How Much Oil? It Depends on Whom You Ask

Estimates of the oil yet to be found in the United States vary, but U.S. Geological Survey estimates remain among the most optimistic

The oil wells among the grazing cattle and cotton fields of west Texas have been pumping for more than 50 years. By 1976, this region had produced about 19 billion barrels of oil, an amount equal to 6 years of production from the entire United States. Experts believe, with some confidence, that another 8 or 9 billion barrels of recoverable oil remain in the ground in the known oil fields there. But their estimates of how much remains to be discovered in new fields vary by a factor of 2 and more, even though west Texas is one of the most thoroughly explored areas in the world.

Many experts in industry believe that, no matter how enthusiastic the search may be after decontrol of the price of oil, little new oil remains to be found in west Texas or the other aging oil provinces of the lower 48 states. But with the recent release of its new estimates, the United States Geological Survey (USGS) retains its relatively optimistic outlook for the lower 48 states. The USGS estimates are widely used by government agencies and some oil companies to forecast energy supplies.

For other sites, the USGS and industry find greater agreement. The offshore regions and especially Alaska, they say, offer real possibilities of stopping or slowing America's slide into greater dependence on foreign supplies of oil. But that general agreement is based on the same subjective methods of assessing undiscovered oil used by the USGS to arrive at the relatively large estimates of the west Texas potential. Offshore and in Alaska, these methods become even more subjective as the amount of useful information becomes scarcer. The variability of recent assessments, most clearly illustrated by those for west Texas, raises questions about the role of enthusiasm for the hunt in gauging the nation's future energy supplies.

To make its estimates, the USGS geologists attempt to determine whether each step in the formation of an oil deposit could have occurred in the proper order at a particular place. The geologic process of oil formation, and thus this resource assessment procedure, is a complex one. The history of today's oil deposits in west Texas goes back more than 550 million years. Then, the area was a shallow, submerged shelf extending out into the ocean. Silt and clay washing off the land and the microscopic shells of marine animals began to pile up on the shelf, along with decaying organic matter from the land and the sea. The shelf first began to subside and form a basin, and then, about 300 million years ago, the same forces that raise mountain ranges warped it into several smaller basins separated by shallower platforms and shelves.

Later, during the geologic period called the Permian (which lasted from 280 to 225 million years ago), great reefs grew along the margins of the basins. As layer after layer of sediment accumulated, the resultant heat and pressure converted some of the buried organic matter into oil and gas. As this oil and gas leaked away from its source, impermeable layers of rock, such as shale, trapped some of the oil and gas within more porous rocks, such as the limestone of the reefs. The chance arrangements that enclosed porous reservoir rock with impermeable seals resulted from the draping of sediments over the reefs or the warping and breaking of rocks under the stresses that formed the Permian Basin itself.

In view of this complex history, numerous questions about the Permian Basin needed to be answered. How much rock porous enough to form a reservoir remains undrilled? Was there a source of oil and gas nearby? Was that source heated enough to make plenty of oil or gas? Were the reservoir rock and its seal in place, properly shaped into a trap, when the source rock released the oil or gas? Could the trap have since ruptured and spilled its contents?

The USGS Resource Appraisal Group (RAG), headquartered in Denver under the direction of Gordon Dolton, approached these kinds of questions by first putting the matter in the hands of a petroleum geologist familiar with a particular province, such as the Permian Basin. This expert gathered the relevant data—seismic surveys, analyses of rock strata penetrated by drilling, rock outcrop maps, and records of drilling success—and presented them to a meeting of the full group. Then, the expert and each group member made their own estimates of the undiscovered recoverable oil and gas in the province, compared them, and hammered out a consensus.

For the Permian Basin, the RAG final mean estimate, released late this February,* was 2.9 billion barrels of oil, with a 95 percent chance that at least 1.0 billion barrels remain to be found and a 5 percent chance that more than 6.2 billion barrels are yet to be discovered. The mean estimate for undiscovered natural gas was 33.3 trillion cubic feet, which would have the energy content of 6.3 billion barrels of oil (5.27 trillion cubic feet of wet gas equals 1 billion barrels of oil equivalent, or 1 billion BOE).

Another study†, a federal interagency report released in 1980, arrived at considerably less optimistic estimates of the undiscovered resources in the Permian Basin. Actually, it presented two separate estimates, each based on data developed by two different groups within the USGS. The USGS Office of Resource Analysis in Reston, Virginia, provided an estimate of 1.3 billion barrels of recoverable oil and 3 billion BOE of gas. That is less than 50 percent of the RAG 1981 estimate. Those familiar with the estimates attribute the difference to the use of different methods by the two groups. The estimate of the Office of Resource Analysis depended on a statistical treatment of the exploratory drilling in the Permian Basin—how much oil was found over the years for each foot of well drilled. Detailed geologic understanding did not enter directly into it.

