GEOLOGY OF THE SNAKE RIVER RANGE NEAR ALPINE, IDAHO

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CONTENTS

	Page
Abstract	1
Introduction	1
Location of area	1
Purpose of study	3
Acknowledgements	3
Stratigraphy	4
General section	4
Pre-Cambrian rocks	4
Cambrian system	9
Flathead quartzite	9
Gros Ventre formation	9
Boysen limestone	10
Ordovician system	11
Bighorn dolomite	11
Devonian (?) system	12
Leigh formation	12
Devonian system	12
Darby formation	12
Mississippian system	13
Madison limestone	13
Brazer limestone	13
Pennsylvanian system	14
Wells formation	14
Permian system	14
Phosphoria formation	14

Triassic system 15
Dinwoody formation 16
Woodside formation 16
Thaynes formation 16
Ankareh formation 17
Jurassic system 17
Nugget sandstone 17
Twin Creek formation 18
Preuss sandstone 18
Stump sandstone 18
Cretaceous (?) system 19
Gannett Group 19
Cretaceous system 20
Bear River formation 20
Aspen formation 21
Frontier formation 21
Miocene (?) series 21
Camp Davis formation 21
Pleistocene deposits 25
Structure 26
General features 26
Laramide structures 28
Blowout Canyon thrust 28
Needle Peak thrust 28
Ferry Peak thrust 29
St. John thrust and related structures 29
Folding of thrust sheets 31

Mid-Tertiary structures 31

Long Spring graben faults 31

Grand Valley fault 32

Snake River fault 33

Grand Valley rift 33

Age relationships 34

Relation of local Laramide structures to regional structures ... 34

Spacial relations 34

Time relations 37

Relation of Mid-Tertiary faults to regional structures 38

Physiography 39

Resume of geologic events 41

References cited 44

ILLUSTRATIONS

Figure — Page

1. Index map 2

2. Tectonic map 36

Table

1. Generalized geologic column, Snake River Range 5

2. Summary of Cenozoic events 40

Plate — Following page

1. Geologic map of Snake River Range near Alpine, Idaho-Wyoming 44

2. Cross section of area 44

ABSTRACT

This report describes the geology of a section of the Snake River Range near Alpine, Idaho, and its relation to the regional geology of western Wyoming, southeastern Idaho, and north-central Utah. The rocks exposed include formations of Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, and Miocene ages. The Paleozoic and Mesozoic rocks were thrust and folded into northwest and southeast trending structures during the Paleocene phase of the Laramide orogeny and again folded and deformed during the Eocene phase of the Laramide. Dating of the Laramide phases is based on the relationships between the structures and their orogenic deposits in southeastern Wyoming and the Hoback Range of west-central Wyoming. Mid-Tertiary rift valley faulting accompanied the deposition of the Miocene (?) beds which, in the final stages of deposition, buried the fault-scarps. The recognition and dating of this disturbance is based on comparison with similar structures in the Hoback Range. Erosion followed the Mid-Tertiary disturbances and partly exhumed the rift valley. This erosion was cyclic and aided by glaciation.

INTRODUCTION

Location of Area

The Snake River Range embraces a group of subparallel maturely dissected, northwesterly trending ridges located midway along the Idaho-Wyoming state line (See index map, Figure 1). Alpine, Idaho, is a small village astride the state line at the southwest end of the Snake River Range. The range extends 30 miles north and north-

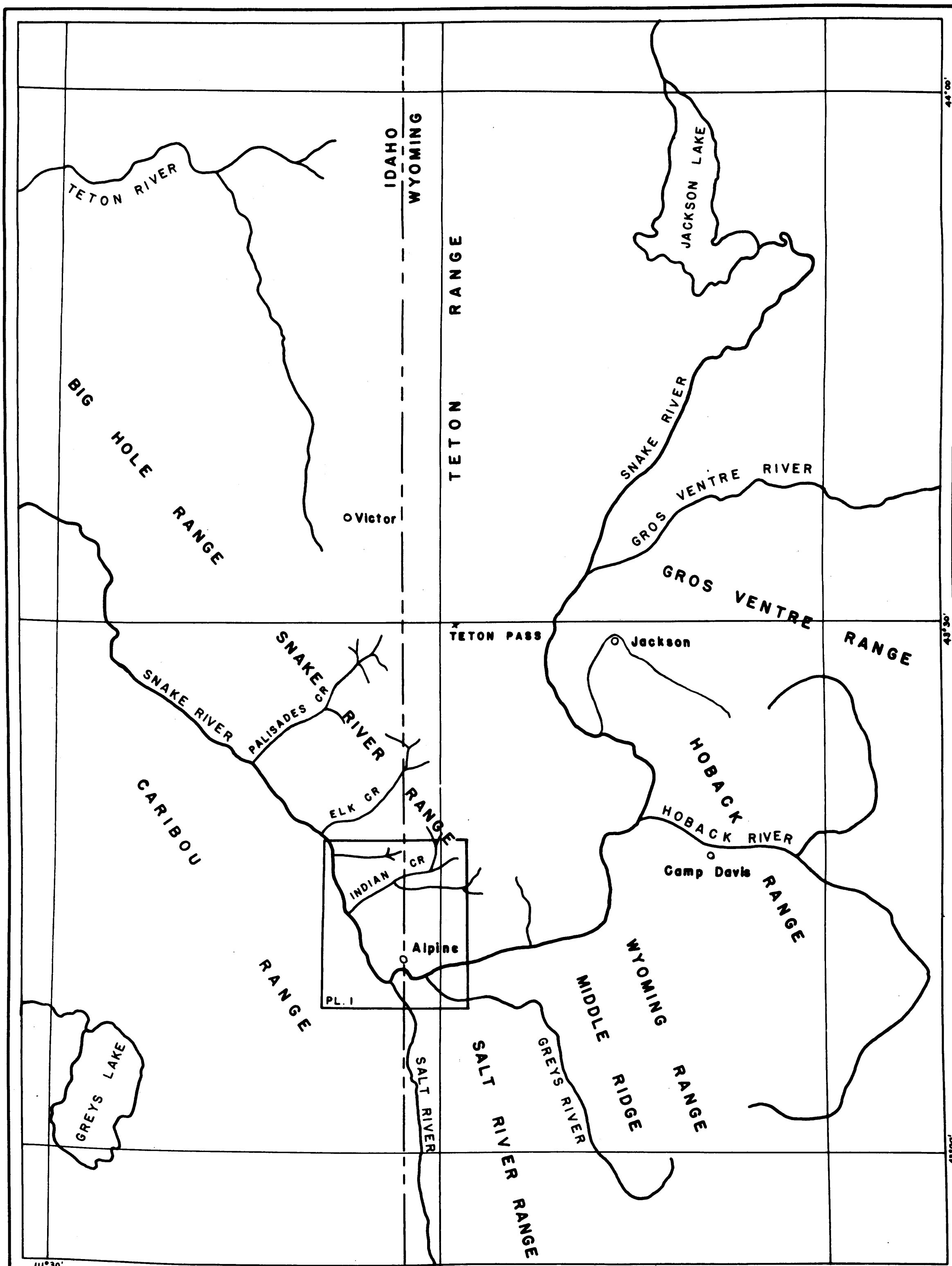

Figure I. — Index Map

west of Alpine where it branches. The northwest branch is known as the Big Hole Range, and the north branch, north of Teton Pass, as the Teton Range. South and southeast of Alpine lies the Salt River Range, Middle Ridge, and Wyoming Range.

The area mapped is shown on the geologic map, Plate 1, and lies partly in the Snake River Range and partly in the adjacent Grand Valley of the Snake River. The Grand Canyon of the Snake River bounds the area on the south, Indian Creek on the north, a north-south line through Ferry Peak on the east, and the Caribou Range on the west. The area is partly in Bonneville County, Idaho, and Lincoln County, Wyoming, and the Snake River Range portion is in the southern tip of the Targee National Forest.

Purpose of Study

The primary purpose of the study was to map and describe the structure of the Snake River Range near Alpine and to relate it to the regional structure. The secondary purpose was to study the Middle Tertiary disturbance and related deposits and to determine their relationship to regional Tertiary disturbances.

A number of parties were working on the Snake River Range at the time of the author's study as part of a general program of mapping under the direction of the Camp Davis staff. Some of the conclusions of the present paper must be held provisional pending the results of the major work on the region.

Acknowledgements

The field work was done through the summer of 1946. During this period the author was assisted at different times by

Richard Dunlop and Dean Kilburn, students at the University of Michigan. A. J. Eardley, Professor of Geology, University of Michigan, and chairman of the author's thesis committee, assisted the author materially in recognizing the major structural trends and in preparing the manuscript. The Irwin, Idaho, (1935) and Jackson, Wyoming, (1935) quadrangle topographic maps were used for control and U.S. Forest Service aerial photographs (1940) were used for detailed mapping.

STRATIGRAPHY

General Section

The rocks of the area studied range in age from Cambrian to Quaternary and aggregate more than 16,000 feet in thickness. The area was part of the Rocky Mountain geosyncline. The down-warping of the geosyncline was interrupted at intervals by uplifts and the corresponding retreat of the seas caused several unconformities. The major unconformities in the area studied separate the Ordovician from the Cambrian, the Mississippian from the Devonian, the Triassic from the Permian, and the Tertiary from the underlying systems.

The main features of the Snake River Range section are given in Table 1.

