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Geology of the Lost Creek-Modesty Creek Area Deerlodge County, Montana

Howard B. Nickelson

Robert L. Pott

GEOLOGY OF THE LOST CREEK-MODESTY CREEK AREA

DEERLODGE COUNTY, MONTANA

by
HOWARD B. NICKELSON
ROBERT L. POTT

A Thesis
Submitted to the Department of Geology
in partial fulfillment of the
Requirements for the degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
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INTRODUCTION

The Lost Creek-Modesty Creek area lies in the northwest corner of Deerlodge County, Montana, in the southeastern portion of the Philipsburg Mountains. Anaconda may be seen five miles to the south. The area is bounded on the south by Lost Creek Valley, on the west by the 113th meridian, on the north by Modesty Creek Valley or the Powell County line, and on the east by the eastern slopes of Timber Gulch and a south tributary of Modesty Creek. The area mapped and studied includes 18 sections in the northern part of T.5 N., R.11 W., and in the southern part of T.6 N., R.11 W.

Geology of this portion of Montana had not been mapped previously; consequently the purpose of this thesis is to make a geological reconnaissance of the stratigraphy and structure of the area. An attempt was made to correlate the geology of the Philipsburg Quadrangle mapped by Calkins and Emmons, and also the reconnaissance survey conducted by Bergis (1946) in the Lost Creek Valley, with that of the Lost Creek-Modesty Creek area.

In 1915 the United States Geological Survey published a folio by Calkins and Emmons on the geology of the Philipsburg Quadrangle, which adjoins the area now under study to the west. The Philipsburg Quadrangle is bounded by parallels 46° and 46°30' and by meridians 113° and 113°30' and covers 827.42 square miles. Free use of their descriptions of stratigraphy, historical geology and structure has been made in this report, because this folio is the only available source of reliable information for the area.

Twelve days of field mapping were accomplished by the writers during the month of October; however further mapping was prevented in early November because of adverse weather conditions. Plane table, telescopic alidade, and stadia rod were used to map the greater portion of the area, and heavily timbered sections were mapped by the Brunton compass and pacing.

The assistance offered by Dr. E. S. Perry in the field and in the correlation is appreciated. We are indebted to Frank Miles and V. A. Stermitz for their cooperation in lending their jeeps, without which it would have been far more difficult to gain access to the rugged terrain.

GEOGRAPHY

RELIEF AND DRAINAGE

In the southeast portion of the Flint Creek range, Philipsburg Mountains, a part of the Rocky Mountain system, the relief ranges from 5,500 feet to over 9,000 feet within a few miles. Elevation in the upper parts of Lost Creek, Racetrack Creek and Modesty Creek canyons rises from 6,500 feet to 8,000 feet within one quarter of a mile, due largely to Pleistocene glaciation. Lying to the north the most rugged portion of the range is expressed in the summit of Mt. Powell (elev. 10,145 feet). Lying between lower Lost Creek and lower Modesty Creek, the broad Deerlodge Valley floor rises gently to the western foothills, which in turn rise in elevation very rapidly for several miles before they tend to level off. Then the main mountain mass rises more abruptly to develop finally into a rolling plateau.

Lost Creek, Antelope Creek, Modesty Creek and Racetrack Creek drain toward the east, emptying into the Deer Lodge River (Clark Fork on the Forestry Service map), and eventually into Columbia River. The foothills are dissected into gulches by numerous intermittent east-flowing streams. Segregating the mountains from the foothills is a stream pattern that is superimposed upon a north-south fault system. (See Plate 10.)

ACCESSIBILITY

One may easily reach the foothills of the area from Butte by traveling west on oiled Highway No. 10 and 10A to within a mile of the city limits of Anaconda, where an oiled highway from Deerlodge intersects Highway 10A. About 200 yards west of the intersection a graveled road going north joins the two oiled highways, (Refer to Plate 1) and roads leading up Lost, Antelope, Modesty, and Racetrack Creeks join this graveled road.

A good county dirt road leads up Lost Creek to the mouth of the canyon. Five miles from the Lost Creek intersection, the Timber Gulch road turns north several hundred yards below the old limestone quarry. The intersection of the Antelope Creek road and the north-south graveled road is where the Montana Power high tension lines pass over the graveled road. This road is fair for about two miles, then becomes very poor. Two miles farther up the graveled road another poor road leads into the area surveyed, and follows the steep north ridge of Spring Gulch.

The Modesty Creek road, which is well marked by the Forest Service, follows this creek, and is a fair road for two and a half miles. Several branch roads take off from this road, but they are all rather poor. The Timber Gulch, upper Antelope Creek, Spring Gulch, and upper Modesty Creek roads are all poor, and it is recommended that jeep type vehicles be used. Timber Gulch, Antelope Creek and Spring Gulch roads are interconnected in

MONTANA

Area, 147,138 sq. m.
Pop. 559,456

PRINCIPAL CITIES

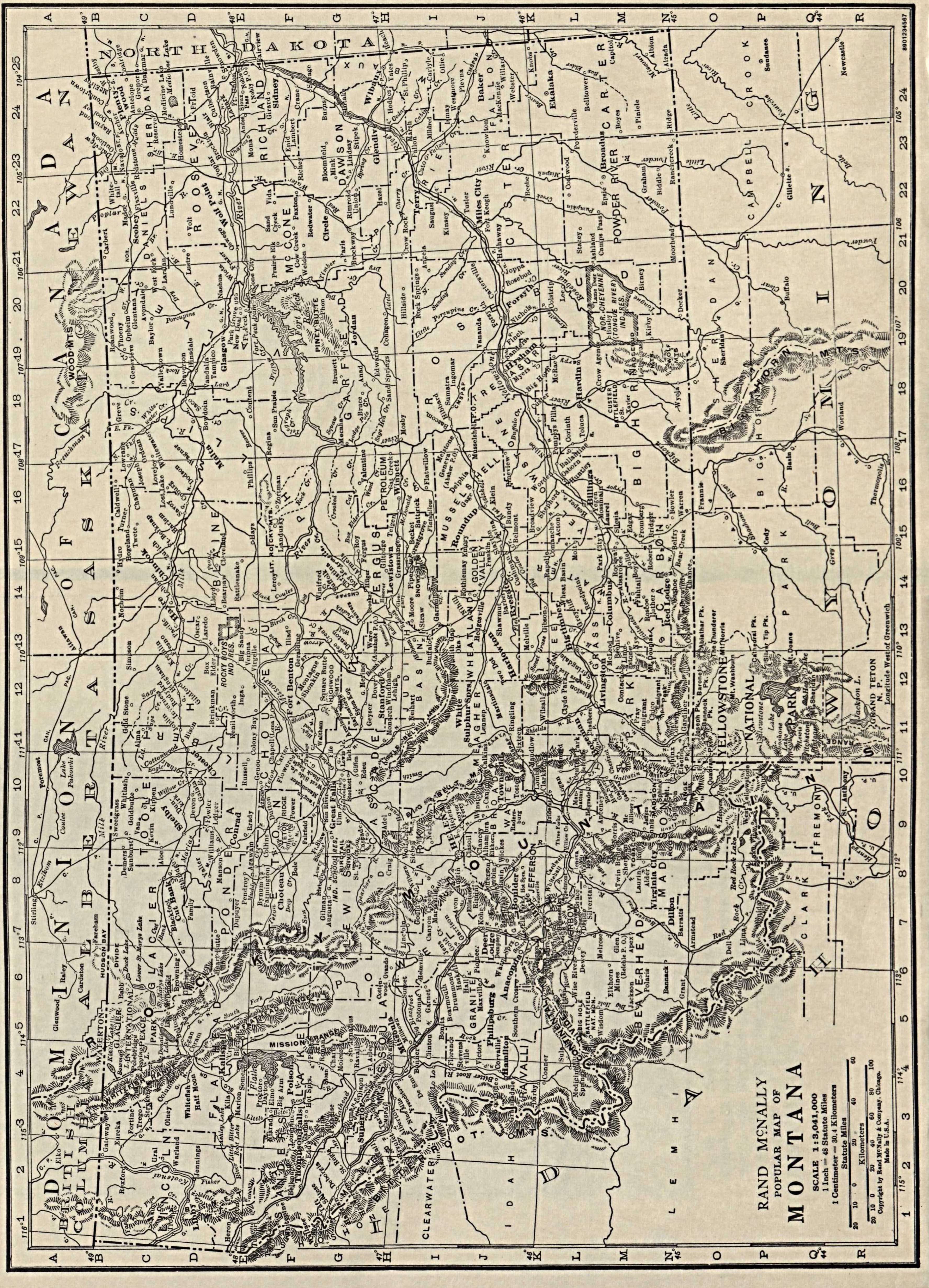
Pop.—Thousands

11 Anaconda. . K 6
1 Baker. . . . . J 25
2 Big Timber L 13
23 Billings. . . . L 16
1 Black Eagle F 10
9 Bozeman. . L 10
2 Browning. . C 6
37 Butte. . . . . . K 7
2 Chinook. . . C 14
1 Choteau . . . F 8
1 Columbus. M 14
1 Conrad. . . . E 9
3 Cut Bank. . C 8
3 Deer Lodge. J 7
3 Dillon. . . . . N 7
1 E. Helena. . . J 9
2 Forsyth. . . K 20
1 Ft. Benton F 11
4 Fort Peck. E 20
4 Glasgow. . E 19
5 Glendive. . H 24
30 Great Falls G 10
2 Hamilton. . . J 4
2 Hardin. . . . L 18
1 Harlem. . . D 15
2 Harlowton. J 13
6 Havre. . . . D 13
15 Helena. . . . . J 8
8 Kalispell. . . E 4
3 Laurel. . . . M 15
6 Lewistown H 14
2 Libby. . . . . D 1
7 Livingston M 12
2 Malta. . . . D 17
7 Miles City. J 22
18 Missoula. . . H 4
1 New Deal. D 19
1 Phillipsburg. J 5
2 Plentywood C 24
2 Polson. . . . . F 4
1 Poplar. . . . E 23
3 Red Lodge N 14
1 Ronan. . . . . G 4
3 Roundup. . J 15
1 Scobey. . . . C 22
3 Shelby. . . . . D 9
3 Sidney. . . . F 24
1 Terry. . . . . I 22
1 Townsend. . J 10
2 Walkerville K 7
2 Warmsprings J 7
3 Whitefish. . D 4
2 Wolf Point E 22

