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DOE/RO/00100--T1

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OIL SHALE COMMERCIALIZATION STUDY

(For the State of Idaho, Office of Energy)

By

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ABSTRACT

Ninety four possible oil shale sections in southern Idaho were located and chemically analyzed. Sixty-two of these shales show good promise of possible oil and probable gas potential. Sixty of the potential oil and gas shales represent the Succor Creek Formation of Miocene age in southwestern Idaho. Two of the shales represent Cretaceous formations in eastern Idaho, which should be further investigated to determine their realistic value and areal extent. Samples of the older Mesozoic and Paleozoic sections show promise but have not been chemically analyzed and will need greater attention to determine their potential.

Geothermal resources are of high potential in Idaho and are important to oil shale prospects. Geothermal conditions raise the geothermal gradient and act as maturing agents to oil shale. They also might be used in the retorting and refining processes. Oil shales at the surface, which appear to have good oil or gas potential should have much higher potential at depth where the geothermal gradient is high. Samples from deep petroleum exploration wells indicate that the Succor Creek shales have undergone considerable maturation with depth of burial and should produce gas and possibly oil.

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Most of Idaho's shales that have been analyzed have a greater potential for gas than for oil but some oil potential is indicated.

The Miocene shales of the Succor Creek Formation should be considered as gas and possibly oil source material for the future when technology has been perfected.

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INTRODUCTION

This study was initiated by and undertaken in behalf of the Idaho Department of Energy. The writer was intrigued by the proposal for these reasons: In recent years Idaho has received great attention from energy companies and governmental agencies in regard to oil and gas potential within the state. The writer has been actively involved in the research and exploration of this potential. Results to date indicate that Idaho does have a high potential for crude oil and natural gas. The search for petroleum source materials has revealed the presence of shales in various stratigraphic sections which are rich in organic matter. One of the most favorable appearing shale sections is that of the Succor Creek Formation of Miocene age. This formation is widespread and relatively thick, making it a prime target for investigation. Other shale sections in the Mesozoic and Paleozoic rocks of eastern Idaho are also suspect in regard to shale oil potential.

This preliminary study concentrated on the Miocene shales but some spot samples were taken from the older shales. Only a few of these (Cretaceous in age) were analyzed.

The purpose of the study was (1) to find possible oil shale areas in Idaho. (2) Sample the possible sections and have samples analyzed chemically. (3) Relate possible oil shale sites to regional geology, age, and environmental aspects. (4) List all sites in terms of priority in regard to value. (5) Relate each site to geologic conditions, topography, roads, etc. (6) Show area of shale outcrops. (7) Compare Idaho shales to other oil shales. (8) Relate shale areas to geothermal resources potential.

(9) Give land ownership and mineral ownership of general areas.

(9) List those organizations that might be interested in this survey.

AREAS SAMPLED

The general area covered by this study includes most of southern Idaho. Certain specific sites were picked for sample collecting based on the surficial appearance of their shaley sections. See enclosed maps in appendix B. These sites include:

- (1) six sites in the Horseshoe Bend area, Boise County, Idaho.
- (2) One site in the Squaw Butte area, Gem County, Idaho,
- (3) One site in the Succor Creek area, Owyhee County, Idaho,
- (4) One site in the Coal Mine Basin area, Owyhee County, Idaho,
- (5) One site in the Dry Creek area, Owyhee County area, (6) One site in the Sheaville area, Owyhee County, Idaho, (7) Four sites in the Highway 34 area, Caribou County, Idaho, (8) Four sites in the Fall Creek area, Bonneville County, Idaho, (9) One site in the Soda Springs area, Caribou County, Idaho. (10) Nine sites in the Blackfoot River area, Caribou County, Idaho. (11) Two sites in the Pass Creek area, Butte County, Idaho, (12) One site in the Dry Creek - 2 area, Custer County, Idaho.

For sample site description and specific location, see heading - Field Notes on Sample Sites.

FIELD NOTES ON SAMPLE SITES

Site 1 (HSB-1)

Location: Horseshoe Bend area, Boise Co., Idaho, NW $\frac{1}{4}$, NW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 34, T.7N.-R.2E., 0.2 mile south of Payette river bridge on Hy. 15; west side.

Surface: Road cut.

Physiography: Base of foot hills near the Payette river flood plain.

Dip of beds: 36° max.

Size of exposure: 180 feet wide, 15 feet thick

Sample type: Random composite at 10' intervals.

Cultural features: One residence located 100 feet from the outcrop, Hy. 15 is 50 feet from the outcrop.

Environmental factors: Outcrop is near a paved highway and local residence and is only one mile from the center of the town of Horseshoe Bend and 0.2 mile from the Payette river. Mass movement of surface regolith and soil is common in this area.

Additional information: Lithologies are of Succor Creek Fm, (Miocene).

Site 2 (HSB-2)

Location: Horseshoe Bend area, Boise Co., Idaho, SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 4, T.6N.-R.2E., on Hy 15, 2 miles south of the Payette river bridge at the Olo junction on the state highway (Robbs Creek), west side.

Surface: Mostly cheatgrass with some bitterbrush and wild raspberries.

Physiography: Rolling foothills.

Dip of beds: 40°-53°

Size of exposure: 300 feet wide, 70 feet thick.

Sample type: Random composite of seven intervals.

Cultural features: Highway 15 and Robbs Creek state highway nearby.

Environmental factors: Surface soil is unstable, mass-movements are common.

Additional information: Lithologies are of Succor Creek (Miocene).

Site 3: (HSB-3)

Location: Horseshoe Bend area, Boise Co., Idaho, NE¼, Sec. 9, T.6N.-R.2E., west side of Hy. 15, 2.4 miles south of the Payette river bridge, along a road cut.

Surface: Cheatgrass and other weeds cover 90% of the road cut.

Physiography: Rolling foothills with recent slumping.

Dip of beds: 10°

Size of exposure: 900 feet wide, 40 feet thick.

Sample type: Fifteen vertical composite samples at 10'-25' vertical intervals. The 15 samples were 50 feet apart.

Cultural features: Hy. 15.

Environmental factors: Surface soil is unstable, mass movements are common. The town of Horseshoe Bend is only 2.4 miles away.

Additional information: This site contains numerous lenses of fine quartz sand, one of which is $3\frac{1}{2}'$ thick, rich in organic matter, and bound on top and bottom with shale. Succor Creek Fm. (Miocene).

Site 4 - (HSB-4)

Location: Horseshoe Bend area, Boise co., Idaho, $SE\frac{1}{2}$, $SW\frac{1}{4}$, Sec. 9, T.6N.-R.2E., west side of Hy. 15, 3.95 miles south of the Payette river bridge.