Pre-Cambrian rocks

The oldest rocks that underlie the Paleozoic sedimentary series in this region are Pre-Cambrian crystalline granites, gneisses, and schists generally referred to the Archean system (Blackwelder, 1915, p. 101). This complex is largely igneous rock, although some of the schistose and gneissic rocks may have had a

Table 1.--GENERALIZED GEOLOGIC COLUMN, SNAKE RIVER RANGE

Age	Formation	Thickness (feet)	Lithology
Pleistocene and Recent	Valley alluvium	0-500+	Talus, valley fill, terraces, alluvial fans glacial valley moraines (Pinedale), and piedmont gravels.
Miocene (?)	Camp Davis formation	5000±	Fanglomerates, tan to gray; has lavas, pebble conglomerates, sands, and white, gray to green tuffaceous beds in the lower part. Contains lenses of calcareous conglomerates and marly limestones. Cliff former in places.
Upper Cretaceous (Colorado)	Frontier formation	645	Sandstone and shale, greenish gray in upper part, olive brown in lower part, calcareous; has discontinuous beds of gray and rusty quartzite and conglomerate at the base; local thin coal beds.
	Aspen formation	2015	Shale, siltstone, and sandstone, gray green, siliceous, many conspicuous beds of gray and pale green porcelainite; has one thin bed of limestone near the base. Tempskya occurs near the basal beds.
Lower (?) Cretaceous	Bear River formation	880	Shale, black, nonresistant; has gray calcareous cross-bedded sendstone, and green siltstone and quartzite in the middle. The basal unit is rusty brown thin bedded quartzite with some black shale. Cliff former.
Lower Cretaceous(?)	Gannett Group: Draney limestone	245	Limestone, dark gray; weathers gray to brown; has lavender calcareous nonresistant shale in middle.
	Gannett Group: Bechler shale	35	Shale and mudstone, red; forms red soil covered slopes.

Table 1.--Continued

Age	Formation		Thickness (feet)	Lithology
Lower Cretaceous(?)	Gannett Group	Peterson limestone	125	Limestone, dark gray, resistant, massive to thin bedded; weathers white, gray, and purplish gray; few gastropod fossils.
		Ephraim Conglomerate	535	Shale, red, purple, and lavender, sandy, nonresistant; many discontinuous beds of light gray resistant quartzite, conglomerate, and pebbly sandstone in the lower half; has lenticular beds of purple or lavender impure limestone and gray, thin-bedded, nodular limestone throughout the formation.
Upper Jurassic	Stump sandstone		140	Sandstone or sandy limestone, brownish gray or greenish gray; has dark bluish-gray limestone near the top. Cliff former.
	Preuss sandstone		55	Sandstone, red, shaly; poorly exposed through a red sandy soil.
	Twin Creek formation		970	Limestone, light gray, brittle; weathers to dull gray splintery and platy fragments; fossiliferous in places; has 35 feet of red, nonresistant shale in middle. Cliff former.
Middle (?) Jurassic	Nugget sandstone		340	Sandstone, dull reddish-brown, massive, local aeolian cross-bedding, resistant; weathers to orange red slopes; has 6 inches of pale greenish-gray calcareous sandstone at the base.
Triassic (?)	Ankareh formation		550	Shale, deep red, nonresistant; with gray quartzite and red sandstone.

Table 1.--Continued

Age	Formation	Thickness (feet)	Lithology
Lower Triassic	Thaynes formation	1000	Limestone, dull gray, sandy; weathers yellowish gray; with some gray to brown very calcareous sandstone; has 295 feet of deep red soil in the middle containing fragments of red siltstone, shaly sandstone, and gray sandy limestone.
	Woodside formation	1130	Shale and sandstone, brick red, nonresistant; poorly exposed.
	Dinwoody formation	760	Mudstone, dull olive green to brownish gray, thin bedded, fine grained; has a few layers of gray, impure, resistant limestone in the lower part.
Permian	Phosphoria formation	176	Rex chert member: Dolomite and limestone, gray, brown to black, silty and cherty; upper 23 feet contains dark gray to black sandstone, quartzite, and shale which weathers white. Total 147 feet. Phosphatic shale member: Phosphate rock, mudstone and shale, gray, brown to black. Total 29 feet.
Pennsylvanian	Wells formation	1140	Quartzite and sandstone, white to gray in lower part, yellow to brown in upper part; upper 300 feet contains gray cherty dolomite and limestone with abundant fossils. Cliff former.
Mississippian	Brazer and Madison limestones	1425	Brazer limestone: Limestone, bluish gray, massive, and gray, thick to thin-bedded, fine to coarse-grained limestone; weathers to light gray with velvety luster; Cliff former. Total 880 feet. Madison limestone: Limestone, gray to blue black, thin bedded, coarse to fine-grained; weathers gray to brown; conspicuous because of its dark color; Cliff former. Total 545 feet.

Table 1.--Continued

Age	Formation	Thickness (feet)	Lithology
Upper and middle Devonian	Darby formation	570	Limestone and dolomite, dark gray to sooty black, interbedded with a few beds of yellowish-brown siltstone, and gray to brown sandstone. Upper 210 feet contains shale, siltstone, and sandstone, yellow, purplish red, and brown, calcareous, sandy; weathers yellow, brown, dark gray, olive, and red.
Devonian (?)	Leigh formation	40	Dolomite, milk white, dense, thin, brittle and flaggy; contains fish plates.
Upper Ordovician	Bighorn dolomite	400	Dolomite, light to dark gray, coarse- to fine-grained, massive; has some pink to gray irregular banding or mottling; weathers chalk to white gray with a pitted surface. As much as 150 feet of red sandstone, siltstone, shale, and conglomerate comprises the upper part of the formation in places. Cliff former.
Upper Cambrian	Boysen limestone	145	Limestone, blue to brownish-gray, oolitic in places; has many green partings and yellow to brown mottled areas.
Middle Cambrian	Gros Ventre formation	850	Upper shale member: Shale, green, nonresistant, and gray to yellowish-gray oolitic limestone and intraformational breccia. Total 240 feet. Death Canyon limestone member: Limestone, bluish-gray, thin bedded in upper part, massive and coarse-grained in lower part, has irregular yellow partings and mottlings; Cliff former. Total 450 feet

sedimentary origin (Schultz, 1918, p. 17). These older rocks occur in the Teton Range where the steeply dipping gneisses and schists have been intruded by pegmatite, granite, and basic dikes (Horberg, 1938, p. 13). No exposures of these rocks have been reported in the Snake River Range.

Cambrian system

Flathead quartzite.--In the Teton region and elsewhere in northwestern Wyoming and Montana the Middle Cambrian Flathead quartzite is the lowest Cambrian formation and consists of pale brown to reddish sandstone, conglomerate, and quartzite. The beds are streaked and spotted in places due to ferric oxide and, where quartzitic, form pronounced ridges or outcrops. In the Tetons the thickness is 140 feet. Here the unconformity at the base is marked by an undulatory surface of low relief overlain by a thin conglomerate (Horberg, 1938, p. 13). The overlying 35 foot section of ferruginous sandstone, oolitic hematite, and green sandy shale is now assigned to the lower Gros Ventre shale. The formation was named by Peal (1893, pp. 20-21) for exposures in Flathead Pass, Threeforks quadrangle, Montana, and has not been reported in the Snake River Range.

Gros Ventre formation.--The Gros Ventre formation of northwestern Wyoming and central-southern Montana includes an upper and lower shale division and a massive intervening cliff-forming limestone, the Death Canyon member. The lower portion of the formation is generally not exposed in the Snake River Range. H. R. Wanless (personal communication) reports a complete section of the Gros Ventre formation in the thrust sheet exposed in the Snake River Grand Canyon where erosion is active. The Death Canyon limestone and upper shale member are also exposed on the west face of Ferry Peak and in the anticline along Indian Creek (see geologic map, Plate 1).

The lower shale member as exposed in the Teton Range consists of ferruginous sandstone, oolitic hematite, hematitic shale, and glauconitic shale. This member is conformable with the Flathead quartzite and is 135 feet thick. The Death Canyon member is a bluish-gray, thin to massively bedded, coarse-grained, cliff-forming limestone with many yellow to brown irregular bands and mottled areas which are characteristic of the Cambrian limestones in this region. The limestone is oolitic in places, the first such limestone in the Paleozoic section. It contains Middle-Cambrian fossils. The Death Canyon member is 450 feet thick in the Snake River Range. The Death Canyon was named by Miller (1936, pp. 119-120) after the type locality on the divide between Death Canyon and Teton Canyon in the Teton Range. The upper shale member consists of 240 feet of green, nonresistant shale with yellowish-gray oolitic limestone and intraformational briccia. The formation was named by Blackwelder (1918, p. 417) from a detailed section on Doubletop Peak in the Gros Ventre Range where the section is 796 feet thick.

Boysen limestone.--The Boysen overlies the Gros Ventre formation unconformably and forms a compact unit primarily of massive brownish gray limestone with many green silty partings. It weathers with a pitted surface mottled pink and yellow to brown. The limestone is oolitic in places and carries Upper Cambrian fossils. The Boysen is a cliff former along its outcrop and is exposed on the west face of Ferry Peak and in the anticline along Indian Creek. It was originally described from a typical occurrence in the Gallatin Range by Weed (1896) and is a restriction of Peale's Gallatin limestone (1893 and 1896). The name Boysen was assigned to this section by Deiss (1938, pp. 1104-1105).

