Letters

Oil Resource Estimates

The National Academy of Sciences' Committee on Mineral Resources and the Environment has estimated (*1*) the amount of U.S. oil yet to be discovered and produced as 113 billion barrels (News and Comment, 28 Feb., p. 723), considerably below the U.S. Geological Survey's 1974 estimates of 200 to 400 billion barrels. They conclude that the Geological Survey used misleading arithmetic and also imply that the goals of Project Independence are unlikely to be met. Acceptance of these conclusions is resulting in a clamor for removing financial incentives that would lead to the production of new oil and gas, as well as for a government-financed crash program for synthetic fuels based on coal.

I believe that the committee's result is based on an uncritical acceptance of mathematical curve fitting, rather than on geologic and economic reasoning. Furthermore, their result—even if correct—should not require drastic changes in energy policy (*2*).

Their attack is focused on the Geological Survey's methodology, according to which it is assumed that unexplored sedimentary rock contains about as much oil as the same volume of average drilled-up rock, with the ratio R assumed to lie between 0.5 and 1.0. M. K. Hubbert, however, claims to have derived a value for R of only 0.1 (*3*). He presents a histogram (*3*; *4*, p. 2223) of U.S. oil discoveries, dQ/dh, in barrels of oil per foot drilled, against cumulative exploratory footage and proceeds to approximate it by means of a negative-exponential curve. Such a curve extrapolates rapidly to negligible values of dQ/dh. The area under the curve then gives a rather low value for the ultimate amount of oil, Q_∞, to be discovered by even unlimited drilling (*5*).

A glance at the histogram, however, reveals a rather different situation: dQ/dh for the period from 1860 to World War II is about 200 barrels per foot drilled, followed by a nearly constant value of 35 barrels per foot since 1950. It is likely that the histogram reflects changes in geologic techniques and economics, rather than a uniform trend. Oil exploration started with the discovery of natural seeps and with the recognition of prominent anticlines, and little exploratory drilling was required. Later, seismic techniques located other anticlines and structural traps. Presently, only extensive drilling can uncover stratigraphic traps. There is no guarantee that the curve will decrease exponentially in the future, as Hubbert assumes, and thus there is no reliable way of estimating Q_∞. For example, advances in exploration technology, such as the "bright spot" seismic technique, could even drive the curve up; the accessibility of new oil provinces offshore certainly would. Economic changes which discourage unproductive exploratory drilling, such as a change in the present tax law which allows deduction of most drilling expenses, or a decrease in the current high price of oil, could also drive the curve up.

The Academy committee seems to have accepted Hubbert's analysis without question, but then simply estimates a middle value. It quotes various industry estimates, which are not further substantiated; these estimates are also quite low but probably because they are not comprehensive and address themselves mainly to commercial prospects. But the committee does not discuss or reference the two-volume study (*4*) of the American Association of Petroleum Geologists, which uses the volumetric method and arrives at the high estimate of 485 billion barrels of undisovered recoverable oil.

Fortunately, policy should not be affected by the committee's results. A large increase in the rate of U.S. oil production requires mainly the opportunity to test new oil provinces, principally offshore and in Alaska, on federal lands. No one would deny that the oil content there should be similar to that of average onshore rocks (*5*).

Pending such an exploration program, a crash program now for synthetic fuels would lock in the U.S. consumer to high-cost energy unnecessarily.

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References and Notes

1. *Mineral Resources and the Environment* (National Academy of Sciences, Washington, D.C., 1975.
2. This critique of the Academy committee's estimates of oil and gas resources reflects in no way on the many other conclusions of their comprehensive report.
3. M. K. Hubbert, in (*1*), appendix to section 2, p. 9.
4. ———, *Am. Assoc. Pet. Geol. Bull.* **51**, 2207 (1967). The histogram covers the period 1860 to 1965. All Alaskan and most offshore discoveries are omitted.
5. Hubbert fits the curve through the extreme points of the histogram and gives a value for Q_∞ of 168 billion barrels, of which 136 billion had already been discovered by 1965. Had he applied his method 10 years earlier, Q_∞ would have been only 93 billion barrels, which is less than the 115 billion barrels that had actually been discovered by 1955.
6. I. Cram, Ed., *Future Petroleum Provinces of the United States—Their Geology and Potential* (American Association of Petroleum Geologists, Tulsa, Okla., 1971).
7. It may well be greater, especially in the Southern California borderlands, which are offshore from the Los Angeles Basin. This basin has one of the highest oil contents (per rock volume) known in the world.

Autism, Stress, and Ethology

Nikolaas Tinbergen is to be applauded for his innovative attempt (5 July 1974, p. 20) to apply the methods of ethology to the study of pathology. However, his conclusion that autism is caused by psychological stress rather than by organic factors is at such variance with that of scores of researchers from many countries that the usefulness of the approach, or at least of Tinbergen's application of it, is thrown into question.

Tinbergen appears to have misinterpreted a study in which I participated when he writes, in attempting to discredit the biogenic view, that evidence "such as that on blood platelets" leads to erroneous conclusions in which causation is supposedly inferred from correlational data. The study in question (*1*) used my diagnostic checklist to subdivide a group of psychotic children into those who exhibited Kanner's syndrome and those with an undifferentiated form of psychosis. The determination of the 5-hydroxytryptamine (5-HT) efflux from the blood platelets, which was done in a blind study, showed a