Surface: Mostly bare of vegetation, some cheatgrass.

Physiography: Rolling foothills

Dip of beds: 10°

Size of exposure: 500 feet wide

Sample type: Nine vertical composite samples at 5' vertical intervals and 50' apart laterally.

Cultural features: Only Hy. 15.

Environmental factors: Surface soil is unstable and mass-movements common. Four miles from the town of Horseshoe Bend. (Succor Creek Fm. Miocene).

Site 5 - (HSB-5)

Location: Horseshoe Bend area, Boise co., Idaho, $NE\frac{1}{2}$, $NE\frac{1}{4}$, Sec. 20, T.6N.-R.2E., $5\frac{1}{2}$ miles south of the Payette river bridge, on west side of Hy. 15 on the north end of a sand and gravel pit.

Surface: Very little vegetation; drainage cut along side highway.

Physiography: Rolling foothills.

Dip of beds: 28°

Size of exposure: 75 feet long, 35 feet thick.

Sample Type: Three composite samples at 5' vertical intervals and 25' apart laterally.

Cultural features: Only Hy. 15

Environmental factors: Surface soils are unstable, mass-movements common. Sand and gravel quarry nearby.

Additional information: The lithology here consists of clay, silt, and sand grading into one another in a cyclic manner. The clays are rich in organic matter and fissile. Succor Creek Fm. (Miocene).

Site 6 - (HSB-6)

Location: Horseshoe Bend area, SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 34, T.7N.-R.2E., on a road 0.2 mile south of the Payette river bridge. This is the first road to the west of Hy. 15 southward from the bridge.

Surface: Weeds and grasses cover the area.

Physiography: Rolling foothills.

Dip of beds: 34°

Size of exposure: Discontinuous over a width of 475 feet, 18 feet thick.

Sample type: Two composite samples 5' vertical intervals and 200' apart.

Cultural features: Only the roads.

Environmental factors: Site is just outside Horseshoe Bend city limits and just above the Payette river.

Additional information: The lithology consists of interbedded shales and sands, capped with gravel. Succor Creek Fm. (Miocene)

Site 7 - (SB-1)

Location: Squaw Butte area, Gem co., Idaho, SE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 8 T.7N.-R.1W., 3.9 miles north on Van Duessen road from the intersection of Hy. 52 and Black Canyon road, on the west side of the road just north of a sand and gravel pit.

Surface: Outcrop is bare of vegetation.

Physiography: Rolling foothills

Dip of beds: 14 $^{\circ}$

Size of exposure: 220 feet wide, 10 feet thick.

Sample type: One random composite sample.

Cultural features: Ranch house, stock pond, gravel pit and secondary road nearby.

Environmental factors: Only the proximity to cultural features.

Additional information: The lithology is rich in plant Chalk Hills Fm. (Pliocene).

Site 8 - (SC-1)

Location: Succor Creek area, Owyhee co., Idaho, SW $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 35, T.2S.-R.6W., 3.8 miles south of Idaho-Oregon border on Hy. 95, east side of road.

Surface: Sage brush and annual grasses.

Physiography: Steep hills and gullies.

Dip of beds: 5 $^{\circ}$

Size of exposure: One half mile wide, 100 feet thick.

Sample type: Four random composite samples. Sample 1 was taken from the east slope, sample 2 from a stream channel, sample 3 from west side of road, and sample 4 from the head of the drainage.

Cultural features: Only the highway.

Environmental factors: One or two springs exist on the site and Indian archaeological sites possibly exist here. Succor Creek Fm. (Miocene).

Additional information: The lithology consists of interbedded ashy shale, lignite layers, sapropelic layers and silt, brown to white in color.

Site 9 - (CMB)

Location: Coal Mine Basin area, Owyhee co., Idaho, SE $\frac{1}{4}$, NE $\frac{1}{4}$, and NE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 12, T.3S.-R.6W, on the end of the road terminating on a ridge just above Coal Mine Basin, 6.75 miles south of the Idaho State line on Hy. 95.

Surface: Sample sites are bare, valley floor is covered with sagebrush and mixed grasses.

Physiography: Steeply sloping hills with intervening deep valleys.

Dip of beds: 5°-10°

Size of exposure: 1 mile long, 50' thick.

Sample type: Three composite samples consisting of grouped specific samples taken at 5-10 foot intervals down the slopes.

Cultural features: None

Environmental factors: The area is a collecting site for low grade opal, chalcedony, and petrified wood. Several springs are present in the valley and Indian archaeological sites are possibly present along the valley's intermittent stream.

Additional information: The lithology of the samples consists of lignite layers, sapropelites, and a few sandy layers. Succor Creek Fm. (Miocene)

Site 10 - (Dry Creek)

Location: Dry Creek area, Owyhee co., Idaho, SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 19, T.2S.-R.5W and NE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 19, T.2S.-R.5W., one sample from northeast exposure above Dry Creek and one from the bed of Dry Creek.

Surface: Sage brush and mixed grasses.

Physiography: Low hills and intermittent drainage.

Dip of beds: 7°

Size of exposure: one-fourth mile long and 30 feet thick.

Sample type: Random composite sample

Cultural features: None

Environmental factors: Antelope grazing area and high probability of Indian archaeological sites.

Additional information: Lithology consists mainly of organic rich shale, lignite and some coal. Succor Creek Fm. (Miocene).

Site 11 - (Texas Basin)

Location: Texas Basin area, Owyhee co., Idaho, SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 19, T.25.-R.5W.

Surface: Barren of vegetation.

Physiography: Badland erosion, sample from broad slope.

Dip of beds: None measured.

Size of exposure: Not measured

Sample type: Random composite sample.

Cultural features: None

Environmental factors: Several springs in the area, antelope grazing area, high probability of Indian archaeological sites.

Additional information: Upper face of the slope contained organic matter, none in lower part. Succor Creek Fm. (Miocene).

Site 12 - (Sheaville)

Location: Sheaville area, Owyhee co., Idaho, NE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 1, T.2S.-R.6W. and NE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 11, T.2S.-R.6W.

Surface: Barren of vegetation

Physiography: Rolling hills.

Dip of beds: 8°

Size of exposure: 500 feet wide

Sample type: Three random composite sample.

Cultural features: None

Environmental factors: Road cut on Hy. 95.

Additional information: Lithology consisted of organic rich beds, which were very thin shales to 1 foot thick sandy, ashy shales. Succor Creek Fm. (Miocene)

(McCoy Creek Road - Sample 1) - Note: Reconnaissance

Location: McCoy Creek area, Bonneville co., Idaho.

