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Properties of Utah Tar Sands—Asphalt Wash Area, P.R. Spring Deposit

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PROPERTIES OF UTAH TAR SANDS–ASPHALT WASH AREA, P.R. SPRING DEPOSIT

by

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ABSTRACT

This Bureau of Mines report presents the analysis of three cores from the Asphalt Wash area of the P.R. Spring tar sand deposit of northeastern Utah. Two tar sand zones are indicated in the Asphalt Wash Area. Total net thickness of the tar sand ranges from 23 to 39 ft, with occurrences between 56 and 263 ft in depth. The sand has average porosity of 24.7 pct of bulk volume, average permeability before and after extraction of 87.5 and 596 md, respectively, and average oil saturation of 58.1 pct of pore volume. Oil gravity averages 10.9° API.

INTRODUCTION

In Utah, there are 24 tar sand deposits that have been explored enough to determine that they contain approximately 28 billion barrels of oil (8).[3] Seventeen of these deposits are in the Uinta Basin and contain between 10 and 11.3 billion barrels of viscid "sweet" oil, with an average sulfur content of less than 0.5 pct (9). The P.R. Spring deposit contains 4 to 4.5 billion barrels of this oil.

The present methods of oil extraction from tar sands, mining and plant extraction, are economically prohibitive in most of the Utah tar sand deposits owing to the amount of overburden in these areas. The expansion of in situ recovery technology to tar sands would provide a supplemental source of oil to help stem the growing shortage of clean hydrocarbon fuels.

The Bureau of Mines is conducting research on tar sands with the following objectives: (1) To determine the technical and economic feasiblity of using in situ methods for the recovery of oil from tar sands, and (2) to develop a system for classifying tar sands relative to those characteristics that effect in situ recovery. Toward the latter end, 17 cores from 3 tar sand deposits in the Uinta Basin in northeastern Utah have been analyzed. These cores were cut

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[3] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

luring the summer of 1973 as part of a tar sand evaluation program of the Utah eological and Mineral Survey (UGMS), which was supported by the Bureau of lines. Results of analyses of these cores are being presented in a series of eports: The first (4) concerns the Threemile Canyon area, P.R. Spring eposit, and gives details of the UGMS program; the second (3) concerns the outh Seep Ridge area, P.R. Spring deposit; and the present report gives the hysical properties that have been determined on tar sand obtained from three oreholes that were drilled along a generally east-west line in the Asphalt ash area of the P.R. Spring deposit.

ACKNOWLEDGMENT

The Bureau of Mines wishes to express appreciation to the UGMS for the ores used in this study, and especially to Howard Ritzma, assistant director f the UGMS, for the help and advice that he has contributed to this study of he characteristics of Utah tar sands. Appreciation is also extended to P.R. eterson, private consultant, of Salt Lake City, for detailed geological escriptions provided with the cores.

DESCRIPTION OF AREA

The Asphalt Wash area is in the northeast part of the P.R. Spring tar and deposit, which covers approximately 350 square miles of proven or inferred ar sands in Uintah and Grand Counties of northeasten Utah. The deposit ccurs in all or parts of townships 12 to 17 south, ranges 21 to 25 east, Salt Lake base and meridian. The geographical and geological features of this general area were previously described (4).

Access to the Asphalt Wash area is via graded roads from Bonanza, Utah, which is 25 miles to the North, and from Ouray, Utah, which is 40 miles to the northwest. Locations of the Asphalt Wash coreholes, together with the other UGMS coreholes in the P.R. Spring deposit, are given in table 1. Of the three Asphalt Wash coreholes, PR-5 is centrally located about 3.6 miles east of PR-1, and 3.9 miles west of PR-4, as shown in figures 1 and 2. In figure 2, the solid bands indicate the tar sand zones; however, the solid bands do not represent continuous

