GEOLOGY OF THE BROWNE LAKE AREA, SOUTHWESTERN MONTANA

By

Robert M. Hutchinson

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INTRODUCTION

Location and size of area

The Browne Lake area lies mainly in the northeastern corner of Beaverhead County, Montana. Its eastern corner extends into Madison and Silver Bow Counties. The area includes 140 square miles and is bounded by meridians 112° 55' and 112° 15' and parallels 45° 31' and 45° 40' (See index map, Plate 1, and Figure 1, area 5, page 2).

Accessibility

Melrose, population 300, lies in the eastern part of the area. Butte, Montana is 25 miles to the north and Dillon 30 miles to the south. U. S. Highway No. 91 and a branch line of the Oregon Short Line Railroad go through Melrose.

Previous work

Detailed geologic mapping has been carried out previously on all except the western side of the area. One hundred and forty-four square miles were mapped to the north in 1925 by Richards and Pardee for the U. S. Geological Survey (See Figure 1, page 2). Approximately 200 square miles were mapped in 1934 by Uuno M. Sahinen for the Montana Bureau of Mines and Geology (See Figure 1, area 2). At the present time, the U.S. Geological Survey is mapping just south of the Browne Lake area (See Figure 1, area 3). To the northwest the Hecla Minining district was mapped by Thor N. V. Karlstrom for the Montana Bureau of Mines and Geology in 1946 and 1947 (See Figure 1, area 4). A reconnaissance geologic map of a portion of southwestern Montana was published in June 1934 by the Montana Bureau of Mines and Geology (See Figure 1, page 2).

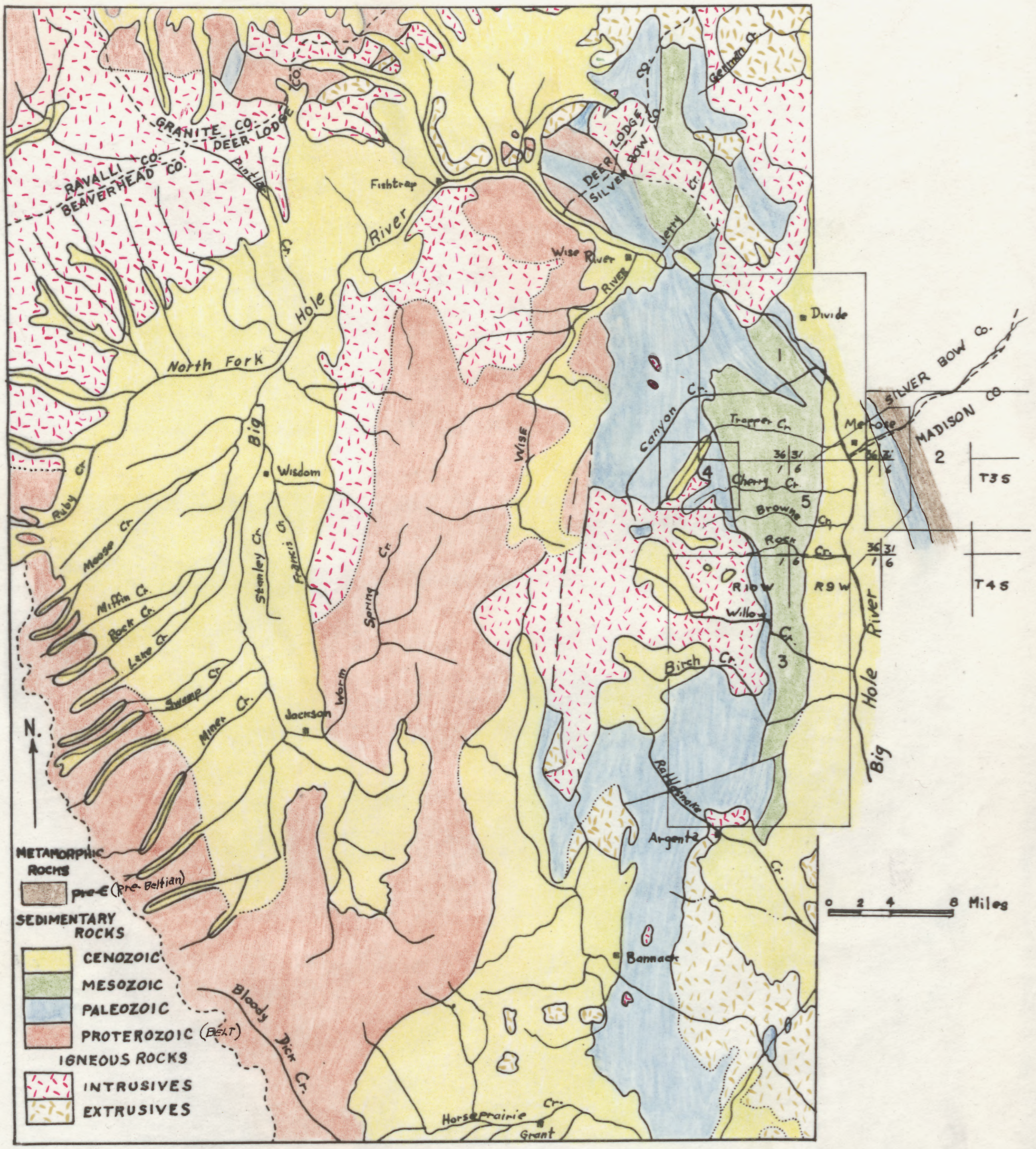


Figure 1

RECONNAISSANCE GEOLOGIC MAP OF A PORTION OF SOUTHWESTERN MONTANA

From Preliminary Geologic Map of Western Montana, Mont. Bur. of Mines and Geol., Memoir No. 12, June 1934. Area 1 was mapped by Richards and Pardee for the U.S. Geological Survey in 1925. Area 2 was mapped by Uuno M. Sahinen for the Mont. Bur. of Mines in 1934. Area 3 is now being mapped by the U.S. Geological Survey. Area 4 was mapped by Thor N. V. Karlstrom for the the Mont. Bur. of Mines in 1947. Area 5 was mapped by Robert M. Hutchinson for a master's thesis in 1947.

Purpose of work

The purpose of the field work was to obtain as complete a picture as possible of the areal geology within the Browne Lake area. Particular attention was paid to the structural and stratigraphic geology. In some places it was necessary to use structural interpretations for an understanding of the stratigraphic sequence, and in others an understanding of the stratigraphic sequence helped to solve the structure. An effort was made to map contacts of the igneous rocks with sedimentary rocks and to outline where possible the shape of the igneous bodies. Fairly complete sampling of the igneous rocks was made for future petrographic study.

Acknowledgments

All field work was done under the guidance of Prof. A. J. Eardley of the Department of Geology, University of Michigan. Prof. Eardley initiated the correspondence with Dr. Eugene S. Perry of the Montana School of Mines who kindly suggested the area. Dr. Perry also furnished the author with aneroid barometers and offered facilities of the Montana School of Mines for drafting work. Prof. Eardley visited the area to check the geological mapping, and it was through his advice and guidance that the author recognized clearly the larger structures which form part of the broader regional structure. Thor N. V. Karlstrom of the Montana Bureau of Mines and Geology spent several days with the author in the field establishing good structural and stratigraphic relationship between the adjoining areas. Dr. Helen L. Foster of the U. S. Geological Survey spent two days in the field with the author and gave advice in working with the stratigraphy of the Mesozoic rocks, and Dr. Eugene H. Walker gave much helpful advice on interpretation of physiography. Dr. Frederick S. Turneaure was interested in the contact phenomena and tungsten mineralization occurring in the western part of the area. Professor G. M. Ehlers and Dr. Erwin C. Stumm of the Department of Paleontology identified fauna from the Three Forks formation. Prof. Lewis B. Kellum endeavored to identify fauna from the Mesozoic formations, but the fossil material proved inadequate for identification. Prof. L.L. Sloss of Northwestern University and W. B. Myers of the U. S. Geological Survey kindly permitted the author to use and reproduce the stratigraphic section they measured and described through part of the Paleozoic formations exposed along Camp Creek in the eastern part of the area. Loren Wicks, senior in the Department of Geology, gave able assistance in the field.

STRATIGRAPHY

General features

The areal and structural geology of the Browne Lake area is recorded on the geologic map (Plate 1). Table I presents the stratigraphic column which begins with early Pre-Cambrian schists and ends with Recent alluvium. This sequence is interrupted by gaps in the late Pre-Cambrian, the Ordovician-Silurian, and in parts of the Mesozoic. Igneous rocks are represented by coarse-grained intrusives of Tertiary age and by Tertiary volcanics. A detailed description of the exposed rocks follows. Unless otherwise stated, all sections were measured on the north side of Camp Creek.

Pre-Cambrian rocks

According to the evidence cited by Uuno M. Sahinen (page 13), the schist which underlies the eastern part of the area is probably sedimentary in origin and is tentatively correlated with the Cherry Creek group of the Algonquin. As evidence of sedimentary origin he cites the presence of detrital zircon and two different kinds of Plagioclase found in thin section study of the schist. The prevailing rock type is a coarse-grained feldspar-biotite schist with small amounts of quartz. Garnet is abundant locally.

Cambrian system

<u>Flathead quartzite</u>. The Flathead quartzite of middle Cambrian age rests unconformably upon the underlying pre-Beltian schist. The section measured showed a thickness of 87 feet composed principally of thick-bedded massive quartzite and sandstone. Shale partings are present in a few places (See Plates 5, 6, 7 and 8).

