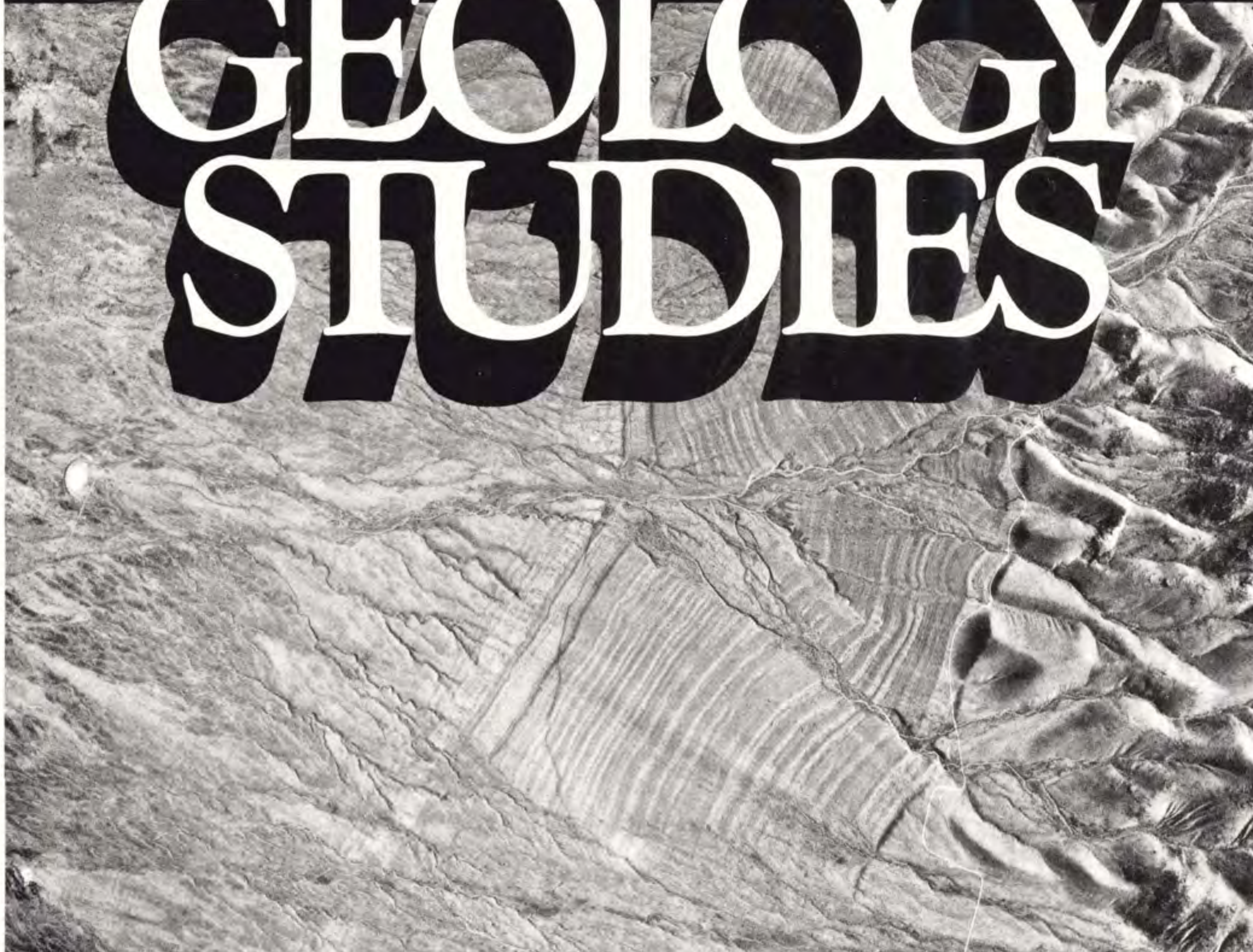
BRIGHAM YOUNG UNIVERSITY

GEOLOGY STUDIES



VOLUME 27, PART 2

NOVEMBER 1980

Brigham Young University Geology Studies

Volume 27, Part 2

CONTENTS

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

A publication of the

Department of Geology

Brigham Young University

Provo, Utah 84602

Brigham Young University Geology Studies is published by the department. *Geology Studies* consists of graduate-student and staff research in the department and occasional papers from other contributors. *Studies for Students* supplements the regular issues and is intended as a series of short papers of general interest which may serve as guides to the geology of Utah for beginning students and laymen.

ISSN 0068-1016

Distributed November 1980

11-80 600 46504

Geology of the Sage Valley 7½′ Quadrangle, Caribou County, Idaho, and Lincoln County, Wyoming*

JOHN L. CONNER
Texaco, Inc.
P.O. Box 2420
Tulsa, Oklahoma 74102

ABSTRACT.—The Sage Valley Quadrangle straddles the Idaho-Wyoming border in the central part of the Overthrust Belt. Approximately 5,400 m of primarily sedimentary strata are exposed, including from the Pennsylvanian Wells Formation through the Tertiary Salt Lake Formation. Rocks within the Cretaceous Gannett Group previously mapped as Ephraim Conglomerate are now known to include Ephraim Conglomerate, Peterson Limestone, Bechler Conglomerate, Draney Limestone, and Smoot Formation. Rocks previously mapped as the Cretaceous Wayan Formation in the quadrangle are now mapped as Smoot Formation and Tygee Member of the Bear River Formation.

Two major thrust sheets, the Absaroka and Meade Plates, are recognized in the quadrangle. Six major imbricate thrust faults, including the West Sage Valley Branch, the East Sage Valley Branch, the West Tygee Branch, the East Tygee Branch, the West Hardman Branch, and the East Hardman Branch, were mapped as well as two minor unnamed thrust faults. Several minor east-west trending tear faults and normal faults offset the thrust faults, the fold axes, and individual rock units. The Boulder Creek Anticline, the Afton Anticline, the Spring Creek Syncline, an unnamed anticline, and an unnamed syncline are major north-south trending folds mappable across the quadrangle and were probably formed contemporaneously with thrusting.

Only a single deep well has tested the hydrocarbon potential of the quadrangle; additional tests seem warranted. Phosphate rock from the Phosphoria Formation and other occurrences of materials for construction were evaluated for exploitability.

INTRODUCTION

The Sage Valley 7½-minute quadrangle is included in the region mapped by Mansfield and others (Mansfield 1927) during early investigations of the western phosphate field. The Sage Valley Quadrangle straddles the Idaho-Wyoming border in the central part of the Overthrust Belt and is approximately 35 km northeast of Montpelier, Idaho, and 7 km west of Afton, Wyoming (fig. 1). A .8-km-wide strip along the western border of the quadrangle is in the Caribou National Forest, and a 15.5-km² area in the southeast corner of the mapped area is in the Bridger National Forest. The remainder of the quadrangle is privately owned, and permission to cross private lands must be obtained from local owners. Numerous ranch and U.S. Forest Service dirt roads branch from gravel roads along Crow Creek and along the eastern border of the map area and provide ready access to most of the area. Primitive roads lead into all but the most rugged areas.

Previous Work

Geologic studies done in the region prior to 1927 were summarized and updated by Mansfield (1927). He mapped the Crow Creek 15-minute quadrangle on a scale of 1:62,500 as part of his study of the geology of southeastern Idaho. Stratigraphic nomenclature used by him is applicable to most units in the quadrangle. Kummel (1954) more recently described the regional Triassic stratigraphy of southeastern Idaho and adjacent areas. Eyer (1964) also made a significant contribution in his study of the Cretaceous rocks of western Wyoming and southeastern Idaho. Petroleum and phosphate mining companies continue to study this region, but no well data or geophysical information has thus far been published on the Sage Valley Quadrangle.

Mansfield (1927, p. 131–72) summarized the structural history of southeastern Idaho and western Wyoming. Armstrong and Cressman (1963) described the prominent folded Bannock Overthrust, which was later named the Meade Overthrust by Cressman (1964, p. 62).

Several quadrangles near and adjacent to the Sage Valley Quadrangle have been mapped recently, mostly by the U.S. Geological Survey, to define and evaluate deposits of phosphate rock. Montgomery and Cheney (1967) mapped the geology of the Stewart Flat 7½-minute quadrangle, adjacent to the west, and Cressman (1964) mapped the geology of the Georgetown Canyon–Snowdrift Mountain area, which is adjacent to the southwest (fig. 1). In addition, Gulbrandsen, McLaughlin,

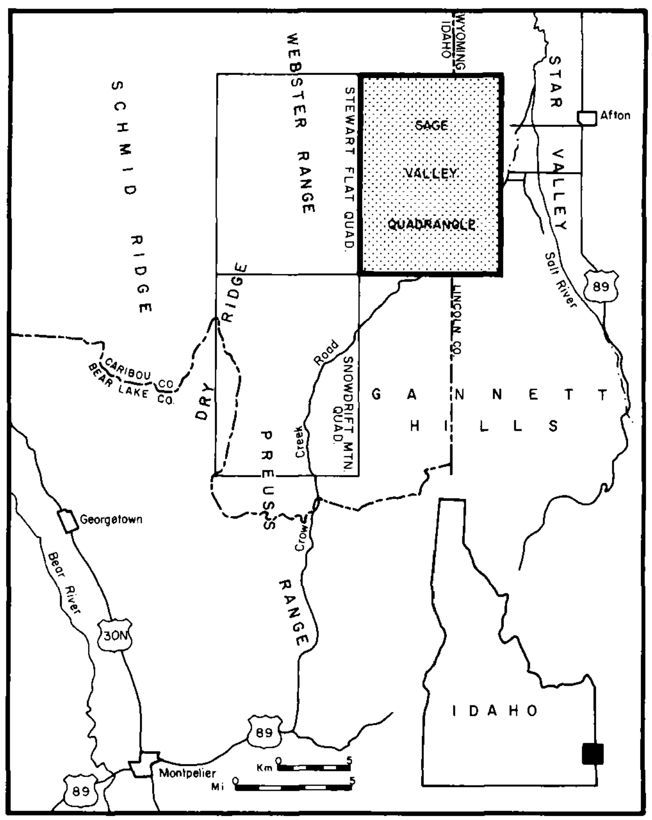


FIGURE 1.—Index map of the Sage Valley Quadrangle in southeastern Idaho and western Wyoming.

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, April 1980. Thesis chairman: James L. Baer.

Honkala, and Clabaugh (1956) mapped the Johnson Creek 7½-minute quadrangle, Cressman and Gulbrandsen (1955) mapped the Dry Valley 7½-minute quadrangle; and Rioux, Hite, Dyni, and Gere (1975) mapped the Upper Valley 7½-minute quadrangle, all nearby. Other U.S. Geological Survey and private sector studies have been published that deal mainly with the phosphate deposits.

Field Methods

Fieldwork was done between June and October 1979. Structural features and contacts were plotted on colored aerial photographs (scale 1:15,000) and subsequently transferred to the 1:24,000 scale topographic base map of the Sage Valley 7½-minute quadrangle (fig. 1). Stratigraphic sections were measured using a 15-m tape, a Brunton compass, and an Abney level. Samples of rocks were taken for later detailed description and fossil analysis.

ACKNOWLEDGMENTS

The writer wishes to express appreciation to Drs. James L Baer and J Keith Rigby for their time and numerous helpful suggestions pertaining to the geology and the preparation of the thesis Marlon Nance, Gary Oberhansley, and Floyd Hatch helped with the fieldwork. Special thanks to Dr. Morris Petersen for helping on identifications of the Thaynes fossils. Steve Sperry helped with the laboratory work Doug Taylor, Dave Jenkins, Dick Hill, and Lynn Meibos assisted with the preparation of the structural contour map. Some drafting was done by personnel of the Gulf Oil Company of Casper, Wyoming. The thesis was partially funded by grants from Conoco, Inc , Marathon Oil Co., and Brigham Young University Department of Geology

Gratitude is expressed to Kent Nield and his family of Afton, Wyoming, and Ray "Pete" Peterson of Cokeville, Wyoming, for their support during the fieldwork. I especially wish to thank my parents, Jack and Wilma Conner, for their support during the thesis work.

STRATIGRAPHY

General Statement

The Sage Valley Quadrangle contains an exposed stratigraphic sequence of sedimentary rocks about 5,400 m thick (fig. 2). Formations of this sequence involved in Upper Cretaceous to Paleocene thrust faulting and folding range from the Middle Pennsylvanian Wells Formation to the Lower Cretaceous Tygee Member of the Bear River Formation The Tertiary Salt Lake Formation, a freshwater lacustrine deposit that covers a major portion of the low-lying areas of the quadrangle, was deposited after the thrust faulting and folding. Younger alluvium, colluvium, salt, and travertine deposits are considered to be of Quaternary age Igneous rocks have been mapped in nearby areas but are absent in the quadrangle.

Pennsylvanian and Permian Systems

Wells Formation

Richards and Mansfield (1912, p. 689–93) proposed the name *Wells Formation* for an 800-m-thick sequence of sandstone and limestone that is exposed on the north side of Wells Canyon in the Snowdrift Mountain Quadrangle, Idaho. At the type locality, the Wells Formation was divided by Richards and Mansfield (1912, p. 691) into an upper calcareous sandstone or siliceous limestone unit, a middle sandy unit, and a lower sandy and cherty limestone unit. McKelvey and others (1956, p. 2842) later restricted the Wells Formation to the lower two of these units The Wells Formation is used in this report in this modified sense, and the two units are referred to as the upper and lower members. Cheney and others (in McKelvey and others 1959, p. 12–15) defined the upper unit as the Grandeur Tongue of the Park City Formation, to be discussed later

The Wells Formation crops out in the core of the Boulder Creek Anticline west of Sage Valley (plate 1). Only the upper member of the Wells Formation crops out within the quadrangle, and it forms a low, tree-covered ridge It is overlain apparently conformably by the Grandeur Tongue of the Park City Formation A partial measured section, 238 m thick, containing only the upper units, was measured on the east flank of the anticline The measured section consists of light colored, fine-grained sandstone that forms alternating ledges and slopes The sandstone is composed mainly of quartz grains, usually well cemented by silica, though porosities, probably secondary in origin, of up to 15 percent were observed in some units The matrix of some of the sandstone units is calcareous. Much of the sandstone is brecciated and rehealed. It is apparent that the breccia is not sedimentary in origin, but resulted from fracturing of the rock, slight rotation of the fragments, and recementation. A light gray sandy limestone unit was observed near the top of the formation. No fossils were observed in exposures of the formation in the quadrangle

The lower one-third of the upper member of the Wells Formation is Middle Pennsylvanian (Desmoinesian), and the upper two-thirds are of Permian age. Whether all the Wells Formation of Permian age is Wolfcampian or whether Leonardian rocks are present at the top is unknown These age determinations, reported by Cressman (1964, p 24–29), are based upon fossil collections from the Snowdrift Mountain Quadrangle and surrounding areas

Subsidence in this part of the Cordilleran geosyncline in the Early Permian resulted in the shallow-water marine deposition of the sandstone and carbonate rocks of the upper member of the Wells Formation. Most of the sand grains were derived from the craton to the east (Cressman 1964, p. 85–87).

Grandeur Tongue of the Park City Formation

The Grandeur Tongue is a northward extension of the Grandeur Member of the Park City Formation, named by Cheney and others (in McKelvey and others 1959, p. 12) for Grandeur Peak, Salt Lake County, Utah The rocks assigned to the Grandeur Tongue in the Sage Valley Quadrangle (fig. 2) were previously included in the Wells Formation, as the cherty limestone member, by Richards and Mansfield (1912, p. 689–93). Because of the thinness of the unit and the absence of good exposures within the quadrangle, the Grandeur Tongue was not mapped separately but was grouped as a map unit with the upper member of the Wells Formation.

The Grandeur Tongue is exposed on the east flank of the Boulder Creek Anticline in sections 19, 20, 29, and 30, T. 8 S, R. 46 E, in the quadrangle but is faulted out at the surface south of section 29 At the type locality, the Grandeur Member is approximately 80 m thick and consists of limestone and dolomite, some of which contain chert nodules and minor calcareous sandstone A partial section was measured 1 km west of Sage Valley on the north side of Pole Creek (see appendix). The tongue is estimated to be approximately 25 m thick, although only the lower 7 m are exposed. The exposed beds are composed of very finely crystalline, medium gray dolomite that weathers to a light gray. Numerous small fractures contain secondary sparry calcite. The unit is most often seen as a float-

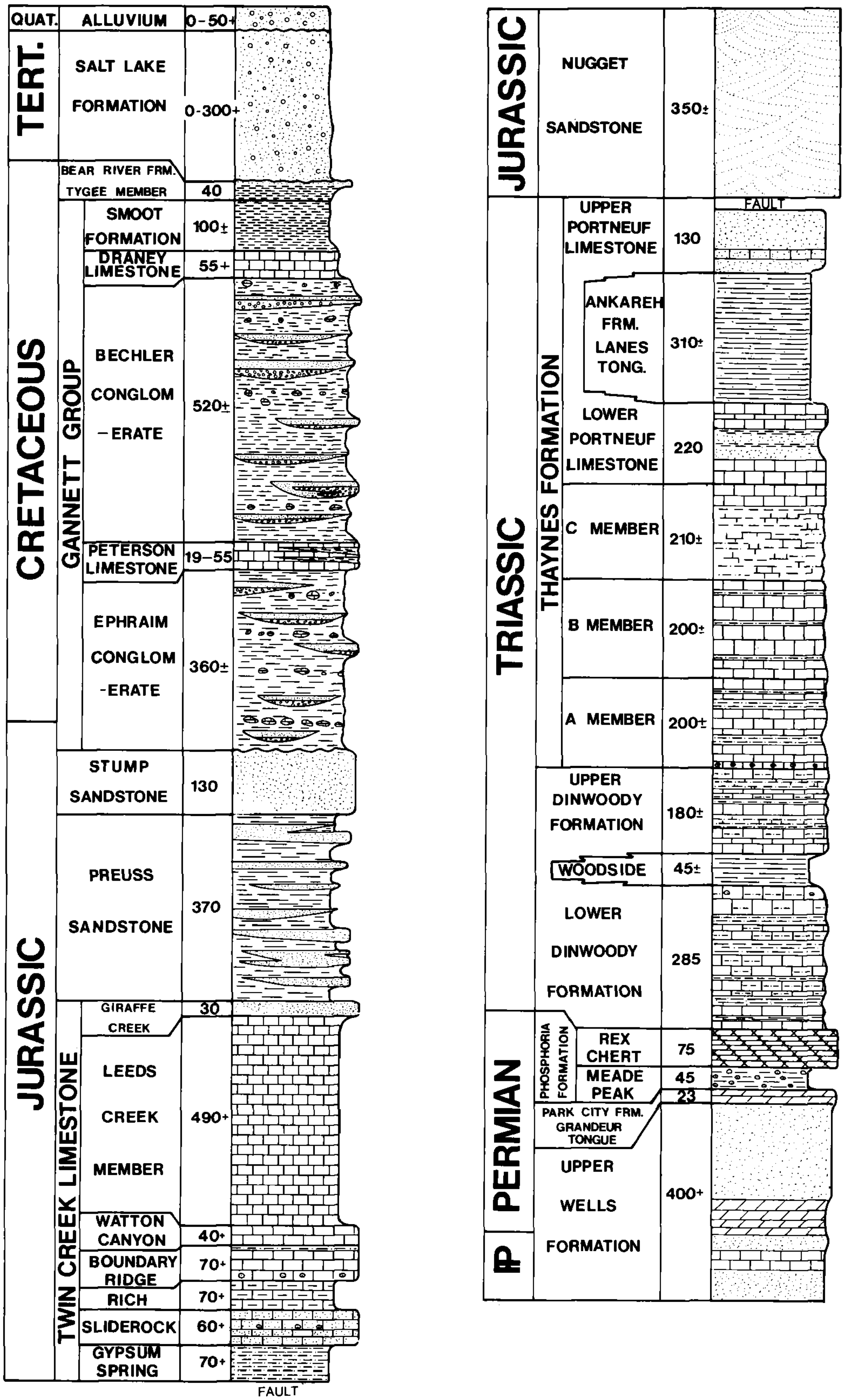


FIGURE 2.—Generalized stratigraphic column for the Sage Valley Quadrangle. Thicknesses are in meters.

covered slope with rare ledges. The Grandeur Tongue is underlain apparently conformably by the upper member of the Wells Formation, the lower boundary of the Grandeur Tongue drawn at the base of the dolomite unit. The upper limit of the Grandeur Tongue is at the shoulder at the bottom of the swale formed in the conformably overlying Meade Peak Member of the Phosphoria Formation. No fossils were observed in exposures in this quadrangle.

