The Oil Resources in Tar Sand Deposits in the United States

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SUMMARY

This report summarizes the data available at the Laramie Energy Technology Center. An effort was made to catalogue U.S. tar sand resources, identify U.S. and state maps showing tar sand deposits, and attempt to compare tar sand oil recovery processes.

A review of the available data indicated there were oil resource estimates on the deposits most discussed, namely in California, New Mexico, Texas, and Utah, but the data were actually limited. Almost no definitive data were available for the California deposits. Most of the available data were from four or five major Utah deposits. The most data were from the P. R. Spring and Asphalt Ridge Northwest deposits. A good example of the availability of data was at the P. R. Spring deposit where 17 core holes had been drilled in an areal extent of the deposit of 240 to 270 square miles. This equates to about one core hole per 14 square miles. The majority of the available data is from a few core holes and visual inspection of the outcrops. There are some good data for small areas available but more data are needed to obtain a better knowledge of the potential oil resource from tar sand deposits. The emphasis on developing alternative resources such as from tar sand is relatively new, so no doubt good data will be forthcoming.

The latest maps showing the tar sand deposits in the United States and for individual states were published in 1964. Utah, where most of the activity on tar sand deposits is taking place, has had its Survey update their maps showing tar sand deposits. Individual state surveys are becoming more interested in identifying their tar sand deposits, so this should result in new maps on deposits.

Economic comparisons to determine the best recovery method of oil from tar sand deposits are not feasible at this time. There are a number of research recovery projects in operation, but most of these are bench models plus a few field tests. The background data are not available to make a logical determination as to which process is more efficient or economical. The basis for most of the present data is from in situ thermal recovery in heavy oil reservoirs. It is just too soon to make a comparison of what process should be used to recover oil from tar sand.

OVERVIEW

Occurrences of tar sand deposits in the United States are numerous and widespread (Figure 38). Deposits are known to exist in 22 of the 50 United States. The two deposits identified in Figure 38 as locations 1 and 2 are shown to be too large for available data. Present data indicate that heavy oil resources are included with the tar sand resources. The reader is mislead by the size of these deposits when observing Figure 38 because the tar sand resources of these locations are not included in the tables.

The largest deposits are known to exist in the state of Utah (Figure 39). Utah's tar sand deposits contain between 23 and 29 billion barrels of the United States' 24.8 to 36 billion barrels of oil resources from tar sand. Six of the Utah deposits contain 78 percent of the oil resource in the United States, and the state contains 81 percent of the total U.S. oil resource.

WORLD OIL RESOURCES

Global resources of oil should be compared to obtain a perspective of their significance to a particular source. The importance of the various sources of oil is seen in Table 1. If we consider natural crude oil as the base source of oil, because of its ease of extraction, a correlation can be made between crude oil reserves and needed development of other oil sources.

As seen in the table, Canada has the least crude reserves and therefore must look to other sources for an oil supply. The abundant resource in tar sand would therefore be a logical source for development of a needed reserve, namely oil. Not only are the Canadian deposits large, they are accessible for development. Canada is the only country of the world which is producing oil from tar sand. In 1978 Canada produced about 64 million barrels of oil from its tar sand deposits. Development of the oil resources from tar sand and oil shale is dependent upon technology and economic conditions. In the U.S., emphasis on technological development had been in the extraction of oil from oil shale because of the large resource base. Now, because of declining oil production and increasing imports of oil, the U.S. is also

