PETROLEUM PRODUCTIVE CAPACITY

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A Report of

THE
NATIONAL PETROLEUM COUNCIL

1952

PETROLEUM PRODUCTIVE CAPACITY

A Report on
PRESENT AND FUTURE SUPPLIES
OF OIL AND GAS

Presented by the
COMMITTEE ON OIL AND GAS AVAILABILITY
on JANUARY 29, 1952 *to the*
NATIONAL PETROLEUM COUNCIL

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THE NATIONAL PETROLEUM COUNCIL

The purpose of the National Petroleum Council is to advise or inform the Secretary of the Interior or the Director of the Oil and Gas Division with respect to any matter relating to petroleum or the petroleum industry submitted to it by or approved by the Secretary or Director. During the existence of the Petroleum Administration for Defense, the Council has an additional purpose of advising or informing the Petroleum Administrator or the Deputy Administrator with respect to any matter relating to petroleum or the petroleum industry submitted to it by or approved by the Administrator or the Deputy Administrator.

NATIONAL PETROLEUM COUNCIL

1625 K STREET, N. W.
WASHINGTON 6, D. C.

January 29, 1952

Honorable Oscar L. Chapman
Secretary of the Interior and
Petroleum Administrator for Defense
Washington, D. C.

My dear Mr. Secretary:

Pursuant to the request of Mr. H. A. Stewart, Director of the Oil and Gas Division, the Department of the Interior, dated December 1, 1950, that the Council make a new and comprehensive study of present and probable future petroleum productive capacity and availability to the United States, I have the honor to transmit to you herewith a report on petroleum productive capacity, a report on present and future supplies of oil and gas, which was prepared by the Committee on Oil and Gas Availability and unanimously approved by the Council on January 29, 1952.

In the preparation of this report the Council has kept actively in mind the importance of the assignment, as expressed in the following quotation from Mr. Stewart's letter of December 1.

> "In view of the present situation and because of the significance of oil and gas to national security and defense, it is a matter of public importance that a new and even more comprehensive study of oil and gas productive capacity and availability be prepared.
>
> "Therefore, I request that the Council make a new and comprehensive study of present and probable future petroleum productive capacity and availability to the United States, including gas as well as liquid petroleum, foreign as well as domestic sources, and that the Council submit the results of this study with such recommendations as it deems appropriate at the earliest possible date."

The major finding of the Council's study as summarized briefly in the report is as follows:

> "Available supplies of oil and gas in the United States and the world are greater than ever before and are still increasing rapidly. Granted continuation of reasonable economic incentives and adequate supplies of materials, crude oil and natural gas may be counted upon to be available in abundance for the foreseeable future."

The results of the committee's comprehensive study and the conclusions which have been approved by the Council are presented to you in the interest of national security and defense and I believe to be a matter of public importance.

Respectfully submitted,

/s/ WALTER S. HALLANAN

Walter S. Hallanan, Chairman
National Petroleum Council

UNITED STATES
DEPARTMENT OF THE INTERIOR
OIL AND GAS DIVISION
WASHINGTON 25, D. C.

December 1, 1950

Mr. Walter S. Hallanan, Chairman
National Petroleum Council
1625 K Street, N.W.
Washington, D. C.

Dear Mr. Hallanan:

In his letter to you of June 14, 1949, the Secretary of the Interior requested the National Petroleum Council to consider the problem of providing a substantial domestic reserve productive capacity to be available in the event of an emergency. The Council appointed a committee which prepared a valuable report, dated January 26, 1950, entitled "U. S. Crude Petroleum Productive Capacity."

In view of the present situation and because of the significance of oil and gas to national security and defense, it is a matter of public importance that a new and even more comprehensive study of oil and gas productive capacity and availability be prepared.

Therefore, I request that the Council make a new and comprehensive study of present and probable future petroleum productive capacity and availability to the United States, including gas as well as liquid petroleum, foreign as well as domestic sources and that the Council submit the results of this study with such recommendations as it deems appropriate at the earliest possible date.

Sincerely yours,
/s/ H. A. STEWART
H. A. Stewart, Director

reasonable economic incentives, and a favorable climate for private investment, further worldwide increases in availability of petroleum may be expected for many years in the future. This report recognizes the prospects for development of new sources of energy and that the fuel needs of the nation for purposes of national security and economic progress can best be served by competition. With particular reference to petroleum supplies, however, additional large land areas upon which the prospects for future petroleum production are favorable are known and the industry's technology for finding and developing oil which has advanced markedly can reasonably be expected to continue its advancement. These elements of physical existence and improved techniques operating within an economic framework which embraces continued freedom in private competitive enterprise assure ample supplies of petroleum within the foreseeable future.

Respectfully submitted,

/s/ L. F. McCOLLUM
L. F. McCollum, Chairman
NPC Committee on Oil
and Gas Availability

Houston, Texas
January 29, 1952

Mr. Walter S. Hallanan, Chairman
National Petroleum Council
Washington, D. C.

Dear Mr. Hallanan:

Transmitted herewith is the final report of the Committee on Oil and Gas Availability appointed by the National Petroleum Council. The report has been prepared in response to a request made of the National Petroleum Council by Mr. H. A. Stewart, Director of the Oil and Gas Division of the United States Department of the Interior. Mr. Stewart requested, in his letter of December 1, 1950, that a study be made of "present and probable future petroleum productive capacity and availability to the United States, including gas as well as liquid petroleum, foreign as well as domestic sources."

A section of the study relating to the availability of oil and gas during the period 1951 through 1955 was submitted by this committee to the National Petroleum Council in an interim report dated July 24, 1951. The figures on availability of foreign oil included in that report have been revised to reflect accelerated completion of facilities in the Middle East as a result of the Iranian dispute.

The data contained in this report indicate that availability of all oils in the United States, under maximum efficient rates of production, is expected to rise from 7,300,000 barrels daily in January, 1951, to a figure within a range of 7,789,000 to 8,838,000 barrels daily by 1955. Corresponding figures for all foreign areas, exclusive of Russian-dominated countries, show an expected availability by 1955 within the range of 6,669,000 to 7,427,000 barrels per day, compared to an availability of 4,703,000 barrels per day in January, 1951. These statistics indicate that the total availability of the areas considered in this report was 12,003,000 barrels daily in January, 1951, and that this availability may be expected to range from 14,458,000 to 16,265,000 barrels daily by 1955, assuming maximum efficient rates of production.

The committee's estimates dealing with natural gas show that actual production in 1950 was 6.9 trillion cubic feet and that the range of availability is expected to be between 9.5 and 11.9 trillion cubic feet in 1955. Since the limiting factor on utilization of natural gas is the capacity of transportation facilities, these projections are deliberately conservative.

The foregoing estimates made by this committee are predicated upon a continuation of economic incentives, maintenance of conservation practices, adequate supplies of materials and manpower, and no changes in federal tax provisions and regulations with respect to petroleum production.

The outlook for petroleum supplies in the long-term view is favorable. Analyses and studies made by this committee reveal that, with continuing demand for petroleum products,

FOREWORD

This report has been prepared at the request of the Oil and Gas Division of the Department of Interior. It summarizes an intensive study by hundreds of experts in the oil industry over a period of a year and represents the best judgment of the industry as to the future.

The report answers recurrent fears that we are running out of oil. It concludes that abundant supplies of crude oil and natural gas may be counted upon for the foreseeable future granted continuation of reasonable economic incentives and adequate supplies of materials. The outlook is for an increasing supply of oil and gas in the United States.

Supplies of oil and gas in the United States in 1950 were nearly three times as much as in 1925. They have accounted for all of the increase in energy used in the United States during this time, while coal has remained at a static level. Oil and gas supplied substantially more energy than coal in 1950 despite the common view that resources of oil and gas are smaller than those of coal.

The report describes large areas favorable for accumulation of oil in the earth in the United States and in foreign countries. About 80 per cent of the surface of the United States is considered favorable for petroleum deposits. This area is about a hundred times as large as the area proved productive by all discoveries to date. Available evidence proves that large additional discoveries of oil and gas may be expected both in presently producing areas and in prospective areas.

The discovery of oil has been related to the amount of exploration and drilling. Currently the industry is devoting more effort than ever before to such work. It is spending several billion dollars a year in exploration and drilling and continuing to achieve large discoveries through this work.

Improved technology has added greatly to the ability of the industry to supply oil and gas. New methods have been devised to locate specific areas in which oil may have accumulated. Drilling equipment has been improved so that wells can now be carried as deep as four miles into the earth. In 1951 the industry was drilling about 475,000 feet a day, equivalent to more than 90 miles into the earth each day. This search for and development of oil is finding substantial new deposits.

The report shows a substantial increase in available supplies based merely on continuing the current rate of drilling. By 1955 supplies are expected to be greater than in January 1951 by not less than 1,324,000 barrels daily in the United States and 2,171,000 barrels daily in foreign areas outside of those dominated by Russia. This minimum expectation is almost equal to the increase in production in the five-year period from 1946 to 1951. Under favorable conditions the increase in available supplies during the next few years will be much larger.

The major conclusion of the report is as follows:

> "The United States and the world can count upon increasing supplies of oil and gas not only for the next few years but for the foreseeable future provided that reasonable economic incentives, adequate materials, and a favorable climate for private investment prevail."

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PETROLEUM PRODUCTIVE CAPACITY

A Report to the National Petroleum Council on Present and Future Supplies of Oil and Gas

Prepared by the Committee on Oil and Gas Availability

SECTION I—INTRODUCTION AND SUMMARY

More than a year has been spent in an intensive study of petroleum supplies. This study reviews present and future supplies, domestic and foreign, but with particular attention to the prospects for the United States. Thousands of hours of work have been spent on it by scores of experts in the industry. Numerous meetings have been held at various stages of the work. Well known experts, qualified by both training and experience, have taken part in the preparation of this report. Many of these men had worked on the report on availability prepared by the American Petroleum Institute in 1948 and the report issued by the National Petroleum Council on "U. S. Crude Petroleum Productive Capacity" in January 1950. As a result, this report reflects the best judgment of oil industry specialists who have studied this subject for years.

The major finding of our studies can be summarized briefly:

> **Available supplies of oil and gas in the United States and the world are greater than ever before and are still increasing rapidly. Granted continuation of reasonable economic incentives and adequate supplies of materials, crude oil and natural gas may be counted upon to be available in abundance for the foreseeable future.**

The facts and analyses which led to this conclusion are summarized in this introduction. The second section of the report deals with supplies expected through 1955. The final section deals with the long-term outlook, based on analysis of the main forces determining oil supplies.

Basis of the Present Report

On December 1, 1950, Mr. H. A. Stewart, Director of the Oil and Gas Division of the Department of the Interior, requested the National

Petroleum Council to make a "comprehensive study of present and probable future petroleum productive capacity and availability to the United States, including gas as well as liquid petroleum, foreign as well as domestic sources."

At a meeting in January 1951, this Committee was appointed by the National Petroleum Council to make a study of petroleum availability. The Committee divided its work into two major phases. The first dealt with supplies available now and the probable range through 1955. The second phase was a study of the long-term outlook.

Intensive studies were made of the range of available domestic and foreign supplies expected from 1951 through 1955. For the United States, the work was done for each of five major areas by groups of specialists. Both oil and natural gas were considered. The results of these area studies were reviewed and combined into national totals.

Foreign supplies were studied by major areas. The estimates have been presented by hemispheres, as the course of development among countries may change as new discoveries are made. Natural gas was not considered in foreign areas, although in time it may be an important source of energy.

Estimates of available domestic and foreign supplies through 1955 are presented in Section II.

The long-term outlook was studied by several different groups of specialists. They considered the natural occurrence of oil in the earth, technology, and economics. Separate reports by these groups were brought together into the composite summary presented in Section III.

Approach to the Problem

The study requested was undertaken as a scientific inquiry. We have worked to assemble, analyze, and evaluate all the data bearing on the problem. We have sought to give as full an answer as possible. Some questions, such as how much oil remains to be found, involve speculations about unknowns which make numerical estimates of questionable value, if not dangerously misleading. Consequently, the evidence available on this subject has been presented as an analysis of future prospects in order to avoid the dangers of speculative estimates.

Our study has been approached with full realization of its difficulties. We do not believe that in 1900 or 1925 the best informed opinion of the industry would have considered probable the actual developments which have taken place in petroleum. We know that as recently as 1946 industry experts were presenting to Government committees estimates of demand and supply which have already proved to be conservative. We know that a similar projection of available supplies made in 1948 by the American Petroleum Institute has been exceeded. These facts are cited as a reminder of the difficulties of predicting what a dynamic industry can accomplish.

A consistent underestimating of the future is apparent in past estimates about the oil industry. It is natural that we should tend to be conservative in looking forward into an unknown future. Many of the forces that will shape that future are still to be determined by individuals and governments. A cautious view seems wise under such circumstances. We have tried in this study to be as realistic as possible. Still, the future may prove that we have been conservative in projecting how far and how fast we may move ahead.

Any estimate for the future must consider past experience. Future estimates are largely a projection of what we have learned in the past and what we know now. One fact stands out clearly from the oil industry's past; namely, the remarkable rate at which supplies have been increased. A backward glance at 1925 and 1900 shows the following changes in the production of mineral fuels in the United States. (See Table 1.)

The heat value of oil and gas produced in the United States more than tripled between 1925 and 1950. Domestic oil and gas supplies now exceed those of coal substantially in heat value. Thus, despite past fears that we had very little oil, a dynamic petroleum industry has been able to serve consumers well by a great increase in supplies in direct competition with other energy resources. If this change seems strange in terms of the common view that our resources of coal are much greater than those of oil, it is only because there has been confusion between potential resources and their actual economic availability.

The Meaning of Availability

An inquiry as to available supplies requires an answer in economic rather than physical terms. It must deal with the ability to supply a commodity at a price which makes it of value. The mere existence of a mineral in a natural state does not mean that it is available. Even known valuable minerals may be worthless because the cost of making them available is greater than their value.

A simple example proves that material existence is not the same as economic availability. A cubic mile of sea water has about $93,000,000 in gold and $8,500,000 in silver. These precious metals in the oceans are enough to make every person in the world a millionaire. They have not made us rich for a simple reason. The cost of extracting them exceeds their value. Thus, gold in the ocean is not available to us even though we know it exists. It might as well not exist unless technology develops enough so that we can recover it at a cost that makes it of real value.

TABLE 1

Mineral Energy Production in the United States*

	Coal Million Tons	Crude Oil Million Barrels	Gas‡ Billion Cu. Ft.	British Thermal Units—Trillions				Per Cent of Total		
				Coal	Oil	Gas	Total	Coal	Oil	Gas
1900	270	64	128	7,020	369	254	7,643	91.9	4.8	3.3
1925	582	764†	1,189	15,195	4,430	1,278	20,903	72.7	21.2	6.1
1950P	560	1,972†	6,124	14,542	11,438	6,583	32,563	44.7	35.1	20.2

* Bureau of Mines, Preprint from Minerals Yearbook 1950, *Coal—Bituminous and Lignite,* page 59. In this tabulation the Bureau of Mines has used revised values for heat content as follows: 26,200,000 B. t. u. per ton of bituminous coal and lignite, 25,400,000 B. t. u. per ton of anthracite coal, 5,800,000 B. t. u. per barrel of crude oil, and 1,075 B. t. u. per cubic foot of natural gas.

† Excludes production of natural gasoline in 1925 of 27 million barrels and of natural gas liquids in 1950 of 181 million barrels.

‡ Marketed production of natural gas.

P Preliminary.

Future available supplies of fuels have not been viewed generally in economic terms. In comparing future fuel resources of the United States, estimates of the total amount of coal and lignite underlying the surface of the United States have usually been compared with proved reserves of oil and natural gas. Such comparisons are meaningless. They fail to consider (1) whether the solid fuels are economically available and (2) potential petroleum resources that may be found in the future. The difference between estimates of coal reserves and those commercially available is expressed in the following statement:

> "One conclusion should be crystal-clear from this estimate of the coal reserves in the United States: Unless truly fantastic improvements in the state of the arts are achieved, our descendants will have to pay far more for coal than the prices paid both in the past and at present. Large portions of the coal reserves listed by Campbell are of such poor quality, are located in such out-of-the-way corners, are so unfavorable as to thickness of vein, depth, etc., that only unheard-of ingenuity or desperate need will render them available for use. In other words, they are not commercial reserves now, and they may never be." *

The petroleum industry almost always deals with known, recoverable reserves. Estimates of proved reserves are limited to that part of discovered oil which can be recovered by known methods and at present levels of costs and prices. None of the large quantities of oil known to exist in proved fields but not expected to be recovered by prevailing methods of production or at prevailing prices are counted as reserves. Reserve estimates are modified as development indicates more oil in place or more productive acreage, or experience demonstrates that improved technology, lower costs, or higher prices will permit greater recovery than previously expected. They are made field by field and are not approximations for large areas, as in the case of estimates of coal.

Failure to take into account economics has caused considerable confusion in thinking about available fuel resources. Coal and lignite have been stressed as far outweighing oil and gas, without any consideration of the costs of making them available to fuel-consuming areas. Potential supplies of oil and gas have been underestimated by considering only the presently proved reserves or conservative estimates, amounting to minimum figures of the lowest possible order of magnitude, of what may be found in the future.

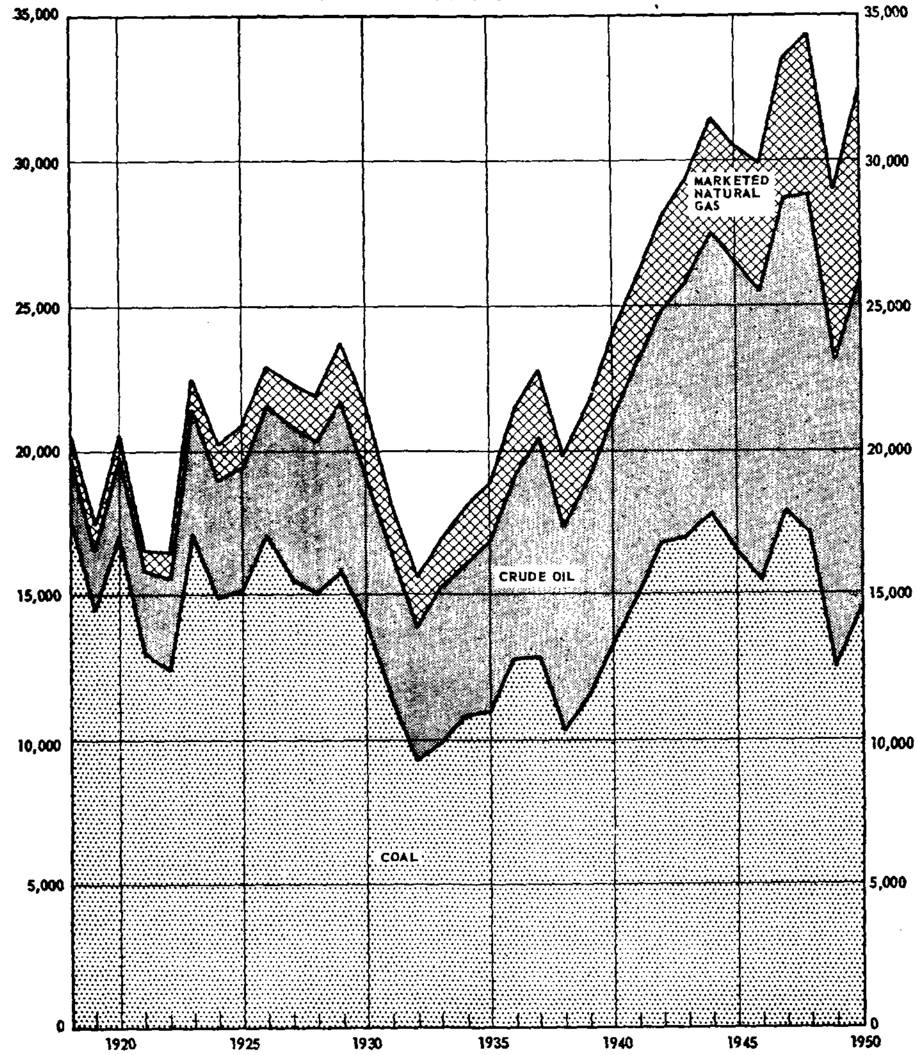
Consideration of the fuel resources of the United States must face economic realities. In spite of past comparisons indicating much more coal available than oil and gas, the fact remains that oil and gas have been the source of all the increase in mineral energy produced in the

* Zimmermann, Erich W., *World Resources and Industries*, Rev. Edition, page 462.

CHART I

U. S. Mineral Energy Production

Trillion British Thermal Units



United States since 1920 (See Chart 1). While proved reserves of petroleum have increased greatly, estimates of probable ultimate coal reserves have been reduced substantially. Such changes mean that the oil industry has been able to discover, develop, and deliver increased petroleum resources at attractive prices by comparison with competitive fuels. Thus, an inquiry as to future fuel supplies must concentrate on as the annual rate of production at that time. Nevertheless, the United States did not run out of oil in six years. Recoverable proved reserves of crude oil and natural gas liquids at the end of 1950 were 29.5 billion barrels. The production of oil in the United States in the period 1926-1950 was 34 billion barrels. In other words, the 59 billion barrels of oil produced and added to reserves since 1926 are thirteen times as much as the estimate of proved reserves in 1926.

Forces Determining Availability

How has it happened that the availability of oil and gas has increased rapidly while that of coal lagged behind? The trend might have been expected to be the other way on the basis of views as to the potential resources of these fuels. The answer to this apparent paradox is simple. Availability of any mineral is determined more by economics and technology than by mere physical existence.

Supplies of a resource are determined by three factors: (1) natural existence, (2) technology, and (3) economic incentives.

If a material does not exist in nature, it cannot be made available. Even if a material exists in nature, its availability depends upon a technology capable of locating and supplying it at a price that causes it to be in demand. Finally, economic incentives are necessary to develop availability even after deposits, technology, and markets are established. Without adequate economic incentives, no new capital will be risked to locate or develop new deposits needed to supply future demands.

These three factors have been considered at length in the studies of this Committee and in the preparation of this report. In the final analysis, it is economics which makes an available resource out of natural deposits. The petroleum industry has been able to develop supplies of oil and gas in proportion to the demand. When economic depressions have brought about a decrease in demand, there has been a slowing down of the search for more oil. When the demand for oil and gas has advanced rapidly, the search for and development of petroleum resources has been increased. To date, development of new supplies has been closely related to the rate of drilling.

Despite increasing difficulty and expense of finding oil, the industry has been able to continue supplying its products at reasonable prices by means of improved techniques. The price of crude oil today is less than it was in 1920, although commodity prices generally are higher now than then. Whether such relation can continue will depend on the balance of forces at work on costs. Thus far technical progress has been a major factor in keeping the cost of oil low. Such progress may well continue to affect the long-term trend.

the significant question of economic availability, not the theoretical question of potential resources. This study centers, therefore, on the prospects for continuing to find and develop new petroleum supplies at a cost that will permit or encourage their use.

The Record of Fuel Availability, 1900-1950

The rapid increase in availability of oil and gas relative to coal is evident from the record. In 1900 the availability of oil and gas was only 10 per cent as much as that of coal. By 1925, petroleum availability had increased ninefold and was nearly 30 per cent that of coal. During the past twenty-five years, coal availability has shown practically no increase while oil and gas more than quadrupled. As a result, petroleum now exceeds coal substantially in availability as well as in actual consumption. The figures on the availability of these fuels in volume and heat value are compared below:

TABLE 2

Availability of Coal, Oil, and Gas in the U. S.

	Coal and Lignite Capacity at 280 Days (Million Tons) *	Liquid Petroleum † (Million Barrels)	Natural Gas** (Billion cu. ft.)	Trillion B.t.u.‡	
				Coal & Lignite	Oil & Gas
1900.......	312	64	236	8,129	623
1925.......	810	791	1,189	21,173	5,857
1950.......	824	2,665	8,805	21,554	24,860

* Basic Data Relating to Energy Resources, Senate Committee on Interior and Insular Affairs, 1951, page 73, for bituminous coal and lignite. The latest capacity shown was for 1949 and that figure has been used for 1950. Capacity on anthracite coal was assumed to be the same as production shown on page 78.

† Production of crude oil in 1900 and crude oil and natural gasoline in 1925 considered to be at capacity; 1950 availability based on estimates for January 1951.

** Production of natural gas in 1900 and 1925 considered to be at capacity; 1950 availability represents the average of the upper and lower ranges of 1951 availability.

‡ Based on 26,200,000 B.t.u. per ton of bituminous coal and lignite, 25,400,000 B.t.u. per ton of anthracite coal, 5,800,000 B.t.u. per barrel of crude oil, 5,500,000 B.t.u. per barrel of natural gas liquids, and 1,075 B.t.u. per cubic foot of natural gas.

The great increase in availability of oil and gas has been achieved despite the low estimates of proved reserves. In September 1926, the Federal Oil Conservation Board reported that proved reserves were estimated at about 4.5 billion barrels or only about six times as much twenty-five years earlier. In Canada it was thirty-three years after the first major discovery at Turner Valley in 1914 before the full possibilities of the area became apparent with the discovery of Leduc, some 190 miles northeast of Turner Valley.

Future availability of oil is frequently approached on the assumption that each new field reduces the possibilities of further discovery. A discovery may mean one less field to be found, but it may also mean that (1) remaining fields will be found more rapidly or (2) that it will lead to discovery of fields that might not be found otherwise. The discovery of a new producing field provides additional information as to formations and structures in which more oil may be found. The discovery of production in reef formations in Scurry County, for example, suggested the search for oil in places where other new oil fields have been found in West Texas. The discovery of the Leduc field in Alberta, Canada, led to numerous additional important discoveries in the same area. The recent discoveries in the Williston Basin in North Dakota and Montana suggest possibilities for locating oil fields in a vast new province. These examples illustrate the manner in which new discoveries add to the knowledge by which the petroleum industry finds additional fields. Discoveries of new fields frequently improve, rather than decrease, the possibilities of finding more oil.

Most of the drilling to date has been to the relatively shallow formations. As a rule the wells drilled in the search for oil have been stopped at the first important producing horizon reached. Only subsequently has the search been carried deeper in some of these fields, frequently with the discovery of additional producing horizons. To date, by far the major part of the oil discovered has been at depths less than 5,000 feet. Up to January 1, 1950 only about 600 exploratory wells had been drilled below 12,000 feet, although in a large part of the prospective area the sediments in which petroleum deposits may occur extend deeper than 15,000 feet. As technology has improved and made deeper drilling feasible, a great new volume of prospective area has opened up for testing in the future. Important discoveries have been made in recent years at depths that would have been beyond the technical or economic limit prior to 1940.