The Grandeur Tongue in southeastern Idaho is dated as Early Permian (Leonardian) by Williams (in McKelvey and others 1959, p. 36-37) on the basis of brachiopod collections.

Origin of the Grandeur Tongue is generally discussed in McKelvey and others (1959). These rocks, as exposed in the Sage Valley Quadrangle, probably originated as a bioclastic limestone or calcareous sandstone deposited under fairly shallow-marine conditions. Subsequently, they were subjected to a secondary dolomitization.

Phosphoria Formation

The Phosphoria Formation was named from Phosphoria Gulch, which is about 4 km north of Meade Peak, in southeastern Idaho (Richards and Mansfield 1912, p 684). At the type locality in Phosphoria Gulch four members are recognized: the basal Meade Peak Phosphatic Shale Member, the overlying Rex Chert Member, the unnamed cherty shale member, and the uppermost Retort Phosphatic Shale Member. Two other members–the lower chert member, laterally continuous with the lower beds of the Meade Peak Member, and the Tosi Chert Member, laterally continuous with the upper part of the Retort Member and the cherty shale member–are not present at the type locality but are present in the broader area of characteristic development of the Phosphoria Formation (McKelvey and others 1959, p. 20-21.)

Members mapped in the Sage Valley Quadrangle have a total combined thickness of approximately 120 m and include, from the bottom up, the Meade Peak Phosphatic Shale Member, the Rex Chert Member, and the unnamed cherty shale member The Rex Chert and cherty shale member are combined as a single map unit (plate 1). Montgomery and Cheney (1967, p. 25-26) noted, near the top of the cherty shale member in the Stewart Flat Quadrangle, adjacent to the present map area on the west (fig. 1), mudstone and phosphorite beds that represent tongues of the Retort Phosphatic Shale Member. They were not seen in the Sage Valley Quadrangle either because of burial by weathered debris or because of thin development No fossils were seen in exposures of this formation in this quadrangle.

The Phosphoria Formation is probably Leonardian or Guadalupian in age, as suggested by work on fossil collections from the Phosphoria Formation by Williams (in McKelvey and others 1959, p. 38-41).

Meade Peak Phosphatic Shale Member. The Meade Peak Phosphatic Shale Member of the Phosphoria Formation was named by McKelvey and others (1956, p. 2845) for Meade Peak, Idaho At its type locality in Phosphoria Gulch in Idaho, the Meade Peak Member consists of approximately 60 m of dark, carbonaceous, phosphatic, and argillaceous rocks.

The Meade Peak beds are in fault contact with the Wells Formation and the Grandeur Tongue of the Park City Formation within the present quadrangle The member may be missing or covered by Salt Lake Formation in places on the east limb of the Boulder Creek Anticline south of section 29, T 8 S, R. 46 E, in the Sage Valley Quadrangle. In sections 18, 19, 20, and 29, T. 8 S, R. 46 E, the Meade Peak Member is apparently in normal contact with the conformably underlying Grandeur Tongue of the Park City Formation and with the conformably overlying Rex Chert Member of the Phosphoria Formation.

The shaly Meade Peak Member is not naturally exposed in the quadrangle but is represented as a covered swale between the more resistant Grandeur Tongue and Rex Chert beds. It is estimated to be approximately 45 m thick Five bulldozer trenches in sections 29 and 32, T 8 S, R. 46 E, offered the only exposures seen during the mapping in 1979. The Meade Peak beds are entirely faulted out in two of the trenches Where exposed in the other trenches, the member consists of interbedded black, oolite-pelletoid phosphate and dark brown to black phosphatic mudstone These lithologies suggest that these beds are near the top of the member (McKelvey and others 1959, p 21; Montgomery and Cheney 1967, p 22).

McKelvey (in McKelvey and others, 1959, p. 23-25) summarized evidence bearing on the depositional environment of the Meade Peak phosphatic beds. He indicated that the sediments accumulated under a variety of conditions on the gently shoaling bottom of a large embayment that probably was flooded by cold, phosphate-rich water from the open ocean

Rex Chert and Cherty Shale Members. The Rex Chert Member of the Phosphoria Formation was named by Gale (Richards and Mansfield 1912, p. 684) for Rex Peak in the Crawford Mountains, Rich County, Utah. The Rex Chert was first described by Richards and Mansfield (1912) in Phosphoria Gulch, its type locality, as consisting of approximately 45 m of massively bedded chert that contains some interbedded limestone near the base and some cherty mudstone near the middle and that is overlain by approximately 30 m of cherty mudstone in the upper part of the member. McKelvey (in McKelvey and others 1956, p 2847-48) restricted the Rex Chert to the lower 45 m of massively bedded chert and basal limestone and proposed the upper 30 m of cherty mudstone as a separate member of the Phosphoria Formation

The Rex Chert in the Sage Valley Quadrangle is in fault contact with the Wells Formation and the Grandeur Tongue of the Park City Formation in section 32, T 8 S, R. 46 E, and section 19, T. 9 S, R. 46 E. Elsewhere, within the quadrangle, in the Boulder Creek Anticline, the Rex Chert is in apparent normal contact with the Meade Peak Member of the Phosphoria Formation. The contacts between the Meade Peak, the Rex Chert, the cherty shale member of the Phosphoria Formation, and the lower member of the Dinwoody Formation are all apparently conformable.

The combined thickness of the Rex Chert and cherty shale members, as suggested by map pattern, is approximately 80 m although the thicknesses obtained from the map are not everywhere reliable because the upper contact was located in the field by float or by topography

The Rex Chert forms a resistant ledge or cliff and consists mainly of light gray to black chert. The bedding of the chert ranges from even to wavy or lenticular with units from 3 to 550 cm thick. Stylolites are present in many beds The limestone and cherty mudstone reported in other areas (McKelvey and others 1959, p 21; Montgomery and Cheney 1967, p 22) were not observed in this quadrangle, probably because of weathering and burial by erosional debris. The cherty shale member does not crop out in the quadrangle but is marked by slopes of medium brown soil and an occasional fragment of cherty mudstone

McKelvey (in McKelvey and others 1959, p 26-28) summarized various arguments and evidences for the origin of the

Rex Chert. The arguments include that it is silica chemically precipitated directly from sea water, silica derived from volcanic rocks, or silica produced by accumulation and alteration of spiculites, among other organically precipitated origins. The present study adds little to the resolution of the argument.

The cherty mudstone is, in part, a basinward facies of the Rex Chert Member and was probably deposited in somewhat deeper water than were the Rex Chert beds. The surface of deposition for both members was continuously below wave base (McKelvey and others 1959, p. 27–29).

Triassic System

Dinwoody Formation

The Dinwoody Formation was named by Blackwelder (in Condit 1916, p. 263) for Dinwoody Canyon on the northeastern flank of the Wind River Mountains in Wyoming. The name *Dinwoody Formation* was first used in southeastern Idaho by Kummel (1954, p. 167), who assigned it to rocks previously mapped as Woodside Shale by Mansfield (1927, p. 86–87).

As originally defined in its type area, the Dinwoody Formation consisted of approximately 60 m of gray and olive shaly siltstone and shale, with thin, brown, pelecypod-bearing limestone beds near the base (Blackwelder 1918, p. 424–26). Newell and Kummel (1942, p. 941) later restricted the Dinwoody Formation in its type area to include only the dominantly silty strata between the underlying Phosphoria Formation and the top of the resistant siltstones. The formation thus includes only the lower half of the original Dinwoody Formation, with a restricted total thickness of approximately 30 m in the type area.

The Dinwoody Formation crops out in the study area on the Boulder Creek Anticline in sections 7, 8, 17, 18, 20, and 29, T. 8 S, R. 46 E (plate 1). It is split into an upper and a lower member by a tongue of the Woodside Formation. The two members have a combined total thickness of approximately 470 m.

Kummel (1954, p. 182–83) assigned a Lower Triassic (Otoceratan-Flemingitan) age, equivalent to the Griesbachian through the Dienerian stages of Silberling and Tozer (1968, p. 10), to the Dinwoody Formation on the basis of ammonite occurrences.

Kummel (1957) summarized the depositional history and facies relationships of the Dinwoody Formation. Rocks of the

FIGURE 3.–Lower Dinwoody Formation on the north side of Smokey Creek Canyon in the Boulder Creek Anticline. Note the small folds superimposed on the larger anticline (black line marks a key unit).

Dinwoody Formation in the Sage Valley Quadrangle were probably deposited under shallow marine conditions. Numerous fragmented fossils were seen in the limestone units. Sedimentary structures seen in some of the siltier units include cross-bedding, ripple marks, and roll structures, indicating that at least some of the formation was deposited in a fairly high-energy environment.

Lower Member of the Dinwoody Formation. The lower member of the Dinwoody Formation crops out in sections 17, 18, 20, and 29, T. 8 S, R. 46 E (plate 1), with the best exposures occurring on the north side of Smokey Creek Canyon (fig. 3). Sheldon and Carswell (in Montgomery and Cheney 1967, p. 28–29) measured a partial section on the north side of Smokey Creek Canyon in section 18, T. 8 S, R. 46 E, a few hundred feet within the border of the Sage Valley Quadrangle.

The lower member of the Dinwoody Formation is approximately 280 m thick. It consists mostly of thin-bedded to fissile, grayish brown, calcareous siltstone and shale that grade upward into thick-bedded calcareous siltstone and silty limestone. The limestone is gray and fine to medium crystalline, with most units containing rare to numerous bivalve fragments. The upper 40 to 60 m of the lower member is thicker bedded and forms more prominent ledges than the underlying shaly units. Roll structures, cross-bedding, and ripple marks occur in siltier units in the upper part of the lower member.

The base of the member was mapped at the upper limit of cherty float from the Cherty Shale Member of the Phosphoria Formation because the contact is covered. Cressman (1964, p. 39) stated that the contact is sharp and conformable, where exposed, and marked by a thin, nodular phosphorite bed which is the uppermost unit of the Phosphoria Formation. The top of the lower member of the Dinwoody Formation was mapped at the lower edge of the shale developed in the Woodside Formation. These units appear to be conformable.

Upper Member of the Dinwoody Formation. The upper member of the Dinwoody Formation crops out in sections 7, 8, 18, and 19, T. 8 S, R. 46 E, of the Sage Valley Quadrangle (plate 1). It was calculated to be approximately 180 m thick, based on map pattern, and contains generally the same rock types as the lower member: i.e., grayish brown shale, calcareous siltstone, and silty limestone. Shale units are much thinner, and the limestone units are thicker bedded and form prominent ledges and ribs in the upper part of the upper member. Siltier beds are commonly cross-bedded. The limestone units are infrequently cross-bedded and usually contain numerous fossil fragments.

The apparently conformable contact with the underlying Woodside Formation was mapped at the shoulder at the top of the swale developed in the Woodside Formation. Contact with the overlying A Member of the Thaynes Formation, as defined in this report, is at the base of the *Meekoceras*-bearing limestone of the Thaynes Formation. This contact is apparently conformable.

Woodside Formation

The Woodside Formation was named by Boutwell (1907, p. 446) after Woodside Gulch in the Park City District of Utah, where it consists of approximately 360 m of fine-grained, dark red shale with minor local beds of siltstone or fine-grained sandstone. Buff, brown, and greenish gray beds also occur but are relatively thin and rare.

The Woodside Formation is exposed along the flanks of the Boulder Creek Anticline in sections 7, 17, and 18, T. 8 S, R. 46 E, of the Sage Valley Quadrangle (plate 1). The formation is poorly exposed within the quadrangle and generally forms a swale between the more resistant upper and lower members of the Dinwoody Formation. It generally weathers to a red soil with rare, red, silty shale float. The Woodside Formation is approximately 45 m thick in the mapped quadrangle, based on outcrop pattern. The apparently conformable contact with the underlying lower member of the Dinwoody Formation was mapped at the lower edge of the swale developed on the Woodside Formation. The apparently conformable contact with the overlying upper member of the Dinwoody Formation was mapped at the upper edge of the swale.

No fossils were found in the Woodside Formation in the Sage Valley Quadrangle, but the age of the formation is Lower Triassic by virtue of its intertonguing relationship with the Scythian Dinwoody Formation.

Kummel (1957) summarized the depositional history and facies relationships of the Woodside Formation and related formations. Poor exposure of the Woodside Formation in the mapped area made additional observations about depositional environments of the formation impossible.

Thaynes Formation

The Thaynes Formation was named by Boutwell (1907, p. 448) for Thaynes Canyon in the Park City District of Utah. In his study of southeastern Idaho, Mansfield (1927, p. 87) raised the Thaynes to group rank but did not map separate units within the group, which then included, from the bottom up, the Ross Fork Limestone, the Fort Hall Formation, and the Portneuf Limestone. Kummel (1943, p. 316) redefined the Thaynes as a formation and described several informal members that are roughly correlative to the Ross Fork Limestone and the Fort Hall Formation. Kummel (1954, p. 171–79) included the overlying Timothy Sandstone as the uppermost member of the Thaynes Formation. It is in this sense that the formation is used here.

Members of the Thaynes Formation mapped in the Sage Valley Quadrangle are the same as those used by Montgomery and Cheney (1967, p. 32–35). The C Member and the Timothy Sandstone Member are not exposed in the mapped area.

Depositional history and facies of the Thaynes Formation were discussed by Kummel (1957). In the Sage Valley Quadrangle, the formation is of marine origin with represented environments ranging from euxinic basins, indicated by the black limestones, to high-energy, well-oxygenated environments above wave base, indicated by abundant shell fragments in some of the light colored limestone units and the well-sorted, well-rounded sand grains in the upper Portneuf Limestone Member.

Kummel (1954, p. 182–83) assigned a Lower Triassic (Owenitan-Prohungaritan) age, equivalent to the Smithian through Spathian stages of Silberling and Tozer (1968, p. 10), to the Thaynes Formation on the basis of ammonite occurrences.

A Member. The A Member of the Thaynes Formation crops out on the flanks of the Boulder Creek anticline in sections 6, 7, 8, and 17, T. 8 S, R. 46 E (plate 1). It is estimated to be approximately 200 m thick, on the basis of map pattern. The A Member consists of weakly, poorly, or nonresistant, poorly exposed, thin-bedded, black and gray, calcareous mudstone and shaly limestone with a 5- to 10-m-thick basal limestone unit, which contains the *Meekoceras* fauna of Kummel (1954, p. 171), and a 50- to 60-m-thick fossiliferous upper limestone unit. The *Meekoceras*-bearing limestone exhibits a strong petroliferous odor when crushed. The basal contact of the Thaynes Formation was mapped at the base of the *Meekoceras*-bearing limestone (fig. 4). The top of the member was mapped at the top of the 50- to 60-m-thick, fossiliferous gray limestone unit that contains the brachiopod *Pugnoides triassicus* in its upper part.

Ammonites collected from the lower limestone unit of the center of the NW¼, section 17, T. 8 S, R. 46 E, in the Sage Valley Quadrangle include:

Meekoceras gracilitatus
Meekoceras mushbachanum (?)
Arctoceras tuberculatum
Pseudosageceras multilobatum
Prosphingites slossi
Owenites koeneni

Conodonts recovered from the lower limestone at the same location include the following:

Neogondolella milleri
Neogondolella sp. (?)
Hadrodontina sp.
Neospathodus collinsoni
Neospathodus sp. (?)
Ellisonia triassica
Neospathodus waageni
Cypridodella unialata

Two unidentified gastropods, one a convolute planispiral species and the other a low-spired conispiral species, were also

FIGURE 4.–*Meekoceras*-bearing limestone from the A Member of the Thaynes Formation north of Smokey Creek Canyon.

FIGURE 5.–Nugget Sandstone (Jn), lower unit of Portneuf Limestone Member of the Thaynes Formation (Ŧ tpl) and the Lanes Tongue of the Ankareh Formation (Ŧ al) east of Sage Valley.

FIGURE 6.–West Tygee Branch of the Meade Overthrust east of Sage Valley (black line); Jn = Nugget Sandstone, Ŧ tpl = lower unit of Portneuf Limestone Member of the Thaynes Formation.

collected. This list does not include all fossils present in the unit, and more work should be done at this locality. Publications of Kummel and Steele (1962) and Solien (1979) were used to identify a majority of the specimens.

B Member. The B Member of the Thaynes Formation is also exposed on the flanks of the Boulder Creek Anticline in sections 7, 8, and 9, T. 8 S, R. 46 E (plate 1). Only the lower 60 m of the member are exposed in the mapped area, however. Montgomery and Cheney (1967, p. 32) estimated the total thickness of the member to be approximately 200 m in the adjoining Stewart Flat Quadrangle (fig. 1). The member generally consists of poorly exposed, brownish gray, thinly bedded, calcareous siltstone, interbedded with gray and black thin-bedded limestone and shale. The contact with the underlying A Member of the Thaynes Formation is mapped at the top of the resistant, gray, *Pugnoides*-bearing limestone of the A Member.

Portneuf Limestone Member. The Portneuf Limestone Member of the Thaynes Formation was named by Mansfield (1915, p. 492) for exposures at the head of the Portneuf River in the Fort Hall Indian Reservation in Idaho.

The Portneuf Limestone Member crops out east of Sage Valley in sections 4, 8, 9, 16, 17, and 20, T. 9 S, R. 46 E, and sections 28, 29, 32, and 33, T. 8 S, R. 46 E (plate 1). It is divided into an upper and a lower unit by the Lanes Tongue of the Ankareh Formation (fig. 5). Lowest beds of the lower unit are in fault contact with the younger Nugget Sandstone (fig. 6). Youngest beds of the upper unit have been removed, either by tectonism or by erosion.

The lower unit of the Portneuf Limestone consists of a lower resistant, medium to dark gray, massively bedded, cherty limestone; a middle sequence of poorly exposed calcareous siltstone with interbedded yellowish gray, medium- to coarse-grained, calcareous sandstone; and an upper resistant, gray, thin- to thick-bedded, bioclastic limestone. No fossils were observed in the lower two units, but a silicified fauna collected in the upper unit includes numerous specimens, some articulated, of the brachiopod *Spiriferina roundyi*, columnals of *Pentacrinus whiteii*, unidentifiable echinoid spines and fragments, and an unidentified gastropod. The lower unit of the Portneuf Limestone is estimated to be approximately 220 m thick, on the basis of map pattern.

The upper unit of the Portneuf Limestone consists of medium gray to yellowish gray, well-sorted, well-rounded, very fine-grained quartz sandstone. Carbonate and silica matrix is variable in amount. A 3-m-thick, medium gray, sandy limestone unit occurs near the base. The upper unit of the Portneuf Limestone is estimated to be approximately 130 m thick, on the basis of map pattern.

