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BEDROCK GEOLOGY OF THE RIDGWAY AREA, NORTHWESTERN FLANK, SAN JUAN MOUNTAINS, COLORADO

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INTRODUCTION

The Ridgway area is located on the northwestern flank of the San Juan mountain uplift in southwestern Colorado (fig. 1). The Uncompahgre River flows through the area, and the town of Ridgway is near the center. The local stratigraphic section consists of beds from Devonian through Late Jurassic in age in the subsurface. On the surface, the Upper Jurassic Morrison Formation, the Cretaceous Dakota Formation and Upper Cretaceous Mancos Group are exposed. Several wells have been drilled in the area and a small gas field is located in the eastern part. Regional high heat flow and structure resulting from Cenozoic uplift of the San Juan Mountains to the south have induced convective circulation of local ground water, resulting in several small hot springs.

The Ridgway area borders the southwestern margin of the late Paleozoic and early Mesozoic Uncompahgre Highland, which influenced the thickness and facies of late Paleozoic strata (fig. 2). The patterns of late Paleozoic and early Mesozoic tectonics and sedimentation are described here. The Dakota and Mancos Formations, which have not been previously studied in detail in this area, also are described. Finally, the origins of the Ridgway gas field and hot springs are explained.

GENERAL STRATIGRAPHY

Sedimentary rocks of Jurassic through Cretaceous age are exposed in the area. Beds of Devonian through Jurassic age rest unconformably on Precambrian granites and gneisses in the subsurface. A stratigraphic column for the area is shown in Figure 3. The Elbert and Ouray Formations (Upper Devonian) consist of shales, sandstones, and limestones. The lower Mississippian Leadville Limestone rests unconformably on the Devonian strata. The Molas and Hermosa Formations (Pennsylvanian) and the Cutler Formation (Permian) are predominantly conglomerates, sandstones, shales, and limestones. These formations were deposited on the flank of the Pennsylvanian Uncompahgre uplift. The Upper Triassic Dolores Formation, consisting of red sandstones and shales, rests unconformably on the Cutler Formation. The Dolores Formation is overlain by the Entrada Formation, an Upper Jurassic sandstone.

The Morrison Formation, Late Jurassic in age, is exposed on the surface and consists of alternating layers of shale, siltstone, sandstone, and limestone. The overlying Dakota Formation and Mancos Group (Cretaceous) are described more fully in the section on Cretaceous stratigraphy.

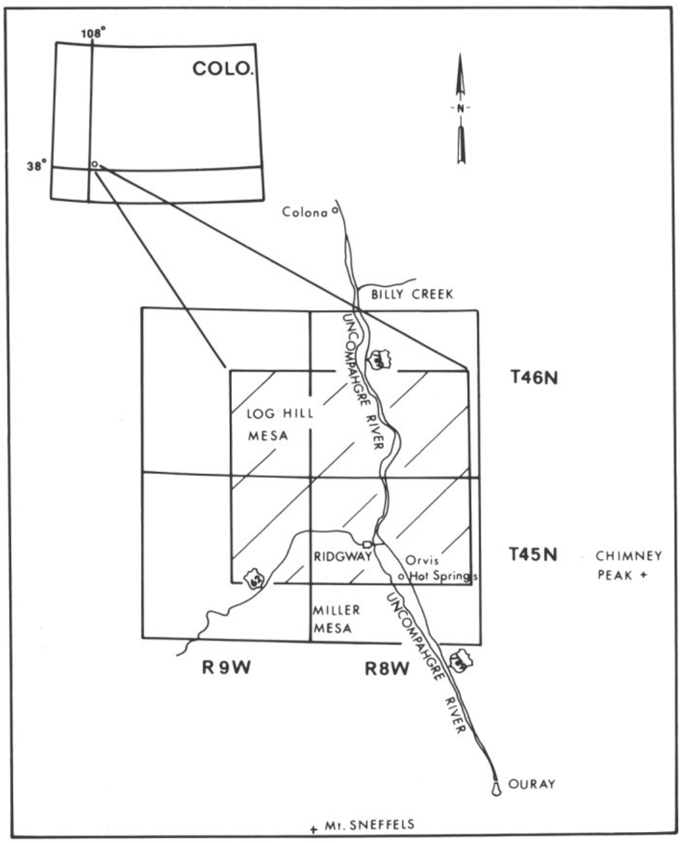

Figure 1. Location of study area.

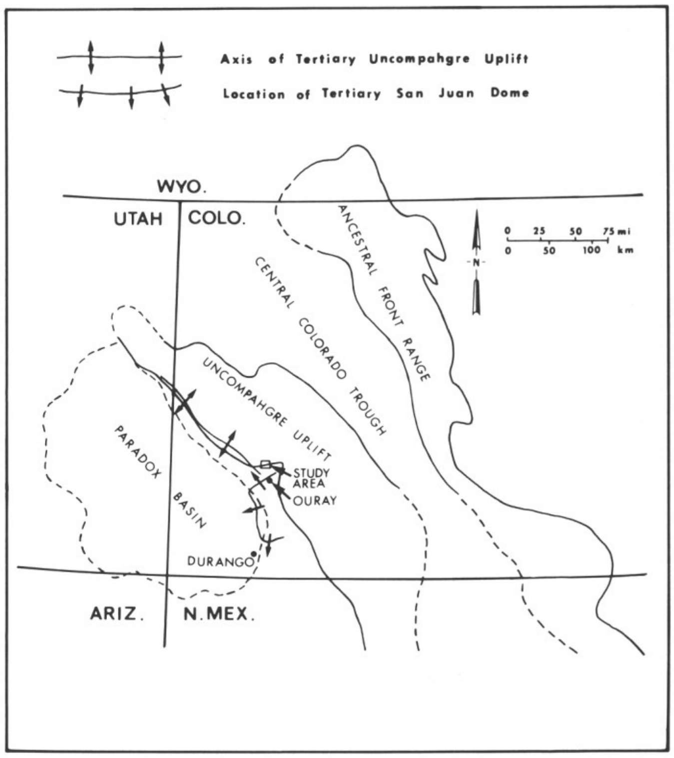

Figure 2. Location of study area relative to Pennsylvanian structural elements, and to the Tertiary Uncompahgre uplift and San Juan dome (after Mallory, 1960; Kelley, 1955).

