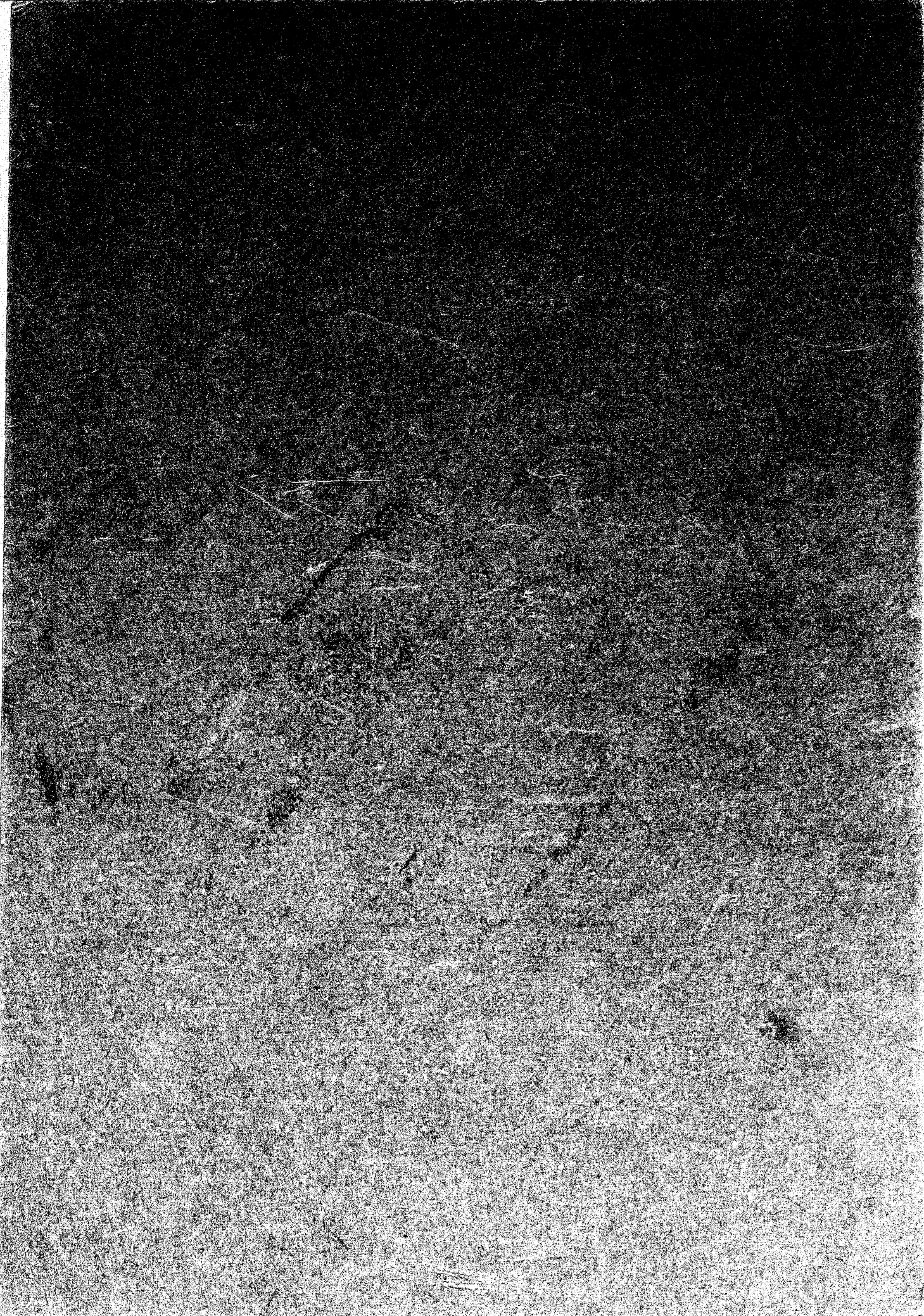
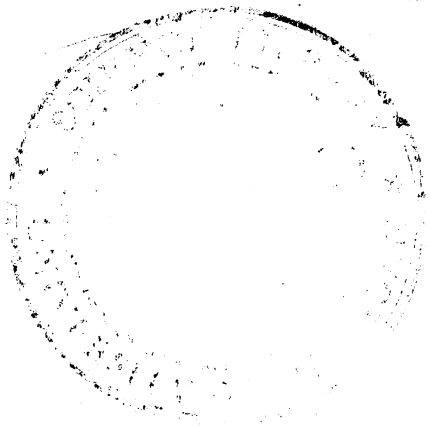


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GEOLOGY OF A PORTION OF THE GALLATIN RANGE IN SOUTHWESTERN MONTANA

By

Frederick H. Reiter

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology, University of Michigan, 1950.

TABLE OF CONTENTS

	Page
Table of Contents.	I
Plates and Figures.	III
Index Map.	IV
Acknowledgments.	1
Previous Field Work.	1
Geographical Location and Accessibility.	2
Physiography.	3
Topography.	3
Drainage.	4
Glaciation.	7
Landslides.	10
Stratigraphy.	13
Pennsylvanian.	13
Amsden formation.	13
Quadrant quartzite.	14
Permian.	17
Phosphoria.	17
Triassic.	18
Jurassic.	18
Ellis group.	18
Sawtooth formation.	18
Rierdon formation.	20