Pop.—Hundreds

4 Absarokee. M 14
3 Alberton. . . H 3
4 Arlee. . . . . . H 4
4 Augusta. . . . G 8
4 Bainville. . D 25
3 Bearcreek. N 15
6 Belgrade. . L 10
7 Belt. . . . . . G 11
2 Bigfork. . . . E 4
6 Big Sandy. E 13
8 Bridger. . . N 15
1 Broadview K 15
5 Boulder. . . . K 8
3 Brockton. . E 23
4 Cascade. . . . H 9
5 Chester. . . D 11
7 Circle. . . . . G 22
2 Clyde Park L 11
6 Columbia Falls D 4
3 Corvallis. . . J 4
3 Crow Agency L 18
6 Culbertson D 24
5 Darby. . . . . K 4
4 Denton. . . G 13
4 Dodson. . . D 16
4 Dutton. . . . E 9
7 Ekalaka. . . K 24
4 Ennis. . . . . M 9
9 Eureka. . . . . B 3
9 Fairview. . E 25
3 Frazer. . . . E 21
3 Frenchtown H 4
4 Froid. . . . . D 24
5 Fromberg. M 15
3 Geraldine. . F 13
4 Hays. . . . . E 15
2 Hingham. . D 12
2 Hobson. . . H 13
1 Homestead D 24
7 Hot Springs F 3
4 Hysham. . K 19
2 Ismay. . . . . I 24
5 Joliet. . . . . M 15
3 Joplin. . . . . D 11
2 Judith Gap I 13
4 Kevin. . . . . . C 9
6 Lima. . . . . . P 7
8 Lodge Grass M 18
6 Manhattan L 10
4 Medicine Lake. . . . C 24
2 Melstone. . . I 17
2 Moore. . . . H 13
9 Nashua. . . E 20
5 Neihart. . . . I 11
3 Opheim. . . C 20
2 Outlook. . . B 23
6 Plains. . . . . G 3
3 Plevna. . . . . J 4
4 Richey. . . . F 23
3 Ryegate. . . J 14
5 Saco. . . . . . D 18
8 St. Ignatius G 4
3 St. Regis. . . G 2
5 Sandcoulee G 10
6 Sheridan. . . M 8
5 Somers. . . . . E 4
4 Southern Cross. . . . . K 6
5 Stanford. . H 12
7 Stevensville. J 4
5 Stockett. . . G 10
7 Sunburst. . . C 9
4 Sweetgrass. . B 9
7 Thompson Falls. . . . . F 2
9 Three Forks L 9
8 Troy. . . . . . . C 1
5 Twin Bridges M 8
6 Valier. . . . . . D 8
3 Victor. . . . . . J 4
4 Westby. . . . B 25
8 Whitehall. . L 8
9 White Sulphur Springs. . . J 11
6 Wibaux. . . H 25
3 Wilsall. . . . K 11
3 Winifred. . G 14
4 Winnett. . H 16
4 Wisdom. . . . L 5

(P. I. & C. 8901)



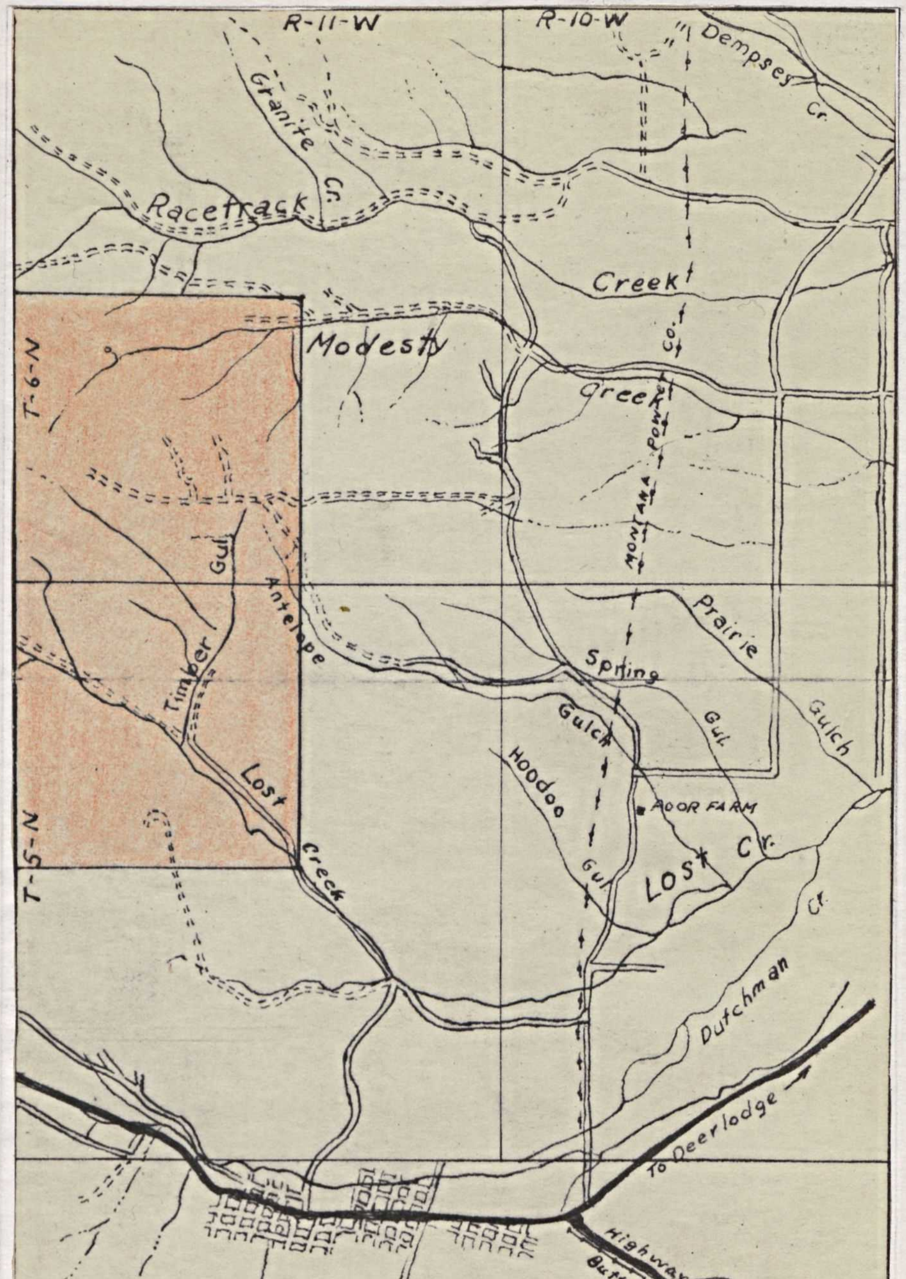


Plate 1. Sketch map of area from Anaconda to Racetrack Creek, showing the area mapped, and roads and streams of the vicinity. The colored area represents the included geologic map. Scale $\frac{1}{2}$" = 1 mile. After Deerlodge National Forest Map, 1938

the uplands. The north-south graveled road continues on to and up Racetrack Creek. Three graveled county roads take off from this road and lead to the Deerlodge Valley and Highway No. 10. These three roads intersect the north-south road respectively at one-half mile north of the Poor Farm, at Modesty Creek, and at Racetrack Creek.

CLIMATE AND VEGETATION

The region is high and semi-arid with 15 to 20 inches annual precipitation. Snow may be expected from September through May, and the temperature ranges from 90°F. to minus 40°F. The summers are warm with cool nights due to the proximity of the mountains.

The vegetation is typical of Montana uplands where timbered slopes with interspersed grassy parks and foothills covered with bunch grass prevail. The creeks are lined with willows and aspen. Vegetation in the area is well illustrated by the accompanying photographs.

East of Timber Gulch and the south tributary of Modesty Creek, the landscape is predominantly bunch grass with sparsely scattered clusters of fir, jack pine, and juniper trees. West of the tributary to Modesty Creek the survey was mostly restricted to short shots in heavy down-fallen timber. Grassy parks in the timber areas are usually underlain by limestone. Plate 2 shows the timbered and grass-covered areas west of Timber Gulch. Stands of fir and pine occupy the upper Lost Creek canyon. Progressing down the creek the conifer type vegetation gives way to willow and quaking ash which border the creek.

Small cattle ranches lie in the broader portion of Lost Creek and Antelope Creek valleys. The region is inhabited by grouse, deer, elk and their natural predators. Small trout are found in the larger creeks, namely Lost, Modesty and Racetrack Creeks.

In the foreground is Timber Gulch, and the rugged cliffs in the left background are the south canyon wall of Lost Creek. All the sediments seen in the picture are Belt except at the extreme right Cambrian strata crop out.

Plate 2. Panoramic photograph showing mountain front west of Timber Gulch and Lost Creek canyon.

Plate 2

GEOMORPHOLOGY

Differential rock erosion has sculptured the land surface of the region to its present shape. Extreme metamorphism has played an important part in the control of the relief. The indurated Beltian formations are great mountain formers, with local ridges present due to hard resistant quartzite masses; gullies and depressions are usually found along eroded faulted zones. (See Plate 2.)