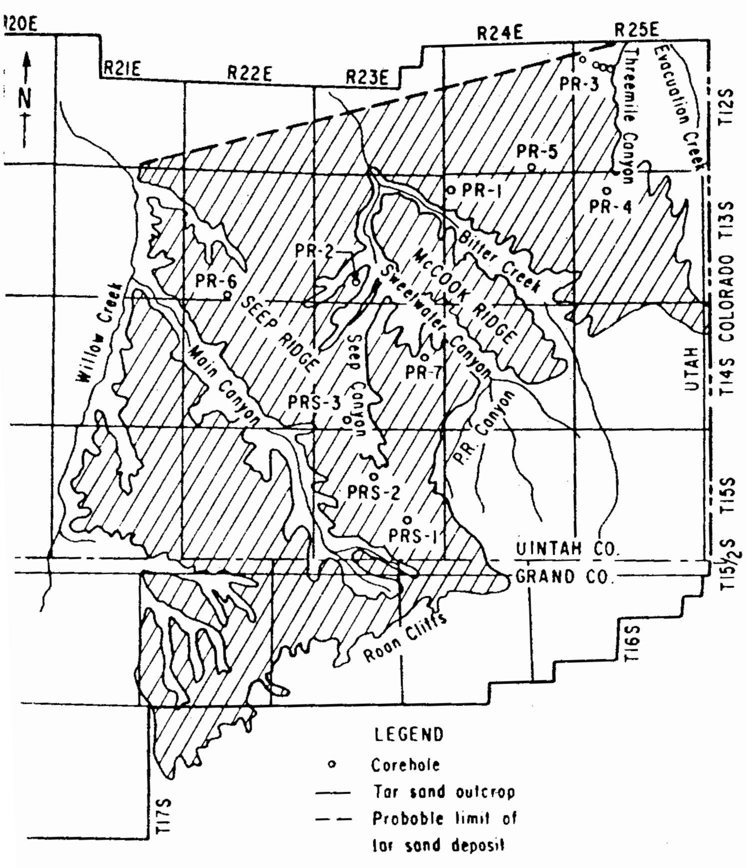

FIGURE 1. - Map of P.R. Spring tar sand deposit.

saturation at every point. The strata in this area increase in depth toward the west from PR-4.

TABLE 1. - UGMS corehole locations and elevations in the P.R. Spring deposit

Corehole	Location	Surface elevation, ft
ASPHALT WASH AREA		
PR-1	SWNESW sec 6,T 13 S,R 24 E	6,210
PR-5	NESWNE sec 34,T 12 S,R 24 E	6,437
PR-4	NESESW sec 5,T 13 S,R 25 E	7,187
SOUTH SEEP RIDGE AREA		
PRS-1	SENENE sec 27,T 15 S,R 23 E	8,010
PRS-2	NESENW sec 16,T 15 S,R 23 E	7,702
PRS-3	NESWSE sec 32,T 14 S,R 23 E	7,387
THREEMILE CANYON AREA		
PR-3A	NWNESW sec 8,T 12 S,R 25 E	6,302
PR-3B	NENWSW sec 8,T 12 S,R 25 E	6,361
PR-3C	SWSWNW sec 8,T 12 S,R 25 E	6,430
PR-3D	SESWNE sec 7,T 12 S,R 25 E	6,512
OTHER P.R. SPRING COREHOLES		
PR-6	SESWSW sec 33,T 13 S,R 22 E	6,707
PR-2	SESESE sec 29,T 13 S,R 23 E	6,346
PR-7	SWNWNE sec 14,T 14 S,R 23 E	6,798