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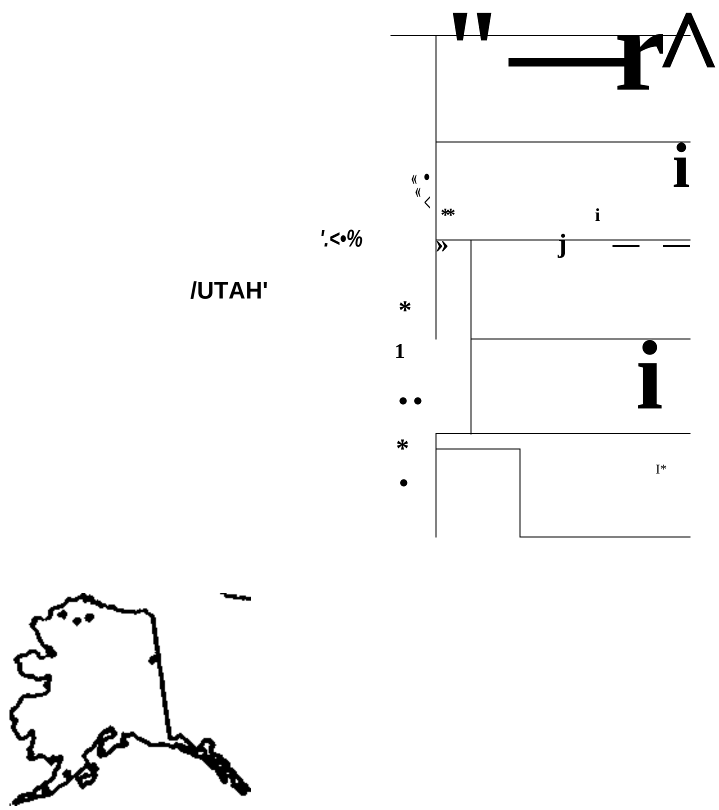

Figure 38. Tar Sand Occurrences in the U.S.

