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Some Geologic Aspects of Coal Accumulation, Alteration, and Mining
In Western North America: A Symposium

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Oil-Impregnated Rocks of Utah: Distribution, Geology and Reserves

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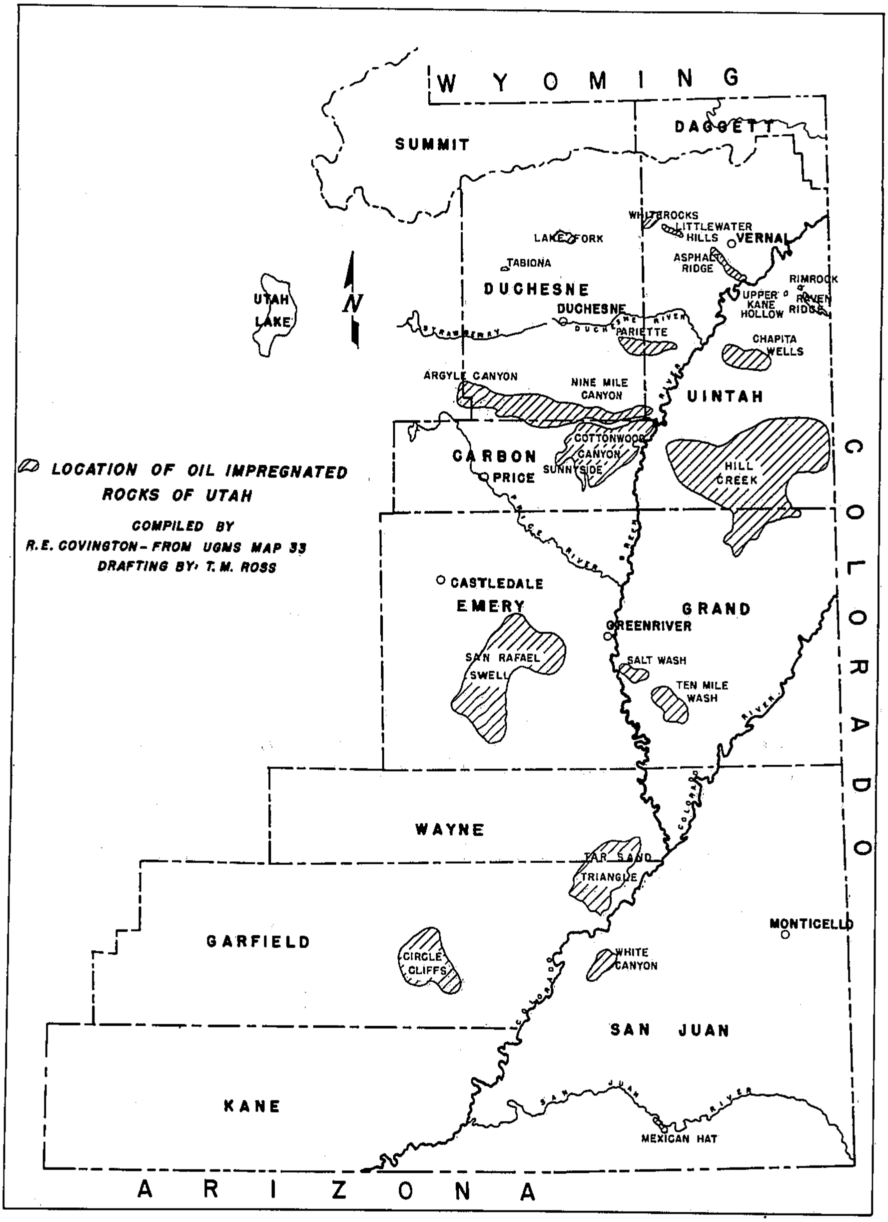
ABSTRACT.—Oil-impregnated rocks of Utah contain in excess of 24 billion barrels of gross oil in place. All the major deposits are located in the eastern half of the state in two areas, the Uinta Basin of northeastern Utah and the Central Southeast area. Oil in most of the Uinta Basin deposits originated in the lacustrine Green River Formation of Eocene age and, on the south flank of the Basin, are all located within this formation or in the underlying Wasatch Formation. On the north flank, the oil occurs in rocks of Jurassic, Cretaceous and Tertiary age. The largest oil-impregnated sandstone deposit in the Uinta Basin, the Sunnyside deposit, has gross oil in-place estimated at 4 billion barrels. This deposit is discussed in detail. In the Central Southeast area, most of the oil-impregnated rocks are of Permian and Triassic age. The Tar Sand Triangle is the largest deposit and contains 12.5 billion barrels of gross oil in-place in the Permian White Rim Sandstone. Recent activity on these deposits is discussed.

