BEAVERHEAD NATIONAL FOREST LEASING EIS
REASONABLY FORESEEABLE DEVELOPMENT SCENARIO

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INTRODUCTION

Oil and gas drilling that may occur as a result of a renewed oil and gas leasing program on the Beaverhead National Forest will be controlled by a combination of economic and geologic factors. A decision by the Forest Service and BLM to lease does not guarantee that activity will take place on the Beaverhead National Forest. Over the next 15 years, companies may decide current economics warrant leasing land in the Beaverhead but are not good enough to warrant drilling.

The economics of oil and gas development are known to be highly variable. Economics play a very large role in controlling how many, if any, exploratory wells will be drilled. However, the consistent availability of lands for leasing and exploration also play a role in how many wells will be drilled. To illustrate this, one should note the number of wells that have been drilled outside the Beaverhead National Forest boundary where lease availability has been consistent over the years, versus the two wells that have been drilled inside the forest (Table 1).

While the geology itself will not change, the understanding of oil and gas geology in this part of Montana can change dramatically each time a new oil and gas test is completed. This is especially true in this part of Montana, where so few deep wells have been drilled to date. In addition, technological advances which have occurred over the last ten years, such as horizontal and long-reach directional drilling, can turn a previously uneconomic deposit into an economic venture.

To develop a reasonably foreseeable development (RFD) scenario, it is necessary to deal with the geologic uncertainties by making assumptions. The assumptions must be reasonable, supportable, and based on best present knowledge. The following discussion examines the overall geology and historical activity of the area. This will then be used to make a reasonable projection of future oil and gas development activity that may result from a leasing decision on the Beaverhead National Forest.

GEOLOGIC REPORT

GEOGRAPHIC SCOPE

The EIS includes all the acres within the administrative boundaries of the Beaverhead National Forest, excluding Congressionally-designated wilderness areas. All other portions of the Beaverhead National Forest (NF) are covered in the RFD. Any Federally-owned oil and gas underlying private surface within the boundaries of the Beaverhead National Forest is also included in this analysis.

The Beaverhead NF can be divided up into six discrete geographic units; the Pioneer Range, the Tendoy Range, the Bitteroot Range, the Gravelly Range, the west half of the Madison Range, and the Tobacco Root Mountains,.

TABLE 1 **Oil and Gas Exploration Tests in the vicinity of Beaverhead National Forest, Montana.**

WELL NAME	LOCATION	COUNTY	YEAR	DEPTH (FT)	LOWEST FM TESTED	RESULTS	REMARKS
RUBY OIL #1 BAYERS	T3S,R5W,SEC 18,NWSW	MADISON	1951	835	NOT REPORTED	P&A	
MADISON OIL #1-A BEYERS	T3S,R5W,SEC 18 SWSE	MADISON	1954	2650	NOT REPORTED	P&A	
AMOCO #1 JACK HIRSHEY	T3S,R16W,SEC 27 NENE	BEAVERHEAD	1981	16048	PRECAMBRIAN	P&A	GAS SHOWS IN TERTIARY
NARCO #3-8 STATE	T4S,R5W,SEC 8 NENW	MADISON	1982	3525	PRECAMBRIAN	P&A	
AMOCO #2 JACK HIRSHEY	T4S,R15W,SEC 31 NWNW	BEAVERHEAD	1983	9550	PRECAMBRIAN BELT	P&A	NO SHOWS
BUFFALO OIL #1 NEYHART	T5S,R7W,SEC 3,NENE	MADISON	1954	2633	MADISON?	P&A	
O'KEEFE #1 HUEY TURNER	T5S,R7W,SEC 13 NESW	MADISON	1973	500	MADISON	P&A	
AMERICAN QUASAR 29-1 REBISH	T5S,R7W,SEC 29 SWSE	BEAVERHEAD	1978	6330	DEVONIAN	P&A	
MAY PETROLEUM #1 HAGENBARTH	T5S,R8W,SEC 12 NENW	BEAVERHEAD	1978	4039	PENN QUADRANT	P&A	
AMERICAN QUASAR 27-22 HAGENBARTH	T5S,R9W,SEC 27 SENW	BEAVERHEAD	1980	12048	PRECAMBRIAN	P&A	
NARCO #7-23	T6S,R7W,SEC 23 SWNE	MADISON	1982	8225	METAMORPHICS	P&A	
BEAVERHEAD #1 THOMPSON	T6S,R9W,SEC 19 SWSE	BEAVERHEAD	1955	4211	NOT REPORTED	P&A	
TEXACO #1 J.S-A GRANGER	T7S,R1E,SEC 18 NESE	MADISON	1984	8585	GRANITE	P&A	
SAM POYNTER #1 BULLWHEEL	T7S,R1W,SEC 17 NWNW	MADISON	1939	1978	MADISON?	P&A	OIL SHOWS 1851-1978'
HAGENBARTH #1 CROWLEY	T7S,R10W,SEC 2 NWNW	BEAVERHEAD	1927	812	NOT REPORTED	P&A	
FARMERS UNION #3 STRAT TEST	T7S,R10W,SEC 10 NENE	BEAVERHEAD	1971	800	VOLCANICS	P&A	
FARMERS UNION #1 STRAT TEST	T7S,R10W,SEC 16 NESW	BEAVERHEAD	1971	960	VOLCANICS	P&A	
HELIS ESTATE 1-27 BOOMHAUER	T8S,R1E,SEC 27 SWSW	MADISON	1984	3263	PRECAMBRIAN	P&A	
HELIS ESTATE #1-27 CONLEY RANCH	T8S,R5W,SEC 27 SENE	MADISON	1984	6382	METAMORPHICS	P&A	
BEAVERHEAD-ALBERTA OIL #1	T8S,R9W,SEC 35 NENE	BEAVERHEAD	1917	1800	NOT REPORTED	P&A	
BEAVERHEAD-ALBERTA #2	T8S,R9W,SEC 35 NESW	BEAVERHEAD	1924	2500	NOT REPORTED	P&A	
BEAVERHEAD-ALBERTA #3	T8S,R9W,SEC 35 NESW	BEAVERHEAD	1928	1225	TERTIARY	P&A	
BIG DOME OIL #1	T8S,R9W,SEC 35 SESE	BEAVERHEAD	1918	100	NOT REPORTED	P&A	
AMERICAN QUASAR #9-1 MAY FED	T9S,R9W SEC 9 NWSW	BEAVERHEAD	1977	4351	DEVONIAN	P&A	LODGEPOLE GAS SHOWS
GEORGE METLAN #1	T9S,R9W,SEC 15 NENE	BEAVERHEAD	1898	500	NOT REPORTED	P&A	
BEAVERHEAD #1-A BROWN	T10S,R11W,SEC 24 NWNE	BEAVERHEAD	1954	1142	NOT REPORTED	P&A	
HORSEPRAIRIE OIL #1	T10S,R12W,SEC 1 SWSW	BEAVERHEAD	1919	1050	NOT REPORTED	P&A	
BEAVERHEAD OIL #1 HANSEN	T10S,R12W,SEC 2 SWSW	BEAVERHEAD	1954	4210	CAMBRIAN	P&A	OIL SHOW-DEV JEFFERSON
LUFF #1-27 HANSEN	T10S,R12W,SEC 27 NESW	BEAVERHEAD	1980	11000	MADISON	P&A	
MARATHON OIL 1-20	T12S,R5W,SEC 20 NESW	BEAVERHEAD	1987	7711	MADISON	P&A	OIL SHOW IN HANGING WALL
AMOCO #1 MCKNIGHT CANYON	T12S,R10W,SEC 21 SESW	BEAVERHEAD	1986	16000	LODGEPOLE	P&A	
UNION TEXAS #1 METZEL-FEDERAL	T13S,R2W,SEC 5 NWNW	BEAVERHEAD	1970	4125	CAMBRIAN PARK	P&A	
SHELL OIL #34X-13 UNIT	T13S,R5W,SEC 13 SWSE	BEAVERHEAD	1964	10244	MADISON	P&A	
MUDDY CREEK OIL #1	T13S,R10W,SEC 29	BEAVERHEAD	1918	1150	TERTIARY	P&A	
MUDDY CREEK OIL #2	T13S,R10W,SEC. 29	BEAVERHEAD	1921	1050	TERTIARY	P&A	
AMERICAN QUASAR #29-1 PEET	T14S,R4W,SEC 29 SWNE	BEAVERHEAD	1978	12227	CAMBRIAN FLATHEAD	P&A	
FARMERS UNION #9-31 LIMA	T14S,R7W,SEC 31 NESE	BEAVERHEAD	1976	15715	CRET THERMOPOLIS	P&A	
CITIES SERVICE #1 EMERICH	T14S,R7W,SEC 33 NWNE	BEAVERHEAD	1953	11213	JR MORRISON	P&A	
FARMERS UNION #2-33 LIMA	T14S,R7W.SEC 33 NWNE	BEAVERHEAD	1975	13909	AMSDEN	P&A	DEAD OIL SHOW-KOOTENAI, PHOSPHORIA
AMOCO SNOWLINE #1	T15S,R7W,SEC 10 NESE	BEAVERHEAD	1982	14410	CRETACEOUS	P&A	OS,GS IN MC, ENCOUNT 2 THRUSTS
NEIGHBORING IDAHO							
EXXON MEYERS FEDERAL #1	T14N,R35E,SEC 14, SWNE	CLARK CO, IDAHO	1982	18540	PRECAM GRANITE	P&A	GS IN MADISON (465 MCF)