Page

Swift formation. 24

Morrison formation. 25

Cretaceous. 25

Kootenai formation. 25

Bear River formation. 26

Aspen formation. 26

Igneous Rocks. 27

Intrusive Rocks. 28

Extrusive Rocks - Flows. 28

Extrusive Rocks - Volcanic Agglomerate and Fossil Forests. . . 30

Structure. 34

Regional. 34

Local. 37

Faulting. 37

Intrusives. 41

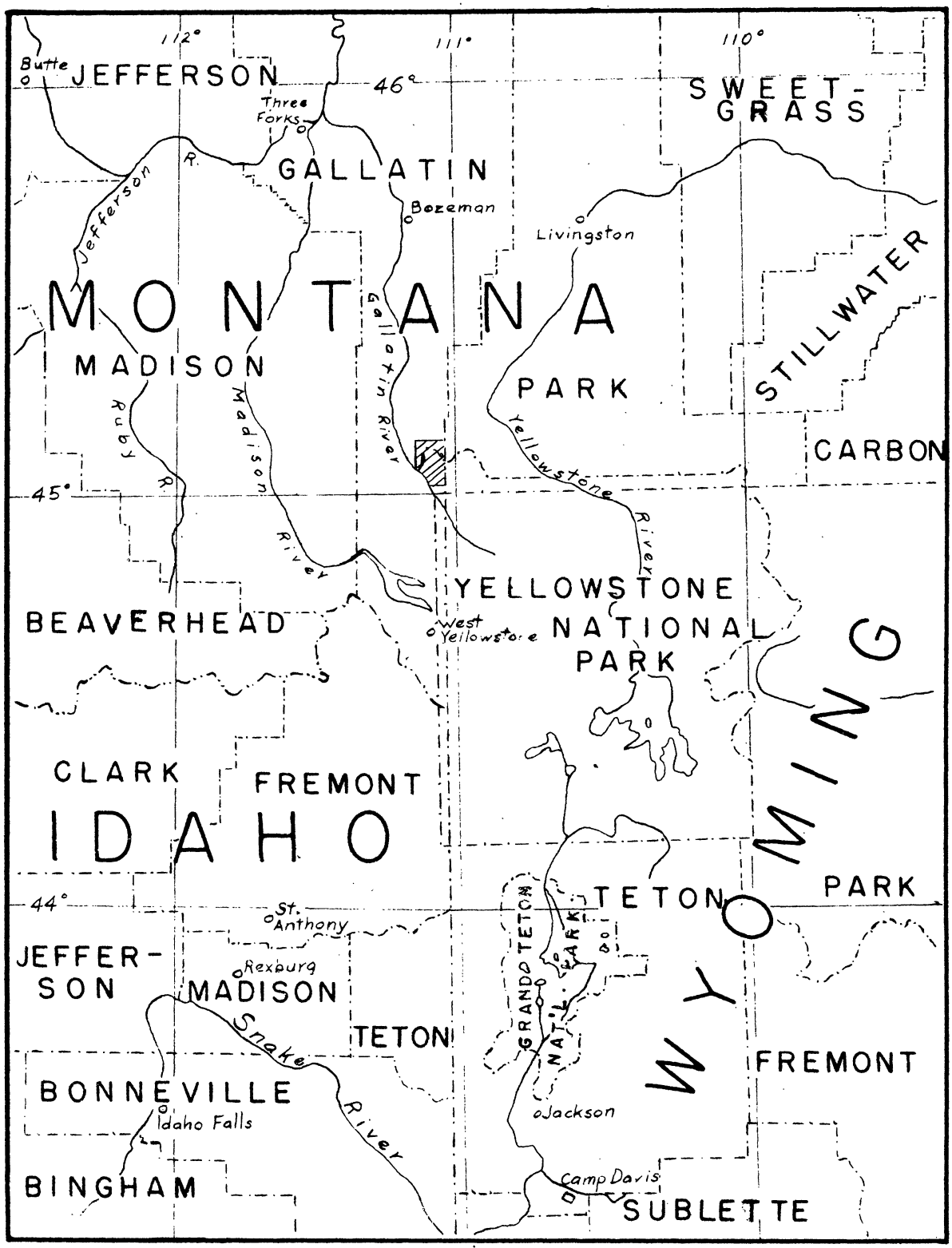
Bibliography

PLATES

	Page
Plate 1	
Index Map.	IV
Plate 2	
Glacial till - Taylor Fork.	9
Plate 3	
Major Structural Features of Gallatin-Madison Region.	36
Plate 4	
Monument Mtn. - Gardiner - Beartooth Thrusts.	38
Plate 5	
Geologic Map.	Back pocket

FIGURES

		Page
Fig. 1.	Panorama - Crown Butte, Aspen Formation	5
Fig. 2.	Panorama - Crown Butte, Monument Mtn. Thrust.	6
Fig. 3.	Panorama - Aspen formation, Monument Mtn. Thrust.	6
Fig. 4.	Landslide - "Cirque".	11
Fig. 5.	Landslide - "Rock Glacier".	11
Fig. 6.	Landslide - Recent Movement.	12
Fig. 7.	Fossil Forests.	32
Fig. 8.	Tree Trunk of Stone.	33
Fig. 9.	Jurassic - Intrusive Contact	



INDEX MAP

PLATE 1

ACKNOWLEDGEMENTS

The author is greatly indebted to Dr. Armand J. Eardley of the University of Utah and Dr. Robert M. Garrels of Northwestern University for their advice and assistance during the field work on which this report is based. Special mention is due Dr. John Chronic of the University of Michigan for his advice in the field and helpfulness in the preparation of this manuscript. The author also wishes to acknowledge the criticism of William J. Liddicoat and Paul R. May. Thanks are also due Dr. G. W. Sinclair who extended the use of his library to the writer.

PREVIOUS FIELD WORK

Previous field work has been extremely limited in the area under study and that immediately surrounding it. In 1893 Peale published, "The Paleozoic Section in the Vicinity of Three Forks, Montana" and in 1896 the U.S.G.S. Three Forks Folio was published by the same author. During the many years of Peale's work, only cursory examination was given to the area under consideration.

During 1947 and 1948 J. A. Wilsey Jr., graduate student at Princeton University, undertook geological reconnaissance in this region for the Phillips Petroleum Company. Since his death in 19 the result of his labors has become the confidential property of Princeton University and the Phillips Petroleum Company.

GEOGRAPHICAL LOCATION AND ACCESSIBILITY

The area dealt with in this report is located in part in the northwest corner of the Yellowstone National Park and in part in Gallatin County, Montana. It is bounded on the south by the Gallatin River and by U.S. Highway 191, on the west by a high angle thrust fault and on the east by Specimen Creek, a tributary of the Gallatin River, flowing from the northeast. The northern boundary was arbitrarily chosen at approximately 45° 06' North Latitude.

The area is readily accessible by all modes of transportation. West Yellowstone, Montana lies approximately 35 miles to the south and is served by the Union Pacific Railroad and a major airline. From West Yellowstone, U.S. Highway 191, a good hard-surface road, may be taken to the area. The area may also be reached via U.S. Highway 191 from Gallatin Gateway, about 50 miles north of the area, which is the terminus of the Chicago, Milwaukee, St. Paul, and Pacific Railroad. Sixteen miles further to the northeast on the same highway lies Bozeman, a town of 8000 population, which is served by the Northern Pacific Railroad and several western airlines.

Within the area itself transportation by foot is mandatory but is greatly facilitated by U.S. Forest Service and National Park Service access trails and innumerable game trails.

PHYSIOGRAPHY

The Gallatin Range, bounding the Yellowstone Park on the north and northwest, is a bold range extending from Mt. Holmes, at the south end, far northward into Montana, where it presents a sharply defined ridge along the west side of the Yellowstone Valley. Electric Peak, on the northern boundary of the Park, is the highest point of the range and attains an altitude of 11,100 feet. The western slope of the range is drained by the Gallatin River which has its headwaters southeastward near Mt. Holmes on the Yellowstone Plateau and flows into the Missouri River at Three Forks, Montana. In the area under consideration the river has a gradient of approximately 50 feet per mile and is referred to as the "Lower Basin" (Peale, 1896). The Gallatin Range in general consists of peaks having fairly accordant crests which range in altitude from 7,000 to 10,000 feet and indicates an old erosion surface from which the mountains have been carved. The surface of the Gallatin Range consists largely of volcanic breccias (Fenneman, 1931).

Igneous activity, glaciation, and stream erosion have been the controlling factors in the genesis of the present topography. The peaks and hills in the area owe their expression to two different modes of origin. The peaks to the north along the park boundary consist almost entirely of volcanic breccias. Crown and Lava Buttes to the west are capped with a thick series of rhyolite flows. (Plate 2) The peaks in the immediate vicinity of Specimen Creek

are ~~due to~~ intrusive igneous masses.

The upper portion of the Gallatin River, like the Madison River, follows an anticlinal valley (Fenneman, 1931). Such a stream channel could only result from long continued erosion which had started on a high plateau, or, best of all, a peneplain. The present canyon was deepened largely during the halt in the post-Miocene uplift termed the "Old Valley" cycle (Pardee, 1950) and may have been remodeled by glaciation. The Gallatin River has a very wide alluviated floodplain on which large glacial boulders are frequently found.

The pattern of the tributaries of the Gallatin River is chiefly dendritic and they meander over fairly broad valleys. Specimen Creek, for example, cut a very wide valley at one time which it can no longer maintain. The streams were loaded with glacial debris which was deposited in their beds and now meander over broad floodplains.

Tepee Creek, near the western border of the area, averages only 2 feet in width but has intrenched itself from 2-4 feet in a floodplain 30-50 feet wide so that the creek is generally invisible. Approximately 10-12 feet above the level of the floodplain, remnants of an old terrace (Pleistocene ?) may be seen. Like most of the other streams in the area, the creek is deflected toward the northwest where it flows out onto the floodplain of the Gallatin River.

Glaciation in the area was chiefly of the alpine type. Evidence for this conclusion is seen today in the canyon-broadening and glacial deposits in the upper reaches of the

Figures 1, 2, 3 - Panoramic View of Western Portion of Area Showing Topography, Characteristic Appearance of Aspen Formation; ink line indicates position of Monument Mountain thrust fault, "T" indicates the overthrust side.



Figure 1. Rhyolite-capped Crown Butte in right center; ridge in background is line of Monument Mtn. thrust; Cretaceous Aspen formation in foreground; Gallatin River lies in left background.



Figure 2. Monument Mtn. thrust clearly visible in middle background; Daly Creek in center flowing right to left.



Figure 3. Thrust (in background) dies out; Aspen formation in foreground.

creeks. The glaciers developed on the Yellowstone Plateau and in the Gallatin Range. The Gallatin Range is generally thought to have held only local glaciers (Weed, 1893) which nestled in the cirques about the crest of the range or rarely extended a short distance down the valleys. The upper parts of the Gallatin Valley and Specimen Creek are excellent examples of glacial valleys.

