THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

Report of Investigations No. 33

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Front cover. Wood River Area, Absaroka Mountains, Wyoming.

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GEOLOGIC SETTING

The northern part of the Washakie Wilderness and the nearby roadless areas (referred to collectively as the study area in subsequent discussions) are in part of a Laramide sedimentary basin, a westward extension of the Bighorn Basin. This basin lies between the crystalline and metamorphic cores of two major Laramide mountain ranges, the Beartooth Mountains on the north and the Washakie Range on the south (Figure 1). Within the basin are Paleozoic, Mesozoic, and lowest Tertiary sedimentary strata. The cores of these two mountain ranges and the intervening sedimentary basin are overlapped by gently-dipping to flat-lying volcaniclastic rocks of the Absaroka Range. This range differs from the Beartooth Mountains and the Washakie Range in that it is not a structural uplift but rather is an erosional remnant of the vast sheet of volcaniclastic strata that formerly extended eastward across the Bighorn Basin (McKenna and Love, 1972) and southeastward across the Wind River Basin (Love, 1970). The volcaniclastic rocks have been mapped and described by D.W. Rankin (written communication, 1982).

The potential for oil and gas resources within the region, including the study area, has been appraised by Dolton and Spencer (1978) and by Spencer and Dersch (1981).

Both the trends of anticlines and synclines in the western part of the Bighorn Basin and the distribution of oil seeps suggest that Mesozoic and older sedimentary rocks extend northward and northwestward from the study area into Yellowstone National Park. The oil in these seeps probably originated in Mesozoic strata and then migrated upward through the volcaniclastic cover at Calcite Springs, Rainbow Springs, and Sweetwater Mineral Springs (Figure 1; Love and Good, 1970).

A seismic line extending east-west along the North Fork Shoshone River crossed two northwest-trending anticlines, the Clearwater Creek and the Sweetwater Creek, in pre-volcanic strata (Brittenham and Tadewald, 1985). The Sweetwater Creek anticline underlies the area of oil seeps described by Love and Good (1970) and is strongly reflected in the volcaniclastic strata of the Wapiti Formation. This coincidence suggests that oil is migrating upward from Cretaceous and (or) older strata on a Laramide structure or a later fold underlain by igneous rocks intruded into the Eocene volcaniclastic strata.

Twenty-four oil fields in the anticlines that fold Mesozoic strata are present in the Bighorn Basin within 15 miles of the east margin of the study area, and several anticlines project into it (Figure 1). These relations suggest, but do not prove, that part of the study area has a good potential for oil and gas resources.

Seven dry holes have been drilled outside but within two miles of the boundary of the study area (Figure 1). Data from these holes and from the oil fields adjacent to the study area indicate that the following thicknesses of sedimentary rocks probably underlie parts of the volcaniclastic cover in the study area:

Formation	Thickness in Feet
Cody Shale (Upper Cretaceous)	2,500
Frontier Formation (Upper Cretaceous)	500– 700
Mowry and Thermopolis Shales (Lower Cretaceous)	800– 900
Cloverly and Morrison Formations (Lower Cretaceous and Upper Jurassic)	400– 600
Sundance and Gypsum Spring Formations (Upper and Middle Jurassic)	300– 500
Triassic Rocks	800–1,450
Phosphoria Formation and equivalent rocks (Permian)	100– 200
Pennsylvanian rocks	400– 600
Madison Limestone (Mississippian)	500– 800
Darby Formation (Devonian)	100– 250
Bighorn Dolomite (Ordovician)	300– 450
Cambrian rocks	900–1,100

Detailed geophysical studies such as those initiated by Brittenham and Tadewald (1985) and drilling would be required to determine the configuration of structures and possible stratigraphic traps involving pre-Tertiary strata in the study area and the volume of oil and gas source rocks that could contribute hydrocarbons to these traps. A gravity survey of the adjacent Teton Wilderness, directly to the west, defined a negative gravity anomaly which may represent a deep sedimentary basin, the Younts Basin(?) on the east side of the Washakie Range (Figure 1; Kulik, 1981). If additional work confirms that this possible basin is as deep as 20,000 feet, it would indicate that the study area is on a Laramide structural shelf, probably complicated by a series of northwest-trending anticlines and synclines, *en echelon*, similar to those exposed east of the volcaniclastic cover.