Oil-impregnated rocks of Utah contain very significant reserves of oil, estimated to be in excess of 24 billion barrels. The deposits are located in two areas of eastern Utah, the Tar Sand Triangle of central southeastern Utah, which contains an estimated 14 billion barrels of oil, and the Uinta Basin of northeastern Utah, which contains an estimated 11 billion barrels. The location of the known deposits is indicated on the index map (Figure 1). The deposits will be reviewed briefly, except for the Sunnyside deposit, which will be discussed in more detail. A brief resumé of the *in situ,* reverse combustion process to recover oil from tar sands along Northwest Asphalt Ridge is described by Lee C. Marchant in the accompanying paper.

The Uinta Basin contains 25 deposits (Ritzma, 1974) of which four are classified by size as "Giant" (more than 500 million barrels of in-place oil). These include the Asphalt Ridge, Hill Creek, P. R. Springs, and Sunnyside deposits. There are three Utah deposits classified as "Very Large" (100-500 million barrels). These are the Argyle Canyon, Raven Ridge, and Whiterocks deposits. In the "large" category (10-100 million barrels) there are seven deposits—the Asphalt Ridge Northwest, Cottonwood-Jack's Canyon, Littlewater Hills, Minnie Maud Creek, Pariette, Rim Rock, and Willow Creek deposits. Nearly all of the deposits in the Uinta Basin contain oil which originated in Tertiary age source beds, the lacustrine Green River Formation. Over half of these are *in situ* type deposits, with the oil originating in the Green River Formation and remaining there or in the subjacent Wasatch Formation.

The Asphalt Ridge and Northwest Asphalt Ridge bituminous sandstone deposits are located a few miles west of Vernal, Utah. Bitumen saturation occurs in beds of Cretaceous and Tertiary age. In-place oil reserves are estimated at 1.3 million barrels, with approximately one-half of the reserves occurring in each of the two different age groups. The author believes that the oil in the Cretaceous Mesaverde Formation originated in adjacent Cretaceous source beds. Substantiating data is that the Mesaverde bitumen is very similar in chemical analysis to an intermediate-base crude oil and the fact that a very definite oil-water contact is present (fossil oil-water contact). Bitumen in the Duchesne



TEXT-FIGURE 1.—Index map of location of oil impregnated rocks of Utah.

River Formation more closely resembles the very high, paraffin base Green River Formation crude oils.

The bituminous sandstones of Asphalt Ridge area are the remnants of several Mesaverde and Duchesne River oil fields that have been exhumed by Quaternary erosion. The oil in the Asphalt Ridge and Rim Rock Sandstones is found on two prominent anticlinal noses, one near the north end of Asphalt Ridge and the other near the south end. These anticlines had their inception in late Cretaceous or early Paleocene time as the result of Laramide Orogeny. Additional uplift, faulting and regional tilting occurred in Eocene, Oligocene, and Quaternary times. Pre-Duchesne River regional tilting and truncation exposed the oil bearing sands, allowing the lighter fractions of the oil to escape. The immobile, asphalt-like bitumen was left.