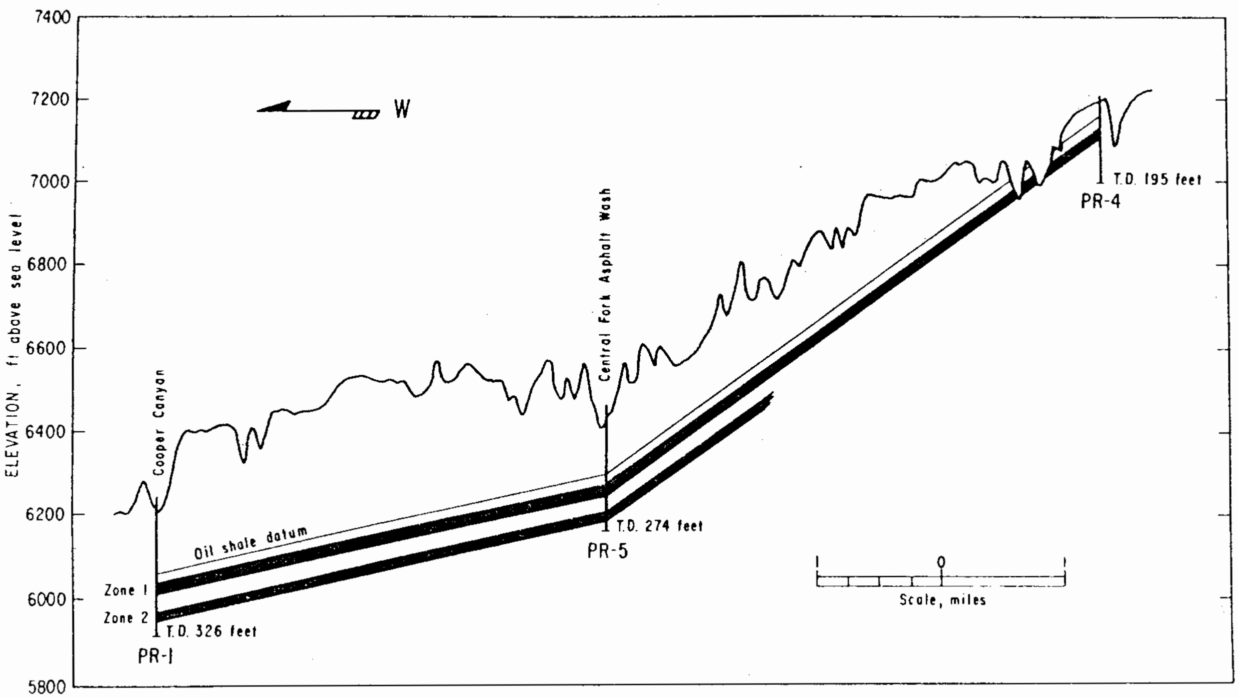

FIGURE 2. - Cross section of Asphalt Wash area.

The Asphalt Wash area is highly dissected and is cut by branches of Bitter Creek on the south and southwest, by branches of Evacuation Creek on the east, and by the West Fork and Central Fork of Asphalt Wash throughout the remaining area. Several of the intercanyon areas merge in the higher central portion to form an area known as Big Park. Surface elevations decrease from 7,200 ft in the east to 6,200 ft in the west, as shown in figure 2, and decrease from 7,000 ft in the south to 6,000 ft in the north.

All of the surface in the Asphalt Wash area, except the northwestern corner, consists of members of the Green River Formation. The Evacuation Creek Member crops out in the northern portion of the area. The Parachute Creek Member is found on the ridge tops and higher central region, where the coreholes of this report are located. The Mahogany oil shale bed, an excellent geologic marker, is exposed in the Parachute Creek Member. The Douglas Creek Member is exposed in the southern, highly dissected edge of the area and in the bottom of East Seep Canyon. The younger Uinta Formation covers the northwestern corner of the area.

ANALYTICAL PROCEDURES

Core Sample Preparation

The cores are NX size (2-1/8-inch-diameter), and were cut in 10-ft lengths, using air as the drilling fluid. The top half of each foot of core was wrapped in plastic and transported to the Bureau's Laramie Energy Research Center for analysis.

Three sets of samples were prepared from each core to determine oil and water saturation, porosity, permeability, and compressive strength. For the oil and water saturation test, 50 to 60 grams of sample are chipped from the top of each 1/2 ft. For porosity and permeability tests, a 3/4-inch-diameter plug is cut adjacent to where the chips are taken; the plug is trimmed to 1 in length, with the ends perpendicular to the sides. Two full-diameter cores, trimmed perpendicular to the sides to 2 inches long, are used for the compressive strength tests. Each full-diameter core sample represents about 10 ft of saturated interval; intervals less than 4 ft thick are not sampled for compressive strength testing. The oil extracted from the full-diameter core samples is used for oil characterization tests.

Drilling and cutting of samples is usually done with water as the drilling fluid. Occasionally the drilling of the 3/4-inch plugs becomes difficult in highly saturated cores owing to a tendency for the oil and rock flour to "ball-up" on the bit. This difficulty is overcome by using a sodium hydroxide solution as drilling fluid.

