ENVIRONMENTAL PROBLEMS OF OIL SHALE
UINTA BASIN, UTAH

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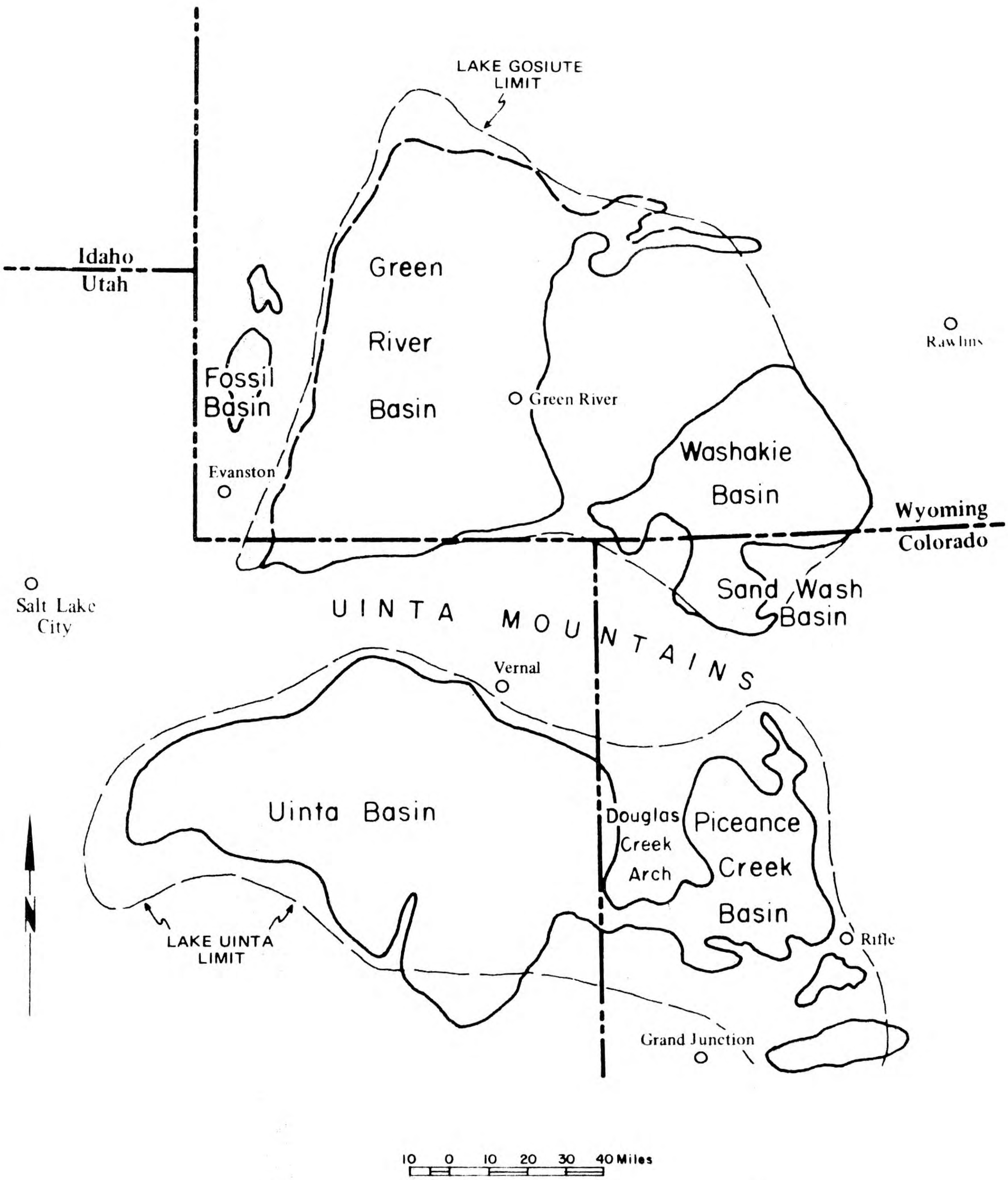
TABLE OF CONTENTS



BASINS IN WHICH OIL SHALE IS FOUND

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

ENVIRONMENTAL PROBLEMS OF OIL SHALE UINTA BASIN, NORTHEAST UTAH

ILLUSTRATIONS

I. PREFATORY STATEMENT (Frontispiece)

Utah's oil shale underlies some 6,100 square miles of the Uinta Basin, northeast Utah. Richer, thicker shale considered amenable to development is concentrated in 1,200 square miles in the southeast part of the basin.

The 1,200-square-mile optimum area is isolated, sparsely populated semi-desert typical of large areas of western United States. It supports little industry and there are only minor recreation and scenic values. This report primarily concerns the optimum area where oil shale development is most likely to take place.

Total oil contained in oil shale in the basin is variously estimated at 900,000,000,000 to 1,300,000,000,000 (900 billion to 1.3 trillion) barrels. Oil contained in shale of 15+ gallons per ton grade, 15 or more feet thick is estimated at about 290 billion barrels. The optimum area in the southeast part of the basin contains between 90 and 115 billion barrels of oil. Value of this potential energy source greatly outweighs any other known or foreseeable land use value of the area.

Utah's oil shales were deposited at the same time, in much the same environment and are similar in most respects to the Piceance Basin deposits of adjacent Colorado. Deposits in both states occur in the Parachute Creek Member of the Green River Formation (Eocene age) mostly within the Mahogany oil shale bed (or zone). Structure of Utah's deposits is uncomplicated, and the oil shale is situated favorably in various parts of the optimum area for open cut and underground mining and almost all methods of in situ extraction now under consideration.

Environmental protection in development of the oil shale resource presents problems requiring early and continuing attention. These problems relate to surface and subsurface waters, the atmosphere, land use and restoration, and aesthetics. The problems are recognizable and generally well known. Technology and capability exists for solution of many as presently recognized and known. Other problems will--and must--yield to patient, careful scientific and technical effort. The process of problem recognition and solution must of necessity be one of evolution as the oil shale industry develops.

Costs of environmental protection cannot be reliably estimated without more specific knowledge of the time, place and manner in which the oil shale resource is to be developed and without detailed knowledge of the framework of laws and regulation which will govern such development. Utah's deposits have not been explored in detail and no experimental or pilot field projects have been undertaken in this State. Utah's deposits are similar in many respects to those of adjacent Colorado with important differences that may make environmental protection problems and the costs of their solution less severe than those encountered in Colorado.

There is urgent need to acquire basic geological, biological and meteorological data for use by industry and government in planning for oil shale development and environmental protection. How to develop the large oil-impregnated sandstone deposit which underlies the oil shale in the southern part of the area is also a serious concern.

Another need is to frame adequate laws and regulations to govern the oil shale development and related activity in that part of the State likely to be affected.

The entire oil shale region of Wyoming, Colorado and Utah is within the drainage area of the Colorado River. Therefore, the water supply for development of oil shale and preservation of the quality of the water returned after use are matters of great importance.

Every effort should be made to resolve conflicts of land ownership and leasing policy in advance of development. To effect the greatest efficiency and economy in development and the highest degree of environmental protection, every effort should be made to unitize operations within the optimum area for oil shale development. Operations must be carried on on development tracts or lease blocks large enough to permit maximum efficiency and economy of operation, with one set of regulations and standards for development and a single master plan for reclamation and restoration of this land during and after development.

II. INTRODUCTION

A. MEMORANDUM OF MAY 28, 1970

This report is prepared by the Committee on Environmental Problems of Oil Shale, State of Utah, in response to the request of Mr. Gordon Harmston, Executive Director, Department of Natural Resources, for information to meet the requirements set forth in a memorandum dated May 28, 1970 to the Under Secretary of Interior from Assistant Secretary for Mineral Resources, Hollis M. Dole, and Assistant Secretary for Public Lands, Harrison Loesch, directing that a report be prepared by the States and appropriate Federal agencies in accordance with the requirements set forth in Section 102 (2) (c), Public Law No. 91-190, National Environmental Policy Act of 1969.

This report is the environmental statement so requested.

B. COMMITTEE ON ENVIRONMENTAL PROBLEMS OF OIL SHALE

The membership of this committee is as follows:

Chairman

Howard R. Ritzma, Petroleum Geologist
Utah Geological and Mineralogical Survey, University of Utah
Salt Lake City, Utah

Members

R. LaVaun Cox, Executive Director
Utah Petroleum Council, Salt Lake City, Utah

Max D. Eliason, Vice President
Skyline Oil Company, Salt Lake City, Utah

Members (Continued)

Cleon Feight, Director
Division of Oil and Gas Conservation, State of Utah
Salt Lake City, Utah

Charles R. Hansen, Director
Division of State Lands, State of Utah
Salt Lake City, Utah

Gordon Harmston, Executive Director
Department of Natural Resources, State of Utah
Salt Lake City, Utah

Dr. George R. Hill, Dean
College of Mines and Mineral Industries
University of Utah
Salt Lake City, Utah

Charles R. Henderson, Member
Board of Oil and Gas Conservation, State of Utah
Vernal, Utah

James Keogh, Chief
Division of Lands and Minerals
U. S. Bureau of Land Management
Salt Lake City, Utah

John E. Phelps, Director
Division of Fish and Game, State of Utah
Salt Lake City, Utah

Paul S. Rattle, Manager
Utah Mining Association
Salt Lake City, Utah

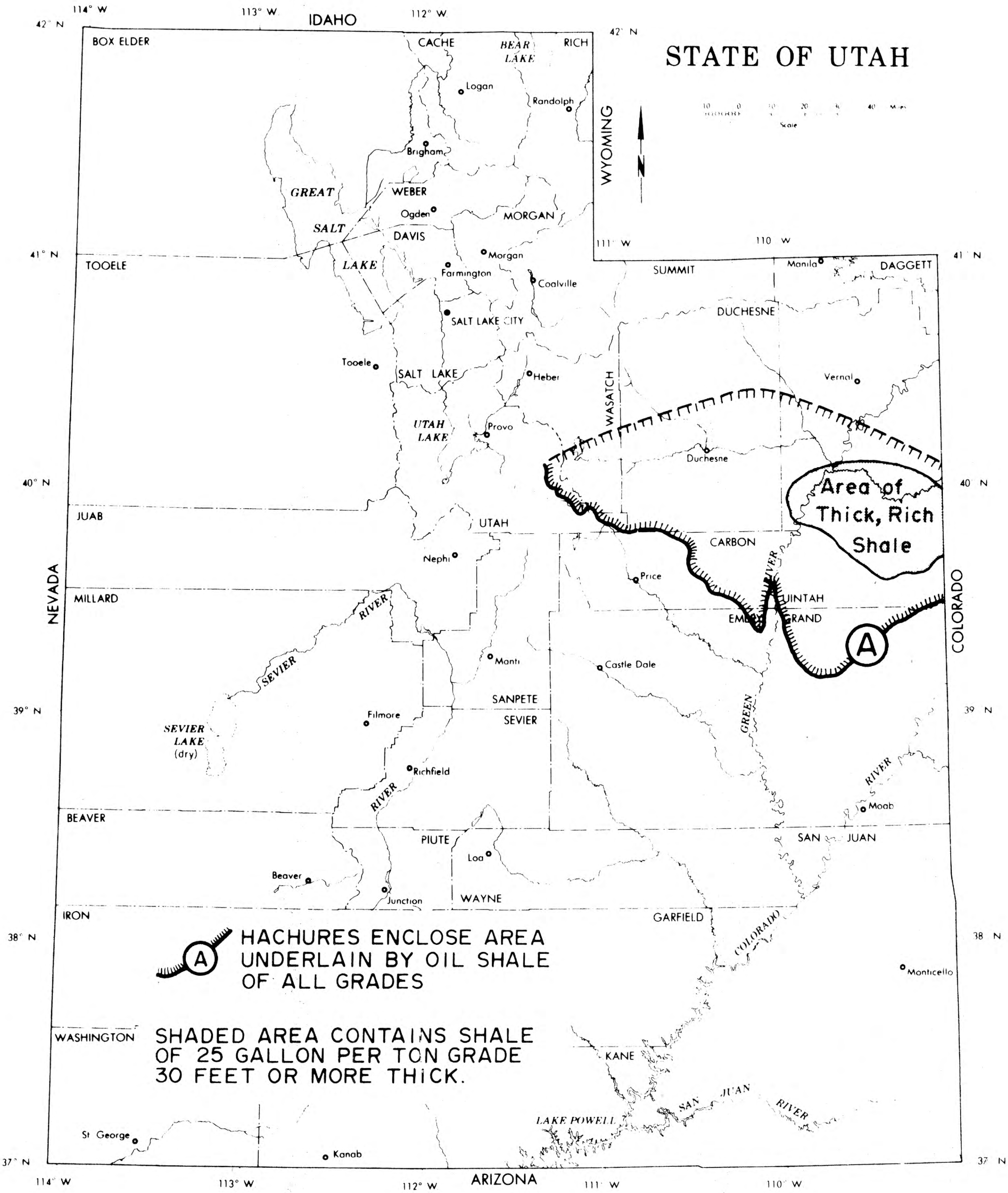
Lynn M. Thatcher, Director
Bureau of Environmental Health, State of Utah
Salt Lake City, Utah

C. PREPARATION OF REPORT

The report has been prepared under the direction of Howard R. Ritzma, Petroleum Geologist, Utah Geological and Mineralogical Survey, Chairman of the Committee. It has been assembled from survey of the published literature and from unpublished material contributed by the U.S. Geological Survey and U.S. Bureau of Mines. A large volume of material was contributed by the U.S. Bureau of Land Management, and other information was furnished by the Divisions of Fish and Game and Oil and Gas Conservation, Department of Natural Resources, State of Utah.

