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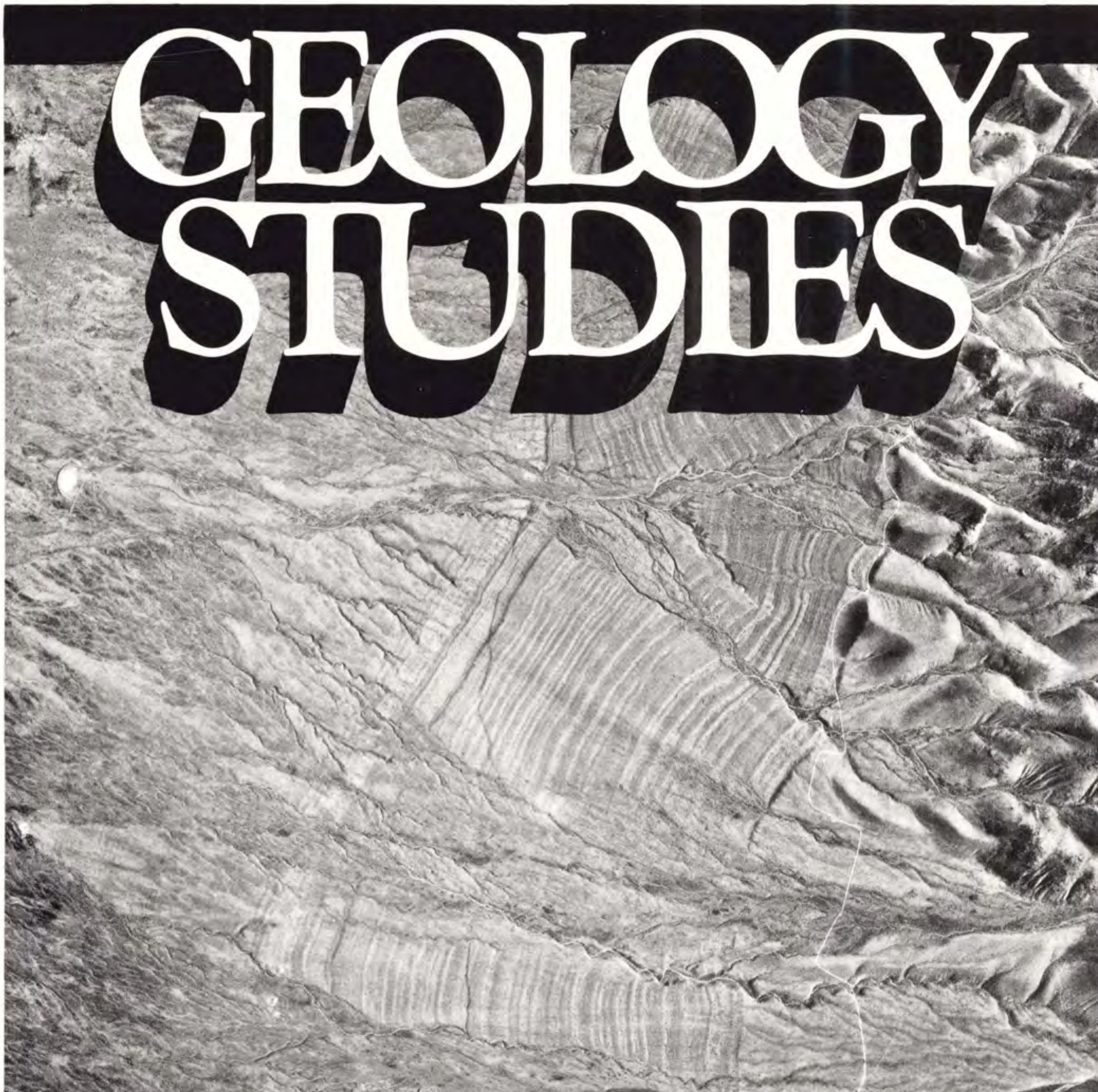
GEOLOGY STUDIES



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THE GLORY OF GOD IS INTELLIGENCE

Cover: Air photo of House Range fault scarp. Courtesy of Lee Piekarski.

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Geology of the Elk Valley Quadrangle, Bear Lake and Caribou Counties, Idaho, and Lincoln County, Wyoming*

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ABSTRACT –The Elk Valley Quadrangle straddles the Idaho-Wyoming border in the Overthrust Belt Formations exposed range from Pennsylvanian (?) to Recent and occur in two thrust plates, located northwest and southeast of the Meade Thrust Fault, the major structural feature of the quadrangle The upper or Meade Plate consists of Upper Paleozoic and Mesozoic rocks from the Wells Formation through Preuss Sandstone Some of these units are overturned Others are incomplete and cut by small, imbricate branches from the Meade Thrust Fault Tertiary Salt Lake Formation unconformably overlies the Wells, Phosphoria, Dinwoody, and Thaynes Formations, Nugget Sandstone, and Twin Creek Limestone

Eight major north-northwest-trending folds are delineated on the lower or Absaroka Plate, which consists of Jurassic and Cretaceous rocks from the Twin Creek Limestone through the Bechler Conglomerate of the Gannett Group Heretofore, all Cretaceous rocks exposed in the quadrangle have been designated as Ephraim Conglomerate The Peterson Limestone, the second formation up in the Gannett Group, thins and lenses from north of the mapped area to the southern part of the quadrangle The Camel Hollow Fault, a major tear fault, was mapped in the Absaroka Plate as were numerous high-angle transverse faults and a thrust fault which terminates in a fold

Alluvial fans, stream valleys, and landslides are the main geomorphological elements of the Elk Valley Quadrangle A pinnacle and several hogbacks are observed in the mapped area

Three oil wells have been drilled in the quadrangle on the Elk Valley structure Each showed gas-cut mud and traces of oil, but all were plugged and abandoned Further exploration, including a detailed seismic correlation on the Elk Valley structure, is justified

INTRODUCTION

Location

The Elk Valley 7½ minute Quadrangle straddles the Idaho-Wyoming border (fig. 1). The quadrangle lies, in part, in Caribou and Bear Lake Counties in southeastern Idaho, and in part, in Lincoln County in southwestern Wyoming. The area is approximately 32 km northeast of Montpelier, Idaho, and 24 km southwest of Afton, Wyoming A maintained, gravelled and dirt road that connects Afton, Wyoming, with Montpelier, Idaho, passes through the northwest corner of the quadrangle. The remainder of the area is accessible via U S. Forest Service dirt roads and pack trails. Most of the area is within the Caribou National Forest in Idaho, and the Bridger National Forest in Wyoming.

Purpose of the Work

The Elk Valley-Sublette and Afton anticlines of the Elk Valley Quadrangle have received considerable attention from petroleum companies. To date, three oil wells have been drilled in Elk Valley, two by May Petroleum Company and one by Amerada Corporation. In addition, two wells were drilled on the Afton Anticline within 1 km of the eastern border of the quadrangle. All five wells were dry in terms of oil and gas production, but a gas chromatograph show in the Amerada well and drill stem tests recovering gas cut muds in the two May wells give encouragement for future exploration

The geology of southwestern Wyoming and southeastern Idaho was described by Mansfield (1927). Structure and stratigraphy of this area were described by him largely for the first time. Availability of excellent colored aerial photographs and an accurate topographic base, at a scale of 1 24,000, prompted a more detailed study than was possible in earlier investigations. It was possible to delineate surface details that were not mapped previously and to document a more detailed structural evaluation in this disturbed zone. This work could possibly help in future petroleum exploration.

Previous Work

Mansfield (1927) summarized geologic studies completed in southeastern Idaho and southwestern Wyoming previous to 1927. He mapped the Crow Creek 15′ Quadrangle, the quadrangle that includes the four 7½′ maps in figure 1, at a 1:62,500 scale for part of this publication. Cressman (1964) and others mapped the Snowdrift Mountain 7½′ Quadrangle (fig. 1), and Montgomery and Cheney (1967) mapped the Stewart Flat 7½′ Quadrangle to the northwest (fig 1) of the Elk Valley Quadrangle These latter studies were undertaken to evaluate and document the phosphate and uranium potential of the area. Because the Elk Valley Quadrangle has minimal outcrops of upper Paleozoic rocks in which the phosphate deposits are located, it was not mapped as part of the same study.

Eyer (1964) both measured and checked previously published stratigraphic sections of the Gannett Group in the overthrust area. One of his measured sections lies in the mapped area. A similar study of the Thaynes Formation was undertaken by Stephenson (1964). One of his measured sections is located approximately 15 km north of the Elk Valley Quadrangle No detailed studies of the structural, stratigraphic, or geologic relationships in the Elk Valley Quadrangle have been published.

Methods of Investigation

Preliminary work was initiated during the spring of 1979, and fieldwork was accomplished between June and September 1979. Geologic observations were recorded on aerial photographs, at a scale of 1.15,840, in the field. These data were later transferred to a preliminary topographic base map at a scale of 1:24,000 with a Bausch and Lomb Stereo Zoom Transfer Scope. Stratigraphic sections were measured with a 15-m cloth tape and a Brunton compass. Library research and thesis writing were done in the fall and winter, 1979–1980.

Acknowledgments

Many people have provided the help and support which have made completion of this thesis possible. I would like to

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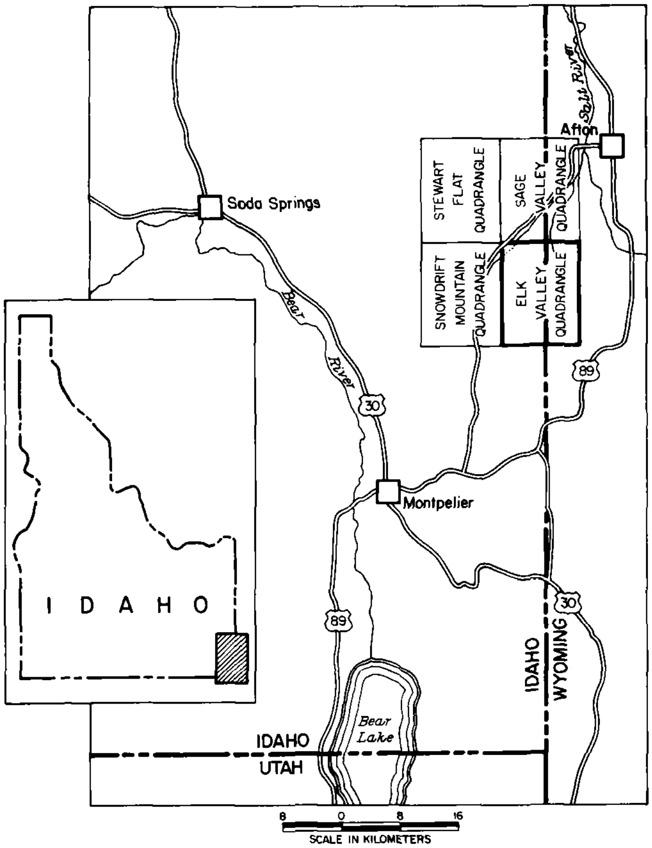

FIGURE 1.–Index map showing location of Elk Valley Quadrangle.

thank Dr. J. Keith Rigby, my thesis chairman, for his help and advice both in the field and while I was writing the thesis. Dr. Lehi F. Hintze and Dr. James L. Baer visited in the field and offered some helpful suggestions. Lyle A. Hale provided valuable assistance in early planning and later stages of this thesis project. I am grateful for two air flights with Orson W. White, M.D., in addition to a three-day horse pack trip with Joseph L. Hatch, M.D. I would like to thank the property owners who allowed me to travel across their properties, especially Harvey Kennington, Alfred Sorenson, and Lester Wade. John Conner, a fellow graduate student who mapped the Sage Valley Quadrangle to the north of the Elk Valley Quad rangle (fig. 1), cooperated on stratigraphic and structural interpretation. Robert Ballou, John Thornton, and Gina Veigle helped with fieldwork. The structure contour map (fig. 22) was constructed by Jim Dean, Terry Gosney, John Kitzmiller, Jim Smith, Carolyn Hurst, and Ralph Lambert. Financial assistance was provided by Champlin Petroleum Company through the efforts of Mr. Joe S. Dixon and by the Brigham Young University Geology Department.

I would like to thank my parents and my wife's parents for all their help and support. A special thank-you goes to my wife, Carol, who helped with typing, proofreading, and illustration layouts.

GEOGRAPHY

Most of the Elk Valley Quadrangle lies in the Gannett Hills, located between the Webster Range, on the west, in Idaho and the Salt River Range, on the east, in Wyoming. The northeastward-trending valley of Crow Creek, the northwestward-trending Elk Valley, and the eastward- and northward-trending valley of Spring Creek are the three major valleys found in the area. Elevations range from approximately 1,950 m above sea level on Crow Creek to peaks at 2,560 m. The area drains via Crow and Spring Creeks, tributaries of the Salt River, into the Snake River.

STRATIGRAPHY

General Statement

Stratigraphic units exposed in the Elk Valley Quadrangle range from Late Pennsylvanian to Quaternary. Upper Pennsylvanian through Middle Cretaceous rocks crop out in a series of northward- to northwestward-trending folds superimposed on two thrust plates. Outcrops on the northwestern thrust plate, north of Crow Creek Valley, include rocks that range from Late Pennsylvanian (?) through Middle Jurassic, with Tertiary strata unconformably overlying the older units. Thicknesses and sequences of these units are complicated by small-scale thrusting along branches of the main thrust fault. Rocks on the lower, southeastern thrust plate, southeast of Crow Creek Valley, have ages ranging from Upper Jurassic through Cretaceous. Some unconformably overlying Tertiary beds are also found on this plate. The exposed stratigraphic section on this plate totals approximately 1,770 m thick. Formations exposed in the quadrangle consist of the following, from oldest to youngest (fig. 2): Wells Formation (Pennsylvanian [?] and Permian): Grandeur Tongue of the Park City Formation, and Phosphoria Formation (Permian); Dinwoody, Thaynes, and Ankareh Formations (Triassic): Nugget Sandstone, Twin Creek Limestone, Preuss Sandstone, and Stump Sandstone (Jurassic); and the Gannett Group composed of Ephraim Conglomerate (Jurassic and Cretaceous), Peterson Limestone, and Bechler Conglomerate (Cretaceous). Tertiary Salt Lake Formation occurs in the northwest corner of the map on the northwestern thrust plate. Alluvium, landslide debris, and salt deposits in the mapped area are considered to be of Quaternary age.

Pennsylvanian and Permian Systems

Wells Formation

The Pennsylvanian (?) and Permian age Wells Formation was named by Richards and Mansfield (1921, p. 689–93) from Wells Canyon, 5 km west of the Elk Valley Quadrangle. Wells Formation is the oldest unit exposed in the map area. It crops out on the northwestern thrust plate in the northwest corner of the quadrangle. Only uppermost Wells beds are found in the mapped area, and it is possible that only the Permian part of the formation is represented.