Vitrain reflectance studies of many black shales of various ages in and near the Teton Wilderness to the west (Love and others, 1975) which have been exhumed from under the cover of Absaroka volcaniclastic rocks, record paleotemperatures suitable for hydrocarbon maturation; none of the shales was even moderately metamorphosed. The following additional indirect evidence supports this observation. D.W. Rankin (written communication, 1982) described several large igneous intrusive masses in the southern part of the study area. One of these, the Dollar Mountain intrusive (Figure 1), uplifted a block of Paleozoic rocks more than two miles long (Rouse, 1940). Rocks within this block range in age from Cambrian to Pennsylvanian. Despite local contact metamorphism, the Madison Limestone contains oil stains apparently unaffected by the igneous activity (observed by W.R. Keefer, oral communication, 1982, during field work on the Stratified Primitive Area, Ketner and others, 1966).

OIL AND GAS POTENTIAL

In evaluating oil and gas potential of possible stratigraphic and structural traps in the study area, many variables must be considered. These include:

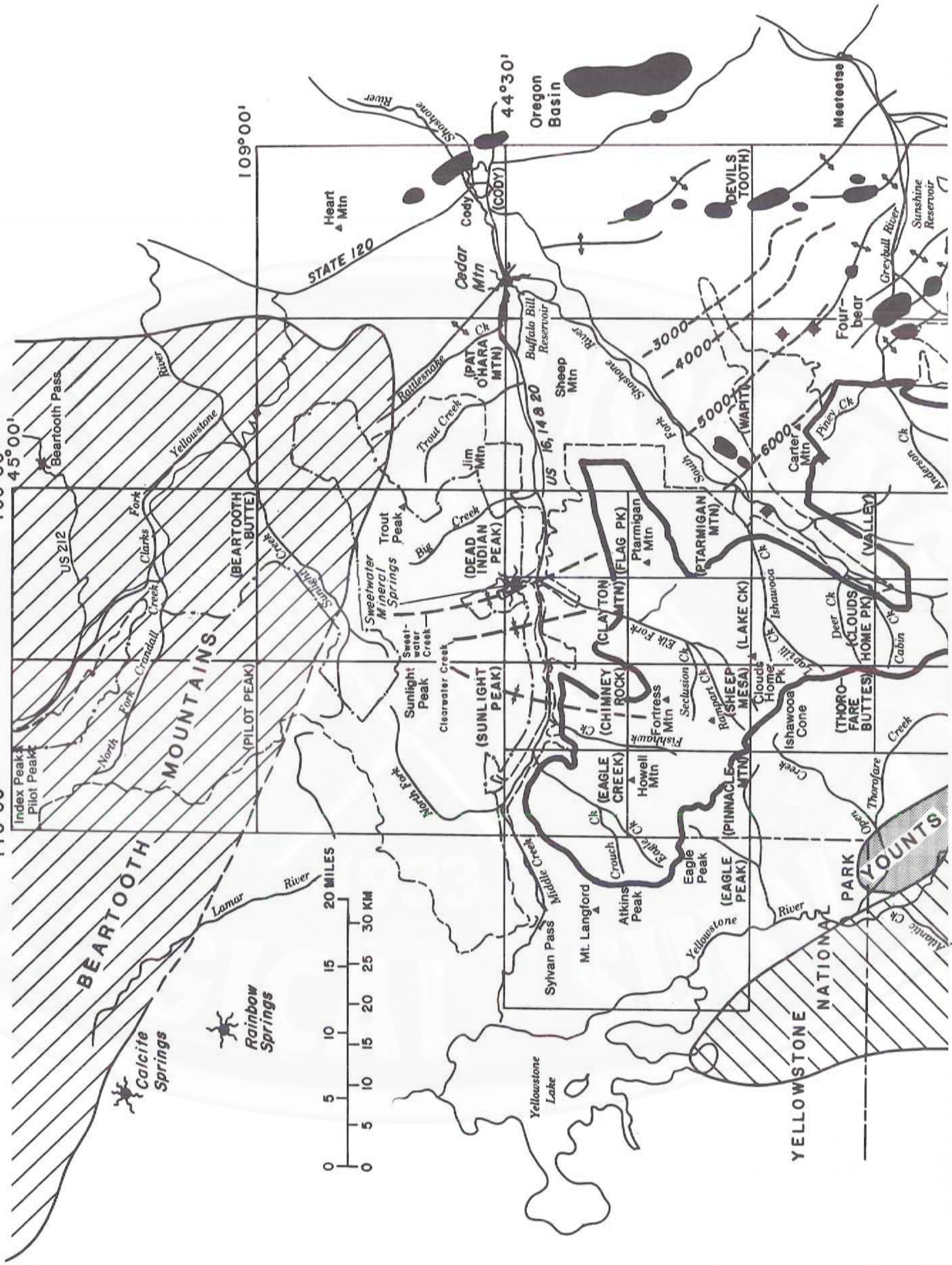
Laramide folding

In general, throughout intermontane basins of the Rocky Mountain region, the old folds (early Laramide) tend to be more prolific producers of oil and gas than younger folds. Most anticlines directly east of the study area were formed during the later part of the Laramide Revolution, before deposition of the Willwood Formation (lower Eocene) and, in part, at least, after deposition of the Fort Union Formation. It is postulated that most of the anticlines beneath the volcaniclastic rocks of the Absaroka Range were formed at about this same time.

Intra- and post-volcanic folds and other structures