Available evidence proves that large additional discoveries of oil and gas may be expected. They will occur in both present major producing areas and prospective areas and at depths ranging from shallow to very deep. The amount of oil and gas deposits remaining underneath the surface of the United States may be many times the quantity discovered to date. There is no satisfactory way of estimating the oil and gas reserves underlying the surface or what part of that volume will be found and developed commercially. It would require the drilling of an

The Existence of Petroleum Deposits

Large areas are favorable for accumulation of oil in the earth, both in the United States and in foreign countries. The sedimentary area considered favorable for petroleum deposits covers about 80 per cent of the surface of the United States. Early in 1951 a symposium on the possible future oil provinces of North America conducted by the American Association of Petroleum Geologists showed that 1,660,000 square miles in the United States are considered to have prospects for future production. Part of the prospective area overlaps some parts of producing provinces, but the producing provinces have 200,000 square miles in addition to the 1,660,000 square miles included in the future prospective areas. The prospective area amounts to one billion acres, or about one hundred times as much as the area proved productive by all discoveries to date.

Some measure of the potentialities of the prospective petroleum provinces is indicated by the following:

1. Of the 34 provinces considered to have possibilities in 1941, 20 have already proved to have production during the past ten years.
2. In 43 of the 60 provinces listed in the 1951 symposium there are positive evidences of the existence of oil and gas, such as seepages, good showings in the wells drilled to date, or some actual production.
3. About 15 per cent of the area in the 60 provinces listed in the latest symposium is already under lease.

It should be noted that a long time is required to explore a province even after initial discovery of production. In Texas, major discoveries continue to be made regularly more than fifty years after the first impressive discovery at Spindletop. Many of the large fields in Texas, including the huge East Texas field, have been found since 1929. It was 1949 before the Spraberry Trend in West Texas began to be developed commercially, although it will probably prove to have the largest productive area of any field yet found in the United States. A few additional examples from many possible illustrations show that important discoveries continue to be made in old areas for a long time. The recently discovered gas field in Leidy township, Pennsylvania, is only about fifty miles away from the famous Bradford field discovered about 1875. A major field was found in 1950 at Castaic Junction, California, within four miles of the first commercial production in that state at Pico Canyon in 1876. The North Snyder Reef field in Scurry County, West Texas, was discovered in 1948 quite close to the Sharon Ridge discovery of and developing oil at an accelerated rate, roughly in proportion to the amount of drilling. There has been a steady expansion of production and proved reserves. In other words, the rate of development of new oil has increased with demand. This achievement results from better ways of locating and producing petroleum. Evidence on this point is presented in Section III. It is mentioned briefly here because it is the basis of our conclusion that availability of oil and gas can continue to increase.

The technology for locating oil has improved dramatically through the years. The widespread use of geology dates from about 1915 and is still increasing. The application of geology to surface evidence and subsurface conditions has been supplemented within the past quarter century by geophysical methods. Refinements in geophysical methods, plus the accumulation of additional knowledge through drilling, result in the location of many prospects and fields which could not have been found by earlier techniques. Aerial reconnaissance and the use of helicopters hasten the search for oil in areas previously inaccessible. Various methods of testing formations have been devised and improved to locate productive horizons. Improvements in all phases of exploration are constantly being made, with the result that new fields are being located at record rates.

Production technology also has advanced tremendously. Drilling methods make it possible to carry wells to depths unheard of twenty-five years ago. Now we can produce horizons that would have been overlooked or dismissed as non-commercial in earlier days. Understanding of the behavior of fluids in a reservoir and the adoption of conservation practices have increased the amount recoverable from many fields. Wider spacing of wells makes it possible to develop economically fields with a small recovery per acre. Such fields might not have been commercially productive in the days of close spacing. Longer life for wells and other methods of reducing costs have added to the recovery of oil. These and other methods by which improved technology has added to availability in the past and will add to it in the future are discussed in Section III.

Economic Factors Affecting Availability

Technology is important but economics is controlling in determining availability of oil and gas. It is the hope of realizing a profit which spurs operators to search for oil and to improve technology. A change in the price of crude oil relative to costs automatically affects incentive. It may thereby influence future availability apart from changes in technology and prospects. Economic factors affect both demand and supply. They influence not only how much oil is available but how that oil will be used in meeting fuel requirements.

enormous number of wells through the entire sedimentary column all over the United States to make such an estimate. It would take literally hundreds of years to drill just one exploratory well per square mile in the prospective area of the United States at the 1950 rate of over 5,000 wildcats drilled in the search for new fields.

The conditions and circumstances described lead to the conclusion that it is impossible to make a satisfactory estimate of the amount of oil to be discovered in the United States in the future. The United States Geological Survey in 1951 stated this conclusion as follows: "The time has not yet arrived when a definitely accurate estimate of ultimate potential production can be made." * The United States Geological Survey added the following positive statement on the future outlook:

> "If the future can be judged by the past, oil and gas will be found in sufficient quantities for many years to come. In the United States adequate production has been a direct function of economic incentive. Until the unpredictable date at which that incentive fails to provide the needed supplies, there will be no convincing evidence that we have reached the limits of our ability to expand the potential ultimately recoverable reserves of petroleum." *

Existing conditions and expert opinions indicate that we may continue to count on ample supplies of oil for a long time. It may well be that other sources of energy, such as solar heat or nuclear fission, will decrease the economic importance and need for petroleum before the industry has time to locate or test all the deposits that exist.

In the opinion of this Committee there is reason to believe that the quantity of oil remaining to be discovered is of a large order of magnitude. It will take a very long time at current or accelerated exploration rates to test the prospective area thoroughly.

With respect to foreign resources, it is only necessary to mention briefly that vast deposits have already been located in the Middle East, Latin America, and Canada, principally by American companies. These resources have been found with a fraction as much exploratory effort as in the United States. Since the sedimentary area in foreign countries is very large, there is still much exploration to be done abroad. The excellent results of the early stages of foreign exploration indicate that tremendous foreign oil deposits remain to be found.

Technical Factors Affecting Availability

The technology to discover and develop petroleum resources is extensive and constantly improving. The industry has been finding

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* United States Geological Survey, *Fuel Reserves of the United States,* 1951, pages 30, 35. (A statement prepared for the Senate Committee on Interior and Insular Affairs.)

Tax policies are among the economic factors affecting availability of petroleum. Income taxes, particularly at high rates, have an adverse effect on availability by their influence on incentive and on funds available for further development.

Income tax provisions with respect to natural resources involve peculiar problems in that production of such resources represents the liquidation of the basic capital. Since income taxes are expected to apply only to ordinary income, special provisions are needed in order to protect producers of oil and gas against unfair and excessive taxation as they produce their capital assets (oil and gas). The capital in a petroleum-producing property cannot be considered merely the amount of money invested in it. Such a narrow view overlooks the large amounts of capital risked and lost on unsuccessful ventures. Unusual measures are required to deal with these special circumstances. Congress has had to devise special tax provisions to provide fair tax treatment and to encourage continuance in the business by oil and gas producers. During the past twenty-five years these provisions have been in the form of percentage depletion.

Congress recognized the peculiarities of oil production in the early application of income taxes by providing that a producer should be allowed to recover as capital the value of his property after oil was discovered on it. Subsequently, percentage depletion was substituted in 1926 as a simple, equitable method of allowing for discovery value. Existing provisions of the income tax laws have encouraged discovery and development of petroleum in the past. That has meant larger available supplies. Unfavorable changes in these provisions would decrease future discovery and availability, while liberalization would serve to stimulate exploration and increase availability.

Closely related to the economic factors affecting availability are state conservation laws. The passage of laws regulating the drilling of wells and the withdrawal of oil as a means of preventing waste and assuring equity among operators has added immeasurably to the recovery of oil. Additional recovery has meant more oil and reasonable prices. The regulation of production to market demand in order to prevent waste has increased long-term availability by checking the wastes involved in rapid dissipation of flush production.

Regulation of production to prevent waste (by the use of restrictions to maximum efficient rates and to market demand) reduces the violent fluctuations in the price of oil but does not fix the price. The effect of conservation is to give customers more oil at a lower average price than would prevail in the absence of conservation because of the lower investment and operating costs under orderly development.

The effect of economics on the ability of available oil supplies to satisfy requirements can be illustrated by the experience with respect to gasoline. The yield of gasoline from a barrel of crude oil in 1950 was 43 per cent, or twice as much as in 1917. One barrel of crude oil in 1950, therefore, was worth as much as two barrels in 1917 in terms of gasoline supplies. In addition, a gallon of gasoline of the quality supplied today provides 50 per cent more power than that supplied twenty-five years ago. Whether we use the extra power to get more mileage per gallon or to drive heavier, more powerful cars with the same mileage per gallon as before is a matter of economics and individual choice.

If we were really faced with a problem of limited oil supplies, it would be extremely simple to increase automotive mileage per gallon of gasoline by using from among engines now in production those with the lowest gasoline consumption. It would also be quite simple to increase the yield of gasoline substantially above present levels at some increase in costs. Such changes could extend greatly the period of years for which a specific quantity of reserves would suffice to meet demands. Consumers have not chosen to use technical progress to cut down on consumption of petroleum because the favorable combination of quality and low price achieved by the oil industry has made attractive the consumption of its products.

There must be reasonable opportunity for development of resources as well as economic incentives in order to bring about availability. Any government actions which interfere with the opportunity to search for oil will handicap future supplies. Nationalization, expropriation, or failure to permit exploration can retard drastically the development of supplies. Artificial controls of price or materials may do the same.

The experience of the United States demonstrates that a system of private, competitive enterprise results in a more active search for oil than one of government ownership or control. Although the United States has only a relatively small portion of the world's area favorable for the production of petroleum, the amount of oil discovered in the United States to date nearly equals total discoveries in the rest of the world. Such a significant difference is clearly related to the competitive search for oil in this country. Petroleum technology has been improved by American ingenuity under the stimulus of competition, and has then been carried to the far corners of the world.

The competitive search for oil by thousands of operators finds many fields that would be missed under a system of exploration by a government bureau or by a monopoly enterprise. There are countless examples of fields which have been discovered after numerous failures in the same area by other operators.

in production from 1946 to January 1951. Under favorable conditions, availability in 1955 may exceed production in January 1951 by more than 5,300,000 barrels daily.

TABLE 3

Changes in Production 1946-1951, and Projected Availability, 1951-1955, For All Petroleum Liquids—Thousand Barrels Daily

	U. S.	Excluding Russian Dominated Areas	
		Foreign	Total
1946 Production	5,074	2,243	7,317
January 1951			
Production	6,465	4,498	10,963
Availability	7,300	4,703	12,003
1955 Availability Range			
Lower	7,789	6,669	14,458
Upper	8,838	7,427	16,265
1955 Increase Over January 1951 Production			
Lower	1,324	2,171	3,495
Upper	2,373	2,929	5,302

Part of the domestic reserve productive capacity in 1951 resulted because imports of crude oil and products, particularly residual fuel oil, amounting to 825,000 barrels daily exceeded exports by about 420,000 barrels daily.

Available supplies of natural gas in the United States will also increase. By 1955 it is expected that they will be 9.5 to 11.9 trillion cubic feet annually, compared with production of about 6.9 trillion cubic feet in 1950 and 4.9 trillion cubic feet in 1946. No estimates have been prepared on foreign natural gas because of the relatively limited use of such gas for fuel.

Past experience indicates that even the upper range of supplies projected in these studies may be exceeded under favorable conditions. By January 1951, availability exceeded by 7.8 to 14.3 per cent the range which had been estimated for that time in 1948 by the American Petroleum Institute's Committee on Long-Term Availability. The rate of drilling exceeded the expectations of the industry as a result of high demand and improved economic incentives. Consequently, available

The actions of government with respect to taxes, conservation, price controls, and other matters can affect materially the search for and availability of petroleum. Government attitudes toward business enterprise can offset or reverse normal economic forces. Regulations which prevent or discourage further search for oil, whether in the form of nationalization, excessive taxes, interference with the development of new areas, or price controls, seriously decrease the availability of petroleum as compared with what would be achieved under normal economic forces. It is through the avoidance of restraints and handicaps to the search for oil and the maintenance of a favorable climate for investment of risk capital that government policy can contribute effectively to promoting greater availability of petroleum for the future.

The economics of price and cost is basic in determining availability of a resource. The availability of oil and gas has increased because the industry has been able to develop new resources at costs which permitted attractive prices for these fuels. Because of these attractive prices, the demand for oil and gas has increased nearly fourfold in the past twenty-five years.

The industry's achievements have been remarkable in controlling costs and keeping prices low despite the impact of inflation, the necessity of drilling deeper, and of other forces working toward higher costs. The great area available for exploration, improved technology, and wider spacing of wells have been the major factors back of this achievement. Costs have increased, frequently very sharply, for drilling and carrying on each operation, but the industry has worked diligently to overcome such trends with economical investment and better methods. Competition has spurred such efforts. Consequently, costs have been controlled and prices have remained at levels that are attractive in terms of other fuels, of commodity prices generally, or of the hours of work required by the average worker to buy a gallon of petroleum products.

Increasing Availability for 1951-1955

Granted continued adequacy of economic incentives and adequate supplies of steel, the availability of oil and gas in the United States and foreign countries will increase steadily during the next five years. Careful studies have been made of the probable range of available supplies. The details of these studies appear in Section II for 1951-1955.

Under the conditions set forth in Section II, it is estimated that the availability of petroleum liquids in 1955 will be higher than production in January 1951 by not less than 1,324,000 barrels daily in the U. S. and 2,171,000 barrels daily in foreign areas outside of those dominated by Russia. This minimum expectation is almost equal to the increase nology makes new forms of energy available at reasonable cost, other competitive fuels tend to lose position. Within the first half of the twentieth century coal has lost position to oil and gas. That change occurred not because of any lack of coal resources but for economic reasons.

No one can be sure what changes will occur in energy supplies in the next fifty years. Oil and gas may continue to gain position in the energy market, to hold their own in an expanding market, or lose position. The latter prospect, if it should occur, is more likely to be the result of economic competition from other forms of energy than from a lack of potential resources.

Our fuel needs for national security and economic progress are best served by competition. Abundant fuel supplies at low cost, which have meant so much in our economic progress, have been the result of competition. Any fuels policy interfering with that competition will be a threat to our future supplies of energy and will mean increased costs to consumers.

Summary

The present study of petroleum availability leads to the following conclusions:

1. Available supplies of oil and gas will continue to increase rapidly for the near future.
2. Large quantities of oil and gas remain to be found in the United States and foreign countries.
3. Techniques for finding and producing oil have improved greatly, are currently being improved, and will continue to improve.
4. Increasing availability of petroleum can be counted on in the United States and worldwide provided reasonable economic incentives and a favorable climate for private investment are maintained.
5. Energy from other sources at attractive prices may finally bring about a decrease in petroleum demand before any lack of prospects causes a decrease of available supplies.
6. Competition among fuels is the best way to supply our needs for energy at the lowest cost.

In short, the United States and the world can count upon increasing supplies of oil and gas not only for the next few years but for the foreseeable future provided that reasonable economic incentives, adequate materials, and a favorable climate for private investment prevail.

supplies outran the upper range projected in 1948. The present projection for 1951-1955 assumes a continuation of drilling at about the 1951 rate throughout the period. It may prove to be conservative if drilling increases to higher levels under the stimulus of rising demand or greater economic incentives.

The Long-Term Outlook

In 1900, petroleum production in the world was 400,000 barrels daily, half of which was in Russia. By January 1951, production of all petroleum liquids outside of Russian dominated areas had increased to nearly 11,000,000 barrels daily, whereas production of Russian dominated areas was estimated to be less than one million barrels daily. Clearly, petroleum availability increased rapidly in the first half of the twentieth century. The rate of discovery and development during this period has been upward and the proved reserves at the end of 1950 were the highest in the experience of the industry.

The outlook for development of petroleum resources during the last half of the twentieth century is favorable. Demand, reasonable economic incentives, and a favorable climate for private investment may bring about a further increase in availability of petroleum for many years to come. A study of potential resources suggests ample opportunity for still further development in the United States and worldwide. New sources of power may prove limiting factors on availability of petroleum before completed development of natural petroleum resources is approached. As usual in a free economy, economics will govern our choice and use of fuels.

The prospects for development of new sources of energy are real. Only recently authorizations have been made for the construction of the first submarine and airplane to be powered by plants using nuclear fission as a source of energy. At the end of 1951 the Atomic Energy Commission announced that useful electric power had been produced in Idaho for the first time by atomic energy. These developments suggest that it may not be long before atomic energy may provide a commercial source of power. In that case, petroleum and coal would be faced with major new competition.

Nuclear fission is not the only feasible form of energy that may be developed to compete with petroleum and coal. We may learn to harness the heat of the sun as an effective and economical source of power. Such a development might also foretell revolutionary developments in the field of energy which would be of economic benefit to all in the long run.

The role of different forms of energy in supplying power is constantly changing as a result of technology and economics. Such changes will continue to take place in any dynamic, free economy. As tech-

SECTION II—THE IMMEDIATE OUTLOOK FOR OIL SUPPLIES

Crude oil production has increased at a remarkable rate since 1900. (See Chart 2.) The rate of increase continues to be rapid. Analysis of the immediate outlook through 1955 indicates still larger supplies provided that several major conditions are realized. These conditions include continuation of reasonable opportunity and economic incentive to develop new oil, a legal and political climate which will not discourage the investment of private capital, and materials and manpower in amounts at least equal to those available in 1951.

Estimates have been made of the anticipated range of available oil supplies for the United States and foreign countries outside of Russian-dominated areas. The estimates indicate supplies available under efficient production practices. They are not a forecast of production, as demand may be less than the amount available. It is normal for the expanding oil industry to operate with some margin of spare capacity. A substantial reserve capacity exists now and probably will continue to exist for the near future in the absence of emergency conditions.

Projected development will mean an increase in available oil supplies through 1955 at a rate comparable with the rapid expansion of 1946-1951. (See Table 4.)

Except for upward revisions in foreign availability, the estimates in this report are the same as in the Interim Report presented to the National Petroleum Council on July 24, 1951. Revisions of the foreign estimates reflect accelerated completion of facilities in the Middle East following the loss of Iranian supplies. The earlier estimates had been made prior to the interruption of production in Iran.

The report on availability for the United States includes estimates of natural gas. Available supplies of natural gas are expected to increase substantially by 1955 even though the estimates are deliberately conservative because the limiting factor on the use of natural gas is still the capacity of pipe line facilities rather than the maximum efficient rate of production. It is estimated that by 1955 the range of available domestic supplies of natural gas will be 9.5 to 11.9 trillion cubic feet, compared with the actual production in 1950 of 6.9 trillion cubic feet. It is apparent from these figures that there is room for substantial growth in production and demand for natural gas.

TABLE 4

Changes in Production and Availability of Petroleum Liquids, Thousand Barrels Daily

	United States	Other Western Hemisphere	Total Western Hemisphere	Eastern Hemisphere	World	Estimated Russian-Dominated Areas*
				(Exclusive of Russian-Dominated Areas)		
Production						
1946	5,074	1,446	6,520	797	7,317	572
Jan. 1951	6,465	2,245	8,710	2,253	10,963	880
Increase	1,391	799	2,190	1,456	3,646	308
Availability						
Jan. 1951	7,300	2,319	9,619	2,384	12,003	
1955—Upper	8,838	3,279	12,117	4,148	16,265	
1955—Lower	7,789	2,903	10,692	3,766	14,458	
Increase 1951-55						
Upper	1,538	960	2,498	1,764	4,262	
Lower	489	584	1,073	1,382	2,455	

* Crude oil production only, based on reports of *World Oil,* February 15, 1951 and Bureau of Mines World Petroleum Statistics, January, 1951.

Availability of domestic petroleum in January 1951 exceeded the peak production attained during World War II (in the second quarter of 1945) by 2,130,000 barrels daily. The increase in availability since 1945 of more than 41 per cent results from the drilling of new wells and reflects the additions to proved reserves of crude oil and natural gas liquids. In the six years 1945-1950 there were drilled in the United States 211,000 wells, including 146,000 oil and gas producers and service wells. The increase in estimated proved reserves of petroleum during this period is shown in the following tabulation:

TABLE 5

Proved Reserves of Petroleum Liquids Estimated by the American Petroleum Institute

(Million Barrels)

	Crude Oil	Condensate	Natural Gas Liquids (Incl. Condensate)	All Liquids
Jan. 1, 1945..........	19,784.5	668.7	2,970.0-Est.*	22,754.5*
Jan. 1, 1946..........	19,941.8	885.0	2,990.0-Est.*	22,931.8*
Jan. 1, 1951..........	25,268.4		4,267.7	29,536.1

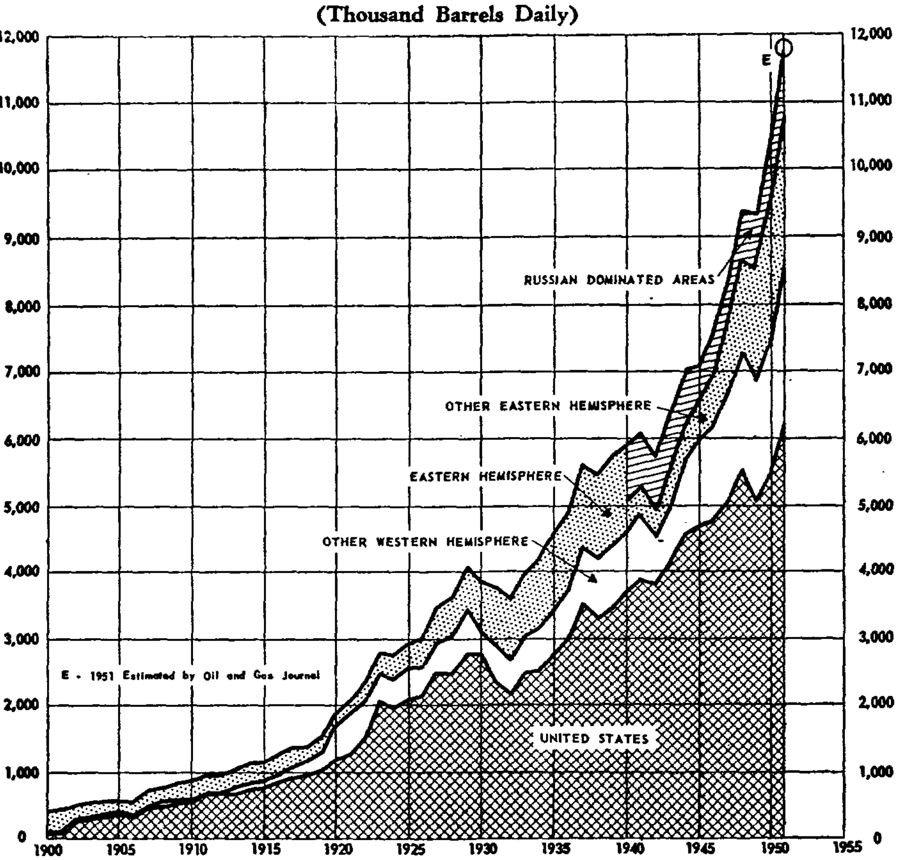
* Up to the end of 1945 the American Petroleum Institute estimated reserves of crude oil and condensate but not other natural gas liquids. After 1945 the reserve estimates were for crude oil and all natural gas liquids, including condensate. For the years 1946 through 1949 the reserves of natural gas liquids were 15.13 to 15.21 per cent of the estimated crude oil reserves. To arrive at 1945-1946 reserve figures comparable with that for January 1, 1951, reserves of natural gas liquids were taken at 15 per cent of the crude oil reserves.

The availability of domestic petroleum and the reserve productive capacity over production in January 1951 are set forth below by districts for the United States. (See Table 6.)

By January 1951 availability exceeded by 525,000 to 915,000 barrels daily, or a margin of 7.8 to 14.3 per cent, the range of availability which the American Petroleum Institute report on Long-Term Availability* in 1948 had estimated would be developed by that time. The availability developed by January 1951 was nearly as high as that anticipated under favorable conditions for 1953 by the API report three years ago. These comparisons show that the upper availability projected in 1948 on the basis of favorable developments has been achieved more than two years ahead of schedule. Availability has increased more rapidly

* Report on the Long-Term Availability of Petroleum by the National Oil Policy Committee of the American Petroleum Institute, November 1948.

CHART 2
World Crude Oil Production
(Thousand Barrels Daily)



The following sections summarize the reports prepared as a result of careful study of domestic and foreign prospects for petroleum development.

U. S. Availability of Oil and Gas, 1951-1955

(Report submitted to National Petroleum Council, July 24, 1951)

The availability of domestic petroleum continues to increase at a substantial rate. As of January 1951 the available production from the United States at maximum efficient rates was 7,300,000 barrels daily of crude oil and natural gas liquids, or 835,000 barrels daily more than actual production. Availability will increase still further during 1951 and the next four years, provided that steel supplies are not reduced below the levels requested for 1951 and economic incentives remain unchanged.

than projected by the American Petroleum Institute Subcommittee on Long-Term Availability principally because well completions have been greater than anticipated. This development emphasizes the fact that changes in availability are directly related to drilling.

The rapid increase in availability since 1945 has been due to additional drilling in recent years as more steel became available. During World War II drilling was curtailed drastically to save steel. Consequently, an average of only 12,000 oil wells was completed annually in the war years 1942-1945. Nearly twice as many oil wells were completed annually in 1948-1950, when the industry drilled about 23,000 oil wells annually. The number of wells drilled during the war years 1942-1945 was slightly less than adequate to maintain available production, as the availability from new wells did not quite offset the normal decline of old wells. The more rapid rate of drilling after 1945 had a great impact on availability because every additional well above the number required to offset decline increases availability by the full amount of its efficient productive capacity.

The increase in availability since 1945 was brought about by the expenditure during the past five years of about ten billion dollars for exploration and development. In the early part of the postwar period demand increased as fast as availability. By 1948, however, availability was increasing more rapidly than demand. A high level of activity continued through 1949 even though crude oil production and income decreased and demand remained relatively constant. In 1950 drilling increased to record levels as demand and production again moved upward. The large expenditures and high level of development activity in 1946-1950 served to provide the productive capacity which made it possible to meet record demands in 1950 and still have a margin of reserve capacity.

The factors which have developed new capacity and created reserve productive capacity have already been reviewed in a report submitted January 26, 1950 to the National Petroleum Council by a Committee on Crude Petroleum Reserve Productive Capacity.* These factors have been: aggressive competition in the search for oil, a market providing adequate economic incentives through reflection of changes in supply and demand, and conservation practices developed by the industry and state conservation agencies. The same factors will continue to be of major importance in the development of productive capacity, and any estimates of what such productive capacity may be in the future must take these conditions into account.

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* "U. S. Crude Petroleum Reserve Capacity," January 26, 1950, National Petroleum Council.