Thickness of the Wells Formation within the quadrangle is unknown because of its limited exposure due to partial burial and faulting. The estimated thickness of this incomplete section is approximately 230 m. A partial section 240 m thick was measured 6 km to the north of the thesis area (section 1, appendix). Total thickness of the formation at the type section is 730 m (Mansfield 1927, p. 72). Cressman (1964, p. 18) reported total thicknesses ranging between 460 and 600 m on the Snowdrift Mountain Quadrangle, adjacent on the west to the Elk Valley Quadrangle.

The Wells Formation consists of very light gray to medium gray sandstone and limestone (section 1, appendix). These rocks weather light gray, tan, or reddish brown. The sandstone is slightly calcareous to calcareous, very fine grained to fine grained, well cemented, and massively bedded. The limestone is light to medium gray and weathers to a light gray. It is sandy, vuggy, and massively bedded.

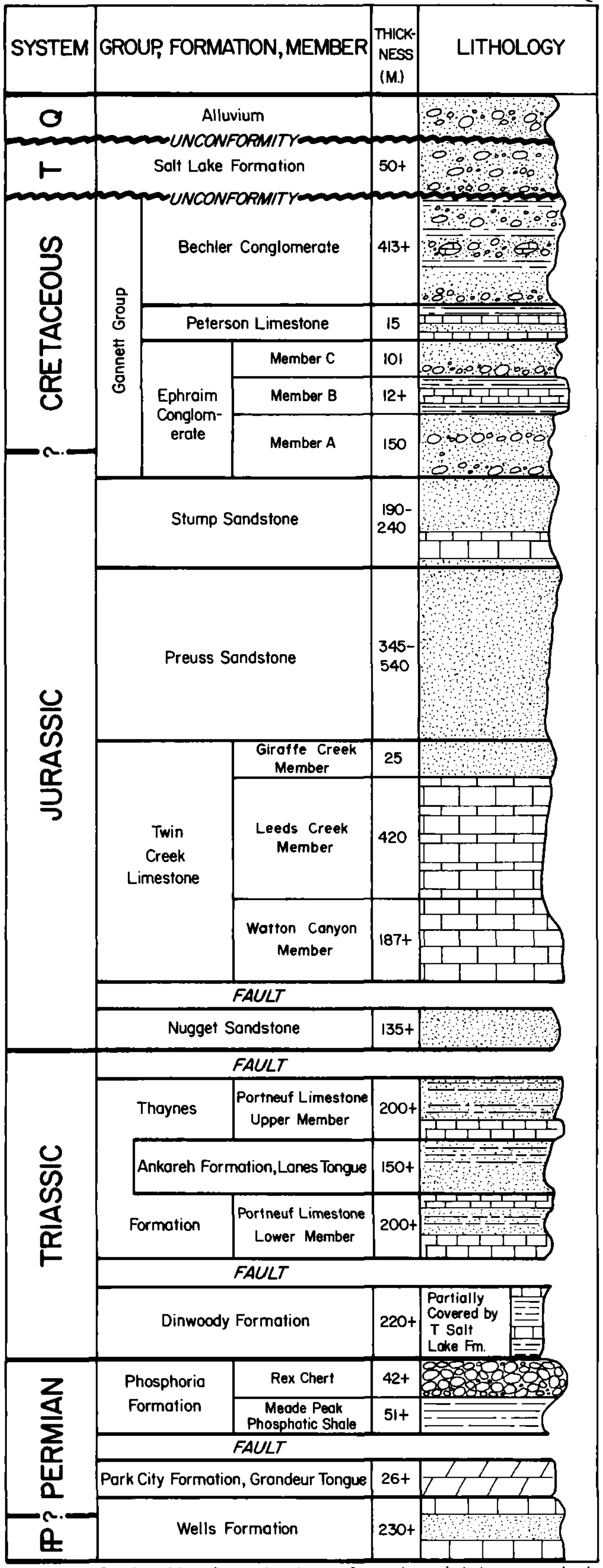

FIGURE 2.–Stratigraphic column showing surface units and their structural relationship in Elk Valley Quadrangle.

The Wells Formation was grouped with the overlying Grandeur Tongue of the Park City Formation for mapping purposes. Cressman (1964, p. 27) stated that fossil evidence "indicates that the Upper Wells Member contains some beds of Middle Pennsylvanian age, but the upper two-thirds are Permian." No fossils were observed in the poor outcrops of the unit during the present study.

Permian System

The Grandeur Tongue of the Park City Formation and the younger Phosphoria Formation crop out in the northwest corner of the Elk Valley Quadrangle, on the upper thrust plate. Thicknesses of the Permian units are unknown because of their limited extent and exposure, partial burial, and faulting.

Grandeur Tongue of the Park City Formation

The Grandeur Tongue of the Park City Formation was named by Cheney and others (in McKelvey and others, 1959, p. 12–17) from Grandeur Peak in Salt Lake County, Utah. The unit crops out in sections 19 and 30, T. 9 S, R. 46 E, in the northwest corner of the Elk Valley Quadrangle. Cressman (1964, p. 25) reported a 26-m thickness for the Grandeur Tongue in the Snowdrift Mountain Quadrangle to the west. This unit consists of medium gray, very finely crystalline, blocky dolomite (section 1, appendix). These beds weather to light gray and are poorly exposed.

Rocks of the Grandeur Tongue were grouped with the underlying Wells beds for mapping purposes because of the thinness of the tongue and because of limited exposures of both units in the quadrangle. The Grandeur Tongue of the Park City Formation is difficult to distinguish from the overlying Phosphoria Formation because of poor exposures and because the basal Phosphoria member, the Meade Peak Phosphatic Shale Member, is buried and almost totally obscured.

The Grandeur Tongue conformably overlies the Wells Formation. Fossils were not observed in the unit during the present study.

Phosphoria Formation

The Phosphoria Formation was named by Richards and Mansfield (1912, p. 684) from Phosphoria Gulch in the Snowdrift Mountain Quadrangle adjacent on the west to the thesis area. The formation crops out in the northwest corner of the Elk Valley Quadrangle in sections 19 and 30, T. 9 S, R. 46 E. A complete thickness of the formation could not be determined because of faulting and poor exposure. Cressman (1964, p. 33) reported a thickness of 138 m at the type locality on the Snowdrift Mountain Quadrangle, where the formation consists of three members, from oldest to youngest: Meade Peak Phosphatic Shale, Rex Chert, and an unnamed cherty shale. The Meade Peak Shale and Rex Chert crop out in the mapped area.

The Phosphoria Formation is overlain conformably by the Dinwoody Formation. However, the contact is obscured in the study area because both beds are overlain unconformably by the Tertiary Salt Lake Formation. Fossils were not observed during the present study.

Meade Peak Phosphatic Shale Member. The Meade Peak Phosphatic Shale Member of the Phosphoria Formation was named by McKelvey and others (1956, p. 2845) from Meade Peak in the Snowdrift Mountain Quadrangle. The member has an inferred but totally buried position between outcrops of the Grandeur Tongue of the Park City Formation, below, and the Rex Chert, above. An estimated thickness in the mapped area is approximately 51 m. Cressman (1964, p. 33) reported that thicknesses of the Meade Peak Member range from 45 to 60 m on the Snowdrift Mountain Quadrangle.

The Meade Peak Member consists of dark, carbonaceous, phosphatic, and argillaceous rocks at the type section (McKelvey and others 1959, p. 22). The contact between Meade Peak and Rex Chert members was not seen on the Elk Valley Quadrangle but was observed in tractor-cut trenches in the Sage Valley Quadrangle, adjacent on the north (John Conner personal communication 1979), where the contact was placed at a change from older phosphorites and mudstones to younger chert.

The source of the Meade Peak sediments and their depositional environment is a debated subject. It is generally concluded that Meade Peak sediments accumulated in a marine environment and were deposited by upwelling, cold, phosphate-rich waters (McKelvey and others 1959, p. 25).

Rex Chert Member. The Rex Chert Member was named by Richards and Mansfield (1912, p. 684) from Rex Peak in the Crawford Mountains of Rich County, Utah, and overlies the Meade Peak Member. The estimated thickness of the Rex Chert beds in the quadrangle is approximately 42 m. Cressman (1964, p. 31) reported a 47-m thickness for this unit. Rex Chert consists of various cherty rocks, with differing amounts of argillaceous and carbonaceous matter. The Rex Chert Member is overlain conformably by the unnamed cherty shale member of the Phosphoria Formation, which was not observed in the thesis area. The boundary of the Rex Chert with the unconformably overlying Salt Lake Formation was mapped at the change from soil containing dark chert fragments, below, to a reddish brown soil, above.

Many ideas have been proposed for the source of the silica in the Rex Chert. McKelvey (1959, p. 25) stated that the silica accumulated in a marine environment.

Triassic System

Triassic rocks crop out on the upper thrust plate in the northwest corner of the Elk Valley Quadrangle as incomplete sections of the Dinwoody and Thaynes Formations. The Dinwoody Formation is mostly buried by the Salt Lake Formation and is possibly faulted as well. The Thaynes Formation is not present in its entirety because of faulting.

Dinwoody Formation

The Dinwoody Formation was named by Blackwelder (in Condit 1916, p. 263) from Dinwoody Canyon in the Wind River Range. The formation crops out in section 19, T. 9 S, R. 46 E, in the northwest corner of the mapped area. The thickness of this formation was not measured because of extensive burial by the unconformably overlying Salt Lake Formation. The estimated thickness for exposed Dinwoody beds is approximately 220 m. Cressman (1964, p. 37, 39) reported a thickness of 490 m in the Snowdrift Mountain Quadrangle to the west. He divided the Dinwoody Formation into an upper and lower member, both of which were mapped throughout the Snowdrift Mountain area. These members probably extend into the present map area but could not be differentiated because of limited exposure. The formation consists of interbedded gray limestone that weathers light gray, and olive brown shale and siltstone that weather brown.

The Dinwoody-Thaynes boundary is obscure but was placed at a fault (?) boundary where float changes from limestone, shale, and siltstone, below, to predominantly limestone, above. The *Meekoceras* assemblage of fossils in the basal Thaynes Formation, which normally defines this contact, was not observed. The Dinwoody Formation conformably overlies the Phosphoria Formation.

Thaynes Formation

The Thaynes Formation was named by Boutwell (1907, p. 448) from Thaynes Canyon near Park City, Utah. The formation crops out in the northwest corner of the Elk Valley Quadrangle. Thickness of this unit was not measured because it is tectonically thinned and broken by faults. The estimated exposed thickness in the mapped area, however, is approximately 550 m. Cressman (1964, p. 40) stated that the Thaynes Formation is 760 to 975 m thick in the Snowdrift Mountain Quadrangle.

Thaynes Formation crops out in the mapped area in one of the seven minor thrust slivers of the upper thrust plate (plate 1). The oldest Thaynes rocks exposed in the quadrangle, the lower Portneuf Limestone Member, occur on the east of the thrust slice. Older Thaynes units are not exposed in the mapped area because of faulting but are exposed in the Sage Valley Quadrangle to the north (John Conner personal communication 1979). The youngest Thaynes unit observed, the upper Portneuf Limestone Member, crops out on the west of the thrust slice. Rocks mapped in the upper Portneuf Member include a Portneuf to Timothy Sandstone transition sequence but were mapped together as upper Portneuf only. Members younger than the Portneuf Limestone are not exposed because of faulting.

The Lanes Tongue of the Ankareh Formation occurs between the upper and lower members of the Portneuf Limestone in the mapped area. The intertonguing relationship of Thaynes and Ankareh beds was described by Kummel (1954, p. 174) in parts of western Wyoming and southeast Idaho, by Cressman (1964, p. 42–43) in the Snowdrift Mountain Quadrangle to the west of the present quadrangle, and by Stephenson (1964, fig. 1) in eastern Idaho.

Thaynes Formation outcrops were distinguished from overlying Nugget Sandstone by a color and lithologic change from older gray limestone, to float of younger slope-forming orange or reddish gray sandstone. Thaynes Formation normally overlies the Dinwoody Formation conformably. However, this normal succession is probably interrupted by faults in the mapped area. No fossils were observed in Thaynes beds during the present study.

Portneuf Limestone Member. The Portneuf Limestone Member of the Thaynes Formation was named by Mansfield (1916) from exposures near the head of the Portneuf River in the Fort Hall Indian Reservation of Idaho. This member crops out only in the northwest corner of the quadrangle in sections 20, 29, and 30, T. 9 S, R. 46 E.

The Portneuf Limestone Member is informally divided into an upper and a lower unit because of its interfingering relationship with the Ankareh Formation. The lower member of the Portneuf Limestone crops out in sections 20 and 29, T. 9 S, R. 46 E. It is bounded by a faulted contact with the Nugget Sandstone to the east and in normal succession by the Lanes Tongue of the Ankareh Formation on the west. Exposures of lower beds consist of two medium brown to medium gray, very fine-grained, ledge-forming limestone units (fig. 3). Float from reddish brown to olive brown siltstone and shale (?) occurs in an eroded swale betwen the limestone beds. Total thickness of this unit is unknown because of structural complications.

The upper member of the Portneuf Limestone crops out in sections 20, 29, and 30, T. 9 S, R. 46 E. It is bounded on the east, below, by the Lanes Tongue in normal sequence, but by a fault (?) contact with the Dinwoody Formation on the west. Outcrops consist of fine- to massively grained, tannish brown to olive gray limestones, sandstones, and siltstones. Rocks in this unit weather to olive brown, are thinly bedded, and form slopes. The total thickness of this part of the Portneuf Member is unknown because it is broken by faults and is partially buried by the Salt Lake Formation.

Observed beds in the upper Portneuf Member are somewhat similar to descriptions of the Timothy Sandstone Member of the Thaynes Formation in areas to the west of the Elk Valley Quadrangle (Cressman 1964, p. 42; Stephenson 1964, p. 59, 75, and 87). No distinction between Timothy Sandstone and upper Portneuf Member was made, however, in the present map area because of the abundant limestone beds in the upper Portneuf Member and lack of "many dark colored chert grains" (Cressman 1964, p. 42) in what is called the Timothy Sandstone Member.

Ankareh Formation

The Ankareh Formation was named by Boutwell (1907, p. 452) from Ankareh Ridge near Park City, Utah. The formation crops out in sections 20 and 29, T. 9 S, R. 46 E, in the northwest corner of the Elk Valley Quadrangle. Only the Lanes Tongue of the Ankareh Formation (Kummel 1954, p. 175) is exposed in the quadrangle. The Wood Shale Tongue, an upper Ankareh Formation member, is not exposed in the mapped area because of faulting.