Members of the committee are mostly officials of the State of Utah and their report, as such, primarily reflects State attitudes based on information available to the State.

Figure 1



OIL SHALE AREAS
UINTA BASIN, NORTHEAST UTAH

III. ORIENTATION

A. LOCATION AND POLITICAL SUBDIVISIONS (Figures 1, 2 & 3)

Utah's oil shale deposits are in the Uinta Basin, northeast Utah. The total area underlain by oil shale covers about 6,100 square miles in Uintah, Duchesne, Carbon, Utah, Wasatch and Emery counties. But the principal area of thick, rich shale lies in Uintah County in the valley of the White River, southward to the heights above the Roan Cliffs, from the Colorado-Utah boundary west to the Green River. This area of about 1,200 square miles in southeast Uintah County contains oil shale deposits suitable for exploitation by open cut or strip mining, underground mining and possibly by all in situ methods proposed to date.

Figure 1 outlines the overall area underlain by oil shale in Utah and pinpoints the area of optimum oil shale occurrence. Since the latter is the area most likely to be directly affected by oil shale exploitation, it is the area primarily discussed in this report.

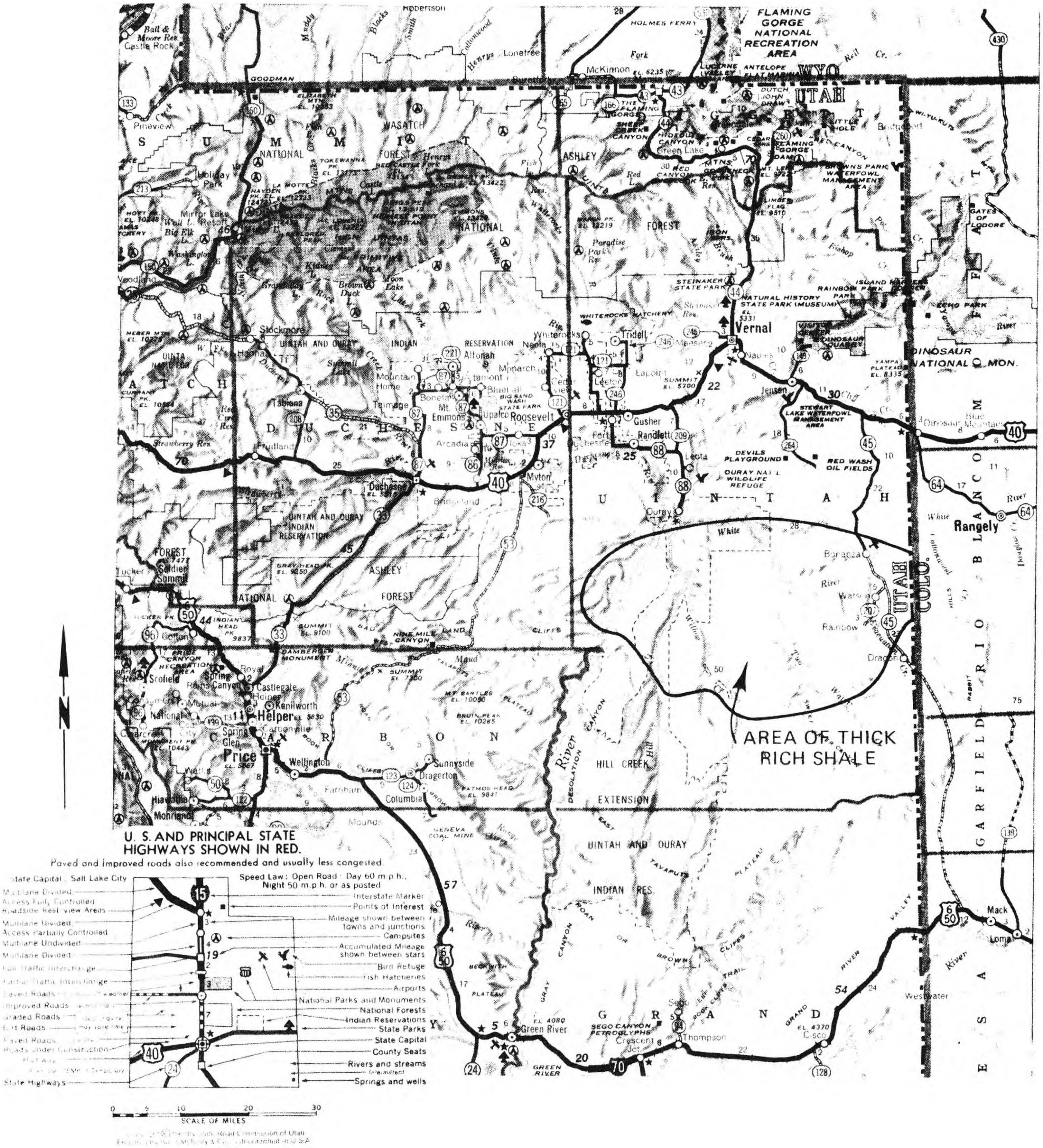
B. POPULATION AND INDUSTRY (Figure 2)

Northeast Utah is very sparsely populated with most of the population centered in irrigated agricultural areas and small cities. Population figures for Uintah County and Vernal, the county seat, are as follows:

	1960	1970	Difference
Uintah County	11,582	12,684	+9.5%
Vernal	3,655	3,908	+6.9%

The communities of Ouray and Bonanza north of the oil shale area have about 100 inhabitants each. Bonanza is a center for gilsonite mining, and

Figure 2



GEOGRAPHY,
ROADS AND ACCESS
UINTA BASIN, NORTHEAST UTAH

Ouray is principally an agricultural center. The abandoned towns of Watson, Rainbow and Dragon formerly were railroad stations and gilsonite mining towns along a narrow-gauge railroad which connected Watson with Mack, Colorado in the Grand Valley south of the Book Cliffs. Gilsonite is now transported by way of a water slurry pipeline built along the same general route as the now dismantled railroad.

The area of rich, thick oil shale south of Ouray and Bonanza has from ten to fifteen semi-permanent residents living on three ranches operated on a seasonal basis. A small number of persons who commute from Vernal, Red Wash and Grand Junction, Colorado travel through the area servicing oil and gas wells on a more or less regular basis.

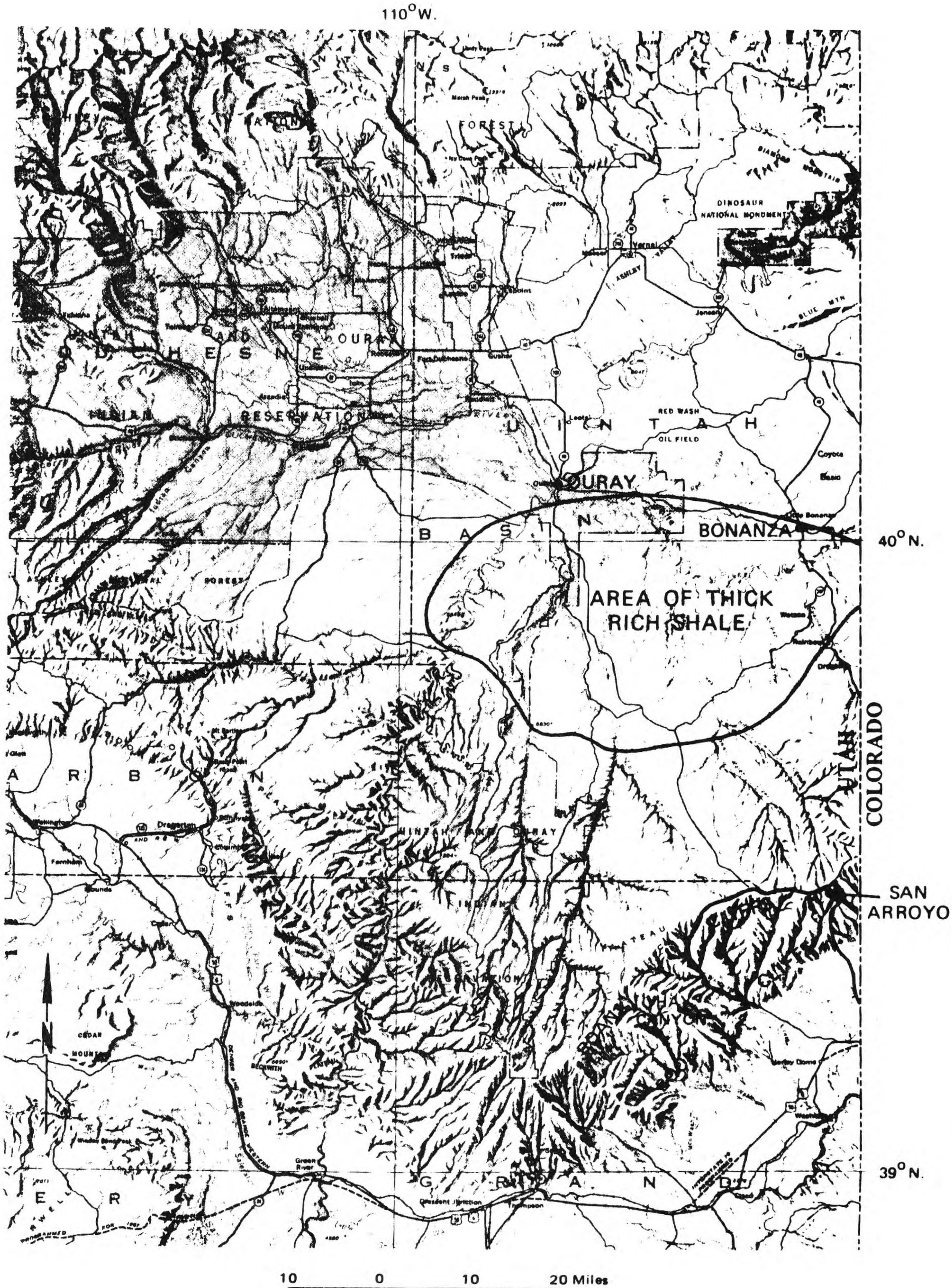
Eleven gas fields and three oil fields are located within the optimum oil shale area. Several of the gas fields also have individual oil wells or small areas of mixed gas and oil production within the field.

The scattered ranches, gilsonite mining, minor production of building stone, and transient oil and gas well servicing make up the total industry of the area.

C. GEOGRAPHY AND TERRAIN (Figures 3 & 4)

The Uinta Basin is a structural basin (geologic downwarp) and topographic basin. The surface of the land slopes into the basin from all sides, from the broad crests of the Uinta Mountains (12,000 to 13,000 feet) on the north to the lower heights of the Book and Roan Cliffs (8,000 to 10,000 feet) on the southeast to northwest. The basin is bounded on the west by the 10,000 foot

Figure 3



TOPOGRAPHY AND DRAINAGE
UINTA BASIN, NORTHEAST UTAH

Wasatch Plateau and is separated from the Piceance Basin country of western Colorado on the east by low ridges and dissected plateau areas ranging in elevation from 6,000 to 8,000 feet. The lowest part of the basin and the area toward which all drainage trends is the valley of the Green River near Ouray where the elevation is about 4,800 feet.

The Uinta Basin would be a basin of interior drainage were it not for the anomalous course of the Green River across the basin from northeast to south. The Green gathers all the drainage of the Uinta Basin and carries it out to the south through the rugged Desolation Canyon. From Ouray at about 4,800 feet, the river falls 500 feet in 50 straightline miles through this canyon and enters Grand Valley north of the town of Green River. The canyon through which the river meanders is from 2,000 to 3,500 feet deep and is cut in the north-dipping Tertiary and Cretaceous rocks that otherwise form the Roan and Book Cliffs. The passage of the Green through these escarpments has created rugged, dissected terrain that is very difficult to traverse.