Ordovician System

Bighorn dolomite.--The Bighorn dolomite is conspicuous in Wyoming and southern Montana where it overlies unconformably the Boysen limestone. The formation forms prominent cliffs weathered white with a deeply pitted surface due to a reticutating network of silica. Freshly broken surfaces appear mottled and in places show pink to gray irregular bands. In the Snake River Range as much as 150 feet of red to brown sandstone, silstone, shale, and conglomerate comprise, in places, the uppermost part of the formation but gives way to massive dolomite within short distances (Gardner, 1944, p. 10). This section was observed in the Alpine horst by the author (see geologic map, Plate 1). These red beds may represent the erosion surface developed during the Silurian hiatus. They may occupy a stratigraphic position similar to the Leigh dolomite in the Teton and Gros Ventre ranges where that formation has been considered Richmond or possibly early Silurian (see Leigh formation). Darton (1904, pp. 394-401) described the Bighorn in the Bighorn Mountains, Wyoming, as consisting of three members from Trenton to Richmond in age. This division was not recognized by the author in the Snake River Range where the formation is a prominent cliff-former in the thrust sheets of Ferry Peak. Miller (1930, p. 196-213) concludes the whole formation is of Richmond age. Kirk (1933. p. 42) considers the lower Bighorn to be pre-Maysville and post-Trenton.

Devonian (?) system

Leigh formation.--The Leigh dolomite overlies unconformably the massive Bighorn dolomite from the Teton Range eastward to at least the Wind River Mountains and northward into the Absaroka Range. Blackwelder (1918, p. 418) found the interval so distinctive in Leigh Canyon in the Tetons that he advanced the Leigh from a member of the Bighorn dolomite (Tomlinson, 1917, pp. 118, 255-257) to formational rank and described it as thin, dense, brittle and flaggy dolomite with smooth milk-white surfaces. In almost every section it is 30 to 40 feet thick and is overlain unconformably by the Darby formation (Devonian). Blackwelder credits Ulrich and Kirk with assigning it to the Richmond horizon of the late Ordovician. Fish plates have recently been found in the formation by the staff of Camp Davis, and from these Professor E. C. Case, University of Michigan, believes it could not be older than upper Silurian and is perhaps Devonian. The Leigh was mapped as a unit with the Bighorn dolomite in the author's area.

Devonian system

Darby formation.--The Darby formation generally makes up covered slopes between the more resistant Bighorn and Madison limestones in northwestern Wyoming. It consists of a lower dark gray limestone and dolomite member and an upper red, yellow, brown, olive, and gray nonresistant shale, siltstone, and sandstone member. A discontinuous 5 foot bed of pebbly quartzite is at the base of the formation. In places it weathers with a pitted surface deeper than that of the Bighorn and appears to be brecciated. At a distance, the limestones and dolomites of the formation appear thinner and darker than the Bighorn or Madison. It rests unconformably upon the Leigh formation and is separated from the overlying Madison limestone (Mississippian) by an erosion surface. The name Darby was introduced by Blackwelder (1918, p. 420) and is apparently equivalent to Peale's Threeforks shale and upper Jefferson limestone of Yellowstone National Park. The type area is in Darby Canyon on the west slope of the Teton Range.

Mississippian system

Madison limestone.--In the northern Rocky Mountains the Madison limestone is the basal member of the conspicuous Mississippian cliff forming limestones. Its thin bedding, gray to blue-black color, coarse grain, and rough weathered surface characterize it in the Snake River Range. It weathers tan to dark brown. Many small cup corals, high and low-spired gastropods, and spiriferoid brachiopods are included in the fauna. Mansfield (1927, p. 60) assigned the Madison to the Lower Mississippian. It lies unconformably on the Darby formation and is followed conformably by the Brazer limestone. It was named by Peale (1893, pp. 33-39) from its occurrence in the Madison Range in southwest Montana.

Brazer limestone.--In conformable succession above the Madison limestone is the massive blue-gray Brazer limestone named from Brazer Canyon in the Crawford Mountains, Idaho, by Richardson (1913, pp. 407, 413). The upper members are brecciated and cut by calcite veins. It is generally fine grained to sub-lithographic. In places the beds contain chert nodules and streaks of chert. The weathered surface is light-gray with a velvety luster and smooth feel. Some gypsum beds may be found in the upper part. The fauna includes large cup corals and compound corals of the Lithostrotian type. The Brazer is middle and upper Mississippian in age. Both the Madison and Brazer are represented in the area but the boundary between the two is not clear, and since they form a convenient unit, they were mapped together for this report. The Madison-Brazer limestone is a prominent cliff-former throughout the area.

Pennsylvanian system

Wells formation.--A series of sandy limestones, calcareous sandstones, shales, and sandstones with brown to yellow rocks predominating which represent the Amsden formation of Wyoming succeeds the Brazer Limestone. The Amsden is transitional from Upper Mississippian to Lower Pennsylvanian in age (Bachrach, 1945). Above these strata are other quartzites and sandstones with dolomites and limestones in the upper part equivalent to the Tensleep sandstone of Wyoming. This entire series between the Brazer limestone and the black shales of the Phosphoria formation is referred to the Wells formation. Abundant brachiopods and bryozoa are found. The formation was named by Richards and Mansfield (1912, pp. 683, 684, 689-693) from Wells Canyon, Crow Creek Quadrangle, Idaho. The Wells is prominent in North and South forks of Indian Creek in the glaciated section where it forms the nearly vertical valley walls.

Permian system

Phosphoria formation.--The thin Phosphoria formation is usually covered and recognized only by its black shales, phosphorite float, or black residual soil. The upper or Rex chert member consists mainly of dark gray to black cherty dolomite and limestone. The phosphatic shale or lower member is concealed by soil in most places but is easily located between the Rex chert on the top and the resistent Wells formation on the bottom. It is a gray to brown phosphate rock with alternating beds of gray to brown calcareous and phosphatic mudstones, shales, and limestones. The name was derived from Phosphoria Gulch, Bear Lake County, Idaho, by Richards and Mansfield (1912, pp. 683-689). Winchester (1923, p. 76) concluded that the Phosphoria could not be regarded as oil shale in view of the very low yield from samples distilled. Samples collected from Palisade Creek, 16 miles northwest of Alpine, upon distillation yielded three gallons of oil per ton of material.

Triassic system

The Triassic system in this region consists of several thousand feet of shales, sandstones, and limestones. These beds in western Wyoming have been divided into four formations on the basis of lower tan beds, the Dinwoody formation, a succeeding shale formation of typical red beds, the Woodside formation, an intervening limestone formation, the Thaynes formation, and an upper red bed zone, the Ankareh formation. The Thaynes carries an abundant fauna of Lower Triassic age (Mathews, 1931). Over a large area the strata are found to vary in thickness and composition. In southeastern Idaho, Mansfield (1927) has made a number of subdivisions and has abandoned the use of the name Ankareh. In northeastern Utah Richardson (1941, p. 26) has found only the Woodside, Thaynes and Ankareh to be mappable units. In the Snake River Range all four formations are mappable and outcrop east of the St. John thrust sheet. Refer to geologic map, Plate 1.

Dinwoody formation.--The Dinwoody is largely thin-bedded, olive-green to brown-gray marine mudstone with a few layers of impure limestone in the lower part. It weathers to a tan soil slope. Equivalents of this formation were called Dinwoody in western Wyoming by Blackwelder from the Wind River Range (1918, p. 425, and Condit, 1916, p. 263) and Woodside in southeastern Idaho by Boutwell (1907, pp. 439-458) from the Park City district, Utah. The Dinwoody is now restricted in the type area (Newell and Kummel, 1942, pp. 941, 947) to the dominantly silty strata between the Phosphoria and the top of the resistant silt stones midway in the original section. The formation thickens rapidly in southeastern Idaho where it grades into the Woodside formation, and is equivalent to the lower part of the red beds of that formation. The Dinwoody is Lower Triassic in age and is unconformable with the Phosphoria formation.

Woodside formation.--The brick red nonresistant Woodside shales and sandstones form a red soil covered slope with poorly exposed outcrops. It was named by Boutwell (1907, pp. 439-458) in the Park City district where it underlies the Thaynes formation and overlies the Park City formation (Phosphoria and Wells formations). The Woodside of western Wyoming is considered (Newell and Kummel, 1942, p. 947) to be equivalent to the upper half of the type Woodside. It is lower Triassic in age.

Thaynes formation.--The Thaynes formation includes beds between the Woodside and Ankareh shales. The outcrops show gray to yellowish-gray limestones and brown to gray clacareous sandstones including some red shales and siltstones. The Thaynes was named by Boutwell from the Park City district (1907, pp. 439-458) and lies conformably upon the Woodside formation. It is Lower Triassic in age (Newell and Kummell, 1942, pp. 947).

Ankareh formation.--Ankareh formation includes red beds between the Thaynes limestone and the Nugget sandstone (Jurassic). The nonresistant shales form red slopes with poor outcrops. The Ankareh may be an erosion product formed during a period of base leveling to the north. The formation was named by Boutwell from the Park City District (1907, pp. 439-458) but subsequent work in adjoining areas showed his type section to include some of Veach's Nugget sandstone proposed the same year for approximately equivalent deposits in southwestern Wyoming. Boutwell then redefined his Ankareh formation (1912, p. 59) calling the upper white sandstone member the Nugget sandstone. The Ankareh formation is Middle to Upper Triassic in age (Mansfield, 1927, p. 374).