Porosity and Permeability Tests

Porosity and permeability are determined on the 3/4-inch plugs both before and after the oil is extracted. The plugs are weighed and dimensionally measured before testing.

Porosity is calculated from sand grain volume that is measured in a Boyle's law porosimeter by helium displacement (5) and from bulk volume that is measured in a mercury pycnometer (6). Porosity is calculated by the equation

$$\phi = \frac{V_B - V_S}{V_B} 100,$$

where V_B is bulk volume, V_S is sand grain volume, and ϕ is the porosity expressed in percentage of bulk volume.

Permeability is determined using a Hassler-type permeameter (2) and the equation

$$K = \frac{2546\ q\ \mu\ L}{D^2} \frac{P_o}{(P_i^2 - P_o^2)},$$

where K is the permeability in millidarcy, q is the flow rate in cubic centimeters per second, μ is gas viscosity in centipoise, L and D are sample length and diameter in centimeters, respectively, P_o is atmospheric pressure in atmospheres, and P_i is the injected pressure in absolute atmospheres.

After determining porosity and permeability, the plugs are extracted with benzene in a Soxhlet extractor for 24 hours and then dried in an oven at 200° F for 24 hours. After cooling, they are reweighed, and the extracted porosity and permeability are determined.

Compressive Strength Testing

Compressive strength is determined on one of the full-diameter cores before oil extraction and on the other after extraction, using a commercially available tension-compression tester rated at a maximum load of 200,000 pounds. An increasing load is applied to a core until it destructs. Compressive strength is calculated using the load at failure and the core dimensions, in accordance with an ASTM procedure (1).

Both cores are weighed (one before and one after compression testing) and then extracted with benzene in a modified Soxhlet extractor until the refluxing benzene is clear. The Soxhlet is modified to permit continuous refluxing instead of cyclic refluxing and manual draining of the upper reservoir. The usual fiber thimble is replaced with a glass thimble fitted with a 145μ to 165μ fritted disk. Following extraction, the samples are dried and reweighed. The benzene-oil mixture for each pair is filtered, and the benzene is removed by distillation. The residual oil is recovered for analysis of the oil properties.

Oil and Water Saturation Determinations

Oil and water saturations are determined with the chip samples by the Dean-Stark method (7), which gives the water volume directly. Toluene is used as the solvent for this extraction because of its immiscibility with water. The oil weight is determined by the difference in saturated and extracted sample weights minus the weight of the water. Knowing the specific gravity of the oil, the porosity of the plugs, and the volume and weight of oil and water extracted, the oil saturation is calculated as percent of pore volume and percent of initial sample weight. Water saturation is calculated as percent of pore volume.

TAR SAND CHARACTERISTICS

Several properties of the tar sands have been determined both before and after removal of the oil by solvent extraction. For simplicity, "saturated" refers to the condition before oil extraction, and "extracted" refers to the condition after oil extraction.