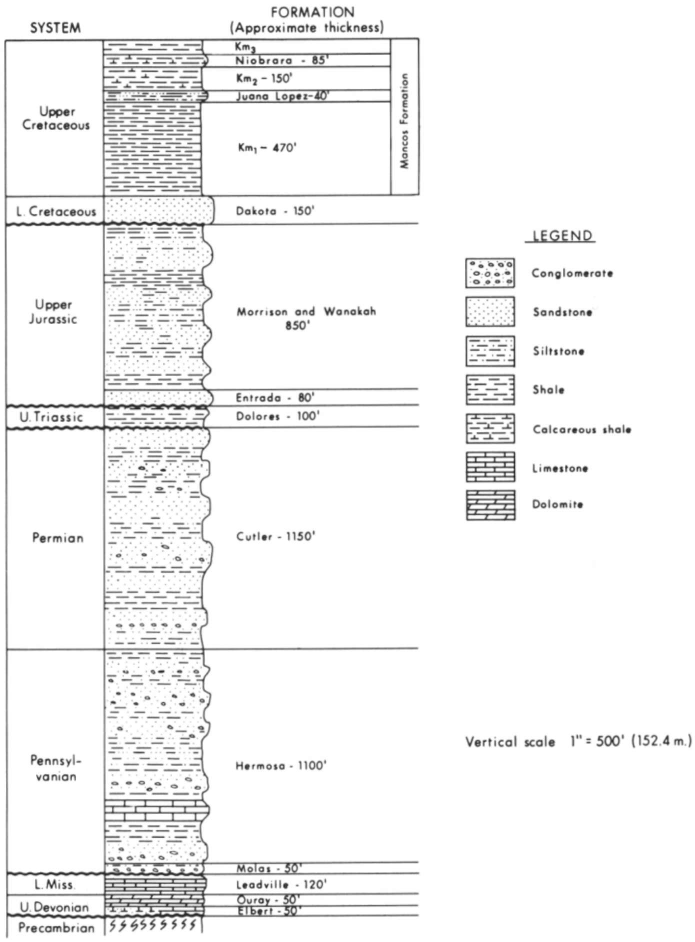

Figure 3. Generalized stratigraphic section of Ridgway area. Thicknesses obtained from Whitlock Swanson 1A well and surface measurements.

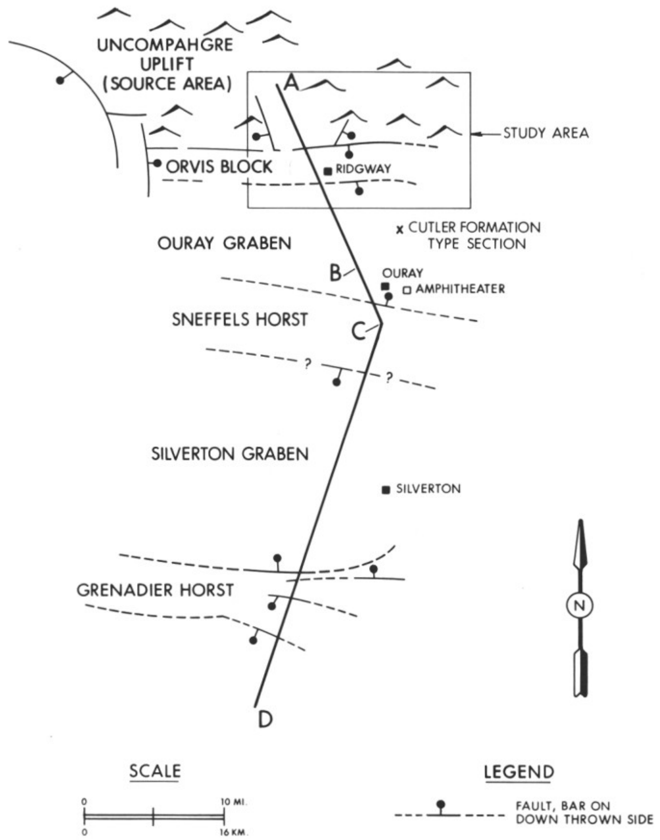

Figure 4. Map showing Paleozoic paleotectonic elements on west and northwest flank of San Juan dome in relation to the study area (after Weimer, 1980). A-B-C-D is line of section shown in Figure 6.

STRUCTURAL GEOLOGY

North-dipping Mesozoic strata on the northwestern flank of the San Juan dome are interrupted by west-striking faults and folds in the Ridgway area. The Laramide structures observed on the surface are related to three basement fault blocks—the Ouray graben, Orvis terrace, and Uncompahgre horst (fig. 4). Recurrent movement on these fault blocks has occurred throughout the Phanerozoic.

The most prominent structural feature in the area is the Ridgway fault, which strikes west across the northern part of the area (fig. 5). The Ridgway fault separates the Uncompahgre fault block from the Orvis fault block. At Loghill Mesa, where the stratigraphic separation on the fault is 350 m, the Morrison and Dakota Formations are exposed on the northern, upthrown side. The dip of the Uncompahgre block is a fairly uniform 3-4° to the north. The Morrison Formation, where in fault contact with the Benton Formation below Loghill Mesa, dips steeply to the south. This zone of high dip in the Morrison is mapped as "fault zone" in Figure 5 and is the result of the strata forming a drape fold over basement faults (see section on structural interpretations below). The fault trace immediately south of Loghill Mesa is covered by colluvium and is considered to lie at the most southerly outcrop of the Morrison Formation. The throw on the Ridgway fault decreases toward the east, and the fault dies out in Sec. 1 of T.45N., R.8W. Figure 9 shows throw on the fault is 46 m at this locality.

Two faults striking north-northwest across Loghill Mesa offset the Dakota Formation in the northwestern part of the area (fig. 5). Between the two faults is a monocline in the Dakota. These faults are believed to be Paleozoic faults reactivated during the Laramide orogeny.

Two northeast-trending fault blocks in the Uncompahgre River Valley north of the Ridgway fault have acted independently from movement on the Ridgway fault. Topographic expression of these faults is best seen in the displacement of the Dakota Formation in Sec. 27, T.46W., R. 8W. The outcrop patterns indicate that the fault blocks acted in a stair-step manner (fig. 5). However, the Dakota outcrop located in the south in Sec. 3, T.45N., R.8W. is in a graben. This indicates the eastern fault block has had a scissor-like movement. The northern extent of these faults is not known due to Quaternary cover.

Two other fault blocks are associated with the northeast-trending blocks. One fault in Sec. 34, T.46N., R.8W. strikes due north and joins a northwest-striking fault. To the south, the fault dies out in Sec. 3, T.45N., R.8W. The fault joins the northeast-striking fault at a place where the relative displacement changes on the northeast-striking fault.