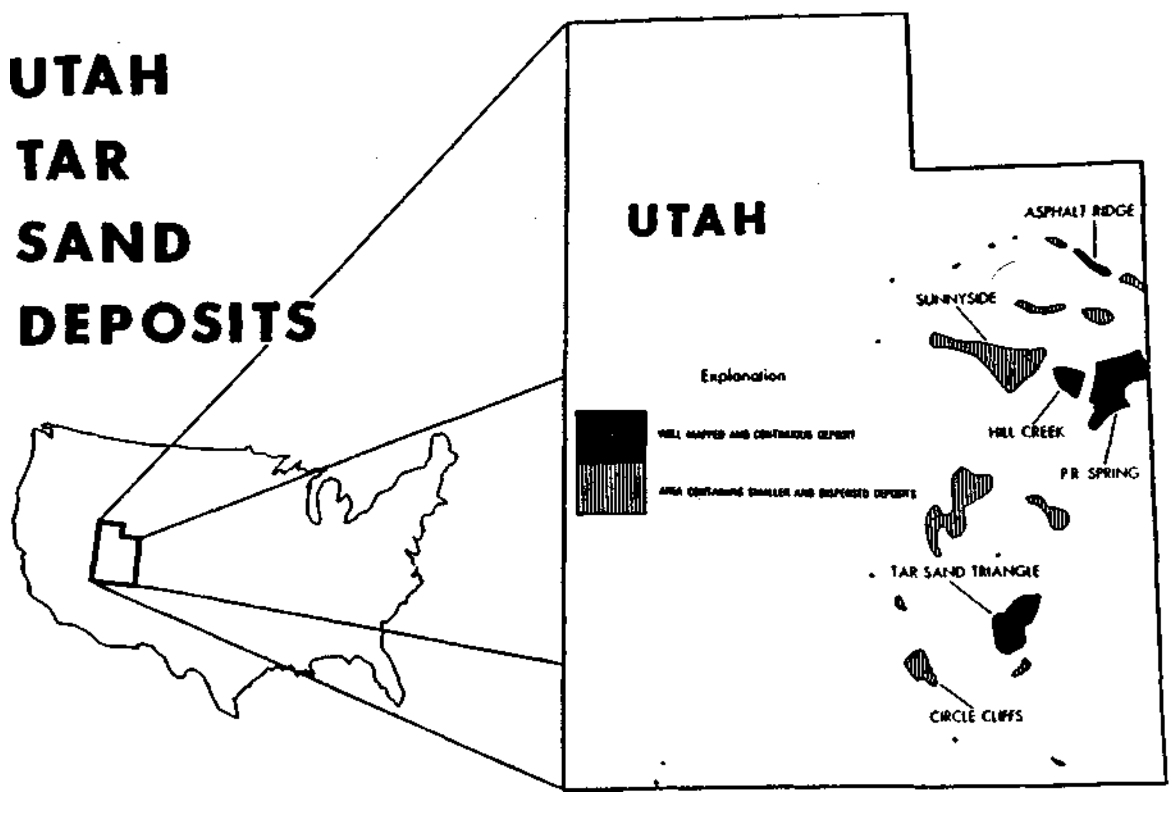

Figure 39. Major Utah Tar Sand Deposits

TABLE 1 - COMPARISON OF WORLD RESOURCES AND RESERVES FOR TAR SANDS, OIL, AND OIL SHALE

Commodity	Africa	Canada	Europe	Venezuela	USSR	U.S.A.	Totals
Tar Sand							
Resource 10^9 bbl.	1.75	2,000.00	0.4	1,000.00	168.00	362	3,206.35
Reserve 10^9 bbl.[17]	.175	333.00	.06	100.00	16.00	2.90	452.135
Crude Oil							
Resource 10^9 bbl.	475.8[s7]	50	198.3[27]	140.0	55S.3[27]	260.0	1,542.4
Reserve 10^9 bbl.	57.1	6.8	23.8	17.9	67.0	26.5	199.1
Oil Shale							
Resource 10^9 bbl.	356^	0	1.043[37]	0	—	2,800.00	4.199
Reserve 10^9 bbl.	1.4		4.1			11.0	16.5

[y] Country estimates
[27] Resource calculated on assumption that reserves are 12% of original oil in place
[37] Estimated on basis of U.S. recovery

advancing its technology for extraction of oil from tar sand deposits. The examples of what is happening in the U.S. and Canada is a picture of what is happening world wide. New technology along with the more favorable economic conditions for extraction of oil from tar sand will see a development of tar sand deposits world wide.

GEOLOGY

Tar sand deposits are found in rock ages from the Pliocene Epoch of Tertiary Age to rocks of Mississippian Age (Table 2). The majority of the deposits found in rocks of Mississippian and Pennsylvanian Ages are located east of the Rocky Mountains. These mountains are located in the western third of the United States. The major deposits are found in younger rocks primarily in the Epochs of the Tertiary Age.

In California, the deposits are found in the two youngest Epochs of the Tertiary Age. These deposits are found along the coast between the cities of San Francisco and Los Angeles. Several of the tar sand deposits are near conventional heavy oil reservoirs.

Utah has 53 tar sand deposits with the majority of the deposits in the eastern half of the state. The Uinta Basin in the northeast portion of the state contains 25 deposits of which 23 are located in rocks of Tertiary Age. The other two deposits are in rocks of Cretaceous and Permian Ages. The 22 deposits in the central southeast portion of the state are found in rocks of Permian and Triassic Ages. A point of interest regarding the Triassic Age deposits is the fact that very little oil has been found in Utah in rocks of this age.

Most of the deposits occur in sandstone which, with finer grain size, grades into siltstone. About 99 percent of the deposits are located in either sandstone or siltstone. These oil-impregnated sandstone or siltstone deposits do not necessarily occur as a single bed but rather as a number of beds within the formation. The Utah deposits are a good example of this type of deposition. The number of beds varies from one bed to as high as twelve beds but averages from one to three beds.

MAJOR U.S. DEPOSITS

The major deposits in the United States are shown in Table 3. From this table it is evident that the majority of the deposits are located in California and Utah. A lack of sufficient information on other deposits throughout the United States does not permit the inclusion of those resource estimates in this table.

Programs are under way in California, western Missouri, northeastern Oklahoma, Texas, and Utah to evaluate the tar sand resources. Other states have expressed interest to the Department of Energy for cooperative efforts to evaluate tar sand resources. In addition to these efforts, the Department of Energy is engaged in resource evaluation work at the Laramie Energy Technology Center.

California's Division of Oil and Gas has recently reviewed its tar sand occurrences and revised the estimate of the oil in place at seven deposits. These revisions have increased the resource estimate ranges from 270 to 323 million barrels to the 1,407.8 to 3,092.6 million barrels shown in Table 3. Although these new resource estimates are just that — "estimates" — more intensive investigation is required to prove these figures. This initial work indicates that the resource potential is much larger than previously anticipated.

