The Responsibility of Geologists and Petroleum Engineers in Meeting Exploration Demands in the Future

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Abstract

The oil industry should be preparing right now for the high future demands of petroleum products, even though there are adequate reserves to handle present demand. Engineers and geologists, in particular, should cooperate and strive to use data at hand to increase the efficiency of methods of finding new oil. Several important areas of cooperation are discussed and examples are given of instances in which such cooperation led to significant discoveries. Broader responsibilities of engineers and geologists are also pointed out.

Introduction

In 1962, the United States produced 3.02 billion bbl of crude oil and natural gas liquids. This is the first time that total liquid hydrocarbon production has exceeded 3 billion bbl. In 1962, the United States also set a new record for natural gas by producing 13.7 trillion cu ft. At this rate of production, this country will have consumed its proven reserves of 38.7 billion bbl of liquid hydrocarbons in 12 1/2 years and its proven reserves of 273.8 trillion cu ft of gas in 20 years.

Annual demand, however, is increasing at an established rate of 2 1/2 to 3 1/2 per cent/year for oil and 4 1/2 to 5 per cent/year for gas. Therefore, in order to maintain an adequate reserve position during the next 10 years, the United States must find 45 billion bbl of oil and 275 trillion cu ft of gas. In short, the petroleum industry's geologists and engineers must find and produce more oil and gas in the foreseeable future than has ever been produced in an equivalent previous period. In view of this challenge, one can only conclude that the basic law of supply and demand on which this country's economy is, or has been, based promises a bright future for the industry.

This rosy glow in the early morning sky is viewed at the moment, however, by an industry which is in a deep valley full of dark shadows. At a time when all signs point to an ever-increasing demand for new reserves and greater productive capacity, the industry finds itself with more products to sell than present consumers can use. In addition, there is the problem of the loss of investment capital as a result of the continuing threat of increasing federal control. The sum of these two factors equals a reduction in exploration and production which is revealed by declining activity over the last 10 years.

Industry Reaction

Fig. 1 presents a brief resume of exploration and development in the United States since 1953. Geophysical activity is down 50 per cent from a high of 8,240 crew months in 1955 to a low of 4,231 crew months in 1962. Exploratory drilling is down 33 per cent from a peak of 16,207 wells in 1956 to 10,797 wells in 1962. Finally, as the inevitable result of a decline in exploration, development drilling has dropped 16 per cent from a high of 42,000 wells in 1956 to 35,408 in 1962.

This current problem is further complicated by still
another factor. Exploratory drilling is not only the lowest it has been during the last 10 years, but the per cent of profitable discoveries is continually decreasing. Fig. 2 is taken from data compiled by the AAPG and shows by bar graph the number of wildcat wells drilled each year for each profitable oil and/or gas field found. A profitable field is defined as one which has proven to be profitable after six years of development history. The companion curve on this same graph shows the per cent of profitable discoveries in the total number of wildcat wells drilled. For example, in 1945 the industry found one profitable field with every 26 wildcat wells drilled, a ratio of 3.75 per cent. In 1956, 52 wildcat wells were required to find one profitable field, a ratio of 1.87 per cent.

As a result of the reduction in exploration and development, the reserve position of the nation is deteriorating. Fig. 3 shows the net change in the country's reserves at the end of each year indicated. At the end of 1953, the United States had 1.43 billion bbl more of crude oil and natural gas liquids than it did at the end of 1952. Conversely, at the end of 1962, a decrease in discovery of new reserves left the country 107 million bbl below its reserve position at the end of 1961. Up to the present time, natural gas reserves have shown an increase at the end of each year; however, as revealed on Fig. 3, the rate is decreasing and the general slope of the curve is downward.

Although all signs point to future demands increasing at a compounding rate (Fig. 4), the petroleum industry is not justified in spending the large sums necessary to find new reserves when it is unable to utilize the productive capacity which it now has. This type of investment foolishness can be practiced only by those industries which have an artificial market or a guaranteed rate of return provided by a benevolent government. When consumers' requirements grow until they exceed productive capacity, the industry will once again be able to conduct a strong exploration program. The question is what should the industry be doing now in the dark shadows of pre-dawn until that bright new day arrives?