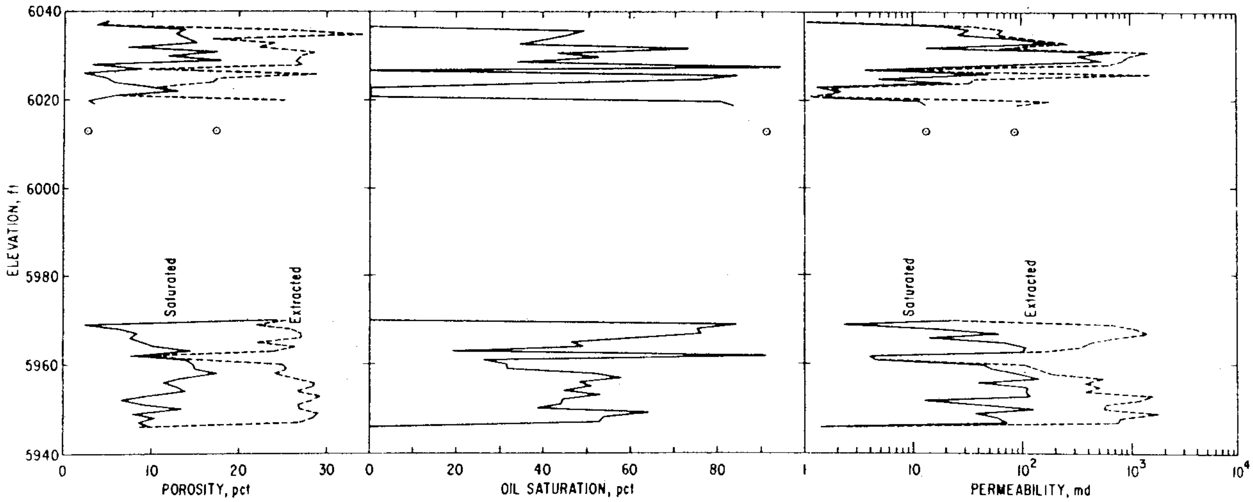

FIGURE 3. - Porosity, oil saturation, and permeability versus elevation, corehole PR-1.

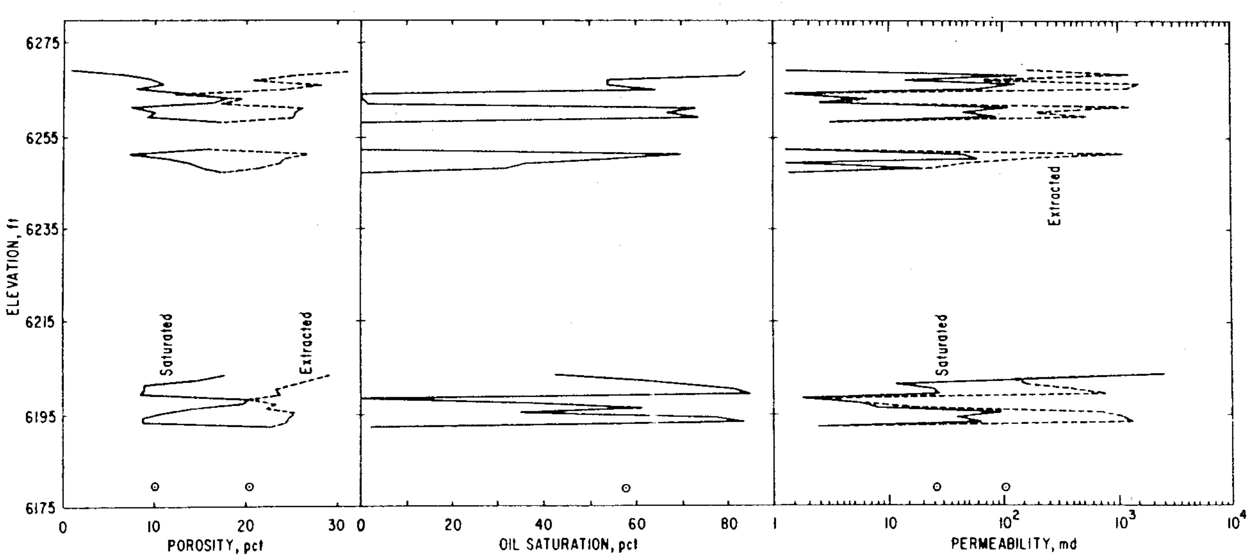

FIGURE 4. - Porosity, oil saturation, and permeability versus elevation, corehole PR-5.