The resistant Flathead quartzite covers great areas in the northwest portion of the map, and blankets the eastern tilted mountain slope. Calkins and Emmons suggest a tilted plateau that exists as an old erosion surface in this area. The resistant Meagher marble surrounded by circular bands of Wolsey shale causes local elongated east-west knolls. Fault zones have played an important role in the development of the stream drainage patterns throughout the entire area. Timber Gulch and the tributaries of Modesty Creek emphasize this condition. East of the north-south drainage the Cretaceous and Tertiary formations are not metamorphosed; they erode as large rounded hills with dendritic stream systems.

Thick deposits of early Tertiary gravels in the foothills give evidence of extreme erosion of all the upper Paleozoic and Mesozoic strata during a preceding cycle. These gravels probably existed as alluvial fans which were later carved and modified by tilting, and by periods of glaciation.

The general area shows evidence of strong glaciation. Lost Creek and Racetrack Creek in their upper parts occupy typical U-shaped canyons caused by valley glaciers. Modesty Creek does not seem to have had the intense glacial activity seen in the other two creeks, but it probably existed as a tributary to the Racetrack glacial ice stream. The Racetrack Valley

A. The creek in the foreground is the South Tributary of Modesty Creek. Beyond the V formed by the two hills in the foreground is a ridge formed by lateral moraine which divides Modesty Creek from Racetrack Creek. The ridge in the right center is Tertiary early gravels. The picture was taken in the vicinity of the thrust fault.

B. Photograph showing the thrust fault at the upper end of the south tributary of Modesty Creek. The mine dump is composed of Meagher marble, and the flat thrust fault lies just above the mine dump.

Plate 3. Photographs of the south tributary of Modesty Creek.

glacier dumped a huge terminal moraine in Deerlodge Valley, and left distinguishing lateral moraines which divide Modesty Creek and Racetrack Creek. (See Plate 3A.)

The Lost Creek Valley glacier did not leave a noticeable terminal moraine, but ground moraine and huge boulders are left in the lower valley. An ideal example of a hanging valley is apparent directly across Lost Creek Valley from Timber Gulch. (See Plate 8A.)

From Plate 8B it can be seen that the glacier in Lost Creek valley must have flowed around or stopped at a resistant mass of Quadrant quartzite which remains as a hill in the middle of the valley. The plateau region was probably affected only by a scouring action which present erosion has obliterated.

STRATIGRAPHY

The geologic formations of this district range in age from Archeozoic to Recent. Thick conformable sediments of Upper Algonkian rocks are exposed in this particular area. However, better than 30,000 feet of the lower formations of this series do not crop out, and in excess of 20,000 feet of strata were eroded off the top of the Belt. An irregular unconformity marks the contact with the Middle Cambrian. Continuous deposition took place during Middle and Upper Cambrian. Ordovician and Silurian sediments were either eroded or not laid down in this section of the Cordilleran trough. Devonian strata are absent in Lost Creek but do appear several miles to the south near Foster Creek. Mississippian and Pennsylvanian rocks are present in the area. At the top of the Pennsylvanian is an unconformity causing omission of Permian and Triassic strata. Jurassic sediments were laid down on the Pennsylvanian. An unconformity separates

SECTION OF LOST CREEK-MODESTY CREEK AREA, DEERLODGE COUNTY, MONTANA

System	Series	Formation	Symbol	Thickness	Column	Lithology
Quat.	Recent	Alluvium	Qal			Gravel and sandy wash in valley bottoms
	Pleistocene	Moraines	Qm			Valley glacial deposits
Tertiary	Miocene	Andesitic extrusive	Ta	400-500		Grey biotite-andesite flows--rounded hills
	Eocene	Early gravels	Teg	500±		Indurated gravels, well-rounded pebbles as terraces and rounded hills
Cretaceous	U.Cret.	Colorado formation	Kc	1500±		Upper part grey and olive green ss.; lower third black fissile shale. Sandstones form ridges.
	L.Cret.	Kootenai formation	Kk	1500±		Upper part calcareous shale and ss. Lower part mottled red and green shale--forms smooth slopes
Jur.		Ellis formation	Je	200		Dark calcareous sh. and olive green ss. and thin-bedded impure grey limestones--depressions
Penn.		Quadrant quartzite	Pq	200		Light-colored pure quartzite-generally forms ridges
		Amsden formation	Pa	300		Red shales and impure limestones
Miss.		Madison formation	Mm	800-1500		Non-magnesian limestone, thick-bedded; white, U. part; blue grey, M. part; weathered grey, L. part--forms ridges and cliffs
Cambrian						
		Meagher limestone	Ꞓm	350		Chiefly magnesian marble--gentle slopes with ledges
		Wolsey shale	Ꞓw	340		Banded green and brown argillite; outcrops rare
		Flathead fm	Ꞓf	170		Thick-bedded vitreous pinkish white to pale grey qtz. Forms cliffs and ledges.
Algonkian	Belt	Spokane formation	As	9000±		Metamorphosed grey, green and brown colored argillite and quartzite--appear as rounded hills
		Newland formation	Anl	4500		Chiefly metamorphosed to light to dark greyish green and chocolate calcareous lamellae of argillite and impure marbles--rounded hills and ridges.

the Jurassic and Cretaceous formations. In the time interval of late Cretaceous and early Tertiary the strata were greatly deformed by folding and faulting, and widely intruded by igneous rock. Early Tertiary indurated gravels and patches of tuff and lava overlie portions of the area. Glacial and alluvium deposits were laid down in Quaternary time.

A geologic column or section of the formations has been constructed from the work by Calkins and Emmons, with changes in the Middle Cambrian. (See Plate 4.) Further correlation studies by Dr. E. S. Perry have placed many of the old formational names used by Calkins and Emmons with the generally accepted standard section for Montana stratigraphy, as shown in Figure 1.

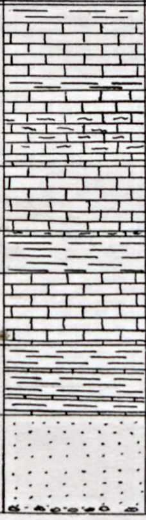
Formations of Standard Section	Section	Formations of Emmons and Calkins	Characteristics
Basal Jefferson (Devonian)		Maywood	Limy shale and limestone beds
Dry Creek Formation		Red Lion	Limestones and shales
Pilgrim Limestone			Limestone
Park Shale		Hasmark Formation	Shale
Meagher Limestone			Limestone
Wolsey Shale		Silver Hill Formation	green shale, lime beds, shale beds
Flathead quartzite		Flathead	quartzite

Fig. 1. Correlation of Emmons' and Calkins' Cambrian formation with the standard section taken from Three Forks Area

PROTEROZOIC ERA

<u>Algonkian System (Belt Series)</u>

There are no near exposures of Archeozoic sediments. The principal formations of the Belt series all appear in the Philipsburg Quadrangle;

however, only the Newland and Spokane crop out on the mapped section of this report. Below is a table of the formations comprising Upper Algonkian or Belt Series.

Beltian Formations [1, 2]

Formation	Thickness (ft.)	Outcrops in Philipsburg Quadrangle
Angular Unconformity - Cambrian-Algonkian Erosion Interval		
Missoula Group	15000*	absent
Marsh or Miller Peak	3000*	absent
Helena	4500*	absent
Spokane	9000	present and exposed in Lost Creek
Newland	4500	present and exposed in Lost Creek
Ravalli	2000	present
Prichard	5000±	present
Neihart	1000±	present

* according to Deiss

Neihart Quartzite [2]

"The exposures of the Neihart quartzite in the Philipsburg quadrangle are all in the southeastern part of the Anaconda Range. They are white to pale-grey thick-bedded medium- to coarse-grained vitreous quartzite. Its purity decreases somewhat upward, and near the top thin beds of green and grey mica schist are intercalated. The quartz grains are elongated by pressure, producing a characteristic obscure lamination. The quartzite forms high summits with some steep cliffs."

Prichard Formation [2]

"Exposures of the Prichard formation are confined to a few square miles in the Anaconda Range. The largest area comprises the lofty summits of

Mount Evans and Mount Howe, and others lie to the east and south. The formation is chiefly dark bluish-grey schists and gneisses derived from argillaceous sediments, interbedded, especially near the top and bottom, with a subordinate amount of quartzitic sandstone; deep reddish brown on weathered outcrops. It is greatly altered by contact metamorphism."

Ravalli Formation/2

"The formation occurs in a northeast-southwest zone that crosses the crest of the Anaconda Range near the central meridian of the quadrangle and, being composed of resistant rocks, it is well exposed. On the whole, however, the formation is considerably less metamorphosed than the older ones.

"The lower part of the formation is light-grey banded, thick-bedded fine-grained quartzite, somewhat sericitic; upper third light to dark grey quartzitic sandstones alternating with dark-bluish and greenish-grey shales. Contact metamorphism alters the shales to mica schist and produces knotted and gneissoid textures in the quartzites. Rugged and steep-sided ridges with heavy talus are formed."

Newland Formation/2

"The Newland formation is chiefly light-greenish to dark bluish-grey calcareous shales and impure shaly limestones containing magnesium and iron carbonates and silica and weathering yellow to buff. A little cross-bedded calcareous quartzite occurs in thin beds. The shales in the uppermost part exhibit sun cracks. The beds are altered by contact metamorphism chiefly to hard flaggy pale-green hornstone. The topography is gently rounded hills, except where affected by contact metamorphism."

