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Energy is one of our basic natural resources. Oil constitutes an important part of this resource but domestic production is dropping while imports are rising. Today, oil represents about one-half of the total energy consumed in this country, and demand is expected to grow at the rate of about 2 percent per year during the next 10 years. Increased reliance on imports can be reduced by synthetic fuels produced from the oil shale deposits of the Green River Formation in Colorado, Utah, and Wyoming. These deposits are so enormous (600 billion barrels in high-grade shale alone), that any limitations on production are set by economic, environmental, political, or technological constraints.

According to the Project Independence Blueprint, a shale oil production of 1,000,000 barrels per day could be attained by the year 1985. This would meet the goal established by President Ford in his recent State-of-the-Union Message.

This paper outlines the work that the Bureau of Mines is doing in oil shale mining research to further this goal. It describes the results of our first year's contract research program, and our plans for the future. Oil shale research is part of the Bureau's overall Advancing Mining Technology Program. The objectives of our program are to develop, test, and demonstrate improved low-cost mining and waste management methods and equipment that are capable of producing the large tonnages of oil shale and shale oil needed by the 1980's. Oil shale and associated minerals must be mined safely and economically, using methods that will allow maximum recovery of the mineral resource with acceptable environmental impact. The immediate objectives of the program are to assess the technical and economic feasibility of various surface and underground mining methods and of modified in situ extraction systems, evaluate the mineral resources, and determine the environmental impacts of an oil shale mining industry.

The Green River Formation, which covers some 25,000 square miles, is estimated to contain about 4 trillion barrels of oil equivalent. Oil shales with commercial potential are estimated to contain about 1.8 trillion barrels. Of this amount, some 600 billion barrels are contained in deposits classified as high-grade shale. Of this total, some 470 billion barrels are located in the Piceance Creek Basin of Colorado. This concentration of thick, high-grade shale beds and associated minerals of potential value make the Basin an attractive target for oil shale development.

It follows then that the major focus of our research program is directed to the Piceance Creek Basin. Because of the varied geology, hydrology, and topography of the oil shale region, no one mining method can be expected to suit all conditions. Rather, different mining methods and equipment will have to be developed to meet the specific requirements of a mine in a given locale. Hence, it is necessary to investigate a range of mining and waste management technologies.

Various modifications of the room-and-pillar mining method have been demonstrated for mining the thin, rich Mohogany Zone in the upper beds of the formation. Our attention has, therefore, been directed to the problems of mining the thick, deep beds of the lower Zone near the center of the Basin. This Zone contains the major portion of the resource. Since the program was planned primarily as a contract research program, contracts have been let for technical and economic feasibility studies of underground mining systems, integrated open pit mining, and modified in situ

retorting systems. Results of the first year's work under these contracts is summarized below.

UNDERGROUND MINING

Low-cost, large-scale underground mining of the thick, deep beds of the central Piceance Creek Basin is technically feasible. Six mining systems were evaluated and ranked on the basis of technical feasbility, costs, resource recovery, reclamation, environmental impact, and health and safety. Four systems were selected as being the most promising: Chamber and Pillar, Sublevel Stoping with Backfill, Block Caving using LHD's, and Advance Entry and Pillar. The first two methods have the lowest production cost and environmental impact. Resource recovery is highest with Block Caving and lowest with Advance Entry and Pillar. Estimated mining costs ranged from $1.04 per ton for Chamber and Pillar to $1.31 for Block Caving with LHD's.

INTEGRATED OPEN PIT

Mining, backfilling, and reclaiming the oil shale resource of the Basin with one or more large integrated open pit mines offers several advantages. A preliminary mine site was selected and a method for opening a pit was planned. Production capacity was set at 1 1/4 million tons per day, and cutoff grade was 15 gallons per ton. Total material moved peaked at 2.5 million tons per day. The selected mining system used the largest mining equipment available. Mine development started with six mining units producing 360,000 tons per day, and production rose to 530,000 tons per day within a year. This production is larger than the largest open pit mine in the country. It might be possible to do this technically, but it would require a tremendous effort.

MODIFIED IN SITU RETORTING

Underground mining, rubblization, and in situ retorting is technically feasible, environmentally acceptable, and economically competitive. Ten conceptual systems were evaluated and ranked. The four best systems were then evaluated objectively. The two systems with the greatest potential were Room-and-Pillar Vertical Drill and Blast and Tunnel Boring-Horizontal Ring Drill and Blast. Operating costs ranged from $4.38 to $5.32 per barrel.

In addition to oil shale, the Lower Zone contains an estimated 32 billion tons of nahcolite, containing 65 percent by weight of soda ash and an estimated 19 billion tons of dawsonite, containing 35 percent by weight of alumina. Plans are underway to obtain bulk samples of these minerals for process development by the Metallurgy Group of the Bureau of Mines. Geologic and hydrologic investigations have been completed, a site selected, and a call for bids for core drilling issued. If successful, the drilling program will be followed by the boring of a large-diameter shaft for access to the Lower Zone. Two waste management studies, a geophysics study, a bit-and-cutter test for tunnel boring, and health and safety studies of dust and toxic gases are underway.