This finding-rate approach does include one geologic principle, plus a bit of common sense. The geologic principle is that oil and gas fields come in a range of sizes—in the Permian Basin they range from 1000 BOE to 2 billion BOE each. Although the vagaries of geologic processes combine to form many more small fields than large ones, the few large ones still contain most of the oil and gas, note Lawrence Drew and David Root of the Office of Resource Analysis. The Permian Basin contains about 4000 known

*G. L. Dolton *et al.*, *U.S. Geol. Surv. Open-File Rep. 81-192* (1981).
†*U.S. Geol. Surv. Circ. 828* (1980).

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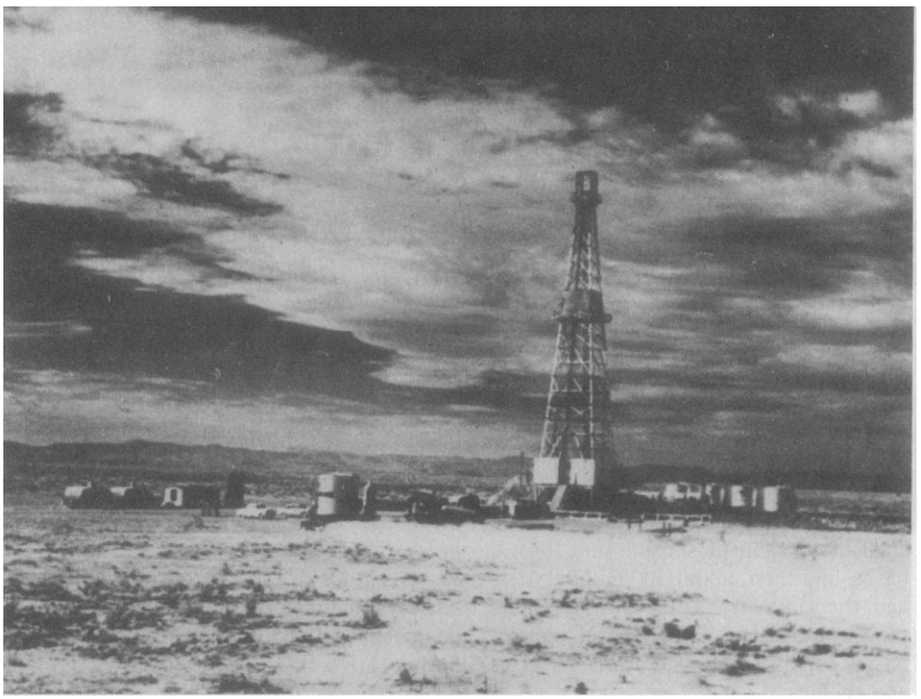


Gulf Oil Corporation

West Texas oil field

fields, but the 70 fields holding 100 million BOE or more account for 60 percent of the oil and gas discovered so far. The bit of common sense is that the large fields are found first. Not only are drillers more likely to stumble upon them first even if drilling is random, but such fields also show up more readily as prospects in geophysical surveys.

Because most of the oil is found in a few large fields, a pattern of declining discovery developed in the Permian Basin that is typical of most basins. Between 1930 and 1950, drillers sank more than 6000 wells and discovered about 60 percent of all of the oil that had been found in this basin up to 1974. They then had to drill another 24,000 wells to find the other 40 percent. The USGS Reston group used this pattern of a sudden drop in the finding rate followed by a continuing slow decline as the basis of an extrapolation to future drilling results.

The other Permian Basin estimate reported in the interagency study fell about midway between the finding rate estimate of the Office of Resource Analysis and the official estimate of RAG derived by a subjective evaluation method. This was a third USGS estimate, which was prepared by Dolton, several other authors of the official RAG estimate, and other researchers in the Denver office. Although they followed the same basic procedures as RAG later used to make its estimate, the Denver group came up with a mean estimate of only about 2.0 billion barrels of recoverable oil and 3.3 billion BOE of recoverable gas remaining undiscovered. After RAG took the Denver group's 120-page report‡ as the starting point for its own assessment, it raised the estimate by almost 1 billion barrels of oil and 3 billion BOE of gas. Dolton explains that "reanalysis of the data led us to a more optimistic view of what would be there."

RAG has been unduly optimistic in the past as well, according to the interagency report. In its first detailed estimate of U.S. undiscovered recoverable oil and gas,§ RAG reported a mean estimate for region 5, an area that includes the Permian Basin, of 8 billion barrels of oil and 13.3 billion BOE of gas. No specific estimate for the Permian Basin was made. The interagency report notes that region 5 includes other basins besides the Permian, but it concludes that "only a small part of the large discrepancy between the two estimates [8 and 1.3 billion barrels of oil] can be attributed to geography; most of it has to be reckoned as a downward revision of resources ascribed to the Permian Basin in Circular 725."