TABLE 6

U. S. Availability and Production of Petroleum, January 1951

(Thousand Barrels Daily)

District	Availability			Production			Reserve Productive Capacity		
	Crude Oil	Nat. Gas Liquids	All Oils	Crude Oil	Nat. Gas Liquids	All Oils	Crude Oil	Nat. Gas Liquids	All Oils
1—East Coast	54	19	73	54	19	73	0	0	0
2—Mid-Continent	1,083	72	1,155	1,077	72	1,149	6	0	6
3—Southwest	4,161	383	4,544	3,525	377	3,902	636	6	642
4—Rocky Mountains	350	9	359	292	7	299	58	2	60
5—California*	1,079	90	1,169	959	83	1,042	120	7	127
U. S.	6,727	573	7,300	5,907	558	6,465	820	15	835

* Including Elk Hills.

report represents the combined views of the members of these groups for their areas and of this Subcommittee.

The studies of future prospects indicate that substantial amounts of reserves and additional productive capacity will be developed in the next five years if present economic incentives are maintained and the industry can secure sufficient steel and manpower to continue at about the current level of operations, which includes the drilling of more than 43,000 wells a year. If additional steel were available, more wells would be drilled by the industry and greater availability would be developed to the extent warranted by demand and economic incentives. The estimates contained herein take into account existing limitations on steel, since these limitations currently determine the rate of drilling and the development of new petroleum availability. In addition, any substantial loss of key technical men to military service will make it difficult for the industry to carry on the exploration and development activities projected.

The Subcommittee has projected a range of availability which will result from the anticipated drilling. The lower figure of that range is one that can easily be attained with steel supplies continued at the rate allocated for 1951, while the upper figure may be attained with success in new discovery and development comparable with that realized during the past five years. It is estimated that by 1955 availability will be 7,789,000 to 8,838,000 barrels daily, a gain of 32 to 50 per cent in five years over the actual production of 5,900,000 barrels daily of all petroleum liquids in 1950. The estimated availability in 1955 exceeds the availability in January 1951 by an amount ranging from 489,000 to 1,538,000 barrels daily for the lower and upper cases. For the projected availability of all petroleum liquids see Table 7.

These estimates assume that there will be no reduction of the incentive to search for and develop new resources, that sufficient steel and manpower will be available, and that the development of the Continental Shelf will be permitted. Artificial price controls or large increases in taxes which affect the economic incentives for further development can upset the amount of development activity carried on by the industry and reduce availability. Interference with present or prospective markets for petroleum by arbitrary action limiting the uses which might be made of petroleum would also change the outlook for availability. Lack of steel to drill the number of wells projected or of personnel to carry out the program would affect directly the development of new productive capacity. Failure to permit and encourage development of the Continental Shelf may also result in less availability than anticipated in this report.

permitted to proceed immediately with normal development. Assuming that drilling is encouraged by prompt settlement and reasonable leasing, it is estimated that about one thousand wells will be drilled on the Continental Shelf over the next five years. These wells are estimated to increase availability from this area in the order of magnitude of 100,000 to 200,000 barrels daily, depending on the need for oil. Any delay in development will necessarily reduce availability within the five years below the estimate included in this report.

Natural Gas Availability

The Subcommittee has also made studies of natural gas availability. These studies considered separately gas associated with oil, including dissolved gas, and gas not associated with oil (non-associated gas) for each of the five districts in the United States. These studies merely indicate the magnitude of availability of natural gas, since the rate of withdrawal without waste from non-associated gas reserves is subject to considerable range. The Subcommittee has deliberately used conservative estimates of availability of non-associated gas because the limiting factor on utilization of natural gas at the present time is still the pipe line facilities for transporting gas. The current availability of natural gas substantially exceeds the combined total of local consumption plus the capacity of existing large pipe lines.

Availability of associated gas was determined in relation to the availability of oil with which it would be produced. Generally, the production of gas associated with oil is expected to maintain about the same relation to available oil production as at present. The estimated availability of associated gas in 1951 from wells existing at the beginning of the year represents 5.8 per cent of the proved reserves of associated and dissolved gas of 54.6 trillion cubic feet as of January 1. This rate of availability of associated gas is lower than the rate of depletion that

TABLE 7

U. S. Availability of Petroleum

(Thousand Barrels Daily)

Average For Year	Crude Oil Projected Range*		Nat. Gas Liquids Projected Range		Total Liquids Projected Range	
	Lower	Upper	Lower	Upper	Lower	Upper
1951	6,842	6,988	567	578	7,409	7,566
1952	6,976	7,333	620	674	7,596	8,007
1953	7,065	7,624	679	760	7,744	8,384
1954	7,105	7,854	676	773	7,781	8,627
1955	7,114	8,053	675	785	7,789	8,838

* These estimates assume that production is continuously at the maximum efficient rate. If production is less than availability at times the decline in availability from old wells will be reduced and the availability in subsequent years will be increased slightly.

It is estimated that the availability of crude oil production from the Continental Shelf is now about 18,000 barrels daily, or much less than had been projected in the 1948 report of the American Petroleum Institute. Major factors responsible for this unfavorable development have been the controversy raised by the Federal Government over the title to these lands, which had been considered to be owned by the states adjoining the Continental Shelf, and the high costs experienced in offshore operations. The uncertainty with respect to title has virtually halted exploration and development, and will affect activity on the Continental Shelf so long as it continues. In preparation of this report the Subcommittee has assumed that the controversy over title to these lands will be settled promptly and that the industry will then be permitted to proceed immediately with normal development. Assuming that drilling is encouraged by prompt settlement and reasonable leasing, it is estimated that about one thousand wells will be drilled on the Continental Shelf over the next five years. These wells are estimated to increase availability from this area in the order of magnitude of 100,000 to 200,000 barrels daily, depending on the need for oil. Any delay in development will necessarily reduce availability within the five years below the estimate included in this report.

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The availability of non-associated gas from wells existing January 1, 1951 was estimated to be at most 4.3 per cent of the proved reserves of non-associated gas of 130.6 trillion cubic feet. In the lower case, the rate of withdrawal from proved reserves of non-associated gas would be only 3.3 per cent in 1951. These rates of withdrawal are less than would occur in case of depletion over a 20-year life contemplated in many long-term contracts for large interstate transmission lines.

The estimates of natural gas availability arrived at by the Subcommittee range from 8.1 to 9.5 trillion cubic feet in 1951 to 9.5-11.9 trillion cubic feet in 1955. The upper availability estimate for 1951 is 39 per cent more than the production in 1950. By 1955, the estimated availability is 38-72 per cent more than the production in 1950. The following tabulation shows the estimated range of availability of natural gas:

TABLE 8

Projected Availability of Natural Gas
(Billion Cubic Feet Annually)

Year	Non-Associated Gas		Associated Gas		Total Gas	
	Lower	Upper	Lower	Upper	Lower	Upper
1951	4,738	6,149	3,326	3,398	8,064	9,547
1952	5,085	6,619	3,403	3,593	8,488	10,212
1953	5,398	7,055	3,462	3,760	8,860	10,815
1954	5,690	7,467	3,501	3,891	9,191	11,358
1955	5,966	7,860	3,523	4,003	9,489	11,863

Summary

The petroleum industry of the United States has accomplished the following in the past five-year period 1946-1950:

For Petroleum Liquids

1. Produced 10.2 billion barrels of crude oil and natural gas liquids.

2. Increased proved reserves of all petroleum liquids by more than 6.5 billion barrels, after replacing with new reserves the 10.2 billion barrels produced during the period.
3. Increased availability of all petroleum liquids to 7,300,000 barrels daily in January 1951 and to an estimated range of 7,409,000-7,566,000 barrels daily for the year 1951, compared with production in 1946 of 5,074,000 barrels daily, which was then about the availability at maximum efficient rates.

For Natural Gas

1. Produced 29.7 trillion cubic feet of natural gas.
2. Increased proved reserves by 37.8 trillion cubic feet, after replacing with new reserves the 29.7 trillion cubic feet produced during the period.
3. Increased net production of natural gas from 4.9 trillion cubic feet in 1946 to 6.9 trillion cubic feet in 1950.
4. Increased availability to an estimated 8.1-9.5 trillion cubic feet annually in 1951.

These achievements of increasing reserves and availability have been realized even though demand was at a high level at the end of World War II and continued to increase sharply thereafter. They are the result of an active program of exploration and development and of large capital expenditures.

Careful study of the prospects for future discoveries and development indicates that the present situation is about as promising as it was at the beginning of 1946. The higher rate of production now does mean that there is a larger volume of normal decline which must be offset before drilling can increase availability, but on the other hand, drilling is now at a much higher rate than in 1946.

Granted continuation of sufficient materials and manpower and the same incentives prevailing in recent years, the petroleum industry can increase still further availability of both oil and natural gas over the next five years. Careful studies show that by 1955 availability in the United States can be increased to the range of 7,800,000-8,800,000 barrels daily for crude oil and natural gas liquids compared with production of 5,900,000 barrels daily in 1950. Similarly, the availability of natural gas can be increased by 1955 to the range of 9.5 to 11.9 trillion cubic feet as against actual production in 1950 of 6.9 trillion cubic feet. Consequently, the petroleum industry will be in a position to meet increased demands for oil and gas during the five-year period 1951 through 1955.

The Immediate Outlook for Foreign Oil Supplies

The prospects for rapid development of foreign oil supplies are excellent for countries outside of Russian-dominated areas. (This report excludes throughout the following Russian-dominated areas: Albania, Austria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, Russia, Sakhalin, and Yugoslavia.)

Foreign areas have very great prospects for future discoveries. There has been relatively little exploration and drilling in these areas by comparison with the United States. With reasonable opportunity, there is no question that foreign oil supplies can be increased rapidly in the future. In fact, the adequacy of transportation facilities is likely to be the controlling factor on the amount of oil supplies that can be made available from foreign areas, rather than the productive capacity of the wells.

It must be noted, however, that large investments of private capital have been the basis of increasing oil supplies in foreign countries. Large additional amounts of private capital will have to be risked in order to continue this expansion. Such risks can and will be taken only if economic and political conditions remain favorable to private investment. This report assumes that conditions will continue to be favorable for private investment in foreign countries, that markets will warrant further rapid development, and that supplies of materials and manpower will be no less than in 1951.

From 1946 to January 1951 foreign oil production doubled, with an increase of 2,255,000 barrels daily outside of Russian-dominated areas. The average increase in availability anticipated in foreign countries from January 1951 to 1955 under the conditions set forth above exceeds the increase in production in the past five years. A particularly rapid development is projected for the Middle East.

Prior to World War II, foreign areas did not produce enough oil to meet foreign demand. Exports from the United States in excess of its imports helped to make up the deficit. Important developments in foreign production took place in the years 1939-1945. As a result, foreign areas emerged from the war with production approximately equal to their demand. At the end of the war the excess of supply over demand in the Western Hemisphere outside of the United States was about equal to the deficit of the Eastern Hemisphere. Since 1947 foreign areas have had an increasing margin of supply over demand and become net exporters of oil to the United States. Demand in these areas increased at a compound rate of over 13 per cent annually, but supply has increased even faster. (See Table 9.)

TABLE 9

Foreign Petroleum Production and Demand Excluding Russian-Dominated Areas

(Thousand Barrels Daily)

	Production‡			Demand			Balance		
	Western Hemis.*	Eastern Hemis.†	Total Foreign†	Western Hemis.*	Eastern Hemis.†	Total Foreign†	Western Hemis.*	Eastern Hemis.†	Total Foreign†
1938	859	606	1,465	488	1,297	1,785	371	−691	−320
**	—	—	—	—	—	—	—	—	—
1946	1,446	797	2,243	826	1,351	2,177	620	−554	66
1947	1,606	975	2,581	933	1,666	2,599	673	−691	−18
1948	1,779	1,368	3,147	1,049	1,799	2,848	730	−431	299
1949	1,815	1,700	3,515	1,093	2,040	3,133	722	−340	382
1950	2,056	2,102	4,158	1,237	2,346	3,583	819	−244	575

* Outside of the United States.
** War years omitted.
† Exclusive of Russian-dominated areas.
‡ Crude oil and natural gas liquids.

As a starting point for projecting future availability an estimate was made of productive capacity as of January 1951. At the time the estimate was made there had been no disruption of Iranian supplies. This estimate is presented in Table 10.

The loss of Iranian supplies about the middle of 1951 brought about accelerated completion of facilities in other Middle East countries. By July 1951, available foreign supplies had increased by 630,000 barrels daily over the level of January 1951, principally in the Middle East. This increase was realized through advanced completion of oil-handling facilities in Middle East countries other than Iran under the necessity of offsetting the decrease in Iranian production. Since Iranian supplies are potentially available and may again enter world markets in case of satisfactory conclusion of the dispute, it was necessary to increase estimates of available oil for 1951. For subsequent years the present estimates of availability are about 500,000 barrels daily higher than in the earlier Interim Report, reflecting the acceleration in availability of supplies from other Middle East countries.

Continued increases in productive capacity of foreign areas are expected over the next five years. The principal gains, as in the past, will probably be in the Middle East and Latin America. Important discoveries in Canada in recent years indicate that this area will have a more rapid development of supplies ahead than in the past. It is difficult, however, to predict the course of development by individual countries. Therefore, the estimates of available oil supplies have been projected in this report only for the Western Hemisphere and the Eastern Hemisphere, exclusive of Russian-dominated areas. These estimates have been made in terms of a range believed to indicate the probable developments. Separate estimates are presented of supplies of gas liquids available along with crude oil. Since these supplies are comparatively unimportant, a single estimate is presented rather than a range. The combined results of these estimates are shown in Table 11.

Available foreign supplies were estimated to be 4,703,000 barrels daily in January 1951 and 5,335,000 barrels daily in July 1951. Because of the sharp increase about the middle of the year, the estimate for July is higher than the average availability for the year 1951. By 1955, in the absence of interference with normal developments anticipated, availability in foreign countries exclusive of Russian-dominated areas is expected to be in the range of 6,669,000-7,427,000 barrels daily. (See Chart 4.) In all probability, the expansion of supplies from January 1951 to the year 1955 will equal or exceed the increase in production of 2,255,000 barrels daily from 1946 to January 1951. Supplies available

TABLE 10

Comparison of Productive Capacity and Oil Production for Foreign Countries Excluding Russian-Dominated Areas, January 1951

(Thousand Barrels Daily)

	Productive Capacity			Production			Reserve Productive Capacity		
	Crude Oil	Nat. Gas Liquids	All Oils	Crude Oil	Nat. Gas Liquids	All Oils	Crude Oil	Nat. Gas Liquids	All Oils
Canada	165	2	167	95	2	97	70	—	70
Latin America	2,130	22	2,152	2,126	22	2,148	4	—	4
Total	2,295	24	2,319	2,221	24	2,245	74	—	74
Europe and Africa	86	24	110	86	24	110	—	—	—
Middle East	2,000	—	2,000	1,874	—	1,874	126	—	126
Far East	270	4	274	265	4	269	5	—	5
Total	2,356	28	2,384	2,225	28	2,253	131	—	131
Total Area	4,651	52	4,703	4,446	52	4,498	205	—	205

for the world will advance even more because of the gains in the United States. (See Chart 5.)

Unfavorable political or economic developments may affect the rate or location of development of availability. The Iranian dispute, for example, accelerated expansion in other countries of the Middle East and the Western Hemisphere.

Where and at what rate foreign supplies will be developed will depend on conditions that prevail with respect to encouragement of investment of private capital.

TABLE 11

Projected Foreign Availability of Petroleum Excluding Russian-Dominated Areas

(Thousand Barrels Daily)

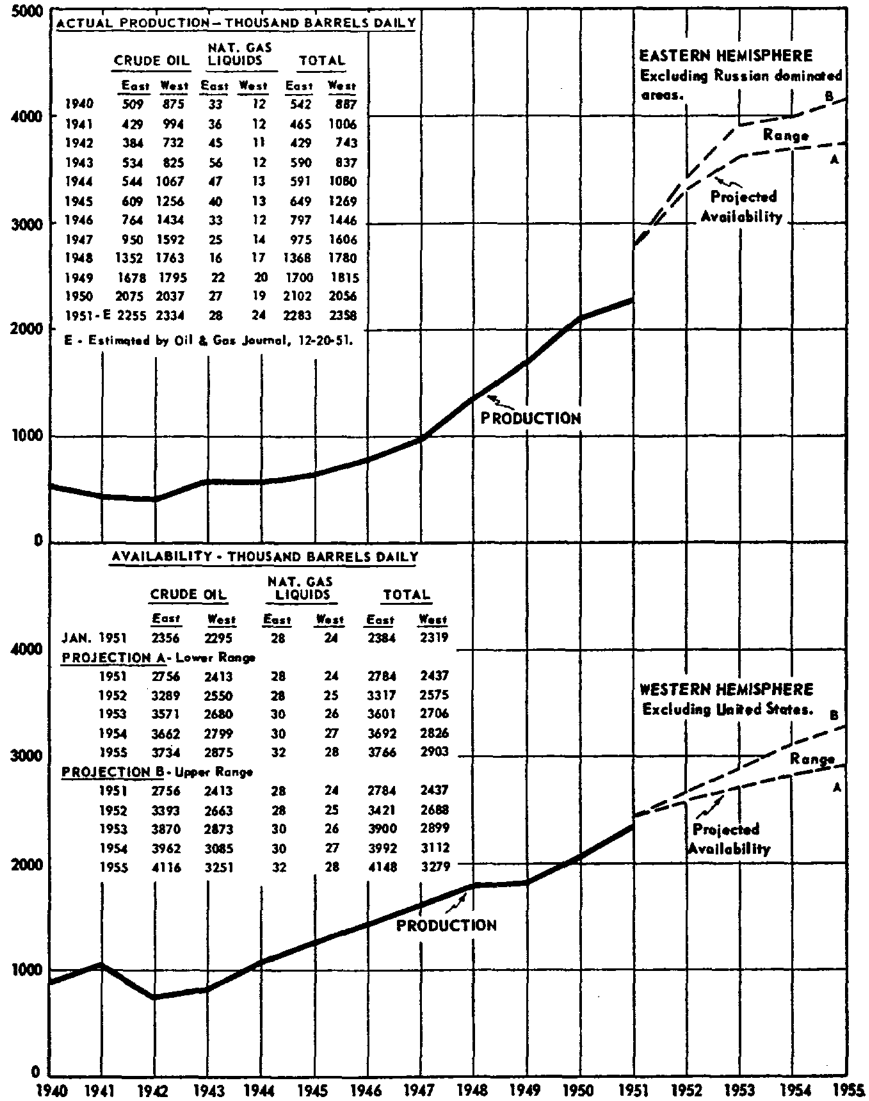
Annual Average	Crude Oil				Natural Gas Liquids		Total Petroleum	
	Western Hemis.		Eastern Hemis.		Western Hemis.	Eastern Hemis.		
	Lower	Upper	Lower	Upper			Lower	Upper
1951	2,413		2,756		24	28	5,221	
1952	2,550	2,663	3,289	3,393	25	28	5,892	6,109
1953	2,680	2,873	3,571	3,870	26	30	6,307	6,799
1954	2,799	3,085	3,662	3,962	27	30	6,518	7,104
1955	2,875	3,251	3,734	4,116	28	32	6,669	7,427

The rate at which crude oil productive capacity will be expanded in foreign areas will depend not only on the drilling of oil wells but also on the completion of many other facilities. Among the factors taken into account in these estimates are the facilities for handling oil in the field, the transportation facilities for moving crude oil to tide water, the installations required for the welfare of personnel, and the requirements for maintenance of plant and equipment. It is possible that such facilities may be completed even faster than projected in this report. Particularly in the Middle East, developments are underway which will add rapidly to availability in 1952 and 1953.

As recently as 1949, foreign oil production in the Western Hemisphere was greater than that in the Eastern Hemisphere outside of areas dominated by Russia. It is anticipated that future developments will bring about a much more rapid increase in supplies in the Eastern

CHART 4

Foreign Production and Availability of Total Petroleum Liquids
Excluding Russian-Dominated Areas
(Thousand Barrels Daily)



ACTUAL PRODUCTION – THOUSAND BARRELS DAILY

	CRUDE OIL		NAT. GAS LIQUIDS		TOTAL	
	East	West	East	West	East	West
1940	509	875	33	12	542	887
1941	429	994	36	12	465	1006
1942	384	732	45	11	429	743
1943	534	825	56	12	590	837
1944	544	1067	47	13	591	1080
1945	609	1256	40	13	649	1269
1946	764	1434	33	12	797	1446
1947	950	1592	25	14	975	1606
1948	1352	1763	16	17	1368	1780
1949	1678	1795	22	20	1700	1815
1950	2075	2037	27	19	2102	2056
1951-E	2255	2334	28	24	2283	2358

E - Estimated by Oil & Gas Journal, 12-20-51.

AVAILABILITY - THOUSAND BARRELS DAILY

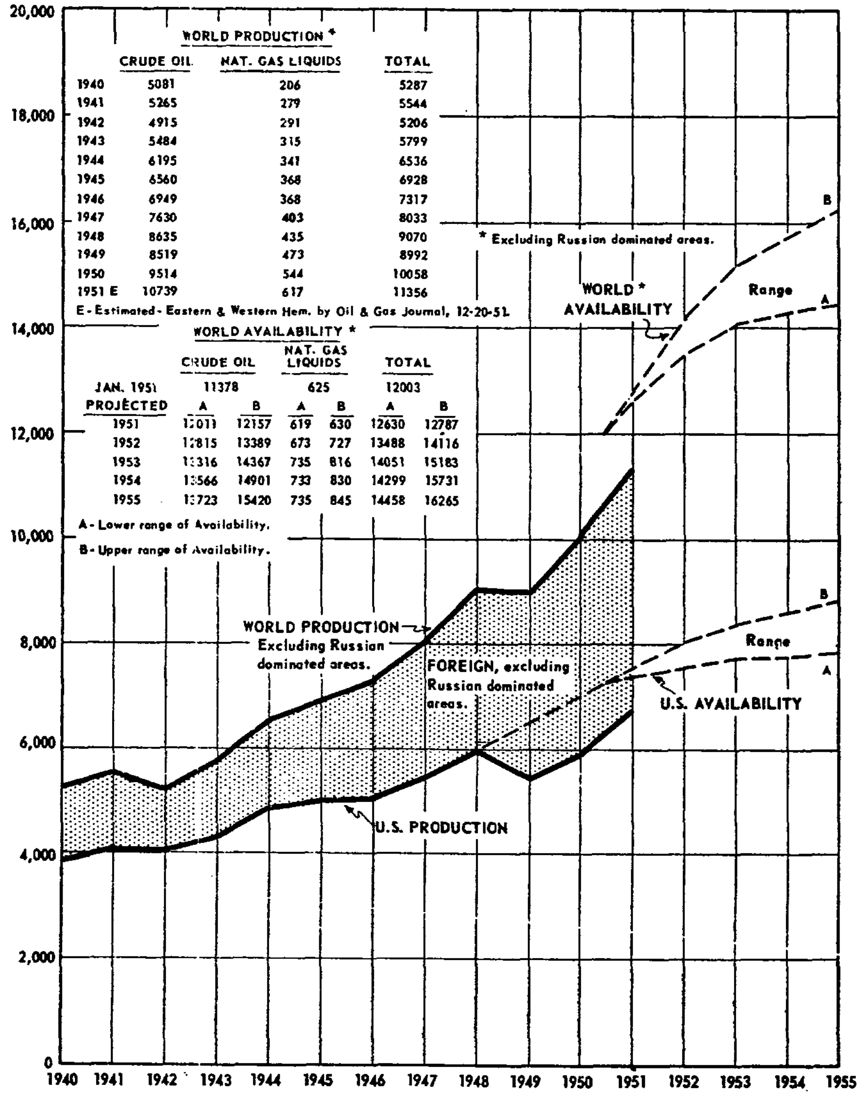
	CRUDE OIL		NAT. GAS LIQUIDS		TOTAL	
	East	West	East	West	East	West
JAN. 1951	2356	2295	28	24	2384	2319
PROJECTION A- Lower Range						
1951	2756	2413	28	24	2784	2437
1952	3289	2550	28	25	3317	2575
1953	3571	2680	30	26	3601	2706
1954	3662	2799	30	27	3692	2826
1955	3734	2875	32	28	3766	2903
PROJECTION B- Upper Range						
1951	2756	2413	28	24	2784	2437
1952	3393	2663	28	25	3421	2688
1953	3870	2873	30	26	3900	2899
1954	3962	3085	30	27	3992	3112
1955	4116	3251	32	28	4148	3279

Hemisphere than in the Western Hemisphere. Roughly two thirds of the increase in foreign oil availability anticipated for 1951-1955 is estimated to be in the Middle East and Far East. The limiting factor in developing availability in these areas probably will continue to be

CHART 5

World Production and Availability of Total Petroleum Liquids, Excluding Russian-Dominated Areas

(Thousand Barrels Daily)



transportation facilities, as the proved and prospective reserves capable of further development by drilling are large.

Careful studies indicate increasing supplies of foreign oil in the future, provided that favorable conditions exist for continued investment of private capital.

SECTION III—LONG-TERM PROSPECTS FOR PETROLEUM SUPPLIES

In the next few years, for which prospects can be judged by present knowledge, the outlook is for increasing supplies of petroleum. In terms of national needs we must consider the prospects beyond the next few years. Where do we stand today with respect to petroleum supplies for the long term? The world's oil and gas production is now closing a hundred years of commercial significance. In that century petroleum fuels have become a major factor in economic progress. They have changed our transportation, agriculture, industry, and our whole way of life. Particularly in the United States, our standard of living depends largely upon abundant supplies of mineral fuels. Can we count on ample supplies of petroleum and all fuels for the foreseeable future of twenty-five to fifty years?

Several facts bear on our future prospects. Our technology for finding and producing oil is better than ever before. The effort being spent on the search for oil is also at a high level. The areas remaining to be explored for oil in the United States and foreign countries are very extensive. These facts have an important bearing on prospects for future petroleum supplies.

Today the production of oil and gas far exceeds the most optimistic views of even ten years ago. World oil production has doubled in ten years. This year it will be greater than in 1925 by four times for the world and three times for the United States. Proved reserves are far greater than ever before and are still increasing rapidly. Such achievements could hardly have been anticipated in 1925. They have been made possible by progress in technology and a more intensive search for oil. They represent the high potential of a dynamic industry. The industry is doing more now than ever before to develop new supplies for our future needs. It is impossible to foretell how much may be achieved in the next fifty years. It would not be surprising, however, for supplies in the next fifty years to exceed those of the past half century.

In foreign countries, discoveries and production have been amazing relative to the small amount of exploration and drilling done. The Middle East alone already has known reserves about twice as large as those of the United States. It is producing only one third as much oil as the United States. Under favorable economic and political conditions it may in time supply more oil than the United States. Latin America is producing as much as the Middle East and is still in the early stages of development. Canada is just starting to develop its vast oil possibilities. There are other large provinces, such as Alaska, which may provide additional future supplies. Their development still lies ahead.

Foreign countries have an area favorable for oil finding ten times as large as that of the United States. Granted reasonable opportunity and conditions the oil industry may develop in these areas much more oil than in this country. Foreign countries are now producing less oil than the United States, but their rate of expansion since World War II has been greater. The continued rapid growth in foreign production anticipated through 1955 is only part of what may be expected for the long run if favorable conditions prevail. Judging by what we know today, the potential future world supplies of oil are very great. It might almost be said that we have just begun to scratch the surface of the world in the search for oil.