GEOLOGIC BACKGROUND

The Beaverhead National Forest is partially within the Rocky Mountain Overthrust Belt and partially within what is known as the Central Rocky Mountain Foreland Province (Figs. 1 & 2). Both areas are considered highly prospective for oil and gas. Most of the drilling activity in southwest Montana in the past has been focused in the Foreland Province.

The Pioneers, Tendoys, and Bitteroots(Beaverhead) are within the Rocky Mountain Overthrust Belt. The Gravelly/Snowcrest, Madison, and Tobacco Root Ranges are within the Central Rocky Mountain Foreland Province (Lageson, 1985).

The Rocky Mountain Overthrust Belt (Fig. 1), also known as the Sevier Thrust Belt, is characterized by low angle thrust faulting (Beutner, 1977). East of this line, in the Central Rocky Mountain Foreland Province, thrust faults still occur, but they are at a much higher angle and involve basement rock (granite and Precambrian cores of mountains).

Knowledge of the existing geology of the Beaverhead National Forest is based on surface mapping, the 2 wells that have been drilled in the forest, and the 37 other oil and gas tests that have been drilled in the region around the forest (Table 1). A diagram outlining the names and ages of geologic formations encountered in southwest Montana is shown in Figure 5.

While 39 wells may seem like a large number of tests, Table 1 indicates that 24 of those were drilled less than 5000 feet deep, which is not considered an adequate depth to test the deep structures of Southwest Montana. It is not unusual to have 39 straight dry holes in frontier areas. In the Wyoming Overthrust Belt, 134 wells were drilled before a major discovery was found at Ryckman Creek field in 1976 (Hodgden and McDonald, 1977, p.50-52). The Ryckman field has since produced in excess of 150 billion cubic feet of gas and 50 million barrels of oil.

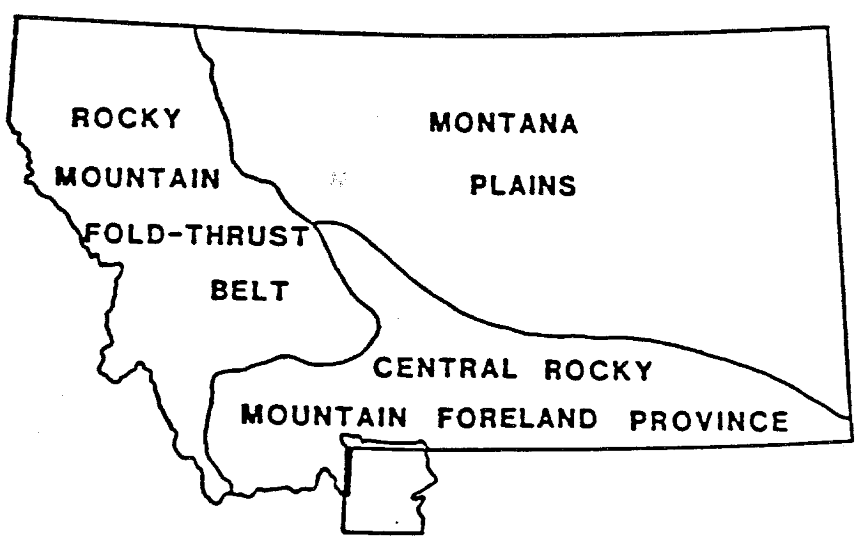


FIGURE 1: Generalized Geologic provinces of Montana. The Beaverhead NF is within both the Rocky Mountain Fold and Thrust Belt and the Central Rocky Mountain Foreland Province (from Lageson, 1985).