Lanes Tongue of the Ankareh Formation. The Lanes Tongue of the Ankareh Formation was named by Kummel (1954, p. 173). Preserved and exposed thicknesses of this unit, like the Portneuf Limestone Members, are variable because of tectonic complications. The Lanes Tongue Member consists of reddish brown, fine-grained siltstone and shale. It is poorly exposed in the mapped area where it forms float-covered swales between the more resistant ledges of the upper and lower units of the Portneuf Limestone Member of the Thaynes Formation.

Jurassic System

Jurassic rocks crop out throughout the Elk Valley Quadrangle in the cores of the four major anticlines on the southeastern, lower thrust plate. Rocks of Jurassic age are also exposed in the northwestern, upper thrust plate. Four formations make up the Jurassic System. The two upper formations, Preuss Sandstone and Stump Sandstone, have complete sections within the quadrangle. The lower two formations, Twin Creek Limestone and Nugget Sandstone, are either incomplete because of thrusting or not fully exposed in anticlinal cores. Jurassic rocks are approximately 1,100 m thick in the mapped area.

Nugget Sandstone

The Nugget Sandstone was named by Veatch (1907, p. 56) from outcrops near the Nugget Railroad Station in Lincoln County in southwestern Wyoming. The formation crops out as a thrust slice on the upper plate in the northwest corner of the quadrangle in sections 20 and 29, T. 9 S, R. 46 E. Thrusts along the contact with the Thaynes Formation, below, and the Twin Creek Limestone, above, make it difficult to determine where within the formation these beds would occur in a normal section. Thickness of this incomplete section was not measured but was estimated at approximately 135 m. Cressman (1954, p. 45) observed thicknesses of between 275 and 500 m for the formation in the Snowdrift Mountain Quadrangle to the west.

The Nugget Sandstone consists of massive, pinkish or reddish orange, fine-grained sandstone. Cross-bedding was not observed in the limited outcrops. Exposures consist of low, discontinuous ridges and swales with float of small to large blocks of sandstone that have weathered to orange or reddish gray (fig. 4).

The Nugget Sandstone correlates with the Navajo Sandstone of southern and eastern Utah (Hintze 1973, p. 63). It represents eolian deposits with prominent cross-bedding combined with minor lacustrine deposits (Picard 1974, p. 123–24). The formation normally overlies the Thaynes Formation conformably. However, this is not the case in the thesis area where beds in the lower Portneuf Member of the Thaynes Limestone have been faulted against the Nugget Sandstone.

Twin Creek Limestone

The Twin Creek Limestone was named by Veatch (1907, p. 56) from outcrops near the Twin Creek railroad station in

FIGURE 3.–Ledge-forming, resistant unit of Thaynes Limestone Formation, upper Portneuf Member, north of Crow Creek road in SE ¼, section 30, T. 9 S, R. 46 E, Idaho.

FIGURE 4.–Low, discontinuous ridge of Nugget Sandstone north of Crow Creek road in the NW ¼, section 29, T. 9 S, R. 46 E, Idaho. Crow Creek Valley in background.

southwestern Wyoming. The formation crops out in the lower thrust plate in the northeast part of the quadrangle, in the core of the easternmost anticline. The formation is also exposed in the upper thrust plate, both north and south of Crow Creek Valley. Three of the seven members of the formation, originally subdivided by Imlay (1950, p. 37–41), were distinguished in the mapped area. These three uppermost units are his Members E, F, and G. These members were later named, from oldest to youngest, the Watton Canyon, Leeds Creek, and Giraffe Creek Members (Imlay 1967, p. 3).

Only partial sections of Twin Creek Limestone were measured in the mapped area because the lower part of the formation is not exposed in anticlinal cores and because the upper beds have little structural competency and have been broken and distorted by thrusting. Cressman (1953, p. 48) reported thicknesses of between 900 and 1,500 m for the formation in the Snowdrift Mountain Quadrangle to the west.

With the exception of the Giraffe Creek Member, good exposures of Twin Creek Limestone are rare because of the shaly nature of the observed units. However, these units are distinguishable because of their light to medium gray weathered color, in addition to their stratigraphic position between the overlying reddish brown Preuss Sandstone and the underlying pinkish or reddish orange Nugget Sandstone.

The Twin Creek Limestone conformably overlies the Nugget Sandstone and represents a major marine invasion into the Rocky Mountain area during Middle Jurassic time (Hintze 1973, p. 64). No fossils were observed in this formation during the present study.

Watton Canyon Member. The Watton Canyon Member of the Twin Creek Limestone was named by Imlay (1967, p. 41) from Watton Canyon, approximately 13 km west of Woodruff, Utah. Imlay had previously designated the type section as the continuous exposures on the north side of Birch Creek, north of Watton Canyon (Imlay 1950, p. 40). Incomplete sections of this member are exposed east of the quadrangle in the core of the easternmost anticline and along the main thrust fault on the south side of Crow Creek. Cressman (1964, p. 50) reported thicknesses of between 35 and 275 m for this member in the Snowdrift Mountain Quadrangle to the west. The member has a calculated exposed thickness of at least 187 m in the mapped area.

The Watton Canyon Member consists of light blue gray limestone. It is thin to massively bedded and very fine grained. The boundary between the Watton Canyon and overlying Leeds Creek Members was located where weathered rock changes from older, resistant, blocky beds and float to younger limestone that weathers to shaly float chips. In addition, this member is usually a ridge-forming unit (fig. 5).

Leeds Creek Member. The Leeds Creek Member of the Twin Creek Limestone was named by Imlay (1967, p. 45). He had previously described the type section at a location on the north side of Leeds Creek in southwestern Wyoming (Imlay 1950, p. 40). Incomplete sections of this member occur in the mapped area on the flank of the easternmost anticline and in the outcrop belt along the main thrust fault trace, south of Crow Creek. A partial section was measured through the upper part of this member, but an accurate thickness could not be determined because of poor exposures, weathered slopes, and lack of bedding. The Leeds Creek Member is approximately 420 m thick in the Crow Creek area. Cressman (1964, p. 50) reported a thickness of 490 m for this member from the Giraffe Creek Quadrangle, adjacent on the south to the Elk Valley Quadrangle.

FIGURE 5.–Blocky, ridge-forming unit of Watton Canyon Member, Twin Creek Limestone in roadcuts along the Crow Creek road in NE ¼, section 17, T. 31 N, R. 119 W, Wyoming.

The Leeds Creek Member consists of thin-bedded, very fine-grained, olive or light to medium gray limestone (section 2, appendix). It weathers to very light gray chips and joint-controlled pencillike fragments (fig. 6). The boundary between the Leeds Creek and overlying Giraffe Creek members is gradational, but it was placed at the change from underlying, predominant limestone to younger, predominant sandstone.

Giraffe Creek Member. The Giraffe Creek Member of the Twin Creek Limestone was named by Imlay (1967, p. 50). He had previously designated the type section as exposures on the north side of Thomas Fork Canyon in southwestern Wyoming (Imlay 1950, p. 40). Imlay named this member after Giraffe Creek, which flows into Thomas Fork Canyon about 1.5 km east of the type section. Complete sections of this member occur in the mapped area in the core of the easternmost anticline and along the main thrust fault trace, south of Crow Creek. The Giraffe Creek Member was measured as 25 m thick (section 2, appendix), but thicknesses may vary from area to area because of gradational boundaries.

The Giraffe Creek Member consists of medium tan to greenish gray sandstone (section 2, appendix). It weathers light tan to olive gray. Rocks in this member are slightly calcareous, fine to medium grained, thin to massively bedded, and are ledge- to cliff-formers (fig. 7). The contact between the Giraffe Creek Member and the Preuss Sandstone was placed where float or outcrops change from greenish gray, below, to reddish brown, above. This transition often occurs in a small strike val-

FIGURE 6.–Pencillike fragments of Leeds Creek Member, Twin Creek Limestone in roadcuts along Crow Creek road in NE ¼, section 17, T. 31 N, R. 119 W, Wyoming.

ley between the older, ledge-forming Giraffe Creek Member and the younger, slope-forming Preuss Sandstone (fig. 8).

Preuss Sandstone

The Preuss Sandstone was named by Mansfield and Roundy (1916, p. 8) from Preuss Creek in the Snowdrift Mountain area to the west of the thesis area. The formation crops out south of Crow Creek on the flanks of the three major anticlines of the mapped area. Thickness of this formation in the quadrangle ranges from a measured thickness of 345 m on the west flank of the easternmost anticline (section 3, appendix) in section 4, T. 31 N, R. 119 W, to a calculated thickness of 540 m on the west flank of the westernmost anticline in section 29, T. 10 S, R. 46 E.

FIGURE 7.–Ledge-forming sandstone unit of the Giraffe Creek Member, Twin Creek Limestone north of Crow Creek road in NE ¼, section 17, T. 31 N, R. 119 W, Wyoming.

Preuss Sandstone consists of reddish brown, calcareous, sandstone (section 3, appendix). It weathers to brown or tannish red. Sandstone in this formation is fine to medium grained, thin to massively bedded, and occurs in beds from 0.3 m to greater than 2.0 m thick (fig. 9). These ledges lie between slope-forming intervals covered with brown soil and sandstone float that makes up most of the mapped belt of the formation. An alternating resistant-nonresistant, interbedded sandstone and shale cycle occurs in the Preuss Sandstone throughout all but the eastern part of the quadrangle. This pattern makes it possible to divide the formation into five informal members, designated as A–E from the bottom up (fig. 10). These members help to define details of the structure of the area.

A roadcut on the Sage Valley Quadrangle to the north shows a rhythmic alternation of sandstone and shale sequences throughout the upper part of the formation (John Conner personal communication 1979), but similar exposures of the shaly units, in particular, do not occur in the weathered sequences of the thesis area.

Salt, gypsum, and anhydrite beds were encountered near the base of the Preuss Sandstone in the May Petroleum Incorporated Federal Elk Valley #1 well and in the May Petroleum Incorporated-Tucker and Snyder Incorporated May Federal 1-8 well. Beds like these may account for spring-deposited salt beds, such as at the Old Salt Works in section 28, T. 9 S, R. 46 E, in addition to several other saline springs in areas adjacent to the Elk Valley Quadrangle.

The Preuss Sandstone is distinguished from the overlying Stump Sandstone by a change in the color of outcrops and float from reddish brown, below, to olive gray, above. The Preuss Sandstone conformably overlies the Twin Creek Limestone and represents a marginal marine, prodeltaic to tidal-flat deposit (Hileman 1973, p. 99). Fossils were not observed during the present study.

Stump Sandstone

The Stump Sandstone was named by Mansfield and Roundy (1916, p. 81) from Stump Peak, approximately 30 km north of the Elk Valley Quadrangle. The formation crops out in the mapped area south of Crow Creek, on flanks of the three major anticlines. Thickness in the mapped area ranges from a measured thickness of 190 m on the western flank of the easternmost anticline in section 32, T. 31 N, R. 199 W (section 4, appendix), to a calculated thickness of 240 m on the western flank of the westernmost anticline in section 39, T. 10 S, R. 46 E.

Stump Sandstone consists of interbedded, light gray to dark gray sandstone and limestone (section 4, appendix). These rocks weather light brown to olive brown. The sandstone is calcareous, glauconitic, fine grained, and thin to massively bedded, and it shows minor to abundant cross-bedded units. The limestone is sandy, cross-bedded, and blocky bedded. Pipiringos and Imlay (1979, p. 1) suggest that the term *Stump Formation* should replace the more commonly used *Stump Sandstone* because of the amount of limestone found in the formation.

Stump Sandstone beds range up to approximately 12 m thick, especially those in the lower part of the formation near the basal contact (fig. 11). The basal sandstone, which forms a prominent ridge throughout most of the mapped area, and another resistant unit in the upper part of the formation make it possible to divide the Stump Sandstone into three informal members. The alternating sandstone, shale, sandstone informal Stump sequence is similar to the informal divisions of the

FIGURE 8.—Strike valley between Twin Creek Limestone and Preuss Sandstone in section 21, T. 30 N, R. 119 W, Wyoming.

Preuss Sandstone (fig. 12). These members, labeled A–C from the bottom up, help define the structure of the area.

The Stump Sandstone is distinguished from the overlying Ephraim Conglomerate of the Gannett group by a change in color of outcrops and float from the older, medium or olive gray Stump beds to the younger brownish red Ephraim beds above. The contact was difficult to determine in places, and placement is only approximate locally. Stump Sandstone conformably overlies Preuss Sandstone and is a marine deposit (Pipiringos and Imlay 1979, p. 1). Fossils were not observed during the present study.

Jurassic and Cretaceous Systems

Ephraim Conglomerate

The Ephraim Conglomerate was named by Mansfield and Roundy (1916, p. 82) from Ephraim Valley, 4 km southwest of Elk Valley. Rocks of both Jurassic and Cretaceous ages are included in the Ephraim Conglomerate, the basal formation of the Gannett Group (Eyer 1964, p. 5). The Ephraim Conglomerate occurs widely throughout the quadrangle where it crops out south of Crow Creek along flanks and in troughs of the three major synclines.

Thickness of the Ephraim Conglomerate in the mapped area ranges from measured thicknesses of 284 m, near "the Elbow" of Spring Creek (Eyer 1964, p. 116) in sections 5 and 6, T. 29 N, R. 119 W, to 263 m on the east side of Spring Creek, 10.5 km to the north (section 7, appendix, and fig. 13) in section 5, T. 30 N, R. 119 W. Thickness of individual conglomerate beds decreases to the north away from the apparent source area (fig. 13). Thicknesses of the Jurassic and Cretaceous parts of the Ephraim are unknown.

In general, the Ephraim Conglomerate consists of several ledge-forming sandstone and conglomerate beds separated by a partially covered, argillaceous limestone and calcareous mudstone unit. This poorly exposed limestone unit is mappable as float and can usually be traced on the ground and on aerial photos. This limestone bed makes it possible to divide the Ephraim Conglomerate into three members, informally termed Members A–C from the bottom up, with the limestone unit as Member B. Best exposures of Ephraim Conglomerate in the mapped area occur on ridges on dip slopes of the two eastern synclines (fig. 12). Eyer (1964, p. 7) informally designated the Ephraim beds as Ephraim Formation instead of Ephraim Conglomerate because of the amounts of other constituents found in the formation, such as limestone, sandstone, siltstone, and shale.

Ephraim Conglomerate is locally difficult to distinguish from the overlying Peterson Limestone. This contact is most easily recognized in the northern part of the quadrangle where outcrops and float change from older reddish brown sandstone to younger light to medium gray limestone.

Ephraim Conglomerate conformably overlies the Stump Sandstone and represents a marine to nonmarine, and fluvial to lacustrine, series of deposits. The formation bridges the Jurassic-Cretaceous boundary (Eyer 1964, p. 5, 35). Marine Jurassic fossils and nonmarine Cretaceous microfossils have been found in the lower and upper beds of the formation, respectively (Eyer 1964, p. 35).