A small, west-trending graben joins the north-striking fault in Sec. 34, T.46N., R.8W. The only surficial evidence of this block is where the Niobrara Formation is faulted against the Benton Shale. The eastern extent of this block is not known and is arbitrarily interpreted because of poor exposure.

An anticline formed north of the Ridgway fault, apparently in association with the uplift of the Uncompahgre fault block. The anti-

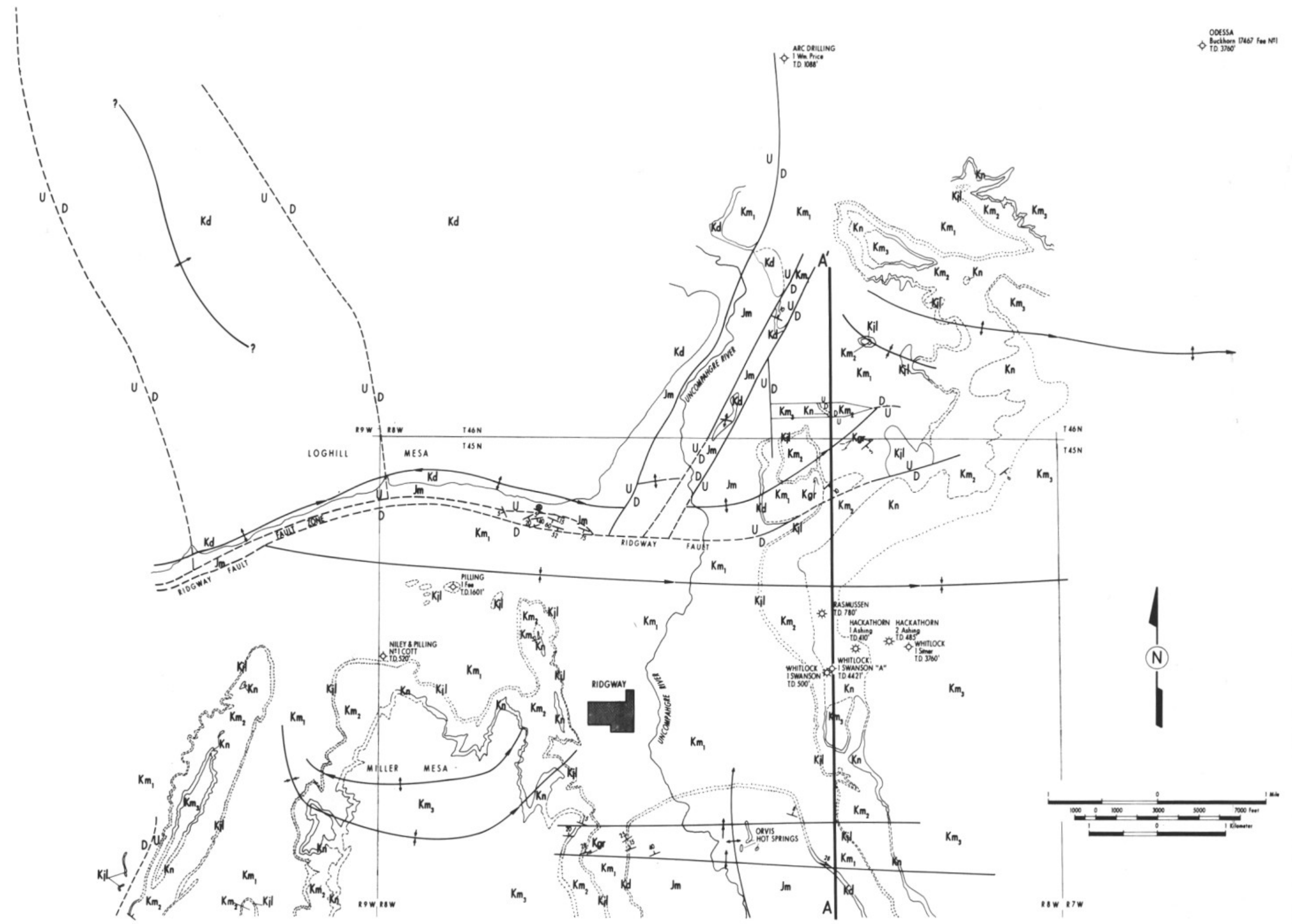

Figure 5. Bedrock map of the Ridgway area. Formation symbols are: Jm=Morrison; Kd=Dakota; Km_1=Mancos 1; Kjl=Juana Lopez; Km_2= Mancos 2; Kn=Niobrara; Km_3=Mancos 3. Sections along A-A' shown in Figures 8 and 9.

clinal axis trends east-west across Loghill Mesa and is apparently displaced by the rotation of the fault blocks along the Uncompahgre River. The trend of the axis in the eastern part of the area is the same as on Loghill Mesa, indicating the eastern and western parts of the Uncompahgre fault block remained horizontally stable with respect to one another during uplift.

In the northeastern part of the area, a small syncline and a larger anticline trend west. These structures are seen in outcrops of the Niobrara and Juana Lopez members of the Mancos Formation. In the southern part of the study area there is a north-trending anticlinal axis (fig. 5), which is a continuation of a feature mapped by Luedke and Burbank (1962) in the Ouray quadrangle. Of greater importance is the monocline in the same area. At the southern edge of Figure 5, the Morrison through Niobrara Formations have low north dip on both sides of the Uncompahgre River. The beds dip steeply for 1 km northward, then flatten to gentle dip (3-4°). This monocline corresponds with the location of Orvis hot springs and is interpreted to have formed in response to basement faulting at depth (see structural interpretations below). The monocline dies out to the west in Sec. 20, T.45N., R.8W.

On Miller Mesa, the Km, and Niobrara members of the Mancos are deformed into an anticline and syncline. Mapping indicates the anticline has structural closure (fig. 5). Both the anticline and syncline have an arcuate trend.

A syncline lies south of the Ridgway Fault and parallel to it. The best surface expression of the syncline is north of the Ridgway gas field where the Niobrara forms a southward dip slope in Sec. 2 of T.45N., R.8W. and is dipping northerly at the southeastern corner of Sec. 10, T.45N., R.8W. (fig. 5).

PALEOTECTONIC AND STRUCTURAL INTERPRETATIONS

In the Ridgway area, most of the deformation apparently is related to basement tectonics, mainly by drape folding of strata (force folding) over basement fault blocks. The study area is important for evaluating Paleozoic tectonics of the San Juan Mountains. Although no Paleozoic strata are exposed in the area, thickness variations are known from subsurface data. Where exposed in the San Juan Mountains, the Paleozoic beds have been described in detail. To assist accurate structural interpretations, Paleozoic outcrop data are reviewed here.