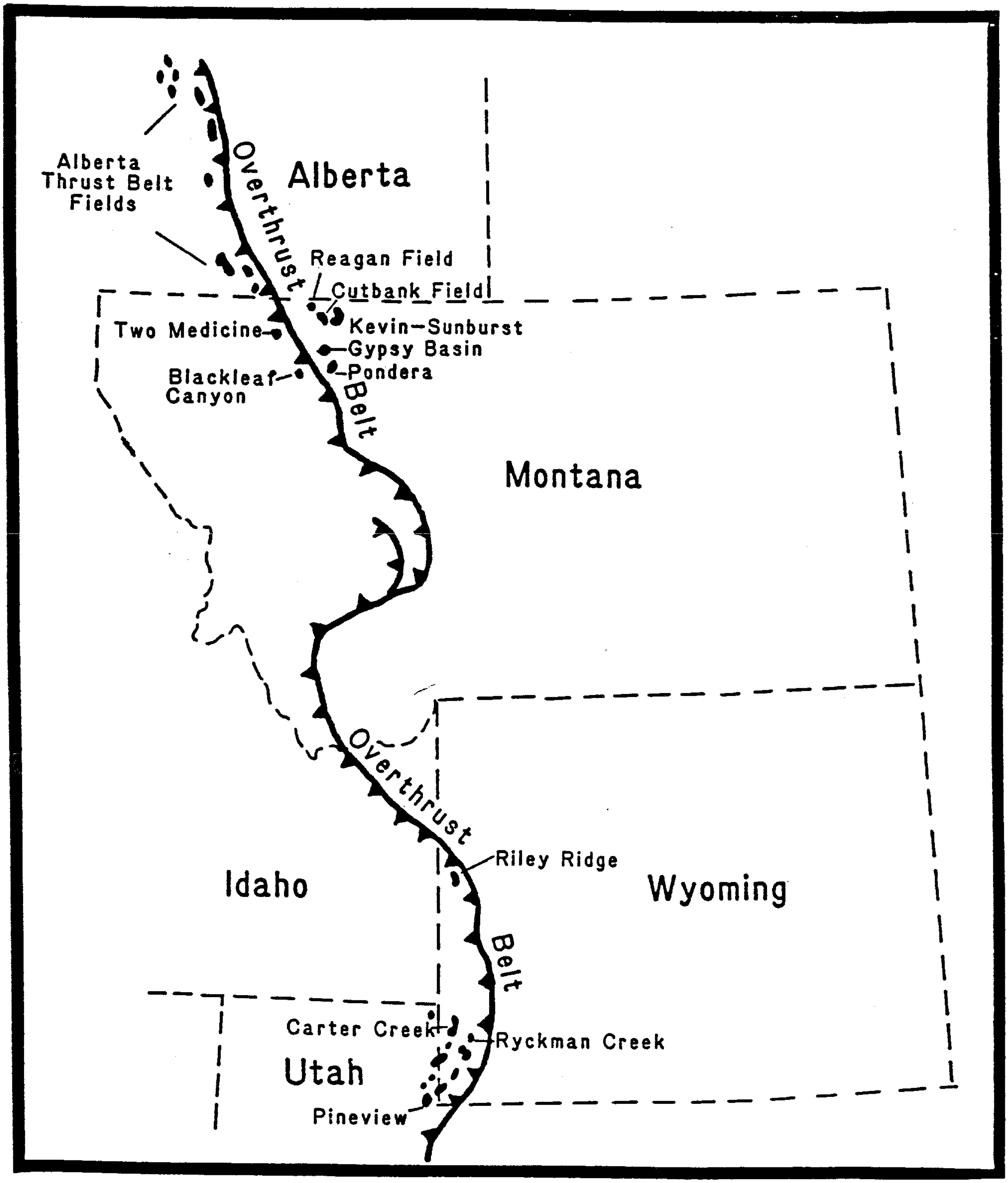


FIGURE 2: Regional map of the Rocky Mountain Overthrust Belt showing major fields developed along it. The Montana fields east of the Overthrust Belt are not technically considered overthrust-type fields. (Modified from Lewis and Clark NF, 1990, p.III-2, Map 3.1)

THE OVERTHRUST BELT

The leading edge of the overthrust belt bends abruptly to the west in southwest Montana (Fig. 2). This bend is termed the Southwest Montana Re-entrant by geologists (Beutner, 1977). The reason for this bending is not well understood by geologists, but it is thought to be due to obstacles, such as the Blacktail-Snowcrest Uplift, which got in the way of the eastward-moving overthrust belt at the time of thrusting (Perry, Dyman, and Sando, 1989).

The overthrust belt is characterized by slabs of older rocks which have been thrust eastward over younger rocks, often concealing folded younger rocks underneath (Fig. 3).

Geologists believe this overthrusting occurred during the Rocky Mountain uplift. At that time, giant slabs of rock several thousand feet thick peeled off as the crust bulged upward. The slabs slid eastward off the bulging crust over progressively younger rocks (Alt and Hyndmann, 1986, p. 14).

The reason why the Montana overthrust belt is thought to be highly prospective for hydrocarbons, is that the two major ingredients needed to create an economic deposit, source rocks and traps, are known to occur.

Source rocks are simply a carbon rich layer of rocks, usually a shale, that will generate and release oil and gas at high temperatures and pressures. Source rocks usually are found below a trap (Fig. 3), but occasionally occur above the trap. The Permian Phosphoria Formation and Mississippian Big Snowy Group are known to contain source rocks at sufficient depths throughout the southwest Montana overthrust belt to generate hydrocarbons (Perry, 1988).

Once oil and gas has been generated from a source rock, it tends to migrate upward. Unless it encounters a "trap", the hydrocarbons will continue to migrate upward until it naturally seeps out of the ground. In order to trap hydrocarbons, two geologic conditions must exist. First, a sufficient "reservoir" rock (which can be thought of as a hydrocarbon sponge) is needed to store the hydrocarbons (Fig. 3). The Mississippian-aged Madison Limestone, Pennsylvanian-aged Quadrant Sandstone and Cretaceous-aged sandstones have sufficient porosity and permeability in the overthrust belt to act as a good reservoir rock (Perry, 1988). In addition, an impermeable seal is needed to prevent the hydrocarbons from migrating out of the reservoir. The Jurassic-aged shales which lie directly over the Madison Limestone have been shown to provide an excellent seal for reservoirs in other parts of the overthrust belt (Fig. 3).

The eastward "thrusting" of the plates has created traps in southwest Montana which can accumulate oil and gas beneath some of the slabs or "thrust sheets", hidden from conventional surface mapping techniques.

Oil and gas has been found in the overthrust belt in Canada and Wyoming, but major pools in the Montana portion of the belt have yet to be discovered (Figs. 2 & 4). This is partly due to restrictions on entering Federal lands in Montana over the last 15 years but also due to the extremely complicated geology and great depth required to penetrate the Montana thrust sheets.

The wells drilled in the Montana Overthrust Belt in the 1970s and 80s were based on early seismic interpretations. Results from these early drill holes has provided a means to refine the existing seismic information and improve the geologic interpretations. These changes in the interpretations are what industry people refer to as a "learning curve." Many geologists believe the seismic interpretation learning curve is at a point where the Montana Overthrust Belt is now poised for a major discovery.