The oil-producing Aspen Creek anticline (Figure 1) was folded in part after middle Eocene deposition. The South Fork, Reef Creek, and Heart Mountain low-angle detachment faults in and near the eastern margin of the study area have been mapped by Rankin (written communication, 1982). These fault systems affect the accuracy of oil and gas resource appraisals in that these overriding masses conceal structures in the underlying autochthonous strata. Structures in the overriding plates of Mesozoic and Paleozoic rocks have little relation to folds in rocks of the same ages at depth. Large, contorted, lithified slide masses of Absaroka volcaniclastic rocks, emplaced in part during Eocene time and in part during the Quaternary (Bown, 1982), commonly bear no relation to structures in underlying strata. The Absaroka volcaniclastic rocks dip southwestward regionally at about two degrees. McKenna and Love (1972, Figure 2A and p. 11) suggested that this westward tilting may reflect crustal rebound along the west margin of the Bighorn Basin due to rapid reexcavation of the basin in Late Cenozoic time.

The Jack Creek Dome, mapped by D.W. Rankin (written communication, 1982) and Fisher and Ketner (1968), is a major tectonic feature entirely expressed at the surface by Eocene Absaroka volcaniclastic rocks. The dome is asymmetric, with dips as much as 35 degrees on the west, an amplitude of as much as 1,800 feet, and an areal extent of 8 to 10 miles (Figure 1). The origin of the dome is not known. It has no magnetic expression (U.S. Geological Survey, 1973). Several small intrusive bodies of granodiorite were mapped by D.W. Rankin within the area of the dome, but whether they are parts of larger igneous bodies at depth is not known. Two oil test holes were drilled on the northwest flank of the dome (Figure 1). Both bottomed in the Tensleep Sandstone (Pennsylvanian), one at a depth of 4,769 feet and the other at 4,992 feet. No igneous rocks were encountered and no oil and gas shows were reported. Inasmuch as the oil-producing Aspen Creek anticline was recurrently uplifted after deposition of the volcaniclastic rocks, there may be closure in Mesozoic and Paleozoic rocks of the Jack Creek Dome at depth. The apex of a pre-Tertiary dome, if present, need not coincide with that in the volcaniclastic rocks, two miles or more southeast of the test holes.