Utah, the state with the largest resource base, has been the most active state in the determination of the tar sand resource. The evaluation work in Utah is being done by the Utah Geological and Mineral Survey. The Survey has found that the Uinta Basin contains 8.8 to 11.3 billion barrels of oil in place, and central southeast Utah contains 14.1 to 17.9 billion barrelsof oil in place. In the Uinta Basin 95 percent of the total resources are in four giant deposits. In central southeast Utah 93.5 percent of the resources are in two giant deposits. Even with the extensive work done by the Utah Survey, the resource estimates are not that firm because many assumptions had to be made because good data are lacking. Some of the assumptions made were based on porosity, percent pore space filled with oil, percent water saturation, and deposition at least 1,320 feet back of the outcrop. Here, we have a state with the most intensive investigation active and yet only a limited amount of definitive data. The primary cause for entrapment of oil is associated with stratigraphic factors, principally porosity and permeability variations, rather than structure.

OIL CHARACTERISTICS

Data on the oil characteristics are very limited as is seen in Table 4. If the oil characteristics are known for

TABLE 2 - GEOLOGICAL AGE OF DEPOSITS

Slate and Deposit	Formation	Type of Rock	Age
Alabama	Bangor, Hartselle, Pride Mountain	Sandstone & Limestone	Mississippian
California			
Edna	Pismo	Sandstone	Upper Miocene Lower Pliocene
Oxnard	Vaca	Sandstone	Pliocene
Santa Maria	Foxen	Sandstone	Pliocene
Richfield	Pe petto	Sandstone	Pliocene
Sisquoc	Careago	Sandstone	Pliocene
South Casmalia	Sisquoc	Mudstone	Upper Miocene Lower Pliocene
North Casmalia	Sisquoc	Mudstone	Upper Miocene Lower Pliocene
Kentucky	Big Cliffy, Bee Spring, Kyruck	Sandstone	Late Mississippian Early Pennsylvanian
New Mexico			
Santa Rosa	Santa Rosa	Sandstone	Triassic
Texas			
Uvalde	Anacasho	Limestone	Cretaceous
Utah			
Tar Sand Triangle	White Rim, Cedar Mesa, Moenkopi, Skinarump	Sandstone Conglomerage	Permian Triassic
P. R. Spring	Green River	Sandstone Siltstone	Eocene
Sunnyside	Wasatch	Sandstone Siltstone	Eocene
Circle Cliffs	Moenkopi	Sandstone Siltstone	Triassic
Asphalt Ridge	Duchesne Rimrock	Sandstone Siltstone	Eocene Cretaceous
Hill Creek	Green River	Sandstone Siltstone	Eocene
San Rafael Swell	Mossback, Kaibab	Sandstone to Limestone	Triassic Permian
Asphalt Ridge, NW	Asphalt Ridge, Rimrock		Cretaceous
Raven Ridge	Green River	Sandstone Siltstone	Eocene
Whiterocks	Navajo	Sandstone Siltstone	Jurassic
Wickiup	Moenkopi	Sandstone Siltstone	Triassic
Argyle Canyon	Green River	Sandstone Siltstone	Eocene

the California deposits, it is in individual company files. These oil characteristics are very important if the deposits are to be considered for any type of experimental work, in situ projects, or strip mining. Information on the Utah deposits is the most plentiful but some of this data are questionable. Specific Gravity data in published reports is the most consistent of the data. There is quite a variation in the API gravity of the oil in published reports, in one case by as much as 10° API. Sulfur content varies but there is not as much published information on the weight percent of sulfur. Information on the viscosity or pour point of the oil is limited to information from one publication. In one publication, the viscosity is listed as high at reservoir temperatures. From Table 3, we can see that the sulfur content is low in all but two of the Utah deposits. Sulfur content in the Tertiary rocks of the Uinta Basin ranged from. 19 percent to .62 percent and in the Permian and Triassic rocks of southeast Utah ranged from 2.94 percent to 4.36 percent.

The API gravity of the oil is relatively consistent for all the deposits except the Tar Sand Triangle deposit in Utah and the Uvalde deposit in Texas. Work done by the Utah Geological and Mineral Survey indicated that the Oil characteristics can vary from deposit to deposit in the same Basin even though the source rock from which the oil migrated is from the Green River formation of Eocene Age.

