GEOLOGY AND PETROLEUM RESOURCES OF THE MAJOR OIL-IMPREGNATED SANDSTONE DEPOSITS OF UTAH

by Jock A. Campbell and Howard R. Ritzma

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TABLE OF CONTENTS

GEOLOGY AND PETROLEUM RESOURCES OF THE MAJOR OIL-IMPREGNATED SANDSTONE DEPOSITS OF UTAH

ILLUSTRATIONS

TABLES

GEOLOGY AND PETROLEUM RESOURCES OF THE MAJOR OIL–IMPREGNATED SANDSTONE DEPOSITS OF UTAH

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ABSTRACT

Near surface, oil-impregnated rock deposits in Utah are estimated to contain as much as 29 billion barrels of petroleum. Over fifty individual deposits have been identified, primarily through field mapping. Over 96 percent of the oil in place occurs in sandstone host rocks in six giant deposits.

Four of the deposits occur in the Uinta Basin of northeastern Utah, and contain petroleum which probably originated in the Green River Formation (Eocene). Three of these deposits, P. R. Spring, Hill Creek, and Sunnyside, also occur in the Green River Formation, but the Asphalt Ridge deposit occupies only older and younger strata.

Two deposits occur in marine and marginal marine strata in the dissected plateau region of southeastern Utah. The Tar Sand Triangle is the largest deposit in the state, and occurs in the White Rim Sandstone (Permian). Circle Cliffs is a giant, low-grade deposit in sandstone and siltstone of the middle Moenkopi Formation (Triassic).

The oil-impregnated sandstone bodies of the deposits are of variable number, thickness, and petroleum content, and occur under the influence of a variety of structural and topographic conditions. Tables provide summaries of various characteristics of the petroleum and the reservoir strata.

INTRODUCTION

Descriptions of the oil-impregnated rock deposits of Utah were first compiled by Ball Associates (1965). At that time, it was estimated that there were between 2.0 and 4.3 billion barrels of oil in place. Work done primarily under the direction of Ritzma (1979) has enlarged that estimate to between 22.4 and 29.2 billion barrels of oil in place. Field investigations have consisted mainly of reconnaissance mapping with topographic maps and aerial photographs, using a visual method of classification of oil-impregnated sandstone[3] quality (table 1). Mapping has been supplemented with laboratory analyses of outcrop samples, and locally with drill hole data.

[1] Chief Petroleum Geologist, Utah Geological and Mineral Survey, Salt Lake City, Utah 84108

[2] Assistant Director, Utah Geological and Mineral Survey, Salt Lake City, Utah 84108

Ritzma (1979) summarizes over 50 deposits, but over 96 percent of the petroleum is contained in six giant deposits (figure 1), described herein. The regional significance of some of the more important deposits has been discussed by Baars and Seager (1970), Blakey (1977), and Campbell and Ritzma (1976).

Because there is only partial subsurface information available for these deposits, only about half the total estimated resource falls into the classification of measured and indicated resources (table 2).

Development of these resources has been limited by economic, technical, and political factors. Although advances are being made in the former two categories, it is still not possible to lease tar sands on Federal land, which predominates on 4 of the 6 deposits discussed here. The State of Utah recognized the substance contained in oil-impregnated rocks as petroleum, and as such, considers it producible under the terms of an oil and gas lease.

The oil-impregnated sandstone deposits occur in a variety of stratigraphic and structural circumstances. They are separated here into two groups: the Uinta Basin group, all of which contain petroleum which probably originated in Eocene lacustrine source rocks of the Green River Formation, and the central-southeast group, which occur in and probably originated in marine source rocks of Permian and Triassic age.

UINTA BASIN

The Uinta Basin group consists of 25 deposits, 24 of which contain petroleum that originated in lacustrine rocks of the Green River Formation (Eocene). This consideration is based on knowledge of the stratigraphic framework, and conventional petroleum occurrences in the basin (Fouch, 1975; Ryder and others, 1976) and on the very low sulfur content of the oil-impregnated sandstones, (Wood and Ritzma, 1971; Ritzma 1979), a characteristic which they share with the conventional crude oils of the basin. However, some of the deposits occur in strata of Permo-Pennsylvanian, Triassic-Jurassic, and Cretaceous age, which results from the complex

[3] The term oil-impregnated sandstone as used in this report is essentially synonymous with oil sand, tar sand, and bituminous sandstone. The term oil is preferrable to tar inasmuch as it is a more accurate description of the substance under discussion. The term sandstone is preferred for use in conjunction with the Utah deposits, since they occur principally in consolidated rocks rather than in unconsolidated sand.

TABLE 1. FIELD CLASSIFICATION OF OIL-IMPREGNATED SANDSTONE QUALITY

Rank	Quality	Visual Appearance	Approximate saturation (percent of pore space)
5	Very Rich	Pore spaces completely filled with bitumen; rock oozes oil.	70 and over
4	Rich	Pore spaces completely filled and rock glistening black.	50-70
3	Moderate	Pore spaces completely filled and rock dull black.	30-70
2	Weak	Pore spaces incompletely filled and rock light gray.	10-30
1	Very Weak	Pore spaces not filled with bitumen but rock stained gray or brown, commonly spotty.	0-10
0	Barren	No visible evidence of bitumen saturation.	0

structural boundary between the Uinta and Wasatch Mountains, and the Uinta Basin (Campbell, 1975b; Campbell and Ritzma, 1976; Ritzma, 1975).

Asphalt Ridge and Asphalt Ridge, Northwest

Asphalt Ridge is perhaps the best known of the Utah deposits, having been first studied by Spieker (1931). Asphalt Ridge is a northwest-trending cuesta about 15 miles (24 km) long, in which the strata dip from 9 to 35 degrees southwesterly (figures 2 and 3). Oil impregnation occurs for approximately 12 miles (19 km) along the strike of the ridge in two units separated by an angular unconformity. These are the Mesaverde Group (Late Cretaceous) and the Uinta (?) and Duchesne River Formations (Eocene-Oligocene). The Mesaverde is composed of two formations of marine origin, the Asphalt Ridge Sandstone (lower), and the Rim Rock Sandstone, which are separated by a thin tongue of the Mancos Shale (Walton, 1944). The Rim Rock Sandstone is from less than 100 to over 300 feet thick, due to variable truncation of the unit prior to deposition of younger strata (Kayser 1966). The greatest exposed thickness of oil impregnation in the Rim Rock Sandstone is at least 113 feet (35 m) at the northwest end of Asphalt Ridge (Spieker, 1931, p. 83). No oil impregnation is known to occur in the Asphalt Ridge Sandstone at Asphalt Ridge proper.

These strata are overlain unconformably by the Duchesne River Formation (Eocene) of continental origin, consisting of conglomerate, sandstone, siltstone, and shale. Oil impregnation at the Uintah County asphalt quarry was 190 feet (58 m) thick where it was measured by Spieker (1931, p. 84). The petroleum masks the character of the host rock, but at least part of this section is in the Duchesne River Formation.

Development of the deposit for paving material goes back at least to the 1920's (Spieker, 1931). However, several small underground workings here and at Asphalt Ridge, Northwest, may predate the quarry. A number of unsuccessful shallow wells were drilled downdip of the exposures between 1910 and 1950 in the hope of locating fluid petroleum below an asphaltic seal. Gulf Oil Corporation drilled two core holes for permeability measurements in bituminous sandstone at about 600 feet (185 m) in 1957. More recently, Major Oil Company operated a pilot extraction plant near the southeast end of the ridge in 1972. Sohio Natural Resources Company received permission from the State