The upper unit was not assigned to the Timothy Sandstone Member of the Thaynes Formation here because previously published descriptions of sandstone units in the Timothy Sandstone do not contain limestone beds (Mansfield 1927, p. 91, 93; Cressman 1964, p. 42, 44; Kummel 1957, p. 466). Kummel (1954, p. 173) noted several sandstone beds, similar to those of the Timothy Sandstone, in the upper part of the Portneuf Limestone in the Grays Range. The upper unit of the Portneuf Limestone in the Sage Valley Quadrangle, thus, is probably a transition zone between the basinward, more calcareous facies described by Kummel (1954, p. 173) and Cressman (1964, p. 44) as the Portneuf Limestone, and the near- to onshore sandstone-conglomerate facies of the Timothy Sandstone.

Lanes Tongue of the Ankareh Formation

The Ankareh Formation was named by Boutwell (1907, p. 452) for Ankareh Ridge in the Park City District of Utah and originally included beds now assigned to the Nugget Sandstone. Boutwell (1912, p. 59) subsequently redefined the Ankareh Formation to exclude the Nugget Sandstone. The Ankareh Formation there consists chiefly of red shale and siltstone, with interbedded coarse, very light gray sandstone and rare, thin, fossiliferous limestone beds. Gale and Richards (1910, p. 479–80) introduced the name Ankareh into southeastern Idaho, apparently for beds now named the Lanes Tongue of the Ankareh Formation. Mansfield (1927, p. 84) abandoned the name Ankareh in southeastern Idaho, however, and included what is now the Lanes Tongue in the Thaynes Formation. Kummel (1954, p. 173) named the red beds in the Thaynes Formation the Lanes Tongue of the Ankareh Formation, and that nomenclature is followed in this report.

The Lanes Tongue is exposed east of Sage Valley in sections 4, 9, 16, 17, and 20, T. 9 S, R. 46 E (plate 1). The Lanes Tongue is poorly exposed within the quadrangle and forms a swale between the more resistant upper and lower units of the Portneuf Limestone Member of the Thaynes Formation (fig. 5). The Lanes Tongue generally weathers to a red soil with rare, red silty shale float. It is approximately 310 m thick in the Sage Valley Quadrangle, on the basis of map pattern. No structure could be mapped within the unit, and the thickness may be exaggerated because of structural deformation. The apparently conformable contact with the underlying lower unit of the Portneuf Limestone was mapped at the top of the uppermost limestone bed in the lower Portneuf unit. Similarly, the apparently conformable contact with the overlying upper unit of the Portneuf Limestone was mapped at the base of the lowermost resistant sandstone bed of the upper Portneuf unit.

No fossils were found in the Lanes Tongue of the Ankareh Formation in the Sage Valley Quadrangle, but its age within the quadrangle is Lower Triassic by virtue of its intertonguing with the Scythian Thaynes Formation.

Jurassic System

Nugget Sandstone

The Nugget Sandstone was first described by Veatch (1907, p. 56) for a sequence of yellow, pink, and red sandstone beds bounded by the limestone of the Thaynes Formation, below, and the limestone and shale of the Twin Creek Limestone, above The formation was named for Nugget Station on the Oregon Short Line Railway in southwestern Wyoming. Gale and Richards (1910, p. 480) separated the Nugget Sandstone from the underlying Ankareh Formation and were first to apply the name in southeastern Idaho. Mansfield (1920, p 61–62) restricted the Nugget Sandstone to beds between underlying rocks now known as the Wood Shale Tongue of the Ankareh Formation and the overlying Twin Creek Limestone, but apparently included in the top of the formation the red-bed unit that was subsequently placed in the Twin Creek Limestone by Imlay (1950, p. 37) The Nugget Sandstone is used in this report as restricted by Imlay.

The Nugget Sandstone crops out between the East Tygee and the West Tygee branches of the Meade Overthrust, in a north-south belt from sections 27 and 28, T. 8 S, R 46 E, to sections 20 and 21, T. 9 S, R. 46 E, and in a thrust slice on the west limb of the Spring Creek Syncline from section 10 southward to section 34, T. 8 S, R. 46 E (plate 1). The Buck Mountain exposures of the Nugget Sandstone rest in fault contact above the stratigraphically younger Twin Creek Limestone and, in turn, are overlain structurally on the west by faulted lower Portneuf Limestone Member of the Thaynes Formation (fig. 6)

Near Buck Mountain, the Nugget Sandstone consists mainly of dark to light red, yellow, and white, fine-grained, calcareous sandstone. It appears fairly homogeneous throughout the section. Clay and silt-size particles vary in amount throughout the section, but porosity seems minimal Cross-bed sets up to 15 cm high are weathered into relief on the summit of Buck Mountain, but planar laminations are the predominant sedimentary structure in other areas of the quadrangle The Buck Mountain section of Nugget Sandstone is estimated to be approximately 350 m thick, on the basis of map pattern.

On the west limb of the Spring Creek Syncline, upper beds of the Nugget Sandstone are overturned on the Gypsum Spring Member of the Twin Creek Limestone but with a normal depositional contact. Lower Nugget beds are covered by Salt Lake Formation. Along the Spring Creek Syncline, the Nugget Formation is a red to reddish brown, blocky, thick-bedded, fine-grained sandstone The top of the formation here was mapped at the contact of the more resistant Nugget Sandstone with the less resistant red shale and siltstone of the Gypsum Spring Member of the Twin Creek Limestone. Nugget Sandstone exposed in this section is estimated to be approximately 230 m thick, on the basis of map pattern. No marker beds were seen in either the Buck Mountain section or the Spring Creek Syncline section to allow correlation of the two outcrop belts.

No fossils have been found in the Nugget Sandstone, so its exact age is still debated. High ahd Picard (1965, p. 56) found a thin conglomerate at the base of the Nugget Sandstone and an angular disconformity between the Nugget and the underlying Popo Agie Formation and suggested that this represents the Triassic-Jurassic boundary and the base of the Nugget Sandstone The upper boundary of Nugget beds is a disconformity of regional extent (Love 1957, p. 43). Imlay (1967, p 19) considered the overlying Gypsum Spring Member of the Twin Creek Limestone to be a middle Bajocian (Middle Jurassic), so the Nugget Sandstone is probably Early Jurassic in southeastern Idaho

Pacht (1977), Kamis (1977a), and Picard (1977) present the most recent discussions of the origin and diagenesis of the Nugget Sandstone in Utah and Wyoming In the Sage Valley Quadrangle, the Nugget was probably deposited in close proximity to a dune-covered, sandy shoreline. Differentiation of subaqueous deposits from subaerial deposits is difficult in the mapped area.

Twin Creek Limestone

The Twin Creek Limestone was defined for exposures of marine limestone, shale, and sandstone along and near Twin Creek between Sage and Nugget in western Wyoming by Veatch (1907, p. 56). The name was subsequently used in the Sage Creek area by Mansfield (1927, p. 97). Imlay (1950) divided the formation into seven members that, from bottom to top, were called members A–G. Member A was renamed the Gypsum Spring Member by Oriel (1963). Members B–G were renamed, in ascending order, the Sliderock Member, the Rich Member, the Boundary Ridge Member, the Watton Canyon Member, the Leeds Creek Member, and the Giraffe Creek Member by Imlay (1967). The modified nomenclature of Oriel and Imlay is used in this report (fig. 2)

The entire Watton Canyon Member, the upper part of the Boundary Ridge Member, and the lower part of the Leeds Creek Member are not exposed in the Sage Valley Quadrangle. Undifferentiated, but probably middle, Twin Creek Limestone crops out along the Hardman Branch of the Meade Overthrust in sections 2, 3, and 11, T. 9 S, R. 46 E, and section 34, T. 8 S, R. 46 E (plate 1).

The Twin Creek Limestone is overlain apparently conformably by the Preuss Sandstone and is disconformably underlain by the Nugget Sandstone. Hintze (1973, p 62) indicated an unconformity between the Rich and Boundary Ridge Members in northern Utah, but none was indicated by Imlay (1967, p. 31, 37), nor was an unconformity in evidence in the Sage Valley Quadrangle The Twin Creek Limestone is apparently conformable throughout.

Gypsum Spring Member. The Gypsum Spring Member of the Twin Creek Limestone crops out along the Hardman Branch of the Meade Overthrust in sections 10, 15, 22, and 27, T. 8 S, R 46 E, and along the East Tygee Branch of the Meade Overthrust in sections 9 and 10, T. 9 S, R 46 E, in the studied quadrangle (plate 1).

The Gypsum Spring Member is approximately 70 m thick, on the basis of map pattern, and consists mainly of soft, red siltstone and shale with rare interbeds of yellowish gray limestone. In a roadcut in section 9, T. 9 S, R. 46 E, a few green and gray mudstone beds are seen within the red units. The member generally weathers to a swale between the more resistant Nugget Sandstone and Sliderock Member of the Twin Creek Limestone

Imlay (1967, p 52) reported crinoid columnals in what he interpreted as a thrust-faulted section of the Giraffe Creek Member of the Twin Creek Limestone in the SW ¼, section 15 T 8 S, R. 46 E, within the Sage Creek Quadrangle. Absence of definitive fossil data, plus the lithologic characteristics of the unit and structural style of the area, leads me to reassign these beds to the Gypsum Spring Member (plate 1).

Imlay (1967, p 19) assigned a middle Bajocian (Middle Jurassic) age to the Gypsum Spring Member

The Gypsum Spring Member was probably deposited under shallow-marine to lagoonal conditions. The bedded gypsum, deposited in other areas (Imlay 1967, p. 17–18) but not observed in the present quadrangle, indicates a warm and arid climate, and the limestone indicates a more nearly normal marine environment.

Sliderock Member. The Sliderock Member of the Twin Creek Limestone crops out in the same localities as the Gypsum Spring Member but is also exposed in section 16, T. 9 S, R. 46 E, and as a small inlier in the Salt Lake Formation in section 34, T. 8 S, R. 46 E, and section 3, T. 9 S, R. 46 E, within the quadrangle (plate 1).

The member is approximately 60 m thick, on the basis of map pattern, and consists mainly of tan-weathering, sandy calcarenite interbedded with some dense, gray limestone. The best exposures occur in the small inlier, and rocks there consist of sandy, dense limestone with some beds containing rip-up clasts and other beds containing coquinas of the pelecypods *Ostrea sp.* (?) and *Gryphaea sp.* (?). These beds may be lower Rich Member, but were assigned to the Sliderock Member on the basis of lithology. Contact with the overlying Rich Member was mapped at the top of the more resistant, thicker-bedded limestone of the Sliderock Member. The contact with the underlying Gypsum Spring Member was mapped at the top of the uppermost red bed of that member. Imlay (1967, p. 24) reported the occurrence of the pelecypod *Gryphaea planoconvexa fraterna* Imlay, the diagnostic fossil of the Sliderock Member in W ½, section 10, T. 9 S, R. 46 E, in the quadrangle.

Imlay (1967, p. 26) assigned a middle Bajocian (Middle Jurassic) age to the Sliderock Member.

The Sliderock Member was probably deposited in shallow, warm, marine water of normal salinity, as suggested by *Gryphaea* and other fossils (Imlay 1967, p. 30).

Rich Member. The Rich Member of the Twin Creek Limestone crops out in sections 9, 10, 16, and 21, T. 9 S, R. 46 E, in the Sage Valley Quadrangle (plate 1).

The member is approximately 70 m thick, on the basis of map pattern, and consists mostly of light gray to olive gray, dense, shaly limestone.

Imlay (1967, p. 31) assigned the Rich Member a probably late Bajocian (Middle Jurassic) age.

The Rich Member was probably deposited in a shallow sea of normal salinity, as indicated by the abundant *Gryphaea*. A fairly high-energy environment is indicated for at least part of the time by the fragmented condition of the fossils.

Boundary Ridge Member. The Boundary Ridge Member of the Twin Creek Limestone crops out in sections 9, 10, 16, and 21, T. 9 S, R. 46 E, of the quadrangle (plate 1).

Only the lower 70 m of the member is exposed, but the Stump Creek section, as reported by Imlay (1967, p. 8), suggests that only about the upper 20 m of the member is covered. The member consists mainly of thin- to thick-bedded, dense, gray limestone similar to that of the Leeds Creek Member. Near the top of the member in section 10, T. 9 S, R. 46 E, a 5-m-thick, nonresistant, red siltstone forms a band of red soil but is not exposed. No fossils were seen in this member in the mapped area.

Imlay (1967, p. 39) assigned a probable Bathonian (Middle Jurassic) age to the Boundary Ridge Member.

The Boundary Ridge Member was probably deposited in a shallow marine to littoral or lagoonal environment under climatic conditions similar to those that existed during deposition of the Gypsum Spring Member (Imlay 1967, p. 40).

Leeds Creek Member. The Leeds Creek Member of the Twin Creek Limestone crops out in the quadrangle in the core of the Afton Anticline from section 9 southward to section 33, T. 31 N, R. 119 W, and on the west limb of the Spring Creek Syncline in sections 14, 15, and 22, T. 9 S, R. 46 E (plate 1).

A partial section of the upper 150 m of the member was measured along Spring Creek (see appendix). Cressman (1964, p. 50) suggested a total thickness of approximately 490 m for the member in outcrops to the west. The Leeds Creek Member is poorly exposed, medium to dark gray, shaly limestone that weathers to form light colored slopes covered with splintery float. In the road metal pits along Spring Creek in section 16, T. 31 N, R. 119 W, medium to thick bedding occurs in the member (fig. 7), although most exposures are closely jointed and bedding generally could not be determined.

The Leeds Creek Member grades upward into the Giraffe Creek Member, but the contact can be closely located at the top of the splintery limestone of the Leeds Creek Member and below the more resistant sandstone of the overlying Giraffe Creek Member. No fossils were seen in this member in this quadrangle.

Imlay (1967, p. 48–49) assigned a Callovian (lower Upper Jurassic) age to the Leeds Creek Member.

The bulk of the Leeds Creek Member was probably rapidly deposited under shallow marine conditions as a soft calcareous mud (Imlay 1967, p. 49–50).

FIGURE 7.–Leeds Creek Member of the Twin Creek Limestone in the gravel pit near the mouth of Spring Creek in the core of the Afton Anticline.

FIGURE 8.–Giraffe Creek Member of the Twin Creek Limestone along the Spring Creek road in the Afton Anticline.

Giraffe Creek Member. The Giraffe Creek Member of the Twin Creek Limestone crops out in the same general belt parallel to the Leeds Creek Member. In addition it occurs in two tight anticlinal folds in sections 21 and 22, T. 9 S, R. 46 E, in the quadrangle (plate 1).

A section 31 m thick of the Giraffe Creek Member was measured along Spring Creek (see appendix) and consists of thin- to thick-bedded, olive gray and greenish gray, very fine- to medium-grained, ripple-marked, cross-bedded, calcareous, glauconitic sandstone. The sandstone is interbedded with silty to sandy, gray to green, glauconitic limestone, with the sandier units ripple marked and cross-bedded (fig. 8). The member grades upward into the softer red siltstone and sandstone of the Preuss Sandstone. The less resistant lower beds of the Preuss Sandstone form a swale between the resistant ledge-forming Giraffe Creek member and more resistant younger Preuss Sandstone beds. No fossils were seen in this member in the mapped area.

Imlay (1967, p. 52) assigned a Callovian (lower Upper Jurassic) age to the Giraffe Creek Member.

The Giraffe Creek Member was probably deposited under shallow-marine to littoral conditions, in a fairly high-energy environment suggested by widespread ripple marks and cross-bedding.

Preuss Sandstone

The Preuss Sandstone was named by Mansfield and Roundy (1916, p. 81) for Preuss Creek, about 18 km northeast of Montpelier, Idaho, where it consists mostly of reddish brown, pale red, and grayish red, calcareous, fine-grained sandstone. The sandstone is in 2- to 20-cm-thick beds and is probably interbedded with nonresistant, commonly covered shale. A typical Preuss exposure is a rounded hill covered with red soil that contains sandstone float and with a few widely spaced sandstone ledges. The Preuss Sandstone is apparently con-formably underlain by the Giraffe Creek Member of the Twin Creek Formation and overlain by the Stump Sandstone.

The Preuss Sandstone crops out on the east and west flanks of the Spring Creek Syncline, on the nose of the Afton Anticline, and as a small inlier in the Salt Lake Formation in sections 15, 21, and 22, T. 9 S, R. 46 E, in the Sage Valley Quadrangle (plate 1).

A section of the Preuss Sandstone was measured on the north side of Spring Creek, where it consists of 372 m of poorly exposed, grayish red to reddish brown, very fine- to fine-grained, calcareous sandstone (see appendix). The sandstone is probably interbedded with shale and siltstone, but these lithologies are not exposed.

A partial but detailed section of the Preuss Sandstone, which includes the uppermost 137 m of the formation, was measured about 0.8 km west of Fairview, Wyoming, along the access road to the Mobil Max Smith #1 well (see appendix). Here, the Preuss Sandstone consists of several rhythmic sequences of interbedded sandstone and mudstone (fig. 9), in which the sandstone beds are progressively thinner from base to top within each sequence. The sandstone tends to be channel fillings that feather out laterally. Ripple marks and cross-bedding are common in the thicker sandstone units, and ball-and-pillow structures are less common. The interbedded mudstone is generally brown, calcareous, and ripple marked, and bedding within these rocks is usually distorted by loading. Green mudstone beds are exposed at the top of several of the rhythmic sequences. Several minor reverse faults are well exposed in Preuss outcrops along the Mobil well road (fig. 20). Reverse faults of this nature, that are usually not exposed, may account for much of the thinning and thickening of the formation in other areas, depending upon their number and displacement.

Hodgden and McDonald (1977, p. 57, 58) list two wells drilled approximately 1 km north of the Sage Valley Quadrangle in Tygee Valley, the deepest of which penetrated approximately 800 m of Preuss and bottomed in probable Twin Creek Limestone. The Preuss section consists of interbedded shale and salt, of which 130 m of strata are salt-bearing. Pure salt beds range in thickness from 2 to 7 m, for an aggregate thickness in the well of 30 m. No salt was detected in the Mobil Max Smith #1 well, which penetrated a 438-m-thick section of the Preuss (Jan Patterson personal communication 1980). A salt spring, reportedly associated with a salt bed in the Preuss (Mansfield 1927, p. 339), is located along Crow Creek, south of the Sage Valley Quadrangle. No salt was seen in the measured sections although salt hopper crystal casts and gypsum stringers were seen in the section along the Mobil well road (see appendix). Salt in the salt spring of Alkali Flat, in the Sage Valley

FIGURE 9.—Preuss Sandstone along the Mobil well road in the Afton Anticline.

FIGURE 10.—Stump Sandstone north of the Crow Creek road in the Afton Anticline.

Quadrangle, is probably associated with the Preuss at depth. Salt water may be percolating upward along the East Tygee Branch of the Meade Overthrust. Data from these several areas suggest that the salt is localized as a primary sediment within the Preuss Formation or that the salt is migrating from Preuss beds of upper fault slices with groundwater percolating along the planes of thrust faults, having originated at depth. The latter is probably the more likely in the Sage Valley Quadrangle because all the salt occurrences are coincident with traces of various thrust faults.

The Preuss Sandstone is not fossiliferous in the Sage Valley Quadrangle. Imlay (1952, p. 1747) assigned a middle to upper Callovian (lower Upper Jurassic) age to the Preuss beds on the basis of ammonite collections elsewhere.

The Preuss Sandstone in the Sage Valley Quadrangle probably represents a tidal-flat to lagoonal environment The bidirectional ripple marks indicate an oscillatory direction of water movement and suggest that the sandstones may be fillings of tidal channels. The salt hopper crystal casts indicate a hot, arid climate, as does the gypsum The green mudstone beds indicate a return to more normal salinities for short periods. Imlay (1952) and Hileman (1973, p. 80–89) discussed the marine origin and the paleoenvironments of the Preuss Sandstone on a regional scale.