Spokane Formation[2]

A nearly complete section of the Spokane is displayed in the canyon of Flint Creek between Georgetown Lake and Philipsburg Valley. The thickness here is nearly 10,000 feet, which does not include the material eroded from the formation in pre-Cambrian time. Metamorphism has altered the rocks in the Anaconda Range and the Lost Creek area. The part of the Spokane which was observed by the writers is the top member, consisting of dark green argillite with wavy bands of quartz throughout. Fine-grained, light-grey quartzite beds are present in upper Timber Gulch area. (See Plate 5B.) Other beds are green argillite with white spots of quartz scattered throughout in a leopard-skin pattern.

"In unmetamorphosed areas the formation is deep red shale and sandstone with subordinate green layers. Shale, somewhat sandy, predominates in the lower third, sandstone above. The shales are commonly ripple marked, sun-cracked and rain-pitted; the sandstones are commonly cross bedded and contain mud fragments, and some have small well rounded quartz pebbles. The formation forms gently rounded hills and high knobs and ridges."

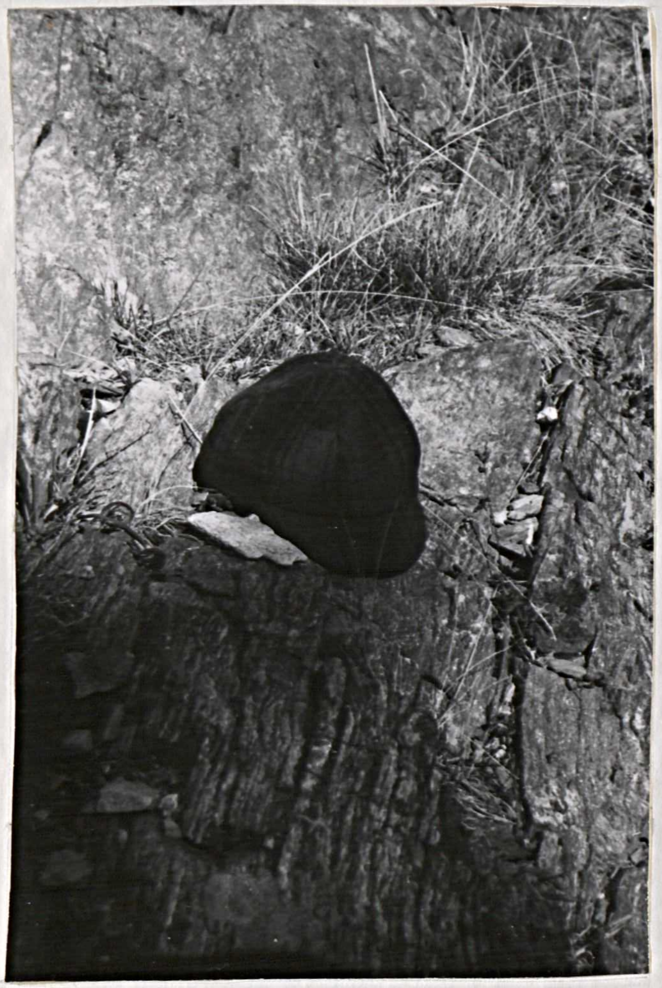
The geologic map shows Belt undifferentiated around the Flathead quartzite and these areas are probably Spokane formation; time did not permit the differentiation between the Belt series.

PALEOZOIC ERA

Cambrian Period

Flathead Quartzite

The Flathead is a resistant and unusually prominent formation consisting of white or flesh colored compact pure vitreous quartzite. At the top and bottom of the formation are grayish impure quartzites that may be confused with similar parts of the Spokane formation. Basal conglomerates



A

B

A. This photograph taken in the upper Timber Gulch area shows the banded structure in the Wolsey shale. The rock is a green argillite.

B. This photograph was taken in the upper Modesty Creek area on the south canyon wall. It illustrates the slabby nature of this formation. The area is intruded by aplite and graphic granite lit-par-lit igneous rocks, probably Spokane formation.

Plate 5. Photographs showing outcrops of Belt formation and Wolsey shale

are found in places. Observations place the thickness of the formation at about 200 feet, which is greater than the average of 100 feet for most of the state. It was deposited as the Middle Cambrian seas spread over the peneplain surface of the Beltian deposits. In most localities the Flathead crops out as ledges or as small cliffs, but on dip slopes it is covered and must be recognized by quartzitic fragments.

Wolsey Shale

According to the Calkins and Emmons terminology, this formation is a part of the Silver Hill. (See Figure 1.) It is approximately 340 feet thick, and may be divided into three members. The lower member is a dark green shale that has in places a sandstone at the base. Limestones with thin brown siliceous laminae occupy the middle member. At the top a strongly-banded brown, white and green shale is interbedded with laminated limestones. The formation was generally eroded more readily than others, and forms slight depressions around the Meagher, and it crops out where it has been intensely metamorphosed. The green coloration is due to amphiboles, and the brown to biotite./2 (See Plate 5A.)

Meagher Limestone

The Meagher limestone occurs as a hard resistant white marble which Emmons and Calkins tentatively correlated as Silver Hill, and which the writers correlate as basal Hasmark. (See Fig. 1.) In areas where metamorphism has not changed it to marble, the rocks are a white magnesium limestone whose character remains the same throughout the 350-foot bed. The surfaces weather to a gritty appearance, probably due to the difference in solubility of calcite and dolomite.

Park Shale

Calkins and Emmons tentatively call this formation the top member of the Silver Hill formation; however, it appears to correspond to the middle member of the Hasmark. (See Fig. 1.) It was not observed in the mapped area.

It is a dark-green to brown shale very similar to the Wolsey shale, with a maximum thickness of 100 feet.[2]

Pilgrim Limestone

The Pilgrim is a cream-white 550-foot formation of magnesium limestone which ordinarily forms cliffs and blocky talus. Emmons and Calkins tentatively place it at the base of the Hasmark formation; however, the writers believe it is the top member of the Hasmark. (See Fig. 1.) It was not found in the mapped area.

Dry Creek Formation[2]

The Dry Creek correlates with the Red Lion formation and is the uppermost formation of the Cambrian Era. (See Fig. 1.) This 280-foot formation does not occur in the mapped area. The formation is chiefly limestone with thin wavy siliceous laminae, reddish purple in color. At the base the thin-bedded magnesium limestones are interstratified with black to olive green shales. Outcrops are prominent.

<u>Devonian Period</u>[2]

Jefferson Limestone

The member which Emmons and Calkins call the Maywood formation of Silurian age is probably the basal member of the Jefferson limestone of the Devonian period. This 250-foot member consists of yellow-stained, thin-bedded grey, light green to purple or red magnesium limestones and calcareous shales. The Jefferson limestone is pale grey to dull black, thick bedded, and somewhat magnesian. This 1250± foot mass of limestone forms steep slopes with prominent outcrops in some places, and does not occur in the mapped area.

Mississippian Period

Madison Limestone

Three members compose the Madison formation, which is about 1000_ feet thick in the quadrangle. The lower member is a dark flaggy limestone with some interbedded black shales. Dark thick limestone beds containing chert comprise the middle part. Bold outcrops of the white thick massive upper strata form ridges and large cliffs.[2]

The pure non-magnesian limestone of the upper portion was probably the only member observed by the writers, and it was recrystallized to a dense white marble by metamorphism which also destroyed the fossil content. Contact metamorphism by igneous intrusion locally discolored the marble to shades of brown and white. (See Plate 8A, B.)

Pennsylvanian Period

Amsden Formation

Since the Emmons and Calkins survey of 1916 the red shales and limestones below the Quadrant quartzite have been named the Amsden formation. Controversy still exists as to whether the Amsden is Upper Mississippian or Lower Pennsylvanian, but it is usually placed in Pennsylvanian. The writers included the Amsden in the Quadrant formation but mapped the quartzite separate from the shale and limestones, as illustrated on Plate 10. In order to differentiate the Amsden from the Quadrant quartzite the symbol Pa is used for the Amsden formation.

The Amsden, which is approximately 300 feet thick, is composed chiefly of magnesian limestones and shales. The upper limestone portion crops out in the Timber Gulch area; the lower members are missing due to a fault. The shale weathers to a deep brick red with round pale green spots as if it had been spattered with paint. The shales grade into flaggy, impure magnesian limestone ranging in color from dull red to white.

Quadrant Quartzite

The Quadrant quartzite is a pure thick-bedded quartzite about 200 feet thick and resembles the Flathead quartzite. The quartzite matrix is grey with darker grey angular fragments throughout. It forms cliffs with large blocky talus. (See Plate 8A.)

Permian Period

Phosphoria Formation

Emmons and Calkins report small outcrops near Philipsburg that show a yellow, iron-stained cherty rock interstratified with beds of phosphate rock with oolitic texture. They did not attempt to put this formation in the Permian Period as the Phosphoria, but lumped it in at the top of the Quadrant. Farther north near Hall extensive exposures of the Phosphoria have been mined for phosphate rock. The Phosphoria formation was not observed on the small exposure on the east ridge of Timber Gulch where the Quadrant is present. It is possible that the period of erosion following the Phosphoria time eroded the Phosphoria from the area studied.

MESOZOIC ERA

Jurassic Period

Ellis Formation

No Triassic is to be found in this part of Montana, and therefore the Ellis formation of Jurassic age rests disconformably on Paleozoic strata.

The Ellis consists of about 400 feet of rusty-weathering shale, sandstone, conglomerate and limestone containing Jurassic fossils. The lower member consists of a soft shale lying on the top of the Quadrant quartzite in the exposure seen on the east ridge of Timber Gulch. No fossils were found anywhere in the formation. Sandstones and shales predominate, and the sandstones form small ledges.

