Reconnaissance examination of selected oil sand and oil spring occurrences in Wyoming

by

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INTRODUCTION

Numerous oil seeps and oil sands have been reported in the literature in Wyoming. Clark and Glass (1982) reviewed the literature for reports of occurrences and catalogued 78 reported occurrences of shallow or outcropping oil sands and oil seeps in Wyoming. The majority of these references are quite old, with vague descriptions of locations and formations containing the oil. The purpose of this study was to do a reconnaissance field examination of selected occurrences to better describe the occurrence and make some assessment as to the potential economic importance of the deposit. A reconnaissance geologic map of the occurrence was constructed from field observations and existing maps from the literature. The deposit was sampled, described and photographed. Since it was impossible to visit 78 reported occurrences, the author visited only those surface occurrences which appeared significant based on the descriptions in the literature. A total of ten occurrences were visited and described during the summers of 1984 and 1985 (Figure 1). The author attempted to locate additional reported occurrences, but either the description in the literature was too vague to locate the deposit or evidence of the occurrence could no longer be located due to developmental activity in the area. Also, a few of the occurrences which were located were deemed to be insignificant and were not described in detail or sampled.

The oil sand occurrences examined were all in sandstones of varying depositional environments and ranged in age from Tertiary to Pennsylvanian. Examples of both structural and stratigraphic traps were examined. Both oil seeps examined appeared to be related to nearby faults. Some of the occurrences contain live oil at the outcrop while others appeared to contain primarily dead oil.

DESCRIPTION OF POTENTIALLY SIGNIFICANT OCCURRENCES

Rattlesnake Hills Occurrence

The Rattlesnake Hills occurrence, located 45 miles west of Casper (Figure 1), was the largest and most significant deposit examined. Topographically the hills result from erosion of the northwest plunging Rattlesnake anticline which formed in the Laramide. Precambrian rocks are exposed in the core of the anticline and numerous Eocene volcanic vents and intrusives occur on the southeast end of the structure; the most conspicuous being Garfield Peak, a quartz latite intrusive. Sediments exposed on the northeast flank range in age from Cambrian to Eocene, with some evidence of Oligocene stream gravels capping some ridges on the northeast flank of the anticline (Pekarek, 1978). The anticline is asymmetrical with a steeper southwest flank which is broken by a reverse fault. Strikes average about N 45° W and dips vary from 10° to 50° in the rocks of Paleozoic and Mesozoic age on the northeast flank (Pekarek, 1978). The Rattlesnake Hills geologic feature, in general, has been discussed in numerous geological reports dating back to 1869. These references are listed in Pekarek's paper.

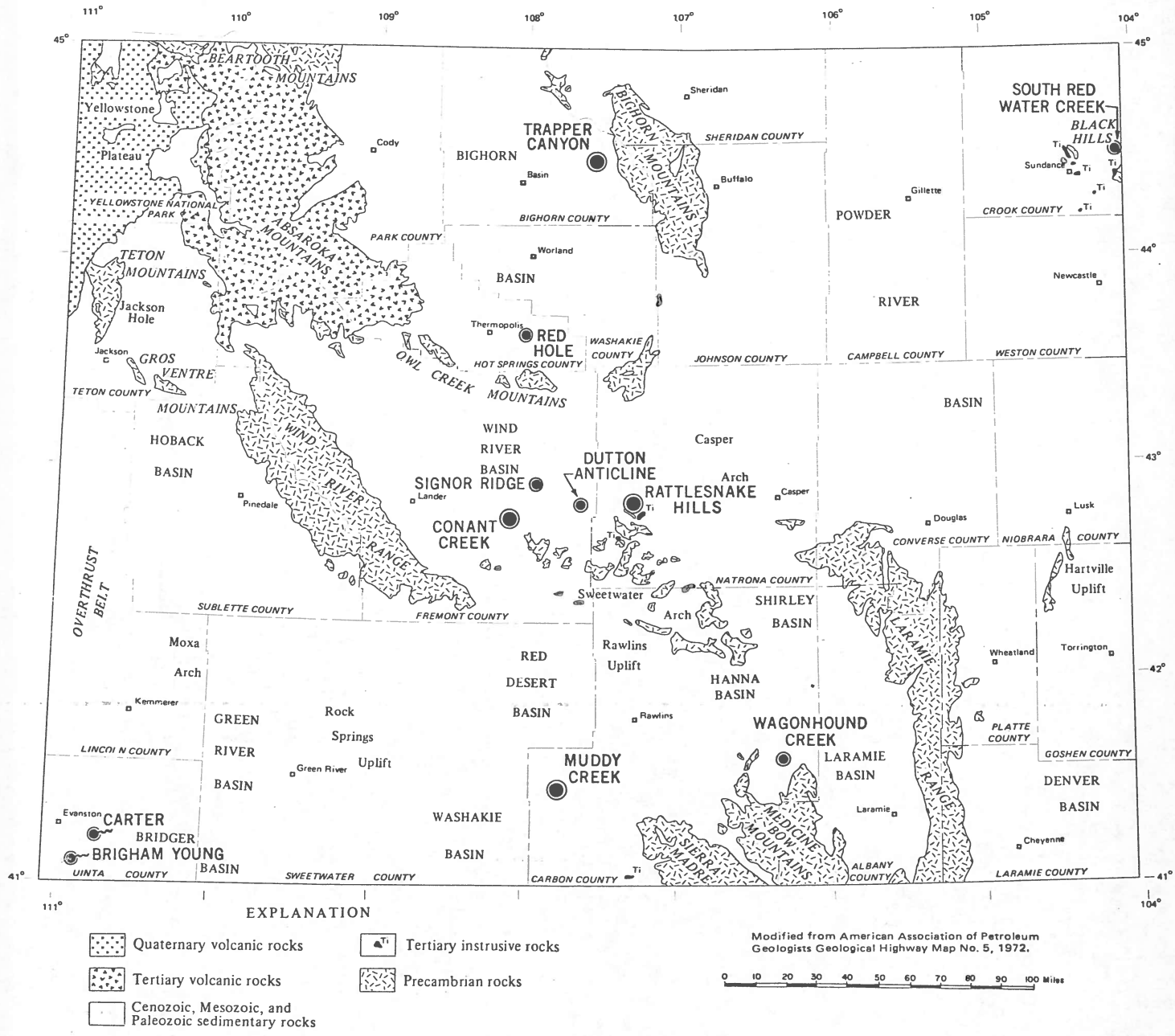
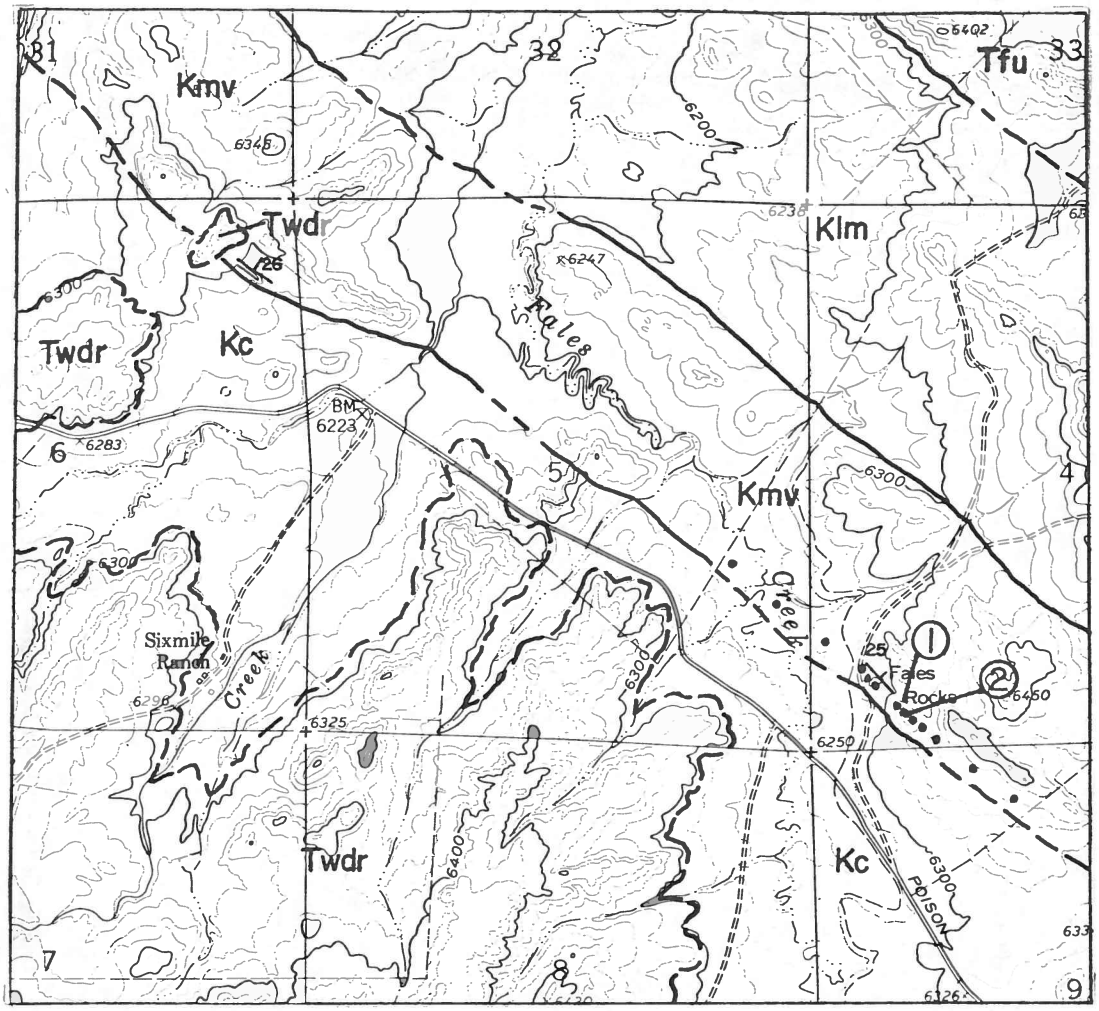


Figure 1. General location map showing oil sand and oil spring occurrences examined in this report. Large oil sand occurrences = ◉, smaller oil sand occurrences = ◉, and oil spring occurrences = ⊂

During our reconnaissance field examination, we concentrated on outcrops in the Upper Cretaceous Mesaverde Formation, the Upper-Cretaceous Frontier Formation and the Lower Cretaceous Muddy Sandstone, as they appeared to be the most significant in terms of oil saturation. Earlier authors had mentioned intermittent occurrences in other Lower Cretaceous sandstones, Jurassic and Triassic sandstones, and some isolated occurrences in the Madison Limestone.

The initial oil saturated outcrop examined was a sandstone in the lower portion of the Mesaverde Formation in the SW 1/4, SW 1/4, Section 4, T. 33 N., R. 87 W. (Figure 2). Barwin (1961) applied the name Fales Member of the Mesaverde Formation to this regressive shallow marine sandstone. This particular feature is known locally as "Fales Rocks." Approximately 60-70 feet of sandstone is exposed at the outcrop and only the upper 30-40 feet is impregnated with intermittent live and dead oil (Figure 3). Some portions of the outcrop exhibit tar flowing on the surface. However, a large portion of the stained outcrop contains dead oil. The lower barren zone was either flushed by groundwater or it may have been tight at the time the oil migrated into the trap. The sandstone is fine-grained, subangular, moderately sorted, and gray to buff in color, with oil stained outcrops tending toward a dark gray. The sandstone is quite friable containing limonite zones, small spherical iron concretions, and dark minerals, probably amphibole. The outcrop exhibits massive bedding with some local cross-bedding in the upper portion. It is overlain by the Wallace Creek Tongue of the Cody Shale and underlain by the Cody Shale (Barwin, 1961). The outcrop strikes approximately N. 50° W. and dips 20° - 30° E. Exact dip and strike measurements could not be obtained due to poor bedding surfaces. The outcrop of tar or oil stained sandstone is covered, continuing along strike, both to the northwest and to the southeast. This sandstone re-appears in outcrop to the northwest in the NE 1/4, NE 1/4, Section 6, T. 33 N., R. 87 W. and in the SW 1/4, SE 1/4, Section 31, T. 34 N., R. 87 W. However, no oil or tar staining could be detected in the outcrop and the sandstone appeared to be identical in characteristics to the lower barren zone of the "Fales Rocks" outcrop.

An oil impregnated sandstone outcrop of the Frontier Formation was examined near the center of Section 2, T. 33 N., R. 88 W. (Figure 4). The outcrop strikes N. 35° W., and dips 39° E. The exposed outcrop is 10-15 feet thick with varying degrees of oil or tar staining throughout. Live oil or tar occurrs primarily in the lower part of the outcrop, with mostly dead oil present the upper portion. The sandstone is medium grained, subrounded, moderately well sorted, and buff to gray in color, with heavily stained zones appearing darker gray. The sand has a "salt and pepper" look reflecting the dark mineral content, probably amphibole. Some portions of the outcrop contain siltstone and shale rock fragments in the sandstone. In this area, the Frontier sandstone is overlain by Cody Shale and underlain by Frontier carbonaceous shales and usually forms a prominent hogback (Figure 5). The sandstone is covered in many places along strike, northwest and southeast. Bedding characteristics range from massive to thin bedded with some local cross-bedding. This sandstone is considered the top of the Frontier Formation and is referred to



T. 33. N., R. 87 W. Scale: 1" = 2,000'

Map Explanation

Twdr = Wind River Fm.
Tfu = Fort Union Fm.
Klm = Lance and Lewis Fms.
Kmv = Mesaverde Fm.
Kc = Cody Shale
= Formation contact, dashed where covered or projected

$\swarrow_{26}$ = Dip and strike direction and dip angle
(1) = Sample locality and number
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone outcrop

Figure 2. Reconnaissance geologic map showing oil saturation in the lower Mesaverde Formation (Fales Member) on the east flank of the Rattlesnake Hills.