There seems little room for difference of opinion about the great amount of oil available in the world in the long run. Prospects must be measured in generations, and perhaps in centuries, rather than in decades. In case of peace and uninterrupted world trade, it might be expected that oil would move freely between countries. Exports and imports would normally balance oil supply and demand among countries as in the past. In an uncertain world, however, petroleum is of strategic importance. Dangers are involved in relying too much on imports of oil which might be cut off in an emergency. For that reason, we must consider with care the future supplies available to the United States.

A survey of prospects for oil in the United States is useful for several reasons. It will indicate the future outlook for an area in which there has been much exploration. It will indicate the forces which determine future supplies. Finally, it will deal directly with fears sometimes heard that we are running out of oil in this country.

The following sections will be limited largely to the United States, and particularly to its oil supplies. Natural gas will be dealt with only incidentally, as it is located and developed by the same processes as oil. Conclusions with respect to future prospects of oil will apply equally to natural gas. The analysis in the following sections will consider the forces determining oil supplies, the exploration process that makes oil available, the size of the prospective oil area, progress in development and recovery, economic factors, and the way in which fuel requirements can be met from different sources.

What Determines Oil Supplies?

Existence of oil in the earth does not alone determine available supplies. If mere physical occurrence governed supplies we would have had the largest amount available upon initial discovery and a constantly declining available supply since then. Actually, the trend has been exactly opposite. Available supplies have increased steadily since the discovery of oil.

Oil supplies are made available by a process of exploration, drilling, and recovery. In exploration we must first find oil in the earth. After we find oil we must drill enough wells to recover it. Finally, we must produce those wells for twenty to forty or more years in order to deplete a field. This process obviously takes a long time. The wells producing today will continue to produce for many years. The prospects already discovered by past exploration will continue to provide discoveries for many years. The exploration now being done will mean still more prospects to be tested and developed in the future. The combination of these forces will govern future supplies.

Future supplies are not determined by the reserves known today. The estimates of proved reserves prepared annually by the American Petroleum Institute are limited strictly to the oil which will be recovered from areas already proved and largely through wells already in production. These estimates represent only that part of the oil in place underneath the earth which is known to be recoverable under current operating practices and economic conditions. Revisions of these estimates are made as drilling provides additional information on the proved area in a field and as evidence develops that the recovery may be more or less than previously anticipated. Further drilling may extend the proved area of a field materially. Improved operating conditions may mean a larger recovery per well. Economies in production or an increase in price may extend the productive life and increase the recoverable reserves.

The estimates of proved reserves do not include any allowance for oil that may be found in the future. They are minimum figures which are subject to further revision, as development drilling extends the limits of known fields. These estimates deal with the industry's immediate underground inventory. The size of the proved reserves largely determines the rate at which supplies can be made available currently, but not the amount of future supplies. The industry is constantly drawing from its underground proved reserves by production, but it is also constantly engaged in exploration and drilling which add new proved reserves. Over the fourteen years for which estimates of proved reserves have been prepared annually by the American Petroleum Institute, the new oil developed through discoveries, extensions, and revisions has been 1.59 times as much as the oil produced. It is the development of proved reserves at a more rapid rate than production that increases available supplies. Clearly, proved reserves are not the measure of future supplies.

A common mistake made in discussing future oil supplies is to consider only proved reserves. Frequently these proved reserves are compared with the current annual production to arrive at the number of years that supplies will last. By such calculation it would have seemed almost any time in the past that supplies could last only ten to twenty years. On this basis there have been many predictions that we are running out of oil. Such predictions have been false in the past. They are nonsense today because they fail to consider the rate of oil finding and development. It is future discoveries, not presently known reserves, that will determine available supplies for the long run.

Statistics on proved reserves and production are set forth in Table 12 and shown on Chart 6. They provide proof that proved reserves are only part of the supplies available over a period of years. Two examples will illustrate this point: (1) In September 1926, the Federal Oil Conservation Board reported that known oil reserves in the United States were about 4.5 billion barrels. That much oil was produced in the next five years, but by then proved reserves had increased greatly. (2) At the end of 1937, known reserves were estimated to be 15.5 billion barrels. That much oil was produced in the next ten years. Still, at the end of 1947 the estimate of proved crude oil reserves was 21.5 billion barrels, or nearly 40 per cent higher than a decade earlier.

These examples show that the proved reserves at any time are only part of the supplies that will become available for the future. The total proved reserves become available over a period of years at the efficient rate of production from those reserves as they are depleted. In addition, large new supplies become available from the discovery and development of other reserves. The sum of the supplies available from wells producing today and from wells drilled in the future determines the long-term prospects for petroleum supplies. Available supplies really depend on the rate at which we search for and develop new oil. If we stop that process, the available supplies will decline, because the amount which wells can produce will decrease as they are depleted. If we carry on enough development to offset depletion caused by production, available supplies can be maintained at a constant rate. If the development of new reserves is at a rate exceeding production, available supplies will increase. To determine the prospects for future petroleum supplies, therefore, we must study with care the exploration process.

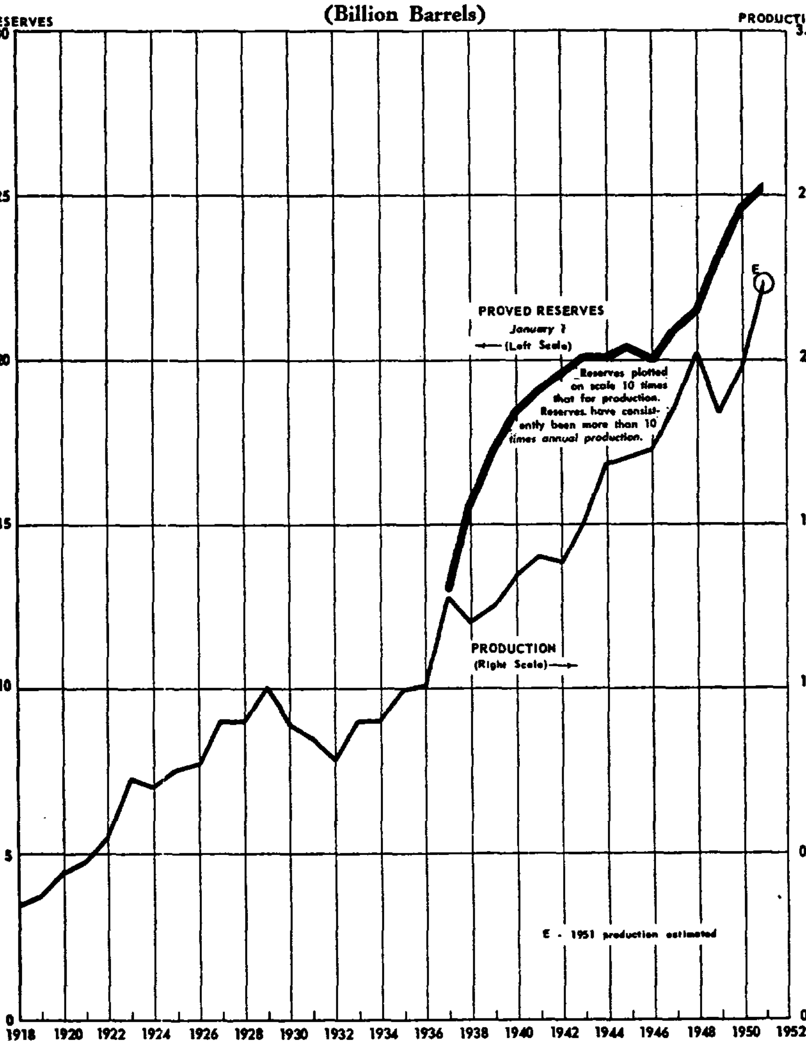
The rate at which we discover oil in the earth is a function of (1) knowledge and technology and (2) the effort spent on exploration and drilling. Both of these factors change with time. It is because of this

TABLE 12
U. S. CRUDE OIL PRODUCTION AND PROVED RESERVES

	Crude Oil Production* (Thousand Barrels)	Proved Crude Oil Reserves Million Barrels January 1	Ratio of Reserves on January 1 to Annual Production
1918	355,928		
1919	378,367		
1920	442,929		
1921	472,183		
1922	557,531		
1923	732,407		
1924	713,940		
1925	763,743		
1926	770,874	4,500.0†	
1927	901,129		
1928	901,474		
1929	1,007,323		
1930	898,011		
1931	851,081		
1932	785,159		
1933	905,656		
1934	908,065		
1935	996,596		
1936	1,009,687		
1937	1,279,160	13,063.4**	10.2
1938	1,214,355	15,507.3	12.8
1939	1,264,962	17,348.1	13.7
1940	1,353,214	18,483.0	13.7
1941	1,402,228	19,024.5	13.6
1942	1,386,645	19,589.3	14.1
1943	1,505,613	20,082.8	13.3
1944	1,677,904	20,064.2	12.0
1945	1,713,655	20,453.2	11.9
1946	1,733,939	19,941.8	11.5
1947	1,856,987	20,873.6	11.2
1948	2,020,185	21,487.7	10.6
1949	1,841,940	23,280.4	12.6
1950	1,971,845	24,649.5	12.5
1951	2,250,000 P	25,268.4	11.3

P—Preliminary.
* Bureau of Mines.
† Report of the Federal Oil Conservation Board to the President of the United States, September 1926, Part I, Page 8.
** American Petroleum Institute, 1937-1951, exclusive of natural gas liquid reserves reported at 4,267.7 million barrels on January 1, 1951.

CHART 6
U. S. Crude Oil Production and Reserves
(Billion Barrels)



change that the rate of discovery of oil varies, although the sedimentary area in which oil may be found remains constant.

Our knowledge of where we may find oil in the earth has progressed steadily. Initially, the search for oil was associated with surface showings in seeps. Later, a geologic theory was developed that oil might be found where there were anticlines in the structure of the earth. With the passing of time, other geologic conditions have been connected with the occurrence of oil. Faults, salt domes, stratigraphic traps, and reefs have been found to indicate possible accumulation of oil underground. Each new idea as to the conditions under which oil occurs opens up possibilities in old and new areas.

Our knowledge of subsurface geology grows by the hour with the drilling of more wells. In 1951 the industry drilled about 475,000 feet a day. About one fourth of this drilling is in exploratory wells that are being studied deliberately to find out where oil may occur. The information provided by these wells adds steadily to our knowledge of where we may find still more oil.

Technology also improves steadily. We have made great strides in the tools to hunt for oil, to reach it, and to locate its exact position in the earth. Similarly, progress has been made in equipment and techniques for increasing the recovery of oil after it is found. Thus, technology combined with knowledge adds to our ability to find oil.

The effort spent on the search for oil also changes. As more supplies are needed, we carry on additional exploration and drill more wells. The results of exploration with a specific technology have generally been about in proportion to the effort spent on the search for areas of similar geologic conditions. Available supplies for the future will be influenced by increases or decreases in the rate of search for oil. The rate of exploration and drilling may be influenced by economic forces independent of changes in prospects or technology.

Changing conditions with respect to knowledge and technology make it futile to predict how much oil remains to be found in the United States. The sedimentary areas in which oil may be found do not change, but our ideas of where oil may be found in that vast area constantly expand. Speculations as to how much oil will ultimately be found are necessarily limited by what we know today, as any allowance for future progress is only a guess. Past speculations on this point have proved conservative. They have had to be revised upward consistently as further experience and progress made it necessary to raise our sights. These speculations cannot even give us an approximate range, for they are subject to great change within a short time. Two illustrations show how conservative these predictions can be and how rapidly they may change.

In 1920 the United States Geological Survey estimated the oil remaining in the ground at 7 billion barrels and made the following statement about future supplies in its annual report:

"Fortunately, it is simply impossible to discover and take out the oil remaining in the ground in the United States, 7 billion barrels, in so short a period as eighteen years. Instead of mining our petroleum so rapidly we must either depend more and more on oil from other sources or get along with less oil. Our children will doubtless do both."

Since 1920 there have been produced in the United States about 38 billion barrels of crude oil. At the end of 1951 the proved reserves of crude oil and natural gas liquids in the United States will exceed 30 billion barrels. We have already found about ten times as much oil as the U. S. Geological Survey estimated remained in the ground in 1920, and are still finding oil at a rapid rate.

In the case of natural gas, one estimate of future supplies was revised upward by 70 per cent in a period of six years. This estimate of future production was changed from 300 trillion cubic feet or more in 1944 to 510 trillion cubic feet or more in 1950.* The later estimate was related to figures on the probable ultimate recovery of oil. Consequently, it would have to be revised upward as future experience causes a revision of the estimates of oil remaining to be discovered.

The preceding illustrations show the limitations of speculation about oil and gas reserves remaining to be found. It would have been foolish to base national policy with respect to fuels in 1920 on the assumption that only 7 billion barrels of oil remained in the ground. The speculations at that time were proved to be wrong by later evidence. Current speculations, which range widely in themselves and change rapidly, will probably prove to be incorrect. The error lies in trying to determine future discoveries on the basis of present knowledge, when all experience shows that these discoveries will be determined by the developments still ahead in the operations of a dynamic industry.

A fuller appreciation of the forces which will determine future oil supplies can be gained by an analysis of the exploration process. Consequently, the following section describes this process and the manner in which it will contribute to future supplies.

The Exploration Process

Oil in the earth is only a potential resource. Effort is required on our part to find it and make it available. Supplies are determined by the rate at which we develop new resources, not by the amount of the resources which may exist in the earth.

In the search for oil we are guided by the knowledge that petroleum may have accumulated in any sedimentary deposits, particularly those of marine origin. Wherever the subsurface contains sand, lime, or shale, there may be petroleum.

Of the three million square miles of area in the continental United States approximately 80 per cent consists of sedimentary formations considered favorable for petroleum deposits.† The oil and gas dis-

* Terry, Lyon F., "The Future Supply of Natural Gas" presented at the annual meeting of the American Gas Association, October 2, 1950.

† *World Geography of Petroleum,* page 21, American Geological Society, special publication No. 31, 1950.

covered to date has been developed on about one per cent of the prospective area. Future supplies will depend upon the rate at which we find oil in some 2,400,000 square miles of sedimentary area.

The sediments under the surface of the United States range in thickness from a few feet to 50,000 feet or more. Oil has been found at depths of less than 100 feet and greater than 15,000 feet. One well in Mississippi is reported to have encountered gas at a depth in excess of 20,000 feet.

There is no direct method of telling where oil exists in the vast sedimentary area. Through experience the industry has come to associate the occurrence of oil with certain typical geologic conditions beneath the surface. These conditions provide a situation in which deposits of oil and gas may have accumulated in some sedimentary formations and been sealed off or trapped, so that the accumulation is of commercial significance. Exploration is designed to find locations underneath which the geology may be favorable for the accumulation of oil. These locations are termed prospects. The prospects must be tested by drilling to determine whether the geologic interpretation is correct and whether petroleum actually exists. Only about one exploratory well out of nine drilled in non-producing areas finds oil or gas. Many of the discoveries are small and provide little return on the capital risked even though they add to reserves.

Geology and Geophysics

The chief tools used in locating specific areas under which oil and gas may lie are geology and geophysics. Geology is the study of the earth. Petroleum geology interprets surface and subsurface data. In many areas the manner in which formations outcrop at the surface provides clues as to subsurface conditions. In other areas, such as the plains, information on subsurface geology may be inferred from data provided by geophysics or by actual drilling of wells. Surface and subsurface geology are combined with geophysics as a rule in the scientific search for oil.

Around 1920 the principle of physics that sound travels at different rates in hard and soft formations was applied by what is known as geophysics. Small explosions of dynamite set off sound waves, and equipment located at various points around the explosion measured the time required by the shock to be reflected by formations underground. These measurements permitted interpretation of subsurface conditions even before wells were drilled. Subsequently, many refinements have been made in geophysics. The refinements permit better measurement, more accurate interpretation, and greater speed. Different geophysical methods may be used to supplement each other. They are used with other geologic information to select locations to be tested by drilling.

The intensive use of scientific exploration methods is relatively new. It was not until about 1915 that geology began to be applied generally to the search for oil. The application of geophysics came even later. The number of persons engaged in the scientific search for oil has increased steadily. In 1951 there were in operation in the United States some 600 geophysical crews and thousands of geologists.

The progress made in knowledge and techniques of petroleum exploration has been tremendous. Geologic concepts have advanced from simple principles to the recognition of many types of subsurface oil traps. Each new concept adds to the area in which we look for oil and helps find more oil.

The effectiveness of subsurface geology has been improved in several ways. Study of the wells drilled, whether productive or dry, has provided more pieces to fill in gaps in our knowledge of underground geology. New methods have been devised for obtaining precise subsurface information. Techniques for securing cores of the section being penetrated by a well permit careful study of the fossils and correlation with similar studies on other wells. Readings of conditions throughout the depth of a well by means of techniques known as electric loggings and radioactive logging provide detailed information not available otherwise. Recently a dipmeter has been developed which measures the angle of inclination of the sediments penetrated by a well. This information about the area surrounding the well may be valuable in finding or developing oil.

Many new inventions are adapted to the search for oil by the industry. Aerial mapping has provided a quick method of surveying large areas which might be difficult or take a long time to cover by conventional methods. Special aerial photographs when viewed with a stereopticon permit measurement of topographic features in three dimensional relief. Airplanes have also been used for rapid application of some geophysical techniques to large areas.

Geophysical methods have undergone marked improvement. The equipment has been made more reliable and sensitive. By the use of helicopters and special vehicles for swamps, geophysics has been applied to areas that could not ordinarily be reached. New techniques were devised for geophysical exploration of the shallow waters of the Continental Shelf. Radio surveying techniques were used in this work and have been adapted to exploration on some land areas. Electronic developments have been applied to provide more precise geophysical information. In short, the apparatus, the method, and the interpretation in geophysics have improved vastly. These improvements make it possible to detect many prospects previously missed in old areas and to carry the search into new areas at a high level of efficiency.

Exploratory Drilling

The drill is the final exploration tool, as geology and geophysics cannot indicate whether oil and gas actually exist. Sometimes wells are drilled without scientific evidence in what is termed random exploration. Some of these wells drilled on a hunch find oil, but the odds are much better for the scientific methods. Of the exploratory wells searching for new fields in 1950, 13 per cent of those drilled on scientific evidence resulted in discoveries but only 3 per cent of those drilled without a technical basis found oil or gas.

The drill serves not only to determine whether oil exists but also to provide geologic information. By inspection of the fossils in some of the materials penetrated by the drill it is possible to identify the formation and relate its position to that in other wells. Occasionally, wells are drilled strictly for geologic information to find how formations occur beneath the surface rather than to test for the actual location of oil.

On the average, eight out of nine exploratory wells drilled away from producing areas are dry holes. Even the dry holes may help to find oil, however, by providing additional information on subsurface conditions. Such information may indicate the possible existence of oil at another location.

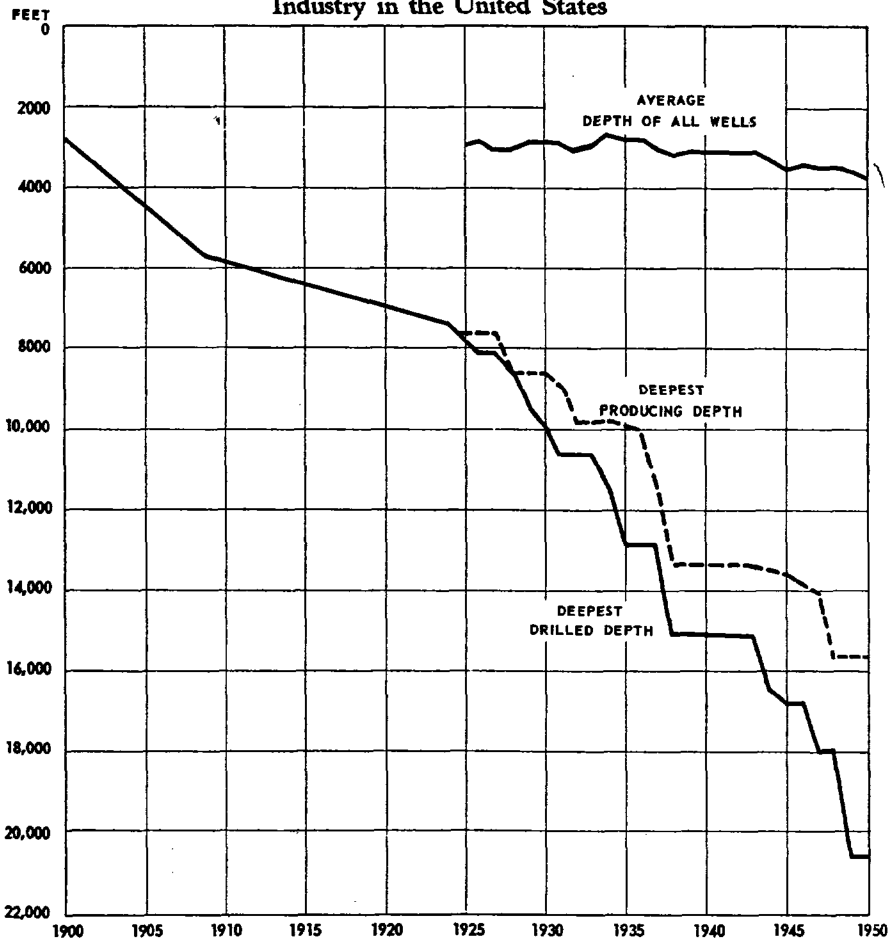
Improvement in Drilling

Progress in drilling has been a major factor in the development of large oil supplies. After a prospect which may have oil is located, it is necessary to drill wells to reach the prospective formation, to identify any formations that have oil and gas, and to complete wells as successful producers.

The first commercial oil well in the United States was less than 70 feet deep. Early drilling methods consisted of raising and dropping a heavy bit which penetrated the earth. This process, known as the cable tool method, was limited as to depth and required a good deal of time. Most wells are now drilled by the rotary method. In this method a drill pipe is rotated from the surface to make the bit cut deeper into the earth. The material cut by the bit is removed continuously by a drilling mud pumped down inside the drill pipe and back up to the surface between the drill pipe and the wall of the hole.

The deepest well drilled up to 1900 was only about 3,000 feet. In the next twenty-five years the maximum depth reached was increased to nearly 8,000 feet. By 1951 drilling had been carried deeper than 20,000 feet. Chart 7 shows the history of the record depths attained from 1900 to 1950, and the average depth of all wells since 1925. As technology changes the limits that are physically possible and economically feasible, the trend is toward deeper wells. The high cost of deep wells means

CHART 7
Depth of Wells Drilled by the Petroleum Industry in the United States



that fewer wells can be drilled to recover a specific quantity of oil from deep fields than from shallow ones.

Rotary drilling is much faster than cable tool drilling. It presents problems of identifying formations that may have oil and gas, however, for without special techniques this drilling method might hide the contents of the formation. The industry has developed instruments that can be run down into the hole as the well is drilled to measure different properties which provide clues as to the possible location of oil. These tools provide a log of information related to depth. Various logging methods are used, such as thermal, electric, radioactive, and neutron logging. These methods measure the temperature, the resistance of various formations to electric currents, and other factors. Mud logging is also used to detect minute traces of oil and gas in the drilling fluid as it returns from the bottom of the well to the surface. The material cut by the bit is also analyzed for information. Special equipment is used to take a core of the section being penetrated by the drill, so that this section may be studied for fossils and other indications as to geologic age and probable oil content. The combination of these various methods makes it possible to locate even thin sections containing oil and gas. In some fields a well may penetrate twenty or thirty separate formations which have oil and gas.

Control over the direction of drilling has made it possible to reach oil that might not otherwise be economically available. Techniques for directional drilling permit completion of a well at a predetermined distance and depth from the surface point at which the drilling takes place. Wells drilled on the shore of California by this method reach out underneath the Pacific Ocean to produce oil lying beneath the water. Directionally drilled wells have also been used from the expensive platforms built in the Gulf of Mexico, in order to test formations within an extensive radius and reduce the cost of developing the oil.

After the presence of petroleum is indicated, the production possibilities of the formation are determined. These possibilities are tested either while the well is still being drilled or after the final depth has been reached and the well is completed. The production tests measure the amount of oil or gas recovered in a period of time. They indicate whether the production is of commercial significance, and the rate at which the well may produce.

The actual completion of the well also contributes to the successful recovery of oil. Before techniques were perfected for controlling pressure, many discoveries would blow out and waste a great deal of oil. This seldom happens now because of the careful controls maintained in drilling a well.

Some wells have relatively small initial production. Under ordinary circumstances they might not be worth operating. Special means are used to increase the flow of oil to the well. These include treatment with acid, fracturing by the application of high pressure, and shooting with nitroglycerine. All of these methods help open new channels of flow for the oil through the formations to the well.

The design of drilling equipment has been improved to reduce costs and permit access to difficult locations. The modern unitized drilling rig can be set up quickly and moved with little loss of time to another location after a well is completed. Drilling barges have been designed for use in swamps. These barges are floated to the location, sunk in the water to provide a foundation while drilling proceeds, and then refloated to other locations. Drilling equipment has been placed on boats for some of the operations in the Gulf of Mexico.

The speed of drilling has been increased by various methods. Improved types of bit at the bottom of the drill are used to penetrate rock and other formations more rapidly. A recent development has been of the "jet bit" which uses high velocity circulation of the drilling fluid at the bit in order to increase the rate of penetration. With these methods new drilling records have been set of the penetration of over 2,500 feet in eight hours.

The preceding review does not exhaust the list of improvements made in exploration and drilling. The information presented has been designed to illustrate progress and the way in which supplies are made available that previously could not have been counted upon. It shows that supplies are a function of exploration and drilling rather than of oil in the earth. Consequently, it emphasizes the importance of an active search and dynamic technology in any consideration of future long-term prospects.

Achievements of Exploration

The combination of information secured by geology, geophysics, and drilling is adding constantly to our knowledge about where to hunt for oil. Improved knowledge and techniques, taken together with a more active search, explain the remarkable progress that has occurred in the development of new oil resources.

The accomplishments of the exploration processes in the past are evident from development of increasing supplies of oil. As there is available an official estimate of reserves, prepared by the Federal Oil Conservation Board in 1926, it is interesting to measure the accomplishments before and after that year.

In the years 1859-1925, 700,000 wells were drilled by the oil industry in the United States. Some 8.7 billion barrels of oil were produced during those years and the proved reserves were estimated to be 4.5 billion barrels in 1926. Therefore, the wells drilled in the period developed a total of about 13 billion barrels. In the period 1926-1951 about 696,000 wells were drilled and 34.5 billion barrels of oil were produced. Proved reserves of crude oil at the end of 1951 will be at least 21.5 billion barrels more than in 1926. Consequently, the oil developed in the past 26 years has been at least 56 billion barrels, or more than four times as much as in the preceding 67 years, although the number of wells drilled was approximately the same in both periods.

