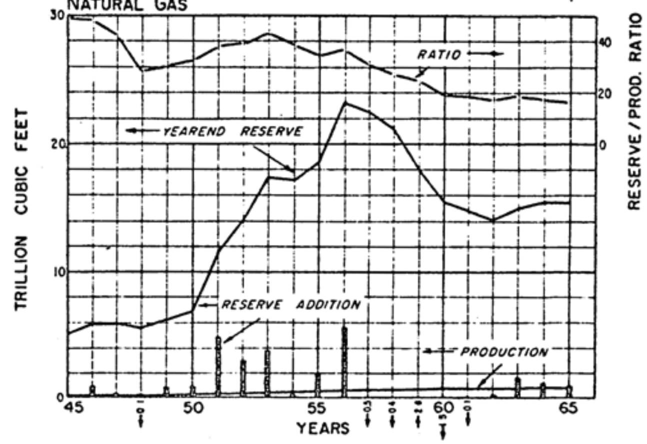
Development Wells



Fracturing Treatments



Natural Gas



NEW MEXICO

TEXAS

Texas entered the year 1946 with both exploratory and development drilling at the lowest levels that would be seen over the next twenty years. Exploratory drilling started to increase in 1947 and continued this trend for the next ten years. Geophysical activity had increased to a relatively high level by 1948 and it wasn't until 1953 that it commenced the downward trend that would continue for the rest of the period under study.

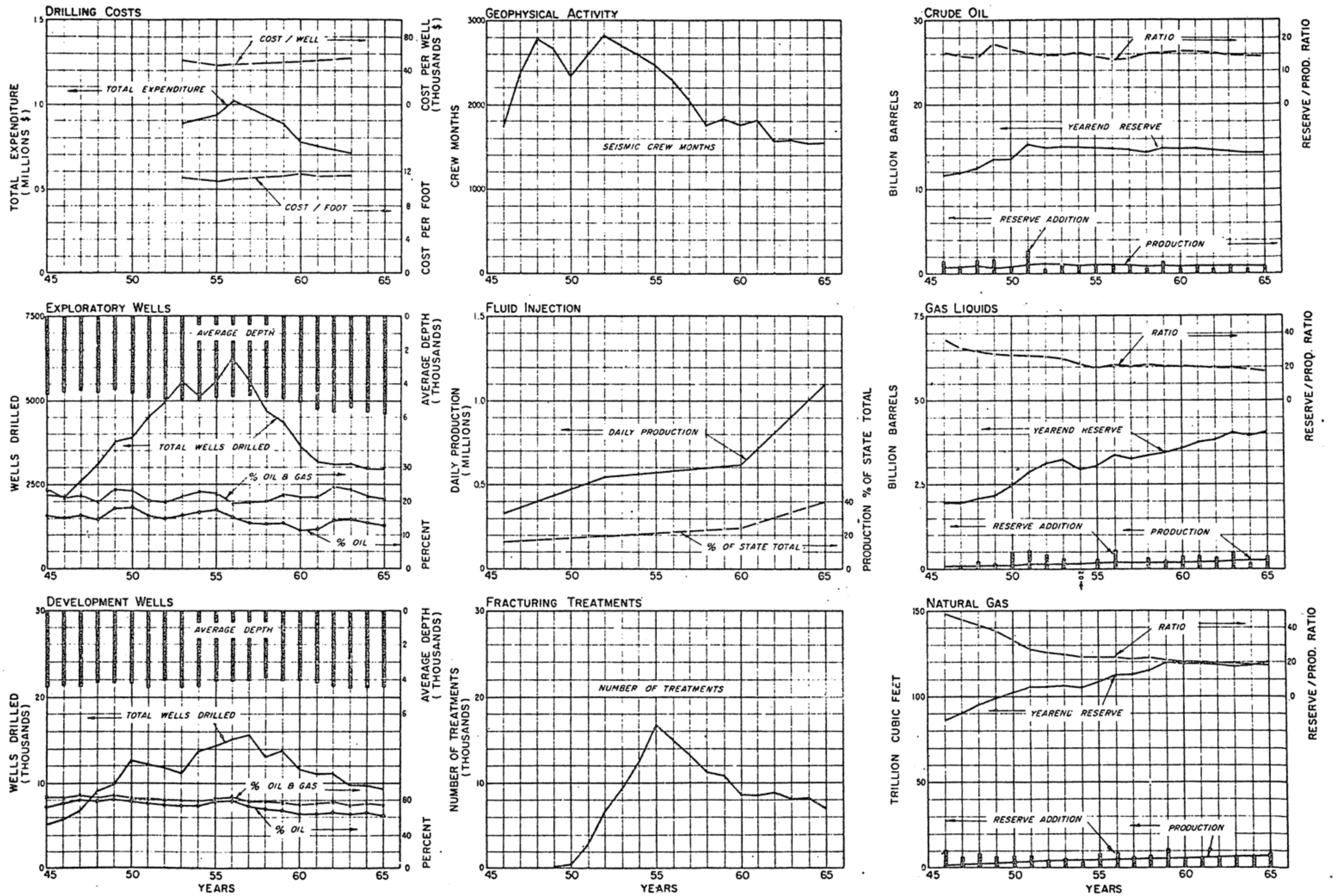
The initial increase in exploratory drilling (1945-49) occurred principally in North Texas (R.R. Districts 7B and 9), where the number of wildcats tripled during this five-year period. In 1949, North Texas accounted for 42% of the exploratory wells drilled in the State. Most of this activity was confined to the shallow Pennsylvanian production in Cook, Montague and Wilbarger counties. During the period 1945-49, activity also increased significantly in Southwest Texas (R.R. Districts 1 and 4) as a result of a backlog of prospects in the Frio, Jackson and Yegua. Activity in the remainder of Texas increased at a relatively slow rate during the first few years after the war.

During the period 1950-55, the discovery of Sprayberry (1946) and Scurry-Snyder (1948) increased the activity level in West Texas. The discovery and expansion of the South Boling area in Wharton County in 1952 caused activity to increase in the Gulf area. The Frio-Yegua were primary objectives, with Cook Mountain and Wilcox Trends being secondary. The discovery in 1953 of the Neches Field in East Texas caused exploratory drilling to increase 16% over 1952's levels. Twenty-nine discoveries were made and 18 new fields were opened, with new production ranging from Upper Cretaceous to the Jurassic. This high level of activity in East Texas held through 1957. The number of fracturing jobs in Texas peaked in 1955 and undoubtedly stimulated both exploratory and development drilling.

Exploratory drilling peaked in Texas at over 6,000 wells during 1956. Activity was high throughout Texas, with the Frio-Vicksburg-Jackson Trends in Southwest Texas, the Frio and Yegua Trends in the Gulf area, the Devonian and Ellenburger in West Texas, and Ordovician discoveries in North Texas all being major contributors to this exploratory drilling peak.

Exploratory drilling declined from its high in 1956 to a plateau of around 3,000 wells per year in 1961, which has held through 1965. Activity in some parts of Texas experienced minor increases during the past ten years, but failed to offset the over-all decline in exploratory effort. The deeper Devonian and Ellenberger of West Texas and deeper targets in the Anadarko-Hugoton areas of the Panhandle (R.R. District 10) have stimulated activity during the past ten years, but geologic opportunity has declined in many of the other areas of Texas. The trend since 1956 has also been toward more gas discoveries, expecially in the areas experiencing "spurts" of exploratory activity.

Drilling and producing technology has had a major influence on the exploration and development activities of Texas. Specific applications and projects are discussed in the subdivision summaries which follow.


DRILLING COSTS
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
GEOPHYSICAL ACTIVITY
SEISMIC CREW MONTHS
CREW MONTHS
CRUDE OIL
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
BILLION BARRELS
RESERVE / PROD. RATIO
EXPLORATORY WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
FLUID INJECTION
DAILY PRODUCTION
% OF STATE TOTAL
DAILY PRODUCTION (MILLIONS)
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
BILLION BARRELS
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DEVELOPMENT WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED (THOUSANDS)
AVERAGE DEPTH (THOUSANDS)
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
NUMBER OF TREATMENTS (THOUSANDS)
YEARS
NATURAL GAS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
TRILLION CUBIC FEET
RESERVE / PROD. RATIO
YEARS

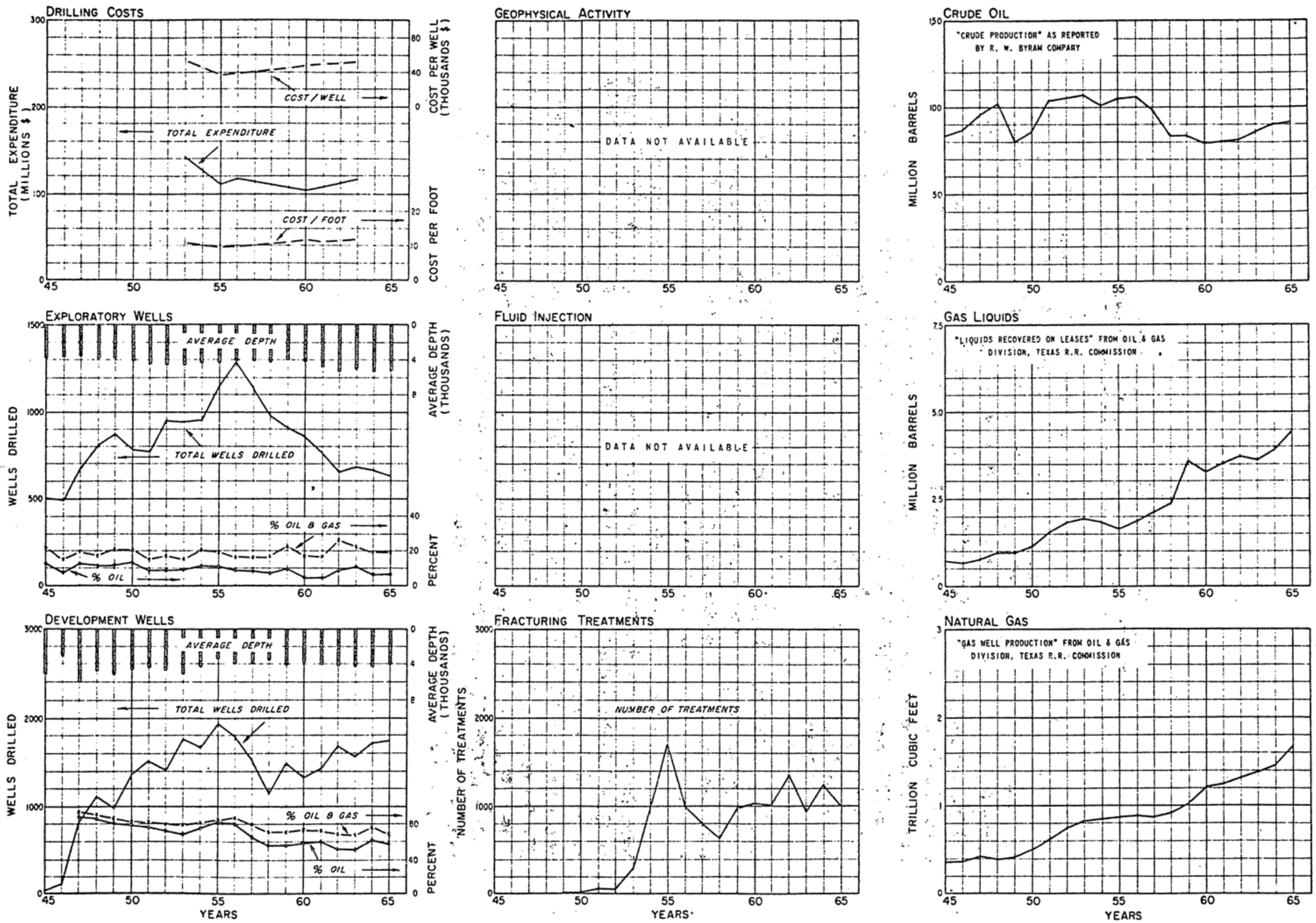
TEXAS TOTAL

TEXAS
R. R. Commission Districts I and IV (Southwest)

A low level of exploratory activity existed in this area in 1945; however, in 1947 a rapid and steady increase in exploratory drilling occurred. Minimum activity during the war years produced a significant backlog of prospects in the Frio, Jackson and Yegua, and provided the incentive for the intensive drilling campaign which followed and peaked in 1956. Exploratory activity has been declining since 1956 as a result of a declining success ratio and the absence of significant new discoveries. Gas and gas condensate completions have increased since 1957 compared to crude oil. The advent of fracturing, which peaked in 1955, was also responsible for a certain amount of the increase in total wells drilled in southwest Texas.

Starting in 1952 there was significant infill drilling in some of the older fields such as Big Foot, Darst Creek and LaVernia. These were generally lime reservoirs that responded to fracturing. Old reservoirs were extended and exploration searched for new lime pools.

The Edwards lime development along the Big John-Person-Panna Maria trend from 1960 to 1964 showed the effects of new technology. Wells from 10,000 to 12,000 feet were drilled using the latest in drill bits and improved muds. Hole deviation problems were controlled by large drill collars, reamers, stabilizers and packed hold techniques. Formation evaluation in these complex reservoirs would have been difficult and expensive without the 1950 improvements in electric logs. Another factor of importance in encouraging development was a sound policy of well spacing which was set at 160 acres in the Big John portion and 80 acres in Person and Panna Maria.



TEXAS RRC DIST 1 & 4 (SOUTHWEST)

TEXAS

R.R. Commission Districts II and III (Gulf)

Exploratory activity in the Gulf portion of Texas was at a modest level at the beginning of the postwar period, but a gradual increase occurred from 1945 to 1955. Total exploration declined since 1956 and has been accompanied by the search for deeper objectives in the Frio and Oligocene.

Although 1952 was a record-breaking year for total drilling operations, no single discovery found major reserves. In 1953 most reserve additions came from extensions and deepenings, with a few new fields resulting from subsurface and seismic interpretations.

A second exploratory drilling peak occurred in 1956 with the Frio and Yegua Trends being the primary objectives. Accompanying the drilling of deeper targets, the number of gas discoveries is increasing and crude discoveries declining.

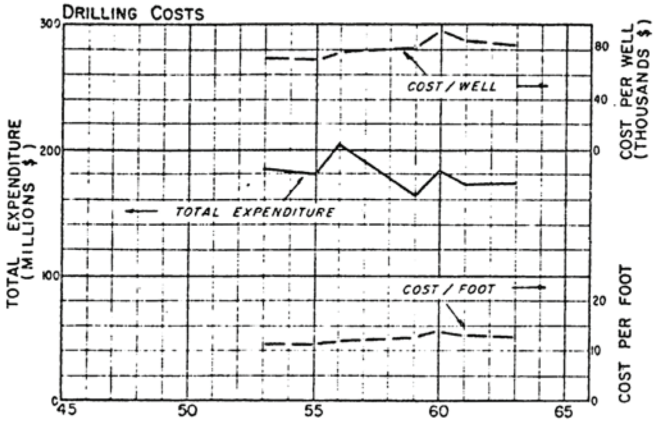
Major oil reserves, dating back to the prolific 1901 discovery of Spindletop, were established in this area prior to 1945. Production rates during the 1945-1965 period have been largely a function of market demand.

Improvements in drilling technology have not had the impact in this area that has been noted in others. In 1945, wells were being drilled below 12,000 feet at relatively low cost. The soft sands and shales were penetrated easily, using fresh water - native mud systems. However, jet bits were developed in this area and have been a significant contribution in all parts of the country.

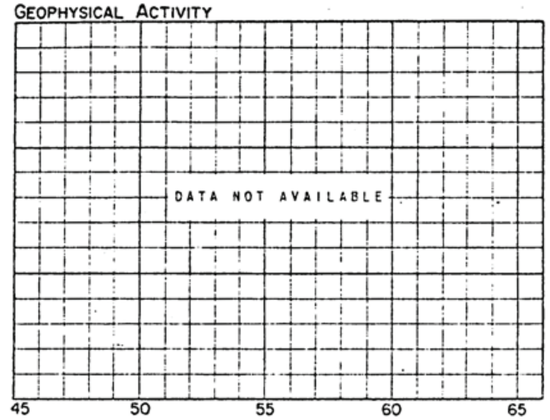
Fluid injection is of minor significance in this area, with only 21 injection projects, 12 water and 8 gas. Two of the water injections were attempts to recover cellar oil and three of the gas injection projects were initiated to recover attic oil.

Of principal importance has been the Katy Field, which was unitized about 1945. Cycling has produced 11 million barrels of condensate through 1964, and it is estimated that final recovery will exceed 50 million barrels.

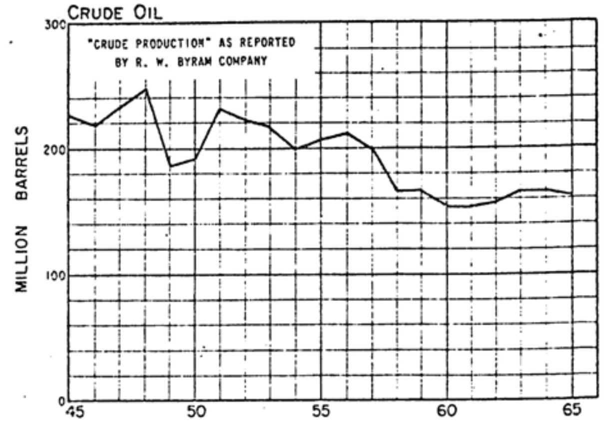
DRILLING COSTS



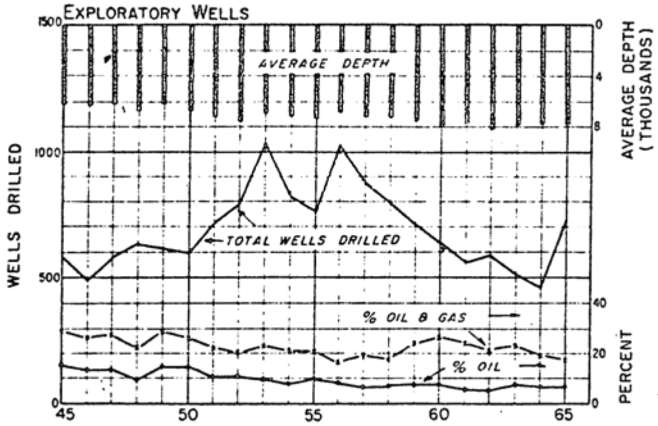
GEOPHYSICAL ACTIVITY



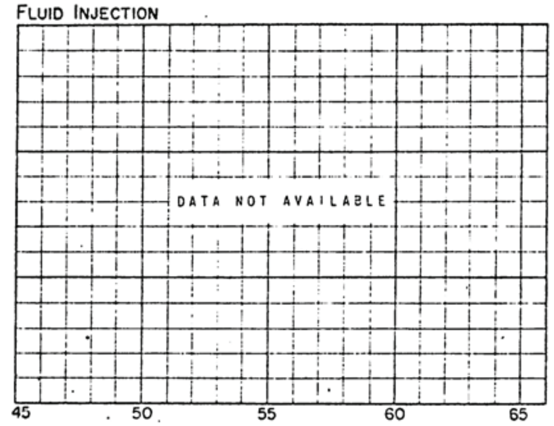
CRUDE OIL



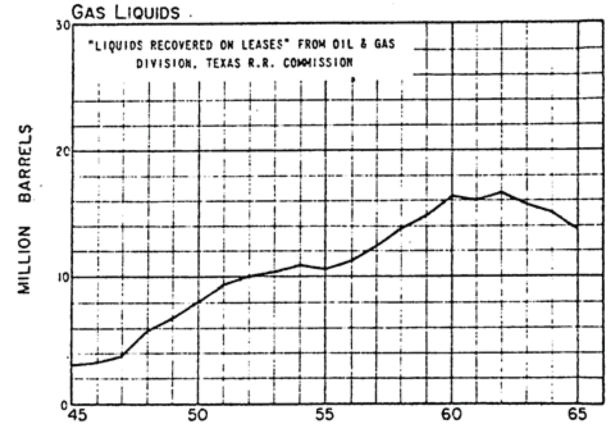
EXPLORATORY WELLS



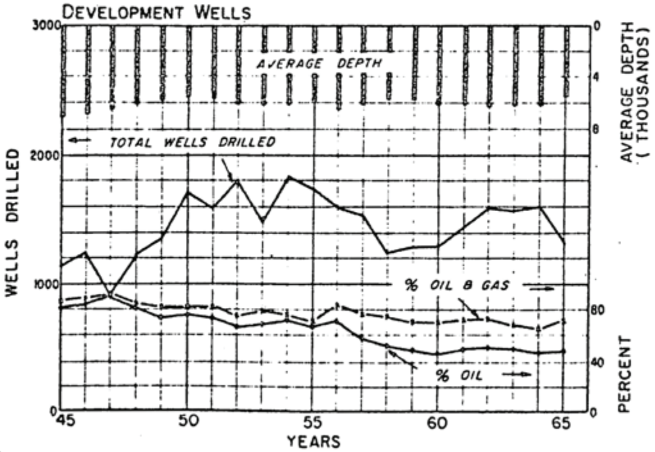
FLUID INJECTION



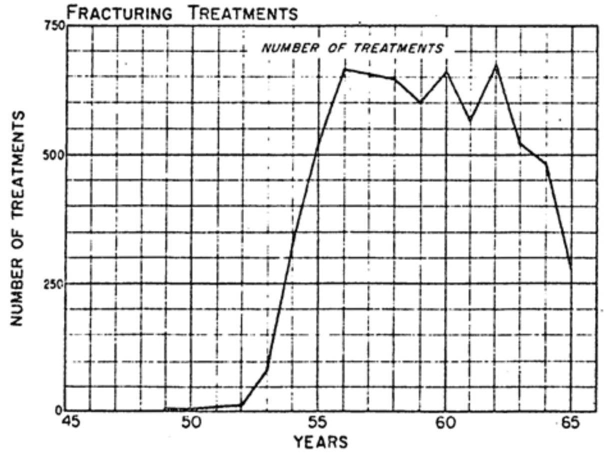
GAS LIQUIDS



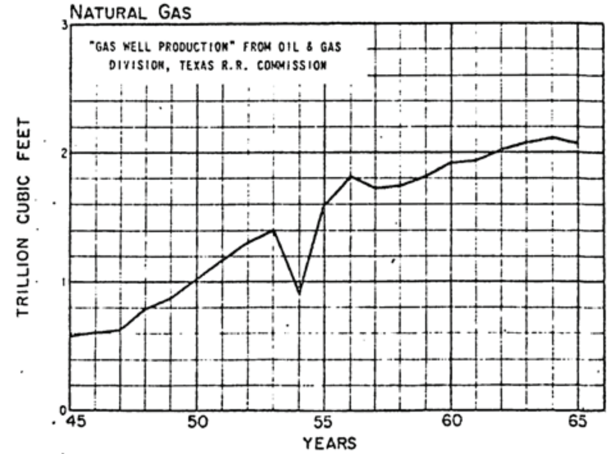
DEVELOPMENT WELLS



FRACTURING TREATMENTS



NATURAL GAS



TEXAS RRC DIST 2 & 3 (GULF)

TEXAS
R.R. Commission Districts V and VI (East)

Exploratory drilling activity was at a low ebb in 1945 and gradually rose to a maximum in 1955. During the peak in exploratory drilling, the Woodbine was the primary objective, with Lower Cretaceous (Pettit-Rodessa) becoming more prevalent, however, new production ranged from Upper Cretaceous to the Jurassic.

Geophysical activity declined steadily from 1955 to 1965, and the bulk of new reserves came from extensions of old fields, rather than new fields, during this same period. The high incidence of fracturing in 1954 and 1956 appears to have contributed to the total of exploratory wells, particularly in District V.

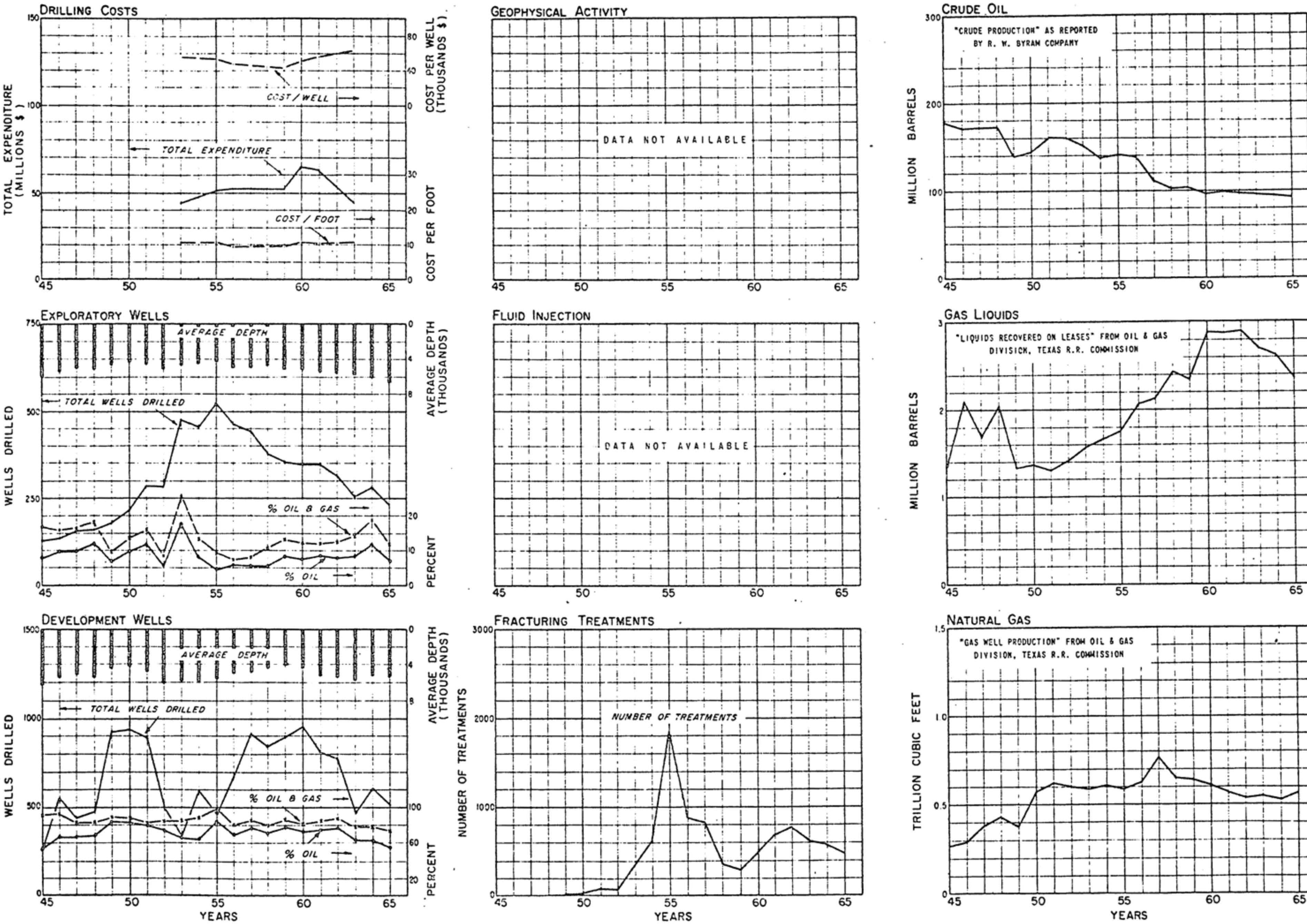
Oil production has continued to decline during the period under study and gas production has remained at relatively the same level, which would again indicate an increasing frequency of gas discoveries.

Large crude oil reserves had been accumulated in this area before 1945. Prolific discoveries at Corsicana, Balcones fault trend, and Van preceded the most important discovery of all, that of the East Texas field in 1930. However, these developments were all at shallow depth and demanded or used little of petroleum technology.

Beginning about 1960, deep drilling, particularly to the James lime in the Fairway field, has benefited from the accumulated technology. Bit, mud and drill stem stabilizing techniques contributed to developing this sizeable field, whereas it would not have been economically feasible in 1945.