Drape Folding and Basement Faulting

The concept of drape folding of sedimentary beds over basement-controlled fault blocks has been discussed in detail in the past sixteen years (Prucha and others, 1965, Stearns, 1971, 1975, 1978, Mathews, 1978, Mathews and Work, 1978), primarily to explain Laramide and post-Laramide structural features in the Wyoming province (Prucha and others, 1965). In drape folding, the structural basement reacts to stresses by faulting and rigid-body rotation (brittle deformation). The overlying sedimentary layers are then deformed primarily by forced folding (ductile deformation). The final geometry of the fold is controlled by various factors, including the degree of welding of the strata to the basement and the physical nature of the sedimentary sequence.

Stearns (1978) presented three general classes of sedimentary sections that deform differently in response to basement block movement: 1) a non-welded sedimentary section containing a stiff or non-thinning stratigraphic unit; 2) a welded, stiff, non- thinning controlling member; and 3) a section which is welded to the forcing member but is ductile and capable of thinning during the folding process. The Middle Paleozoic section in the Ridgway area is best classified as a welded, stiff, non-thinning stratigraphic section, whereas the younger upper Hermosa and Cutler formations contain enough ductile shales so that they are susceptible to thinning during deformation.

Regional Paleozoic Tectonics

The Paleozoic sedimentary rocks presently exposed in the San Juan Mountains were deposited in the Paradox basin. Mallory (1960) described two major Pennsylvanian highland areas in Colorado, the Uncompahgre highland and Front Range highland, both of which trended generally northwest (fig. 2). Baars (1965, 1966), Baars and See (1968), Spoelhof (1974, 1976), and Weimer (1980) described three major Paleozoic positive elements in the San Juan Mountains region (figs. 4, 6), the Grenadier horst, Sneffels horst, and Uncompahgre horst; and two intervening grabens, the Silverton graben and the Ouray graben. Recurrent relative movement of these fault blocks occurred throughout the Paleozoic, affecting both sediment thicknesses and facies distribution. Strata of Cambrian through Mississippian age are about 100 m thick in the Silverton and Ouray grabens, and thin to 30 m over the Sneffels and Grenadier horsts.

Spoelhof (1974, 1976) described in detail several episodes of Paleozoic movement of fault blocks bounding the Grenadier horst (figs. 4, 6): post-Late Cambrian—pre-Late Devonian, Late Devonian and Early Missippian, Late Mississippian, and throughout the Pennsylvanian.

Recurrent movement along the Sneffels horst also has been documented. The Cutler Formation at its type section (Sec. 12, T.44N., R.8W.) is 610 m thick (fig. 4) (Cross and others, 1905). The Cutler Formation thins to the south, and in one area near the Amphitheater east of Ouray (fig. 4), the Dolores Formation (Upper Triassic) rests on the Hermosa Formation (Luedke and Burbank, 1962). The entire Cutler section has been beveled across the top of the Sneffels horst. Lee and others (1976; see also Supplemental Log 2, this guidebook) described the angular unconformity existing between the dipping beds of the Cutler Formation and the overlying Dolores Formation (fig. 4 in their article). The steep dip of the Cutler Formation is due to drape folding over recurrently moving basement faults bordering the Sneffels horst. The regional thinning southward of the Cutler Formation and the angular relationship between the Cutler and Dolores formations suggest that movement of the Sneffels horst occurred in post-Cutler and pre-Dolores time (Late Permian or Early Triassic). This time period previously was considered to be one of tectonic quiescence.

The Ridgway area lies at the edge of the Uncompahgre highland. Data from wells #1 and #2 (fig. 7; Table 1) indicate that about 9.1 m of Dolores Formation rests on Precambrian basement. Data from well #8 indicate the Elbert Formation overlies the Precambrian. About 760 m of Paleozoic strata present in well #8 are absent in wells #1 and #2. Mallory (1960) projected the edge of the ancient Uncompahgre Uplift along the Ridgway fault. This writer agrees with his interpretation. However, data from well #4 indicate that a minimum of 61 m of Permo-Pennsylvanian strata occur below the Dolores Formation on Loghill Mesa. This change in thickness in strata is probably fault bounded and would correspond with the western-most fault striking northwest across Loghi I I Mesa. This evidence suggests that the boundary trend of the Uncompahgre highland changes in the Ridgway area (fig. 4) from west to northwest.

A restored Paleozoic cross section was constructed in the Ridgway area (fig. 8). To the north of the Ridgway fault, 10 m of Dolores Formation rests on the basement. The Dolores Formation is 33.5 m thick in wells #5, #6, #8, #11, and #12, suggesting that the ancient Uncompahgre uplift remained a positive element in the Ridgway area until late in the time of deposition of the Dolores Formation. The Orvis fault block is bounded on the north by the Ridgway fault and on the south by the Orvis fault. The Orvis fault is

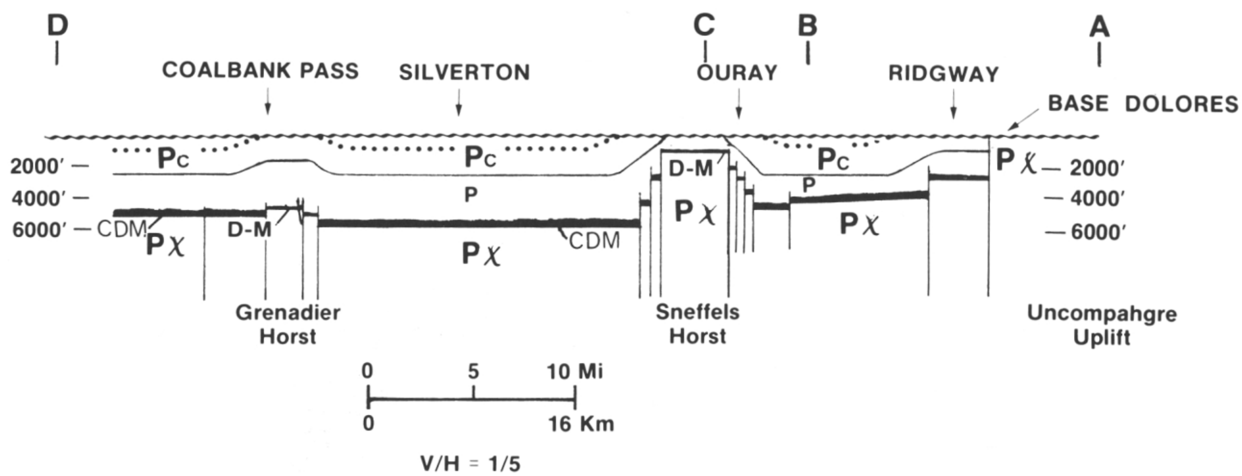

Figure 6. Regional north-south section restored to base of Dolores Formation showing thinning of Paleozoic section and erosion of the Cutler Formation across top of paleotectonic elements. Formation symbols are: Px=Precambrian; CDM=Ignacio, Elbert, Ouray, and Leadville; D-M=Elbert, Ouray and Leadville; P=Molas and Hermosa; Pc=Cutler. Line of dots in Pc is phantom horizon to show truncation at base of Dolores (after Weimer, 1980). See Figure 4 for location of line of section.