In the latest decade for which final figures are available, 1941-1950, the industry drilled 306,000 wells and developed 23 billion barrels of oil. The rate of development for the past ten years is comparable with or slightly greater than that for the longer period, 1926-1951. In other words, the rate of development of reserves has been in proportion to drilling during the past quarter century of scientific exploration, without any downward trend. The search is more expensive now than in the past, and frequently it is necessary to drill to much deeper depths. The trend toward higher costs has been partially offset by improved technology and the wider spacing of wells.

In 1951 there were drilled nearly 45,000 wells in the search for and development of oil and gas in the United States. Of these wells, about 37.5 per cent were dry holes. The other wells, nearly 28,000 in number, added to our ability to produce oil and gas. At recent drilling rates the industry would complete another 700,000 wells in about fifteen years to equal the total drilled in 1859-1925 and in 1926-1951. How much oil these wells will develop will depend on the success of the exploration process as it is applied to the large prospective area. Since ingenuity and technology continues to progress, we may expect reasonable success in the development of supplies for the future provided there is a sufficiently large favorable area in which to continue the search. The evidence on the magnitude of the area still prospective for oil is encouraging.

Size of the Prospective Oil Area

The prospective area in which the industry thinks oil and gas may be found is about one hundred times as large as the area of all the oil and gas fields discovered in the United States during the past 92 years of exploration. Our ideas as to the size of the prospective oil area have increased as a result of additional knowledge.

The search for oil was concentrated largely in Pennsylvania, New York, and Ohio until about 1890. By 1900, West Virginia, Indiana, and California also had attained substantial oil production. Until this time Texas and other states which subsequently have proved very productive were hardly considered prospective areas. By 1910, Illinois, Kansas, Oklahoma, Texas, and Louisiana had been added to the list of states producing over a million barrels a year. In the next decade substantial production was developed in Wyoming and Kentucky. Between 1920 and 1930, Arkansas, New Mexico, Colorado, Kentucky, Michigan, and Montana were added to the list of states in which substantial production had been developed. Mississippi was added to the list in the following decade, and Nebraska and Utah during the past ten years. Other states, such as North Dakota, Florida, and Alabama, may in time be added to the list with substantial production. The growth in the number of states with crude oil production in excess of a million barrels annually from one in 1870 and eleven in 1910 to twenty-one in 1950 is shown in Table 13.

TABLE 13

STATES WITH ANNUAL CRUDE OIL PRODUCTION IN EXCESS OF ONE MILLION BARRELS

States by Rank and Production in Million Barrels

Rank	1870	1880	1890	1900	1910	1920	1930	1940	1950†
1	Pa. 5	Pa. 25	Pa. 27	Ohio 22	Cal. 73	Okla. 106	Texas 290	Texas 493	Texas 829
2		N.Y.* 1	Ohio* 16	W.Va.* 16	Okla.* 52	Cal. 103	Cal. 227	Cal. 224	Cal. 328
3			N.Y. 2	Pa. 13	Ill.* 33	Texas 97	Okla. 216	Okla. 156	La. 209
4				Ind.* 5	W.Va. 12	Kan. 39	Kan. 42	Ill. 148	Okla. 165
5				Cal.* 4	Ohio 10	La. 36	La. 23	La. 104	Kan. 108
6				N.Y. 1	Texas* 9	Wyo.* 17	Ark.* 20	Kan. 66	Ill. 62
7					Pa. 9	Ill. 11	Wyo. 18	N.M. 39	Wyo. 60
8					La.* 7	Ky.* 9	Pa. 13	Ark. 26	N.M. 48
9					Ind. 2	W.Va. 8	N.M.* 10	Wyo. 26	Miss. 38
10					Kan.* 1	Pa. 7	Ky. 7	Mich. 20	Ark. 31
11					N.Y. 1	Ohio 7	Ohio 6	Pa. 17	Colo. 23
12							Ill. 6	Mont. 7	Mich. 16
13							W.Va. 5	Ky. 5	Pa. 12
14							Mich.* 4	N.Y. 5	Ky. 10
15							N.Y.* 4	Ind.* 5	Ind. 10
16							Mont.* 3	Miss.* 4	Mont. 8
17							Colo.* 2	W.Va. 3	N.Y. 4
18								Ohio 3	Ohio 3
19								Colo. 2	W.Va. 3
20									Nebr.* 2
21									Utah* 1
Total	1	2	3	6	11	11	17	19	21

Source: Bureau of Mines.
* Passed one million barrels annual production during preceding decade.
† Other states which had production of less than one million barrels in 1950 were: Alabama, Florida, Missouri, Tennessee, and Virginia.

The sedimentary area of the continental United States prospective for oil is about 2,400,000 square miles or approximately 80 per cent of the land area. About two thirds of this sedimentary area is included in the possible future oil provinces classified by the American Association of Petroleum Geologists in a symposium published in February 1951. The prospective future oil provinces described in this study contain 1,660,000 square miles, including certain portions of the Continental Shelf to a water depth of 120 feet. Another 200,000 square miles in presently producing areas not included in the classification of "future oil provinces" must be added to arrive at a total of 1,860,000 square miles with favorable prospects for future discoveries.

Future Oil Provinces

The study published by the American Association of Petroleum Geologists in 1951 on possible future oil provinces was similar to one published in 1941. These studies were made by local geological societies, representatives of geological surveys, and individual geologists familiar with specific provinces. These specialists considered all available evidence in classifying geologic provinces from the standpoint of future oil prospects. Each study was limited by the technology and geologic concepts prevailing at the time. In 1941 it was not considered feasible to include in the possible future oil provinces the offshore Continental Shelf or the sediments deeper than 15,000 feet. Progress by 1951 resulted in the inclusion as possible oil provinces of the offshore Continental Shelf and sediments as deep as 20,000 feet.

The 1941 report on future oil provinces by the American Association of Petroleum Geologists described 34 provinces. By 1951 oil and gas fields had been proved to exist in 20 out of the 34 provinces listed ten years earlier. The names of these 20 provinces listed in the 1941 study and some of the fields discovered in them since 1941 are shown in Table 14.

In about 100,000 square miles of the 1,860,000 square miles in the producing and prospective provinces, oil possibilities are considered to be only remote at this time, but this opinion may be changed with later developments. In forty-three of the sixty prospective provinces there are some evidences of oil and gas. About one fifth of the prospective area has sediments extending below 15,000 feet. It is estimated that some 15 per cent of the area included in the future oil provinces is already under lease by oil companies. Such lease operations indicate active consideration of the prospects by oil companies. The prospective provinces discussed by the American Association of Petroleum Geologists are shown on a map and described briefly in Exhibit A.

The size of the prospective oil area is impressive. It is large in relation to the area in which oil has been found. It is also very large in relation to the rate at which exploratory work is being carried on. Although an estimated 140,000 exploratory wells have been drilled in the United States through 1950, huge areas remain in which very little exploration has been done. For example, only about 150 exploratory

TABLE 14

Geological Areas Listed in the 1941 Study of Future Oil Provinces by the American Association of Petroleum Geologists in which Discoveries had been made by 1951

Name of Province	No. on Map	Fields Discovered
1. Sacramento Basin (Incl. San Joaquin Valley)	8	Helm, several in Coalinga area
2. Calif. Coastal Embayments	9	Cuyama Valley, Russell Ranch, San Ardo
3. South Central Montana	19	Elk Basin
4. Powder River Basin	20	Mush Creek, Sussex
5. Big Horn	21	Worland, Elk Basin
6. Green River Basin	23	Church Buttes
7. Wind River Basin	22	Big Sand Draw, Steamboat Butte
8. Unita Basin	25	Roosevelt
9. Eastern Colorado	30	Sterling Area
10. N. and S. Dakota	31	Williston Basin
11. W. Nebraska	32	Gurley
12. Salina & Forest City Basins	33 & 34	Borada and 15 other small pools Falls City area
13. S. E. Okla., N. W. Ark.	35	60 producing gas fields, little oil
14. Anadarka-Panhandle	36	Elk City, Apache, Ringwood
15. Northern Llano Estacado	37	Anton Irish
16. Trans-Pecos	38	13 oil and 2 gas fields
17. Mississippi	43	Baxterville, Cranfield, Heidelberg, Gwinville, others
18. South Alabama		Gilbertown
19. Florida	46	Sunniland
20. Appalachian Basin	55, 56 57, 58, 59	Canton (Ohio), Rose Hill (Va.), Leidy (Pa.).

wells were drilled in 1950 in the vast prospective area included in the following fifteen states: Arizona, Florida, Georgia, Idaho, Maryland, Missouri, Nebraska, Nevada, North Carolina, North Dakota, Oregon, South Dakota, Utah, Virginia, and Washington.

The volume of sediments remaining to be tested is as impressive as the area. The average depth of all wells drilled to date is less than 4,000 feet. Even in producing areas prospects remain to be explored at greater depths. There are already hundreds of examples of fields in which deeper production has been found long after oil was initially discovered. In early years it was customary to stop drilling with the first substantial production encountered. Later drilling to greater depths in such old fields is constantly finding additional production.

The size of the prospective oil area is so large that it would take many years and a great deal of capital to complete an intensive search. Recently the oil industry has been spending several billion dollars annually in exploration and drilling. It has been completing more than 10,000 exploratory wells a year. Even at this rate the exploratory wells drilled in fifty years would be less than one to three square miles. Many areas have required even more intensive exploratory drilling than this in the process of testing prospects, for it is not unusual to drill several dry holes in a small area before finally locating oil production.

The question may be raised whether the area remaining to be explored is likely to result in much less discovery of oil relatively than the area already explored. At first glance it might seem that the prospects most likely to contain abundant oil would have been tested first. Such an assumption is not true because of the nature of the exploration process. We are unable to tell at any time where the most prolific fields may occur. Prior to 1900, Texas was not considered a good prospective oil area, but it has since been proved to contain a great deal of oil. It was not until nearly 1925 that West Texas, which is now considered to be one of the great oil provinces, was considered to be a good prospective area. The East Texas field, with the largest proved reserves discovered in this country, was not found until 1930. The Spraberry trend, which seems to cover the largest producing area of any field yet found in the United States, was brought into production in 1949. There probably are still to be found very good producing areas which have not in the past been considered as favorable as those presently producing. The recent discoveries in North Dakota and Montana, for example, may open up an area which the future may prove to have been very favorable for oil production.

Time Required to Explore Prospective Areas

There are several reasons why much of the prospective oil area has not already been explored. In the first place, the sedimentary area is so large that there has not been sufficient time in which to carry out a thorough exploration of all of it. In the second place, exploratory drilling has been concentrated in relatively small regions where oil was being found. Furthermore, some of the prospective area has only been brought into the picture as progress made it possible to carry the search into more difficult and deeper areas. Finally, the search is not likely to be carried into new areas until there is an economic prospect for success in case of discovery. Initially the cost of transportation of oil was quite high and discoveries in areas remote from markets would have been of no commercial value. Even within the past fifteen years there are examples of fields known to exist which were not worth commercial development because of economic circumstances. One of these fields was Rangely in Colorado. For another economic reason the development of the Spraberry trend in West Texas, now underway, would not have been feasible at the price of crude oil that prevailed in the period 1930-1945.

It takes a long time to explore a new province thoroughly and develop its oil possibilities. Two examples will illustrate this point. The first discovery of oil along the Gulf Coast was made at Spindletop, Texas, in 1901. The entire coastal strip from the Mexican border to Florida has numerous geologic similarities. It is characterized by thick sediments that dip toward the coast and out under the Continental Shelf. Active exploration in Texas and Louisiana developed substantial production along the Gulf Coast. It was not until the 1930's, however, that many of the large oil fields of the Gulf Coastal area were found. It was 1933 before oil was discovered in Mississippi, 1943 when it was discovered in Florida, and 1944 when it was discovered in Alabama. Alabama and Florida produce less than a million barrels of oil a year and their prospects still remain to be tested in the future. Thus, the Gulf Coastal province has large areas remaining to be tested more than fifty years after the initial discovery of oil. Available supplies from the area are at a level greater than ever before and may well increase in the future.

Another example of the time required to explore an area is evident in Canada. The first well in the province of Alberta was drilled in August 1894. The first major discovery was made in 1914 at Turner Valley. Through the year 1947 a total of 775 dry holes had been drilled in the province of Alberta, but there was little success in finding oil. In 1947, an important discovery was made at Leduc, 190 miles northeast of Turner Valley. Increased exploration followed rapidly. Within a few years discoveries have amounted to about 1.5 billion barrels. By the end of 1950 over 100 million acres had been leased by oil companies in the provinces of Alberta and Saskatchewan. More than a hundred geologic crews were operating in the area and 140 rigs were engaged in drilling wells. In this case it was thirty-three years from the initial discovery of a major field to the subsequent sharp expansion of exploration and production. Several decades may pass before the oil prospects of this large region are reasonably tested and production approaches its maximum rate.

Progress in exploration frequently provides the key required to extend the search into new areas. As geophysical techniques are improved, for example, the areas in which good interpretations can be made increase. Thus, it becomes possible to apply such methods where they were not previously effective. Improvements in the method of applying a process also extend the limits in which the search can be made. This was true in the case of the application of geophysics to the Continental Shelf. In other cases improvements in drilling techniques make it possible to enter a new area. The Continental Shelf and the swamps of Louisiana both illustrate this point.

Evaluation of Future Prospects

The prospects for finding oil in the future may be analyzed separately for the areas in which substantial production has already been achieved and those in which little production has been developed to date.

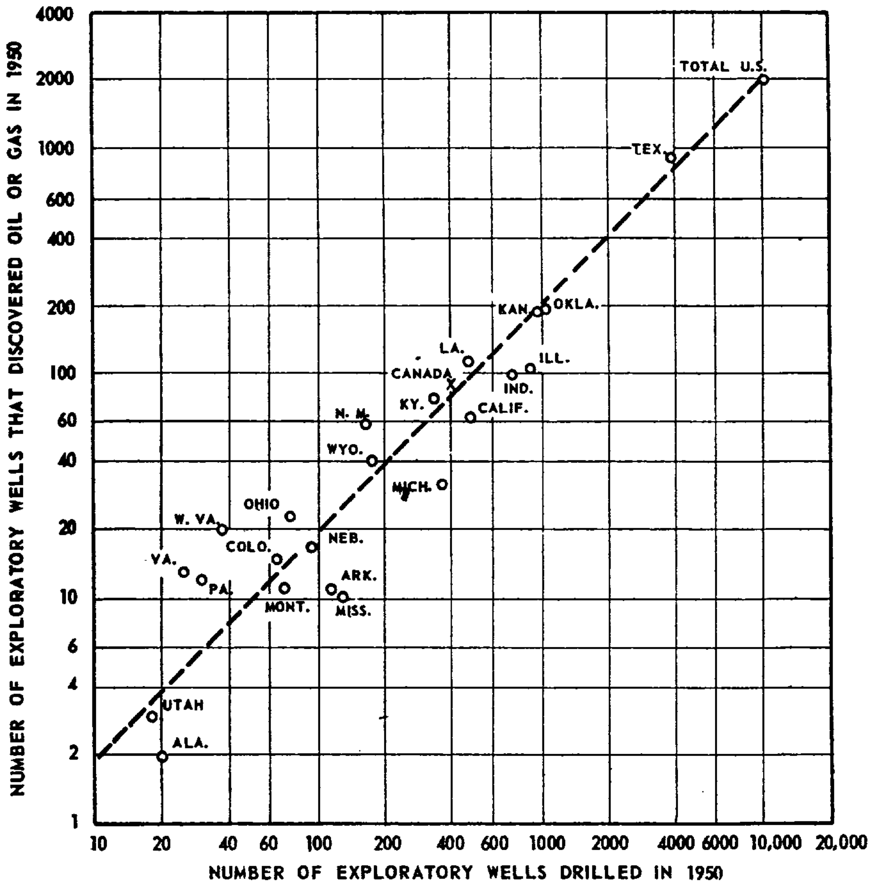
The reasons why the older producing provinces remain prospective are as follows: (1) improvements in exploration reveal new prospects not evident by earlier methods; (2) the ability to drill deeper opens up prospects below the shallow producing fields; and (3) the accumulation of information through exploration and drilling suggests possibilities of production elsewhere in the same formations that have proved productive in the past.

The prospects for finding substantial oil in areas which have had little exploration in the past may be considered good for the following reasons: (1) the geologic conditions of these prospective areas are generally similar to those of areas already producing; (2) there are already indications of the existence of oil and gas in some of the prospective areas, although very little exploration has been done; and (3) large sums of money are being risked by oil companies on exploration and leasing in prospective areas.

The best evidence of the continued discovery of oil is in the experience that discovery is in proportion to the exploratory effort and in the current high level of exploration. In the states in which extensive drilling was carried on during 1950 the number of oil and gas discoveries was directly proportional to the number of exploratory wells. Of the exploratory wells drilled in non-producing areas about one in nine resulted in a discovery. Of all exploratory wells drilled, including extensions and deeper tests in producing areas, about one in five discovered new oil. The relation between the total number of exploratory wells drilled and the number of discoveries is shown on Chart 8.

The amount of new oil realized through discoveries, extensions, and revisions also proves to be in proportion to exploratory drilling. In the ten states which had discoveries, extensions, and revisions in excess of 100 million barrels for the three-year period 1948-1950 the volume of

CHART 8
Exploratory Wells Drilled and Oil and Gas Discoveries in 1950— United States and Canada

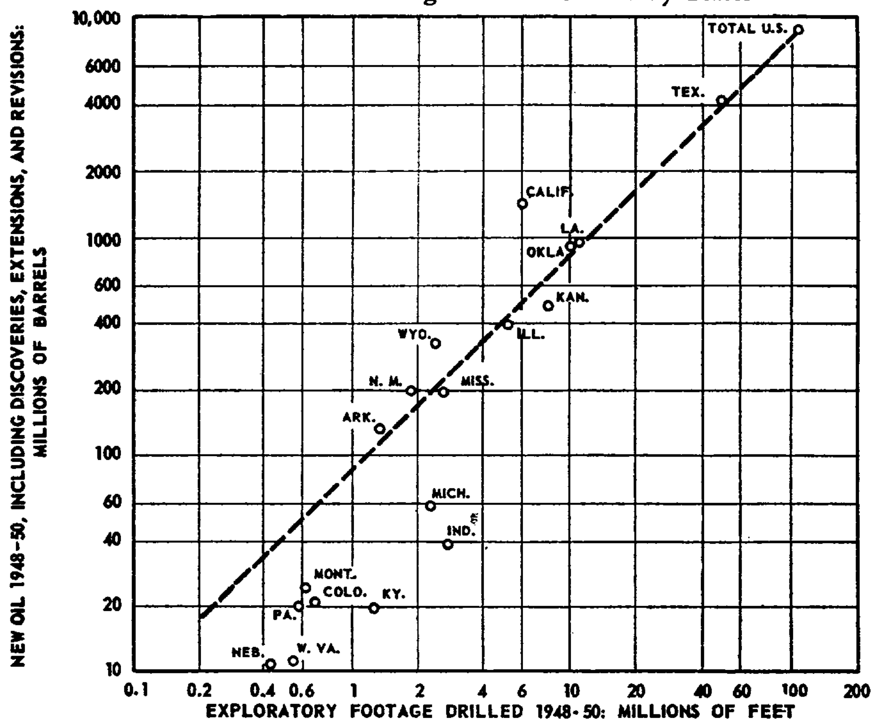


new oil was directly proportional to the exploratory footage drilled. The relationship is shown in Chart 9.

The size of the prospective oil area is so large that exploration will have to be carried on for scores of years to test the possibilities thoroughly by present methods and at present rates. There is no lack of places in which the search for oil may be successful. As our technology improves steadily the search is being extended successfully to additional areas not previously considered prospective. A major new device for finding oil may accelerate the discovery in the prospective area, but it is not essential to future supplies. The progress made by the industry in the discovery of oil has been largely in the improvement of processes known for a long time.

CHART 9

Oil Discovered and Footage Drilled 1948-50 by States



In these circumstances, the size of the prospective oil area is no limitation on the supplies of oil for the foreseeable future of twenty-five to fifty years. The rate at which supplies will be developed will depend upon the influence of economic forces on exploration and drilling.

Greater knowledge, improved technology, and increased exploratory work can continue to operate for a long time to come in a vast prospective area that gives promise of large supplies of oil for the foreseeable future.

Progress in Development and Recovery

The amount of oil supplies is affected by the recovery from the fields discovered as well as by the amount of oil in the earth. Oil exists in the porous spaces of sand, lime, and shale formations. It is frequently associated with gas and water. The method of occurrence prevents complete recovery of the oil in place underground. The amount of oil recovered from a particular field may vary substantially, depending on conditions in the reservoir and on producing practices. Great progress has been made in increasing recovery through improvements which add to efficiency and reduce costs. Such progress means larger supplies of oil.

Many of the improvements in drilling exploratory wells, already described, are equally important in the more numerous development wells that make discovered oil available. Methods of completing wells in producing formations have been improved. These methods increase the flow of oil to the well. Careful completion of wells can reduce the amount of gas produced with oil and control the amount of water produced with the oil. The ratio of gas to oil produced from a well affects the pressure in the producing formation and thereby influences the recovery of oil. Generally, maintenance of pressure in the producing formation is a means of helping assure the fullest recovery of oil. The loss of gas can be minimized simultaneously with an increase in the recovery of oil by keeping the gas-oil ratio low.

Conservation of Oil

Great progress has been made in understanding and controlling the flow of fluids in an oil reservoir, particularly since about 1925. In many early operations wells were completed in such manner that gas was lost in tremendous quantities and much oil was trapped in the reservoir by irregular encroachment of water. During the period 1916 through 1929, there gradually developed an awareness that these methods of production resulted in waste and a loss of oil that could be recovered. The industry began to devote increasing attention to reservoir engineering. As a result, new conservation methods were evolved. Most of the important producing states adopted conservation laws providing for control of the drilling of wells, the gas-oil ratio, the rate of production, and other factors which affect the efficient recovery of oil. These conservation measures have increased the recovery of oil in place, prolonged the life of many wells, and helped to reduce costs so that more oil was economically recoverable.

Conservation of oil and gas is based on scientific knowledge accumulated through the years. The manner in which oil, gas, and water in a reservoir operate has been studied by careful observation. Mathematical techniques have been applied to the analysis of available data. Models have been devised in which the effects of different rates of production upon recovery can be studied. Electronic calculating machines are sometimes used to handle the many variable factors involved in connection with the production of a field. All this work has served to prove that too rapid production from a reservoir decreases the amount of oil recovered and involves physical waste both underneath and above ground. Actual field experience has demonstrated the value of new production practices.

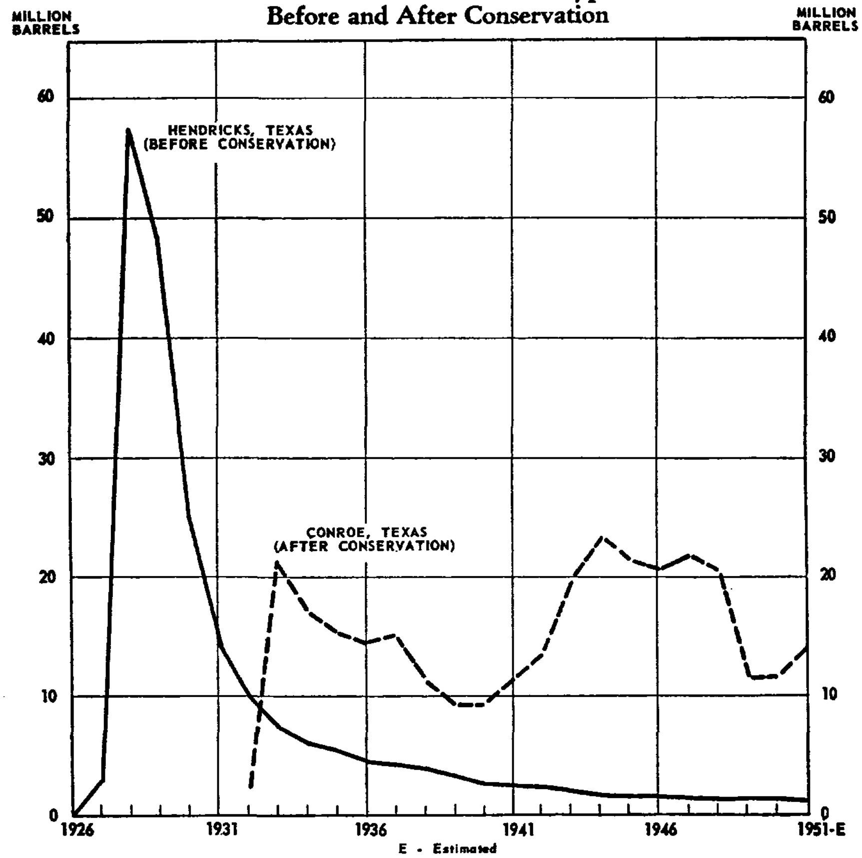
Engineering studies have established that for each reservoir there is a rather closely definable maximum rate at which oil can be produced efficiently. If production exceeds this rate, physical waste occurs and the amount of oil recovered from the field decreases. Conservation laws of the producing states take into account this principle and provide for regulation of production in order to prevent waste. Experience has shown that when physical factors alone are considered without respect to market outlets, waste may occur because of uneven withdrawals by different operators whose market outlets vary. If adjoining wells produce at different rates, there may be irregular encroachment of water and other developments which cause physical waste, in addition to the inequity resulting among the operators from the different rates of production per well. Consequently, many states take into account market demand as well as physical factors in the conservation measures used to prevent physical waste.

The understanding of efficient methods of production and the adoption of conservation laws have brought about an entirely different pattern of production from fields. Now the pattern is generally for a sustained level of production over a long period of years. Prior to about 1925 new fields generally were developed very rapidly and produced at excessive rates in the earlier years, after which there was a very sharp decline in production. The difference in the production pattern before and after the effective application of conservation principles could be illustrated by the history of many fields. (See Chart 10.) In Table 15 there is a comparison of three fields with uncontrolled production prior to conservation and four fields developed later under conservation. The uncontrolled fields declined to 10 per cent of their peak annual production within four to nine years. The controlled fields, on the other hand, were still producing at 50 to 63 per cent of their peak annual rate from twelve to twenty years after they were discovered.

Another example of sustained productivity under conservation is the East Texas field. This field has been the largest discovered in the United States to date, in terms of amount of reserves that will be recovered. At the end of 1950 it was twenty years old, but had produced only about half of the oil that will be recovered. In 1951 the field produced about 273,000 barrels daily, or 50 per cent as much as the peak annual rate in 1933. The pressure in the field has been maintained at a substantially constant level since 1942 despite the production of about a billion barrels of oil. Efficiency of recovery has been increased not only by controlling the rate of production but also by returning to the producing formations a large amount of the salt water that comes up with the oil. Maintaining the pressure in the reservoir has kept gas in solution in the oil and preserved the fluidity of the oil. As a result,

CHART 10

Pattern of Crude Oil Production in Typical Fields Before and After Conservation



the recovery of oil from the East Texas field will be high. The remarkable performance of this great field under conservation is shown by Charts 11 and 12.