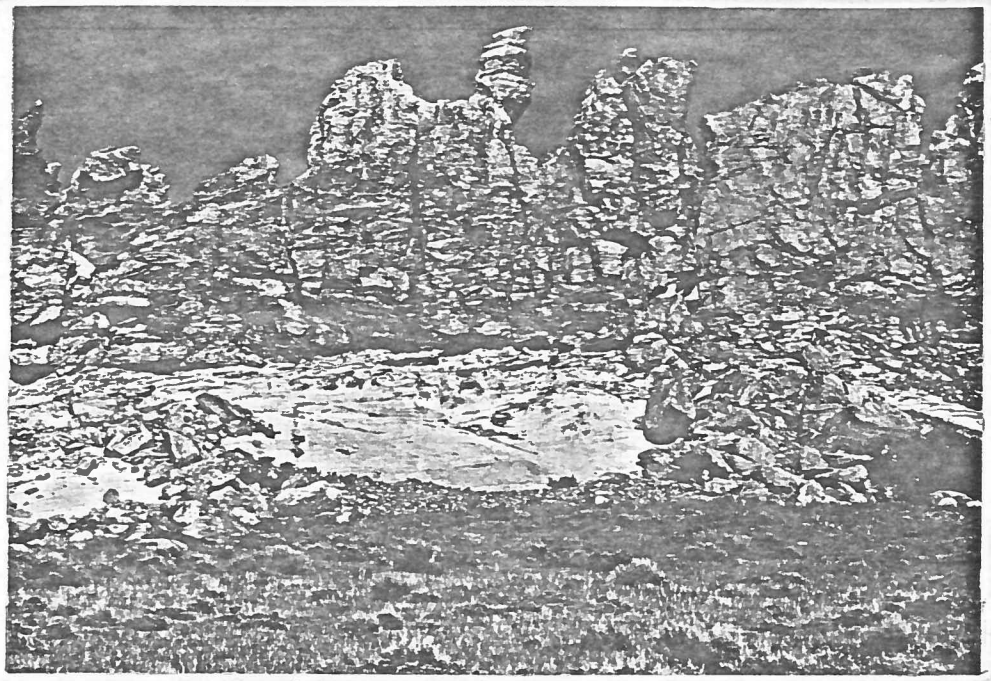
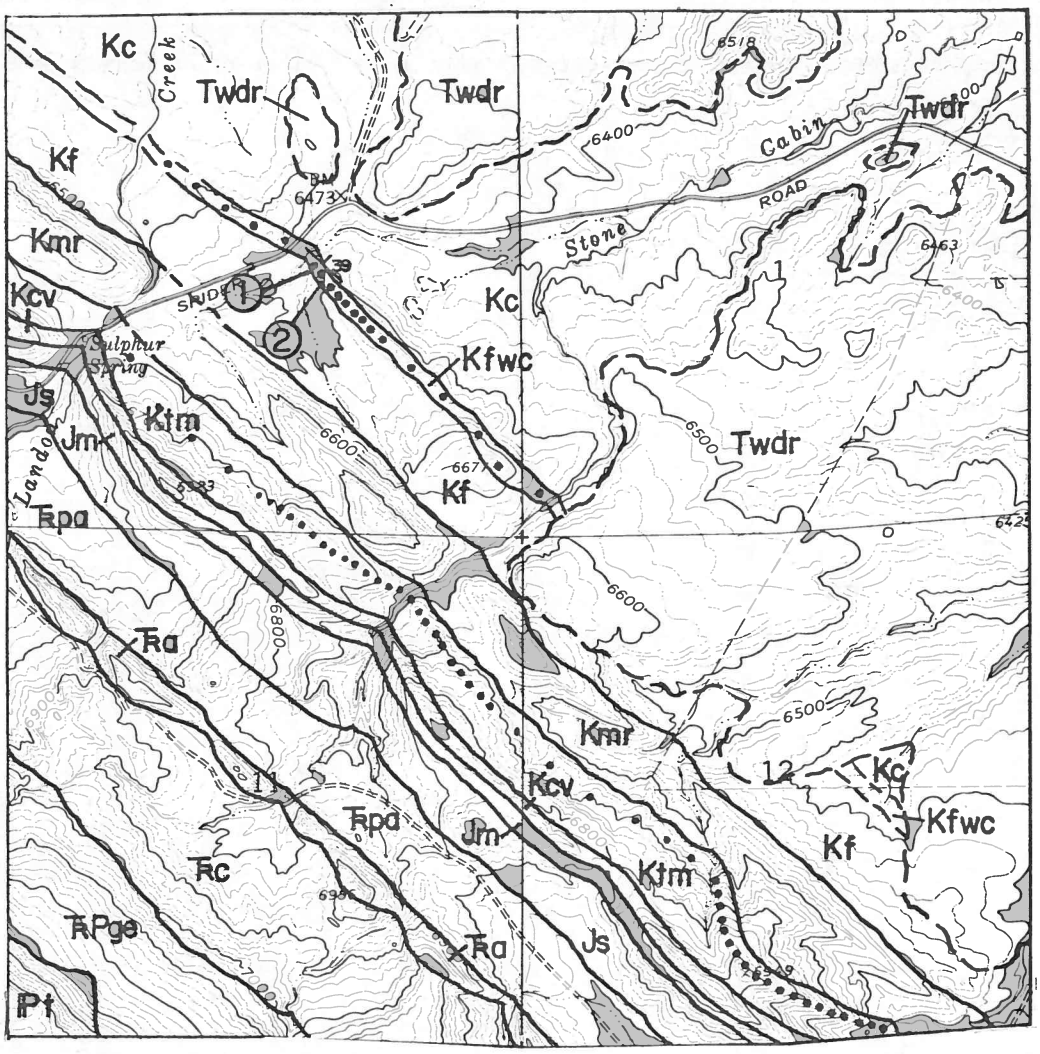


Figure 3. Oil saturated outcrop of the Fales Member of the Mesaverde Formation on the east flank of the Rattlesnake Hills. Upper dark zone is oil saturated and lower light colored zone is barren.



T. 33 N., R. 88 W. Scale: 1" = 2,000'

Map Explanation

Twdr = Wind River Fm.
Kc = Cody Shale
Kfwc = Wall Creek Member of Frontier Fm.
Kf = Frontier Fm.
Kmr = Mowry Shale
Ktm = Thermopolis Shale and Muddy Sandstone
Kcv = Cloverly Fm.
Jm = Morrison Fm.
Js = Sundance Fm.
Rpa = Popo Agie Fm.
Ra = Alcova Limestone Member-Chugwater Group
Rc = Chugwater Group-includes Red Peak Fm.
RPge = Goose Egg Fm.
Pt = Tensleep Sandstone
= Formation contact, dashed where covered or projected
39 = Dip and strike direction and dip angle
(1) = Sample locality and number
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone outcrop

Figure 4. Reconnaissance geologic map showing oil saturated outcrop in the Frontier Formation and Muddy Sandstone on the east flank of the Rattlesnake Hills. Geology modified from Pekarek (1974).

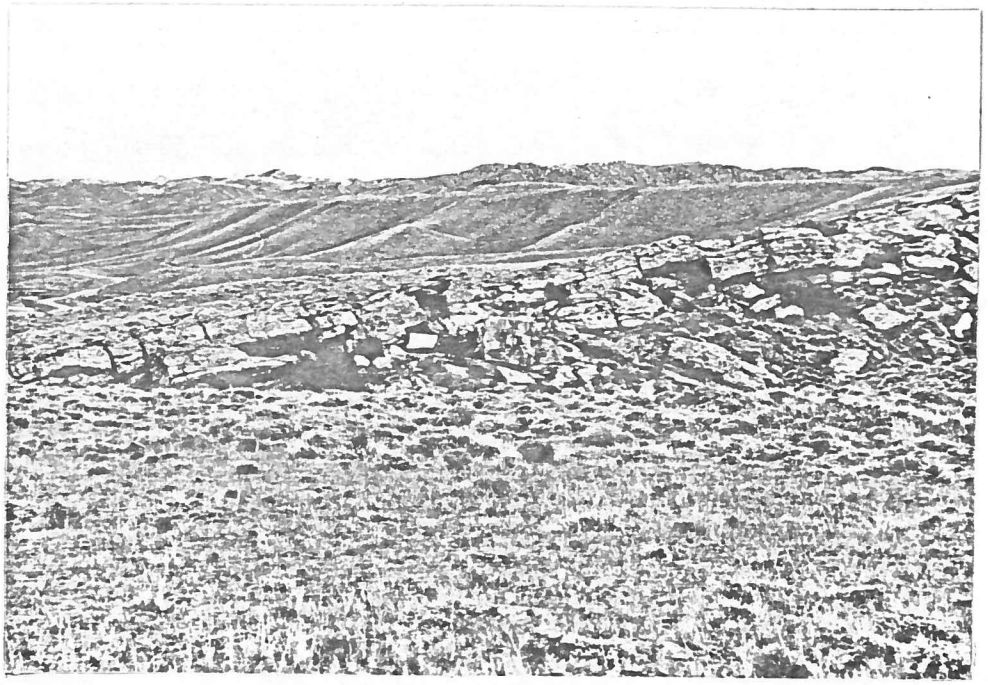


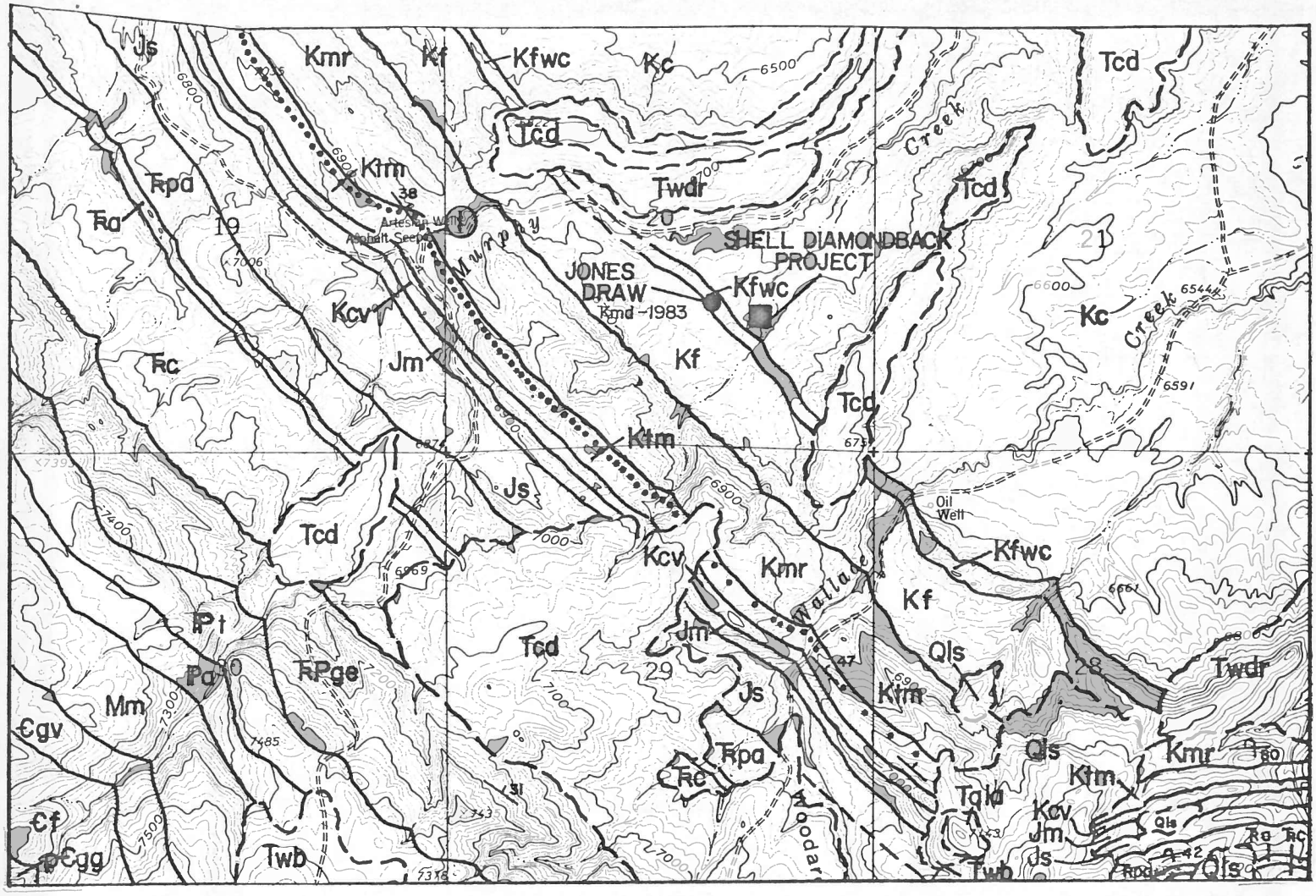
Figure 5. Oil saturated outcrop of the Wall Creek Sandstone Member of the Frontier Formation on the east flank of the Rattlesnake Hills. Flat lying unit in the background is the Wind River Formation which is in angular discordance with the Frontier Formation and the Cody Shale.

as the Wall Creek Sandstone Member of the Frontier Formation (Pekarek, 1978).

A live-tar seep and associated oil or tar saturated Muddy Sandstone outcrop was examined in the NE 1/4, SE 1/4 of Section 19, T. 33 N., R. 87 W. (Figure 6). The sandstone outcrop strikes N 34° W, dips 38° E, and is approximately 20 feet thick. Live oil or tar seeps were noted on both the north and south sides of Murphy Creek (Figure 7). The Muddy Sandstone is very fine to fine grained, subangular to subrounded, well sorted, and light to darker gray in color depending on oil saturation. The sandstone is relatively clean, containing a few dark minerals. Cross-bedding is present, consistent with near shore shallow marine bar deposition. The unit is overlain by shale and a thin oil stained sandstone unit and is underlain by carbonaceous Thermopolis Shale. The Muddy Sandstone forms a prominent pine vegetated hogback in the area (Figure 8). Oil or tar saturation in the unit appears to be fairly continuous in outcrop for more than five miles along the northeast flank of the Rattlesnake Hills. Dresser (1974) sectioned 19 different outcrops of Muddy Sandstone along the northeast flank and oil staining was noted in the sandstone units at each outcrop. The average cumulative thickness of oil stained sandstone units for the 19 described sections is 27.2 feet with a range of 9 to 50 feet. This five mile saturated zone runs from the Garfield Peak intrusive to the northwest where the Poison Spider Road cuts through the hogback in the SW 1/4 of Section 2,T. 33 N., R. 88 W. Based on the work of Dresser (1974) and our field reconnaissance of the area, the Muddy Sandstone appears to be the most significant oil saturated unit associated with the Rattlesnake Hills, probably holding the best potential for future development.

Six oil and gas fields are currently producing in the immediate vicinity of the Rattlesnake Hills occurrence (Figure 9) . Grieve field, North Grieve field and Forgey field all produce from stratigraphic pinchouts of relatively thick shallow marine sands of the Muddy Sandstone. A structural trap accounts for Muddy Sandstone production from Wallace Creek field and a structural/stratigraphic trap, in the case of Cody Shale production from Raderville field. Development nearest the oil impregnated outcrops includes a well completed in late 1983 by Kirkwood Oil and Gas in the SW 1/4, NW 1/4, SE 1/4 of Section 20, T. 33 N., R. 87 W. This well was initially tested at two barrels of oil per day from the Muddy Sandstone and was shut-in until October of 1985 when 20 barrels of oil were produced and the name Jones Draw was applied to the field.

The Muddy Sandstone tar seep mentioned above led Shell Oil Company, in 1964, to attempt production of heavy oil from the Muddy Sandstone downdip. Several wells were drilled in a cluster in Section 20, T. 33 N., R. 87 W. and steam was injected unsuccessfully into the Muddy Sandstone (Figure 6 and 9). As a result of this attempt referred to as the Diamondback Project, some reservoir data and reserve data was made available by Shell Oil Company and profiled in a report on tar sand deposits published by the Interstate Oil Compact Commission (1984). According to the IOCC report, an oil/water contact is located at a depth of 1400 feet, porosity averages 25%, permeability averages 1000 mil-



T. 33 N., R. 87 W. Scale: 1"=2,000'

Map Explanation

Qls = Landslide deposits
Tcd = Channel deposits
Twb = Wagon Bed Fm.
Twdr = Wind River Fm.
Tqla = Quartz latite agglomerate
Kc = Cody Shale
Kfwc = Wall Creek Sandstone Member of Frontier Fm.
Kf = Frontier Fm.
Kmr = Mowry Shale
Ktm = Thermopolis Shale & Muddy Sandstone
Kcv = Cloverly Fm.
Jm = Morrison Fm.
Js = Sundance Fm.
Trpa = Popo Agie Fm.
Tra = Alcova Limestone Member of Chugwater Group
Trc = Chugwater Group-Red Peak Fm.
TRPge = Goose Egg Fm.
PPt = Tensleep Sandstone
PPa = Amsden Fm.
Mm = Madison Limestone
Cgv = Gros Ventre Fm.
Cf = Flathead Sandstone
pCgg = Precambrian granite gneiss
13 = Dip & strike direction & dip angle
80 = Dip and strike direction & dip angle for overturned beds
1 = Sample locality & number
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone outcrop
= Formation contact, dashed where covered or projected.