Topographic map coverage for the area is almost complete as follows:

AMS Base - 1:250,000 scale

Grand Junction, Colo.; Utah quadrangle NJ 12-3

Vernal, Utah; Colo. quadrangle NK 12-12

U.S.G.S. Base - 1:62,500 scale (15" quadrangles) (Figure 4)

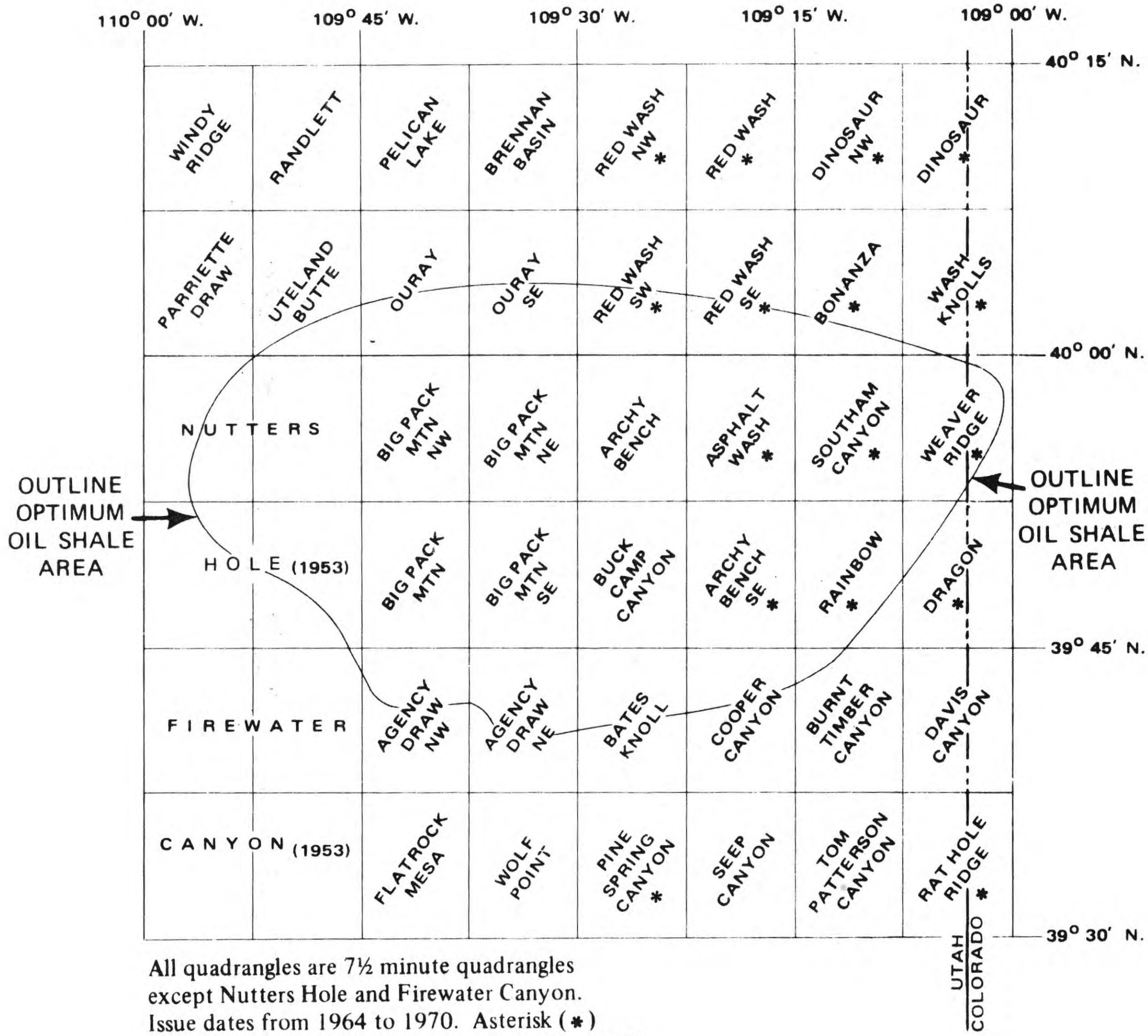
Nutters Hole

Firewater Canyon

U.S.G.S. Base - 1:24,000 scale ($7\frac{1}{2}$" quadrangles)

See index map (Figure 4)

Figure 4



All quadrangles are 7½ minute quadrangles except Nutters Hole and Firewater Canyon. Issue dates from 1964 to 1970. Asterisk (*) indicates quadrangle for issue in late 1970 or 1971. Nutters Hole and Firewater Canyon issued 1953.

15 and 7½ minute

TOPOGRAPHIC MAP COVERAGE

OPTIMUM OIL SHALE AREA

UINTA BASIN, NORTHEAST UTAH

D. ACCESS (Figure 2)

The area is isolated. It lies between the main east-west highway (US 40) across northeast Utah and the route traversed by US 6-50, Interstate 70 and the Denver and Rio Grande Western in the Grand Valley south of the Book Cliffs. There are few connecting roads between these two main east-west routes of travel. One such connecting road (Colorado 139) crosses Douglas Pass between Loma and Rangely in Colorado. To the west for the next 100 miles, there are no north-south connecting roads except graded dirt roads passable only in favorable weather or by four-wheel drive vehicles. Two paved roads lead south from US 40: Utah 45 to Bonanza near the Utah-Colorado border and Utah 209 and 88 to Ouray. Southward from these points graded gravel and dirt roads fan out over the oil shale area. These roads serve ranches (mostly occupied seasonally) and oil and gas fields. On the southeast border of the Uinta Basin the Book and Roan Cliffs which rise 3,000 to 3,500 feet out of the Grand Valley to the Roan Plateau make a formidable barrier to access from the south. Only two dirt roads ascend the cliffs from the Utah-Colorado boundary westward for 100 miles to Utah Highway 53 from Wellington to Myton. The eastern road in the San Arroyo Gas Field just west of the Utah-Colorado boundary serves gas field and pipeline operations; and the west road at Hay Canyon about 10 miles farther west is used mainly by grazing interests.

In the exploitation of the oil shale resource, the easiest natural routes of access are from the north, from Vernal, Jensen and Ouray in the Uinta Basin. Even with modern road building equipment, the Book and Roan Cliff escarpents would appear to present difficult and very costly barriers to the construction of main line roads. Construction of pipelines and tramways, however, would be feasible.

E. CLIMATE

The area of interest falls into the category of high altitude, high latitude desert. It is characterized by cold, dry winters and hot, dry summers, with large daily variation in temperature. A typical midwinter day might range from -15° to $+30^{\circ}$; midsummer from 45° to 95°.

Annual precipitation ranges from 5 or 6 inches at Ouray and increases with elevation to 12 to 15 inches thirty miles southeast. Some high areas along the crest of the Book Cliffs may receive 20 to 25 inches of precipitation annually.

Winter precipitation falls mainly as snow during infrequent storms. Evaporation rates are high and open areas may remain relatively free of snow for much of the winter. Summer precipitation comes principally from scattered thunderstorms. Severe thunderstorms may dump very large quantities of water for brief periods of time in small areas and cause flash flooding. Quite often the effects of the flooding may extend far downstream from the locale of the storm.

Prevailing winds are from the west and southwest with wide local variation depending on weather situations.

Drainage of colder air from higher elevations into basins and valleys creates well defined down-valley and down-canyon winds in all seasons.

Collection of cold air in valley bottoms may create marked temperature inversions and fog conditions, particularly ice fogs during persistent periods of stagnant high pressure during winter.

F. DRAINAGE (Figure 3)

The area containing rich, thick oil shale is drained by north and north-west-flowing streams which head in the high (8,000 feet+) country along the Book and Roan Cliffs. Most flow into the west-flowing White River which enters the Green southeast of the town of Ouray. From east to west drainages tributary to the White River are: Evacuation Creek (perennial), Asphalt Canyon (ephemeral), Bitter Creek (perennial), Cottonwood Wash (ephemeral), Sand Wash and Cottonwood Wash (both ephemeral).

The lower portion of Bitter Creek is also known locally as Two Water Creek below the confluence of Bitter Creek from the east and Sweetwater Creek from the west.

Willow Creek drains most of the western part of the optimum oil shale area. It flows directly into the Green River five miles south of Ouray and receives tributary drainages such as Main Canyon (ephemeral) and Hill Creek (perennial).

Many ephemeral drainages discharge through side canyons directly into the Green in the far western part of the area, among these being Kings Canyon and Tabyago Canyon from the east and Four Mile Wash from the west.

All the above mentioned streams and drainages are fed by numerous, usually ephemeral tributary drainages. Some of these may head in springs and contain sizable amounts of water for short distances downstream from the source.

After spring snow melt and summer rains and during wet weather cycles, all streams may flow sizable amounts of water. During dry cycles, all streams, even those normally perennial, may flow intermittently through much of their courses. Except for the headwater areas of spring-fed streams (Hill and Willow Creeks), water quality is generally poor with high silt and mineral content common.

Most springs occur in areas above 6,000 feet in the southern part of the area. Elevation, amount of precipitation, and the quantity, quality and circulation of surface and subsurface waters are closely interrelated.

G. WATER SUPPLY

It is estimated that Utah has sufficient water available from the White, Green and Colorado rivers to supply an oil shale industry producing one to two million barrels of oil per day. This estimate includes water use in the industry, in related urban growth and in potential ancillary industries that could develop in the oil shale region. Use will be limited by restrictions on water consumption by existing compacts between the states of the Colorado River Basin and by treaty with Mexico.

Several unknown factors loom. One is water use and possible loss in dampening stored spent shale to minimize dust contamination of the atmosphere. Particle size, a factor which varies considerably with processes, greatly affects the potential for contamination and, thus, water consumption. Water may also be used as a medium for slurry transport and in compaction of spent shale in open cuts and underground workings.

Water consumption in some phases of oil shale development will be accelerated by high evaporation rates and strong winds.

Water used for compaction or dampening of spent shale in open cuts and underground workings may not be "consumed" as such, but possibly, in part, will enter the subsurface circulation of water and become part of the total water resource of the area over a period of years.

Amount and quality of shallow and deep subsurface waters, almost untapped at present, is virtually unknown and should be investigated as a supplemental supply. Circulation of shallow and deep subsurface waters in the area is also little known. The potential of subsurface aquifers and reservoirs for disposal of waters with excessive mineral content is also an unknown quantity.

Since the oil shale region - Utah, Wyoming and Colorado - lies wholly within the Green-Colorado River system and is tributary to Lake Powell and lower Colorado River, feasibility of oil shale development depends on commitment of water supply, use of water, and protection of water quality in the Colorado River downstream from the oil shale development.

Water use must be highly efficient. Consumptive use and loss must be minimized. It is apparent that close cooperation of the three oil shale states and the Federal government will be necessary to bring this about.

H. SOILS

The soils of the area are mostly those which weather from outcropping claystone, shale, marlstone and oil shale. Some of the larger stream courses have developed narrow bands of alluvial soil suitable for cultivation. With little clastic material in the bed rock of the area, soils are mostly clayey or finely silty, highly calcareous and quite alkaline. Most are impervious and contribute to high rates of runoff after precipitation and snowmelt.

Soil cover on the divides between streams is generally thin. At higher elevations in the southern part of area where vegetative cover is greater, residual soils with somewhat higher organic content and ability to retain water have developed.

The residual soil which results from weathering of the Green River Formation is of considerable importance. Spent shale, Green River Formation with kerogen removed, has much the same composition as this residual soil, the principal difference being that spent shale contains the saline minerals and fine clays which disappear by solution and transport as soil forms naturally. The natural soils contain greater concentrations of residual sand, silt and naturally introduced organic matter.

Experimental work shows that treatment of spent shale with artificially introduced organic matter, nutrients, silt and sand produces a soil on which native and introduced plants readily grow. Pursuit of this work holds great promise for stabilization and revegetation of filled open cuts and spent shale disposal areas.

I. VEGETATION

A rough division of vegetative types can be made by elevation and is related to precipitation and soil.

4500-6000 - Sagebrush, rabbitbrush and greasewood with cottonwood and willow along stream courses.

6000-7500 - Sagebrush, juniper and pinyon.

7500-9500 - Sagebrush, serviceberry, aspen and fir.

Variable grass cover exists at all elevations.

J. GAME AND FISH AND SCENIC CONSIDERATIONS

The optimum oil shale area supports a population of deer, elk and antelope and a modest population of game and non-game animals, such as bear, cougar (mountain lion), coyote, bobcats, porcupine, rabbits and others. A variety of native and introduced game birds also thrives in the area.

There is some trout fishing in the headwater areas of Hill and Willow Creeks, most particularly in the Towave Reservoir on the Uintah and Ouray Indian Reservation in the upper reaches of Hill Creek. Several unusual varieties of non-game fish are found in the Green River.

The Desolation Canyon of the Green River has been designated as a national historic landmark. The Sand Wash Historical landmark has been designated at the north entrance to Desolation Canyon. "River-running" and hunting trips from boats have in recent years gained popularity in the Desolation Canyon area. Trips generally begin near the Sand Wash area. Other reserved areas and sites in the area are: one scenic overlook, one watershed study area, a winter deer range area, five public water reserves (each 40 acres), two undeveloped campground sites and the Ouray Wildlife Refuge along the Green River north of Ouray.

Of the above, the following areas and reserves are those that actually lie within the area of optimum oil shale occurrence:

1. About 20 miles of the Green River south of Ouray to mouth of Desolation Canyon. This is mostly outside of the historic landmark area but is within an area under consideration as a "wild" or scenic river.

2. Sand Wash Historical Landmark

3. Book Cliffs Scenic Overlook

4. Winter deer range area

5. Four public water reserves

Most of the area of Desolation Canyon designated as a historical landmark lies outside of the area of optimum oil shale. The fishing areas on Hill and Willow Creeks are also outside the area. Most of the hunting areas lie to the south and southwest with the exception of the winter deer range and the southern fringes of the area through Ts. 12 and 13S, Rs. 19 through 25E.

The game, fish and recreation aspects are important and worthy of protection. Temporary loss of small portions of the optimum oil shale area from year to year over a period of 75 to 100 years would be a necessary and acceptable consequence of total development of the oil shale resource. Since reclamation and restoration of the land would follow closely on the development, less than 5% of the total optimum oil shale area would be subject to environmental dislocation at any one time and less than 1% would be severely affected at any one period of 2 or 3 years in a time span 25 to 50 times as long.

With careful management the wildlife and game values of the area can be preserved while oil shale development is in progress. Over a period of decades land restoration and revegetation could result in enhancement of the wildlife habitat.