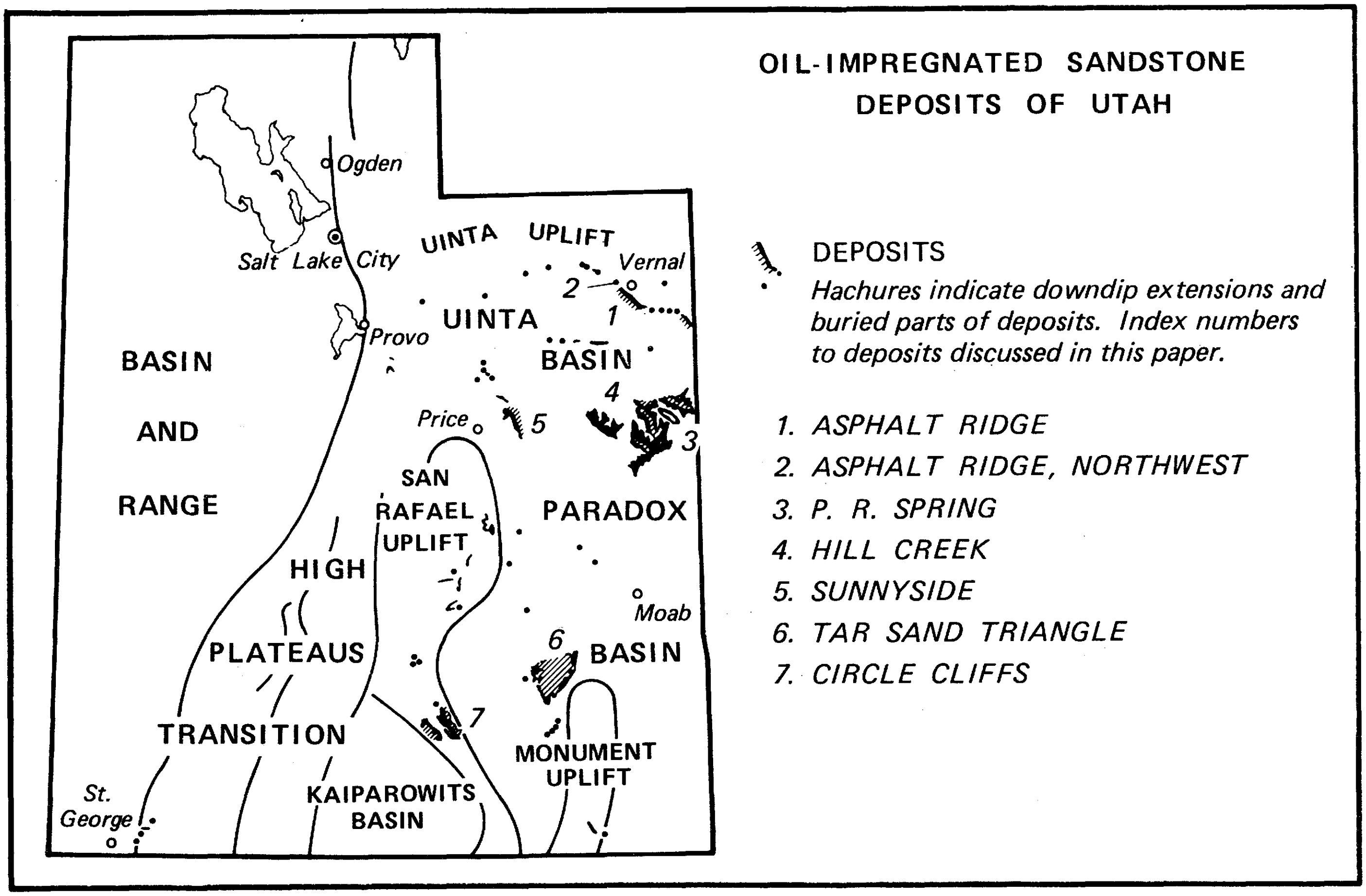


Figure 1

of Utah in 1974 to conduct a surface mining and processing operations in the same area (figure 2), and pilot extraction activities have been carried out by Aminoil, U. S. A., Arizona Fuels Corporation and Major Oil Company since that time. There is no present activity at the mine.

Very little subsurface data which would help to determine the size of the petroleum resources at Asphalt Ridge is available. The estimate of 1.05 billion barrels (Ritzma, 1979) assumes that the oil impregnation observed at the surface (figure 2) is continuous in the subsurface to a distance of one-quarter mile (400 m) behind the outcrop. Because the strata are inclined more steeply than the topography (figure 3), overburden increases rapidly to the southwest of the exposed tar sands, limiting the quantity of material that can be economically mined. However, Sohio estimates that from 100 to 200 million barrels of oil could be recovered by mining from their properties (written communication, R. C. Madsen).

The Asphalt Ridge, Northwest deposit is separated from Asphalt Ridge by a northeast-trending fault (figure 2). The deposit differs from the Asphalt Ridge deposit in that it occurs mainly in the subsurface, and that both the Rim Rock Sandstone and Asphalt Ridge Sandstone are oil-impregnated, in addition to the Duchesne River Formation. The only oil-impregnated outcrop at Asphalt Ridge, Northwest is in the eastern part of the area, just west of the fault that separates the two deposits. As much as 38 ft. (12 m) of oil impregnation occurs along a distance of about 3000 feet (928 m) of outcropping Asphalt Ridge sandstone in this area.

To the south and west the strata are truncated by Tertiary sediments, such that the Rim Rock Sandstone and petroleum-bearing Tertiary strata occur entirely in the subsurface. Drilling to date has encountered oil impregnation between 30 and 2000 feet (9 to 610 m). The area underlain by heavy oil here may be as large as 1200 acres (4.9 km^2). Insufficient information is available for accurate resource calculation, but Ritzma (1979) has conservatively estimated 100 to 125 million barrels of oil in place. Available subsurface reservoir data is summarized in table 3.

Standard Oil Company (Ohio) conducted field

TABLE 2. GENERAL CHARACTERISTICS OF MAJOR OIL-IMPREGNATED SANDSTONE DEPOSITS OF UTAH.

Map Index No.	Name of Deposit	Oil in Place in Millions of Barrels: Estimated	Oil in Place in Millions of Barrels: Measured and Indicated	Stratigraphic Unit	Areal Extent mi^2 / km^2	No. of Principal Pay Zones*	Gross Thickness of Pay (Range in feet/meters)*	Overburden Thickness (Range in feet/meters)	Gravity °API (Range)*	Sulfur wt. % Oil (Range; mean)*	Nitrogen wt. % Oil (Range; mean)*
1	Asphalt Ridge	1,048	873	Duchesne River Formation Rimrock Sandstone	20 - 25 50 - 65	2 - 5	10 - 135 3 - 40	0 - 500+ 0 - 150+	8.2 - 12.9 (10.4) [4]**	0.19 - 0.76 (0.52) [3]**	0.9**
	Asphalt Ridge Northwest	100 to 125		Duchesne River Formation Rimrock Sandstone Asphalt Ridge Ss.	0 - 0.94(?) 0 - 1.45(?)	2 - 3	30 - 225 9 - 70	0 - 2000+ 0 - 600+	(14)	0.30 - 0.49* (0.40) [4]	0.17 - 0.93* (0.69) [4]
2	P. R. Spring	4,000 to 4,500	3,700	Green River Formation (Mainly Douglas Creek Member)	240 - 270 600 - 700*	1 - 13 (5.6) [13]	14 - 212 (98) 4 - 65 (30) [13]	0 - 370+ 0 - 115+	5.8 - 15.3 (9.5) [37]	0.22 - 0.42 (0.33) [30]	0.67 - 1.8 (1.16) [3]**
3	Hill Creek	1,160	830	Green River Formation (Mainly Douglas Creek Member	115 - 125 300 - 320	6 - 13 (8.3) [3]	152 - 189 (166) 46 - 58 (51)[3]	0 - 500+ 0 - 150+ [3]	5.5 - 17.3 (9.1) [14]	0.33 - 0.61 (0.45) [9]	0.63 - 0.86 (0.73) [9]
4	Sunnyside	3,500 to 4,000	2,000	Green River Formation	35 - 90 90 - 215	2 - 13 (6.7) [10]	40 - 1175 (616) 12 - 358 (188) [10]	42 - 400 (172) 12 - 122 (53) [10]	7.6 - 9.2 (8.6) [5]**	0.50 - 0.60 (0.55) [2]**	
5	Tar Sand Triangle	12,500 to 16,000	6,100	White Rim Ss. of the Cutler Group	200 - 230 500 - 600	1	5 - 300+ 1.5 - 90+	0 - 2000 0 - 610	-3.6 - 9.6 (4.3) [12]**	2.67 - 6.27 (3.8) [12]**	0.3 - 0.7 (0.56) [12]**
6	Circle Cliffs	1,300	1,137	Moenkopi Fm.	28 70	1 - 3	5 - 310 1.5 - 95	0 - 500+	-11.1 - 6.8 (-2.96) [12]**	2.37 - 4.36 (3.6) [12]**	0.35 - 0.90 (0.59) [12]**
		23,608 to 28,133	14,640								

*Figures in brackets [ ] represent number of samples. Figures in parentheses ( ) are arithmetic means.

**Outcrop samples or surface measurements. All other technical data from drill-hole samples and measurements.

Data from Gwynn, 1971; Holmes et. al., 1948; Johnson et. al., 1976; Johnson et. al., 1978; Kayser, 1966; Peterson and Ritzma, 1974; Ritzma, 1979; Wood and Ritzma, 1972, and unpublished sources.