The terraces and canyons cut across the foot slopes of the Gallatin Range deserve special mention as striking examples of the erosion performed by streams marginal to the ice sheet. On the high ridges to the north of the mapped area, snowfields and cirques are found. Small, low, terminal moraines are found along many of the creeks and a prominent lateral moraine exists where Black Butte Creek flows out onto the floodplain of the Gallatin River. The creek is clearly deflected by the moraine which juts outward into the valley, trending obliquely downstream. Chronic (personal communication) has suggested that this may be equivalent to the Bull Lake glaciation. Two smaller moraines are found further up Black Butte Creek which are possibly equivalent to Pinedale (?). The ancient glaciation was probably Illinoian, equivalent to the Buffalo glaciation south of the park and was followed by erosion on the Black Rock surface.

At one time glacial ice must have been quite thick in the valleys as noted by a deposit of glacial till in the

valley of nearby Taylor Fork. Plate 2 shows the till, plastered against the side of the valley, about 1200 feet above the creek.

In an adjoining area, Austin and Stoever (1950) have found evidence which augments the author's conclusion of multiple glaciation in this area.

The valley of the Gallatin River itself was apparently unglaciated to any great extent in this area. At any rate, prominent glacial features are lacking. However, along the margin of the floodplain, a considerable variety of rocks are found, many of which are large pre-Cambrian boulders which could only have come from far-removed areas. The author finds it difficult to visualize boulders of this size and shape being transported by streams. It is possible that small tongues of ice extended out into the Gallatin Valley and deposited this debris upon melting. On the south side of Daly Creek at the top of a hill directly opposite the end of Crown Butte pegmatite and coarse granite fragments are present. Petrified wood is also found here. It seems unlikely that glaciers once filled the valley to this elevation. It is possible that the volcanic agglomerate once covered this entire area and has since weathered away. There is no evidence of this except in the variety of rocks present in this immediate locality. Toward the north in the area which is covered with agglomerate, there are numerous boulders of various kinds of intrusive and extrusive igneous rocks, together with some sedimentary fragments.

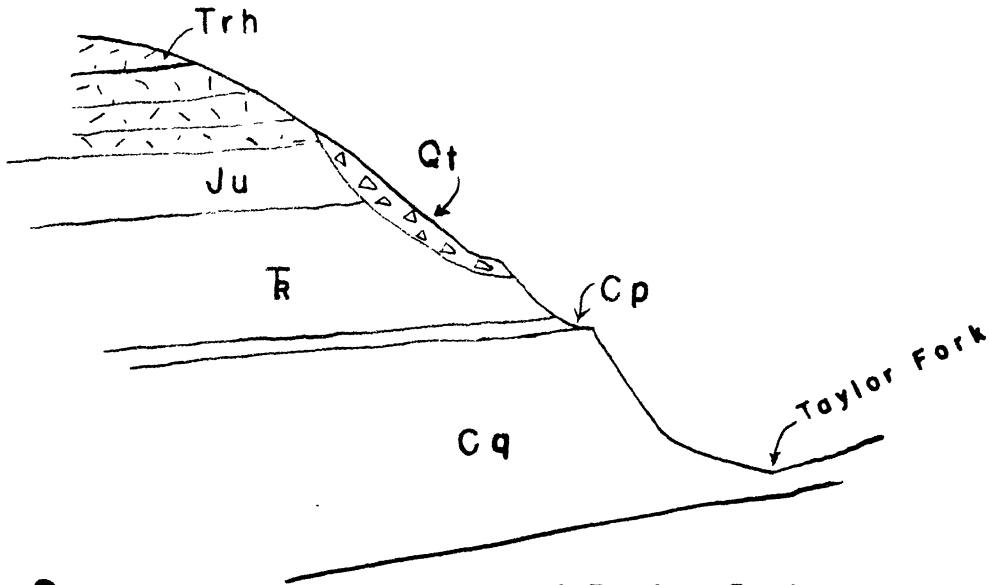


Plate 2- Glacial till in valley of Taylor Fork. Trh-Tertiary rhyolite, Ju-Jurassic, Tr-Triassic, Cp-Phosphoria fm., Cq-Quadrant quartzite, Qt-Glacial till.

According to Bevan (1945) the sources of the Yellowstone glaciers north of Yellowstone National Park were in the Beartooth-Absaroka Mountains. He believes further that glaciers of large volume originated along the south side of the high alpine divide which extends, with only a single important gap, from Stillwater Canyon north of Cooke City, Montana toward the Yellowstone Valley north of Gardiner. These included long, broad, valley glaciers and also a possible continuous ice-cap connection with the ice-cap on the Yellowstone Plateau.

In the Gravelly Range to the northwest, H. W. Scott (1938) has found evidence of Eocene glaciation. Earlier, W. W. Atwood (1915) suggested the possibility of extensive Eocene glaciation throughout the Cordilleran province.

In the area around Lava Butte landslides of rhyolite, having the appearance of rock glaciers, are prominent features. (See Figures 4-6). Cirque-like features are found at the cliffs of Lava Butte. Trees growing upright in the center of some of the rock masses indicate that they are now stationary. One, however, shows recent movement. (Figure 6)

There are innumerable springs and small ponds in the area, many of which exist throughout the year. They are found both in the volcanic rocks and in the Cretaceous Aspen formation. The presence of these features can apparently be attributed to the porous nature of the rocks.



Figure 4. Shows middle of "cirque", note amphitheater-like shape; picture taken from "lip"; beginning of "glacier and moraine" seen in foreground; rock mass drops down rapidly toward valley from here; trees growing in center indicate that most of the mass is stationary now.



Figure 5. View of same rock mass as in Plate 4; looking S 30° E toward source; "lip" in background; note large angular blocks.

With regard to vegetation, the author, in contrast to Jacques (1950), was unable to notice any correlation between the type of vegetation and the origin of the soil. The distribution of aspen, conifers, and sagebrush is controlled in this area by the moisture content of the soil, and appears to be totally independent of the rock from which the soil was derived.



Figure 6. Slide adjacent to that of preceding plates; looking westward shows slide or "rock glacier" path; rock piled up in center and on both sides; earth on sides was buckled and overturned like furrow and trees were pushed over.

STRATIGRAPHY

Both sedimentary and igneous rocks are exposed in the area. The sedimentary rocks range in age from Early Pennsylvanian to Early Cretaceous. Igneous rocks of late Cretaceous (?) and Tertiary age are also present. Names were attributed to the sedimentary rocks through comparison with known formations in other areas. At no place in this area is the entire stratigraphic section for any one geologic period exposed. Fossils were rarely found because of the poor exposures, although fossils are quite numerous in adjacent area. A brief description of the units found in this area is presented below. For detailed sections in adjacent areas the reader is referred to Austin and Stoever (1950) and other authors noted in the bibliography. Much of the historical notation on the stratigraphy was obtained from Wilmarth (1938).

Pennsylvanian

The formations of Pennsylvanian age, although exposed in only a few places in the area, are very prominent and form conspicuous and precipitous cliffs.

Amsden formation

The Amsden formation was originally named by N. H. Darton (1904). The formation consists of 150 to 350 feet of red shales, white limestones, and cherty and sandy limestones in its type locality, the Amsden branch of the Tongue River, west of Dayton, South Dakota.

In the Gallatin Range the Amsden formation is well exposed, although in the mapped area, only 50 to 80 feet of this formation is exposed. To the west of the Specimen Creek campground it is composed of unfossiliferous, white to buff, cherty limestone. It forms prominent cliffs and in places has a brecciated and cavernous appearance.

Quadrant Quartzite

In 1893, after consultation with A. Hague and W. H. Weed, A. C. Peale named the Quadrant formation, a series of red arenaceous limestones, thinly bedded cherty limestones, and quartzite layers near Three Forks, Montana. In the type section this formation rests conformably on the Madison limestone and is overlain by the Upper Jurassic Ellis formation. In his original definition of the Quadrant, Peale included the underlying Amsden formation of Mississippian and Pennsylvanian age and the overlying Phosphoria formation of Permian age. In 1896, W. H. Weed redefined the Quadrant quartzite for Quadrant Mountain which lies on the Gallatin Range in the northwestern corner of Yellowstone National Park. As described by Weed, this formation consists of white, yellowish, and pink beds of quartzite with intercalated granular limestone, the beds having an average total thickness of 400 feet in the Gallatin Range. Weed considered this formation to lie conformably on the Madison limestone and therefore included the beds now known to be Amsden. The beds between

the Quadrant and the Ellis formations were named the Teton formation and included both the Permian and Triassic sediments. Later usage however included the Permian strata in the Quadrant formation. Hence it is easy to see why confusion existed for so long when discussion concerned rocks lying above the Mississippian Madison limestone and below the Jurassic Ellis formation since the name Quadrant was generally used to encompass all of them. The type section of the Quadrant described under the heading "The Quadrant Quartzite" (Weed, 1899) is found at its exposure on the southeast corner of Quadrant Mountain and is early Pennsylvanian in age (Scott, 1935) who remeasured the section (which is reproduced below) and ascribed the lower 100 feet of Weed's Quadrant, which was covered by talus blocks, to the Amsden formation.