Member A. Member A of the Ephraim Conglomerate has the same general distribution as the formation. It is 150 m thick in section 5, T. 30 N, R. 119 W, in the northeast quarter of the Elk Valley Quadrangle (section 7, appendix).

Member A consists of interbedded light gray or grayish white sandstone and conglomerate. It weathers from light gray to reddish gray. Sandstone units are cross-bedded and massively bedded. Conglomerate beds contain chert and limestone pebbles up to 0.6 cm across. The contact between Members A and B is placed at a float change in color and lithology from older, light grayish red sandstone, below, to light blue gray limestone, above.

Member B. Member B of the Ephraim Conglomerate has the same general distribution as the formation as a whole. It is 12 m thick in section 5, T. 30 N, R. 119 W, in the northeast quarter of the mapped area (section 7, appendix). Even here, however, the unit is partially covered and may be thicker.

Member B consists of interbedded medium brownish gray limestone and mudstone. The limestone weathers light bluish gray, and is very finely crystalline. The mudstone is reddish purple. It weathers to a gray soil and is poorly exposed. The contact between Members B and C was mapped at the top of float from the older, light bluish gray limestone and below float of the younger brownish red sandstone.

Member C. Member C of the Ephraim Conglomerate has the same general distribution as the formation. Thickness of this unit is 101 m in section 5, T. 30 N, R. 119 W, in the northeast corner of the mapped area (section 7, appendix).

This member consists of interbedded, light reddish gray sandstone and conglomerate. Both rock types weather reddish brown. This unit is locally calcareous, cross-bedded, and thick bedded. Conglomerate beds contain chert pebbles up to 2.5 cm across. The contact between Member C of the Ephraim Conglomerate and the Peterson Limestone was mapped at changes in color and lithology of outcrops and float of older, reddish brown sandstone, to younger light gray limestone.

FIGURE 9.–Resistant bed in Member D, Preuss Sandstone, in section 18, T. 29 N, R. 119 W, Wyoming.

FIGURE 10.–Members A–E, Preuss Sandstone and Member A, Stump Sandstone, on western flank of Elk Valley-Sublette Anticline, south of road to Elk Valley in section 32, T. 10 S, R. 46 E, Idaho.

Cretaceous System

Rocks of Cretaceous age crop out in the Elk Valley Quadrangle in the troughs of the three main synclines of the lower, southeastern thrust plate. The Cretaceous System in the mapped area is represented by three of the five formations assigned to the Gannett Group (Eyer 1964, p. 5, 6). These are, from oldest to youngest: middle and upper rocks in the Ephraim Conglomerate, the Peterson Limestone, and all but the uppermost beds of the Bechler Conglomerate. Younger rocks, including the remainder of the Bechler Conglomerate, the Draney Limestone, and the Smoot Formation, which was raised to formation status by Eyer (1964, p. 23), comprise the rest of the Gannett Group and are not preserved in the quadrangle.

The Gannett Group was named by Mansfield and Roundy (1916, p. 82) from the Gannett Hills that surround the thesis area. Thickness of these Cretaceous rocks varies throughout the mapped area because part of the section has been removed by erosion.

All the Cretaceous rocks in the Elk Valley Quadrangle were mapped by Mansfield (1927, plate 7) as Ephraim Conglomerate, which gives a total Ephraim thickness much greater than the thickness in Ephraim Valley, the type section, or in areas along strike to the north. Mansfield's definition also contrasts with measured sections described by Eyer (1964). Mansfield apparently included all the Cretaceous rocks he observed in the Crow Creek Quadrangle in the Ephraim Conglomerate. He evidently did not recognize the thinning and lensing of the Peterson Limestone beds as they are traced from the northern border of the quadrangle into the southern areas (fig. 13).

Peterson Limestone

The Peterson Limestone was named by Mansfield and Roundy (1916, p. 82) from the Peterson Ranch, 15 km north

FIGURE 11.—Resistant beds in Member A, Stump Sandstone, north of Crow Creek road in section 17, T. 31 N, R. 119 W, Wyoming.

FIGURE 12.—Members A–C, Stump Sandstone, on eastern flank of Spring Creek Syncline in sections 16 and 17, T. 30 N, R. 119 W, Wyoming.

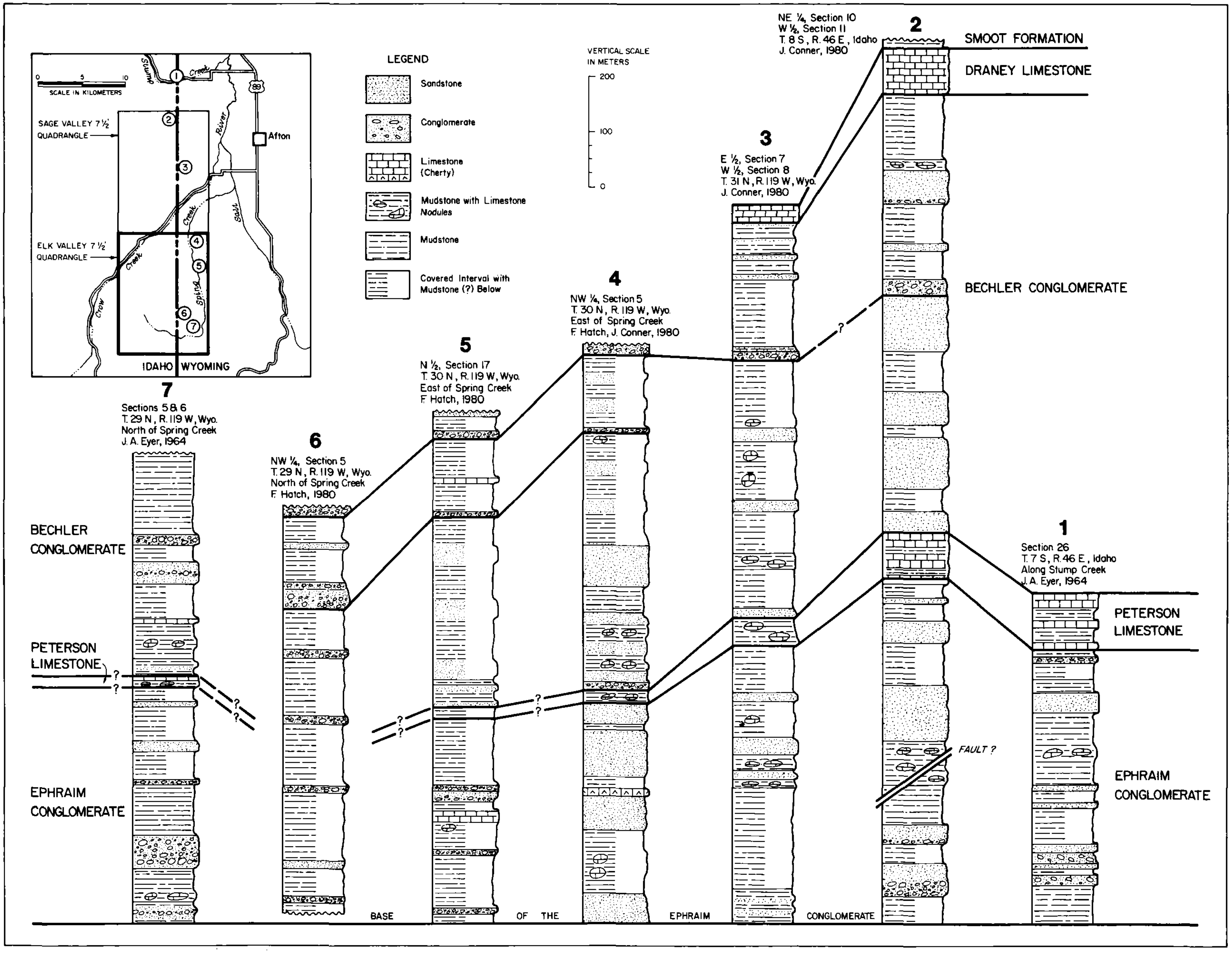

FIGURE 13.—Stratigraphic correlation of Gannett Group across Elk Valley and Sage Valley Quadrangles.

of the Elk Valley Quadrangle. The limestone crops out in the mapped area in the two easternmost synclines. The formation can be traced, both on air photos and in the field, along the flanks in the eastern syncline from the northern border of the quadrangle into the central part of the area, but it is then obscured or loses its identity. The Peterson Limestone has a measured thickness of approximately 15 m both near "the Elbow" of Spring Creek in sections 5 and 6, T. 29 N, R. 119 W, and on the east side of Spring Creek, 10.5 km to the north in section 5, T. 30 N, R. 119 W (section 7, appendix and fig. 13). The formation is much thinner here than the 73 m of limestone observed at the type section by Eyer (1964, p. 12). Eyer (1964, p. 12) informally designated these rocks as the Peterson Formation instead of Peterson Limestone because of the thickness of other constituents such as mudstone in the formation.

The Peterson Limestone consists of interbedded, light to medium gray limestone, siltstone, mudstone, and shale (section 7, appendix and fig. 13). The limestone is nodular and microcrystalline. The siltstone, mudstone, and shale are reddish brown and poorly exposed. The best exposures of this formation are in saddles between the resistant ridges of the underlying Ephraim Conglomerate and the overlying Bechler Conglomerate on the east flank of the easternmost syncline.

The Peterson Limestone conformably overlies the Ephraim Conglomerate. Eyer (1964, p. 36) reported that the Peterson is primarily an algal limestone of freshwater, lacustrine origin.

Bechler Conglomerate

The Bechler Conglomerate was named by Mansfield and Roundy (1916, p. 82) from Bechler Creek, 20 km north of the Elk Valley Quadrangle. The formation crops out in the mapped area in northwesterly trending belts in the troughs of the two easternmost synclines. Thickness varies throughout the quadrangle because upper beds have been removed by erosion. However, preserved thicknesses range from 260 m near "the Elbow" of Spring Creek in sections 5 and 6, T. 29 N, R. 119 W (Eyer 1964, p. 115) to 413 m on the east and west sides of Spring Creek, 10.5 km to the north in section 5, T. 30 N, R. 119 W (section 7, appendix and fig. 13). Thickness of individual conglomerate beds decreases to the north (fig. 13). Eyer (1964, p. 15) informally designated the Bechler as Bechler Formation instead of Bechler Conglomerate because of the interbedded limestone, sandstone, siltstone, and shale found in the formation.

Bechler Conglomerate consists of interbedded very light gray to reddish brown sandstone, conglomerate, and nodular limestone (section 7, appendix and fig. 13). The entire unit weathers reddish brown. The sandstone is calcareous, fine grained, thin to thickly bedded, cross-bedded, and in beds or ledgy units from 5 to 30 m thick. Conglomerate layers are massively bedded, form ledges and cliffs, and vary from 2 to 13 m thick (fig. 14). Conglomerate units contain chert cobbles up to 20 cm across and limestone boulders up to 36 cm across (fig. 15). Cressman (1964, p. 55) suggested that many of these limestone and sandstone fragments may have been derived from erosion of the Wells and Brazer Formations.

Sequences with conglomerate beds at the base which fine upward make it possible to subdivide the Bechler Conglomerate into five informal units, labeled A through E from the bottom up. Best conglomerate exposures of these members are those west of Spring Creek Valley in section 31, T. 30 N, R. 119 W, section 6, T. 31 N, R. 119 W, and sections 23 and 26, T. 9 S, R. 46 E. Outcrop patterns of these units are only approximate because of thinning and thickening of the conglomerate beds. However, this pattern was used to help define the structure (plate 1).

The Bechler Conglomerate conformably overlies the Peterson Limestone. Eyer (1964, p. 37) reported that the formation represents a nonmarine, fluvial to lacustrine, depositional environment, similar to that in which the Ephraim Conglomerate accumulated. Eyer (1964, p. 37) stated that "fossils are usually found in the upper portion of the formation," but none were collected during the present study.

Tertiary System

Salt Lake Formation

The Salt Lake Formation was named by Hayden (1869, p. 92) from the Weber and Salt Lake Valleys of northern Utah. The formation crops out in the northern and northwestern parts of the Elk Valley Quadrangle where an estimated thickness of 50 m or more may have accumulated.

Outcrops of the Salt Lake Formation in the mapped area consist of interbedded, light brown to very light gray cal-careous sandstone and conglomerate. The best exposures in the quadrangle are located in canyons north of Crow Creek near the western map border. Cobbles in the conglomerate are sub-

FIGURE 14.–Massively bedded conglomerate units, Bechler Conglomerate north of road to Elk Valley in section 31, T. 10 S, R. 46 E, Idaho.

FIGURE 15.–Chert cobbles and limestone boulders in member D of Bechler Conglomerate southeast of The Pinnacle in the SE ¼, section 31, T. 30 N, R. 119 W, Wyoming.

rounded and appear to have been locally derived, perhaps from the Thaynes Formation (fig. 16). The formation is also commonly light gray to light brown float, rubble, and colluvium without bedding. In the Snowdrift Mountain area to the west, the Salt Lake Formation consists of a lower tuffaceous member and an upper conglomeratic member (Cressman 1964, p. 57). Yen (1946, p. 485) observed oolitic limestone and molluscan faunas in the tuffaceous member and reported that the formation had a lacustrine origin.

FIGURE 16.–Thaynes Formation (?) limestone pebbles in Salt Lake Formation north of Crow Creek road in section 31, T. 9 S, R. 46 E, Idaho.

Mansfield (1927, p. 110–12) dated the Salt Lake Formation as Pliocene (?). The formation was dated in the Soda Springs area as Pliocene-Pleistocene from gastropods by Yen (in Cressman 1964, p. 58), and as Pliocene from diatoms by Lohman (in Cressman 1964, p. 58). Studies in the mid-1950s by Slentz (1955, p. 24) and Adamson and others (1955, p. 2) subdivided the Salt Lake beds into smaller formations. Overall, these studies divided the Salt Lake sequence into tuffaceous, lacustrine formations of Oligocene to Pliocene age with overlying conglomerate units. Because there are no tuffaceous beds in the mapped area, the preserved rocks are probably in Cressman's upper member and are Pliocene (?) in age.

Salt Lake Formation unconformably overlies Twin Creek Limestone, Nugget Sandstone, and Thaynes, Dinwoody, Phosphoria, and Wells Formations in the mapped area. Fossils were not observed during the present study.

Quaternary System

Quaternary deposits within the quadrangle are mainly unconsolidated sediments. These alluvial deposits occur along streams throughout the area but have been separately mapped in Elk Valley and along the valleys of Spring Creek and Crow Creek.

Alluvial fans of unconsolidated silt, sand, pebbles, and cobbles have been built at canyon mouths and are locally large enough to be separated from the alluvium of the valley floor. The largest fans occur at the mouths of tributaries into Crow Creek Valley and Elk Valley.

