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COVER Remnants of uplifted marine terraces are common in the Southern Alps of New Zealand (bottom). Individual (upper left picture) is collecting widely scattered beach pebbles from an exhumed 320,000-year-old shore platform (altitude 1620 meters) at the base of a degraded sea cliff. Highly rounded quartz pebbles (11 to 12 millimeters in diameter) from notched ridge crest have frosted surfaces and impact marks made in a high-energy sedimentary environment. See page 1225. [W. B. Bull, University of Arizona, Tucson, AZ 85721, and A. F. Cooper, University of Otago, Dunedin, New Zealand]

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Energy Future

Events of 1986 have been traumatic for many people associated with the U.S. petroleum and natural gas industries. Prices at the wellhead have plunged, employment has been sharply curtailed, drilling has dropped to near longtime lows. Thus far, effects on production, consumption, and imports have not been great, but a continuation of present trends would lead to nationwide trauma at a later date. Because of longtime constants involved in developing energy sources, this country cannot afford complacency.

At one time, the United States was the world's lowest cost producer of petroleum and a substantial exporter. But the easy-to-find and inexpensive-to-produce oil has been found and exploited. There remains a large amount of oil in place (more than 300 billion barrels), but most of it is costly to produce: \$10 to \$15 a barrel and more.

When oil was selling above \$30 a barrel in 1981 and there was a widespread expectation of even higher prices, 4561 rigs were drilling. In July 1986, with oil at about \$10 a barrel, the number of active rigs dropped to less than 700. In November, when the price rose to \$14, about 850 were drilling.

The large-scale drilling of 1980 to 1985 was barely sufficient to maintain a constant level of production. In 1986 production has dropped from about 9 million barrels a day (mbd) to 8.7. Experts agree that with prices at or near present levels the drop will continue. In the meantime, conservation is passé. Consumption is up, and imports have risen nearly 1 mbd. A Conoco report estimates that in the year 2000 oil imports will rise to 11 mbd. Imports of oil and its products were 4.8 mbd in 1983. Conoco also estimates that in 2000, the United States will be importing about 60 percent of its oil, mainly from the Middle East. Well ahead of that point, the stage would be set for a gigantic price squeeze. With a huge deficit in international trade, how would the United States pay for oil imports?

The drop in drilling is increasing U.S. energy vulnerability through a drop in natural gas reserves. Earlier, adequate gas supplies provided a cushion against shortages of oil. Vestiges of a "gas bubble" remain, but in the absence of large-scale drilling, reserves of gas are being drawn down twice as fast as they are being replaced. An abnormally cold winter could lead to shortages in deliverability.

During the next several years, additional nuclear plants will be generating electricity, but their capacities will be limited. The contributions of fusion and of renewable forms of energy will be comparatively negligible during the next decade. That leaves coal as the source of energy that could be exploited to minimize energy adversities. A considerable amount of oil and gas is burned merely to make heat. New technology permits coal to be burned cleanly for many of these applications. The cost of coal per million Btu's at mine mouth averages about \$1. With residual oil at \$12 a barrel, the cost of heat from it is \$2 per million Btu's. During the last several years, the price of coal has been dropping. Productivity of mines has improved. Accident rates are lower. Competition among the 3000 coal mining companies is intense. Enormous reserves of coal are available.

Coal can be gasified to form methane. It can be liquefied to yield fluids for transportation. Fortunately, progress is being made in both of these applications. The Great Plains methane plant in North Dakota, though not a financial success, is a technical success operating at about 100 percent of design capacity: operators are on a learning curve, and have identified bottlenecks which, if corrected, could enable them to run at 120 to 140 percent of design capacity. Experiments designed to point the way to obtaining transportation fluids from coal are looking very promising. One approach is to co-process coal with residual oil, upgrading the mixture to useful fluids by hydrogenation. In a second approach hydrogenation is achieved through an improved two-step donor solvent procedure.

The United States could lessen oil and gas shortages during the next decade by instituting soon an import fee of \$5 to \$10 a barrel on oil. This would lead to development of more oil and gas while fostering conservation. The nation could achieve a longer term energy security by expediting advanced technology for utilization of coal.

—PHILIP H. ABELSON