RAG did lower its region 5 estimates in its 1981 revision of Circular 725, dropping its oil estimate from 8 to 5.4 billion barrels. Two and one-half billion barrels of that are allocated to basins outside the Permian. That not only leaves too much in the Permian Basin, says Richard Meyer, a USGS researcher in Reston and coordinator of the interagency Permian project, but it also attributes far too much undiscovered resources to other basins that are as played out as the Permian. The entire region has been extensively drilled, Meyer says, but 80 percent of the oil and gas discovered has been found in the Permian. Thus, other basins such as the Fort Worth are unlikely to contribute much to region 5's total of 5.4 billion barrels. Even if prices were well above the $40 per barrel assumed in the interagency report, he says, that much oil would not be found.

Other recent estimates of the Permian's potential tend to support the interagency report's less optimistic view. A report‖ prepared for the USGS and the U.S. Department of Energy by Richard Nehring of the Rand Corporation, released 11 April, proposes the lowest estimates of all—0.4 billion barrels of oil and 1.0 billion BOE of gas. Nehring used the finding-rate approach but did not predict the few large-field discoveries or the large number of very-small-field discoveries anticipated by the interagency study. Exxon, which is widely regarded as one of the few oil companies making detailed, independent resource assessments, has an estimate for the Permian so close to that of the interagency report that "you would think someone cheated," according to Ralph Garrett of Exxon USA in Houston. For basins like the Permian, Exxon leans heavily on the finding-rate approach.

RAG's tendency toward higher estimates extends to the rest of the lower 48 states. In 1975, the mean estimate for the onshore provinces of the lower 48 was 44 billion barrels of oil. In 1981, it was up to 48 billion barrels, buoyed in large part by a bright outlook for the Rocky Mountain Overthrust Belt. Nehring's mean oil estimate, which is certainly among the lowest, is 4.7 billion barrels, only one-tenth of the USGS estimate. Independent estimates made by major oil companies, although not as low as Nehring's, are generally much smaller than those of RAG, according to industry sources. These estimates generally depend on finding-rate studies. One of the major oil companies has estimated that less than one-half of the RAG assessment remains to be discovered. Herman Frannsen of the International Energy Agency in Paris encountered this more pessimistic outlook during a survey of assessment methods that he made of about 20 American oil companies.

Why is there a difference between the subjective geologic method as applied by RAG and methods that lean heavily on the finding-rate approach? Defenders of the geologic method are quick to point

‡*U.S. Geol. Surv. Open-File Rep. 79–838* (1979).
§B. M. Miller *et al.*, *U.S. Geol. Surv. Circ. 725* (1975).
‖*The Discovery of Significant Oil and Gas Fields in the United States* (Rand Corporation, Santa Monica, Calif., 1981)

out that the finding-rate method is inherently conservative. It allows for no new developments—no refinements in geophysical surveying techniques, no new ideas about the kinds of traps to look for, no unsuspected large fields, no dramatic shifts in the economics of petroleum.

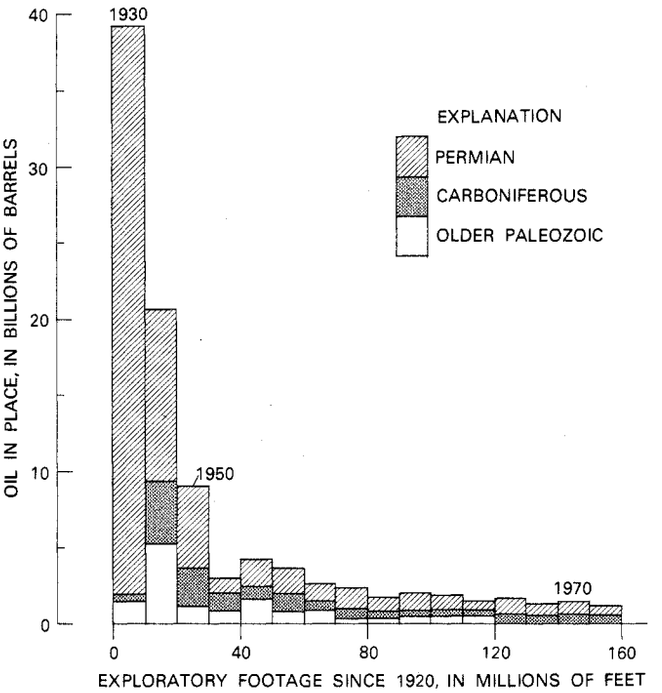
Proponents of the finding-rate method respond that, yes, such developments can and have affected the rate at which oil has been found, but the effect in the lower 48 states has been minor. Nehring notes in his report that "the amount of crude oil discovered in the onshore lower 48 states has declined at an accelerating rate since the peak in the decade around 1930. From this decade to the decade around 1940, it dropped 15 percent, another 34 percent in the decade around 1950, and 59 percent in the decade around 1960. The peak in the amount discovered coincides with the peak in the number of giant oil and composite [oil and gas] discoveries." The amount discovered in the Permian Basin peaked around 1930 as well, in spite of technological advances, price increases, and the resulting flurries of drilling. Once the big, readily located fields have been discovered, it is all downhill, according to this point of view.