IV. GEOLOGY

A. STRUCTURE AND STRUCTURAL HISTORY (Frontispiece)

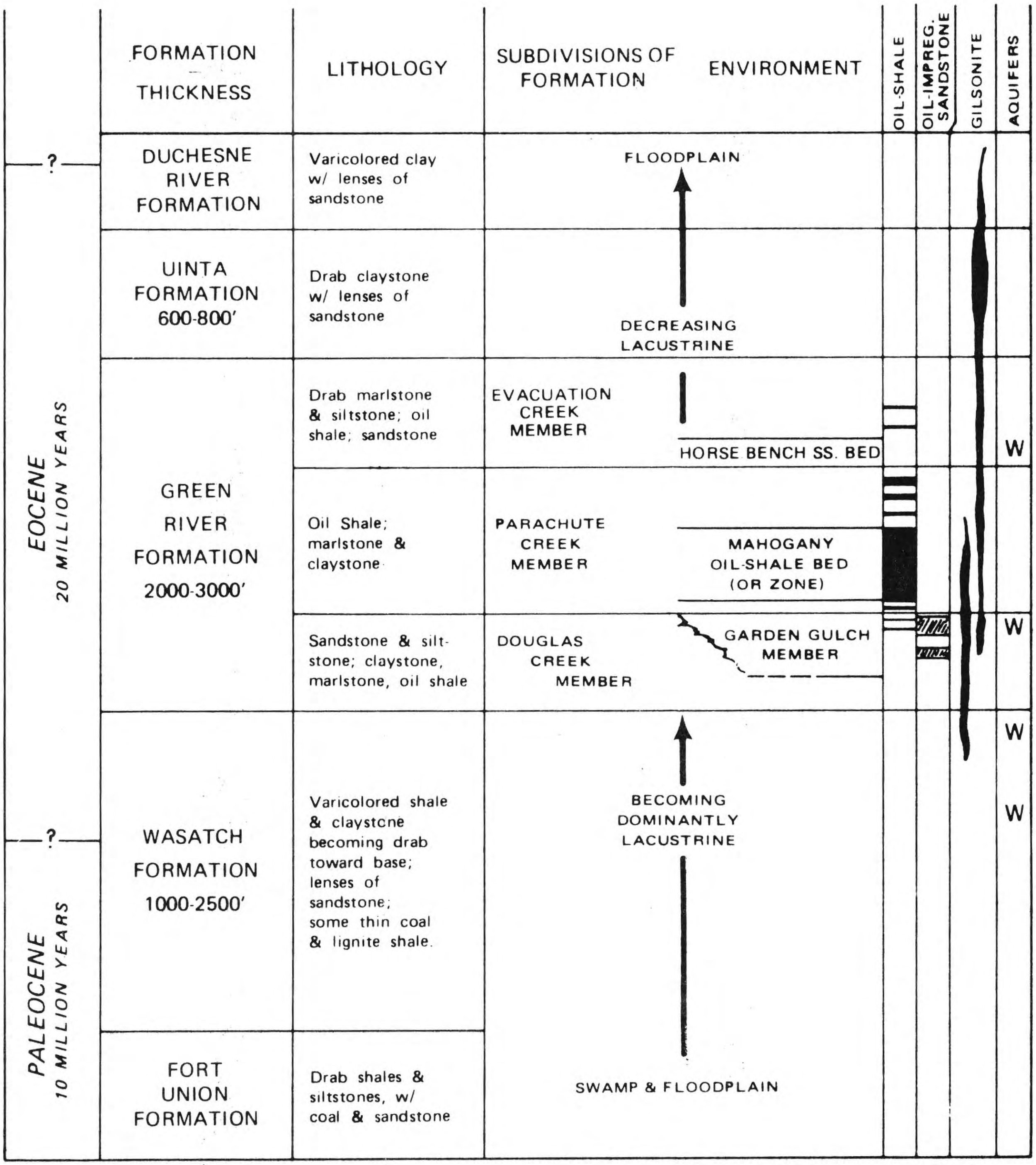
The Uinta Basin took shape in Early Tertiary time - Paleocene and Eocene epochs - from 70 to 40 million years ago. The basin is a generally east-west trending downwarp with a broad embayment-like extension to the southeast. The basin has generally gentle flanks on the west, south and east with few structural complications. The north flank formed by the strongly up-folded and faulted Uinta Mountains is a complex area of strongly folded beds, truncations, unconformities, overlaps, and normal and thrust faulting.

During much of Eocene time the Uinta Basin was the site of a large lake (called Lake Uinta) that waxed, waned and changed shape with climatic conditions and the structural activity of the uplifts around its margins. In this lake the sediments comprising the Green River Formation were deposited. The abundant organic matter of the lake was locked into the finely layered lake sediment and preserved in the combination of kerogen (a prototype of petroleum), clay, silt and dolomite known as oil shale. Some of the organic material was also converted to paraffin-base crude oil, natural gas and a variety of solid hydrocarbons. Several of these solid hydrocarbons are unique to the Uinta Basin. The most common, gilsonite, is mined in significant quantities, the only such production in the world.

B. STRATIGRAPHY (Figure 5)

Terminology used to describe the sediments of the Uinta Basin is shown in Figure 5.

Figure 5



TERTIARY FORMATIONS
OPTIMUM OIL SHALE AREA
UINTA BASIN, NORTHEAST UTAH
Showing stratigraphic position of oil shale, oil-impregnated sandstone, gilsonite and principal aquifers.

From older to younger, the sediments represent transition from floodplain and swamp deposits (Fort Union & Wasatch) upward through dominantly lacustrine beds (Green River) and back to floodplain deposits (Uinta and Duchesne River). The Tertiary sediments thus record the downwarp of the basin, filling of the basin by sediment from surrounding areas, sediment deposition in Lake Uinta during its gradual growth to maximum extent in Parachute Creek time, and decline and waning stages of the lake into Uinta Formation time.

C. RESERVE ESTIMATES AND VALUE OF RESOURCE

Of the hydrocarbons generated in Lake Uinta, by far the greatest volume was preserved as kerogen in the oil shales of the Green River Formation. If lower grades of oil shale, 15 gallons per ton or less and including thin beds, are considered for the entire basin, the total oil in place can easily be estimated as several trillion barrels.

Using parameters of a more limited nature Quigley and Price (1963) estimated 1,300 billion barrels. Another survey using different parameters estimated a possible 900 billion barrels. Cashion (1967, p. 30), considering shale of 15+ gallons per ton grade 15 or more feet thick, estimated total potential reserves to be 321 billion barrels. Due to differences in reliability of data, 290 billion barrels is classed as inferred potential reserves and 31 billion barrels in southeastern part of basin is classed as indicated potential reserves.

Considering shale of 25+ gallons per ton grade in beds 25 to 30 feet thick or more within the optimum area, the Utah Geological Survey for this study estimates from 90 to 115 billion barrels of oil in place.

As a yardstick of the magnitude of this resource, United States annual demand for oil in 1970 will be 5.3 billion barrels. By 1980 annual consumption may reach 7.6 billion barrels annually and by 1985 may be 8.0 billion barrels.

Oil shale is one of the greatest potential mineral resources in the United States. Utah's deposits form a significant part of the nation's future energy resource, second only to the large potential in adjacent Colorado. As a factor in national security, development of Utah's oil shale probably greatly outweighs any other known land use value of the area in which it occurs.

D. RELATION TO COLORADO AND WYOMING (Frontispiece)

The geologic situation of the Uinta Basin is similar to that of the Piceance Basin of northwestern Colorado and dissimilar to that of the Green River Basin of Wyoming.

The oil shales of the Green River Formation were laid down in Eocene time in two apparently separate lakes which existed on either side of the present site of the Uinta Mountains. The environment of deposition of the northern lake, called Lake Gosiute, was considerably different from that of Lake Uinta south of the mountains; and the deposits of oil shale found in what is now the Green River Basin of Wyoming (also small area in northwestern Colorado) are generally not as rich nor as thick as those in Utah and the Piceance Basin of Colorado. Direct stratigraphic correlation from north to south has been all but impossible.

In contrast, the Uinta Basin oil shale and that of adjacent northwestern Colorado were both deposited in Lake Uinta under much the same conditions. The deposits of the two areas are separated by the more geologically recent Douglas Creek Arch uplift along which the oil shales have been removed by erosion.

The same stratigraphic names are used in the two basins and many key beds, including the Mahogany oil shale bed, are directly correlative from one to the other.

With such strong geologic similarities and the similarity of terrain, climate, soils and other physical factors in the two basins, it is likely that development of oil shale in the two states will be closely parallel. Environmental problems and the costs of coping with them are likely to be much the same.

E. MINERAL RESOURCES OTHER THAN OIL SHALE (Figure 5 & 8)

As shown in Figure 5, most oil shale is found in the Mahogany oil shale bed (or zone) of the Parachute Creek Member of the Green River Formation. Thinner, less rich oil shales found in the Garden Gulch, Douglas Creek, upper Parachute Creek and Evacuation Creek members are probably not of commercial value.

1. Oil-impregnated sandstone (Figure 5 & 8)

The Tertiary formations of the Uinta Basin have also generated a very large volume of other hydrocarbons. Oil-impregnated sandstone (tar sand) occurs widely across the basin in a variety of situations. In the optimum oil shale area the main occurrence is in the uppermost sandstones of the Douglas Creek Member of the Green River Formation from a few to 60 feet below the base of the Mahogany oil shale. The P.R. Spring oil-impregnated sandstone deposit underlies the optimum oil shale in Ts. 12 & 13S., Rs. 21 thru 25 E. and extends downdip to the north for an undetermined distance. That portion of the deposit underlying the optimum oil shale area probably contains 1.1 billion barrels of oil. The whole deposit, most of which lies farther south, contains 3.7 to 4.0 billion barrels of oil. Most of the deposit is under lease but unexploited. The oil is a low gravity, low sulfur, paraffin base crude oil. Scattered, minor deposits occur in Uinta Formation sandstones along the northern edge of the optimum oil shale area.

2. Gilsonite

Gilsonite, a solid hydrocarbon occurs in vertical veins which strike northwest-southeast across the optimum oil shale area. The veins apparently result from differential filling of open joints with liquid petroleum presumably derived from the Green River Formation. Gilsonite is mined by mechanical and hydraulic means and most is transported by water slurry pipeline to a refinery in nearby Fruita, Colorado. Gilsonite is also sacked and trucked to market. The mining and processing of gilsonite is the area's largest industry at present.

3. Petroleum (natural gas and oil)

Petroleum (natural gas and oil) is also found in the area. Most gas and oil is produced from sandstones in the Green River and Wasatch formations (Eocene and Paleocene) and the Mesaverde Formation (Upper Cretaceous). Sandstones in the Douglas Creek Member of the Green River Formation and uppermost Wasatch Formation are major producers of oil and gas in the Greater Red Wash Field and other fields 6 to 10 miles north of the optimum oil shale area. This oil is a medium gravity, low sulfur, paraffin base crude oil with a high wax content.

Within the optimum oil shale area and vicinity the thick older Cretaceous, lower Mesozoic and Paleozoic section beneath the Mesaverde has been little tested and can be considered to have excellent gas and oil prospects at depths between 5,000 and 18,000 feet.

Production of the principal fields within the optimum oil shale area is summarized as follows:

Pool	CHAPITA WELLS Wasatch	ISLAND Wasatch	OURAY Green R.	OURAY Wasatch	PARIETTE BENCH Green R.	ROCK HOUSE Wasatch
Year Disc.	1953	1961	1956	1957	1962	1960
Year 1st Prod.	1953, 1961	1961	1956	1962	1962	1960
Year Shut-in	1959, -					
Oil Prod. (bbls)			combined			
1969	719		694		27,240	
Cumulative	23,224	3,286	9,729		194,732	7,973
Gas Prod. (mmcf)			combined			
1969	1,431	56	659		9	522
Cumulative	15,564	2,440	8,819		182	5,863

Less important oil production is recorded at Agency Draw and River Junction fields. Gas is also produced in the Bitter Creek, Bonanza, Buck Canyon, Evacuation Creek, Oil Springs, Southman Canyon and Uintah fields.

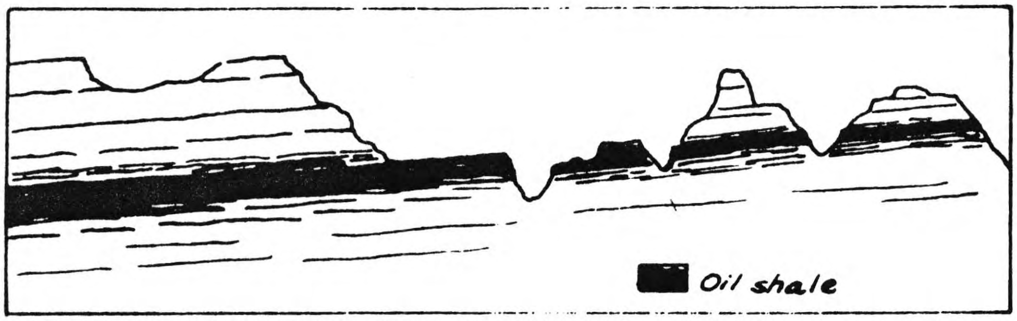
F. AQUIFERS AND SUB-SURFACE WATER (Figure 5)

With few exceptions the only porous strata in the area which transmit water in any quantity are sandstone beds. Principally these are: the Horse Bench Sandstone (lower Evacuation Creek Member of Green River Formation) in the southwestern part of the area and sandstones in the upper Douglas Creek Member and Wasatch Formation in the southern and southwestern part of the area.