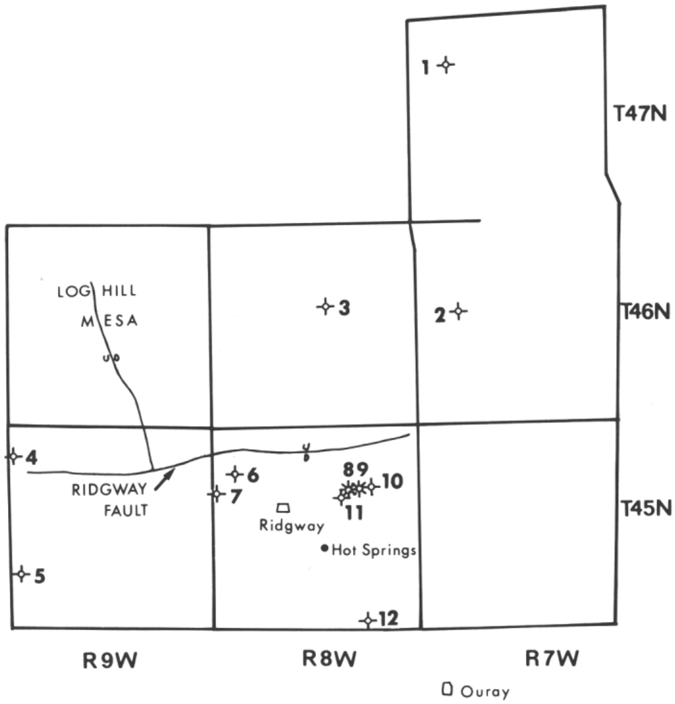

Figure 7. Location map of wells drilled in the Ridgway area. Well information in Table 1.

not visible at the surface; however, field observations and well data suggest its existence. The Paleozoic strata in the Ouray graben are about 365 m thicker than in the Orvis block. Most of this thickness increase is within the Cutler Formation. By analogy, increases in stratigraphic thickness in the Upper Paleozoic sediments in the San Juan Mountains are fault bounded.

On the surface, a zone of steep dip occurs in the Dakota and Morrison Formations in the southern part of the study area (figs. 5, 9). This writer has interpreted this feature as drape folding of strata over a Laramide basement fault.

The thickness of strata in the Ouray graben is taken from surface measurements (Luedke and Burbank, 1962) and from subsurface

Table 1. Wells in the Ridgway area.

Well No.	Name	Thickness of Permo-Pennsylvanian (Hermosa and Cutler Fms).	Thickness of pre-Pennsylvanian Strata
1	Odessa Buckhorn 8477 Fee 1 SW NW Sec. 8, T. 47N, R. 7W. T. D. 4895 ft (1492 m) Precambrian	0	0
2	Odessa Federal 1746-7 Fee 1 NE SW Sec. 17, T. 46N., R. 7W. T. D. 3760 ft (1146 m) Precambrian	0	0
3	Arc Drilling 1 William Price C., Sec. 15, T. 46N., R. 8 W. T. D. 1088 ft (332 m) Wanakah	0 (est.)	0
4	Cheyenne Oil Ventures Hall Bros. 1 SW SW Sec. 6, T. 45N., R. 9W. T. D. 2506 ft (763 m) Penn.-Perm. (probably Cutler)	200 ft	?
5	Davis McClure 1 SE NW Sec. 30, T. 45N., R. 9W. T. D. 5539 ft (1688 m) Miss. or Dev.	3870 ft (1180)	324 ft (99 m)
6	Pilling Fee 1 C SW NE, Sec. 7, T. 45N., R. 8W. T. D. 1601 ft (488 m) Cutler	2400 ft (est.) (732 m)	220 ft (est.) (67 m)
7	Niley and Pilling 1 Cott SW SW Sec. 7, T. 45N., R. 8W. T. D. 520 ft (158 m) Benton	2400 ft (est.) (732 m)	220 ft (est.) (67 m)
8	Whitlock Swanson 1-A NE NE Sec. 15, T. 45N., R. 8W. T. D. 4421 ft (1348) Dev.	2400 ft (732 m)	220 ft (est.) (67 m)
9	Hackathorn Drilling 1 Ashing Ranch NE SE SW Sec. 11, T. 45N., R. 8W. T. D. 410 ft (148 m) Benton	2400 ft (est.) (732 m)	220 ft (est.) (67 m)
10	Hackathorn Drilling 2 Ashing Ranch NE SE SW Sec. 11, T. 45N., R. 8W. T. D. 485 ft (148 m) Benton	2400 ft (est.) (732 m)	220 ft (67 m)
11	Whitlock 1 Sittner C SW SE, Sec. 11, T. 45N., R. 8W T. D. 3760 ft (1146 m)	2400 ft (est.) (732 m)	220 ft (67 m)
12	Intex Halls 1 SE SW Sec. 35, T. 45N., R. 8W. T. D. 2413 ft (736 m) Tertiary Intrusive in Hermosa (Penn.)	3500 ft. (est.) (1016 m)(surface exposure plus well data)	---