110°00'
109°30'
45°00'
109°00'
44°30'
Beartooth Pass
Index Peak
Pilot Peak
US 212
Clarks Fork
Crandall Creek
North Fork
BEARTOOTH MOUNTAINS
(BEARTOOTH BUTTE)
(PILOT PEAK)
Yellowstone River
Heart Mtn
STATE 120
Cody
(CODY)
Shoshone River
Oregon Basin
Meeteetse
Cedar Mtn
Buffalo Bill Reservoir
Rattlesnake Ck
(PAT O'HARA MTN)
Sheep Mtn
Trout Creek
Jim Mtn
US 16, 14 & 20
Trout Peak
Big Creek
(DEAD INDIAN PEAK)
Sunlight Creek
Sweetwater Mineral Springs
Sweetwater Creek
Sunlight Peak
Clearwater Creek
(SUNLIGHT PEAK)
North Fork
(CLAYTON MTN)
(FLAG PK)
Ptarmigan Mtn
(PTARMIGAN MTN)
Elk Fork
(CHIMNEY ROCK)
Fortress Mtn
Fishhawk Ck
Seclusion Ck
Rampart Ck
(SHEEP MESA)
(LAKE CK)
Ishawooa Ck
(EAGLE CREEK)
Howell Mtn
(PINNACLE MTN)
Clouds Home Pk
Ishawooa Cone
Deer Ck
(CLOUDS HOME PK)
Cabin Ck
(THOROFARE BUTTES)
Creek
South Fork Shoshone River
3000
4000
5000
6000
(WAPITI)
Carter Mtn
Piney Ck
Anderson Ck
(VALLEY)
DEVILS TOOTH
Greybull River
Sunshine Reservoir
Four-bear
Crouch Ck
Eagle Ck
Eagle Peak
(EAGLE PEAK)
Middle Creek
Mt. Langford
Atkins Peak
Sylvan Pass
Yellowstone River
Thorofare Creek
Open Ck
YOUNTS
Atlantic Ck
YELLOWSTONE NATIONAL PARK
Lamar River
Calcite Springs
Rainbow Springs
Yellowstone Lake
0 5 10 15 20 MILES
0 5 10 15 20 25 30 KM