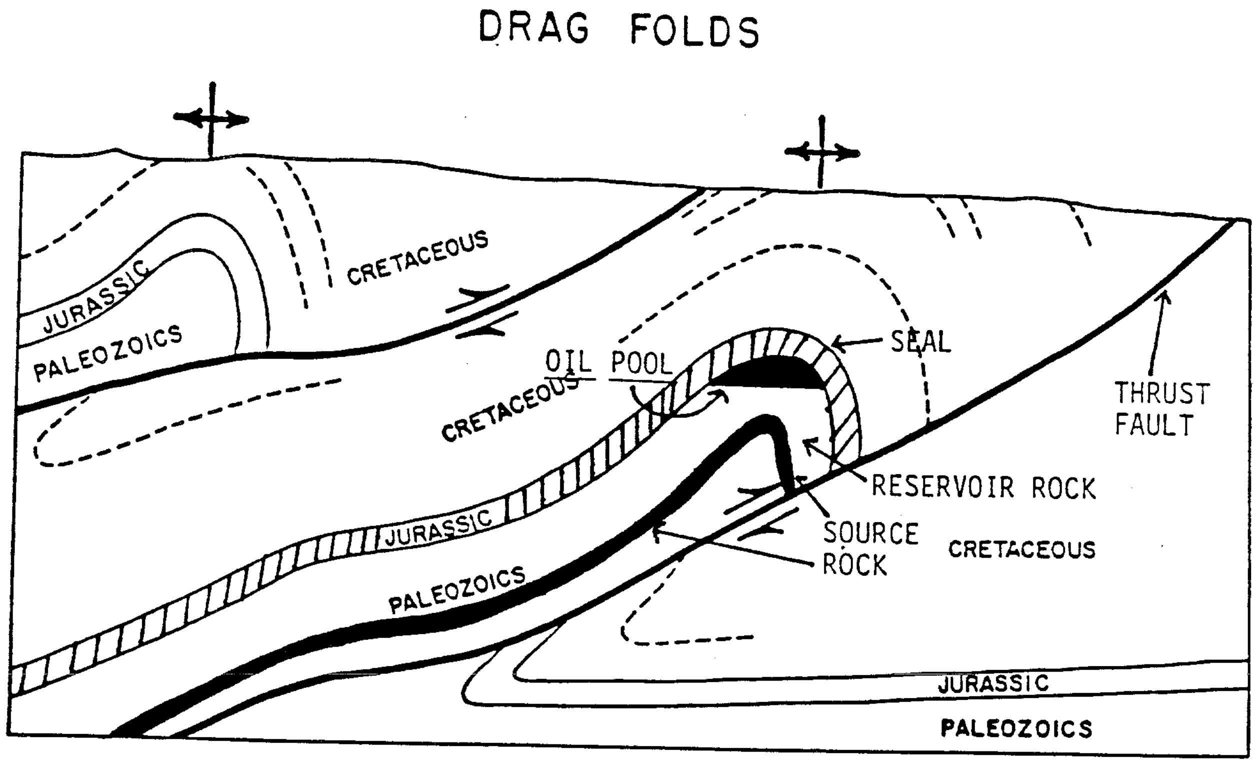


FIGURE 3: Cross section through a typical drag fold trap that oil and gas companies are interested in searching for in the Montana overthrust belt (modified from Hurley, 1959).

An excerpt from a Montana Geological Society Guidebook (1979, p. 19) summarizes industry's opinion of the Montana overthrust belt:

> "Although it appears that considerable drilling has been done in the Montana overthrust belt, it must be noted that many dry holes were drilled east of thrusted Paleozoic strata. Some were drilled on 'velocity highs' and some just missed the eastern edge of thrust sheets.... In the 300 miles from the Canadian border to the Idaho state line, only 30 or so wells have actually penetrated Paleozoic thrust sheets. Several of these wells have had significant shows of gas, condensate and oil. It appears that Montana overthrust belt exploration is just now attaining the well control and seismic data necessary for optimum location of drill sites."

Figure 3 shows the typical "hidden" geologic structure that oil and gas companies are likely to be searching for in the Beaverhead National Forest.