Figure 6. Reconnaissance geologic map showing oil saturated Muddy Sandstone outcrops on the east flank of the Rattlesnake Hills. Geology from Pekarek (1974).

Figure 7. Live oil seep flowing from the Muddy Sandstone on the north side of Murphy Creek, east flank of Rattlesnake Hills.

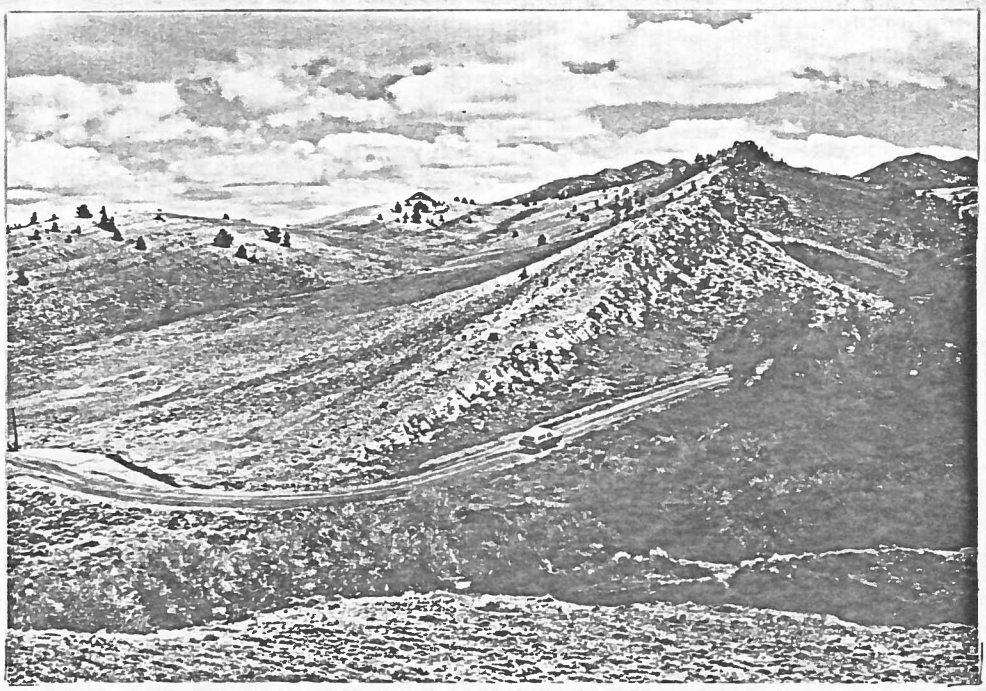


Figure 8. Oil saturated Muddy Standstone outcrop on the south side of Murphy Creek, east flank of the Rattlesnake Hills. A live oil seep is located where the dipping Muddy Sandstone outcrop intersects Murphy Creek in the foreground.

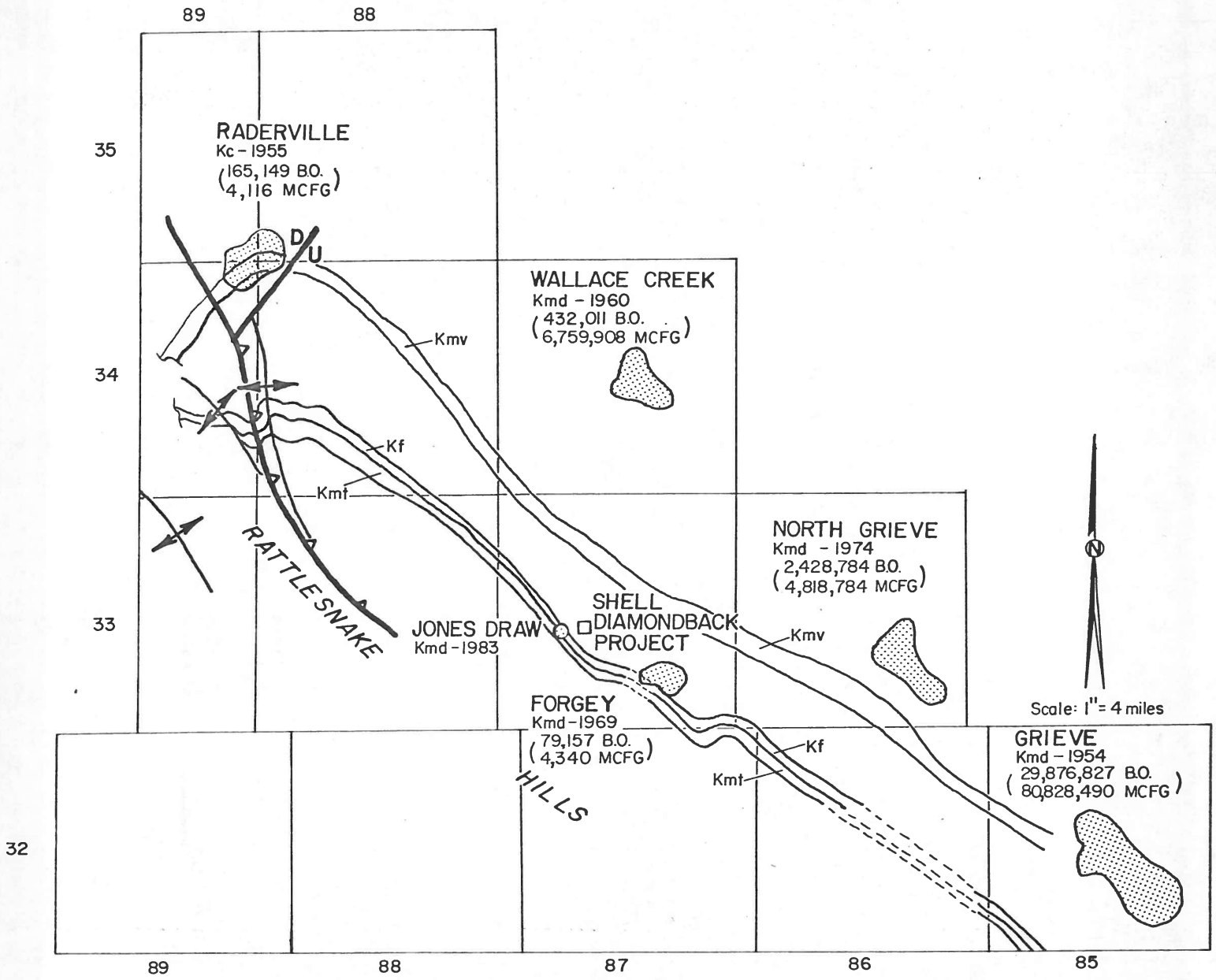


Figure 9. Generalized map of the Rattlesnake Hills vicinity showing Mesaverde Formation (Kmv), Frontier Formation (Kf), and Muddy Sandstone/Thermopolis Shale (Kmt) outcrops and nearby oil and gas fields with producing formations, discovery date, and cumulative production through 1984. Map modified from Lageson and others (1980).

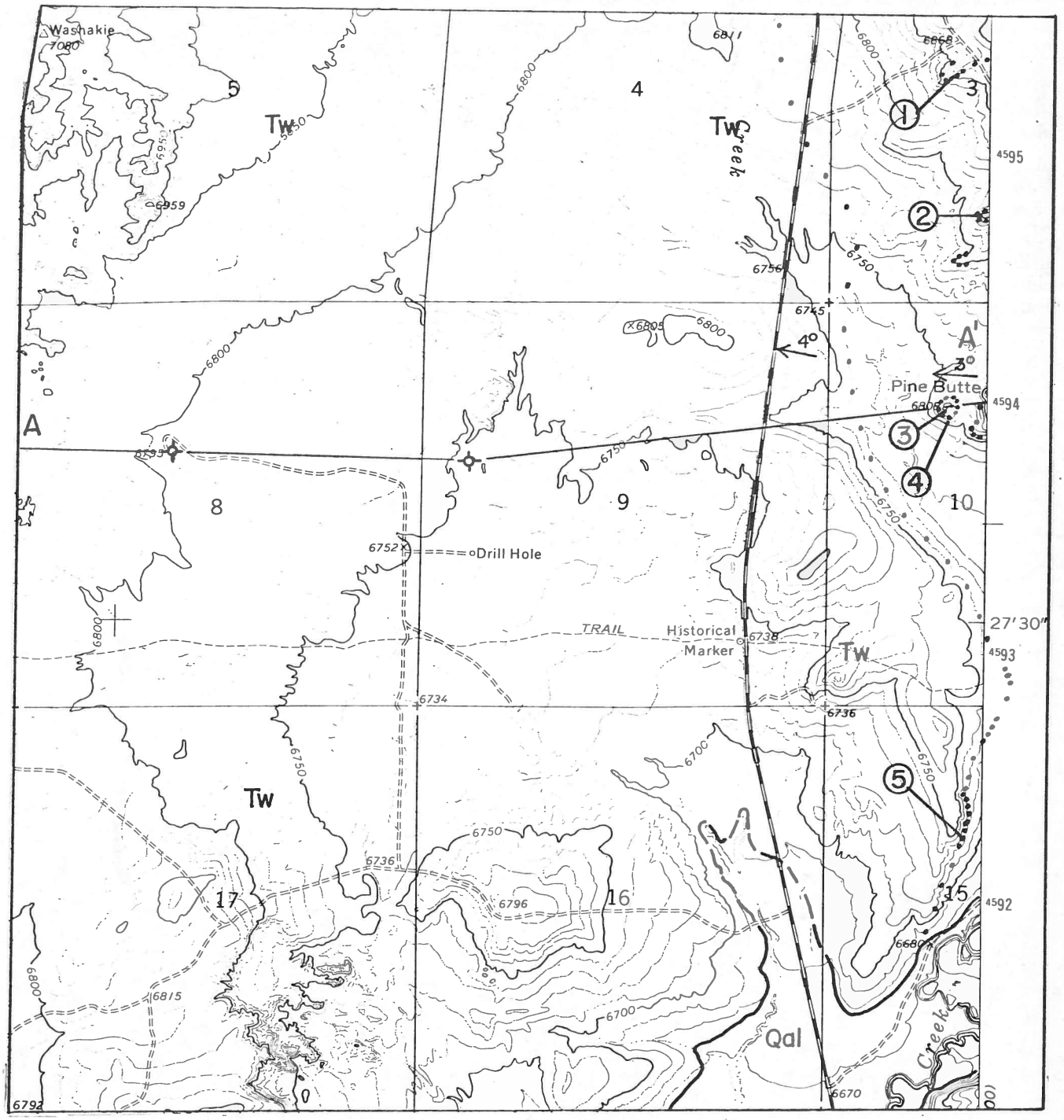
lidarcies, oil saturation averages 41% with a maximum of 60% and reservoir thickness averages 38 feet with a maximum of 50 feet. Resource-in-place estimates total 45 million barrels over a 1500 acre area. The richest areas identified by Shell appear to be downdip from the thickest oil saturated sand developments noted by Dresser (1974) in outcrop. The oil which was produced in small amounts from the steam injection attempt had a viscosity of 12,000 centipoise, with 10,000 centipoise or greater at reservoir temperature defined as a tar sand deposit.

In summary, the oil and gas production near the Rattlesnake Hills occurrence is related for the most part to stratigraphic trapping mechanisms sourced primarily from the Lower Cretaceous Mowry Formation. Judging from the relatively low density of drilling in the general area to the northeast of the saturated outcrops it would appear there is good potential for additional discoveries. Apparently the best potential for shallow tar sand or heavy oil production lies in the Muddy Sandstone, as demonstrated by the Shell Diamondback Project. Other formations with potential include the Frontier Formation, Mesaverde Formation, and possibly some stray sands developed in the Cody Shale. Some additional shallow drilling is needed to determine rich areas like those outlined by Shell for their project.

Muddy Creek Occurrence

The Muddy Creek occurrence is located approximately 35 miles southwest of Rawlins on the eastern flank of the Washakie Basin (Figure 1). The area of interest is bounded on the east by the Sierra Madre Uplift and on the west by the Washakie Basin. In the immediate area examined, rocks of Eocene/Paleocene Wasatch Formation crop out, with the lower Wasatch fluvial sandstones being oil saturated. The area was initially discussed in the literature by C. E. Jamison (1913) and mentioned by Blackstone (1955) in a report on the Muddy Creek area. Hail (1957) also describes the occurrence and lists the results of sample analysis done to determine uranium content of the oil. All previous workers have assigned these oil saturated sands to the Eocene/Paleocene Wasatch Formation and the author found no evidence to the contrary and feels these sands are in the lower Wasatch, which is probably Paleocene.

Oil stained or saturated outcrops were examined in Sections 3, 10 and 15 of T. 17 N., R. 92 W. (Figure 10). Additional small isolated occurrences are described in Sections 22 and 27 in Bureau of Mines Monograph 12 (Ball and Associates, Ltd., 1965). These latter two small occurrences were not located by the author. Outcrops were sampled and examined at five different localities along a two mile stretch (Figure 10). Sample localities 1-4 are in erosional outliers of lower Wasatch fluvial sandstones. Sample locality 5 represents the outcrop of lower sandstone which dips to the west, overlain by red and white banded claystones and shales. Dips in the area are quite shallow 2° -4° to the west or southwest with a strike of approximately N 30° W. (Blackstone, 1955). These lower Wasatch sands are underlain and intertongue with white and gray shales and siltstones.



T. 17. N., R. 92 W. Scale: 1"=2,000'

Map Explanation

Qal = Stream alluvium
Tw = Wasatch Fm.
4° = Approximate dip direction and angle
A–A' = Location of cross-section
(1) = Sample localities and number
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone outcrop
= Dry and abandoned oil test

Figure 10. Reconnaissance geologic map showing oil saturated sandstones in the lower Wasatch Formation at the Muddy Creek occurrence. Geology modified from Blackstone (1955).

An erosional outlier of lower Wasatch Formation was sampled and described in Section 3, T. 17 N., R. 92 W. and is labelled sample locality 1 in Figure 10. This lower sand contain a 2-3 foot oil saturated zone that is medium to coarse grained with intervening conglomerate lenses. The oil saturated sandstone is angular to subangular poorly sorted, and the oil saturated zone weathers to purplish gray in color. Numerous light colored siltstone fragments which are quite angular in shape, are incorporated in the sandstone. The thin overlying and underlying barren sandstones are fine grained, subangular, moderately sorted, and buff colored. These barren sandstones were cemented with calcite and are tight. Cross-bedding is exhibited throughout the outcrop (Figure 11). Occassional zones of limonite staining were noted. Feldspar grains were numerous in these sand units and they should probably be termed arkosic sandstones. The entire outcrop is 7-8 feet thick.

Section 3 and is represented as sample locality 2 in Figure 10. The overall outcrop is 8-10 feet thick with an oil saturated zone near the top which is 2-3 feet thick. Interspersed oil zones were noted mixed with buff colored tight zones in the lower portion of the outcrop. The tight zones are cemented with calcite. The oil saturated zones in the arkosic sandstone are medium to coarse grained, angular to subangular, moderately to poorly sorted, and gray to purplish gray in color. Conglomerate lenses are present along with limonite zones and cross-bedding. Angular light colored siltstone fragments were also noted in the sandstone.

Sample locality 3 (Figure 10) is the thickest overall sandstone outcrop with approximately 25-30 feet of sandstone. The saturated zone was 4-5 feet thick in the most richly saturated portion (Figure 12). The saturation lessens in the upper 15-20 feet of the outcrop (Figure 13). The upper tight zone is cemented with calcite. Description of the oil saturated zone is similar to localities 1 and 2, a medium to coarse grained arkosic sandstone with buff to brown colored siltstone fragments and lenses of fragments. Limonite zones are numerous in both the saturated and unsaturated portions. Cross-bedding is common, especially in the lower part of the outcrop, and both cross-bedding and massive bedding with lesser cross-bedding in the upper part of the outcrop.