Stump Sandstone

The Stump Sandstone was named by Mansfield and Roundy (1916, p. 81) for Stump Peak, a short distance to the north of Sage Flat, in southeastern Idaho. Pipiringos and Imlay (1979, p. C1) use the name *Stump Formation,* but the rocks are termed the *Stump Sandstone* in this report.

The Stump Sandstone crops out on the east and west flanks of the Spring Creek Syncline and on the nose of the Afton Anticline (fig. 10) in the Sage Valley Quadrangle (plate 1). The formation generally crops out as a ridge above slopes on the conformably underlying Preuss Sandstone. Their contact was mapped at the top of the red Preuss float. A swale is usually developed between Stump Sandstone and the unconformably overlying Ephraim Conglomerate. That contact was mapped at the top of the green, glauconitic sandstone float of the Stump Sandstone. Upper Stump beds are generally less competent than the ridge-forming lower beds (fig. 10) and form float-covered slopes.

A 129-m-thick section of the Stump Sandstone was measured on the north side of Spring Creek in section 17, T. 31 N, R. 119 W, in the Sage Valley Quadrangle (see appendix). The formation there consists mostly of grayish green, very fine- to fine-grained, glauconitic, silty, calcareous, quartz sandstone, with some interbedded grayish green, calcareous, sandy siltstone. Most of the units are cross-bedded, with some of the cross-bed sets weathering into relief. Some of the units are ripple marked. No fossils were found in the Stump Sandstone in the Sage Valley Quadrangle

Only the Curtis Member of the Stump Sandstone, as used by Pipiringos and Imlay (1979, p. C3–C9), is present within the Sage Valley Quadrangle, and it is assigned a middle Callovian (lower Upper Jurassic) age by Pipiringos and Imlay (1979, p. C6). The Redwater Member of the Stump Formation is present to the north and east of the Sage Valley Quadrangle, and it is assigned an early to early middle Oxfordian (Upper Jurassic) age by Pipiringos and Imlay (1979, p. C13, C15) on the basis of ammonoid collections.

The fossils seen in other areas (Pipiringos and Imlay 1979) suggest a shallow-marine origin for the Stump Sandstone. A marine origin is also suggested by the glauconite present in most of the units. A fairly high-energy environment, probably above wave base, is suggested by the common cross-bedding and the ripple marks

Cretaceous System

Gannett Group

The Gannett Group was named by Mansfield and Roundy (1916, p 82) for the Gannett Hills, which lie immediately to the south of the quadrangle, in southeastern Idaho and western Wyoming. They divided the group into five distinct formations that include, from the bottom up, the Ephraim Conglomerate, Peterson Limestone, Bechler Conglomerate, Draney Limestone, and Tygee Sandstone. Cobban and Reeside (1952, p 1030) removed the Tygee Sandstone from the Gannett Group and included it as the lowermost member of the Bear River Formation. Randall (1960, p. 175) called the black shale beds below the sandstone of the Tygee the basal unit of the Tygee Member. Eyer (1964, p. 6) named the red shale unit below the black shale of the Tygee Member and above the gray limestone beds of the Draney Limestone the Smoot Formation The nomenclature used in this study for units below the Smoot Formation is that of Mansfield and Roundy (1916, p 82) and that for the Smoot Formation and the Tygee Member of the Bear River Formation is that of Randall (1960) and Eyer (1964) (fig. 2)

The contact of the Gannett Group with the unconformably underlying Stump beds was mapped at the top of the uppermost green, glauconitic sandstone float of the Stump Sandstone. The contact of the Gannett Group with the overlying Tygee Member of the Bear River Formation is apparently conformable, on the basis of field evidence, but Eyer (1967, p. 1387) noted a discontinuity in sedimentation between the two on the basis of his petrographic studies. The contact was mapped at the bottom of the lower black shale of the Tygee Member. The Gannett Group is apparently conformable throughout.

Eyer (1964, p. 33–34) summarized previous literature concerning the age of the Gannett Group. He stated that presently known fossil evidence indicated that the lower part of the Ephraim Conglomerate is Upper Jurassic and that the upper part is lowermost Cretaceous (Aptian). Eyer (1964, p. 33–34) also assigned an Aptian age to the Peterson Limestone, Bechler Conglomerate, and Draney Limestone. The Smoot Formation straddles the Aptian-Albian boundary.

Five sections of the Gannett Group were measured along the Spring Creek Syncline in the Sage Valley (see appendix) and Elk Valley Quadrangles for this report, and two were taken from Eyer (1964, p. 112–16) so that thickness, lithologies, and other trends within the Gannett Group could be documented in the Sage Valley and Elk Valley Quadrangles (fig. 11).

Ephraim Conglomerate. The Ephraim Conglomerate crops out on the east and west limbs of the Spring Creek Syncline (plate 1). In the Sage Valley Quadrangle, the Ephraim Formation generally forms low hills covered with reddish soil, but with occasional outcrops of ledge-forming sandstone and conglomerate that become thicker and more prominent to the south and west. The contact with the underlying Stump Sandstone has already been discussed.

Conglomeratic units of the Ephraim conglomerate have a fine- to coarse-grained sandstone matrix, are commonly cross-bedded, and appear to be lenticular channel fillings that pinch out laterally (fig 12), particularly in the northern part of the quadrangle. Conglomerate beds become more laterally contin-

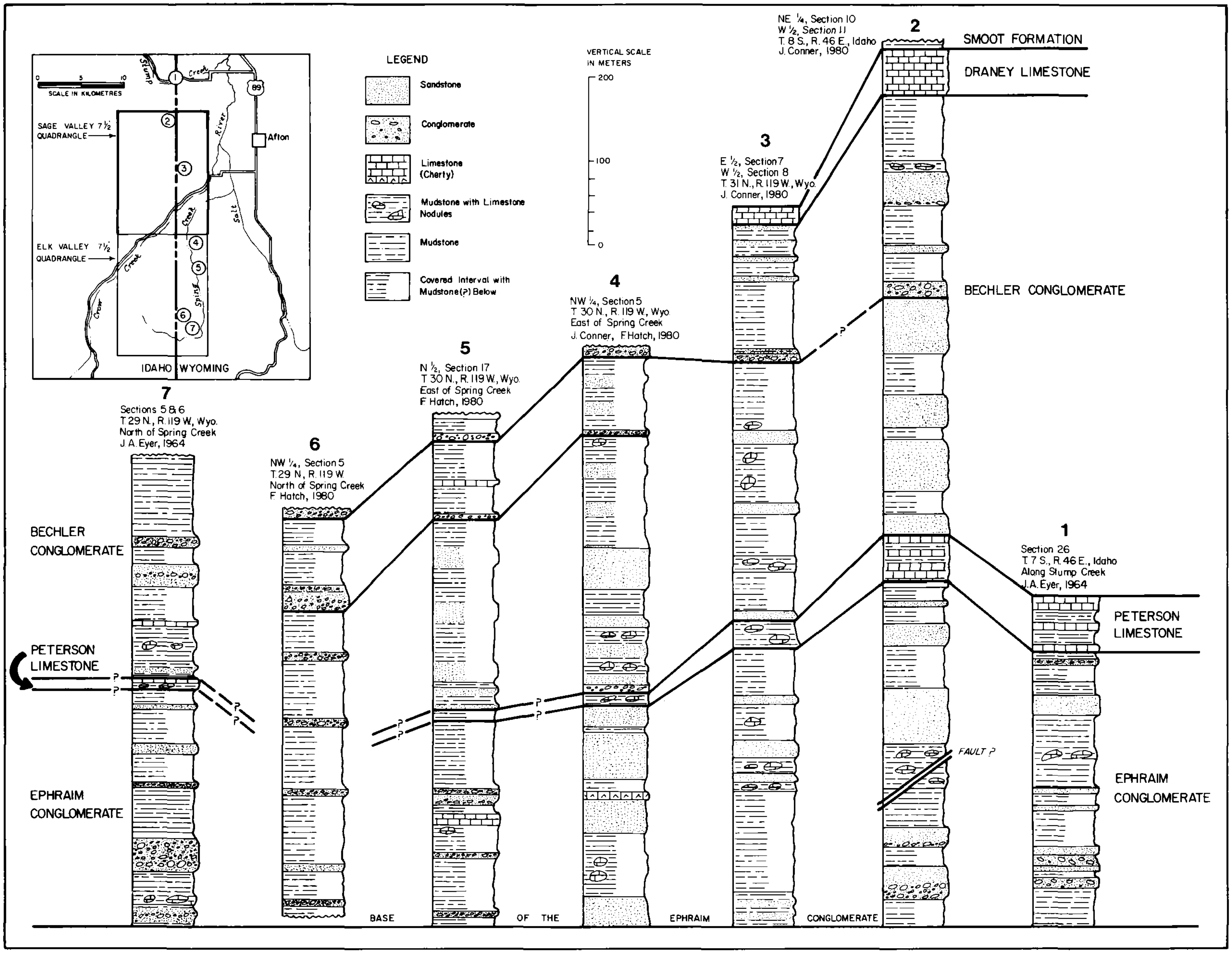


FIGURE 11.–Columnar sections of the Gannett Group from Stump Creek to the southern border of the Elk Valley Quadrangle. Correlations are shown by solid lines, queried where tentative.

FIGURE 12.–Conglomerate and sandstone channel in the lower Ephraim Conglomerate along the north side of the Stump Creek road on the east limb of the Spring Creek Syncline.

uous to the south and west. The largest clasts are cobbles about 24 cm in diameter, seen in section 7 of figure 11, although pebbles ranging from 0.5 to 2.5 cm in diameter are more common. Conglomerate units generally grade upward into sandstone beds that fill the same channel and are similarly cross-bedded. Not all the sandstone units are underlain by conglomerate, however.

The sandstone and conglomerate channels are probably within and overlain by reddish mudstone, shale, and siltstone although these lithologies are rarely exposed, except in deep gullies or on steep hillsides. Purplish gray, nodular limestone float is present on some of the covered mudstone units, probably having weathered out of the mudstone. Such float is laterally persistent. The nodular limestone generally decreases in amount toward the south and west. One sample of the nodular limestone had a strong petroliferous odor when crushed.

The Ephraim Conglomerate is from 263 to 412 m thick within the Sage Valley Quadrangle, although section 2 (fig. 11) is probably anomalously thick because of undetected reverse faulting.

Eyer (1964, p. 35) discussed the depositional environment of the Ephraim Conglomerate on a regional basis. In the Sage Valley Quadrangle, the Ephraim beds probably represent fluvial to lacustrine conditions. The red mudstone that contains limestone nodules probably represents low-energy, freshwater lacustrine conditions that exist part of the time on a delta or on coalescing deltas and their submerged extensions. Channels filled with sandstone and conglomerate represent the fluvial portion of the delta development.

Eyer (1964, p. 11–12) summarized fossil occurrences in the Ephraim Conglomerate. He reported marine fossils from lower Ephraim beds, probably from below the lowermost conglomerate unit, and nonmarine fossils from middle and upper Ephraim beds. Thus, Ephraim beds indicate a transition from a marine to a nonmarine environment near the Jurassic-Cretaceous boundary. No fossils were seen in the Ephraim Conglomerate in the Sage Valley Quadrangle in the present study.

Peterson Limestone. The Peterson Limestone crops out on the east and west flanks of the Spring Creek Syncline (plate 1). In the northern part of the Sage Valley Quadrangle, the limestone is a prominent ledge- and shoulder-forming unit, but, owing to rapid facies changes into more argillaceous rocks, it generally forms a swale in the middle and southern parts of the quadrangle.

In sections 2, 3, 10, and 11, T. 8 S, R. 46 E, on the west limb, and in sections 20, 29, and 32, T. 32 N, R. 119 W, and sections 5 and 6, T. 31 N, R. 119 W, on the east limb of the Spring Creek Syncline, the Peterson Limestone consists of massively bedded, medium to dark gray, cliff-and ledge-forming limestone with rarely exposed interbeds of gray calcareous shale (fig. 11). One sample of limestone from the Peterson had a slight petroliferous odor when crushed. When the same sample was dissolved in hydrochloric acid, droplets of oil were seen on the surface of the liquid. This oil was probably present as kerogen material within the limestone rather than as petroleum migrating into it. Abundant mollusk fragments are seen in some of the limestone units. Here, the contact with the underlying Ephraim Conglomerate was mapped at the base of the lowermost massively bedded limestone. Eyer (1964, p. 112) included a covered interval, approximately 45 m thick, of reddish brown soil with abundant limestone nodules below the massively bedded limestone, thus indicating that the contact is gradational. The contact with the overlying Bechler Conglomerate was mapped at the top of the uppermost massively bedded limestone.

The Peterson Limestone changes character rapidly near the middle of the quadrangle. In sections 15, 22, 27, and 35, T. 8 S, R. 46 E, and sections 2 and 23, T. 9 S, R. 46 E, on the west limb, and in sections 7, 18, 19, 29, 30, and 32, T. 31 N, R. 119 W, on the east limb of the Spring Creek Syncline, the Peterson becomes a poorly exposed, reddish and grayish green mudstone that thins to the south and west. Abundant limestone nodules occur within the mudstone but become less common toward the south and west (fig. 11). No fossils were seen in these sections. The contact with the underlying Ephraim Conglomerate in this part of the outcrop belt was mapped at the bottom of the swale developed in the mudstone-nodular limestone unit, that here represents the Peterson Limestone. The contact with the overlying Bechler Conglomerate was mapped at the top of the Peterson swale which coincides with uppermost occurrences of nodular limestone.

The Peterson Limestone ranges from 19 to 55 m thick within the Sage Valley Quadrangle. It thins toward the south and west (fig. 11).

Eyer (1964, p. 36) and Holm, James, and Suttner (1977, p. 67–69) discussed the depositional environments of the Peterson Limestone on a regional basis. The massive facies of the Peterson Limestone in the Sage Valley Quadrangle probably represent a shallow (less than 15 m deep), freshwater lacustrine environment. The gray shales interbedded with the limestone beds probably represent only a slightly higher-energy environment. The red mudstone and nodular limestone of the southern and southwestern facies were probably deposited in an argillaceous lacustrine to floodplain environment similar to the one in which the mudstone and nodular limestone of the Ephraim Conglomerate were deposited.

Bechler Conglomerate. The Bechler Conglomerate crops out on the east and west limbs of the Spring Creek Syncline (plate 1). In the Sage Valley Quadrangle, the Bechler Conglomerate is similar in appearance to the Ephraim Conglomerate and forms low hills covered by reddish soil, with occasional outcrops of ledge-forming sandstone and conglomerate that become thicker and more prominent to the south and west.

Conglomeratic units of the Bechler Conglomerate have a fine- to coarse-grained sandstone matrix, are commonly cross-bedded, and appear to be lenticular channel fillings that pinch out laterally, particularly in the northern part of the quadrangle. They become thicker and more continuous to the south and west. A 13-m-thick conglomerate unit near the top of the Bechler beds can be correlated across the quadrangle (fig. 11). Clasts are up to 36 cm in diameter in this unit in section 4 of figure 11. Clasts in the other conglomerate units are more commonly 1 to 3 cm in diameter. The conglomerates usually grade upward into a sandstone that is filling the same channel and is similarly cross-bedded though not all the sandstone units are underlain by conglomerate.

Sandstone and conglomerate channels are probably within and overlain by reddish mudstone, shale, and siltstone. These latter lithologies are rarely exposed, except in deep gullies or on steep hillsides, such as in section 11, T. 8 S, R. 46 E, where red mudstone with greenish blebs crops out. Purplish gray, nodular limestone is present as weathered debris on some of the covered mudstone units and is probably weathered out of the mudstone units. These calcareous mudstones form laterally persistent units. The nodular limestone occurs in more horizons in the Bechler Conglomerate than in the Ephraim Conglomerate, and limestone also appears to be more abundant in the Bechler beds although it decreases in amount to the south and west, paralleling the limestone distribution in the Ephraim Conglomerate.

Complete sections of the Bechler Conglomerate range in thickness from 472 m to 524 m within the Sage Valley Quadrangle. South of Crow Creek, uppermost units of the Bechler are lost to erosion, so a formation thickness could not be obtained (fig. 11).

The depositional environment of the Bechler Conglomerate was probably similar to that of the Ephraim Conglomerate. Most of the Bechler units within the Sage Valley Quadrangle were deposited in a lower-energy environment than was the Ephraim Conglomerate, as suggested by the more abundant nodular limestone units and the less-common, finer-grained conglomeratic units. There were periods of deposition in higher-energy environments, however, than any documented by the Ephraim Beds within the quadrangle because of the larger clasts and broader extent of two conglomerate units within the Bechler outcrops (fig. 11).

Draney Limestone. The Draney Limestone crops out along the axis of the Spring Creek Syncline north of Crow Creek but is not present south of Crow Creek because of erosion (plate 1). In the Sage Valley Quadrangle, the Draney Limestone forms low hills covered by grayish brown soil and abundant light gray limestone float. It is less resistant than the Peterson Limestone and forms low ridges rather than prominent ledges.

The Draney Limestone consists of poorly exposed, massive, gray limestone beds in the lower part and thin-bedded limestone interbedded with gray calcareous mudstone in the upper part. The thin-bedded limestone and mudstone weather and cover the underlying units. The limestone beds are generally fossiliferous, with some beds made up almost entirely of oriented gastropods and bivalve fragments. Most of the fossils show signs of transport. Oil droplets were noted as residues when two Draney Limestone samples were dissolved in hydrochloric acid. One of the samples contained carbon (?) flecks that would not centrifuge out. These shows are probably from kerogen deposits within the limestone and not from petroleum migrating into the formation. A few fragments of unidentifiable silicified wood were found as float weathered out of the formation in section 14, T. 8 S, R. 46 E.

The Draney Limestone has a maximum thickness of approximately 55 m in the Sage Valley Quadrangle, on the basis of map pattern (fig. 2). The contact with the underlying Bechler Conglomerate was mapped at the upper edge of red soil and sandstone float from the Bechler Conglomerate. The contact with the overlying Smoot Formation was mapped at the uppermost occurrence of brown soil and gray limestone float from the Draney Limestone.

Eyer (1964, p. 37), Holm, James, and Suttner (1977, p. 267–269), and Brown and Wilkinson (1979) discussed the depositional environment of the Draney Limestone on a regional basis. The depositional environment of the Draney Limestone was probably similar to that of the Peterson Limestone. The Draney beds are laterally more continuous in the Sage Valley Quadrangle and contain no red mudstone, unlike the Peterson Limestone, which indicates a facies freer of terrigenous material.

Smoot Formation. The Smoot Formation crops out along the axis of the Spring Creek Syncline between section 11, T. 8 S, R. 46 E, and section 35, T. 8 S, R. 46 E, in the Sage Valley Quadrangle (plate 1). The Smoot beds form low hills covered by red soil and generally erode to a low area between the more resistant Draney Limestone outcrops on either limb of the Spring Creek Syncline. The Smoot Formation probably consists of nonresistant, calcareous, red mudstone and siltstone although outcrops are rare. No fossils were found in Smoot rocks within the mapped area.

The Smoot Formation is approximately 100 m thick in the Sage Valley Quadrangle. Contact with the underlying Draney Limestone has been discussed previously. The contact with the overlying Tygee Member of the Bear River Formation was mapped at the top of the red siltstone of the Smoot Formation and the base of the black shale of the Tygee Member.

Eyer (1964, p. 37–39) discussed the regional depositional environment of the Smoot Formation. He collected nonmarine fossils in the lower part of the Smoot Formation and brackish-water to marine faunas from the middle and upper Smoot beds, thus implying a significant environmental change near the Albian-Aptian boundary. The mudstone and siltstone are thought to represent a beach-mudflat environment, similar to the physical environment seen in the modern Bear Lake, Idaho, area.