Phosphoria

Quadrant	Feet
Gray brecciated limestone	7
Quartzitic sandstone	2
Light gray, cherty, siliceous limestone with sandstone lenses, brachiopod fragments and foraminifera	14
Massive, saccharoidal, tan-colored sandstone	15
Brown to white quartzite	2
Cherty, compact limestone	6
Cross-bedded, ripple-marked quartzite, black on surface	11
Calcareous quartzite	8

Quadrant (Continued)

	Feet
Cross-bedded, coarse grained, tan-colored sandstone, erosional surface at base	6
Light gray, cherty, and fossiliferous limestone	8
Hard sandstone, like quartzite	29
White to brown quartzite	10
Gray limestone	2
Cross-bedded gray quartzite, sandy at base, calcareous at top	116
	236

Amsden

Madison

Twenty miles north of the type locality at Cinnabar Mountain the Quadrant is 125 feet thick and is composed entirely of quartzite. The calcareous zones thin rapidly eastward toward the Big Horn Mountains where equivalent sandstone beds are called the Tensleep formation. The name Tensleep was first used by Darton (1904) for a sequence of beds exposed in the walls of the lower canyon of Tensleep Creek, Wyoming. Knappen and Moulton (1930) believe that the uniform size of the sand grains and the steeply inclined cross beds of the Tensleep in the Big Horn Mountains indicate an eolian origin for at least the lower part of the formation in that region; whereas the upper calcareous part represents marine material which has been mostly re-worked. The sandstone of the Tensleep grades westward into the Quadrant quartzite. Likewise,

the upper calcareous zones in the Tensleep grade into siliceous limestone and finally into nearly pure limestone beds in the upper part of the Quadrant. True marine characteristics replace the eolian characteristics of the Tensleep in the Big Horn Mountains, and at Quadrant Mountain practically the entire formation is of marine origin. The Tensleep is considered equivalent to the Quadrant by Gardner (1945). To avoid possible confusion as to age, introducing possible questions of origin but primarily because of its proximity to the type section, use of the name Quadrant quartzite has been made in this paper.

In the area mapped, the Quadrant is exposed at the top of the hill just to the west of the Specimen Creek campground, and along the Monument Mountain thrust. In both localities the formation is a hard, well-cemented, tan sandstone. The conspicuous Quadrant talus is dark gray to black and is generally covered with lichens. The beds are very resistant to erosion and form prominent cliffs which are maintained because of their vertical jointing and blocky fracture.

Permian

Phosphoria formation

The Phosphoria formation is totally lacking in this area, although it is exposed in varying thicknesses in the surrounding region. Its absence is attributed to the long erosion interval after the Permian and Triassic.

Triassic

Triassic strata in the area are only exposed in a small wedge near the Monument Mountain thrust and U.S. Highway 191 and it was not possible to definitely assign any formation name to these beds. The strata in this locality consist of red and reddish brown siltstones and shales. In the lower beds Dr. J. Chronic discovered several specimens of Lingula sp.

In the surrounding region the Triassic is found in varying thicknesses up to 350 feet. This variation is due to the erosion interval prior to Jurassic time.

Jurassic

Ellis group

The Ellis formation was named by Peale (1893) and described by Iddings and Weed in 1894 and again by Peale in 1896 (Wilmarth, 1938). In these descriptions the Ellis group includes those rocks overlying the Quadrant formation and underlying the Cretaceous. Cobban (1945) has noted three major lithologic divisions and named them, from oldest to youngest, Sawtooth, Rierdon, and Swift, raising the Ellis to group rank.

Sawtooth formation

This formation was named by W. A. Cobban (1945) from the Sawtooth Range in which it is well exposed. The type locality for this formation is in Rierdon Gulch. In the

type section, the beds are composed of a basal fine-grained sandstone, a medium dark gray shale containing a few thin dark limestone layers, and an upper highly calcareous siltstone. For the detailed type section and fossil lists the reader is referred to Cobban (1945) and Imlay (1945).

A detailed section of the Sawtooth formation in the Gallatin Range is included in the entire Jurassic section which is presented below. This section was measured in the valley of Taylor Fork approximately 2¼ miles upstream from its junction with the Gallatin River.

Detailed Section of Ellis Group - Measured in Taylor Fork on north side of valley. Measurements made with Jacob staff.

Swift formation		Feet
28.	Shale - arenaceous in places; light greenish gray; glauconitic; soft; fractures and weathers into small fragments. . .	7.5
27.	Sandstone - light brownish yellow to orange brown; soft, very porous and friable; thin bedded; weathers to medium coarse sand	7.5
26.	Shale - grayish green grading to bluish green and then to greenish blue; impure; glauconitic; brittle.	11.0
25.	Sandstone - argillaceous; light brown; porous and friable; gritty; harder than bed below.	1.0
24.	Sandstone - light greenish gray; soft, friable and porous.	8.0
23.	Sandstone - grayish white; coarse-grained; hard; massive; salt and peppery. . .	1.0
22.	Sandstone - dark greenish gray; glauconitic; soft, porous and friable.	3.0

21. Sandstone - mottled gray; calcareous; massive; fossiliferous. 2.0

20. Sandstone - dark greenish gray; soft, friable, porous. 7.0

19. Sandstone - light brown; arkosic; calcareous; hard; massive cliff former; weathers in rounded form with tan color. 12.0

18. Sandstone - dark gray brown, oolitic calcareous; weak and very porous; medium coarse grained; well bedded at base; weathers to buff gray. 8.0

17. Sandstone - mottled bluish and brownish gray; calcareous; hard, dense; medium grained; cliff former. 1.0

16. Sandstone - light gray; very calcareous; medium grained; gritty; porous and friable. 14.0

83.0

Rierdon formation

15. Limestone - grayish tan; oolitic; massive, dense; secondary calcite crystals. 2.5

14. Shale - brownish red to chocolate; calcareous, weak; coarse grained; friable. . . 22.0

13. Shale - light yellowish green; calcareous; very fine grained; weak, friable; weathers into small angular fragments. . . 6.0

12. Shale and limestone interbedded - weak, dark yellowish brown shale; interbedded nodular mottled gray limestone; light brown weathering soil; one 8 in. dense gray limestone lens. 32.5

11. Shale - light olive gray; dense; Pentacrinus columnals, Gryphaea sp. 2.5

10. Limestone - olive gray on fresh surface, light olive gray on weathered surface; hard, dense, massive, almost lithographic; fossiliferous (pelecypods). . . . 1.5

67.0

Sawtooth formation — Feet

9. Limestones and dirty shales interbedded-light olive gray to moderate yellowish brown; limestone hard, dense, very fossiliferous (pelecypods-molds and impressions); nodular shale, soft, friable, also concoidal fracture, dark yellowish brown shale also. 30.0

8. Limestone - argillaceous; brown to purplish gray; hard, dense; fine grained; nodular; irregular fracture; very fossiliferous; calcite fillings. 2.5

7. Shale - arenaceous; dirty brown; soft, friable; weathers into angular fragments. 1.0

6. Shale - arenaceous; brown, lighter at base; hard; fine grained; fractures in uneven plates at base, nodular at top; well laminated at base. 0.5

5. Sandstone - light blue gray; hard, dense; fine grained; smooth fracture surface; resistant, weathers in smooth rounded form; tan to buff on weathered surface; calcareous on weathered surface. 2.3

4. Sandstone - argillaceous; variegated gray color; nodular, uneven appearance; rather friable; pinkish tan to buff on weathered surface. 0.5

3. Sandstone - argillaceous; very light gray; very thin bedded; fine grained; friable; micaceous; very porous but resistant; weathered surface tan to buff. 0.3

2. Shale - arenaceous; blue gray on fresh surface; slightly calcareous; fine grained; hard; thin bedded. 0.5

1. Sandstone - argillaceous; light gray on fresh surface; weak, fine grained; tan to buff on weathered surface. 0.5

38.1

Total.....188.1

The thickness of the Sawtooth is quite variable over the whole region. In the area mapped, complete exposures of the Jurassic were lacking and it was extremely difficult to affix formational names to the small outcrops present. A partial section was measured, however, approximately ½ mile north of Highway 191 along the west side of Wickiup Creek where the beds dip 30° to the northeast, and that portion which the author has assigned to the Sawtooth is presented below. The thicknesses given for individual beds are slightly arbitrary since the beds were measured by digging a series of holes along a slope at right angles to the strike of the beds.