Jointing, fracturing and small-scale structural and stratigraphic variations in the near-surface sedimentary rocks exert important control on the movement of shallow subsurface waters. Locations of springs and oil seeps are especially

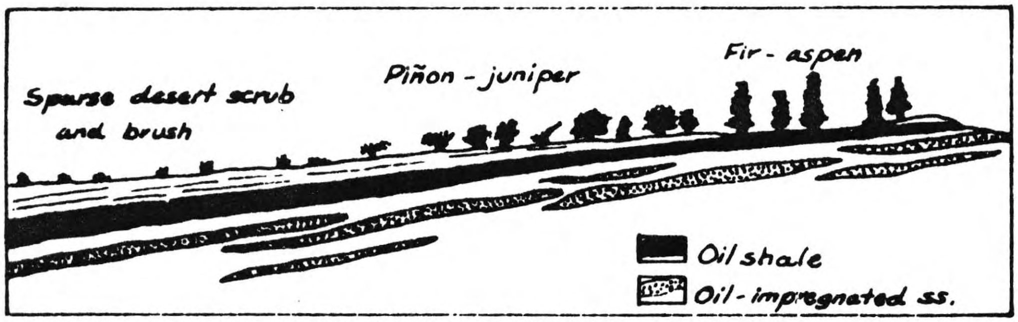
Figure 6

DIAGRAMATIC SECTIONS



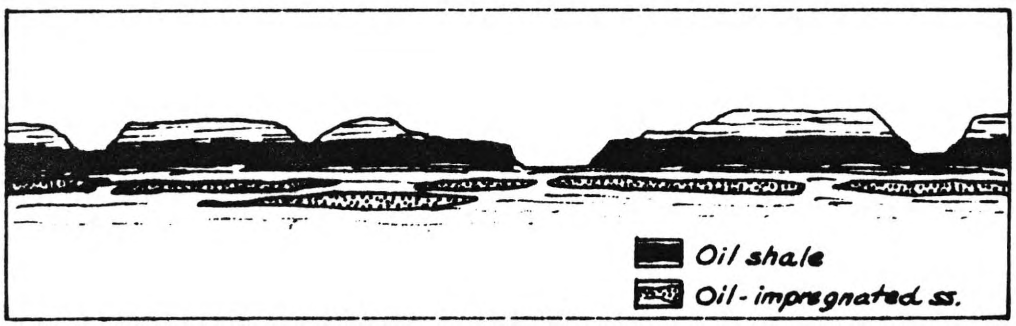
EAST EDGE OF BASIN
Evacuation Creek
Hells Hole Canyon and
Bonanza areas

INTRICATELY ERODED AREAS, DEEP CANYONS AND MESAS



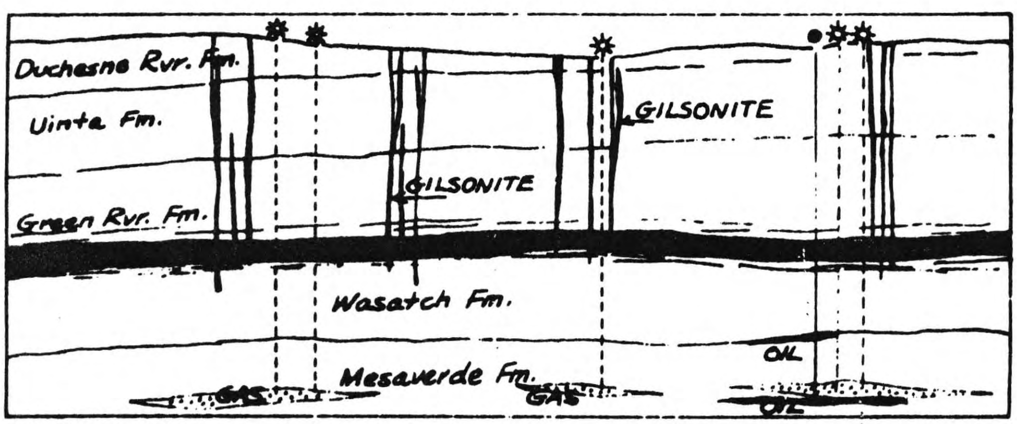
SOUTHEAST PART
OF BASIN
McCook Ridge

LONG, NARROW, NW-SE-TRENDING DIP SLOPES



SOUTH MARGIN
OF BASIN
Roan Plateau

NARROW N-S VALLEYS OF MEDIUM DEPTH INCISED
IN PLATEAU LEAVING BROAD INTERFLUVES



NORTHERN PART
OF OPTIMUM AREA
Lower White River

DEEPER BASIN

PHYSICAL SITUATIONS
OIL SHALE DEPOSIT
OPTIMUM OIL SHALE AREA
UINTA BASIN, NORTHEAST UTAH

On a large scale the criss-cross jointing and fracturing exerts considerable influence on topographic detail and on the course of smaller drainages. In a closer view strong jointing causes the well bedded sequences of the Green River Formation to weather into blocky and slabby masses. Jointing possibly will be an assist in open cut mining but may be an adverse factor in underground workings.

Jointing has been observed to exert a strong control on the location and volume of perennial and ephemeral springs and seeps. The importance of joint systems in circulation of shallow subsurface water is apparent.

Location of oil seeps in the area underlain by oil-impregnated sandstone has been observed to be related to jointing and fractures and also to related circulation of ground water.

The strong joint patterns of the area, their lateral and vertical persistence and frequent filling with the solid hydrocarbon, gilsonite, pose potential leakage and contamination problems for in situ methods of oil shale production. Containment of nuclear explosions used to excavate retorting chambers would be difficult in a strongly jointed area and particularly in one crossed by numerous gilsonite veins. Containment or control of thermal processes, fire-fronts, gases, solvents, etc. must also be considered high risk operations in strongly jointed areas.

Closely spaced joints might provide natural permeability in oil shale which otherwise would be nearly impermeable. In this case the permeability could be a favorable factor in certain in situ processes.

Detailed knowledge of the natural jointing and fracturing appears very important to many problems affecting oil shale and environmental control. It is a subject that has been little investigated in Utah.

controlled by strong jointing. The effects have been noted but no detailed or regional study has been undertaken.

Extent and direction of circulation of deeper subsurface waters--at depths of 1,000 feet or greater--is almost totally unknown.

G. JOINTING AND FRACTURING

The area is dominated by prominent lines of jointing and fracturing of N 65° W average strike. In a few instances there is displacement along these alignments ranging from a few to 100 feet. Since the joints and fractures closely parallel the trend of the Uncompahgre Uplift, they are presumably related to this buried uplift which lies beneath the southeast Uinta Basin. The dominant joint fracture trend is accompanied by two well developed sets of cross-joints, fractures and rare faults, one at right angles (about N 25° E strike) and another set which ranges from N 55° to N 70° E. The same general pattern is also noted in the Piceance Basin of northwestern Colorado.

The jointing and fracturing in the Uinta Basin is remarkable for its lateral extent and persistence with depth. Gilsonite veins which fill many of the larger NW to SE joints are known to extend downward for 1,500 feet or more. Many of these are nearly vertical and smooth-walled. They range from a few inches to more than 17 feet in width. The cross sets of joints and fractures are not as well developed and are not known to contain gilsonite. The jointing and fracture patterns are especially notable on aerial photographs because of the subtle control exerted on soil development, soil moisture and vegetation.

V. THE OIL SHALE

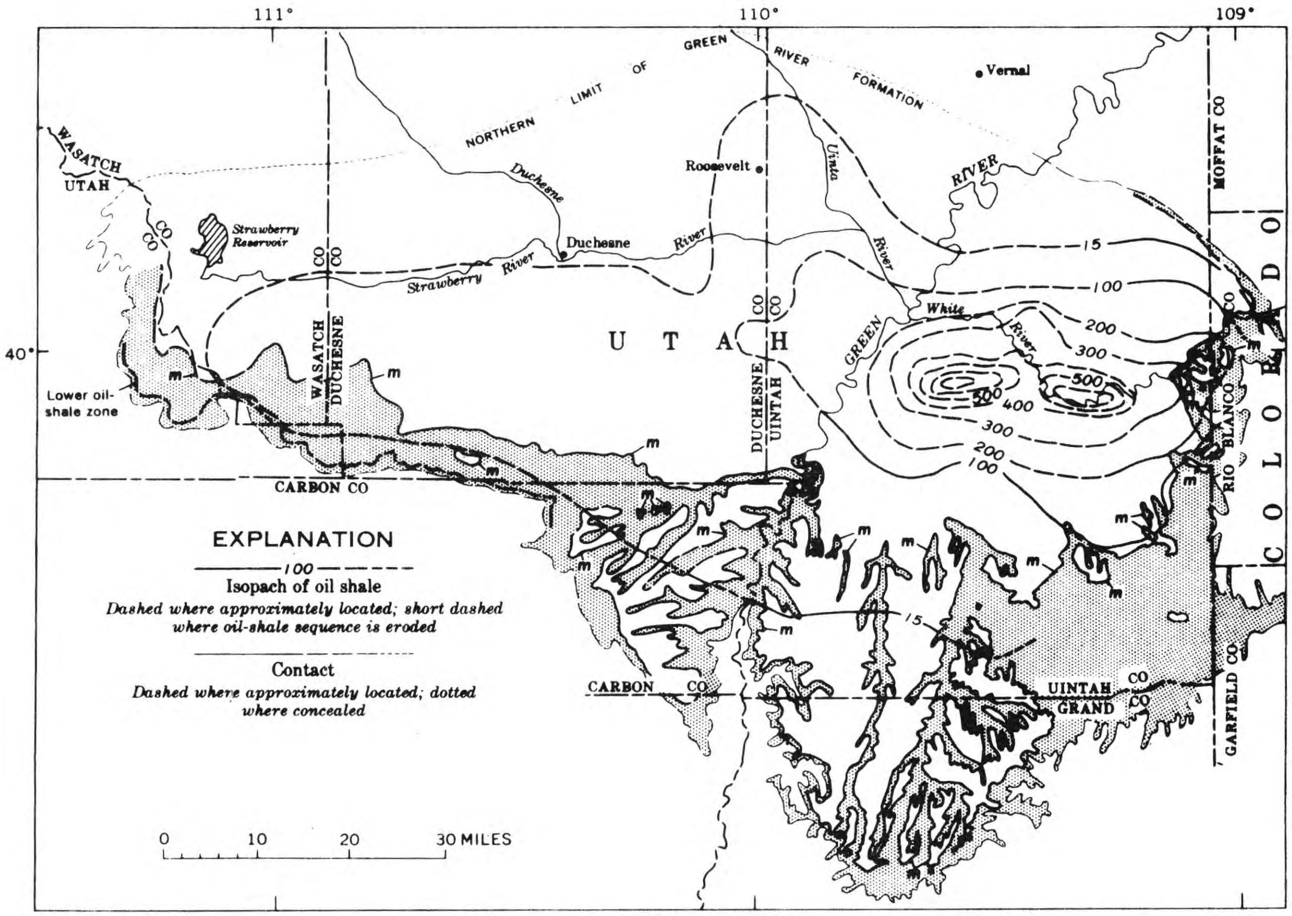
A. HOW IT IS SITUATED (Figures 6, 7 & 8)

Oil shale of 15+ gallon per ton grade thickens from a few feet on the south edge of the basin to as much as 600 and 700 feet in T. 10 S., Rs. 22, 23 & 24 E. Thicker and richer grades of shale increase gradually northward (basinward) from east, south and southwest into the optimum area. On the north edge of the optimum oil shale area rich, thick oil shale rapidly passes into barren marlstone and siltstone across a narrow east-west transition area through T. 8 S., Rs. 20 thru 25 E. Thus the optimum oil shale area is quite widespread from east through west around the south edge of the basin and sharply delimited on the north.

The optimum oil shale area does not coincide with the deepest part of the Uinta Basin. Thus the top of the oil shale zone is found at depths from 2,500 to as much as 9,000 feet in the northern and western parts of the basin, but the grade of the shale is generally low. Oil shale of low grade -- less than 15 gallons per ton -- is thought to make up a considerable part of the Green River Formation in areas of the Uinta Basin outside of the optimum area. This organic shale may comprise 1,000 to 1,500 feet of a total 4,000 to 5,000-foot thickness of the Green River. The amount of oil locked up in this low-grade shale is tremendous, but a practical way of extracting this great potential resource is not known.

Within the optimum area oil shale is found in three general physical situations (Figure 6):

1. Deeply incised canyons with many erosional remnants (buttes and mesas). This is typical of the northeast portion of the area in Ts. 9, 10 & 11 S., R. 25 E.



Thickness, in feet, of oil-shale beds of the Green River Formation, Uinta Basin area, that will yield an average of 15 gallons of oil per ton. Thickness interval is 100 feet with 15-foot cutoff. Stippled pattern shows outcrop area of the part of the Green River Formation underlying the Mahogany bed (m). Outcrop area west of the Green River modified from Bradley (1931, pl. 1).

(From Cushion: U.S.G.S. Professional Paper 548)

THICKNESS MAP
15 GALLON PER TON OIL SHALE
UINTA BASIN, NORTHEAST UTAH

along the Utah-Colorado boundary. The deep erosion results from the down-cutting of the White River, Evacuation Creek and smaller drainages (Figure 10B).

A similar situation exists in Ts. 11 & 12 S., Rs. 18 and 19 E. along the Green River.

Low-dipping oil shale strata are exposed in near vertical canyon walls, a situation which largely rules out open cut (or strip) mining. However, the terrain does lend itself favorably to underground mining with tunnels driven inward from the canyon walls.

2. Broad, sinuous bands of exposure along north-south trending ridges. The ridges are the interfluve areas between canyons of moderate depth cut into the northwest and north-dipping beds of the Green River Formation. This situation is typical of the southeast and south margin of the optimum area.

In this situation open cut mining along the valley edges is feasible. With increasing overburden mining could then continue underground beneath the ridges (Figure 10A).

3. Basin area of no exposures with oil shale dipping northward beneath increasing cover of upper Green River and Uinta Formation beds.

This situation lends itself to underground mining from shafts and, in special situations, to possible in situ methods of extraction.

B. PROTOTYPE AREAS (Table 1)

Four types of possible exploitation are considered feasible in Utah. Prototype areas for each type have been chosen as follows (see figure 8).