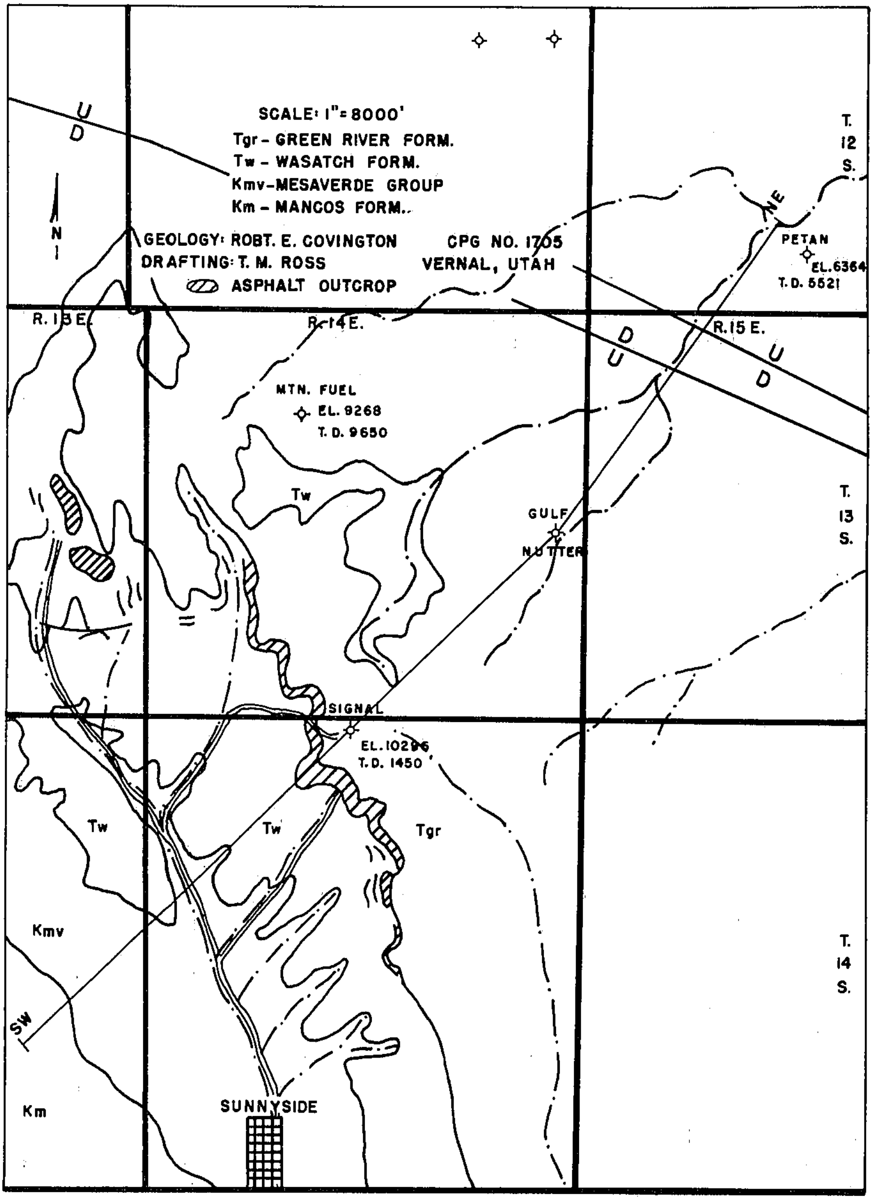
Bitumen saturation in the Duchesne River Formation is stratigraphically trapped by updip pinchouts of lenticular, fluvial sandstones and conglomerates. The bitumen deposits show no relationship to the unconformities along which the Duchesne River Formation overlaps the Mesaverde, Wasatch, Green River, and Uinta Formations. The bitumen is distributed in sandstones and conglomerates throughout the formation as much as several hundred feet above the unconformity (i.e., many authors in past have thought that the oil in the Duchesne River Formation migrated from Green River Formation up and across unconformities into the Duchesne River sandstones and conglomerates).

In most cases on Asphalt Ridge, if porosity and permeability are developed in the Duchesne River sandstones and conglomerates, they are oil saturated and the degree of saturation is directly related to porosity. There also is a decided higher concentration of oil saturation on anticlinal features. Some of the thicker, more extensive sandstones show definite oil-water contacts.