Four landslides are differentiated on the geologic map (plate 1). One of the major slides is located at the southeast end of Elk Valley, near the head of Spring Creek (fig. 17). The other large landslide is located in the western part of the quadrangle, 3 km southwest of Elk Valley. The smaller landslides

FIGURE 17.–Large landslide southeast of Elk Valley in sections 27 and 28, T. 10 S, R. 46 E, Idaho. Landslide mass takes up middle and lower left portion of photo.

were mapped in section 3, T. 10 S, R. 46 E, and in sections 6 and 7, T. 29 N, R. 119 W.

One major salt deposit, the Old Salt Works, occurs in the Elk Valley Quadrangle and several other less extensive deposits occur in the surrounding area. The Old Salt Works is located on the Kennington Ranch (fig. 18), where a 6 m thick salt layer was mined until the early 1900s, when other means of obtaining salt became more economic (Mansfield 1927, p. 322). An area of approximately 5,000 m becomes white through the summer months as salt water from a seep evaporates and leaves a layer of salt on the ground around the seep and in Crow Creek Valley.

Mansfield (1927, p. 322) reported that the Old Salt Works is "a bed of salt," implying that the bed is a layer of the surrounding Preuss Formation. However, even though drilling records indicate that there are salt beds in the lower part of the Preuss, it is more probable that salt at this spring has been deposited as evaporated saline water. The salt is probably dissolved out of salt-bearing formations, like the Preuss Sandstone, as water flows to the surface along fault planes. Alignment of several salt springs in the area surrounding the Elk Valley Quadrangle seems to be closely controlled by traces of branches of the Meade Thrust Fault.

STRUCTURAL GEOLOGY

General Statement

A thrust fault zone, tear faults and other high angle faults, and major north-south folds are the prominent structural features in the Elk Valley Quadrangle. They are illustrated on the geologic map and cross sections of the mapped area (plate 1). Mansfield (1927, p. 123–206) gave a comprehensive overview of the geologic history of southeastern Idaho and western Wyoming and included the present map area within that overview. Cressman (1964, p. 85–90) gave a review of the geologic history of the Snowdrift Mountain Quadrangle, to the west of the mapped area.

The Meade Thrust Fault zone in the northwestern part of the quadrangle includes a major and several minor thrusts (plate 1). The fault zone separates the Elk Valley Quadrangle into two distinct areas on two thrust plates of the Overthrust Belt. The upper, or Meade Plate occurs in sections 19–22 and 28–32 of T. 9 S, R. 46 E. The Meade Thrust Fault and minor related slices, overturned beds, and the eastern flank of an anticline are the structural elements of the area. The lower, or Absaroka Plate, is exposed throughout the rest of the mapped area. Eight north- to northwest-trending folds, several transverse faults, and a minor thrust fault that terminates in a fold are the dominant structures of the lower plate.

Meade Thrust Fault

The Meade Thrust Fault, the major fault within the quadrangle, is entirely within Idaho. It is the westernmost thrust fault in the area (fig. 19). This fault was originally termed the Bannock Thrust Fault by Richards and Mansfield (1912, p. 695) but was renamed the Meade Thrust Fault by Cressman (1964, p. 62), who showed that the fault is only one segment of the Bannock Thrust Fault zone.

The Meade Thrust Fault is exposed in the Elk Valley Quadrangle along both sides of Crow Creek Valley. The East Meade branch and one smaller thrust fault are exposed southeast of Crow Creek Valley. The West Meade branch and four smaller, imbricate thrust slices are exposed northwest of Crow Creek Valley (plate 1, section A-A′). These smaller faults place older units on top of younger units, from west to east, across the northwest corner of the mapped area. Although these faults have limited exposure in the quadrangle, they are extensively exposed throughout the Sage Valley Quadrangle, to the north (John Conner personal communication 1980).

The best exposure of the Meade Thrust Fault in the Elk Valley Quadrangle occurs in sections 28, 29 and 32, T. 9 S, R. 46 E, where upper members of the Jurassic Twin Creek Limestone, on the Meade Plate, are thrust and overturned against

FIGURE 18.–Surface salt deposit surrounding Old Salt Works in NE ¼, section 28, T. 9 S, R. 46 E, Idaho.

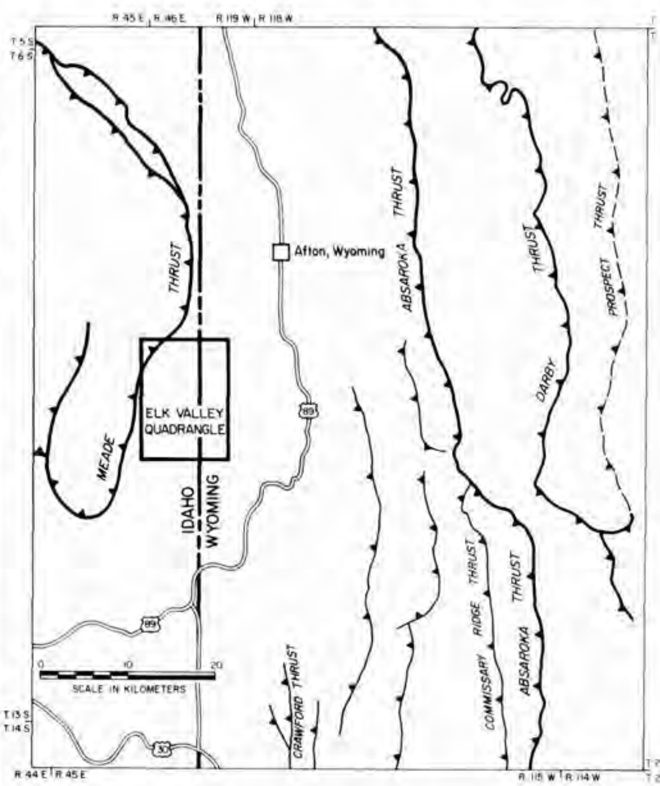

FIGURE 19.–The Meade Thrust Fault and its relation to other thrust faults in southeast Idaho–western Wyoming.

lower members of the Jurassic Preuss Sandstone on the Absaroka Plate (fig. 20). Traces of the fault are inferred beneath alluvium and through nonresistant units, like the Preuss Sandstone near the Old Salt Works. However, the fault is easily located adjacent to overturned beds of the Twin Creek Formation. Stratigraphic displacement on the Meade Thrust Fault is small in the mapped area compared to the 4,000 to 5,000 m of displacement observed by Cressman (1964, p. 69) on the Snowdrift Mountain Quadrangle to the west, where the thrust fault separates Jurassic beds, below, from Mississippian beds, above.

Salt beds of the Old Salt Works (fig. 18), in section 28, T. 9 S, R. 46 E, and other salt springs are aligned along the projected trace of the Meade Thrust Fault. Salt appears to have accumulated at this and other sites in the nearby area where salty water wells to the surface along faults.

Movement along the Meade Thrust Fault can be broadly dated from stratigraphic relations within the Elk Valley Quadrangle as post-Bechler Conglomerate (Early Cretaceous) and pre-Salt Lake Formation (Pliocene ?). Cressman (1964, p. 78) and Armstrong and Cressman (1963, p. 319) reported that the fault was initiated at the end of Early Cretaceous time and continued intermittently until Late Cretaceous or possibly Paleocene time. Cressman (1964, p. 75) stated that relative movement of the Meade Thrust Fault within the Snowdrift Mountain area was from the west-northwest. He observed that total horizontal displacement of the fault is from 29 to 32 km in the Snowdrift Mountain area.

Structure of the Meade Plate in the Elk Valley Quadrangle

The upper or Meade Plate makes up only a small part of the total area of the Elk Valley Quadrangle. However, faulting along the Meade Thrust Fault zone has cut many units and produced many incomplete formations in outcrops, ranging from the Pennsylvanian (?) Wells Formation through the Upper Jurassic Preuss Sandstone (plate 1).

Overturned units occur in two different places on the Meade Plate in the mapped area. Beds of Upper Twin Creek Limestone are overturned along the Meade Thrust Fault near Crow Creek in sections 28, 29, and 32, T. 9 S, R. 46 E. In addition, the Wells and Phosphoria Formations are also overturned in sections 19 and 30, T. 9 S, R. 46 E, on the eastern flank of the Boulder Creek Anticline.

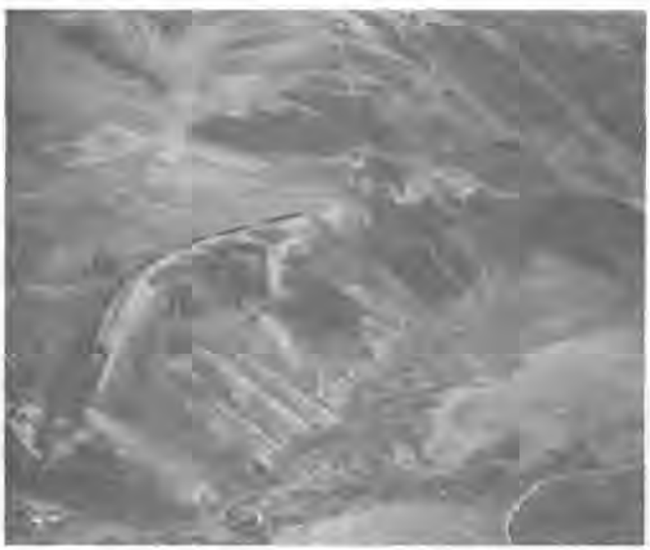

FIGURE 20.–Aerial view of upper members of the Twin Creek Limestone thrust and overturned against lower members of Preuss Formation on Meade Thrust Fault, south of Crow Creek in sections 28, 29, 31, and 32, T. 9 S, R. 46 E, Idaho.

The Boulder Creek Anticline, the only fold exposed on the Meade Plate in the mapped area, is the westernmost fold in the Elk Valley Quadrangle (plate 1). The axis of this anticline lies west of the mapped area. The fold is overturned toward the east in the Snowdrift Mountain (Cressman 1964, p. 66–67), Sage Valley, and Elk Valley Quadrangles. Flank dips along the overturned eastern limb in the latter quadrangle range between 39° and 64°.

The only normal fault in the Meade Plate in the study area occurs south of Crow Creek, in section 31, T. 9 S, R. 46 E, and section 6, T. 10 S, R. 46 E. The fault places Member E (?) of the Preuss Sandstone against the Leeds Creek Member of the Twin Creek Limestone. The fault is considered to be a normal fault because Preuss Sandstone has been dropped down against nonoverturned Twin Creek Limestone beds.

Structure of the Absaroka Plate in the Elk Valley Quadrangle

The Absaroka Plate occurs below the Meade Plate and covers most of the Elk Valley Quadrangle. Formations exposed on the plate within the quadrangle range from Upper Jurassic Twin Creek Limestone through Lower Cretaceous Bechler Conglomerate of the Gannett Group (plate 1). A discussion of individual folds and faults found in this part of the mapped area follows. Names of folds originally designated by Mansfield (1927, plate 7) have been retained. New names are here applied to previously undesignated folds (plate 1).

Red Mountain Syncline

The Red Mountain Syncline is the westernmost fold of the Absaroka plate in the Elk Valley Quadrangle. The syncline trends northeastward across the western border of the mapped area (plate 1). The north end of the fold is cut by the Camel Hollow Fault (plate 1). The Red Mountain Syncline is narrow and asymmetric north of the Camel Hollow Fault. Dips average 15° on the west flank and 27° on the east flank (plate 1). The west flank dips approximately 150 m/km, and the east flank about 370 m/km. The fold broadens south of the fault where the east flank has an average dip of 35° or approximately 410 m/km. Rocks of Member C of the Stump Sandstone are preserved in the axial trough north of the Camel Hollow Fault, and beds from Member A (?) of the Bechler Conglomerate are preserved along the axis of the fold south of the fault. Fold width ranges from approximately 2 km to 5.5 km and amplitude ranges from 270 m to 1,100 m, from north to south across the Elk Valley Quadrangle. The Red Mountain Syncline plunges southward at approximately 150 m/km (fig. 21).

Elk Valley-Sublette Anticline

The Elk Valley portion of the Sublette Anticline trends northward across the quadrangle to where it is terminated by the Meade Thrust Fault trace. The anticline is offset by the Camel Hollow Fault (plate 1).

The Elk Valley Anticline is a broad fold throughout its exposure in the mapped area. However, it narrows south of Elk Valley. The fold is nearly symmetrical (plate 1, section B-B'). Flank dips on the fold average 40° on the west, and 35° on the east (plate 1), or 410 m/km on the west and 230 m/km on the east. Member A of the Preuss Formation is the oldest unit exposed in the core of the anticline. Maximum fold width is 8.2 km and amplitude is 1.25 km (fig. 21). The Elk Valley Anti-

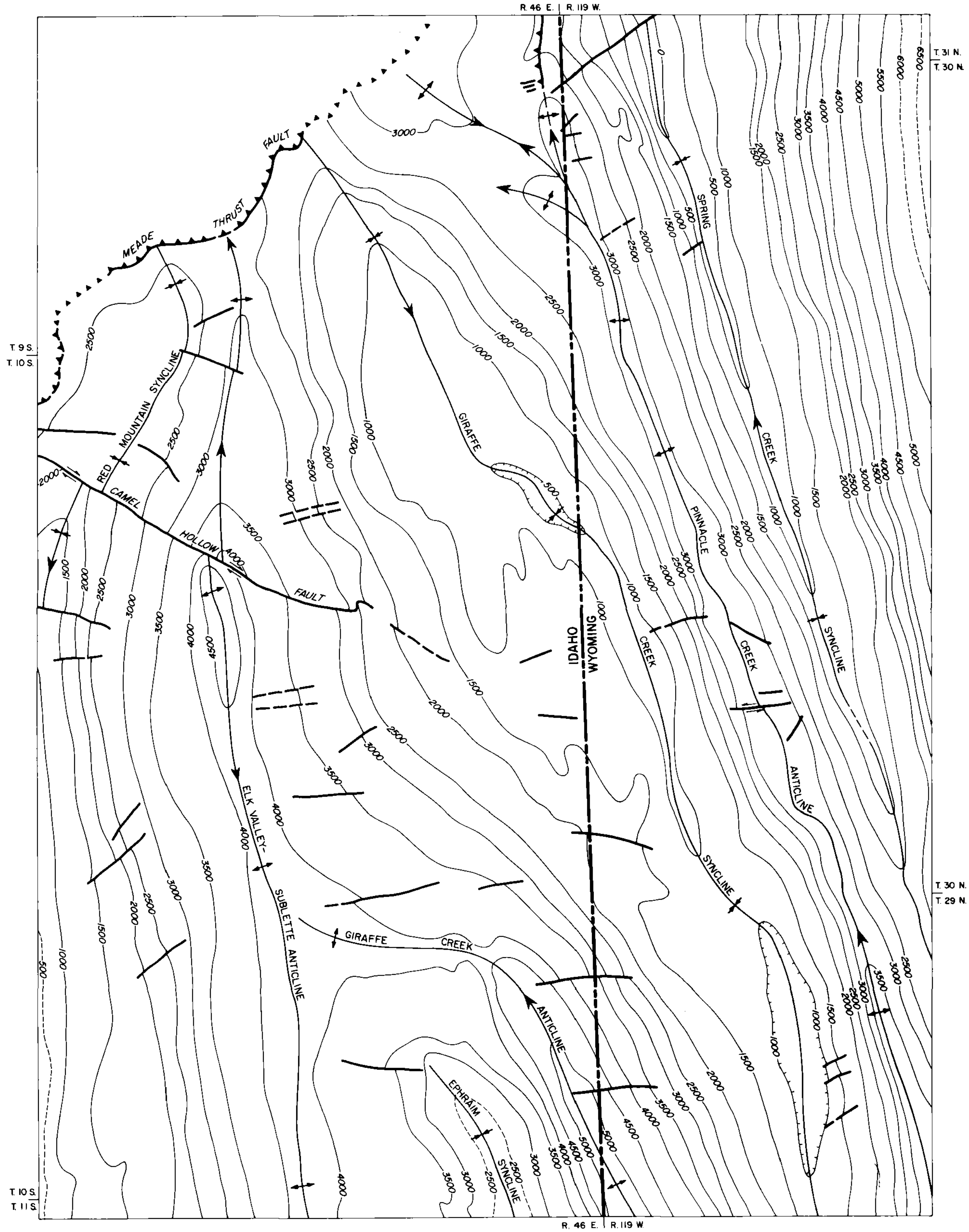

FIGURE 21.–Structure contour map of Elk Valley Quadrangle. Contours are on top of Nugget Sandstone at 500 ft (152.5 m) intervals.

cline plunges northward on the north side of the Camel Hollow Fault at 145 m/km or an average of 10°. The fold plunges 30 m/km, or 2°, southward from a culmination a short distance south of the Camel Hollow Fault (fig. 21).