I. STRIP MINING

First choice -- T. 12 S., R. 21 E. Sec. 34: N$\frac{1}{2}$, SE$\frac{1}{4}$; Sec. 35: S$\frac{1}{2}$

T. 13 S., R. 21 E.

Sec. 1: All; Sec. 2: E$\frac{1}{2}$, NW$\frac{1}{4}$; Sec. 12: NE$\frac{1}{4}$

T. 13 S., R. 22 E.

Sec. 6: SW$\frac{1}{4}$; Sec. 7: All; Sec. 8: SW$\frac{1}{4}$; Sec. 15: SW$\frac{1}{4}$;

Sec. 16: SE$\frac{1}{4}$, W$\frac{1}{2}$; Sec. 17: E$\frac{1}{2}$, NW$\frac{1}{4}$; Sec. 18: NE$\frac{1}{4}$;

Sec. 21: All; Sec. 22: NW$\frac{1}{4}$

Second choice -- T. 12 S., R. 24 E.

Sec. 13: All; Sec. 14: S$\frac{1}{2}$; Sec. 23, 24, & 25: All;

Sec. 26: E$\frac{1}{2}$; Secs. 35 & 36: All

T. 13 S., R. 24 E.

Sec. 1: All; Sec. 2: N$\frac{1}{2}$; Sec. 12: N$\frac{1}{2}$

II. VERTICAL SHAFT

First choice -- T. 10 S., R. 24 E.

Secs. 11 thru 15 & 22 thru 24: All

Second choice -- T. 11 S., R. 23 E.

Secs. 25 & 36: All

T. 11 S., R. 24 E.

Secs. 19, 20 & 29 thru 32: All

III. CANYON WALL MINE

First choice -- T. 11 S., R. 18 E.

Secs. 11 thru 14, 23 & 24: All

T. 11 S., R. 19 E.

Secs. 18 & 19: All

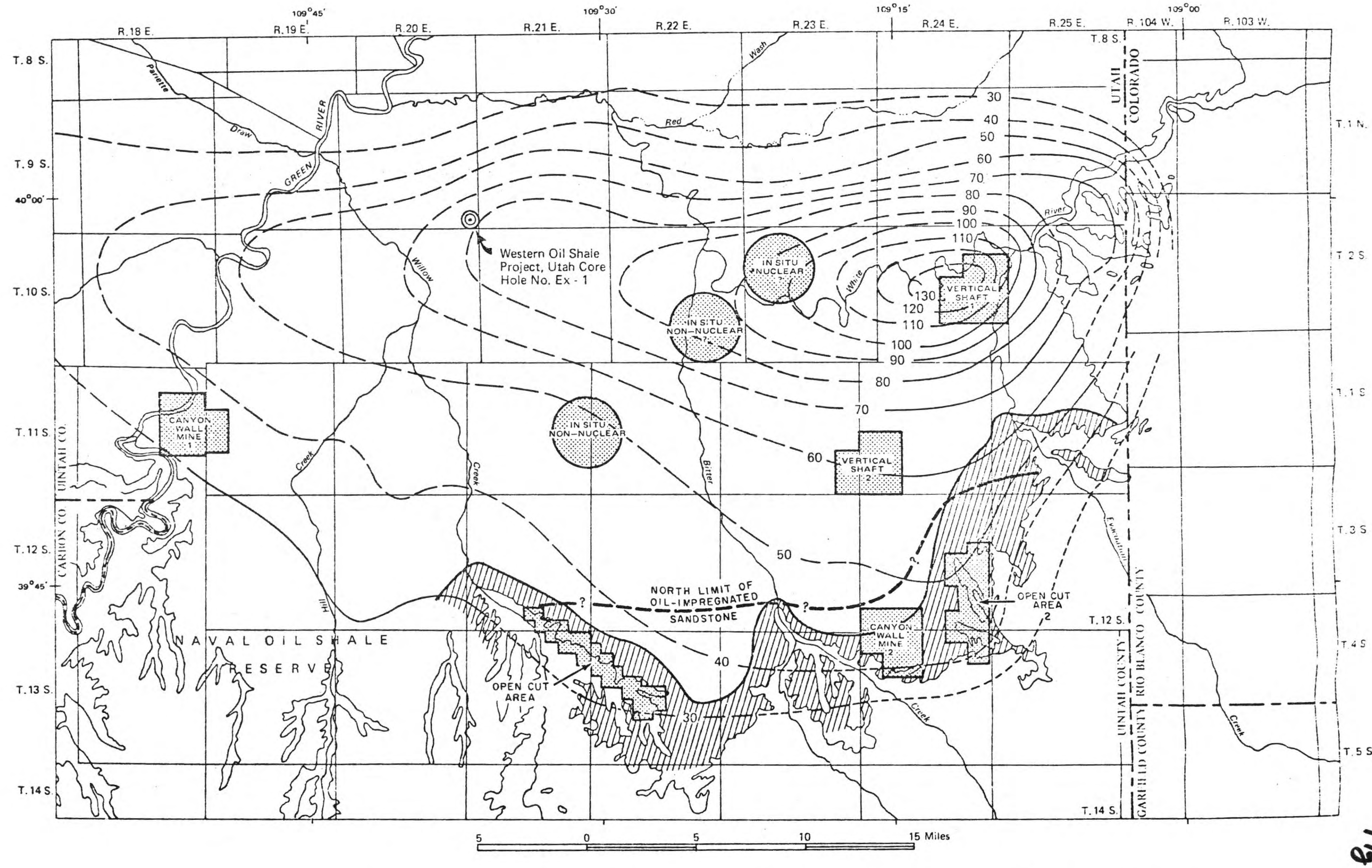


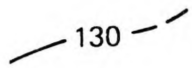
Fig. 8

Prototype Areas, Oil-Shale Development, Eastern Uinta Basin, Utah

Figure 8

EXPLANATION

Outcrop of Mahogany oil shale

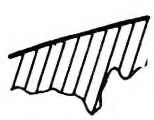


Line showing thickness, in feet, of a continuous sequence of oil-shale beds that will yield an average of 25 gallons of shale oil per ton. Solid where based on oil-yield data from cores; long dashed where based on oil-yield data from outcrop or cuttings from exploratory walls; short dashed where Mahogany oil-shale bed is eroded.

Prototype area for exploitation by mining.

Prototype area for exploitation by in situ methods.

Site of experimental core hole possibly to be used as test site for nuclear explosion. (To create chimney for use as retort)



Area suitable for stripping or open cut mining.

III. CANYON WALL MINE (Cont.)

Second choice -- (might begin with stripping)

T. 12 S. R. 24 E.

Secs. 31 thru 33: All

T. 13 S., R. 24 E.

Secs. 4 thru 6, 8 & 9: All

IV. IN SITU

a. Possibly nuclear device could be used -
Centering in NW quadrant of T. 10 S., R. 23 E.

b. Non-nuclear? or definitely non-nuclear
Centering in SE quadrant of T. 10 S., R. 22 E.

c. Non-nuclear (gas injection?)
Centering around common corner of Secs. 18 & 19 T. 11 S., R. 22 E. and Secs. 13 & 24, T. 11 S., R. 21 E.

All locations are in Uintah County, Utah.

These have been chosen as typical areas in which developments of various type might take place.

A summary of geological conditions in these areas is shown in Table 1.

C. HOW IT IS LIKELY TO BE DEVELOPED

1. Overall considerations

Prospects for development of the oil shale resource in Utah, as well as in Colorado and Wyoming, are uncertain. Whether such development will begin depends on a complex interplay of problems, situations and decisions of a political, economic, geological and technological nature.

The problems and situations range in magnitude from those of world politics, war and peace, population control and international trade, down to the water supply

Table 1

Prototype Area	Surface Land Form / Elevation Range	Structure of Oil Shale	Oil Shale Thickness (IN FEET) 15 GPT Grade	25 GPT Grade	30 GPT Grade	Overburden Thickness / Comments
Open Cut Mining 1	Southwest-facing valley wall sharply incised with side canyons. 5800-6000′	North dip-140′ per mile.	50-70	30-35	15-20	0-200′ This operation could progress to underground mining.
Open Cut Mining 2	Gently dissected plateau. 6700-7000′	Northwest dip-200 to 250′ per mile.	80-150	40-50	25-35	0-100′
Canyon Wall Mining 1	Steep-walled meandering canyon bordered by badlands. 5000-5600′	North dip-200′ per mile.	60-80	30-40	15-20	0-1000′
Canyon Wall Mining 2	Gently dissected plateau. 6000-6400′	Northwest dip-150′ per mile.	80-125	40-45	25-30	0-600′ This could be a combination of open cut and underground mining.
Vertical Shaft Mining 1	Deeply dissected plateau with steep-walled canyons. 5000-5500′	West-northwest dip-250′ per mile.	350-650	90-135	60-75	400-1100′
Vertical Shaft Mining 2	Gently dissected plateau. 5700-6000′	Northwest dip-125′ per mile.	250-350	55-65	40-45	400-700′
In Situ Nuclear?	Deeply dissected plateau with steep-walled side canyons. 5000-5300′	North-northwest dip-250′ per mile.	400-600	85-105	50-60	1400-2200′ Area is moderately jointed. Gilsonite veins lie to south in canyon area.
In Situ Non-Nuclear?	Moderately dissected plateau. Badlands cut in soft Uinta Formation. 5000-5200′	North-northwest dip—200′ per mile.	400-550	70-90	45-55	900-1600′ Area is moderately jointed with gilsonite vein complex to north.
In Situ Non-Nuclear	Moderately dissected plateau. Badlands throughout. 5500-5800′	North dip-150′ per mile.	200-300	45-55	35-40	1000-1500′ Area is moderately jointed. Few small gilsonite veins.

After Cashion (unpublished maps)

GEOLOGICAL SUMMARY
OIL SHALE PROTOTYPE AREAS

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File No. 1380 A

available in a minor tributary drainage. The geological and technological problems and situations are already well known and being subjected to study of varied depth.

Economic predictions point, almost without exception, to a growing and almost desperate world-wide shortage of energy. Development of oil shale to alleviate this shortage, at least in part, seems inevitable at some as yet undetermined date. Developed aggressively, oil shale can figure importantly as an energy source, along with coal, oil-impregnated sandstone and nuclear energy.

2. Local considerations

Utah ranks second in the nation in oil shale resources, far below Colorado in volume and grade of shale, but considerably above Wyoming. In reserves of 25 gallon per ton + shale, the grade most likely to be exploited, Colorado is thought to contain 80% of the total, Utah 15% and Wyoming 5%.

One of Utah's advantages in oil shale is in its strippable deposits. In these areas, open cut mining could proceed until overburden became excessive and then operations could turn into underground mining. This type of operation may be the first kind of exploitation undertaken in Utah.

One sizable operation of this sort, open cut or underground, of the magnitude now considered feasible and practicable as an economic unit, would be the second largest extractive industry in the State of Utah. If several such mines were to be developed, oil shale would be the State's largest industry even while supplying only a small part of the nation's total energy supply.

3. Unknown factors

The principal unknown factors in the oil shale picture are the political and political-economic decisions -- most to be made by Federal officials -- that can set an oil shale industry in motion or hold it in abeyance indefinitely.

Most important of these is the question of when and on what terms Federal lands will be made available for leasing and exploitation of the oil shale resource.

There is good reason to believe that if the land and leasing problems were to be settled expeditiously, an oil shale industry could progress from a pilot plant stage to commercial production in the period 1976 to 1980. Utah is considered prime territory for development of the industry.

VI. ENVIRONMENTAL CONCERNS

A. RECOGNITION OF PROBLEMS (Figure 9)

Utah recognizes that consideration of environmental protection is extremely important in planning for development of the oil shale resource.

That part of Utah in which development will take place is at present sparsely populated and has been relatively untouched by human activity. It is high latitude, high altitude desert or semi-desert. Life in this area is limited but exists in delicate balance and could be damaged by uncontrolled development. The tremendous size and value of the oil shale resource could attract development on a scale dwarfing anything known in the nation today.

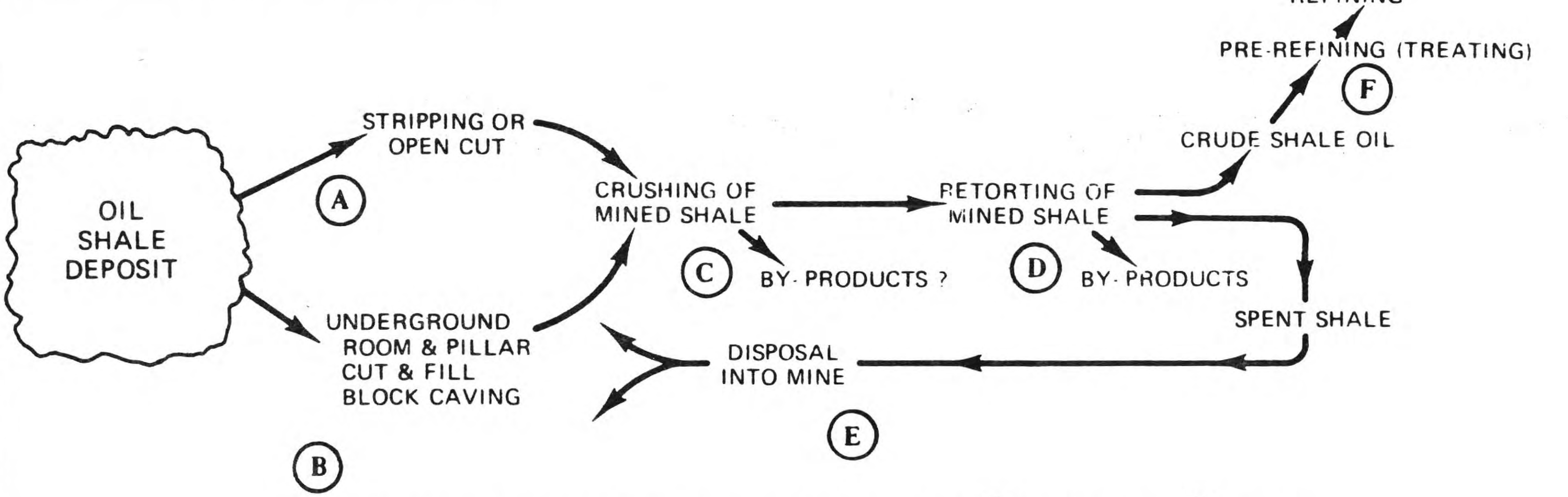
The geological and biological detail on which careful planning for environmental protection must be based is generally not available for Utah's oil shale area.

