The study area has several hundred domestic and livestock water wells, most of which are less than 500 ft deep. Water levels in these wells generally are less than 300 ft below the surface. Delineation of the potentially strippable coal zone and determination of its relation to the shallow aquifers permit an estimate of the probable effects of surface mining on ground water.

Acquisition and interpretation of similar types of geologic, hydrologic, and related data in other areas that have potential for resource development will provide decision makers with tools necessary for proper assessment of environmental impacts.

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INTERPRETIVE TECHNIQUES IN REMOTE SENSING

With increasing availability of aircraft and satellite remote-sensor data the working geoscientist now has a new tool at his fingertips. He can gain much from some of these data simply by applying traditional photointerpretive techniques, but still more can be gained if he selectively employs some specialized interpretive techniques. Proper use of the new interpretive techniques requires that the user have a basic understanding of the data he is using—how it is obtained and what it represents. He also must keep in mind the limitations of the data, such as its spectral, spatial, and brightness resolution.

With these considerations in mind, the geoscientist can select the type of remote sensor data that will apply best to his problem and then tailor the processing and analysis of the data to obtain the maximum amount of information with the least expense.

The geoscientist may employ various forms of optical or digital image enhancement or he may choose to use the computer in helping him make his discriminations and classifications. Some enhancement techniques are employed with visual-image analysis, such as color-additive and color-subtractive viewing, stereoscopic and pseudostereoscopic photo interpretation. A few procedures can be accomplished only through computer analysis (brightness ratioing, atmospheric correction), but most are effective with either imagery or digital data. This latter group includes contrast stretching, density slicing, cluster analysis, pattern recognition, frequency analysis, and edge enhancement. Most of these procedures can be done in several ways, with the accuracy of the results and the efficiency of the operation largely dependent on the equipment used. Thus, the economics of the situation are the final consideration in the implementation of most of the more complex interpretive techniques.

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WATER AND COAL DEVELOPMENT IN POWDER RIVER BASIN

A large part of future energy demands may have to be satisfied by coal, uranium, and oil shale, with coal assuming most of this burden. By the year 2020 the value of products from coal may exceed the combined value of all products of Wyoming's other minerals. Coal can either be shipped out or used in state. In-state use has been projected to require mining 360 million tons each year by 2020. Sufficient mineable coal is available to meet the demand. To utilize this coal, large quantities of water are needed.

More than 75% of Wyoming's coal reserves are in the Powder River basin which is a water-short region. Annual water requirements for a 1,000-megawatt steam-electric power plant average 14,000 acre-ft; for a 100,000 bbl per day coal liquefaction plant 20,000 to 65,000 acre-ft; and for a coal gasification plant with a capacity of 250,000,000 MCFD of pipeline gas a minimum of 10,000 acre-ft. More than 500,000 acre-ft of water will be needed annually (10.6×10^6 bbl per day) in the Powder River basin. Three alternate schemes for supplying this water have been investigated by the Wyoming Water Planning Program. The total water demand cannot be met without importing water.

Water is the controlling factor in the in-basin use of Powder River basin coal. Large quantities of water cannot be imported without political agreement. The long-range water availability affects the feasibility of in-basin use of coal and land reclamation.

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HYDROCARBON ACCUMULATION IN SAN ANDRES FORMATION OF PERMIAN BASIN, SOUTHEAST NEW MEXICO AND WEST TEXAS

Porous limestones and dolomites in the San Andres Formation (Middle Permian) serve as reservoirs for many oil and gas accumulations found in the Permian basin of southeast New Mexico and West Texas. The mature state of field discovery, development, and exploitation associated with exploratory effort directed toward the San Andres, together with the wide range of factors which have been found to characterize its hydrocarbon traps, allow it to serve as an example which illustrates many of the basic truths and concepts of modern petroleum geology.

San Andres carbonate and evaporite rocks, together with their lateral formational and lithofacies equivalents, were deposited during a gross cycle of marine transgression and regression. Reservoir porosity is restricted generally to rocks deposited in shelf-margin reef, shallow-marine and intertidal environments. Many of these environments may be identified on the basis of characteristic lithology, depositional features, and fauna. A knowledge of environmental-lithologic patterns is essential to understand the stratigraphic controls affecting hydrocarbon accumulation.

Regional San Andres structure consists of a broad south-plunging syncline characterized by gentle easterly dips from outcrops in central New Mexico and westerly dips from outcrops in central Texas toward an axis near the New Mexico-Texas line. Local closed anticlines, noses, and flexures, which overlie either basement uplifts and faults or older shelf-margin reefs, interrupt the regional structural grain and significantly influence hydrocarbon accumulation.

Potentiometric data indicate that fresh water entering the San Andres in the high mountainous New Mexico outcrop area flows easterly through porous units and becomes highly saline before reaching a discharge area along the lower lying outcrop belt in central Texas. Groundwater movement has caused east-tilting oil-water contacts in many of the oil fields.

Examination of the productive fields indicates hydrocarbon accumulation is controlled by highly variable combinations of (1) structural, (2) stratigraphic, and (3) hydrodynamic elements. Trap types recognized range from large closed anticlines with apparent horizontal hydrocarbon-water contacts to more obscure and subtle traps of unclosed structural/stratigraphic or stratigraphic type with notably nonhorizontal hydrocarbon-water contacts.