Ephraim Syncline

The Ephraim Syncline, named here, has the shortest axial length of any major fold exposed in the Elk Valley Quadrangle. It is traceable southeastward from the northwest quarter of section 34, T. 10 S, R. 46 E (plate 1), to immediately across the southern border of the mapped area in section 3, T. 11 S, R. 46 E, on the Giraffe Creek Quadrangle (Mansfield 1927, plate 9).

Member A of the Ephraim Conglomerate is preserved in the trough of the Ephraim Syncline. The fold is narrow, and its axial plane dips to the east. Flank dips on the fold average 32° on the west and 41° on the east, or 260 m/km on the west and 780 m/km on the east. Maximum fold width is 3.3 km, and the fold is 600 m high across the southern half of section 34, T. 10 S, R. 46 E (fig. 21).

Giraffe Creek Anticline

The Giraffe Creek Anticline, named here, extends northwestward across the southern border of the mapped area to Elk Valley (plate 1). The axis swings to west-northwest in the northern half of section 27, T. 10 S, R. 46 E. This anticline is a branch of the Elk Valley-Sublette Anticline and, like the Ephraim Syncline, has a short length when compared to other folds in the Elk Valley Quadrangle. Mansfield (1927, plate 9) traced the axis of this anticline southward to section 19, T. 29 N, R. 119 W on the Giraffe Creek Quadrangle.

The Giraffe Creek Anticline is a tight, narrow fold throughout its length. Dips on the anticline average 40° on the west flank and 35° on the east flank (plate 1), or 780 m/km on the west and 560 m/km on the east. Member A of the Preuss Sandstone is exposed along the core of the fold. Fold width and amplitude average 3.5 km and 1.3 km, respectively, in the mapped area. The fold plunges 4°, or 63 m/km, to the north (fig. 21).

Giraffe Creek Syncline

The Giraffe Creek Syncline is a large fold which extends northward from beyond the southern border of the quadrangle to the Meade Thrust Fault trace (plate 1). The axis of the syncline trends northward from the southern map border to Spring Creek, but then swings northwestward from Spring Creek to the north. The east limb of the Giraffe Creek Syncline is steep, with dips ranging from 42° to 62° (plate 1, section B-B′). The west limb is less steep, with dips ranging between 19° and 42°. The east flank dips 320 m/km, and the west flank dips 230 m/km. The fold is open, and minor second-order folds occur on the major structure, suggesting that it is a minor synclinorium with structural "ripples," particularly on the west flank (fig. 21).

Rocks of Member E of the Bechler Conglomerate are still preserved in the trough of the syncline. They are the youngest beds in the Elk Valley Quadrangle. Fold width and amplitude averages 5.8 km and 0.8 km across the widest section of the fold (fig. 21). The syncline plunges southward in the northern part of the quadrangle at 130 m/km, or an average of 7°. The fold does not plunge measurably in the southern part of the quadrangle (fig. 21).

Pinnacle Creek Anticline

The Pinnacle Creek Anticline, named here, extends from the southeast corner of the mapped area to the Meade Thrust Fault (plate 1). The axis trends north-northwest through the central and southern portion of the mapped area but changes to west-northwest in sections 26 and 35, T. 9 S, R. 46 E. The anticline is narrow and tightly folded (plate 1, section B-B′). Where the fold trend changes, the structure widens, and dips become less on both flanks but most notably on the western part of the fold (plate 1, section A-A′). Dips south of the change in axial trend average 53° on the west flank and 40° on the east flank. The dips lessen north of the change in trend. Overall, the anticline dips 700 m/km on the west flank and 580 m/km on the east flank.

Rocks of Member A of the Stump Sandstone are exposed along most of the axis of the Pinnacle Creek Anticline. However, the Preuss Formation cores the fold at the north end of the anticline, south of Crow Creek Valley. Fold width and amplitude decrease, from north to south, from 3.5 km to 1.7 km and from 900 m to 300 m, respectively (fig. 21). The fold plunges northward at an average of 16 m/km, or 1°, for a 1,500-m section at the northern exposed end of the fold which plunges gently to the south (fig. 21). The south central end of the Pinnacle Creek Anticline is cut by a left-lateral tear fault (plate 1).

Spring Creek Syncline

The Spring Creek Syncline extends across the mapped area from the eastern border to the northern border and on northward into the Sage Valley Quadrangle (plate 1). This fold has a north-northwest trend across the quadrangle. The west limb of the syncline is steep, with dips averaging 68° (plate 1, section A-A′). The east limb dips average 50°. The fold flanks dip 580 m/km on the west and 540 m/km on the east.

Rocks of Member D of the Bechler Conglomerate are preserved in the axial trough of the Spring Creek Syncline. Outcrop patterns of the resistant conglomerate units at the bases of members D, C, and B show east and west dips and define the trough of the syncline across the quadrangle (fig. 22). Fold

FIGURE 22.–Spring Creek Syncline axis defined by resistant conglomerate unit, center, at base of member B of Bechler Conglomerate. Photo location is NW ¼, section 4, T. 29 N, R. 119 W, Wyoming.

width and amplitude average 4.6 km and 900 m, respectively, across the widest parts of the fold. The fold plunges northward at an average of 55 m/km (fig. 21).

Afton Anticline

Only the western flank of the Afton Anticline is exposed in the Elk Valley Quadrangle. This anticline is the easternmost fold in the mapped area and its axis trends north-northwest, parallel to the Spring Creek Syncline but just east of the quadrangle border. Long (1960, p. 188) reported that the axial plane migrates markedly to the west in the subsurface.

Rocks of the Watton Canyon Member (?) of the Twin Creek Limestone are exposed in the core of the Afton Anticline, east of the quadrangle border. The Leeds Creek and Giraffe Creek Members of the Twin Creek are exposed on the flank of the structure in the mapped area. The anticline is almost completely outlined by the Preuss Sandstone (Long 1960, p. 187).

Faults

Tear Fault. Two tear faults are differentiated on the geologic map (plate 1). The southeast-trending Camel Hollow Fault is located in sections 6–9, 15, and 16 of T. 10 S, R. 46 E. It is a right lateral fault, and it offsets the axes and flanks of the Red Mountain Syncline and the Elk Valley-Sublette Anticline approximately 250 m. The fault terminates in a fold in the southeast part of section 9, T. 10 S, R. 46 E (fig. 23), and dies out laterally in sections 15 and 16, T. 10 S, R. 46 E. Strike-slip motion on the fault is indicated by right lateral displacement of Members B and D of the Preuss Sandstone on both flanks of the folds.

A second tear fault was delineated in section 29, T. 30 N, R. 119 W. This east-trending fault has left lateral motion and offsets beds of Members A and C of the Stump Sandstone on both flanks of the Pinnacle Creek Anticline. Displacement along the fault is approximately 35 m.

Armstrong and Cressman (1963, p. 19) stated that this type of tear fault is related to eastward movement of "blocks" within the thrust plates during faulting. Failure can also occur with a tearing motion near thrust faults (Armstrong and Cressman 1963, p. 19).

Transverse Faults. The direction and amount of displacement on most of the faults in the Elk Valley Quadrangle is difficult to determine. The majority of these faults probably have a tear or strike-slip motion, similar to that of the two tear faults previously described. However, because these faults do not show displacement across both limbs of folds and because horizontal slickensides were rarely observed, they are designated here as transverse faults. Map patterns suggest that these faults dip at high angles (plate 1, section B-B′). Such transverse faults occur throughout the quadrangle in two different systems. One system trends east-west and the other trends southwest-northeast. These faults are due to minor intrablock movement during thrusting. A good exposure of this type of fault occurs in section 14, T. 10 S, R. 46 E, on the west flank of the Giraffe Creek Syncline (fig. 24). Estimated horizontal displacement on the fault is 50 m. Vegetation patterns help delineate some of these faults at the surface. Vegetation growth and a dip slope, with rock of the Stump Sandstone Member A exposed in the bedding plane, define the transverse fault in the southern half of section 16, T. 10 S, R. 46 E (fig. 25).

Normal Faults. Most of the faults within the Elk Valley Quadrangle are treated as transverse faults for reasons cited above. However, there are a few normal faults in the mapped area. One normal fault mapped in sections 33 and 34, T. 10 S, R. 46 E (plate 1), trends west-northwestward and has a trace length of approximately 1,000 m. It is downthrown to the north. Reported displacement of the fault is between 130 and 170 m (Newcomb 1967, p. 270).

FIGURE 23.—Camel Hollow Fault as it terminates in fold east of Elk Valley in SE ¼, section 9, T. 10 S, R. 46 E, Idaho. Resistant beds are member A of Stump Sandstone.

FIGURE 24.—High-angle transverse fault on west flank of Giraffe Creek Syncline in section 14, T. 10 S, R. 46 E, Idaho. Estimated horizontal displacement is 50 m.

FIGURE 25.–Vegetation pattern defining transverse fault east of Elk Valley in S ½, section 16, T. 10 S, R. 46 E, Idaho.

Thrust Faults. A minor thrust fault, which terminates southward into an anticlinal fold, occurs in sections 22, 23, 26, and 27, T. 9 S, R. 46 E (plate 1). Although the fault has limited exposure in the mapped area, it was mapped through the entire length of the Sage Valley Quadrangle to the north (John Conner personal communication 1980). The axis of the minor anticline trends to the south where it terminates in homoclinal dips in Member E of the Preuss Sandstone.

GEOMORPHOLOGY

Valleys and Other Landforms

The three major valleys in the mapped area (plate 1) are Crow Creek Valley, Elk Valley, and the valley of Spring Creek. Crow Creek Valley crosses through the northwest quarter of the mapped area. Valley width ranges from 0.5 to 1.5 km. The valley is eroded along the Meade Thrust Fault trace where rocks have been crushed and shattered.

Elk Valley is located in the southwest quarter of the thesis area. The width of the valley ranges between 0.4 and 1.3 km. Erosion of nonresistant Preuss beds in the breached core of the Elk Valley Anticline formed this valley.

Spring Creek flows across the southern and eastern parts of the quadrangle. The valley of Spring Creek varies from 50 to 250 m wide. North of the "elbow of Spring Creek," the creek flows in a subsequent valley cut along less resistant beds in the Bechler Conglomerate.

A pinnacle and several hogbacks are also significant landforms in the Elk Valley Quadrangle. The Pinnacle, named by Mansfield (1927, plate 7), is a rock column located in the southwest quarter of section 31, T. 30 N, R. 119 W. This pillar-shaped column is one of the higher points of the quadrangle, with a summit elevation slightly above 2,550 m above sea level. The Pinnacle is held up by a resistant, conglomerate unit at the base of Member D of the Bechler Conglomerate.

Several hogbacks held up by Member A, the resistant member of the Stump Sandstone, are traceable across the mapped area. Many of these resistant ridges are continuous for long distances along flanks of folds of the quadrangle. Ledges as high as 15 m were observed on some of the most prominent Stump Sandstone hogbacks, such as those along the Red Mountain Syncline, Pinnacle Creek Anticline, and Spring Creek Syncline (fig. 11).

Alluvial Fans

Alluvial fans are developed throughout the Elk Valley Quadrangle (plate 1). The majority of the large fans in the mapped area occur at the mouths of tributaries into Elk Valley and Crow Creek Valley. The largest alluvial fan in Elk Valley is located in the center of section 28, T. 10 S, R. 46 E. It measures approximately 610 m, from apex to base, and 700 m across the base. The largest fan in Crow Creek Valley in the mapped area occurs in the southwest quarter of section 22, T. 9 S, R. 46 E. The fan measures about 520 m from apex to base, and 230 m across the widest part of the base.

Landslides

Four landslides have been mapped in the Elk Valley Quadrangle (plate 1). Two of them cover large areas, but the other two are rather small. The largest landslide is located in sections 27 and 28, T. 10 S, R. 46 E (fig. 17). The landslide mass, which measures 850 m by 460 m, probably dammed up Spring Creek and created a shallow lake in Elk Valley. Landslide debris is still preserved on both sides of Spring Creek. Following movement and damming, lake level rose high enough for water to spill over the dam and cut through the slide debris. A second, smaller landslide also occurs along Spring Creek. This slide, located in sections 6 and 7, T. 29 N, R. 119 W, probably had a minimal effect on the flow of water down Spring Creek because of its small, 240 m by 200 m, dimensions.

The other large landslide is located in the northern half of section 31, T. 10 S, R. 46 E. Most of the debris of this landslide is located just outside the mapped area on the Snowdrift Mountain Quadrangle, but the arcuate, scarred, upland source area is within the present mapped area.

The fourth landslide in the quadrangle is in the northeast quarter of section 3, T. 10 S, R. 46 E. It is small in relation to the other three slides in the quadrangle.

ECONOMIC GEOLOGY

Hydrocarbons

Oil and gas exploration in the overthrust area of Idaho and Wyoming started in the early 1900s (Hodgden and McDonald 1977, p. 37). Some major discoveries within the last five years south of the present map area have brought seismic crews and drilling rigs to the thrust belt for renewed exploration.