Tygee Member of the Bear River Formation

The Tygee Member of the Bear River Formation crops out along the axis of the Spring Creek Syncline in section 14, T. 8 S, R. 46 E, in the Sage Valley Quadrangle (plate 1). The Tygee

FIGURE 13.–Black shale unit of the Tygee Member of the Bear River Formation at the center of the Spring Creek Syncline.

FIGURE 14.–Cross-bedding in the sandstone unit of the Tygee Member of the Bear River Formation at the center of the Spring Creek Syncline.

FIGURE 15.–Vertical burrows in the sandstone unit of the Tygee Member of the Bear River Formation at the center of the Spring Creek Syncline (quarter for scale).

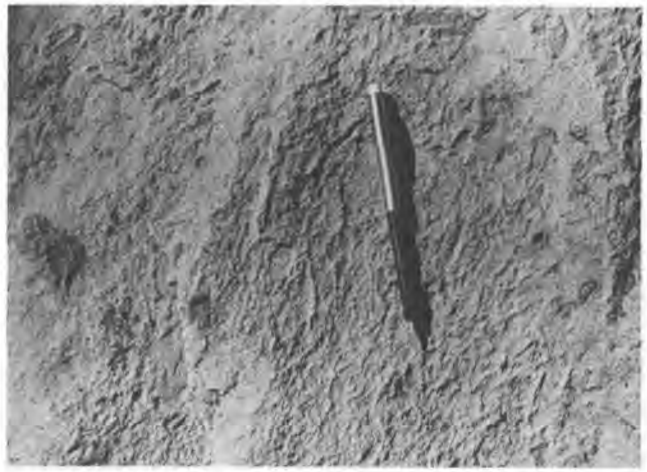


FIGURE 16.–Fucoidal markings in the sandstone unit of the Tygee Member of the Bear River Formation in the center of the Spring Creek Syncline.

Member forms a knoll above the less resistant red mudstone of the Smoot Formation. Only the lowermost 45 m of the Tygee Member are present within the quadrangle; the remainder has been removed by erosion.

The Tygee Member can be divided into two units in the mapped area. The lower unit is a weakly resistant, dark brown to black, very thinly bedded shale that breaks into small pencil-like fragments at the outcrop (fig. 13). No fossils were found in this dark shale unit which is approximately 40 m thick and is overlain by the upper unit–a 5-m-thick layer of quartz sandstone. The sandstone is grayish yellow, calcareous, poorly sorted, medium to coarse grained, cross-bedded (fig. 14), and ripple marked. Vertical burrows (fig. 15) and fucoidal markings (fig. 16) occur in several beds. The contact between the two units is sharp, but no unconformity is suggested.

Eyer (1964, p. 40) assigned an Albian (Lower Cretaceous) age to the Tygee Member of the Bear River Formation.

The dark shale of the Tygee Member was probably deposited under brackish to normal-marine conditions in a lower-energy environment. The dark color indicates reducing conditions, but no other environmental indicators were found. The sandstone was probably deposited above wave base in fairly shallow, well-oxygenated water–possibly a fluvial environment. The organisms that produced the fucoidal markings were probably restricted to fairly shallow water. The cross-bedding and ripple marks indicate a fairly high-energy environment. Kamis (1977b) discusses the petrology and reservoir capabilities of the Tygee Member.

Tertiary System

Salt Lake Formation

The white and light gray tuff, marl, sandstone, and conglomerate exposed in Sage Valley, Tygee Valley, and along the west flank of Star Valley were assigned to the Salt Lake Formation by Mansfield (1927, p. 110), and this terminology is followed in this report.

The Salt Lake Formation overlies older rocks and structures with angular unconformity. The formation is easily eroded and forms low hills covered with light colored soil and occasional float fragments consisting of rounded pebbles or cobbles originally derived from other formations. The formation is poorly exposed, and, although Cressman (1964, p. 57) divided it into an upper and a lower member, such a division was not made in the Sage Valley Quadrangle. The best exposures of the formation occur in section 8, T. 8 S, R. 46 E, on the north ridges above the deeper stream valleys. Here the Salt Lake Formation dips approximately 15° to the east and consists of locally derived, subrounded to rounded pebbles and cobbles, probably from the Thaynes Formation. They are cemented by a light colored marl that sometimes makes up over 80 percent of the rock volume. The formation ranges up to 300 m in thickness within the Sage Valley Quadrangle. No fossils were found in the Salt Lake Formation in the mapped area.

Mansfield (1927, p. 111–12) assigned a Pliocene (?) age to the Salt Lake Formation in the Slug Creek Quadrangle, Idaho. Cressman (1964, p. 57–58) summarized previously published fossil data that indicate an age of Oligocene to Pleistocene for the formation southwest of the Sage Valley Quadrangle. Eardley (1944, p. 845–46) recognized that when intermountain valleys west of the Wasatch become better known stratigraphically, the Salt Lake Formation may be found to include several distinct units within the Tertiary that may be separated by considerable time gaps.

The fossils listed by Cressman (1964, p. 57–58) indicate a freshwater environment, probably lacustrine, although there was probably some fluvial influence as indicated by the pebbles and cobbles present in the float.

Quaternary System

Colluvium and Alluvium

Colluvium areas mapped within the Sage Valley Quadrangle consist mostly of poorly sorted, nonstratified rock debris forming hill wash and talus that covers the lower slopes of many hills. In many places, it merges with fluviatile deposits and forms alluvial fans that may have considerable extent, such as those in Sage Valley. Areas mapped as alluvium consist mostly of poorly sorted, somewhat stratified gravel, sand, silt, and clay. The term is restricted to floodplains and sites of active accumulation of sediments by water movement.

The contact between the colluvium and the alluvium is locally gradational, but the colluvium generally has more topographic relief than the alluvium and has been dissected to a greater degree by running water. The Quaternary cover is probably not over 50 m thick at any point within the mapped area.

Unidentified vertebrate remains, some possibly Pliocene in age, were found in the gravel pit in section 28, T. 32 N, R. 119 W, from approximately 5 to 25 m below the original ground surface. Several organic-rich layers were also noted. Tarlike blebs, some having a petroliferous odor, were scattered, apparently irregularly and in varying amounts, in some of the coarser-grained units.

FIGURE 17.–Salt Spring in Alkali Flat. The logs lining the pit were used to keep the spring open when it was used commercially to produce salt. Note the salt encrustations.

Travertine

Small patches of travertine are associated with active springs on the west side of Sage Valley in the NE ¼ of section 18, T. 9 S, R. 46 E. Other small patches of travertine also occur along Sage Creek in section 20, T. 9 S, R. 46 E, some associated with active springs, others not. The travertine is generally white, gray, or buff, very porous, and forms low mounds, ledges, or coatings over colluvium or older rocks. No fossils were found in the travertine in the Sage Valley Quadrangle although Mansfield (1927, p. 113) reported local occurrences of gastropods and casts of grass stems in the calcareous deposits.

Salt

A saline spring is present in Alkali Flat in the SE ¼ of section 16, T. 8 S, R. 46 E, of the Sage Valley Quadrangle (fig. 17). The salt forms white encrustations on the ground near the spring and along the outflow course. Mansfield (1927, p. 338–40) reported the chemical content of the salt from nearby saline springs as nearly pure sodium chloride, which is probably also true for the spring in Alkali Flat. The salt was recovered in the late 1800s, mostly for local use, by boiling the water off in large pans. The origin of the salt was previously discussed in the Preuss Sandstone section.

STRUCTURE

General Statement

Rocks are exposed in the Sage Valley Quadrangle in a series of north-south-trending arcuate belts that are concave to the east. The Meade Overthrust Fault zone (fig. 18) is recognized in the western and central parts of the quadrangle, where it forms a series of six major branches that generally follow the

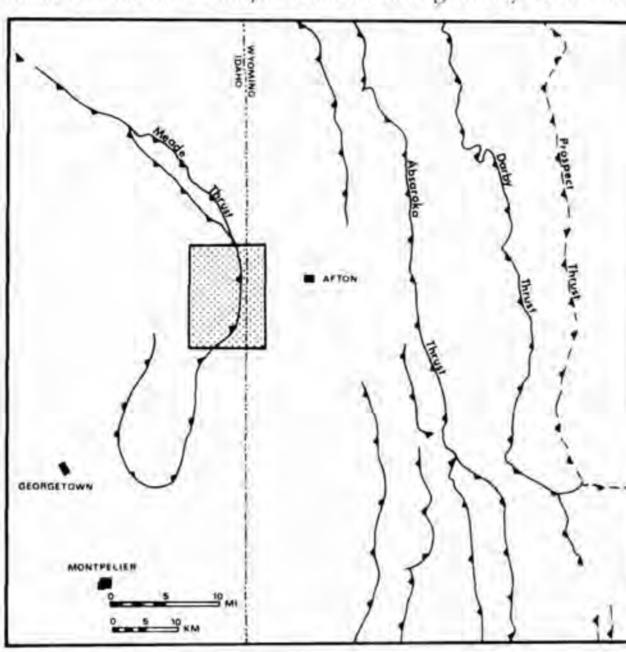


FIGURE 18.–Map of the major thrust fault zones in southeastern Idaho and western Wyoming (modified after Blackstone 1977).

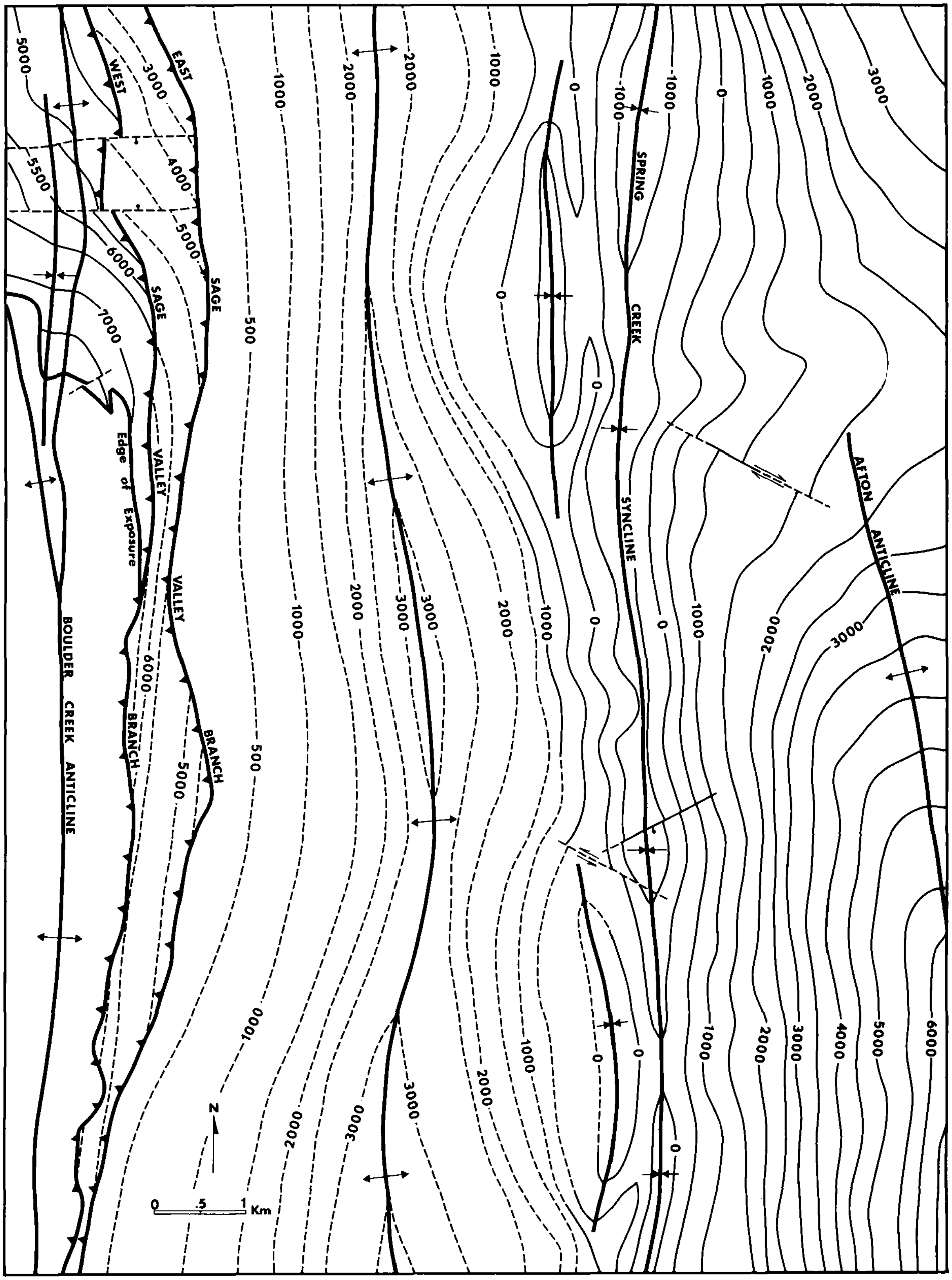


FIGURE 19.–Generalized structural contour map of the Sage Valley Quadrangle. Contours are on top of the Nugget Sandstone in the Absaroka Plate east of the East Sage Valley Branch and on top of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation in the Meade Plate west of the East Sage Valley Branch. Inferred contours are dashed (contour interval = 500 feet).

strike of the rock units. Two minor thrust faults were also found, and several more minor thrust faults are probably present but remain undetected beneath the unconsolidated cover. Rocks exposed on the upper, or Meade Plate, are almost exclusively Paleozoic through Lower Jurassic in age. Rocks exposed on the lower, or Absaroka Plate, are middle Jurassic through Lower Cretaceous in age. Rocks on both the upper and lower plates have been compressed into a series of asymmetric, north-south-trending folds (fig. 19). Numerous small east-west-trending tear faults and normal faults, which were probably formed contemporaneously with thrust faulting, offset the folds and thrust faults.

The model for the thrust faulting and deformation is similar to one proposed by Dahlstrom (1970) for the Canadian Rocky Mountains. The mechanism for thrusting is thought to be gravity sliding, as proposed by Rubey and Hubbert (1959). Lowell (1977) postulated underthrusting as the mechanism for the development of the thrust faults, but this hypothesis has not been widely accepted. Further detail of thrust fault development in Idaho and Wyoming is described in a paper by Armstrong and Oriel (1965).

Thrust Faults

The Meade Overthrust Fault zone, formerly the Bannock Overthrust of Richards and Mansfield (1912), consists of six major branches and is the major zone recognized in the Sage Valley Quadrangle. Figure 18 shows the position of the Meade Overthrust relative to the other overthrust zones in western Wyoming and southeastern Idaho. The glide plane for the sole of the Meade Overthrust is within the Twin Creek Limestone (Cressman 1964, p. 68–69) until the thrusts ramp sharply upward through the Jurassic and Cretaceous sections (plate 1, section A-A′ and B-B′). The horizontal displacement of the east ern edge of the Meade Plate is approximately 29 to 32 km (Cressman 1964, p. 76), and the stratigraphic displacement is approximately 3,600 to 4,500 m. Initial movement of the Meade Overthrust Fault, complemented by movement of the Crawford Overthrust Fault, is documented by deposition of most of the Echo Canyon Conglomerate (Blackstone 1977, p. 381) which has been dated as Upper Cretaceous (Olson 1977, p. 93). The age of thrusting in the Sage Valley Quadrangle can be determined only as post-Tygee Member of the Bear River Formation (Lower Cretaceous) and pre-Salt Lake Formation (Pliocene [?]). The faulting was probably a relatively cold event as indicated by the absence of major metamorphic zones. Steep dips near the trace of the thrust faults are generally interpreted as drag features related to movement of the fault.

The East Hardman Branch of the Meade Overthrust is named here. The fault enters the Sage Valley Quadrangle approximately 1 km east of the Draney ranch, along the west limb of the Spring Creek Syncline (plate 1). It parallels the Spring Creek Syncline along Hardman Hollow, crosses Crow Creek, and exits the quadrangle near the Idaho-Wyoming border. In sections 22 and 28, T. 8 S, R. 46 E, it splits and rejoins, forming a second small imbricate slice or horse. The fault terminates to the south in an anticline approximately 1 km south of the Sage Valley Quadrangle (Floyd Hatch personal communication 1980). To the north, it is thought to terminate just north of the quadrangle border in a similar fold because of an anomalously thick section of Ephraim Conglomerate (fig. 11, section 2) measured just within the border of the quadrangle and the more normal thicknesses of Ephraim Conglomerate measured just north of the quadrangle (fig. 11, section 1; Mansfield 1927, p. 102–3). Structural displacement along the fault ranges to no more than a few hundred meters at maximum near the central part of its trace. The minimum dip of the fault plane is approximately 20°, with the dip of the beds becoming vertical to overturned near the terminal points. The East Hardman Branch of the fault was probably formed by imbrication within the footwall.

The West Hardman Branch of the Meade Overthrust, named here, generally parallels the East Hardman Branch, though near the north and south borders of the quadrangle, the fault swings slightly more toward the west (plate 1). The northern and southern limits of this branch and the remaining major branches could not be determined, but their terminations are probably beyond the Sage Valley Quadrangle. The West Hardman Branch is probably the frontal edge of the Meade Plate (plate 1, sections A-A′ and B-B′). Its stratigraphic and structural displacements have been discussed previously. The fault plane dips between 20° and 45° near the surface.

The East Tygee Branch of the Meade Overthrust, named by Mansfield (1927, p. 152), is exposed only in sections 9, 10, and 16, T. 9 S, R. 46 E, in the Sage Valley Quadrangle, where it faults older Nugget Sandstone over younger Twin Creek Limestone (plate 1). Its trace is covered by Salt Lake Formation in the rest of the quadrangle, but evidence of its presence is indicated by the salt spring in Alkali Flat. The East Tygee Branch is a fairly high-angle fault, with dips approaching 70° W. at some locations at the surface, but it rapidly flattens westward in the subsurface (plate 1, sections A-A′ and B-B′). Structural displacement could not be accurately calculated, but is probably not more than a few hundred meters. The East Tygee Branch was probably formed by imbrication of the overriding plate.

The West Tygee Branch of the Meade Overthrust, named by Mansfield (1927, p. 152), is exposed in sections 4, 9, 16, 17, and 20, T. 9 S, R. 46 E, in the Sage Valley Quadrangle, where the fault places older Thaynes Formation over younger Nugget Sandstone (plate 1; fig. 6). The fault is covered by Salt Lake Formation in the remainder of the quadrangle. The dip of the fault plane of the West Tygee Branch is approximately 70° near the surface but rapidly flattens westward in the subsurface (plate 1, sections A-A′ and B-B′). Structural displacement is approximately 300 m where the fault is best exposed. The West

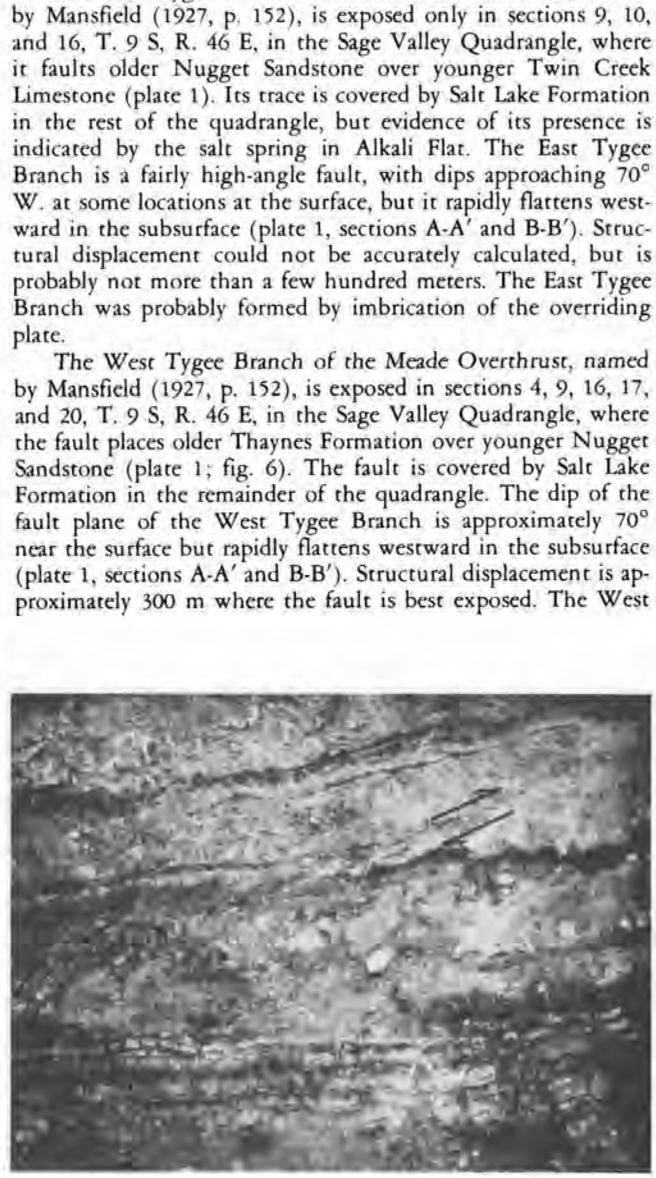


FIGURE 20.–Minor thrust fault in the Preuss Sandstone along the Mobil well road. Note the drag folds (arrows show relative displacement).