**Engineering and Geological Cooperation**

The first thing members of this industry should do is recognize the situation as it is for what it is—a difficult period in the life of a strong industry whose existence is essential to the national economy and vital to the national defense. Second, members of the industry must realize that until conditions improve, the funds available for exploration and production will continue to be limited. Therefore, it follows that efficiency and economy must characterize every operation. There are vital roles to be played by the geologist and petroleum engineer, both separately and jointly. It is a fact of life in the petroleum industry that production follows discovery, discovery follows successful exploration, and successful exploration is a function of sound geological and geophysical study and evaluation. In anticipation of the severe demands of the future, exploratory activity now and in the months and years ahead must be primarily directed toward the discovery of
large new reserves. In the next decade, geologists in the Texas-Louisiana Gulf Coast region will be concentrating their exploration for important new fields in the following general categories:

1. New trends which become available for exploration as their potential is recognized or as the industry is able to drill to greater depths and to extend the downdip limits of formations with proven productive capabilities. At the present time, the lower Cretaceous trend is an example of the former and the downdip Wilcox exploration an example of the latter;
2. Deep-seated structures whose existence is not reflected in shallow horizons;
3. Remnant accumulations of oil and gas associated with earlier movements of known salt domes; and
4. Stratigraphic traps.

Concurrently, petroleum engineers will be applying efficiency and economy to their continuing efforts to increase reservoir yield by: (1) developing, improving and applying new techniques of drilling, completing and producing; (2) perfecting new and improved methods of stimulation; and (3) developing better techniques of secondary recovery and making more universal application of these techniques to producing areas.

All of these endeavors are well recognized and in effect in every conscientious company. However, there is an area of joint responsibility between geologists and petroleum engineers which, up to this point in the industry's history, has been neglected. Fifteen years ago, members of the industry recognized a need for better coordination between geologists and geophysicists. Although it took approximately 12 years for this coordination to become effective, it is now obvious that today most exploration integrates the unique contributions of both the geologist and the geophysicist.

In meeting the challenge of future demands, the exploratory activity of aggressive companies must now also utilize the additional strength available through the joint efforts of geologists and petroleum engineers.

There are a number of areas in which these two professional groups can combine their talents to augment the exploratory effort.

Producing Reservoirs

Geologists and petroleum engineers have a great opportunity to find new reserves by working together in areas above, below and around producing reservoirs.

Traditionally, geologists seek and find, and petroleum engineers develop and produce. Once a discovery is made, the geologists tend to lose interest and turn over the responsibility for the area to the petroleum engineers. Once the engineers assume responsibility, they are prone to devote their interest only to development of the initial reservoir or reservoirs found with the discovery well. Although development planning and drilling rightfully fall under the jurisdiction of the petroleum engineers, this does not mean that the geologists have no responsibility to continue to explore the area, nor does it mean that the engineers have no obligation to look for and identify data which might have exploratory significance.

The sharing of this joint responsibility occurs in two phases. First, the geologists and petroleum engineers should both be certain that the transition from wildcat prospect to producing field is accomplished with a full disclosure of all information, including revised geophysical interpretations. Too often petroleum engineers are forced to take over a producing area in its early stages of development with little more than a vague description of the general nature of the local geology.

Therefore, the geologists have an initial responsibility to provide the engineers with complete information on all the geological complexities which are known or expected. Second, geologists and petroleum engineers should evaluate the exploratory potential of all new data obtained from development drilling. A check list of items for joint investigation should include:
1. Studying all electric logs for (A) unexpected structural relationships, (B) faults, (C) isopach thinning or thickening, and (D) lithological changes indicating possible new reservoirs;
2. Observing and explaining differences or changes in bottom-hole pressure, gas-oil ratio, gravity, fluid contacts and fluid analyses;
3. Recording and explaining changes in the decline rates of bottom-hole and flowing pressures;
4. Evaluating the significance of reservoir limit determinations to (A) help locate fault traces, and (B) establish possible reservoir pinchouts;
5. Comparing the areal extent of production indicated from subsurface control with the areal extent indicated from material balance determinations.