Started on road from turn off going around Grey's Lake along McCoy Creek eastward approx. 8.5 miles. (Sec. 22, T.3S.-R.43E) we were stopped by snow conditions.

Samples were taken at these sites:

- A. One-half mile east of turn off, north side of road, SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 21, T.3S.-R.43E.
- B. 4 miles east of turn off (3.5 miles east of sample A), north side of road, SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 24, T.3S.-R.43E.
- C. 4.25 east of turn off (.25 miles east of site B), north side of road, SE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 24, T.3S.-R.43E.
- D. 4.35 miles east of turn off (.1 mile east of site 3), north side of road, SW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 19, T.3S.-R.44E.
- E. 4.75 miles east of turn off (.4 mile east of site D), north side of road, NE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 19, T.3S.-R.44E.

Surface: Snow covered

Physiography: Mountainous terrain.

Dip of beds: 43°

Size of exposure: Not measured

Sample type: Five random composite samples, creataceous in age.

Cultural features: None

Environmental factors: Water quality of McCoy Creek drainage system and wild life habitat.

Additional information: Lithology consists mostly of cretaceous shales.

Site 13 (Highway 34-1)

Location: Hy. 34 area from Wayan, Idaho to Freedom, Wyoming.

Sample 1 - Near mile post 102.9, SW $\frac{1}{4}$, Sec. 13, T.5S.-R.45E.

Surface: covered by grasses.

Physiography: Stream valleys.

Dip of beds: Not measured

Size of exposure: 400 feet long, 50' thick.

Sample type: Random composite

Cultural features: None

Environmental factors: Major water shed, big game habitat.

Additional information: The sampled lithology is Cretaceous shale.

Site 14 - (Hy. 34-2)

Location: Mile post 106.3, NE $\frac{1}{4}$, Sec. 15, T.15S.-R.45E.

Surface: Grass covered

Physiography: Stream valleys

Dip of beds: 63°

Size of exposure: 600 feet long, 150 feet thick.

Sample type: Two random composite samples (1-A & 1-B).

Cretaceous shale.

Cultural features: None

Environmental aspects: Considerable folding; big game habitat.

Site 15 - (Hy. 34-3)

Location: Mile post 107.3, SE $\frac{1}{4}$, Sec. 10, T.5S.-R.45E.

Surface: Grass covered

Physiography: Stream valleys

Dip of beds: 63°

Size of exposure: 260 feet long, 100 feet thick.

Sample type: One random composite sample. (Cretaceous sh.)

Cultural features: None

Environmental factors: Watershed and big game habitat.

Site 16 - (Hy. 34-4)

Location: Mile post 108.7, NW¼, Sec. 12, T.5S.-R.45E.

Surface: Grass covered.

Physiography: Stream valleys

Dip of beds: 65°

Size of exposure: 175 feet long, 30 feet thick.

Sample type: One random composite sample. (Cretaceous sh.)

Cultural features: None

Environmental factors: Watershed and big game habitat.

Site 17 - (FC-1)

Location: Fall Creek area, Bonneville co., Idaho, southwestern side of the Snake River and west of Swan Valley.

Turn south from Hy. 26 at west end of the bridge spanning the Snake River about 2¼ miles east of Swan Valley. Near power pole no. 15PGIA, NE¼, SE¼, Sec. 18, T.1N.-R.43E.

Surface: Mostly grass, some riparian vegetation and herbs & shrubs.

Physiography: Stream valley

Dip of beds: 67°

Size of exposure: 235 feet wide, 200 feet thick.

Sample type: Three random composite samples.

Cultural features: None

Environmental factors: Good big game habitat, good river fishing, sizable beaver population, major watershed.
Additional information: There is an oil and gas potential in this area, it being a part of the overthrust belt. The sampled lithology consists of fissile, rippled, organic shales (Cretaceous).

Site 18 - (FC-2)

Location: Fall Creek area, Bonneville co., Idaho (see FC-1), at mile post 106-8, NE¼, Sec. 15, T.5S.-R.45E.

Surface: Same as FC-1

Physiography: Same as FC-1

Dip of beds: 53°

Size of exposure: 600 feet long, 150 feet thick,

Sample type: Two random composite samples (1-A & 1B).
Cretaceous shale.

Cultural features: None

Environmental factors: Same as FC-1

Site 19 (FC-3)

Location: Fall Creek area, Bonneville co., Idaho
(See FC-1), at milepost 107.3, SE¼, Sec. 10, T.5S.-R.45E.

Surface: Same as FC-1

Physiography: Same as FC-1

Dip of beds: 65°

Size of exposure: 260 feet long, 100 feet thick.

Sample type: One random composite sample. Cretaceous shale.

Cultural features: None

Environmental factors: Same as for (FC-1).

Additional factors: Lithology consists of very fissile Cretaceous shales.

Site 20 - (FC-4)

Location: Fall Creek area, Bonneville co., Idaho
(see FC-1), at milepost 108.7, NW¼, Sec. 12, T.5S.-R.45E.

Surface: Same as FC-1.

Physiography: Same as FC-1

Dip of beds: 65°

Size of exposure: 175 feet long, 30 feet high.

Sample type: One random composite sample.

Cultural features: None

Environmental factors: Same as for FC-1.

Site 21 - (SP-1)

Location: Soda Springs area, Caribou co., Idaho,
center of Sec. 18, T.8S.-R.43E., on Trail Canyon road,
9.5 miles from Phillips 66 station in Soda Springs, ID.

Surface: Forested, pine and aspen and many grasses.

Physiography: Hilly terrain.

Dip of beds: 7°

Size of exposure: 600 feet long, 15 feet thick.

Sample type: One composite sample.

Cultural features: Low density subdivision

Environmental factors: Subdivision of Soda Springs, forested
land.

Additional information: Lithology consists of silty shale
with some organic matter, Permian or Triassic in age.

Site 22 - (BR-1)

Location: Blackfoot River area, Caribou co., Idaho, on Diamond Creek road, 6.3 miles south of Johnson guard station, common border of SE $\frac{1}{4}$ -SW $\frac{1}{4}$, Sec. 16, T.19S.-R.45E.

Surface: Forested (pine and aspen)

Physiography: Hills and canyons

Dip of beds: 54⁰

Size of exposure: Not measured, small..

Sample type: One random composite sample (BR 1).

Cultural features: None

Environmental factors: Forest land.

Additional information: Lithology consists of green-grey dense shale, age is Penn. or Perm.

Site 23 - (BR-2)

Location: Blackfoot River area, Caribou co., Idaho, on Diamond Creek road, 6.1 miles south of Johnson guard station, on common side of SE $\frac{1}{4}$ & SW $\frac{1}{4}$, Sec. 16, T.9S.-R.45E.