Conservation of Natural Gas and Associated Liquids

Conservation has made possible many other measures that increase supplies of oil and gas. The stable rate of production over a long period of years, instead of a high peak for a short time followed by a long decline, has made it possible to install equipment for the conservation of gas produced with oil and for the recovery of the liquids contained in that gas. Such operations would not have been economically feasible in the days of wide-open, inefficient production. The significance of this progress is evident from the fact that the production of natural gas liquids in 1951 of about 565,000 barrels daily was almost

10 per cent as large as the total production of crude oil, and exceeded the combined production from New Mexico, Mississippi, and Kansas. Chart 13 shows the growth in production of natural gas liquids.

Tremendous advances have been made in the conservation of natural gas. Throughout much of the industry's history, gas produced with oil has generally been flared because it was not economically feasible to utilize it. Today, the majority of the gas produced with oil is captured and put to further use. Only in isolated cases where costs are prohibitive to economic use does natural gas continue to be flared in any large

TABLE 15

Comparison Controlled and Uncontrolled Fields

Field	Year of Discovery	Peak Annual Production As Per Cent of Estimated Ultimate Production	1950 Production As Per Cent of Peak Annual Production	Years After Discovery For Production to Decline to 10% of Peak Annual Rate
Uncontrolled Fields				
Seminole City, Okla....	1926	26.6	2.6	4
Powell, Texas	1923	26.4	1.1	6
Hendricks, Texas	1926	24.5	2.1	9
Controlled Fields				
Conroe, Texas	1931	3.9	51.7	—
Hastings, Texas	1934	4.4	60.2	—
Tom O'Connor, Texas.	1934	4.1	61.7	—
Magnolia, Ark.	1938	6.7	63.0	—

Source: U. S. Bureau of Mines, American Institute of Mining and Metallurgical Engineers, and Oil and Gas Journal Reviews for 1950.

amounts. Careful completion of wells and controlled methods of production reduce the amount of gas produced with oil and help preserve any gas cap or pressure needed for the recovery of oil.

The conservation of gas produced with oil is an economic problem which requires for its solution an adequate market to create a value for the gas that will pay for the cost of saving it. Improved methods of transporting natural gas over long distances at relatively low costs have created large new markets for natural gas. These markets have meant better prices for gas, and better prices have naturally stimulated conservation.

CHART 11
Crude Oil Production in the East Texas Field
(Million Barrels)

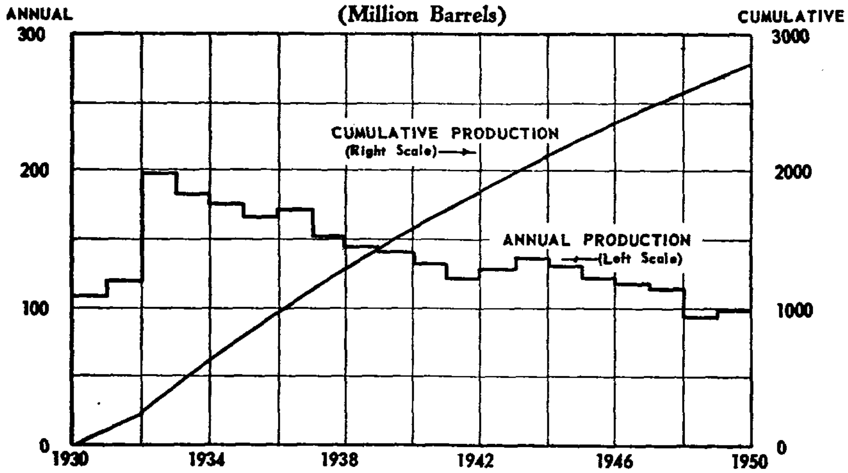
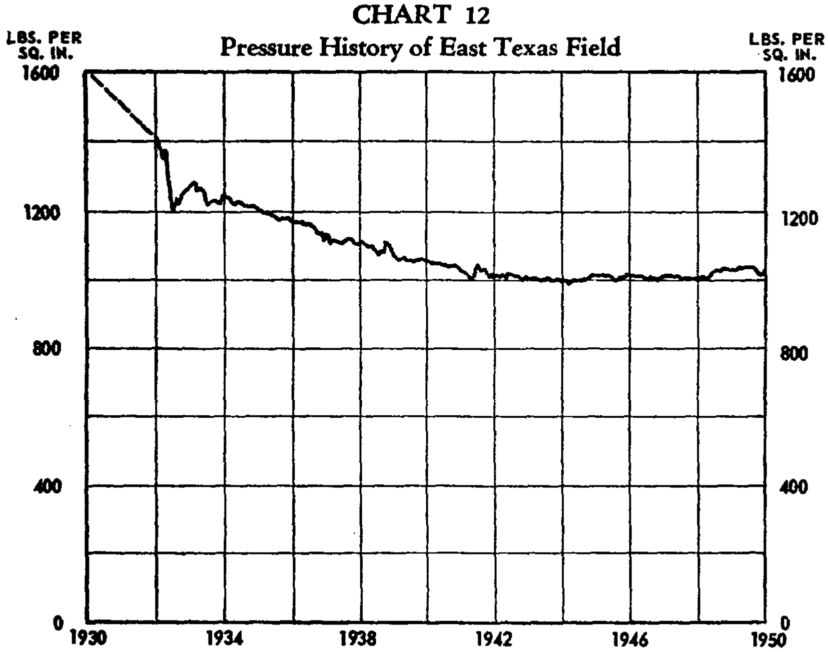


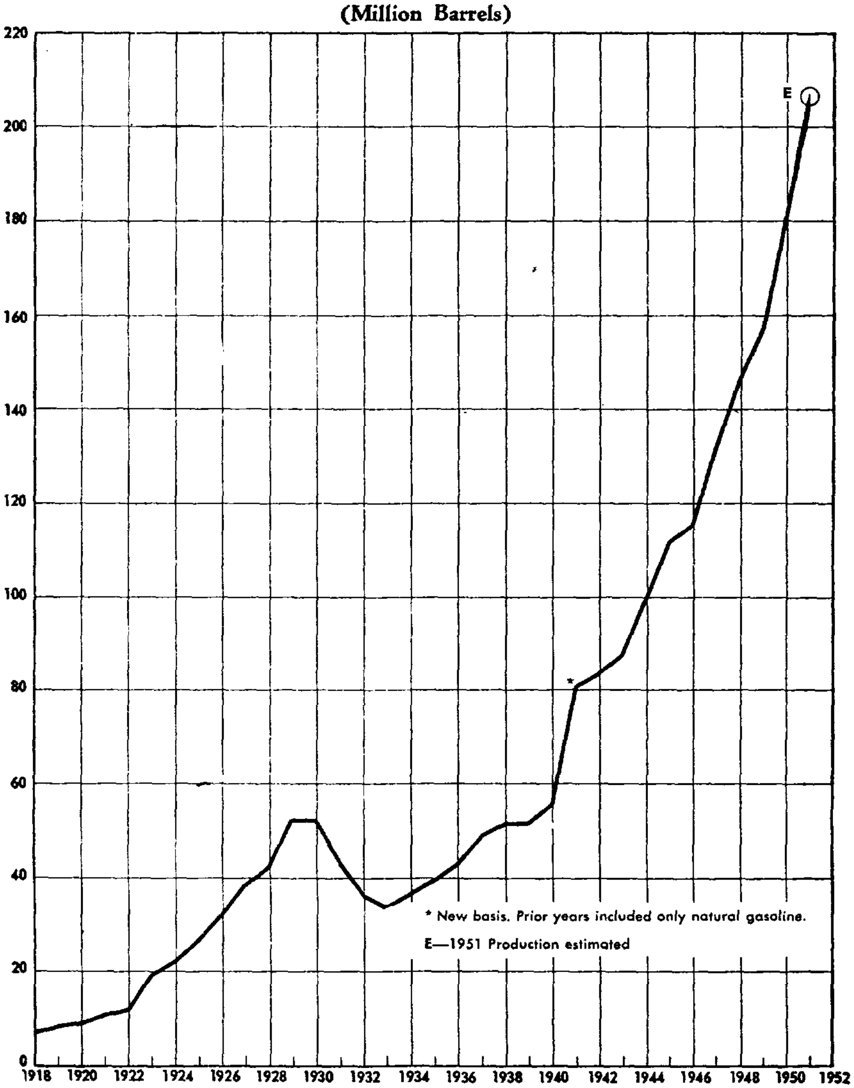
CHART 12
Pressure History of East Texas Field



Benefits of Conservation

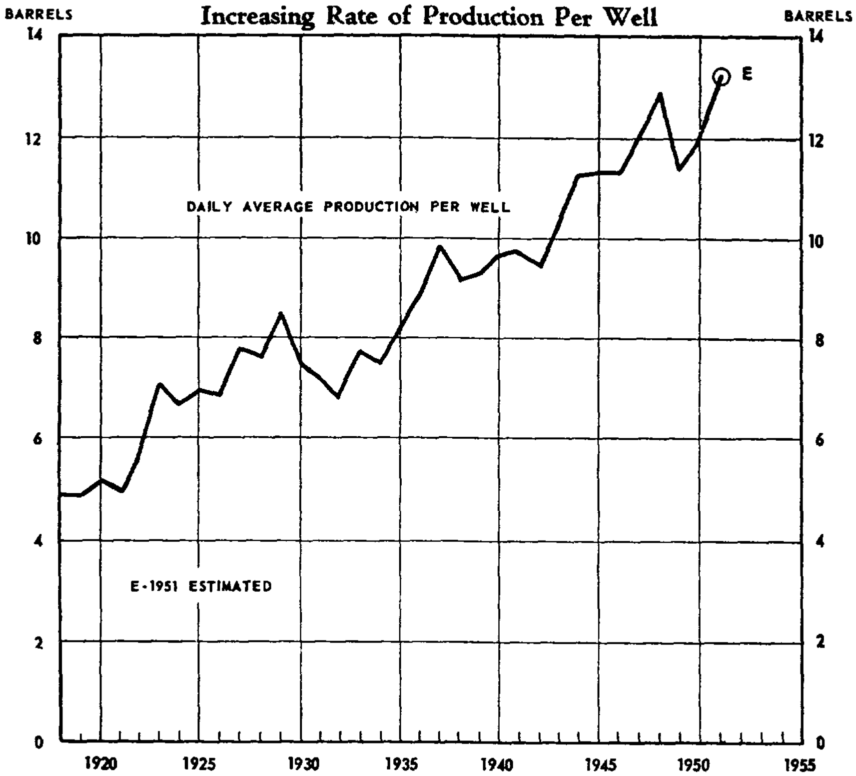
Conservation has meant larger supplies and lower development costs for crude oil. The fact that conservation increases the recovery of oil adds to supply and thereby acts to bring about a balance with demand

CHART 13
U. S. Production of Natural Gas Liquids
(Million Barrels)



at a lower level of price than would prevail if supplies were smaller. Conservation has also made a great contribution to lower prices through its help in reducing costs. Under unregulated competition without conservation measures, wells were drilled very closely. Such close development meant a high cost for drilling, in addition to the loss of recoverable oil that followed when production was too rapid.

CHART 14
Increasing Rate of Production Per Well



Conservation practices have permitted new fields in the past twenty years to be developed with many less wells. It is now generally the practice in the industry to drill only one oil well to each 10 to 80 acres, depending on the field, because that spacing pattern will drain the recoverable oil from such areas when production is controlled at efficient rates. In earlier days fields were developed with such close spacing that wells were frequently drilled on an acre or a fraction of an acre. Such extravagant methods of development meant a relatively high cost for oil. Efficient methods of development under conservation practices reduce costs and make it possible to recover oil that would not have been economically available under the old practices.

The favorable effect of conservation on production is evident in the upward trend of production per well. Chart 14 and Table 16 show this trend. The average daily production per well in 1951 was nearly twice as much as in 1925 and about three times as much as in 1918. In 1918 there were about 200,000 wells producing an average of 975,000 barrels daily or less than 5 barrels a day. In 1951 there were about

TABLE 16

TREND OF CRUDE OIL PRODUCTION PER WELL

	Annual Crude Oil Production* Thousand Barrels Daily	Producing Oil Wells at End of Year*	Daily Average Production Per Well
1918	975.2	203,375	4.8
1919	1,036.6	227,000	4.8
1920	1,210.2	251,000	5.1
1921	1,293.7	274,500	4.9
1922	1,527.5	284,880	5.5
1923	2,006.6	290,100	7.0
1924	1,950.7	299,100	6.6
1925	2,092.5	306,100	6.9
1926	2,112.0	318,600	6.8
1927	2,468.8	323,300	7.7
1928	2,463.0	327,800	7.6
1929	2,759.8	328,200	8.4
1930	2,460.3	331,070	7.5
1931	2,331.7	315,850	7.2
1932	2,145.2	321,500	6.7
1933	2,481.2	326,850	7.7
1934	2,487.8	333,070	7.5
1935	2,730.4	340,990	8.1
1936	3,004.6	349,450	8.7
1937	3,504.5	363,030	9.8
1938	3,327.0	369,640	9.1
1939	3,465.6	380,390	9.2
1940	3,697.3	389,010	9.6
1941	3,841.7	399,960	9.7
1942	3,799.0	404,840	9.4
1943	4,125.0	407,170	10.2
1944	4,584.5	412,220	11.2
1945	4,695.1	415,750	11.3
1946	4,750.5	421,460	11.3
1947	5,087.8	426,280	12.0
1948	5,519.8	437,880	12.8
1949	5,046.5	448,680	11.4
1950	5,402.5	461,130P	11.9P
1951	6,164.4P	472,389P	13.2P

* Bureau of Mines.

P—Preliminary estimates.

475,000 oil wells which produced 6,164,000 barrels daily and could have produced efficiently about 6,900,000 barrels per day. Clearly, the cost of oil would have been much greater in 1951 if the production per well had been only as much as it was in 1918. In that case, it would have taken several times as many wells to produce the oil we used in 1951. The investment and operating costs of the larger number of wells would have meant a much higher cost for oil.

Secondary Recovery

Additional oil supplies have been realized through secondary methods of recovery as well as by the methods already described for increasing the primary recovery from a field. Knowledge about proper methods of recovery indicated that substantial quantities of recoverable oil had been left in some fields that appeared to be depleted. This knowledge suggested that further production might be realized from these fields by the development of methods for additional or "secondary" recovery. Secondary recovery methods consist principally of injecting gas or water into an oil-producing formation in order to stimulate production. It is reported that gas was injected into a producing oil sand in Venango County, Pennsylvania, as early as 1890-1891 to stimulate oil production. Air was injected for this purpose into a producing formation in Ohio in 1911. Water injection was used in the Bradford field in Pennsylvania beginning about 1925 and resulted in a great increase in production.

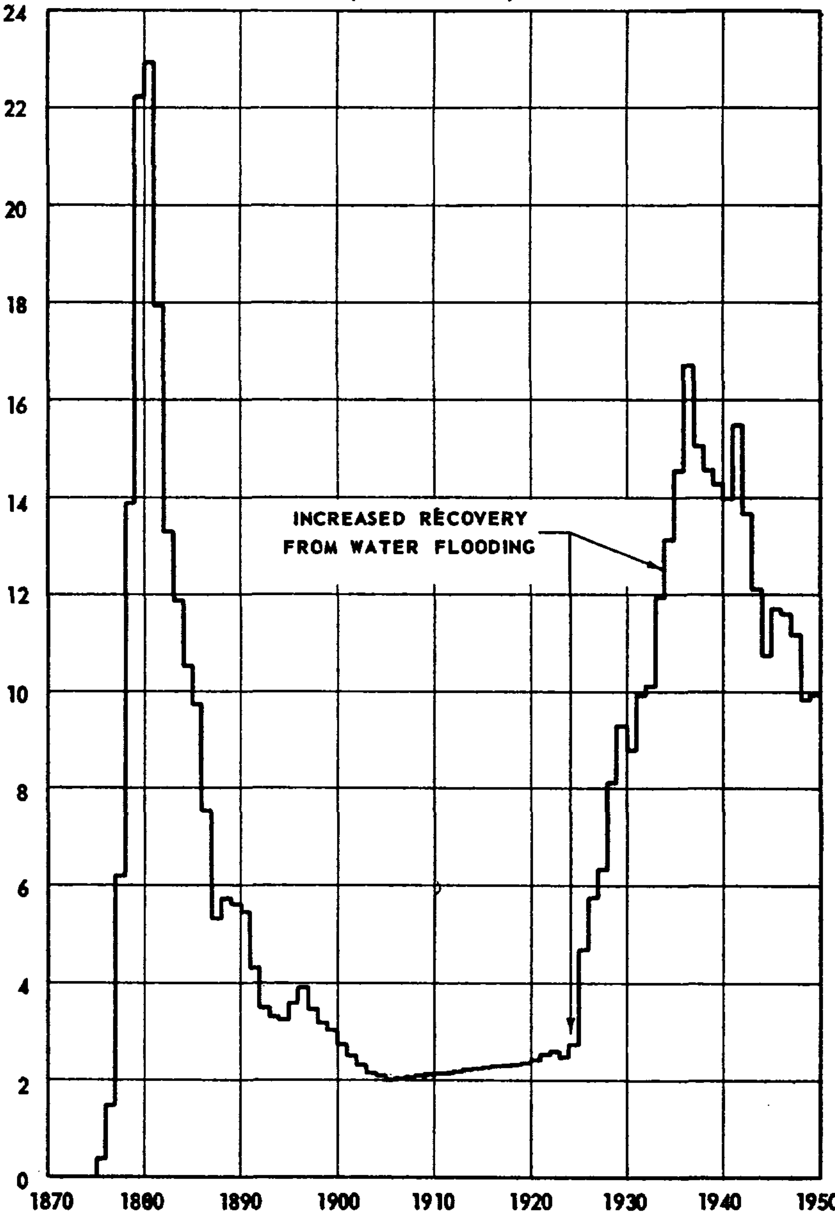
The Bradford, Pennsylvania field reached its peak of primary production in 1881. Production declined rapidly, as usual at that time. By 1890 it was less than one-fourth as much as in 1881, and by 1905 it was down to 10 per cent of the peak annual rate. Intensive water flooding increased the annual rate of production in the field sharply from 1925 through 1937. At that time production was about three-fourths as much as it had been in the peak year of 1881. By the end of 1950 the total oil production from the Bradford field had reached about 534 million barrels, of which it is estimated more than half had resulted from secondary recovery. (See Chart 15.) The field still has substantial reserves remaining to be produced by secondary recovery.

Secondary recovery has been applied principally in shallow fields in the older producing regions of the East. It is being extended rapidly to the Mid-Continent area, particularly North Texas, Oklahoma, Kansas, and Illinois. In many cases a substantial increase in production has resulted. Secondary recovery methods will increase supplies of oil from many old fields if the economic incentive exists for the investment in the process.

Rate of Progress in Production Technique

The progress in knowledge about development and production techniques has been remarkable. It has occurred under a system of

CHART 15
Production History of Bradford, Pa., Field Showing Results of Secondary Recovery
(Million Barrels)



freedom of opportunity and competition. Thousands of individuals and companies have been engaged in exploration, development, and production. They have devised innumerable improvements which add to our supplies of oil at reasonable costs. Technical information has been widely distributed and freely discussed throughout the industry. There are no barriers to the exchange of such information. Patented improvements are free to all users in many cases or generally available under licenses. Professional societies, trade associations, and industry publications have contributed to the spread of information which helps to find and develop oil. The Interstate Oil Compact and the producing states have had a part in the broad conservation movement and in improving the distribution of knowledge essential to technological progress by the industry.

The knowledge and technology of the petroleum industry in 1951 must be rated as remarkable by the standards as recent as 1925. The continuous rate of progress in these fields is impressive. We can only speculate about the extent of such progress for the future. There is no way of guessing what inventions, improvements, and advances in knowledge may be made in the next twenty-five or fifty years. We can say, however, that there is every reason to expect a continuation of our past progress, granted reasonable economic climate and incentives. Each invention and addition to our knowledge has a cumulative effect on our ability to progress in the future. History shows an accelerated rate of technological progress. Granted conditions reasonably similar to those under which past progress has been made, there should be no question that the oil industry can and will make further substantial progress in its knowledge and technology.

Economic Forces Determine Fuel Supplies

The existence of oil and adequate technology are necessary, but they are not enough to make supplies available. Economics is the final force determining oil supplies. That is to say, there must be the economic incentive to develop production. Also, oil products must be available at prices that will attract buyers.

We have already noted that it takes an intensive search and a lot of drilling to find oil. That effort takes a great deal of money. The amount of money which will be risked on the effort depends on the prospects of making a return in keeping with the risks. Unless an adequate return is expected, the development of oil will not be undertaken.

In the United States billions of dollars are spent annually in the search for and development of new oil. Without that continuous effort supplies would soon begin to decline. The investment in development of new resources depends on the prospects for profitable return. Under normal economic conditions it is the relation between costs and prices which determines whether it is attractive to carry on an intensive search for oil. Changes in profit margin can affect development of oil supplies apart from any changes in prospects or technology, as illustrated by the experience during the depression.

There was a sharp decline in exploration and drilling in the United States in the years 1931-1933. This change occurred as a result of lower crude oil prices. The chances of finding oil and the technology of exploration and development remained the same, but the economic incentive to carry on the search for oil decreased. The average price of crude oil in the years 1931-1933 was 73 cents a barrel, a decrease of 40 per cent from the average price of $1.21 a barrel in the preceding three-year period. As a result of reduced effort in the search for oil, substantially less oil was added to reserves in 1931-1933 than in the preceding three-year period. In the following three years the price of crude oil improved to an average of $1.02 a barrel. Exploration and drilling also increased, reflecting the improved economic incentive.

It requires great sums of money to search for oil in old and new areas. In some ventures, such as the Continental Shelf and foreign countries, several hundred million dollars may be spent initially before any substantial production or income is developed. The production and income in case of success is realized slowly over a long period of years. Whether the initial investment is recovered and any profit made depends on prices and costs over a long period. In making the initial investment it is necessary to consider the time required to recover the capital as well as the risk of losing it on unsuccessful ventures.

Much effort and capital have been spent in developing oil in the United States. Producers have been free to search for oil wherever they wished, and to sell their oil at the market prices determined by supply and demand in competition with other fuels. There have been no restraints on the markets which might be reached. The risks have been great, and many operators have been unsuccessful. In addition, even the successful operators have experienced numerous failures and losses of investment. Still, the freedom for individual initiative and the expectation of being allowed to enjoy the rewards of any unusual success have brought about the venture of large sums of money in the search for oil. The willingness of operators to risk their capital in the hazardous search for oil has developed a great availability of oil products in the United States.

Competition

Oil supplies in this nation have been developed under a competitive system with thousands of individuals and firms engaged in the business.

Different individuals and companies frequently explore the same area again and again. There are many cases of discoveries in areas of repeated failures by others. It is this competitive search which results in the continuing discovery of oil even in old areas already intensively explored by many operators. Freedom of enterprise and reasonable economic incentives have found great supplies of oil in the United States.

The economic rewards to an industry depend upon its ability to produce at a price that makes the product attractive to buyers. There is competition not only within an industry but among industries. Oil producers compete with each other and also with the producers of other forms of energy, such as coal. It has been the efficiency of the oil industry in supplying its products that has enabled it to build a great market in competition with coal. The oil industry has developed efficient, low-cost methods of drilling, producing, refining, and transporting liquid fuels. By supplying its products at attractive prices, it has built up large markets in direct competition with coal for home heating and industrial heating. In these fields its important advantage, in addition to a reasonable price, has been convenience and cleanliness.

Competition among fuels is keen and continuous. The coal industry is making progress in mechanization as a means of reducing costs. Experiments are being conducted on the transportation of coal in small particles together with liquids in a pipe line as a means of reducing the cost of moving coal to market. Such progress is spurred by the competition from oil. Similarly, progress in reducing costs for oil products is spurred by competition from coal. Consumers benefit greatly from this free competition among fuels. They would stand to lose from any decrease in that competition. Therefore, it would be contrary to the interest of consumers to permit any artificial restraints on the competition among fuels.

Dangers of Artificial Government Controls

The idea of artificial controls by government over the use of fuels recurs from time to time. It usually takes the form of proposals to prohibit the use of oil or gas for certain purposes. The argument for such controls is generally based on the theory that supplies of oil or gas are so short that they should be "saved" for future generations. The effect of the proposals would be to give coal a monopoly in certain markets. The very restriction on the use of oil and gas would interfere with the development of new supplies for the future. The report of the National Petroleum Council on "U. S. Crude Petroleum Reserve Productive Capacity," dated January 26, 1950, brought out the fact that crude oil discoveries and reserves are affected by the volume of production as well as price. Limitations on the market for petroleum.

therefore, would reduce the incentives for future discoveries in the same way as restrictions on price.

To insist that coal should be used instead of oil or gas because of fears of shortages in the future would mean that consumers would be deprived of the right to use available oil and gas which they prefer to buy because of their low price and other advantages. The imposition of such a penalty on consumers is not justified by present or future prospects for oil and gas supplies. Any government controls over the use of fuels would involve political considerations as to which areas and individuals should be forced to use the higher priced fuels. The economic power of such political controls over the progress of an area and the costs of individual firms would be very great. Such controls would violate the basic principle of reliance on competition which is at the root of American economic progress. Furthermore, it would make the erroneous assumption that technology is static. The truth is, of course, that our technical progress is so rapid that new and cheaper methods of securing fuel may be devised while oil and gas supplies are still very abundant.

Interrelation of Demand and Supply

Economic forces not only determine supplies but also demand. When supplies are abundant it is natural that demand should keep pace. Similarly, if demand tends to outrun supplies, price changes in a free market quickly work to restore a balance. In a free market demand and supply are inseparably related through price.

In the United States we use petroleum supplies very freely. Our consumption of petroleum per capita is about twenty times as much as that of the rest of the world, although our consumption of all forms of mineral energy per capita is about ten times as much as that in the rest of the world. We use powerful, heavy cars which realize much less mileage per gallon than the light cars generally used in Europe. The reason for this difference is the low price of gasoline in the United States. The gasoline produced now is 50 per cent more powerful than that supplied twenty-five years ago and its price, exclusive of tax, is almost exactly the same as in 1925. With the pay for one hour, the average manufacturing worker could buy more than twice as many gallons of gasoline, including higher taxes, in 1951 as in 1925. (Average hourly earnings in all manufacturing industries were $0.547 in 1925 and $1.59 in 1951. The average retail price of a gallon of gasoline, exclusive of tax, was 20.09 cents in 1925 and 20.27 cents in 1951. Including tax, the average retail price of a gallon of gasoline was 22.20 cents in 1925 and 27.01 cents in 1951. Therefore, with an hour's pay the average worker in manufacturing industries could buy 5.88 gallons in 1951 compared with 2.46 gallons in 1925.)