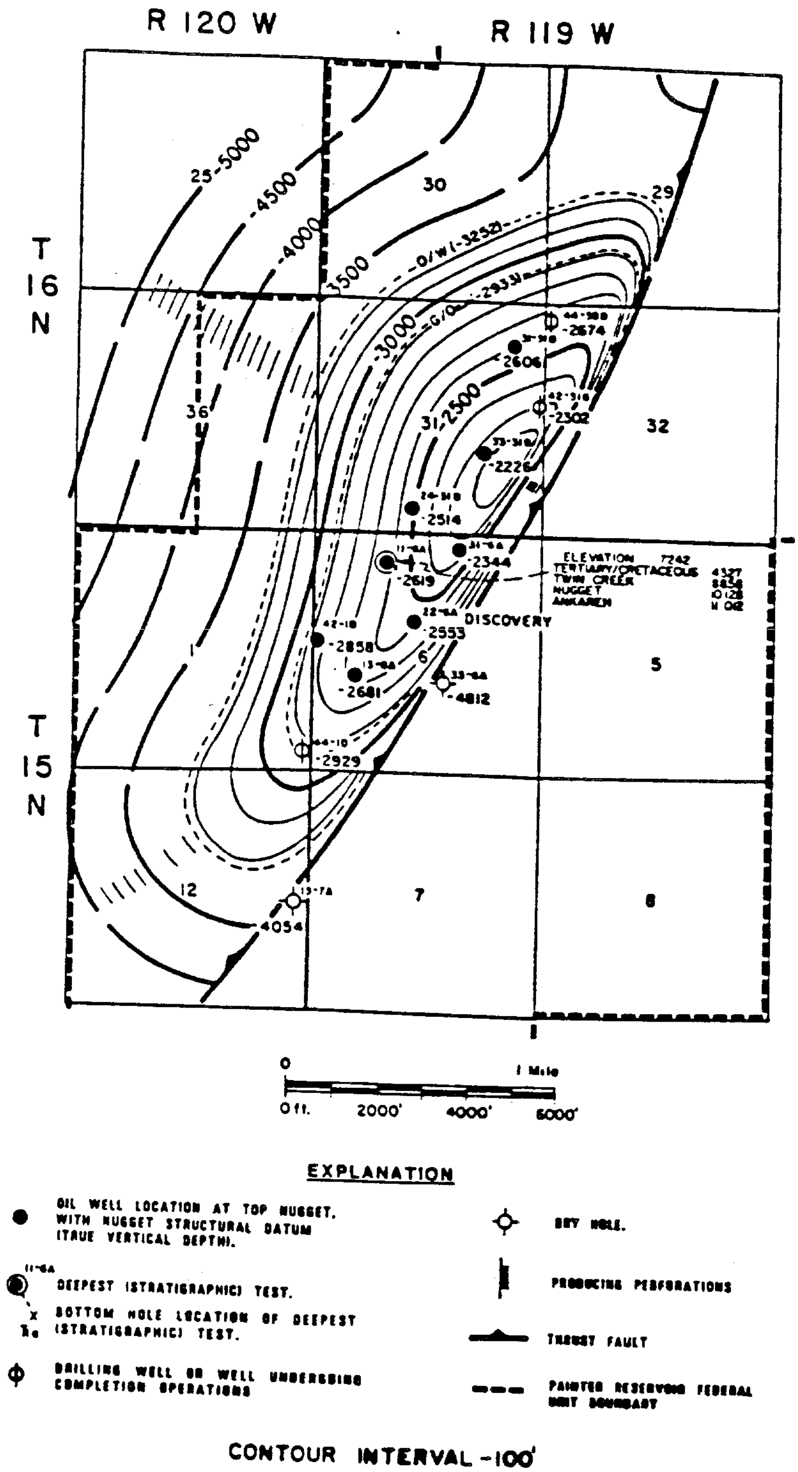
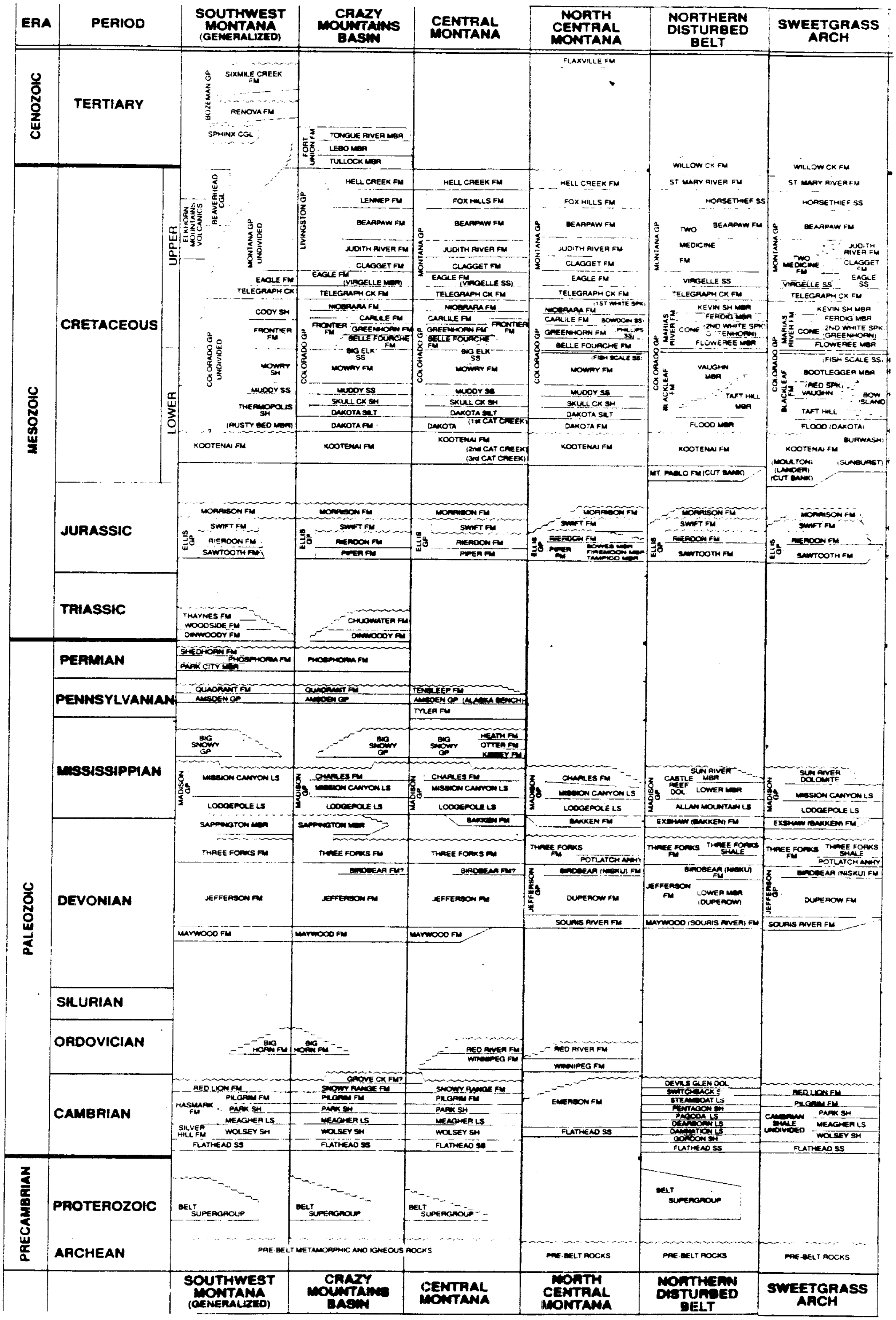


FIGURE 4: Map view of an actual overthrust drag fold-style trap, Painter Reservoir Field, Uinta County, Wyoming, discovered in 1977. Geologists believe the Montana Overthrust Belt may contain many more fields like this (Jones, 1979).