Section of Jurassic Strata - Measured ½ mile north of Highway 191 along west side of Wickiup Creek. Jurassic rocks are in contact with intrusive porphyry.

Sawtooth formation	Feet
3. Siltstone - alternating light yellowish brown and light and reddish brown beds interbedded with dark olive green shales; all beds well laminated, non-calcareous, friable; silts cross-bedded in places. . . .	23.0
2. Sandstone - argillaceous; buff to light tan with greenish cast; calcareous; fine-grained; soft; calcite veinlets; weathers to light gray or white. m.	15.0
1. Shale - light blue green on fresh surface; calcareous; medium grained; soft; thin bedded and well laminated; weathers to light gray. .	6.0
	44.0

Along Specimen Creek the Jurassic rocks wedged in among the porphyry intrusives (see fig. 3) belong to the Sawtooth formation (?). The beds dip 60° to the north and consist of approximately 30 feet of greenish gray to blue shales and 10 feet of a hard, brown conglomerate containing numerous black phosphatic pebbles and one specimen of Belemnites densus Meek and Hayden.

Rierdon formation

The Rierdon formation was named by Cobban (1945) for a group of alternating gray limy shales and limestones found overlying the Sawtooth formation in Rierdon Gulch, Montana which is considered the type locality. For lists of Rierdon fossils, the reader is referred to Austin and Stoever (1950), Cobban (1945), and Imlay (1945). Presented below is the remainder of the Jurassic section (continued from p. 22) which was measured along Wickiup Creek and which the writer has assigned to the Rierdon formation on the basis of similar lithology.

Rierdon formation		Feet
13.	Limestone - blue gray, hard, dense, fossiliferous, small intercalated shale beds.	15.0
12.	Shale - dark gray, calcareous, hard.	2.5
11.	Sandstone - tan to buff, calcareous, well-bedded, have interfingers of greenish gray and tan to buff sandstones at base.	1.0
10.	Shale - light greenish gray, calcareous, hard, brittle.	2.5

9.	Sandstone - light gray, calcareous, thin bedded, fine grained, cross-bedded, moderately resistant, weathers in broad thin plates with overall rounded form, contains lenses of massive sandstone.	10.0
8.	Sandstone - alternating light gray and dark brown, calcareous, thin bedded and well laminated, fine grained.	2.0
7.	Shale - arenaceous, variegated brown, green, and gray; irregular fracture, brittle, non-calcareous.	1.0
6.	Shale - arenaceous, light greenish gray, calcareous, thin bedded, concoidal fracture. . .	1.0
5.	Sandstone - light gray, well laminated, non-calcareous, thin bedded, soft, friable. . .	20.0
4.	Shale - arenaceous, dark greenish gray on dry surface, dark olive green on wet surface, glauconitic, well laminated and cross bedded, hard.	35.0
		90.0

On page 20 will be found a detailed section of the Rierdon formation which was measured on Taylor Fork.

Swift formation

Cobban (1945) applied the name, Swift formation, to marine Jurassic rocks consisting of dark gray non-calcareous shales overlain by fine-grained glauconitic flaggy sandstone. The type locality for these rocks is at Swift Reservoir on Birch Creek, Montana. A detailed section of the Swift as it occurs in the Gallatin Range will be found on pages 19 and 20. No known rocks of the Swift formation are found in the area mapped.

Morrison formation

The Morrison formation is entirely lacking in the area mapped.

Cretaceous

The Cretaceous formations in the area have been termed Kootenai, Bear River, and Aspen. Nowhere, however, are these formations completely exposed in the mapped area. The names of the latter two formations have been used because of the similarity of the rocks with those of the Camp Davis area in Wyoming.

Kootenai formation

The Kootenai formation was named by Sir William Dawson in 1885 for a series of sandstones, shales, and conglomerates with seams of coal found in the Kootenai Mountains of Montana (Wilmarth, 1938). In this area the Kootenai consists of massive tan sandstones, black shales, nodular limestone, a prominent gastropod limestone member, and hard gray-brown conglomerate. Although coal seams are found in the surrounding region none were found in this area. To the north these coal beds are of economic importance. The Cretaceous of Montana contains rich coal beds most of which are of Kootenai age (Weed, 1891). Bituminous coal was mined nearby in the Upper Gallatin basin near Virginia City and the well-known Bozeman coal field to the north.

In the area under consideration in this report, a

small exposure of the Kootenai conglomerate is found in the saddle to the south of Black Butte. This conglomerate is quite coarse and contains black phosphatic chert, quartz, and quartzite pebbles.

The gastropod limestone is found just below the rhyolite of Lava Butte on the slope leading down to U.S. Highway 191. Downslope below a covered interval, there is a very resistant, massive, light tan, quartzitic sandstone.

Bear River formation

The Bear River formation was named by F. B. Hayden (1869) for a sequence of coal bearing strata at Bear River City, Wyoming. At that time the formation was believed to be of Tertiary age but it was later determined to be of Upper Cretaceous age from fossil flora and vertebrates found in the strata.

In the Gallatin Range, the Bear River formation is found to the south of Lava Butte, approximately ½ mile up Black Butte Creek. The exposure is quite small and consists of soft black shales, a hard, tan, gritty, medium fine grained, cross-bedded sandstone, overlain by soft black shales.

Aspen formation

The Aspen formation was named by A. C. Veatch (1907) for exposures near Aspen Station in Uinta County, Wyoming. In the type section the formation consists of black and gray shales containing abundant fish scales.

The Aspen formation is widely exposed in the southern Gallatin Range, but due to the topography and the gentle dip of the beds only a small portion of the formation is generally visible. In the Taylor Fork area the Aspen formation consists of grayish salt and pepper sandstones, porcellanites, bentonites, and shales.

In the area mapped, the greater number of exposures consist of porcellenite. This rock has also been called vitrified or welded tuff. This porcellenite is extremely fine grained and hard and weathers into splintery fragments forming a very characteristic talus. It is believed to be water laid volcanic ash in which high silica replacement has occurred. It ranges in color from light blue gray to reddish brown, and frequently has a well-laminated appearance. Plant fossils are occasionally found within these porcellenites.

At other exposures light gray salt and pepper sandstones are found, some of which are massive while others are thin bedded and somewhat argillaceous. To the south of Lava Butte, an outcrop of the Aspen formation consists of a light tan salt and pepper sandstone which is cross-bedded and moderately resistant.

Igneous Rocks

Igneous rocks in this area consist of Late Cretaceous- Early Tertiary intrusives and Tertiary extrusives. Within some of these extrusives there are spectacular fossil forests.

Intrusive Rocks

The intrusive rocks are exposed on both sides of Specimen Creek campground and for several hundred yards upstream on both sides of Specimen Creek. Black Butte, several miles down the Gallatin Valley, is entirely composed of the intrusive rocks. A large mountain directly across the Gallatin River from the campground is largely composed of the same material, and there are numerous other exposures on both sides of the Gallatin River for over a mile upstream. Many of the intrusive rocks consist of quartz dacite porphyry or andesite porphyry with hornblende and late epidote. Liddicoat (personal communication), who is making a detailed study of the igneous rocks in the adjacent area, has found that while the intrusives look quite similar megascopically, when studied in thin section they are found to vary considerably. The intrusives apparently are of a laccolithic type although in places they are discordant.