TABLE I

Stratigraphy of the Browne Lake area

			Thickness (feet)
Quaternary			
	Recent		
		Alluvium	Unknown
		Talus	Unknown
	Pleistocene		
		Glacial deposits	Unknown
		High terrace gravels	20-200
Unconformity			
Tertiary			
	Late Miocene		
		Volcanic flows, tuffs and breccias	460
		Dikes and sills	1-10
Unconformity (?)			
Tertiary			
	Oligocene to Middle Miocene		
		"Basin beds"	0-500
Unconformity			
Cretaceous			
	Upper Cretaceous		
		Colorado group (undifferentiated)	700-1000
Unconformity (?)			700
	Lower Cretaceous		
		Kootenai formation	
Unconformity			
	Lower Triassic		
		Dinwoody formation	500
Permian			
		Phosphoria formation	100-300
Carboniferous			
	Pennsylvanian		
		Quadrant quartzite	625
	Mississippian		
		Amsden formation	75
		Madison limestone	1300
Devonian			
	Upper Devonian		
		Three Forks formation	140
		Jefferson limestone	404
Unconformity			
Cambrian			
	Upper Cambrian		
		Dry Creek formation	124
		Pilgrim dolomite	241
	Middle Cambrian		
		Park shale	161
		Meagher dolomite	635
		Wolsey shale	220
		Flathead quartzite	87
Unconformity			
Pre-Cambrian			
	Pre-Beltian		
		Feldspar mica-schist, garnetiferous	Unknown
			8012 total

Wolsey shale. Conformably overlying the Flathead quartzite is the Wolsey shale of middle Cambrian age. A section 220 feet thick was measured. The base of the formation consists mainly of thin-bedded shale ranging from light greenish-gray to silvery-purple. Some sandstone lenses are present. The middle portions are buff-colored dolomitic shale which grades sharply into the overlying magnesian limestones of the Meagher formation.

Meagher formation. The Meagher formation is middle Cambrian in age. A section of 635 feet was measured. The lower portions of the formation consist mainly of sugary textured, from buff to tannish-gray to blue-black dolomite. The upper portions are dolomitic limestone, light gray, fine-grained and laminated with alternating bands of coarser-grained dark gray dolomite. Mottled and banded zones are common.

Park shale. The Park shale is middle Cambrian in age and rests conformably upon the underlying Meagher formation. A section of 164 feet was measured. The basal portions of the formation consist of variegated, thin-bedded, colored from olive-green to lavendar chocolate-brown to greenish-gray-lavender shales grading at the top into greenish-brown shale. The formation grades sharply into the Pilgrim formation.

Pilgrim formation. The Pilgrim formation is upper Cambrian in age. The section measured is 240 feet thick. The rock is dolomite which is medium to thick-bedded, light to very light gray, finely laminated and sugary. Some indistinct color mottling is present.

Dry Creek formation. The Dry Creek formation is upper Cambrian in age and rests conformably upon the underlying Pilgrim formation. The section measured is 50 feet thick and the formation is light gray to grayish-pink dolomite. The contact between the upper tan to buff dolomite of the Dry Creek formation and the lower part of the Jefferson formation is sharp and unconformable.

Devonian system

Jefferson formation. The Jefferson formation is upper Devonian in age. The section measured on the north side of Camp Creek is 405 feet thick. The lower 79 feet of the formation is very sandy and shaly dolomite. It grades upwards gradually into a continuous series of interbedded dolomites and limestones. These beds range in color from light to dark gray to black. Textures range from fine to medium, sugary, and the beds throughout range from thin to medium-bedded, ½-inch to 18 inches in thickness. Colonial corals, crinoids, algae, and twig-like bodies are abundant. Strong mottling and finely banded beds occur throughout. Darker colored beds are strongly petroliferous. Accurate thickness of the top of the formation is uncertain because of minor folding in the section measured. Plate 21 shows typical outcrops of the Jefferson formation.

Three Forks formation. The Three Forks formation is upper Devonian in age, and as nearly as can be determined, rests conformably upon the underlying Jefferson formation. The section measured is 140 feet thick. Four lithologic units were recognized: (1) shale, sandy, orange-colored, thin-bedded; (2) limestone, argillaceous, gray-brown, thin-bedded; (3) shale, thin-bedded, fissile, greenish-gray, crammed with Devonian fossils such as brachiopods, crinoids and bryozoa; and (4) siltstone, yellowish-brown to yellow, finely laminated with inclusions of brown-weathering limestone occurring with increasing frequency near the top. Contact with the overlying Madison limestone is gradational. Plate 9 shows beds of typical lower Madison limestone.

Carboniferous system

Madison limestone. The Madison limestone is Lower Mississippian in age. The measured section is 745 feet thick. The complete thickness could not be measured because the upper part of the formation was covered by Tertiary "Basin beds" and Pleistocene terrace gravels. R.W. Richards and J. T. Pardee (page7) report a thickness of 1300 feet in the Melros Phosphate field six miles to the northwest.

In the section measured the lower 335 feet are limestone, thin-bedded, light blue-gray with thin shale partings (See Plate 9). Above this are 305 feet of medium-bedded, light blue-gray limestone with thin shale partings. Above this is 115 feet of thick-bedded, massive, light blue-gray limestone.

Amsden formation. No exposures recognizable as Amsden were found in the area. Position of the formation was mapped on the basis of stratigraphic position and topographic expression. Seventy-five feet of Amsden formation were measured eight miles to the south of Camp Creek on the east side of McCarthy Mountain by Dr. Helen L. Foster (personal communication). A section of Amsden was inspected to the north in the Melrose Phasphate field and found to compare favorably in lithology and thickness with that described by Dr. Foster. The formation in its lower portions is light blue, thin-bedded limestone, in part cherty. It grades upwards into limey and silty shales, maroon-red in the central portion and light tan to buff at top.

Pennsylvanian system

Quadrant quartzite. Immediately and apparently conformably overlying the Amsden formation are about 625 feet of siliceous beds. No section was measured but Richards and Pardee (page 7) reported 700 feet of Quadrant in the Melrose Phosphate field. Their figure includes the 75 feet of Amsden formation at the base. In the Browne Lake area, the greater part of the Quadrant is quartzite. The lower half of the formation has a decidedly pinkish to reddish tinge and the upper half contains much vitreous white quartzite (See Plate 10).

Permian system

<u>Phosphoria formation</u>. Outcrops of the Phosphoria formation are poorly exposed and true thicknesses and lithologic descriptions could not be obtained. Richards and Pardee (page 8) report 100 to 300 feet of Phosphoria formation present in the Melrose Phosphate field three miles to the north. Material found one mile north of Browne Lake and thought to be Phosphoria is a dark-colored, fine-grained rock, somewhat granular, and resembles a black thin-bedded limestone.

Triassic system

<u>Dinwoody formation</u>. Directly above the Phosphoria formation and in apparent conformity with it are about 500 feet of shale and interbedded limestone. Sections measured six miles west of Melrose on the north side of Trapper Creek are 500 feet thick. The lower 150 feet is shale, with light to dark brown weathered surfaces containing abundant Lingula. Central and upper portions of the formation contain increasing amounts of limestone, some weathering light gray-blue and some buff. The rocks are thin-bedded. Shales predominate over limestone.

Cretaceous system

<u>Kootenai formation</u>. The Kootenai formation is assigned to the Lower Cretaceous on the basis of the stratigraphic evidence

listed in Richards and Pardee (page 12). A thickness of 700 feet was measured on the west side of Storm Peak. A bed of conglomerate occurs at the base and lies unconformably upon the surface of the underlying Dinwoody formation (See Plate 11). Where exposed, the conglomerate has an average thickness of nine feet and is followed by 65 feet of quartzitic sandstone. Thin-bedded, platy to fissile, maroon and light grayish-green shales occupy the central part of the formation. These are topped by a series of medium-bedded, light gray to blue limestones.

Colorado group (undifferentiated). The Colorado group is assigned to the Upper Cretaceous on the basis of stratigraphic position. Throughout the central part of the area, a thick bed of conglomerate occurs at the base but to the east and west it grades laterally into quartzitic sandstones. A continuous sedimentary series is represented in eastern and western parts of the area. It is not known definitely yet whether an unconformity is present where the conglomerate bed occurs at the base of the Colorado group (See Plate 13). The quartzitic sandstones at the base grade upwards into limey, buff-colored sandy shales, and these are succeeded by platy, thin-bedded, black to greenish-gray shale. (See Plate 12). Sections measured indicate a minimum of 700 feet, but a thickness of at least 1000 feet is possible. Additional views of the Colorado group are shown in Plates 14, 15 and 16).

Tertiary system

"Basin beds". The Tertiary "Basin beds" have been dated as Oligocene to Miocene (Richards and Pardee, pages 14 and 15). They occupy large areas throughout the Big Hole River Valley and at the mouth of Trapper Creek and Rock Creek where they rest unconformably upon the eroded surface of the underlying Colorado formation. The "Basin beds" consist mainly of fine beds of volcanic ash, light-colored clay, sand, paper-thin shale and thin beds of fresh-water limestone. No accurate estimate of their thickness could be made, but Richards and Pardee report possibly as much as 500 feet. (R.W. Richards and J.T. Pardee, page 14). Views of the "Basin beds" are shown in Plates 17 and 18.