ERA
PERIOD
SOUTHWEST MONTANA (GENERALIZED)
CRAZY MOUNTAINS BASIN
CENTRAL MONTANA
NORTH CENTRAL MONTANA
NORTHERN DISTURBED BELT
SWEETGRASS ARCH
CENOZOIC
TERTIARY
MESOZOIC
CRETACEOUS
UPPER
LOWER
JURASSIC
TRIASSIC
PALEOZOIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN
PROTEROZOIC
ARCHEAN
BOZEMAN GP
SIXMILE CREEK FM
RENOVA FM
SPHINX CGL
ELKHORN MOUNTAINS VOLCANICS
BEAVERHEAD CGL
MONTANA GP UNDIVIDED
EAGLE FM
TELEGRAPH CK
CODY SH
FRONTIER FM
COLORADO GP UNDIVIDED
MOWRY SH
MUDDY SS
THERMOPOLIS SH
(RUSTY BED MBR)
KOOTENAI FM
MORRISON FM
ELLIS GP
SWIFT FM
RIERDON FM
SAWTOOTH FM
THAYNES FM
WOODSIDE FM
DINWOODY FM
SHEDHORN FM
PHOSPHORIA FM
PARK CITY MBR
QUADRANT FM
AMSDEN GP
BIG SNOWY GP
MADISON GP
MISSION CANYON LS
LODGEPOLE LS
SAPPINGTON MBR
THREE FORKS FM
JEFFERSON FM
MAYWOOD FM
BIG HORN FM
RED LION FM
PILGRIM FM
HASMARK FM
PARK SH
MEAGHER LS
SILVER HILL FM
WOLSEY SH
FLATHEAD SS
BELT SUPERGROUP
PRE BELT METAMORPHIC AND IGNEOUS ROCKS
FORT UNION FM
TONGUE RIVER MBR
LEBO MBR
TULLOCK MBR
LIVINGSTON GP
HELL CREEK FM
LENNEP FM
BEARPAW FM
JUDITH RIVER FM
CLAGGET FM
EAGLE FM
(VIRGELLE MBR)
TELEGRAPH CK FM
NIOBRARA FM
CARLILE FM
COLORADO GP
FRONTIER FM
GREENHORN FM
BELLE FOURCHE FM
BIG ELK SS
MOWRY FM
MUDDY SS
SKULL CK SH
DAKOTA SILT
DAKOTA FM
KOOTENAI FM
MORRISON FM
SWIFT FM
RIERDON FM
PIPER FM
CHUGWATER FM
DINWOODY FM
PHOSPHORIA FM
QUADRANT FM
AMSDEN GP
BIG SNOWY GP
CHARLES FM
MISSION CANYON LS
LODGEPOLE LS
SAPPINGTON MBR
THREE FORKS FM
BIRDBEAR FM?
JEFFERSON FM
MAYWOOD FM
BIG HORN FM
GROVE CK FM?
SNOWY RANGE FM
PILGRIM FM
PARK SH
MEAGHER LS
WOLSEY SH
FLATHEAD SS
BELT SUPERGROUP
HELL CREEK FM
FOX HILLS FM
BEARPAW FM
MONTANA GP
JUDITH RIVER FM
CLAGGET FM
EAGLE FM
(VIRGELLE SS)
TELEGRAPH CK FM
NIOBRARA FM
CARLILE FM
GREENHORN FM
FRONTIER FM
BELLE FOURCHE FM
BIG ELK SS
MOWRY FM
MUDDY SS
SKULL CK SH
DAKOTA SILT
DAKOTA
(1st CAT CREEK)
KOOTENAI FM
(2nd CAT CREEK)
(3rd CAT CREEK)
MORRISON FM
SWIFT FM
RIERDON FM
PIPER FM
TENSLEEP FM
AMSDEN GP (ALASKA BENCH)
TYLER FM
HEATH FM
OTTER FM
KIBBEY FM
CHARLES FM
MISSION CANYON LS
LODGEPOLE LS
BAKKEN FM
THREE FORKS FM
BIRDBEAR FM?
JEFFERSON FM
MAYWOOD FM
RED RIVER FM
WINNIPEG FM
SNOWY RANGE FM
PILGRIM FM
PARK SH
MEAGHER LS
WOLSEY SH
FLATHEAD SS
BELT SUPERGROUP
FLAXVILLE FM
HELL CREEK FM
FOX HILLS FM
BEARPAW FM
JUDITH RIVER FM
CLAGGET FM
EAGLE FM
TELEGRAPH CK FM
NIOBRARA FM
(1ST WHITE SPK)
CARLILE FM
BOWDOIN SS
GREENHORN FM
PHILLIPS SS
BELLE FOURCHE FM
(FISH SCALE SS)
MOWRY FM
MUDDY SS
SKULL CK SH
DAKOTA SILT
DAKOTA FM
KOOTENAI FM
MORRISON FM
SWIFT FM
RIERDON FM
PIPER FM
BOWES MBR
FIREMOON MBR
TAMPICO MBR
CHARLES FM
MISSION CANYON LS
LODGEPOLE LS
BAKKEN FM
THREE FORKS FM
POTLATCH ANHY
BIRDBEAR (NISKU) FM
JEFFERSON GP
DUPEROW FM
SOURIS RIVER FM
RED RIVER FM
WINNIPEG FM
EMERSON FM
FLATHEAD SS
PRE BELT ROCKS
WILLOW CK FM
ST MARY RIVER FM
HORSETHIEF SS
TWO MEDICINE FM
BEARPAW FM
VIRGELLE SS
TELEGRAPH CK FM
KEVIN SH MBR
FERDIG MBR
MARIAS RIVER FM
CONE
2ND WHITE SPK
(GREENHORN)
FLOWEREE MBR
VAUGHN MBR
BLACKLEAF FM
TAFT HILL MBR
FLOOD MBR
KOOTENAI FM
MT PABLO FM (CUT BANK)
MORRISON FM
SWIFT FM
RIERDON FM
SAWTOOTH FM
SUN RIVER MBR
CASTLE REEF DOL
LOWER MBR
ALLAN MOUNTAIN LS
EXSHAW (BAKKEN) FM
THREE FORKS
THREE FORKS SHALE
BIRDBEAR (NISKU) FM
JEFFERSON FM
LOWER MBR (DUPEROW)
MAYWOOD (SOURIS RIVER) FM
DEVILS GLEN DOL
SWITCHBACK S
STEAMBOAT LS
PENTAGON SH
PAGODA LS
DEARBORN LS
DAMNATION LS
GORDON SH
FLATHEAD SS
BELT SUPERGROUP
PRE BELT ROCKS
WILLOW CK FM
ST MARY RIVER FM
HORSETHIEF SS
BEARPAW FM
JUDITH RIVER FM
TWO MEDICINE FM
CLAGGET FM
EAGLE SS
VIRGELLE SS
TELEGRAPH CK FM
KEVIN SH MBR
FERDIG MBR
2ND WHITE SPK (GREENHORN)
FLOWEREE MBR
(FISH SCALE SS)
BOOTLEGGER MBR
(RED SPK)
VAUGHN
BOW ISLAND
TAFT HILL
FLOOD (DAKOTA)
BURWASH
KOOTENAI FM
(MOULTON)
(LANDER)
(CUT BANK)
(SUNBURST)
MORRISON FM
SWIFT FM
RIERDON FM
SAWTOOTH FM
SUN RIVER DOLOMITE
MISSION CANYON LS
LODGEPOLE LS
EXSHAW (BAKKEN) FM
THREE FORKS FM
THREE FORKS SHALE
POTLATCH ANHY
BIRDBEAR (NISKU) FM
DUPEROW FM
SOURIS RIVER FM
RED LION FM
PILGRIM FM
CAMBRIAN SHALE UNDIVIDED
PARK SH
MEAGHER LS
WOLSEY SH
FLATHEAD SS
PRE BELT ROCKS

Detailed geology of the Pioneer, Tendoy, and Bitteroot(Beaverhead) segments in the Overthrust Belt portion of the forest now follows.