Jurassic system

Nugget sandstone.--The Nugget sandstone overlies the Ankareh formation unconformably and consists of massive red-brown sandstones locally silicified to a quartzite. A light colored to white calcareous conglomeratic sandstone occurs locally at the base of the formation. The Nugget forms high ridges or broad rounded slopes due to its resistant character. Aeolian cross bedding is conspicuous in places. The name was introduced by Veatch (1907, p. 56) but, as originally defined, included some of the Ankareh red bed members. The name Nugget is now restricted to the upper sandstone members in southeastern Idaho by Mansfield (1920, p. 52) who also assigned it to the Lower Jurassic system (1927, p. 7).

Twin Creek formation.--The Twin Creek formation overlies the Nugget sandstone and in the region of this report consists principally of grayish-white splintery limestones with a thin poorly exposes non-resistant red shale in the middle (Gardner, 1944, P. 7). Veatch (1907, P. 56) proposed the name Twin Creek formation from exposures on Twin Creek east of Sage, Wyoming. Dobrovolny (1940, p. 431) reports the formation thins northward from 3500 feet in the type area at Twin Creek, Wyoming, to 430 feet at Camp Davis, Wyoming. The 970 foot section in the Snake River Range suggest the presence of the Gypsum Spring formation now recognized in the Camp Davis area below the Twin Creek. The Gypsum Spring (Love, et al., 1945) in its type section in the Wind River Basin has a basal red siltstone followed by a sequence of gypsum, limestone, shale, and dolomite which is somewhat similar to the lower 285 feet of splintery limestone and red shale in the Snake River Range. The Twin Creek formation contains Gryphea, Pentacrinus, and Camptonectes in the upper beds and is Middle to Upper Jurassic in age (Imlay, 1945, pp. 1019-1022).

Preuss sandstone.--The Preuss sandstone overlies the Twin Creek limestone with a minor unconformity. It is a white and pink to deep dull red and usually calcareous sandstone becoming very shaly in places. The Preuss weathers to a dull red sandy soil with few markers excepting the more calcareous sandstones. Mansfield and Roundy (1916, pp. 76, 81) named the Preuss from Preuss Creek about 12 miles northeast of Montpelier, Idaho. The Preuss is Upper Jurassic in age (Mansfield, 1927, p. 99).

Stump sandstone.--The Stump sandstone conformably overlies the Preuss sandstone and consists mainly of thin bedded gray to greenish-gray fine grained sandstones weathering brown and with platy fragments. In places there are compact calcareous sandstones or dense dark gray limestones. There is abundant glauconite increasing in amount toward the top of the formation. Mansfield and Roundy (1916, pp. 76, 81) named the formation in southeastern Idaho for Stump Peak. The Stump sandstone is Upper Jurassic (Mansfield, 1927, p. 101).

Cretaceous (?) system

Gannett group.--The Gannett group as described by Mansfield and Roundy (1916, pp. 76, 82, 83) includes five distinct subdivisions, the lowest resting conformably upon the Stump sandstone. In southeastern Idaho, the type area, the group includes from top to bottom: Tygee sandstone, 100 feet; Draney limestone, 200 feet; Bechler conglomerate, 1,775 feet; Peterson limestone, 205 feet; and Ephraim conglomerate, 1,025 feet. The lower four subdivisions only are recognized in the Snake River Range. The group was named from exposures in the Gannett Hills in southeastern Idaho and southwestern Wyoming and thins noticeably to the east. Mansfield (1927, pp. 101-105) has placed the Gannett in the Lower Cretaceous although he formerly thought the Ephraim and Peterson to be Jurassic (1916, pp. 76, 82). Gardner (1944, p. 7) considers the age of the group to be Cretaceous with question.

The Ephraim conglomerate is the basal formation of the Gannett group and conformably overlies the Stump sandstone. It consists of red shales, quartzites, conglomerates, pebbly sandstones, and impure limestones in the area studied.

The Peterson limestone lies between the Ephraim and Bechler conglomerates. The massive to thin bedded dark gray limestone are resistant and weather white to gray. They contain some gastropod fossils.

In the Snake River Range the Bechler conglomerate has been called the Bechler shale by Gardner (1944, p. 7), as it consists of a few stringers of red shale and mudstone showing through a red soil-covered slope. In southeastern Idaho the Bechler is a gray, reddish, and "salt and pepper" sandstone with interbedded conglomerates.

The Draney limestone overlies the Bechler conglomerate (shale) and is the uppermost member of the Gannett group in the Snake River Range. The dark gray limestones are poorly exposed and nonresistant and weather to a gray or brown. The middle unit is a nonresistant, calcareous, lavender shale.

Cretaceous system

Bear River formation.--The Bear River was named by Hayden (1869, 91, 92) from strata in southwest Wyoming near the towns of Bear River and Evanston and considered them to be of lower Tertiary age. Veatch mapped the formation in 1905 (1907, pp. 60-64) and placed the Bear River formation between the underlying Beckwith and the overlying Aspen formation. Aurelle La Rocque, graduate student of the University of Michigan, has tentatively placed these beds in the Lower Cretaceous after extensive collecting of fossils in the Camp Davis area. In the Snake River Range the Bear River formation consists of black, nonresistant shale, thin gray limestones and calcareous crossbedded sandstones, olive-green siltstones, and rusty brown thin bedded quartzites and sandstones with interbedded black shales. It is unconformable with the Gannett group. Fresh water invertebrate fossils are abundant in the limestones.

Aspen formation.--Veatch (1907, p. 64-65) described the Aspen shale from exposures near Aspen Station, Uinta County, Wyoming, as lying between the Frontier and Bear River formations. The olive-green siliceous shales, siltstones and sandstones contain abundant beds of mottled gray, green, and pink porcelainite with a few lenses of limestone near the base. Sandstones in the lower part are "salt and pepper" type. The shales contain fish scales. The Aspen was assigned to the Colorado epoch by Veatch and is conformable with the Bear River formation.

Frontier formation.--The Frontier formation was described by Knight (1902, p. 791) as a coal-bearing sandstone underlying the Hilliard formation near the town of Frontier, Wyoming. Veatch (1907, p. 69) placed the Frontier formation between the Hilliard formation and the Aspen formation. In the Snake River Range the formation consists of calcareous, gray to brown, soft sandstones and shales with a discontinuous gray to rusty quartzite and conglomerate at the base. The top of the section is removed by erosion. A section measured on Deadman Mountain, Wyoming Range, in 1946 by Ross and St. John, graduate students of the University of Michigan, showed 5290 feet of Frontier with the upper part cut out by the Darby thrust (see tectonic map, Figure 2). Veatch has placed the Frontier formation in the Colorado epoch.

Miocene (?) series

Camp Davis formation.--The Camp Davis formation is exposed along the front of the Snake River Range where it now forms the foot hills. The formation was deposited mostly in a piedmont environment and in the Alpine area 2000 - feet are now exposed with an average dip of 20° east-northeast. It rests unconformably upon underlying Paleozoic rocks. The Snake River fault (see geologic map, Plate 1) terminates the formation along the Caribon Range front to the west. The Snake River has not cut to the base of the formation nor do the strata capping the highest hills appear to be the uppermost units. Three members appear to be present near Alpine. They are, ascending, a lower pebble conglomerate and tuffs, a gray fanglomerate, and an upper tan fanglomerate.

The lowest member of the formation is exposed in the channel of the Snake River and is considered by the author to have been deposited in a valley-flat environment. This member represents deposits in the lowlands during the early stages of development of the piedmont. Under conditions of extensive aggradation the lowland was completely covered by piedmont deposits and later exhumed. The lowest member consists of Paleozoic pebble conglomerates interbedded with thin sands, sandy shales, and thin to medium bedded tuffs. The beds are characterized by a lesser range in partical size and better sorting and stratification than the overlying piedmont deposits, absence of large fragments, and presence of fresh water fossils.

The volcanic tuffs are massive and not well stratified. They suggest lakes or swamps on a valley floor. The tuff beds grade in color from bottom to top through green and gray to white. The sands and conglomerates become progressively coarser toward the top and contain some interbedded tuffaceous sands. Pleistocene river deposits conceal the contact between the valley-flat member and the overlying piedmont members. Fifty feet of this lower member is now exposed.

Fanglomerates comprise the remainder of the Camp Davis formation. At their base 250 to 350 feet of gray fanglomerate was measured. A pebble count of this member indicated an average composition of 23% Wells quartzite, 70% Madison-Brazer limestone, 3% Darby limestone, 3% Bighorn dolomite, and 1% Cambrian limestone. This member usually has a white lime cement but the overall color is gray due to the Madison-Brazer fragments. A local increase in the percentage of Cambrian limestone imparts a yellowish surface where weathered. Above the gray fanglomerate is 1600+ feet of tan fanglomerate which caps the Camp Davis formation as now exposed. The color is due to the cementing material and a decrease in the Madison-Brazer limestone with the introduction of more light colored Wells and brown to red Triassic fragments.

The particles range widely in size. Beds of cobbles and boulders 3 to 18 inches in diameter have broad but irregular distribution. Two boulders 5 and 8 feet in greatest dimension were noted. Lenses and beds of sand and pebbles are not uncommon but never in uniform or continuous layers for long distances. Pebbles and boulders of various sizes are jumbled together with their long axes trending in all directions except where they show a tendency to parallel bedding. Boulders are cemented with a matrix of pebbles and sand. Some large boulders are isolated in beds of smaller clastics.