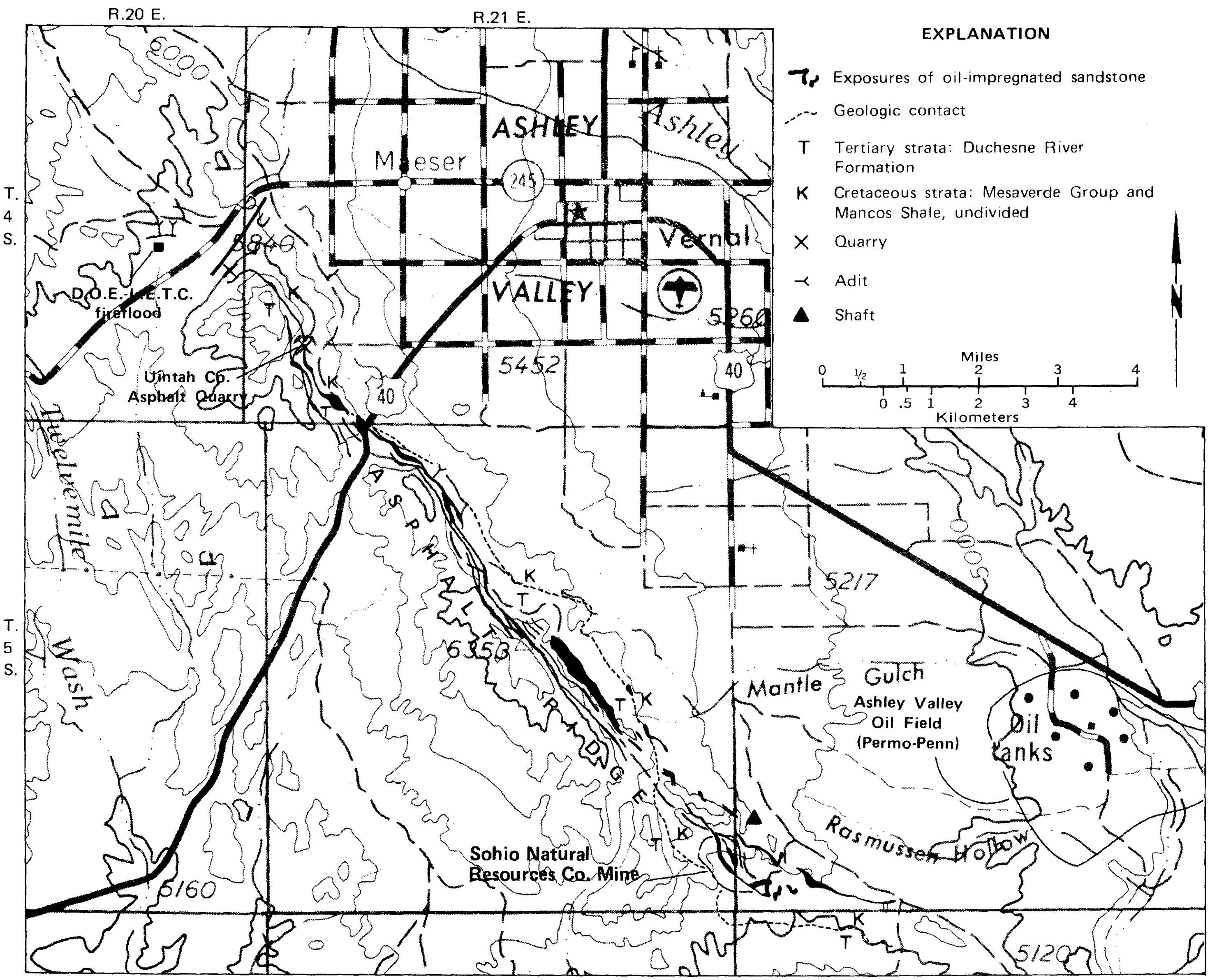
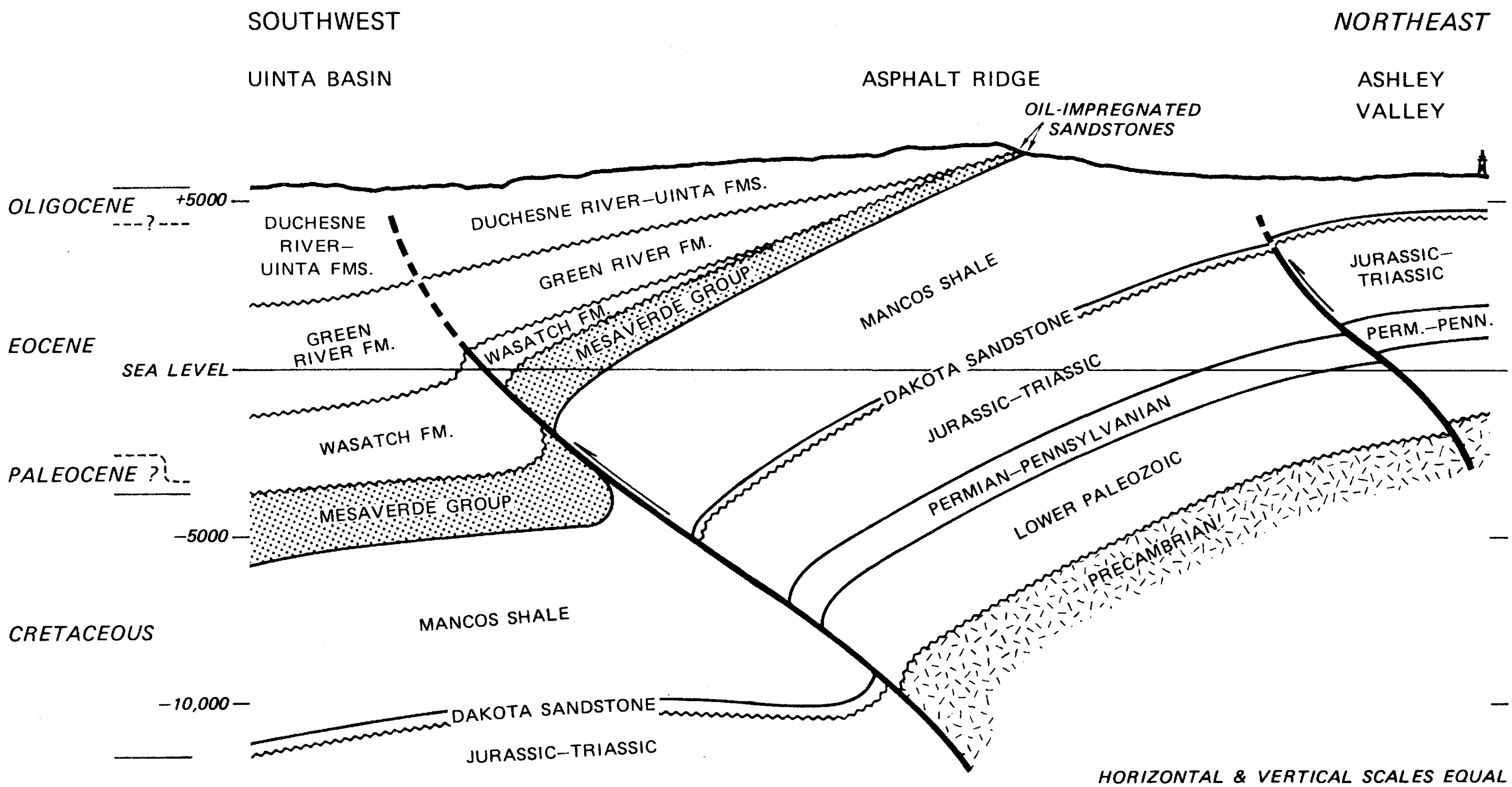


Figure 2. General geology and oil-impregnated sandstones of Asphalt Ridge and Asphalt Ridge Northwest, Northeastern Uinta Basin, Utah

Figure 3

ASPHALT RIDGE

SECTION A–A′ (SCHEMATIC)*



* *Based on surface, subsurface, and seismic data.*
After Ritzma, 1974; Campbell, 1975.

TABLE 3. DEPOSIT QUALITY,
ASPHALT RIDGE, NORTHWEST,
UINTAH CO., UTAH*

Stratigraphic unit	Depth feet/meters	Net Oil sand feet/meters	Gallons per ton range/mean	Liters per metric ton range/mean	Gallons per cu. yd. range/mean	Liters per cu. meter
Duchesne River Formation	37-219	79	0.13-18.90	0.54-78.6	0.24-33.80	1.19-167.31
	11-67	24	5.11	21.26	9.39	46.48
Rimrock Sandstone	221-340	63	1.96-29.90	8.15-124.38	3.57-52.80	17.67-261.36
	67-104	19	18.89	78.58	32.86	162.66

*All data from a single drill hole, SW1/4 SE1/4 SE1/4 Sec. 23, T. 4 S., R. 20 E.

TABLE 4. GENERAL PHYSICAL CHARACTERISTICS OF THE P. R. SPRING OIL-IMPREGNATED SANDSTONE DEPOSIT, UINTA BASIN, UTAH.

	Barren Rock Overlying Deposit		Barren Rock Between Oil Sands		Gross Oil Sand Interval Thickness		Net Oil Sand Thickness		No. of Beds	Oil Sand Bed Thickness	
	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)		(ft)	(m)
Mean	110.1	33.6	13.1	4	97.7	29.8	35.2	10.7	5.6	6.4	1.9
Range	9.0-369	2.7-112.5	2.0-58.5	0.6-17.8	14.5-212	4.4-64.6	10.0-101.5	3.0-30.9	1-13	0.5-29.5	0.2-9.0

Data source: 13 core holes (Peterson and Ritzma, 1974).

permeability studies near the outcrop in the eastern part of the area in 1959-60. The Laramie Energy Technology Center of the U. S. Department of Energy has conducted *in situ* combustion experiments in the area (figure 2) since 1975 (Land and others, 1975; Johnson and others, 1978; Marchant and others, this volume).

Most of the surface in the Asphalt Ridge area is owned by the State of Utah. The nearby towns of Vernal and Roosevelt offer oil field services and a regularly-scheduled airline serves Vernal. Truck lines, but no railroad, also serve the area.

P. R. Spring

The P. R. Spring deposit is located in the south-eastern part of the Uinta Basin, terminating along the south-facing Book Cliffs at 7800 to 8400 feet (2400 to 2600 m) altitude. The petroleum occurs in the upper part of the Douglas Creek Member of the Green River Formation, immediately below the oil-shale bearing Parachute Creek Member (Byrd, 1970). The deposit occupies up to 13 fluvial and lacustrine sandstone units of deltaic origin. Regional dip is northwesterly at 2 to 4 degrees. It is evident from field mapping and drilling to date that the deposit becomes progressively more deeply buried to the north, and may extend farther north than indicated by studies to date (figure 4). In general, the most numerous oil-impregnated sandstone units occur in the southern part of the deposit (Peterson and Ritzma, 1974; Peterson, 1975), probably nearest the sediment source for the delta complex (Picard and High, 1970). There is not yet sufficient information to determine the possible influence of local geologic structure (figure 4) on the distribution of oil-impregnated sandstone units. It seems probable that the petroleum originated in stratigraphically equivalent, fine-grained lacustrine strata in the deeper part of the basin to the north. Many of the bituminous sands are exposed parallel to the six major northward-draining valleys for distances up to 25 miles (40 km). Overburden increases in the several miles between the valleys, such that the overlying rock may attain a thickness of over 370 ft. (115 m). Individual petroleum-saturated beds range from 0.5 to 30 ft. (.15 to 9 m) in thickness. Table 4 summarizes the physical characteristics of the deposit based on thirteen coreholes drilled in 1972 and 1973 (Peterson and Ritzma, 1974). Tables 5 and 6 summarize reservoir properties and general quality of the deposit from the same data base.