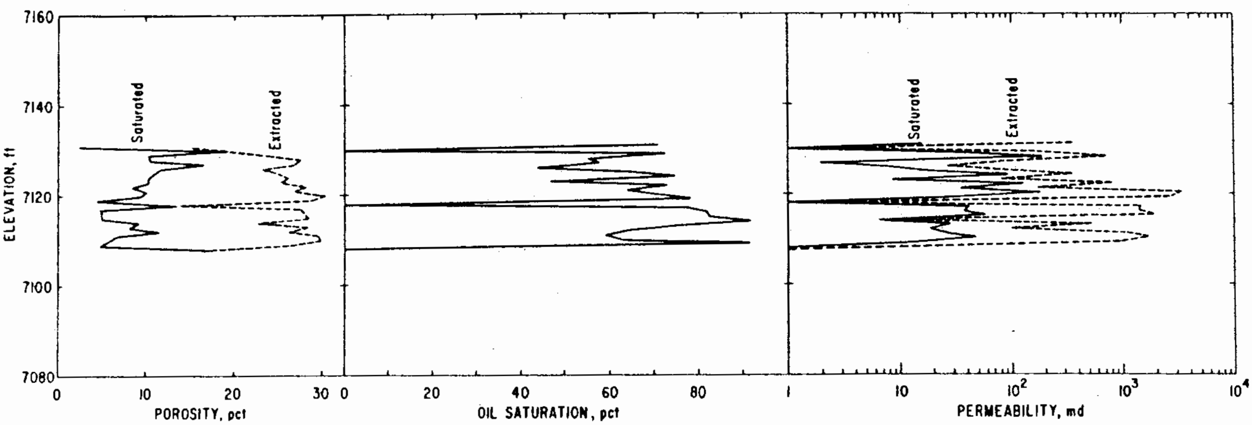

FIGURE 5. - Porosity, oil saturation, and permeability versus elevation, corehole PR-4.

Elevation, depth, thickness, physical properties, and range of physical properties for PR-1, PR-5, and PR-4 are listed in table 2. Porosity, oil saturation, and permeability for each core are plotted versus elevation in figures 3, 4, and 5. In figures 3 and 4, the circled dots represent isolated footage that was analyzed.

Saturated porosity averages 9.9 pct of bulk volume and ranges from 0.7 to 20.3 pct. Extracted porosity averages 24.7 pct and ranges from 8.1 to 34.3 pct.

Saturated and extracted permeabilities average 87.5 and 596 md, respectively. The saturated permeability ranges from 0.4 to 1,993 md; only 19.8 pct of the samples have a permeability greater than 100 md. Extracted permeability shows a greater range of values, from 0.4 to 3,437 md; 70.9 pct of the samples have permeability greater than 100 md, and 23.3 pct have permeability greater than 1,000 md.

Oil saturation averages 58.1 pct of pore volume and ranges from 0 to 94.7 pct. Oil saturation, in percent of sample weight, averages 6.8 pct and ranges from 0 to 11.7 pct.

Water saturation ranges from 0.1 to 10.7 pct of pore volume and averages 1.8 pct. The water saturation for 77 pct of the samples is less than 2.0 pct; it is greater than 5.0 pct for only 5 pct of the samples.

The saturated bulk density ranges from 2.002 to 2.457 g/cm^3 and averages 2.139 g/cm^3. The sand grain density averages 2.655 g/cm^3 and ranges from 2.561 to 2.774 g/cm^3.

Compressive strength, which is an indication of the relative degree of sand consolidation, averages 3,993 and 4,007 psi for the saturated and extracted samples, respectively.

The extracted oil has an average specific gravity of 0.994 and ranges from 0.979 to 1.015. Average oil gravity is 10.9° API.

TABLE 2. - Summary of core analysis and corehole data, Asphalt Wash area

Corehole	PR-1			PR-5			PR-4			Overall
	Av	Min	Max	Av	Min	Max	Av	Min	Max	av
Surface elevation....ft above mean sea level..	6,210	-	-	6,420	-	-	7,187	-	-	-
Top of tar sand, depth....................ft..	174	-	-	151	-	-	56	-	-	127
Bottom of tar sand, depth.................ft..	263	-	-	241	-	-	79	-	-	194
Net thickness of tar sand.................ft..	39	-	-	24	-	-	23	-	-	29
Porosity, saturated......................pct..	9.9	2.2	17.9	10.8	0.7	20.3	9.0	2.5	18.9	9.9
Porosity, extracted......................pct..	24.3	8.1	34.3	24.5	19.8	31.0	25.5	13.9	30.3	24.7
Permeability, saturated...................md..	89.7	2.3	671	123	0.5	1,993	44.6	0.4	191	87.5
Permeability, extracted...................md..	534	4.7	1,819	507	1.8	2,000	795	0.4	3,437	596
Oil saturation..............pct of pore vol..	54.2	0	94.7	59.1	0	84.9	63.5	0	91.7	58.1
Oil saturation.............pct of sample wt..	6.1	0	11.7	6.9	0	11.4	7.9	0	11.3	6.8
Water saturation............pct of pore vol..	2.1	0.1	10.7	1.7	0.1	4.1	1.4	0.1	5.9	1.8
Bulk density, saturated...............g/cm^3..	2.152	2.004	2.368	2.127	2.002	2.303	2.128	2.019	2.457	2.139
Bulk density, extracted...............g/cm^3..	2.014	1.793	2.355	2.012	1.832	2.116	1.962	1.810	2.335	1.999
Sand grain density....................g/cm^3..	2.663	2.561	2.774	2.664	2.585	2.761	2.632	2.597	2.747	2.655
Compressive strength, saturated.........psi..	4,092	2,465	5,063	3,756	1,621	5,439	4,099	3,506	5,270	3,993
Compressive strength, extracted.........psi..	4,616	3,893	5,664	3,152	1,728	4,269	4,049	3,632	4,280	4,007
Oil specific gravity at 60° F................	0.992	0.979	0.999	0.989	0.987	0.991	1.001	0.990	1.015	0.994
Oil gravity........................° API..	11.1	10.1	13.0	11.6	11.3	11.9	9.9	7.9	11.4	10.9