Quaternary system

Terrace gravels. A thin cover of surface gravels seems to occur nearly everywhere on top of the "Basin beds". These gravels were probably brought down from the mountain areas nearby to the east and west. Boulders of rock types prevalent in the area make up these gravels (See Plates 19 and 22). On the basis of their relative position and fresh appearance, they appear to be Pleistocene in age and range in thickness from 20 to 200 feet.

Glacial deposits. Moraines that mark the extent of valley glaciers cover the valley floors of upper Cherry Creek and Rock Creek. The moraine in Cherry Creek reaches an elevation of 6540 feet above sea level, and that in Rock Creek ends at 6500 feet. The morainic material is fresh in appearance and consists largely of quartz monzonite (?) boulders carried from the Pioneer Mountains eight miles to the west. The glacial deposits are Pleistocene in age.

Alluvium. Weathering of all surface materials is supplying sediment for the sands and gravels now being deposited by tributary streams flowing into the valley of the Big Hole River.

Talus. Large areas of talus are accumulating on all mountain slopes, but time was taken to map only one such area which is one-half mile northwest of the White Elephant Mine at the base of a steep cliff of igneous rock.

STRUCTURAL GEOLOGY

Paleozoic and Mesozoic rocks in the western part of the area have been compressed into a series of folds which trend northwest-southeast. A large syncline and anticline, overturned to the east, follow continuously throughout most of the western part of the area. A klippe of Quadrant quartzite occupies the northwestern part of the area and underlies approximately eight square miles. Probably, it had its origin to the west and was thrust eastward into its present position. It is underlain by rocks of Mesozoic age.

Structurally the valley occupied by the Big Hole River is a synclinorium, the lowest part of which seems to have been closely followed by the channel of the Big Hole River. The rocks which occupy the synclinorium and show at the surface are principally Mesozoic in age.

The Paleozoic rocks, where exposed in the eastern part of the area, dip fairly uniformly to the west and rest unconformably upon the underlying pre-Cambrian schist. Foliation in the schist dips 3 to 4° less steeply to the west than the overlying Flathead quartzite (See Plate 8).

Low-angle reverse faults occur in the north central part of the area a mile north of Cherry Creek, at the head of Camp Creek and in the southeastern part of the area. These faults were developed during the period of orogeny that folded the rocks and have possible dip slips of 2000, 800 and 1300 feet, respectively. High-angle to vertical faults for the most part exhibiting relatively small displacements, are numerous in rocks of Paleozoic and Mesozoic age. Plate 16 shows one of these high-angle faults.

Tertiary volcanics and "Basin beds", capped with Pleistocene terrace gravels, cover broad areas of the valley of the Big Hole River. Their structure differs little from the attitude in which they were originally deposited.

PHYSIOGRAPHY

In the Browne Lake area there are traces of three or more pediments graded to former higher base levels. Along the axis of the Big Hole River valley another pediment is now developing (See Plate 17).

The intrusion of the batholith to the west and the elevation both of it and of the rest of the region predates any landforms now in existence. Study of the physiographic forms in the Browne Lake area leads to no clues which might indicate how far erosion of the elevated land had progressed by the close of Eocene time. Fenneman mentions the possible formation of a peneplain in the Northern Rocky Mountain province at the end of Eocene time (Fenneman, N.F., page 193). Blackwelder presents an hypothesis in which he advocates a peneplane Pliocene in age (Blackwelder, E., page 410-414).

An attempt to use the pediment surfaces in the Browne Lake area to reconstruct an erosion surface that might have existed throughout southwestern Montana at the close of the Eocene epoch is subject to error because of the small size of the Browne Lake area. If the erosion surface that existed at the end of the Eocene epoch was a peneplain, and if the present Big Hole River had an ancestral river flowing upon that surface, it is difficult to depict the course of the channel followed by that river upon the surface of the peneplain. It may have been the same as it is now.

The present course of the Big Hole River may follow the course of Eocene time, but there seems to be no definite way to prove this point. It is also not known if the basin that was filled with "Basin beds" and through which the Big Hole River flows had its origin through depression of the Eocene surface in Lower Oligocene time or whether the basin is erosional in origin. In the latter case, diastrophism interrupted erosion in Lower Oligocene time to produce a closed basin.

The summary of events presented in Table II is thought to most nearly represent the sequence of events. A tentative chronology of the development of the erosion surfaces from oldest to youngest follows.

(1) Paleocene and Eocene epochs: Erosion of the highlands produced by the Laramide orogeny and development of an erosion surface the traces of which probably lie above 11,000 feet. The surface may extend down to as low as 10,000 feet.

(2) Oligocene and Miocene epochs: During the Oligocene epoch the surface was depressed locally into a dish-like basin at the edge of which a pediment developed. The remnants of this pediment are now at elevations of 8000 to 9000 feet (See Plate 4). The materials derived from the erosion of the pediment surface were deposited in the local basin as the Tertiary "Basin beds" of clay, fresh-water limestone, papery shales and beds of volcanic tuff. Increasing amounts of volcanic activity marked the close of the Miocene epoch. Figures 2, 3, 4 and 5, pages 22 and 23, depict the changes that took place.

The Eocene surface upon which the "Basin beds" were deposited is thought to have been observed just out of

TABLE II

Summary of Events

Recent to Upper Pleistocene	Deglaciation and renewed downcutting of Big Hole River to present level. Incipient development of pediment at elevation of 5200 feet.
Pleistocene to Upper Pliocene (?)	Glaciation and alluviation of valley floors. Formation of moraine.
Upper Pliocene to Middle Pliocene	Lowering of course of Big Hole River. Development of pediment graded to elevation of 5400 feet.
Middle Pliocene to Lower Pliocene	Reestablishment of axial drainage by Big Hole River through the basin. Development of a pediment surface extending from elevation of 7000 to 8000 feet.
Miocene to Oligocene	Deformation of surface in Lower Oligocene epoch and deposition of "Basin beds". Increasing amounts of volcanism in Upper Miocene. Cutting of pediment durface extending from elevation of 8000 to 9000 feet.
Paleocene to Eocene	Erosion of highlands and development of erosion surface whose remnants now probably lie above an elevation of 11,000 feet.
Lower Paleocene to Late Upper Cretaceous	Laramide folding and thrusting.
Upper Cretaceous	Uplift and deposition of basal conglomerate of the Colorado group (undifferentiated).
Lower Cretaceous	Sharp uplift of a highland to the west with trough of subsidence on the east and deposition of basal conglomerate of Kootenai formation.
Jurassic to Middle Triassic	Uplift and erosion. Was part of Cordilleran geanticline.
Triassic to Devonian	Submergence and deposition.
Silurian to Ordovician	Uplift and erosion.
Upper Cambrian to Middle Cambrian	Submergence and deposition.
Pre-Cambrian (Pre-Beltian)	Deposition, folding, uplift, metamorphism and erosion.

the area mapped, in the extreme southeast corner of the area mapped. Here the "Basin beds" seem to lie on top of a surface which is smooth and dips gently to the northwest towards Melrose, in the valley center.

At the close of the Miocene epoch the scene was one of drainage to a basin with scattered lakes.

(3) Lower to Middle Pliocene epoch: Integration of drainage with establishment or reestablishment of axial drainage through the valley. Some downcutting occurred, at present indeterminate in amount, and a pediment surface now between the elevation of 7000 and 8000 feet was developed across the "Basin beds" and volcanics. Evidence is found in high terrace gravels and benches (See Plates 19 and 22).

(4) Middle to Upper Pliocene epoch: Lowering of the course of the Big Hole River and development of a new pediment graded to a new base level of 5400 feet (See Plate 17).

(5) Upper Pliocene (?) and Pleistocene epochs: Glaciation. Alluviation of the valley floors and moraine formation.

(6) Upper Pleistocene and Recent epochs: Deglaciation and renewed downcutting of the Big Hole River to present level. Widening of the valley by meandering and incipient development of a newer pediment at 5200 feet (See Plate 17).

<u>Erosional history of Trapper Creek, Cherry Creek, Rock Creek and Camp Creek</u>. At the close of the Miocene epoch these four creeks probably existed as several of many tributary streams flowing into the basin area. Rejuvenation of the Big Hole River in Lower Pliocene time also served to rejuvenate these tributary streams. The four streams cut their way down rapidly through the soft sediments of the

"Basin beds". It seems probable the "Basin beds" were once more extensive and covered the flanks of Storm Peak and Beals Mountain to the west as well as the Paleozoic rocks to the east. The creeks were securely entrenched in the soft "Basin beds" and when they encountered the Paleozoic and Mesozoic rocks beneath they maintained their courses across the strike of the formations. Since the close of the Pliocene epoch, the streams have been able to maintain their superposed positions and now flow approximately at right angles to the strike of the beds.

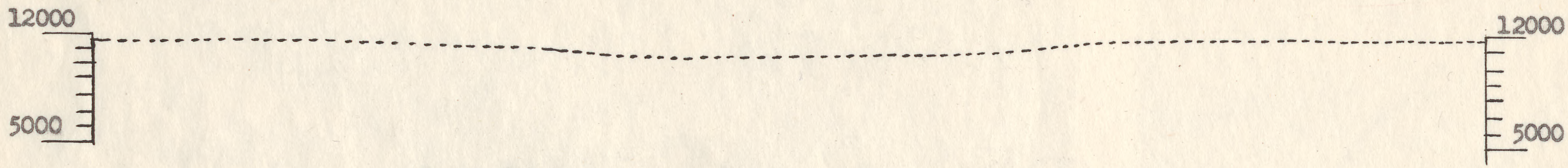
Valley glaciers occupied the headwaters of Trapper Creek, Cherry Creek and Rock Creek in the Pleistocene epoch and eroded them into U-shaped valleys (See Plate 4). Meltwater from these glaciers increased erosion of the "Basin beds" from the flanks of the valley bordering the Big Hole River and deposited gravels on top of the "Basin beds". These gravels are angular to sub-rounded cobbles and boulders derived from the rocks of the Browne Lake area (See Plates 17 and 18 which show these gravel caps from a distance).