The piedmont deposits are not well stratified or sorted. Cut and fill structure is common. Nowhere is there more than the slightest approach to sorting except that the average size of fragments at the base of a thick stratum is coarser than at the top. From a distance, bedding planes appear regular and parallel, but in detail irregularity is extreme. The suite of materials tends to be homogeneous lithologically with Paleozoics predominating. This suggests a source area in the Snake River Range.

The boulders and pebbles are subangular as a rule with a small percentage well rounded. Some of the particles have undergone decomposition but most are the result of rock breaking. Decomposition is largely pre-deposition in age. No organic matter was in evidence indicating a torrential nature of deposition. Lenses or beds high in calcium carbonate or of impure limestone are exposed in the formation north and south of Indian Creek. It is possible that these represent basins between the fans or depressions in the piedmont surface where small lakes or swamps developed. These lime strata appear to be at or near the top of the gray fanglomerate.

This series of sandstones, tuffs, conglomerates, limes and fanglomerates is referred by the author to the Camp Davis formation after comparison with the type area along the west flank of the Hoback Range, 20 miles to the northeast. Similarity of composition, environment of deposition, and structural setting between these two piedmont deposits is the basis of comparison. The Camp Davis formation in the Hoback Range was described by members of the Camp Davis staff (Unpublished manuscripts) as 200+ feet of lower gray conglomerate, 50 feet of light gray freshwater limestone and tuff, and 2000 feet of upper red or tan conglomerate. Its deposition followed the Laramide folding and thrusting and accompanied Tertiary high-angle faulting. Accumulation was against the fault escarpments which were eroded and buried during the subsequent deposition. A fossil horse tooth was found in the fresh water limes near the base of the type section which proved it to be upper Miocene or lower Pliocene in age (Eardley, 1942, p. 1800).

In the Calamity Point area, 14 miles northwest of Alpine, the Camp Davis contains two andesite members 1200 and 300-1000 feet thick respectively. According to Enyert (1947) the lavas are zeolitic hypersthene augite andesite sills typically massive and dark gray in color with a compact silty member between. The contacts of the silts are indurated. The sills are considered by Enyert to be intrusive into the gray conglomerate with the tan conglomerate resting unconformably on the gray.

In the past the Camp Davis formation has been referred to as the Almy conglomerate of Paleocene age by Veatch (1907, p. 76-87) and Schultz (1914, p. 30). In the area of the author's study, Kirkham (1924, pp. 29-30) has referred to the Camp Davis as the Salt River formation of Eocene age.

Pleistocene and recent deposits

Glacial moraines of the Pinedale stage (Blackwelder, 1915, p. 324), equivalent to the late Wisconsin in the middle west, are conspicuously developed 5 miles east of the range front in North and South Forks of Indian Creek. These moraines are distinguished by their fresh appearance and almost uneroded condition.

Coarse stream deposited gravels 10 - 20 feet thick were mapped on remnants of a terrace cut across the inclined Camp Davis formation at an elevation of 6200-6400 feet. The terrace may represent the Circle surface of Blackwelder and thus the gravels may be Bull Lake or early Wisconsin outwash (Blackwelder, 1915, p. 316).

STRUCTURAL GEOLOGY

General features

At least two epochs of deformation are recognizable in the Alpine area, the Post-Cretaceous Laramide orogeny and the middle Tertiary disturbance. The main structures of the Snake River Range are extensive low-angle thrust faults and parallel folds. The secondary structures belong to the Middle Tertiary epoch and are high-angle normal faults which parallel the Grand Valley of the Snake River.

Four major west-southwest dipping thrust sheets in imbricate arrangement make up the range east of Alpine. In each, older Paleozoic strata are thrust over folded or broken younger Paleozoic strata. Drag folds and small high-angle faults along the course of some of the thrusts are of minor importance. All thrusts are somewhat folded transverse to their general strike.

The thrusts have been named following consultations with Richard Enyert and Joseph McIntosh who have mapped adjacent areas on the north. The uppermost one will be called the Blowout Canyon thrust and the second will be designated the Needle Peak thrust, both names coming from topographic features north of the area of this report. Refer to the Irwin topographic sheet for localities. The third thrust will be called the Ferry Peak thrust for its development along the west face of Ferry Peak. Refer to the geologic map, Plate 1. The fourth and the lowest thrust will be called the St. John thrust, a name proposed by Kirkham (1924, p. 33) for a thrust that crosses the lower Snake River Canyon. He apparently did not recognize that there were several thrusts in the range and therefore it seems best to select the one with the greatest displacement, which is the lowest one, and reserve the name for it. Schultz (1918, p. 36) also recognized only one thrust. The traces of the fault lines are very sinuous and the underlying thrusts appear to be sheared or cut off by the overlying thrusts as evidenced by overlapping traces. Consult the geologic map.

Three Mid-Tertiary high-angle faults lie in the foot hills west of the Snake River Range and trend parallel to the base of the mountains. They are not confined to the poorly consolidated Camp Davis formation as Paleozoic bedrock is exposed in places along the fault scarps. Discontinuity of structures, repetition of strata, scarps, and springs characterize the fault traces.

The two eastern-most faults bound the Long Spring graben (Refer to Plate 1). These faults are accordingly known as the east and west Long Spring graben faults. The third fault is known as the Grand Valley fault and is postulated to parallel the Snake River along the east side of Grand Valley. The upthrown block between the west Long Spring graben and Grand Valley faults is designated the Alpine horst. The faults are generally steep high-angle faults. The scarps are high and abrupt where the contrast in lithology is greatest and are more subdued where the contrast is slight. They disappear where the faults pass under the Camp Davis formation.

Kirkham (1924, p. 33) has described a normal fault paralleling the Snake River along the west side of Grand Valley at the base of the Caribou Range. This nearly vertical fault, which he has called the Snake River Fault, is downthrown on its east side and compliments the Grand Valley fault forming a rift valley or fault trough here called the Grand Valley rift.

Laramide structures

Blowout Canyon thrust.--The Blowout Canyon thrust appears from beneath the mantling Camp Davis formation near the junction of the North and South Forks of Indian Creek where the Gros Ventre shale and Boysen limestone are thrust vertically upon Madison limestone. The thrust overrides the underlying Needle Peak thrust at North Fork and continues to the north through Paul Peak to Blowout Canyon where it is very well exposed. A tear fault in the thrust sheet along North Fork canyon normal to the strike of the thrust fault is indicated by the 30° SW dip of the Boysen strata north of the canyon and the nearly vertical dip in the same beds south of the canyon. It appears that the north side was relatively down-faulted and thrust forward while the south side was bent upward. The fault can be traced northwestward to Blowout Canyon where it was named. It has been mapped nearly to Palisades Creek by Enyert (1947).

Needle Peak thrust.--The Needle Peak thrust is first crossed in ascending Jordan Canyon and Long Spring Canyon, which traverse the strike of the beds east of Alpine. Refer to the Irwin topographic sheet. The main trace of the overthrust here on Ferry Peak is very sinuous and irregular. The sheet is broken into many minor imbricate thrusts all dipping steeply west-southwest. The many minor thrusts repeat chiefly the members of the Boysen and Bighorn formations. The less competent Boysen limestone may have failed under compression along the silty partings and was then overthrust by the more competent Bighorn dolomite. The lower thrust sheets may have been dragged along by higher overriding thrust sheets. It is significant to note that the imbricate structure has developed in the Needle Peak thrust only where the Boysen formation is present. As the thrust is traced northward the imbricated section passes beneath a mantle of Camp Davis formation to emerge at South Fork of Indian Creek as a single sheet of Bighorn dolomite thrust upon Madison limestone. At the North Fork of Indian Creek the stratigraphic displacement has decreased so that Madison rests on Madison. The thrust then passes under the overlying Blowout Canyon thrust in Paul Peak. North of Blowout Canyon the thrust reappears in Needle Peak and can be traced northwestward between the overlying Blowout Canyon thrust and underlying Ferry Peak thrust. Drag folds are exposed in the Needle Peak thrust sheet in the canyon of the Snake River below the highway at the mountain front.

Ferry Peak thrust.--The Ferry Peak thrust is conspicuously exposed on the south face of Ferry Peak where the Snake River has cut through the range. Here the Gros Ventre formation has been thrust upon the Madison formation. At the Snake River level a complete Gros Ventre section is present. A Cambrian klippe of the sheet tops Ferry Peak. The Death Canyon limestone member of the Gros Ventre formation and the Boysen limestone form flat-irons on the west face of Ferry Peak. The sinuous trace of the thrust can be followed to the South Fork of Indian Creek where the sheet passes beneath the higher Needle Peak thrust. It reappears on the east side of Needle Peak to the north.

St. John thrust and related structures.--The St. John thrust parallels the canyon east of Ferry Peak for two miles where Cambrian and Ordovician strata are thrust upon Ordovician, Devonian and Carboniferous strata. The St. John thrust appears to be the major overthrust in the area of this report. Its thrust sheet in this and adjoining areas to the north extends 5 - 7 miles back from its observed positions along the front of the range. In South Fork of Indian Creek a great dragfold in footwall Mississippian, Pennsylvanian, Permian, and Triassic formations indicates that the overriding sheet moved from west to east. Here Cambrian, Ordovician, Devonian and Mississippian formations have been thrust over the vertical to overturned footwall beds. On the pass east of Ferry Peak the Ordovician strata are thrust on upturned Pennsylvanian, Permian and Triassic strata. On the divide between North and South Forks of Indian Creek the dragging of footwall beds is less severe and as the great drag fold becomes less pronounced a large anticline develops in the hanging wall of the thrust sheet. This anticline is exposed in North Fork of Indian Creek where Cambrian, Ordovican and Devonian formations rest against vertical Mississippian limestones. This structure was noted by Schultz (1918, p. 46). It is probably the same one forming Baldy Mountain and observed on Palisade and Elk Creeks and called the Elk Creek anticline by Enyert (1947). Refer to the Irwin quadrangle for localities.