At one time or another every petroleum engineer or geologist has acknowledged the value to exploration of incorporating this type of information in geological interpretations, but in actual practice little progress has been made. If future demands are to be met, exploration must make full use of all engineering data.

Examples of Successful Cooperation

Here are three examples of new producing areas which have been found as a result of observing and acting upon one or more of these several criteria. West Bastian Bay field, Plaquemine Parish, La., with estimated reserves exceeding 2 trillion cu ft of gas was discovered by the Pan American Petroleum Corp. as a result of subsurface and seismic work initially generated by observing 15 ft of isopach thinning in the bottom of a nearby field well. The well containing the diagnostic thinning was not a Pan American well. Undoubtedly this phenomenon was also observed by representatives of the company who drilled the well, but apparently no one pursued the lead or recommended any action. The important point is that this single thread of evidence initiated a chain of events which ultimately resulted in the discovery of a field with recoverable reserves worth half a billion dollars. The data were there for anyone to see, but the monthly production checks are being mailed to the company whose explorers not only saw the evidence but also visualized its signiﬁcance and took positive action.

The second example, the Fairway field in Anderson and Henderson counties of northeast Texas, is probably one of the most important discoveries made in the U. S. in the last 10 years. At the present time, the productive area covers 23,000 acres and the field limits are still undefined on the south. Since discovery in 1960, over 150 producers have been completed. The alert operator who discovered Fairway field became interested in the area because of the productive performance of the discovery well and only producer in the Frankston field. During the first few months of production, this well experienced an increase in the gravity of the oil, an increase in the flowing tubing pressure and an increase in the gas-oil ratio. At the end of five years of production, the bottom-hole pressure had dropped only 20 psi, indicating possible access to a large reservoir. Recognizing the significance of this productive history and incorporating it with the known geology in the area, the Fairway Operating Co. assembled a block and discovered a field which in the first 2½
years of its life has already produced 5½ million bbl of oil.

A third example of the kind of reserves that remain to be discovered in and around known producing areas is the Arnold-David field, Nueces County, Tex. Arnold-David field, discovered in 1960, contains over 80 producing oil wells completed at an average cost of $42,000/well. Proved reserves under primary recovery are estimated in excess of 20 million bbl. The new producing area is located on the east flank of the old Luby field, discovered in 1937. In the 23 years since discovery the eastern limits of Luby had never been defined by a dry hole. Several aspects of the Luby field accumulation puzzled those who worked the area. For one thing, one of the several sands which produced at Luby was gas productive whereas the rest were all oil reserves. In addition, the gas-water contact in this unique sand had never been established. Finally, there were known sands in wells regionally downdip from Luby which were not present in field wells. With the discovery of Arnold-David field, several of these mysteries cleared up. The gas sand proved to be the gas cap of an oil sand whose column occurred further downdip. Several of the sands which were developed downdip but not present in the old field wells were found pinching out on the east flank of the Luby uplift, providing multiple stratigraphic reservoirs.

There are certain characteristics common to all of these examples: (1) all are major fields with new large reserves; (2) the clues which led to their ultimate discovery were available to everyone; and (3) none of the discoveries was made by the company whose well or wells provided the information which stimulated the exploration.

This last point is particularly puzzling. It sometimes appears that the last company to take advantage of new information has the first one which had an opportunity to do so.

With examples such as these, it is obvious that important new reserves of oil and gas still remain to be discovered in and around producing fields. Typically, the odds for success on exploratory drilling in this category range from 23 to 70 per cent.