Since the Pleistocene epoch, the superposed strems have continued to erode deeper into Paleozoic, Mesozoic and Cenozoic rocks. Streams following softer beds in the Mesozoic rocks have produced jagged surfaces on the Kootenai and Colorado formations (See Plates 14, 15 and 16). Erosion of the Tertiary "Basin beds" has produced smooth, rounded surfaces (See Plates 17 and 18).

Where streams were low in erosive power they have followed the edges of the volcanic flows (See Plate 19). In other places, such as Cherry Creek, superposition was slow enough and abrasive power high enough to maintain a channel cut down through the series of Tertiary volcanic flows. (See Plate I).

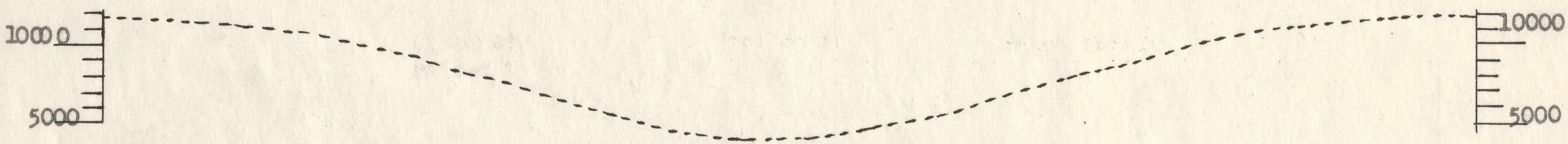
Old stream meanders and scalloped terraces are visible along many stream banks on the bottom lands of the Big Hole River valley.

Figure 2



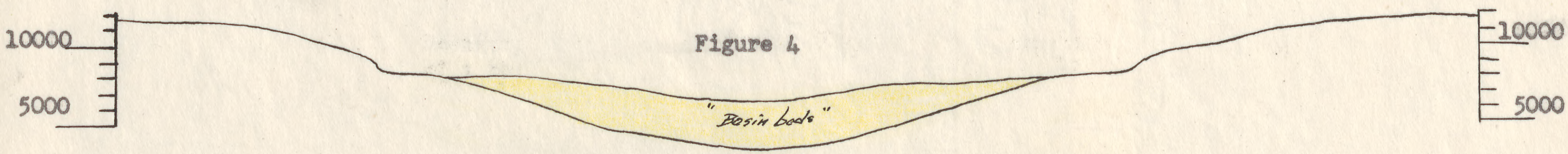
Close of Eocene epoch. Erosion surface has been uniformly raised to elevation of 11000 to 12000 feet.

Figure 3



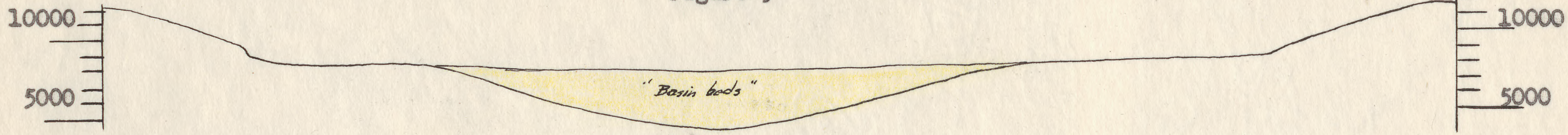
Downwarping of surface during Oligocene and formation of a basin.

Figure 4



Deposition of "Basin beds" and filling of the basin. Pediment surface eroded during Oligocene and Miocene epochs. This surface now lies at elevations 8000 to 9000 feet.

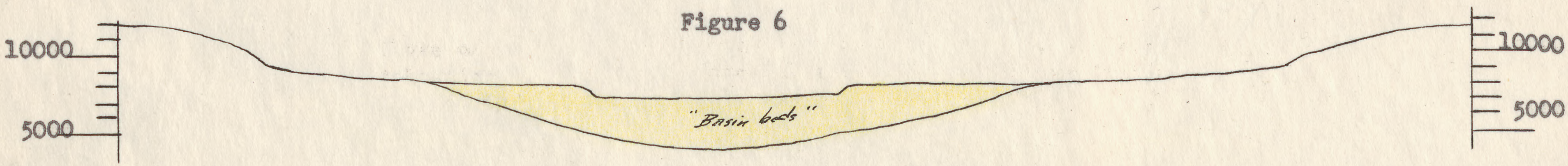
Figure 5



Upper Miocene epoch

Close of period of deposition of "Basin beds" and associated volcanics. Pediment surface fully developed and has drainage to a basin with scattered lakes.

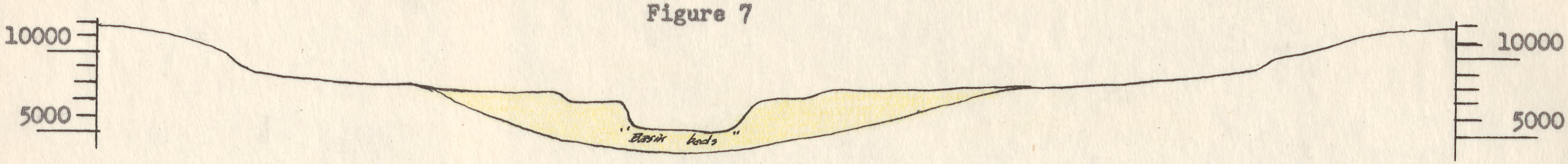
Figure 6



Lower Pliocene epoch

Integration of the drainage. Establishment or reestablishment of axial drainage through the valley. Some downcutting, at present indeterminate in amount and development of a pediment across the "Basin beds" and volcanics. This pediment surface now lies at elevations of 7000 to 8000 feet. Evidence is found in high level gravels and benches.

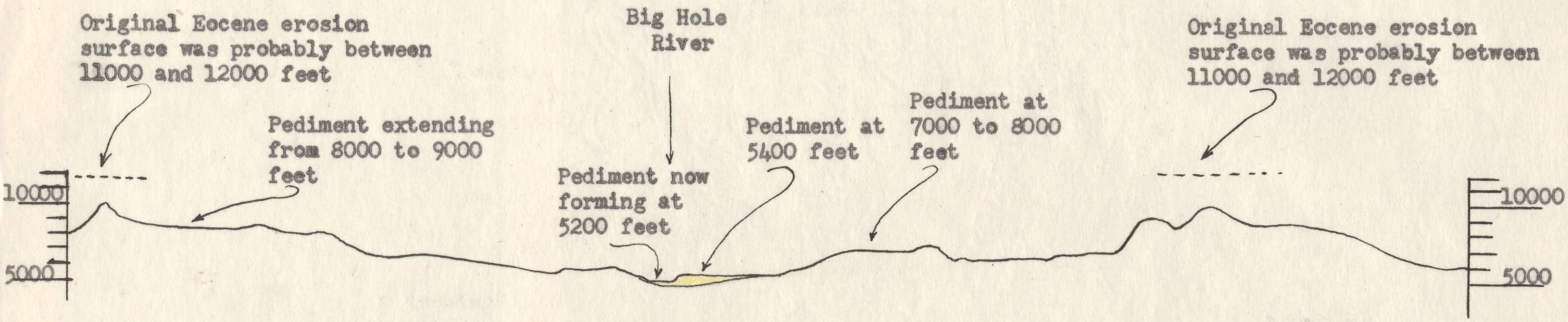
Figure 7



Upper Pliocene epoch

Lowering of course of Big Hole River. Development of new pediment graded to new base level of 5400 feet approximately. Continued regional erosion.

Figure 8



Actual topographic profile taken from Dillon Quadrangle sheet of 1893. Pediment surfaces that remain at the present time are indicated. The profile runs approximately N. 30° E. across the valley of the Big Hole River, several miles south of Melrose, looking north.

IGNEOUS ROCKS

The intrusive igneous rock in the western part of the area forms a portion of what is probably the batholith known in this region as the Boulder. Structurally the flanks of the intrusive in the western part of the area lie in concordant and discordant contact with the sediments.

To the eye, the rock is equigranular with medium texture. Parallel textures occur at the contact with the Madison formation for a distance of two to three feet into the igneous rock. In color the rock varies from light to medium gray, mottled black and white, and darker than a syenite or granite (See Plate 29).

The microscope shows the rock to be holocrystalline, hypidiomorphic-granular and medium-grained. The essential constituents of the rock are acid-plagioclase (calcic-andesine to sodic-oligoclase), orthoclase and usually two mafic minerals, biotite and green hormblende. Quartz is abundant and may make up to 30% of the rock by volume. Minor accessories are apatite, zircon, sphene, and carbonate. Microscopic analysis of eight thin sections shows the rock is a granodiorite. Specimens for the thin sections were obtained at a distance not greater than 1500 feet from the contact with the Madison formation (See Plate I).

A thickness of 460 feet of Tertiary volcanic flows and pyroclastics was measured three miles south of Melrose in the E 1/2 S. 10, T. 3S., R. 9W. (See Figure 9, page 27). The flows and pyroclastics cover an irregular area of approximately 11 square miles and may have erupted from either a series of fissures or from several unmapped local vents occurring within the area covered by the volcanics.