DISCUSSION OF RESULTS

Based on the occurrence of oolitic-algal beds, the tar sand in the Asphalt Wash area can be divided into two major zones, as shown in figure 6. The oolitic-algal beds are found in each core and are separated by barren shale and siltstone. The first zone also occurs approximately 30 ft below the oil shale beds which occur in all three cores.

Zone 1, the top zone, averages 17 ft in thickness and has an oil saturation of 60.9 pct, as shown in table 3. Zone 2 has about the same thickness (18 ft), but the oil saturation is lower (53.9 pct).

TABLE 3. - Properties of tar sand by well and zone

Well	PR-1	PR-5	PR-4	PR-1	PR-5	PR-4	All 3	All 3
Zone	1	1	1	2	2	2	1	2
Net thickness of tar sand......ft..	16	12	23	23	12	0	17	18
Porosity, saturated...........pct..	8.9	9.1	9.0	10.6	12.5	-	9.0	11.3
Porosity, extracted...........pct..	23.2	25.0	25.5	25.1	23.9	-	24.7	24.7
Permeability, saturated........md..	128	47.2	44.6	62.9	199	-	71.5	110
Permeability, extracted........md..	401	532	795	627	483	-	609	577
Oil saturation....pct of pore vol..	57.1	61.0	63.5	52.2	57.3	-	60.9	53.9
Water saturation..pct of pore vol..	2.6	1.9	1.4	1.7	1.5	-	1.9	1.6
Bulk density, saturated.....g/cm^3..	2.183	2.147	2.128	2.130	2.107	-	2.150	2.122
Sand grain density..........g/cm^3..	2.664	2.633	2.632	2.661	2.696	-	2.642	2.673
Compressive strength, saturated psi..	4,812	2,915	4,099	3,852	5,437	-	3,823	4,248
Compressive strength, extracted psi..	3,893	2,594	4,049	4,858	4,269	-	3,538	4,710
Oil specific gravity at 60° F......	0.979	0.989	1.001	0.996	0.989	-	0.993	0.995
Oil gravity................° API..	13.0	11.6	9.9	10.6	11.6	-	11.0	10.7

Saturated porosity for zone 1 is lower than for zone 2; however, both zones have the same extracted porosity.

A higher saturated permeability is found in zone 2, but the extracted permeability is higher in zone 1.

The oil specific gravity differs by only 0.002 between zones 1 and 2, and the water saturation is higher in zone 1 than in zone 2 by only 0.3 pct

Zone 2 has higher sand grain density and higher compressive strength than zone 1.

Tar sand properties in the Asphalt Wash area not only vary between zones, but also vary within a zone with direction of increasing depth. Thickness of tar sand in zone 1 is greatest at PR-4 and least at PR-5, whereas the tar sand of zone 2 decreases in thickness from PR-1 to PR-5 and is not present in PR-4.

Saturated porosity in zone 1 is approximately constant, while the extracted porosity, extracted permeability, and oil saturation decrease in the direction of increasing depth. All other properties increase in the direction of increasing depth, except compressive strength, which shows no general trend.