If at some distant future date we were really faced with a problem of limited oil supplies, many changes would occur in demand to bring about a balance with supply. There would then be an economic incentive and reason for using lighter cars with motors which would secure much greater mileage per gallon of gasoline. If such circumstances developed, the price of gasoline would increase and the industry would find it attractive to make more gasoline and less fuel oil out of a barrel of crude oil. As a result of such changes other forms of energy might be used in place of fuel oil and a larger proportion of the oil supplies might be used for automotive transportation. It is through such adjustments that a free economy provides users with the best and cheapest form of fuel available at any time. That freedom of choice on the part of consumers may seem extravagant to some, but it is the very key to the great economic progress of the United States and its abundance of fuels. Without such freedom of choice the mainspring of progress through competition would be removed to our great loss.

Confusion About Coal Supplies

Proposals for restrictions on the use of oil and gas are generally based on the theory that at best the supplies of these fuels are so small relative to the reserves of coal that greater use of coal should be forced upon consumers despite their wishes in the matter or the higher costs involved. These proposals have confused physical existence with economic availability. Coal is available only after it is mined, not when it is still in the earth. Whether it is economically useful depends on the costs of mining, transportation, and distribution in competition with other fuels. More coal is not used because at prevailing prices many consumers find it cheaper or more convenient to use oil or gas instead of coal.

The costs of making available much of the coal in the earth would be prohibitive. Some of the estimated reserves are buried so deep that they are of questionable significance. Others are in thin seams, and some are so remote from markets that high transportation costs would make them very expensive regardless of the cost of mining. The doubtful economic value of large parts of the estimated coal reserves has been expressed as follows by a distinguished authority:

> "One conclusion should be crystal-clear from this estimate of the coal reserves in the United States: Unless truly fantastic improvements in the state of the arts are achieved, our descendants will have to pay far more for coal than the prices paid both in the past and at present. Large portions of the coal reserves listed by Campbell are of such poor quality, are

located in such out-of-the-way corners, are so unfavorable as to thickness of vein, depth, etc., that only unheard-of ingenuity or desperate need will render them available for use. In other words, they are not commercial reserves now, and they may never be." *

The basic question in a discussion of available energy resources is how much can be supplied at prices that are attractive to consumers. The question of how much energy resources exists is entirely secondary to that of costs in any discussion of availability of energy resources.

Governmental Actions Affect Oil Supply

Economic forces in the modern world are subject to great influence by government action. There are many government measures which affect the supply of oil. Several immediate examples of such influence can be noted in the United States:

1. Price and Material Controls

In the years 1942-1946 and again beginning with 1950, the government has imposed controls over prices and materials which have affected the entire economy. The experience of World War II shows how such controls influence oil supplies. During the years 1942-1945 drilling decreased because of controls over materials and price ceilings which tended to result in lower profit margins as wages and other costs increased. As a result, the new oil reserves developed through discoveries, extensions, and revisions were less in this period than in the preceding or succeeding four-year periods of time. In the years 1938-1941 when the average price of crude oil was $1.08 a barrel, discoveries, extensions, and revisions of proved reserves were estimated to be 9.3 billion barrels by the American Petroleum Institute. During the next four-year period of war controls, similar estimates amounted to only 7.5 billion barrels. In the first four postwar years, following removal of government controls, the estimates of new discoveries, extensions, and revisions, were 13 billion barrels. The average price of crude oil in 1946-1949 was $2.12 a barrel, which amounted to $1.34 a barrel in terms of dollars of the same purchasing power as in 1938-1941. This example shows the adverse effects of government control and the stimulus to development provided by economic incentives.

2. Tax Policies

Tax policies also have an important effect on development of resources, particularly as tax rates reach high levels. A natural resource industry presents unique and difficult taxation problems because it is

* Zimmermann, Erich W., *World Resources and Industries*, Rev. Edition, page 462.

engaged in using up its basic capital as it produces the resources. It is necessary in this case to distinguish between capital and current income properly subject to the usual income tax rates. The capital in a producing property cannot be viewed merely as the money invested in that property, for large amounts of additional capital were risked and lost in related unsuccessful ventures. When Congress first applied income taxes it recognized that some special provisions were required for oil production in order to protect operators against unfair taxation compared with other industries. Several types of allowances were tried before Congress finally decided in 1926 on a simple method of percentage depletion as a means of distinguishing between capital and income properly subject to regular income tax rates.

The percentage depletion provisions of the income tax laws and the option to recover drilling costs immediately instead of over a period of time have become a part of the industry's basic economic structure. Adverse changes in these provisions would reduce the economic incentive for further search. Liberalization of the provisions on the other hand could stimulate the search and development of new oil. Governmental tax policies in this field can and will have an important bearing on future availability of oil supplies. Increasing tax rates in themselves tend to reduce the economic incentive for investment of risk capital. Any additional tax burdens due to changes in percentage depletion or the option to expense intangible drilling costs could have a prompt and serious effect on future oil supplies.

3. *Artificial Regulations*

Another example of the impact of artificial regulations on available supplies is provided by the efforts of the Federal Power Commission to regulate the price of natural gas on a cost basis as though the production of natural gas were a utility business rather than a hazardous resource development business. The Federal Power Commission has actually asserted control in some cases over the price of gas produced at the well and has set prices which are far below the market level determined by supply and demand under free competition. The threat that such regulations might be applied generally to gas producers definitely affects the economic incentive to develop natural gas supplies. To the extent that the economic incentive is reduced, there is a tendency for the effort devoted to the development of future supplies to decrease.

4. *Delay in Development of the Tidelands*

Another influence of government on future supplies in the United States has developed from the action of the Federal Government in seeking to assert its control over the Continental Shelf. Previously the states had exercised control over oil producing, fishing, dredging, and other activities on the Continental Shelf. When technological progress and the need for oil led to the willingness of oil companies to risk capital in exploring for the potential resources in this submerged area, it was the state which granted oil leases. Subsequently, the Federal Government brought suits against the states claiming control over the Continental Shelf. The controversy over control has delayed substantially the testing of the potential resources of this area and the development of new oil supplies.

The impact of government action on oil supplies is even more apparent in foreign countries than it is in the United States. The willingness of a country to grant concessions and permit exploration is essential if its potential resources are to be explored and tested. Furthermore, there must be assurance that in case of discovery and development, the investors who have taken the risks will be allowed to enjoy the results of any success. Unreasonable taxes, expropriation, or nationalization all constitute a serious threat to future supplies, not only in the countries where they occur but in other countries as well, because of their effect on willingness to risk capital in foreign areas.

Failure to permit private enterprise in the search for oil is a grave threat to the development of future oil supplies in an area, as evidenced by the backward position of Russia in oil production, despite its great potential resources. Russia's large area should have potential oil resources greater than those of the United States. At present Russia's oil production is only about 10 per cent as much as that of the United States; however, whereas in 1900 it was actually greater than in the United States. Similarly, the expropriated oil industry in Mexico has failed to keep progress with the developments in the rest of the Western Hemisphere, although prospects in that country are considered good.

It has been the extraordinary ability of the petroleum industry to supply liquid fuels at reasonable prices that has created the huge market for oil products and thereby provided the incentive for the risk of further capital in the search for still more supplies. These developments have taken place under the stimulus of keen competition within the industry and with other industries supplying fuels. They have proved of great benefit to us in terms of our economic progress and national security. It is essential that we realize, therefore, the basic forces which have provided us with an abundant supply of reasonably priced fuels in the past in order that we may benefit in formulating fuel policies for the future. It is competitive enterprise and economic incentive for the risking of venture capital which has provided us with abundant supplies of oil. Government planning and control has not been the basis of our fuel supplies. On the contrary, the experience of foreign countries shows that government planning and control is a handicap rather than a help to the development of large oil supplies. We must realize, therefore, that our future oil supplies depend upon keeping in effect active competition and reasonable economic incentives, and not upon the adoption of any other government plans or policies.

Alternate Sources of Liquid Fuels

The concern over future oil supplies comes down to the question of continuing to have liquid fuels at attractive prices which will permit us to maintain or increase our consumption in this form. We know that the United States could supply its needs for energy with much less liquid fuel than it uses today if that were economically necessary. We also know that if we are willing to pay higher prices, liquid fuels in large quantities can be made from oil shale, from natural gas, from coal, and from tar sands. At much higher prices for liquid fuels, however, the demand would be considerably less for fuel in this form and greater for alternate fuels in the form of gas or coal. The form in which we use energy is largely a matter of relative cost and convenience.

Liquid fuels are particularly convenient and economical for transportation. The automobile, airplane, steamship, and diesel engine provide low-cost transportation by virtue of the large amount of energy available in compact form from liquid fuel. As we have noted before, however, the amount of liquid fuel we use for transportation could be modified greatly if the cost of that fuel were higher. It should also be noted that other forms of fuels may be used in place of liquid fuels for transportation. Coal can be used for railroad locomotives and steamships at a higher cost than that currently paid for oil. Automobile engines could be run by gas from the burning of coal or wood. Contracts have been let for submarines and airplanes to use atomic energy. Technical progress may in time make atomic energy for commercial transportation quite attractive. It is possible that coal burning turbines may be developed for railroad and other forms of transportation. New methods may be devised for converting heat from the sun into cheap power for use in many different ways. The possibilities for the interchange of fuels through technology and economic adjustment are tremendous.

About one-fourth of the energy used in the United States at the present time serves to run mobile equipment, while the other three-fourths is for stationary units. In supplying heat for stationary units, price and convenience determine whether coal, oil, or gas will be used. Such abundant supplies of oil have been developed in the United States that we find it attractive and cheap to use large quantities of heating oil and residual fuel oil in stationary equipment. Roughly half of the oil used in the United States is for automobiles, airplanes, steamships, and diesel locomotives. Most of the remaining oil is used in stationary units, with a small part being made into lubricants and special products.

There is no economic hurdle other than the attractive price of oil, considering its convenience, to keep coal from capturing the markets for fuel used in stationary units. The increasing importance of oil and gas relative to coal has occurred simply because consumers have found it attractive to use liquid fuel and gas instead of coal and because the petroleum industry has made available large supplies.

Flexibility in Products Made from Crude Oil

If future developments should make oil seem less abundant relative to demand than it is today, and therefore higher in price by comparison with other fuels, many adjustments could take place among fuels. The amounts of different products made from a barrel of crude could, at some additional cost, be changed greatly. Much more gasoline might be made at the expense of distillate and residual fuel oil, but the cost of the gasoline would then be higher than it is now. In that case, gas and coal would first be used as a direct replacement for heating oil and fuel oil rather than as a source of synthetic gasoline. Such change would provide the cheapest solution of our energy requirements, for there is a considerable loss of heat and a high cost involved in converting coal from its solid state to liquid fuels. Since we use large quantities of fuel in solid, liquid, and gaseous forms, the natural development in case of any tendency toward a shortage of crude oil would be to use it for the liquid fuels which would be most expensive to supply from other sources.

Currently, the industry converts about 43 per cent of a barrel of crude oil into gasoline. Equipment is now in use which can secure a larger yield of gasoline from a barrel of crude oil, but it is not economically attractive to do so in terms of the relative prices and costs of making the various products. It would require only a few cents increase in the price of gasoline relative to heating and fuel oils to bring about larger production of gasoline from a barrel of crude. Processes are also known by which almost all of a barrel of crude oil could be changed into gasoline, but the cost of gasoline made by these processes would be considerably higher. The important point about petroleum refining technology is the great flexibility which can be attained in the output of products, depending upon economic incentives.

Liquid fuels can be made if necessary from materials other than crude oil. In terms of cost, the substitutes most closely approaching a competitive basis seem to be shale oil and gasoline from natural gas. The latter possibility seems limited because natural gas is such a convenient fuel in the form in which it exists in nature. It is easier and cheaper to make more gasoline from crude and to use natural gas directly in place of fuel oils than it is to convert natural gas into gasoline.

Oil from Shale

The ultimate prospects for production of liquid fuels from oil shales are good, even though costs are not yet competitive. A pilot plant is now in operation at Rifle, Colorado, using this process. The cost of gasoline from shale is still substantially higher today than the cost from crude oil. Improved technology and any tendency toward a scarcity of crude oil, however, might make gasoline from shale oil competitive ultimately. There are technical problems involved in the development of large supplies of oil from shale, however, particularly with respect to sufficient water for the plants and a low cost for disposing of the large amount of shale left after the extraction of the oil.

Shale oil may not be commercially attractive unless crude oil proves to be much more difficult and expensive to find than it is currently. The investments in shale oil plants are tremendous and the risks in competition with crude oil from domestic and foreign sources are consequently quite serious. Ultimately, however, if the need for liquid fuels should prove to be greater than can be supplied from natural petroleum, the development of oil from shale might prove commercially attractive and would be undertaken by private capital. In the meantime, the wise course seems to be to continue research on the production of shale oil and to let economic forces determine the natural development of this supply under competitive conditions.

It has been estimated that there may be more than 100 billion barrels of oil that can be recovered from shale in the Rocky Mountain area. Whether this oil can or will be recovered will depend on economics. Cheaper supplies of energy from other sources may be available in such quantities that the use of shale oil will be very limited. Technological progress might make liquid fuels obsolete while supplies of oil are still abundant and before the commercial development of oil shales is feasible. We cannot say that oil shale will ever be developed commercially, but it may be an alternate source of gasoline at a cost only a few cents more than that from crude oil.

Liquid Fuel from Coal

The potential supplies of liquid fuels from coal are even greater than those from oil shale. If economic costs are completely ignored, theoretically the coal reserves of the United States could be used to make several hundred billion barrels of liquid fuels. As a matter of practical economics, however, the cost of liquid fuels in this form would be prohibitive under present technology and competitive conditions.

The cost of gasoline from coal would be a great deal more than that from oil shale and, of course, than the current price of gasoline.

The capital investment required for development of gasoline from coal would be enormous. Government estimates indicate a plant investment of about $10,000 for the capacity to produce one barrel daily of liquid products from coal. The increase in demand for petroleum products in the United States in 1951 was more than 500,000 barrels daily. It would take an investment of five billion dollars to supply from coal merely the increase in demand for liquid fuels between 1950 and 1951. The cost of operation and the price of liquid fuels from coal would have to be so much higher than current prices for oil products that the demand inevitably would be only a fraction of what it is now.

Liquid fuels can be made from coal and have been made by that means in foreign countries, by both hydrogenation and synthesis. It is possible, although not economically feasible, to make liquid fuels from coal in this country. We know that liquid fuels can be made by several different processes from shale, coal, and gas if the need or desirability of doing so arises.

There are some who propose that the United States government should immediately undertake to build large plants for the manufacture of oil from shale or coal. Even small quantities of oil by these processes would require tremendous investments by the government and subsidies to permit production, as the products could not compete commercially with those made from crude oil. Construction of such plants obviously could be undertaken only if the government would guarantee markets for the products at a higher price than it needs to pay for products made from crude oil. The danger and fallacy of such proposals, in addition to their tremendous cost to the taxpayers, is that they would automatically interfere with the market for natural petroleum and act to reduce the economic incentives for the development of new crude oil. There is no real need for the government to undertake these expensive and uneconomical projects when private capital is available to supply all of the liquid fuels required.

Reserve Petroleum Productive Capacity

The petroleum industry of the United States has a substantial reserve capacity currently, and available supplies continue to increase at a rapid rate. It is the existence of adequate capacity to meet normal needs which provides the greatest assurance of supplies in case of any national emergency. Such was the experience in World War II when enormous military requirements were met without government investments in oil production. The small naval reserves owned by the government in Elk Hills made very little contribution to the supplies of oil for war, because they were not developed and ready when the emergency came. There is substantial leeway for cutting the civilian use of petroleum products in case an emergency requires supplies for military use greater than the reserve capacity of the industry, and additional capacity can be developed if the industry is given enough steel for drilling new wells.

The principal risk which may lie ahead for the United States in continuing to rely on crude oil supplies is in becoming unduly dependent upon foreign sources that might be cut off suddenly. It is for that reason that the National Petroleum Council has stressed the importance of adequate supplies of domestic production and the desirability of keeping imports in the position of supplementing domestic supplies. The degree of accessibility of foreign oil in case of an emergency will be of paramount importance. Oil from Canada might be almost as accessible as that from the United States. On the other hand, oil from the Middle East might be quite inaccessible in case of an emergency. Consequently, the United States must look primarily to supplies in the Western Hemisphere which it must count upon protecting and having available in any emergency. So long as its imports come primarily from such Western Hemisphere sources, the principal concern need be only with keeping the proportion of imports to domestic supplies in reasonable relation, so that domestic supplies still continue to be our primary source.

The advantages to the nation and consumers of using the cheapest available fuels is quite clear from our own history. That policy takes advantage of competition among fuels and within each fuel industry to provide us with abundant supplies of energy at the lowest cost. That policy has served to make the United States the leading nation in the production of oil, gas, and coal, and in the development of technology for producing these fuels which are still the indispensable sources of power for economic progress. Technology permits such great flexibility in the use of fuels that economics becomes the determining force at any time in deciding how much of the different forms of fuels we will use.

The economic outlook is that we will continue to have abundant supplies of oil and of all forms of energy for a long time to come.

Conclusion

This study of the long-term prospects for petroleum supplies has dealt with two major issues:

1. The forces which have made and will continue to make oil available.
2. The prospects for oil supplies for the foreseeable future.

The following conclusions result from this study:

We have today in the United States and the world larger supplies and larger proved reserves of oil and gas than ever before.

Our tools and techniques for finding and developing petroleum have improved greatly and continue to improve rapidly.

Competition has proved an extremely effective device for stimulating development of new resources and new processes which serve to supply us with fuels.

The economic forces of a free market continue to be the best method of developing abundant fuel supplies at low cost for consumers.

Fuel supplies needed for national security as well as economic progress are provided best by relying upon competition.

There still exist excellent prospects for the development of ample new reserves of oil and gas in the United States and in foreign countries.

We have the potential resources, the technology, and the economic framework for continuing to enjoy large supplies of fuels.

The major threat to future oil supplies would be any interference with economic incentives which might act to prevent the normal developments that would otherwise occur.

Our prospects are good for the discovery of petroleum and for ample supplies of fuels generally for the foreseeable future.

EXHIBIT A

POSSIBLE FUTURE PETROLEUM PROVINCES

The symposium on "Possible Future Oil Provinces of North America," published in the bulletin of the American Association of Petroleum Geologists, Volume 35, February 1951, is the basis for this summary. Decisions as to the possible future oil provinces were made by local geological societies, members of geologic surveys, and other specialists particularly well informed on the geology of various areas. The symposium thus presents the general views of the industry because of the manner in which it was prepared.

The present symposium brings up to date a similar study of the United States and Canada made by the American Association of Petroleum Geologists in 1941. The 1941 symposium described 34 provinces considered to have possibilities for future discoveries. By 1951 discoveries of oil and gas had been made in 20 of the 34 provinces. The 1951 study lists 60 provinces with future oil prospects. Technological progress has led to inclusion in the more recent study of the Continental Shelf and sediments as deep as 20,000 feet.

The location of the possible future petroleum provinces in the United States is shown on Figure 1. The areas of these provinces have been computed by planimeter. Including that part of the Continental Shelf to 120 feet water depth contour, the area of the 60 provinces is 1,660,000 square miles. The Continental Shelf area included in this total is 77,000 square miles. The symposium gives a figure of 235,000 square miles, but 100,000 square miles covered by water 120 to 656 feet deep, and 58,000 square miles off the shores of Mexico have not been included in the present estimate. No mention was made in the symposium of the Continental Shelf of the southeastern United States which has an area of about 30,000 square miles to a water depth of 120 feet. This area is not included in the preceding total of 1,660,000 square miles.

Some of the prospective areas relate to deeper producing possibilities in provinces that already have shallow production. This is true, for example, of the western Gulf Coast shown as No. 41 on the map. The area of presently producing provinces not duplicated by that of future oil provinces is 200,000 square miles. The sum of the areas in presently producing provinces and possible future petroleum provinces, excluding duplications, is 1,860,000 square miles.

A brief description of the 60 possible future petroleum provinces listed by the American Association of Petroleum Geologists follows.

FIGURE 1

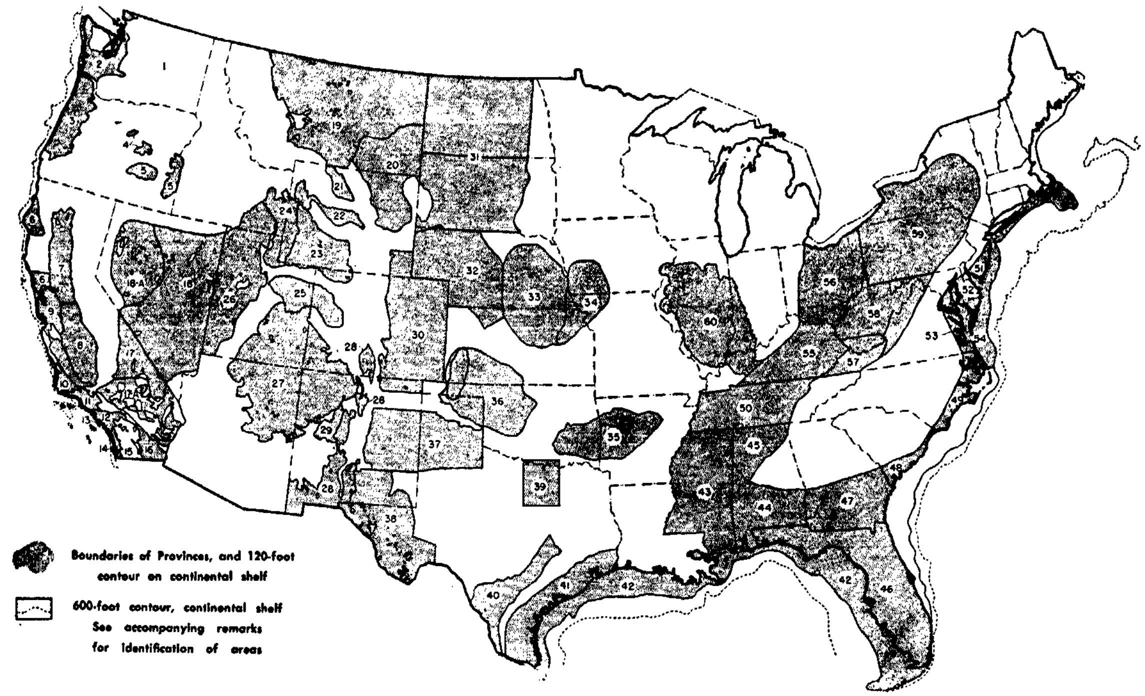


FIGURE 1. SOME POSSIBLE FUTURE PETROLEUM PROVINCES OF THE UNITED STATES IN ADDITION TO PRESENTLY PRODUCING AREAS THAT ALSO HAVE PROSPECTS FOR FUTURE PRODUCTION*

Based on a symposium on "Possible Future Petroleum Provinces of North America" conducted by the American Association of Petroleum Geologists and published, February, 1951

*The Symposium from which this summary was prepared dealt with geologic provinces or areas considered to have possibilities for future discoveries. Some of the geologic provinces, such as No. 41, are deeper formations underlying present production. Some presently producing areas, such as the State of Mississippi, were included on the basis that they still are at an early stage of development. Some other producing areas, such as the Permian Basin of West Texas, were considered to belong more in the category of proved provinces than prospective, although they may still have substantial prospects for future discoveries. The bounding of certain provinces by state boundaries or certain latitude or longitude apparently resulted from the manner in which assignments were divided between local geologic groups for study.

SUMMARY DESCRIPTION OF POSSIBLE FUTURE PETROLEUM PROVINCES SHOWN ON FIGURE 1

1. **Eastern Washington**

   This area of 54,000 sq. mi. receives only brief mention and is not considered prospective at present. Most of the area is covered by Miocene volcanics. There is a non-commercial gas field in Benton County.

2. **Western Washington**

   An area of 15,000 sq. mi. having a section of interbedded sediments and volcanics up to 11,000 feet or more. There are at least 13 authentic oil and gas seeps, 35 small gas wells, and showings of light oil in several wells.

3. **Oregon Coast Range**

   An area of 14,000 sq. mi. having a 20,000 to 25,000-foot section, about half of which is volcanic. Three-fourths of the sediments present are marine. There are no authentic seeps, but some asphaltic residue associated with volcanics and some siltstone having a kerosene odor.

4. **Central Oregon**

   1,400 sq. mi. having a 35,000 ft. predominantly marine section. No seeps are present, but there are Mesozoic black shales, asphaltic residues, fetid limestones and calcareous sandstones, fossil shells containing a volatile amber oil. Remotely prospective.

5. **Southeastern Oregon**

   An area of 6,000 sq. mi. in part covered by Tertiary volcanics. Thickness and nature of section is largely unknown, but contains appreciable sediments and volcanics. Section has been penetrated by one well to 6,500 feet. Strong showings of gas at very shallow depth. Remotely prospective.

6. **Northern Coast Ranges of California**

   Includes an area of 2,000 sq. mi. which is considered to have fair prospects. One minor gas field in the Eel River Basin, many oil and gas seeps and tar sands. In places, the section is in excess of 12,000 feet.

7. **Sacramento Valley**

An area of 14,000 sq. mi. In part, the section is in excess of 20,000 feet. 28 commercial gas fields have been discovered. One major gas field. Excellent prospects.

8. **San Joaquin Valley**

An area of 14,000 sq. mi. Maximum depth to basement is in excess of 30,000 feet. Major oil discoveries in the Helm and Coalinga areas. Excellent future prospects.

9. **Central Coast Ranges**

Includes 4,500 sq. mi. of sediments considered to have good prospects. Major oil discoveries at San Ardo, Russell Ranch and South Cuyama. Many oil seeps and outcropping tar sands.

10. **Santa Maria**

Area of 2,000 sq. mi. Maximum depth to basement 16,000 feet. 16 producing areas discovered.

11. **Ventura Basin**

Area of 5,000 sq. mi. Maximum depth to basement estimated to be 60,000 feet. 53 oil fields and 2 gas fields discovered.

12. **Los Angeles Region**

Prospective area of 2,000 sq. mi. Long the most productive California area. Much possible vertical and lateral extension. Estimated maximum thickness of sediments, 25,000 feet. 41 oil fields and 1 gas field discovered.

13. **Continental Shelf, Southern California**

Lithologic character and structure similar to adjoining Ventura and Los Angeles Basins, and should have similar oil content. Area 2,000 sq. mi.

14. **Southern Coastal Region**

Area of 1,000 sq. mi. Remotely prospective. Only 30 wildcats drilled. Several wells to basement without showings. Maximum depth to basement, 6,000 ft. Seeps and other evidence of oil lacking.

15. **Southern Mountain Region**

Area of 6,000 sq. mi. Remotely prospective. 70 exploratory wells. Evidence of oil and gas scant. Some production in two wells, abundant showings near Placerita.