The P. R. Spring deposit is remote from transportation and services. The northernmost part of the deposit is over 20 miles (32 km) from a paved road, and 66 miles (108 km) from the town of Vernal (Fouch and others, 1976, p. 381). The southern part of the deposit is about 45 miles 70 km) farther by existing roads. There is also access from Interstate 70 to the south through the rugged terrain of the Book Cliffs.

Because of increasing overburden between valleys, mining is likely to be carried out first parallel to the valleys. However, the southern part of the deposit (figure 4) should be investigated for mineable areas which may be overlain with moderate thicknesses of barren rock.

The earliest attempt of record to recover petroleum from the deposit was a well drilled in sec. T. 15 S., R. 23 E., by John Pope in 1900 (Hansen and Scoville, 1955, p. 94). This was also the first well drilled for petroleum in the Uinta Basin.

Most of the land in the area is administrated by the U. S. Bureau of Land Management, but there are also scattered State and private lands in the area.

Hill Creek

The Hill Creek deposit (figure 5) appears to differ from the P. R. Spring deposit only in detail. Data from three core holes (tables 7, 8, and 9) indicate that there tend to be more oil-saturated units (6 to 13), but that oil saturation is lower compared to the P. R. Spring deposit. The ranges of values have less spread than for the P. R. Spring deposit, which is to be expected with less than one-third the number of samples. The data for the two deposits have not been compared statistically. The deposit is estimated to contain 1.16 billion barrels of oil in place (Ritzma, 1979). About two-thirds of the deposit is located on the Uintah and Ouray Indian Reservation. About another third is administered by the U. S. Bureau of Land Management, and there are also several sections of state and private lands overlying the identified resource. The northwest quarter of the deposit extends into the U. S. Naval oil shale reserve. The deposit is remote from all-weather roads and services.

Sunnyside

The Sunnyside deposit is the largest and best exposed of several southwestern Uinta Basin oil-impregnated sandstone deposits. It is less remotely located than the other deposits of the southern Uinta Basin, being less than 10 miles from a paved state highway and a spur of the Rio Grande Railroad.

The Sunnyside deposit is located at the southwestern topographic margin of the Uinta Basin at a maximum altitude of over 10,000 feet (3020 m). The deposit is well exposed in two dimensions along the Roan Cliffs (figure 6). The topography of the area is rugged, with over 3000 feet (920 m) of local relief at the Roan and Book Cliffs. The relief is at first disturbing, but might be used to advantage in moving overburden

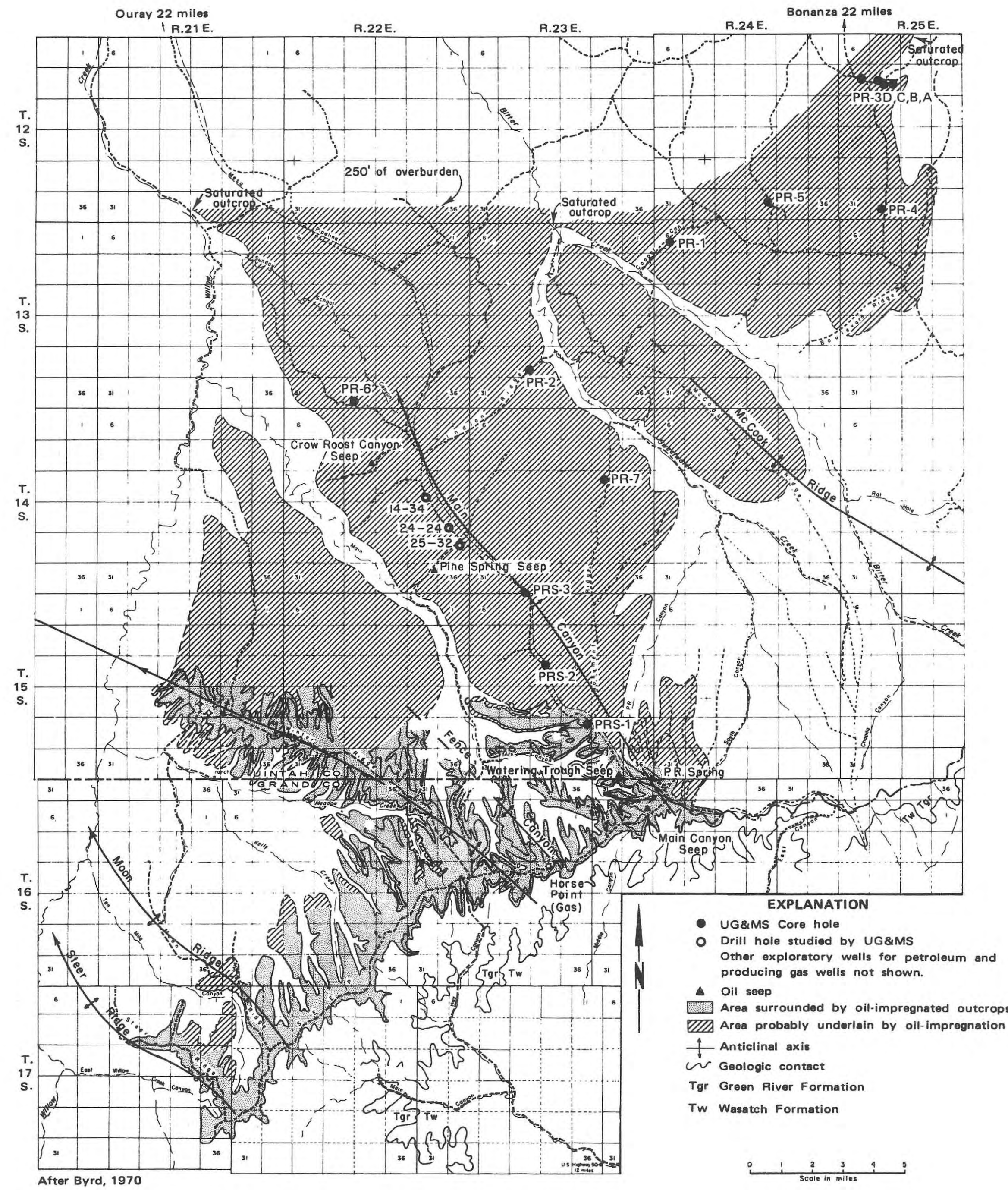


Figure 4. P.R. Spring oil-impregnated sandstone deposit, southeastern Uinta Basin, Utah

and ore in mining and processing. It is this relief which provides access to the resource.

The most comprehensive published study of the deposit to date is by Holmes, Page and Averitt (1948). Whereas they placed the bituminous sandstone in the Wasatch and basal Green River formations, those strata are entirely within the Green River Formation as defined by Ryder and others (1976). They also now refer the underlying red bed facies to the Colton Formation rather than to the Wasatch Formation. The oil-impregnated sequence is composed of fluvial and marginal lacustrine sands, part of a delta complex with a southwesterly source. The main oil-impregnated zone at Sunnyside is as much as 860 feet (265 m) thick, containing 680 net feet (210 m) of oil sand. This is overlain

TABLE 5. RESERVOIR CHARACTERISTICS, P. R. SPRING OIL-IMPREGNATED SANDSTONE DEPOSIT, UINTA BASIN, UTAH.[1]

	Permeability (millidarcys) Before Oil Removal	Permeability (millidarcys) After Oil Removal	Porosity (Percent)	Pore Saturation Percent Oil	Pore Saturation Percent Water
Range	0.01-9930	0.09-9930	12.1-39.3	1.4-91.1	0.5-70.4
Mean	219	1097	26.8	48.2	14.3
S. Dev.	738	1303	4.6	21.6	13.2

(1) Data base 454 core analyses (Peterson and Ritzma, 1974).

TABLE 6. ORE QUALITY, P. R. SPRING OIL-IMPREGNATED SANDSTONE DEPOSIT, UINTA BASIN, UTAH

	Gallons /Ton (1)	Liters/ Metric Ton (1)	Percent Volume (1)	Percent Weight (1)	Gravity-°API(2) Extracted	Gravity-°API(2) Retorted	Field Classification (1)(3)
Mean	14.7	61.3	12.9	6.1	9.5	21.5	3.4(4)
Range	0.2-32.4	0.8-135.2	0.2-28.2	0.1-13.5	5.8-15.3	19.0-24.2	1.5
S. Dev.	6.8	28.6	6.0	2.9	2.6	1.2	

(1) Data base: 454 core analyses (Peterson and Ritzma, 1974).
(2) Data base: 37 petroleum analyses (Peterson and Ritzma, 1974).
(3) See table 1.
(4) Weighted mean.