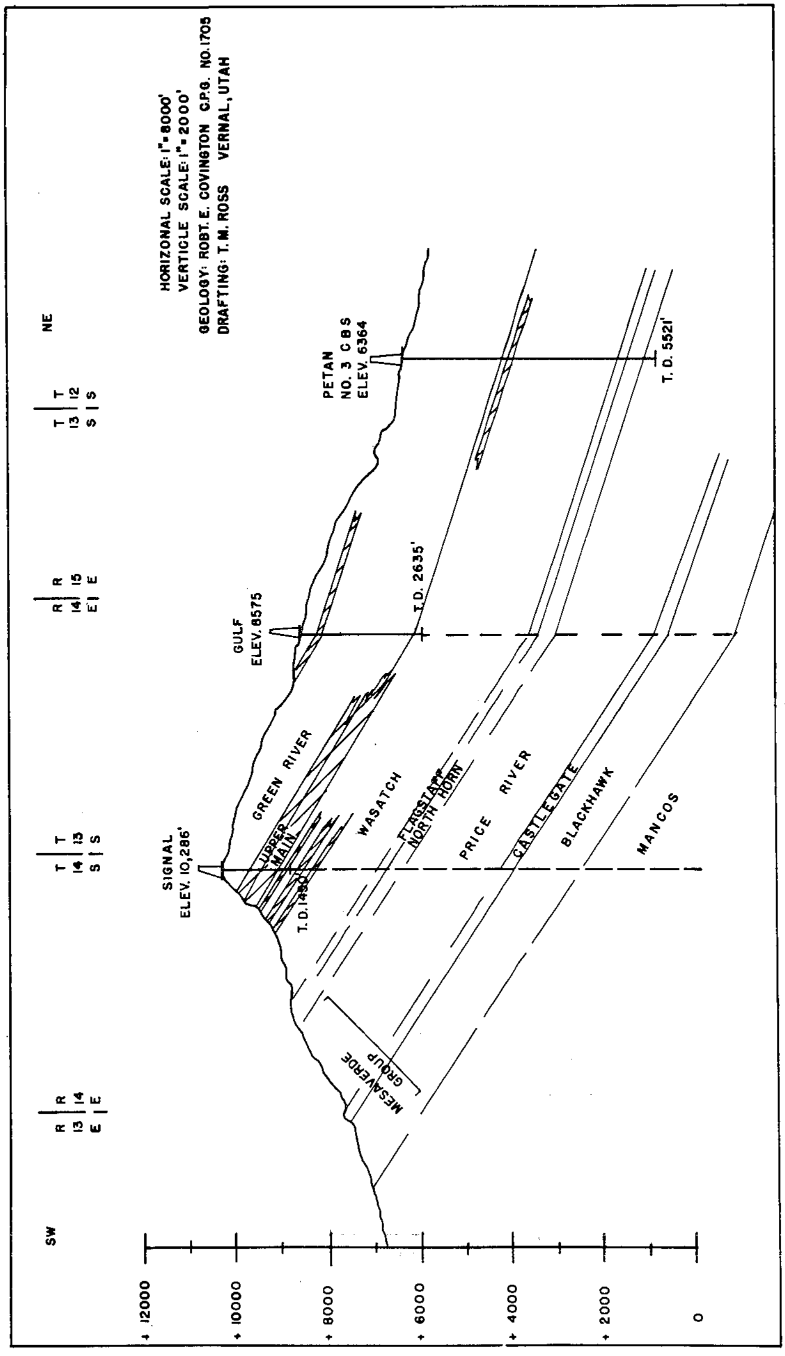
The source for the oil in the Duchesne River sandstones and conglomerates is probably the organically-rich lacustrine beds of the Green River Formation from which the oil migrated through open fractures during the intense period of Post-Duchesne River faulting. Post-Duchesne River faulting and fracturing has been mapped on Asphalt Ridge in great magnitude and abundance, some of which exhibit shows of oil or bitumen.

In Whiterocks Canyon, Uintah and Duchesne counties, Utah, T2N-R1E and R1W, SLM, the Jurassic Navajo sandstone is oil-impregnated. The formation is 1,000' in thickness and has a 62° southeast dip. Bitumen saturation extends vertically to an average depth of 550' and is present 200' above the canyon floor for a total saturated interval of 750'. Proven in-place reserves are 125 million barrels, with another 125 million barrels possible to the northeast and southwest. A Tertiary source has been proposed for this deposit, with the oil moving updip from Green River lacustrine beds into the eolian Navajo along the Tertiary-Jurassic unconformity. However, there is no evidence of bitumen saturation along this unconformity. Two wells drilled downdip by the Carter Oil Company had no significant shows of oil or dead oil staining in the Green River Formation to indicate that this formation was the source of the Navajo oil. The author believes that the Whiterocks prospect was a structurally controlled oil field of very large proportions, now exhumed. The source beds were either the Jurassic Twin Creek limestone or the Permo-Pennsylvania Phosphoria limestones.