Fluid injection and unitization are important in this area, primarily in their application of technology. The New Hope field was an early and significantly successful pressure maintenance project. Water injection was started in 1945. Also of great technological as well as economic interest has been successful maintenance of pressure in the East Texas field by water injection and disposal operations. The Northeast Hallsville Tatum Crane Unit, formed in 1963, has applied water, gas and polymer injection to effect maximum recovery through a pressure maintenance operation. The Fairway field was unitized in 1965 for a pressure maintenance operation. The field is developed on an average density of 130 acres per well.

Fluid unjection has not only applied to discoveries of recent years. The Corsicana Shallow field, discovered in 1894, is now being waterflooded and produced 1.6 million barrels in 1964. Since flooding started in 1950, it has produced 41 percent of its cumulative oil production.



TEXAS RRC DIST 5 & 6 (EAST)

TEXAS

Texas R. R. Commission Districts 7B and 9 (North Texas)

Exploratory activity at the beginning of the period was at a relatively low level and was confined, primarily, to development of the shallow Pennsylvanian in Cooke, Montague, and Wilbarger counties. There was a steady increase in activity from 1945-1949.

After reaching a peak in 1949, drilling declined in North Texas, but new Ordovician field discoveries in Grayson County (Sandusky, Big Mineral) and the accompanying Pennsylvanian discoveries (Sadler, Sherman) resulted in extensive exploratory efforts. Exploration activity was at a particularly high rate from 1950-57. The use of fracture treatment has been of particular importance in the over-all development of North Texas in this period. Since then, exploration has decreased in general.

Since 1960, a considerable amount of exploratory effort has been directed toward the deep Marietta Basin. This amount of exploration, however, has not been adequate to offset the overall general decline.

Exploration technology, particularly seismic reflection techniques, was responsible for multiple discoveries in this area in the early 1940's. Shallow sediments had established production years earlier but new seismic techniques allowed the mapping of deeper formations. The period of 1945 to 1956 reflects the effect of these discoveries and extensive development drilling that followed.

Drilling technology has also made major contributions. The rock penetrated in going to the lower Pennsylvanian sands and to the Ordovician was in general hard and dense. It was difficult to apply needed weight to the bit and avoid intolerable hole deviations. Shales such as the Atoka sloughed badly with the drilling practices of 1950.

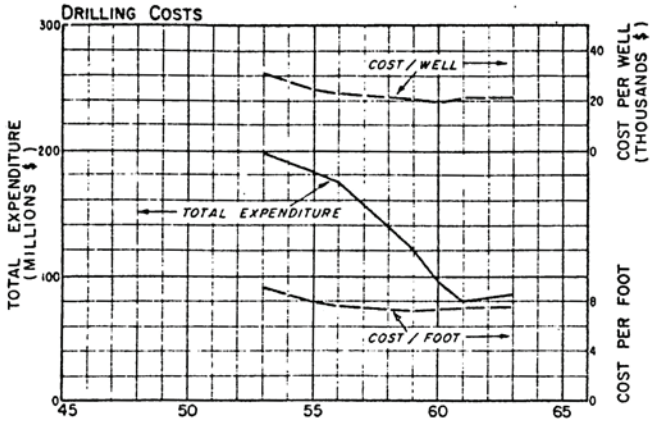
During this period there were major improvements in bit tooth design and in bit bearings. There was also extensive controversy over optimum mud properties with differences arising in the proper balancing of such factors as viscosity and water loss, among others. New and important technological advances were the final result.

Fracturing has been applied to many of the fields in this area. The Baker (Strawn) sand in Sherman field and the 4,200-foot sand in Fargo would not produce in commercial quantities without fracturing. Cumulative production from the Strawn reservoir of Sherman field has now exceeded ten million barrels, and exceeds the production of any other reservoir in this multipay field.

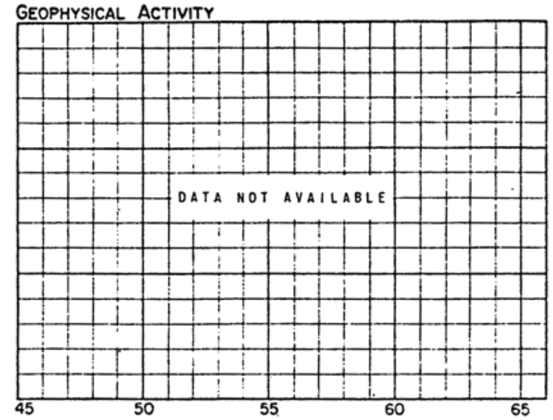
Fluid injection and unitization were products of technology that made major contributions. A pressure maintenance operation using gas injection was started in the large K.M.A. field in 1939. By 1940 it was the largest cooperative program in the history of the industry, involving 150 operators, and 1,300 wells on 25,000 acres. Gas injection continued into 1956 and has since been followed by waterflooding. At the end of 1962 production had exceeded 110 million barrels and the annual production is approximately four million barrels.

At the end of 1961, this area had 154 unitized fluid injection projects which at that time was 48 percent of the total units in Texas.

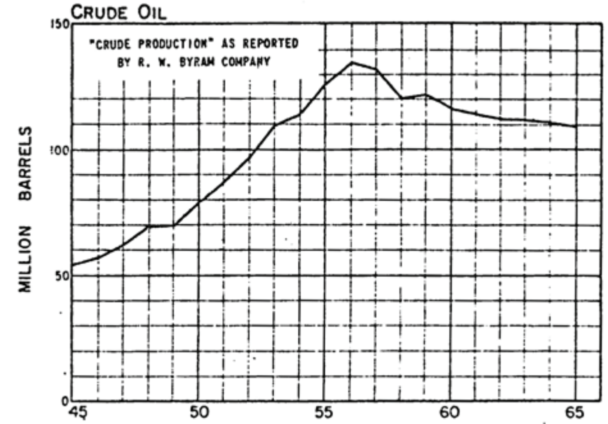
DRILLING COSTS



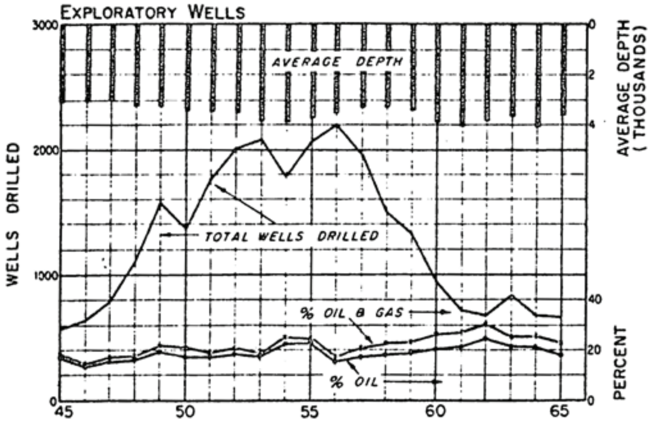
GEOPHYSICAL ACTIVITY



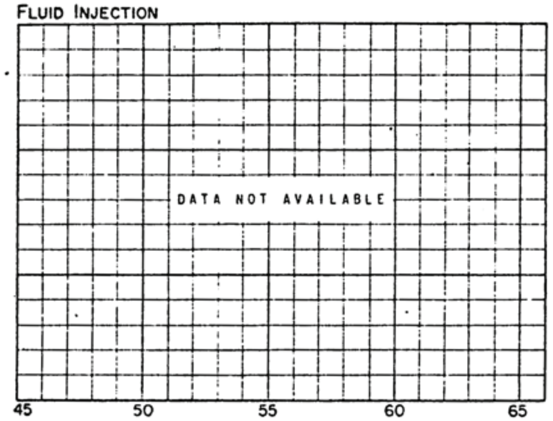
CRUDE OIL



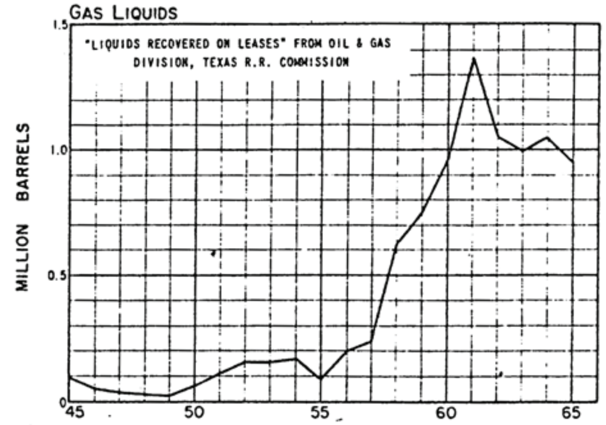
EXPLORATORY WELLS



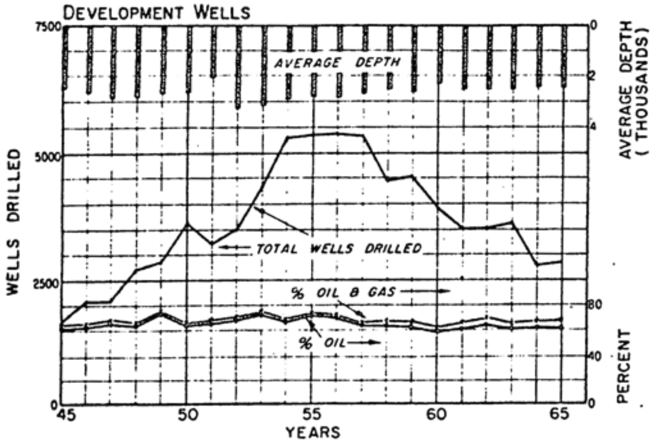
FLUID INJECTION



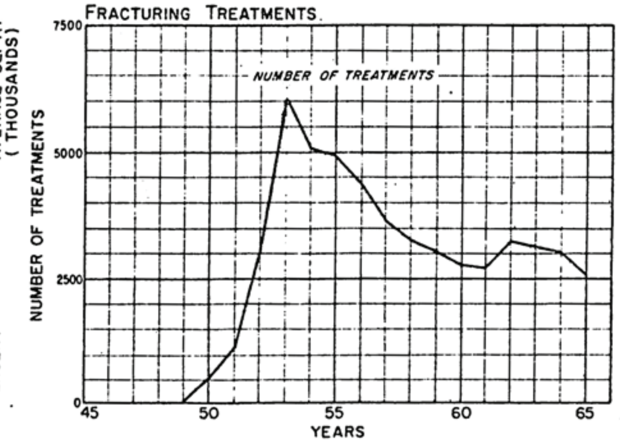
GAS LIQUIDS



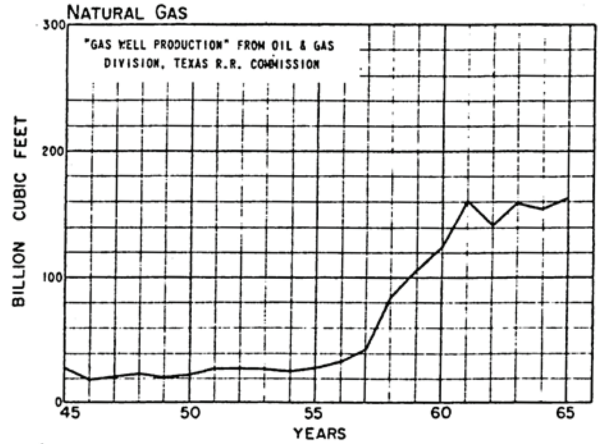
DEVELOPMENT WELLS



FRACTURING TREATMENTS



NATURAL GAS



TEXAS RRC DIST 7B & 9 (NORTH)

TEXAS

Texas R. R. Commission Districts 7C and 8 (West Texas)

In 1945 and for the next several years, exploration activity was at a relatively low level and drilling was confined primarily to the shallow Permian on the Central Platform area. However, the discovery of Spraberry (1946) and Scurry-Snyder (1948) initiated extensive exploration and development which continued until around 1956.

In the following years, considerable exploratory effort was directed toward the deeper Devonian and Ellenburger horizons in West Texas. Some of this was evident as early as 1945, but it was of particular importance through the period 1955-1957. Since 1957, exploration has generally declined in West Texas, although the period from 1960-1964 has shown renewed activity, much of it in the Delaware Basin.

No significant developments in geologic technology were apparent in the area for the period 1945-1965. Geophysical technology, however, progressed notably through this period and undoubtedly contributed to the overall exploratory effort.

Development drilling in West Texas became active soon after the end of World War II, and much of the technology of faster drilling was initiated in this area. The average amounts of reduction in drilling time made during this report period cannot be precisely determined, but 50 percent would be a fair estimate. The time savings increases with increased depth. Improved drilling fluids, including air and gas, more and heavier drill collars, permitting more weight on the bit, button bits and jet bits were the major contributions to faster drilling.

A recent example is the deep drilling in the Delaware Basin. This development has presented numerous major problems that new technology has solved, and made development feasible. In the beginning, wildcats drilled to below 20,000 feet required about two years. Later drilling reduced this to about 14 months, and wildcat wells completed thus far in 1966 have averaged a little more than 9 months. Development wells in the Gomez field in 1965 averaged almost 10 months, but in 1966 have averaged about 8 months, and it appears that still shorter drilling times will be attained on future wells. Development below 20,000 feet has been made feasible by the advances in technology during the period of this study.

New technology of completing wells was also a major factor in continued West Texas development. New logging devices and better interpretation of old methods permitted more precise location and evaluation of producing sections in thick rock intervals. Through this, stimulation treatments were concentrated more effectively and better completions resulted. Fracturing proved to be of particular importance in developing producing sands, and logging and completion methods were just as important as in carbonate reservoirs.

As in other areas, improvements in well spacing technology had significant development import. Forty acre spacing was the generally accepted pattern in 1945. In the early 1950's, 80 acre spacing was provided in a few pools and the number has continuously increased.

Fluid injection projects, primarily of the pressure maintenance variety, have become a large factor in maintaining production and increasing the recoverable reserves. Notable among these are the large SACROC Unit water injection project of Scurry County and the Block 31 project of Crane County. The first application of a high pressure miscible gas displacement recovery program began at Block 31 in 1949.

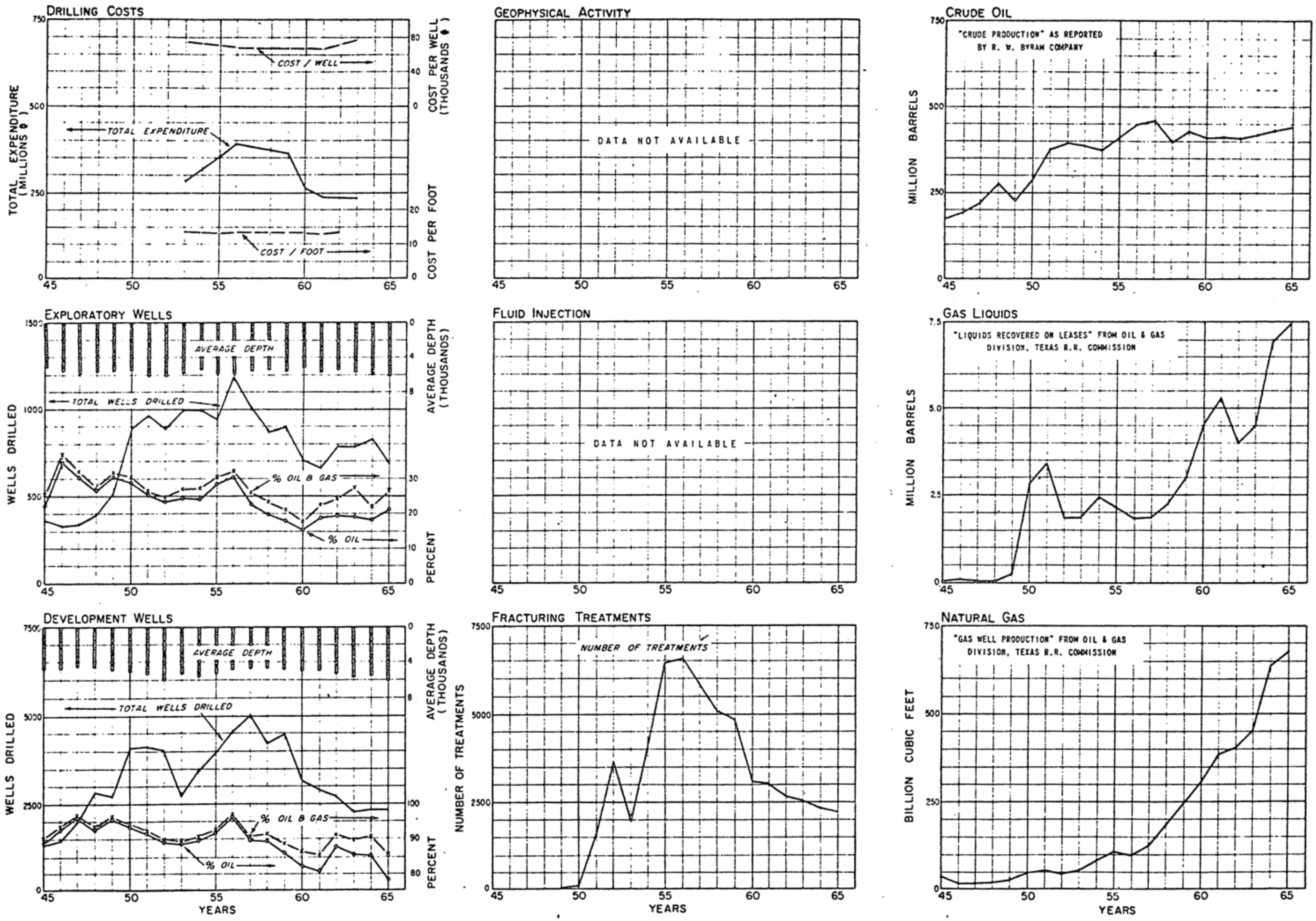
The Spraberry field of West Texas furnishes an excellent case history covering many aspects of new technology. The producing area of over 200 square miles reached peak development in the early 1950's. Production is from a relatively thick, silty sand. A large majority of the wells had small, natural producing rates, but after fracturing would often produce from 100 to several hundred barrels per day. Earlier wells required about 35 days to drill, but as methods were improved wells were drilled in 20 to 22 days, and more recent wells now require only 17 to 19 days. The first development was on 40 acre spacing and many of those will not produce ultimately enough to return the cost of drilling and operating. Later development was on 80 acre spacing, some on 160 acre spacing, and the proportion that will be profitable is much greater. A number of water injection projects are now in operation. Results from some of the earlier ones were not encouraging and many technical problems were present, but injection experience is now more promising and holds further promise for this marginal area.

In summary, the natural producing capacity of the wells in a large part of the Spraberry area was so poor that probably as much as two-thirds of the area would never have been developed except for the benefits of faster drilling, fracturing and better completion practices introduced into the industry after 1945.

Another area of illustration is the "sand belt" area of producing pools extending some 90 miles from Lea County, New Mexico through Winkler and Ward Counties, Texas. The producing section is composed of dolomite and sand lenses that vary greatly in thickness and number. Development has been ordinarily limited to areas having more favorable sand thickness and quality. Faster drilling, fracturing, and new logging and log interpretation methods have combined to cause the extension of old producing pools whose original development was completed many years ago, as well as the drilling of new areas.

The magnitude of new technology on development in the "Basin sands" area is shown by the statistics on four pools: North Ward Estes, discovered in 1927; Kermit, 1928; Emperor, 1936; and South Ward, 1937. In these four pools there was an addition of almost 2,000 wells from 1949 through 1964, 40 percent of which were drilled in 1956 through 1958. The developed area increased to almost 200,000 acres, from 33,000 in 1949, and spacing for the new area was 83 acres per well, contrasted with 13 acres in 1949.

Numerous secondary recovery projects have been started in the area. In 1950, there were three by water injection and 74 at the end of 1959. Seventeen were added in 1960 and 1961, all with water injection. All such developments have added substantial oil reserves and maintained much higher rates of production.



TEXAS RRC DIST 7C & 8 (WEST)

TEXAS

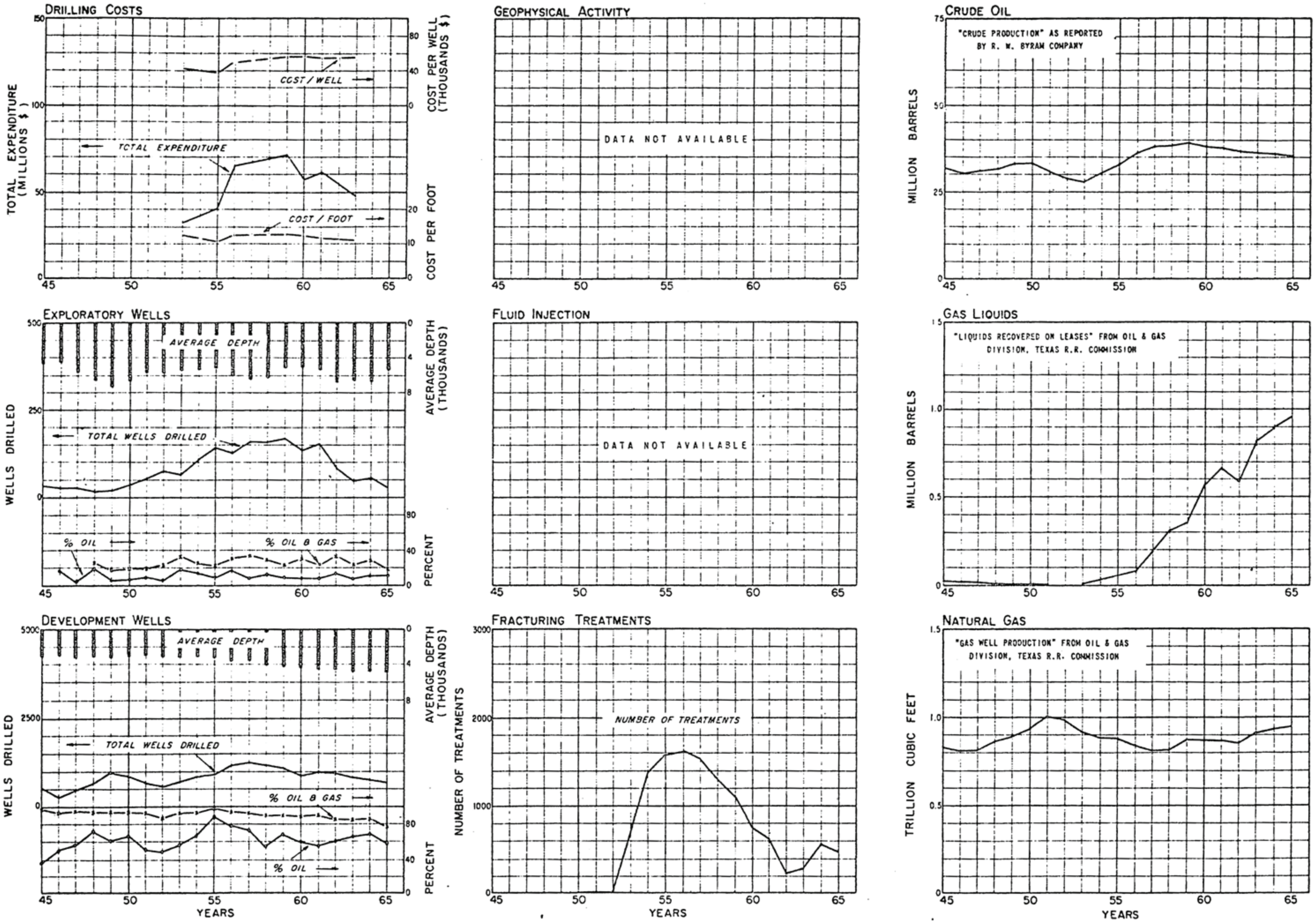
Texas R. R. Commission District 10 (Panhandle)

Exploratory activity began the period of study at a low level of activity. Most drilling was confined to the Hugoton and Panhandle Fields. Exploration increased steadily from 1950 to 1961 and has since declined.

Recent development in the Texas Panhandle has been largely in the northern part where sands of middle Pennsylvanian through upper Mississippian age are productive of both oil and gas. The producing formations are all lenticular which is a major factor controlling field limits. In many cases the sands are thin and can only be located and evaluated by coring or by using newer logging and improved interpretation methods.

Frequently commercial production is obtained only after fracturing and improved cementing practices have made selective fracturing more effective. Improved drilling, jet bits, improved tooth design, more weight on the bit, and better drilling fluid have together brought the benefits of faster drilling to this area.

In the northern part of the Texas Panhandle, technological advances since 1945 have caused a large part of the exploration and development that has occurred. The largest technological influence in the older producing areas has been fluid injection. Twenty-eight projects were installed during the study period. Development of electrical logging equipment for use in areas of salt deposits and the development of better porosity tools have contributed considerably to the overall activity in the Panhandle area.



TEXAS RRC DIST 10 (PANHANDLE)

ROCKY MOUNTAIN

AREA

ARIZONA

Exploration activity in Arizona was very minimal through the period 1945-57. The first commercial production in the state was discovered in 1954 at the East Boundary Butte Field, Apache County, in the Hermosa formation. The most significant discovery of the period under study occurred in 1957 at the Pinta Dome Field, where helium-bearing gas is now being produced from the Coconino formation. All activity has essentially been confined to the northeast corner of the state.

Exploratory drilling increased in 1958 and remained relatively high (± 25 wells per year) through 1965 as increasing interest in the relatively unexplored Black Mesa Basin helped offset the fact that no significant discoveries were being made. Excluding the two discoveries mentioned above, there were less than twenty scattered wells in Arizona considered as productive of oil or gas in 1965.

No plot of data for Arizona is included because of the limited amount of Exploration and Production activity.

COLORADO

Colorado had a backlog of development wells to drill in the Rangely field at the start of 1945, and these were completed by 1949. Exploratory drilling did not begin to pick up significantly until 1951.

Aside from sporadic activity in southeastern and western Colorado, the most significant event in the period 1945-65 was the discovery of oil in the "D-J" sands in the Denver-Julesburg Basin in 1949.

After the discovery of the D-J production in 1949, total drilling activity in Colorado reached a peak of 1,500 wells in 1955. Most of these were drilled in the D-J play, and this play continues to account for about 75% of the wells drilled in Colorado. This play has also had the most influence on the decline of exploratory and development wells during the period 1955-65. The early part of the D-J play (1949-53) was characterized by one or two major companies. The period 1953-55 began with a large field discovery (Adena) and ended with a high level of drilling activity. The period 1955-60 was a period of farmouts and support wells as the majors attempted to evaluate their large acreage holdings. This period ended with wholesale lease expirations and during 1961-65 drilling was maintained at a low but rather constant rate.

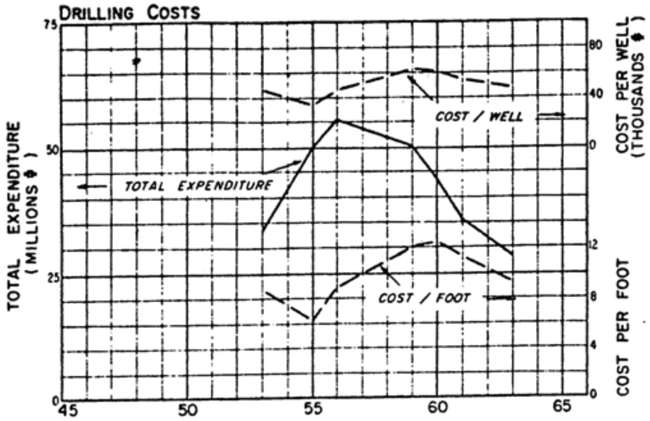
Activity in Colorado during the period studied is almost entirely the result of one play. All trends of activity can be explained by geologic opportunity, with economic or technological factors of less importance. The use of formation fracturing was coincidental with the discovery and development of the Denver-Julesburg Basin, and contributed to the over-all activity.

Denver-Julesburg Basin production is from thin, lenticular sandstone in the Dakota section. Three-fourths of the pools cover an area of less than 640 acres and the producing section is less than ten feet in thickness. Some of the early development was on ten and twenty acre spacing, but later development has been on 40 acres, with some 80 acre spacing. Wider spacing practice has encouraged activity, as well as improvements in drilling technology which have increased penetration rates. Fluid injection operations are also being initiated at a steady rate.