Surface: Same as BR-1.

Physiography: Same as BR-1).

Dip of beds: 76⁰

Size of exposure: 500 feet long.

Sample type: One random composite sample (BR-2,A,B,C).

Cultural features: None

Environmental factors: Same as BR-1

Additional information: Lithology is soft shaley siltstone with some organic matter.

Site 24 - (BR-3)

Location: Blackfoot River area, Caribou co., Idaho,
5.9 miles south of Johnson guard station on Diamond Creek
road, SW corner of NE $\frac{1}{4}$, Sec. 16, T.9S, R.45E.

Surface: Same as BR-1.

Physiography: Same as BR-1 with beaver ponds on the creek.

Dip of beds: 35 $^{\circ}$

Size of exposure: 250 feet long, 10' thick.

Sample type: One random composite sample (BR-3A&B)

Cultural features: None

Environmental factors: Same as BR-1

Additional information: Lithology consists of soft shaley
siltstone with some organic matter. Late Paleozoic in age.

Site 25 - (BR-4)

Location: Blackfoot River area, Caribou co., Idaho,
4.29 miles south of Johnson Guard station on Diamond Creek
road on border of SW $\frac{1}{4}$ & SE $\frac{1}{4}$, Sec. 4, T.9S.-R.45E.

Surface: Similar to BR-1

Physiography: Similar to BR-1 but the valley is narrower.

Dip of beds: 67 $^{\circ}$

Size of exposure: 10 feet long, 6 feet thick.

Sample type: One random composite sample.

Cultural features: None

Environmental factors: Same as BR-1

Additional information: Lithology is dark gray, hard and
laminated. Late Paleozoic in age.

Site 26 - (BR-5)

Location: Blackfoot River area, Caribou co., Idaho, 0.29 miles south of Diamond Creek road and 0.08 miles north of Johnson gaurd station, along the border of sections 16 & 21, T.8S.-R.45E.

Surface: Forested with pine and aspen.

Physiography: Hilly and deep canyons.

Dip of beds: 45°

Size of exposure: 100 feet long, 5 feet thick.

Sample type: One random composite sample.

Cultural features: Close proximity to Ranger's station.

Environmental factors: Same as BR-1

Additional information: Lithology is dark gray blocky siltstone containing organix matter. Perm. or Triassic in age.

Site 27 - (BR-6)

Location: Blackfoot River area, Caribou co., Idaho, on Diamond Creek road, SE¼ of Sec. 17, T.8S.-R.45E.

Surface: Forested with pine and aspen

Physiography: Canyon slope

Dip of beds: 13°

Size of exposure: 100 feet long, 5 feet thick.

Sample type: One random composite sample.

Cultural features: None

Environmental factors: Same as BR-1

Additional information: Lithology consists of dark brown calcareous shale, rather hard. Perm. or Triassic in age.

Site 28 - (BR-7)

Location: Blackfoot River area, Caribou co., Idaho,
off Diamond Creek road, S.E. corner of NW¼, Sec. 8, T.8S-R.45E.

Surface: Forested with pine and aspen.

Physiography: Canyon slope.

Dip of beds: 15°

Size of exposure: 100 feet long, 30 feet thick.

Sample type: One random composite.

Cultural features: None

Environmental factors: Same as BR-1

Additional information: Lithology is brown slabby shaley
limestone, rather hard. Triassic age.

Site 29 - (BR-8)

Location: Blackfoot River area, Caribou co., Idaho,
off Diamond Creek road, eastern side of NE¼, Sec. 36,
T.7S.-R.44E.

Surface: Aspen and meadow land.

Physiography: Small hill on valley floor.

Dip of beds: 37°

Size of exposure: 1200 feet long, 200 feet thick.

Sample type: One random composite.

Cultural features: Farmland

Environmental factors: Private farmland.

Additional information: Dark gray shale.

Site 30 - (BR-9)

Location: Blackfoot River area, Caribou co., Idaho,
S.E. corner of SW¼, Sec. 9, T.7S.-R.44E.

Surface: Grassy meadow.

Physiography: Small hill in farm meadow.

Dip of beds: 34°

Size of exposure: 300 feet long, 15 feet thick.

Sample type: One random composite.

Cultural features: Farm.

Environmental factors: Farmland.

Additional information: Brown shaley siltstone with organic matter.

Site 31 - (PC-1)

Location: Pass Creek area, Butte co., Idaho, on Pass
Creek road, 150' north of Lion Creek on the west side of the
road.

Surface: Grasses and sage brush.

Physiography: Low hills with gentle slopes.

Dip of beds: Not measured.

Size of exposure: 75 feet long, 10 feet thick.

Sample type: One random composite

Cultural features: None

Environmental factors: None

Additional information: Lithology consists of greenish
brown shaley siltstone.

Site 32 - (PC-2)

Location: Pass Creek area, Butte co., Idaho, 0.4 mile north of site (PC-1).

Surface: Same as (PC-1).

Physiography: Same as (PC-1)

Dip of beds: Not measured.

Size of exposure: 100 feet long, 25 feet thick.

Sample type: One random composite.

Cultural features: None

Environmental factors: None

Additional information: Lithology ranges from fine to coarse siltstone, light brown in color.

Site 33 - (DR-1)

Location: Dry Creek - 2 area Custer co., Idaho, S.W. corner of SE¼, Sec. 33, T.10N.-R.25E.

Surface: Grasses and sagebrush in the valley and pine trees on the slopes.

Physiography: Mountainous.

Dip of beds: 75°

Size of exposure: 400 yards long, 150 feet thick.

Sample type: One random composite.

Cultural features: None

Environmental factors: None

Additional information: Lithology consists of reddish siltstone and gray limestone mixture. See photographs of important sites in appendix C.

CURRENT KNOWLEDGE OF THE ENERGY POTENTIAL OF OIL SHALE

Culberson and Rolniak (1981) have summarized this subject very well. The following points from their summary are important to an appreciation of this study:

- (1) Oil shale will probably be refined competitively with crude oil by the mid-1980's.
- (2) A variety of options exist to overcome the major adverse properties of oil shale and remove its impurities.
- (3) Oil shale consists of fine grained sedimentary rock with a relatively high content of Kerogen.
- (4) Kerogen is solid organic material of high molecular weight and low solubility.
- (5) The only practical method of recovering hydrocarbons from oil shale is by heating the rock to temperatures around 500°C.
- (6) Western shale oil deposits (primarily Colo, Utah, & Wyoming) represent 20-30 times the known reserves of conventional crude oil in the U.S. The Green River formation alone has an estimated 54 billion barrels of recoverable oil with an assay of 30 gal/ton and another 600 billion barrels of reserves with an assay of 25 gal/ton.
- (7) Rising world petroleum prices; decontrol of U.S. petroleum prices; desire for a secure energy source; match of potential shale oil products and future refined products demand; and potential shortfalls of liquid hydrocarbons from petroleum have made shale oil production very attractive.