Cursory examination of thin sections of the volcanics shows them to be pyroxene-andesites. Richards and Pardee (page 18) describe the volcanics as andesitic in composition. Their petrographic analysis refers only to the northern tip of the flows that lies one-half mile south of Trapper Creek. Views of the volcanics and associated breccias are shown in Plates 19, 20, 27 and 28.

Narrow, more or less continuous basic dikes cut the Colorado group of sediments and the youngest of the volcanic flows (See Plates 23, 24 and 26). Andesite and latite sills have been intruded into Paleozoic and Mesozoic rocks.

A detailed geologic section of the rocks in contact with the quartz-diorite is shown in Figure 10, page 27. Megascopic examination indicates the rocks are composed of alternating bands of magnesium and lime-silicates, fine-grained hornfelsic material, and thick bands of garnet. The rocks were probably derived from the thermal metamorphism of the magnesium Madison limestone.

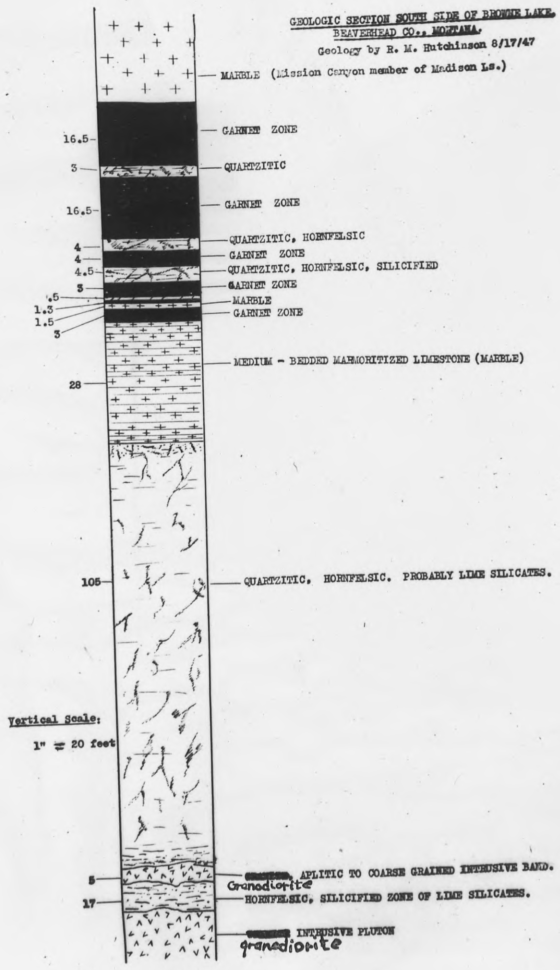


Figure 10

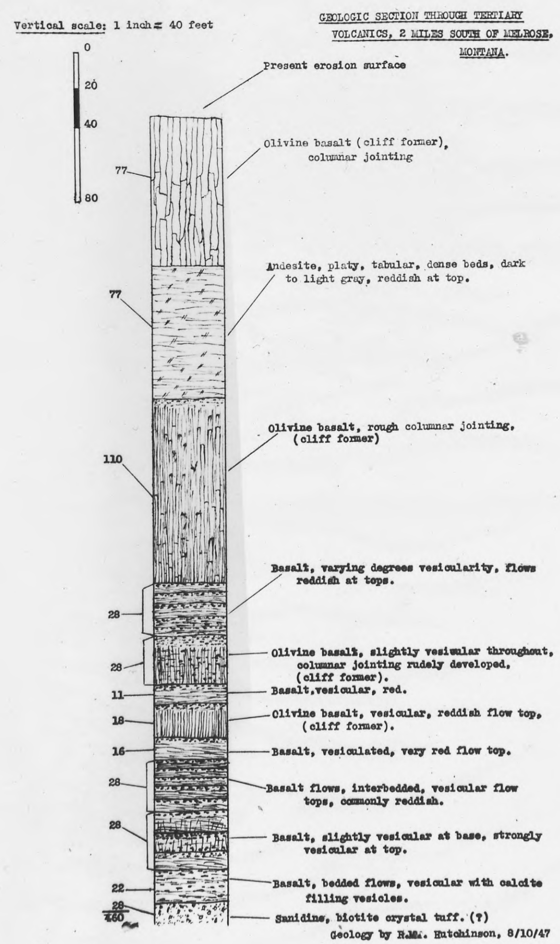


Figure 9

Plate 2

View east from Storm Peak across the Big Hole River Valley. The river flows in the axis of the valley and is eroding a series of "Basin beds" deposited in early Tertiary time.

Plate 3

Lake Agnes in the southwestern part of the Browne Lake area. Southwest view.

Plate 4

Panoramic view west from Beals Mountain looking toward the Pioneer Mountains. These mountains have been strongly glaciated by mountain glaciers in the Pleistocene epoch. Cirques and elongate U-shaped valleys were eroded and are now being filled with slides of talus. Heavy stands of yellow and white pine cover the flanks of the mountains.

In the immediate foreground are the headwaters of Cherry Creek which were glaciated by valley glaciers. These glaciers came from the Pioneer Mountains to the west.

In the middle distance is a pediment surface which extends from 8000 to 9000 feet. This surface may have been eroded during the Oligocene and Miocene epochs.

Plate 5

Massive outcrop of Flathead quartzite (Middle Cambrian in age) lying unconformably upon pre-Cambrian (pre-Beltian) feldspar-mica schist. View looking north on north side of Camp Creek.

Plate 6

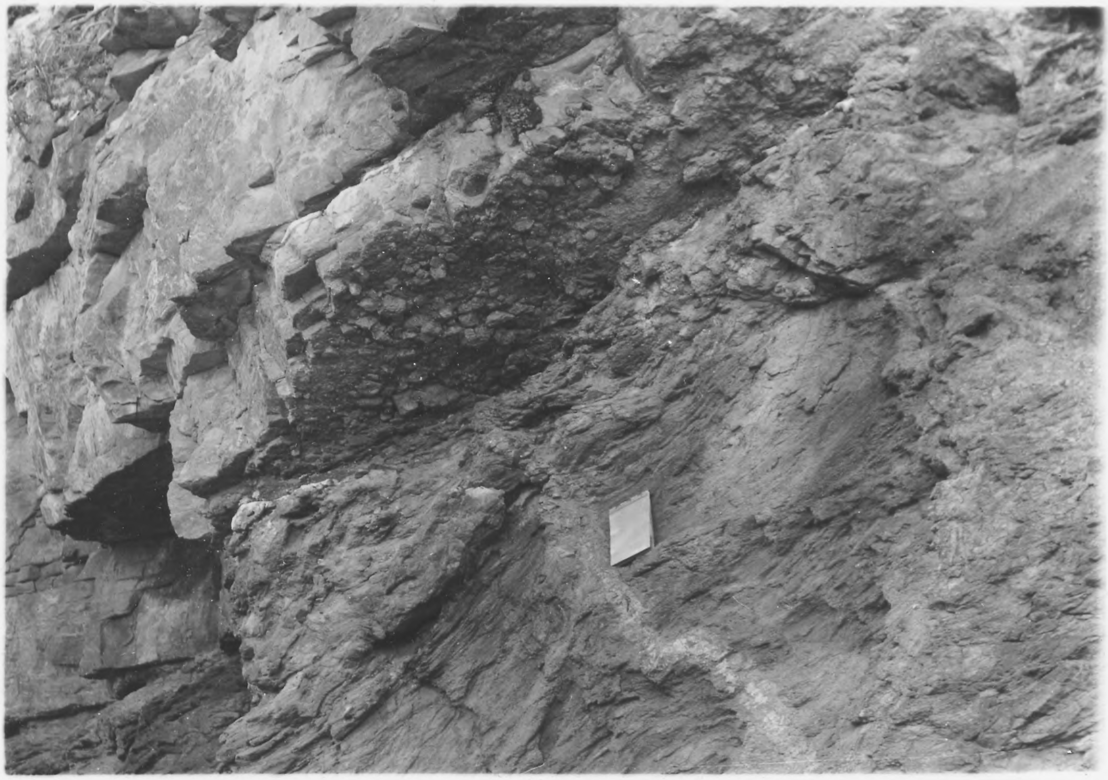
Detailed view of the unconformity shown in Plate 5.

Plate 7

Unconformity between the Flathead quartzite (Middle Cambrian in age) and the underlying pre-Cambrian (pre-Beltian) feldspar-mica schist. Cobbles of a basal conglomerate lie unconfomably upon the eroded surface of a small pegmatite dike cutting the schist. View north on north side of Camp Creek.

Plate 8

Detailed view of the unconformity between the Flathead quartzite (Middle Cambrian in age) and the underlying pre-Cambrian (pre-Beltian) feldspar-mica schist. View looking north on the north side of Camp Creek.