The AAPG annually compiles statistics on exploratory drilling. Exploratory wells are defined as wells drilled in search for new and as yet undiscovered pools or for long extensions of pools already partly developed. Exploratory wells are classified into five categories.

The first is new field wildcats—wells drilled for a new field on a structure or in an environment never before productive. These are the tests usually considered as wildcat wells.

The other four categories all define exploratory wells drilled in association with established production.

Outpost tests are wells drilled for long extensions of partially developed pools. New pool wildcats are wells drilled for a new pool on a producing structure but outside the limits of the proven area. Deeper pool tests are exploratory wells drilled inside the limits of proven production for new pools below the deepest producing horizon. Shallow pool tests are wells drilled inside the limits of production for new pools above the deepest producing horizon.

Table 1 shows the average per cent of exploratory wells drilled in each category from 1950 through 1962, and the average per cent of wells in each category which were productive. Over the last 13 years, 55.6 per cent of all exploratory wells were drilled as new field wildcats. Only one out of nine, or 11 per cent, of the new field wildcats were completed as oil and gas producers. The other four categories of exploratory wells, however, show a much more promising success ratio. In the same 13 year period, outpost wells recorded a 32.14 per cent success record; new pool wildcats, 23 per cent; deeper pool tests, 38.5 per cent; and shallow pool tests, 70.5 per cent.

On the basis of these statistics, it is obvious that geologists and petroleum engineers exploring together above, below and around established pools and utilizing to full advantage all of the significant data available have a remarkable opportunity to find and produce the important new reserves which will be necessary to meet the growing demands of the future. To make this joint effort a success, geologists must realize that engineering data is as valid an exploratory tool as is the electric log or the geophysical device, and strive to obtain and incorporate all engineering information in geological interpretations.

At the same time, petroleum engineers must realize that their data have potential exploratory value, must develop an aggressive, inquisitive attitude, and must promptly advise the geologists of all unusual and significant data they uncover. The exercise of this responsibility on the part of the geologists and engineers is a professional duty and not one that can be or should be officially delegated by management.

**Exploration Programs**

Geologists and petroleum engineers should work together in planning long-range exploration programs. This is particularly true in the Gulf Coast region where productive trends coincide with geological trends. Joint studies of fields typical of the various producing trends should identify those whose economic and engineering performance show the highest rate of return per dollar invested. Therefore, during a time when limited exploration money is available, it is only logical to spend it exploring those geological trends whose fields have demonstrated the highest profitability.

**Evaluation of Wells**

There needs to be joint work in planning and evaluating all wells drilled. Too many engineers think that the best well is the one which has been drilled and plugged at the least expense. Too many geologists think that any sort of completion is better than a dry hole.

As a result of poor planning, too many companies suffer the embarrassment of having one of their plugged wells produce for someone else or one of their condemned prospects produce in an offset well 30 ft below their total depth. In planning jointly for the evaluation of wells, geologists and engineers should utilize development wells to explore whenever possible and anticipate information which will be desired or needed later so
that it can be obtained in initial wells. They should also think of secondary objectives which can be achieved by early planning; and conduct objective post-mortems of all wells drilled to evaluate the accomplishment of planned objectives and identify new data with potential exploration value.

Development Programs

Geologists and engineers should work together in planning development programs to eliminate the drilling of unnecessary wells. This can be accomplished in several ways.

Exploratory units should be formed by the various companies represented on a geological prospect prior to the drilling of the initial well. With the establishment of an area of mutual concern a proper spacing pattern can be developed which is based on geological and engineering data rather than conflicting interests.

As soon as possible after discovery, fieldwide units should be formed not only to assure proper spacing and protect property rights but also provide the framework for early initiation of secondary recovery programs.

For every unnecessary development well which is not drilled, additional funds become available for the exploratory wells which must be drilled to meet future demands. In his 1962 report to the Federal Power Commission, Ira H. Cram, chairman of the Executive Committee of the Continental Oil Co., predicted that producers will have to drill an average of 62,300 wells/year over the next 10 years in order to meet the nation's demand for oil and gas. The significance of this figure comes into focus when compared to the all time high of 58,200 wells drilled in 1956 and the 46,200 wells drilled in 1962.