- (8) Shale oil projects already underway in Colorado and Utah will produce at least 450,000 barrels of oil per day by 1990 according to latest estimates.
- (9) There are two major types of shale retorting technology - direct combustion heating and indirect heating. The different methods have different yields. The first method yields low-BTU gas and light oil, the second yields medium to high-BTU gas and heavier oil.
- (10) Refining problems of raw shale include (a) Limited quantities of shale oil can be used in mixed feedstocks to some refineries, but severe hydrotreating is required to upgrade shale oil if it is to be used in large quantities. (b) The high nitrogen content of raw shale oil is the major problem because nitrogen is a catalyst poison for catalytic reforming and cat cracking. (c) Pour point, oxygen, arsenic and other metals also contribute to special handling and refining problems.
- (11) Process testing of shale oil refining in conventional refineries has been done by various companies. The results highlight potential yields, product qualities, and refining problems. These testing refineries include; (a) Gary Western refinery, 1975; (b) Chevron Salt Lake City refinery, 1977; (c) Plateau refinery, 1979; (d) Sohio Toledo refinery, 1978. Results are discussed in the Culberson-Rolniak paper entitled Shale Oil Likely Prospect for Refining—Oil & Gas Journal; July 20, 1981.

- (12) Pilot plant studies of ways to upgrade shale oil reveal these factors: (a) pretreatment and especially hydrotreating are the key steps to refining shale oil. (b) Arsenic compounds exist across the entire boiling range, but are highly concentrated in the heavy ends. (c) Clay treating and acid treating have been found useful in correcting thermal stability problems. (d) The major units needed to process raw shale oil are hydrotreaters to process 100% of the raw shale oil and hydrogen generation facilities. With severe hydrotreating and hydrocracking a conversion-type refinery can convert most of the raw shale oil to gasoline and middle distillates.
- (13) Raw shale oils having pour points of 70 to 90°F cannot be readily transported through existing crude oil pipelines where the average ground temperature may be less than 40°F. Several possible options to overcome this problem are given.
- (14) Several methods of hydrotreating are discussed which include: Naphtha hydrotreating, Distillate hydrotreating, & Gas oil hydrotreating.
- (15) Estimates indicate that shale oil production is now marginally attractive but several problems are slowing down the development. These problems include: time to handle all factors of preparation; uncertainty about the long-range pricing policies of OPEC; lack of technology in many companies; environmental problems and regulations; uncertainty of long range product quality; socio-economic problems of increased population in rural areas unprepared

to handle it; financing difficulties; and resource ownership and governmental moratorium on leasing.

- (16) It is estimated that 1.2 to 1.5 million barrels per day of oil from oil shale will be under production by the year 2000.

Considering all these points, Idaho's oil shales are not likely to be economically mined for another decade or more but will eventually come onto the market.

INTERPRETATION OF GEOCHEMICAL ANALYSES

(See Appendix A)

I. Miocene Shale.

Total organic carbon. Of 60 surface samples of Miocene shale (Succor Creek Fm.) representing 7 different sites in southwestern Idaho, organic carbon content indicated the following: 16.6% contained sufficient organic carbon to be an "excellent" source rock for petroleum; 6.6% enough to be a "very good" source rock; 10% enough to be a "good" source rock and 20% enough to be a "fair" source rock. In other words, 53.3% of the Succor Creek shale sampled contained enough organic carbon to be considered a possible source material for oil or gas. However, organic carbon content alone is not sufficient to identify an "oil shale"; other factors, such as, type of organic material, degree of maturity, hydrocarbon components, kerogen type and temperature required for alteration, must also be considered.

Type of organic material. In all 60 samples nearly all of the organic matter consists of herbaceous kerogen, woody plant detritus, and coaly-inertinite. There were only minor amounts of amorphous-sapropel in 2 or 3 samples.

Maturation index or visual kerogen thermal alteration index. All but one of the 60 Succor Creek Fm. samples are immature in terms of thermal alteration. The one exception (sample CMB-2,S.3,4) was moderately mature.

The type of organic material in combination with the thermal alteration index indicates that the Succor Creek shales have a

good potential for biogenic methane gas, but a very meager potential for oil or thermally derived gas. These are all surface samples, however; the more deeply buried material could be quite different in this respect.

Pyrolysis. When $T^{\circ}C$ max. (maximum temperature of hydrocarbon generation) is plotted against $P1/P1 + P2$ ($P1$ = volatile hydrocarbons. $P2$ = thermally generated hydrocarbons) the resulting graph indicates the following: Of the 60 Succor Creek Fm. samples 31.6% has some oil potential, 29% has some thermally derived gas potential, 39.4% are immature with only a biogenic gas potential.

Additional information. A special sample of the best appearing Succor Creek Fm. shale from the Horseshoe Bend site was analyzed more completely by Geochem Laboratories. Analyses included - total organic carbon; C_{15+} (heavy hydrocarbon) extraction; deasphalting and liquid chromatography; C_{15+} gas chromatography on the P-N (Paraffin-Naphthene) chromatofraction; visual kerogen assessment; and vitrinite reflectance measurement. The results were as follows: "Very good" organic carbon content; both amorphous and herbaceous organic matter and a maturation index of 1+ to 2-; total C_{15+} Soxhlet extract is high (883.0 ppm); the hydrocarbon content is relatively low (175 ppm); the non-hydrocarbon content is high (708 ppm); the PN/Arom (Saturates/Aromatics) ratio is low; Asphaltenes are more prominent than either the aromatics or the saturates. The sample contains a significant amount of sulphur (34 ppm).

These results indicate that the shale in this area has generated dry gas (mostly methane); it does however, have the potential to generate significant quantities of both condensate and liquid hydrocarbons under a higher geothermal regime (greater burial depth or in a hotter part of the basin).

The high geothermal resources potential known to exist in Idaho indicates a higher than normal geothermal gradient, particularly in those areas of greater potential (see Map 7, Appendix B). We might therefore, expect greater liquid hydrocarbon generation from this type of source material in Idaho than would normally occur elsewhere.