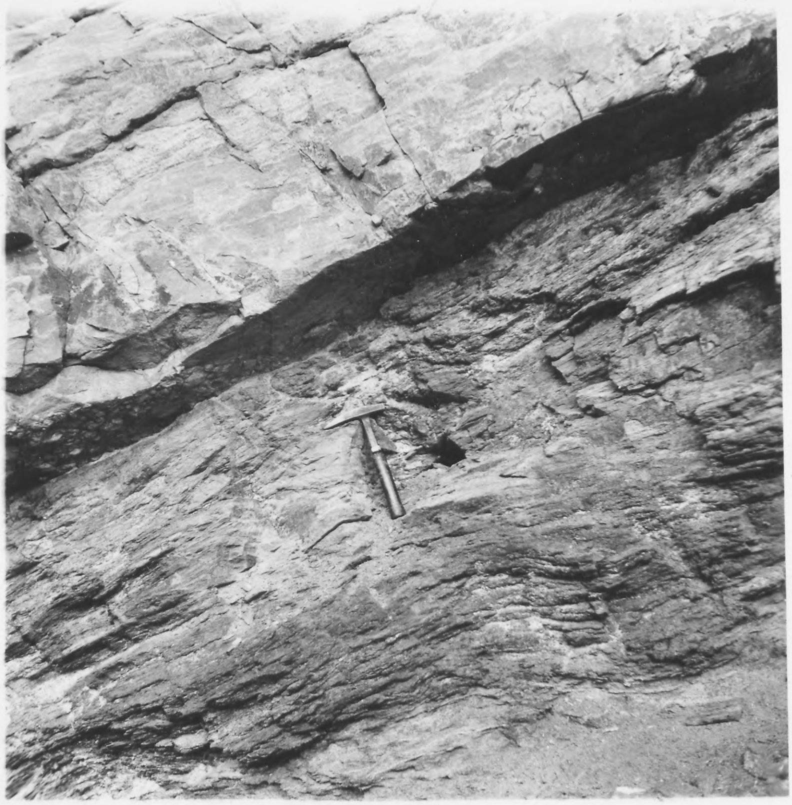
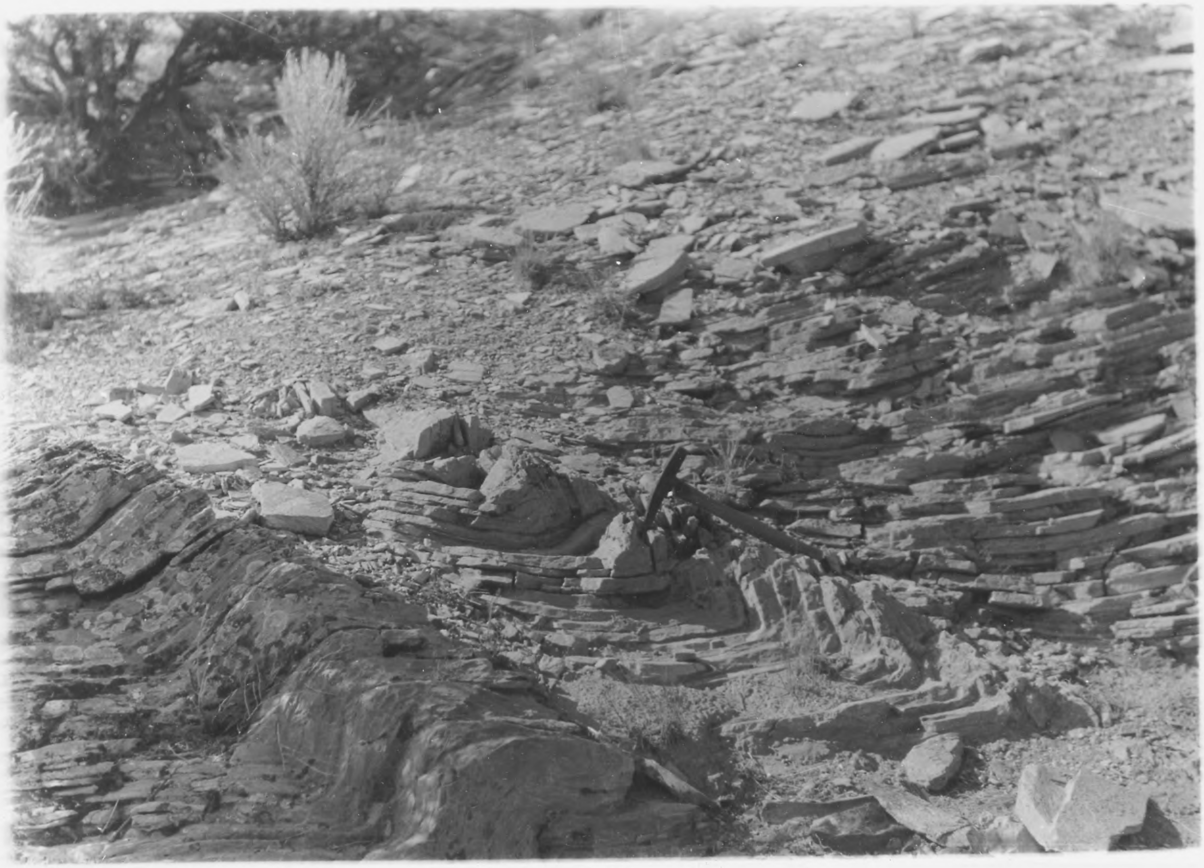


Plate 9

Minor folding developed in the lower, thin-bedded member of the Madison limestone. Photograph taken one mile north of Camp Creek looking north.

Plate 10

Outcrops of Quadrant quartzite showing their blocky character. Photograph was taken on the south slope of Beals Mountain.



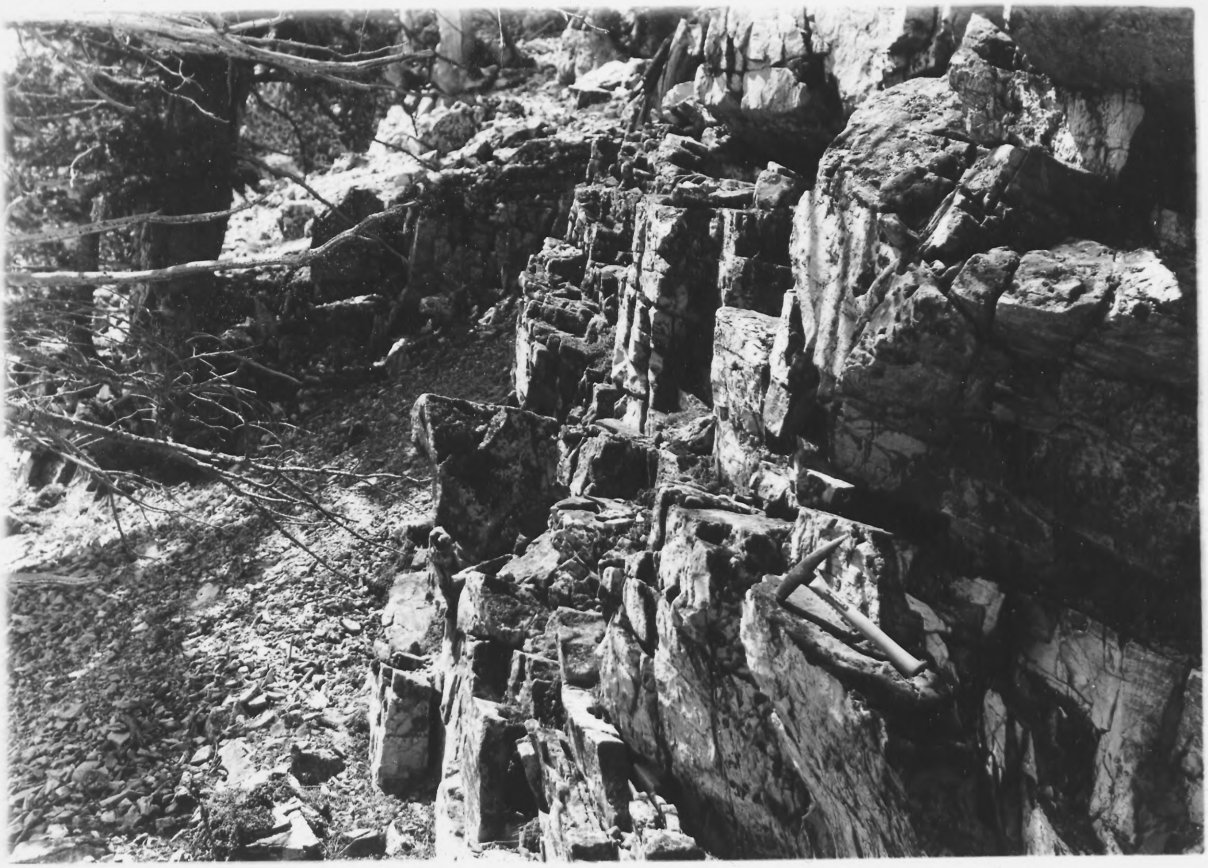


Plate 11

Unconformity between the Kootenai formation (Lower Cretaceous in age) and the underlying Dinwoody formation (Lower Triassic in age) Photograph taken on the west side of Storm Peak.

Plate 12

Outcrops of shales and sandy shales of the Colorado group (undifferentiated) two-and-a-half miles down the eastern slope of Storm Peak.

Plate 13

Conglomerate occurring at the base of the Colorado group (undifferentiated). A section measured here showed 115 feet of conglomerate. Photograph was taken looking north three miles east of Storm Peak.

Plate 14

Sharply contrasting dips in the Colorado group (undifferentiated). Steep dips shown on the right flatten out quickly to the left. The structure is the west limb of a broad synclinorium and is best shown on Plate 1, Section F-F'.

Plate 15

Folded beds of conglomerate and sandstone occurring in the lower part of the Colorado group (undifferentiated). View south across Cherry Creek.

Plate 16

A high-angle fault cutting beds of the Colorado group (undifferentiated). View taken looking north one-and-a-half miles south of Cherry Creek.