Tygee Branch was probably formed by imbrication of the overriding plate.

The trace of the East Sage Valley Branch of the Meade Overthrust, named here, is not exposed in the Sage Valley Quadrangle, but is covered by Salt Lake Formation and Quaternary deposits (plate 1). It is exposed just south of the quadrangle border, however, where older Dinwoody Formation is faulted over younger Thaynes Formation (Floyd Hatch personal communication 1980). Position of the fault within the quadrangle is inferred to account for the close juxtaposition of the upper unit of the Portneuf Limestone and the Dinwoody and Paleozoic formations in section 29, T. 8 S, R. 46 E (plate 1). There is not enough space to allow for a normal sequence between the outcrops. The dip of the fault plane is probably steep near the surface, but it, too, probably flattens out rapidly at depth. Structural displacement along the fault is estimated to be approximately 1000 m within the Sage Valley Quadrangle. The East Sage Valley Branch was probably formed by imbrication of the overriding plate.

The West Sage Valley Branch of the Meade Overthrust, named here, is exposed along the west side of Sage Valley, where older Paleozoic units are thrust over younger Paleozoic units (plate 1). This branch probably offsets the Lower Dinwoody Formation north of Sage Valley, but the trace could not be accurately located there because of poor exposure. The dip of the fault plane is 70° to 80° at the surface, but it also probably flattens rapidly in the subsurface (plate 1, sections A-A′ and B-B′). Structural displacement along the fault is estimated to be approximately 200 m in the Sage Valley Quadrangle. The West Sage Valley Branch was probably formed by imbrication of the overriding plate.

Two minor thrust faults were mapped east of the East Hardman Branch along the west limb of the Spring Creek Syncline in the Absaroka Plate. Several small thrust faults having displacements of approximately 2 to 3 m were found in the Preuss Sandstone along the Mobil well road (fig. 20). More are probably present in rocks of the Spring Creek Syncline but were concealed. These faults were probably formed by imbrication of the footwall.

Steep and overturned dips near the thrust fault traces are interpreted as fault drag features. Minor brecciation and no metamorphic zones were found. A series of tight folds in the Twin Creek Limestone along Crow Creek (fig. 21) are associated with the West Hardman Branch of the Meade Overthrust.

Tear Faults and Normal Faults

Numerous tear faults were mapped in the Sage Valley Quadrangle (plate 1), most with mappable traces not over 1 km long with no displacements in excess of a few meters. More are present but have little displacement, and many were probably undetected. Most such faults are oblique to tangential to the principal structural grain, trending generally east-west, and offset thrust faults, fold axes, and individual beds. A tear fault may be present along Crow Creek to account for the offset of the Peterson Limestone on the west limb of the Spring Creek Syncline. The tear faults were probably formed contemporaneously with thrusting, which permitted differential movement related to differential stresses between components within the thrust sheet. None of the tear faults seem to offset the Salt Lake Formation.

Several east-west-trending normal faults were mapped in the Sage Valley Quadrangle (plate 1). Most have traces less than 1 km long, and most have vertical displacements of less than 10 m. The largest of these is the Draney Creek Fault that can be traced into the Stewart Flat Quadrangle (Montgomery and Cheney 1969, p. 38). The Draney Creek Fault is indicated by the apparent offset of the *Meekoceras*-bearing limestone of the Thaynes Formation. The fault has an approximate structural displacement of 150 m. These normal faults apparently do not offset the Salt Lake Formation and thus may be related to thrusting. It is possible that they are basin-and-range normal faults, but no north-south-trending normal faults were found in the quadrangle, which would be expected in a basin-and-range structural environment.

FIGURE 21.—Tight folds in the Twin Creek Limestone in the road metal pit between Hardman Hollow and Poison Creek along the Crow Creek road.

Folds

The Afton Anticline (fig. 22) is the easternmost fold in the Sage Valley Quadrangle (plate 1; fig. 19). The structure trends generally north-south, plunging northward at approximately 1° (18 m/km) until near the middle of the quadrangle, beyond where it plunges steeply, at approximately 15° (268 m/km), and terminates in section 5, T. 31 N, R. 119 W. The Leeds Creek Member of the Twin Creek Limestone is the oldest unit exposed in the Afton Anticline in the Sage Valley Quadrangle. A cross-section through the Afton Anticline by Long (1960, p. 188) shows that the anticline probably does not continue deeper than the plane of the Absaroka Overthrust Fault, and is, therefore, not a fold formed in the Absaroka Plate by faulting and folding within the underlying thrust sheet or sheets.

The Spring Creek Syncline extends beyond the northern and southern borders of the Sage Valley Quadrangle (fig. 23) and has a maximum width of approximately 5 km near the northern edge of the quadrangle (plate 1). The syncline does not appear to plunge in either direction within the quadrangle. Rock units remain at a fairly constant elevation within the trough. Several minor synclines and anticlines are present on the flanks of the Spring Creek Syncline but are probably only shallow structures (plate 1, sections A-A′ and B-B′) formed by local wrinkling at the time of movement of the Meade Plate. The western limb of the Spring Creek Syncline is overturned throughout most of its exposure in the Sage Valley Quadrangle. That overturning is probably also related to movement along the Meade Overthrust. The youngest rocks preserved within the Spring Creek Syncline are in the Tygee Member of the Bear River Formation. The depth to which the syncline persists is unknown, but it may be a fold within the Absaroka Plate that was formed by deformation and movement of the plate or plates underlying the Absaroka Plate.

A north-south-trending anticline, with no surface expression is indicated beneath the Meade fault zone, in cross-sections A-A′ and B-B′ (plate 1) and figure 19. It is probably an extension of the Pinnacle Creek Anticline, which is present in the Elk Valley Quadrangle (Floyd Hatch personal communication 1980). The fold is in Twin Creek Limestone and Nugget Sandstone, two of the important reservoir rocks in the overthrust belt. The anticline may persist at depth, and seismic studies would help determine its extent and closure. The anticline may be a fold within the Absaroka Plate that was formed by movement and deformation of the plate underlying the Absaroka Plate, although the crest of the anticline has been deformed by movement of the Meade Plate.

All the folds described previously are on the Absaroka Plate in the Sage Valley Quadrangle. The folds described next are on the overlying Meade Plate, with some originating as folds controlled by deformation of the Absaroka or deeper plates.

An unnamed north-south-trending syncline was mapped on the east side of Sage Valley, in sections 29 and 33, T. 8 S, R. 46 E, and sections 4, 8, 9, and 17, T. 9 S, R. 46 E (plate 1). The syncline flattens and terminates to the south. Its western flank is overturned in the middle of section 4 and is buried beneath the Salt Lake Formation from section 29, north. Youngest rocks exposed in the syncline are in the Triassic Thaynes Formation. The syncline plunges approximately 1° (18 m/km) to the north. The syncline was probably formed by the movement of the Meade Plate and does not continue below the plane of the Meade Fault.

The Boulder Creek Anticline is a north-south-trending fold exposed along the western edge of the Sage Valley Quadrangle (plate 1; fig. 19). North of section 30, T. 8 S, R. 46 E, the anticline splits, with one branch trending toward the northwest and the other continuing to the north. The anticline plunges approximately 2° to 3° (36 m/km to 54 m/km) to the north. Several minor synclines and anticlines are present on the flanks of the Boulder Creek Anticline (fig. 3; plate 1), but most are probably shallow structures. The eastern limb of the anticline is overturned in places, which may be a function of fault drag created by movement along the West Sage Valley Branch of the Meade Overthrust zone. The oldest rocks exposed in the anticline in the Sage Valley Quadrangle are upper Wells Formation. The Boulder Creek Anticline is interpreted to be a fold in the Meade Plate formed by deformation and movement of the Absaroka or deeper plate. The oldest unit contained within the anticline on the Meade Plate in the Sage Valley Quadrangle is the Mississippian Madison Limestone, which rests on Jurassic Twin Creek Limestone (plate 1, sections A-A′ and B-B′).

GEOLOGIC HISTORY

An area comprising western Wyoming and southeastern Idaho was the site of deposition within part of the Cordilleran

FIGURE 22.–Afton Anticline. Looking north across the Crow Creek road from the eastern edge of the Sage Valley Quadrangle.

FIGURE 23.–Spring Creek Syncline. Looking north into the Auburn Quadrangle from near the north edge of the Sage Valley Quadrangle.

miogeosyncline of approximately 7,900 m of primarily sedimentary rocks from the Cambrian through the Late Triassic or Early Jurassic (Cressman 1964, p. 85). Early rocks had basically an eastern source, but beginning in the Late Triassic or Early Jurassic, most of the sediments were derived from uplifts in the miogeosyncline, to the west, north, and south (Hileman 1973, p. 71–78), changing the depositional area to an exogeosyncline. An exposed sequence of sedimentary rocks 5,400 m thick details the depositional record from the Upper Pennsylvanian to the Early Cretaceous in the Sage Valley Quadrangle.

The Paleozoic and Triassic rocks are exclusively marine and are generally widespread deposits. The phosphate and chert of the Phosphoria Formation indicate periods of deep, quiet water with a minimum of carbonate deposition. The black shales indicate less deep environments of deposition for the Thaynes and Dinwoody Formations. All were probably formed under reducing conditions in a deep basin. The limestone and sandstone units generally contain sedimentary structures indicative of a higher-energy environment, often above wave base. The Lanes Tongue of the Ankareh Formation and the Woodside Formation signal regressions of marine water; and continental deposits are the dominant lithologies. The limestone present above each of the continental deposits indicates a transgression of the sea and a return to more nearly normal marine conditions. The origin of the Triassic rocks of southeastern Idaho and western Wyoming has been discussed by Kummel (1957).

The environment of deposition of the Jurassic formations has been discussed by Imlay (1957) and Hileman (1973, p. 71–100). The Nugget Sandstone is partially eolian and partially littoral in character in the Sage Valley Quadrangle. Marine regressions are marked by the Nugget Sandstone, the Gypsum Spring Member, and the red beds of the Boundary Ridge Member of the Twin Creek Limestone, and the tidal flat-lagoonal environment of the Preuss Sandstone. Transgressions are marked by deposition of the Sliderock Member through the limestone units of the Boundary Ridge Member of the Twin Creek Limestone, deposition of the Watton Canyon through the Giraffe Creek Members of the Twin Creek Limestone, and deposition of the Stump Sandstone. The Leeds Creek and Giraffe Creek Members of the Twin Creek Limestone contain the earliest sediments in the Sage Valley Quadrangle derived from uplifts in the geosyncline to the west (Hileman 1973, p. 79).

The Cretaceous-Jurassic boundary marks the change from a marine environment to a freshwater lacustrine environment (Eyer 1964, p. 11–12). The Smoot Formation marks the change back to brackish-normal marine conditions. Deposition of the sandstone of the lower Cretaceous Tygee Member of the Bear River Formation, the youngest prethrusting rock unit preserved in the Sage Valley Quadrangle, was probably initiated by an orogenic pulse to the west (Eyer 1969, p. 1387). This deposition took place in a shallow foredeep in front of the area being uplifted on the west (Blackstone 1977, p. 369). Deposition of the conglomerates of the Gannett Group and later Cretaceous and Tertiary formations seems to coincide with movement of thrust plates that began to develop and slide from an uplift to the west (Blackstone 1977, p. 381). Thrust faulting continued into the Tertiary, but apparently ended prior to deposition of the Pliocene (?) Salt Lake Formation.

The present ranges and basins of the mapped area were defined by warping or normal faulting in middle Tertiary time (Cressman 1964, p. 89). Lakes were formed in the basins, and the Salt Lake Formation was subsequently deposited. Deposition of the Salt Lake Formation may have continued into the Pleistocene. Some volcanic material is present in the tuffaceous member of the Salt Lake Formation of Cressman (1964, p. 57), but none was recognized in the Sage Valley Quadrangle. Normal faulting continued after deposition of the Salt Lake Formation, and the area is still seismically active (Smith and Sbar 1974).

Mansfield (1927, p 11-20) discussed the physiographic development of southeastern Idaho and western Wyoming and distinguished a number of erosional surfaces that are Tertiary and Quaternary in age. Little can be added to Mansfield's discussion by this study of the Sage Valley Quadrangle.

ECONOMIC GEOLOGY

Phosphate

As mentioned in the section on the Phosphoria Formation, a series of five test trenches have been dug on the west side of Sage Valley. Three of these contain exposures of phosphate rock characteristic of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation whereas the other two do not. South of section 29, T. 8 S, R. 46 E, in the Sage Valley Quadrangle, phosphate occurrences are probably not economic because of their limited size and the amount of overburden to be removed. North of section 29, however, a complete section of the Meade Peak Phosphatic Shale Member is present and will be economic if a method of transport were brought into the area or the mill proposed by the J. R. Simplot Company is constructed. No mining of phosphate has taken place to date within the Sage Valley Quadrangle.

Petroleum

Several hydrocarbon test wells have been drilled around the Sage Valley Quadrangle (Hodgen and McDonald 1977, p. 50–51), but none have produced hydrocarbons in economic quantity In 1979, Mobil Oil Company drilled the Max Smith #1 well in the SE ¼ of the SW ¼, section 5, T. 31 N, R. 119 W, in the Sage Valley Quadrangle. This well was plugged and abandoned after reaching a depth of 4,136 m, bottoming in the Wells Formation.

Source beds, such as the Thaynes Formation and the Phosphoria Formation, and reservoir beds, such as the Nugget Sandstone and the Twin Creek Limestone, are in close proximity to each other within the Sage Valley Quadrangle Two anticlinal structures, the Boulder Creek Anticline and the unnamed anticline shown in cross sections A-A′ and B-B′ of plate 1 and figure 19, should be tested for hydrocarbon accumulation. The amount of closure on the structures could be determined from seismic data. The requirements of structure, source beds, and reservoir beds necessary for the accumulation of hydrocarbons have all been met in the Sage Valley Quadrangle Other structural and stratigraphic traps may also be present within the quadrangle

Water

The major perennial streams within the Sage Valley Quadrangle are Crow Creek, Sage Creek, South Sage Creek, Draney Creek, and Pole Creek. Several other small unnamed streams flow either all year or parts of the year, depending upon the precipitation of the previous winter. Numerous springs exist throughout the quadrangle and are used primarily for watering livestock and some irrigation. Pole Creek and Sage Creek are used for the irrigation of Sage Valley, and water is diverted from Crow Creek for some irrigation Considerable groundwater potential is present within the quadrangle, but abundant surface water has limited its development.

Salt

Salt from the saline spring in Alkali Flat (fig. 17) was formerly produced for local use by boiling off the water in large pans (Mansfield 1927, p. 339). No salt is produced in the quadrangle at the present, and the saline spring has been partially developed into a salt lick for livestock.

Other Mineral Deposits

A gravel pit is currently in production in section 28, T. 32, N, R 119 W, in the Sage Valley Quadrangle. The material is unconsolidated sand and gravel from a Quaternary colluvial deposit and is used primarily for fill material. Two road metal pits are found along Spring Creek and another along the Crow Creek road between Hardman Hollow and Poison Creek. All three produce fractured rock from the pencilly limestone of the Twin Creek Limestone which was apparently used for the surfacing of the unpaved roads in the area. The road material produced from these pits, while suitable for gravel on the unpaved roads, is too soft for use as road metal on heavily traveled, paved roads Higher quality road metal could be produced by crushing the conglomerate-sandstone rocks in the Cretaceous units or some of the dense limestone and sandstone present in some of the Paleozoic, Triassic, and Jurassic units.

Some of the Twin Creek Limestone units, some of the Cretaceous limestone units, and possibly the Portneuf Limestone Member of the Thaynes Formation, though it may be too siliceous, could be used to manufacture Portland cement if the population and industry develop in southeastern Idaho and western Wyoming to make it economically feasible (Mansfield 1927, p. 331–332) The travertine deposits could be a source of high-grade lime (Mansfield 1927, p. 332) though the deposits in the Sage Valley Quadrangle are probably too small to be economic

SUMMARY

As a result of this study, the structure and stratigraphy of the Sage Valley Quadrangle are delineated in much greater detail than before. A revised stratigraphic nomenclature for southeastern Idaho and western Wyoming was successfully applied in the mapped area, clarifying some inconsistencies present in previously published works. Six major imbricate thrust faults related to the Meade Overthrust fault zone were recognized in the Sage Valley Quadrangle, including the previously undetected East Sage Valley Branch of the Meade Overthrust

A number of minor thrust faults, previously undetected, were also identified.

At least two folding events are evident: the first is related to compression at the time of movement of the Meade Overthrust Fault, and the second is associated with movement of the Absaroka Overthrust Fault or younger overthrust faults which deformed the Absaroka Plate as well as the Meade Plate The anticlinal structures were grossly evaluated for hydrocarbon potential. Occurrences of potentially economic phosphate were noted in the quadrangle, as well as occurrences of several other materials for construction.

Several subjects could be pursued to improve the understanding of rocks in the Sage Valley Quadrangle: (1) detailed paleontological studies of the *Meekoceras*-bearing limestone of the Thaynes Formation in the mapped area would be useful in establishing a correlation between this and other units in the western United States, (2) detailed petrographic and environmental studies of the Paleozoic and Mesozoic formations in the mapped area to better define hydrocarbon occurrences and drillable prospects, and (3) a detailed seismic program to further delineate deeper structures with hydrocarbon reservoir potential in the Sage Valley Quadrangle.