In addition to the surface samples, a set of samples taken from a deep exploration well near Meridian, Ada co., Idaho, were analyzed. The analyses included - total organic carbon; lithologic descriptions; visual kerogen assessments as to type and maturation; C₁₅+ extraction, and liquid chromatography and paraffin-naphthene gas chromatography. Results include -

- (1) From the surface to 12,100 feet depth the rocks consist of interbedded volcanics and fluvial-lacustrine sediments.
- (2) Twenty four samples were analyzed, 10 of which, in addition to the above listed analyses, were analyzed for C₁₅+ soxhlet extraction, and deasphalting.
- (3) 10 samples contained sufficient organic matter to be considered prospective source rock units. Values range from .43% to 1.95% T.O.C.
- (4) The 10 samples contained "poor" to "fair" amounts of C₁₅+ total extractable bitumen and "poor" to "good" amounts of C₁₅+ total hydrocarbons.

This means that the samples represent fair sources of hydrocarbons. (5) The organic matter is predominantly woody-material. These materials are mainly gas producers rather than oil.. (6) Samples between the surface and 2100 feet are thermally immature and consist of Pliocene-Pleistocene lacustrine sediments from Lake Idaho beds. (7) Samples from 3,840 feet to 8,700 feet are thermally mature. They are capable of generating both liquid and gaseous hydrocarbons but primarily gas would be expected. These are probably also Pliocene-Pleistocene Lake Idaho beds. The Succor Creek Fm. in this well was encountered at a depth of 9,400 feet. Samples below 8,700 feet were not analyzed. It is expected that the Miocene lake beds (Succor Creek Fm.) being at greater depths will be more mature and better source material. (8) The upper section of this well (1000'-2100') represents a fair source for biogenic methane gas. The lower section (3,840'-8,700') is a "poor" source for oil but a "fair" source for gaseous hydrocarbons.

Numerous shallow, moderate, and a few deep exploration wells have been drilled in southwestern Idaho. Many of these wells have encountered good gas and oil shows. It is believed by many in the petroleum industry that the Miocene shales of the Succor Creek Formation are the source of these shows. Apparently, these shales have generated not only biogenic methane but also other thermally generated hydrocarbon gases and oils. A rather wide range of hydrocarbon fractions have been found in small amounts in these wildcat wells.

II. Cretaceous Shale.

Of the 34 samples analyzed only 4 (11.8%) were interpreted as having more than a "poor" potential as oil shale. Most had only minor amounts of organic matter, hardly enough to analyze. Three samples had a "fair" potential and one had a "very good" potential according to the T.O.C., which was 2.2%. Even though the Cretaceous shales generally were "poor" source materials, the few samples with "fair" to "very good" ratings indicate the need for further closer investigation of the Cretaceous sections. Other older shales (Paleozoic and Mesozoic) were also sparsely sampled but lack of sufficient funds precluded chemical analyses at this time.

III. Most Promising Sites.

Coal Mine Basin, Dry Creek, and Horseshoe Bend sites appear to have the greater potential for shale petroleum according to the geochemical indexes from surface samples. Subsurface well data and geochemical analyses of deep samples plus local and regional geology indicate that much of southwestern Idaho has a good potential for shale oil and gas from the Succor Creek Formation. (see articles 7, 8, 9 of Source Literature and Geothermal Resources Map 7).

NATURE AND USES OF GEOTHERMAL RESOURCES ACCORDING
TO GEOTHERMAL RESOURCES COUNCIL - 1972

Geothermal resources are steam, hot or warm water, and the natural gases and compounds associated with them, which are the products of the inherent heat of the earth. These resources are usually associated with and related to Tertiary or recent volcanic features of the siliceous type, faults, large rifts or grabens, and permeable rocks in areas of considerable influent meteoric water. A geothermal system consists of a circulating cell of hot water and/or steam capped with nonpermeable strata and fed with meteoric water through fissures or restricted permeable zones. Such cells that have been found to date are at depths less than 10,000 feet and have a range of water temperatures from 150 to 388°C. There are 3 major types of systems.

(1) The vapor-dominated ("dry-steam") system which require a potent heat supply and low initial permeability. After an early hot water stage a system becomes vapor dominated when net discharge exceeds recharge. The two primary examples today are the Geysers field in California and the Larderello field in Italy. The near surface rocks of these fields are relatively tight and do not allow large quantities of meteoric water to reach the deeper parts of the systems. Surface springs are typically low in discharge, strongly acid (pH 2-3), low in chloride. In general, where surface springs are low in chloride and subsurface waters are similarly low (less than 20 ppm) a

vapor-dominated system is indicated. Shut-in well head pressures in typical steam wells tend to increase with depth up to a maximum of about 32 kg/cm^2 . Temperatures may even decrease at greater depth. The maximum temperatures in these fields are from 236° to 241°C . Recorded temperatures of the vapor-dominated reservoirs are significantly lower than in some hot-water reservoirs.

(2) The water-dominated ("hot-water") systems are usually found in permeable sedimentary or volcanic rocks or in granite that is fractured and faulted. Discharge from these systems is relatively high (a few lpm to several hundred lpm) per spring. The near-boiling hot waters of moderate to high discharge are nearly always high in alkali chloride, SiO_2 , B, and As. The surrounding ground is commonly bleached and hydrothermally altered to a porous siliceous residue similar to hot spring sinter. It may contain sulfur, white, yellow, and orange sulfate minerals and kaolinite. pH is usually 2.5 to 5 and Fe, Al, Ca, and Mg are abundant relative to Na and K. Temperatures increase with depth to a base temperature and stabilize. Maximum temperature for most is not over 200°C but some do reach as high as 388°C . Most hot springs from these systems deposit sinter (amorphous silica). The water contains at least 240 ppm of SiO_2 .

(3) The warm-water ("sedimentary") system is usually found in deep sedimentary basins and have temperatures far below the boiling point. Some are related to the basic type of volcano of recent age. Deposition around springs from these systems

usually consists primarily of travertine (CaCO_3). This system is not usually considered as a typical geothermal system because of its low temperatures.

The major use of geothermal resources is the production of electrical power from the dry steam energy, steam flashed from hot water, or the energy from hot water transferred to a low boiling point fluid such as freon or butane. Geothermal resources are multi-purpose resources, however, and are used for such purposes as space heating, refrigeration, air conditioning, agriculture, new water source through desalination, source of chemical compounds, processing of diatomite, paper pulp, and plastic explosives, resorts, and certain kinds of fisheries.

World Status of Geothermal Resources Development:

Countries that have already successfully developed geothermal electricity include the United States (California), Italy, New Zealand, Japan, the Soviet Union, and Iceland and these countries are progressing with further developments at a rather rapid rate. Exploration and development is underway in 25 additional countries with good results reported from the Philippines, and Taiwan. At least 80 countries have favorable indications of a geothermal potential. Some of the more important areas include Algeria, Greece, Guatemala, India, Israel, and Yugoslavia. At the present time the worldwide capacity of geothermal power plants is about 800 mw, about the size of a single modern nuclear power plant. Development in the U.S.A. should increase

the capacity by five fold by 1980. The rest of the world should double theirs by this time. The United Nations is actively helping the underprivileged nations to develop this power.