RESERVOIR CHARACTERISTICS

Data on reservoir characteristics for the majority of the deposits are lacking as can be seen in Table 5. The most complete data again are from the Utah deposits. Although there are variations in the porosity of the Utah deposits, overall the porosities for the deposits are high. Oil saturation of the pore space are consistently over 50 percent except for the Hill Creek and Whiterocks deposits. The saturation at the Hill Creek deposit is known to be low according to the Utah Survey, so the data presented are assumed to be accurate.

The weight percent of oil varies from a low of 3.7 percent to a high of 10.5 percent. In various publications, the weight percent differs as much as four percentage points, mostly upward, so the accuracy of these data should be verified. For comparison, the Athabasca tar sand deposit has an average weight percent of about 11 and an *economic* cutoff limit of above 6 percent. It should be pointed out that the economic limit is dependent upon a number of factors such as: temperature, location, product distribution, and labor force. Therefore, the economic limit can change depending upon the location of the deposit.

The thickness shown for the Uvalde deposit is a gross thickness and not a net thickness. In the Utah deposits

TABLE 3 — TAR SAND RESOURCES OF U.S.

State and Deposit	Estimated Resources (Millions of Barrels) Low	High
California		
Edna	141.4	175
Oxnard	565	565
Santa Maria	500	2,000
Richfield	40	40
Sisquoc	29	106
South Casmalia	46.4	46.4
North Casmalia	40.0	40.0
Other deposits	16.0	20.2
California Total	1,407.8	3,092.6
Kentucky	33.5	37.3
New Mexico: Santa Rosa	57.2	600
Texas: Uvalde	124.1	3,000
Utah		
Tar Sand Triangle	12,504	16,004
P.R. Spring	4,000	4,500
Sunnyside	3,500	4,000
Circle Cliffs	1,000	1,507
Asphalt Ridge	1,000	1,200
Hill Creek	300	1,160
San Rafael Swell	385	470
Asphalt Ridge, Northwest	100	125
Raven Ridge	75	100
Whiterocks	65	125
Wickiup	60	75
Argyle Canyon	60	75
Other deposits	1,255	171.3
Utah Total	23,164.5	29,512.3
United States Total	24,787.1	36,242.2

there can be as many as twelve beds in a gross section, but the average number of beds is from one to three. The gross thickness of the sand formations ranges from five to 35 feet at Hill Creek to a high range of 15 to 550 feet at Sunnyside. The beds are lenticular and high to correlate even within a deposit with the limited amount of core data available.

The overburden range differs widely in California but is quite consistent in Utah. Good overburden control is lacking because of the limited number of core holes drilled. More core holes would help define the depth of overburden so the method of recovery can be determined such as in situ or strip mining.

The yield of the reservoirs differs from a low of 3.7 gallons per ton in Alabama to a high of 31.4 gallons per ton at Whiterocks in Utah. The data on yields vary as did the weight percent data, which are in direct correlation. More definitive values must be obtained to make these data»meangingful.

AVAILABLE MAPS

Monograph 12, Surface And Shallow Oil-Impregnated Rocks And Shallow Oil Fields In The UnitedStates, was a cooperative effort of the United States Department of Interior Bureau of Mines and the Interstate Oil Compact Commission (Table 6). This publication contains a map of the United States (Figure 38), and individual state maps. Shown on the state maps are the counties and the location of the tar sand deposits. Detail on the maps are limited because they are on 8^-inch by 11-inch pages. The report was published in 1964 and has not been updated.

TABLE 4 — OIL CHARACTERISTICS

	Specific Gravity 60/60°F	Pour Point °F	Viscosity @60°Fcp	Gravity °API	Welght% Sulfur	Nitrogen
Alabama						
California						
Edna					3.0	1.2
Oxnard						
Santa Maria						
Richfield				12		
Sisquoc						
S. Casmalia						
N. Casmalia						
Kentucky						
New Mexico						
Santa Rosa	.987	170-190	32,000	11.9	2.2	0.1
Texas						
Uvalde				-2	10	
Utah						
Tar Sand Triangle	1.042	95		5.48	3.79	0.56
P. R. Spring	.998	115	10^6 @ 70° F	10.3	0.43	1.0
Sunnyside	1.004	115		9.5	0.6	
Asphalt Ridge	.98	95		12.9	0.39	0.9
Hill Creek	1.004			9.4	0.4	0.77
San Rafael Swell					3.82	
Asphalt Ridge, N.W.	.97	140-150	10^6	14.3	0.4	1.4
Raven Ridge	1.014			8.0	0.35	0.77
Whiterocks	.996			10.6	.48	1.3
Wickiup					2.43	
Argyle Canyon					.3	0.83