Problems related to environmental protection are very complex and range widely through a variety of scientific disciplines -- principally geology and mineralogy, botany and zoology, chemistry and soil science. These problems, however, do not defy solution and much preliminary work has been done.

B. TYPES OF EXPLOITATION

Two major development routes are considered: (1) mining and above ground retorting and (2) in situ processing. Two types of mining are considered: (a) stripping or open pit and (b) underground mining by room and pillar, cut and fill or block caving methods.

EXPLOITATION OF OIL-SHALE RESOURCE
BY CONVENTIONAL MINING METHODS
AND ABOVE–GROUND RETORTING



ENVIRONMENTAL PROBLEMS AT VARIOUS STAGES (A) THROUGH (F) ABOVE

(A) STRIPPING OR OPEN CUT MINING
- Stabilization of pit
- Erosion and leaching (wind, water)
- Restoration of surface
- Re-vegetation

(B) UNDERGROUND MINING
- Surface subsidence
- Leaching
- Dust

(C) CRUSHING
- Dust and noise
- Storage of crushed shale
- Storage or disposal of fines
- By-product separation (salines)

(D) RETORTING
- Air pollution (gases, particulates)
- Water pollution (liquids)
- Thermal (cooling liquids, heat to air)
- By-products (disposal or storage)

(E) SPENT SHALE DISPOSAL
- Storage subsequent to disposal
- Mine or open cut disposal
- Problems related to varying properties of spent shale (different processes)

(F) PRE-REFINING AND REFINING
- Similar to those of existing oil refining complexes

H. R. Ritzma July, 1970

Figure 9

Several types of in situ processes are proposed: (1) a. non-nuclear fracturing (natural, hydraulic, chemical explosive and electric) and b. nuclear fracturing or creation of a chimney with retorting by fire-flooding in fractured formation or chimney or (2) in situ hydrogenation by gases or vapors in fractured formations, tunnels, well bores or chimneys with product recovery by gas lift or (3) thermal process using underground nuclear reactor and (4) several others.

C. ENVIRONMENTAL PROBLEMS (Figure 9, Table 2)

Environmental problems common to both mining and in situ development are: (1) surface disturbance of the land from roads, water and fuel lines, plant sites, ancillary facilities and housing areas (2) municipal growth in nearby areas (3) pre-refining and refining of crude shale oil and (4) protection of wildlife and fish habitats, scenic and aesthetic values.

Environmental problems of mining and above-ground processing are outlined in figure 9 and Table 2.

The most important problems appear to be those concerned with erosion of open cuts, storage areas for crushed shale and fines, and storage and disposal areas for spent shale. Unstable conditions and erosion from day to day processes or from flash flooding or extraordinary snowmelt has the potential of carrying quantities of clay-size particles and silt and possibly dissolved saline minerals into the small drainages and streams and eventually into the Green and Colorado river systems.

Open cuts, storage areas and disposal areas will have to be designed and maintained in such manner as to minimize slope wash and possible solution of saline minerals.

Shale fines and spent shale can be disposed of in open cuts or underground workings. Experimental work points to feasible means of accomplishing this. Such disposal simplifies the problem of restoring land to original contours. Experimental work points to feasible means of re-vegetating surfaces of disposal areas and stabilizing slopes of storage areas to minimize water and wind erosion.

Care must be exercised in open cut and underground mining and in creation of in situ cavities to prevent blockage or disturbance of major aquifers or joint conduits for water.

Environmental problems of proposed in situ methods of exploitation are too diverse and not well enough known to permit listing here. In many cases, the proposed in situ method of development is not well enough perfected to permit definition of the environmental problems related to it. In situ development employing nuclear devices produces problems of radiation in addition to those usually related to other in situ techniques. Experiments to date indicate that most problems of in situ methods are similar to those encountered in secondary oil recovery and respond to the same control technology.

Nuclear fracturing or creating retorting cavities by nuclear explosives has been suggested. Grade of shale appears to limit this kind of in situ exploitation to a narrow band through Ts. 9 & 10 S., Rs. 20 to 24 E. Thickness of cover ranges from 1,500 to 2,500 feet through much of this area. Greater depths and cover occur to the north and west, but grade of shale sharply decreases in those directions. Whether there is sufficient cover to permit nuclear explosions within the limited optimum area of the Uinta Basin is a critical question. The matter is further complicated by deep canyons cut by the White River, by extensive natural

SUMMARY OF ENVIRONMENTAL PROBLEMS OF OIL SHALE
(PART A) PROBLEMS COMMON TO MINING AND IN SITU

PROBLEM	SOLUTION	ACTION ON SOLUTION
(1) Surface disturbance of land from roads, water and fuel lines, plant sites, ancillary plant sites and housing areas.	Regional and local planning and zoning.	Some local zoning in effect. Regional and local planning in progress with present emphasis on legislative action at State level. Federal lands make up great bulk of affected area. Policy will have to be set by Federal agencies and officials.
(2) Urbanization of nearby areas.	Regional and local planning and zoning.	Similar to (1) above except greater emphasis on local zoning and planning. Uintah County and City of Vernal have adequate laws to cover most anticipated growth situations and are aware of possible additional safeguards.
(3) Pre-refining and refining of crude shale oil	Air and water pollution standards.	State and Federal regulations do and will require compliance with standards of environmental quality legislation.
(4) Protection of wild life and fish habitats, scenic and aesthetic values.	Land use and land reclamation and restoration standards.	Some legislation in effect; additional legislation under study.

NEEDS

Detailed, basic geologic, hydrologic, biologic and meteorologic data on which to base planning and zoning. Regional data is needed to accomplish items (1) and (4) above; more localized information is needed for item (2).

SUMMARY OF ENVIRONMENTAL PROBLEMS OF OIL SHALE (PART B) PROBLEMS COMMON TO MINING AND ABOVE-GROUND PROCESSING NOT COMMON TO IN SITU METHODS

PROBLEM	SOLUTION	ACTION ON SOLUTION
(1) Stabilization of open cut.	Technology to meet acceptable regulatory standards exists and is perfected.	Existing regulatory standards not adequate. Now standards to be legislated.
(2) Erosion (water and wind) and leaching of mined shale.	Technology to meet acceptable regulatory standards exists and is perfected.	No regulatory standards. Standards to be legislated.
(3) Subsidence above underground workings (MAY APPLY TO IN SITU PROCESSES)	Spent shale to be returned to mine workings and compacted. Technology perfected in part.	No regulatory standards. Standards to be legislated.
(4) Crushing process - dust and noise; handling and storage of crushed shale and fines; separation of by-product salines, and handling and storage of by-product salines.	Equipment and technology exists for all phases of crushing process. Essentially a closed system with no major emissions to air or into subsurface waters.	Existing regulatory standards not adequate. New standards to be legislated.
(5) Retorting — air and water pollution; thermal pollution of water and air; by-product storage.	Technology to meet acceptable standards is mostly existent. The problems are similar to those of petroleum refining and transport.	Existing regulatory standards adequate for air and water pollution; by-product handling and storage is an unknown factor because exact physical makeup of products are not known.

PROBLEM	SOLUTION	ACTION ON SOLUTION
(6) Spent shale storage (prior to disposal in open cuts and underground workings)	Technology to meet standards is in part existent and mostly perfected. Main problem is complete containment of very large volumes of shale.	Existing regulatory standards not adequate. New standards to be legislated.
(7) Spent shale disposal in open cuts and underground workings.	Technology and equipment is in part existent and should be perfected with more pilot project effort. This problem is closely allied to (3).	Regulatory standards as in (3) above. More work is needed on the different physical properties of spent shale. The relation of this to the retorting process and how these variations can be used to ease disposal problems.

NEEDS

Detailed, basic geologic, hydrologic, biologic and meteorologic data on which to base planning and zoning, particularly for items (1) (3) (6) and (7) above.

jointing and by the presence of numerous gilsonite veins. The possibility of leakage of radioactivity from nuclear detonations should be carefully considered.

D. PROGNOSIS FOR UTAH (Figure 8)

1. Parameters

Of the three oil shale states--Colorado, Utah and Wyoming--Colorado is thought to contain 80% of the reserve of 25+ gallons per ton shale, Utah 15% and Wyoming 5%. These reserve estimates are well founded and are not likely to show appreciable change.

Important changes may occur in reserves of shale of lesser grade, 10 to 25 gallons per ton, probably in the 10 to 15 gallon bracket, with very sizable increases in Utah. But these lower grades of shale are the least likely to be exploited in the foreseeable future.

2. Open cut mining

Utah enjoys one clear advantage in oil shale. Of the three oil shale states it has the only high grade deposits suitably situated for open cut mining. These occur in the southern part of the Uinta Basin from the valley of Willow Creek in T. 12 S., R. 21 E. eastward to the valley of Evacuation Creek in T. 11 S., R. 25 E. (Figure 8). In this area, oil shale of 25 gallons per ton grade covers or underlies about 95 square miles. Overburden ranges from none to 250 feet. Thickness of 25 gallons perton shale ranges from 25 to 75 feet with most in the 30 to 45 foot range. Gross oil in place in these sections ranges from 25 to 80 million barrels per square mile. A rough estimate of the gross oil in place in these 95 square miles is 4.0 to 4.2 billion barrels. Recovery of about one-third of this oil would keep two 50,000 barrel per day retorts busy for 40 years.

The shale in this area is located in an area of easy terrain and access. It is easily mined and with a small volume of overburden. For this reason, and despite its modest grade and thickness, this shale may be the first in the nation to attract development efforts.

It is likely that open cut operations could proceed until overburden became excessive, and then the operation could turn to underground mining.

3. Underground Mining

Utah contains oil shale deposits amenable to mining roughly comparable to those in Colorado in grade but not in quantity. However, one sizable operation in Utah in a well selected area could draw from a 100 year supply of shale at a volume that would make it the largest extractive industry in the State.

Underground mining of oil shale is feasible and may come to commercial fruition about the same time as strip or open cut mining. Since the two types of mining produce the same raw material, mines of either type could share crushing and retorting facilities if they were located close enough to minimize transportation costs (Figure 9).

4. In Situ Processing

Prospects for in situ development of oil shale in the United States are much less certain than those of "conventional" mining methods.

The above statement is not to be construed as diminishing the importance of in situ methods of oil shale development. However, it is likely that the several now proposed in situ methods will have to progress through a number of stages involving experimentation, pilot projects, trial and error and plant site construction.

It is likely that a decade or more will be required to bring these proposed in situ methods to operating reality. Some methods will be discarded along the way. New methods or variations of older technology may develop out of the trial-and-error testing of now-proposed in situ methods.

VII. COSTS OF ENVIRONMENTAL PROTECTION

The Utah Committee on Environmental Problems of Oil Shale has not attempted any cost studies related to environmental protection. Reasons for this are enumerated as follows:

1. The problems to be solved and the technology to be used in solving them are not fully known. This is especially the case in problems related to in situ processes.

2. No experimental or pilot field projects have been undertaken in Utah.

3. The framework of laws and regulations governing future environmental protection in oil shale areas is not fully established. Standards and requirements for compliance undoubtedly will have profound effects on costs.

4. The time when these problems will arise is uncertain. Dollar costs, or per barrel costs, are very likely to be considerably different in the context of 1975, 1985 or later.

The committee feels that assignment of costs to solution of various environmental protection problems is premature and not properly a function of government. This committee, as constituted, primarily reflects State government concerns.

There is a danger that thinking and planning on oil shale can become "locked into" figures that are not valid to the time or place of oil shale development. A prime example is the astronomical two trillion barrel "reserve" figure for oil shale which has been seized on by innumerable self-appointed experts and twisted to fit a dismaying set of purposes.

Costs of environmental protection are necessarily part of the costs of oil shale production. These are industry's costs and should be determined by industry.

Government's function should be to establish the framework of laws and regulations within which industry can work. When this framework has been established, then industry can proceed to integrate the costs of environmental protection into the total costs of production.

It has been pointed out that there are strong geological and physical similarities between the Uinta Basin of Utah and the adjacent Piceance Basin of northwestern Colorado. The conclusion is inescapable that oil shale production and related environmental protection problems and costs will be much the same in the two basins.

The Uinta Basin has several advantages over the Piceance Basin which may make several problems less severe and decrease costs:

1. Lesser overall relief and generally more gentle slopes, thus making problems of slope wash of lesser magnitude.

2. Less precipitation, also making drainage, leaching and slope wash problems of lesser magnitude.

3. More isolation and almost no population thus making oil shale development a lesser intrusion into the existing environment of the oil shale area and surrounding region.

4. Lower average elevation throughout the area.

5. Less importance of the area as wildlife habitat in contrast to the Piceance Basin of Colorado

VIII. UTAH'S PLAN FOR ACTION

A. BASES

The State of Utah is fully cognizant of the potential importance of oil shale in the national energy picture and as a possible large new industry in the State. At the same time the unpredictable aspects of oil shale development are well known to this committee and to others who know the Utah oil shale situation well.