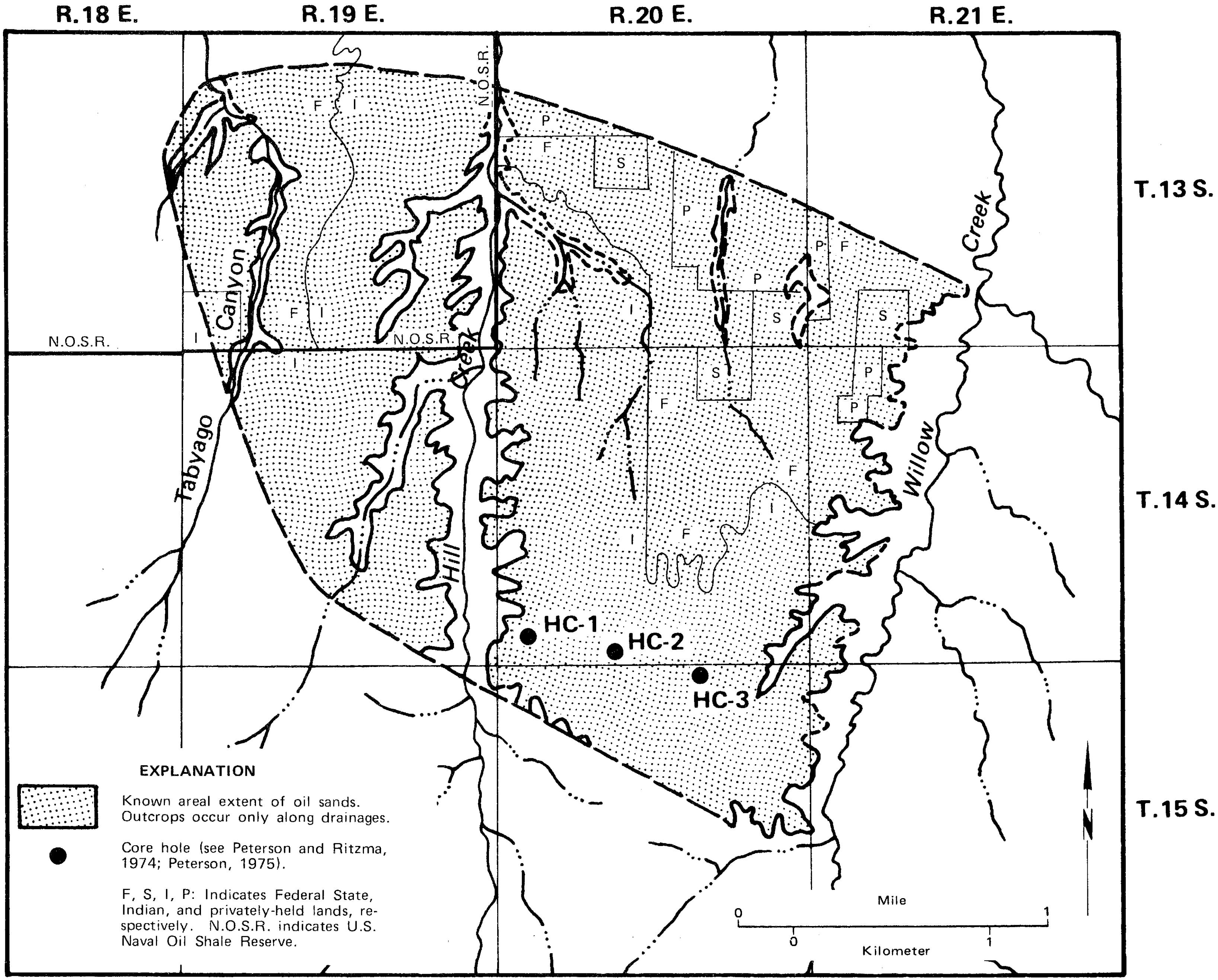


Figure 5. Hill Creek oil-impregnated sandstone deposit, southern Uinta Basin, Utah.

TABLE 7. GENERAL PHYSICAL CHARACTERISTICS OF THE HILL CREEK OIL-IMPREGNATED SANDSTONE DEPOSIT, UINTA BASIN, UTAH

	Barren Rock Overlying Deposit (ft)	(m)	Barren Rock Between Oil Sands (ft)	(m)	Gross Oil Sand Interval Thickness (ft)	(m)	Net Oil Sand Thickness (ft)	(m)	No. of Beds	Oil Sand Bed Thickness (ft)	(m)
Mean	224.2	68.3	12.6	3.8	166.0	50.6	60.8	18.5	8.3	7.3	2.2
Range	42-325	13-100	2.0-60.5	0.6-18.4	152.5-189	46.5-57.6	53.5-65.0	16.3-19.8	6-13	1.0-24.0	0.3-7.3

Data source: 3 core holes (Peterson and Ritzma, 1974).

TABLE 8. RESERVOIR CHARACTERISTICS, HILL CREEK OIL-IMPREGNATED SANDSTONE DEPOSIT, UINTA BASIN, UTAH.[1]

	Permeability (millidarcys) Before Oil Removal	After Oil Removal	Porosity (Percent)	Pore Saturation Percent Oil	Percent Water
Range	0.01-1140	2.4-1355	11.6-30.5	3.7-82.1	1.0-89.8
Mean	125.1	322.5	22.4	36.6	16.8
S. Dev.	228.6	316.8	3.43	19.5	14.5

(1) Data from 129 core analyses (Peterson and Ritzma, 1974).

TABLE 9. ORE QUALITY, HILL CREEK OIL-IMPREGNATED SANDSTONE DEPOSIT, UINTA BASIN, UTAH

	Gallons /Ton (1)	Liters/ Metric Ton (1)	Percent Volume (1)	Percent Weight (1)	Gravity-°API(2) Extracted	Retorted	Field Classification (1)(3)
Mean	8.8	36.7	8.1	3.7	7.9	21.1	2.2(4)
Range	1.0-21.2	4.2-88.5	0.9-20.1	0.4-8.9	5.5-10.5	20.0-22.1	1-4
S. Dev.	4.7	19.4	4.4	1.9			

(1) Data base: 129 core analyses (Peterson and Ritzma, 1974).
(2) Data base: 5 petroleum analyses (Peterson and Ritzma, 1974).
(3) See table 1.
(4) Weighted mean.

TABLE 10. RESERVOIR ROCK CHARACTERISTICS AND ORE QUALITY, SUNNYSIDE OIL-IMPREGNATED ROCK DEPOSIT, UINTA BASIN, UTAH

	Porosity[1] percent volume	Permeability[2] millidarcys	Oil Saturation[3] Volume percent	Weight percent	percent pore space	Water Saturation[3] percent pore space	Gallons per ton	Liters per metric ton
Mean	23.1	570	12.8	5.4	51.8	20.9	14.3	59.5
Range	3.7-35.6	0.0-5370	0.3-28.4	0.1-11.7	2.0-90.0	0.0-97.0	0.3-32.0	1.25-133.1
S. Dev.	6.5	700	6.0	2.5	28.3	16.1	9.4	39.1

1 1627 Samples from 10 core holes

2 804 Samples from 6 core holes

3 1404 Samples from 7 core holes

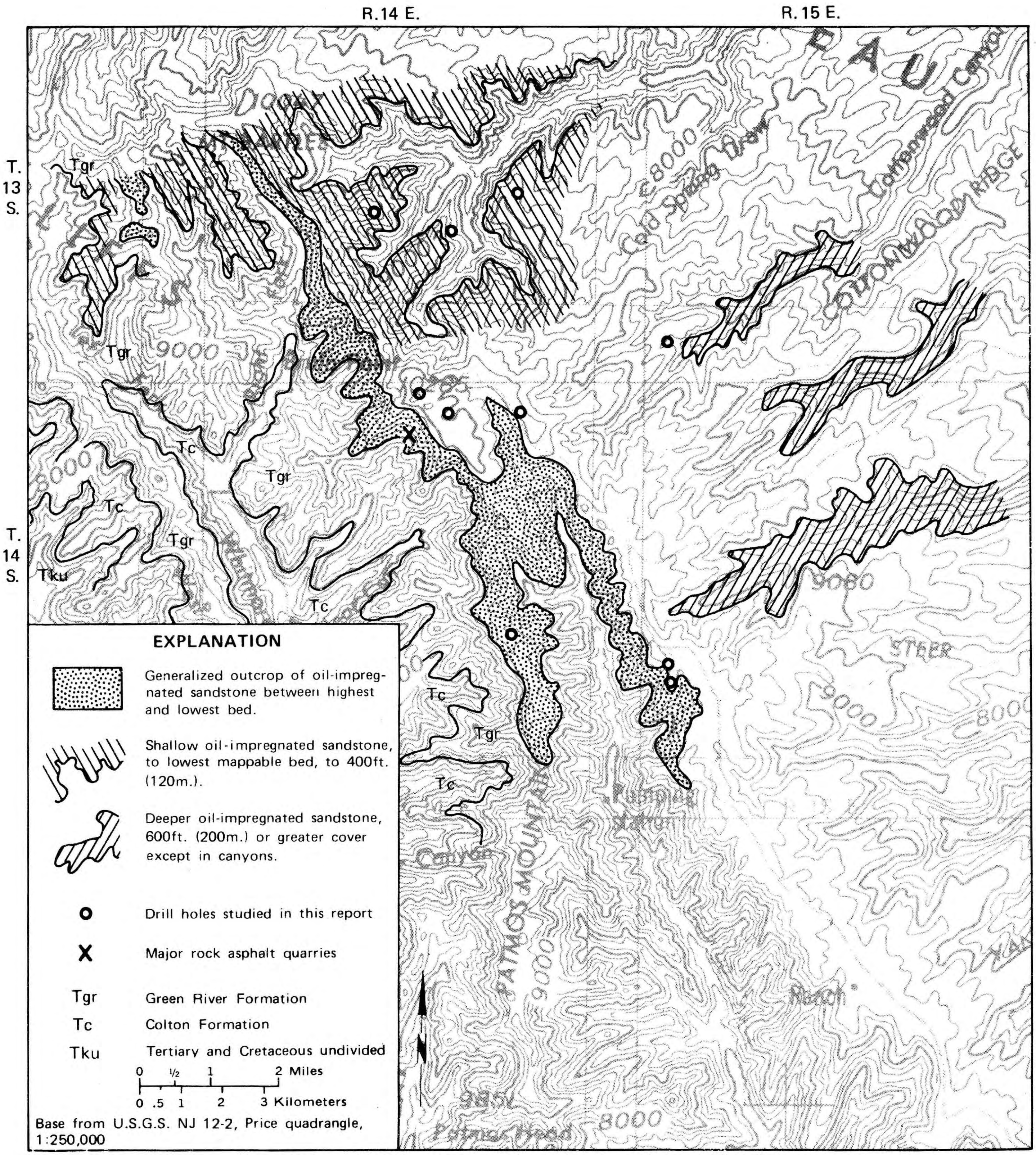


Figure 6. Sunnyside oil-impregnated sandstone deposit, southwestern Uinta Basin.

by about 400 feet (122 m) of predominantly fine-grained rocks in which thin but prominent oil shale beds are present. Oil-impregnated sandstones are fewer and thinner in this part of the section. Facies relations and correlations established by Ryder and others (1976) and by Fouch and others (1976) indicate that these strata are approximately equivalent to the Douglas Creek and Parachute Creek members of the Green River Formation in the eastern Uinta Basin.