Extrusive Rocks - Flows

The volcanic flows, which form prominent buttes in the southern part of the area, consist chiefly of quartz sanadine rhyolite porphyry and occasionally andesite porphyry. Flow structure is generally common but some rhyolite was found which appeared tuffaceous and there is some which may have been slightly vesicular. The rhyolites are exposed in small patches in the vicinity of Wickiup Creek but

the best exposures are found at Crown and Lava Buttes. It is believed that the rhyolite flowed down from the northeast into the valleys which then existed. The flows lie unconformably upon the Cretaceous sediments and are dated as of Late Tertiary age, probably Pliocene (?), on the basis of fossil vertebrates and flora.

The writer believes these rhyolites are equivalent to the great rhyolite floods mentioned by Howard (1937) which followed the Early Pliocene Canyon Basalt.

While the composition of the rhyolites is apparently constant, the flows vary considerably in color. A description of the sequence of quartz sanadine rhyolites in the cliff at Crown Butte is presented below.

		Feet
5.	Deep red - porphyry, aphanitic groundmass, massive, blocky, vertically jointed, flow structure prominent.	50
4.	Purple - porphyry, phenocrysts smaller and less numerous, glassy groundmass, has bedded appearance, horizontal joints or fracture planes very prominent.	25
3.	Light gray - porphyry, has vesicular appearance, massive, with irregular fracture, phenocrysts larger, aphanitic groundmass.	15
2.	Light pink with some light purple porphyry, massive, blocky, vertically jointed, glassy groundmass, slightly vesicular, some secondary mineral crystallization.	100
1.	Dark gray - porphyry, massive, has thick bedded appearance, irregular fracture and joint system, aphanitic groundmass, phenocrysts small.	404
Talus		
		2304

Extrusive Rocks

Volcanic Agglomerate and Fossil Forests

A series of volcanic agglomerates and breccias cover the eastern and northern portion of the area mapped, totaling over 50% of the total area. These rocks are more basic than the flows described on preceding pages and are far older. The chief rock type is andesite, and the author regards the volcanic series as being equivalent to Howard's (1937) early acid series. These strata rest upon the unevenly eroded Paleozoic and Mesozoic rocks, and form most of the rugged mountains which enclose the area on its northern and eastern sides. They are virtually horizontal and apparently conformable throughout their entire thickness.

A large part of this immense volcanic sequence is filled with the silified remains of ancient forests. (Figure 8). Erosion has since exposed parts of the fossil forests, which are found at altitudes of 7000 to 10,000 feet. These displays are far superior to those of the Lamar River Valley described by Read (1933) and other authors. Until the Chapmans' studies (1935), reports on the fossil forests of Yellowstone National Park completely neglected those in the Gallatin corner of the Park. The fossil forests in this area and other portions of the Park are unique in that, unlike most of the known fossil "forests", the trees are found standing upright as they originally grew. Petrified logs and stumps with branching roots still attached are found in greatly varying sizes. The stumps and frequently

the boles themselves are found protruding vertically from the ground in the position in which they grew, while broken trunks are commonly imbedded in the breccias. (Figure 9) The wood is now beautifully colored, mostly yellow or brown, but white, black, and green colors are common. Wood and leaf impressions were found and identified provisionally by the writer as Sequoia magnifica Knowlton. Leaf impressions of fern, pine, and willow were also found. Specimens were also found which had apparently been attacked by fungi and in other cases insects, prior to petrification.

These forests were first believed to be of Miocene age (Knowlton, 1914) and this belief continued for nearly 15 years, until subsequent study had shown that the forests were of Eocene age. Read (1933) concluded the age of the Yellowstone flora as older than Miocene, either Upper Eocene (?) or Lower Oligocene (?). Jones and Field (1929) arrived at similar conclusions as to the age of the breccias from their study of the geologic history of the Grand Canyon of the Yellowstone. However, both Young (1940) and Chapman and Chapman (1935) both regard the forests as Eocene.

The flora is a redwood association but differs from the great Middle Tertiary redwood forests of western North America in the presence of a large number of species common in definitely known Eocene horizons which have not yet been reported from younger strata. The obvious conclusion is that the flora contains certain elements which can be accounted for only by regarding the assemblege as older than Miocene.



Figure 7. A few miles from the widely known and easily accessible phenomena of Yellowstone Park lie remarkable and little known exposures of fossil tree stumps which were petrified in an upright position. In the photograph above at least six different layers of petrified trunks are visible.

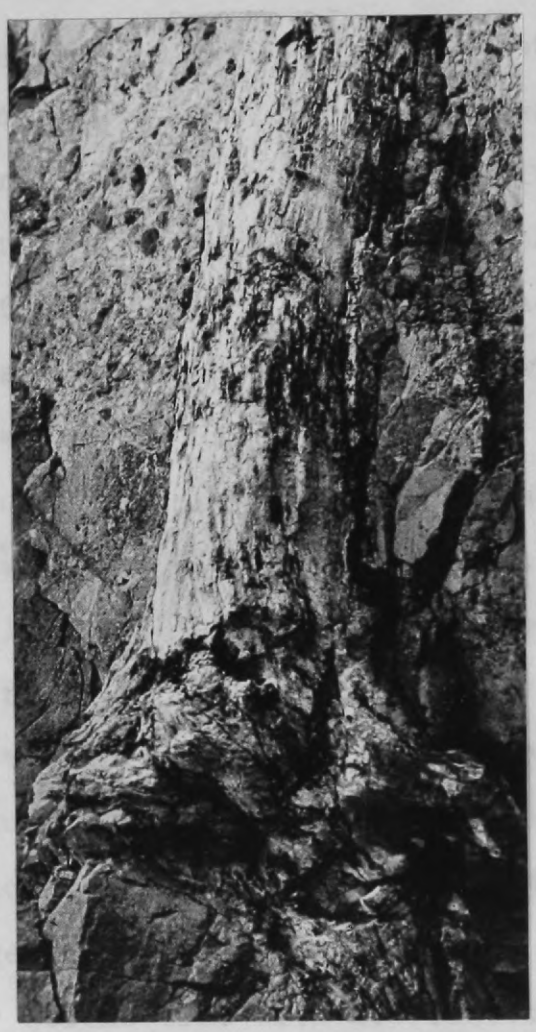


Figure 8. Tree Trunk of Stone

According to some scientists this petrifaction has been caused by the replacement, molecule by molecule, of the wood substance in solution. Another theory is that the wood is not replaced at all, but that silica in solution filters between the solid parts of the wood and is deposited around the fibers which always remain.

STRUCTURE

Regional

The Gallatin Valley is an intermontane structural valley in a region of discordant complex structure. The Laramide orogeny began in the late Cretaceous with the formation of broad asymmetric folds trending northward. The narrow north-trending Gallatin, Madison, and Ruby valleys are respective anticlinal crests of the Bridger, Madison, and Jefferson anticlines (Fix, 1940) which were slow in rising and were breached by erosion.

The intensification of stresses resulted in the formation of southwest trending overthrust faults cutting across the ranges (Paleocene ?) but did not destroy the control of the original structural pattern. In late Paleocene or early Eocene, steep thrust faults cut earlier structures. The Spanish Peaks uplift, most important feature of this faulting, rose obliquely across the Gallatin, Madison, and Tobacco Root Ranges. Beneath this mass rose the Boulder Batholith in early Eocene time with associated block faulting which continued through the late Tertiary. The author is of the opinion that the stocks found in the Specimen Creek area and the Upper Gallatin Valley are related to the batholith at least in age.

The Laramide orogeny probably ended in early Eocene time and was followed by a long erosion interval. Differential uplift caused intense faulting at the end of the Eocene, during the Oligocene, Miocene, and Pliocene, (the

most severe uplift occurring late in the latter period), and continuing through the Quaternary. The mountain ranges and intermontane valleys still have the north-south elongation developed by the first structural pattern in early Paleocene time although later epochs of deformation have in turn greatly increased the structural complexity of the region. Frequent earthquakes prove that deformation is still going on.