APPENDIX

Measured Sections

Section 1

Partial section of Grandeur Tongue of the Park City Formation and Wells Formation, measured on the north side of Pole Creek, 1 0 km west of Sage Valley, SW ¼, section 31, T 8 S, R 46 E, Caribou County, Idaho

Unit No.		Thickness (meters) Unit	Cumulative Section
Bottom of the Meade Peak Member of the Phosphoria Formation, an unexposed interval-top of Grandeur Tongue of the Park City Formation			
13	Covered	unknown	
12	Dolomite medium gray, weathers light gray, very fine crystalline, blocky, ledge	6 7	245 0
	Partial thickness of the Grandeur Tongue of the Park City Formation	6 7	
Wells Formation, upper member			
11	Sandstone light tannish gray, weathers tan, calcareous, fine grained, porous, friable, blocky, massive bedded, partially covered, slope	35 9	238 3
10	Limestone (?) light to medium gray, weathers light gray, massive bedded, sandy, vugs up to 1 3 cm across compose up to 5% of the volume, ledge	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, massive bedded, slope	31 6	147 3
7	Sandstone light gray, weathers tannish brown, very fine grained, hard, calcareous, massive bedded, shoulder.	19 8	115 7
6	Sandstone light gray, weathers brownish red, very fine grained, well cemented, calcareous, massive bedded, ledge-former grading to cliff-former the last 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 containing calcite, fractured with no orientation, massive bedded, chert quantity increases to massive bedded at the top of the unit, ledge	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, massive bedded, ledge	3 8	47 8
3	Sandstone medium gray, weathers light gray, very fine grained, very well cemented by silica, slightly calcareous, massive bedded, shoulder	7 9	44 0
2	Sandstone· white to light gray, weathers brownish gray, slightly calcareous, very fine grained, well cemented, well sorted, massive bedded, shoulder	13 7	36 1
1	Covered brown soil Sections end at an unknown location in the upper member, Wells Formation	22 4	22 4
	Partial thickness of the upper member, Wells Formation	238 3	
	Total section thickness	245 0	

Section 2

Partial section of Twin Creek Limestone, measured on the north side of Spring Creek, SE ¼, section 17, and SW ¼, section 16, T 31 N, R 119 W, Lincoln County, Wyoming

Unit No		Thickness (meters) Unit	Cumulative Section
Giraffe Creek Member			
11	Sandstone alternating bands of light brown, thinly laminated sandstone and grayish green thickly bedded sandstone, cross-laminated, calcareous, glauconitic, ripple marked, flaggy, fissile, some burrowing traces, cliff Contact with overlying Preuss Sandstone located at disappearance of red soil	20 7	181 0
10	Sandstone light green, weathers light brownish green, fine grained, massive, calcareous, glauconitic, blocky, friable, climbing ripples showing current direction from south to north, 1 cm thick interbeds of siltstone, cliff	1 1	160 3
9	Limestone medium gray, weathers tan, very fine crystalline, thinly laminated with cross laminations, very sandy, thin to thick bedded, flaggy to blocky, interbeds of light gray, calcareous, poorly consolidated claystone, cliff	7 1	159 2
8	Sandstone light brown, very fine grained, thin bedded with poorly exposed cross-beds, calcareous, blocky to flaggy, cliff	2 5	152 1
	Total thickness of Giraffe Creek Member	31 4	
Leeds Creek Member			
7	Limestone medium to light gray, weathers light brown, very fine crystalline, very finely laminated to thinly bedded, shaly in thin laminations, very silty, some very fine sand grains, rippled, cliff	8 7	149 6
6	Limestone partially covered, light to medium gray, weathers to light gray, very silty to very shaly, very thinly laminated, rippled, flaggy, rare 5-cm-thick beds of light brown, calcareous siltstone, shoulder	6.8	140 9
5	Limestone partially covered, light gray, weathers light brownish gray, shaly, finely laminated, shoulder	36 9	134 1
4	Limestone partially covered medium to dark gray, weathers medium gray, shaly, lithographic, needlelike when broken, shoulder	20.2	97 2

3	Limestone similar to unit 5	9 8	77 0
2	Limestone similar to unit 4	58 0	67 2
1	Covered float similar to units 4 and 5 Base of member not exposed Thickness of Leeds Creek Member estimated to be 488 m (Cressman 1964)	9 2	9 2
	Total thickness of exposed Leeds Creek Member		149 6
	Total section thickness	181 0	

Section 3

Section of Preuss Sandstone measured on the west side of Spring Creek, SE ¼, section 17, T 31 N, R 119 W, Lincoln County, Wyoming

		Thickness (meters)	
Unit No		*Unit*	*Cumulative Section*
7	Covered red soil, sandstone float, grayish red, weathers pinkish gray, fine to medium grained, medium grained sand decreasing, moderately sorted, indistinctly laminated, calcareous Contact with overlying Stump Sandstone located at disappearance of red soil	91 8	372 0
6	Covered red soil, sandstone float similar to unit 7, medium-grained sand increasing	40 0	280 2
5	Covered red soil, sandstone float, grayish red, weathers light brownish red, very fine to fine grained, silty, well sorted, thinly laminated, calcareous	56 8	240 2
4	Sandstone grayish red, weathers light reddish brown, very fine to fine grained, silty, well sorted, thinly laminated, calcareous, shoulder	12 5	183 4
3	Covered red soil, sandstone float, grayish red, weathers brownish red, fine grained, silty, well sorted, calcareous, thinly laminated	26 1	170 9
2	Sandstone reddish brown, weathers light brownish red, very fine grained, calcareous, well sorted, blocky, shoulder	16 6	144 8
1	Covered red soil, sandstone float, grayish brown, weathers brown to brown red, very fine to fine grained, cross laminated with some laminations weathering into relief in the fine grained units, moderately sorted, silty in part Contact with underlying Twin Creek Limestone located at disappearance of white soil	128 2	128 2
	Total thickness of Preuss Sandstone	372 0	

Section 4

Partial section of Preuss Sandstone measured along Mobil well road 8 km west of Fairview, Wyoming, NW ¼, section 9, and SW ¼, section 4, T 31 N, R 119 W, Lincoln County, Wyoming

		Thickness (meters)	
Unit No		*Unit*	*Cumulative Section*
49	Covered red soil Contact with overlying Stump Sandstone located at base of green, glauconitic sandstone of Stump	57 7	137 2
48	Sandstone (40%) and mudstone (60%) sandstone mottled moderate brown to pale red, fine grained, calcareous, very argillaceous, silty, medium bedded, mudstone, moderate brown, calcareous, splintery, very thinly bedded, rippled, some medium-grained sand	1 6	79 5
47	Sandstone pale red, very fine grained, very thick bedded, cross-bedded, ripple marks, rare thin interbeds of brown, silty, calcareous mudstone, sandstone feathers out laterally	1 4	77 9
46	Sandstone (40%) and mudstone (60%) similar to unit 48	2 2	76 5
45	Sandstone pale red, very fine grained, very thick bedded, cross-bedded, ripple marks, some thick interbeds of brown, very thinly bedded mudstone similar to unit 48, quartz-filled vugs to 5 cm in diameter in top sandstone	2 5	74 3
44	Sandstone (80%) and mudstone (20%) similar to unit 48, sandstone thick bedded	1 2	71 8
43	Sandstone (50%) and mudstone (50%) similar to unit 48, three 3-cm-thick interbeds of grayish yellowish green, micaceous mudstone	1 0	70 6
42	Sandstone (90%) and mudstone (10%) similar to unit 48	3 4	69 6
41	Sandstone similar to unit 47	4	66 2
40	Sandstone (70%) and mudstone (30%) similar to unit 48	6	65.8
39	Sandstone pale red, very fine grained, very thick bedded, cross-bedded, some thin interbeds of brown, silty, calcareous mudstone, sandstone feathers out laterally	1 1	65 2
38	Sandstone (70%) and mudstone (30%) similar to unit 48	5 0	64 1
37	Sandstone (80%) and mudstone (20%) similar to unit 48, some rare, green mudstone blebs in the brown mudstone, 15 cm thick grayish yellowish green mudstone at top of unit	1 7	59 1
36	Sandstone (80%) and mudstone (20%) similar to unit 37, 25 cm thick pale greenish yellow mudstone at top of unit	1 7	57 4
35	Sandstone pale yellowish brown, very fine grained, calcareous, silty, thick bedded, cross-bedded	2 0	55 7
34	Sandstone (60%) and mudstone (40%) similar to unit 48, some rare grayish yellowish green mudstone blebs in the brown mudstone	2 8	53 7
33	Sandstone pale yellowish brown, very fine grained, calcareous, silty, thick bedded, cross-bedded	7	50 9
32	Sandstone (50%) and mudstone (50%) similar to unit 48	1 7	50 2
31	Sandstone (60%) and mudstone (40%) similar to unit 37, 20-cm-thick moderate greenish yellow, weathers grayish yellow, mudstone at top of unit	1 9	48 5
30	Sandstone light brownish gray, very fine grained, some cross-bedding, thin interbeds of brown, silty, calcareous mudstone	9	46 6
29	Sandstone (60%) and mudstone (40%) similar to unit 48, 50-cm-thick sandstone at base of unit of composition similar to unit 30	1 0	45 7
28	Mudstone moderate brown, splintery, calcareous, rippled in upper and lower parts, massive and silty in middle part, secondary gypsum stringers, discontinuous 5-cm-thick green mudstone at top of unit	1 0	44 7
27	Sandstone similar to unit 30	9	43 7
26	Sandstone (40%) and mudstone (60%) similar to unit 37, 31-cm-thick green mudstone on top of unit	2 1	42 8

25	Sandstone (40%) and mudstone (60%) similar to unit 37, 8-cm-thick green mudstone on top of unit	2 3	40 7
24	Sandstone light brownish gray, very fine grained, some cross-bedding, thin interbeds of brown, silty, calcareous mudstone, some green mudstone interbeds, 5-cm-thick green mudstone on top of unit	1 2	38 4
23	Sandstone (70%) and mudstone (30%) light brownish gray sandstone, similar to unit 37 except thicker bedding	9	37 2
22	Sandstone (70%) and mudstone (30%) similar to unit 37, salt hopper crystal casts, mud chips, 8-cm-thick green mudstone at top of unit	3 8	36 3
21	Mudstone similar to unit 28	7	32 5
20	Sandstone (90%) and mudstone (10%) similar to unit 48	2 4	31 8
19	Sandstone (50%) and mudstone (50%) similar to unit 37 except in 50-cm-thick units, 15-cm-thick green mudstone at top of unit	1 2	29 4
18	Sandstone (50%) and mudstone (50%) similar to unit 19, 10-cm-thick grayish yellowish green mudstone at top of unit.	2 2	28 2
17	Sandstone (40%) and mudstone (60%) similar to unit 48, rare, secondary, vertical gypsum stringers	2 2	26 0
16	Sandstone mottled moderate brown to pale red, fine grained, calcareous, very argillaceous, silty, medium bedded, some thin interbeds of moderate brown mudstone, sandstone feathers out laterally	1 5	23 8
15	Sandstone (50) and mudstone (50) similar to unit 37, cross-bedded sandstone, 23-cm-thick grayish yellowish green mudstone at top of unit	3 4	22 3
14	Sandstone similar to unit 16, friable	1 0	18 9
13	Sandstone (40%) and mudstone (60%)· similar to unit 37, 5-cm-thick grayish yellowish green mudstone on top of unit	2 5	17 9
12	Sandstone mottled moderate brown to pale red, very fine to fine grained, calcareous, very argillaceous, massive	1 8	15 4
11	Mudstone lower ⅓ grayish yellowish green, upper ⅔ moderate brown, splintery, calcareous	4	13 6
10	Sandstone (60%) and mudstone (40%) similar to unit 48	3 4	13 2
9	Sandstone similar to unit 16	8	9 8
8	Sandstone (85%) and mudstone (15%) similar to unit 48, orangish pink sandstone	3	9 0
7	Sandstone (95%) and mudstone (5%) similar to unit 48, very fine-grained sandstone	4	8 7
6	Mudstone moderate brown, splintery, very thinly laminated, silty, calcareous, some fine-grained sand, bimodal ripples indicating E-W current direction with water motion toward east the predominant direction, 3-cm-thick grayish yellowish green mudstone at top of unit	9	8 3
5	Sandstone pale red, very fine grained, very argillaceous, ripple marks, rip-up clasts, calcareous, massive at base becoming laminated toward top of unit	4 3	7 4
4	Sandstone (60%) and mudstone (40%) similar to unit 48	1 2	3 1
3	Sandstone mottled grayish red to pale red, very fine grained, very argillaceous, calcareous, massive	6	1 9
2	Sandstone (70%) and mudstone (30%) similar to unit 48	7	1 3
1	Sandstone grayish orangish pink, very fine grained, calcareous, massive argillaceous Base of unit not exposed	6	6
	Total thickness of exposed Preuss Sandstone section Base of formation not exposed	137 2	

Section 5

Section of Stump Sandstone measured on the west side of Spring Creek, NW ¼, section 17, T 31 N, R 119 W, Lincoln County, Wyoming

		Thickness (meters)	
Unit No		*Unit*	*Cumulative Section*
14	Sandstone and siltstone alternating slopes and ledges up to 1 5 m in thickness, sandstone–gray to greenish gray, weathers light brownish gray, fine grained, slightly calcareous, cross laminated, blocky, ledge, siltstone–medium gray, friable, very calcareous, thinly laminated, flaggy, slope Contact with overlying Ephraim Conglomerate located at disappearance of green soil	16 8	128 9
13	Sandstone medium gray, weathers light grayish green, very fine grained, calcareous, silty, glauconitic, silty, finely laminated with cross-laminations, poorly preserved ripple marks, flaggy, ledge	17 4	112 1
12	Sandstone light grayish brown, weathers light brown, very fine grained, thin laminated, with cross-laminations, calcareous, fissile, silty, slope	11 5	94 7
11	Sandstone light grayish green, weathers light brownish gray, thinly laminated with cross-laminations, calcareous, very fine grained, beds of blocky material to 60 cm thick, slope	14 8	83 2
10	Sandstone alternating massive and thinly laminated units up to 30 cm thick, massive units similar to unit 5, thinly laminated units similar to unit 9, form alternating ledges and slopes	11 2	68 4
9	Sandstone grayish green, weathers light green, very fine to fine grained, laminated with cross-lamination sets to 5 cm in height, calcareous, glauconitic, silty, poorly preserved ripple marks, flaggy, alternating slopes and ledges	18 3	57 2
8	Sandstone medium gray, weathers grayish brown, thinly laminated, with cross-lamination sets to 8 cm in height, very fine to fine grained, calcareous, glauconitic, silty, flaggy, ledge	9 2	38.9
7	Sandstone medium gray, weathers grayish brown, thinly laminated with cross-laminations to 30 cm in height, calcareous, trough cross-laminations, current directions N-S, flaggy, ledge	4 9	29 7
6	Sandstone light green, weathers grayish green, thinly laminated with cross-laminations to 5 cm in height, sandy, calcareous, flaggy, glauconitic, ledge	3 4	24 8
5	Sandstone medium gray, weathers grayish brown, thinly laminated with cross-laminations to 30 cm in height, trough cross-laminations, calcareous, very fine to fine grained, flaggy, ledge	6 5	21 4

4	Sandstone: light grayish green, weathers grayish green, very fine grained, calcareous, glauconitic, thinly laminated with cross-laminations to 5 cm in height, flaggy, ledge.	3.7	14.9
3	Sandstone: medium gray, weathers light grayish brown, fine grained, very calcareous, thinly laminated with poorly preserved cross-laminations, flaggy, ledge.	1.4	11.2
2	Sandstone: dark gray, weathers to grayish olive, medium grained, cross-bedded in sets up to 8 cm in height with some weathering into relief, very calcareous, poorly sorted, ripple marks, tight, ledge.	4.9	9.8
1	Covered: olive brown soil. Contact with the underlying Preuss Sandstone located at appearance of red soil.	4.9	4.9
	Total thickness of Stump Sandstone	128.9	

Section 6

Partial section of Gannett Group (Ephraim Conglomerate, Peterson Limestone, Bechler Conglomerate) measured .8 km east of the Draney Ranch, NE ½, section 10, and W ½, section 11, R. 46 E, T. 8 S, Caribou County, Idaho (section 2 of fig. 11).

		Thickness (meters)	
Unit No.		*Unit*	*Cumulative Section*
Bechler Conglomerate			
35	Covered: red soil. Contact with overlying Draney Limestone located at disappearance of red soil and appearance of gray soil and limestone float.	89.1	991.4
34	Limestone: medium gray to medium purple, weathers to light gray, nodular, massive, slope. Probably interbedded with red mudstones and siltstones.	11.8	902.3
33	Sandstone: light gray, weathers light gray, fine to coarse grained, angular to subangular, poorly sorted, less than 1% pebbles, calcareous, forms lenticular bodies interbedded with red soil, ledge.	39.6	890.5
32	Covered: red soil.	46.1	850.9
31	Sandstone: medium gray with purple tint, weathers light to medium gray, fine grained, calcareous, ledge.	10.6	804.8
30	Covered: reddish gray soil.	33.3	794.2
29	Conglomerate: light to medium gray, weathers medium gray, up to 50% pebbles that are up to 5 cm in diameter, coarse-grained sand matrix, subangular to angular, poorly sorted, calcareous, very porous, friable, forms lenticular bodies – some lenticular interbeds of fine-grained sand, ledge.	20.5	760.9
28	Sandstone: interbedded red and medium gray, medium to coarse grained, calcareous, cross-bedded, ledge, gray sandstone decreases upward.	65.8	740.4
27	Covered: red soil.	46.7	674.6
26	Sandstone: grayish red, weathers grayish reddish brown, medium grained, calcareous, rare interbeds of medium gray sandstone, weathers light brown, occasional purple tint, medium grained, calcareous, up to 60 cm thick, ledge.	38.7	627.9
25	Covered: red soil.	13.3	589.2
24	Sandstone: light to medium red, weathers reddish grayish brown, medium grained, poorly sorted, calcareous, interbeds of medium gray, medium-grained sandstone up to 30 cm thick, ledge.	28.5	575.9
23	Sandstone: light gray, weathers light gray brown, medium to coarse grained, poorly sorted, massive, blocky, very calcareous, porous, less than 1% pebbles, interbedded with light to medium gray, medium-sized sandstone in units up to 50 cm thick, shoulder.	29.7	547.4
22	Covered: alternating bands of red and gray soil.	28.8	517.7
21	Sandstone: light gray, weathers light grayish brown, salt and pepper, medium to coarse grained, massive, blocky, very calcareous, porous, less than 1% pebbles, ledge. Contact with underlying Peterson Limestone located at disappearance of white limestone float.	21.4	488.9
	Total thickness of Bechler Conglomerate	523.9	
Peterson Limestone			
20	Covered: brown soil, limestone float.	3.4	467.5
19	Limestone: medium gray, weathers light gray, massive, blocky, microcrystalline, abundant fossil debris but few whole shells, ledge.	20.2	464.1
18	Limestone: similar to unit 19, weathers light brown.	3.5	443.9
17	Limestone: medium gray, weathers light gray, massive, microcrystalline, blocky, abundant fossil debris but few whole shells, ledge. Contact with underlying Ephraim Conglomerate located at top of purplish gray sandstone unit.	27.8	440.4
	Total thickness of Peterson Limestone	54.9	
Ephraim Conglomerate			
16	Sandstone: light to medium purplish gray, weathers light purplish gray, very fine grained, slightly calcareous, massive, blocky, shoulder.	7.8	412.6
15	Covered: red soil.	16.5	404.8
14	Sandstone: light gray, weathers medium gray, salt and pepper, medium to coarse grained, calcareous, poorly sorted, cross-bedded, blocky, porous, 10% pebbles to 1.4 cm in diameter, lenticular shape – possibly a channel, cliff.	7.0	388.3
13	Covered: red soil, red and gray sandstone float.	19.5	381.3
12	Sandstone: light gray, weathers medium purplish gray, salt and pepper, fine to medium grained, calcareous, poorly sorted, blocky, ledge, fines upward, interbedded with dark red sandstone, weathers medium grayish red, fine grained, massive, some conglomerate lenses with pebble to 1.4 cm in diameter, red sandstone drops out in lower 6 m.	28.3	361.8
11	Covered: red soil, reddish gray, fine-grained sandstone float.	50.4	333.5
10	Sandstone: dark gray, weathers light brownish gray with red tint, fine grained, calcareous, shoulder, interbedded with dark red sandstone, weathers medium grayish red, fine grained, massive, some conglomerate lenses with pebbles to 1.4 cm in diameter.	34.8	283.1
9	Sandstone: medium purplish gray, weathers medium purplish gray, fine grained, massive, cross-bedded, blocky, cliff.	36.5	248.3
8	Covered: limestone and conglomerate float.	29.6	211.8
7	Limestone: medium gray, weathers light to medium gray, purple tint, massive, nodular, shoulder.	25.9	182.2

