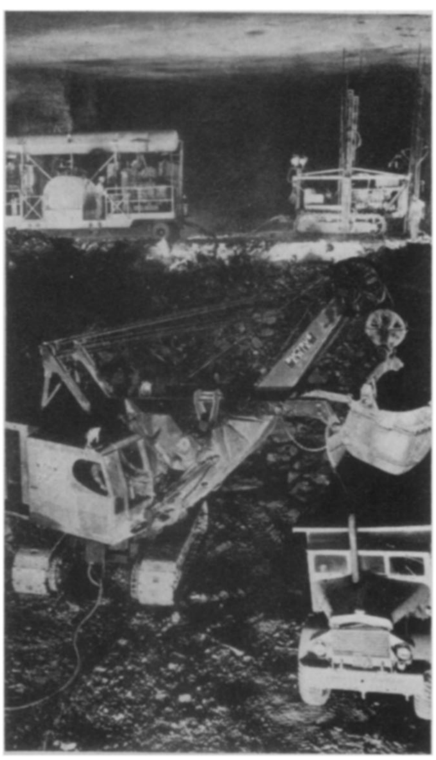
Rich oil shale exposed in a quarry near DeBeque, Colo. (left). High-grade oil shale is concentrated in four western states, but the low-grade variety is found over large areas (right). Working in an oil-shale mine near Anvil Points, Colo. (lower left).

Illustrations: US Geological Survey

by Dietrick E. Thomsen

To survive the next few decades mankind will have to do some novel things with fossil fuels now lying underground and underwater



The energy crisis is real. That is the considered opinion of a physicist who knows a great deal about energy-producing reactions, Edward Teller of the Lawrence Livermore Laboratory. The crisis is real for the United States and Europe; it is almost catastrophic for Japan and it is very difficult for the developing countries who are not as readily able to switch from one fuel to another or from one technology to another as are the developed countries. Just at the time their economies began to gather a little speed, they have been stopped dead.

In the short run, "One can say that this is all due to the obstinate or vicious nature of a few countries," says Teller. "It is not my job to sing the praises of Saudi Arabia," he continues, but there is a real shortage probable in a somewhat longer run, and ironically it may have been beneficial to have the Arabs behave in such a manner as to "bring to our attention in a forceful manner to a situation we cannot avoid till the end of the century."

Teller made these remarks as he opened a colloquium on the physics and chemistry of the energy crisis, which was part of the "World of Knowledge" meeting in January at the University of Miami in Coral Gables, Fla. Teller says he is happy that no one is considering armed intervention. but rather that the question is being raised on the technological level, and he asks: "What can we do about fossil fuels—oil, coal, oil shale? We may imagine that these are well understood, but great technical innovations are possible on the short term."

Indeed such innovations are necessary. Much has been said lately about the improved use of nuclear energy either through fission breeder reactors or through fusion reactors, but those are long-term solutions. In fact those who spoke about breeders and fusion at this meeting gave somewhat more pessimistic estimates of the time it will take before these things come on line than has usually been customary. Another option is direct use of solar energy, but technology for this is still in the experimental stage. For the decade or two or three to come, we must look to the remaining fossil fuels. What are they and where are they?

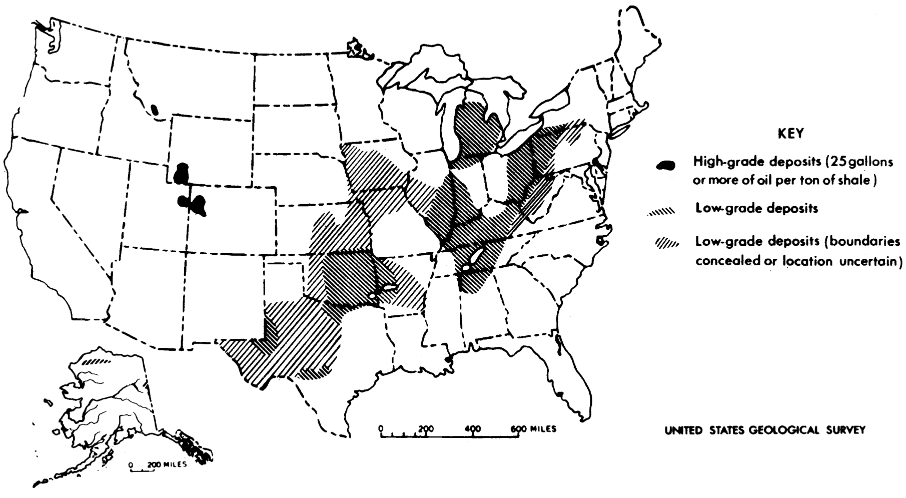
First of all, there may be more oil around than we know of. That is the opinion of marine geophysicist J. L. Worzell of the Marine Biomedical Institute of the University of Texas. He suggests that we look for oil on the continental slopes, the areas where the bottom of the ocean inclines downward from the continental shelf toward the abyssal depths of the mid-ocean. To make the suggestion plausible he presents arguments to show that oil could be there.

Oil is formed from organic detritus that has been prevented from oxidizing. Whether the process is chemical, physical, biological or a combination is not known, but the organic matter and the protection from oxidation are necessary.

Do these conditions occur in deep-sea regions far from land and off the continental shelf? Worzell invokes the so-called turbidity currents in support of a contention that they do. Turbidity currents are caused by pieces of the continental shelf that break off and slide down the slope. They do carry and bury organic matter. "Green leaves have been found in turbidity currents," says Worzell, thus giving evidence that the known condition for oil production, organic matter protected from oxidation, is present. "Conceivably more hydrocarbons are buried in the deep sea than on the shelf," Worzell suggests.

