LETTERS

Oil and Gas Resources

Debates in the form of letters to *Science* may not be very useful for solving complex scientific problems, but some of the comments of S. Fred Singer (Letters, 2 May, p. 401) require clarification. The National Academy of Sciences' Committee on Mineral Resources and the Environment was not established to review Project Independence (which was announced long after the committee began its work), nor to judge the U.S. Geological Survey's estimates of undiscovered oil and gas resources relative to those of the oil industry. It was intended to "provide an ongoing, balanced, long-term review of problems affecting mineral resources and the environment" (*1*, p. vi).

In the committee's report (*1*), a short section includes a brief discussion of five main methods that have been used by various organizations and individuals to estimate the quantity of oil and gas that is yet to be discovered in the United States and in other large segments of the world. These methods are "(a) straight volumetric, (b) geological basin analysis, (c) probabilistic exploration/engineering analysis, (d) analysis of historical production and discovery data, and (e) analysis of discovery index" (*1*, p. 90). These methods, used separately and in combination, yield estimates having a range that is small compared with the amount of oil and gas recoverable from oil shale and coal. The main point is that the annual production of oil in the United States is about 0.5 billion tons, the annual consumption of refined oil products is about 0.8 billion tons, proved reserves are about 5 billion tons, and undiscovered resources are estimated to be about 15 billion tons (a judgment value derived from an estimated range of about 10 to 60 billion tons). In comparison there are 3000 billion tons of proved oil reserves and estimated undiscovered resources each in oil shale and coal. No amount of curve fitting or debating can bring the estimates of undiscovered oil resources in oil fields up to those of oil in oil shale and coal. An additional complication, of course, is the great dependence of the production of oil from any source material upon environmental considerations (tanker transport, offshore drilling and pipelines, strip mining, sulfur and other emissions) and upon political considerations (depletion allowances, foreign and domestic taxes, bonus bids, entitlements, price controls, nationalization, conflicting uses of ocean-floor areas). Estimates of future supplies of oil and gas are so dependent upon unknown scientific factors and unknown environmental and political factors as to be almost unknowable, and they are by no means susceptible to simplistic solutions.

An encyclopedic bibliography was not intended by the committee, but the members were well aware of a far greater volume of literature than it cited. Singer refers especially to "the two-volume study of the American Association of Petroleum Geologists, which uses the volumetric method and arrives at the high estimate of 485 billion barrels of undiscovered recoverable oil." In reality, this reference is to an article by Cram (*2*), who listed 432 billion barrels of crude oil and 49 billion barrels of natural gas liquids (a total of 481 billion barrels) as the *ultimate* petroleum potential. From this must be subtracted the amount that already had been produced and the amount considered as proved reserves, leaving a total of only 199 billion barrels of undiscovered resources of oil (equal to 27 billion tons). This complication illustrates the care that must be taken in working with petroleum statistics. Incidentally, Singer might find Hubbert's 1974 analysis (*3*) a useful supplement to the 1967 study (*4*) that he cites.

Reference is made by Singer, as well as by the Environmental Protection Agency in its announcements, to "bright spot" processing of continuous seismic profiles. This is merely one of several computer techniques for accentuating sharp changes in acoustic impedance at depths below the ocean floor; these changes can be due to accumulations of oil or gas (within certain depth ranges), to peat or coal, or to still other factors. As with most new techniques, too much is claimed for it; in fact, its use already has resulted in many dry holes that might otherwise not have been drilled. Singer also refers to high prospects for oil in California offshore basins, as though these basins should be as productive as the Los Angeles Basin that now is beneath dry land. Investigations (*5*) indicate that the thick sandy turbidites that form the oil reservoir rocks in the Los Angeles, Ventura, San Pedro, Santa Monica, and Santa Barbara basins (all on land or nearshore) cannot reach the offshore basins; in fact, the most prospective areas far offshore are likely to be the ridges between the basins (the nonbasin areas). In the case of other ocean-floor regions, it is questionable whether drilling will be permitted off Alaska, where earthquakes during the past few years indicate that there is great potential hazard to offshore oil fields, and whether drilling will actually occur off the Atlantic coast, where the presence of oil and gas has been considered probable for more than a decade. In a way, debates about the environmental and political controls on oil and gas production are akin to the medieval debates about how many angels can dance upon the head of a pin. However, new attempts to improve the scientific aspects of the question about undiscovered resources of oil and gas are now proceeding rapidly. Increased effort is being made by the U.S. Geological Survey, whose recent work is likely to lead to a reduction of its previous estimates (*6*). The results of a research conference on "Methods of estimating undiscovered petroleum resources" held at Stanford University in August 1974 are soon to be published (*7*) and another conference at Stanford on "Probability methods in oil exploration" is scheduled to be held from 20 to 22 August 1975. These and other new research programs and conferences are likely to sharpen the estimates of undiscovered oil and gas resources of the United States and of the world in the near future.