A mile east-northeast of the St. John thrust between North and South Forks of Indian Creek are drag folds and a minor thrust in the gently eastward dipping Pennsylvanian, Permian and Triassic formations. The drag folds are overturned to the northeast and the thrust dips to the southwest. The thrust dies out before reaching North or South Fork of Indian Creek. East of the thrust is a high-angle fault of small displacement. The size of the drag folds are out of proportion to the amount of thrusting evidenced. This minor thrust may have been dragged along by the higher overriding St. John thrust and the drag folds are thus related to the major thrust. East of this zone the phosphatic shales of the Phosphoria formation are well exposed.

Folding of thrust sheets.--The thrust sheets are broadly folded parallel with the strike of the thrusts and more closely folded normal to the strike. A prominent example of the broad folding parallels the range front and is exposed in North Fork of Indian Creek (see geologic map, Plate 1). This fold extends throughout the length of the Snake River Range and has been called the Elk Creek anticline by Enyert (1947). In the cross section (see Plate 2) this flexture is expressed by the steepening of the thrust planes which here have a monoclinal form. Several minor folds were observed to parallel the Elk Creek anticline to the east.

The transverse folds have been observed in all thrust sheets. These are particularly noticeable on the west face of Ferry Peak where flat irons have developed along the crests of the folds. The strikes of the Paleozoic strata in Alpine horst and Long Spring graben evidence folding normal to the trend of the thrust sheets (see geologic map, Plate 1).

The average dip of the thrust sheets in the author's area is 55^{o} which exceeds that normally allowed for thrust faulting. This indicates post-thrust folding parallel with the strike of the thrust. The transverse folding must represent a post-thrusting disturbance with forces, at least locally, at right angles to those associated with the thrusts.

Mid-Tertiary structures

Long Spring graben faults.--The eastern high-angle fault strikes north-northwest along the foot of the Needle Peak thrust sheet at the base of Ferry Peak. Remnants of a fault-line scarp are found in the Bighorn dolomite and Madison limestone where the fault crosses the folded thrust sheet. The fault looses its identity a short distance to the north and south where it passes under the Camp Davis formation. The downthrown side of this fault forms the east flank of Long Spring graben. The west Long Spring graben fault can be traced along the range for four miles. Erosion along this fault has exposed the Boysen, Bighorn and Darby formations. The more resistant Bighorn dolomite forms a fault-line scarp in places. To the south the fault passes under the highest Snake River terrace. Northward it passes under the Camp Davis formation where its trace is followed in a stream valley and marked by springs. The west Long Spring graben fault dies out in North Fork Indian Creek.

Long Spring graben has been partially exhumed by erosion of the poorly consolidated Camp Davis formation with which it was formerly filled. The more resistant Paleozoics form fault-line scarp valley walls. Northward, the graben remains filled with Camp Davis and looses all physiographic expression. It is believed that this graben was formed during the period of Camp Davis deposition and that it was eroded and buried nearly as rapidly as it formed. The faults mark exhumed scarps which are properly called fault-line.

Grand Valley fault.--The Grand Valley fault is the western-most of the three high-angle faults at the foot of the Snake River Range. This fault with its downthrown side on the west is clearly indicated where it forms the west side of the Alpine horst. The fault is postulated to extend throughout the length of Grand Valley along its east side where it forms the east flank of the Grand Valley rift. South of the Alpine horst the fault passes under the Grand Valley alluvium. To the north it passes under the Camp Davis formation where the fanglomerates have buried the fault line. Its presence northward is based on the indirect evidence of calcareous spring deposits and the alignment of fresh water springs along the front of the Snake River Range (Enyert, 1947). The Camp Davis is banked up against the horst from which it has only been partly stripped away by erosion.

The Alpine horst is formed of Paleozoic strata and is an upthrown block of the folded and broken Needle Peak thrust sheet. Its structure is a continuation of the folding and thrusting seen in the face of Ferry Peak. The erosional remnant of Camp Davis formation capping the structure is unfolded and dips gently to the northeast similar to the adjacent Tertiary strata. This indicates the horst was completely buried in the later stages of Camp Davis deposition.

Snake River fault.--Kirkham (1924, pp. 33) has traced the Snake River fault approximately 30 miles along the front of the Caribou Range from north of Garden Creek where it appears from beneath the Camp Davis formation to a fault-line paralleling the Salt River south of Alpine. The vertical displacement is never more than 2000 feet. The evidence for the fault opposite the author's area is a prominent escarpment in Cretaceous, Jurassic, and Triassic formations. Hot springs mark the trace of the fault.

Grand Valley rift.--The Grand Valley rift is bounded by the Grand Valley and Snake River faults. The Camp Davis was banked against both fault scarps and subsequently buried the Grand Valley fault and probably the Snake River fault to the same extent. A similar condition is found in the type area of the Camp Davis formation along the Hoback Range. Here the Hoback fault (see tectonic map, Figure 2) is believed to have created a trough in which the Camp Davis formation accumulated (Eardley, personal communication). The Hoback fault may have continued active during the early stages of accumulation but eventually the Camp Davis covered the scarp and overlapped the surface back of it. This is the setting postulated for the Grand Valley rift. In the erosional cycles that followed the final Camp Davis deposition very little of the Grand Valley fault has been exhumed but the Snake River escarpment was more extensively exposed.

Age relationships.--The relation of the Camp Davis formation to the Grand Valley, Snake River and Long Spring graben faults is considered similar to those of the Hoback fault to the Camp Davis along the Hoback Range. There they are of the same age. A horse tooth found near the base of the Camp Davis in the Hoback Range has proved it to be upper Miocene or lowermost Pliocene in age. Similarity of structural setting and lithology between the Camp Davis formation of the Hoback Range and the fanglomerates of the Snake River Range indicates they may be correlated. The Grand Valley Snake River and Long Spring graben faults are, therefore, said to be upper Miocene or lowermost Pliocene.

RELATION OF LOCAL LARAMIDE STRUCTURES TO REGIONAL STRUCTURES

Spacial relations

Thrust faults and major folds are the characteristic Laramide structures. Two divisions are dominant, namely a western or trough zone composed of ranges formed out of the thick sediments of the Rocky Mountain geosyncline, and an eastern or shelf zone, composed of ranges and wide intermontain valleys formed out of shelf sediments and their basement complex.

The ranges in the trough zone of the Laramide orogeny are sculptured out of sharp folds and thrusts in the great thicknesses of Proterozoic, Paleozoic, and Mesozoic strata. Pre-Cambrian rocks are not exposed in many ranges but from central Utah northward to western Montana those of Proterozoic (Beltian) age become increasingly widespread until they predominate in the latter place. The Laramide system in the Central Rockies includes ranges that formed from geosynclinal sediments of eastern Idaho, western Wyoming, central and western Utah, and eastern and southern Nevada. The belt starts at the Idaho Batholith and extends southeast to the Snake River lava plains where it is covered by Tertiary and Pleistocene lavas and alluvium. From beneath the lavas it continues southeastward to the Snake River and Hoback ranges and thence southward into Utah. Refer to tectonic map, Figure 2.

Great thrusts dominate the Laramide structure in the trough zone. Most of the overriding sheets moved eastward but several, especially in Montana and Canada, moved westward. The great thrusts in the region of this report range up to nearly 300 miles in length with dislocations up to 40 miles (Mansfield, 1927, p. 382). The Bannock and Absaroka are thrusts of this magnitude. The Blowout Canyon, Needle Peak, Ferry Peak, St. John, and Darby thrusts are of somewhat lesser magnitude. The Blowout Canyon, Needle Peak, and Ferry Peak thrusts have been grouped as the Palisades complex by Enyert (1947). This complex and the St. John thrust may be branches of the greater Absaroka which generally parallels them to the east. All of these