The Hill Creek deposit is located in the south flank of the Uinta Basin in Townships 13, 14, & 15 South—Range 18, 19, 20, & 21 East, Uintah and



TEXT-FIGURE 2.—Geologic map of Sunnyside area in Carbon County, Utah.



TEXT-FIGURE 3.—Geologic cross profile, Sunnyside to Dry Creek, Carbon County, Utah.

Grand Counties, Utah. Bitumen saturation is in sandstones and siltstones of the Douglas Creek and Parachute Creek Members of the Green River Formation, the probable source beds of the oil. Reserves are estimated to be 4 to 5 billion barrels of oil in-place. The deposits are highly lenticular.

The largest deposit of oil-impregnated rock in the Uinta Basin is known as the Sunnyside deposit. The bitumen impregnated sandstones and siltstones are located in Carbon County, Utah in Township 12, 13, & 14 South—Range 13, 14, & 15 East. In-place oil reserves are estimated to be in excess of 4.6 billion barrels, of which 1.25 are measured, 1.75 are indicated and the remainder is inferred. The oil-impregnated sands occur at topographic elevations which range from 8,500 to 10,000 feet. The bitumen-bearing beds are in the upper third of the Wasatch and the lower part of the Green River Formation. The Wasatch Formation is primarily fluvial and the Green River Formation is primarily lacustrine, although considerable intertonguing of the two occurs in the Sunnyside area. Wasatch sands are highly lenticular, with varying degrees of porosity and permeability. Sandstones of the Green River Formation, although they have greater lateral continuity, in general have lower porosities, lower permeabilities, and consequently are less richly saturated than the Wasatch sands.

This deposit is the remnant of a stratigraphically trapped oil field that has been exhumed by recent erosion. The stratigraphic factors which directly control the accumulation in this deposit are:

(1) The proximity of the sands to overlying, underlying and downdip (basinward) source beds. The closer the reservoir beds are to the source beds, the higher the degree of saturation, assuming other factors such as structure, porosity and permeability to be constant.

(2) The degree of saturation is directly related to the porosity and permeability of the reservoir rock.

(3) The original oil was trapped in a delta complex which extended to the north into ancient Lake Uinta during Eocene time. This has been determined by the construction of isopachous, isolith and sand percent maps.

(4) The deposits contain three major types of reservoirs: (a) deltaic, (b) offshore bars and (3) barrier bars associated with the delta.

Lithofacies maps point out a zone or band around the edge of the ancient lake having the greatest percentage of reservoir quality sand in juxtaposition to organic lacustrine sediments. This is where the greatest accumulation of oil occurred.

The structural factor which strongly influenced and directed the movement of hydrocarbons from the source beds into the reservoir rocks is the regional monoclinal dip which ranges from three to ten degrees to the northeast. Monoclinal structure is interrupted by gentle, north plunging anticlinal noses. A brief review of the vital economic data of this deposit may be of interest. The sands contain an average of 9% bitumen by weight, or 38.2 gallons per cubic yard, or 1,457 barrels per acre foot. Core analyses show the sands to have porosities which range from 25 to 30 percent by volume, and permeabilities ranging from 150 to as high as 650 millidarcies. Water saturations are extremely low, probably averaging 5%. Problems associated with thermal recovery by steam injection or by fire flooding are as follows: (1) the lenticularity of the sands, (2) the fact that bitumen-rich sandstones grade both vertically, laterally, and in a downdip direction into lean to barren sandstones, often within several hundred feet, (3) the lack of a nearby, adequate supply of large volumes of good quality water, and (4) lack of local markets. These are the major drawbacks to economic development.

During the period from 1955 to 1967 Signal Oil & Gas Company undertook an exploratory program to determine the economic feasibility of an *in situ* mining operation. The objective was to drill horizontal test wells into the Wasatch oil-impregnated sands to determine the economic and technical feasibility of producing oil by application of steam.

Three horizontal wells were drilled and equipped for steam injection and production operations. A 5.8 MM BTU/hr. steamer was used. The holes were drilled into the westerly cliff face of the old Utah Rock Asphalt Quarry to a depth of about 370' (horizontal). The central well was used as a producing well and the other two were used for steam injection. The holes were cored to obtain engineering data on porosity, permeability, oil saturation, water saturation, and to help maintain a straight hole.