The rate of development around the world will depend on many factors such as the economic conditions, political climate, environmental conditions, and social pressures in addition to the nature and potential of the resources.

Governmental Geothermal Research in the U.S.A.

Most of the governmental research and exploration in the geothermal field is done by the Department of Interior through the U.S.G.S. and by the Department of Reclamation. Prior to 1971, no specifically funded geothermal resources program was in force but some modest research was done by the U.S.G.S. as a part of their energy and mineral programs. The following results were obtained:

1. Demonstration that hot-spring fluids were predominantly of meteoric origin.
2. Development of a geothermal system model involving the circulation of meteoric water to many thousands of feet.
3. Demonstration through drilling that temperatures in the upper parts of the geothermal system are controlled by the reference boiling-point curve.
4. Recognition that acid-sulfate springs do not represent deep water but result from steam that has boiled from

chloride water at depth and condensed near the surface, with subsequent atmospheric oxidation of H_2S to H_2SO_4 .

5. Recognition of SiO_2 content in water as an indicator of high subsurface temperature.
6. Detailed documentation of the near-surface hydrology, geology, and geochemistry of a hot-water geothermal system.
7. Estimated that the total recoverable water of a salinity less than 35,000 ppm in the Imperial Valley is 1.1 billion acre-feet, of which 200 million acre-feet is at a temperature of $150^{\circ}C$ or greater.
8. Demonstration of pressures up to 90 psi in excess of hydrostatic, probably resulting from near surface "self-sealing" by deposition of silica, clays, and zeolites from hot water.
9. Discovery of many hydrothermal explosion craters, some as much as a mile in diameter.
10. Development of a theory to account for the difference between vapor-dominated and hot-water geothermal systems.
11. Determination of the solubility of various kinds of silica and development of the silica geothermometer, the Na/K geothermometer and the Na-K-Ca geothermometers.
12. Published a documented analysis of the geothermal resources of the U.S.A.

In 1971 Congress appropriated an increase of \$500,000.00 for geothermal classification, examination, and research by the

U.S.G.S. This research began in May, 1972. Most of the work will be done in California where the geothermal conditions are better known; then the results of the study can be applied elsewhere. Some work will be done in Idaho near the Yellowstone area.

The research program will include (a) sampling and chemical analysis of hot springs and wells, (b) hydrologic analysis, (c) electrical and electromagnetic surveys, (d) seismic noise surveys, (e) conductive heat-flow studies, (f) thermal infrared investigations, (g) reconnaissance techniques.

Geochemical studies include research on the SiO_2 , Na-K-Ca, and Cl^{12} - Cl^{13} methods of predicting subsurface temperatures, and temperature dependent rock-water interactions from drill cores, low-water and ion-ion interaction between normal water and water with chemicals in solution, and others..

A major effort to understand the physics of hydrothermal systems will be supported by diamond drilling at relatively shallow depths to supplement data from private industry at greater depths. Finally, a project specifically to estimate the geothermal resources of the U.S.G.S. will be started..

Exploration Techniques:

Concentrations of geothermal energy in the subsurface are not easily found. The effort requires use of all available exploration techniques. These techniques include: (1) good geologic mapping, (2) investigation of surface indicators of

of geothermal anomalies, (3) sampling of hot springs and wells and alteration products for geochemical indexes, (4) all conventional geophysical methods, (5) micro-seismic and ground noise surveys, (6) infrared and other remote sensing methods, (7) test drilling.

At the present time the consensus is that good geologic mapping is most important, the best geophysical tools are resistivity surveys and temperature gradient surveys, and the best geochemical techniques are the geothermometers and particularly the silica content of hot springs and wells.

Relatively new techniques which appear to hold great promise of success are ground noise survey, microseismic surveys and scanning imagery through visible light to infrared by remote sensing devices.

Environmental and Economic Aspects:

The restrictions being placed on the petroleum, coal, and nuclear energy systems today by an environmental conscious society might force a shift to a new energy source and geothermal energy is a very favorable substitute if sufficient quantity can be established.

Geothermal energy is very low in all types of pollution, safer and less expensive than the conventional energy systems as indicated on Table 1.

Each KW of electricity requires 20 lbs of steam per hour. Typical production is between 100,000 + 500,000 lbs. per hour per well which equals 5000-25000 KW per well. A 1000 MW plant

would require 60 wells at 15000 KW each. Typical shut-in pressures are from 200 to 400 psi.

The geothermal electrical power systems in this country have been explored, researched, and developed by a combined effort of power companies and petroleum companies in California. This seems to be the most plausible kind of cooperative for a geothermal power development.

Things to Look for and Record When Drilling a Well in a Prospective Geothermal Area:

In addition to the normal conventional geologic tests, logs, and monitoring these recordings are significant:

- (1) temperature gradient,
- (2) temperature of all waters encountered
- (3) chemical analysis of all waters and particularly for SiO₂, Na/K, Na-K-Ca, Cl, B, As, and gas content.
- (4) shut-in pressures of all warm or hot water bodies,
- (5) examination of all strata or other rocks for alteration products and particularly clay, silica, travertine, and zeolites, Fe, Al, Ca, & Mg.
- (6) pH of all waters
- (7) salinity of all waters,
- (8) permeabilities,
- (9) continuous resistivity survey

Idaho's Geothermal Potential: Warner, 1976

The U.S.G.S. has listed Idaho as sixth from the top in number of acres of known geothermal resources (KGRs) and third from the top in acres of prospective value among 14 states of the western U.S.A. Since these estimates were made, Idaho has risen considerably in potential estimates by independent workers. The state has about 15 million acres of prospective value for geothermal resources. It is thought at the present time that most of Idaho's geothermal resources will be associated with "hot-water" type systems.

This might not be the case, however, because the large Snake River ground water aquifer, the relatively deep Snake River down-warp, and high near surface permeabilities could mask the true picture. Hot water or steam rising thousands of feet from great depths would likely be diluted, chemically altered, and reduced in temperature before reaching the surface. Even though this type of geologic setting usually produces the "hot-water" systems it is entirely possible that steam reservoirs can exist at more than one level. Surface indexes in this case would reflect conditions of only the uppermost reservoir. Also the high quantity of amorphous silica in this area in the form of volcanic ash, which is more soluble than crystalline silica, could reduce the efficacy of the surface silica geothermometer. At this time it would be wise to restrain conclusions concerning the types of geothermal systems that may exist in Idaho until further detailed and deeper investigations can be completed.