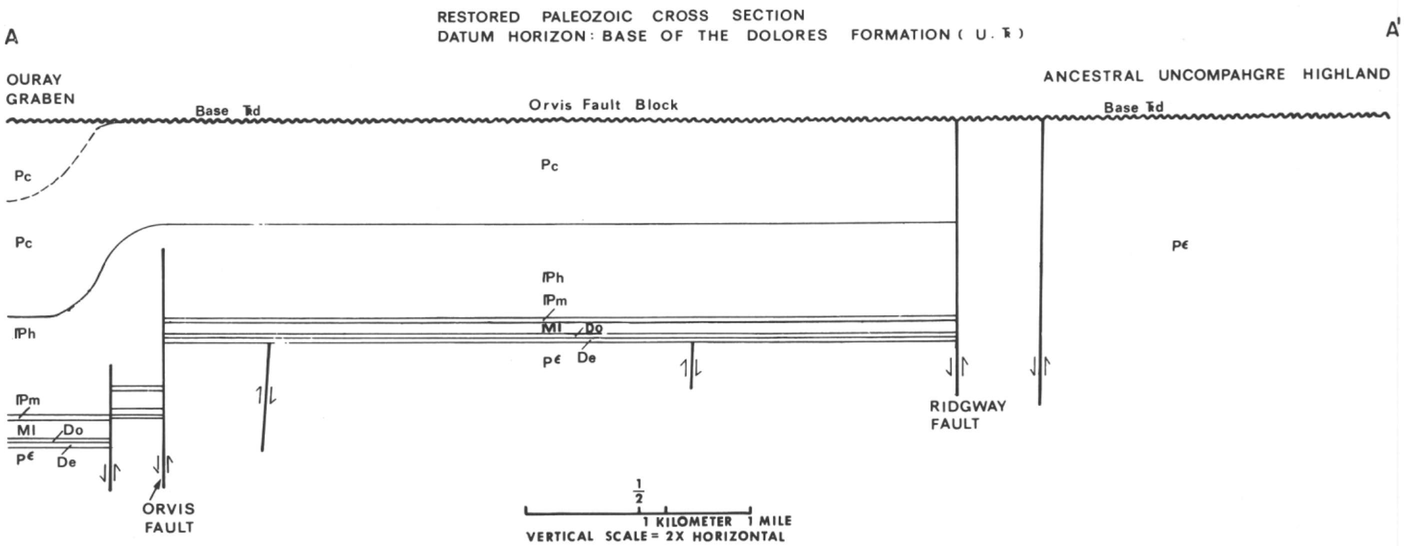

Figure 8. Local north-south section (A-A', fig. 5) restored to base of Dolores Formation (Ꞧ d) showing thinning of Cutler Formation across the Orvis fault. Formation symbols are: P€=Precambrian; De=Elbert; Do=Ouray; Ml=Leadville; ℙm=Molas; ℙh=Hermosa; Pc=Cutler. Dashed line in Pc is phantom horizon to show truncation at base of Dolores.

data (wells #5 and #12). The thicknesses of strata on the Orvis block is from well #8. The thicknesses of the Elbert, Ouray, Leadville, Molas, and Hermosa all increase slightly in the Ouray graben. This evidence suggests the fault blocks were active at the time of deposition of Middle Paleozoic sediments. The Cutler Formation is 320 m thicker in the Ouray graben than in the Ridgway block. This disparity is due to at least two factors. Significant movement on the faults north and south of the Orvis block may have occurred during Cutler deposition and controlled the thickness variations. In addition, significant movement of the Orvis block may have occurred in post-Cutler, pre-Dolores time (similar to that of the Sneffels horst), causing beveling of the Cutler Formation on the Orvis block. Both of these factors probably affected Cutler thickness, although recurrent movement of the Orvis block after Cutler deposition probably caused most of the thickness variation.

The major faults in the restored Paleozoic cross section have all been drawn as vertical. Several authors (Barker, 1969; Spoelhof, 1974, 1976; Weimer, 1980) have demonstrated that most major Precambrian fault zones in this region are vertical. Where the faults are exposed south of the study area (near Ouray and the Grenadier horst), the fault planes are vertical (Spoelhof, 1974, 1976). Non-vertical faults in the cross section are minor, and their existence is inferred from present topography.

The total displacement on the Orvis fault during the Paleozoic is 245 m. Strata of Devonian through Early Pennsylvanian age probably acted as a welded, non-thinning section. Under vertical stresses, these strata deformed in a brittle manner and faulted with the basement. The upper Hermosa and Cutler Formations deformed as a welded, thinning section and responded to block movement by drape folding. A similar response is seen in the "paleodrape" of Hermosa and Cutler Formations in the Ouray Valley (Lee and others, 1976, Fig. 4). The total fault block displacement is great enough that an intermediate fault block is interpreted to exist 400 m south of the Orvis fault. Analogous intermediate fault blocks exist on the north side of the Sneffels horst and Grenadier horst (fig. 6) (Spoelhof, 1974, 1976; Weimer, 1980).

Structural Interpretation

The zone of steeply dipping Dakota and Morrison beds in the southern part of the area (fig. 9) apparently formed in response to Laramide movement on basement faults. This monoclinal feature is interpreted as a drape folding of strata over the upward moving Ouray graben fault block. The movement on the bounding faults is opposite to the direction of the Late Paleozoic movement. Similar reversals in movement on fault blocks in the San Juan region have been noted by Spoelhof (1974, 1976) and Weimer (1980). Thus, in Figure 9, two generations of drape folding are predicted—Permo-Triassic and Laramide. The relative directions of the two forced folds would be in opposite directions, reflecting the reversal in movements on the fault blocks.

Two other faults are inferred to exist on the Orvis fault block. One fault is placed where the steeply monoclinal dipping strata change to gentle dip. Associated with this fault, a rotated block is inferred just north of the Orvis fault. This tilted fault block is then responsible for the dip of the surficial strata. The basement is interpreted to be rotated largely in keeping with Stearns' models (1978). The change in dip on the monocline does not fit well into any one of Stearns' three general classes of sedimentary section. The entire sedimentary section probably reacted partly as in his welded-thinning and partly as in his welded-non-thinning model. When a welded non-thinning section (such as the mid-Paleozoic strata) is folded over basement blocks, minor draping in fact occurs over the subsidiary fault blocks. The overlying strata would react as a welded, ductile section. Hence, the change in dip of the strata would be compensated for by the ductile response of the strata. However, if the fault block beneath the monocline was not rotated, drape folds would occur at the edges of the block. The fault block is interpreted as tilted with minor offset of the lower sedimentary section occurring along the fault.

The strata have a uniform northerly dip across the Orvis fault block until reaching the syncline 1.6 km south of the Ridgway fault (figs. 5, 9). The basement is also believed to follow this regional dip. The syncline could be caused by Laramide movement on the Ridgway fault.