Some observers believe that simple overenthusiasm can lead to higher estimates in the lower 48 when the subjective geologic approach is used. "Every geologist thinks he can find oil in his basin," says Joseph Riva of the Congressional Research Service, a petroleum geologist himself. "A lot of luck is involved. There's a propensity toward being optimistic. It's just part of the gambling nature" of petroleum exploration, he says. Garrett of Exxon agrees that a petroleum geologist looking for oil in the field must have an optimistic attitude to stay in the business. Before Garrett makes a resource assessment, however, he feels that he must filter out the natural enthusiasm of the exploration geologist. Harry Kent of the Potential Gas Committee, a private, nonprofit group, concedes that the optimism of exploration geologists may influence his committee's estimates of undiscovered gas. Its estimates traditionally fall near the high end of the range of all estimates. One reason, he says, may be the composition of the committee—all members are active in natural gas exploration.

Outside of the onshore provinces of the lower 48 states, where drilling has so far been less intense, those attempting to assess undiscovered oil and gas resources must largely abandon any dependence on the finding-rate approach. There has been too little opportunity for drilling to permit statistical treatment. In the offshore provinces and in Alaska, everyone, including oil companies that depend primarily on the finding-rate method elsewhere, must rely on subjective geologic analysis. Unfortunately, geologists know much less about such lightly drilled areas than they do about basins like the Permian.

Permian Basin finding rate

The historic finding rate for oil, 1920 to 1974, in the Permian Basin. After the early drilling found many of the largest fields, the volume of oil found per foot of well drilled dropped dramatically. Smaller fields continue to be found, but most of the oil in the basin must have been in the few large fields. Recoverable oil equals about 30 percent of "oil in place." [Source: U.S. Geological Survey]



With everyone using the same type of approach, estimates of undiscovered resources seem to converge. Nehring's mean estimate for undiscovered oil offshore of the lower 48 states is 3.5 billion barrels, "only" 4.5 times lower than RAG's 15.8 billion barrels. For all of Alaska, the gap is narrower—Nehring's 13.6 versus 19.2 billion barrels. Roy Roadifer of Mobil in New York notes that Mobil, and most of the industry, is less optimistic about the onshore reserves of the lower 48 than the USGS, but Mobil is actually more enthusiastic about the offshore reserves than the USGS. Another indicator of a shift toward closer agreement in frontier areas is a survey being conducted by the private National Petroleum Council of Washington, D.C. According to several participants, estimates of undiscovered resources made by the USGS, oil companies, and consultants for the onshore and offshore frontier areas of Alaska are in the same ball park at least.

The unexplored, frontier areas appeal to industry because they offer the possibility of finding huge fields, ones large enough to help slow the decline in discoveries and production. Estimates of undiscovered oil and gas in frontier and lightly explored regions depend heavily on comparisons with well-known geologic provinces elsewhere, both petroleum-producing and -nonproducing ones. Petroleum geologists believe that those comparisons promise that at least a few really big finds are likely in the frontiers, although many prospects will inevitably not pan out.

Lately, most of the news out of frontier areas has been bad (*Science*, 8 June 1979, p. 1069). Large trapping structures in the eastern Gulf of Mexico, the Gulf of Alaska, and the mid-Atlantic outer continental shelf have turned up dry. The USGS reevaluation of its 12 top outer continental shelf prospects of 1975 led to decreases in the estimates for ten of them. Outside of the Beaufort Sea, for which estimates soared from 4.7 to 13.6 billion BOE of oil and gas, the rest accounted for a net decrease of 13 billion BOE. The estimate for onshore Alaska dropped 6 billion BOE to 18.1 billion BOE.

In the face of that kind of uncertainty, industry would like to be doing less resource analysis and more drilling. Drilling, it is said, is the only way to find out what is really there. In most areas of the lower 48 states, drilling has shown that only modest amounts of gas and especially oil remain to be discovered, according to industry experts. Now, areas such as the Arctic Slope, the Beaufort Sea, the deep waters of the Gulf of Mexico, and the Rocky Mountain Overthrust Belt must be drilled to see if estimates of their resources are any more accurate than those associated with recent disappointments.

—RICHARD A. KERR