The repeated occurrence of turbidity currents leads him to speculate that petroleum production at sea may be continuous rather than having happened all at once in some remote past. He even proposes that we may someday be able to manufacture petroleum if we can learn the details of its formation. If they are chemical or physical, they may require an input of energy

PRINCIPAL OIL-SHALE DEPOSITS OF THE UNITED STATES



that would make the process uneconomical, but if the oil-production process is biological, it would require very little energy, mainly the identification of the organism that does it and putting the organism to work.

There is some stratigraphic evidence for the possible existence of oil in deep-sea areas. A survey of the Gulf of Mexico running from Texas to the Yucatan peninsula yields evidence of salt domes under the deep-sea areas. Salt domes are a particular kind of salt deposit that often occur in conjunction with petroleum deposits. There could be, says Worzell, as much as 16 billion barrels of oil reserves under the Gulf of Mexico. (Total known U.S. reserves at the moment are 34.6 billion barrels.) Under the sea may lie more oil than is now known to lie under the continents.

Drilling in the deep sea is more difficult than drilling in the relatively shallow continental-shelf areas where oil has been sought up to now, but the work of the research ship Glomar Challenger shows that it can be done repeatedly and accurately. Drilling on the slope will be more expensive than drilling on the shelf, but such things as the doubling of the price of crude oil may be a beginning on the way to the necessary economic incentives. Worzell suggests an immediate beginning of regional searches of the continental slope for oil deposits.

Oil shale has been getting into the news lately as a possible petroleum source. On Jan. 18 the Department of the Interior officially accepted the $210-million bid of Standard Oil (Indiana) and Gulf for the rights to try to develop a way to economically get oil out of a 5,089-acre shale tract in northwestern Colorado.

An English horn is neither English nor a horn; similarly, "Oil shale is not oil, does not contain oil and is not shale," says Gary Higgins of the Lawrence Livermore Laboratory. It is a collection of dolomite fragments, 8 or 10 microns in diameter, that have a waxy hydrocarbon attached. When this matter is heated to 1,400 degrees, oil comes off.

The conventional approach would be to dig the stuff up, cook out the oil and throw away the slag. But there's the rub. The cooking process causes the shale to expand so that it occupies more room than it did when it was in the ground. Thus it cannot all be put back into the hole. It must be dumped somewhere.

This prospect produces the anguishing vision of beautiful valleys of western Colorado (where there are large oil-shale deposits) filling up with slag; their streams becoming polluted, etc., *ad nauseam.* Nobody wants the Black Canyon of the Gunnison or the mesa-walled valleys of the Colorado River turned into replicas of the Rhondda Valley in Wales, even if they could get some fine choral music and a powerful motion picture as side effects. Yet the opportunity is a great one. Higgins estimates that the world may have the equivalent of 1,700 billion barrels of oil stored in oil-shale deposits. (The world's known reserves of liquid petroleum are on the order of 600 billion barrels.)

To avoid the problems of slag and pollution, Higgins suggests processing the shale underground by detonating a nuclear explosive deep in the oil-shale bed. The explosion would start a fire that would burn its way down through the shale, leaving behind an oil-like hydrocarbon. It would also compress the surrounding rock sufficiently to make a chamber into which the burned shale could expand, thus making above-ground dumping unnecessary.

Nuclear explosives, however, make people nervous. Witness the opposition of Colorado environmentalists last year to the Rio Blanco test to release natural gas with underground nuclear blasts. There is concern over venting of radioactivity and contamination of ground water with it.

Venting should not be a serious problem, says Higgins, considering the depths at which the oil-shale blasting would be done. Likewise the deep areas of the shale seem to be closed off from the local ground water. There are water deposits associated with the oil shale, salty water, almost of sea-water quality. Tests of the surface water indicate that there is no mixing between this water and the fresh ground water, which argues that any radioactive material deposited in the oil-shale areas would not reach the ground water.

Underground nuclear explosions would also be a good way to gasify coal *in situ*, Higgins suggests. Such a technique would not be useful in the East, where coal seams are characteristically only a few feet thick, but it might be usable in the much thicker seams of, say, Wyoming. And it might be preferable to strip-mining large areas of the scenic Wyoming countryside and converting the coal in retorts above ground. The nuclear explosion would convert the underground coal into methane, hydrogen and oxides of carbon. At the surface the methane and hydrogen could be combined to give methyl alcohol, a fuel that is an excellent substitute for petroleum products in many applications.

Finally there are the tar sands. Tar sands, says Higgins, "are what you would get if you cooked a tar road with a proper amount of water." There are large deposits in the Canadian province of Alberta near Ft. McMurray. The deposits come right to the surface in riverbanks. By cooking the tar with hot water, the oil is extracted and floats to the top of the mixture. Clean sand can then be pumped back into the hole. Higgins suggests that nuclear explosives might be used to make steam below the tar-sand beds. The steam would then percolate through the tar sands leaching out the oil.

Neither the scientists nor the economists present at the colloquium voiced any serious objections to Higgins's suggestions. Teller disagrees about using nuclear explosives on the tar sands, figuring that more conventional ways of making hot water would be better, but he thinks nuclear explosions are right for the oil shale: "It is safer than mining and would bring up no horrible material which then will lie around."

Oil shale, gasified coal, tar sands and natural gas liberated by nuclear explosives are likely—in the view of these scientists—to be the things that will save our style of life in the near future, possibly for the rest of the century. "If it were done, then 'twere well it were done quickly," says Lady Macbeth apropos of the murder of Duncan. It seems that very soon now someone must make up his mind to stick in the knife. □