times, very low densities and very high neutron porosity indices. At the same time the natural gamma ray deflection is very low and the resistivity high.

Because the properties of coal are so distinctive, logging data are of considerable use in evaluating the coal bed itself. For example, methods have been developed to derive percent ash, percent moisture, and percent fixed carbon from log data.

Planning a coal mining operation is an extremely important phase, particularly for subsurface mining. Processed logging data can provide information on the strength and lithology of the adjacent formations; this will help to obtain a safe and economical mine design.

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URANIUM DEPOSITS OF GAS HILLS, WYOMING

The Gas Hills uranium district is in central Wyoming along the southeastern margin of the Wind River basin. The initial discovery was made by Neil E. McNeice in the fall of 1953.

Earliest development of the district's ore reserves was quite slow, but accelerated when the larger, more experienced mining firms became active in the area.

Surface drilling proved to be the most effective tool for finding and developing the uranium ore reserves. New drilling techniques were needed to obtain samples of the below-water-table ores. Many methods were tried, but frozen core drilling and bucket augering proved to be the most reliable for obtaining accurate samples.

Since the initial discovery, the Gas Hills uranium district has produced about 12% of the United States total production.

The present land surface is characterized by barren, subdued, rolling hills. These are traversed locally by steeply dipping hogback ridges of older, more resistant rocks, which are the flanks of truncated, northward plunging folds formed by crustal disturbances prior to the deposition of the Wind River Formation. A steep erosional escarpment that rises abruptly above the north sloping basin floor bisects the region and divides the surface drainage between tributaries of the Wind River on the north and tributaries of the Sweetwater River on the south.

Volcanism occurred during late Eocene time, as evidenced by relic vents at the southern end of the Rattlesnake Hills, and by local volcanic debris in the middle and upper Eocene rocks.

Sedimentary rocks exposed in the Gas Hills uranium district include sandstone, limestone, dolomite, shale, and tuffaceous sandstone, mudstone, and shale. They range in age from Cambrian to Miocene and have a composite thickness of over 14,000 ft.

The source beds for the uranium deposits are arkosic sandstones interstratified with lenticular mudstones and shales. Two distinct types of sandstone are present in the Wind River Formation. The youngest is yellowish-orange to yellowish-gray arkose, derived primarily from Precambrian gneissoid and granitoid rocks; it contains little clay, abundant calcium carbonate, and limonite cement, and is host for all uranium deposits of the district.

The second type of sandstone is pale yellowish-gray to pale olive, derived from areas of schists of Precambrian age; it contains abundant clay matrix.

There are four types of uranium deposits in the district, the most important being the solution-front deposits. They were formed along the margins of highly altered, tabular sand beds that are enclosed by overlying and underlying fine-grained siltstone, claystone, and carbonaceous mudstone beds. Solution fronts can be followed for long distances and individual ore bodies along them may reach thousands of feet in length.

The solution fronts are ideally crescentic or "C"-shaped when viewed in cross section, with thin mineralization forming the tips of the crescents. The uranium minerals occur as earthy brown to black coating on, and interstitial fillings between, the quartz-sand grains. The primary uranium ore minerals are coffinite and uraninite.

The three other types of deposits include transitional-bedded, oxidized, and residual-remnant deposits. Several quite large transitional bedded deposits have been mined, but the oxidized and residual-remnant deposits are commonly small and difficult to mine.

Ground waters, trapped by the southward tilting of the Tertiary rocks during late Miocene time, became stagnant. These waters dissolved uranium and other elements from the enclosing rocks, and after erosion had exposed the highest beds of the Wind River Formation, the mineral-rich solutions gained egress from the enclosing sand aquifers on the north and the solution-front ore deposits began to form.

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CURRENT STATUS OF OIL SHALE DEVELOPMENT IN UNITED STATES

There is no commercial oil shale development in the United States today despite extensive and well known deposits and periodic flurries of interest. In the current energy situation the oil shales of the Green River Formation in Colorado, Utah, and Wyoming are attracting a great deal of interest as a possible secure domestic source of synthetic crude oil. High grade oil shale deposits containing a potential 600 billion bbl of shale oil occur in an 11-million-acre area of the three states. The tempo of predevelopment activity has accelerated during the last year and the prospects for a domestic shale oil industry in the foreseeable future appear good.

Four private industrial groups recently have announced tentative plans for development of private oil shale lands in Colorado. The Colony Development group has operated a semi-works scale facility north of Grand Valley, Colorado, at 1,000 tons per day with room and pillar underground mining techniques and a surface retort using the TOSCO II system. Union Oil Company has done prior experimental mining and retorting on their lands which adjoin the Colony property. Superior Oil Company has announced their intention to explore the lower oil shale zones by an inclined shaft to determine the feasibility of a multi-mineral development producing nahcolite and dawsonite as well as shale oil in the northern part of the Piceance basin. Occidental Petroleum Company has successfully operated an experimental *in-situ* retorting process north of DeBeque, Colorado. A group of 16 companies has joined in a 30-month program to develop and test a new retorting system.