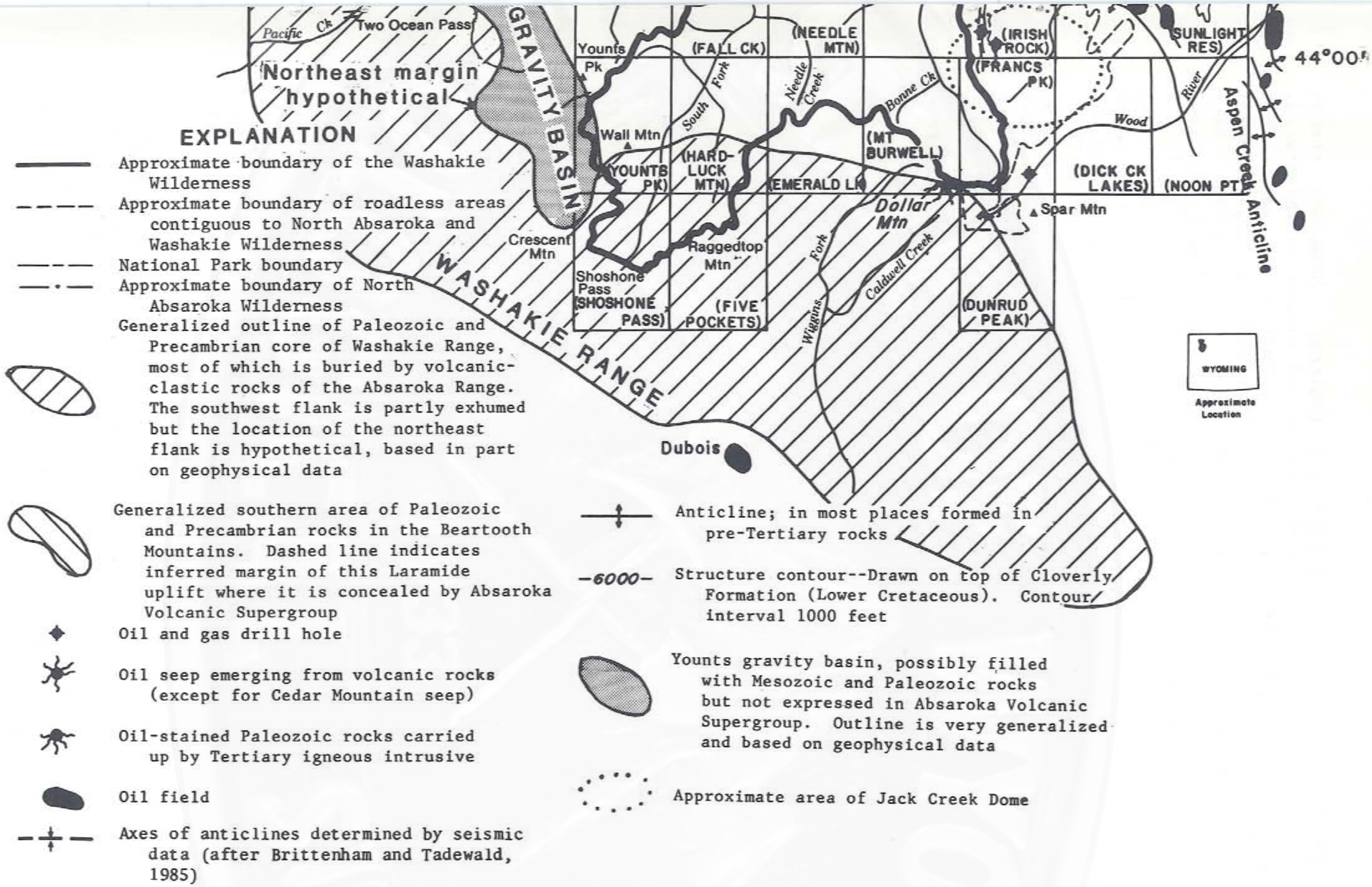


Figure 1. Map showing relation of Washakie Wilderness to major structural and geographic features and to adjacent oil and gas field and oil seeps, Park County, Wyoming.

Depth of pre-Eocene erosion

None of the 24 oil fields east of the study area (Figure 1) is eroded below Cretaceous rocks. It this is true of structures beneath the study area, then possible hydrocarbon traps may not have been breached by erosion and the oil and gas could still be retained.

Reservoir and source rocks

Mississippian, Pennsylvanian, Triassic, and Cretaceous rocks yield oil in one or more of the 24 oil fields shown on Figure 1. Oregon Basin is the only one that had significant oil and gas shows in Cambrian and Ordovician rocks. Most production in the western part of this group of fields is from Triassic (sandstone), Permian (dolomite), Pennsylvanian (sandstone), and Mississippian (limestone and dolomite) strata. The oil in Paleozoic rocks is generally high in sulfur and that in Mesozoic rocks is low. No vitrain reflectance studies of shales are available from rocks adjacent to or within the study area, but possible source shales in the same formations in and adjacent to the Teton Wilderness to the west and southwest (Love and others, 1975) are matured sufficiently for petroleum generation but are not metamorphosed.

A test well drilled through the volcaniclastic rocks a few miles southeast of the study area encountered several hundred feet of oil staining in these strata. Apparently the oil migrated upward or laterally from pre-Tertiary rocks into porous and permeable zones within the volcaniclastics. Therefore, these should be considered as possible reservoir rocks within the study area.

Patterns of folding and faulting

All anticlines adjacent to the study area trend north-northwest or northwest. Most are sharply and asymmetrically folded and faulted. Some are thrust southwestward and others northeastward. The largest, Oregon Basin, was thrust eastward (Gries, 1981, p. 16). Normal faults, some down on the east, others down on the west, cut several anticlines. About half of the townships in the part of the Bighorn Basin directly east of the study area (Figure 1) have at least one anticline with oil and(or) gas production. These structural patterns and the potential productive ratio probably do not diminish within the study area; however, some Laramide structures may have been disrupted by the major Eocene eruptive centers described and mapped by D.W. Rankin (written communication, 1982). The exposed parts of these eruptive centers, however, constitute only about one-fifth of the study area.

