government to enter, with the court's approval, into rather direct management of the manner in which state and local government conduct the people's business.

Legal and constitutional arguments aside, the wisdom of deciding issues as complex, technical, and difficult as nuclear plant siting by statewide ballot is clearly in question. My own view is that the very complexity of the nuclear issue illustrates the wisdom of the founders in decreeing a representative form of government. The record of local and state voters in deciding ballot issues is better than many suppose. But situations in which a weighing of scientific questions complicates questions of risk and economic alternatives in the light of substantial technical disagreement are simply not likely to produce an appropriate result. As a state citizen I would feel deprived of my right to a representative government if a decision on nuclear siting were made by a public debate which was not an informed one (and I personally think an informed public debate on this subject is impossible) and in which the persons I had elected to public office to make decisions for me did not have an opportunity to engage in the give and take of the legislative process.

The emotion of the debate over nuclear plants must not be allowed to distort the necessary discussion of what is the wisest way to make such decisions. The Bicentennial year is a good time to discuss the quality of the process by which we govern ourselves as well as the issues resolved in that process.

BREWSTER C. DENNY
Graduate School of Public Affairs, University of Washington, Seattle

References

1. W. M. Wiecek, *The Guarantee Clause of the U.S. Constitution* (Cornell Univ. Press, Ithaca, N.Y., 1972), p. 1.

Random Drilling

H. W. Menard and George Sharman contend in their article "Scientific uses of random drilling models" (24 Oct. 1975, p. 337) that random drilling can find oil better than current industry practices. However, their treatment of the history of total U.S. oil exploration is misleading in at least five respects. First, the authors' random drilling simulation incorrectly uses total exploratory drilling for finding new fields. Actually, about half of this exploratory drilling has been within or near established fields and has no bearing on new-field discoveries. In ef-

fect, the model thus gives simulated random drilling a completely undeserved twofold advantage. Second, most pre-1930 data are from the pre-geophysics era and have no applicability today. Third, the whole country was never open to exploratory drilling at one time, and the industry had no chance to find the biggest fields first, as does the computer model. Fourth, many of the authors' conclusions about recent giant-field discovery rates are open to serious question, because the raw data are quite inadequate. And, fifth, as noted by Menard and Sharman, major companies find about 60 percent of the oil with 10 percent of the wells—a clear illustration of the value of intensive scientific exploration.

The authors themselves are the first to reject their own ideal of "purely random drilling," since they limit their search to areas of sedimentary rocks. They thus acknowledge industry's first scientific guide to finding oil and successfully avoid misusing 40 percent of their model drilling in the barren areas of igneous and metamorphic rocks. They then opt for random search and choose not to make use of another simple, but powerful, guide—that oil, being less dense, floats on subsurface waters and therefore seeks the highest locations that the geology allows. Today, such prime potential field locations are detectable at most places from the surface by seismic techniques, and the area of search is again markedly and efficiently narrowed. Exploration is further focused on the best areas by additional, more detailed guides concerning the distributions of oil sources, reservoirs, seals, and traps (including stratigraphic ones). It is essential to make use of this immense body of knowledge, rather than to drill aimle

In sum, it seems to us that Menard and Sharman have given their computer nearly a twofold advantage by using wells in established fields, in addition to the proper new-field wildcat wells, to find only new-field oil. This does not even count the computer's ability to focus in a nonrandom way on sedimentary basins. Nor, more important, does it directly address the question of the ability of science in exploration. An unknown, but probably large, portion of industry's wildcat drilling has not been scientifically guided, as noted above, and should be eliminated before judging the impact of technology.

The main contribution of Menard and Sharman is their novel and reasonable field-size assessment of the relatively small undiscovered oil potential of the inland lower 48 states. Unfortunately, they seem to conclude that a likely cause of the declining discoveries is that ". . . the oil industry is no longer searching in the right places." This assertion seems untenable for the inland 48 states, which already is the most intensely drilled region of the world. Furthermore, a profound strength of the industry is that hundreds of different companies are searching with strong individual incentives and with many different ideas and hypotheses, including random drilling. Yet not one of these searchers has come forth recently with any new class of discovery that has altered the declining trends in the inland 48 states. Therefore, as Menard and Sharman at one point rightly conclude, the nation's only realistic hopes for future major oil and gas supplies rest in the frontier areas of the offshore and Alaska. But the right way to search in these hostile and costly environments is not by random drilling.

DAVID A. WHITE
Exxon Production Research Company, Post Office Box 2189, Houston, Texas 77001

THOMAS A. FITZGERALD
Exxon Corporation, 1251 Avenue of the Americas, New York 10020

Since our article was published, we have learned that many petroleum geologists have entertained doubts about the effectiveness of exploration. We have been informed of several comparisons between hypothetical grid drilling and actual exploration which showed little advantage in the latter.

White and Fitzgerald are among those who take a different view—in part because they read implications into our article which were not there and in part because they do not take our conclusions in context. We did not, for example, contend "that random drilling can find oil better than current industry practices," nor did we conclude that "the oil industry is no longer searching in the right places." We merely pointed out that scientific drilling did not do all that much better than random. We concluded from this that not everything is yet known about the factors controlling the distribution of oil. Consequently we believe that systematic drilling in less promising places should be encouraged by whatever incentives are necessary.

As to the specific points in the White and Fitzgerald letter:

1) Our data on "exploratory drilling" prior to 1945 are from Hubbert, as we cited (*1*). The data in early years are quite speculative. To the extent that they include holes within established fields they increase the odds that random drill-

ing will appear successful compared to the historical record.

2) We believe that the regular, consistent relationships that we developed indicate that the decline in the rate of exploratory success is largely a function of chance for a given technology. We do not contest the source of the pre-1930 data; indeed we said that the rate varies with the technology.

3) The whole country was not opened to exploratory drilling immediately, but that does not mean it was not available. The first five giant fields discovered were, respectively, in Pennsylvania, New York, California, Ohio, and Indiana. We are aware that the computer and industry had different targets. The question is, Why did industry explore as it did? Undoubtedly the answer is very complex, with legal and economic factors involved. One major company, for example, used to just lease on a checkerboard pattern. The fact remains that the system of exploration was not designed to sample the country and, hence, was not very good at it. It is not, therefore, necessarily the ideal way to proceed in the future.

4) We have taken our data since 1945 from the annual exploration summaries of the American Association of Petroleum Geologists. We do not accept the serious charge that "the raw data are quite inadequate." The point raised more likely reflects a misunderstanding of the limits of our analysis. Giant fields are still discovered with gratifying frequency in the United States, but in order to maintain a consistent sample we did not include gas fields anywhere or oil fields offshore or in Alaska.

5) White and Fitzgerald seem to assume that the nonmajor companies do not use science and that the numbers quoted are a fair measure of "value." A senior official of a very large, nonmajor company has expressed the opinion that, despite the numbers, exploration by the major companies is less cost effective than that of the smaller companies.

Our introduction of the hypothetical method of random drilling was not intended to initiate a competition of industry versus computer, but rather was meant as a new perspective or standard for measuring the effectiveness of exploration.

W. H. MENARD, G. SHARMAN
Geological Research Division, Scripps Institution of Oceanography, University of California, San Diego, La Jolla 92093

References

1. M. K. Hubbert, *Am. Assoc. Pet. Geol. Bull.* **51**, 2207 (1967).