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OVERVIEW OF GEOTHERMAL ENERGY DEVELOPMENTS

Exploration for geothermal resources includes evaluation of the volcanic history of areas, regional hydrology, geochemistry of hot springs, and certain selected geophysical methods that determine temperature, heat flow, and structure of prospective areas.

Geothermal energy is used mostly for electric-power generation with current worldwide installed capacity of about 1,000 Mw. The only geothermal area in the world completely developed by private enterprise is at the Geysers in northern California, where it has proved to be a viable, mechanically reliable, and environmentally acceptable resource, competing economically with alternative forms of power generation in Pacific Gas and Electric Company's system.

Modern drilling for natural steam was started in the Geysers area in 1955. Pacific Gas and Electric's first power plant, with a 12.5-Mw electric-generating capacity utilizing this steam, went into operation in 1960. By 1970, four units of 82 Mw were on stream. With the annual completion of 110-Mw generating facilities beginning in 1971, the Geysers field is expanding rapidly and it produces today 400 Mw, with the field estimated to be in excess of 1,000 Mw in size.

The National Petroleum Council estimates that by 1985 about 15,000 Mw of geothermal power can be developed in the western United States. With improved exploration, drilling and utilization technology, and modification of certain institutional barriers it has been estimated that geothermal power may be of the order of 75,000 Mw by the year 2000.

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RED WING CREEK FIELD, NORTH DAKOTA—AN EXTRATERRESTRIAL HYDROCARBON TRAP

Red Wing Creek field is on the southwest flank of the Williston basin near the axis of the present basin. The field is centered in Sec. 27, T148N, R101W, McKenzie County, North Dakota. The discovery well was drilled by True Oil Company in August 1972.

Seismic and subsurface data indicate that rocks of Permian, Pennsylvanian, and Mississippian ages have undergone intensive deformation. This has resulted in steep dips and many reverse faults. Rocks of younger and older ages show relatively little tectonic disturbance. The primary trapping mechanism is the result of faulting and uplift of the producing horizons.

The field has 10 wells capable of production. There are six dry holes and one well is being drilled. Two wells have been drilled into the Red River Formation of Ordovician age. No commercial production has been found below the Mississippian.

Mission Canyon formation of Mississippian age is the primary producing zone. Some production has been found in the Kibbey, Charles, and Lodgepole formations, also of Mississippian age. The discovery well has more than 1,100 ft of net pay, making this the best well in the field. Porosities range as high as 25% but most of the reservoir has porosities in the range of 6 to 10%. Oil-water contact ranges from subsea depth of -7,300 to -7,500 ft. Reservoir studies indicate in excess of 100,000,000 bbl of oil in place.

Several theories have been advanced to explain the trap, including salt dome, reef, salt collapse, wrench faulting and astrobleme.

Present data have indicated that the field is producing from the central peak of a meteor impact structure of Jurassic age. The feature has been modified by subsequent salt collapse and differential compaction.

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U. S. GEOLOGICAL SURVEY PETROLEUM EXPLORATION RESEARCH IN ROCKY MOUNTAIN REGION

The roles of the U.S. Geological Survey relative to petroleum exploration and production commonly are ill understood by private industry. The Conservation Division of the Geological Survey is concerned primarily with regulation and supervision relative to oil and gas on public and Indian lands, whereas the Branch of Oil and Gas Resources of the Geologic Division conducts research that (1) contributes to improved exploration procedures, and (2) helps appraise the petroleum potential of frontier areas so as to advise the Executive Branch of Government. Successful cooperation between private industry and the Oil and Gas Branch clearly will further both aspects of this research.

Current research projects in the Rocky Mountain region fall into categories of "topical research" and "geographic research." Of particular regional interest are projects relating to indirect detection of hydrocarbons, generation and migration of hydrocarbons, porosity trends in sandstone reservoirs, Paleozoic source rocks, and Cretaceous structural and stratigraphic traps, among others.

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SUBSURFACE DISPOSAL OF FLUID WASTES IN SASKATCHEWAN

In the Williston basin region, deep-well disposal of industrial fluid wastes is confined largely to the Saskatchewan part of the stable, relatively shallow, tectonic shelf, which is flanked on the south by the deeper basin proper, and is delimited in the north by the Canadian shield.

As of mid-1973, 30 industrial disposal wells had been drilled in Saskatchewan: 20 were in operation, 5 suspended, and 5 abandoned. To year-end 1972, more than 118.995 million bbl of fluid wastes, exclusive of oilfield brines, had been injected into subsurface aquifers in Saskatchewan: (1) waste brines (63,440,000 bbl), resulting from shaft and solution mining, as well as experimental solution of Devonian potash deposits; (2) waste brines (50,930,000 bbl), produced during solution mining of caverns in Devonian halite for subsequent storage of liquefied petroleum gases and dry natural gas; (3) refinery effluent (3,530,000 bbl), comprising sour water and spent caustic from 2 plants; and (4) brines containing small amounts of mercury com-