The strata are inclined about 9 degrees east-northeasterly, gradually decreasing northeastward into the Uinta Basin. Individual sandstone bodies tend to be channel-form, locally attaining a thickness of 330 feet (100 m) according to the section measured by Holmes and others (1948). Thus the net thickness of oil-impregnated sandstone can be expected to vary considerably from place to place. Core drilling to date indicates that the gross oil-impregnated section may diminish by nearly 75 percent within about 1.5 miles (2.4 km) to the east. However, the basinward extent of the deposit in the subsurface is undetermined to date, but oil-impregnated sandstones occur in canyons as much as 8 miles (13 km) northeast of the exposures of the deposit along the Roan Cliffs (figure 6). Technical data for the deposit are summarized in table 10.

The bituminous sandstone at Sunnyside is known to have been quarried as early as 1892. Quarrying has been sporadic, having finally ceased in the late 1940's. Holmes and others (1948) stated that 335,000 tons had been quarried at the time of their study. Between 1931-1945 the material was used for paving in Utah and five other western states. In 1963-1966, Signal Oil Company and Shell Oil Company experimented independently with steamflood techniques. Shell's efforts have been summarized by Thurber and Welbourn (1977).

Land ownership in the area is principally private, but there are several sections of strategically located Federal and State acreage.

CENTRAL SOUTHEAST

The central southeast group of oil-impregnated rock deposits are found in a variety of structural and stratigraphic circumstances. Some are large stratigraphic-structural traps which contain oil which was generated in equivalent or adjacent stratigraphic units; others appears to be leaks from older petroleum-bearing strata, probably through fault zones. Only the two largest deposits will be discussed here.

Tar Sand Triangle

The Tar Sand Triangle is the largest deposit in Utah and is composed of at least six deposits which were formerly thought to be separate occurrences (Bowman, 1969). The deposit lies in a remote and very rugged area with a maximum relief of 3700 ft. (1130 m). It lies north of the Colorado River, and between the Dirty Devil River on the west and the Green River on the east, underlying an area of over 200 sq. miles (320 sq. km). The oil impregnation occurs principally in the White Rim Sandstone, and to a much lesser extent in the Cedar Mesa Sandstone, both of the Cutler Group (upper Permian). Over 99 percent of the estimated petroleum resource is in the White Rim Sandstone (Ritzma, 1979). The petroleum was trapped here in a pinch-out of the White Rim on the northwest plunge of the Monument upwarp. The rocks are inclined northerly at 1 to 3 degrees, with most exposures of oil-impregnated sandstone occurring on cliff faces and canyon walls. Only at the Elaterite Basin in the northeastern part of the deposit are there more accessible exposures.

The thickness of petroleum-bearing White Rim Sandstone is as much as 300 feet (91 m) (figure 7). The limits of the deposit are related to the original oil-water contact on the north and west, and to the depositional wedge edge of the host rock on the southeast (figure 8). The White Rim Sandstone is of shallow margin origin (Baars and Seager, 1970), and consists predominantly of medium to coarse quartz grains (Baker, 1946, p. 45). The unit is known over a broad region for its excellent reservoir characteristics (table 11). Very little other engineering data from relatively unweathered subsurface sources are available for the Tar Sand Triangle, although some have been published by Kuuskraa and others (1978) and Bunger and others (1979). The properties of the reservoir rock, the petroleum, and the oil saturation can be expected to vary, so that some parts of the deposit will be more amenable to development than others. Reports of semifluid petroleum from some drill holes indicate that parts of the deposit may be desirable for *in situ* recovery of the petroleum. Heavy oils recovered by such in situ techniques may be economically competitive with some of the more expensive sources of "conventional" petroleum. Furthermore, production of petroleum through a drill hole can be accomplished with minimum environmental disruption.

The deposit underlies public lands, administered primarily by Federal agencies. As much as a few hundred acres in the northeasternmost part of the deposit are within Canyonlands National Park. About forty percent of the deposit is in the Glen Canyon National Recreation area, much of which is under review by the U. S. National Park Service for wilderness classification. Part of the remaining area to the west is under review for wilderness classification by the U. S. Bureau of Land Management. Therefore this giant, but poorly known petroleum resource is in danger of being lost to potential development because of its unfortunate location in a remote,

TABLE 11. RESERVOIR ROCK AND PETROLEUM DATA FOR THE WHITE RIM SANDSTONE, TAR SAND TRIANGLE, SOUTHEASTERN UTAH.*

	RESERVOIR ROCK PERMEABILITY (Millidarcys)						PETROLEUM				
	Before Oil Extraction	After Oil Extraction	Vertical	Porosity (percent)	Pore Saturation (percent) Oil	Pore Saturation (percent) Water	Gallons /Ton	Liters/ Metric Ton	Gallons /Yd.3	Percent Volume	Percent Weight
No. of Samples	121	121	71	121	121	121	121	121	121	121	121
Mean	268.25	340.10	302.44	19.81	32.16	4.67	7.12	24.40	6.00	6.54	2.98
Range	0.03-2,560	0.07-2,790	0.1-2,200	9.7-31.7	5.8-85.4	0.9-31.4	0.5-30.8	1.7-105.6	0.4-25.9	0.5-26.9	0.2-12.9

*All figures are arithmetic means of data for four wells drilled in T.30 S., R.16 E., Wayne County, Utah. Base data courtesy of Santa Fe Energy Company.