Sample locality 4 is located southeast of locality 3 on the same outlier of Wasatch sandstone (Figure 10). The overall exposed sandstone outcrop is approximately 20 feet thick with nearly six feet of exposed oil saturated sand at the base (Figure 14). The overlying barren, tight sandstone is characterized by cross-bedding and coarse rock debris with numerous limonite cased lenses. The adjacent outlier of Wasatch sandstone, located immediately to the east and referred to as Pine Butte (Figure 10), is also variably saturated with oil on the west side in what appears to be the same sand unit. The oil saturated portion is again in the lower half of the sandstone. The southwest corner of the feature exhibits detachment and small scale sliding of the sand unit on the underlying shale. As most of the outcrop on both of these outliers appears somewhat broken-up, some amount of sliding may have occurred on both outliers.

Sample locality 5 represents the only portion of the occur-

Figure 11. Cross-bedded lower Wasatch Formation sandstone at sample locality 1, Muddy Creek occurrence. Lower cross-bedded unit is oil saturated.

Figure 12. Oil saturated lower Wasatch sandstone at sample locality 3, Muddy Creek occurrence. Oil saturated zone is 4-5 feet thick and capped by barren light colored sandstone.

Figure 13. Barren sandstone outcrop near sample locality 3 at the Muddy Creek occurrence. Unit at the base of the outcrop with vegetation on it is oil saturated.

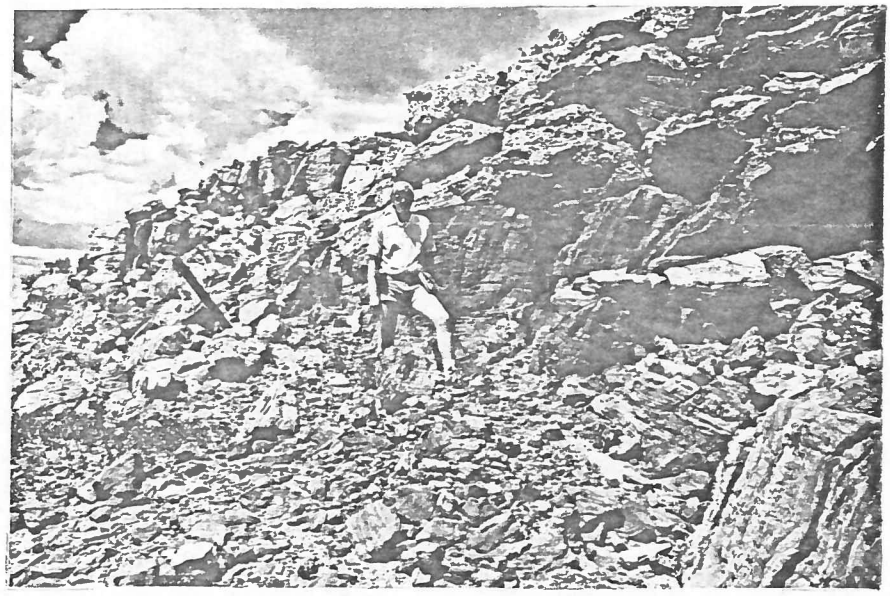


Figure 14. Oil saturated Wasatch outcrop at sample locality 4, Muddy Creek occurrence. Oil saturated zone is 4-5 feet thick and capped by tight, barren sandstone.

rence which is not an isolated erosional outlier. This outcrop is located in the west half of Section 15, T. 17 N., R. 92 W. and is the updip surface occurrence of this lower Wasatch unit (Figure 10). The downdip extent of this sand could not be determined since the sand dipped to the east into the basin, disappearing beneath shale and siltstone overburden. In the case of localities 1-4, the lateral extent could be estimated because they were erosional outliers (see Figure 10). The outcrop is approximately 6-7 feet thick and the entire exposed portion (500-600 feet) is relatively heavily saturated with oil. The character of this arkosic sandstone unit is similar to the other four sample localities. Cross-bedding is common throughout with reworking of the sandstone indicated by the cut and fill channels (Figure 15). Again lenses of siltstone debris and fragments are common, probably derived from older units exposed on the Sierra Madre Uplift to the east. Limonite cased zones are common, especially at the top of the unit. The lateral extent of this saturated sand could not be determined since the outcrop is covered by colluvium to the north and south. However, its estimated position is shown in Figure (10). Following the approximated outcrop to the north, the author located occasional oil saturated sandstone float indicating the continued presence of oil saturated sand to the north. The outcrop of saturated sand is capped by shale and another sand was noted at the top of the ridge overlying this shale sequence. This sandstone, however, is barren and was probably tight at the time of oil migration.

In summary, the Muddy Creek occurrence is a lower Wasatch fluvial sandstone deposit with varying degrees of oil saturation controlled by calcite cemented tight zones and lateral pinchouts. The erosional outlier portion of the occurrence described at localities 1-4 are significant only as an indication of what may be downdip as they are quite small in areal extent (Figure 10). The sandstones examined are basically arkosic, medium to coarse grained with lenses of conglomerate. The cut and fill features, angular sand and feldspar grains, and abundant small scale cross-bedding are all characteristic of fluvial deposits derived from a nearby source, in this case the Sierra Madre uplift. Richer oil saturated zones vary in thickness from two feet at sample locality 1, to 7 feet at locality 5. In terms of adjacent petroleum exploration and development, several gas fields surround the area described. These include Coal Gulch immediately to the west, Baldy Butte to the southwest and Creston to the north. These fields all produce gas from the Lewis Shale and the Almond and Ericson Members of the Mesaverde Formation, and do not appear to be related to the Wasatch oil saturated sandstones described. John Hamilton drilled three shallow tests in 1968 in Sections 8, 9, and 18 of T. 17 N., R. 92 W. and the lower Wasatch sandstones appear to persist downdip to the west at least for 2-3 miles (Figure 16). Examination of the logs indicate, however, that the sands are water saturated. Additional drilling is needed to establish the oil water contact and evaluate these sands to the southwest and north. In addition, the fluvial sandstones occurring above and below the units described should be evaluated in the area. There appears to be good potential for other

Figure 15. Oil saturated outcrop of lower Wasatch sandstone at sample locality 5 on the southern end of the Muddy Creek occurrence. Note cross-bedding and cut and fill features.

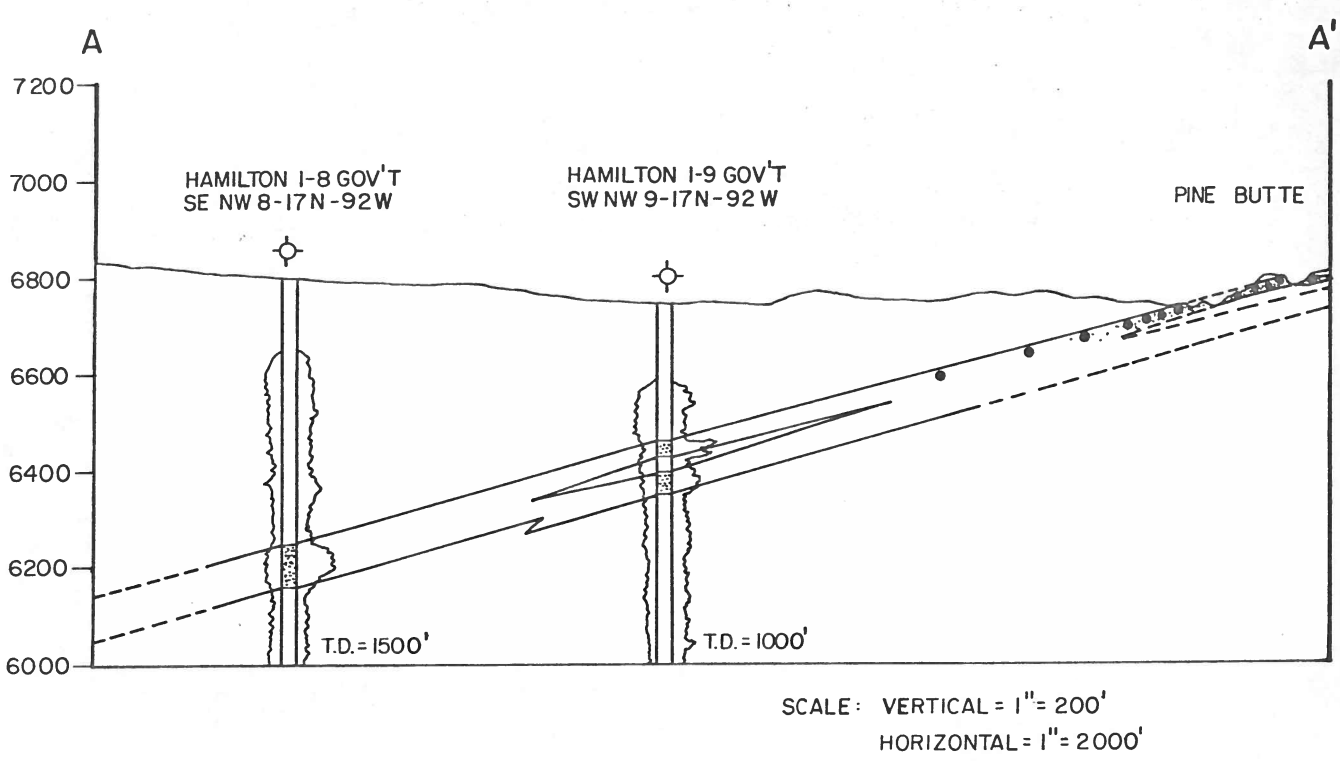


Figure 16. Electric log cross-section showing persistence of lower Wasatch sandstones in the subsurface to the west of the outcrops examined.

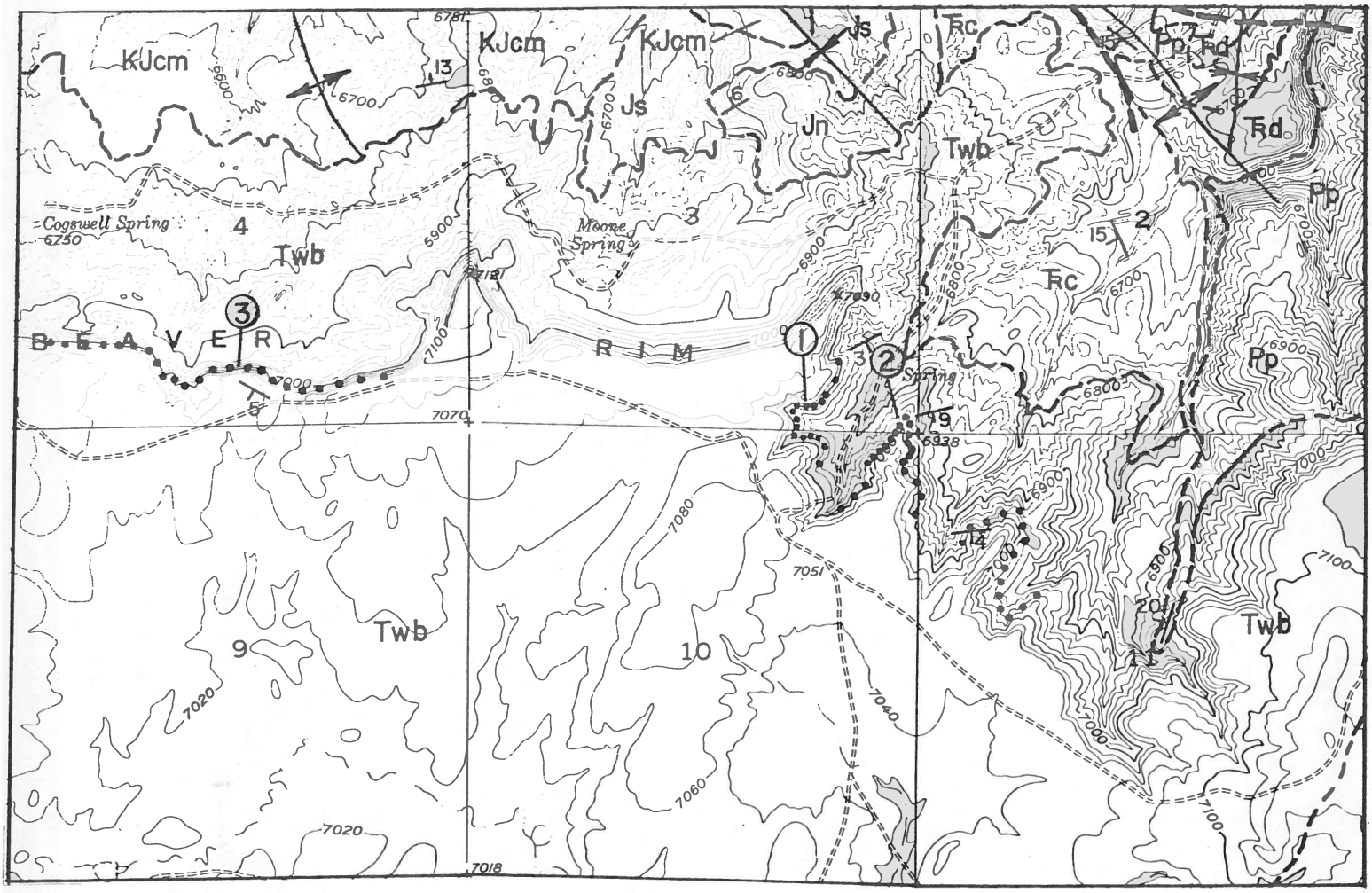
stratigraphic traps for the Cretaceous sourced oil which migrated updip from the basin.

Conant Creek Occurrence

The Conant Creek occurrence is approximately 25 miles southeast of Riverton, on the south side of the Wind River Basin (Figure 1). It is bordered on the south by the Granite Mountains and is located on the west flank of Conant Creek anticline which extends to the north and into the basin. The oil saturated sands occur in the flat lying Eocene Wagon Bed Formation which unconformably overlies lower Eocene rocks (Wind River Formation) and folded Mesozoic rocks. The occurrence is mentioned in the work of Thompson and White (1952) and Van Houten (1954). Van Houten again describes the occurrence along with map locations of saturated outcrops in his 1964 publication. The most recent and detailed discussion of the occurrences appears in Love (1970). These previous studies zeroed in on the uranium content of the oil sands and the thickest oil saturated unit has been strip-mined for uranium in a small pit in the southeast quarter of Section 3, T. 32 N., R. 94 W. (Figure 17). Most of the exposures of oil sand in the area exhibit varying degrees of radioactivity according to these earlier studies.

The outcrop examined occurs intermittently, 2 1/2 miles along the edge of Beaver Rim in Sections 3, 4, 10 and 11 of T. 32 N., R. 94 W. (Figure 17). These outcrops all occur in the Eocene Wagon Bed Formation. Three localities were sampled and described (Figure 18). The most significant outcrop sampled was sample locality 1 in the SE 1/4, SW 1/4, SE 1/4 of Section 3, T. 32 N., R. 94 W. (Figure 17). This locality is situated on the north side of the abandoned strip mine pit of Cheyenne Mining and Uranium Company. The richest oil saturated sand occurrs in the lower part of the pit and ranged from 3 to 5 feet thick. The sandstone is arkocsic, very coarse grained grading into conglomerate in some lenses, poorly sorted, subangular to angular, and light to dark gray depending on oil saturation. The unit is highly cross-bedded and is overlain and underlain by claystone (Figure 18). Additional sandstones units are present in the upper part of the pit wall but they are only oil saturated in thin intermittent lenses. Dip on the sandstone unit is 3° to the southeast with a strike of N 70° E (Van Houten, 1964).