Five oil and gas wells have been drilled in or near the Elk Valley Quadrangle. In 1948, Continental Oil Company drilled the Afton Unit No. 1 on the Afton Anticline, approximately 1,200 m east of the mapped area, in the northwest quarter of section 15, T. 30 N, R. 119 W. The well spudded into Twin

Creek Limestone and was plugged and abandoned at a depth of 1,550 m in the Thaynes Limestone (Long 1960, p. 188). Continental Oil Company drilled a second well on the Afton Anticline, the Afton Unit No. 2, in 1949, again just east of the quadrangle. That well is located in the northwest quarter of section 9, T. 30 N, R. 119 W. It was also spudded into Twin Creek beds and was plugged and abandoned at a depth of 2,204 m in the Dinwoody Formation (Long 1960, p. 180). Both wells encountered vertical dips near the bottom of the hole (Long 1960, p. 188).

The three wells within the mapped area were all drilled on the Elk Valley-Sublette Anticline. In 1963, Amerada Corporation drilled the No. 1 USA-Wild well, located in the northwest quarter of section 28, T. 10 S, R. 46 E. It was spudded into Preuss Formation and bottomed out in the Nugget Sandstone at a depth of 1,254 m (Newcomb 1967, p. 270). A dipmeter test of the dry well showed 21° dips to the east-northeast from the surface to total depth (Newcomb 1967, p. 270). Two gas shows from the Twin Creek were recorded on the gas chromatograph, but analysis of well cuttings and electrical logs indicated low porosity and permeability in the Twin Creek beds. Drill stem tests were taken only in the Nugget Sandstone, and 610 m (2,000 ft) of salty water were recovered (Newcomb 1970, p. 270).

In 1976, May Petroleum Inc. spudded the No. 1 Federal-Elk Valley well in the southeast quarter of section 20, T. 10 S, R. 46 E. Gas-cut mud was recovered from the Twin Creek Limestone during a drill stem test, but it was concluded that the structural seal was not sufficient to hold the gas within the structure (Lyle Hale personal communication 1980). The hole was spudded into Preuss Sandstone and was plugged and abandoned at 1,197 m in Nugget Sandstone. In 1977, May Petroleum Inc. drilled the May Federal 1-8 well in the northwest quarter of section 8, T. 10 S, R. 46 E. The well was drilled to a depth of 5,105 m. It spudded into Preuss Sandstone and was plugged and abandoned in the Dinwoody Formation. The Thaynes and Woodside Formations were repeated. Gas was recovered from three different formations during drill stem tests in the well. Approximately 29 m (95 ft) of gas-cut mud were recovered from a 0.3-m interval of the Gypsum Springs Member of the Twin Creek Limestone; 180 m (592 ft) of gas-cut water and a trace of gas were recovered from a 3.65-m interval in the Nugget Sandstone; and 24,620 m^3 (265,000 ft^3) of gas and a trace of oil flowed from a 10.7 m interval in the Thaynes Formation. A rapid decline of pressure at this interval indicated a limited reservoir (Lyle Hale personal communication 1980).

Unpublished formation tops from the No. 1 Federal-Elk Valley well were used in construction of cross-secton B-B′ of plate 1. Information from the May Federal 1-8 well was also used. Formation repetition below Elk Valley and thickening of the Stump, Preuss, and Twin Creek Formations across the mapped area make it appear that the structure below Elk Valley may not be as simple as shown in cross section B-B′ (plate 1) or on the structure contour map (fig. 22). However, the surface geology, in combination with subsurface seismic data, could be very helpful in determining more about the Elk Valley Anticline. Hydrocarbon exploration should be continued on the Elk Valley structure, and future drilling should explore both the Absaroka plate and possibly the plate below. Further testing of the Afton Anticline may also be warranted.

Phosphate Deposits

Phosphate from the Meade Peak Member of the Phosphoria Formation has been the base of the dominant mineral industry in southeastern Idaho since the early 1900s, when phosphatic rocks were discovered approximately 15 km southwest of the Elk Valley Quadrangle (Weeks and Ferrier 1907, p. 449). Abundant phosphate reserves are located on the Meade Plate west of the study area (Cressman 1964, p. 96–97), where the Phosphoria is exposed or underlies the major synclines. The phosphate potential of the Elk Valley Quadrangle is low, however, because these rocks are deeply buried. One minor outcrop of the Meade Peak Member occurs in sections 19 and 30, T. 9 S, R. 46 E.

Other Deposits

There are no active quarries for road metal, gravel, or other construction materials within the Elk Valley Quadrangle at the present time. Should the need arise, however, road metal could be quarried from Twin Creek Limestone and Stump Sandstone outcrops from a few sites within the mapped area. Two road metal quarries of fractured Twin Creek Limestone are operated sporadically in the Sage Valley Quadrangle to the north (John Conner personal communication 1980). The best quarry sites in the mapped area are along outcrop belts where they are crossed by roads southeast of Crow Creek Valley, east of Spring Creek Valley, and west of Elk Valley.

The Old Salt Works (fig. 18) and other salt deposits in surrounding areas were utilized until the early 1900s. The Old Salt Works is located in the Kennington Ranch in section 28, T. 9 S, R. 46 E. The mine, which was used in early operations, is still open at the surface (fig. 26) but is flooded. None of these deposits are being worked at the present time.

CONCLUSIONS

The Meade Thrust Fault is exposed across the northwest corner of the quadrangle. The fault zone separates the mapped area into the upper Meade Plate and the lower Absaroka Plate. Smaller imbricate thrust faults, overturned beds near the fault traces, and salt springs aligned along the exposed or buried fault traces are expressions of the fault zone in the mapped area. Stratigraphic relations within the quadrangle date movement on the Meade Thrust Fault as post-Bechler Conglomerate (Early Cretaceous) and pre-Salt Lake Formation (Pliocene ?). Evidence from surrounding areas dates faulting as Late Cretaceous to Tertiary, possibly Paleocene.

FIGURE 26.—Flooded mine shaft used to mine salt at Old Salt Works in early 1900s.

The Meade Plate exposes many incomplete formations because of faulting along the thrust zone. These formations range from the Pennsylvanian (?) Wells Formation through the Upper Jurassic Preuss Sandstone. Tertiary Salt Lake Formation unconformably overlies Twin Creek Limestone, Nugget Sandstone, and Thaynes, Dinwoody, Phosphoria, and Wells Formations on the plate. The east flank of the Boulder Creek Anticline, the imbricate thrust slices that place older rocks on top of younger rocks eastward across the northwest corner of the mapped area, and a normal fault are the principal structural elements of the plate.

Rocks of the Absaroka Plate cover most of the Elk Valley Quadrangle. Exposed formations on the plate range from Upper Jurassic Twin Creek Limestone through Lower Cretaceous Bechler Conglomerate. Eight major north-south-trending folds, two tear faults, numerous high-angle transverse and normal faults, and a minor thrust fault, which terminates southward into a small fold, are the dominant structures of the plate.

All the Cretaceous rocks in the Elk Valley Quadrangle were previously mapped as Ephraim Conglomerate of the Gannett Group by Mansfield, but Peterson Limestone and Bechler Conglomerate have been differentiated in the Gannett Group outcrops. The Peterson Limestone thins and is mappable as more or less continuous lenses from the northern map border to the south and subdivides the Gannett rocks.

Three oil wells have been drilled in Elk Valley. Shows of gas-cut mud were observed in two of the wells, and limited amounts of gas-cut mud, gas-cut water, and gas flowed in one of the wells during drill stem testing. Further exploration should be continued on the Elk Valley structure.

A paleontological study of the Twin Creek Limestone and Thaynes Formation is recommended. A study of conodonts, in particular, would help to properly identify the "slice" of Thaynes Limestone that crops out in the northwest corner of the mapped area. Detailed stratigraphic studies of the Preuss Sandstone, Stump Sandstone, Twin Creek Limestone, or Thaynes Formation should also be done. Detailed measured sections would help describe the westward thickening of the Preuss, Stump, and Thaynes beds across the thesis area. A geophysically oriented study, using well control from the five oil wells in or near the quadrangle, would be a valuable study because it would combine known surface data with subsurface information. Porosities and permeabilities of formations with known reservoir rocks in or nearby the Elk Valley Quadrangle could be analyzed. It is also felt that studies concerning petrology, source areas, current direction, and mineral deposition (including road metals and salt) could be undertaken in the mapped area to further enhance the work that has been completed.

APPENDIX

Measured Sections

Section 1

Partial section of the Grandeur Tongue of the Park City Formation, Wells Formation measured on the north side of Pole Creek, 1.0 km west of Sage Valley, in the SW ¼ of section 31, T. 8 S, R. 46 E, Caribou County, Idaho.

Unit	*Description*	*Thickness (meters)*	*Cumulative Thickness (meters)*
	Grandeur Tongue of the Park City Formation		
12	Dolomite: medium gray, weathers light gray; very finely crystalline; blocky; ledge former. Top not exposed.	6.7	245.0
	Top of Wells Formation, Upper Member and Base of Park City Formation		
11	Sandstone; light tannish gray, weathers tan; calcareous, fine grained, porous, friable; blocky, massively bedded; slope former; unit partially covered.	35.9	238.3
10	Limestone (?): light to medium gray, weathers light gray; sandy; vugs up to 1.3 cm across compose up to 5% of the volume; massively bedded; ledge former.	13.0	202.4
9	Covered: brown soil.	42.1	189.4
8	Sandstone: yellowish white, weathers light yellowish gray; fine grained, well sorted, slightly friable, calcareous, porous; massively bedded; slope former.	31.6	147.3
7	Sandstone: light gray, weathers tannish brown; very fine grained, hard, calcareous; massively bedded; shoulder former.	19.8	115.7
6	Sandstone: light gray, weathers brownish red; very fine grained, well cemented, calcareous; massively bedded; ledge former grading to cliff former in the upper 5.8 m.	27.6	95.9
5	Sandstone: medium gray, weathers light gray; very fine grained, very well cemented; vugs up to 2.5 cm across contain calcite; irregular fractures not oriented; massively bedded; ledge former. Chert increases and becomes massively bedded at the top of the unit.	20.5	68.3
4	Sandstone: light gray, weathers reddish brown to gray; fine grained, calcareous, slightly friable; up to 15% porosity in cross-bedded portions; flecks of mafic materials; massively bedded; ledge former.	3.8	47.8
3	Sandstone: medium gray, weathers light gray; very fine grained, very well cemented by silica, slightly calcareous; massively bedded; shoulder former.	7.9	44.0
2	Sandstone: very light gray to light gray, weathers brownish gray; slightly calcareous, very fine grained, well cemented, well sorted; massively bedded; shoulder former.	13.7	36.1
1	Covered: brown soil.	22.4	22.4
	Section ends at an unknown stratigraphic distance above the base of the upper member, Wells Formation.		
	Exposed thickness of Grandeur Tongue of the Park City Formation, and the upper member, Wells Formation 245.0 m.		

Section 2

Partial section of the Twin Creek Limestone, Giraffe Creek and Leeds Creek Members, measured 0.4 km south of First Creek (a west-flowing tributary of Spring Creek), in the SW ¼ of section 4 , T. 31 N, R. 119 W, Lincoln County, Wyoming.

Unit	*Description*	*Thickness (meters)*	*Cumulative Thickness (meters)*
	Bottom of Preuss Sandstone–top of Twin Creek Limestone.		
	Giraffe Creek Member		
11	Covered: upper contact is at change of float from greenish gray to reddish brown sandstone.	11.5	149.4

10	Sandstone: greenish gray, weathers olive gray; slightly calcareous, fine grained; ledge former.	9.5	137.9
9	Sandstone: medium tan, weathers light tan; slightly calcareous, fine to medium grained, medium hard; thin to massively bedded; ledge former.	4.2	128.4
	Total thickness of Giraffe Creek Member, Twin Creek Limestone 25.2 m.		
	Leeds Creek Member		
8	Limestone: medium gray, weathers light gray; fissile in places; thin to massively bedded; ledge former.	4.2	124.2
7	Covered: float of shaly limestone and sandstone: very light gray, weathers brownish light gray; medium grained, calcareous.	70.3	120.0
6	Limestone: medium gray, weathers light gray; very fine grained; thin bedded; slope former.	0.5	49.7
5	Covered: shaly limestone float.	12.9	49.2
4	Limestone: light to medium gray, weathers light gray; very fine grained; thin to massively bedded; slope to ledge former.	2.4	36.3
3	Covered: shaly limestone float.	11.7	33.9
2	Limestone: light to medium gray, weathers light gray; fissile, very fine grained; slope to ledge former.	3.3	22.2
1	Covered: shaly limestone float in the upper part of the member. Base not exposed.	18.9	18.9
	Section ends at an unknown distance above the base of the Leeds Creek Member.		
	Exposed partial thickness of Leeds Creek Member, Twin Creek Limestone 124.2 m.		
	Exposed thicknesses of the upper Twin Creek Limestone 149.4 m.		

Section 3

Section of the Preuss Sandstone measured 0.8 km south of First Creek (a west-flowing tributary of Spring Creek) in the SW ¼ of section 4, T. 31 N, R. 119 W, Lincoln County, Wyoming.

Unit	*Description*	*Thickness (meters)*	*Cumulative Thickness (meters)*
	Bottom of Stump Sandstone–top of Preuss Sandstone.		
25	Covered: contact is at the change from reddish brown to olive gray sandstone float.	74.2	344.3
24	Sandstone: pinkish red, weathers brownish red; medium grained, slightly calcareous; thin bedded; ledge former.	1.7	270.1
23	Covered.	15.4	268.4
22	Sandstone: reddish brown, weathers pinkish brown; calcareous, medium grained, medium hard; massively bedded; ledge former.	0.8	253.0
21	Covered.	5.3	252.2
20	Sandstone: light brown to very light gray, weathers to tannish brown; calcareous, medium grained, thin bedded; ledge former.	1.6	246.9
19	Covered.	11.7	245.3
18	Sandstone: reddish brown; medium grained; massively bedded; slope former.	0.5	233.6
17	Covered.	8.6	233.1
16	Sandstone: reddish brown, weathers brownish red; medium grained; thin to massively bedded; slope to ledge former.	0.5	224.5
15	Covered.	35.5	224.0
14	Sandstone: reddish brown, weathers light red; slightly calcareous, medium grained, medium hard; thin to massively bedded; slope to ledge former.	0.5	188.5
13	Covered.	9.7	188.0
12	Sandstone: reddish brown, weathers light red; slightly calcareous, medium grained, medium hard; thin bedded; slope to ledge former.	0.5	178.3
11	Covered.	3.3	177.8
10	Sandstone: reddish brown, weathers light red; calcareous, medium grained, medium hard; slope to ledge former.	0.3	174.5
9	Covered.	36.2	174.2
8	Sandstone: reddish brown, weathers brown; calcareous, medium grained with interbedded silty layers, medium hard; slope to ledge former.	0.6	138.0
7	Covered with float of sandstone: brownish red; calcareous, fine to medium grained, medium hard.	43.7	137.4
6	Sandstone: reddish brown, weathers brown; calcareous, fine to medium grained, medium hard; slope to ledge former.	0.7	93.7
5	Covered.	5.1	93.0
4	Sandstone: pinkish red; slightly calcareous, medium grained, medium hard; thin to medium bedded; ledge former.	1.6	87.9
3	Covered.	42.0	86.3
2	Sandstone: reddish brown, weathers brown; calcareous, fine grained, moderately well sorted, medium hard; medium bedded; ledge former.	0.5	44.3
1	Covered: contact is at change from very light gray to reddish brown float at the base of the unit.	43.8	43.8
	Bottom of Preuss Sandstone–top of Twin Creek Limestone.		
	Total thickness of the Preuss Sandstone 344.3 m.		