In zone 2 the saturated porosity, saturated permeability, oil saturation, and sand grain density all decrease with depth. The other properties increase in the direction of increasing depth, except compressive strength, which exhibits no overall trend.

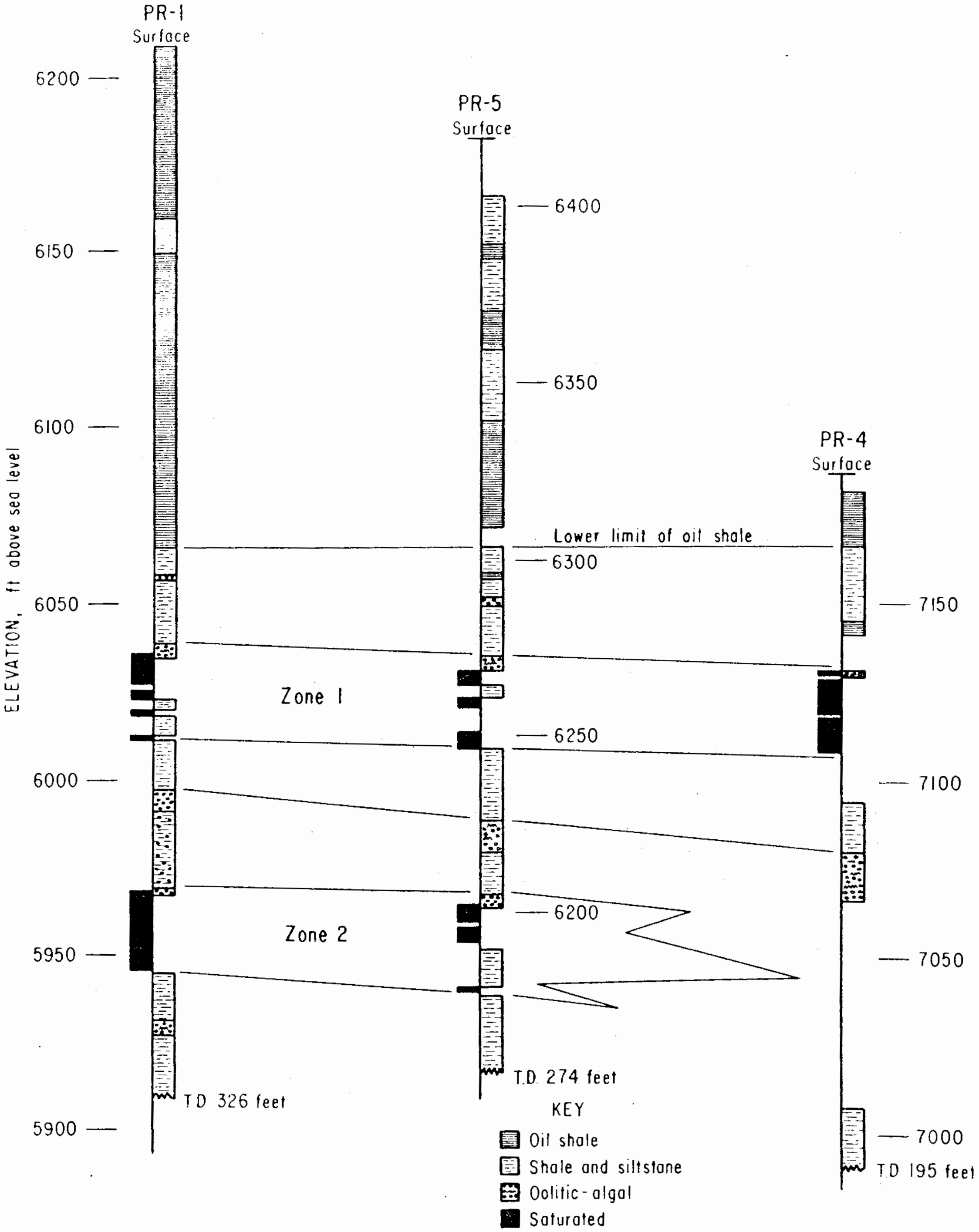

FIGURE 6. - Columnar sections of Asphalt Wash area.

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