The second locality described and sampled is located in the SE 1/4, SE 1/4, SE 1/4 of Section 3, T. 32 N., R. 94 W. (Figure 17). This locality exhibited dead oil in outcrop and the stained outcrop appears to be the same unit described as the richest unit at sample locality 1. The outcrop was excavated in an attempt mine it (Figure 19) and this activity is probably related to the activity in the nearby Cheyenne Mining and Uranium Company pit described above at sample locality 1. As was the case with the sand described a sample locality 1, this very coarse to conglomeratic sand is poorly sorted, angular to subangular, and light to darker gray in color depending on oil saturation. Volcanic debris is common in the sandstone and it is cross-bedded. The exposed portion of the sandstone is approximately six feet thick. Another sandstone unit occurs above the oil sand and no evidence



Map Explanation

Twb = Wagon Bed Fm.
KJcm= Cloverly & Morrison Fms.
Js = Sundance Fm.
Jn = Nugget sandstone
Trc = Chugwater Group
Trd = Dinwoody Fm.
Pp = Phosphoria Fm.
Mm = Madison Limestone
= Formation contact, dashed where covered or projected

= Anticlinal axis
= Synclinal axis
= Approximate trace of fault
15 = Dip and strike direction and dip angle
(1) = Sample locality & number
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone outcrop

Figure 17. Reconnaissance geologic map showing oil saturated outcrops of Wagon Bed Formation at the Conant Creek occurrence. Geology from Van Houten (1964).

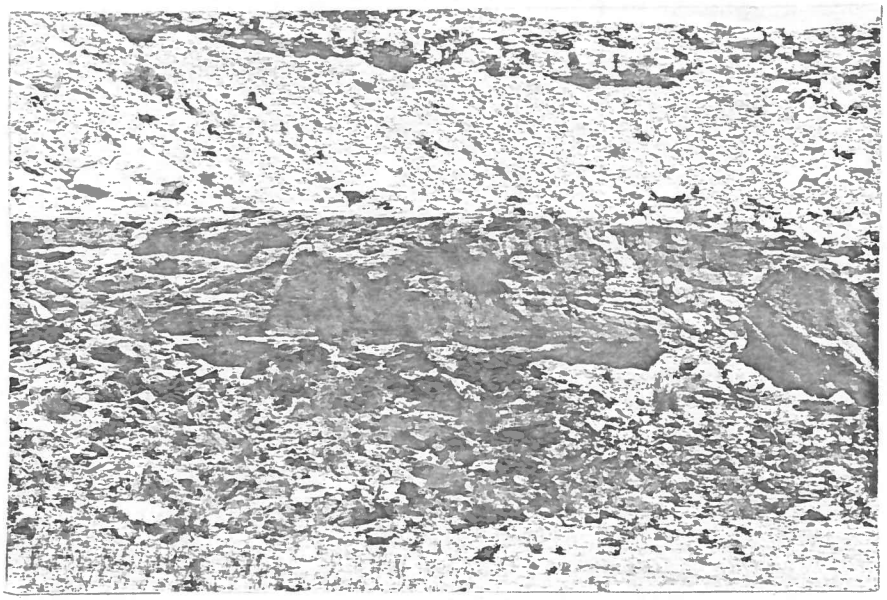


Figure 18. Oil saturated outcrop of Wagon Bed Formation in the abandoned Cheyenne Mining and Uranium Company Pit, sample locality 1, Conant Creek occurrence.

Figure 19. Oil saturated Wagon Bed Formation at sample locality 2, Conant Creek occurrence.

of oil stating was found in it. The dip on this unit is 9° to the southeast with a N 70° E strike.

The third outcrop examined is located in Section 4, T. 32 N., R. 94 W. (Figure 17). This outcrop formed the upper most resistant unit on Beaver Rim and only 4-5 feet is exposed with the remainder being covered by colluvium. The outcrop is composed of very coarse to conglomeritic sandstone with claystone and volcanic debris intermixed. The oil saturation is intermittent and the oil present is dead, exhibiting no liquid characteristics. The outcrop being sparsely oil stained, is buff to yellow in color.

The occurrence, especially in the vicinity of the Cheyenne Mining and Uranium Company uranium pit, is described in some detail by Love (1970). Love examined data from 46 shallow holes drilled for uranium exploration in a five square mile area south and southwest of the above mentioned pit. All available logs and cuttings were studied and though the logs are quite sketchy, Love sites that 35 of the holes penetrate from 5 to 100 feet of radioactive oil stained or saturated sandstone at depths ranging from the surface to 500 feet. The lateral limits of the oil staining could not be determined from this drilling program which was designed to explore for uranium. The sandstone unit described and sampled at sample locality 1 in the uranium pit was also sampled by Love and the analysis indicates that the oil is probably sourced from Paleozoic rocks. The sample analysis is summarized below:

Yield (weight percent)	10.3
Ash (weight percent)	.21
Sulfur (weight percent)	4.51
Nitrogen (weight percent)	.44
Carbon residue (weight percent)	15.4
Nitrogen to carbon residue ratio	.029
Specific gravity at 60° /60° F	1.53

The oil is asphaltic with high sulfur and nitrogen contents and a low nitrogen to carbon residue ratio, all characteristic of Paleozoic sourced oil. Tertiary and Cretaceous sourced oils contain less than 0.50 percent sulfur, less than 0.20 percent nitrogen and their nitrogen to carbon residue ratios are closer to .060. Love (1970) feels that the oil probably migrated upward from Paleozoic sources into the Eocene Wagon Bed sandstones or laterally from the Paleozoic rocks in the core of Conant Creek anticline. Depending on the lateral limits of the saturated Wagon Bed sandstones, several million barrels of oil could be contained in the deposit, much of which would be within feasible limits of strip mining. Immediately adjacent to the Conant Creek deposit are several significant oil fields including Sand Draw, Kirby Draw, Sand Draw-North, and Sand Draw-South. They are all on an anticlinal trend immediately west of the Conant Creek occurrence and produce from reservoirs ranging in age from Pennsylvanian Tensleep through Upper Cretaceous Frontier. Data available on crude analysis from Kirby Creek field indicates a Paleozoic source for Phosphoria oil produced and a Cretaceous source for Frontier oil production (Biggs and Espach, 1960).

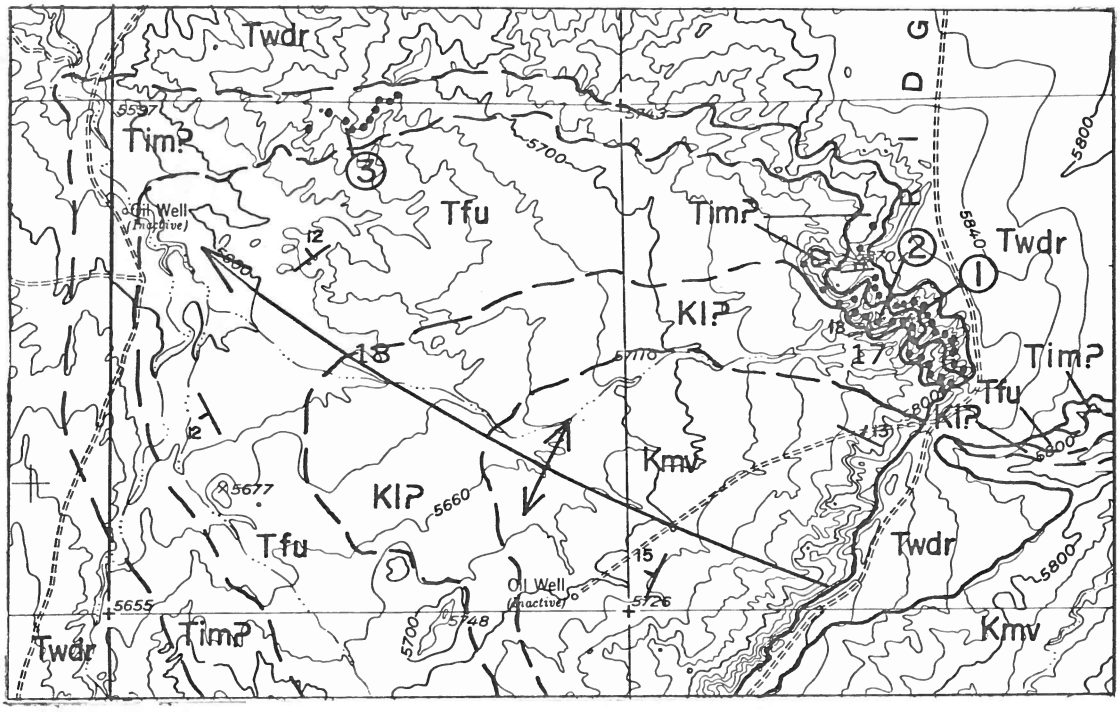
Summarizing, the Conant Creek occurrence represents a probable stratigraphic trap formed in Eocene Wagon Bed fluvial sandstones sourced to the south from the Granite Mountains uplift. The volcanic debris incorporated in the sands is sourced from the Rattlesnake Hills volcanic center to the east and the Yellowstone volcanic center to the northwest. The oil trapped in the occurrenced is sourced from Paleozoic rocks in the Conant Creek anticline, immediately to the east. Judging from the exhumed portion of the trap in outcrop, this would not be considered a potentially significant occurrence. However, exploratory uranium drilling indicates a fairly large, consistent occurrence in the subsurface to the south, possibly several million barrels of oil. Additional drilling is recommended to delineate the occurrence and determine more accurately the volume of resource present. Also other sands below the identified unit should be tested in the area.

DESCRIPTION OF OCCURRENCES WITH LESSER OR UNDETERMINED SIGNIFICANCE

Signor Ridge Occurrence

The Signor Ridge occurrence is located on the southern flanks of the Wind River Basin approximately 25 miles east-south-east of Riverton (Figure 1). The occurrence is on the northwest plunging nose of Muskrat anticline, one of a series of northwest-southeast trending folds along the southern flank of the Wind River Basin. In the immediate area surrounding and including the occurrence, rocks from the Upper Cretaceous Mesaverde and Lance Formations, Paleocene Fort Union Formation and Eocene Indian Meadows (?) and Wind River Formations crop out. Erosional unconformities, in some cases angular, occur between each of the above formations (Keefer and Rich, 1957). Thompson and White (1952) and Keefer and Rich (1957) briefly describe the deposit near the center of Section 17, T. 34 N., R. 92 W., and state the oil saturated sandstone and conglomerate occurs in the coarse fluvial deposits of the Fort Union Formation. Our examination indicates that oil saturated sand may also occur in the Indian Meadows Formation (?). The author favors separating out the upper nearly-flat lying sequence of what was previously called Fort Union and calling it Indian Meadows (?). Pollen dating could substantiate this designation.

Stained or saturated sandstone outcrops occur near the center of Section 17, T. 34 N., R. 92 W. and in the NE 1/4, NE 1/4, NW 1/4 of Section 18, T. 34 N., R. 92 W. (Figure 20). Three localities, indicated on Figure 20, were sampled and described. Sample locality 1 is located in the center of SW 1/4, NE 1/4 of Section 17, T. 34 N., R. 92 W. in what the author feels is an Indian Meadows Formation (?) sandstone unit, previously identified as Fort Union (Thompson and White, 1951). The sandstone unit is cross-bedded and quite variable interfingering with siltstone and claystone (Figure 21). The oil saturated zone is 4-5 feet thick and fine to coarse grained, angular, and poorly sorted, with conglomerate lenses in lower two feet of the oil zone. The fine-grained upper sequnce also contains angular siltstone rock fragments. The stained or saturated outcrop weathers to a light



T. 34. N., R. 92 W. Scale: 1"=2,000'

Map Explanation

Twdr = Wind River Fm.
Tim(?)= Indian Meadows Fm.
Tfu = Fort Union Fm.
Kl(?) = Lance Fm.
Kmv = Mesaverde Fm.
= Formation contact, dashed where covered or projected

= Anticlinal axis
= Dip and strike direction and dip angle
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone outcrop
= Sample locality and number

Figure 20. Reconnaissance geologic map showing oil saturated sandstone in the Fort Union and Indian Meadows (?) Formations at the Signor Ridge occurrence. Geology modified from Thompson and White (1951).

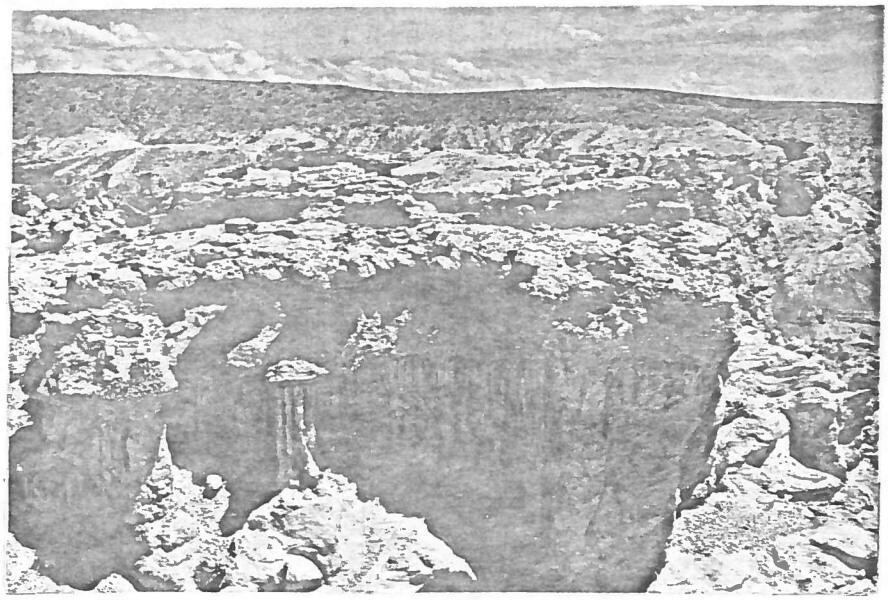


Figure 21. Oil saturated Indian Meadows Formation (?) sandstone, Signor Ridge occurrence. The unit on the skyline is the Wind River Formation.

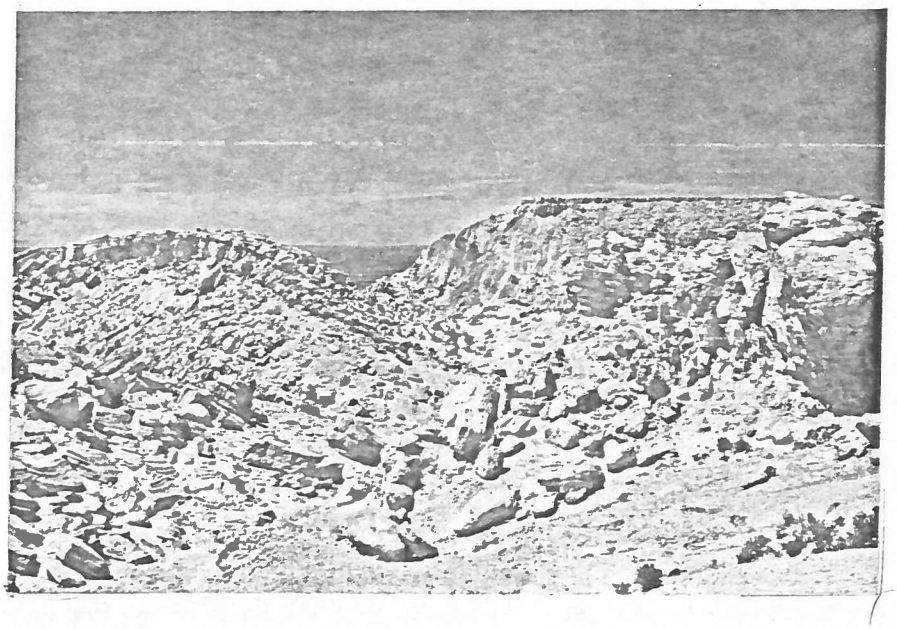


Figure 22. Oil saturated Fort Union sandstone at sample locality 2, Signor Ridge occurrence. Sharply folded unit is Fort Union unconformably overlain by flat-lying Indian Meadows (?).

to medium gray color. The approximate extent of the oil saturated outcrop is shown in Figure 20. The Indian Meadows Formation (?) dips 4° to the north with a N 85° E strike near this sample site.