Cretaceous Period

Kootenai Formation

The base of the formation is characterized by reddish brown, rather coarse sandstone which grades into shales, limy shales and thin-bedded limestones. Emmons and Calkins call the base a mottled red and green shale; however this bed was included in the Ellis formation in mapping. The sandstone probably correlates with the black and white basal sandstone in South Boulder region, and in the central part of the state. Shale beds in the middle of the formation are buff grey and rusty color and grade into limy shales. The upper thin-bedded limestones are interbedded with shale and sandstones, and occur as small black ledges which weather to a dark grey due to minute veinlets of calcite passing through the black matrix.

The gastropod limestone was not observed, but it must be in the area because it is present on lower Lost Creek.[3] The top of the Kootenai was placed above a thin sandstone bed overlying the limestone beds. No fossils were found.

The formation, about 1500 feet thick, occupies rolling rounded hills with a few small ledges caused by the more resistant beds. Locally the sandstone forms cliffs and ledges where it has been metamorphosed.

Colorado Formation

At the base of the Colorado is a black, fissile shale which is about 500 feet thick. It is so black some early prospector thought coal must be present as indicated by several fairly large dumps up Timber Gulch. Sandy layers lie on top of the black shale. The upper portion, generally flaggy with pebbles near the base, is in part grey and olive-green sandstone, interbedded with dark blue-grey to light-grey-green shales, largely sandy. Approximately 1500 feet of Colorado forms smooth slopes and depressions with knobs and ridges of sandstone.

CENOZOIC ERA

Tertiary Period

Sediments of Tertiary period are characterized by great thicknesses of red gravels which were derived from pre-Cambrian, Paleozoic and Mesozoic strata eroded from the mountains to the west which were developed at or shortly before the beginning of the period. Lake deposits lie in the larger valleys, and thick beds of andesites, rhyolites, tuffs and breccias are found along lower Lost Creek, along Antelope Creek, and in the vicinity of Anaconda.

Early Tertiary Gravels

East of the region mapped the gravels occupy large areas, and occur as rounded, grass-covered hills. Except near the upper part of the beds the gravels are consolidated, and they may form small cliffs with a talus of pebbles sliding down the steep slopes, especially in the Modesty Creek area. The predominant pebbles are quartzite with some limestone and shale, but one could probably pick out pebbles representing all formations from the pre-Cambrian upward. Cementing material is largely calcium carbonate, perhaps in part derived from the many pebbles of limestone. The pebbles are mainly rounded but in part angular, and the size ranges from fine sand to three inches in diameter. In general the color is brick red, but it grades into lighter shades of red and yellow to grey. Bands of red clay material exposed in several prospect holes were noticed close to the road in upper Antelope Gulch. An estimated thickness of over 1000 feet of these gravels was observed in the Modesty Creek area. The great thick beds seem to resist erosion quite well, probably due to the ability of water to seep into the gravels instead of running off as in consolidated rocks.

Tertiary Igneous Rocks

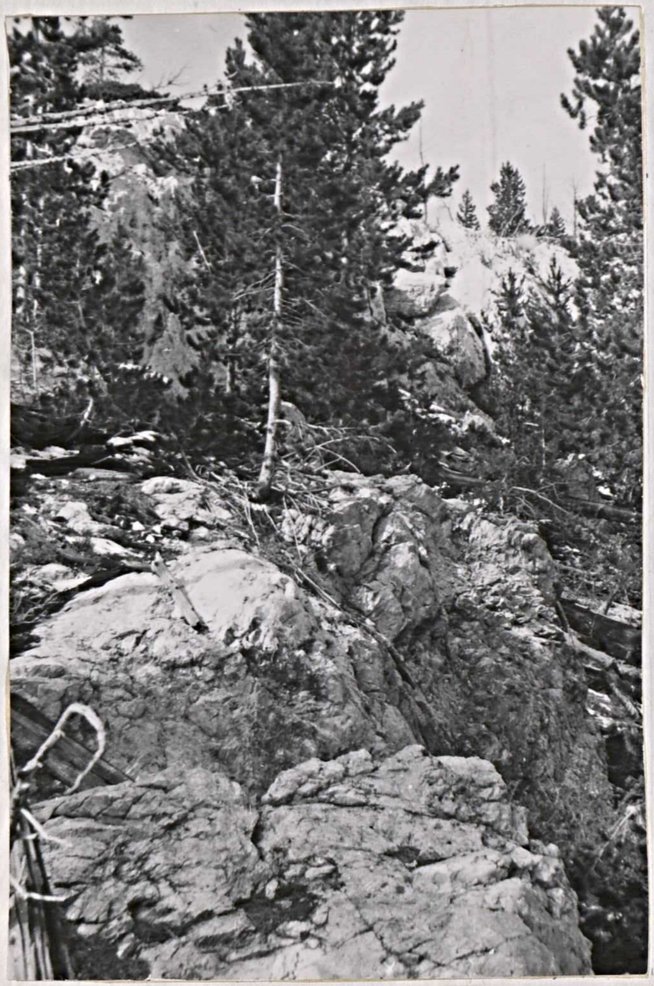
Biotite Granite. The granite that occupies Lower Lost Creek Canyon and the region on to the west is composed chiefly of orthoclase, albite, quartz, biotite and locally some fluorite. Where it is least weathered the rock is whitish in appearance; however, in most places weathering has stained it a light yellowish brown. Exfoliation has occurred in the more exposed areas. Textures range from moderately coarse to fine grained. Quartz is smoky to brownish black in color, whereas the feldspars are yellowish white to cream white. Biotite ranges from about 10 to 15 percent composition. Feldspars compose 65 to 70 percent with quartz making up about 20 percent.

Basic Sill. A diabase in the Spokane formation is present as a sill that extends on westward in the Philipsburg quadrangle for at least fifteen miles. It is cut off by the biotite granite on the south side of Lost Creek canyon and is probably much earlier than the granite.

Diorite. The northeast quarter of section 27 shows a small outcrop of acidic diorite, which is undoubtedly of the same origin as the acidic diorite described by Emmons in the area south of Racetrack Creek. It is darker than the diorite just mentioned, possibly due to its contact with the Meagher which makes it richer in mafic constituents. Evidence in the folio indicates it was intruded as the basic sill at an earlier age than Tertiary. It is a fine-grained tonalite or quartz diorite that approaches a granodiorite. A megascopic examination of a "salt and pepper" looking specimen shows the following approximate percentages: plagioclase 45%, orthoclase 15%, mafic mineral (hornblende and biotite) 30%, and quartz about 10%.

<u>Pegmatites</u>. In sections 28 and 27 a large number of pegmatites crop out in the Cambrian and Beltian formations. The largest, a quartz pegmatite, is exposed in the south-central part of section 28. It is about 1400 feet long and 400 feet wide, and its exposure is shaped like a boot. A thin outer zone of graphic granite was indicated by several pieces of float picked up on the north side. Apparently this outer zone does not border very much of the pegmatite. Approximately 95% of the pegmatite is vitreous white, buff, and rose quartz. Specimens, picked up on the dump of a small adit which entered the base of the quartz cliff, contained large weathered crystals of feldspar with other weathered unidentified minerals. The area surrounding the pegmatite is highly metamorphosed by contact action, especially at the contact with the Wolsey shale. Several small prospect pits were dug in the contact zone. This pegmatite probably could be used as a source of high grade silica. (See Plate 6A, B.)

On the east ridge of a tributary to upper Modesty Creek, numerous graphic granite pegmatites crop out. They are all rather small, the largest being about 200 feet long and 40 feet wide. (See Plate 7A.) Graphic granite and other pegmatite float may be picked up almost anywhere in these two sections. The pegmatite found at the center of the north section line is predominantly graphic granite. North of this pegmatite lit-par-lit injection occurs within Belt strata. (See Plate 7B.)



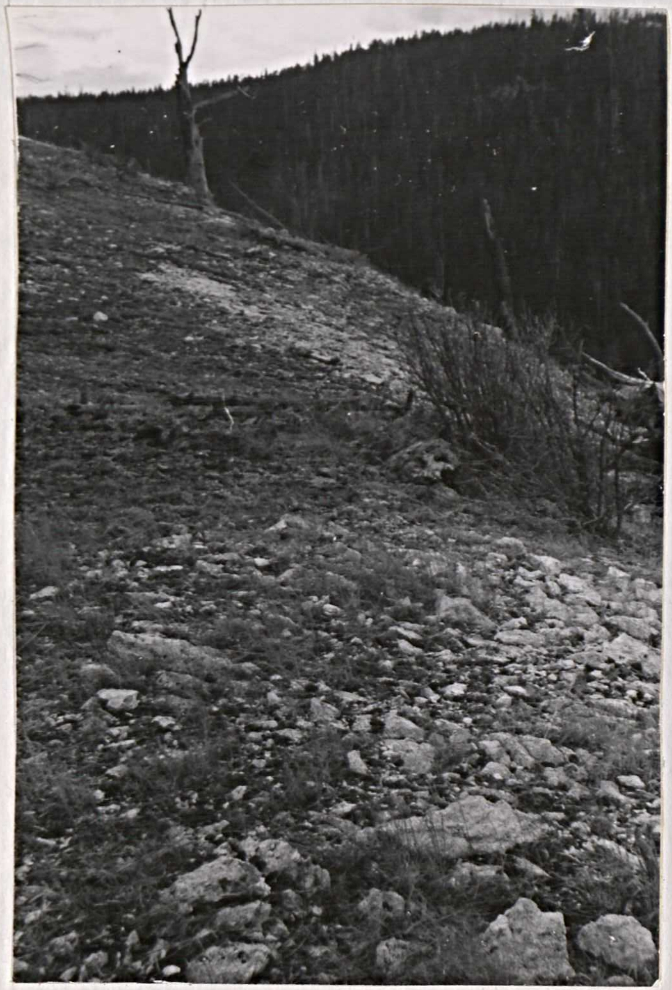
A

B

A. Outcrop of quartz pegmatite at the western end

B. Outcrop of quartz pegmatite at the eastern end

Plate 6. Photographs of the large quartz pegmatite, Modesty Creek area



A

B

A. Three small pegmatites outcropping through the Wolsey shale on the ridge between the two south tributaries of Modesty Creek

B. Lit-par-lit injection of graphic granite in the Belt, probably Spokane, located on upper Modesty Creek, on south canyon wall

Plate 7. Photograph of pegmatites and lit-par-lit injections in Modesty Creek area

Acidic diorite crops out in the region of Thornton Creek, one mile north of section 20, and a small outcrop occurs in the NE$\frac{1}{4}$, section 27. The question arises, Could the parent magma of these acidic pegmatites be the acidic diorite batholith?