With the aid of students of the University of Michigan working in the region, Dr. A. J. Eardley has divided the Laramide Revolution in southwestern Montana into three phases (Bull, 1949). An early Laramide orogenic phase resulted in the folding of the Paleozoic and Mesozoic sediments with axes trending northeast-southwest. A mid-Laramide orogenic phase saw further compression of these folds and upfolded the early Tertiary sediments. During a later orogenic phase several thrust sheets striking north and northwest cut the previous folds. (Plate 3)

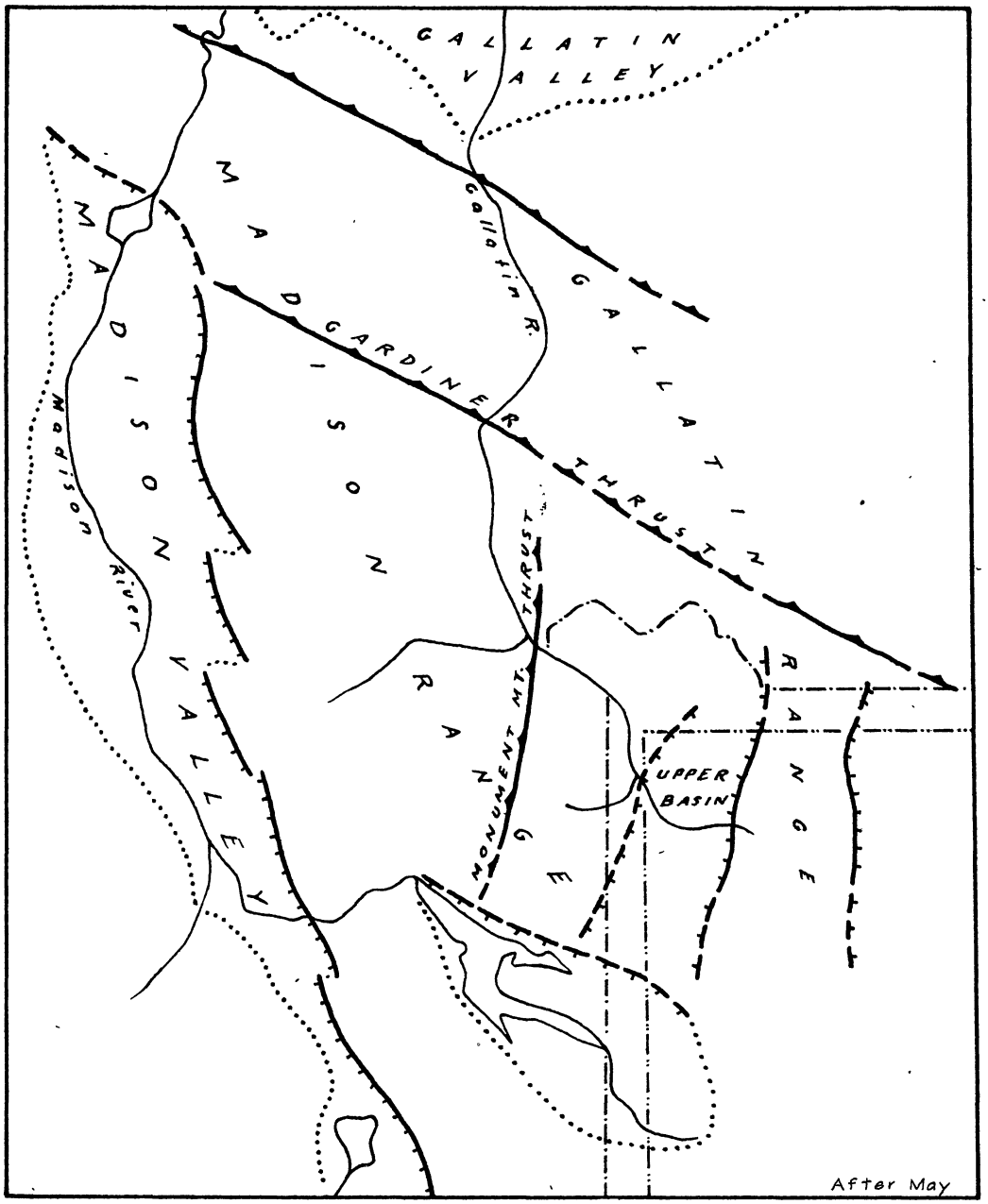


PLATE 3. Major Structural Features of Gallatin-Madison Region.

Local

Faulting

A high angle thrust fault is found on the western border of the area and was named the Monument Mountain thrust by Hume and Leeder (1950). (Plate 4). The fault plane strikes north and dips about 45° west. The movement was toward the east with Paleozoic rocks thrust over the Mesozoic sediments and a pronounced fault line is readily visible. The thrust dies out in an anticline to the north. In the vicinity of Buffalo Horn Creek beyond the northwestern limits of the area studied, a normal fault truncates the larger high angle thrust (Austin and Stoever, 1950). This fault cuts the thrust at approximately 45° and displaces it slightly. Southward the thrust bifurcates with its major axis extending south through Monument Mountain (Hume and Leeder, 1950). Along the eastern side of the fault the Jurassic formations and Cretaceous Kootenai formation are overturned and dip 30° to 50° westward.

The thrust is dated as part of the Laramide orogeny. The Cretaceous Aspen formation is the youngest deformed stratum. The oldest undeformed rocks are the Tertiary rhyolites. In nearby areas however, unmetamorphosed pre-rhyolite coal beds of the Laramie formation are found which could not have been part of the thrust (Hume communication).

Although the Mountain Mountain thrust appears to be a minor structural feature compared to the great regional

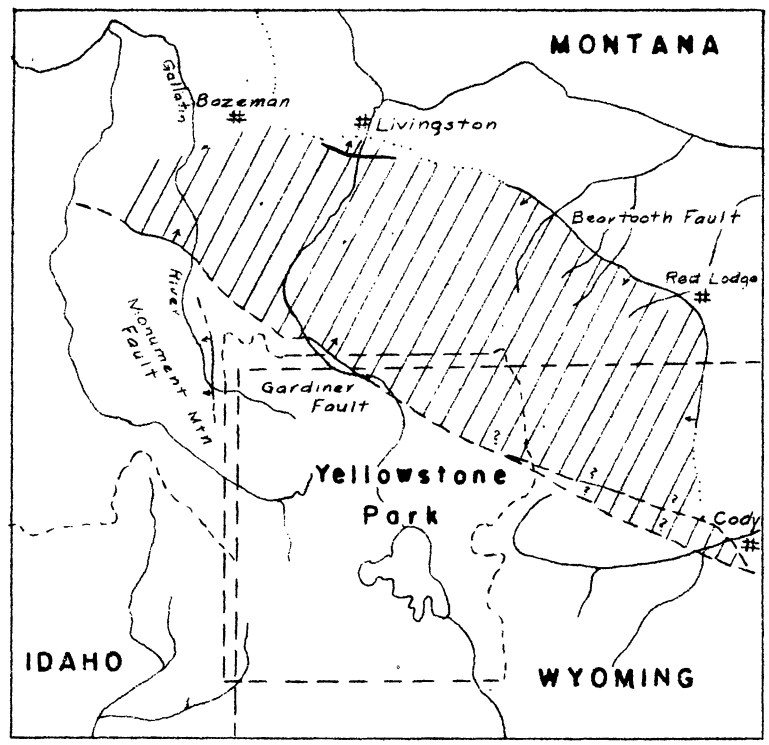


Plate 4 - Relative position of Monument Mtn.- Gardiner - Beartooth Thrusts.
Adopted from Wilson.
↑ - Direction which the fault plane dips.

thrusts, it may be contemporaneous or indirectly related to the Gardiner thrust. This is suggested by the general trend of the two thrusts (Figure 4) and by the intrusive bodies which are found in close proximity to the fault plane. In the Gardiner thrust intrusives are found cutting into the granite hanging wall and consist of dacite and andesite porphyry (Wilson, 1934). Intrusives are likewise found in the vicinity of the Monument Mountain thrust but in this case the intrusives lie approximately three miles in front of the fault plane and therefore could not have intruded along the fault plane as Wilson has postulated for those of the Gardiner thrust.

The intrusives near Specimen Creek consist of andesite and quartz dacite porphyries (Liddicoat, personal communication) which shows a striking similarity in composition to the intrusives associated with the Gardiner thrust. While the Mountain Mountain thrust may or may not have some relation to the Gardiner thrust the writer does believe that there is a genetic relationship between the igneous intrusions and the Monument Mountain thrust.