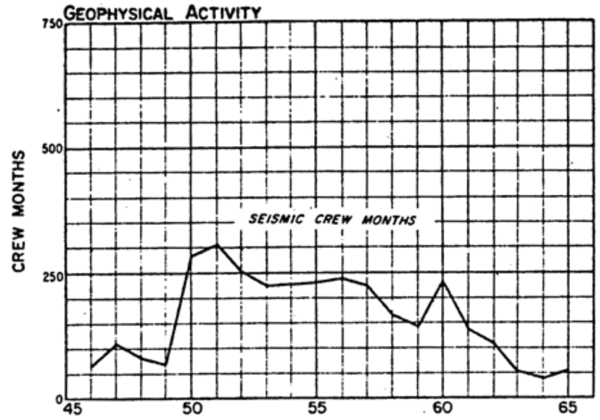
In western Colorado, Rangely is the major producing field with 40 percent of total 1963 production and 48 percent of the State's cumulative production through 1964. The reservoir characteristics of this field showed the need for pressure maintenance and in 1958 a voluntary unit was formed. Injection into this field is primarily responsible for its continuing productive capacity.

Production in southwest Colorado is largely gas from low permeability sandstone of Cretaceous age down to the Dakota. Natural flow in much of the area is too small to be commercial and all wells are fractured on completion. The accumulative effects of improved drilling methods, including bits, more weight on the bits and better drilling fluid, better logging methods, more precise log interpretation, sand fracturing, and wider spacing have extended development and have increased productive capacity and reserves substantially. Without such improvements, not all of the area would have been developed.

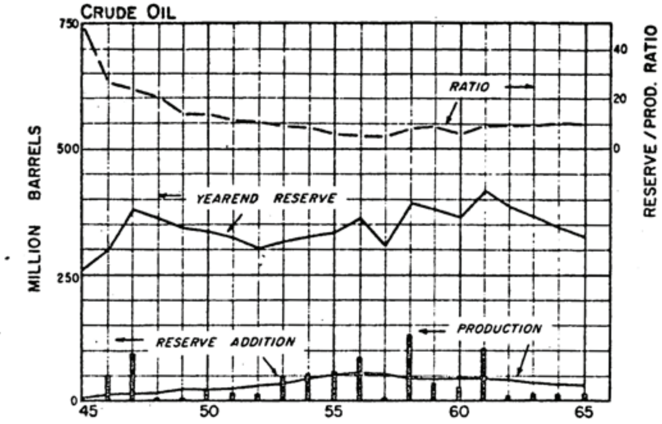
DRILLING COSTS



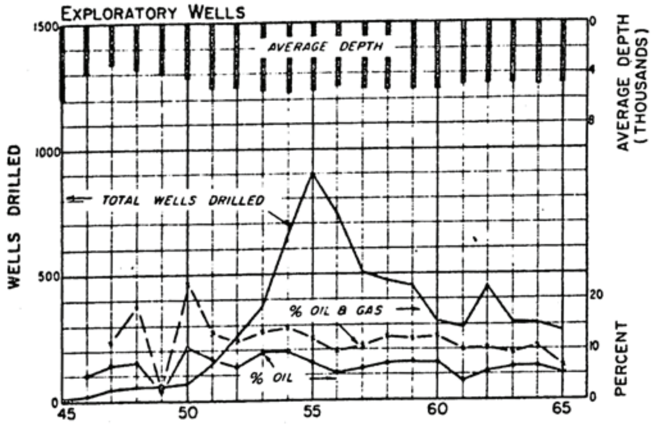
GEOPHYSICAL ACTIVITY



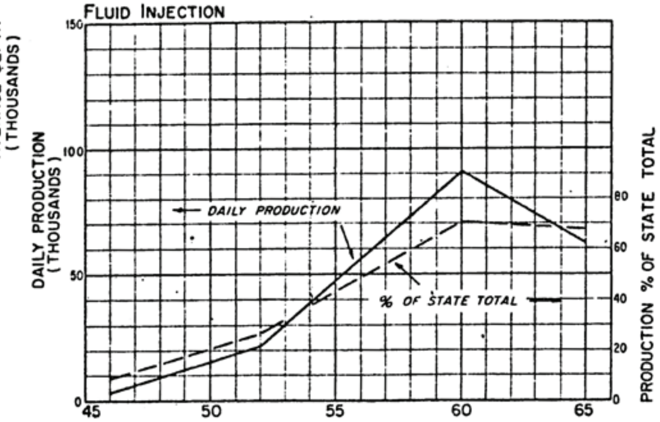
CRUDE OIL



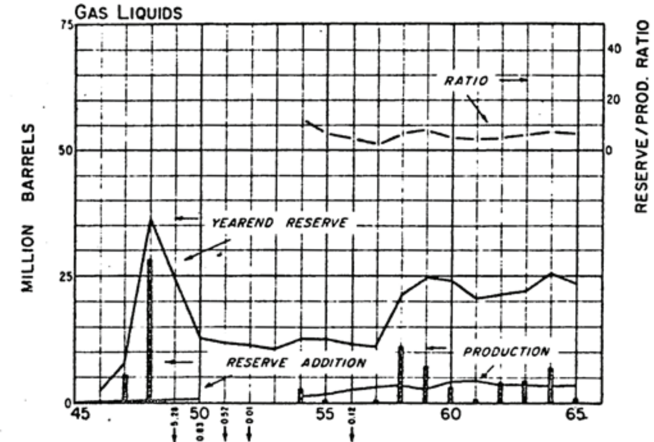
EXPLORATORY WELLS



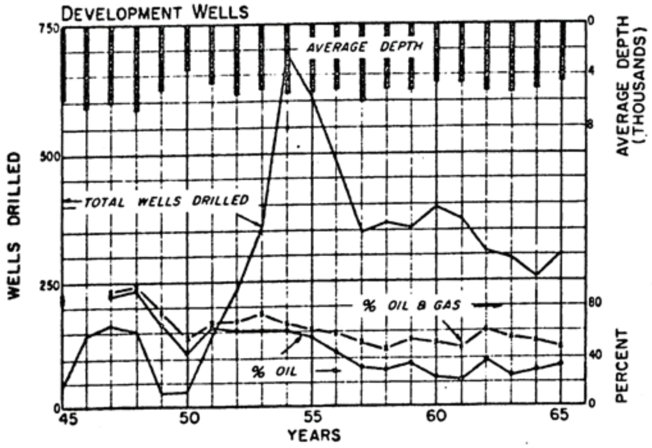
FLUID INJECTION



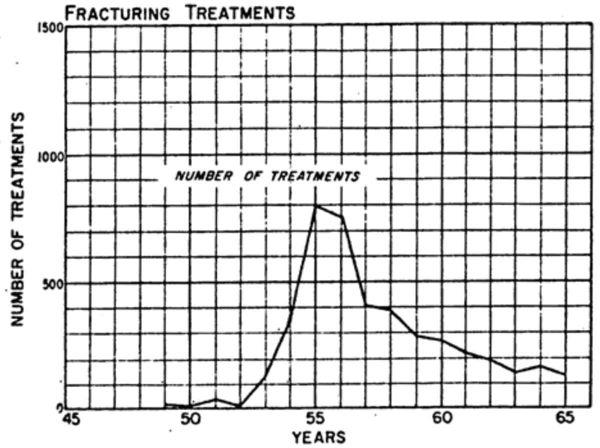
GAS LIQUIDS



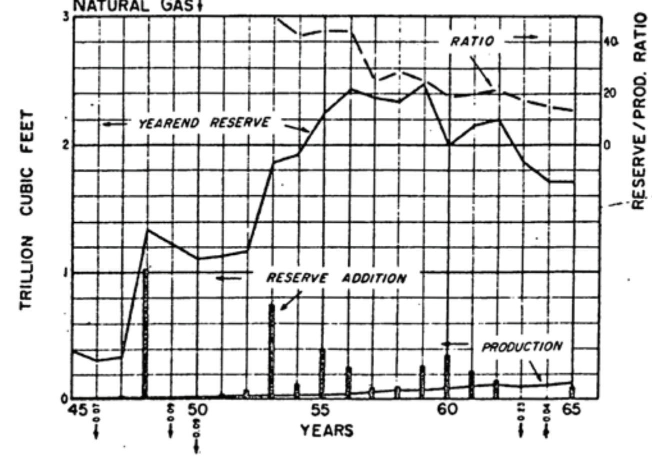
DEVELOPMENT WELLS



FRACTURING TREATMENTS



NATURAL GAS



COLORADO

MONTANA

Activity in Montana in 1945 was mixed. Exploratory wells and geophysical crews were at a low level of activity; however, development wells were at essentially the same level in 1945 that they have been since that time. This early level was caused primarily by the continued development by small operators of the shallow sands in the Kevin-Sunburst and Cutbank areas (Sweetgrass Arch).

The discovery of oil in the Willistin Basin of North Dakota lapped over into eastern Montana, and exploratory activity increased significantly in 1952 along the Cedar Creek Anticline. Exploratory drilling peaked in 1956, with the play divided between central and eastern Montana. Geophysical activity was at a peak in 1953, but declined rapidly to a moderate level and has remained there since 1958.

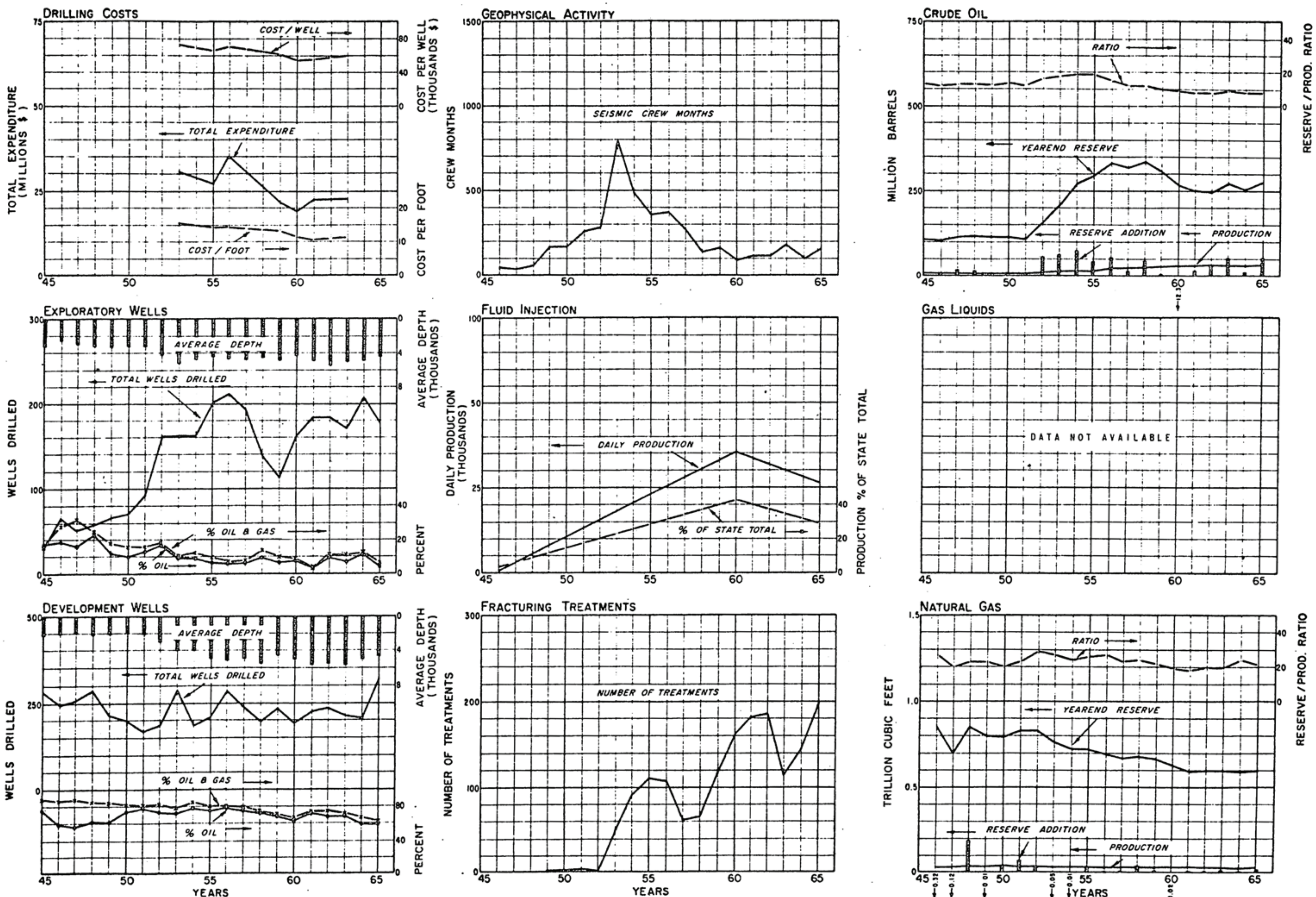
Oil was discovered in the Tyler sand in central Montana in 1956 and helped exploratory drilling to rise that year. The development of this channel-deposited sand was accompanied with many dry holes and a low development success ratio. Successful unitization and waterflooding these discoveries stimulated other exploratory drilling in 1960.

The discovery of additional oil on the Cedar Creek anticline and a resurgence of interest in the Sweet Grass Arch has held exploratory drilling at a relatively high level for the period 1960-65.

Montana crude oil reserves were substantially increased during the period of Williston Basin development, primarily in the Cedar Creek and Poplar area. Reserves reached a high plateau in the 1956-58 period and have since declined although relatively constant since 1963.

Fluid injection has been started in a limited number of fields and 34 such projects were operating in 1965. All but a few used water injection and one thermal recovery project was active. These projects now provide 30% of the state's total production which, however, has declined in recent years.

Formation fracturing has in recent years become more important to Montana oil development. Tyler sand wells and those on the Sweet Grass Arch area respond well to fracturing and the number of treatments each year has shown an over-all rise while these areas have been developed. Fracturing was at an all-time high during 1965 at the end of the report period.



DRILLING COSTS
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
GEOPHYSICAL ACTIVITY
SEISMIC CREW MONTHS
CREW MONTHS
CRUDE OIL
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
MILLION BARRELS
RESERVE / PROD. RATIO
EXPLORATORY WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
FLUID INJECTION
DAILY PRODUCTION
% OF STATE TOTAL
DAILY PRODUCTION (THOUSANDS)
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
DATA NOT AVAILABLE
DEVELOPMENT WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
TRILLION CUBIC FEET
RESERVE / PROD. RATIO
YEARS

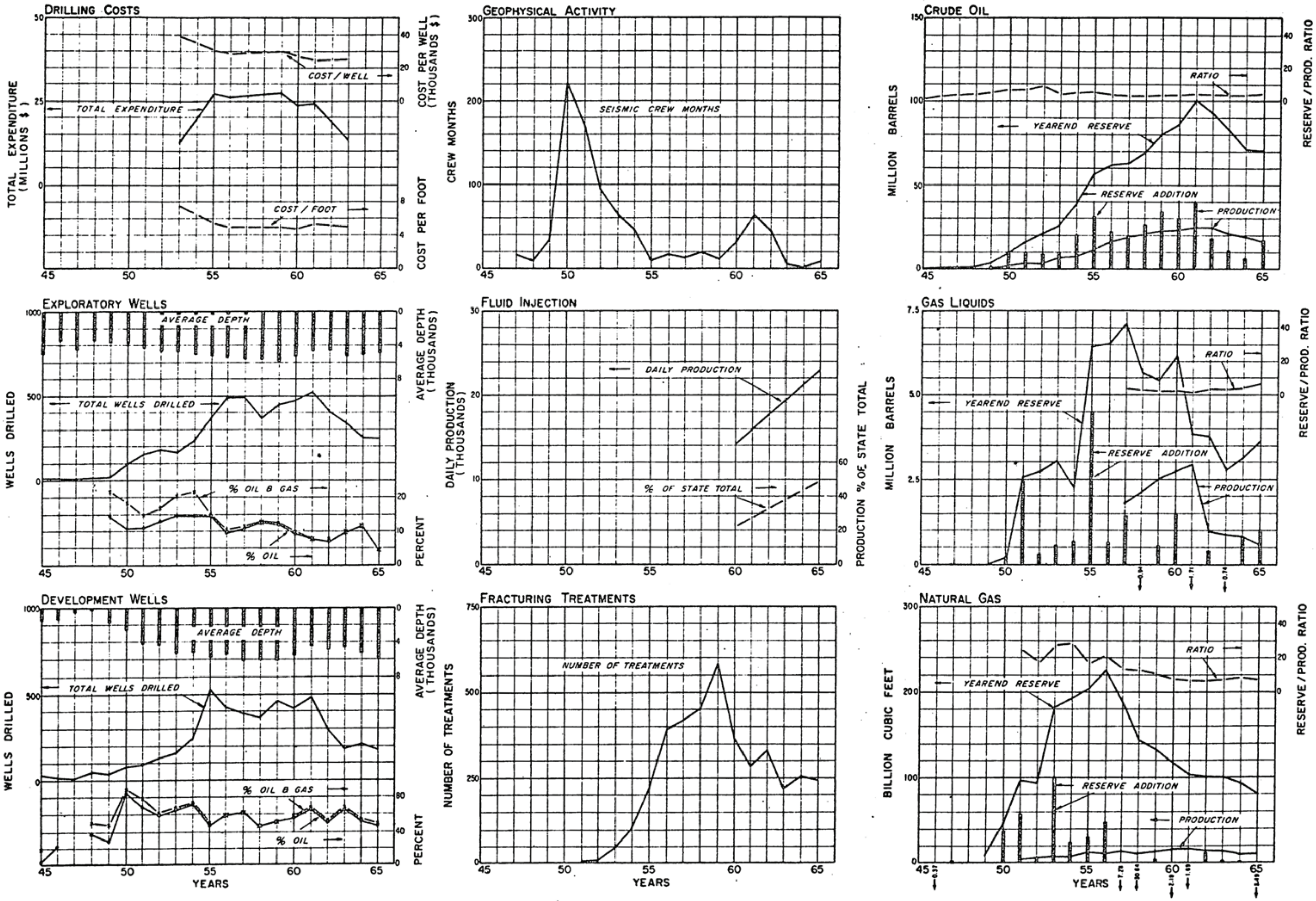
MONTANA

NEBRASKA

During 1945, Nebraska had no production of significance and there was little exploratory activity being conducted. However, following the 1949 opening of the Denver-Julesburg Basin production in Colorado, geophysical and leasing activity increased rapidly. Exploratory drilling reached peaks in 1956-57 and again in 1961 as the program progressed and in 1961, crude oil reserves reached an all-time high.

Oil production in Nebraska is largely from lenticular reservoirs, the Dakota sands in the southwest, and Kansas City-Lansing and pre-Cambrian in the south-central areas. The pools are generally small, over 85% of them covering less than 640 acres. In general, the sands are thin, a very high percentage being under ten feet thick, however improvements in drilling and completion methods have encouraged development. Formation fracturing, which reached a peak in 1959, has also been a favorable influence.

In recent years, fluid injection projects have contributed a larger proportion of the state's production. In 1965, there were 84 such projects in operation including water, gas and miscible phase injection. They were supplying 49% of the state's daily oil production.


DRILLING COSTS
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
GEOPHYSICAL ACTIVITY
CREW MONTHS
SEISMIC CREW MONTHS
CRUDE OIL
MILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
EXPLORATORY WELLS
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
FLUID INJECTION
DAILY PRODUCTION (THOUSANDS)
DAILY PRODUCTION
% OF STATE TOTAL
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
MILLION BARRELS
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
DEVELOPMENT WELLS
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
BILLION CUBIC FEET
RESERVE / PROD. RATIO
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
YEARS

NEBRASKA

NEVADA

At the end of 1965, a total of only 110 wells, exploratory and development, had been drilled in Nevada and all of these were drilled during the past twenty years. Essentially all of the drilling has been in southern Nevada. Peak exploratory drilling occurred in 1954, and in that same year Nevada's first commercial oil production was discovered. The discovery occurred in the Railroad Valley, Nye County, when a volcanic ash at 6,700 feet proved productive. Development was slow, and at the end of 1965 only twelve wells were producing oil.

A second round of increased exploratory effort occurred in 1961, but nothing of consequence was found. Exploratory drilling has been at a minimum (less than ten wells per year) since that time. The Railroad Valley discovery remains Nevada's only production of any consequence.

No plot of data for Nevada is included because of the limited amount of Exploration and Production activity.

NORTH DAKOTA

North Dakota entered the postwar period without oil or gas production and with practically no exploratory activity. However, interest in North Dakota increased rapidly in 1951 after oil was discovered on the Nesson Anticline of the Williston Basin. This was followed by peaks of seismic activity and exploratory drilling between 1952 and 1955. Development drilling increased accordingly but was declining in 1957 when the discovery of the Glenburn Pool in Renville County again stimulated activity in the area.

Exploratory drilling was at an all-time high in 1957 and 1958, but declined to a moderate plateau of around 100 wells per year, which has held since 1960. Geophysical activity has remained at a low level since 1955. No significant major discoveries have been made since 1957, but reserve additions through extensions and fluid injection have helped maintain North Dakota's crude reserves and production.

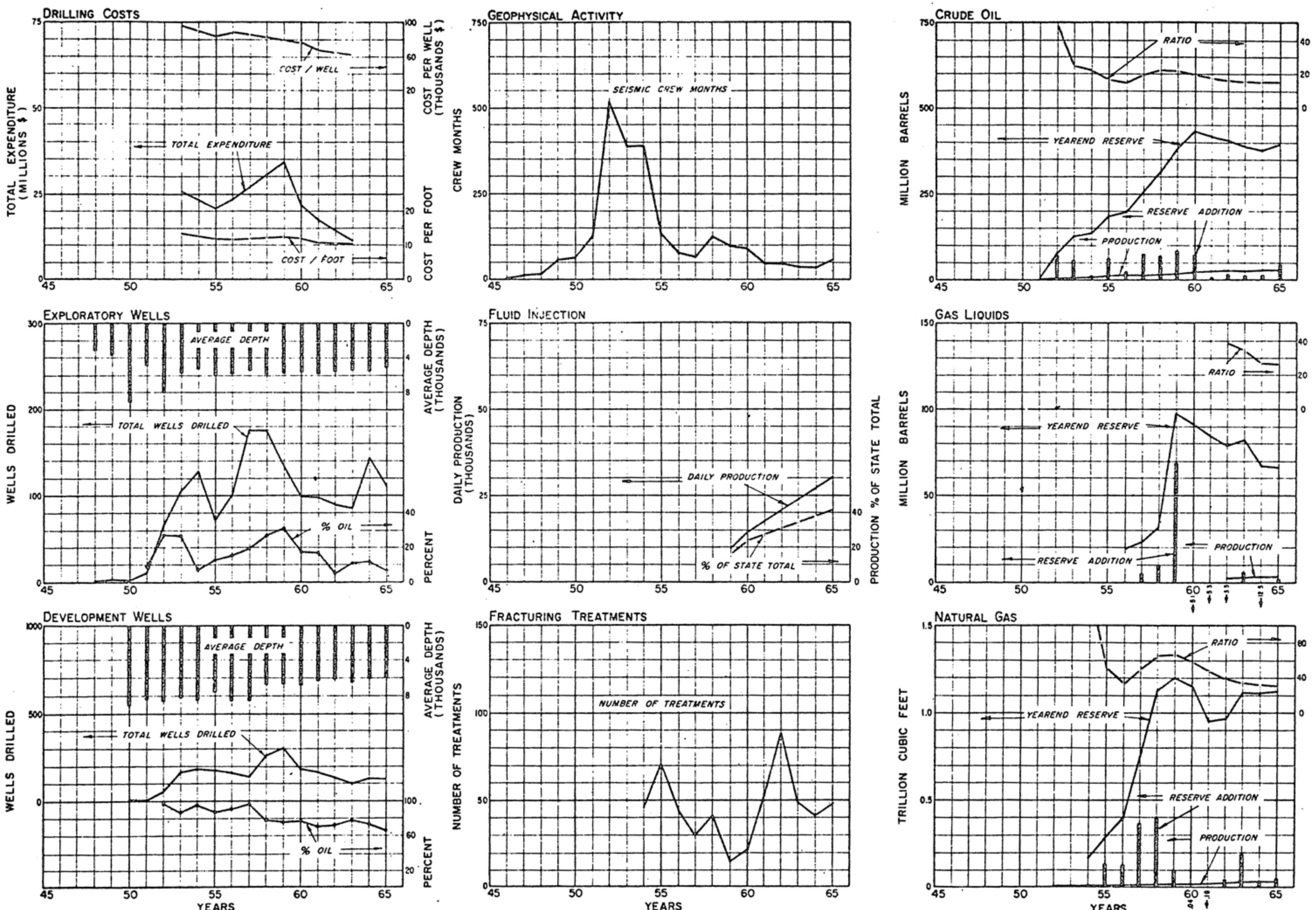
The oil industry of North Dakota has been unique in many respects during this report period. It has grown from oil discovery in 1951 to a fully integrated industry in 1965. The state government benefited by the experience of older producing states and guided the industry with sound judgment. Wide spacing is one of North Dakota's most important contributions to industry development.

North Dakota adopted 40-acre-per-well minimum spacing in the discovery field. After a few wells had been completed, pressure interference tests and engineering studies began to show that wells in the Madison limestone oil reservoir were effectively draining more than 80 acres each. Operators in general limited development drilling to 80-acre density and the first such spacing order was issued in 1953. During 1954 additional 80-acre spacing orders were issued and the engineering proof of efficient drainage on this pattern was well established. In the following years spacing has trended to wider patterns based on evidence of fluid drainage. At January 1, 1966 there were more 320-acre spacing orders than 40-acre and 48 percent of total orders provide spacing greater than 80 acres per well. North Dakota has furnished an excellent illustration of the benefits of applied technology. In this case, an understanding of underground fluid movement prevented the drilling of hundreds of unnecessary wells. Since under North Dakota regulations an 80-acre spaced well was allowed to produce the daily oil of two 40-acre wells, there was no incentive to develop fields on closer spacing than necessary for efficient oil recovery.

Unitization and fluid injection have been major factors in the petroleum industry in North Dakota. The first fieldwide units were formed in the Beaver Lodge and Tioga Madison limestone fields in 1958. Many others have since been formed and all are water injection projects. In 1965, 41% of total State production was from fields under fluid injection.

(North Dakota)

Drilling technology improvements have been significant. The time required to drill a 12,000 foot well in 1954 has been reduced approximately 50 percent and on a 9,000 foot well, 25 percent.



NORTH DAKOTA

SOUTH DAKOTA

Interest in oil and gas exploration in South Dakota was almost nonexistent immediately after World War II. There was no production in the state in 1945, and it was not until after oil was discovered in North Dakota (1951) that exploratory drilling picked up in South Dakota.

The first oil production in South Dakota was discovered in 1954 when the Buffalo Field in Harding County was opened. Exploratory drilling peaked during the next three years (1955-57) at the high for the period under study, but resulted in only one discovery of any consequence at the Barker Dome Field in Custer County.

Since 1957, exploratory drilling has been up and down, but at a relatively low level overall. No discoveries of any consequence were made after the Barker Dome discovery in 1955, and the Buffalo Field remains the most productive find in South Dakota.

Most of the exploratory activity has been concentrated in the western part of the state.

No plot of data for South Dakota is included because of the limited amount of Exploration and Production activity.

UTAH

The first significant oil discovery during this period occurred in 1951 in the Red Wash Field, located in the Uintah Basin. This discovery stimulated additional exploratory drilling in 1952, which continued until 1955; however, development drilling did not increase because the crude had a high pour point and presented many production problems. All phases of exploratory effort were stimulated in 1956, when the Aneth Field was discovered in the Paradox Basin. This was Utah's primary discovery during its history, and development drilling followed at a rapid pace.

The discovery and development of the Aneth Field employed new subsurface mapping techniques and helped stimulate study and research in environmental geology associated with reef buildup.

Seismic activity remained at a relatively high plateau through 1960 before commencing a decline back to pre-Aneth levels. Stimulated exploratory drilling remained relatively strong from 1956 through 1965, however, no significant discoveries were made. Development of the Red Wash Field has helped to arrest the decline in development drilling since its peak in 1958.