The second sample locality is located in the Fort Union Formation in the SW 1/4, SW 1/4, NE 1/4, of Section 17 (Figure 20). An angular unconformity appears between the folded Fort Union Formation and the overlying Indian Meadows (?) (Figure 22). The Fort Union is folded into a small anticline trending almost east to west.

The oil saturated zone is a five foot thick, medium-grained, subrounded, poorly sorted sandstone which weathers to a light purplish gray color. The upper one foot of the unit is barren and tight. Some cross-bedding was noted. An overlying sandstone is only lightly stained. The approximate extent of the heavily stained zone is shown in Figure 20. The dip of the sample site is 18° to the north with a N 70° E strike. The attitude of this unit was measured on the north flank of the small anticline.

Sample locality 3 is in what appeared to be the Indian Meadows Formation (?), in the NE 1/4, NE 1/4, NW 1/4 of Section 18, T. 34 N., R. 92 W. (Figure 20). The outcrops are quite discontinuous and the oil saturation is variable with most outcrops containing dead oil. The significance of these stained outcrops lies in the fact that they demonstrate that the saturation was not limited to the center of Section 17. This unit is 4-5 feet thick and appears similar to the Indian Meadows (?) sandstone sampled in section 17 at sample locality 1. The sample collected is a fine to medium-grained, angular to subangular, poorly sorted sandstone. The outcrop weathers to a light to purplish gray color. The sandstone appears to be dipping at a shallow angle toward the north. However, no good outcrop surfaces could be found to actually substantiate this estimated attitude.

This occurrence appears to be limited to the small plunging anticlinal structure as indicated by the geologic map in Figure 20. Our reconnaissance examination only identified oil saturated sands in the Fort Union and Indian Meadows Formations outcropping on the northeast flank of the structure. No oil staining or saturation was found in the massive sandstones of the Mesaverde Formation outcropping in the SE 1/4, SW 1/4 of Section 17. The potential economic significance appears to be questionable, as the oil saturation is discontinuous and quite variable in outcrop. The downdip extent of the oil saturation can only be determined by drilling and only an indication of increased saturation, especially laterally would warrant any attempt at development. The nearest oil production is in Muskrat field which produces oil and gas form reservoirs ranging in age from Mississippian Madison to Upper Cretaceous Mesaverde. Oil analysis from the Permian Phosphoria reservoir indicate a Paleozoic sourced oil (Biggs and Espach, 1960). However, the oil in the occurrence could be either Paleozoic or Cretaceous sourced.

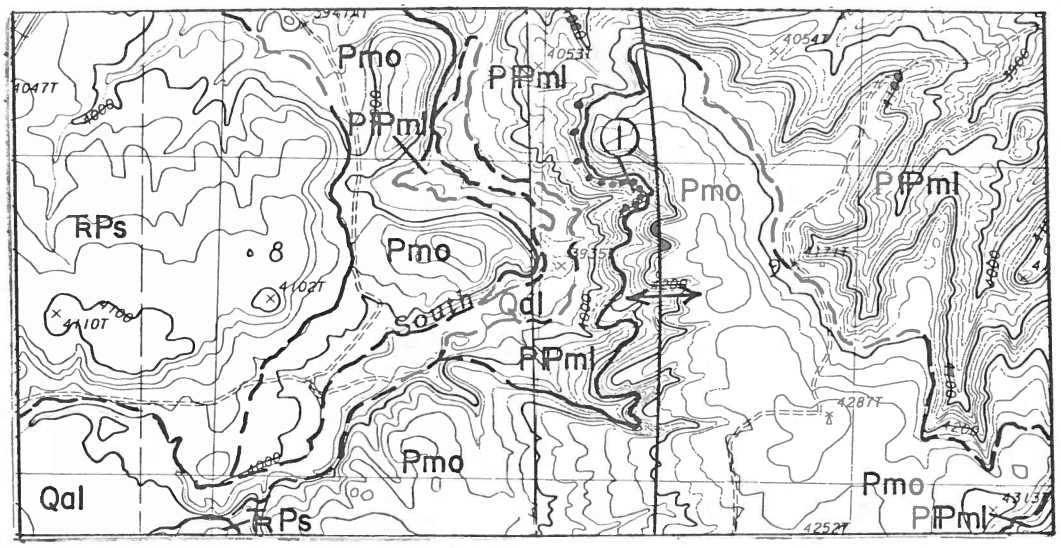
South Red Water Creek Occurrence

The South Red Water Creek occurrence is located on the west flanks of the Black Hills Uplift, approximately 10 miles northeast of Sundance (Figure 1). The oil saturation or staining occurs in

Permian-Pennsylvanian Minnelusa Formation, in what is commonly referred to as the Minnelusa "A" sandstone. Oil seeps and oil stained outcrops were known in the general area since the late 1800's when miners from the Black Hills used the oil from various seeps for lubricating purposes. The nearest field is Rocky Ford, approximately three miles to the southwest. Rocky Ford, however, has only produced 25 barrels of heavy oil from the Minnelusa since its discovery in 1909 and is currently abandoned. The South Red Water Creek occurrence appears to be an undip exhumed example of the same type of trap as Rocky Ford, i.e., a stratigraphic trap formed by undip diagenetically controlled porosity permeability loss, with anhdyrite-filling in the pore spaces (Trotter, 1963). The occurrence has been briefly described by Collier (1922) and Brady (1958).

The outcrop sampled and described is located in the center of the NW 1/4 of Section 9, T. 52 N., R. 61 W. (Figure 23). The oil saturated or stained zone is variable in thickness and is located in the uppermost sandstone of the Minnelusa, which is approximately 50 feet thick in this area. The sandstone unit is capped locally with a thick limestone unit which is overlain by the Opeche Shale, and is underlain by a massive gypsum or anhydrite unit. Most outcrops of this sand unit contains some dead oil which was usually present in cross-bedded sequences. The stained zones usually did not persist laterally and are individually only 3-4 feet thick. The total intermittently saturated or stained zone is approximately 15-20 feet thick at the sample site (Figure 24). Occassional very small pockets of live oil were noted, however, the majority, by far, was dead oil. The stained sandstone which was sampled is fine-grained, subrounded, well-sorted and weathers to a buff to gray color. Numerous white calcite rich streaks are present in the oil stained sandstone, representing small barren zones. The unsaturated portion of the sand is very rich in gypsum or anhydrite. The outcrop often exhibits small calcite nodules on the weathered surface, especially in cross-bedded zones. The sampled area with oil staining coincides approximately with a small anticlinal structure noted by Lisenbee (1985) on his tectonic map of the Blackhills Uplift. Dips are relatively shallow to the west in the immediate sample area. This particular trap is probably both stratigraphically and structurally controlled. The oil present appears to have a Paleozoic source based on analysis of oil from the adjacent Rocky Ford field, which produced from the Minnelusa also.

In summary, the occurrence appears to be of questionable significiance based on the reconnaissance examination. The stained outcrops are variable and pinch out laterally. Very little live oil was noted in the outcrop. However, to determine the potential, drilling would be necessary in the Opeche and Minnekahta covered area to the east and south. The existence of this occurrence, along with the shallow abandoned field to the west, indicate potential for other occurrences in the area which might be explored for when economic conditions dictate.



T. 52 N., R. 61 W. Scale: 1"=2,000'

Map Explanation

Qal = Alluvium
RPs = Spearfish Fm.
Pmo = Minnekahta Limestone and Opeche Shale
PPml = Minnelusa Fm.
= Formation contact, dashed where covered or projected
= Approximate location of anticlinal axis
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone outcrop

Figure 23. Reconnaissance geologic map showing oil saturated outcrops of Minnelusa Formation sandstone at the South Red Water Creek occurrence.

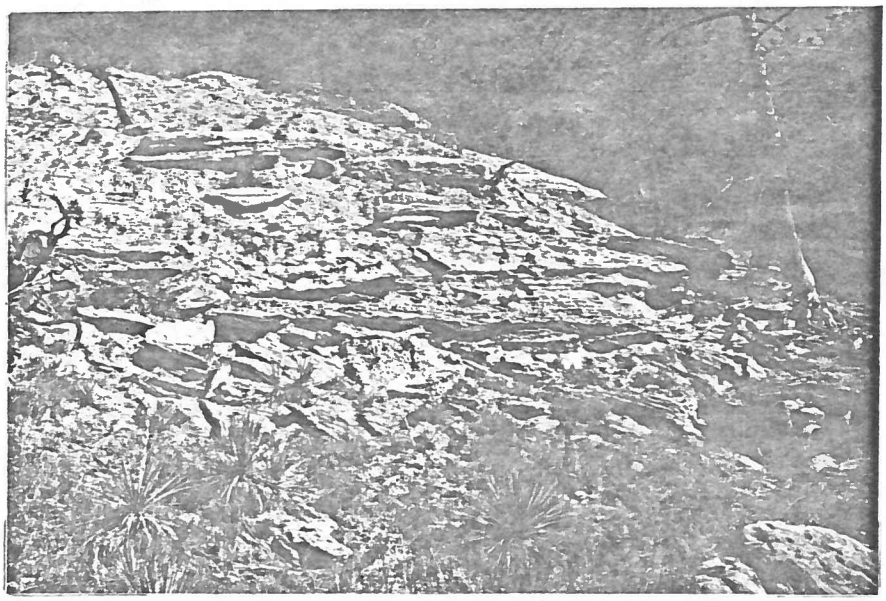


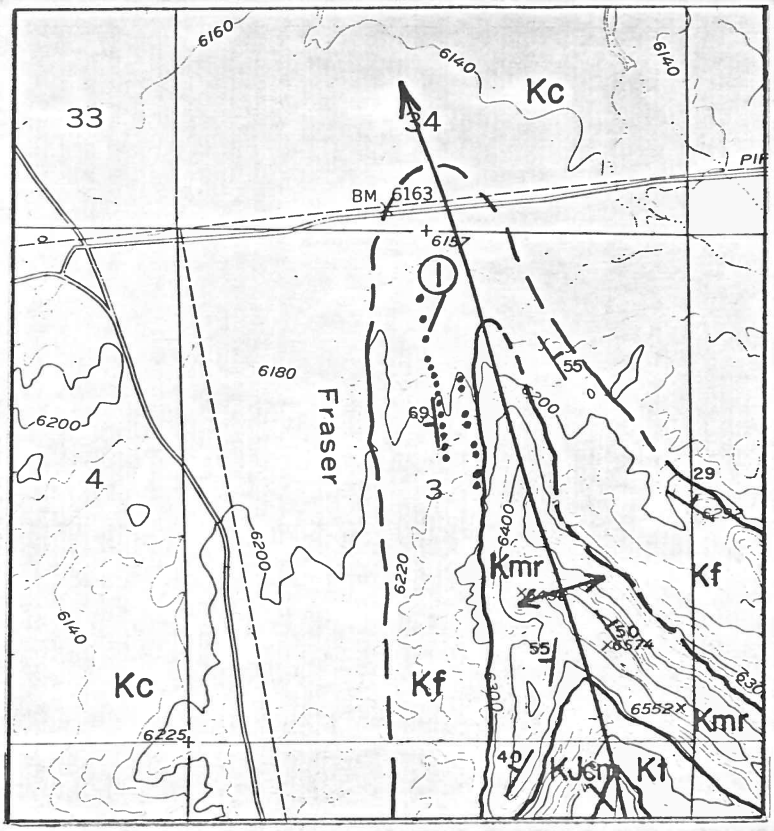
Figure 24. Oil saturated outcrop of Minnelusa Formation at the South Red Water Creek occurrence. Oil saturation occurs primarily in the cross-bedded sequences.

Dutton Anticline Occurrence

Dutton Anticline occurrence is located on the southern flanks of the Wind River Basin, approximately 40 miles southeast of Riverton (Figure 1). Dutton Anticline is another in the list of northwest-southeast trending anticlines. The occurrence examined is located on the northwest plunging nose of the anticline, in the Upper Cretaceous Frontier Formation. The occurrences was initially described in the literature by Aughey (1886), Ricketts (1888), Knight and Slossen (1901) and Hares (1916). A more recent discussion was completed by Van Houten and Weitz (1956). According to these studies oil staining or saturation occurs in a sandstone unit of the Triassic Chugwater Formation, in a sandy zone of the Thermopolis Shale, in the Frontier Formation, and in sandstones and conglomerate lenses in the Wind River Formation at various localities on or near Dutton Anticline. Examination of these reported outcrop occurrences of oil stained sandstones was difficult due to problems with development associated with the Gas Hills uranium mines. As a result, the author was only able to locate and examine the Frontier sandstone occurrence in Section 3, T. 33 N., R. 90 W. on the west flank and plunging nose of Dutton Anticline (Figure 25). The nearest associated oil field is Travis field which is currently shut-in with a cumulative production of 2,949 barrels of oil and 1,159 MCF of gas from the Triassic/Permian Goose Egg Formation and the Alcova Limestone Member of the Triassic Chugwater Group. Travis field is located on the Dutton Anticline axis in Section 13, T. 33 N., R. 90 W. and in all probability the stained outcrops described in the earlier studies are related to this accumulation.

The outcrop examined during this reconnaissance examination is a Frontier Formation sandstone in the SE 1/4, NE 1/4, NW 1/4 of Section 3, T. 33 N., R. 90 W., (Figure 25). The unit is on the west flank of Dutton Anticline and dips at a steep angle, nearly 70° to the west at the location sampled. Oil staining is intermittent and the majority is dead oil. The oil stained sandstone outcrop is only 3-4 feet thick and is covered in many places. The sandstone is medium-grained, subangular to subrounded and poorly sorted, with a "salt and pepper" appearance due to the numerous mafic minerals. Outcrops weathers buff to gray depending on oil saturation.

The occurrence appears to be related to the anticlinal or structural trap (Dutton Anticline) responsible for Travis field. Oil stained outcrops result from the breeched anticline and in all probablity the majority of the oil that was trapped originally has escaped. Based on outcrop appearance, the occurrence does not seem to be significant. Drilling would be necessary to determine downdip extent of the oil in the Frontier sandstones examined as well as other occurrences described in the literature. However, steep dips would preclude mining the oil and a technique would need to be devised to get the oil to flow into the bore hole if significant reserves were found downdip.



T.33 N., R. 90 W. Scale: 1"=2,000'

Map Explanation

Kc = Cody Shale
Kf = Frontier Fm.
Kmr = Mowry Shale
Kt = Thermopolis Shale
KJcm = Cloverly and Morrison Fms.
= Formation contact, dashed where covered or projected
= Dip and strike direction and dip angle
= Oil saturated sandstone outcrop
= Covered or projected oil saturated sandstone
= Sample locality and number
= Dutton Anticline axis

Figure 25. Reconnaissance geologic map showing oil saturated sandstone outcrops in the Frontier Formation at the Dutton Anticline occurrence. Geology from Van Houten and Weitz (1956).