We recognize that there is no certain time table for the development of an oil shale industry in the nation and in Utah. Yet we believe that every effort should be made by the Federal and State governments to adopt policies geared to encourage this potential industry and to make its beginnings possible.

Governor Rampton of Utah has expressed many times the hope that Utah's oil shale deposits would attract the first efforts at extraction of oil and gas on a commercial basis. It is felt that Utah has many favorable locations where such an industry could begin and progress through its formative, trial and error stages to full scale production. It is, of course, the intention of the State of Utah that such development be carried forward in strict compliance with Federal and State environmental quality standards and with careful monitoring of operations should any unforeseen environmental hazards become apparent.

B. PLANS AND GOALS

Considering the uncertain prognosis for exploitation of oil shale, and the environmental concerns that must necessarily and eventually be reckoned with, this Committee recommends the following plan of action by Utah:

FIRST, legislative action within Utah to establish laws and regulations governing open cut mining and reclamation and restoration of lands affected by such mining.

SECOND, legislative action and other actions on the State and local level to initiate regional and local planning and zoning that will insure orderly development and growth in the area likely to be affected by oil shale activity.

THIRD, detailed geologic, hydrologic, biologic and meteorologic studies of the oil shale area of the Uinta Basin to:

(1) provide guidelines for environmental protection planning,

(2) provide the basic data needed to guide the efficient exploitation of the two potential energy resources of the area - oil shale and oil-impregnated sandstone, and

(3) give continuity to data to be shared and used by the oil shale states, particularly regarding contiguous areas in Colorado to the east.

FOURTH, continued action to settle Utah's unfulfilled entitlement to lands in the Uinta Basin.

C. PROGRESS

1. Legislation

On the FIRST item above, the Utah Legislative Council has recommended to the current Legislature that it fund a study of environmental problems associated with mining in the State. The recommendation is in the form of Senate Joint Resolution No. 6, now under consideration. The study and recommendations are to be made for submission to the 40th Legislature which will convene in January 1973.

The chairman of this committee has been a member of the Legislative Council group considering natural resource matters.

Everyone engaged so far in the study of this legal and technical problem has expressed a genuine desire to add to existing laws and regulations so that these may afford adequate and realistic environmental protection.

2. Planning, zoning, proposed regulations, "housekeeping" items

On the SECOND item above, the following agencies of State government have been concerned with matters directly connected with oil shale policy and planning in the Uinta Basin and the optimum oil shale area. In particular the State Planning Office has pressed for a comprehensive land use policy throughout Utah.

Executive Branch

State Planning Office - oil shale policy and planning

Office of Local Affairs - regional and local planning

Department of Natural Resources

Division of State Lands - review and restatement of oil shale leasing policy with emphasis on reclamation and restoration following development.

Division of Oil and Gas Conservation - has had authority from Legislature since 1953 for regulation of production of oil and gas from oil shale. The Division is considering several regulatory routes.

Legislative Branch

Legislative Council - studies leading to legislation on planning, open cut mining and water use policy.

As a result of the work of these groups, the Utah Legislature, now in session in January 1971, is expected to sponsor studies of land use planning, water use and conservation policy and to broaden air and water pollution legislation already in effect. This action, together with existing laws and standards, is expected to provide a higher degree of environmental protection -- in all areas of the State.

The Office of Local Affairs of the Executive Department of State government has also been in informal contact with Uintah County officials to apprise them of possible future planning needs. Comprehensive zoning regulations have been in effect for two decades in the small portion of the county that is privately owned. Federal lands controlled by various Federal agencies, mostly the U.S. Bureau of Land Management, of course, are very important in all local planning and land use considerations.

Uintah County has in effect ordinances governing land use for open cut mining, protective fencing, and restoration of lands subject to open cut extraction methods. Principal application to date has been in sand, gravel and clay pits and gilsonite mines.

Local opinion strongly favors careful planning to accomodate short and long term influxes of population and to control urbanization and industrialization. Vernal, the county seat of Uintah County, has experienced one major oil boom and has successfully adjusted to steady growth based on oil and gas exploration and production activity. It remains one of Utah's most attractive small cities.

The Department of Natural Resources has undertaken through its Division of State Lands a review and restatement of leasing policies on State oil shale lands emphasizing restoration of the surface. The Division of Oil and Gas Conservation considers it premature to formulate regulations for an industry that is not yet in existence. It is, however, actively considering possible regulatory schemes for above-ground retort production and in situ production of oil from shale.

Two housekeeping items have come under scrutiny. First, a conflict in the boundary between Uintah and Grand Counties has been discovered and steps have been taken to resolve it. The disputed ground might figure in pipeline rights of way and sites of other facilities related to oil shale or oil-impregnated sandstone development. Second, some preliminary thought has been given to the position of the Naval Oil Shale Reserve and the Uintah and Ouray Indian Reservation. Both are located in part in areas that would be affected by regional planning and overall development of the oil shale resource. These last two matters will, of course, require action by the Federal agencies administering these lands.

3. Proposed studies

On the THIRD item above, steps have been taken to obtain funding from current and planned State agency budgets to begin necessary studies and to insure funding for such studies in future fiscal periods. These studies will cost the State of Utah considerable money in a period of very tight finances. Funding these studies will require some very hard selling to the current Legislature particularly when their necessity and practicality is wholly dependent on Federal policies and decisions that may not be forthcoming or whose ramifications are not known.

Well publicized, positive action on the part of Federal agencies and officials responsible for establishing oil shale policy would be most helpful in making the need for these studies apparent to the Legislature.

Responsibility for the studies will probably be delegated as follows:

Geology and Hydrology - Utah Geological Survey

Biology and Meteorology - Utah State University and the University of Utah Center for Environmental Studies

Appropriate Federal agencies will be consulted on various phases of the studies, and Federal funding assistance will be sought. Facilities of other State educational institutions will be used, particularly those of Utah State University on biological and soil science aspects of the studies. A comprehensive study of the desert environment has recently begun at Utah State University under a 1.53 million dollar grant funded by the National Science Foundation. Information developed in this study is expected to be of great value and use in planning environmental protection measures in the oil shale regions of Utah and other states.

4. Utah's entitlement to lands

Although not concerned directly with the environmental problems of oil shale, the matter of Utah's selection of 150,000 acres in the oil shale region of the Uinta Basin as part of its unfulfilled entitlement to Federal lands is one of great importance to the State and its citizens.

Favorable action on this selection by appropriate Federal agencies and officials would clear one obstacle to orderly development of Utah's oil shale resource.

IX. UTAH'S UNIQUE SITUATIONS

Utah's position in oil shale is enhanced and complicated by several situations which are, in part, or completely unique to this State.

A. STATE LANDS

Within the optimum oil shale area, the State of Utah is well represented with State-owned lands. These total 85,000 acres, some in scattered tracts but many in sizable contiguous blocks. The situation has developed for two main reasons:

1. Utah's land entitlement to four sections in every township (Sections 2, 16, 32 and 36) in contrast to two sections per township in most western states.

2. A concerted effort on the part of the State of Utah to obtain lands in the oil shale region as part of its unfulfilled entitlement to lands from the Federal domain and in the "lieu lands" exchange program. The State has attempted, wherever possible, to acquire land in blocks so as to make these blocks attractive as lease "packages" for oil shale development.

In addition to the existing ownership of State lands within the oil shale area, Utah has selected about 150,000 acres of its approximate 237,500-acre unfulfilled entitlement to Federal lands in the optimum oil shale area of southeast Uintah County. If this selection is approved, Utah will be a near equal to the Federal government in ownership of lands within the area most likely to be developed and will control most of the area suitable for open cut and shallow depth underground mining.

This committee urges prompt, favorable action on the State's selection applications.

B. OIL-IMPREGNATED SANDSTONE (Figure 8)

The oil shale deposits of the southern part of the optimum area are superimposed on a very large deposit of oil-impregnated sandstone (tar sand), the northern part of the giant P.R. Spring deposit. Top of the oil-impregnated sandstone occurs from a few to 60 feet below the base of the Mahogany oil shale zone, and one to as many as five sandstones may occur downward through 250 to 300 feet of section below the Mahogany oil shale. The deposit contains about 3.7 to 4.0 billion barrels of oil of which 1.1 billions is thought to underlie the area of optimum oil shale (Figure 8). The downdip limit of this deposit is not known, so the estimated reserve of oil in place possibly is conservative.

Two groups of problems arise from the superposition of oil shale on oil-impregnated sandstone on the same tracts of land. First is the basic problem of lease ownership. On Federal lands, present oil and gas leases do not convey the right to develop oil-impregnated (bituminous) sandstone, and no leases have been issued specifically for bituminous sandstone. Several such leasing options are now proposed for Congressional action. Since oil shale has not been subject to leasing, the two substances are unleased on Federal lands.

However, on State of Utah lands the two substances are subject to separate leases, oil-impregnated sandstone in the single-form State hydrocarbon lease, and oil shale on a lease specifically for that substance. Thus State lands may have different lessees entitled to explore and produce two closely related substances on the same tract of land. The situation appears to be one that invites conflict and inefficiency in development

The second group of problems arises from development of the two closely related, superimposed deposits. It would appear almost impossible to develop either resourse without considering the other and certainly it would not be practical to develop the oil shale, engage in extensive land restoration and then commence oil-impregnated sandstone exploitation that would again disturb the land that had been restored.

The situation is one that will require close coordination of operations between Federal and State government agencies, private landowners and industry.

X. CONCLUSIONS

Utah's oil shale is a vitally important part of the nation's potential energy supply and one of the three most valuable potential natural resources in the State.

Techniques of open cut and underground mining and surface retorting to extract this oil are well known and, in part, perfected. In situ methods are still in preliminary experimental stages, and their future is uncertain. It is likely that many methods -- some not yet conceived -- will be employed over a period of a century to accomplish full exploitation.

Development and marketing of this resource will require prodigious mining, retorting, pre-refining and related auxiliary activity and facilities in an area of about 1,200 square miles in the southeast Uinta Basin. The area at present is isolated, sparsely populated semi-desert supporting little industry. Its value for recreation is small but of local importance. There is only modest scenic attraction. By far the greatest value and highest use of this land is for exploitation of the potential energy resource.

Oil shale development activities will disturb and affect the environment of the area and surrounding region. Serious dislocation and damage can be prevented by careful planning and strict, even-handed regulation of the development activity. Planning must be based on accurate data. The planning and regulatory regime must be flexible enough to adapt to change as the industry and techniques progess. It must not become locked into rigid attitudes and controls that could become quickly outmoded in the rapid evolution of problem recognition and solution.

Most of the technology of development of the oil shale resource exists. The rest is certain to follow with sufficient economic incentive. Principal technological gap is that of scale: mainly the enlargement of existing processes and equipment to cope with the gigantic task.

Sound reclamation and restoration of the land may afford a unique opportunity to reshape the land and alter existing patterns of drainage so that erosion can be checked and runoff retarded. The result could be beneficiation of the surface and subsurface waters coursing into the White, Green and Colorado rivers for centuries into the future.

Efficient, economical development of the total oil shale resource in Utah can best be accomplished by operations on a broad scale throughout the whole optimum oil shale area. Such operations, with uniformity of regulations and sharing of costs and responsibilities, would eliminate wasteful duplication of facilities and vastly simplify the problems of land and water management and reclamation and restoration of the whole area to its natural state.

Utah wants to see this great resource totally developed by every feasible method available now and in the future. The State realizes that such development will mean loss of some land for periods of time, some disfigurement and alteration of the landscape and temporary dislocation of the environment. These are necessary <u>but not permanent</u> consequences of the exploitation of this tremendous natural resource.

We have confidence that human intelligence, ingenuity and energy can confront and solve the varied problems associated with this gigantic enterprise.

Utah is moving carefully to accomplish its part of the job.

XI. SPECIAL REFERENCES

The U. S. Bureau of Land Management, State Office (Utah), Salt Lake City, as part of this study, has prepared a comprehensive study of the surface resources of the oil shale area and adjacent country.

"The material consists of a base map, seven opaque mylar overlays and five studies of land covered in part by the proposed area of development. The base map is a Land Ownership and Public Management Map. The overlays are listed as follows:

Utah Oil Shale Program

1. Land Surface Activities
2. Existing Range Improvements
3. Recreation Resources
4. Wildlife Habitat
5. Mineral Leases
6. Erosion Hazard Classification
7. Vegetative Types

"The studies consist of analysis of the resources in areas delineated in part by the development area. The areas are known as Planning Units and are listed as follows:

Unit Name	Unit Number
Bonanza	08-05
Myton	08-06
Hill Creek	08-07
Rainbow	08-08
Book Cliffs	08-09"

(Letter R. D. Nielson to H. R. Ritzma, 11-13-70)

The Rainbow planning unit is almost entirely within the optimum oil shale area. The Bonanza, Myton, Hill Creek, and Book Cliffs units include large areas to the northeast, northwest and south of the area most likely to be developed for oil shale.

Because of the volume of these studies they have not been appended to this report. Copies are available for examination at the following places:

U. S. Bureau of Land Management, State Office (Utah)
Federal Building, 125 South State Street
Salt Lake City, Utah

Utah Geological and Mineralogical Survey
103 UGS Building, University of Utah
Salt Lake City, Utah

Department of Natural Resources
State Capitol
Salt Lake City, Utah

These studies are an unusually complete compilation of information on the surface resources of the area and form a valuable base on which careful planning for oil shale development can begin.

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