A problem arises, however, in explaining the gross thickening of the sedimentary section near the Ridgway fault (fig. 9). Enough ductile material exists in the middle to upper part of the sedimentary section to accommodate in part this spatial problem. A fault proposed at the basement level is believed to be partially responsible for the syncline, and a rotation of the basement would compensate for the spatial problem. On the Uncompahgre block the regional attitude is displayed by the uniformly northerly dipping Dakota beds. In Sec. 3 of T.45N., R.8W., the Dakota and Juana Lopez Formations dip steeply to the south just north of the Ridg-

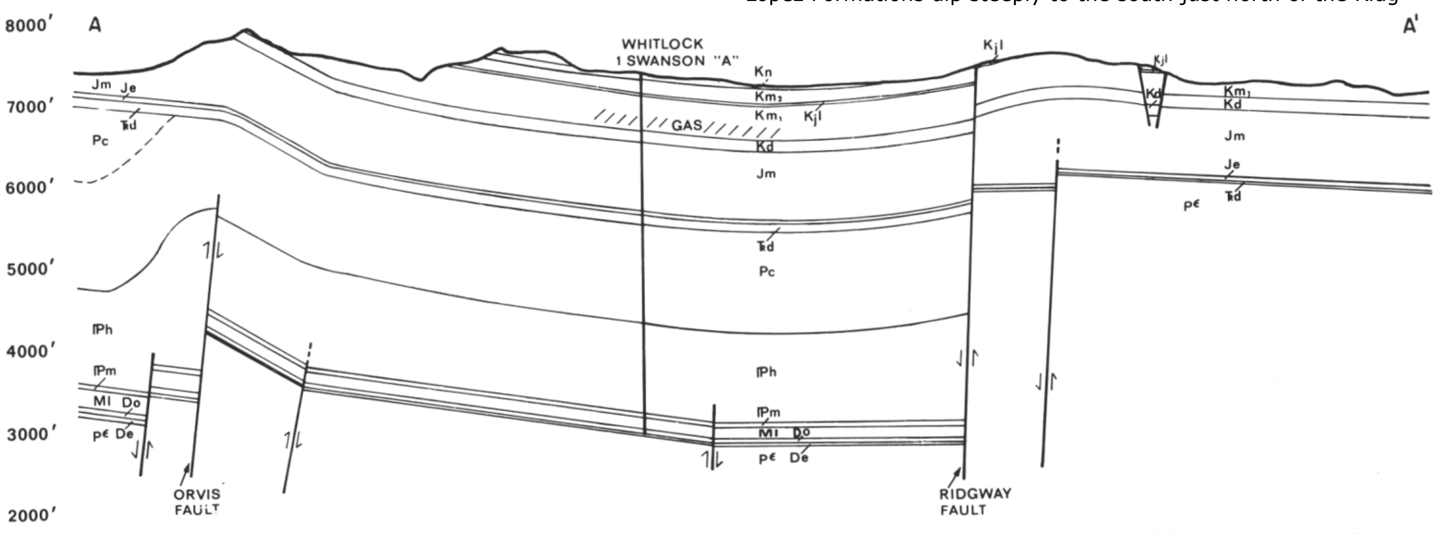

Figure 9. Local north-south section (A-A', fig. 5) showing northerly dipping monocline, Orvis fault, Ridgway gas field, and Ridgway fault. Symbols same as Figures 5 and 8.

way fault. The abrupt change in dip of these strata is interpreted as a drape fold over a basement fault. Hence, a fault has been inferred, north of the Ridgway fault, along the line of dip inflection. Displacement across this flexure is about 107 m. The shales in the Morrison Formation probably acted in a ductile manner and flowed into the area above the downthrown block.

The northernmost structural feature in Figure 9 is a small fault block within the Uncompahgre block. The surficial expression of this small block is in the Niobrara and Benton Formations. This fault block trends west and is attached to the north-trending fault (fig. 5).

The small fault block is interpreted to have formed by extensional faulting in relation to the drape fold 1.6 km to the south. The bounding faults probably die out in Morrison shales. Clement (1977) states that the apparent lengthening of a sedimentary section over a basement fault can be compensated for by normal extensional faulting close to or within the drape region. This normal fault would require a detachment of the sedimentary cover over the basement.

CRETACEOUS STRATIGRAPHY

The Dakota Formation crops out throughout the Ridgway area as a resistent ledge-forming unit. It varies in thickness from 38 to 54 m. Figure 10 is a reference section. The Dakota can be divided into four units based on lithology and depositional environment. The basal unit (unit 1) consists of sandstones and conglomeratic sandstones, poorly to moderately sorted, trough cross-stratified, commonly graded and fining upward. The overlying unit (unit 2) consists of interbedded sandstones, siltstones, shales and coals. The sandstones are medium grained. All lithologies contain abundant coalified plant fragments. The siltstones are flaser bedded and commonly bioturbated. The next overlying unit (unit 3) consists of interbedded sandstones and shales. The sandstones are fine to medium grained, trough cross-stratified, and extensively burrowed. Both lithologies contain carbonaceous material. The uppermost unit (unit 4) consists of interbedded sandstones and shales. The sandstones are cross-stratified to ripple bedded and contain carbonaceous imprints.

The Dakota Formation was deposited in the meander-channel and delta-plain parts of a fluvial system in the latter part of the Early Cretaceous. Unit 1 probably was deposited in a point-bar setting in a meander-channel. Units 2 and 3 were deposited in a delta-plain setting. The deposits resemble those of distributary channels, marshes, splays, lakes, fresh water bays, tidal channels and flats (LeBlanc, 1972). Unit 4 was deposited in a shoreline setting.

Armstrong (1968) identified the source of the clastic material for the Dakota Formation as the Sevier orogenic belt in central Utah. From this area rivers flowed eastward to the Mowry Sea in Colorado and Wyoming. The vertical changes in depositional setting reflect an overall basin deepening or transgression of the Mowry Sea.

Detailed mapping and stratigraphic studies indicate that, based upon two units of distinctive lithology, the Mancos Formation can be subdivided into five units. From oldest to youngest, they are the Km„ Juana Lopez member, Km„ Niobrara, and Km, (figs. 3, 5). The Juana Lopez and Niobrara members have similar lithologic and paleontologic content to their equivalents in the San Juan and Denver basins, respectively.