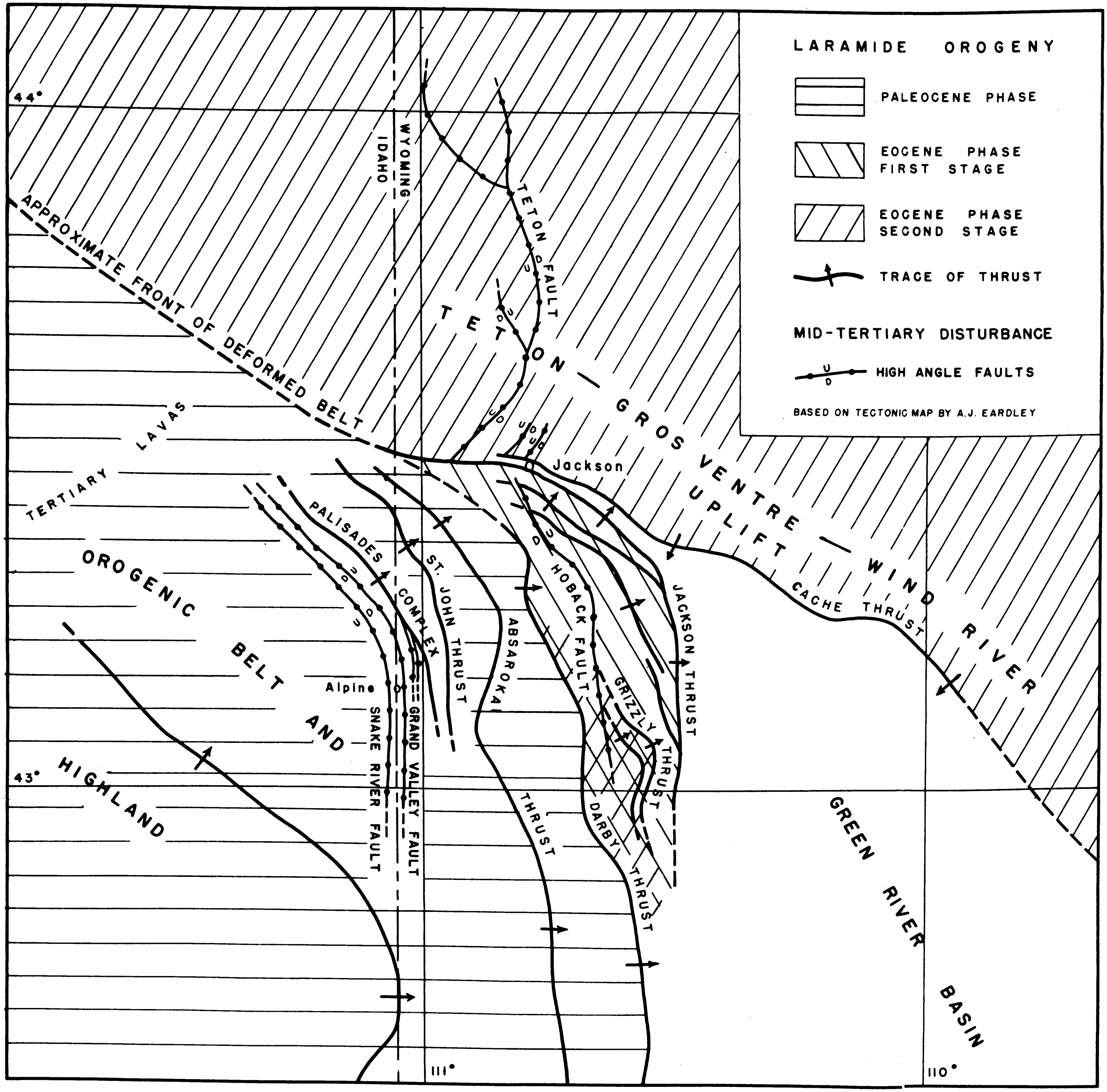

Figure 2. – Tectonic Map

thrusts converge toward the north end of the Salt River Range. (see geologic map, Plate 1).

Time relations

The eastern margin of the trough zone in the Central Rockies is made up of the trough strata of the Mesozoic era, especially Cretaceous strata, together with the orogenic strata of the early Tertiary. Westward only the Paleozoic rocks of the Cordilleran geanticline are involved. In the western part, rocks younger than the Paleozoic are almost entirely absent making accurate dating nearly impossible.

The Absaraka and Darby thrusts, which belong to the group of Snake River Range thrusts, cut the Almy formation (middle Paleocene) but are overlapped by the Knight formation (earliest Eocene) in southwestern Wyoming (Eardley, personal communication). The thrusting here then is late Paleocene. The newly created highlands of the Darby and Absaraka thrusts furnished the clastics of the 15,000 foot Hoback formation (lower Eocene) found east of the Hoback Range and south of the Gros Ventre Range. The thrusts in the area of this report have become separated from the Paleocene and Eocene deposits and the youngest formation involved in the thrusting is the Frontier formation of upper Colorado age. The time of thrusting in the Snake River Range, then, cannot be established on stratigraphic grounds and must be assumed the same as to the south. This thrusting has been called the Paleocene phase of the Laramide by Eardley (unpublished manuscripts). Refer to Table 2.

In the Hoback Range a later phase is evidenced. The Hoback formation is overthrust along its western edge by the Jackson thrust (see tectonic map, Figure 2). The newly created highlands furnished boulders and gravels for the Pass Peak conglomerates (middle Eocene) which in places overlapped the Jackson and related thrust sheets. A second stage of thrusting then took place and the Grizzly thrust (see Figure 2) broke through the strata of the Hoback Range and thrust eastward over the Pass Peak formation. At the same time the Teton-Gros Ventre-Wind River block was elevated and moved as the Cache thrust (see Figure 2) westward over the Pass Peak.

The first stage of thrusting is therefore early Eocene and the second is post-middle of late Eocene. Eardley (unpublished manuscripts) has called these two stages together the Eocene phase of the Laramide orogeny. In the Snake River Range part of the folding of the thrust planes may possibly be ascribed to the Eocene phase of the Laramide.

RELATION OF MID-TERTIARY FAULTS TO REGIONAL STRUCTURES

A zone of north-south trending intermontane valleys and associated normal faults extends from northern Arizona through the High Plateaus of Utah, through the Wasatch Range to the Bear Lake section of southeastern Idaho, along the Idaho-Wyoming boundary to the Caribou Range (Grand Valley and Snake River faults), through western Wyoming to Jackson Hole (Hoback and Teton faults), and beyond into western Montana. Refer to a tectonic map of the United States. Eardley (personal communication) believes this is a long rift zone that extends northward from the Basin and Range Province and is orogenically related to it. In the Snake River and Hoback ranges the age of faulting has been shown to be late Miocene or early Pliocene but this cannot be extended beyond the immediate area.

PHYSIOGRAPHY

Erosion, interupted by deformation, appears to have prevailed in western Wyoming and southeastern Idaho through most of the Eocene, Oligocene, and perhaps part of Miocene time when deformation of note occured (Mansfield, 1927, p. 14). The Miocene deformation elevated the old surface and erosion followed. The relief impressed upon the area at that time was probably as great as it is today. The Camp Davis formation was then deposited in the eroded and down faulted Miocene Grand Valley filling the valley and burying the lower hills and fault scarps. Renewed broad uplift subjected the whole region to erosion. Many of the main valleys today appear to be reexcavated pre-Camp Davis valleys. The great extent and thickness of this formation along the Snake River Range front indicates it was formerly a widespread and thick blanket deposit that has undergone extensive removal.

Three erosion surfaces have been recognized in the Gros Ventre and Hoback ranges by Blackwelder (1915, pp. 310-319) and the Camp Davis staff (unpublished manuscripts). The highest or Union Pass surface cuts folded Paleozoic rocks at 8500-9500 feet, the Black Rock surface cuts the Camp Davis formation at 7500 feet, and the lowest or Circle surface is represented by rock cut terraces and pediments at 6500 feet.

In the Alpine area of the Snake River Range the lower two of these surfaces are recognizable. The Black Rock surface is evidenced where it levels the Camp Davis formation at 7400-7500 feet. The Circle surface is indicated where gravel covered remnants of a terrace cut the inclined Camp Davis formation at 6200-6400 feet.

Table 2.--SUMMARY OF CENOZOIC EVENTS

Epoch	Formations	Orogenic phases	Erosion Cycles Glacial Stages
Recent	Alluvium	Earthquakes	Valley cutting
Pleistocene			Pinedale stage
			Lenore cycle
			Bull Lake stage
			Circle cycle
			Buffalo stage
Pliocene	? Camp Davis formation	High angle, graben and rift valley faulting	Black Rock cycle
Miocene			Uplift and dissection
			Union Pass cycle
Oligocene			Wind River cycle
Eocene		Laramide: 2d stage: Cache & Grizzly thrusts	
	Pass Peak fm.		
		Laramide: 1st stage: Jackson thrust	
	Hoback formation / Knight fm.		
Paleocene	?	Laramide: St. John, Palisade Cp, Absaroka Darby, Bannock thrusts	
	Pinyon congl. / Almy fm. ?		

Blackwelder (1915, p. 328) has identified Buffalo drift (Illinoian or Kansan ?) on the Black Rock surface in its typical occurrence along Buffalo Fork of the Snake River. Refer to Table 2. The gravels on the Circle surface have been attributed by Blackwelder (1915, p. 316) to the outwash deposits of the Bull Lake glacial stage (early Wisconsin). Only the gravels on the Circle terrace are found in the Alpine area.

The erosion since Circle time has been accented several times by rejuvenation of the streams as represented by a succession of terraces (the Lenore cycle of Blackwelder, 1915, p. 319). The work of further interpretation of the erosion history of the area involves largely the recognizition and correlation of the surfaces produced during the successive cycles and is beyond the scope of this paper.

Glacial cirques of an unidentified stage are seen in the north side of Ferry Peak. Mountain glaciation of the most recent order is evidenced 3 miles east of the St. John thrust in North and South Forks of Indian Creek. Above these points the valleys are typically "U" shaped. Terminal moraines fresh in appearance and uneroded indicate this glaciation belongs to the Pinedale stage (late Wisconsin).

RESUME OF GEOLOGIC HISTORY

The oldest rocks of the region, referred to the Archean system, were folded and metamorphosed and subsequently worn down to a peneplain before the middle of the Cambrian period. Throughout the Paleozoic and Mesozoic eras marine sediments were spread over the subsiding surface of the Rocky Mountain geosyncline. There were short episodes when the region was subjected to erosion but it is noteworthy that these periods were not accompanied by major orogenic disturbances.