Andesite. Patches of andesite are found in section 34. These beds comprise most of the outcrop area from sections eastward over the foothills forming the western extremity of Deerlodge Valley. In reality the rock is probably misnamed, and more likely is a rhyolite. It has a medium- to fine-grained matrix. Colors range from light grey to olive green and to dark red. About 15 to 20 percent of the rock is composed of quartz, and biotite is present in widely scattered specks. The quartz crystals average 1 mm. in size, but range from 0.5 to 3 mm., as also does the biotite.

Quaternary Period

Evidence of Pleistocene glaciation is manifest in lateral and ground moraines in the larger valleys, and alluvial deposits present themselves wherever erosional forces have been active. (See section on Geomorphology.)

HISTORICAL GEOLOGY

BELT SERIES

The picture in broad outline of the extensive basin in which the Beltian sediments were deposited in Montana, and of the then existing land areas, is one of an inland sea, perhaps with estuaries, separated by low land masses extending westward from the Archean positive element, "Laurentia".

The land masses, which were composed of Archean granites, gneisses and schists, were scattered throughout an area now extending from Yellowstone Park on the south to beyond the Highwood Mountains near Great Falls. It was the erosion of these lands which for the most part produced the Beltian sediments in central Montana, and the thinning of Beltian rocks against the irregular shore lines which complicated the stratigraphic problems. The axis of the Beltian geosyncline in Montana probably lay to the west of Helena. Whether marine or fresh, these waters in western Montana received the erosion products from the lands to the east, possibly even from the western part of Laurentia. They also received sands and muds eroded from the eastern part of Cascadia. All known evidence indicates that deposition continued uninterrupted until an aggregate of 50,000 feet or more of clastic sediments and impure limestones had accumulated in the central part of the trough.

Beltian sediments in the area mapped occupy a position close to the geosynclinal axis. Shortly after the succession of Beltian deposition, but long before the invasion of Montana by the Middle Cambrian seas, the Beltian strata were subjected to orogenic forces which tilted them as much as 30° in the Philipsburg Quadrangle, and elevated them to more than 20,000 feet in the area of the eastern side of the Big Belt Mountains. /1 Everywhere in the affected area the strata were thrown in gentle folds, but no examples are known of Beltian rocks that were closely folded and faulted in pre-Cambrian time. An astounding amount of erosion (20,000 feet) was effected during early Cambrian time.

PALEOZOIC ERA /2

The long period of post-Beltian erosion was followed in Middle Cambrian time by an invasion of the sea, due to a gradual subsidence of the land that seems to have begun in the southwest and to have moved northward and eastward. At first the sea was shallow, and its earliest deposits were beach sands represented by the Flathead quartzite. The waves were in places vigorous enough locally to pluck fairly large fragments of Algonkian sandstone from the shore, and shape them into pebbles and cobbles.

As the sea became deeper, green muds were deposited, forming a series of beds which is now about 120 feet thick. The green muds graded into limy muds, and in turn to material that formed the magnesian limestone now 120 feet thick. Beds of muds and limy material were deposited on the top of the limestone, forming a formation now 90 feet thick. Again material forming a 500-foot formation of magnesian limestone was deposited in deeper clear water, followed by the deposition of limy muds now represented by 100 feet of limy shale. Again magnesium and calcium carbonate material was deposited, giving a 350-foot formation of magnesian limestone. Dark-colored muds were next deposited, followed by limy material interbedded with sandy stringers. The mass of shale and limestone is now about 300 feet thick. A limy sandstone was laid down upon the newly-formed limestone, followed by more limy material which now forms limy sandstone and limestone. The source of supply must have undergone periodic changes or the sea fluctuated greatly to form this series of shales and limestones.

At the end of Cambrian time the seas receded until Devonian time. The resulting land mass apparently was low lying.

Regarding deposition following Cambrian time Calkins and Emmons[2] write as follows: "Early in Devonian time the land was depressed, apparently with some rapidity, so that deep-sea conditions soon supervened, and they persisted long enough to allow the accumulation of about 1,000 feet of limestone containing marine fossils. No clear local evidence indicates any complete interruption of sedimentation prior to the beginning of Mississippian time, but the absence of any beds demonstrably corresponding to the Threeforks formation, which represents the Upper Devonian in central Montana, suggests the possibility that the area included within the Philipsburg quadrangle was land in late Devonian time." Perhaps the Three Forks shale is a limestone in this area and was not recognized.

"The Mississippian epoch was the last in which the oceanic conditions requisite to the deposition of relatively pure limestone were long maintained. About 1,500 feet of this material, rich in corals and shells of the mollusks and brachiopods which abounded in the waters of the Mississippian sea, was deposited.

"The sharp lithologic distinction between the Madison limestone and the basal part of the Pennsylvanian Quadrant formation is evidence that they were deposited under very different conditions, and that the change was rather sudden. The inequalities in the thickness of the Madison limestone and of the lower member of the Quadrant make it even appear probable that there was an interval of erosion between the two formations. The red shales and impure limestones of the lower member of the Quadrant have yielded marine organic remains; but these forms were probably not oceanic. Their lithologic character suggests that the beds were laid down in some inland sea subject to much evaporation, a hypothesis confirmed by the finding of gypsum beds and molds of salt crystals in the similar rocks of the Quadrant formation in the Great Falls region." The lower member of the Quadrant referred to is probably the Amsden formation.

"The quartzites of the upper part of the Quadrant are probably beach deposits, superposed upon the fine-grained rocks of the lower member after an interval of erosion, for continuous deposition would have been recorded by a gradual instead of an absolutely abrupt lithologic transition. It therefore may be supposed that the inland sea of early Quadrant time was filled or upheaved, and its bed, after a brief period of erosion, again invaded by the sea, whose advancing margin gradually covered the surface with a layer of beach sands."

During Permian time unusual marine conditions were present in which cherts, kerogen shales, phosphate beds, shales and limestones were deposited in a shallow inland sea covering much of southwestern Montana, Idaho, Utah and Wyoming. The origin of the phosphate beds has not been definitely determined. In certain localities of the Philipsburg quadrangle the Phosphoria formation was eroded away during the Triassic period.

MESOZOIC ERA[2]

Calkins and Emmons describe deposition in Mesozoic time as follows. "About the close of Paleozoic time, or in the early part of the Mesozoic era, the sea bottom was again upheaved and exposed to erosion. The absence of Triassic deposits from the Philipsburg area may mean that it was a land surface during the Triassic period, or that Triassic deposits were laid down and afterward removed. The local absence of the upper quartzitic stratum at the Rock Creek locality may be due to this post-Carboniferous erosion, which accounts, at any rate, for the presence of chert pebbles in the Ellis formation. During the part of Jurassic time represented by this formation the region was covered by sea water of rather slight depth. That the shore can not have been remote is attested by the conglomeratic nature of some of the beds, and the presence of much earthy matter even in the limestone.

"The sea bottom upon which the Ellis formation--and possibly some later deposits that have since been removed--had been laid down became a land area in early Cretaceous time and then became the site of fresh-water deposition. The large area in Montana and the adjoining part of Canada which was overlain by the Kootenai formation was perhaps never covered by one continuous lake but appears to have been a great interior basin, occupied partly by lakes and partly by marshes and river flood plains.

In the marshes peat was formed which later solidified into beds of coal that are characteristic of the formation in many areas, though not, so far as known, in the Philipsburg quadrangle. The mud breccias and related features were found on mud flats which were not necessarily of great extent. Limestone beds represent marl deposited on the bottoms of lakes, the later of which contained abundant fresh-water snails and clams.

"As a part of Cretaceous time intervening between the Kootenai and Colorado epochs is not represented in the Philipsburg quadrangle, the region must have been upheaved and eroded within that interval. After having thus become land, the region was once more submerged beneath the sea, whose first deposits consisted of black mud which has solidified as the shaly lower member of the Colorado formation. The sediments contained much carbonaceous matter, which in places outside the quadrangle formed layers of sufficient purity to constitute coal beds. The coarseness of the later beds mapped as Colorado in this area indicates a shallowing of the sea by sedimentation or upheaval."

CENOZOIC ERA[2]

Detailed studies of the Tertiary are lacking, and therefore the chronological sequence of events has not been fully deciphered.

The earth's crust, which had been comparatively stable during Algonkian, Paleozoic and Mesozoic time, was repeatedly crumbled, broken, or tilted in the early Tertiary or late Cretaceous during the Laramide orogeny; and the record of these events is found in the geologic structure. In Tertiary and Quaternary time the region was chiefly land exposed to erosion, which is recorded in the sculpture as well as in the deposits. Igneous activities, which had been almost wholly dormant throughout Paleozoic and Mesozoic time, became vigorously active during a large part of the Tertiary period and are recorded by bodies of intrusive rock, lava flows and pyroclastic deposits. Near the beginning of the Tertiary period, the strata were thrown into folds, and at the same time the surface was probably elevated as a whole. Continued lateral pressures overturned the folds and caused thrust faults. The Lewis overthrust, Philipsburg overthrust and others occurred at this time.