Red Hole Occurrence

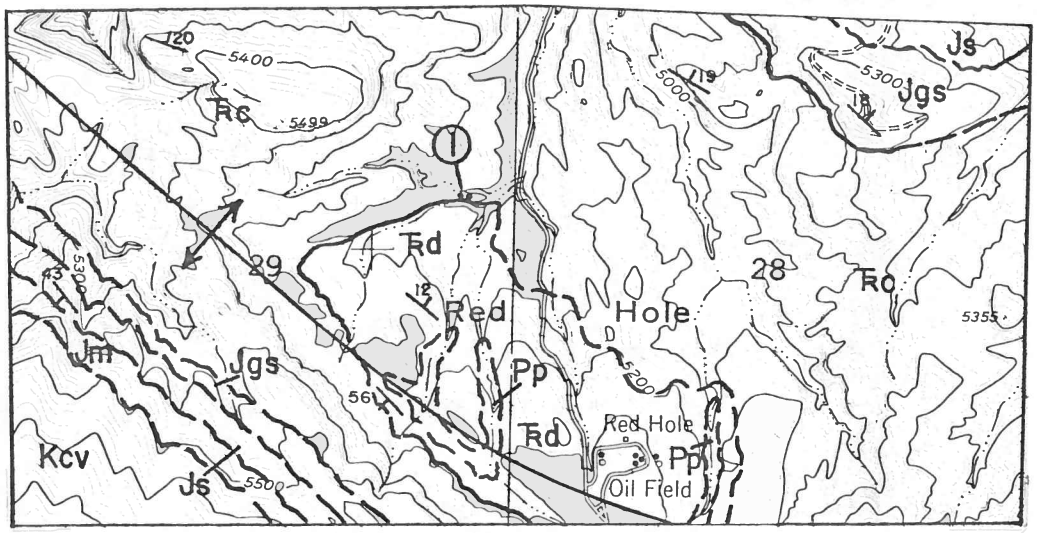
The Red Hole occurrence is located adjacent to Red Springs field, on the north flank of the associated Red Springs Anticline on the south flanks of the Bighorn Basin (Figure 1). The occurrence was initially described is a tar seep in the NW 1/4 of Section 29, T. 43 N., R. 93 W. by Hewett and Lupton (1918). Red Springs Anticline is an assymetrical to the southwest anticline trending northwest to southeast (Figure 26). Red Springs field is located on the crest of the anticline in Sections 22, 28 and 29 and has produced 14,819 barrels of oil from the Madison, Tensleep and Phosphoria, since its discovery in 1919. Heavy oil is produced from the Madison (11° API gravity). Most of the wells are currently shut-in with very little production taking place (206 barrels in 1984). The oil is sourced from Paleozoic rocks, probably the Phosphoria Formation, based on analysis of Madison oil from the field (Biggs and Espach, 1960).

The author attempted to locate the tar seep described by Hewett and Lupton (1917) but was unsuccessful. Flow from the tar seep probably stopped after production commenced from Red Springs Field. However, oil saturated sandstone samples were located in the SE 1/4, NE 1/4 of Section 29, T. 43 N., R. 93 W. (Figure 26). Small samples were found in a drainage and as surface float on an adjacent drainage divide in the red shales of the Red Peak Formation. The oil saturated sandstone probably originated from somewhere in the Chugwater Group, possibly from the sandstones in the Crow Mountain Formation, which, along with the Alcova Limestone, forms the top of the resistant cliffs on the south and north sides of Red Hole (Figure 26). The sandstone samples collected are heavily oil saturated, medium-grained, subrounded to well rounded, moderately well sorted, and dark gray with calcite rich nodules weathering out on the surface. The area was extensively searched for the outcrop which sourced the samples but it was not located.

Based on this reconnaissance examination, the Red Hole occurrence would not justify further economic evaluation. The samples collected probably represent a small localized occurrence which is related to the shallow production from Red Springs field. It represents the type of occurrence, along with tar or oil seeps, which led early oil wildcatters to drill these surface anticlines.

Wagonhound Creek Occurrence

The Wagonhound Creek occurrence is located on the north flank of the Snowy Range Uplift approximately 45 miles northwest of Laramie (Figure 1). Structurally, the occurrence lies on the northeast flank of the Wagonhound Anticline (Blackstone, 1976). This occurrence is in a sandstone in the Eocene Hanna Formation and was initially described and sampled by Hyden and McAndres (1967) and later described by Blackstone (1976). Hyden and McAndres (1967) describe the oil distilled from the saturated sandstone as brownish black and asphaltic with an API gravity of 17.7 . Blackstone (1976) feels that the oil is derived from older reservoirs such as the Sundance Formation, Cloverly Formation or Muddy Sandstone. Migration into the Hanna possibly occurred by



T. 43 N., R, 93 W. Scale: 1"=2,000'

Map Explanation

Kcv = Clovery Fm.
Jm = Morrison Fm.
Js = Sundance Fm.
Jgs = Gypsum Spring Fm.
Tc = Chugwater Group
Td = Dinwoody Fm.
Pp = Phosphoria Fm.

= Anticlinal axis
18 = Dip and strike direction and dip angle
1 = Sample locality and number
= Formation contact, dashed where covered or projected

Figure 26. Reconnaissance geologic map showing location of oil saturated sandstone float samples collected at the Red Hole occurrence. Geology modified from Horn (1963).

direct contact across the angular unconformity or along the fault (Figure 27). There are two associated oil fields to the northwest on the Wagonhound Creek Anticline, Pass Creek field and Elk Mountain field. They are both small structural closures. Pass Creek field, discovered in 1977, has produced 278,064 barrels of oil from Permian/Pennsylvanian Casper Formation through 1984 and Elk Mountain field discovered in 1957 has produced 796,777 barrels of oil from the Jurassic Sundance through 1984.

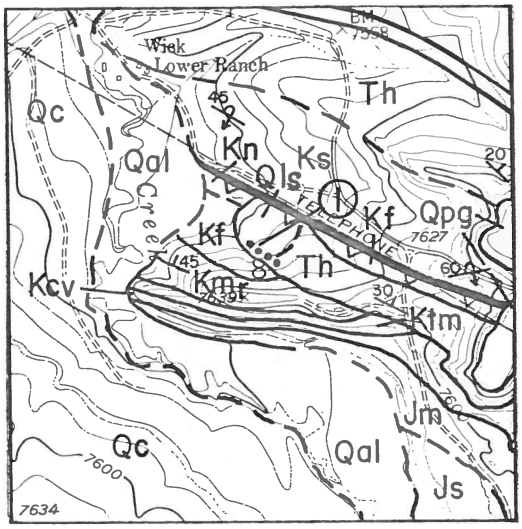
The Wagonhound Creek occurrence was sampled at the outcrop in the center of Section 8, T. 19 N., R. 79 W. (Figure 27). The outcrop is discontinuously oil saturated and appears to be somewhat broken up, indicating it may be in a small slump block or old landslide in the Hanna Formation. The Hanna Formation lies unconformably on top of black Frontier Formation shales at this locality (Figure 27). The oil saturated arkosic sandstone is medium to coarse grained, angular to subangular, poorly sorted, and weathers to a light or darker gray depending on oil saturation. Unsaturated outcrops appear buff to yellowish gray with some limonite staining. The oil saturated portion of the outcrop is quite small and isolated (Figure 28). It has no economic importance in itself but may indicate the possible presence of oil in small structural closures at depth on this portion of the Wagonhound Creek anticline, similar to the two fields noted to the northwest.

Brigham Young Oil Spring

Brigham Young Oil Spring is located in the Wyoming Thrust Belt approximately 10 miles southeast of Evanston (Figure 1). The oil spring was probably well known to early trappers in the area. However, the first published account was in the "Mormons' Guide Book" written by Clayton (1848). The oil spring is described as follows:

"About a mile from this place (the crossing of the road over Sulphur Creek), in a southwest course, is a "tar", or "oil spring", covering a surface of several rods of ground. There is a wagon trail running within a short distance of it. It is situated in a small hollow on the left of the wagon trail, at a point where the trail rises to a higher bench of land. When the oil can be obtained free from sand, it is useful to oil wagons. It gives a nice polish to gunstocks, and has proved to be highly beneficial when applied to sores on horses, cattle, etc."

Similar descriptions of this oil spring were made by Stansbury (1852) and Engelmann (1859). Later, the oil spring was described by Knight and Slosson (1899) and Veatch (1907). Knight attributed the adjacent Absaroka Thrust Fault with being the migration route of the oil. A well was dug at the site of the oil spring by order of Brigham Young in 1848. Accumulated oil was sold to emigrants and some was hauled in small quantities to Salt Lake City for use. The existence of the oil spring led to two unsuccessful attempts to drill oil wells in the vicinity in 1902 (Veatch, 1907). The nearest associated oil production comes from Sulphur Creek field, four miles to the southeast, which produced minor amounts of oil from the Aspen Shale since its discovery in 1942. Stove Creek field is about three miles to the northeast and



T.19N., R. 79W. Scale: 1"=2,000'

Map Explanation

Qal = Alluvium
Qc = Colluvium
Qls = Landslide material
Qpq = Pediment gravels
Th = Hanna Fm.
Ks = Steele Shale
Kn = Niobrara Shale
Kf = Frontier Fm.
Kmr = Mowry Shale
Ktm = Thermopolis Shale and Muddy Sandstone

Kcv = Cloverly Fm.
Jm = Morrison Fm.
Js = Sundance Fm.
= Reverse fault with barbs on upthrown block
$_{45}$ = Dip and strike direction and dip angle
(1) = Sample locality & number
= Oil saturated sandstone
= Formation contact, dashed where covered or projected

Figure 27. Reconnaissance geologic map showing oil saturated sandstone outcrops in the Hanna Formation at the Wagonhound Creek occurrence. Geology from Blackstone (1976).

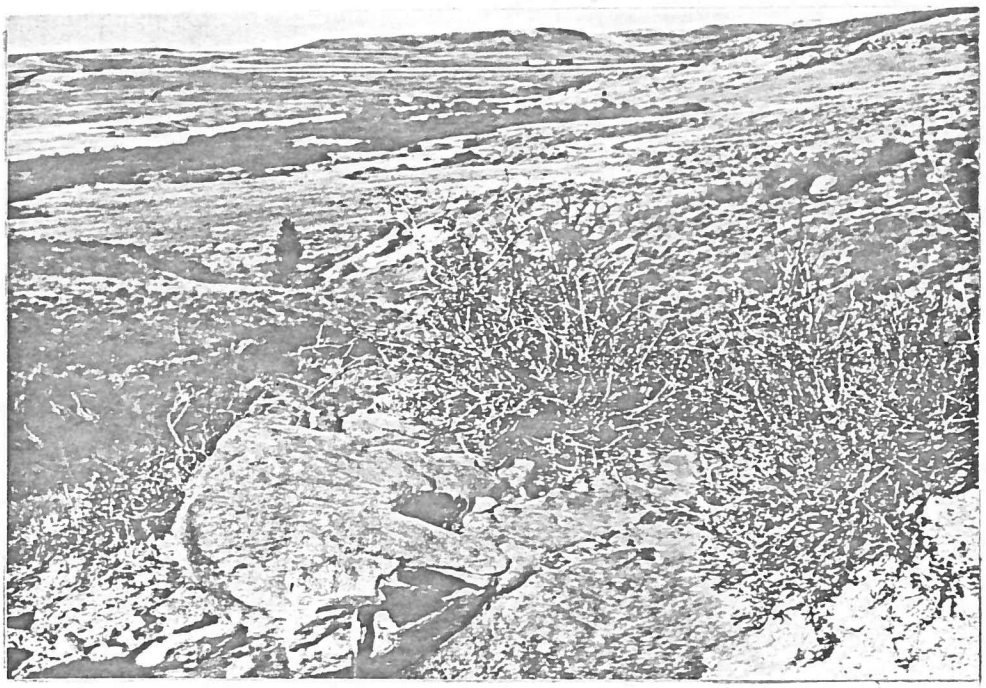
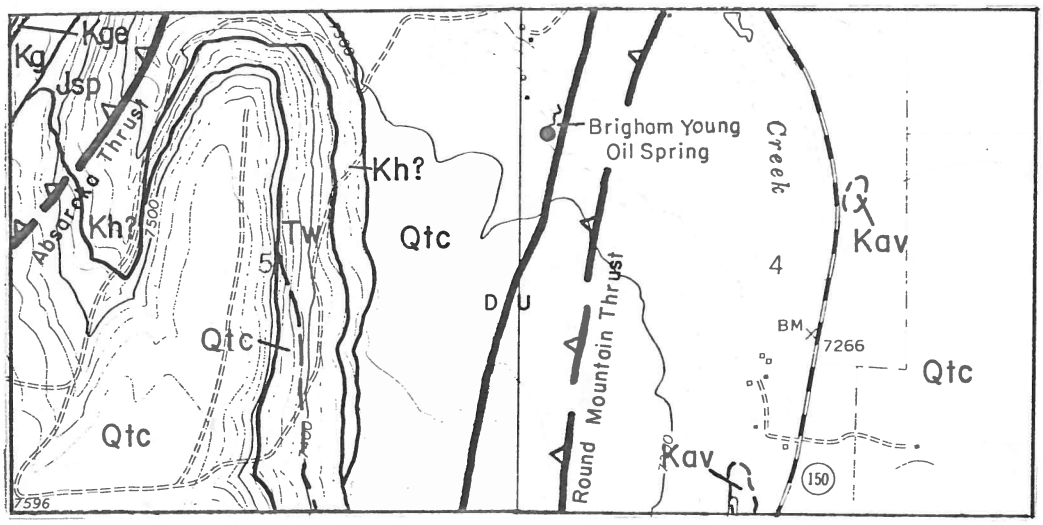


Figure 28. Oil saturated outcrop of Hanna Formation at the Wagonhound Creek occurrence.



T. 13. N. R. 119 W. Scale: 1"=2,000'

Map Explanation

Qtc = Terrace gravel and colluvium
Tw = Wasatch Fm.
Kh = Hilliard Shale
Kge = Ephriam Conglomerate Member of the Gannet Group
Kg = Gannett Group

Jsp = Stump sandstone and Preuss Sandstone
= Thrust fault with barbs on upthrown block
U/D = Normal fault, upthrown block=U and downthrown block=D
= Formation contact, dashed where covered or projected

Figure 29. Reconnaissance geologic map of area around the Brigham Young Oil Spring. Geology modified from Dover and M'Gonigle (in press).

has produced minor amounts of oil from the Frontier and the Bear River Formations since its discovery in 1973.

Field examination of the Brigham Young Oil Spring indicates it is located in Quaternary terrace gravels which appear to overlie faulted Frontier Formation (Figure 29). The fault is probably the Round Mountain Thrust Fault shown by Blackstone (1980). The original well dug in 1848 has been filled in and the oil spring is now represented by a small pool approximately two feet by eight feet of unknown depth (Figure 31). The source of the oil is probably the underlying faulted Frontier sandstone or the thrust fault itself and the associated normal fault (Figure 30). The oil collected was relatively lightweight and light colored and probably originated from Cretaceous source rocks, as does the majority of the Thrust Belt production. The significance of the oil spring is probably mostly historical and possibly the fact that its existence pointed the way for the discovery of the adjacent associated shallow oil fields.