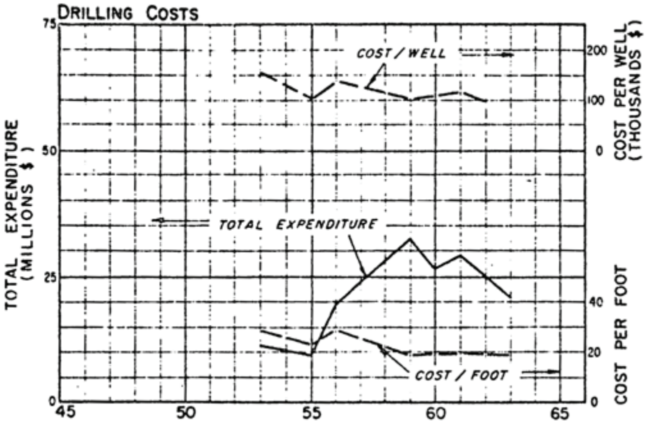
The reservoir characteristics and high pour point of the oil at Red Wash have challenged producing technology. Crude oil temperature is maintained above 130 degrees as it is moved from the wells and collected at a central point. Here it is blended with 70% Rangely crude or available condensate in order to move it by pipeline. A field-wide unit was formed in 1960 and injection programs of both water and gas have been started in the various sands of the field.

Multiple fracturing treatments have also been effective in maintaining producing capacity. As technology has solved producing problems in the field, production has gradually increased to the 1964 rate of 6.7 million barrels.

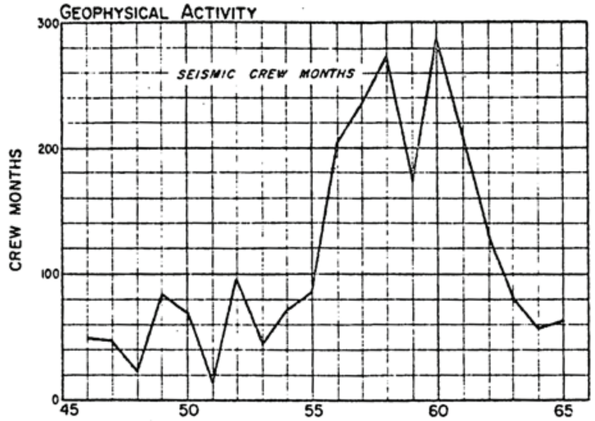
The Greater Aneth area of San Juan County is Utah's largest producing field. It was discovered in 1956 and its development led to one of the classical reservoir drainage studies in the industry's history. After exhaustive investigation, it was determined the wells in even such heterogeneous carbonate reservoirs as at Aneth were effectively draining large areas. Drainage in excess of 80 acres was proven and the general area was developed on 80-acre well spacing. The Aneth investigation was a significant application of reservoir technology that will continue to yield future dividends.

Most fields are under fluid injection programs, and approximately 93% of Utah production comes from such projects.

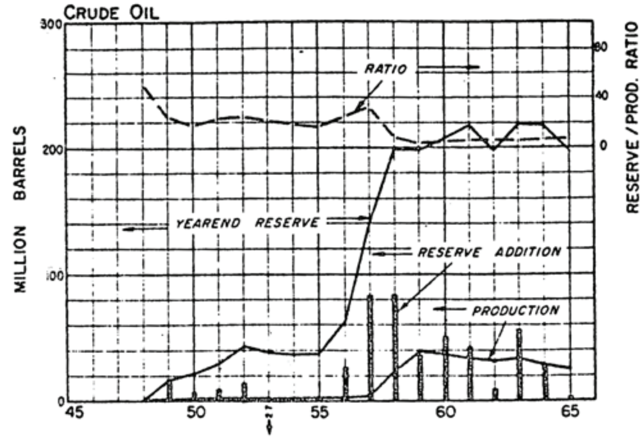
DRILLING COSTS



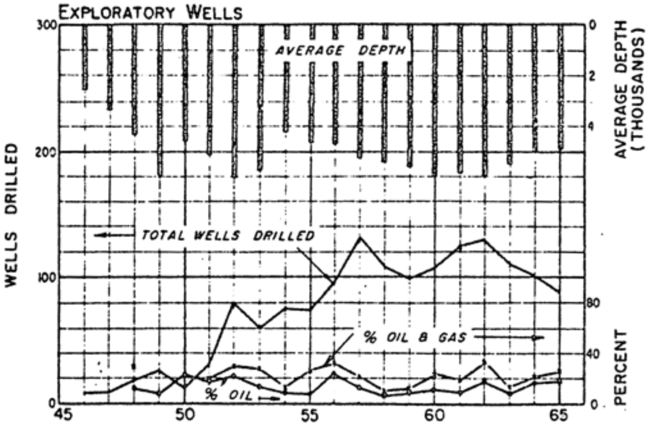
GEOPHYSICAL ACTIVITY



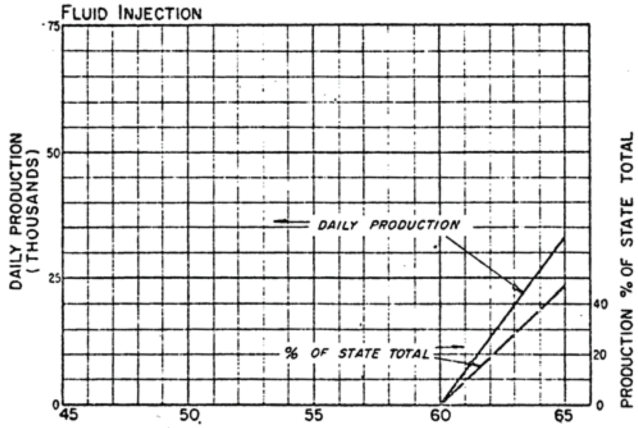
CRUDE OIL



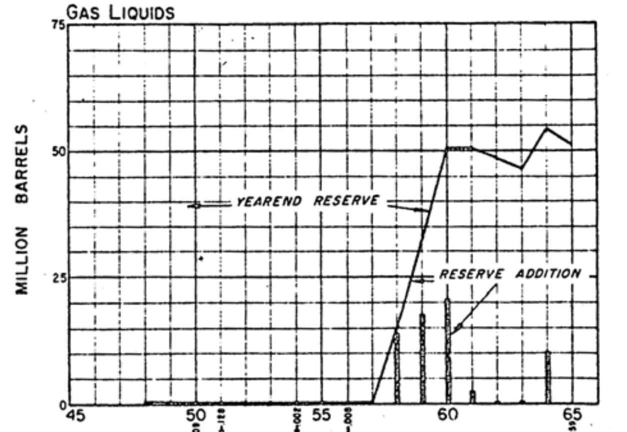
EXPLORATORY WELLS



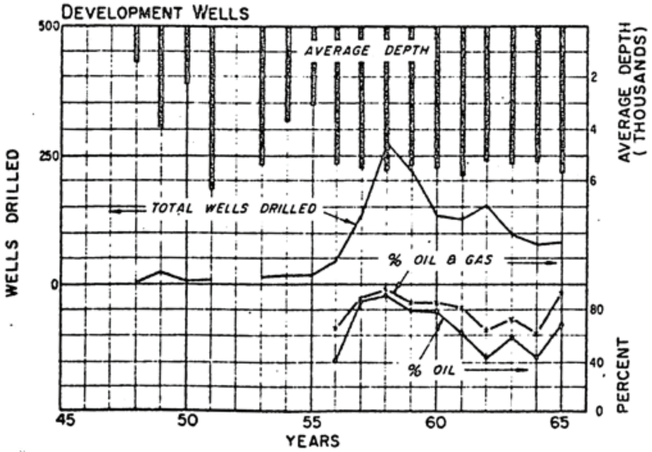
FLUID INJECTION



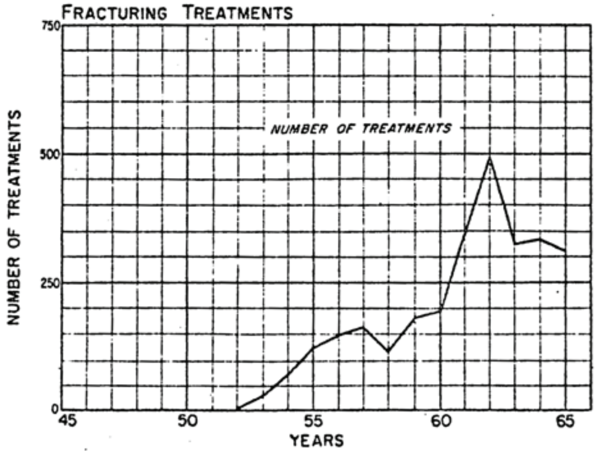
GAS LIQUIDS



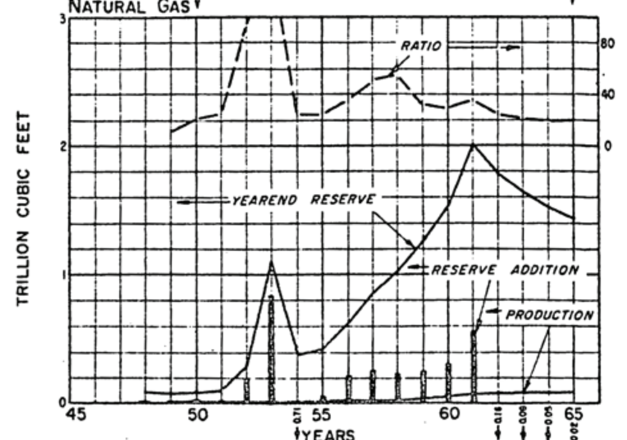
DEVELOPMENT WELLS



FRACTURING TREATMENTS



NATURAL GAS



UTAH

WYOMING

Wyoming entered the postwar years with all activity at a low level; however, geophysical and exploratory drilling activity soon increased. The period 1945 to 1954 was devoted primarily to structural prospecting, and it was during these years that the most significant discoveries of the period under study were made. Exploratory success was above 30% in 1945-48, but continued to decline as a backlog of prospects was tested. Development drilling peaked in 1954 as the structural plays in the Big Horn, Wind River and Powder River Basins were exploited.

Since 1954 stratigraphic prospecting has steadily increased, seismic activity has steadily decreased, and exploratory success has continued to decline to its present 10% level. The Big Piney Tertiary play of the Green River Basin began in 1954, and was followed by the Cottonwood Creek Phosphoria discovery of the Big Horn Basin in 1956, the Dead Horse Creek Parkman play of the Powder River Basin in 1958, and the Patrick Draw development in the Washaki Basin in 1960. A somewhat more sustained play has been the Fall River-Muddy activity in the northeast Powder River Basin, which reached a peak in 1961. Finally, the sustained Minnelusa play of the Powder River Basin reached a peak in 1963 and has since accounted for about 20% of Wyoming drilling. The varied geology of Wyoming has resulted in widespread, but locally concentrated plays, supported somewhat by the sustained Minnelusa activity.

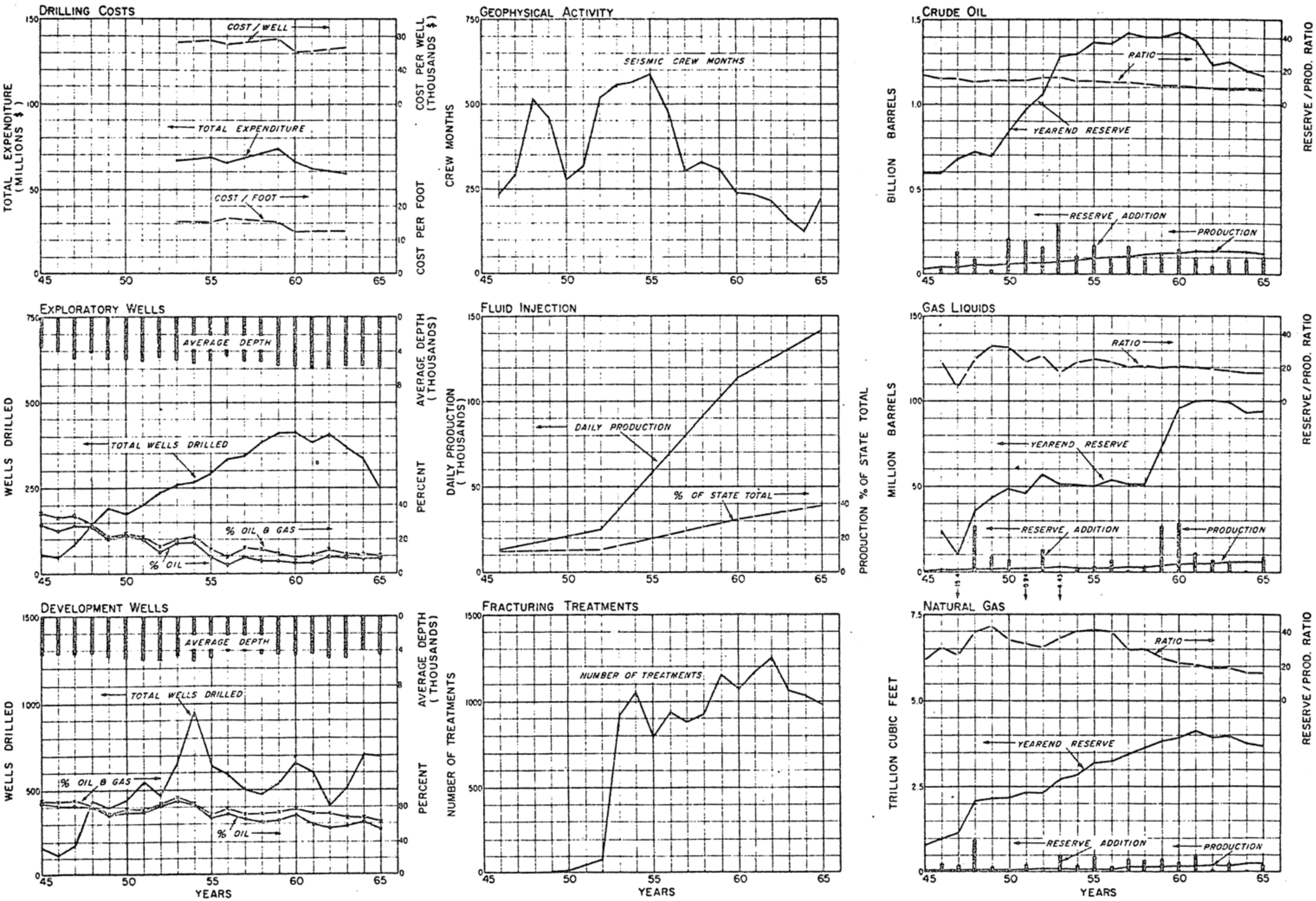
During the development drilling that followed, drilling costs per well and per foot have decreased while well depths have remained relatively constant. As is true for other areas, drilling bits were improved with better cutting characteristics, and bearings were improved to accommodate the heavy weight required to drill hard rock. Larger drill collars provided this needed weight and controlled hole deviation. Drilling muds were improved to stabilize shales.

Fluid injection has been applied with significant success in several large fields. The number of projects has steadily increased and 38% of production in 1965 came from fields with active fluid injection projects. Gas injection started in the Elk Basin Field in 1948 has maintained producing rates and should ultimately double the oil recovery. This project is unique in many respects. It was a pioneer in the process of sulfur recovery. Then, after sulfur removal, the processed gas was burned to increase volume, and the combustion products were injected. Later the compressor engine exhaust gases were also collected and injected.

Salt Creek Field has been under full waterflood in one sand (First Wall Creek) approximately ten years and production now exceeds the 1935 rate. The Second Wall Creek sand is under flood, with every indication that it will also be successful.

(Wyoming)

Computers are being used through automation to operate several large fields in Wyoming. Systems are generally a supervisory control and telemetering facility which monitor key facilities and operate many functions by remote control. A pilot system was tested at Gebo Field in 1962 and its success prompted expansion to other fields. Ten major fields are now operated by computer and are generating new operating technology which may have many future applications.


DRILLING COSTS
COST / WELL
TOTAL EXPENDITURE
COST / FOOT
TOTAL EXPENDITURE (MILLIONS $)
COST PER WELL (THOUSANDS $)
COST PER FOOT
GEOPHYSICAL ACTIVITY
SEISMIC CREW MONTHS
CREW MONTHS
CRUDE OIL
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
BILLION BARRELS
RESERVE / PROD. RATIO
EXPLORATORY WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
FLUID INJECTION
DAILY PRODUCTION
% OF STATE TOTAL
DAILY PRODUCTION (THOUSANDS)
PRODUCTION % OF STATE TOTAL
GAS LIQUIDS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
MILLION BARRELS
RESERVE / PROD. RATIO
DEVELOPMENT WELLS
AVERAGE DEPTH
TOTAL WELLS DRILLED
% OIL & GAS
% OIL
WELLS DRILLED
AVERAGE DEPTH (THOUSANDS)
PERCENT
YEARS
FRACTURING TREATMENTS
NUMBER OF TREATMENTS
YEARS
NATURAL GAS
RATIO
YEAREND RESERVE
RESERVE ADDITION
PRODUCTION
TRILLION CUBIC FEET
RESERVE / PROD. RATIO
YEARS

WYOMING

WEST COAST

AREA

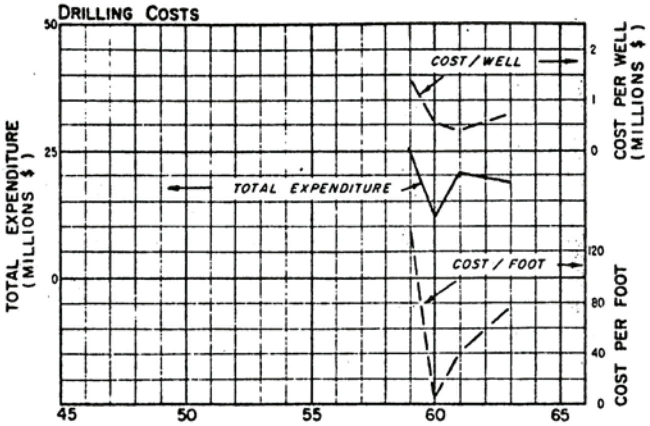
ALASKA

Alaska had no commercial production in 1945, and activity was nonexistent. The discovery of gas and saline water in test borings for coal near Houston in 1954 aroused interest in the feasibility that Tertiary rocks might produce oil and gas. Geophysical activity and surface work started in 1955, and Richfield discovered the Swanson River Oil Field in 1957.

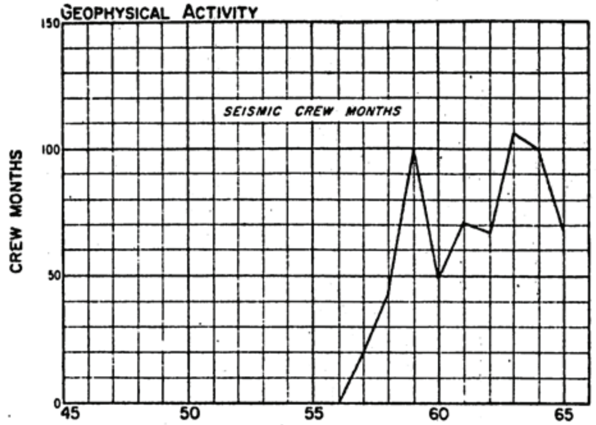
Exploratory drilling and geophysical activity continued after 1957, and in 1962 oil was discovered in the upper Cook Inlet. The use of the airplane and helicopter has played an important role in helping industry to understand the geology in this remote and rugged area, which, in turn, has led to drillable prospects. The development of marine and nonexplosive seismic techniques has also played a major role in establishing Alaska as an oil producing state.

Important technological advances have already come during Alaska's short producing history. Most of these have been directed toward operating problems in the Cook Inlet where strong and variable tidal currents and ice flows have been serious deterrents to platform construction and pipeline operation.

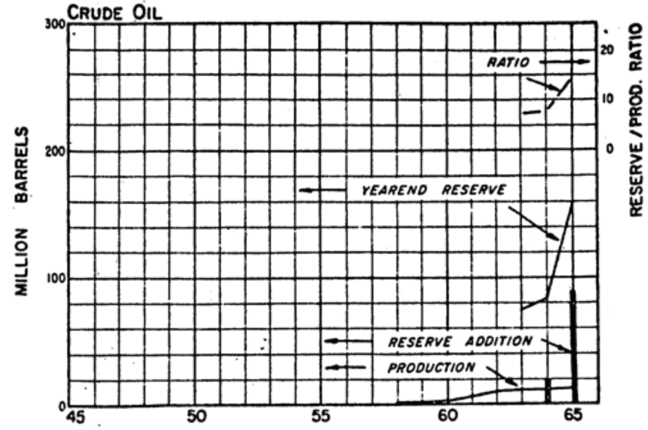
DRILLING COSTS



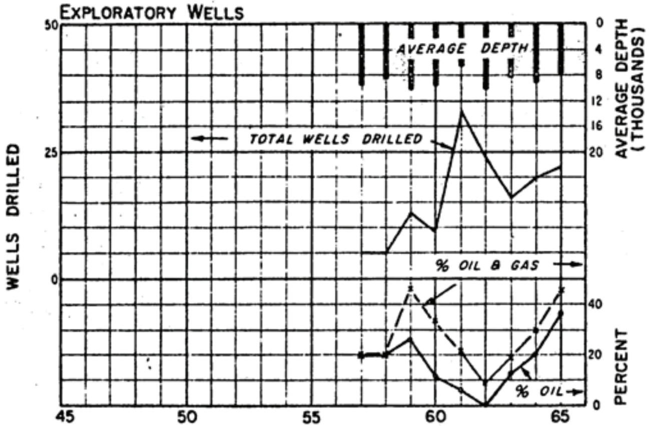
GEOPHYSICAL ACTIVITY



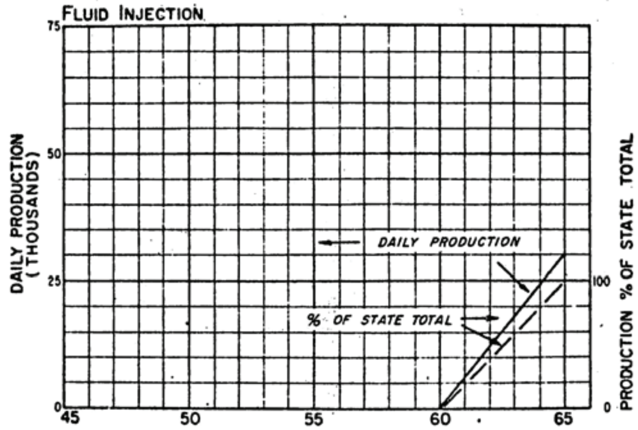
CRUDE OIL



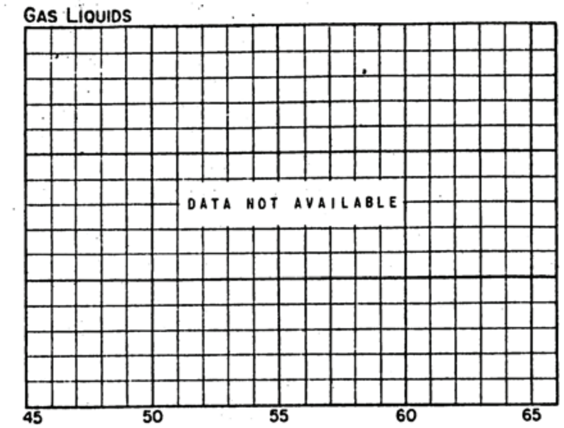
EXPLORATORY WELLS



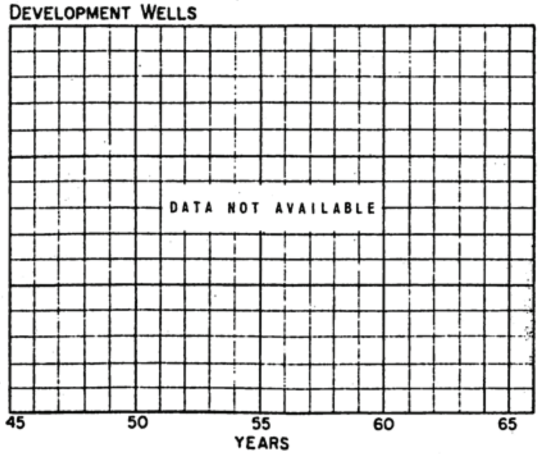
FLUID INJECTION



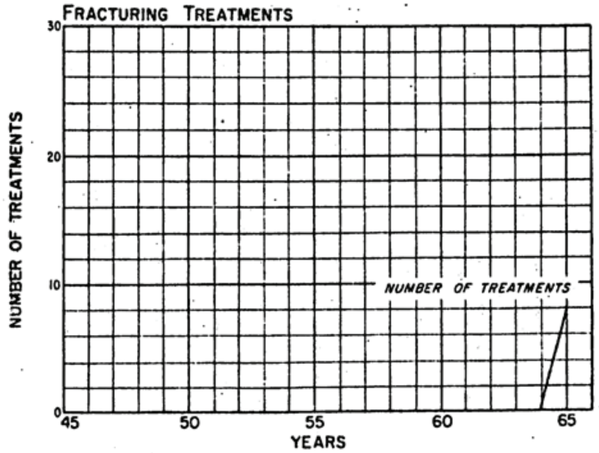
GAS LIQUIDS



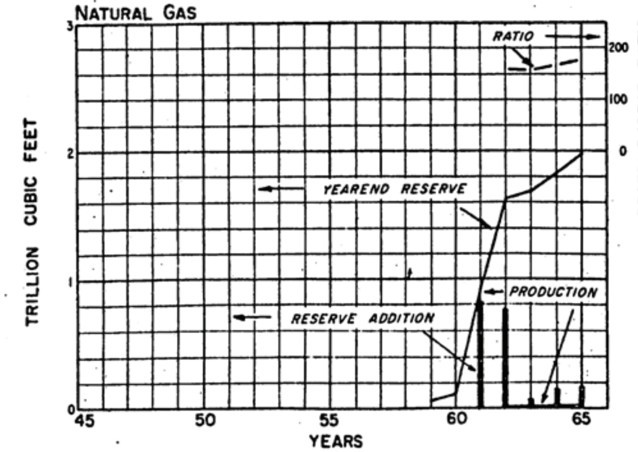
DEVELOPMENT WELLS



FRACTURING TREATMENTS



NATURAL GAS



ALASKA

CALIFORNIA

California entered the postwar year of 1945 with exploratory drilling and geophysical activity at a modest level. Prior to 1945, major reserves and production had been developed from structures readily susceptible to definition by surface geology, followed by the application of the reflection seismograph. Exploratory drilling was declining, while development of previous discoveries was continuing.

Industry expanded into new areas of geologic opportunity with a surge of seismic activity in 1947, followed by an increase in exploratory drilling in 1948. This expanded effort covered essentially the entire San Joaquin and Sacramento Basins, and continued through 1956. Diminishing opportunity and results brought about a decline in activity from 1956 to 1964.

The San Ardo oil discovery in 1947 in the Salinas Valley led to an abrupt surge in development drilling in 1948, and over 900 development wells were drilled in this area in a relatively brief period.

Discoveries of oil in the Cuyama Valley, starting in 1948, resulted primarily from surface and subsurface mapping. The Sacramento Basin gas play caused increased exploratory and development drilling from 1953 through 1957 and continued, after oil plays had declined, through 1961. Its impact is noticeable by the increased percentage of gas discoveries from 1957 to 1962.

The discovery of the Aspholta field in 1962 contributed to a resurgence in drilling in California. New geologic opportunity in the form of deeper pays and stratigraphic traps led to a spurt in exploratory drilling in 1964, and other plays, such as the Los Angeles Townlot and Offshore have been sporadically active since 1950. The adaptation of core drilling methods to offshore areas, the recognition of stratigraphic traps, and the evolution of nonexplosive seismic techniques have improved exploration technology in California. The advent of thermal recovery methods have also caused some exploratory drilling in the 1964-1965 period.

Recently several important offshore discoveries have been announced in the Los Angeles region and Santa Barbara-Ventura areas. The East Area of Wilmington, operated as the Long Beach Unit, is the largest offshore proven field. Production at the end of 1965 averaged 10,000 barrels per day from 18 wells, with an additional 6 wells injecting water. Drilling in 1965 was entirely from one drillsite, but three offshore inlands were under construction from which drilling commenced in 1966.