A few basic sills were injected prior to any strong folding, but the main period of intrusion came between post-Colorado and pre-Eocene time when the batholith forming the Anaconda and Flint Creek ranges was developed. The sequence of major intrusions has been observed to have occurred during the period of strong deformation or just after the close of it.

The order in which the several kinds of magma were intruded is not fully known; however observations in the Anaconda and Flint Creek ranges have virtually proved the following sequence: (1) diabase and other basic sills, (2) acidic diorite of Mt. Haggin and other places, (3) non-porphyritic muscovite biotite granite, (4) acidic grano-diorite, (5) porphyritic biotite granite, (6) porphyritic muscovite biotite granite. Of the position of the medium and basic grano-diorites that are so abundant, nothing is known./2

Ever since the Tertiary upheaval, parts of the Philipsburg quadrangle have been undergoing erosion. The thickness of the rock thus removed must amount to at least 20,000 feet where the oldest strata are exposed, and the average for the Quadrangle as a whole can hardly be less than 10,000 feet. Most of the products of this erosion were evidently carried far away, and the oldest surfaces now extant were carved after the greater part of it had been accomplished./2

During the period of thrust faulting, minor normal faulting occurred. However, the major block faulting that took place was a result of the release of the compressive forces that formed the thrust faults, and the beginning of tension forces. Intrusion at the beginning of block faulting was in its dying stages, but still active. The region had also been reduced to low relief when the block faulting began to take place. As a result of the block faulting the down drop blocks were favorable areas for the accumulation of eroded material from the up raised blocks.

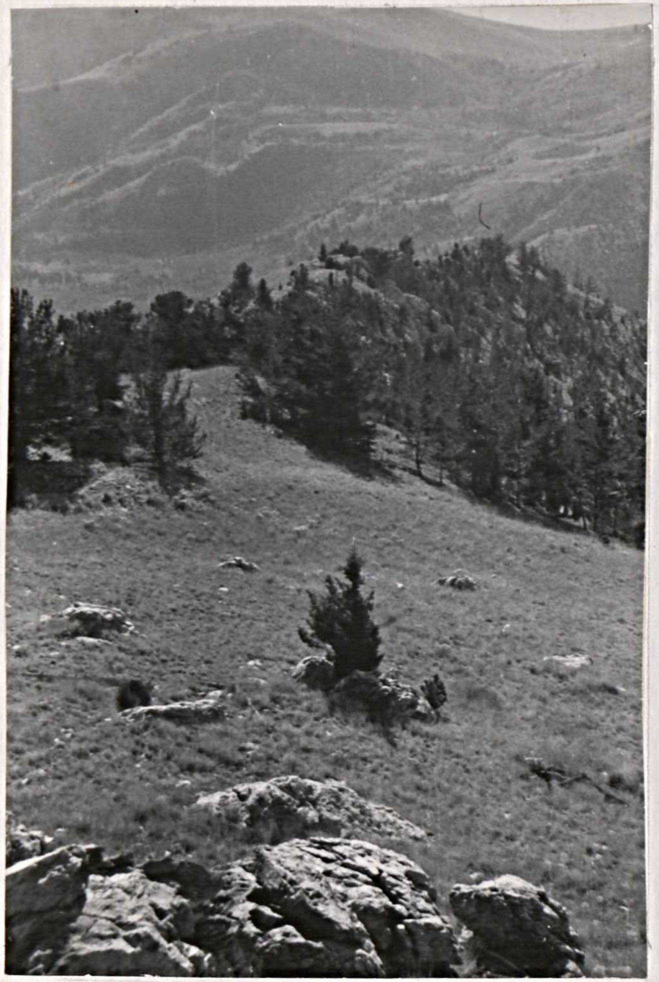
Volcanic eruptions and quiet lava flows during the Miocene epoch and possibly Oligocene probably came principally from the vicinity of Anaconda. They were undoubtedly later than any of the important intrusives.

Tilting of the early gravel beds and the warped peneplain surfaces was next recorded. Broad valleys were formed due to downwarping at this time.

Volcanic material continued to be deposited intermittently during the upheaval and tilting of the gravels. The down warped valleys and basins, occupied in many cases by lakes, were partly filled with volcanic ash, pyroclastics and detrital material.

As the land mass steadily rose, mountain canyons were formed and old stream courses were rejuvenated. By post-Miocene a broad layer of volcanic ash was removed and this vigorous campaign of erosion taking place in the mountains formed an evident series of high terraces.

In early Quaternary time, when the relief in its larger features was similar to what it is now, and the mountains were somewhat higher, the climate became much colder and the precipitation heavier than it had been before. Glaciers formed on the lofty peaks and ridges, and flowed down the canyons eroded by preglacial streams. As they descended into the valleys the warmer air melted them rapidly. Glacial conditions were to come and vanish at least twice and perhaps several times, although positive evidence of more than two glaciations has not been found in the Philipsburg quadrangle.



A

B

A. This view was taken from the Quadrant quartzite cliff on the east side of Timber Gulch looking across Lost Creek. The ridge in the center of the picture is Madison limestone; the large boulders in the foreground came off the Quadrant quartzite cliff. A hanging valley is seen in the background. The prospect hole on the left is dug in an east-west fault that cuts across this area.

B. This view was taken down Lost Creek. A large fault cuts through at the upper white dump. Colorado formations lie above the dump and Madison limestone below it. In the center of the picture a hill of Quadrant quartzite rises up in the glacial valley floor.

Plate 8. Photographic views of Lost Creek

The small amount of erosion that has taken place in the region since the final disappearance of the glaciers is indicated by the relatively unchanged glacial moraines and the polished surfaces of glaciated bedrock. Lakes occupy many of the hollows of glacial basins. A great many lie a few miles west and north of the Lost Creek-Modesty Creek area. Alluvial deposits were formed during post glacial as well as during glacial time. (Refer to Plates 3A, 8A and B.)

STRUCTURE

The structural features of the district are characterized by folding, faulting, unconformities, igneous intrusions, and the results of erosional forces. Due to the complexity of the many fault systems and the cover of alluvium and vegetation over the area, the structure has proved difficult to interpret.

In order to understand the structure, a series of events taking place from early Tertiary age to the present is listed in probable chronological order. Overlapping of phases undoubtedly existed.

1. Folding followed by great thrust faulting with minor thrusts, normal faulting and minor folding
2. Igneous intrusion during and later than thrust faulting
3. Erosion during (1) and (2) and after, forming a peneplain
4. Block faulting and normal faulting
5. Products of erosion and volcanic activity filling the down drop blocks
6. Uplift and tilting of the gravels and volcanic rocks and erosion
7. Glaciation
8. Present erosion

UNCONFORMITIES

The Flathead quartzite lies upon the great erosional unconformity above the Spokane formation of the Belt Series. More than 20,000 feet of Belt sediments were eroded down before the Flathead quartzite of Middle Cambrian time was deposited. The angularity of this unconformity is as much as 30^{0} in the Lost Creek area, but in many places it is hardly apparent./2

Unconformities appear between Cambrian and Devonian, Mississippian and Pennsylvanian, Pennsylvanian and Jurassic, Jurassic and Cretaceous, Lower Cretaceous and Upper Cretaceous, and Upper Cretaceous and Tertiary. The Tertiary early gravels were deposited on previously uplifted and eroded formations of all preceding periods.

FOLDING

All Cambrian formations crop out generally on dip slopes on the eastern face of the mountain in the mapped area. Folding consists of minor synclinal structures.

The Cambrian strata surrounding the common corner of sections 28, 27, 33, and 34 are present as a shallow syncline which plunges approximately 20^{0} southeast. In section 28 a slight synclinal structure occurs in the Cambrian strata. The Quadrant, Ellis, and Cretaceous strata adjoining Timber Gulch form a north-plunging syncline.

FAULTING

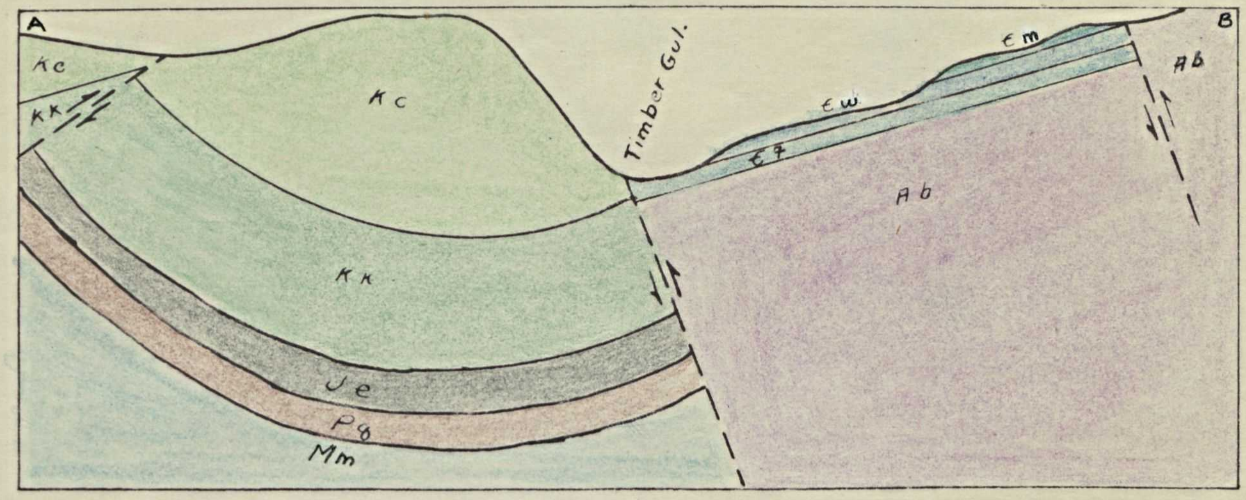
The general trend of faulting in the Philipsburg Quadrangle is northeastward throughout the central and southern areas, and more northward in the northern part; but it is very irregular in the southeastern portion where the structure in general is chaotic. These faults have diversified

Plate 9. Generalized geologic cross sections

A. Cross section on the township line, including the north section line of Section 3 and the $E\frac{1}{2}$ of the north section line of Section 4 as indicated on Plate 10.