The United States Department of Interior has been involved in research and investigation of the Green River oil shales and the technology for their development for many years. It has now initiated a prototype program of leasing for development by private industry of a small part of the approximately 80% of the oil shale resources which are Federally owned. Four years of study and planning and the completion of a six-volume Environmental Impact Statement have preceded this action. If this program is successful the production from the six Federal leases combined with production from private lands could reach an estimated 400,000 bbl per day by the early 1980s and one million bbl per day before the close of that decade.

The first lease offering under the prototype program of a single 5,100-acre tract in northwestern Colorado was on January 8, 1974. Eight offers were received with a high bid of $210,305,600 submitted by a combination of Standard Oil Company of Indiana and the Gulf Oil Corporation. This appears to be the highest per acre bid ever received by the Federal government for the leasing of any mineral deposit. The total of all bonus bids received was $641,126,463.09.

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NUCLEAR FUEL—AN ASSESSMENT

No abstract available.

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LONE PINE FIELD—EXERCISE IN STRUCTURAL GEOLOGY

Lone Pine field, in the northwest part of North Park basin, Colorado, lies between the Park Range on the west and the Sheep Mountain-Delaney Butte thrust on the east. The oil field underlies a surface anticline mapped by Hale in 1965. Seismic work by a major oil company condemned this prospect, and it was farmed out to Burton-Hawks Exploration Company, who drilled the discovery well in November 1971. In general, the structural configuration and drilling depths conformed closely with Hale's cross section interpretation. The discovery well had a gas blowout from the Dakota Sandstone while coming out of the hole for a drill-stem test. After the well was controlled the Lakota Formation was drilled and completed as an oil producer with an I.P.F. of 515 BOPD. Subsequent drilling has found nine more oil wells and one gas well, all south of the discovery. The northern productive limit appears to have been found, with two dry holes just north of the discovery; however, the southern extent of the field remains to be determined. Present oil production extends 1.25 mi along both flanks of the structure, with a gas cap separating the two flanks. Some minor oil production is obtained from the Dakota Sandstone oil ring in two wells.

The Lone Pine structure is a tightly folded, complexly faulted anticline, with 25-45° dips on the east flank and 45-60° dips on the west flank in the oil column. An oil column of approximately 300 ft has been established. Stratigraphic thickness of the Lakota is 70-75 ft, with 60-65 ft of effective pay. Average porosity of the Lakota is 18 percent. Drilling depths range from 2,400 to over 3,000 ft depending on topography and hole deviation. Wells are spaced about 800 ft apart along the east flank; optimum spacing on the west flank is yet to be determined. Each east-flank well proves up an estimated 300,000 bbl of recoverable oil, and west flank wells approximately 150,000-200,000 bbl of oil. A strong water drive hopefully will assure flowing wells throughout the life of the field.

Detailed structural analysis has been essential in guiding development drilling. Large scale, precise structural cross sections are built through each well. Logs are examined closely to determine even the smallest faults. All possible surface data are utilized. Concentric fold form, constant bed thickness and bed length, and a detailed analysis of fault behavior are combined to map as closely as possible the structural attitude in development wells while drilling. The target area for each well is a bank of production (oil ring) only 300-500 ft wide, and attempts are made to penetrate the oil ring near its midpoint to avoid water fingering from below and gas fingering from above. In addition, because of strong tendency for hole deviation in the steeply dipping strata, and the desire to penetrate the Lakota pay "broadside" where possible, the wells must be located at the surface (away from the axis) about 400 ft from the desired location at total depth. Frequent directional surveys while drilling have been necessary, particularly in the early development where unpredictable structural complexities were found.

Despite the problems and additional expense of this type of development drilling, Lone Pine field should prove very profitable. Some of the wells are capable of flowing over 1,000 BOPD; however, all wells are choked back to 100-150 BOPD to prevent premature water fingering, or possible gas fingering.

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MODEL WHICH PRODUCES SYNTHETIC SEISMIC CROSS SECTION

No abstract available.

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DEVELOPMENT IN *IN SITU* PROCESSING FOR SHALE OIL RECOVERY

"Oil Shale" is a kerogenous marlstone found in the Eocene Green River Formation over wide areas of Colorado, Utah, and Wyoming. Oil content averages about 20 gal per ton. Over the past 20 years experimentation in the *in situ* processing has been largely in the direction of downhole fracturing techniques. Nuclear fragmentation also has been considered. U.S. Bureau of Mines experiments on mine-run rock in surface retorts at the Laramie Research Station demonstrated the feasibility of *in situ* retorting once the necessary void volume had been created.

In the Occidental process a volume sufficient to create the required void space is mined beneath the ore which is then fragmented using conventional explosives to form a retort. Heat introduced at the top of the retort initiates retorting which then proceeds downward ahead of the advancing flame front. The oil produced is pumped from a sump at the bottom of the fragmented rock pile.

The Occidental process is not limited by room and pillar mining thicknesses and thus can exploit thicker