Offshore discoveries and thermal recovery methods were primarily responsible for substantial net reserve additions in 1964 and 1965, raising the total to 4.6 billion as of December 31, 1965. Crude production averaged 868,000 barrels per day in 1965 and will average some 935,000 barrels per day in 1966.

Production from fluid injection projects averaged 423,000 barrels per day in 1965, which was nearly 50 percent of the state total. A number of gas and water injection projects were suspended in 1964 and 1965 in order to initiate thermal recovery techniques.

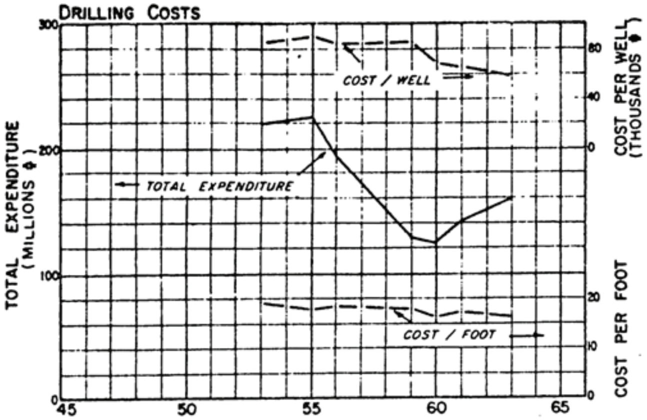
For many years various stimulation methods have been employed to increase recoveries from heavy oil reservoirs in California. Methods included downhole heaters, circulation of distillates, chemical treatments, and washing and packing systems, but none were very successful and did not develop into widespread use.

Experimental steam or hot water injection and in-situ combustion projects had been operating prior to 1964. Technological improvements, particularly with respect to steam injection, resulted in the rapid expansion of this method in 1964. The most common "huff-puff" process is to inject superheated steam for a number of days or weeks and then place wells back on production. Individual well production rates may be increased as much or more than tenfold and increases for large groups of wells of three to five times the prestimulation rate have been accomplished. The process may be repeated as many times as can be economically justified. Shallow "heavy oil" fields are the best prospects due to naturally high fluid viscosity and low primary recoveries.

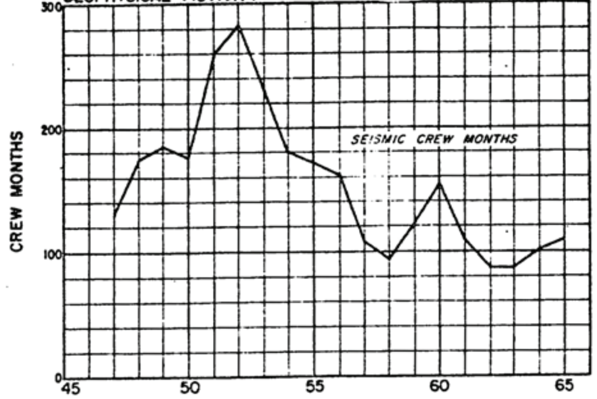
There were an estimated 280 steam projects in 38 fields affecting 4,900 wells at the end of 1965. The estimated production increase from the steam projects was 53,000 barrels per day in 1965, and 75,000 barrels per day more than the prestimulation rate. Also, 16 active in-situ combustion projects in ten fields contributed an estimated increase of 2,900 barrels per day.

Estimated gas reserves declined from 11 trillion in 1945 to 9 trillion in 1955, and have been maintained at this level through 1965. Production increases, however, have reduced the reserve-production ratio from 22 in 1945 to 13 in 1965.

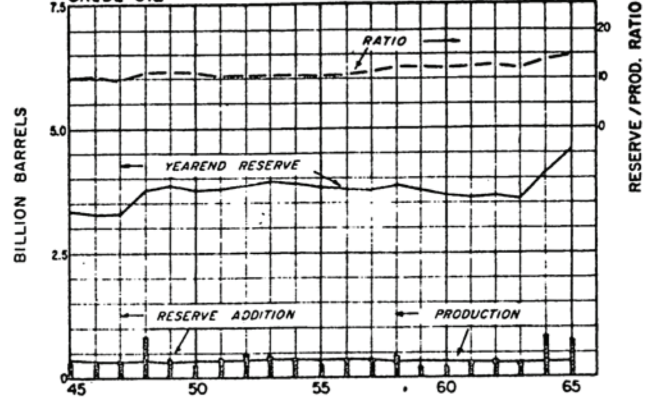
Drilling Costs



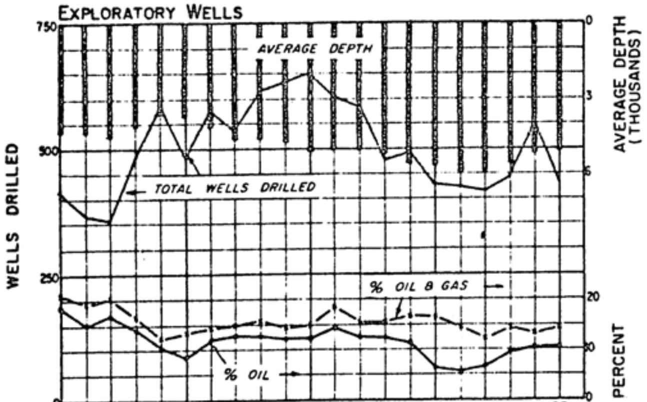
Geophysical Activity



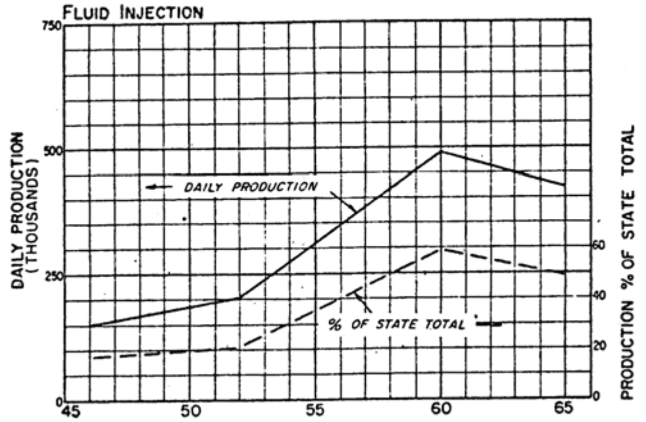
Crude Oil



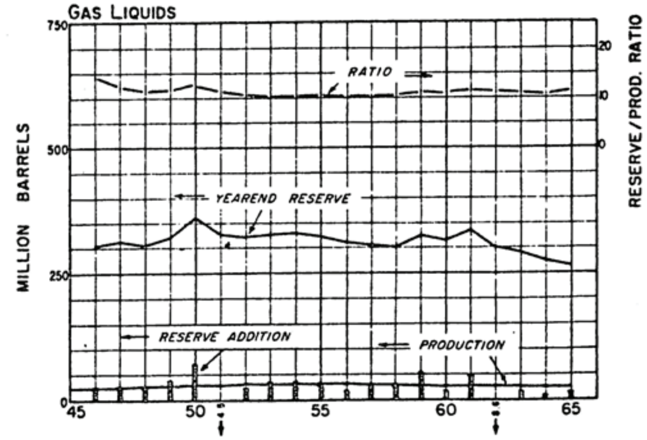
Exploratory Wells



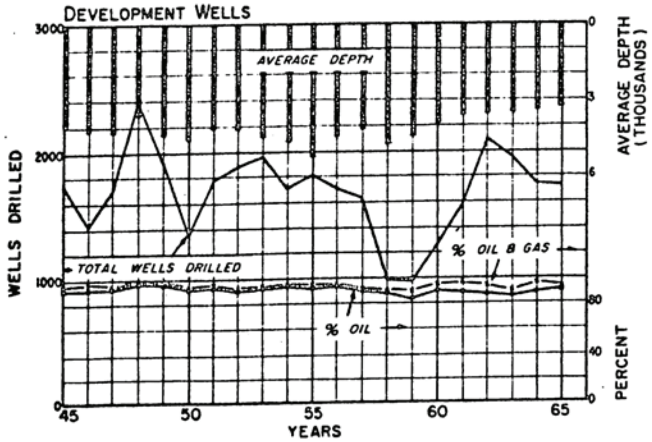
Fluid Injection



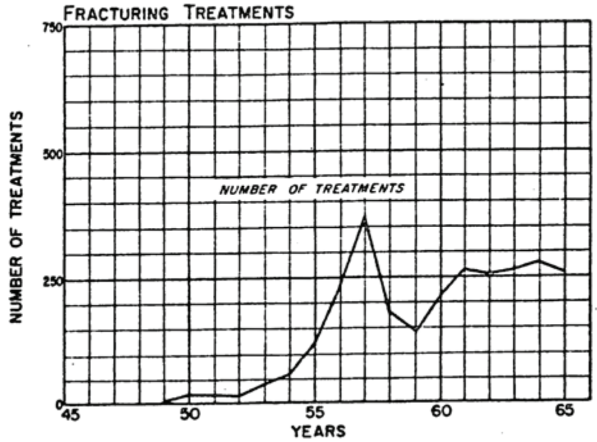
Gas Liquids



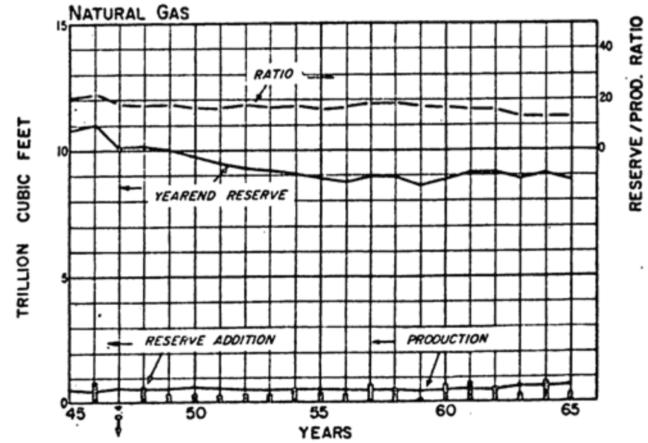
Development Wells



Fracturing Treatments



Natural Gas



CALIFORNIA

OREGON
WASHINGTON

A total of 51 exploratory wells were drilled in Oregon during the period 1945-65, and no commercial oil or gas production was discovered. Oregon remained a state with no oil production, although some interest offshore caused exploratory interest to remain alive.

A total of 100 exploratory wells were drilled in Washington during the period 1945-65 with the level of activity spread evenly over the period. Washington's first oil completion occurred in 1951, but the Miocene accumulation proved to be noncommercial. The first commercial oil production was discovered in 1957 at Ocean City in Grays Harbor County, but this one-well field was abandoned in 1960. At the end of 1965, Washington did not have any hydrocarbon production and exploration remained at a minimal level.

No plot of data for Oregon and Washington is included because of the limited amount of Exploration and Production activity.

P A R T III

REPORT OF THE TASK FORCE

ON

ECONOMIC AND POLICY FACTORS

TASK FORCE ON ECONOMIC AND POLICY FACTORS OF THE NATIONAL PETROLEUM COUNCIL'S COMMITTEE ON FACTORS AFFECTING U.S. EXPLORATION, DEVELOPMENT AND PRODUCTION, 1945 TO 1965

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Gulf Oil Corporation

Stark Fox
Executive Vice President
Independent Oil & Gas Producers of California

Fred L. Hartley, President
Union Oil Company of California

John G. Hurd
Laredo, Texas

Minor S. Jameson, Jr.
Executive Vice President
Independent Petroleum Association of America

Walter R. Koch, President
Texas Independent Producers and Royalty Owners Association

D. A. McGee, President
Kerr-McGee Corporation

C. S. Overmiller
Humble Oil & Refining Company

Ed Parkes, President
United Gas Corporation

John G. Winger
Vice President
The Chase Manhattan Bank

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P A R T III

REPORT OF THE TASK FORCE ON ECONOMIC AND POLICY FACTORS

A. I N T R O D U C T I O N

From the close of World War II to the mid-1950's, all phases of U. S. exploration, development and production activities expanded rapidly. Since the mid-1950's, there has been a slowdown in the growth in production; a moderate decline in total expenditures for exploration and development; and a substantial decline in the total number of exploratory and development wells drilled in the United States.

This report deals with economic and policy factors that contributed to changes in activities in the period 1945-1965. The report includes data on demand, supply, prices and costs, and exploration and development expenditures. Data on geophysical activity, drilling and reserves are included in Part II of the report.

The report covers a number of factors, most of which are interrelated. It is impractical, if not impossible, to isolate and measure separately the impact of each factor. Exploration, development and production activities reflect the combined influence of all factors: economic, policy, geological and technological.

The "petroleum industry's" activities are the cumulative result of investment and operating decisions, made independently by thousands of individuals, partnerships and corporations. The basic and controlling consideration in these decisions is the profitability outlook. As used in this report, profitability outlook, prospective profitability and similar terminology relate to a specific phase of the petroleum industry's activities: the outlook or prospects for profit from new investments in the exploration and development of domestic oil and gas reserves for future production. The significance of the following economic and policy factors lies in their overall effect on the prospects for profit from expenditures to find and develop new reserves - not in the profitability of producing reserves found and developed in the past.

B. ECONOMIC FACTORS

Changes in the rate of growth in demand, in the pattern of supplying demand, in the amount of unused producing capacity, in the relation of prices to costs, and in the structure of the industry were principal economic factors influencing U. S. petroleum activities in the period 1945-1965.

REQUIREMENTS

As shown in Chart A and Table I, the share of total energy needs supplied by oil and gas has increased as follows:

Participation of Petroleum in Total U. S. Energy Consumption

	Percent of Total			Change in Percentage Points	
	1945	1955	1965	1945-55	1955-65
Liquid Petroleum	32.0	43.8	43.0	+ 11.8	- 0.8
Natural Gas	12.6	23.1	30.3	+ 10.5	+ 7.2
Total	44.6	66.9	73.3	+ 22.3	+ 6.4

By 1955, oil and gas supplied about two-thirds of total U. S. energy consumption as compared with less than half in 1945. At the same time, the share of total energy supplied by coal declined steadily from about 50 percent in 1945 to less than 30 percent in 1955.

Chart B and Table II show the annual and five-year rates of change in the use of principal sources of energy, which may be summarized as follows:

	Percent Change in Consumption			
	1945-50	1950-55	1955-60	1960-65
Liquid Petroleum	+ 33.4	+ 29.9	+ 14.3	+ 17.0
Natural Gas	+ 54.8	+ 50.1	+ 38.0	+ 29.9
Total Petroleum	+ 39.5	+ 36.2	+ 22.5	+ 22.0
Coal	- 19.2	- 9.4	- 11.0	+ 19.0

It is apparent that a substantial portion of the growth in oil and gas consumption during the postwar decade can be attributed to supplying markets previously served by coal. Demands for both liquid petroleum and natural gas expanded more rapidly than total energy consumption.

During the next ten years, significant changes occurred in the relative position and rates of growth of both oil and gas consumption.

The share of total energy consumption supplied by liquid petroleum (see Chart A) reached a peak of 45.3 percent in 1959, followed by a slight but steady decline to 43.0 percent in 1965.

The share of energy consumption supplied by natural gas continued to increase, but the increases have been nominal since 1960. As a result of these nominal increases and the declining share supplied by liquid petroleum, total oil and gas consumption reached a peak of 74.1 percent of total U. S. energy requirements in 1962, declining to 73.3 percent by 1965.

Referring again to Chart B and Table II, the combined rate of growth in oil and gas consumption was reduced sharply after the mid-1950's. In contrast to the previous five-year growths of 35 to 40 percent in total oil and gas consumption, the increases were 22.5 percent from 1955 to 1960 and 22.0 percent from 1960 to 1965. During the latter five-year period, the percentage growth in total oil and gas consumption (22.0 percent) has been approximately the same as the growth in total U. S. energy consumption (21.6 percent) Coal consumption, which had continued to decline by 11.0 percent from 1955 to 1960, increased from 1960 to 1965 by 19.0 percent.

Reflecting these changes, the rate of growth in total U. S. domestic and export demand for liquid petroleum (see Chart C and Table III) was reduced from 5.2 percent compounded annually in the postwar decade to 2.7 percent per year in the past ten years. The principal factor was a reduction in the rate of growth in gasoline consumption which declined from 6.5 percent compounded annually during the 1945-1955 period to 2.8 percent per year in the 1955-1965 period. In addition, however, it is significant that the growth in consumption of distillate fuel oils, a portion of which is in direct competition with natural gas, declined from a rate of 9.9 percent yearly in the first period to 2.9 percent annually in the second period, indicating the impact of natural gas on the markets for liquid petroleum.

The rate of growth for natural gas slackened during the second decade, but continued to outpace the growth rates for both liquid petroleum and total energy. Gas consumption increased by 6.0 percent per year in the past ten years as compared with 8.8 percent per year during the postwar decade.

The changes in the relative rates of growth in oil and gas consmuption constituted one of several economic factors affecting U. S. exploration, development and production activities. As previously noted, the impact of a single factor cannot be isolated and measured separately from other factors. Therefore, the overall effect of requirements, together with other economic factors, on industry investments and operations is summarized in a later section of this report.

SUPPLY

The changing pattern of U. S. petroleum supply, as shown in Chart D and Tables III, IV and V, may be summarized as follows:

Petroleum Supply - Thousand Barrels Daily

	Supply			Change	
	1945	1955	1965	1945 to 1955	1955 to 1965
U. S. Production					
Crude Oil	4,695	6,807	7,804	+ 2,112	+ 997
Natural Gas Liquids	315	772	1,210	+ 457	+ 438
Total	5,010	7,579	9,014	+ 2,569	+1,435
Imports					
Residual Fuel	86	416	944	+ 330	+ 528
Crude Oil & Other	225	832	1,523	+ 607	+ 691
Total	301	1,248	2,467	+ 937	+1,219
Total Liquid Supply	5,321	8,827	11,481	+ 3,506	+2,654
Natural Gas Production*	1,977	4,601	8,039	+ 2,624	+3,438

* Crude oil equivalent on a BTU basis.

After 1948, crude oil productive capacity increased more than production. Until the last few years, there was an increasing degree of proration, with allowables progressively reduced in states which take market demand into consideration under their conservation laws and regulations. Estimates of productive capacity, which have been prepared at various times since 1951 by committees of the National Petroleum Council, are compared with production in Chart E and Table VII. Estimates by other groups are lower, but all estimates indicate that capacity increased faster than production from 1948 to 1965 and, as shown in Part I, faster than proved reserves.

At the same time, capacity in foreign areas (particularly the Middle East) also increased rapidly. The cost of these foreign supplies was generally low relative to U. S. costs. The availability of these relatively low-cost supplies brought about increasing U. S. imports. As shown in Chart F and Table IV, the United States changed from a net exporter of crude oil and refined products of 190,000 barrels daily in 1945, to a net importer of 880,000 barrels daily in 1955.

As a result of the expansion of productive capacity more rapidly than required to meet demand, and the change from a net exporter to a substantial net importer, unused crude oil capacity in the United States increased steadily from 1948 to 1965.

The reduced rates of growth in oil consumption since the mid-1950's compounded the effects on U. S. crude oil production of the following factors:

(a) Continuing increases in production of natural gas and natural gas liquids, a substantial part of which supplied markets that otherwise would have been served by crude oil. Gas and gas liquids production accounted for almost 80 percent of the gain in total U. S. oil and gas production during the latest ten years, as compared with less than 60 percent in the previous decade.

(b) Continuing increases in imports, with net imports increasing from 880,000 barrels daily in 1955, to about 2,300,000 barrels daily in 1965.

(c) Continuing advances in refining technology which, by steadily reducing the yield of residual fuel oil and increasing the total quantity of products derived from each barrel of crude oil, resulted in the growth of demand for petroleum products being satisfied by a lower rate of growth in crude oil refinery runs.

While these factors affected crude oil production throughout the period from 1945 through 1965, their impacts were magnified under conditions of slackening rates of growth in oil consumption. As a result, the increase in production from 1955 to 1965, was less than half the increase during the preceding decade.

PRICES AND COSTS

Under World War II price controls, oil prices were not permitted to reflect the economic forces if increasing demands and declining unused productive capacity. In the immediate postwar years, the full capacity of U. S. producing areas was required to meet rapidly increasing demands for petroleum products. Crude oil prices, which had been artificially restrained under wartime controls, responded to this supply-demand relationship, as shown in Chart G and Table VIII.

Well-head prices for crude oil during the period under study have averaged as follows:

Average Crude Oil Price

	Current Dollars (Per Bbl)	Constant 1965 Dollars (Per Bbl)
1946 - 50	$2.20	$2.92
1951 - 55	2.66	3.00
1956 - 60	2.93	3.02
1961 - 65	2.88	2.92

Crude oil prices, which had increased from the close of World War II through the mid-1950's, leveled off and experienced a moderate downward trend during the later years of the period under study, reflecting the changing conditions in the market for crude oil.

As shown in a previous section of this report, natural gas became one of the principal sources of energy during the years following World War II, serving new and greatly expanded markets through the large growth in interstate pipeline systems. Previously, gas was in excess supply, sold in limited markets as a by-product of crude oil. When conditions changed following World War II, gas prices increased steadily in response to economic forces, leveling off during the early 1960's, reflecting the changing market conditions and the influence of Federal regulation of producers' field prices.

Hourly wages and prices for principal materials such as oil field machinery and tubular goods, have increased steadily since the mid-1950's, (see Table IX). Offsetting factors include reductions in the number of employees, improved technology and declining contract footage rates, (see Tables X and XI). The net effect on unit costs cannot be determined, but available information and industry experience in the increasing costs of lease acquisitions, and the growing practice of purchasing proved reserves, leave little doubt that the unit cost of finding new U. S. supplies has been increasing at a time when crude oil prices have leveled off and declined somewhat. In this connection, changes in price have a proportionately greater effect on net income and the funds available for exploration and development expenditures than on gross revenue.

EXPLORATION AND DEVELOPMENT EXPENDITURES

As in the case of other business investments, prospective profitability is the basic economic consideration affecting petroleum exploration and development, taking into account the availability of funds and alternate investment opportunities. Generally, the funds are derived from two sources: capital generated internally by the operations of the industry and capital supplied from outside sources. The incentive to expend funds on exploration and development is difficult to measure, but the changes in incentives are reflected in changes in the relationship between these expenditures and the well-head value of oil and gas to producers, (see Chart H and Table XII).

According to the Joint Association Surveys, estimated U. S. exploration and development expenditures increased from 50 percent of the well-head value of oil and gas to producers in 1948 to about 65 percent in 1955-1956 and declined to an average of about 50 percent in the years 1961-1963.

During the postwar decade, total revenue from oil and gas production, as measured by well-head value, increased by 12.8 percent per year while exploration and development expenditures were increasing by 13.3 percent per year, according to the data in Table XVI. Since 1955, revenue has continued to grow, but at the reduced rate of 3.2 percent per year. Exploration and development expenditures, however, have declined by 1.1 percent per year. Even if the ratio of exploration and development expenditures to total well-head value had not declined, these expenditures would have increased by only 3.2 percent per year in contrast to the 13.3 percent per year expansion in the previous decade.

These trends point to a declining incentive since the mid-1950's, to invest funds in U. S. petroleum exploration and development.

STRUCTURE OF THE INDUSTRY

The declining incentive for investments in U. S. exploration and development since the mid-1950's has been accompanied by a large number of mergers and sell-outs of properties, individual operations and companies. Economic advantages of liquidation vs. continued operations, and economies of large-scale or integrated operations, have contributed to these developments.

Only limited data are available to quantify this changing structure of the industry. One illustration is the large increase in auction sales of drilling rigs beginning in 1960, as shown in Table XIII, reflecting the decrease in the number and activities of drilling contractors.

Although complete figures covering the number of independent producers and the character of their exploration and development operations are not available, their changing role is illustrated in Chart I and Tables XIV, XV, and XVI.

Overall trends in production, income and expenditures by all the smaller units in the industry are indicated by deducting composite production figures for a group of larger companies covered by the reports of the Chase Manhattan Bank from total figures for the United States. It should be noted that the data for both the "Chase Bank Group" of companies* and for the "All Other" group are gross production figures that include royalty interests. They do not, therefore, measure the company-interest or operator-interest production for either group.

---

* Table XIV shows the companies covered by the reports of the Chase Manhattan Bank and the changes in the group during the period under study.

From 1948, the first year for which comparable figures are available, through 1956, gross U. S. production of crude oil by the "Chase Bank Group" of companies increased by 934,000 barrels daily, or 27 percent. Gross production by the "All Other" group that includes independent producers increased by about 700,000 barrels daily, or 34 percent.

Production by the "All Other" group reached a peak in 1956, also the peak year for total U. S. exploration and development expenditures and drilling activity. By 1965, production by the "All Other" group had declined by 210,000 barrels daily, or 7.7 percent.

The increase in crude oil production of 863,000 barrels daily by the "Chase Bank" group of companies from 1956 to 1965, therefore, accounted for all the increase in the U. S. production and well-head value of crude oil during these ten years. This reflects both acquisitions from the "All Other" group and increased activities in areas involving large capital requirements, such as the U. S. Outer Continental Shelf where the increase in crude oil production accounted for over half of the total increase in U. S. production during the past decade.

As shown in Table XVI and Chart I, estimated U. S. expenditures for exploration and development increased rapidly from 1946 through the mid-1950's, both by the "Chase Bank Group" of companies and by the "All Other" group. From 1955 to 1965, however, expenditures by the "Chase Bank Group" increased by $464 million, or about 20 percent, while estimated expenditures by the "All Other" group declined by more than $900 million, or about 40 percent.

The ratios of U. S. estimated exploration and development expenditures to well-head value of oil and gas production for the "Chase Bank Group" of companies and for the "All Other" group are shown in Table XVI and pictured in Chart I.

The average ratio for the "Chase Bank Group" increased from 47.7 percent during the years 1946-1950 to 56.7 percent in the period 1951-1955, declining to an average of 54.9 percent for the years 1956-1960 and 51.3 percent for the latest five-year period 1961-1965.

In contrast, the average ratio for the "All Other" group increased from 63.2 percent during the years 1946-1950 to 79.6 percent in the period 1951-1955. The ratio dropped sharply after 1956 to an average of 45.3 percent in the latest five-year period 1961-1965; less than the ratio for the "Chase Bank Group" of companies.

The relatively high expenditure ratios for the "All Other" group through the mid-1950's (in excess of 80 percent for the years 1952-1956) indicate that the prospects for profit not only encouraged independent producers to reinvest most of their cash flow, but also attracted substantial amounts of capital from outside sources into these operations. Thereafter, the incentives for this group to invest funds and attract outside capital decreased, as the profitability outlook for new investments in exploration and development became relatively less favorable. Some funds not so invested have gone into a wide range of alternate investments.

In summary, the relative position of the smaller industry units, as a group, in U. S. exploration, development and production activities has declined steadily since the mid-1950's. This group, consisting of independent producers and drilling contractors, historically has played an important role in the discovery of oil and gas. The multiplicity of effort in searching for new deposits has thereby been reduced as the incentives and economic opportunities have decreased, although there are still thousands of smaller operators as well as scores of larger companies engaged in drilling and production.

SUMMARY OF ECONOMIC FACTORS

It has been stressed that the significance of the foregoing economic factors, in relation to U. S. exploration and development, lies in their overall effect on the prospects and incentives for profitable investments and operations.

From World War II through the mid-1950's, both oil and gas consumption increased more rapidly than total U. S. energy requirements. This relatively high rate of growth for oil and gas at increasing prices provided an economic climate in which the incentives for petroleum investments were attractive and the prospects for profitable operations were favorable.

Under these circumstances, all phases of U. S. exploration, development and production activities expanded rapidly. Expenditures for U. S. exploration and development rose at a rate more than double the rate of growth in U. S. consumption of petroleum products. Both domestic crude oil productive capacity and imports of relatively low cost foreign supplies increased more rapidly than U. S. consumption. As a result, unused productive capacity accumulated steadily.

To a lesser and lesser extent, oil and gas supplied markets previously served by coal. The growth rate for natural gas was lowered, but gas continued to take markets that otherwise would be supplied by oil. The rate of growth in oil consumption, as compared with the postwar decade, was cut in half.

The lower rates of growth in consumption compounded the effects on crude oil production of increasing imports and more efficient refining technology. As a result, the increase in crude oil production since 1955, was less than half the increase during the preceding ten years.