Pioneer Range. A subcircular mountain mass, the Pioneer Mountains are almost completely surrounded by the broad alluvial valleys of the Big Hole and Beaverhead Rivers. The valleys of the north-flowing Wise River and the south-flowing Grasshopper Creek divide the Pioneer Mountains into two lobes, of which the eastern half is the higher and more rugged. The area is forested except for numerous high peaks along the north-trending crest that are above timberline and some south-facing sagebrush and grass covered slopes. Torrey and Tweedy Mountains at altitudes above 11,000 feet are the highest in the region.

The Pioneer Mountains are about 60 km across and consist mainly of strongly folded and faulted sedimentary rocks ranging in age from Precambrian to Cretaceous. The sedimentary rocks presumably overlie Archean or Proterozoic gneissic granitic rocks that crop out locally in the northeast part of the Pioneers as fault blocks. The Precambrian sedimentary rocks are dominantly quartzitic and have a general resemblance to the Belt Supergroup to the north and northwest. Phanerozoic sedimentary rocks of Cambrian through Mississippian age are dominantly carbonates, and those of Pennsylvanian through Cretaceous are mainly detrital.

They appear to be a great slab of sedimentary rock, a detachment block off the Idaho Batholith, that migrated 50 miles to the east while the granite was still partly molten. As a result of this migration, the eastern flank, which was the leading edge, consists of tightly folded sedimentary formations; the western flank, which was the trailing edge, consists of low, flat-lying and rolling hills.

The eastern Pioneer area is formed mostly of the Pioneer batholith, a composite body of Late Cretaceous to early Paleocene age that has intruded and to varying degrees metamorphosed sedimentary rocks deformed previously by folding and faulting. A few plutons are arranged radially around the batholith. Younger (Eocene and Oligocene) lava flows, more common outside the study area, remain as small erosional elements.

The Pioneer batholith is one of several plutons east of the Idaho batholith within the Cordilleran fold and thrust belt. The main part of the Pioneer batholith crops out in the eastern part of the Pioneer Mountains as a body 20 x 30 km trending north. On the west side, the main part of the batholith narrows to a corridor 5 km wide that extends west at least 15 km into the western part of the pioneer Mountains. The Pioneer batholith has been shown to be a calc-alkalic pluton the same age as (about 68-75 million years ago (mya)), and chemically similar to the Boulder batholith. Rocks of the Pioneer batholith are dominantly biotite-hornblende granodiorite and biotite granodiorite.

Tectonically, the range is on line with the Idaho-Wyoming thrust belt, and several thrusts are known within the range as well as east and west of it.

High-angle faults younger than the plutons are widespread in the Pioneers but seem to have little continuity except for the Comet fault in the Elkhorn district and the Fourth of July fault in the Wise River valley. These two faults probably connect and form a major north-south structure that crosses the entire range. The Comet fault may have helped to localize the veins of the Elkhorn mining district, and may also have had a fundamental control on the hydrothermal alteration and mineralization of Jacobson Meadows. Movement on the Comet-Fourth of July fault probably took place at several times during the Tertiary and perhaps very late in the Tertiary to account for the fact that the eastern Pioneers are several hundred meters higher than the western Pioneers.

Another significant factor in the eastern Pioneer Mountains was glaciation; many of the valleys that head against the crest of the range have been glaciated, and moraines blanket some valleys and lower slopes.

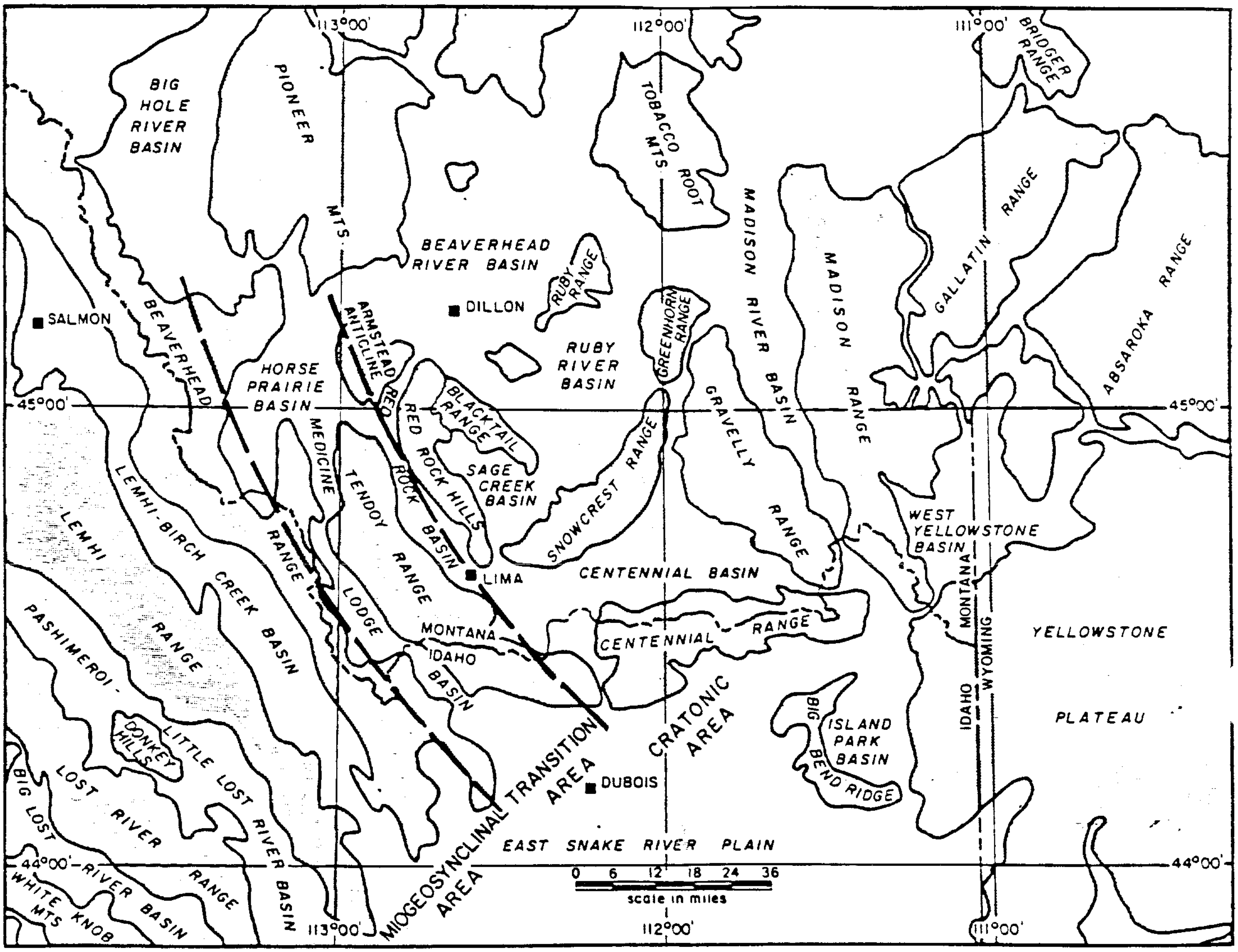


FIGURE 6: Map showing the mountain ranges referred to in the text (from Hildreth, 1981, p.50).