TABLE 5 - RESERVOIR CHARACTERISTICS

	Porosity % (Sat.)	**Oil Sat. % pore**	**Water Sat. %**	**Permeability Md (Sat.)**	**Oil Wt%**	**Net Thickness Ft.**	**Overburden Range Ft.**	Gal/ In.
Alabama		4-56	25		1.5			3.7
California								
Edna								
Oxnard							1800-2500	
Santa Maria								
Richfield						80	2500-3200	
Sisquoc						85	70	30
S. Casmalia								
N. Casmalia								
Kentucky					6.2-10.5			10-15
New Mexico								
Santa Rosa	10-13			100-200	4.5-5.0		50	10.7-12
Texas: Uvalde	30	35-55	30-35	200-1800		70?	1500	
Utah								
Tar Sand Triangle	20	67.4	5	133	9.4	**40**	0-500	12.1
P. R. Spring	26.8	58.1	1.8	219	6.8	35.2	0-500	14.7
Asphalt Ridge	26.5	51-72		5-745			0-500	13-27
Hill Creek	22.4	39	16.8	120	3.7	60.8	0-500	8.8
San Rafael Swell							0-500	
Asphalt Ridge, N.W.	31.1	65	2.4	675	6.07	13.5	0-275	14.5
Raven Ridge							0-500	
Whiterocks	23	23	58	10-127			0-500	4.6-31.4
Wickiup							0-500	
Argyle Canyon							0-500	
Sunnyside	17.5	51.8	20.9	570	5.4		0-500	12.9

The Utah Geological and Mineral Survey has two maps, 44 and 47, showing the oil-impregnated rock deposits. Map 44 is on a scale of 1:500,000 and is called *Energy Resource Map of Utah.* The map shows the location of oil-impregnated rock deposits as well as other known energy mineral deposits. The map also outlines the principal geological structural divisions. Map 47 is on a scale of 1:1,000,000 and is called *Oil-Impregnated Rock Deposits of Utah.* The map shows all the deposits and has a written text on the deposits. The map also identifies the geological structures.

The *Oil Sands Mineral Right Ownership* map is a map of eastern Utah. The map shows the State, Federal and Fee acreage under lease at the various deposits. Located on the map are the various geological structures along with the drainage patterns. The owners of the leases are identified by numbers and listed in the margin of the map.

RECOVERY METHODS

Recovery of oil from tar sand deposits can be accomplished by mining or in situ recovery. At the present time, mining and surface processing are the only methods of oil recovery from tar sand. A number of experimental projects involving both in situ and mining with surface processing have been tried, and present in situ projects are being operated on an experimental scale. These projects are, and have been, tried throughout the country. An economic survey of some Utah deposits was done for the Department of Commerce with one of the results being that in much of the area there was too little overburden (350 feet minimum) for in situ thermal processes and too much overburden for surface mining. If the overburden is not great enough to develop an in situ thermal process, then with a net pay thickness of 60 feet there should be some site amenable to surface mining even if an overburden-to-pay ratio is 1:1.

Possibly a large scale mine could not be started but certainly small scale operations could be started. This point is brought out to illustrate that if the overburden is 350 feet or less (the information in Table 5 indicates the overburden range is from 0 to 500 feet), then at some point the overburden must be in the range of 120 feet (ratio of 1:1) which is in the range of a surface mining operation. This example of a report coming to this type of result further illustrates the lack of sufficient data available necessary to come to reasonable conclusions.