The Post-Cretaceous Laramide orogenic disturbances compressed the Cretaceous and underlying rocks into folds and thrusts trending northwest and southeast. The thrusting produced a series of orogenic deposits by which the time limits of the orogenies can be defined. Refer to Table 2.

The Paleocene phase of the Laramide is represented in the Alpine area by the Blowout Canyon, Needle Peak. Ferry Peak, and St. John thrusts. These thrusts are associated with or are branches of the major Absaroka and Darby thrusts to the east. The Absaroka and Darby are known to be thrust over the middle Paleocene Almy formation and to be overlain by the lower Eocene Knight formation in southeastern Wyoming. They are, therefore, upper Paleocene in age.

The Eocene phase of the Laramide may be represented by the folding of the thrust sheets in the Alpine area. The first stage of this phase is represented in the Hoback Range by the overthrusting of the lower Eocene Hoback formation by the Jackson thrust. The second stage of the Eocene phase resulted in the overriding of the middle Eocene Pass Peak formation from the east by the Cache thrust and by the Grizzly thrust from the west.

The highlands of the Laramide certainly continued to be worn down after the disturbance ceased and the Union Pass surface in the Hoback and Gros Ventre ranges was developed. The region was then involved in a general uplift and subjected to erosion.

The Camp Davis formation was deposited in late Miocene or earliest Pliocene time against the fault scarps and in the fault troughs. It eventually filled the troughs and earlier canyons and covered the fault scarps becoming a blanket deposit of much wider extent than it is at present.

From the end of Camp Davis time to the present the history of the region is one of denudation (Blackwelder, 1915, p. 340). Streams and glaciers have shaped the present topography with interruption by successive uplifts of the region. While the erosion cycles and interruptions were in progress three advances and retreats of glacial ice from the mountains occurred.

The Black Rock erosion surface has been identified as predating the early or Buffalo glacial stage from occurrences outside of the Snake River Range. In a similar manner the Circle erosion surface has been said to predate the middle or Bull Lake glacial stage. These two erosion surfaces have been identified in the Alpine area but it is only with question that Bull Lake outwash has been recognized on the Circle terrace. The final glacial stage, the Pinedale, has been definitely recognized in North and South Forks of Indian Creek. Since the Pinedale glacial retreat only slight changes have been made in the topography.

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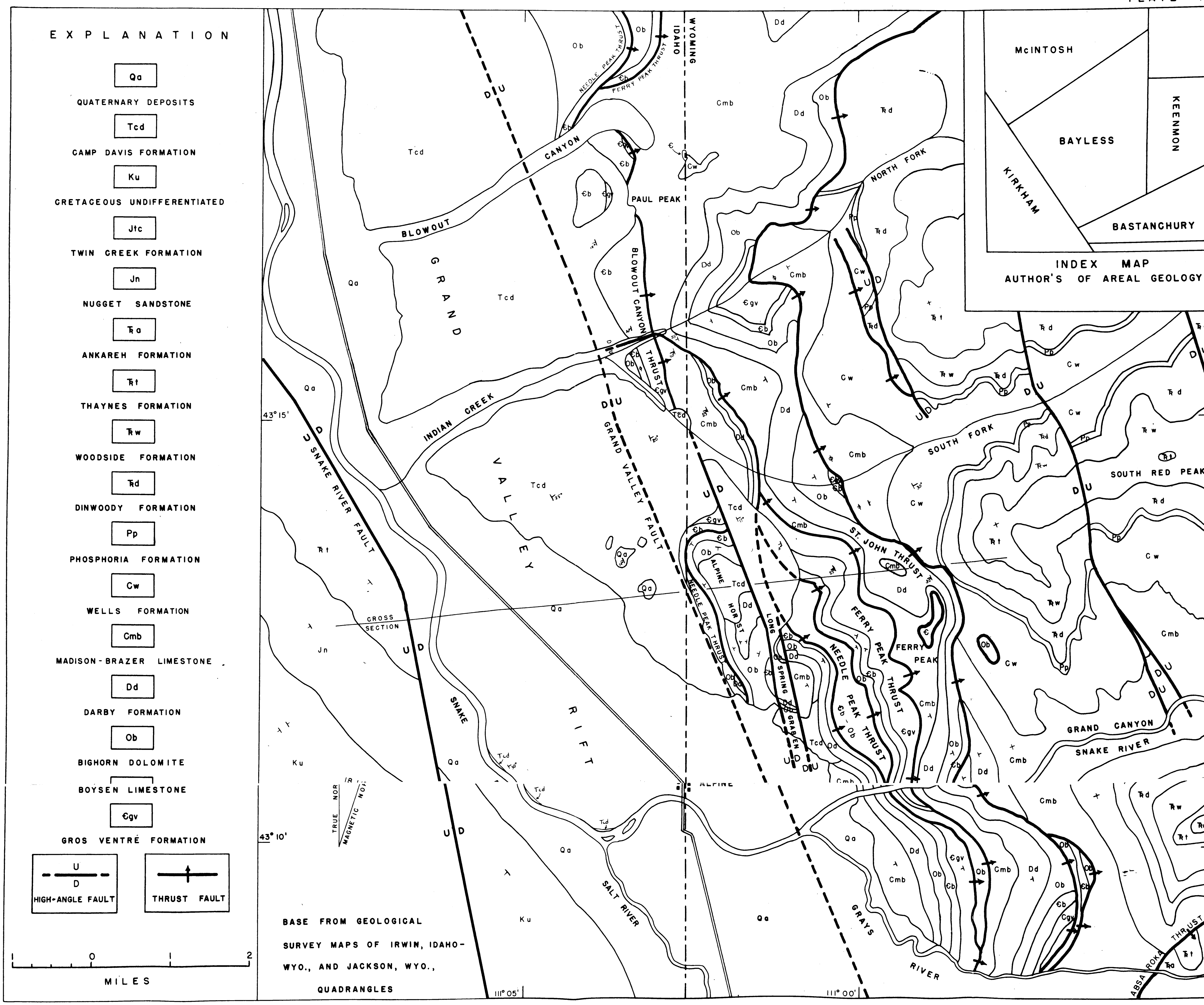
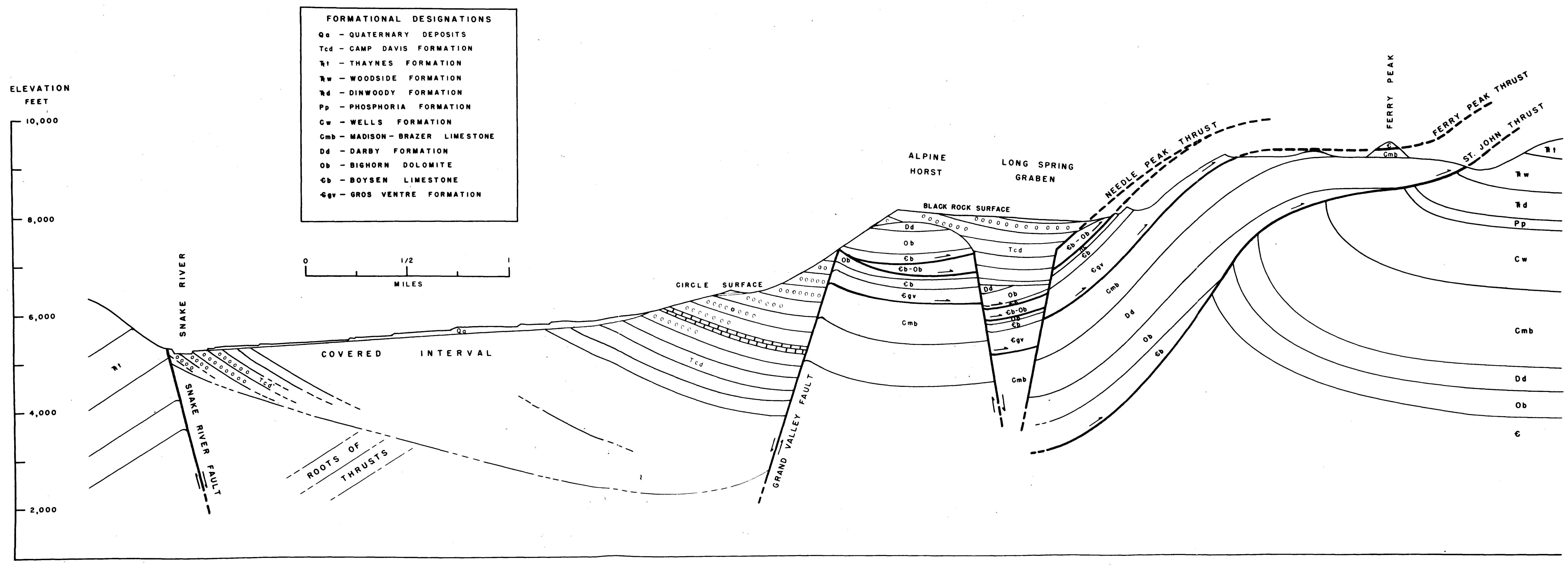
PLATE I



GEOLOGIC MAP OF SNAKE RIVER RANGE NEAR ALPINE, IDAHO-WYOMING

PLATE 2



CROSS SECTION OF SNAKE RIVER RANGE NEAR ALPINE, IDAHO — WYOMING