Effects of igneous intrusions and local metamorphism

A well (Honolulu Oil Company, 22 HOC-Hunt, section 20, T.48N., R.103W.) was completed in 1960 in the northern part of the Fourbear oil field (Figure 1), four miles east of the study area. In this well, 1,065 feet of igneous rocks were cored and described by company geologists as "andesite" and "dacite," beginning at a depth of 5,436 feet, and continuing to the total depth of 6,501 feet. Cambrian limestone directly above the intrusive was reportedly not extensively metamorphosed. The igneous rock is similar to some of the intrusives described by D.W. Rankin (written communication, 1982) in the study area and probably is of Eocene age. This well was plugged back to the Tensleep Sandstone and completed for an initial yield of 350 barrels of oil per day. Thus, the igneous intrusion did not adversely affect oil production.

An oil test hole near the head of Wood River (Mobil Oil Company, F32X-1-P Wilson, section 1, T.45N., R.104W.; the southernmost well shown in Figure 1) was drilled through the lower part of the Wiggins Formation and older Tertiary rocks and a relatively normal sequence of lower Cretaceous and older Mesozoic and Paleozoic strata down to the Tensleep Sandstone at a total depth of 4,860 feet. An igneous sill (petrography not available) was drilled between 3,352 and 3,510 feet. This intrusive did not appreciably affect adjoining Jurassic and Triassic strata. A nearby core hole drilled through quartz monzonite, which intruded andesitic rocks of the Wiggins Formation, has a late Eocene potassium-argon age of 30.2± 1.4 million years (Schassberger, 1972). Most of the major intrusives in the region are of middle and late Eocene age (for other ages, see Smedes and Prostka, 1972; and Love and others, 1976). The previously mentioned oil-stained Madison Limestone on Dollar Mountain (Figure 1), part of the Dollar Mountain Paleozoic roof pendant of Rouse (1940), was uplifted by intrusion of the Dollar Mountain rhyolite pluton. This occurrence demonstrates that oil can survive near a younger major igneous intrusive.

Oil seeps

Of the five localities of oil seeps described by Love and Good (1970) in the Yellowstone-Absaroka area, only one, Sweetwater Mineral Springs (Figure 1) is within the study area. It is especially pertinent to the evaluation of oil and gas resources, however, because the oil emerges through the volcaniclastic rocks of the Wapiti Formation which are folded into a conspicuous anticline. Hewett's (1913, p. 51) description of the oil occurrence follows:

> *"The [oil] spring is unique in that it lies within 100 yards of several small sulfur deposits, situated on the east side of Sweetwater Creek. The sulfur deposits * * * embrace two classes of material: (1) sulfur which lies along the walls of open fractures in the lavas, and from which gases containing Co_2, CH_4 and H_2S are issuing, and (2) sulfur filling the interstices of gravels and surface debris along stream channels. The second class of material probably covers fracture zones. The oil spring is opposite an area 100 feet square into which prospect pits have been sunk showing sulfur cementing angular rock debris to a depth of nine feet. Other smaller deposits of sulfur lie 700 feet farther up the creek.*
>
> *Oil was first recognized issuing from the sands adjoining the creek.*
>
> *In the hole which was dug along the bank, water and oil slowly accumulated and several quarts of clear light oil were thus collected during the summer of 1911. During the writer's visit, a pit was dug near the location of the old one which had been destroyed by freshets. The sand at this point is dark brown and has an asphaltic odor, but otherwise is such as would form bars along rapid mountain streams. In the short time at the writer's disposal only enough oil was collected to give assurance of its identification, but not enough for analysis.*
>
> *Tho the superficial rocks of this region are igneous flows and breccias, these rocks overlie a great thickness of sedimentary rocks ranging in age from Cambrian to Eocene, the Mesozoic section alone being approximately 14,000 feet thick 25 miles east."*