Most of the money necessary to drill these additional wells must be generated within the oil industry. A major source of revenue for the drilling of necessary wells can be made available through the efforts of geologists and petroleum engineers in eliminating the drilling of unnecessary wells.

Technical Developments

If future demands must be met with limited resources, then geologists and petroleum engineers have a responsibility both jointly and individually to develop new tools, new techniques, and new innovations which will save time, money and reserves. The petroleum industry is long overdue for some technical breakthrough in the areas of exploration, drilling and recovery. Essentially, exploration and production still employ the same techniques and tools which have been in use the last 30 years. It is true there have been improvements; but by and large the basic tools have not been altered.

As professional men, geologists and petroleum engineers need to encourage each other to create new tools and techniques for tomorrow. The responsibility for scientific invention must not be relegated solely to the research and development section. In the immediate future, the industry will have to find new methods of improving discovery rates, new ways to reduce drilling costs, new approaches to stimulating flow from low porosity and permeability reservoirs, better methods of achieving more complete recovery of reserves, and better devices for accurate evaluation of potential reservoirs penetrated by the drill.

Supporting Conservation

Geologists and petroleum engineers have a joint responsibility to work together in supporting scientifically valid conservation laws and practices. This is a professional responsibility which becomes more imperative as the complexities of the economy necessitate the establishment of laws and regulations by the various levels of government. It is the professional duty of technically trained men to speak up on every issue whose final disposition should be based on the application of scientific principles. Geologists and petroleum engineers should step forward to offer testimony on issues involving geological and engineering principles.

Through their individual professional organizations, they should form joint committees to study pending legislation and proposed regulations and distribute the results of their findings to the proper decision-making bodies.

It is interesting to note that during the last session of the Texas Legislature, a proposed compulsory pooling bill was introduced. It generated a great deal of discussion. Many special interest groups appeared to voice their personal preferences but a very limited number of professional geologists or engineers, either individually or corporately, made known their scientific or technical opinion. In such a void, issues such as this generally end up being decided on the basis of emotion or in acquiescence to the dominating pressure of the special interest lobbyists.

Promoting Education

In the last six years there has been a 77 per cent drop in the enrollment of petroleum engineers in colleges and universities. The number of engineers graduating and available to the petroleum industry each year in all classifications is less now than the annual turnover in the industry due to retirement, death and other causes. This same general pattern is true for graduating geologists. Therefore, in order to fulfill the responsibilities which will be imposed by the demands of the future, geologists and engineers should be looking for and encouraging outstanding young men to consider careers in petroleum geology or engineering.

Long-Range Possibilities

Finally, in order to assure the discovery of needed future reserves, geologists and petroleum engineers must meet their responsibility as citizens interested in preserving the country's defense capabilities, as members of a major industry essential to the national economy, and as professional men specifically responsible for meeting the nation's exploration and production requirements.

This responsibility must be exercised jointly and individually by working to preserve and maintain a political and economic atmosphere in which the oil industry can wage an aggressive, competitive and rewarding search.

For too long professional men have considered themselves immune from the responsibility of actively engaging in political affairs. Circumstances in this country no longer permit such an attitude. Along with all other concerned citizens, geologists and petroleum engineers must take an active interest in politics, must stay aware of pending legislation and must make their own opinions known to their congressmen and to others.

All predictions of the nation's future growth indicate a compounding need for petroleum reserves. This industry has overcome every crisis with which it has ever been faced. The future will find no exceptions. The petroleum industry will meet the heavy requirements of the future, and the combined efforts of geologists and petroleum engineers will play a major role in satisfying these increasing demands for exploration.

EDITOR'S NOTE: PICTURES AND BIOGRAPHICAL SKETCHES OF MICHEL T. HALBOUTY AND THOMAS D. BARBER APPEAR ON PAGE 311.

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