Steam injection pressures by Huff & Puff test were kept at about 300 psig and injection temperatures ranged between 350° and 450°F. Total input during the test was 400 bbls. of water equal to about 138 MM BTU of heat input. No oil was recovered in this test.

A steam injection test was undertaken using 5.8 MM BTU/hr. with injection pressures and temperatures averaging 140 psig and 370°F respectively. The production well first began to flow colored water and then a "rope-like" emulsion of about 16 barrels of bitumen. The wells were produced for 4 days during which time a fairly constant water cut was observed. The economic and mechanical feasibility of this project is unknown.

The bitumen from the Sunnyside deposits is low in sulphur, contains a relatively high percentage of resins and aromatic hydrocarbons, and makes excellent road paving material. It may be economically feasible to combine petroleum coke derived from cracking the bitumen with coal presently being mined in the Sunnyside area to produce a coking coal of high quality.

A vertical strat test well was drilled by Signal Oil Company in Section 4, Township 14 South—Range 14 East to a total depth of 1,450 feet. This well penetrated most of the oil-impregnated sandstones. The following data were derived from core analyses:

Total thickness of oil-impregnated sandstone:	645'
Net oil sand, thickness:	366'
Average oil saturation:	55%
Average porosity:	25%
Average permeability:	0.75 - 1.75% Darcies

The oil-impregnated sandstones of the Central Southwest area lie on the northwest flank of the Monument upwarp. Surface beds dip gently to the northwest at about 100 feet to the mile. The oil reserves are primarily located in the Permian White Rim sandstone and were stratigraphically trapped by the southeast (updip) pinchout of the sand. Erosion breached the sandstone, diffusing the reservoir energy and allowing the light ends to dissipate. Dispersal of the original water drive has permitted some downdip and downward migration of the oil.

The in-place oil reserves of this area are estimated to be over 14 billion barrels. Minor reserves are in the Permian Cutler and Triassic Shinarump Formations. The area is bounded on the east by the Green River and on the west by the San Rafael Swell, covering Townships 29 thru 33 South—Ranges 14 thru 17 East, Garfield and Wayne counties, Utah. Regional oil-water contact in the White Rim Sand is located at an elevation of +4,300' and trends in a broadly curving arc from the southwest part of Township 32 South—Range 14 East to the northwest corner of Township 29 South—Range 16 East. Between this hypothetical line and the outcrop of the White Rim Sandstone the bitumen saturation will be found at depths ranging from 0 feet on the southeast to 2,000 feet on the southwest.

The area consists of deep canyons and high, flat mesas and plateaus in semi-arid country. With regional dip to the northwest, the canyons of the Green River on the east cut down to beds of the White Rim sandstones. Westward the Triassic Red Beds form steep east-facing escarpments, capped by massive sandstones of Jurassic age.

SUMMARY

The oil industry has shown considerable interest in the area. Most of the lands in the Tar Sand Triangle are under oil and gas leases. A very small area of bituminous sand outcrop is amenable to strip-mining; most of the heavy oil will have to be recovered by steam-injection or fire flood recovery techniques. Santa Fe Industries has proposed a fire flood in Township 30 South—Range 16 East where the heavy oil, saturated White Rim sandstone averages 150' in thickness at an average depth of 1,600'. The prospect is located about 4 miles downdip (northwest) from the outcrop of the oil-impregnated sand. Oil recoveries for 100' of saturated section should average 49,000 bbls./acre or over 30 million barrels of oil per section. Analysis of the oils from the Tar Sand Triangle show sulphur contents which range from 3 to 6 percent as compared with Tertiary and Cretaceous oil-impregnated rocks of the Uinta Basin which average $\frac{1}{2}$ of 1 percent. Water for development can be obtained by drilling wells to the basal Navajo, Coconino, or older formations.

A critical examination of the oil-impregnated rocks of Utah indicates the reserves to be in excess of 16 billion barrels. The successful exploitation of these reserves is in large part dependent upon the economic interplay between the existing price of crude oil and the cost of extracting, refining, and marketing this oil. If the profit incentive is sufficient to attract investment capital, if government and environmental regulations are not over-stifling, and if pilot studies show economic and engineering feasibility, then these deposits will play a major role in helping the United States to become more self-sufficient in fuel needs.

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