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 compounds (221,000 bbl) from a chlor-alkali plant, associated with previously injected wastes (874,000 bbl) from production of the herbidices 2, 4-D, and MCPA.

The depths of injection intervals range from 1,448 to 4,692 ft. The maximum total depth of a disposal well in Saskatchewan is 5,536 ft. Average injection rates are from 3 to 1,100 US gpm and average wellhead pressures vary from the sole influence of gravity to 1,750 psig. More than 44.13% of all industrial wastes injected into the Saskatchewan subsurface are received by clastic aquifers. In 18 injection systems, clastic units (Cambrian and Ordovician; Lower Cretaceous) are the disposal intervals, whereas 13 wells have been completed for disposal into carbonate units (Silurian to Mississippian). There are four multizone completions, each involving disposal of potash brines into a Silurian carbonate aquifer and an Ordovician clastic aquifer. In three disposal systems, mercury compounds are permitted to accumulate in caverns in Devonian evaporite strata.

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ANALYSIS OF ENERGY CRUNCH AND APPLICATION OF COMPUTER TECHNIQUES TO SEARCH FOR OIL AND GAS

No abstract available.

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COMPARISON OF RECENT LABORATORY MODELS TO NATURAL DEFORMATION IN ROCKY MOUNTAIN FORELANDS

Several years ago for the first time the technique for experimental folding of layered real rocks under conditions expected within sedimentary basins was developed in our laboratory. In the initial experiments the samples had to be loaded parallel with the layering simulating horizontal compression. Though these experiments produced many insights into the overall folding process, they are not representative of most folds in the Rocky Mountain forelands where the folds result from differential vertical movements of the basement. However, within the last year the technique has been modified to produce loads at high angles to the layering and now we can produce a form of drape folding that does, indeed, have much in common with folds in the Rocky Mountain foreland. Making one-to-one correlations of simplified laboratory experiments to complicated natural features can be fraught with danger and completely misleading. However, these experiments verify so many long suspected natural phenomena that selected comparisons may be significant.

Scale alone precludes complete observation of natural folds with thousands of feet of displacement, but if correlations to experimentally created folds can be validated, the overall fold process becomes subject to direct observation. Such observations lead to increased confidence in delineation of structural geometries on the natural scale. This is especially true for the more complicated fold forms that usually have to be predicted in the subsurface from limited exploration data. It is gratifying to see that the overall movements in the experiment correlate well with natural folds, because it allows us to develop conceptual models upon which we can draw when dealing with widespread subsurface control or masked seismic data.

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CHURCH BUTTES ARCH, WYOMING AND UTAH

The Church Buttes arch extends from the Bridger Lake field in northern Utah northward through the Church Buttes field to the Big Piney-LaBarge field in southwestern Wyoming, a distance of approximately 120 mi. The arch is considered an overthrust structure. Deformation of the Absaroka thrust zone and the Church Buttes arch occurred during the Late Cretaceous as the result of the same tectonic forces. Folding of the arch resulted in localization of oil and gas accumulations in Mesozoic and Paleozoic rocks. Oil and gas production from combination structural-stratigraphic traps, directly related to the folding of the arch, has been established in the Cretaceous Frontier, Bear River, and Dakota Formations, and the Pennsylvanian Morgan Formation. Continued exploration of the arch should result in additional discoveries in both Mesozoic and Paleozoic rocks.

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WESTERN COAL—CLEAN BLACK ACE IN THE HOLE

In 1973 oil and gas supplied 77% of America's energy, 19% came from coal, less than 5% from nuclear, hydroelectric, and other sources.

Oil and gas make up only 9% of our domestic fossil fuel reserves. Oil shale accounts for 15% and coal 74%. For a nation facing future energy shortages, this arithmetic should tell a story. Sixty-four percent of our domestic coal reserves are in the Dakotas and Rocky Mountain States.

Barely 10 years ago the major oil companies first started a programmed acquisition of western coal resources for the synthetic fuel-from-coal industry. The recent dramatic changes in the price structure of U.S. fossil fuels now make synthetic gas and liquids from coal competitive with traditional supplies.

Coal is not difficult to find. The geology of coal in the western basins is generally simple. Western coal's problems have been geography, economics, and politics.

About 80% of western coal lies under the public domain. Indecision and politics have resulted in a three-year freeze on Federal coal leasing. This has slowed down the timetable for western coal's contribution to the national energy mix.

Western coal's assets are low mining costs and low sulphur. Present resource acquisitions are almost exclusively strippable deposits. Nevertheless, only about 5% of western coal can be surface mined economically with present equipment. The real future may well lie in the development of techniques to mine clean energy from the 95% of the coal reserves which are underground.

For instance, a tract of land 10 mi long and 5 mi wide in the Powder River basin of Wyoming contains more coal Btu's at a depth of 1,000-2,000 ft than all the known oil reserves in the U.S.—onshore, offshore, and the North Slope of Alaska. Herein may be the challenge and the biggest opportunities. For an