Plate 17

Terraces of Tertiary "Basin beds" along the Big Hole River Valley one-half mile east of Melrose. 0-75 feet of Pleistocene terrace gravels cover the "Basin beds"

The surface of these terraces lies at an elevation of approximately 5400 feet, and the valley floor is at approximately 5200 feet.

View was taken looking northeast.

Plate 18

Tertiary "Basin beds" capped with Pleistocene terrace gravels are in the middle distance. The surface of the terrace gravels dips two to three degrees east. Photograph was taken looking north toward Trapper Creek. In the immediate foreground are outcrops of Kootenai limestone.

Plate 19

Tertiary volcanics in places covered by patches of high terrace gravels. View was taken one-half mile south of Cherry Creek and looks south. Streams flow along the edge of the volcanic flows where they lie upon the Colorado group of rocks.

Plate 20

View looking east across the Big Hole River. Dark outcrops of Tertiary volcanics are in the foreground. Camp Creek lies in the center far foreground.


Tv
Tv
Tv
Qtg
Kc
Qtg
Kc
Tv

Plate 21

View north across Camp Creek showing typical outcrops of the Jefferson formation (Dj), the Dry Creek formation (Ꞓdc) and the Pilgrim formation (Ꞓp).

Plate 22

Close-up view of high terrace gravels shown in Plate 19. The gravels have been derived from the more resistant rocks of the Browne Lake area. A large boulder of conglomerate from the Kootenai formation is in the immediate foreground.


Єp
Єdc
Dj

Plate 23

View looking east across the Tertiary volcanics. A narrow basic dike is in the central foreground and cuts the Tertiary volcanics. This dike was traced for a distance of little over a mile.

Plate 24

A basic dike cutting Tertiary volcanics. In the distance to the right are a series of lava flows. The view was taken looking southeast, one-half mile north of Cherry Creek.

Plate 25

Tertiary volcanics two miles southwest of Melrose. The photograph shows alternating beds of volcanic tuff and breccia, interbedded in part.

Plate 26

Small-scale blocky jointing in a basic dike exposed two miles southwest of Melrose.

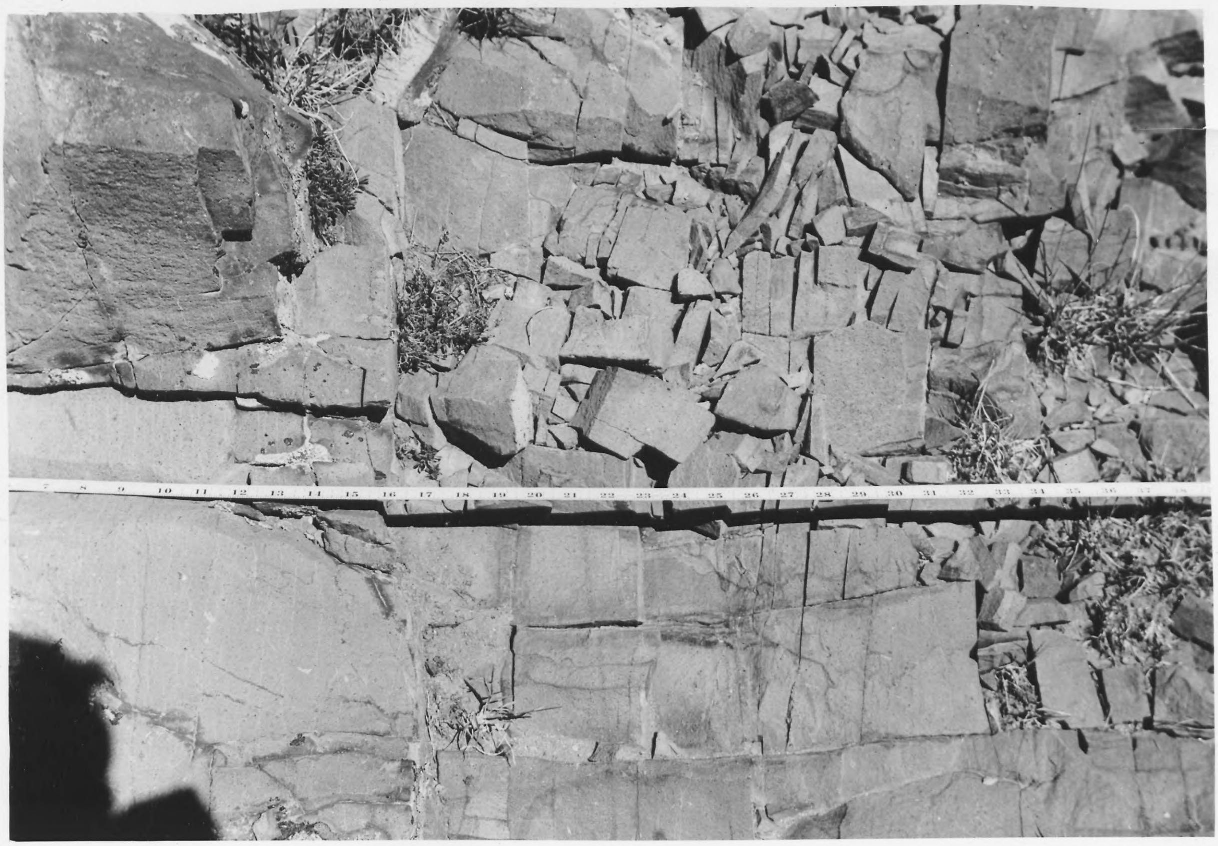


Plate 27

Close-up view of volcanic breccia shown in Plate 25. The angularity and random distribution of the fragments throughout the volcanic tuff is clearly shown.

Plate 28

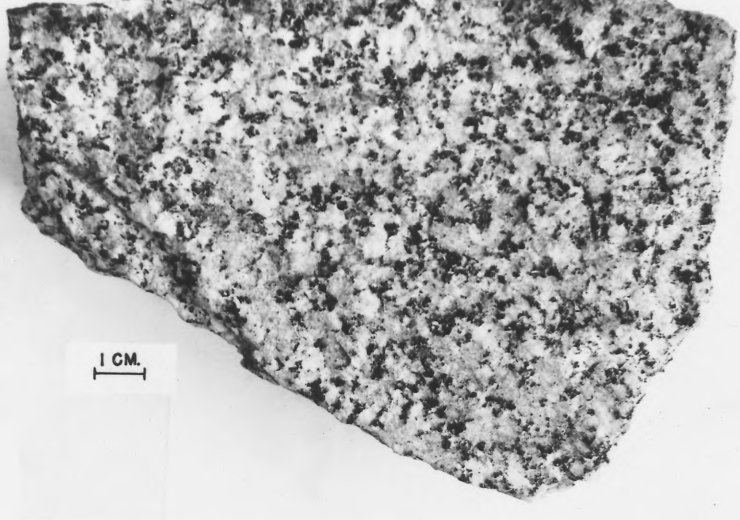
Detailed view of volcanic breccia shown in Plate 25. The angularity and random distribution of the fragments throughout the tuff matrix is clearly shown. The volcanic ash is altering to Bentonite.

Plate 29

Quartz-diorite (Tonalite) in hand specimen.

Plate 30

Quartz-diorite (Tonalite) in thin section. Crossed Nicols. Note the twinned Plagioclase, the rhomb of Sphene and the irregular areas of quartz. (X27).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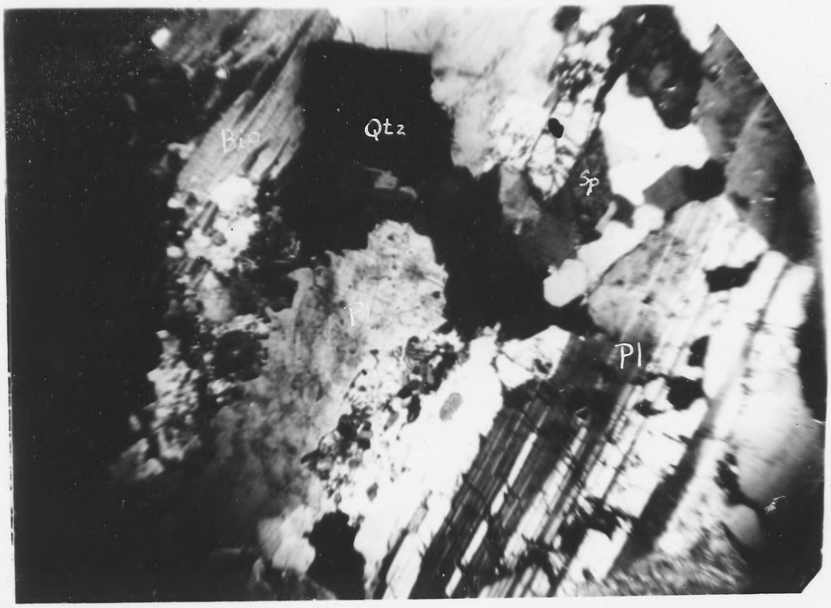
Bio
Qtz
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Pl
Pl

Plate 31

A band of garnet-rich rock overlain by Madison limestone which has been metamorphosed to a marble. The hammer rests at the contact. Scheelite occurs locally with the garnet zones and seems to have been brought in by hydrothermal solutions rich in silica.