The Km, (time equivalent to the Benton Formation) consists of 143 m of black shale that includes the Greenhorn Limestone beds (3.8 m thick) 91.4 m above the base. The guide fossil Pycnodonte *newberryi* and several species of foraminifera were collected from the Greenhorn. The Km, is Cenomanian through middle Turonian

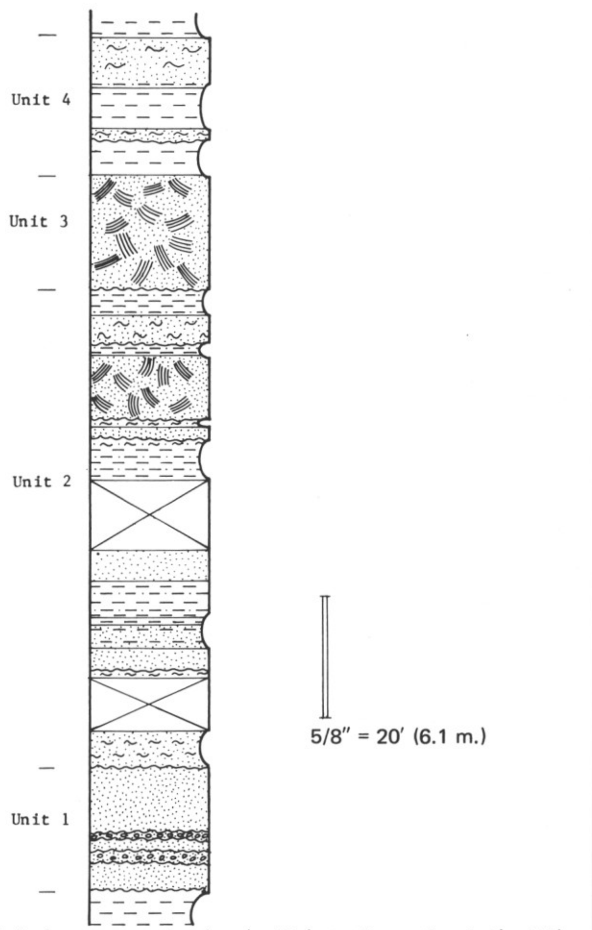

Figure 10. Reference section for the Dakota Formation in the Ridgway area. Symbols as in Figure 3.

in age. The overlying Juana Lopez is 12.2 m thick and consists of alternating layers of calcareous siltstone and black shale. The ammonites *Scaphites warreni*, *Prioncyclus Wyomingenesis*, and *P. macombi*, and the bivalve *Lopha lugubris* were found in the Juana Lopez. It is late Turonian in age and equivalent to the middle and lower part of the upper parts of the Juana Lopez in the San Juan Basin. The succeeding Km_2 is a 47-m thick, calcareous shale unit containing small, ellipsoidal (1 mm) white specks which increase in abundance upward. Km_2 is late Turonian through early Santonian in age and equivalent to the upper Carlile, Fort Hays Limestone, and Lower Smoky Hill Member of the Niobrara of the Great Plains. The Niobrara Formation is 25.9 m thick, consisting of gray, calcareous shales interbedded with white-speckled, gray, calcareous shale. Hattin (1975) described the occurrence of the white specks in carbonate deposits of the Upper Cretaceous in the western interior and found them to be coccoliths and coccolith debris. The bivalve *Inoceramus platinus* encrusted by the oyster *Pseudoperma congesta* is found throughout the Niobrara. The Niobrara is middle to late Santonian in age. Km, is a calcareous shale which weathers yellow. The main body of the Mancos Shale (Km,) is above the Niobrara, although only 60 m is present in the Ridgway area. No section was measured of this unit.

RIDGWAY GAS FIELD

The Ridgway gas field is located 1.6 km east of the town of Ridgway (fig. *7).* Production is limited to two wells, the #1 and #2 Ashing Ranch, which were originally completed for 2800 and 5600 m' per day of gas, respectively. The producing interval is from fractures in the Km, member of the Mancos. Several other wells drilled in the area were dry (Table 1). Gas shows have been noted in several water wells in the area: Rasmussen (Sec. 10. T.45N, R.8W.), Bauer (NW'/4 Sec. 11, T.45N., R.8W.), and Dude Ranch (SW'/4 NE Sec. 14, T.45N., R.8W.). Figure 9 indicates the producing reservoir lies between the monocline to the south and the synclinal axis paralleling the Ridgway fault to the north.

Mallory (1977) describes occurrences of oil and gas in fractured shale reservoirs in Colorado and New Mexico, listing six types of structural expression associated with fractured reservoirs: 1) sharply arched anticline; 2) plunging anticlinal nose; 3) fault control in a major anticline; 4) simple homoclinal dip; 5) change of strike on a monoclinal flexure; and 6) abrupt dip change in a monocline. The last feature best describes the structural setting of the Ridgway gas field.

The Florence-Canon City oil field in Fremont County, Colorado, has a structure similar to the Ridgway gas field. At Florence, about 14 million barrels of oil have been produced from fractured lower Pierre Shale. Oil accumulation occurs in a north-trending syncline with a sharp monoclinal flexure on its east flank (Weimer, 1980). The 4.8 km-wide belt of fractured Pierre shale in which oil has accumulated lies on the gently dipping east flank of the syncline bordering the monoclinal trend on the west. The monocline overlies a basement fault and fracturing is responsible for the reservoir permeability and is related to the faulting and monoclinal bending of the rocks.

The immediate area around Ridgway appears unattractive for further petroleum exploration because suitable structural and stratigraphic configurations are absent. There may be better possibilities in the Cretaceous and older formations to the east of the map area, but a cover of Tertiary volcanic rocks renders exploration difficult.

GEOTHERMAL FEATURES

Geothermal occurrences have been known for a long time in the Uncompahgre River Valley. The word Uncompahgre, a Ute word meaning hot (unca)—water (pah)—spring (gre), is named for the hot springs near Ouray (Borneman and Lampert, 1978). In the Ridgway area, the only surficial occurrences of hot springs are on the Orvis Ranch (Sec. 22, T.45N., R.8W.). The temperature of the water is 52°C. Hot water also is encountered in many of the wells drilled in the area. The Pilling 1 Fee (TD=488 m is now a flowing artesian hot water well. The Whitlock 1 Swanson A (TD=1348 m) is used as a water well by Fred Bussey. The Bauer well (NW/4 Sec. 11, T.45N, R. 8W) has 33°C water.

The hydrology of Orvis Hot Springs has never been fully explained. Reiter and others (1975) studied the variation in heat flow across southern Colorado and concluded that the heat flow value is greater than 100 mw/m^2 in the Ridgway area. Barret and Pearl (1978) studied geothermometer parameters and concluded that the best estimate of the water's subsurface temperature is from 60° to 90°C.

The Orvis hot spring is located close to the monoclinal feature, which suggests fracturing of the rocks in the drape fold probably has created a conduit to permit upward passage of deep ground water.

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