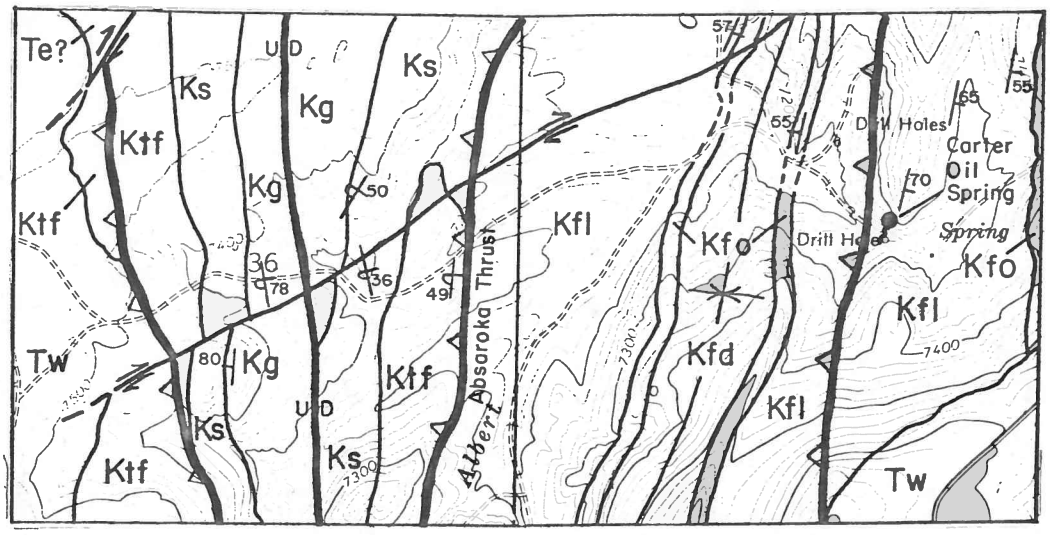
Carter Oil Spring

The Carter Oil Spring is located in the Wyoming Thrust Belt, approximately ten miles east of Evanston (Figure 1). The oil spring was located in 1868 as a result of tunnelling being done for coal exploration by a Mr. J. G. Fiero who owned the ground. The prospect was sold to Judge J. M. Carter. Oil was sold to the Union Pacific for use in equipment libication. An estimated $5000 worth of oil was sold at prices ranging from $.40 to $1.00 per gallon. In 1886, three shallow wells were drilled with limited success, as they were abandoned within a couple of weeks (Veatch, 1907). The earliest description is given in Veatch's report. Earlier workers mention existence of the spring in passing, but do not describe it. The nearest associated production is in Spring Valley field, four miles to the northeast. Spring Valley has produced 240,733 barrels of oil from the Frontier Formation, Aspen Shale, and Bear River Formation since its discovery in 1900.

Reconnaissance field examination of the Carter Oil Spring indicates the spring is flowing from Frontier Formation sandstones dipping steeply to the east (Figure 31). The rocks are sharply folded in the area, and the trace of the Absaroka Thrust is present immediately to the west and the Round Mountain Thrust to the east (Blackstone, 1981). The presence of the spring is probably related to the faulting and represents a similar situation to that noted at the Brigham Young Oil Spring.

Examination of the immediate site indicates attempts at development since the early efforts described above (Figure 32). Currently, a pipe is inserted into the Frontier Formation and is flowing oil at a very slow rate. As with the oil from Brigham Young Oil Spring, this appears to be a light Cretaceous sourced oil. A small holding tank sets near the end of the pipe, but no recent activity is indicated. The significance of the Carter Oil Spring is similar to the Brigham Young Oil Spring, i.e., historical and the fact that its existence probably led to the drilling and discovery of Spring Valley field.

Figure 30. Brigham Young Oil Spring southeast of Evanston, Wyoming.



T. 15 N., R. 118, 119 W. Scale: 1"=2,000'

Map Explanation

Tc = Evanston Fm.
Tw = Wasatch Fm.
Kfo = Oyster Ridge Member-Frontier Fm.
Kfl = Lower Frontier Fm.
Ktf = Thomas Fork Fm.
Ks = Aspen Shale
Kg = Gannett Group
= Formation contact

= Thrust fault with barbs on upthrown block
U/D = Normal fault, U=upthrown block and D=downthrown block
= Strike-slip fault, relative movement indicated by arrows
55 = Dip and strike direction and dip angle
50 = Dip and strike direction and dip angle for overturned beds

Figure 31. Reconnaissance geologic map of area around Carter Oil Spring. Geology modified from Dover and M'Gonigle (in press).

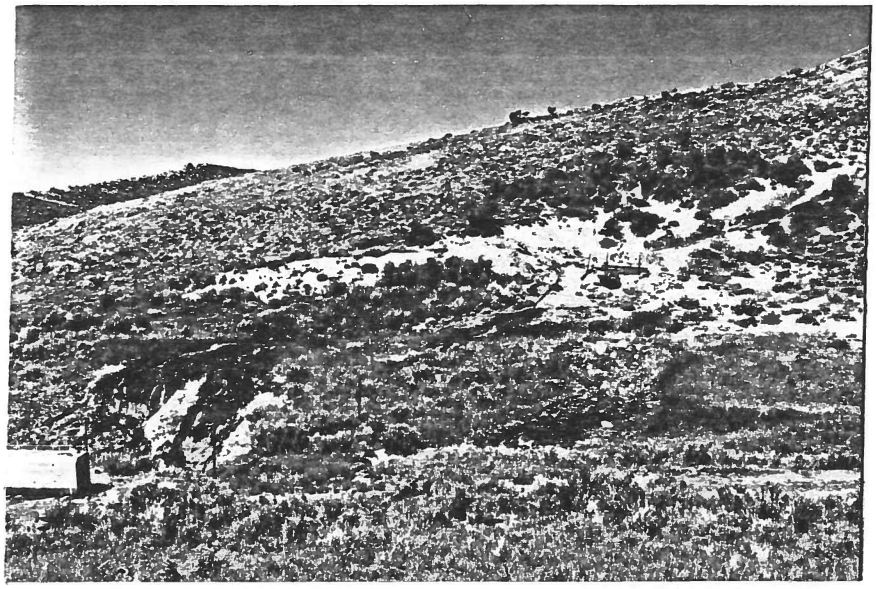


Figure 32. Carter Oil Spring east of Evanston, Wyoming. Oil is flowing from the Frontier Formation in the excavated area in the center right portion of the photograph

SUMMARY

Based on our limited field reconnaissance of the above occurrences, only the Rattlesnake Hills occurrence, Muddy Creek occurrence and the Conant Creek occurrence appeared to possess potential for economic development in the future. The development of these occurrences would be closedly tied to economic conditions, specifically the price of oil which at this time is considerably depressed. In addition, each of the above occurrences requires exploratory drilling to determine the extent, thickness, and depth from the surface to the reservoir. This information could then be used to determine the most efficient method of removal, i.e., some sort of Tertiary injection technique (steam, solvent, etc.) or strip mining. Field examination and data gathered by Love (1970), indicates that the Conant Creek occurrence might be suitable for strip mining. The Rattlesnake Hills occurrence is probably not suited to strip mining due to the steep dips of the potential reservoir rocks. A steam injection project was unsuccessfully attempted by Shell Oil, eliminating that as a potential method. However, it still appears that some sort of tertiary injection technique or combination of techniques developed as a result of new technology, will be the answer. In the case of the the Muddy Creek occurrence, strip mining may be a viable method of removal since it dips are quite shallow. In developing the Conant Creek and Muddy Creek occurrence a mining technique using an adit or tunnel system to concentrate the product, similar to the Tisdale project in Johnson County, might be feasible. However, any recommendation as far as removal techniques for the above occurrences would be speculative at best without information on the size, shape and depth of the deposit.

The Trapper Canyon occurrence on the eastern flanks of the Bighorn Basin, approximately 25 milest east of Greybull (Figure 1) is another potentially economic occurrence not discussed in detail here. Ver Ploeg and DeBruin (1985) discuss this occurrence in detail and the reader is referred to their paper. This occurrence is a strip mineable deposit which contains 1-2 million barrels of oil under a very thin veneer of overburden. The reservoir is a thick sequence of eolian Pennsylvanian Tensleep Sandstone.

The smaller occurrences discussed in this report represent deposits which, due to limited outcrop exposure, could not be evaluated in terms of economic significance or appear to be insignficant small isolated occurrences. The only method of determining economic significance would involve some drilling to determine subsurface extent. Due to their limited exposure at the surface and lack of any encouraging indications, their evaluation would only be warranted if economic conditions, i.e., the price of oil increased substantially. Only a small number of these occurrences were examined and the reader should be aware the numerous occurrences of this type occur throughout the state. Specifically, the southern, northern, western flanks of Wind River Basin contain several occurrences similar to the Signor Ridge and Dutton Anticline occurrences. The reader is referred to (Clark and Glass, 1982) for a list of references and locations pertaining to the other occurrences not discussed here.

It had been intended that the samples collected at the ex-

amined occurrences be analyzed for the sulphur, nitrogren, hydrogen, carbon and oxygen content of the contained oil or tar. Also, the viscosity of the oil or tar was to be determined. This information would be used to determine the quality and possibly the source of the oil or tar. Unfortunately insufficient funds precluded having this analysis done. Analysis will be accomplished at a later date and the results will be published at that time.

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REFERENCES

Aughey, S., 1886, Annual report of the Territorial Geologist to the Governor of Wyoming: Laramie, 120 p.

Ball and Associates, Ltd., 1965, Surface and shallow oil-impregnated rocks and shallow oil fields in the United States: U.S. Bureau of Mines Monograph 12, 275 p.

Barwin, J.R., 1961a, Stratigraphy of the Mesaverde Formation in the southeastern part of the Wind River Basin, Fremont and Natrona Counties, Wyoming: Unpublished M.A. Thesis, University of Wyoming, 78 p.

Barwin, J.R., 1961b, Stratigraphy of the Mesaverde Formation in the southern part of the Wind River Basin, Wyoming: Wyoming Geological Association 16th Annual Field Conference Guidebook, p. 171-179.

Biggs P., and Espach, R., 1960 Petroleum and natural gas fields in Wyoming: U.S. Bureau of Mines Bulletin 582, 538 p.

Blackstone, D.L., 1955, Geology of the Muddy Creek area, Carbon and Sweetwater Counties: Geological Survey of Wyoming Open File Report 55-2, 18 p.

Blackstone, D.L., 1976, Structural geology of the Arlington-Wagonhound Creek area, Carbon County, Wyoming: A revision of previous mapping: Geological Survey of Wyoming Preliminary Report 15, 16 p.

Blackstone, D.L., 1981, Tectonic map of the Overthrust Belt, western Wyoming, southeastern Idaho, and northeastern Utah, showing current oil and gas drilling and development: Geological Survey of Wyoming Map Series MS-8A, scale 1:316,800.

Brady, F., 1958, Evaporite deposits in the Minnelusa Formation in the Sundance-Beulah area, Crook County, Wyoming: Wyoming Geological Association Field Conference Guidebook, p. 45-47.

Clark, M., and Glass, G.B., 1982, Review of reported tar sand occuurrences and recent projects in Wyoming: Geological Survey of Wyoming Open File Report 82-5, 49 p.

Clayton, W., 1848, Latter-Day Saints emigrants guide: St. Louis, 24 p.

Collier, A.J., 1922, Geology of the Osage oil field, Weston County, Wyoming: U.S. Geological Survey Bulletin 736-D, p. 71-110.

Dover, J. and M'Gonigle, J., in press, Geologic map of the Evanston 30' x 60' quadrangle: U.S. Geological Survey Map, scale 1:100,000.

Dresser, H.W., 1974, Muddy Sandstone-Wind River Basin: Wyoming Geological Association Earth Science Bulletin, Volume 7, Number 1, p. 5-70.

Engelmann, H., 1859, Preliminary report on the geology of the country between Fort Bridger and Camp Floyd, Utah Territory; accompanying Simpson's report on wagon routes in Utah Territory: Senate Executive Document Number 10-Volume 10, 35th Congress, 2nd session, p. 52.

Hail, W.J., 1957, Reconnaissance for uranium in asphalt-bearing rocks in the western United States: U.S. Geological Survey Bulletin 1046-E, p. 55-85.

Hares, C.J., 1916, Anticlines in central Wyoming: U.S. Geological Survey Bulletin 641-I, p. 223-279.

Hewett, D.F., and Lupton, C.T., 1917, Anticlines in the southern part of the Bighorn Basin, Wyoming: U.S. Geological Survey Bulletin 656, 192 p.

Horn, G.H., 1963, Geology of the east Thermopolis area, Hot Springs and Washakie counties, Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-213.

Hyden, H.J. and McAndrew, 1967, Geologic map of the TL Ranch quadrangle, Carbon County, Wyoming: U.S. Geological Survey Map GQ 637.

Interstate Oil Compact Commission, 1984, Major tar sand and heavy oil deposits of the United States: Oklahoma City, Interstate Oil Compact Commission, 272 p.

Jameson, C.E., 1913, The Muddy Creek oil field: Wyoming State Geologist Bulletin 3-B, 7 p.

Keefer, W.R., and Rich, E.I., 1957, Stratigraphy of the Cody Shale and younger Cretaceous and Paleocene rocks in the western and southern part of the Wind River Basin, Wyoming: Wyoming Geological Association 12th Annual Field Conference Guidebook, p. 71-78.

Knight, W.C., and Slossen, E.E., 1901, The Dutton, Rattlesnake, Arago, Oil Mountain, and Powder River oil fields: University of Wyoming School of Mines Petroleum Series, Bulletin 4, 57 p.

Knight, W.D. and Slossen, E.E., 1899, The oil fields of Crook and Uinta Counties, Wyoming: University of Wyoming, School of Mines Bulletin, Petroleum Series Number 3, p. 11-25, 30-31.

Lageson, D.R., and others, 1980, Natrona County, Wyoming: Geological Suvey of Wyoming County Resource Series CRS-6, scale 1:250,000, 8 maps.

Love, J.D., 1970, Cenozoic geology of the Granite Mountains area, central Wyoming: U.S. Geological Survey Professional Paper 495-C, 154 p.

Pekarek, A.H., 1974, Structural geology and volcanic petrology of the Rattlesnake Hills, Wyoming: Ph.D. Dissertation, University of Wyoming, 111 p.

Pekarek, A.H., 1978, Stratigraphy and structural geology of the Rattlesnake Hills, Wyoming: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 239-253.

Ricketts, L.D., 1888, Annual report of the Territorial Geolgoist to the Governor of Wyoming: Cheyenne, 88 p.

Stansbury, H., 1852, Exploration and survey of the valley of the Great Salt Lake of Utah, p. 280.

Thompson, R.M., and White, V.L., 1951, Geologic map of the Conant Creek-Muskrat Creek area, Fremont County, Wyoming: U.S. Geological Survey, unpublished map, scale 1:48,000

Thompson, R.M., and White, V.L., 1952, The coal deposits of the Alkali Butte, Big Sand Draw, and Beaver Creek fields, Fremont County, Wyoming: U.S. Geological Survey Circular 152, 24 p.

Trotter, J.F., 1963, The Minnelusa play of ther northern Powder River Basin, Wyoming and adjacent areas: Wyoming Geolgoical Society Guidebook, Northern Powder River Basin, p. 117-122.

Van Houten, F.B., 1954, Geology of the Long Creek-Beaver Divide area, Fremont County, Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-140.

Van Houten, F.B., 1964, Tertiary geology of the Beaver Rim area, Fremont and Natrona Counties, Wyoming: U.S. Geological Survey Bulletin 1164, 99 p.

Van Houten, F.B., and Weitz, J.L., 1956, Geolgoic map of the eastern Beaver Divide-Gas Hills area, Fremont and Natrona Counties, Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-180.

Veatch, A.L., 1907, Geography and geology of a portion of southwestern Wyoming: U.S. Geological Survey Professional Paper 56, 178 p.

Ver Ploeg, A.J., and De Bruin, R.H., 1985, Trapper Canyon tar sand deposit, Big Horn County, Wyoming: An exhumed stratigraphic oil trap: Geological Suvey of Wyoming Report of Investigations 30, 34 p.