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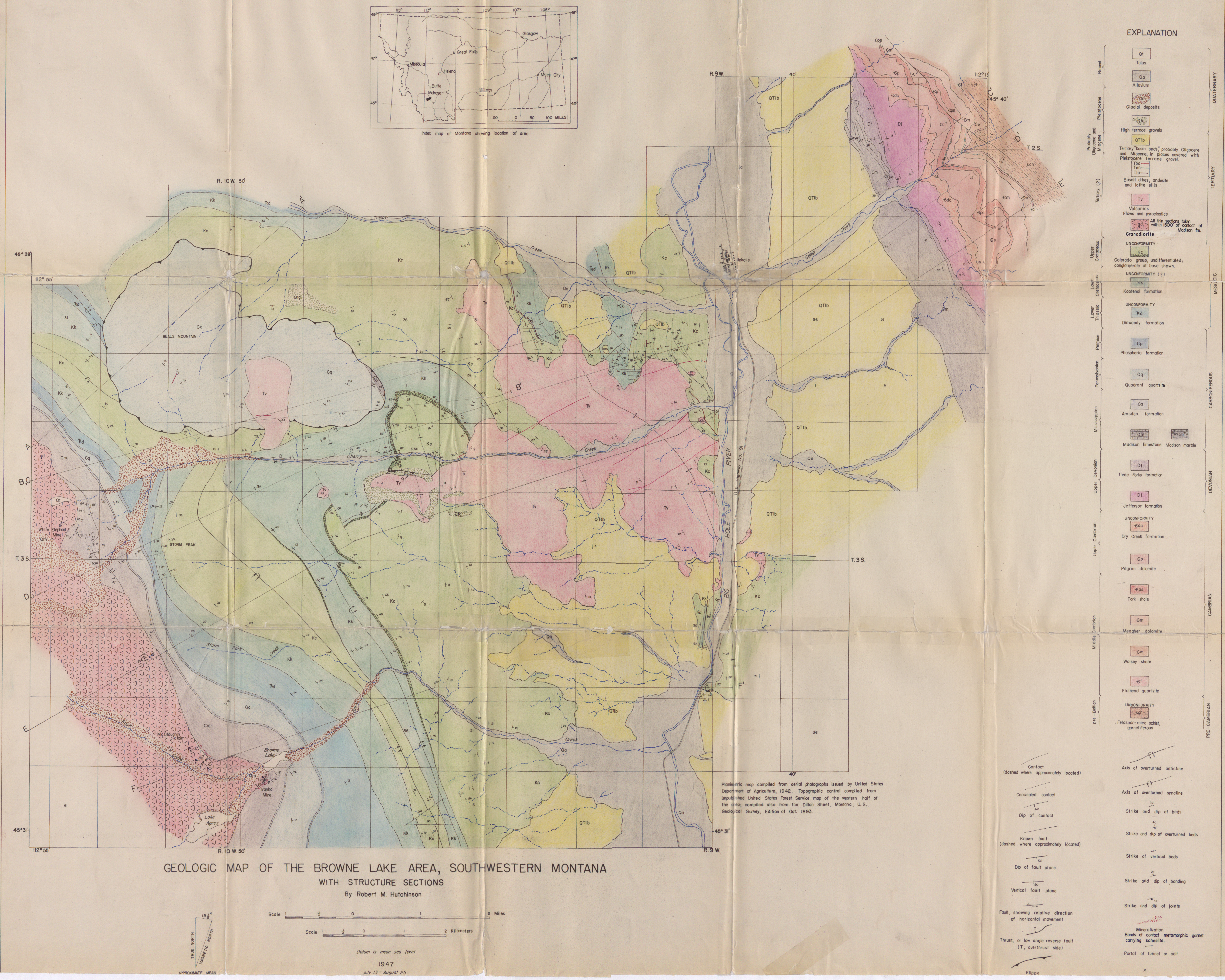
PLATE I



GEOLOGIC MAP OF THE BROWNE LAKE AREA, SOUTHWESTERN MONTANA

WITH STRUCTURE SECTIONS

By Robert M. Hutchinson

1947

July 13 – August 25

DECLINATION 1935

Axis of anticline
(Dashed where approximately located)

Axis of syncline
(Dashed where approximately located)

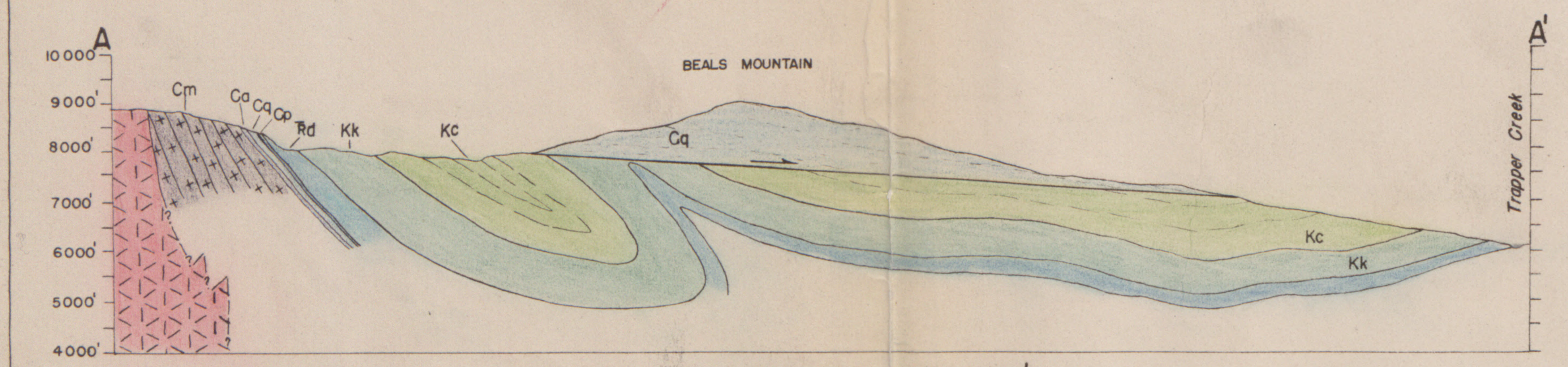
Prospect pit

Dump

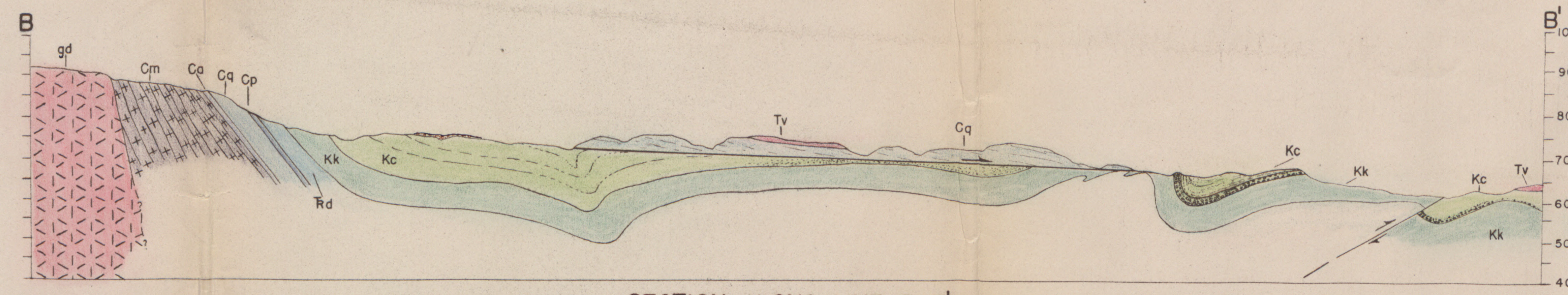
A ——— A'
Line of geologic section

Strike and dip of schistosity

Specimen taken for thin section



SECTION ALONG LINE A-A'

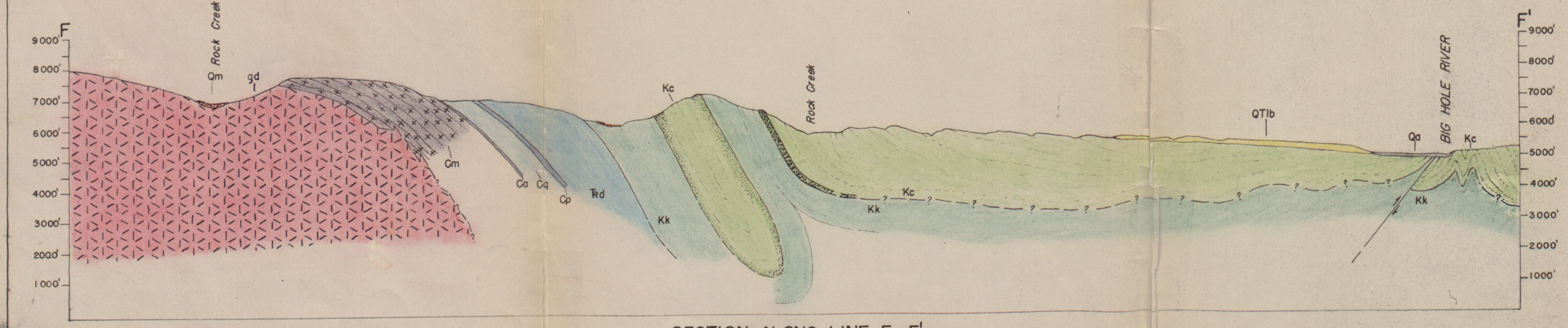


SECTION ALONG LINE B-B'

SECTION ALONG LINE C-C'

SECTION ALONG LINE D-D'

SECTION ALONG LINE E-E'



SECTION ALONG LINE F-F'