The sulfur is probably of volcanic origin, but analytical data on the oil (Love and Good, 1970) suggest that it is low-sulfur Cretaceous oil, rather than high-sulfur Paleozoic oil. More recent field work by J.C. Antweiler (oral communication, 1981) shows that the oil seeps emerging through the Wapiti Formation are more widespread in the Sweetwater area than had previously been recognized, and that not all are associated with Holocene water springs. These seeps emerge at the surface crest of the Sweetwater Creek anticline whose subsurface configuration was defined by geophysical data (Brittenham and Tadewald, 1985). They suggested that the anticline in Mesozoic and Paleozoic rocks is underlain by an igneous intrusive body. However, the northwest trends of the Sweetwater Creek and Clearwater Creek anticlines are parallel to Laramide folds to the east and southeast and may have the same origin.

Several oil seeps in the volcaniclastic strata southeast of the study area were discovered by K.A. Sundell (oral communication, 1985) during several years of field work (Sundell, 1982) in the Absaroka Range. Undoubtedly, other seeps will be found as the patterns of occurrence become more familiar.

Magnetic and gravity interpretations

Magnetic "highs" correlate in a general way with some of the known intrusive igneous bodies, and are of sufficient intensity to indicate that the intrusions may have disrupted older Laramide structures. No magnetic anomalies are parallel to the exposed anticlines east of the study area. A broad west-trending magnetic low crosses the study area south of the middle part, but its significance is not known. Magnetic anomalies are discussed in more detail in a separate report by Long (1985).

Assessment of oil and gas resource potential

The oil and gas potential is probably low in the Paleozoic and Precambrian cores of the Washakie Range and the Beartooth Mountains, outlined in Figure 1. Precambrian rocks along the southwest margin of the Washakie Range are thrust southwestward onto Cretaceous strata (Gries, 1981), but the structure of the northeast flank is not known. The regional tectonic pattern suggests that there is little northeastward thrusting of the main mountain core, even though some of the anticlines, such as Oregon Basin, out in front are thrust eastward. The structure of the south flank of the Beartooth Mountains is unknown except in the western part within Yellowstone National Park (northwest of the area of Figure 1) where along the Gardiner thrust fault, Precambrian rocks moved southwest over Upper Cretaceous strata (Fraser, and others, 1969). The southeast extent of this fault, the possible presence of similar ones still farther southeast, and their effect on oil and gas potential are not known. In order for each structure to be defined by geophysics, a significant monetary investment would be required.

CONCLUSIONS

1. The Sweetwater Mineral Springs oil seeps document the presence of oil beneath the volcaniclastic rocks in at least part of the study area. Additional oil seeps and a test well that encountered several hundred feet of oil staining in volcaniclastic strata southeast of the study area indicate the possibility of widespread migration of oil from older rocks into porous and permeable zones within the volcaniclastics.

2. Regional stratigraphic and structural patterns suggest, but do not prove, that anticlines similar to those producing oil and gas directly east of the study area are present under the area on the western platform extension of the Bighorn Basin.

3. Laramide anticlines, if present in the study area, may have been disrupted by igneous intrusions, but oil traps between these intrusions probably were not destroyed.

4. Although Eocene volcaniclastic strata may be 5,000 feet thick locally, they are thinner in most places. Some 6,000 - 7,000 feet of possibly hydrocarbon-bearing strata directly underlie the volcaniclastic rocks. Hence, a bore hole favorably located structurally could test most potential reservoirs at depths of 15,000 feet or less.

5. If seismic-reflection surveys and(or) magnetotelluric surveys can successfully define at least the larger Laramide folds in Mesozoic and Paleozoic strata beneath the Eocene volcaniclastic rocks of this study area, these surveys would also be of regional tectonic significance because they would help (1) determine the western margin of the Bighorn Basin; (b) locate the northeast flank of the Washakie Range; (c) confirm or refute the existence and configuration of the Younts Basin(?); and (d) determine where and what kind of structural break is between this possible basin and the Bighorn Basin and the implications of that break for oil and gas potential.

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