Tendoy Mountains-The Tendoy Range lies west of Interstate 15 between Clark Canyon Reservoir and the town of Lima. The range is primarily a collection of folded and faulted Paleozoic and Mesozoic sedimentary rocks, but also contains younger volcanic rocks and Beaverhead Conglomerates (Alt and Hyndman, 1986).

Two segments of Beaverhead National Forest are within the range; a north segment and a south segment. Both segments contain the west dipping Tendoy Thrust and Four Eyes Canyon Thrust Sheets (Long, 1990c). The Tendoy Thrust is the easternmost and youngest Sevier-style thrust in the Overthrust Belt of southwest Montana (Perry, et.al, 1989). The Four Eyes Canyon Thrust is made up almost entirely of Mississippian carbonate rocks where it is exposed at the surface.

The southeast dipping Snowcrest Thrust crosses the southern segment in the vicinity of Lima. Southeast of the Snowcrest Thrust trace, the Tendoy Thrust veers eastward along the north boundary of the forest (Long, 1990c).

Bitterroot (Beaverhead) Range. These mountains are the farthest west range in the Beaverhead National Forest. They are also known as the Beaverhead Mountains on the Idaho side of the border and on some state maps (Fig. 6). They will be referred to in this report as the Bitterroot Range. This long north-south trending range is best described in two segments: a north segment containing the mountains west of the town of Wisdom and a south segment with the mountains directly west of the Tendoys.

The far north portion of the north segment of the forest is within the Anaconda-Pintlar Wilderness. The geology of this part of the range is dominated by granitic rocks of the Cretaceous-aged Idaho Batholith. In places, the granitic magma of the batholith intruded into Precambrian rocks to form a combination of granites, gneiss, and schists (Alt and Hyndman, 1986).

The south segment of the Bitterroots consists of several thrust sheets. The two major thrusts are the Medicine Lodge Thrust and the Cabin Thrust. The Medicine Lodge thrust contains only Mississippian shales and limestones which do not exhibit thrust imbrication (Perry, et.al., 1989). The Cabin Thrust is the next thrust westward in the Bitteroots and is marked by Precambrian gneisses at the surface.

THE FORELAND PROVINCE

The mountain ranges east of the overthrust belt in southwest Montana are within the Central Rocky Mountain Foreland Province. A certain amount of thrust faulting also occurs in this province. However, unlike the Overthrust Belt where the overlying rocks have moved from west to east along low angle faults, the thrusting in the foreland province is relatively steep and associated with the fronts of the mountain uplifts.

This part of the foreland is actually characterized by three sets of "differentially uplifted and tilted basement block faults" (Schmidt, et. al., 1988); an eastward trending set of normal faults which were active during Precambrian times; a northwest trending set of Late Cretaceous/Paleocene reverse (thrust) faults; and westward dipping faults of various trends (northeast to northwest). The same source rocks, reservoir rocks, and types of traps that occur in the overthrust belt occur in this foreland province.

A generalized discussion of the geology of the three ranges (Fig. 6) within the foreland province of Beaverhead National Forest, the Gravelly/Snowcrest Range, the Tobacco Root Range, and the Madison Range, follows:

Gravelly/Snowcrest Ranges. The geology of this small area is highly complex and diverse. Over 8000 vertical feet of sediments are exposed representing every geologic period except Ordovician and Silurian. The oldest Precambrian exposure is approximately 2.8 billion years in age, while the most recent Quaternary alluvium and valley fill deposits are less than 60 million years old.

The Gravelly Range lies east of the overthrust belt. In this area over 8000 feet of Paleozoic and Mesozoic marine and nonmarine/ sediments have been deposited on the very old Archean basement rocks. Major structural trends appear to have been established in the basement rocks before the deposition of younger sediments.

Steep reverse, normal, and strike slip faults trend predominantly northwest, northeast, and north, and seem to reflect repeated movement at different times from the Precambrian to the near present. Archean crystalline rocks and younger sedimentary rocks of the craton also have been cut by a few relatively flat faults.

The Odell Creek Fault is a fairly long high angle fault of perhaps 30 miles, trending N30E from the Centennial Valley to the Madison Valley. The Odell Creek Fault has an estimated stratigraphic throw of 4500 feet and a displacement of 3000 feet. Subsequently, the valley was filled with several thousand feet of sediments, then buried under several hundred more feet of Tertiary volcanics. It is believed this buried depression once served as a drainage for a huge glacial lake in the Centennial Valley. Now it serves as the topographical structure for the Chain of Lakes.

Madison Range. This range contains a series of folded Paleozoic and Mesozoic rocks which cover a Precambrian basement of gneisses and schists over much of the range (Alt and Hyndman, 1986). The west side of the range is bounded by a series of near vertical faults, which are so typical of the ranges in the foreland province. Most of the range is within the Lee Metcalf Wilderness.

Tobacco Root Range. The Tobacco Root Mountains are a linear, north-trending range bounded on the east and west by broad intermontane valleys. The highest peak in the range is Mt. Jefferson, at 10,604 feet.

Rocks exposed in the Tobacco Root Mountains range in age from Precambrian to Quaternary. The core of the range is comprised of two major rock types; 1) Precambrian basement rocks in much of the northern, western and southern reaches of the range, and 2) dioritic to granitic batholithic rocks of Late Cretaceous age, emplaced about 70 million years ago, in much of the eastern and central part.

Sedimentary rocks, mainly Paleozoic in age, are present along the northwest and north margins of the uplift and are remnants of the extensive sedimentary section that once covered the region. These sedimentary rocks, which almost everywhere dip away from the range core, appear to have been draped over the edge of the basement block that was initially uplifted in the Late Cretaceous-early Tertiary time (Schmidt, 1975). Basin filled sediments were shed from this and adjacent uplifts along the west and north margins of the range. Block faulting that raised the range to its present height and position began in late Miocene time and continues today (Pardee, 1950).

Topographic relief is nearly 5000 feet along the west face of the range. Thick sections of Paleozoic and Mesozoic sedimentary rocks are exposed in great slabs that lie steeply tilted on the west face. Most of the surface of these slabs appears to be an old desert erosion surface developed during Pliocene time, when the region had an extremely arid climate. The range was intensely glaciated in the Pleistocene and contains many cirques, tarns, and ice-carved valleys. Alluvial fans of glacial outwash spread across the flanks of the range from the mouths of the larger canyons that head high into the range where large ice-age glaciers gouged the valleys. Glacial quaternary deposits commonly blanket the floors of most mountain valleys. The headwaters of this drainage system are a ring of north-facing cirques.