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References and Notes

1. *Mineral Resources and the Environment* (National Academy of Sciences, Washington, D.C., 1975).
2. I. H. Cram, in *Future Petroleum Provinces of the United States—Their Geology and Potential*, I. H. Cram, Ed. (American Association of Petroleum Geologists, Tulsa, Okla., 1971), vol 1, pp. 1–34.
3. M. K. Hubbert, *U.S. Energy Resources, A Review as of 1972* (a background paper prepared at the request of Henry M. Jackson, chairman, Committee on Interior and Insular Affairs, U.S. Senate, 93rd Congr., 2nd sess.) (Government Printing Office, Washington, D.C., 1974).
4. ———, *Am. Assoc. Pet. Geol. Bull.* **51**, 2207 (1967).
5. K. O. Emery, *The Sea off Southern California, A Modern Habitat of Petroleum* (Wiley, New York, 1960).
6. In fact, after this letter was submitted, a news release dated 7 May gave new estimates by the U.S. Geological Survey for total U.S. reserves; these were 50 to 127 billion barrels (7 to 17 billion tons) of crude oil plus 11 to 22 billion barrels (1.5 to 3 billion tons) of natural gas liquids.
7. J. D. Haun, Ed., *Studies in Geology*. No. 1: *Methods of Estimating the Volume of Undiscovered Oil and Gas Resources* (American Association of Petroleum Geologists, Tulsa, Okla., in press).

I heartily commend Reister and Davitian's call for caution (Letters, 7 Mar., p. 790) in accepting optimistic estimates of the U.S. ultimate recoverable oil and gas resources. Sizable variations in the recent estimates reported by various investigators obviously point to significant uncertainties as to what the real truth may be. But it is important also to recognize that, by the very nature of the question, certainty is impossible. All investigators can do is extrapolate from past experience and assume that commercially recoverable oil and gas will actually be found in geological environments similar to those where they have already been discovered. These as yet undiscovered resources must then be quantified into the number of barrels of oil and cubic feet of gas that can be recovered, usually with ill-defined economic circum-

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stances and speculative recovery mechanisms being assumed. One can only admire the tremendous courage of investigators who pronounce their conclusions with confidence in spite of these almost frightening handicaps. Yet, before we accept these estimates, it would be well to examine how such exploratory expectations have fared in the past.

The latest evaluation of the overall exploration statistics (*1*) confirms earlier studies showing that in only one out of some 50 new-field wildcat wells is as much as 1 million barrels of oil or its gas equivalent discovered. A specific example of recent drilling failure, despite the best of hopes, is extensively described in an article in the *Oil and Gas Journal* (*2*): "Ten unsuccessful wildcats have badly wounded hopes for finding major reserves of oil and gas under the first crop of leases in the vast northeastern Gulf of Mexico.... the exploratory opportunities remaining could at best yield only a fraction of the reserves industry expected from this Cretaceous-Jurassic province." The hoped-for prize was the huge Destin anticline structure, over which an Exxon-Mobil-Champlin group acquired, in 1973, six tracts at a cost of some $630 million, and on which it has now drilled six noncommercial wells. Surely this group must have applied the most sophisticated analytical and operational exploration techniques known to the industry. A major discovery may yet result from further testing, but as of now, the gap between optimistic expectations and reality is wide indeed—both psychologically and financially.

There is widespread feeling that if we only apply conservation measures and begin extensive exploratory drilling on the continental shelves, we shall certainly find the billions of barrels of oil needed to make us independent of foreign supplies by 1985. Very little has been done to set up emergency oil stockpiles or to get started on the development of both the technology and financial structures required for alternative energy sources, such as coal conversion, shale oil extraction, and environmentally acceptable increased nuclear energy production. But what if the shelf drilling should turn up many more unproductive "Destins" than expected? As it is, the only certain new net domestic supplies we can count on by 1985 are the 1 to 2 billion barrels per day in 1977 or 1978, when the Alaskan pipeline is operating, and perhaps 500,000 more barrels per day from expanded secondary and tertiary recovery operations. It would be prudent to consider new oil discoveries resulting from the proposed federal offshore leasing program as unscheduled blessings. Policies to safeguard the national security and economic stability of this country should be based on conservative judgments about the results of exploring unknowns rather than on anticipated materializations of plausible possibilities.

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2. D. McNabb, *ibid.* **73**, 21 (10 March 1975).

Alexandering

After reading Tinbergen's reply to the critics (Letters, 2 May, p. 401) of his views on autism, it came as something of a relief to discover that my own researches on Alexander are likely to be spared the further benefits of his ethological approach. Still, at the risk of encouraging any dormant spirit of collaboration which may remain, I must point out that, through a typographical error, an important line (indicated below in italics) was dropped from my communication to *Science*. "Now Tinbergen," I wrote, "devotes half *of his Nobel Prize speech to the promotion* of a curative system which he identifies with the Alexander technique." It may be that the complete sentence would have cleared up (as my entire letter apparently did not) Tinbergen's Alice-in-Wonderland puzzlement about my views: (i) in his Nobel speech Tinbergen appears to be talking not about the Alexander technique—a form of kinesthetic reeducation which I do indeed recommend in my book (*1*, pp. xlv - xlvi) as effective for many people, although not suitable (*1*, p. xxxi) for others—but instead about some form of osteopathic treatment or Esalen massage; (ii) he makes a number of specific *curative* claims for the technique and these are claims which thus far have no scientific support. The final passage of his reply to me does, however, indicate a welcome shift of position. Whereas Bernadette reporting the good news from Lourdes seems comparatively restrained next to Tinbergen in the Alexander half of his Nobel address, he now confines himself to the quite simple and jovial recommendation: "Alexandering may be good for you—why not give it a try?" Tinbergen, it seems, is repeating the wisdom of the onetime label on the Lydia E. Pinkham bottle: "Recommended in conditions for which this preparation is adapted."

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