EXPLORATION RESULTS

On work map #7 surface water temperatures and subsurface temperature estimates from silica content of the water are plotted for 120 hot springs and wells in southern Idaho. The surface temperatures and subsurface estimates are each subdivided into three temperature range categories by use of colored symbols. From these symbols hot trends are outlined, which help to determine the favorable prospect areas. Regional and local geology is also used in refining these areas. The yellow shaded areas on the map, therefore, represent the most favorable prospect areas as determined by use of the geologic setting, surface water temperatures, and geochemical indexes.

The following points are important conclusions derived from this study:

1. The high temperature trends coincide with major fault patterns along regional tectonic trends, such as, subcontinent ridges and transform faults extending from the Pacific Ocean basin.
2. The hot zones follow the general arcuate trend of the left lateral rift, which follows the Snake River course. (See Appendix D)
3. Most of the higher temperatures are found in the northwestern part of the Snake River Plain, where the rifting caused the plain to spread southward away from the batholith during the rifting.
4. The central and eastern portions of the plain are covered with Pleistocene basalts, which act as good ground water reservoirs. Many hot springs might exist beneath the basalts but could be camouflaged by the diluting effect of the groundwater and the veneer of lava.
5. The high temperature zones north of the major rift, coincide with present day surface fault lines. South of the rift, this is not the case. Here the hot zones are some 40 miles west of the present fault lines. This fact indicates that south of the rift, the fault lines have been shifted eastward along the rift and that their deeper portions remain behind and control the conduction of hot water

to the surface. Map #3 is a pre-rift map showing the original positions of the faults. Notice that the hot zones fall directly over these original fault positions. (See Appendix D)

6. The conditions of point #5 indicate that the plain south of the rift is that portion that moved while the batholithic side to the north remained stable during the rifting.
7. Rejuvenation of faulting after rifting could cause new faults to produce hot springs. This might be the case along the Raft River where the Craters of the Moon fault extends across the major rift to the Raft River area.
8. The hot zones within the batholith, with the exception of Long Valley graben, are not considered favorable areas because they lack good reservoir beds in which sizable hot water or steam cells could develop.
9. The hot springs and wells along the major rift of the Snake River would probably be much hotter if it were not for the high diluting effect of the river's ground water.
10. All the above conditions indicate that the left lateral rift along the Snake River course is the major control of the hot springs. For this reason, areas far away from the rift are not considered to be very favorable prospects.

Explanation of prospect areas 1A to 8

The yellow shaded prospect areas on map #7 are numbered 1A to 8 in order of priority.

Area 1A is the most favorable area for these reasons:

- (1) Most of the area falls within the best high temperature trend from both surface temperatures and subsurface estimates.
- (2) The area is located within the zone of greatest deformation along the rift, which includes rifting, normal faulting, and spreading.
- (3) It is also within the Snake River graben where a thick section of sedimentary rocks provides good reservoir conditions.

(4) This area is nearest the basic regional tectonic features which produce the heat source.

Area 1B is similar to 1A but does not have as many high temperature springs. The Snake River is probably a diluting agent here.

Area 2 is very favorable because it contains many relatively hot springs and wells and falls within the Snake River graben. There are also numerous faults within this area which could serve as conduits from the heat source. The subsurface temperature estimates from silica content are not as high as in area #1 but are relatively high compared to most areas.

Area 3 is considered good because it overlies the original pre-rift location of a series of relatively large faults. The surface fault lines are now located in the Raft River area to the east. This area is also within the graben and near the major rift. Very little temperature data is available for this area at the present time.

Area 4 is moderately favorable because the large fault of the Craters of the Moon area probably extends southward through this area. Both young faults such as this one and older pre-rift faulting cut the area. It contains the hottest surface water in southern Idaho. 4A is considered somewhat more favorable than 4B because it contains the hot springs. 4D is lacking in data, but falls within the faulted area.

This general area #4 is within the Snake River downwarp so should contain good reservoir conditions. Pleistocene basalts along this area came up through the fault and this has caused some persons to look with disfavor on the area. I think, however, that the pre-Pleistocene history is more important and that the faulting may have predated the basalts and is more genetically related to the acidic lavas. This area is the one that is being considered for extensive investigation and testing by the Atomic Energy Commission conjointly with the state of Idaho.

Area 5 has been overlooked for the most part because it contains no significant faults and only 2 or 3 relatively hot springs at the surface. If we look at the same area, however, on the pre-rift map we find that this general area was cut by numerous major faults, including the Bannock overthrust. These faults show up on

the surface at the present time, 40-50 miles to the east. Since it is the pre-rift fault positions that contain the hot zones today, this area should be thoroughly investigated, and appears to be a potentially good prospect. (See Appendix D)

Area 6 does not contain very hot springs nor wells but does contain moderately hot water and is considered to be a large graben within the batholithic area. It probably has a relatively thick section of sediments which would serve as reservoirs. It is situated between two high temperature zones so should be considered potentially valuable.

Area 7 is outlined as a potential prospect area because it overlies a zone of pre-rift faulting and is adjacent to the Bruneau hot springs area. The Bruneau hot springs area was not included in the prospect because it contains no major faulting of pre-rift age. The hot springs of that area probably have their source to the northwest in area 1B.

Area 8 lies on the major rift and within a zone of acidic volcanics similar to those of Yellowstone Park, so even though it does not contain any very hot springs, it should be considered as a potentially hot area.

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CONCLUSIONS AND RECOMMENDATIONS

1. Of the 94 shale samples analyzed, only the 60 which represent the Succor Creek Formation of Miocene age, have considerable oil or gas potential.
2. The potential is greater for gas than for oil but in zones of deep burial the oil potential improves.
3. The high geothermal resources potential of southern Idaho greatly enhances the chances of oil or gas generation from the Miocene shales.
4. The most favorable surface sites in regard to shale oil or gas potential appears to be those of Coal Mine Basin, Dry Creek and Horseshoe Bend. (See maps and site descriptions).
5. Two areas have some shale oil potential in the Cretaceous shales namely, Site 2 on Highway 34 and Sites 3 and 4 on McCoy Creek. (See maps and site descriptions).

6. More field work, sampling and analyses are needed to properly evaluate the Cretaceous and older shales of eastern Idaho.
7. The quality of the oil shales of this report is much lower than that of the Green River shales of Utah and Colorado. They should not be considered at this time to be of primary importance in regard to retort experimentation or testing.
8. The Succor Creek (Miocene) shales should be considered as a good gas source and a possible oil source for the future - after 1990.

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