The author realizes that an immediate objection can be raised since it is well known that the structures in the immediate region differ in trend from those to the north and east. Raisz (1939) presents a general picture of the mountain systems depicting the mountains to the south and east of Yellowstone with a general northwest-southeast trend, and trending progressively toward a

north-south direction as they go northward. The mountains of the Gallatin-Madison region are intermediate in position and trend slightly west of north. (Plate 3) Two major structural zones converge toward central Montana (Field, 1932). The first of these lies to the west and south, involving low angle thrusts with movements from west to east with the strike in a general north-south direction. The other zone lies to the north and east. Here the general strike of the structure is toward the northwest, starting at the Hartville uplift in eastern Wyoming and curving in a series of arcuate lines toward the northwest, to meet the western zone of thrusts and disappear in Central Montana. Despite the dissimilarity in regional structural trends, an unequal compressive force from the north and west could in effect create a squeezing action producing the two faults, with their respective fault planes dipping in virtually opposite driections. An analogous situation exists between the Beartooth and Gardiner faults. (See Figure 4).

Intrusives

In the vicinity of Specimen Creek, an igneous mass, which was intruded into the overlying sediments, has now been exposed by erosion. The intrusion seems to be generally concordant although large masses were occasionally broken off and preserved intact within the molten mass. Several instances were found where masses of Jurassic rocks in various attitudes were completely surrounded by the igneous intrusives. Figure 9 represents a highly idealized drawing of the relationship between the Jurassic rocks and the surrounding intrusives, exposed along Specimen Creek. Iddings and Weed (1899) regarded these intrusives as a laccolithic uplift which has been cut into by the Gallatin River.

Just to the west of the Specimen Creek campground there is a large hill composed of the Pennsylvanian Amsden and the igneous porphyry. The Quadrant formation forms a cap on the peak and it is believed that this latter mass was broken off similar to the Jurassic and pushed up during the intrusion. The intrusives in this area consist of andesite and quartz dacite porphyries. The feldspar phenocrysts are very numerous and are occasionally zoned. Hornblende is a common constituent, along with late epidote. At one exposure a large fragment of hornblende gneiss (pre-Cambrian ?) was found included in the porphyry intrusive.

The author found no evidence that mineralization of economic importance had taken place due to the igneous intrusion. However, to the north near Gallatin Gateway,

corundum bearing pegmatite dikes have intruded Archean gneisses and quartzites and these have been exploited commercially (O'Brien, 1947). It is believed that these intrusives were contemporaneous, although not necessarily related to those in this area.

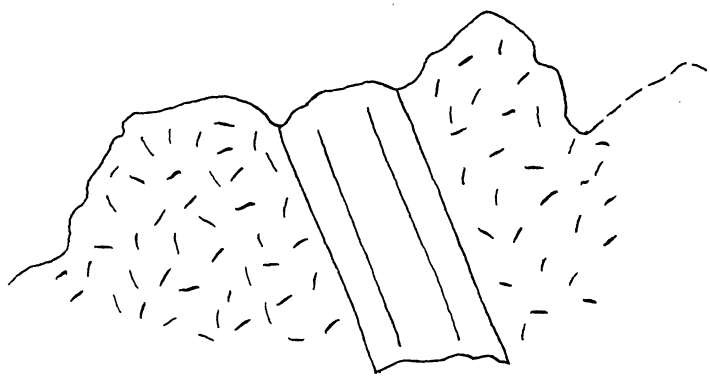


Figure 9. Relation Between Jurassic Rocks and Tertiary Intrusives.

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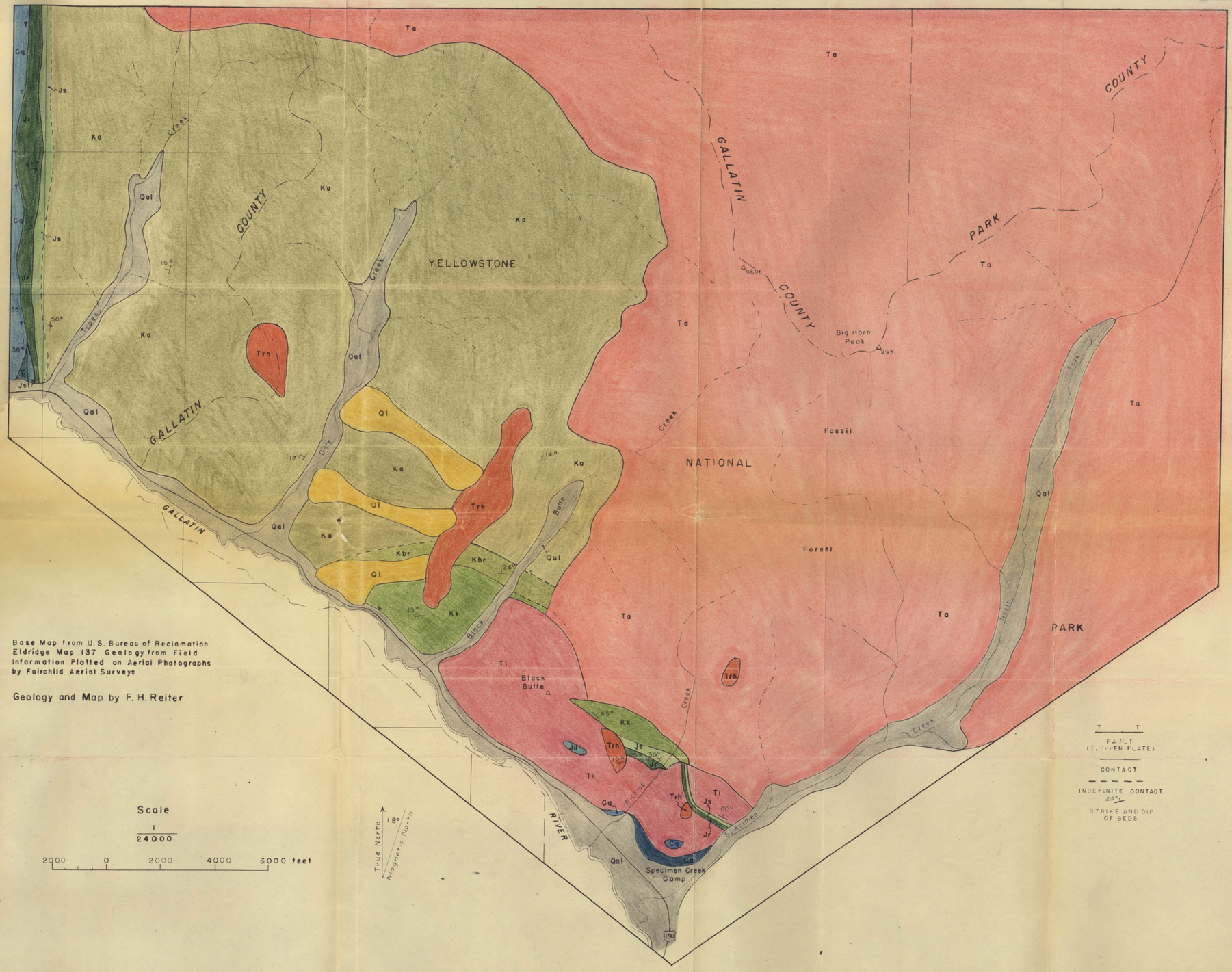
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GEOLOGY OF A PORTION OF THE GALLATIN RANGE, GALLATIN COUNTY, MONTANA



Explanation

Igneous Rocks

TERTIARY — PALEO-MIOCENE PLIOCENE

- Trh — RHYOLITE
- Ta — AGGLOMERATE
- Ti — INTRUSIVE

Sedimentary Rocks

QUATERNARY — RECENT

- Ql — LANDSLIDE
- Qal — ALLUVIUM

MESOZOIC — CRETACEOUS

- Ka — ASPEN FORMATION
- Kbr — BEAR RIVER FORMATION
- Kk — KOOTENAI FORMATION

JURASSIC

- Js — SWIFT FORMATION
- Jf — RIERDON FORMATION
- Jst — SAWTOOTH FORMATION
- Ju — UNDIFFERENIATED

PENNSYLVANIAN TRIASSIC

- R — UNDIFFERENIATED

PALEOZOIC

- Cq — QUADRANT QUARTZITE
- Ca — AMSDEN FORMATION

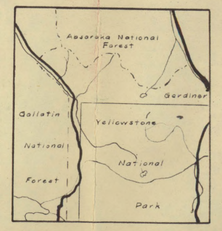


PLATE 5


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