Prices reflected these changes in requirement and supply relationships, with crude oil prices declining moderately, after levelling off in the mid-1950's. Natural gas prices leveled off in the early 1960's.

Summarizing the effects of economic factors since the mid-1950's, incentives and prospective profitability for new investments in U. S. exploration and development were reduced, due in large part, to the cumulative impact of sharply reduced rates of expansion in oil consumption, rising imports, increasing unused U. S. crude oil productive capacity, and a substantially lower growth in the market for domestic crude oil at less attractive prices. Under these conditions, total exploration and development expenditures declined, both in absolute terms and in relation to total U. S. production revenues as measured by the well-head value for oil and gas. Although total expenditures declined, exploration and development increased in some areas, particularly in areas involving large capital requirements and high costs per well, such as the U. S. Outer Continental Shelf. In other areas with lower costs per well, and for smaller operators whose resources limit their ability to risk large amounts of capital, the reductions in economic opportunities and the decreases in exploration and development expenditures and activities were substantially larger than indicated by the overall figures for the United States.

C. RECENT ECONOMIC CONDITIONS

During 1965 and 1966, there have been several changes in conditions relating to economic factors affecting U. S. exploration, development and production.

The growth in total U. S. petroleum demand, which had declined from a rate of 5.2 percent compounded annually in the postwar decade to 2.7 percent during the past ten years, recoverd to a rate of 4.3 percent in 1965, and 5.0 percent for the first nine months of 1966.

U. S. production of petroleum liquids, which had increased by an average of less than 150,000 barrels per day per year during the ten years 1955-1965, increased by about 250,000 barrels daily in 1965, and by even more in 1966. Unused capacity now exists only in a few areas, primarily Louisiana and Texas, and in these areas allowables were increased substantially in 1966.

U. S. crude oil prices, which had been declining, increased by an average of about two cents per barrel since the latter part of 1965, with the areas affected by the changes increasing by about seven cents per barrel.

It is not yet clear whether, when or to what extent the changes in conditions cited above will affect U. S. exploration and development. Drilling activity has continued to decline, with total well completions during 1966 about 13 percent less than during 1965.

D. POLICY FACTORS

Many policies of the State and Federal Governments affect petroleum exploration, development and production. This analysis is limited to significant changes in policy. Basic petroleum policies that did not change, such as percentage depletion and related provisions of the Federal income tax laws, are discussed only if their effects on exploration, development and production have changed materially.

STATE POLICIES

Changes in state conservation laws and regulations had little measurable impact on the overall expansion in U. S.

exploration, development and production activities during the period from World War II to the mid-1950's. In some states, where the primary standard for determining allowables was on a per-well basis, the drilling of development wells increased to obtain additional production.

Since the mid-1950's, and particularly in more recent years, changes in state laws and regulations have resulted in more efficient development and more economic recovery with fewer wells by policies of wider spacing and unitization. Increased discovery allowables have been put into effect in several states, but these changes have been too recent generally to evaluate their effects.

FEDERAL LEASING POLICIES

Federal leasing policies have affected exploration and development on the Outer Continental Shelf where substantial reserves and productive capacity have been developed during the past ten years. Leasing costs involved unusually large expenditures in 1962, that possibly affected exploration and development expenditures in other areas of the United States.

For other Federal lands, changes were made in 1946, in the Mineral Leasing Act to provide a flat 12½ percent royalty on wildcat acreage and to double the acreage that could be held in each state. This change was one of the contributing factors in the large expansion of leasing, particularly in the Rocky Mountain area. In 1960, the Act was changed again. Yearly lease rentals were raised, which contributed to a decrease in leased acreage since 1960 of more than 45,000,000 acres, or 40 percent.

FEDERAL REGULATION OF NATURAL GAS PRICES

Direct Federal regulation of producers' field prices of natural gas resulted from a 1954 Supreme Court decision. By their very nature, Federal Government limitations on field prices for natural gas adversely affect industry activities, although these effects cannot be measured separately from the impact of other factors. Price ceilings have been imposed, prices have been reduced, and investment decisions have been clouded with uncertainty as to the effects of future actions and policies as to gas prices.

FEDERAL LIMITATIONS ON OIL IMPORTS

Government limitations on oil imports were imposed on a voluntary basis in mid-1957, and on a mandatory basis early in 1959, with the following stated purpose and justification:

> "The new program is designed to insure a stable, healthy industry in the United States capable of exploring for and developing new hemisphere reserves to replace those being depleted. The basis of the new program, like that for the voluntary program, is the certified requirements of our national security which make it necessary that we preserve to the greatest extent possible a vigorous, healthy petroleum industry in the United States."

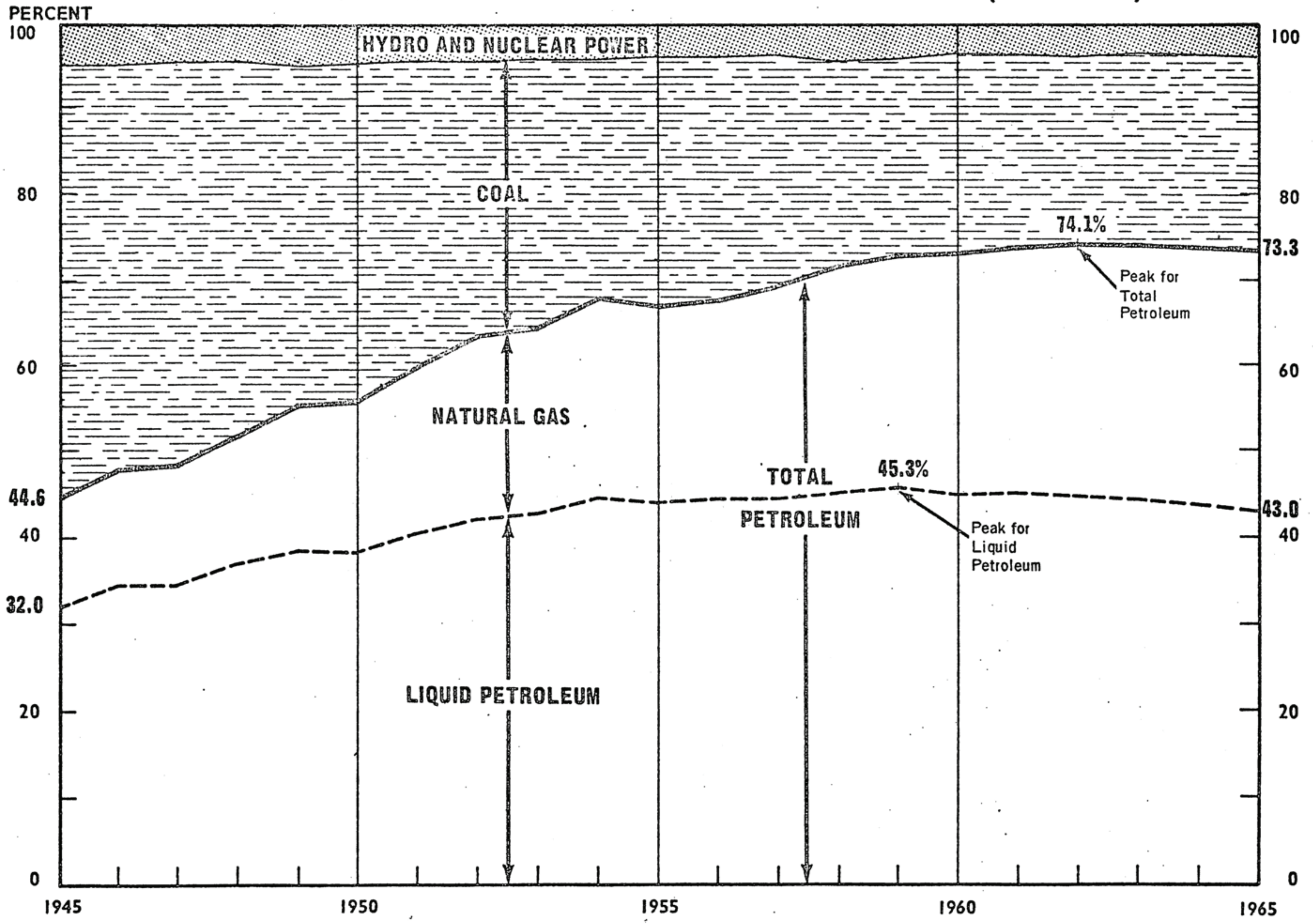
From 1959 to 1965, under the Mandatory Oil Import Program, nonresidual imports increased by 151,000 barrels daily, or 16.6 percent, in Districts I-IV; by 202,000 barrels daily, or 78.3 percent, in District V; and by 353,000 barrels daily, or 30.2 percent, for the United States as a whole. Imports of residual fuel oil increased by 334,000 barrels daily, or 54.8 percent. These import figures are on a Bureau of Mines basis, as shown in Tables III and IV, and differ somewhat from the data on imports released by the Oil Import Administration which, for example, do not cover bonded imports.

In comparison with these changes in imports, domestic production of crude oil and natural gas liquids increased by 1,044,000 barrels daily, or 14.9 percent, in Districts I-IV; District V production increased by 37,000 barrels daily, or 4.0 percent; total U. S. production increased by 1,081,000 barrels daily, or 13.6 percent.

The increase in residual fuel imports has approximated the reduction in domestic production of this product. Nonresidual imports in Districts I-IV have been relatively stable both in relation to total supply as shown in Table V and in relation to domestic production in these Districts. District V imports have been adjusted on the basis of the difference between demand in that District and domestic supplies used in the District.

Evaluation of the Mandatory Oil Import Program in relation to its stated objectives in not within the scope of this report.

PERCENT OF TOTAL U.S. ENERGY CONSUMPTION (1945-1965)

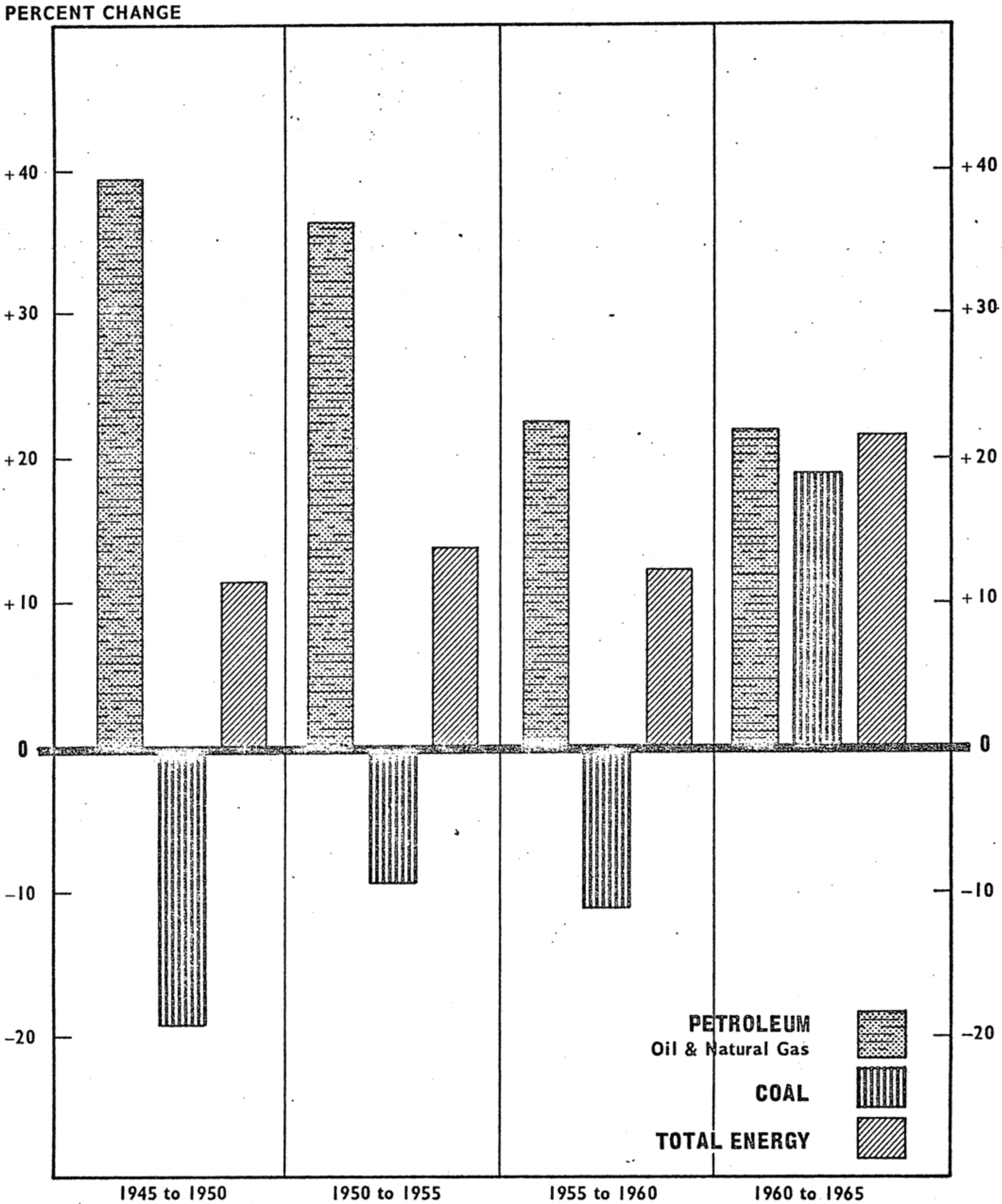


SOURCE: See Table I

Chart

Chart B

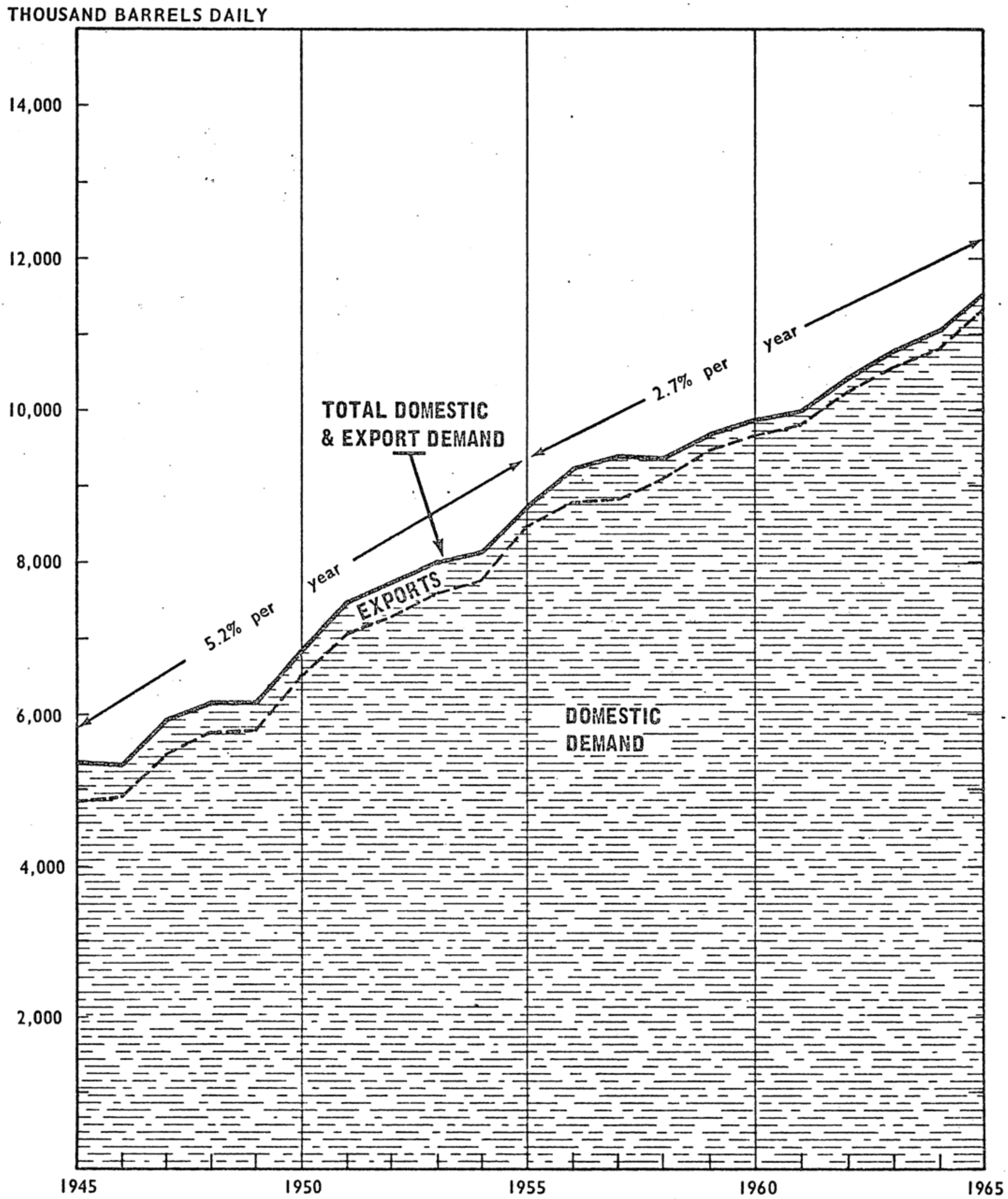
CHANGES IN U.S. ENERGY CONSUMPTION



SOURCE: See Table II

Chart C

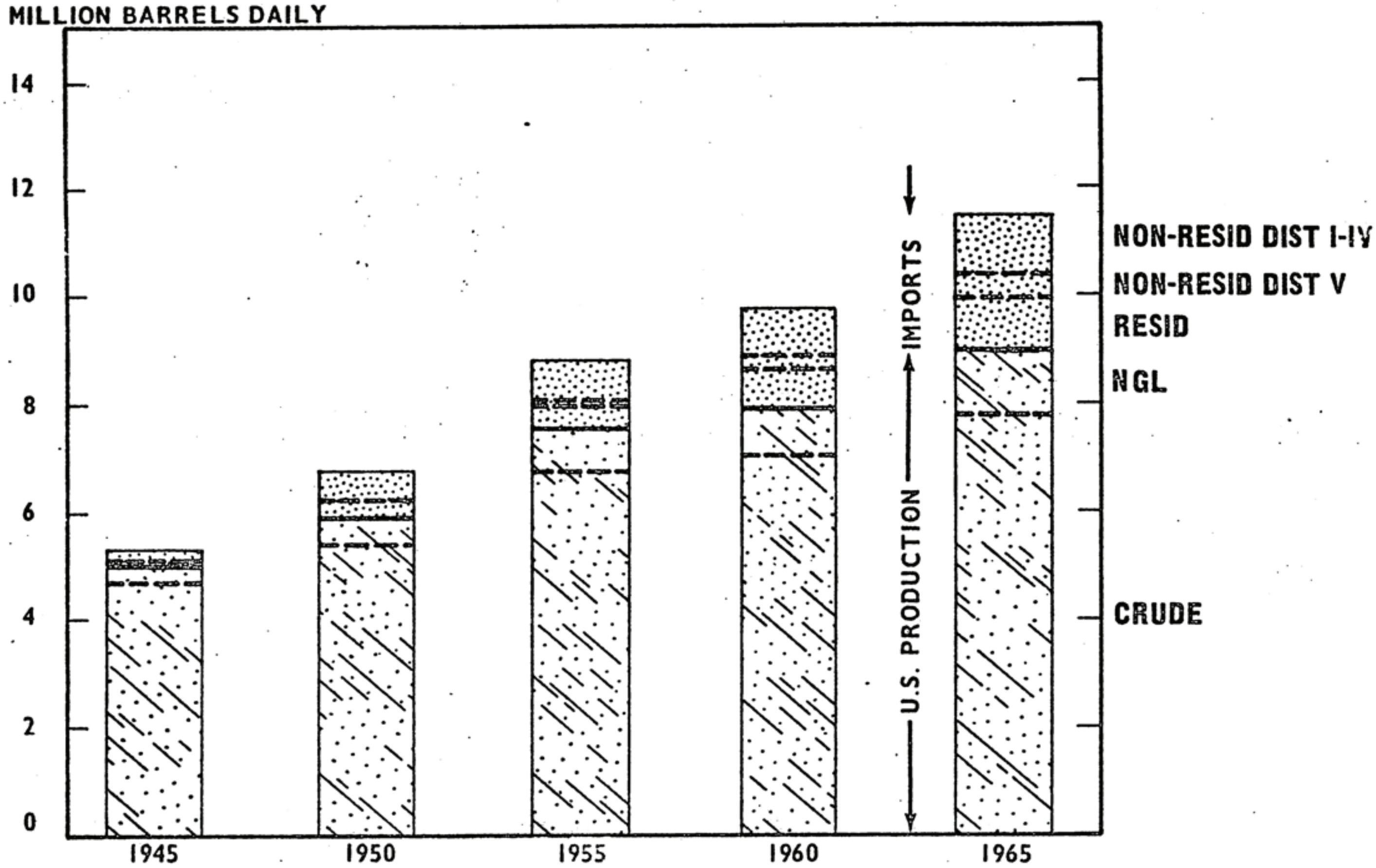
U.S. PETROLEUM DEMAND (1945-1965)



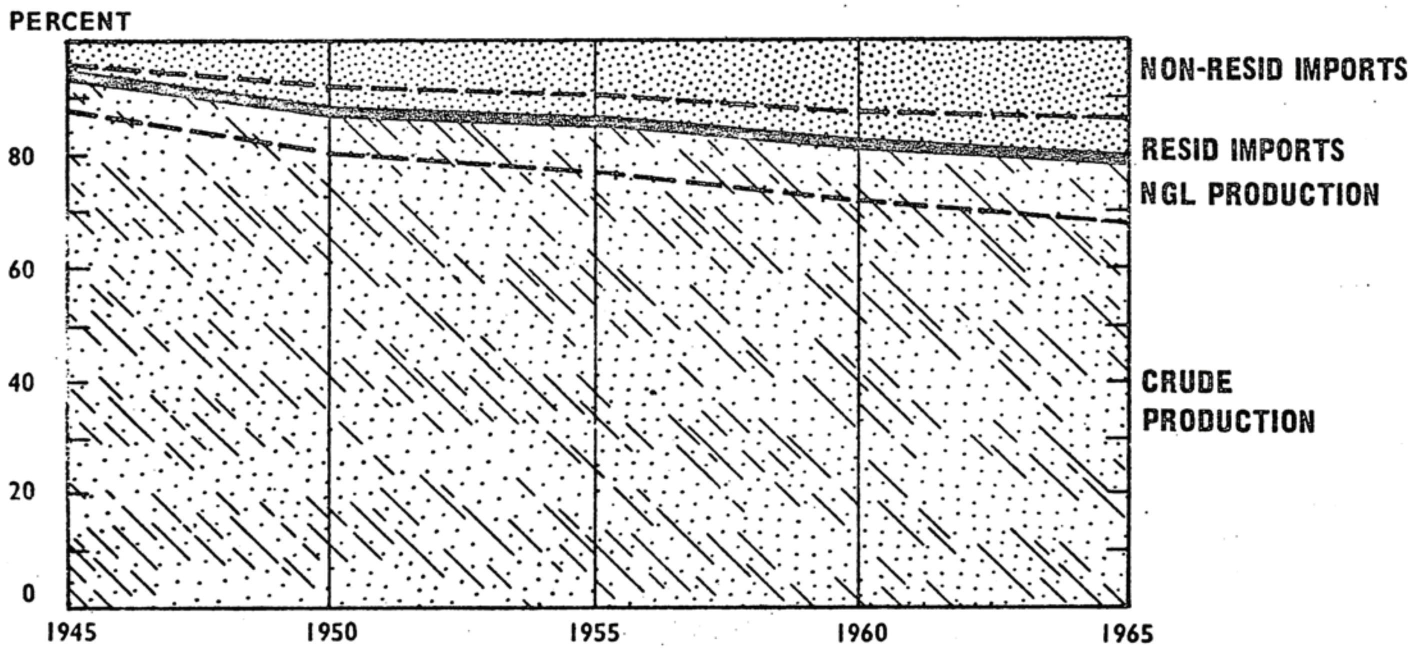
SOURCE: See Table III

Chart D

U.S. PETROLEUM SUPPLY (1945-1965)



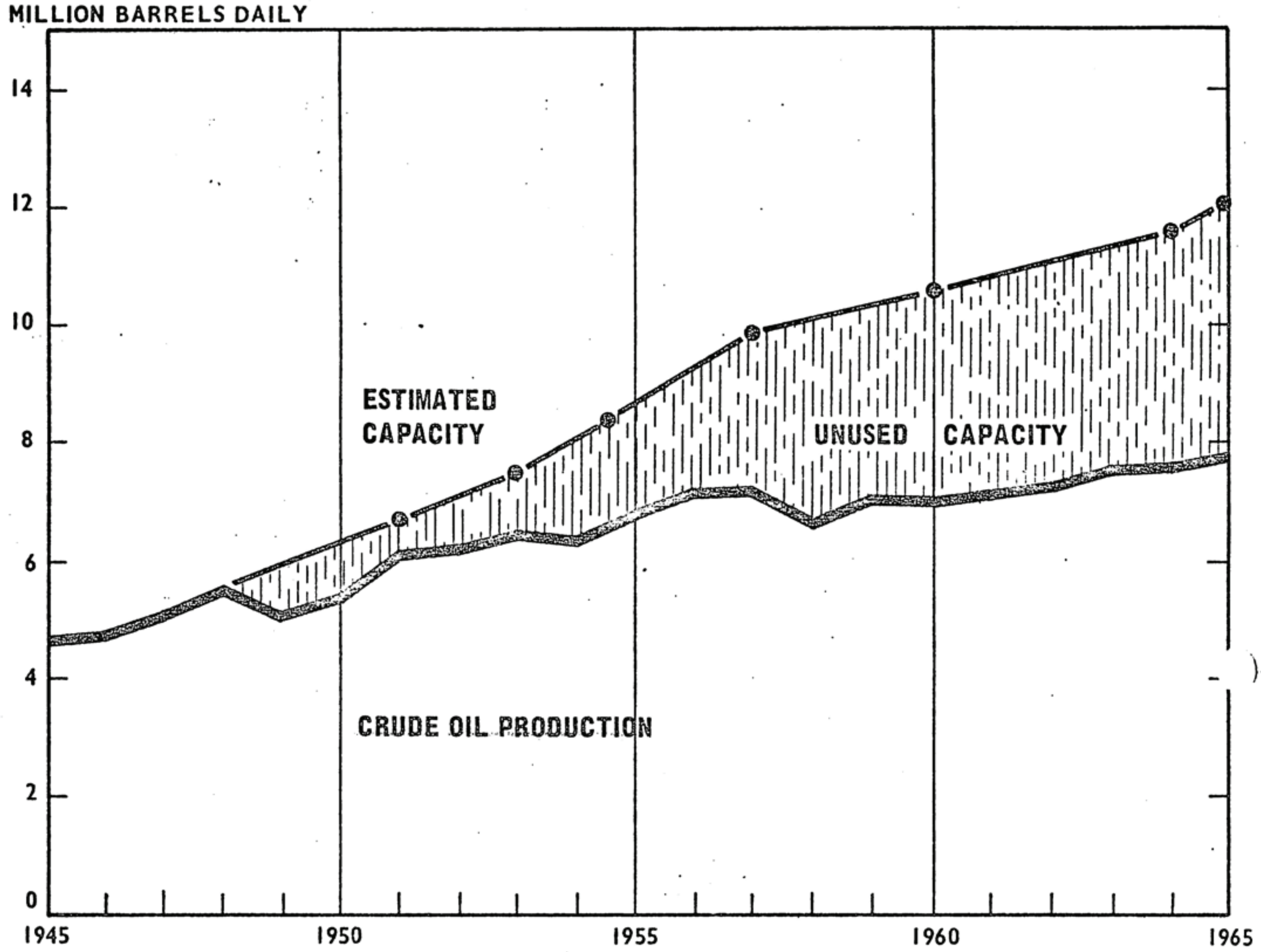
PERCENT OF TOTAL



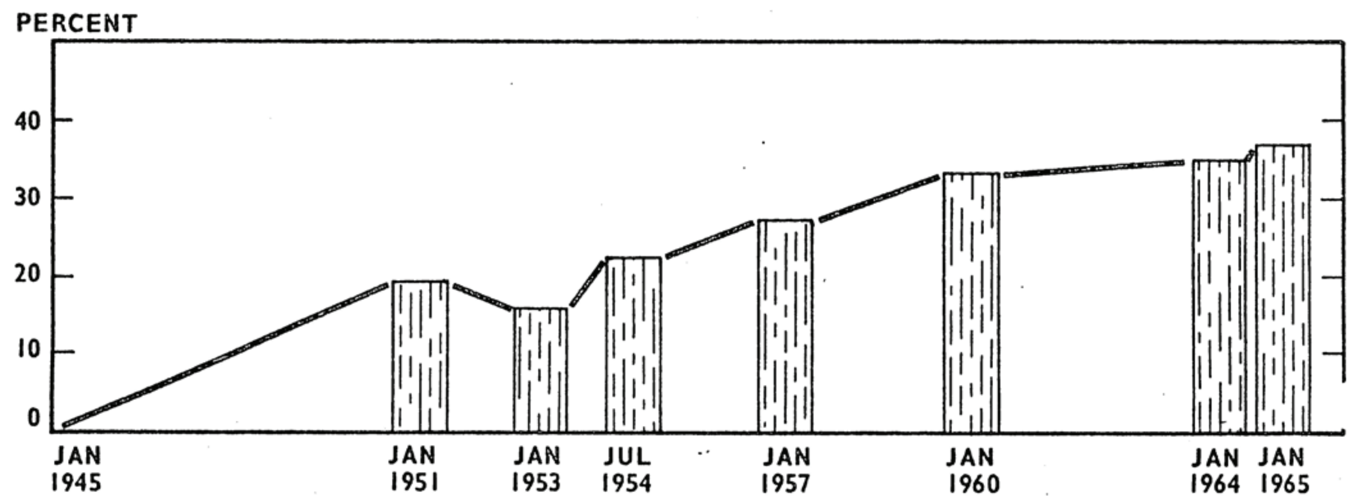
SOURCE: See Tables III, IV and V

Chart E

U.S. CRUDE OIL PRODUCTIVE CAPACITY AND PRODUCTION (1945-1965)