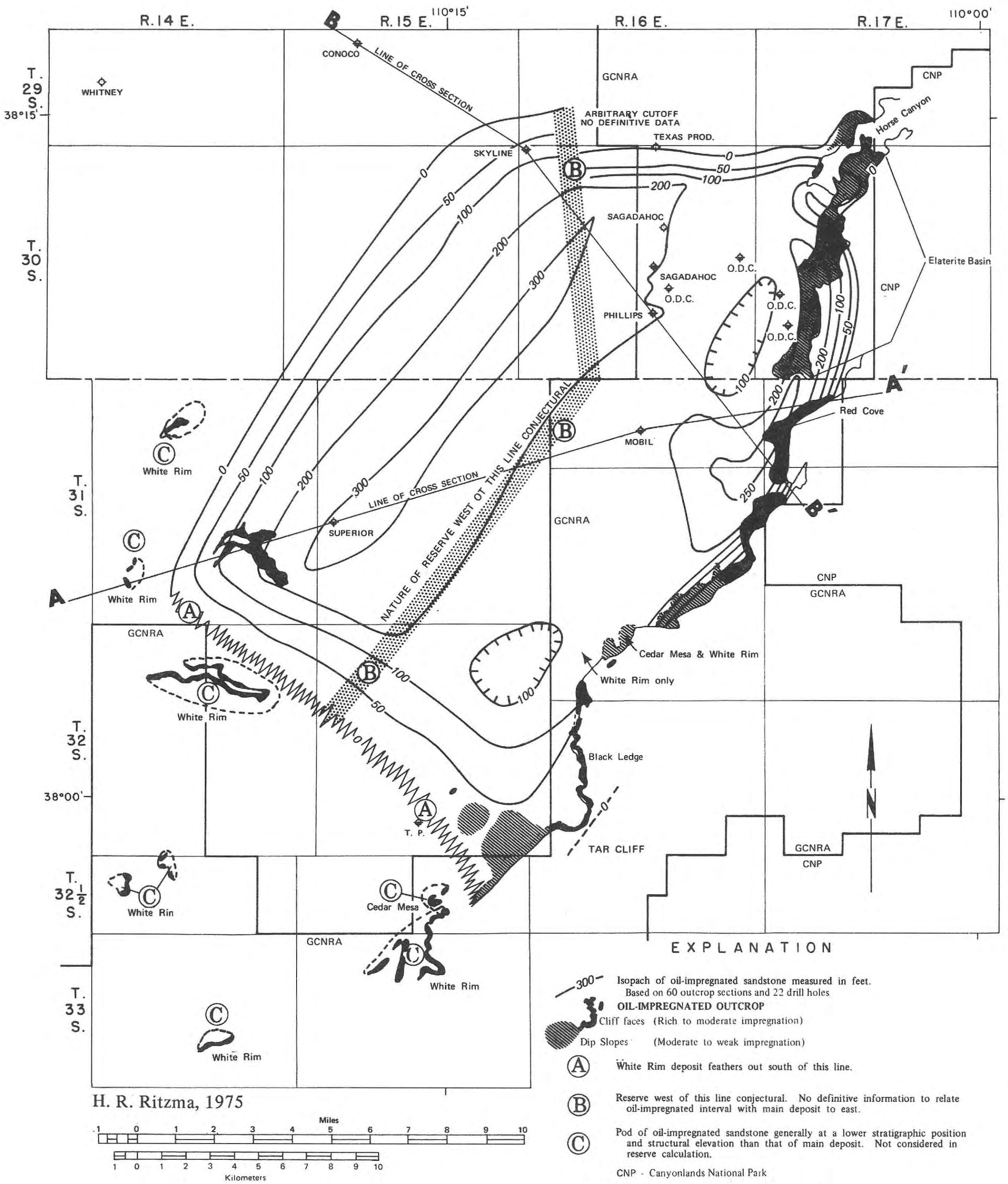
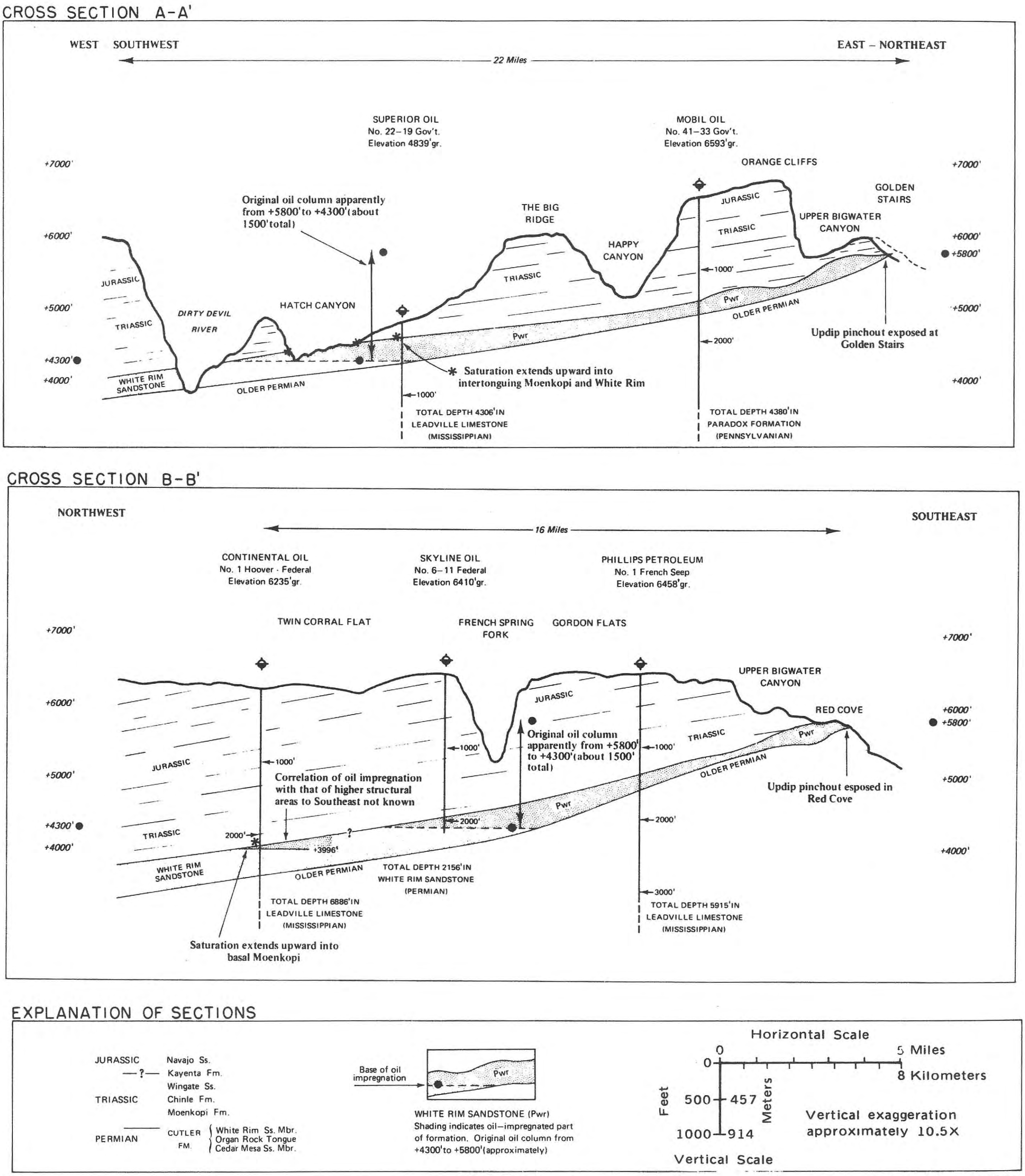


Figure 7. Thickness map of oil saturated White Rim sandstone, Tar Sand Triangle, Wayne and Garfield Counties, southeast Utah.



H. R. Ritzma, 1975

Figure 8

TAR SAND TRIANGLE

SECTIONS SHOWING OIL COLUMN IN WHITE RIM SANDSTONE

WAYNE AND GARFIELD COUNTIES, SOUTHEAST UTAH rugged, and scenic area. Berry (1977) has reviewed the legal and political difficulties faced by his company in its efforts to undertake a pilot fire flood occupying approximately 1½ acres (5000 m²) of ground overlying the deposit.

Circle Cliffs

The Circle Cliffs deposit is a giant, inspissated oil field which is formed in a stratigraphic and structural trap in the Moenkopi Formation and the Shinarump Conglomerate (Triassic) on the anticlinal Circle Cliffs uplift (figure 9). Most of the petroleum occurs in the fine-grained sandstone and siltstone of the Torrey Member of the Moenkopi Formation which is of deltaic origin (Blakey, 1974, p. 36; 1977, p. 80). The reservoir rock is poorly developed in the central part of the uplift, so that the deposit is in two parts (figure 10). The gross oil-impregnated section is as much as 260 feet (80 m) thick on the east flank, and up to 310 feet (95 m) thick on the west flank. The quality of bituminous rock varies from traces of petroleum to black rock which oozes viscous petroleum. Available engineering data are summarized in table 12. Davidson (1967, p. 20) estimates, on the basis of outcrop observations, that most of the eastern part of the deposit is of moderate to rich oil saturation, but that the west flank is generally of lower oil saturation. Field work by the Utah Geological and Mineral Survey indicates that the best parts of the deposit occur in an east-west direction, in an area that includes Muley Twist and Silver Falls tar seep (figure 9).

Most of the east flank of the deposit now lies within the Capitol Reef National Park, and much of the west flank is under wilderness review by the U. S. Bureau of Land Management.

This study is largely taken from the text and slides of a paper presented by Campbell before the First International Conference on the Future of Heavy Crude and Tar Sands held in Edmonton, Alberta, Canada, June 1979. The conference was sponsored by UNITAR (United Nations Institute for Training and Research).

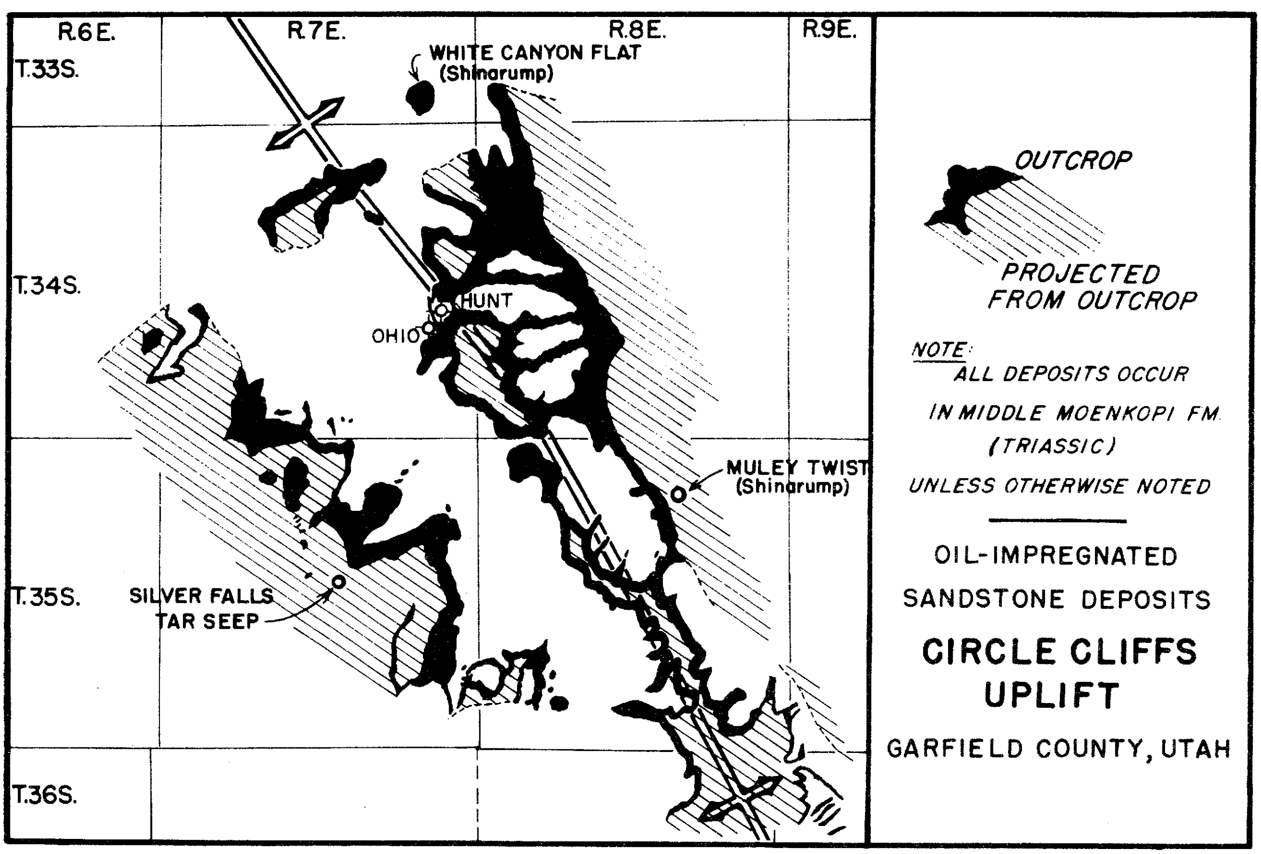


Figure 9.