In Table 7 are eight research projects which are attempting to overcome some of the problems associated with producing oil from tar sand. The research primarily involves in situ recovery methods with most projects involving some form of steam recovery, namely

TABLE 6 — **AVAILABLE MAPS**

Map	**Source**
United States	**Surface And Shallow Oil-Impregnated Rocks And Shallow OH Fields In The United States, Monograph 12,** U.S. Bureau of Mines, Interstate Oil Compact Commission, P.O. Box 53127, Oklahoma City, OK 73152
Individual	Same as above
Utah	Map 47. **Oil-Impregnated Rock Deposits of Utah,** Utah Geological and Mineral Survey, 606 Black Hawk Way, Research Park, Salt Lake City, Utah 84108. Price — $2.00
Utah	Map 44. **Energy Resources Map of Utah,** Utah Geological and Mineral Survey, see above for address.
Utah	**Oil Sands Mineral Right Ownership Utah,** The Pace Company, 650 South Cherry Street, Suite 400, Denver, Colorado 80222. Price — $25.00

steam injection. The Illinois Institute of Technology Research Institute project, although a thermal project, is an attempt to recover oil by a radio-frequency heat process. The eighth project, conducted by the U.S. Bureau of Mines, was actually a field test conducted at the Kern River field during 1979. The results were favorable as a method of extracting the tar sand and bringing it to the surface. Further work in this area is anticipated.

The Laramie Energy Technology Center (LETC) is also doing research on the characteristics of several heavy bitumens and synthetic crude oils. The purpose of this research is to determine the ability of the oil extracted from tar sand to be used as a feedstock for refining.

In addition to the laboratory research, a number of field tests are under way and these projects are shown in Table 8. All of these projects involve in situ recovery methods except one. The Getty Oil Co. project at the McKittrick field in Kern County, California, is testing a mining and surface processing method. Four of the five projects are in California where considerable experience has been developed through use of cyclic steam and steam drive techniques. The fifth project is in Utah, where most of the U.S. tar sand resource deposits occur. All of the pilot tests are on small tracts ranging from .11 acres at the Asphalt Ridge site to 5 acres at Cat Canyon field. The mining project is using a terraced excavation plan of 250-350 acres at a time. The surface processes will test the Dravo solvent and Lurgi retorting processes. Other potential surface processes are the Hot Water Process developed by Al Hack and Associates and In situ Hydrogenation developed by Hydrocarbon Recovery Systems.

Comparisons of economical in situ thermal processes have been attempted and these results are shown in Table 9. Good data is not available to compare the economic value of one process over another. The majority of these comparisons are based on bench scale experiments but until these projects have operated successfully at the field scale level it is too early to judge the merits of one process over the other. The Mining and Hot Water Flotation process developed by Al Hack & Associates, Inc. of Denver was operated at the pilot plant level for a period of one year, in 1961, with good results. This process can possibly be considered the most successful operation. Many of these projects did not take into account one or more of the following: operating costs, royalty interest, upgrading the tar, and taxes. In the LETC project, the economics were figured by starting at a selling price and then working backwards. Paper comparisons have been and will be made but until successful field tests have been performed, good data will not become available. These paper comparisons are of value only if used in their proper perspective for future analyses of field projects.

TABLE 7 — RESEARCH PROJECTS

Researcher	Research Emphasis	Recovery Method	Investigative Areas
University of Southern California	Chemical Additives	Steam-flood	Temperature effect on surfactant absorption and on the mechanism of flow in low tension systems; surfactant floods at elevated temperatures; interfacial tensions on the spinning drop apparatus; and caustic floods at elevated temperature
University of Southern California	Sealed Physical Model	Steam-flood	Effect of the velocity of overriding steam on oil displacement in a reservoir
Sandia Laboratories	Down-hole steam generator	Steam-flood	Develop economic downhole steam generator and modified well completion techniques for use with deep steam injection
Illinois Institute of Technology Research Institute	Radio-frequency	Thermal heat	Electrical behavior of tar sand; uniformity of heating; ability to produce from deposits after heating; net energy ratios; and economic aspects
Standford University Petroleum Research Institute	Temperature effect on reservoir	Steam-flood	Temperature and pressure effect on relative permeability to oil and water, capillary pressure, and electrical resistivity
Laramie Energy Technology Center	Water availability, Injection fluids, and fracturing	Steam drive	Availability of water; practical range of temperature and pressure and type of fluids for steam stimulation; fracturability of tar sand
Carmel Energy, Inc.	Combustion gas and water vapor	Vapor Therm.	Mixture of combustion gases and water vapor
U.S. Bureau of Mines	Hydraulic lift	Mining	Feasibility of bringing tar sand to the surface by hydraulic mining process

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