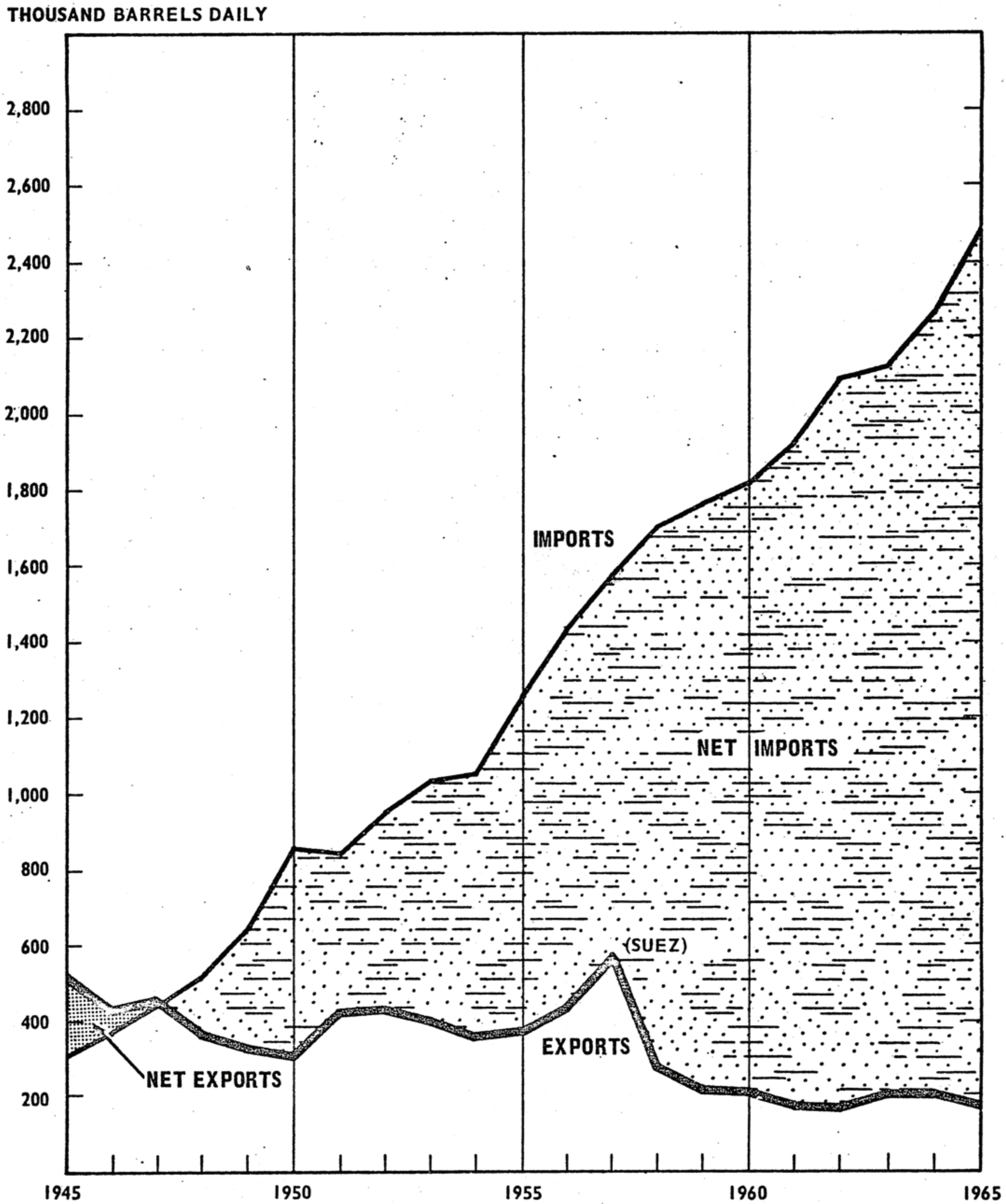
PERCENT OF CAPACITY NOT USED



SOURCE: See Table VII

Chart F

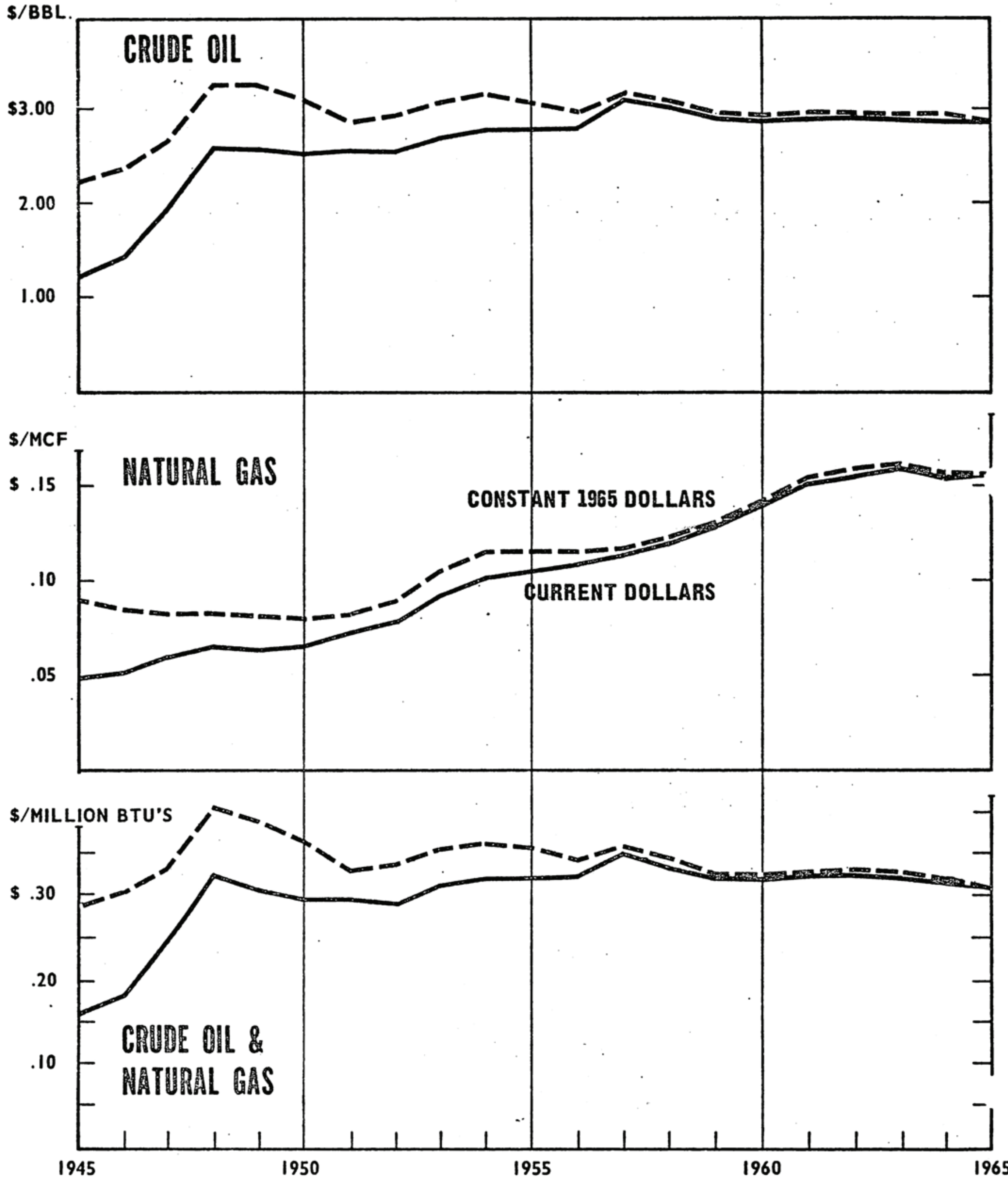
U.S. PETROLEUM EXPORTS AND IMPORTS (1945-1965)



SOURCE: See Table IV

Chart

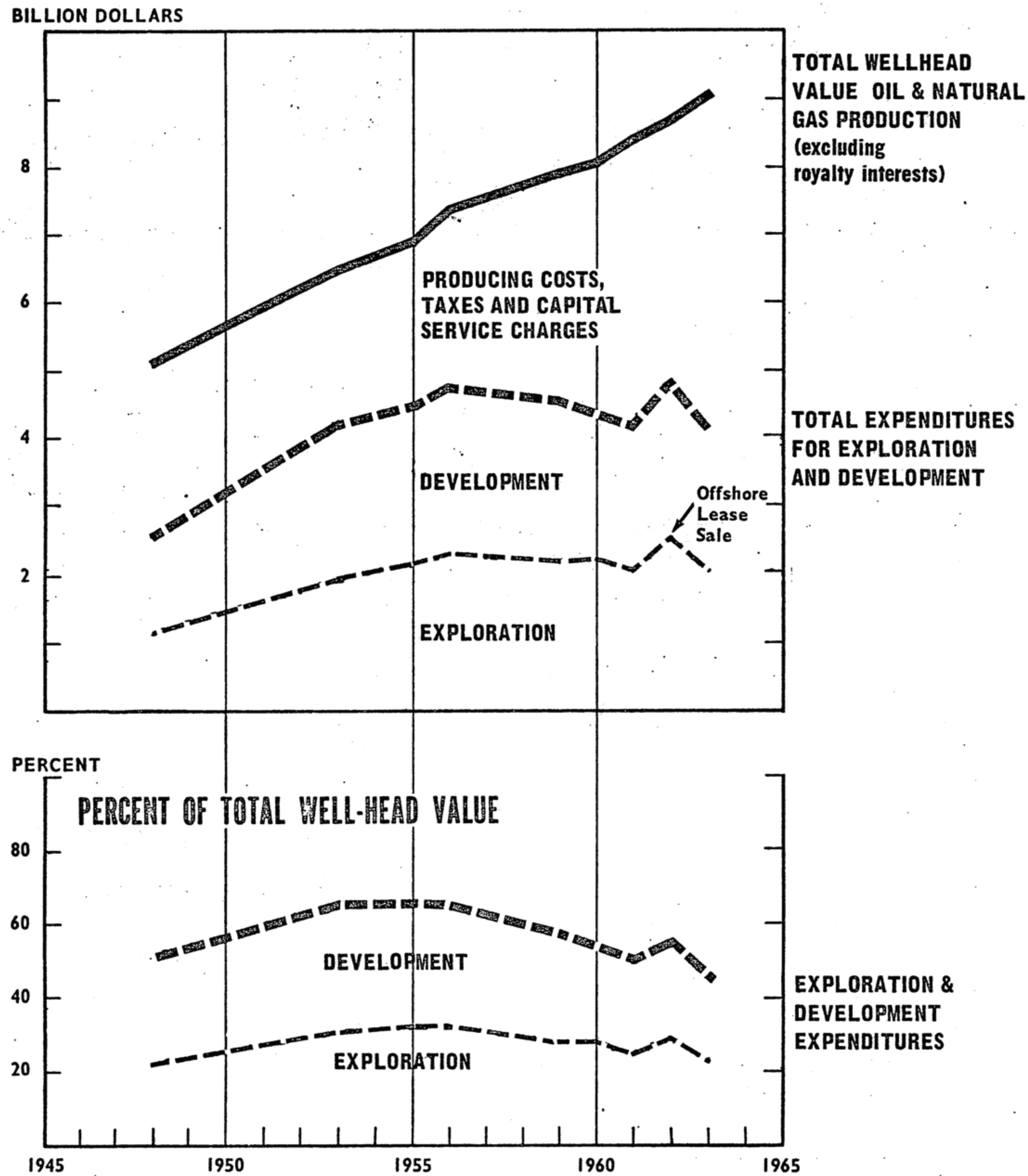
U.S. PRICES FOR CRUDE OIL AND NATURAL GAS (1945-1965)



SOURCE: See Table VIII

Chart H

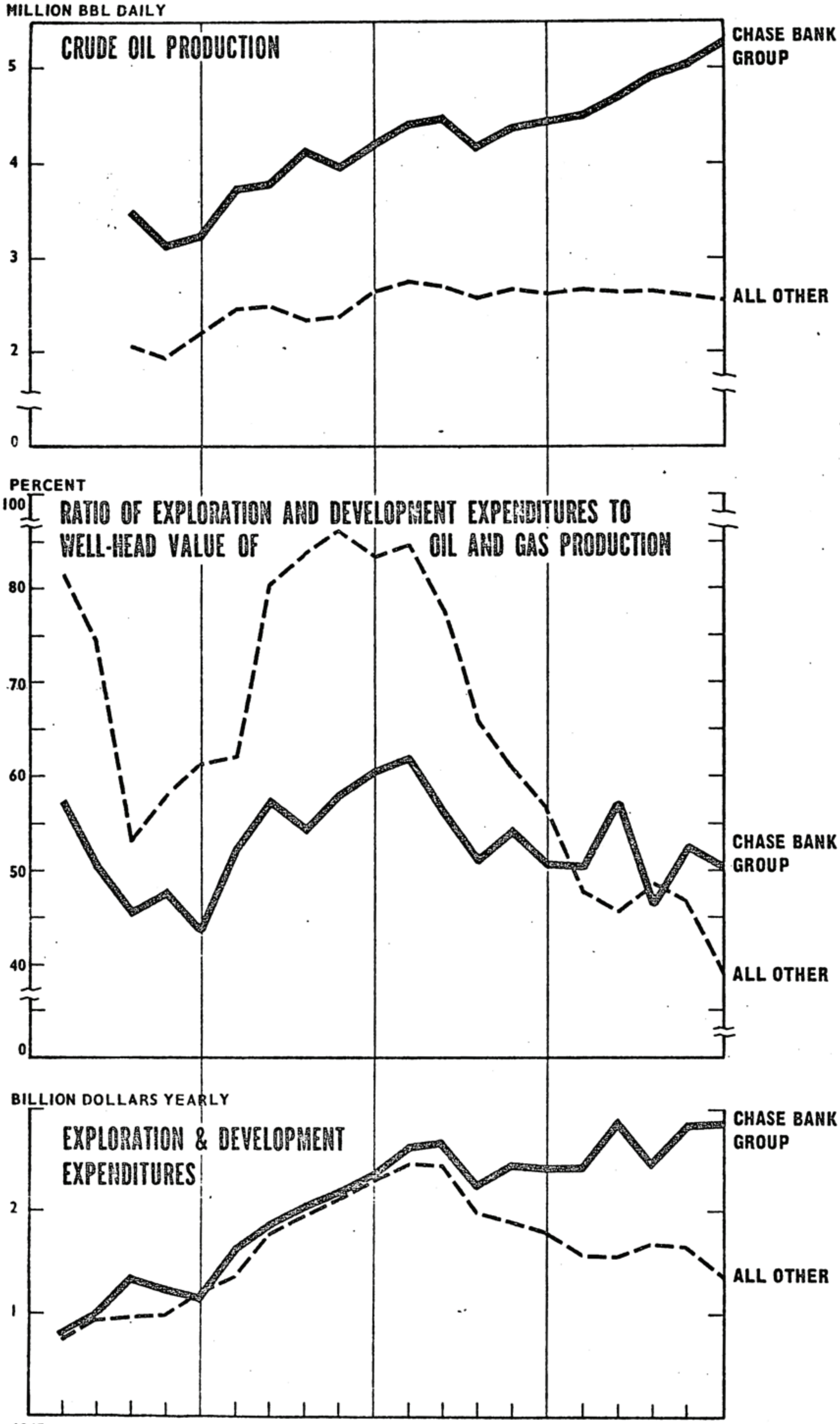
WELL-HEAD VALUE OF U.S. OIL & GAS PRODUCTION AND EXPENDITURES FOR EXPLORATION & DEVELOPMENT



SOURCE: See Table XII

Chart I

For "Chase Bank Group" of Companies and "All Other" Group (1945-1965)



SOURCE: See Tables XIV, XV, XVI

TABLE I

U. S. ENERGY CONSUMPTION
1945-1965

(Energy Consumption in Trillions of BTU's)

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
Crude Oil	9,619	9,987	10,803	11,938	11,459	12,706	13,974	14,380	15,092	15,090	16,328
Natural Gas Liquids	491	493	564	619	660	783	874	954	1,006	1,042	1,196
Subtotal Liquid Petroleum	10,110	10,480	11,367	12,557	12,119	13,489	14,848	15,334	16,098	16,132	17,524
Natural Gas	3,973	4,089	4,518	5,033	5,289	6,150	7,248	7,760	8,156	8,554	9,232
Subtotal Petroleum	14,083	14,569	15,885	17,590	17,408	19,639	22,096	23,094	24,254	24,686	26,756
Bituminous Coal	14,661	13,110	14,302	13,622	11,673	11,900	12,285	10,971	11,182	9,512	11,104
Anthracite Coal	1,311	1,369	1,224	1,275	958	1,013	940	897	711	683	599
Subtotal Coal	15,972	14,479	15,526	14,897	12,631	12,913	13,225	11,868	11,893	10,195	11,703
Hydro Power	1,486	1,446	1,459	1,507	1,565	1,601	1,592	1,614	1,550	1,479	1,497
Nuclear Power	-	-	-	-	-	-	-	-	-	-	-
Subtotal Electricity	1,486	1,446	1,459	1,507	1,565	1,601	1,592	1,614	1,550	1,479	1,497
Total	31,541	30,494	32,870	33,994	31,604	35,153	36,913	36,576	37,697	36,360	39,956

(Percent of Total Energy Consumption)

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
Crude Oil	30.5	32.8	32.9	35.1	36.3	36.1	37.9	39.4	40.0	41.5	40.8
Natural Gas Liquids	1.5	1.6	1.7	1.8	2.1	2.2	2.4	2.6	2.7	2.8	3.0
Subtotal Liquid Petroleum	32.0	34.4	34.6	36.9	38.4	38.3	40.3	42.0	42.7	44.3	43.8
Natural Gas	12.6	13.4	13.8	14.8	16.7	17.5	19.6	21.2	21.6	23.5	23.1
Subtotal Petroleum	44.6	47.8	48.4	51.7	55.1	55.8	59.9	63.2	64.3	67.8	66.9
Bituminous Coal	46.5	43.0	43.5	40.1	36.9	36.7	33.3	30.0	29.7	26.2	27.8
Anthracite Coal	4.2	4.5	3.7	3.8	3.0	2.9	2.5	2.4	1.9	1.9	1.5
Subtotal Coal	50.7	47.5	47.2	43.9	39.9	39.6	35.8	32.4	31.6	28.1	29.3
Hydro Power	4.7	4.7	4.4	4.4	5.0	4.6	4.3	4.4	4.1	4.1	3.8
Nuclear Power	-	-	-	-	-	-	-	-	-	-	-
Subtotal Electricity	4.7	4.7	4.4	4.4	5.0	4.6	4.3	4.4	4.1	4.1	3.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE I

U. S. ENERGY CONSUMPTION (CONT.)
1945-1965

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
	(Energy Consumption in Trillions of BTU's)									
Crude Oil	17,418	17,328	17,428	18,307	18,608	18,989	19,662	20,231	20,707	21,577
Natural Gas Liquids	1,209	1,242	1,240	1,348	1,427	1,498	1,605	1,668	1,769	1,870
Subtotal Liquid Petroleum	18,627	18,570	18,668	19,655	20,035	20,487	21,267	21,899	22,476	23,447
Natural Gas	9,834	10,416	10,995	11,991	12,736	13,228	14,027	14,843	15,648	16,546
Subtotal Petroleum	28,461	28,986	29,663	31,646	32,771	33,715	35,294	36,742	38,124	39,993
Bituminous Coal	11,338	10,838	9,607	9,596	9,967	9,809	10,160	10,722	11,295	12,026
Anthracite Coal	610	528	483	478	447	404	363	361	365	371
Subtotal Coal	11,948	11,366	10,090	10,074	10,414	10,213	10,523	11,083	11,660	12,397
Hydro Power	1,598	1,568	1,740	1,691	1,626	1,628	1,780	1,740	1,858	2,050
Nuclear Power	-	-	-	-	5	17	23	33	34	38
Subtotal Electricity	1,598	1,568	1,740	1,691	1,631	1,645	1,803	1,773	1,892	2,088
Total	42,007	41,920	41,493	43,411	44,816	45,573	47,620	49,598	51,676	54,478
	(Percent of Total Energy Consumption)									
Crude Oil	41.5	41.4	42.0	42.2	41.6	41.6	41.2	40.8	40.3	39.6
Natural Gas Liquids	2.9	3.0	3.0	3.1	3.2	3.3	3.4	3.4	3.4	3.4
Subtotal Liquid Petroleum	44.4	44.4	45.0	45.3	44.8	44.9	44.6	44.2	43.7	43.0
Natural Gas	23.4	24.8	26.5	27.6	28.4	29.0	29.5	29.8	30.1	30.3
Subtotal Petroleum	67.8	69.2	71.5	72.9	73.2	73.9	74.1	74.0	73.8	73.3
Bituminous Coal	27.0	25.8	23.1	22.1	22.2	21.5	21.3	21.7	21.8	22.1
Anthracite Coal	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.7	0.7
Subtotal Coal	28.4	27.1	24.3	23.2	23.2	22.4	22.1	22.4	22.5	22.8
Hydro Power	3.8	3.7	4.2	3.9	3.6	3.6	3.7	3.5	3.6	3.8
Nuclear Power	-	-	-	-	-	0.1	0.1	0.1	0.1	0.1
Subtotal Electricity	3.8	3.7	4.2	3.9	3.6	3.7	3.8	3.6	3.7	3.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: U. S. Department of the Interior

TABLE II

RATES OF CHANGE IN U.S. ENERGY CONSUMPTION 1946-1965
(Percent change)

	LIQUID PETROLEUM		NATURAL GAS		TOTAL PETROLEUM		COAL		HYDRO & NUCLEAR		TOTAL ENERGY	
	YEARLY	5 YEARS ENDING:	YEARLY	5 YEARS ENDING:	YEARLY	5 YEARS ENDING:	YEARLY	5 YEARS ENDING:	YEARLY	5 YEARS ENDING:	YEARLY	5 YEARS ENDING:
1946	+ 3.7	--	+ 2.9	--	+ 3.5	--	- 9.4	--	- 2.7	--	- 3.3	--
1947	+ 8.5	--	+10.5	--	+ 9.0	--	+ 7.2	--	+ 0.9	--	+ 7.8	--
1948	+10.5	--	+11.4	--	+10.7	--	- 4.1	--	+ 3.3	--	+ 3.4	--
1949	- 3.5	--	+ 5.1	--	- 1.0	--	-15.2	--	+ 3.8	--	- 7.0	--
1950	+11.3	+33.4	+16.3	+54.8	+12.8	+39.5	+ 2.2	-19.2	+ 2.3	+ 7.7	+11.2	+11.5
1951	+10.1	+38.2	+17.9	+77.3	+12.5	+51.7	+ 2.4	- 8.7	- 0.6	+10.1	+ 5.0	+21.1
1952	+ 3.3	+34.9	+ 7.1	+71.8	+ 4.5	+45.4	-10.3	-23.6	+ 1.4	+10.6	- 0.9	+11.3
1953	+ 5.0	+28.2	+ 5.1	+62.1	+ 5.0	+37.9	+ 0.2	-20.2	- 4.0	+ 2.9	+ 3.1	+10.1
1954	+ 0.2	+33.1	+ 4.9	+61.7	+ 1.8	+41.8	-14.3	-19.3	- 4.6	- 5.5	- 3.6	+15.0
1955	+ 8.6	+29.9	+ 7.9	+50.1	+ 8.4	+36.2	+14.8	- 9.4	+ 1.2	- 6.5	+ 9.9	+13.7
1956	+ 6.3	+25.5	+ 6.5	+35.7	+ 6.4	+28.8	+ 2.1	- 9.7	+ 6.7	+ 0.4	+ 5.1	+13.8
1957	- 0.3	+21.1	+ 5.9	+34.2	+ 1.8	+25.5	- 4.9	- 4.5	- 1.9	- 2.9	- 0.2	+14.6
1958	+ 0.5	+16.0	+ 5.6	+34.8	+ 2.3	+22.3	-11.2	-15.2	+11.0	+12.3	- 1.0	+10.1
1959	+ 5.3	+21.8	+ 9.1	+40.2	+ 6.7	+28.2	- 0.2	- 1.2	- 2.8	+14.3	+ 4.6	+19.4
1960	+ 1.9	+14.3	+ 6.2	+38.0	+ 3.6	+22.5	+ 3.4	-11.0	- 3.5	+ 9.0	+ 3.2	+12.2
1961	+ 2.3	+10.0	+ 3.9	+34.5	+ 2.9	+18.5	- 1.9	-14.5	+ 0.9	+ 2.9	+ 1.7	+ 8.5
1962	+ 3.8	+14.5	+ 6.0	+34.7	+ 4.7	+21.8	+ 3.0	- 7.4	+ 9.6	+15.0	+ 4.5	+13.6
1963	+ 3.0	+17.3	+ 5.8	+35.0	+ 4.1	+23.9	+ 5.3	+ 9.8	- 1.7	+ 1.9	+ 4.2	+19.5
1964	+ 2.6	+14.4	+ 5.4	+30.5	+ 3.8	+20.5	+ 5.2	+15.7	+ 6.7	+11.9	+ 4.2	+19.0
1965	+ 4.3	+17.0	+ 5.7	+29.9	+ 4.9	+22.0	+ 6.3	+19.0	+10.4	+28.0	+ 5.4	+21.6

Source: Calculated from data in Table I.