6	Covered red soil, gray limestone, red sandstone, and conglomerate float.	47 5	156 3
5	Sandstone dark red, weathers medium grayish red, fine grained, massive, some conglomerate lenses with pebbles to 1 4 cm in diameter, ledge	22 5	108 8
4	Covered red soil with red sandstone float	24 9	86 3
3	Sandstone dark red, weathers medium grayish red, fine grained, massive, some conglomerate lenses with pebbles to 1 4 cm in diameter, ledge	18 2	61.4
2	Conglomerate medium gray, 20% pebbles to 2 cm in diameter, medium-grained sandstone matrix, salt and pepper, hard, ledge	21 0	43 2
1	Covered, red soil, red conglomerate and gray sandstone float Contact with underlying Stump Sandstone located at appearance of green, glauconitic sandstone float and olive soil	22 2	22 2
	Total thickness of Ephraim Conglomerate—about 90 m too thick because of repetition of units by faulting	412 6	
	Total section thickness	991 4	

Section 7

Partial section of Gannett Group (Ephraim Conglomerate, Peterson Limestone, Bechler Conglomerate) measured 2 6 km west of Fairview, Wyoming, W ½ section 8 and E ½, section 7, T 31 N, R 119 W, Lincoln County, Wyoming (section 3 of fig 11)

Unit No.		Thickness (meters) Unit	Cumulative Section
Bechler Conglomerate			
34	Sandstone light grayish brown, weathers light brownish gray, fine grained, friable, cross-bedded, massive, isolated pebbles to 1 4 cm in diameter, ledge Contact with overlying Draney Limestone located at base of gray, fossiliferous limestone	2 5	836 7
33	Covered red soil	18 8	834 2
32	Sandstone light grayish brown, weathers light brownish gray, fine grained, friable, cross-bedded, massive, isolated pebbles to 1 4 cm in diameter, ledge	3 6	815 r
31	Covered red soil	14 8	811 8
30	Sandstone light grayish brown, weathers light brownish gray, fine grained, friable, cross-bedded, massive, isolated pebbles to 1 4 cm in diameter, ledge	6 7	797 0
29	Covered red soil, limestone float similar to unit 16	16 9	790 3
28	Sandstone reddish gray, weathers reddish gray, very fine to medium grained, poorly sorted, some conglomerate lenses with chert pebbles to 1 4 cm in diameter, conglomerate decreases upward, ledge	8 3	773 4
27	Covered, reddish brown soil	82 0	785 1
26	Covered red soil, red sandstone float similar to unit 10	8 6	683 1
25	Conglomerate light pink, massive, quartzite, chert, and limestone cobbles to 20 cm in diameter, interbeds of reddish gray, very fine- to medium-grained sandstone beds to 1 m thick, cliff	12 5	674 5
24	Covered red soil, limestone float near base of unit	82 4	662 0
23	Sandstone reddish gray, weathers reddish gray, very fine to medium grained, poorly sorted, graded bedding at base, ledge	9 4	579 6
22	Sandstone reddish gray, weathers reddish gray, very fine to medium grained, poorly sorted, graded bedding in part, some conglomerate lenses with chert pebbles to 1 4 cm in diameter, conglomerate fines upward, ledge	6 2	570 2
21	Covered red soil, limestone float similar in description to that of unit 14	69 6	564 0
20	Sandstone similar to unit 22	9 4	494 4
19	Sandstone similar to unit 21	3 9	485 0
18	Covered red soil	50 8	481 1
17	Limestone medium purplish gray, weathers light gray, nodular, interbedded red shales may form over 50% of the unit, partially covered, limestones form shoulders, shales form slopes	19 4	430 3
16	Covered: red soil, limestone float similar description to that of unit 14	38 8	410 9
15	Sandstone reddish gray, weathers reddish gray, very fine to medium grained, poorly sorted, graded bedding at base, ledge Contact with underlying Peterson Limestone located at top of nodular limestone unit	7 3	372 1
	Total thickness of Bechler Conglomerate	471 9	
Peterson Limestone			
14	Limestone. medium purplish gray, weathers light purplish gray, nodular, interbedded red shales may form up to 90% of the unit, partially covered, slope. Contact with underlying Ephraim Conglomerate located at base of nodular limestone unit	31 2	364 8
	Total thickness of Peterson Limestone	31 2	
Ephraim Conglomerate			
13	Covered red soil	58 2	333 6
12	Sandstone reddish gray, weathers reddish gray, very fine to medium grained, poorly sorted, graded bedding at base, some conglomerate lenses with chert pebbles to 1.4 cm in diameter fining upward, ledge	9 5	275 4
11	Covered red soil, nodular limestone float near middle of unit	42 8	265 9
10	Sandstone reddish gray, weathers reddish gray, very fine to medium grained, poorly sorted, graded bedding at base, ledge	5 9	223.1
9	Sandstone reddish gray, weathers reddish gray, very fine to medium grained, poorly sorted, graded bedding at base some conglomerate lenses with chert pebbles to 1 4 cm in diameter fining upward, ledge	15 4	217 2
8	Covered red soil, limestone float similar to unit 6 but is purple on a fresh surface	19 5	201 8
7	Sandstone light gray, weathers medium reddish gray, very fine grained, tight, massive, cross-bedded, cliff	9 2	182 3
6	Limestone. medium gray, weathers light gray, some purple tint, microcrystalline, nodular, shoulder.	8 0	173 1
5	Covered red soil	121 4	165 1
4	Sandstone medium reddish gray, weathers medium grayish red, medium grained, 5% chert pebbles to 5 cm in diameter, cliff	4 2	43 7
3	Covered red soil	9 2	39 5
2	Sandstone light gray, weathers medium gray, salt and pepper, 25% chert pebbles to 2 cm in diameter, cliff	7 0	30 3

1	Covered red soil Contact with underlying Stump Sandstone located at appearance of olive brown sandstone float and soil	23 2	23 3
	Total thickness of Ephraim Conglomerate	333 6	
	Total section thickness	836 7	

Section 8

Partial section of Gannett Group (Ephraim Conglomerate, Peterson Limestone, Bechler Conglomerate) measured 0 8 km north of First Creek, a west flowing tributary of Spring Creek, NW ¼, section 5, T 30 N, R 119 W, Lincoln County, Wyoming (section 4 of fig 11)

		Thickness (meters)	
Unit No.		*Unit*	*Cumulative Section*
	Section ends at an unknown location in the upper part of the Bechler Formation on the Spring Creek Syncline axis		
	Bechler Conglomerate		
27	Conglomerate reddish brown, weathers brownish red, chert cobbles to 20 3 cm across and limestone boulders to 35 6 cm across, massive bedded, cliff	12 8	690 9
26	Covered red soil	87 1	678 1
25	Conglomerate reddish brown, weathers brownish red, chert and limestone pebbles to 7 6 cm across, massive bedded, cliff	6 1	591 0
24	Covered reddish brown soil with sandstone, conglomerate, and limestone float in the upper 30 2 m Spring Creek was crossed in the interval and beds may be covered by the valley shoulders and floor	132 3	584 9
23	Sandstone brownish red, very fine grained, calcareous, silty, medium bedded, some limestone float is found in this unit, shoulder	9 6	452 6
22	Sandstone similar to unit 23 without the limestone float	32 4	443 0
21	Sandstone light reddish brown, weathers grayish brown, calcareous (?), cross-bedded, contains conglomerate lenses with chert fragments to 1 3 cm across at the base, massive bedded, ledge	8 1	410 6
20	Shale dark brown, weathers reddish brown, silty, thin bedded, unit contains limestone float, slope	20 0	402 5
19	Shale similar to unit 20 with no limestone float	8 5	382 5
18	Sandstone similar to unit 21, sandstone with conglomerate lenses near the base and a 1 5-cm sandstone ledge between 13 7 and 15 2 m	15 1	374 0
17	Sandstone similar to unit 21	14 5	358 9
16	Sandstone light grayish white, weathers grayish red, fine grained, slightly calcareous unit contains limestone float, slope	5 2	344 4
15	Sandstone similar to unit 16 without the limestone float	19 5	339.2
14	Sandstone similar to unit 16 with limestone float	5 1	319.7
13	Sandstone grayish red, weathers brown red, fine grained, calcareous, medium, hard, cross-bedded, thick bedded, shoulder	24 1	314 6
12	Conglomerate reddish gray, weathers reddish brown, chert fragments to 2 5 cm across, calcite cement, (?) cross-bedded, massive bedded, ledge	12 6	290 5
	Partial thickness of Bechler Conglomerate	413 0	
	? ? ?		
	Peterson Limestone		
11	Limestone medium to dark gray, weathers light gray, microcrystalline, nodular, partially covered by a reddish brown soil—possibly the nodular limestones are interbedded with red siltstones, shales and mudstones, slope Contact with underlying Ephraim Conglomerate located at base of nodular limestone unit	15 0	277 9
	Total thickness of Peterson Limestone	15 0	
	? ? ?		
	Ephraim Conglomerate		
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, a few conglomerate lenses, thick bedded, ledge	24 5	232 5
7	Sandstone similar to unit 13	31 8	208 0
6	Covered	14 4	176 2
5	Limestone medium brownish gray, weathers light bluish gray, very fine crystalline, calcite stringers, siliceous, massive bedded, partially covered, shoulder	11 8	161 8
4	Sandstone light gray, weathers light reddish gray, calcareous, fine to medium grained with 5% chert pebbles which may be up to .6 cm across, cross-bedded, ledge	23 5	150 0
3	Sandstone similar to unit 4 with limestone float	17 6	126 5
2	Covered some limestone float	76 3	108 9
1	Sandstone light grayish white, weathers light gray, hard, fine grained, siliceous cement, nonporous, massive bedded, ledge Contact with underlying Stump Sandstone located at change in sandstone float color from light grayish white to light olive brown	32 6	32 6
	Total thickness of Ephraim Conglomerate	262 9	
	Total section thickness	690 9	

REFERENCES CITED

Armstrong, F C, and Cressman, E R, 1969, The Bannock thrust zone, southeastern Idaho U S Geological Survey Professional Paper 374-J, p 1–22

Armstrong, F C, and Oriel, S S, 1965, Tectonic development of the Idaho-Wyoming thrust belt American Association of Petroleum Geologists Bulletin, v 49, p 1847–66

Blackstone, D L, 1977, The Overthrust Belt salient of the Cordilleran fold belt, western Wyoming, southeastern Idaho, and northeastern Utah Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 367–84

Blackwelder, E, 1918, New geological formations in western Wyoming Washington Academy of Sciences Journal, v 8, p 417–26

Boutwell, J M, 1907, Stratigraphy and structure of the Park City mining district, Utah Journal of Geology, v 15, p 434–58

———, 1912, Geology and ore deposits of the Park City district, Utah U S Geological Survey Professional Paper 77, 231p

Brown, R E, and Wilkinson, B H, 1979, Draney Limestone Early Cretaceous carbonate deposit in western Wyoming and southeastern Idaho (abstract) American Association of Petroleum Geologists Bulletin, v 63, no 3, p 425

Cobban, W A, and Reeside, J B, 1952, Correlation of the Cretaceous formations of the western interior of the United States Geological Society of America Bulletin, v 63, p 1011–44

Condit, D D, 1916, Relations of the Ember and Chugwater Formations in central Wyoming U S Geological Survey Professional Paper 98-0, p 263–70

Cressman, E R, 1964, Geology of the Georgetown Canyon Snowdrift Mountain area, southeastern Idaho U S Geological Survey Bulletin 1153, 99p

Cressman, E R, and Gulbrandsen, R A, 1955, Geology of the Dry Valley Quadrangle, Idaho U S Geological Survey Bulletin 1015-I, 13p

Dahlstrom, C D A, 1970, Structural geology in the eastern margin of the Canadian Rocky Mountains Bulletin of Canadian Petroleum Geology, v 18, no 3, p 332-406.

Eardley, A J, 1944, Geology of the north-central Wasatch Mountains, Utah Geological Society of America Bulletin, v 55, p 819-94

Eyer, J A, 1964, Stratigraphy and micropaleontology of the Gannett Group of western Wyoming and southeastern Idaho Ph D dissertation, University of Colorado, Boulder, 132p

———, 1969, Gannett Group of western Wyoming and southeastern Idaho American Association of Petroleum Geologists Bulletin, v 53, no 7, p 1368-90

Gale, H S, and Richards, R W, 1910, Preliminary report on the phosphate deposits of southeastern Idaho and adjacent parts of Wyoming and Utah U S Geological Survey Bulletin 430-H, p 457-535

Gulbrandsen, R A, McLaughlin, K P, Honkala, F S, and Clabaugh, S E, 1956, Geology of the Johnson Creek Quadrangle, Caribou County, Idaho U S Geological Survey Bulletin 1042-A, p 1-23

High, L R, and Picard, M D, 1965, Sedimentary petrology and origin of analcime-rich Popo Agie Member, Chugwater (Triassic) Formation, west-central Wyoming Journal of Sedimentary Petrology, v 35, p 49-70

Hileman, M E, 1973, Stratigraphy and paleoenvironmental analysis of the Upper Jurassic Preuss and Stump Formations, western Wyoming and southeastern Idaho Ph D dissertation, University of Michigan, Ann Arbor, 203p

Hintze, L F, 1973, Geologic history of Utah Brigham Young University Geology Studies, v 20, part 3, 181p

Hodgden, H J, and McDonald, R E, 1977, History of oil and gas exploration in the Overthrust Belt of Wyoming, Idaho, and Utah. Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 37-69

Holm, M R, and James, W C, and Suttner, L J, 1977, Comparison of the Peterson and Draney limestones, Idaho and Wyoming, and the calcareous members of the Kootenai Formation, western Montana Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 259-70

Imlay, R W, 1950, Jurassic rocks in the mountains along the west side of the Green River Basin Wyoming Geological Association Guidebook, 5th Annual Field Conference, p 37-48.

———, 1952, Marine origin of the Preuss Sandstone of Idaho, Wyoming, and Utah American Association of Petroleum Geologists Bulletin, v 36, no 6, p 1735-53

———, 1957, Paleoecology of the Jurassic seas in the western interior of the United States Geological Society of America Memoir 67, p 469-504

———, 1967, Twin Creek Limestone (Jurassic) in the western interior of the United States U S Geological Survey Professional Paper 540, 105p

Kamis, J E, 1977a, Petrology and reservoir potential of the Nugget Sandstone of southeast Idaho Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 221-38

———, 1977b, The petrology and reservoir capabilities of the Cretaceous Tygee Member of the Bear River Formation in southeastern Idaho Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 339-52

Kummel, B, 1943, The Thaynes Formation, Bear Lake Valley, Idaho American Journal of Science, v 241, p 316-32

———, 1954, Triassic stratigraphy of southeastern Idaho and adjacent areas U S Geological Survey Professional Paper 254-H, p 165-94

———, 1957, Paleoecology of Lower Triassic formations in southeastern Idaho and adjacent areas Geological Society of America Memoir 67, p 437-68

Kummel, B, and Steele, G, 1962, Ammonites from the *Meekoceras gracilitatus* Zone at Crittenden Spring, Elko County, Nevada Journal of Paleontology, v 36, p 638-703

Long, G I W, 1960, Afton Anticline, Lincoln County, Wyoming Wyoming Geological Association Guidebook, 15th Annual Field Conference, p 187-88

Love, J D, 1957, Stratigraphy and correlation of Triassic rocks in central Wyoming Wyoming Geological Association Guidebook, 12th Annual Field Conference, p 39-45

Lowell, J D, 1977, Underthrusting origin for thrust-fold belts with application to the Idaho-Wyoming belt Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 449-55

McKelvey, V E, Williams, J S, Sheldon, R P, Cressman, E R, Cheney, T M, and Swanson, R W, 1956, Summary description of Phosphoria, Park City, and Shedhorn Formations in western phosphate field American Association of Petroleum Geologists Bulletin, v 40, p 2826-63

———, 1959, The Phosphoria, Park City, and Shedhorn Formations in the western phosphate field U S Geological Survey Professional Paper 313-A, p 1-47

Mansfield, G R, 1915, Geology of the Fort Hall Indian Reservation, Idaho (abstract) Washington Academy of Sciences Journal v 5, p 492-93

———, 1920, Triassic and Jurassic formations in southeastern Idaho and neighboring regions American Journal of Science, v 200, p 53-64

———, 1927, Geography, geology, and mineral resources of part of southeastern Idaho U S Geological Survey Professional Paper 152, 402p

Mansfield, G R, and Roundy, P V, 1916, Revision of the Beckworth and Bear River Formations of southeastern Idaho U S Geological Survey Professional Paper 98-G, 10p

Montgomery, K M, and Cheney, T M, 1967, Geology of the Stewart Flat Quadrangle, Caribou County, Idaho U S Geological Survey Bulletin 1217, 65p

Newell, N D, and Kummel, B, 1942, Lower Eo-Triassic stratigraphy, western Wyoming and southeast Idaho Geological Society of America Bulletin, v 53, p 937-96

Olson, G 1977, Catalog of Jurassic, Cretaceous, and Tertiary rock names for the Overthrust Belt and vicinity Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 91-99

Oriel, S S, 1963, Preliminary geologic map of the Fort Hall Quadrangle, Lincoln County, Wyoming U S Geological Survey Oil and Gas Investigations Map OM-212

Pacht, J A, 1977, Diagenesis of the Nugget Sandstone, western Wyoming and north-central Utah Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 207-19

Picard, M D, 1977, Petrology of the Jurassic Nugget Sandstone, northeast Utah and southwest Wyoming Wyoming Geological Association Guidebook, 29th Annual Field Conference, p 239-58

Picard, M D, Aadland, R, and High, L R, 1969, Correlation and stratigraphy of Triassic Red Peak and Thaynes Formations, western Wyoming and adjacent Idaho American Association of Petroleum Geologists Bulletin, v 53, p 2274-89

Pipiringos, G N, and Imlay, R W, 1979, Lithology and subdivisions of the Jurassic Stump Formation in southeastern Idaho and adjoining areas U S Geological Survey Professional Paper 1035-C, 25p

Randall, A G, 1960, Catalog of formation names for the Overthrust Belt and vicinity, western Wyoming Wyoming Geological Association Guidebook, 15th Annual Field Conference, p 169-77

Richards, R W, and Mansfield, G W, 1912, The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah Journal of Geology, v 20, p 681-709

Rioux, R L, Hite, R J, Dyni, J R, and Gere, W C, 1975, Geologic map of the Upper Valley Quadrangle, Caribou County, Idaho U S Geological Survey Geologic Quadrangle Map, no GQ-1194

Rubey, W W, and Hubbert, M K, 1959, Role of fluid-pressure in mechanics of overthrust faulting Part II, Overthrust belt in geosynclinal area of western Wyoming in light of fluid-pressure hypothesis Geological Society of America Bulletin, v 70, p 115-206

Silberling, N J, and Tozer, E T, 1968, Biostratigraphic classification of the marine Triassic in North America Geological Society of America Special Paper 110, 63p

Smith, R B, and Sbar, M L, 1974, Contemporary tectonics and seismicity of the western United States with emphasis on the intermountain seismic belt Geological Society of America Bulletin, v 85, p 1205-18

Solien, M A, 1979, Conodont biostratigraphy of the Lower Triassic Thaynes Formation, Utah Journal of Paleontology, v 53, no 2, p 276-306

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