Section 4

Section of the Stump Sandstone measured 1.6 km north of First Creek (a west-flowing tributary of Spring Creek) in the N ½ of section 32, T. 31 N, R. 199 W, Lincoln County, Wyoming.

Unit	*Description*	*Thickness (meters)*	*Cumulative Thickness (meters)*
	Bottom of Ephraim Conglomerate–top of Stump Sandstone.		
11	Covered: float is typical of Stump Sandstone. Contact is at change from medium or olive gray to brownish red sandstone float.	36.5	190.1
10	Sandstone: medium gray, weathers to light brown; fine grained, calcareous, glauconitic; shoulder former.	4.4	153.6
9	Covered.	72.3	149.2
8	Sandstone: light gray; friable, well sorted, argillaceous; asymmetric ripple marks (current direction		

	from the northeast), thin bedded, ledge former	13 1	76 9
7	Sandstone light gray to olive brown, weathers light brown, calcareous glauconitic, friable, minor cross-bedding, thin to massively bedded, ledge former	12 8	63 8
6	Covered slope with float of sandstone light grayish green, weathers light olive gray, fine grained, calcareous, moderately well sorted, argillaceous, cross-laminated	25 6	51 0
5	Covered	7 9	25 4
4	Limestone medium gray, weathers light or olive brown, sandy, siliceous (?), with some cross-bedded laminae weathered into relief, ledge former	2 7	17 5
3	Limestone dark to medium gray, weathers olive brown, sandy, cross-bed sets up to 7 6 cm high, flaggy, blocky bedded, slope former	5 4	14 8
2	Limestone similar to unit 3, but less flaggy and sandy, ledge former	2 7	9 4
1	Covered contact is at change from olive gray to reddish brown float at the base of the unit	6 7	6 7
	Bottom of Stump Sandstone–top of Preuss Sandstone		
	Total thickness of the Stump Sandstone 190 1 m		

Section 5

Partial section of the Gannett Group (Ephraim Conglomerate, Peterson (?) Limestone, and Bechler Conglomerate) measured 3 2 km east of Elk Valley, 1 2 km north of Spring Creek, in the NW ¼ of section 5, T 29 N, R 119 W, Lincoln County, Wyoming Section 6 of figure 13

Unit	*Description*	*Thickness (meters)*	*Cumulative Thickness (meters)*
	Bechler Conglomerate		
	Section ends within the upper part of the Bechler Conglomerate on the Giraffe Creek Syncline axis		
20	Conglomerate reddish gray, weathers reddish brown, contains black, gray, brown, red, and tan chert pebbles and cobbles from 0 1 to 20 3 cm across and limestone pebbles and cobbles up to 22 9 cm across, cliff former	14 9	501 5
19	Covered reddish brown soil with reddish brown conglomerate float from unit 20	29 0	486 6
18	Sandstone reddish brown, weathers brown, medium grained, cherty, calcareous, thin bedded, slope former	1 8	457 6
17	Covered reddish brown soil	41 2	455 8
16	Sandstone reddish brown weathers to brown	0 2	414 6
15	Conglomerate reddish brown, weathers grayish brown, contains red, gray, brown, and tan chert fragments and pebbles from 0 1 to 6 4 cm across, ledge former	2 6	414 4
14	Covered reddish brown soil with gray brown conglomerate float	13 2	411 8
13	Conglomerate reddish gray, weathers reddish brown, fine to medium grained at base of unit with coarser fragments in the upper layers, contains black, gray, brown, and red chert fragments and pebbles from 0 1 to 12 7 cm across the limestone cobbles up to 12 7 cm across, ledge to cliff former	18 1	398 6
12	Covered reddish brown soil with chert fragments	65 9	380 5
11	Conglomerate purplish gray, weathers gray, contains black, gray, brown, red, and yellow chert fragments from 0 3 to 1 9 cm across and limestone pebbles up to 3 8 cm across, ledge former	1 9	314 6
10	Covered reddish brown soil	59 5	312 7
9	Conglomerate purplish gray, weathers darker, contains brown, gray, and yellow chert fragments from 0 3 to 2 5 cm across and limestone pebbles up to 5 1 cm across, ledge former	1 7	253 2
8	Sandstone brownish red, weathers brown, medium grained, medium hard, thin bedded, slope former	0 3	251 5
	Preserved partial thickness of the Bechler Conglomerate greater than 250 3 m		
7	Covered reddish brown soil with brown sandstone float in the upper 20 m The Peterson (?) Limestone is covered in this interval, but probably crops out elsewhere in the upper part of this unit Total thickness of the Peterson is unknown, but is estimated at no more than 14 m	79 6	251 2
6	Conglomerate light gray, weathers medium gray, contains brown and gray chert pebbles from 0 3 to 1 3 cm across, ledge former	5 6	171 6
5	Covered reddish brown soil with float of light gray conglomerate from unit 6	83 0	166 0
4	Sandstone light purplish gray, weathers medium gray, calcareous, medium grained, medium hard, massively bedded, shoulder former	3 2	83 0
3	Covered reddish brown soil with float from Unit 4	35 9	79 8
2	Conglomerate light to medium gray, weathers darker, contains brown and gray chert pebbles from 0 3 to 1 3 cm across, contains sandstone lenses, ledge former	3 2	43 9
1	Covered float consists of reddish brown soil, fine-grained red sandstone, and conglomerate Conglomerate consists of red sandstone matrix with chert particles up to 3 0 mm across	40 7	40 7
	Section ends an unknown distance above the base of the formation in the lower part of the Ephraim Conglomerate		
	Total thickness of the Ephraim Conglomerate less than 251 2 m		
	Partial thickness of the measured Gannett Group 501 5 m		

Section 6

Partial section of the Gannett Group (Ephraim Conglomerate, Peterson (?) Limestone, Bechler Conglomerate) measured 1 2 km north of Second Creek (a west-flowing tributary of Spring Creek), in the N ½ of section 17, T 30 N, R 119 W, Lincoln County, Wyoming Section 5 of figure 13

Unit	*Description*	*Thickness (meters)*	*Cumulative Thickness (meters)*
	Bechler Conglomerate		
	Section ends within the upper part of		

	the Bechler Conglomerate on the Spring Creek Syncline axis.		
26	Sandstone: light grayish white, weathers medium gray; chert and limestone pebbles up to 3.8 cm across; massively bedded; ledge former.	4.3	599.9
25	Covered with float from unit 24.	17.4	595.6
24	Conglomerate: reddish brown, weathers medium gray; chert and limestone pebbles up to 3.8 cm across, massively bedded, ledge former.	10.5	578.2
23	Covered.	46.5	567.7
22	Limestone: medium gray to light bluish gray; very finely crystalline.	7.4	521.2
21	Covered with limestone float from 29.3 to 34.3 m.	34.3	513.8
20	Conglomerate: reddish brown, weathers light to medium gray; chert and limestone pebbles up to 5.1 cm across; massively bedded; ledge former.	5.4	479.5
19	Covered: float from unit 18 covers the lower part of the unit from 190.5 to 195.6 m.	195.6	474.1
18	Limestone: unit similar to unit 22.	2.3	278.5
17	Shale: dark brown, weathers reddish brown; silty; thinly bedded; slope former.	2.7	276.2
16	Covered.	2.7	273.5
15	Sandstone: light reddish gray, weathers medium gray; very fine to fine grained, calcareous; thinly bedded; ledge former.	2.8	270.8
14	Covered: reddish brown soil and float from unit 13.	17.2	268.0
13	Sandstone: unit similar to unit 15 with large particle size (fine to medium grained).	3.5	250.8
	Preserved partial thickness of the Bechler Conglomerate greater than 352.2 m.		
12	Covered. The Peterson (?) Limestone is covered in this interval, but probably crops out elsewhere near the top of this unit. Total thickness of the Peterson is unknown, but estimated at no more than 14 m. Float from unit 11 covers the upper part of this unit.	79.3	247.3
11	Conglomerate: light brownish red, weathers light grayish red; chert and limestone fragments and pebbles up to 5.1 cm across; thinly to massively bedded; ledge former.	6.5	168.0
10	Sandstone: reddish brown, weathers pinkish red; medium grained, calcareous; thinly bedded; shoulder former.	9.9	161.5
9	Conglomerate: unit similar to unit 11 with chert and limestone pebbles up to 2.5 cm across.	2.5	151.6
8	Covered: float from unit 7.	9.1	149.1
7	Limestone: medium to dark gray, weathers whitish gray; very finely crystalline; vugs up to 2.0 cm across may contain calcite; slope former.	13.9	140.0
6	Covered: reddish brown soil and abundant limestone float. Limestone is medium bluish gray, weathers light bluish gray, cherty, very finely crystalline.	25.8	126.1
5	Covered with float from unit 4.	9.2	100.3
4	Conglomerate: reddish brown, weathers medium grayish brown; chert and limestone fragments and pebbles up to 3.8 cm across; massively bedded, ledge former.	7.4	91.1
3	Covered: float from unit 2 found through the upper 19.9 m.	64.5	83.7
2	Conglomerate: reddish brown, weathers dark reddish brown; chert fragments up to 0.33 cm across; thinly to massively bedded; ledge former. Unit contains numerous sandstone lenses of the same color.	6.4	19.2
1	Covered: contact is at change of float from reddish brown and cherty to light olive brown.	12.8	12.8
	Bottom of the Ephraim Conglomerate–*top of the Stump Sandstone.*		
	Total thickness of the Ephraim Conglomerate less than 247.3 m.		
	Partial thickness of the measured Gannett Group 599.9 m.		

Section 7

Partial section of the Gannett Group (Ephraim Conglomerate, Peterson (?) Limestone, Bechler Conglomerate) measured 0.8 km north of First Creek (a west-flowing tributary of Spring Creek), in the NW ¼ of section 5, T. 30 N, R. 119 W, Lincoln County, Wyoming. Section 4 of figure 13.

Unit	*Description*	*Thickness (meters)*	*Cumulative Thickness (meters)*
	Bechler Conglomerate.		
	Section ends within the upper part of the Bechler Conglomerate on the Spring Creek Syncline axis.		
27	Conglomerate: reddish brown, weathers brownish red; chert cobbles up to 20.3 cm across and limestone boulders up to 35.6 cm across; massively bedded; cliff former.	12.8	690.9
26	Covered.	87.1	678.1
25	Conglomerate: reddish brown, weathers brownish red; chert and limestone pebbles up to 7.6 cm across; massively bedded; cliff former.	6.1	591.0
24	Covered: reddish brown soil with sandstone, conglomerate, and limestone float in the upper 30 m. Spring Creek crosses through this interval, and beds are partially covered by the valley shoulders and floor.	132.3	584.9
23	Sandstone: brownish red; very fine grained, calcareous, silty; medium bedded; shoulder former. Some limestone float occurs in this unit.	9.6	452.6
22	Sandstone: similar to unit 23 but lacks limestone float.	32.4	443.0
21	Sandstone: light reddish brown, weathers grayish brown; calcareous, (?) cross-bedded; contains conglomerate lenses with chert fragments up to 1.3 cm across at the base; massively bedded; ledge former.	8.1	410.6
20	Shale: dark brown, weathers reddish brown; silty; thin bedded; slope former. Unit contains limestone float.	20.0	402.5
19	Shale: similar to unit 20 but lacking limestone float.	8.5	382.5

18	Sandstone: similar to unit 21 with conglomerate lenses near the base. There is a 1.5 m sandstone ledge at the top.	15.1	374.0
17	Sandstone: similar to unit 21.	14.5	358.9
16	Sandstone: very light gray, weathers grayish red; fine grained, slightly calcareous; slope former. Unit contains limestone float.	5.2	344.4
15	Sandstone: similar to unit 16 but without limestone float.	19.5	339.2
14	Sandstone: similar to unit 16 with limestone float.	5.1	319.7
13	Sandstone: grayish red, weathers brownish red; fine grained, calcareous, medium hard, cross-bedded; thick bedded; shoulder former.	24.1	314.6
12	Conglomerate: reddish gray, weathers reddish brown; chert fragments up to 2.5 cm across; calcite cement, (?) cross-bedded; massively bedded, ledge former.	12.6	290.5
	Preserved partial thickness of the Bechler Conglomerate 413.0 m.		
	Peterson (?) Limestone–Bechler Conglomerate contact.		
11	Limestone: medium to dark gray, weathers light gray; microcrystalline; slope former. Unit is partially covered by a reddish brown soil. Nodular limestones are possibly interbedded with red siltstone, shale, and mudstone.	15.0	277.9
	Total thickness of the Peterson (?) Limestone 15.0 m.		
	Ephraim Conglomerate–Peterson (?) Limestone contact.		
10	Sandstone: similar to unit 13.	23.2	262.9
9	Covered.	7.2	239.7
8	Sandstone: light reddish gray; fine to medium grained, partly calcareous, cross-bedded; thick bedded; ledge former. Unit contains conglomerate lenses.	24.5	232.5
7	Sandstone: unit similar to unit 13.	31.8	208.0
6	Covered.	14.4	176.2
5	Limestone: medium brownish gray, weathers light bluish gray; very finely crystalline, calcite stringers, siliceous; massively bedded; shoulder former, partially covered.	11.8	161.8
4	Sandstone: light gray, weathers light reddish gray; fine to medium grained with 5% chert pebbles that are up to 0.6 cm across; calcareous, cross-bedded, porous, and very permeable; massively bedded; ledge former.	23.5	150.0
3	Sandstone: similar to unit 4 with limestone float.	17.6	126.5
2	Covered but with some limestone float.	76.3	108.9
1	Sandstone: very light gray, weathers light gray; hard, fine grained, siliceous cement, nonporous; massively bedded; ledge former. Contact is at change of float from very light gray to light olive brown.	32.6	32.6
	Bottom of Ephraim Conglomerate–top of Stump Sandstone.		
	Total thickness of the Ephraim Conglomerate 262.9 m.		
	Partial thickness of the measured Gannett Group 690.9 m.		

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