TABLE III

U.S. PETROLEUM SUPPLY AND DEMAND 1945-1965
(Thousands of barrels daily)

	SUPPLY									DEMAND				
	U. S. PRODUCTION			IMPORTS					TOTAL NEW SUPPLY					
PERIOD	CRUDE	N.G.L.	TOTAL	RESIDUAL	CRUDE	ALL OTHER*	SUBTOTAL EX RESIDUAL	TOTAL		DOMESTIC	EXPORT	TOTAL	PERCENT CHANGE	CHANGE IN STOCKS (ALL OILS)
1945	4,695	315	5,010	86	204	21	225	311	5,321	4,857	501	5,358	+ 4.4	(37)
1946	4,750	323	5,073	122	236	19	255	377	5,450	4,912	419	5,331	- 0.5	119
1947	5,088	364	5,452	149	267	20	287	436	5,888	5,451	451	5,902	+10.7	(14)
1948	5,520	401	5,921	146	353	15	268	514	6,435	5,775	368	6,143	+ 4.1	292
1949	5,046	431	5,477	206	421	18	439	645	6,122	5,803	327	6,130	- 0.2	(8)
1950	5,407	499	5,906	329	487	34	521	850	6,756	6,507	304	6,811	+11.1	(55)
1951	6,158	562	6,720	327	491	27	518	845	7,565	7,053	422	7,475	+ 9.7	90
1952	6,256	612	6,868	351	573	28	601	952	7,820	7,280	432	7,712	+ 3.2	108
1953	6,458	655	7,113	360	648	26	674	1,034	8,147	7,604	401	8,005	+ 3.8	142
1954	6,342	693	7,035	354	656	42	698	1,052	8,087	7,760	355	8,115	+ 1.4	(28)
1955	6,807	772	7,579	416	782	50	832	1,248	8,827	8,459	368	8,827	+ 8.8	0
1956	7,151	801	7,952	445	934	57	991	1,436	9,388	8,779	430	9,209	+ 4.3	179
1957	7,170	809	7,979	476	1,022	77	1,099	1,575	9,554	8,818	568	9,386	+ 1.9	168
1958	6,709	809	7,518	499	954	247	1,201	1,700	9,218	9,083	276	9,359	- 0.3	(141)
1959	7,054	879	7,933	610	965	205	1,170	1,780	9,713	9,451	211	9,662	+ 3.2	51
1960	7,035	930	7,965	637	1,015	163	1,178	1,815	9,780	9,661	202	9,863	+ 2.1	(83)
1961	7,183	991	8,174	666	1,045	206	1,251	1,917	10,091	9,806	174	9,980	+ 1.2	111
1962	7,332	1,021	8,353	724	1,126	232	1,358	2,082	10,435	10,235	168	10,403	+ 4.2	32
1963	7,542	1,098	8,640	747	1,131	245	1,376	2,123	10,763	10,551	208	10,759	+ 3.4	4
1964	7,614	1,154	8,768	808	1,199	252	1,451	2,259	11,027	10,816	201	11,017	+ 2.4	10
1965(P)	7,804	1,210	9,014	944	1,238	285	1,523	2,467	11,481	11,303	186	11,489	+ 4.3	(8)

(P) Preliminary.
* Includes unfinished oils and light finished products.

Source: U. S. Bureau of Mines

TABLE IV

U. S. PETROLEUM EXPORTS AND IMPORTS 1945-1965
(In thousands of barrels daily)

	Exports			Imports					
					Crude and Other*				Net Exports (+)
	Crude	Products	Total Exports	Resid.	Dist. I-IV	Dist. V	Total	Total Imports	or Net Imports (-)
1945	90	411	501	86	225	-	225	311	+ 190
1946	116	303	419	122	255	-	255	377	+ 42
1947	127	324	451	149	287	-	287	436	+ 15
1948	109	259	368	146	368	-	368	514	- 146
1949	91	236	327	206	436	3	439	645	- 318
1950	95	209	304	329	521	-	521	850	- 546
1951	78	344	422	327	508	10	518	845	- 423
1952	73	359	432	351	568	33	601	952	- 520
1953	55	346	401	360	593	81	674	1,034	- 633
1954	37	318	355	354	644	54	698	1,052	- 697
1955	32	336	368	416	733	99	832	1,248	- 880
1956	78	352	430	445	804	187	991	1,436	-1,006
1957	138	430	568	476	834	265	1,099	1,575	-1,007
1958	12	264	276	499	993	208	1,201	1,700	-1,424
1959	7	204	211	610	912	258	1,170	1,780	-1,569
1960	8	194	202	637	879	299	1,178	1,815	-1,613
1961	9	165	174	666	921	330	1,251	1,917	-1,743
1962	5	163	168	724	967	391	1,358	2,082	-1,914
1963	5	203	208	747	995	381	1,376	2,123	-1,915
1964	4	197	201	808	1,015	436	1,451	2,259	-2,058
1965	3	183	186	944	1,063	460	1,523	2,467	-2,281

* Includes unfinished oils and light finished products.

Source: U. S. Bureau of Mines.

TABLE V

U. S. PETROLEUM SUPPLY 1945-1965
(Percent of total supply)

	U. S. Production			Imports					
					Crude and Other*				
	Crude	N.G.L.	Total Production	Residual	Dist. I-IV	Dist. V	Total	Total Imports	Total Supply
1945	88.3	5.9	94.2	1.6	4.2	-	4.2	5.8	100.0
1946	87.2	5.9	93.1	2.2	4.7	-	4.7	6.9	100.0
1947	86.4	6.2	92.6	2.5	4.9	-	4.9	7.4	100.0
1948	85.8	6.2	92.0	2.3	5.7	-	5.7	8.0	100.0
1949	82.4	7.1	89.5	3.4	7.1	-	7.1	10.5	100.0
1950	80.0	7.4	87.4	4.9	7.7	-	7.7	12.6	100.0
1951	81.4	7.4	88.8	4.3	6.7	0.2	6.9	11.2	100.0
1952	80.0	7.8	87.8	4.5	7.3	0.4	7.7	12.2	100.0
1953	79.3	8.0	87.3	4.4	7.3	1.0	8.3	12.7	100.0
1954	78.4	8.6	87.0	4.4	8.0	0.6	8.6	13.0	100.0
1955	77.1	8.8	85.9	4.7	8.3	1.1	9.4	14.1	100.0
1956	76.2	8.5	84.7	4.7	8.6	2.0	10.6	15.3	100.0
1957	75.0	8.5	83.5	5.0	8.7	2.8	11.5	16.5	100.0
1958	72.8	8.8	81.6	5.4	10.8	2.2	13.0	18.4	100.0
1959	72.6	9.1	81.7	6.3	9.4	2.6	12.0	18.3	100.0
1960	71.9	9.5	81.4	6.5	9.0	3.1	12.1	18.6	100.0
1961	71.2	9.8	81.0	6.6	9.1	3.3	12.4	19.0	100.0
1962	70.2	9.8	80.0	7.0	9.3	3.7	13.0	20.0	100.0
1963	70.1	10.2	80.3	7.0	9.2	3.5	12.7	19.7	100.0
1964	69.0	10.5	79.5	7.3	9.2	4.0	13.2	20.5	100.0
1965	68.0	10.5	78.5	8.2	9.3	4.0	13.3	21.5	100.0

* Includes unfinished oils and light finished products.

Source: Calculated from data in Tables III and IV.

TABLE VI

SHARE OF U. S. PETROLEUM PRODUCTION FOR CRUDE OIL AND NATURAL GAS
1945-1965

	Crude Oil Production (Thous.Bbls)	Natural Gas Production* (Thous.Mcf)	Crude Oil Production (Trillion British Thermal Units)	Natural Gas Production (Trillion British Thermal Units)	Total Oil & Gas Production (Trillion British Thermal Units)	Crude Oil Production (Percent)	Natural Gas Production (Percent)	Total Oil & Gas Productio (Percent)
1945	1,713.655	4,042.002	9,939	4,423	14,362	69.2	30.8	100 0
1946	1,733.939	4,152.762	10,057	4,550	14,607	68.9	31.1	100.0
1947	1,856.987	4,582.173	10,771	5,012	15,783	68.2	31.8	100.0
1948	2,020.185	5,148.020	11,717	5,615	17,332	67.6	32.4	100 0
1949	1,841.940	5,419.736	10,683	5,911	16,594	64.4	35.6	100.0
1950	1,973.574	6,282.060	11,449	6,841	18,290	62.6	37.4	100.0
1951	2,247.711	7,457.359	13,037	8,106	21,143	61.7	38.3	100.0
1952	2,289.836	8,013.457	13,282	8,705	21,987	60.4	39.6	100.0
1953	2,357.082	8,396.916	13,671	9,116	22,787	60.0	40.0	100.0
1954	2,314.988	8,742.546	13,427	9,488	22,915	58.6	41.4	100.0
1955	2,484.428	9,405.351	14,410	10,204	24,614	58.5	41.5	100.0
1956	2,617.283	10,081.923	15,181	10,930	26,111	58.1	41.9	100.0
1957	2,616.901	10,680.258	15,178	11,571	26,749	56.7	43.3	100.0
1958	2,448.987	11,030.248	14,204	11,943	26,147	54.3	45.7	100.0
1959	2,574.590	12,046.115	14,933	13,036	27,969	53.4	46.6	100.0
1960	2,574.933	12,771.038	14,935	13,822	28,757	51.9	48.1	100.0
1961	2,621.758	13,254.025	15,206	14,336	29,542	51.5	48.5	100.0
1962	2,676.189	13,876.622	15,222	15,004	30,226	50.4	49.6	100.0
1963	2,752.723	14,746.661	15,966	15,941	31,907	50.0	50.0	100.0
1964	2,786.822	15,546.592	16,164	16,792	32,956	49.0	51.0	100.0
1965(P)	2,848.514	16,432.000	16,521	17,744	34,265	48.2	51.8	100.0

(P) Preliminary.

* Total production minus repressuring, vent, and waste; includes natural gas liquids later extracted at plants.

Source: U. S. Bureau of Mines.

TABLE VII

U.S. CRUDE OIL PRODUCTIVE CAPACITY AND PRODUCTION
1951, 1953, 1954, 1957, 1960, 1964, and 1965
(Thousands of barrels daily)

	PAD Districts					Total
	I	II	III	IV	V*	U. S.
Productive Capacity						
Jan. 1, 1951	54	1,083	4,161	350	1,079	6,727
Jan. 1, 1953	49	1,238	4,686	394	1,098	7,465
July 1, 1954	43	1,380	5,224	561	1,123	8,331
Jan. 1, 1957	37	1,591	6,613	615	1,011	9,867
Jan. 1, 1960	29	1,555	7,331	664	1,006	10,585
Jan. 1, 1964	30	1,473	8,399	678	1,010	11,590
Jan. 1, 1965	30	1,424	8,936	690	1,027	12,107
Production						
1950	53	1,028	3,167	255	897	5,400
1952	51	1,120	3,803	300	982	6,256
1953	49	1,173	3,872	364	1000	6,458
1956	37	1,358	4,285	512	959	7,151
1959	30	1,334	4,169	664	847	7,054
1963	29	1,330	4,652	677	854	7,542
1964	30	1,329	4,764	640	851	7,614
Unused Capacity						
Jan. 1, 1951	1	55	994	95	182	1,327
Jan. 1, 1953	- 2	118	883	94	116	1,209
July 1, 1954	- 6	207	1,352	197	123	1,873
Jan. 1, 1957	0	233	2,328	103	52	2,716
Jan. 1, 1960	- 1	221	3,162	0	159	3,531
Jan. 1, 1964	1	143	3,747	1	156	4,048
Jan. 1, 1965	0	95	4,172	50	176	4,493
Percent of Capacity Unused						
Jan. 1, 1951	1.9	5.1	23.9	27.1	16.9	19.7
Jan. 1, 1953	- 4.1	9.5	18.8	23.9	10.6	16.2
July 1, 1954	-14.0	15.0	25.9	35.1	11.0	22.5
Jan. 1, 1957	-	14.6	35.2	16.7	5.1	27.5
Jan. 1, 1960	- 3.4	14.2	43.1	-	15.8	33.4
Jan. 1, 1964	3.3	9.7	44.6	-	15.4	34.9
Jan. 1, 1965	-	6.7	46.7	7.2	17.1	37.1

*Includes Elk Hills

Sources: Productive Capacity Estimates from National Petroleum Council
Production from U. S. Bureau of Mines

TABLE VIII

UNIT PRICE AND TOTAL VALUE OF U. S. PETROLEUM PRODUCTION
1945-1965
(In Current and Constant 1965 Dollars)

	Crude Oil				Natural Gas				Total Crude Oil and Natural Gas			
	Price, $/Bbl		Value, Mil $		Price, ¢/MCF		Value, Mil $		Price, ¢/Mil BTU's		Value, Mil $	
	Current	Constant*	Current	Constant*	Current	Constant*	Current	Constant*	Current	Constant*	Current	Constant*
1945	$1.22	$2.22	$2,094	$3,813	4.9 ¢	8.9 ¢	$ 197	$ 359	16.0 ¢	29.0 ¢	$ 2,291	$ 4,172
1946	1.41	2.34	2,442	4,056	5.1	8.5	212	352	18.2	30.2	2,654	4,408
1947	1.93	2.63	3,578	4,870	6.0	8.2	275	374	24.4	33.2	3,853	5,244
1948	2.60	3.26	5,245	6,582	6.5	8.2	333	418	32.2	40.1	5,578	7,000
1949	2.54	3.25	4,675	5,989	6.3	8.1	344	440	30.2	38.7	5,019	6,429
1950	2.51	3.10	4,963	6,134	6.5	8.0	409	506	29.4	36.3	5,372	6,640
1951	2.53	2.83	5,690	6,373	7.3	8.2	543	608	29.5	33.0	6,233	6,981
1952	2.53	2.90	5,785	6,635	7.8	8.9	624	716	29.1	33.4	6,409	7,351
1953	2.68	3.05	6,327	7,200	9.2	10.5	775	882	31.2	35.5	7,102	8,082
1954	2.78	3.15	6,425	7,286	10.1	11.5	882	1,000	31.9	36.2	7,307	8,286
1955	2.77	3.07	6,870	7,619	10.4	11.5	978	1,084	31.9	35.4	7,848	8,703
1956	2.79	2.96	7,297	7,750	10.8	11.5	1,084	1,151	32.1	34.1	8,381	8,901
1957	3.09	3.19	8,079	8,346	11.3	11.7	1,202	1,241	34.7	35.8	9,281	9,587
1958	3.01	3.10	7,380	7,601	11.9	12.3	1,317	1,357	33.3	34.3	8,697	8,958
1959	2.90	2.93	7,473	7,563	12.9	13.1	1,557	1,575	32.3	32.7	9,030	9,138
1960	2.88	2.91	7,420	7,509	14.0	14.2	1,790	1,812	32.0	32.4	9,210	9,321
1961	2.89	2.94	7,566	7,695	15.1	15.4	1,996	2,030	32.4	32.9	9,562	9,725
1962	2.90	2.95	7,774	7,906	15.5	15.8	2,145	2,182	32.5	33.0	9,919	10,088
1963	2.89	2.94	7,966	8,109	15.8	16.1	2,328	2,370	32.3	32.8	10,294	10,479
1964	2.88	2.92	8,017	8,121	15.4	15.6	2,388	2,419	31.6	32.0	10,405	10,540
1965	2.86	2.86	8,158	8,158	15.6	15.6	2,495	2,495	31.1	31.1	10,653	10,653

* Deflated by wholesale price index for all commodities other than farm and food.

Source: Prices and value in current dollars from U. S. Bureau of Mines. Natural gas includes liquids before extraction at plants and, therefore, value of these natural gas liquids to producers.

TABLE IX

TRENDS IN PRICE AND COST FACTORS
1946-1965
(Index Numbers 1957-59= 100)

	U. S. Crude Oil Price	Hourly Wages Oil and Gas Production	Oilfield Machinery Prices	Oil Well Casing Prices
1946	N.A.	48.5	N.A.	N.A
1947	61.7	54.7	60.4	49.3
1948	81.3	61.9	65.5	55.1
1949	82.0	66.0	69.2	57.2
1950	82.0	67.0	70.7	62.5
1951	82.4	72.5	77.9	66.1
1952	82.4	77.5	78.0	67.3
1953	88.4	82.2	81.3	73.2
1954	91.0	84.3	84.2	77.6
1955	91.1	86.2	87.7	81.6
1956	91.6	92.0	93.2	87.1
1957	101.0	96.7	99.6	96.6
1958	101.2	99.5	100.1	100.7
1959	97.8	103.8	100.2	100.7
1960	97.2	105.4	100.3	102.7
1961	97.5	109.7	101.8	100.3
1962	97.7	110.8	103.2	98.6
1963	97.2	114.4	102.6	99.6
1964	96.9	115.7	104.4	103.0
1965	96.7	118.8	104.7	107.8
Averages				
1951-55	87.1	80.5	81.8	73.2
1956-60	97.8	99.5	98.7	97.6
1961-65	97.2	113.9	103.3	101.9

N.A. - Not available

Source: Bureau of Labor Statistics

TABLE X

WAGE BILL FOR U.S. PETROLEUM PRODUCTION EMPLOYEES
1947-1965

	Production Employees Crude Petroleum and Natural Gas Fields (number)	Production Employees Average Weekly Earnings	Annual Wage Bill for Production Employees
1947	128,300	$ 55.98	$ 373,476,168
1948	134,800	62.88	440,763,648
1949	132,700	67.40	465,086,960
1950	130,700	69.53	472,553,692
1951	133,400	75.30	522,341,040
1952	138,000	80.98	581,112,480
1953	140,500	85.47	624,443,820
1954	140,300	86.65	632,163,740
1955	138,400	88.88	638,405,984
1956	136,800	95.88	682,051,968
1957	131,500	100.53	687,424,140
1958	124,500	103.38	669,282,120
1959	117,800	108.12	662,299,872
1960	111,200	108.95	629,992,480
1961	104,500	113.96	619,258,640
1962	99,700	115.46	598,590,824
1963	96,000	120.01	599,089,920
1964	91,900	120.95	577,995,860
1965	88,400	123.62	568,256,416
Changes:			
1947-50	+ 2,400	+ 13.55	+ 99,077,524
1951-55	+ 5,000	+ 13.58	+ 116,064,944
1956-60	-25,600	+ 13.07	- 52,059,488
1961-65	-16,100	+ 9.66	- 51,002,224

Source: Bureau of Labor Statistics.

TABLE XI

FOOTAGE PRICES RECEIVED BY U. S. OIL AND GAS ROTARY DRILLING CONTRACTORS 1946-1965

	Average Contract Price Per Foot	Index (1957-59 = 100)
1946	$5.00	114.4
1947	5.00	114.4
1948	4.75	108.7
1949	4.75	108.7
1950	5.00	114.4
1951	5.50	125.9
1952	5.85	133.9
1953	5.60	128.1
1954	5.10	116.7
1955	4.90	112.1
1956	4.75	108.7
1957	4.51	103.2
1958	4.27	97.7
1959	4.33	99.1
1960	4.11	94.1
1961	4.11	94.1
1962	3.97	90.8
1963	3.88	88.8
1964	3.68	84.2
1965	4.04	92.4

Source: American Association of Oilwell Drilling Contractors.

TABLE XII

ESTIMATED WELL-HEAD VALUE AND EXPENDITURES FOR EXPLORATION AND DEVELOPMENT

Millions of Current Dollars

Year	Well-Head Value: Crude & Natural Gas Gross	Well-Head Value: Crude & Natural Gas Net	Well-Head Value: Other Lease Revenue	Well-Head Value: Total	Expenditures: Exploration	Expenditures: Development	Expenditures: Total Exploration & Development	Percent of Total Receipts: Exploration	Percent of Total Receipts: Development	Percent of Total Receipts: Total Exploration Development
1948	5,578	4,805	239	5,044	1,111	1,420	2,531	22.0	28.2	50.2
1953	7,102	6,132	339	6,471	1,956	2,245	4,201	30.2	34.7	64.9
1955	7,848	6,671	201	6,872	2,183	2,252	4,435	31.8	32.8	64.5
1956	8,381	7,095	225	7,320	2,325	2,436	4,761	31.8	33.3	65.0
1959	9,030	7,676	254	7,930	2,195	2,313	4,508	27.7	29.2	56.8
1960	9,210	7,829	261	8,090	2,242	2,082	4,324	27.7	25.7	53.4
1961	9,562	8,128	284	8,412	2,070	2,070	4,140	24.6	24.6	49.2
1962	9,919	8,431	293	8,724	2,537	2,266	4,803	29.1	26.0	55.1
1963	10,294	8,750	323	9,073	2,045	2,039	4,084	22.5	22.5	45.0

Source: From Joint Association Surveys.

Natural gas value includes liquids before extraction at plants and, therefore, value of these liquids to producers.

TABLE XIII

U.S. AUCTION SALES OF RIGS
1960-1966

Year	Companies	Rotary Drilling	Well Servicing	Cable & Spudders	Total Rigs
1959	First auction sale of oil field rigs occurred in 1960				
1960	5	13	0	0	13
1961	12	44	1	0	45
1962	44	138	31	1	170
1963	45	147	74	17	238
1964	56	208	55	16	279
1965	71	195	65	5	265
1966 (11 Mos.)	54	147	93	23	263
Total	287	892	319	62	1,273

Source: American Association of Oilwell Drilling Contractors from announcements of sales by auction companies.

TABLE XIV

U. S. CRUDE OIL PRODUCTION
"CHASE BANK GROUP" OF COMPANIES AND "ALL OTHER" GROUP
1948-1965

	Crude Production*			Percent		
	Chase Bank Group of Companies	All Other	Total U. S.	Chase Bank Group of Companies	All Other	Total U. S.
1948	3,472	2,048	5,520	62.9	37.1	100.0
1949	3,118	1,928	5,046	61.8	38.2	100.0
1950	3,217	2,190	5,407	59.5	40.5	100.0
1951	3,702	2,456	6,158	60.1	39.9	100.0
1952	3,779	2,477	6,256	60.4	39.6	100.0
1953	4,127	2,331	6,458	63.9	36.1	100.0
1954	3,955	2,387	6,342	62.4	37.6	100.0
1955	4,173	2,634	6,807	61.3	38.7	100.0
1956	4,406	2,745	7,151	61.6	38.4	100.0
1957	4,487	2,683	7,170	62.6	37.4	100.0
1958	4,141	2,569	6,710	61.7	38.3	100.0
1959	4,379	2,675	7,054	62.1	37.9	100.0
1960	4,423	2,612	7,035	62.9	37.1	100.0
1961	4,510	2,673	7,183	62.8	37.2	100.0
1962	4,706	2,626	7,332	64.2	35.8	100.0
1963	4,905	2,637	7,542	65.0	35.0	100.0
1964	5,017	2,597	7,614	65.9	34.1	100.0
1965	5,269	2,535	7,804	67.5	32.5	100.0

* Gross crude oil production, including royalties as well as company-interest production; years prior to 1948 not available for Chase Bank Group of companies.

Source: The Chase Manhattan Bank. Companies included in the Chase Bank Group are as follows (for companies added to the group during the period, the year in which they were added is shown in parentheses): Amerada Petroleum Corporation, Apco Oil Corporation (1953 as Anderson-Prichard Oil), Ashland Oil & Refining Company (1961), Atlantic Richfield Company, Champlin Petroleum Company (1961), Cities Service Company (1949), Continental Oil Company, Getty Oil Company, Gulf Oil Corporation, Hydrocarbons & Polymers Division of Monsanto Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Murphy Oil Corporation (1962), Phillips Petroleum Company, Shell Oil Company, Signal Oil Corporation (1953), Sinclair Oil Corporation, Skelly Oil Company, Mobil Oil Corporation, Standard Oil Company of California, Standard Oil Company (Indiana), Standard Oil Company (New Jersey), Standard Oil Company (Ohio), Sun Oil Company, Sunray DX Oil Company (1953), The Superior Oil Company (1953), Texaco Inc., Tidewater Oil Company and Union Oil Company of California. Other changes in the group were as follows: in 1949, Barnsdall which had been in the group was acquired by a company outside the group; in 1953 Honolulu was added to group and later acquired by a company already in the group; in 1961 the producing operations of Anderson-Prichard, which had been added to the group in 1953, were acquired outside the group; in 1963 the Texas Pacific Coal and Oil, which had been included in the group, was acquired by a company outside the group; all other changes have been due to mergers or acquisitions within the group itself.

TABLE XV

ESTIMATED U. S. EXPLORATION AND DEVELOPMENT EXPENDITURES
"CHASE BANK GROUP" OF COMPANIES AND "ALL OTHER" GROUP
1946-1965

	(Million Dollars)			(Percent)		
	Chase Bank Group of Companies	All Other	Total U. S.*	Chase Bank Group of Companies	All Other	Total U. S.
1946	$ 775	$ 740	$1,515	51.2	48.8	100.0
1947	991	959	1,950	50.8	49.2	100.0
1948	1,318	982	2,300	57.3	42.7	100.0
1949	1,217	998	2,215	54.9	45.1	100.0
1950	1,157	1,168	2,325	49.8	50.2	100.0
1951	1,620	1,355	2,975	54.5	45.5	100.0
1952	1,855	1,770	3,625	51.2	48.8	100.0
1953	2,014	1,961	3,975	50.7	49.3	100.0
1954	2,180	2,120	4,300	50.7	49.3	100.0
1955	2,383	2,292	4,675	51.0	49.0	100.0
1956	2,621	2,454	5,075	51.6	48.4	100.0
1957	2,673	2,427	5,100	52.4	47.6	100.0
1958	2,241	1,984	4,225	53.0	47.0	100.0
1959	2,455	1,895	4,350	56.4	43.6	100.0
1960	2,412	1,788	4,200	57.4	42.6	100.0
1961	2,417	1,583	4,000	60.4	39.6	100.0
1962	2,848	1,577	4,425	64.4	35.6	100.0
1963	2,452	1,673	4,125	59.4	40.6	100.0
1964	2,817	1,633	4,450	63.3	36.7	100.0
1965	2,847	1,363	4,210	67.6	32.4	100.0

Source: The Chase Manhattan Bank (see Table XIV for companies included in Chase Bank Group). Expenditures include exploration expense and lease rentals charged to income account, but exclude production payments and acquisition costs for producing properties purchased.

* The above estimates for total U. S. exploration and development expenditures vary from those shown in Table 12 because of differences in sources of data and estimating procedures. The variations, however, are not such as to nullify the significance of the trends as analyzed in the report.

TABLE XVI

WELL-HEAD VALUE OF U. S. OIL AND GAS PRODUCTION

AND

ESTIMATED EXPLORATION & DEVELOPMENT EXPENDITURES

"CHASE BANK GROUP" OF COMPANIES AND "ALL OTHER" GROUP
1946-1965

	Well-Head Value Oil and Gas Production (Million Dollars)		Exploration & Development Expenditures (Million Dollars)		Ratio of Expenditures To Well-Head Value (Percent)	
	Chase Bank Group of Companies	All Other	Chase Bank Group of Companies	All Other	Chase Bank Group of Companies	All Other
1946	$1,353	$ 905	$ 775	$ 740	57.3	81.8
1947	1,977	1,298	991	959	50.1	73.9
1948	2,899	1,844	1,318	982	45.5	53.3
1949	2,560	1,722	1,217	998	47.5	58.0
1950	2,660	1,905	1,157	1,170	43.5	61.4
1951	3,112	2,187	1,620	1,355	52.1	62.0
1952	3,244	2,204	1,855	1,770	57.2	80.3
1953	3,695	2,340	2,014	1,961	54.5	83.8
1954	3,752	2,460	2,180	2,120	58.1	86.2
1955	3,930	2,741	2,383	2,292	60.6	83.6
1956	4,231	2,897	2,621	2,454	61.9	84.7
1957	4,759	3,134	2,673	2,427	56.2	77.4
1958	4,377	3,011	2,241	1,984	51.2	65.9
1959	4,540	3,127	2,455	1,895	54.1	60.6
1960	4,660	3,163	2,412	1,788	51.8	56.5
1961	4,803	3,339	2,417	1,583	50.3	47.4
1962	4,960	3,464	2,848	1,577	57.4	45.5
1963	5,277	3,466	2,452	1,673	46.5	48.3
1964	5,372	3,487	2,817	1,633	52.4	46.8
1965	5,652	3,513	2,847	1,363	50.4	38.8
Yearly Averages						
1946-50	2,290	1,535	1,092	970	47.7	63.2
1951-55	3,547	2,386	2,010	1,900	56.7	79.6
1956-60	4,514	3,066	2,480	2,110	54.9	68.8
1961-65	5,213	3,454	2,676	1,566	51.3	45.3

Source: The Chase Manhattan Bank (see Table XIV for companies included in Chase Bank Group). Well-head value of crude oil and natural gas is company-interest value, excluding royalties, and includes value of natural gas liquids to producers before extraction of these liquids at plants.