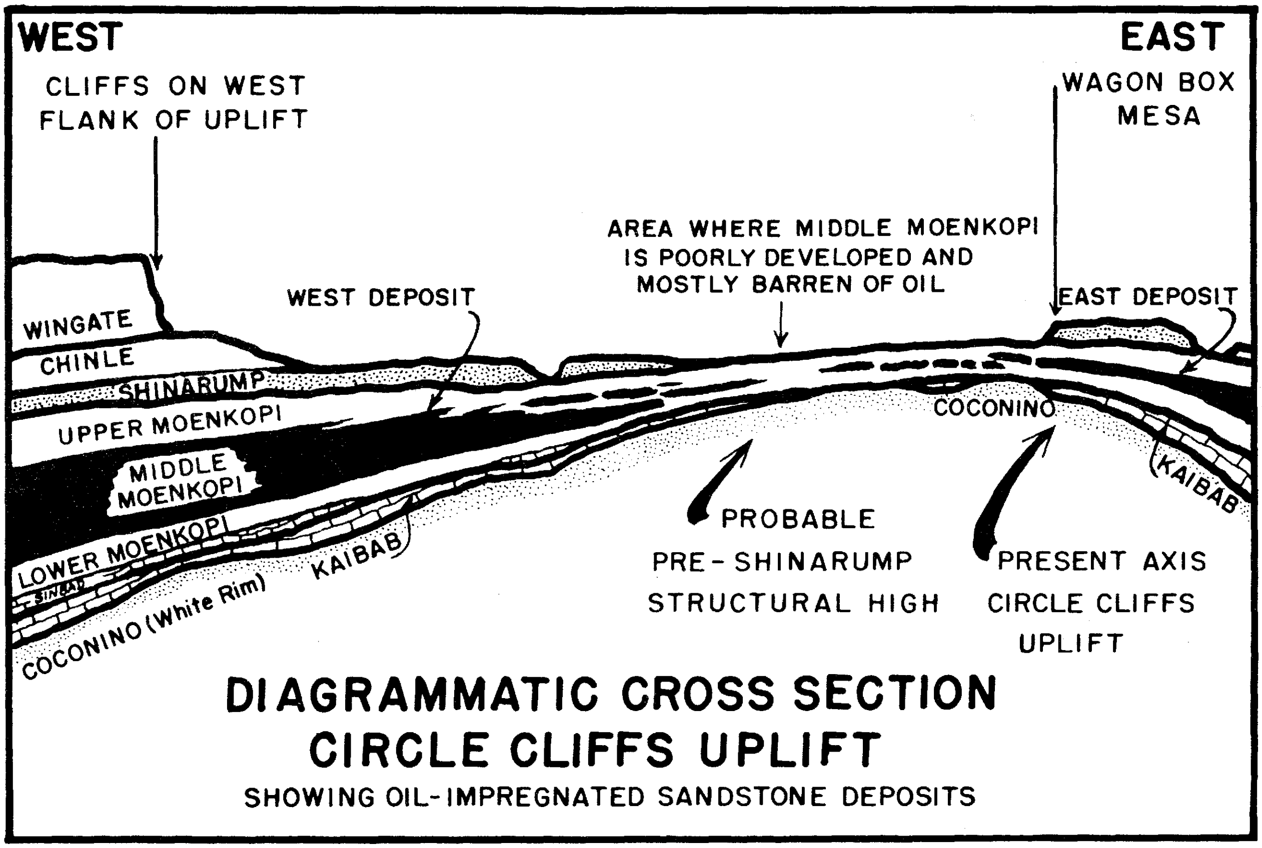


Figure 10

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TABLE 12. SELECTED PROPERTIES OF THE CIRCLE CLIFFS OIL-IMPREGNATED ROCK DEPOSIT, SOUTH-CENTRAL UTAH

	Gravity (°API)	Petroleum (Wt. percent)	Porosity (After oil extraction)	Permeability (After oil extraction)	Sulfur (percent)
CORE HOLES					
West Flank (Moenkopi Fm.)[1]	16.2	7.3	15.25%	1.66 md.	2.7
East Flank (Shinarump Cgl.)[2]	-4.35	---	---	---	3.7
OUTCROP					
West Flank[3] (Moenkopi Fm.)	1.97	---	---	---	4.2
East Flank (Moenkopi Fm.)	2.22	---	---	---	3.6
(Shinarump Cgl.)[4]	2.67	---	---	---	4.0

1 Mean of 4 samples: Courtesy Rio Vista Oil Co., Salt Lake City, Utah.

2 Mean of 2 samples: White Canyon Flat area.

3 One sample: Silver Falls seep.

4 Mean of 2 samples: Muley Twist area.

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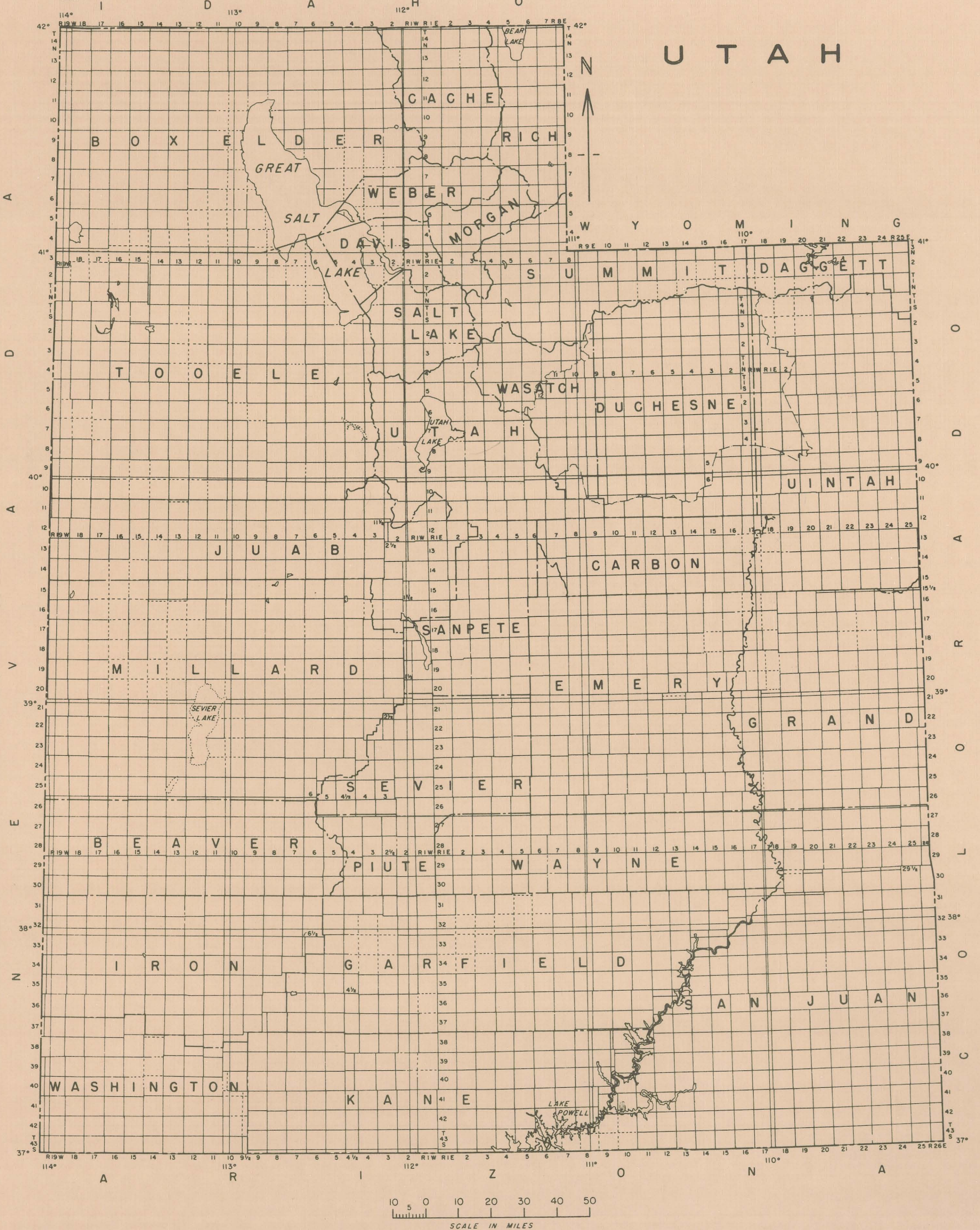

UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
Salt Lake City, Utah 84108

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