16. **Imperial Valley**
Area of 4,000 sq. mi. Remotely prospective. Possibly 25,000 feet of sediments, mostly non-marine. No good evidence of oil or gas.

17. **Eastern Desert and Mountain**
Central subprovince, 12,800 sq. mi., is the most prospective, containing thick normal marine sediments in the eastern part. One known oil seep, associated with volcanic thermal activity. Some showings of oil. Northern subprovince, 41,000 sq. mi., not considered prospective.

17A. **Southern subprovince of 17**
13,700 sq. mi. not considered particularly prospective because of complex structure, metamorphic areas, and predominantly terrestrial sediments. Not sufficiently explored.

18. **Nevada**
Paleozoic Basin, comprising an area of 65,000 sq. mi., is considered prospective. Large area and thickness of sedimentary rock, containing all types of reservoir rock. Poorly explored. One known oil seep, oil stains in Paleozoic limestones, some free oil associated with fossils. At least 30,000 feet of sediments in part of the area.

18A. **Nevada-Permo-Trias Basin**
19,000 sq. mi., considered not prospective chiefly because of lack of exploration, considerable metamorphism. Minor evidences of oil in fossils. Some oil shale.

19. **Central Montana**
An area of 84,000 sq. mi., largely unexplored. Great thickness of sediments. 16 small oil fields and 2 gas fields. One major oil field. Many showings in Devonian and Mississippian.

20. **Powder River Basin**
Area of 35,000 sq. mi. Oil and gas fields and seepages surround the basin. Deep exploration only begun. Good possibilities for stratigraphic traps and reef production. At least 16,000 feet of sediments in deeper parts. Mush Creek and Sussex are major discoveries.

21. **Big Horn Basin**
Area of 3,500 sq. mi., with 17,000-foot section. Many oil and gas fields surround the basin. Major production from Embar formation at 10,000 feet in Worland field and at 8,000 feet at Badger Basin.

22. **Wind River and Jackson Hole Basins**

Area of 6,500 sq. mi., 20,000 feet in deepest parts. Numerous oil seeps. 14 oil and gas fields border area on three sides.

23. **Green River Basin**

Area of 20,000 sq. mi. Section at margin of basin exceeds 30,000 feet. Contains all kinds of structures and suitable reservoir rocks. Numerous evidences and some production of oil and gas. Church Buttes, major gas production.

24. **Overthrust Belt**

Area of 13,000 sq. mi. 60,000 feet of sediments in southern part. Several fields produce oil and gas along the southeastern border of the area.

25. **Uinta Basin**

Area of 14,000 sq. mi. with maximum section of at least 20,000 feet. Roosevelt field is a major producer. Production also at Ashley Creek. Many other indications of oil and gas.

26. **Great Basin**

Area of 38,000 sq. mi. Maximum section of 40,000 feet. Both oil and gas seepages present.

27. **Four Corners Region**

Area of 83,000 sq. mi. Up to 15,000 feet of sediments. Minor Cretaceous, Permian and Pennsylvanian production; many seeps and strong showings of oil and gas.

28. **Rio Grande Basins**

Area includes some 23,000 sq. mi., with sediments ranging from 1,000 to 15,000 feet in thickness. Surface indications of oil and gas lacking.

29. **West Central and Southwestern Basins**

Area of 4,000 sq. mi. (Zuni Basin is included in the Four Corners region on the map.) Average thickness of strata, 8,000 feet. Remotely prospective.

30. **Eastern Colorado and vicinity**

Area of 54,000 sq. mi. Several minor oil discoveries and oil seeps.

31. **North and South Dakota**

Area of 117,000 sq. mi. Maximum of 12,000 feet of sediments. Recent oil discovery in the Williston Basin. Several showings of oil and gas.

32. **Western Nebraska**

Area of 44,000 sq. mi. Average thickness of sediments about 4,000 feet. Minor production and numerous showings.

33. **Salina Basin**

Area of 40,000 sq. mi. Maximum depth of sediments somewhat less than 5,000 feet. Minor production.

34. **Forest City Basin**

Area of 19,000 sq. mi. Maximum depth of sediments about 4,000 feet. Minor production.

35. **Southeastern Oklahoma and Northwestern Arkansas**

Area of 21,000 sq. mi. with sediments ranging from 2,000 to 40,000 feet. Small amounts of oil, 60 producing gas fields.

36. **Anadarko Basin**

Area of 41,000 sq. mi. Maximum depth of sediments in excess of 20,000 feet. Important production on three sides of the area. Elk City a major discovery. Two others, Apache and Ringwood.

37. **Plainview Basin**

Area of 46,000 sq. mi. Maximum thickness of 11,000 feet. Major production in Anton Irish field. Three fields produce from Pennsylvanian reef limestone. Many oil showings.

38. **Trans-Pecos**

Area of 40,000 sq. mi. More than 15,000 feet of sediments. Minor production in 15 oil and gas fields. Prolific production northeast of area. Numerous showings in Delaware Basin.

39. **Fort Worth Basin and Muenster Arch**

Area of 11,000 sq. mi. Maximum depth of sediments, 17,000 feet. 90 sq. mi. already productive. Deeper drilling should result in many discoveries.

40. **Downdip Mesozoic Rocks of South Texas**

Area of 19,000 sq. mi. 4,000 to 15,000 feet of Cretaceous rocks and about 1,300 feet of Jurassic rocks below present production. Present Cretaceous production in Pearsall, Jourdanton and Imogene fields.

41. **Western Gulf Coast**

Area of 26,000 sq. mi. Wilcox, Yegua-Cockfield, and Frio, below 10,000 feet. Important gas-distillate production below 10,000 feet in Wilcox in Central Gulf Coast area and major proved reserve in the Frio at Old Ocean field.

42. **Continental Shelf, Gulf of Mexico**

Area of 77,000 sq. mi. to 120-foot water depth contour. Sediments similar to those of adjoining land area. Shelf off Louisiana might be considered as already proved. (The symposium gives a figure of 235,000 sq. mi., but this includes that part of the shelf off Mexico and assumes the entire shelf out to water depths of 656 feet.)

43. **Mississippi**

Area of 49,000 sq. mi. Already a proved oil province. 3 major oil fields and 2 major gas fields already discovered. Up to 30,000 feet of sediments in southwestern part.

44. **South Alabama**

Area of 26,000 sq. mi. Maximum of 25,000 feet of sediments. One producing field and good showings in other wells.

45. **Northwest Alabama**

Area of 14,000 sq. mi. Numerous showings of oil and gas.

46. **Florida**

Area of 58,000 sq. mi. Estimated maximum of 20,000 feet of sediment in places. One producing field. Excellent possibilities for structural and stratigraphic traps.

47. **Georgia**

Area of 30,000 sq. mi. No commercial production. Several oil seeps and showings.

48. **South Carolina**

Area of 5,000 sq. mi., insufficiently explored. No production, unconfirmed oil seeps.

49. **North Carolina**

Area of 8,000 sq. mi. Section is about 10,000 feet thick in vicinity of Cape Hatteras. Unconfirmed showings of oil and gas in some wells.

50. **Tennessee**

Area of 32,000 sq. mi., poorly explored. Has all requisites of an oil province, source beds, reservoir rocks, and structures. Minor production and good showings. Adjacent areas are productive.

51. **New Jersey and Long Island**

Area of 3,000 sq. mi. of sediments thicker than 1,000 feet. Conditions favorable for stratigraphic traps. No seeps or other indications of oil and gas.

52. **Maryland and Delaware**

Area of 7,000 sq. mi. Like New Jersey and other Atlantic States, the area is insufficiently explored. Possible stratigraphic traps. Beds are thin and lenticular, a fact which discourages development in all these Atlantic coast areas.

53. **Virginia**

Favorable area of 3,000 sq. mi. Same comments apply as to areas 51 and 52.

54. **Continental Shelf, N.E. United States**

Area of 27,000 sq. mi. to the 120-foot depth contour. If geophysical evidence is correct, the dip on land continues out to sea and there should be 13,000 to 16,000 feet of sediments favorable for the accumulation of oil and gas.

55. **Kentucky, east of crest of Cincinnati Arch**

Area of 27,000 sq. mi. in which deeper Paleozoic possibilities remain to be explored. There are many showings and several wells now produce from greater depths.

56. **Ohio, east of crest of Cincinnati Arch**

Area of 33,000 sq. mi. with deep possibilities. One major discovery, Canton gas field, producing from the Silurian.

57. **Southern Basin Area**

Area of 11,000 sq. mi. having excellent deep possibilities. Rose Hill represents first commercial production east of the Appalachian structural front and opens a large area for further exploration. Numerous oil seeps.

58. **Central Basin Area**

Area of 30,000 sq. mi. with excellent deep prospects. Some commercial production developed. Major gas production in deeper part of the basin. Many encouraging showings in the Ordovician.

59. **Northern Basin Area**

Area of 75,000 sq. mi., with good prospects for deep drilling. New discovery in the Devonian has caused increased exploration activity. Many showings of gas and oil below present production.

60. **Eastern Interior Basin**

Area of 52,000 sq. mi. having deep prospects. Within the basin, no wells penetrate more than two-thirds of the probable section, which in places may reach 13,000 feet. Many neglected areas even of formations known to be the best reservoirs in present production.

EXHIBIT B

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El Paso Natural Gas Company

Frederic H. Lahee
Sun Oil Company

A. I. Levorsen
Stanford University

John M. Lovejoy
Seaboard Oil Company of Delaware

Joseph E. Pogue
The Chase National Bank

Wallace E. Pratt
Petroleum Geologist

Carl E. Reistle, Jr.
Humble Oil & Refining Company

J. French Robinson
The East Ohio Gas Company

A. C. Rubel
Union Oil Company of California

A. L. Solliday
Stanolind Oil & Gas Company

Clarendon E. Streeter
Carter, Bradley and Streeter

Henry N. Toler
Southern Natural Gas Company

J. Ed Warren
Independent Petroleum Association of America

W. K. Warren
Warren Petroleum Corporation

George A. Wilson
Interstate Natural Gas Company, Inc.

PANEL ON FUTURE DISCOVERY PROSPECTS

Chairman: Ira H. Cram, Continental Oil Company

Raymond F. Baker
The Texas Company

George S. Buchanan
Sohio Petroleum Company

Monroe G. Cheney
Anzac Oil Corporation

E. DeGolyer
DeGolyer & MacNaughton

A. Rodger Denison
Amerada Petroleum Corporation

G. Clark Gester
Consulting Geologist

K. C. Heald
Gulf Oil Corporation

Serge B. Jurenev
Continental Oil Company

Paul Kayser
El Paso Natural Gas Company

Frederic H. Lahee
Sun Oil Company

A. I. Levorsen
Stanford University

William S. McCabe
Stanolind Oil & Gas Company

Clarence L. Moody
The Ohio Oil Company

Frank A. Morgan
Richfield Oil Corporation

Wallace E. Pratt
Petroleum Geologist

Henry N. Toler
Southern Natural Gas Company

Paul Weaver
Gulf Oil Corporation

Gerald H. Westby
Seismograph Service Corporation

Fred H. Wilcox
Socony-Vacuum Oil Company

PANEL ON IMPROVED DEVELOPMENT AND RECOVERY TECHNIQUES

Chairman: J. ED WARREN, Independent Petroleum Ass'n. of America

Secretary: STUART BUCKLEY, Humble Oil & Refining Company

D. V. Carter
Magnolia Petroleum Company

H. E. Chiles, Jr.
Western Company of Midland

Richard W. French
Sohio Petroleum Company

Jake L. Hamon
Mid-Continent Oil & Gas Association

H. H. Kaveler
Phillips Petroleum Company

Hallan N. Marsh
General Petroleum Corporation

C. V. Millikan
Amerada Petroleum Corporation

Carl E. Reistle, Jr.
Humble Oil & Refining Company

Ivan Salinkov
Standard Oil Company (N. J.)

Clarendon E. Streeter
Carter, Bradley and Streeter

Paul D. Torrey
Lynes, Inc.

W. K. Warren
Warren Petroleum Corporation

PANEL ON ECONOMIC AND POLITICAL FACTORS

Chairman: STEWART P. COLEMAN, Standard Oil Company (N. J.)

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Standard Oil Company of California

Robert G. Dunlop
Sun Oil Company

William H. Garbade
Deep Rock Oil Corporation

Richard J. Gonzalez
Humble Oil & Refining Company

B. A. Hardey
Petroleum Producer

Robert E. Hardwicke
Attorney, Fort Worth

Serge B. Jurenev
Continental Oil Company

Walter J. Levy
Petroleum Consultant

John M. Lovejoy
Seaboard Oil Company of Delaware

Eugene McElvaney
First National Bank, Dallas

Robert L. Minckler
General Petroleum Corporation

Joseph E. Pogue
The Chase National Bank

J. French Robinson
The East Ohio Gas Company

J. Melville Sands
Phillips Petroleum Company

Henri Schwall
Shell Oil Company

George A. Wilson
Interstate Natural Gas Co., Inc.

PANEL ON FUTURE DEVELOPMENT OF SUPPLIES FROM SYNTHETIC SOURCES

Chairman: A. C. RUBEL, Union Oil Company of California

P. C. Keith
Hydrocarbon Research, Inc.

L. C. Kemp, Jr.
The Texas Company

Eger V. Murphree
Standard Oil Development Company
(Alternate, E. J. Gohr)

A. L. Solliday
Stanolind Oil & Gas Company

EXHIBIT C

NATIONAL PETROLEUM COUNCIL
MEMBERS

January 29, 1952

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W. T. Waggoner Estate

Robert O. Anderson, President
Malco Refineries, Inc.

C. H. Arnold, Vice-President and General Manager
Haggart's Service, Inc.

Hines H. Baker, President
Humble Oil & Refining Company

Max W. Ball
Oil and Gas Consultant

Munger T. Ball, President
Sabine Transportation Co., Inc.

T. H. Barton, Chairman of the Board
Lion Oil Company

Fred E. Bergfors, President and Treasurer
The Quincy Oil Company

Jacob Blaustein, President
American Trading & Production Corporation

Paul G. Blazer, Chairman of the Board
Ashland Oil & Refining Company

Rush Maxwell Blodgett, Executive Vice-President
Oil Producers Agency of California

William R. Boyd, Jr., Managing Partner
Boyd, Hardey & Wheelock

Reid Brazell, President and General Manager
Leonard Refineries, Inc.

J. S. Bridwell
Bridwell Oil Company

Russell B. Brown, General Counsel
Independent Petroleum Association of America

H. S. M. Burns, President
Shell Oil Company

Robert H. Colley, President
The Atlantic Refining Company

Howard A. Cowden, President and General Manager
Consumers Cooperative Association

Earle M. Craig, President
National Petroleum Association

Stuart M. Crocker, Chairman of the Board
The Columbia Gas System, Inc.

John F. Cummins, President
Cumberland Oil Company

Horace E. Davenport, President
Independent Oil Men's Association of New England, Incorporated

E. DeGolyer
DeGolyer & MacNaughton

J. C. Donnell, II, President
The Ohio Oil Company

Fayette B. Dow, General Counsel
National Petroleum Association

Warwick M. Downing
Independent Oil Producer

J. Frank Drake, Chairman of the Board
Gulf Oil Corporation

John Dressler, President and Executive Secretary
New Jersey Gasoline Retailers Association and Allied Trades, Inc.

Gordon Duke Oil Marketer

J. L. Nolan, Manager, Oil Department
Farmers Union Central Exchange, Inc.

J. R. Parten, President
Woodley Petroleum Company

Bryan W. Payne, President
Texas Independent Producers and Royalty Owners Association

Wm. T. Payne, President
Mid-Continent Oil & Gas Association

Joseph E. Pogue
Petroleum Consultant

Frank M. Porter, President
American Petroleum Institute

E. E. Pyles, Vice-President
Jergins Oil Company

Walter R. Reitz, Vice-President
Quaker State Oil Refining Corporation

Sid W. Richardson, President
Sid W. Richardson, Inc.

A. S. Ritchie
Independent Producer

M. H. Robineau, President
The Frontier Refining Company

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The Texas Company

Roland V. Rodman, President
Anderson-Prichard Oil Corporation

A. H. Rowan, President
Rowan Oil Company

R. S. Shannon, Director
Pioneer Oil Corporation

W. G. Skelly, President
Skelly Oil Company

P. C. Spencer, President
Sinclair Oil Corporation

Clarendon E. Streeter, President
Pennsylvania Grade Crude Oil Association

Reese H. Taylor, President
Union Oil Company of California

A. W. Thompson, President
American Association of Oilwell Drilling Contractors

R. L. Tollett, President
Western Petroleum Refiners Association

W. W. Vandeveer
Oil Producer

S. M. Vockel, President
The Waverly Oil Works Company

J. Ed Warren
% King, Warren & Dye

Wm. K. Warren, Chairman of the Board
Warren Petroleum Corporation

L. S. Wescoat, President
The Pure Oil Company

John H. White, Vice-President and General Manager
Hewitt Oil Company

Russel S. Williams
Individually Branded Petroleum Association

Robert E. Wilson, Chairman of the Board
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John Wrather
Independent Oil Operator

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Sunray Oil Corporation

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Producers Refining, Inc.

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Max M. Fisher, Executive Vice-President
Aurora Gasoline Company

R. G. Follis, Chairman of the Board
Standard Oil Company of California

Clyde T. Foster, President
The Standard Oil Company (Ohio)

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Oil Marketer

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Union Tank Car Company

B. I. Graves, Vice-President
Tide Water Associated Oil Company

Walter S. Hallanan, President
Plymouth Oil Company

B. A. Hardey
Independent Producer

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Texas Eastern Transmission Corp.

John Harper, Chairman
National Oil Jobbers Council

I. W. Hartman
Oil Producer

Fred W. Herlihy, President
National Oil Marketers Association

Charles S. Hill
Oil Producer

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Atlantic Coast Oil Conference, Inc.

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Standard Oil Company (N. J.)

D. A. Hulcy, President
Lone Star Gas Company

A. Jacobsen, President
Amerada Petroleum Corporation

B. Brewster Jennings, President
Socony-Vacuum Oil Company, Inc.

Carl A. Johnson, President
Independent Refiners Association of California

Charles S. Jones, President
Richfield Oil Corporation

J. P. Jones, President
National Stripper Well Association

W. Alton Jones, President
Cities Service Company

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The Superior Oil Company

Richard Gray Lawton, President
Lawton Oil Corporation

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Seaboard Oil Company of Delaware

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Charlton H. Lyons, President
Independent Petroleum Association of America

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Great American Oil Company

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Ashland, Kentucky

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Honolulu Oil Corporation

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Petroleum Equipment Suppliers Association

Nelson Maynard, President
National Congress of Petroleum Retailers, Inc.

L. F. McCollum, President
Continental Oil Company

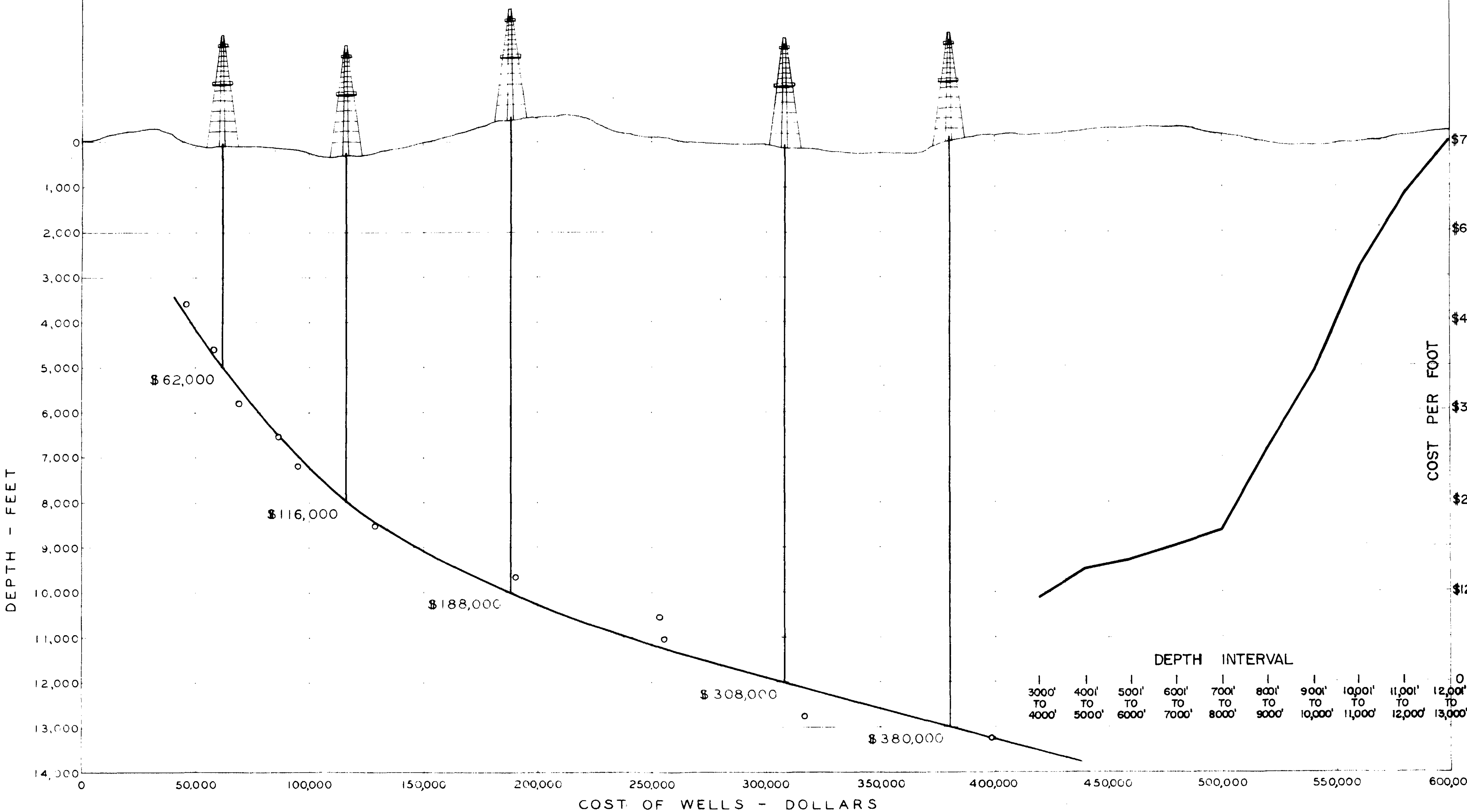
N. C. McGowen, President
United Gas Corporation

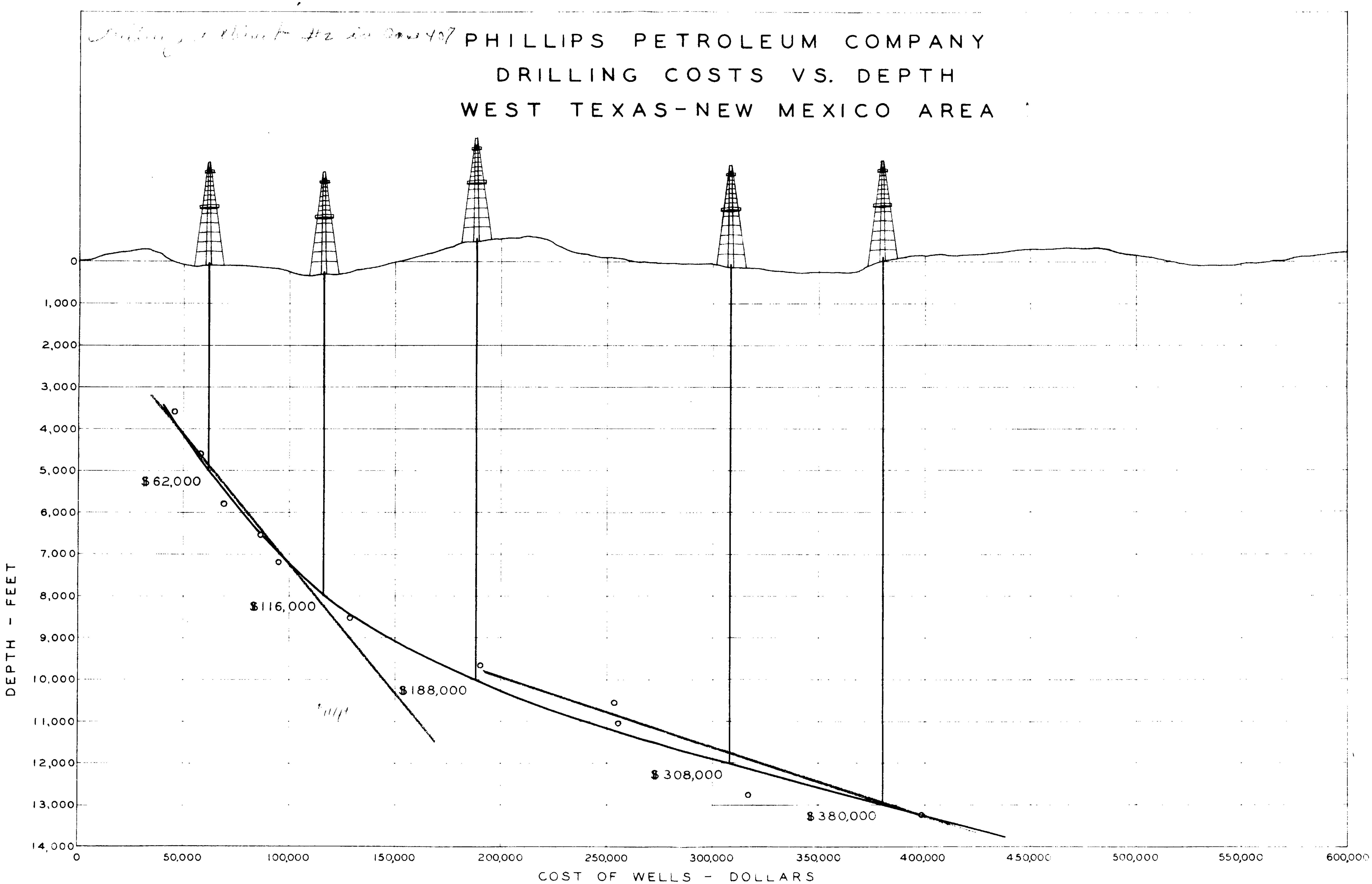
S. B. Mosher, President and General Manager
Signal Oil and Gas Company

Glenn E. Nielson, President
Husky Oil Company

S. F. Niness
National Tank Truck Carriers, Inc.

PHILLIPS PETROLEUM COMPANY
DRILLING COSTS VS. DEPTH
WEST TEXAS-NEW MEXICO AREA




PHILLIPS PETROLEUM COMPANY
DRILLING COSTS VS. DEPTH
WEST TEXAS-NEW MEXICO AREA
DEPTH - FEET
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
$62,000
$116,000
$188,000
$308,000
$380,000
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
500,000
550,000
600,000
COST OF WELLS - DOLLARS