B. Cross section through thrust fault as indicated on Plate 10.

C. Cross section on the north section line of Section 27, including part of the north section line of Section 38, as indicated on Plate 10.



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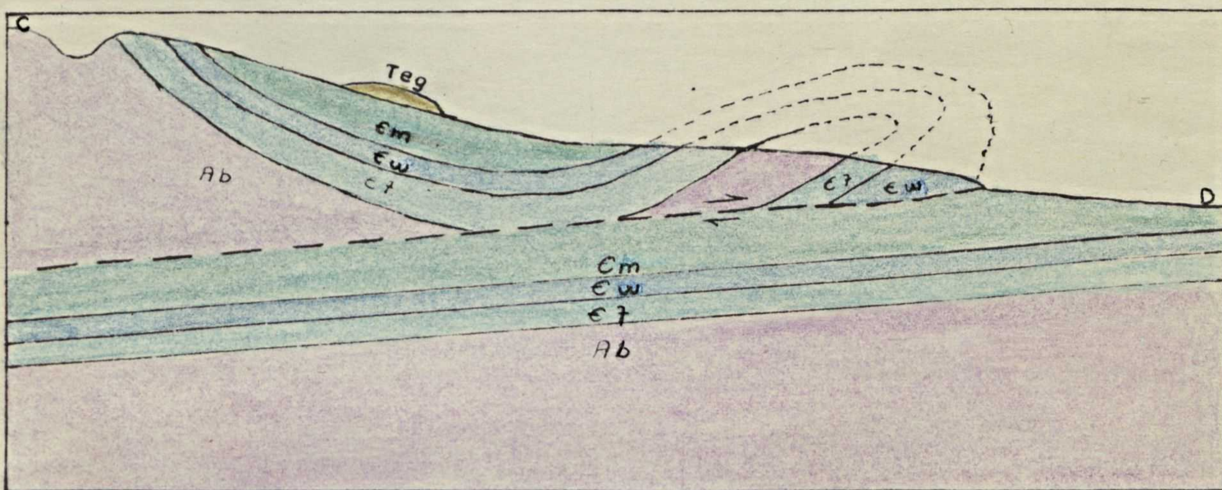

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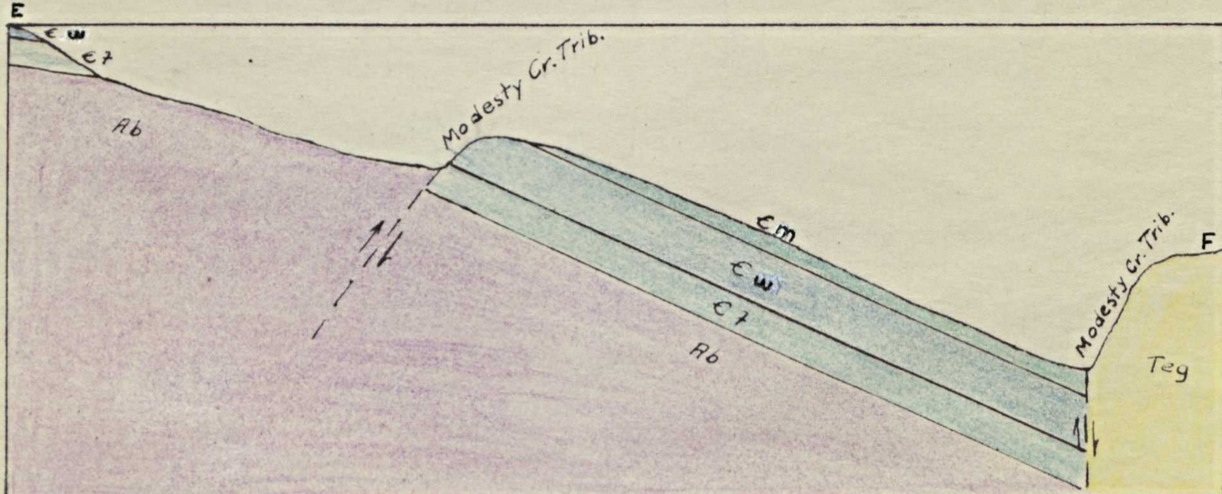

C

Plate 9. Generalized geologic cross-sections

characteristics. Four large over-thrust faults of low dip occur in the following areas: three miles south of Philipsburg, Georgetown Lake area, Lost Creek area, and near Mt. Haggin.[2]

The major faults on the map show a north-south trend with minor faults striking in a northeasterly direction. (See Plate 10.)

The Lost Creek over-thrust is represented in the northwest corner of the map in section 20, and a local overthrust was found in the central and southwest portion of section 27. (See Plates 10 and 9B.) A larger fault, apparently normal, follows Timber Gulch, and it is believed it carries through beneath the Tertiary gravels and follows down the Modesty Creek tributary. It is apparent the east block is down throw because Mesozoic sediments are exposed, whereas the west block on its continued up rising was eroded down to Beltian and Cambrian sediments. Three faults at a probable later date, striking to the east, broke the east block into three parts, and these faults probably all continued into the west block as represented by the fault south of Modesty Creek and the fault at the head of Timber Gulch. (See Plates 9 and 10.) It is not known whether or not the fault that cuts the Quadrant actually continues into the Belt to the west. A fault separating the Colorado shales from the Tertiary gravels is probably present but was not mapped; it is thought to exist because the Colorado occurs at a higher elevation than the gravels. A hypothesis to explain the sequence of events follows.

1. The occurrence of the north-south fault in which the west portion was upraised and the east portion was dropped

2. Three faults striking east-west and dividing the east portion into three blocks

   a. The block occupied by Tertiary gravels was depressed more than the other two blocks and hinged on the south. As a result gravels from the higher blocks filled the depression.

(2.) b. The block occupied by Quadrant, Ellis and Cretaceous sediments is a synclinal structure dipping to the north. This block was broken from the block represented by the Madison and was down thrown, tilted and rotated.

3. The placement of the Cretaceous formations upon the two blocks adjacent to Timber Gulch fault was caused by a low angle fault that came from the east.

4. Later down warping and tilting accompanied by erosion again altered the picture. (See Plates 10, 9A and C.)

In the northeast corner of section 4 the Meagher is exposed against Belt, which places a fault probably following the small intermittent stream. Because of insufficient mapping time, due to early snow, the fault was not shown on the map. (See Plates 9A and 10.) Another north-south fault cuts this block on the west, and a small fault with about a 200-foot displacement follows a gulch on the north, which completes the outline of this down drop block.

The central and southwestern portion of section 27 is developed structurally along a small overthrust of Cambrian and Belt sediments. Erosion has exposed the Belt, Flathead and Wolsey, which are overturned upon the Meagher marble. (See Plates 9B and 3B.) Two parallel faults of hinge type occur in the SE$\frac{1}{4}$, section 28, tipping up the south portion of the block between the faults. They are probably related to the adjoining thrust block.

The Cambrian in sections 27 and 22 is an upraised block. It was apparently tilted on its western end after the erosion, which filled the depressed block east of the large north-south fault now occupied by Tertiary gravels. (See Plate 9C.) The northern half of section 22 was not mapped completely due to adverse weather. The fault in the south half of section 22 is probably of later age than the north-south fault. A quartzite of unknown age lies on an east dip slope between the Modesty Creek tributaries. Limestones of unknown age, dipping eastward, crop out in the triangular area formed by the creeks and the fault.

INTRUSIVES

Intrusive igneous rocks are abundant in the eastern and southern parts of the Philipsburg quadrangle, where they form about half the bulk of the Flint Creek and Anaconda ranges. They occur chiefly in large, irregular, dome-like masses, which may be briefly designated plutonic, but they also occur in dikes and sills. Exposures of the biotite granite, which occupies lower Lost Creek Canyon and the hills farther south near the east edge of the Philipsburg quadrangle and the mapped area form a westward-dipping surface that cuts across bedding of the Newland formation at an acute angle. In section 8 of the map dikes of the granite or of pegmatite penetrate both the Newland formation and the diabase by which it is intruded.[2] (See Plate 10.)

The biotite granite contacts at the edge of the Philipsburg quadrangle in sections 8 and 17 and the contacts of the biotite granite in Lost Creek probably are the same body. (See Plate 10.)

The igneous body in section 15 is probably a cupola from the larger igneous biotite-granite mass up the creek. Because of baking and contact metamorphism, which are present around this small igneous body, Bergis had difficulty in determining the age of adjacent strata.

In sections 29 and 28, the area has been penetrated by numerous pegmatite intrusions. They range in size from 6-inch stringers to a large 400- by 1500-foot mass, and occur in Cambrian and Belt sediments. Many pegmatites are not shown on the map due to their small size and the minimum amount of time available for mapping. They occur throughout the two sections, but are especially abundant in the NW$\frac{1}{4}$, section 27. (See Plates 6A, B, and 7A.) Stringers of lit-par-lit injection are scattered in the Belt between the bedding planes along the south canyon wall of uppermost Modesty Creek. (See Plate 7B.) The age is probably later than that of the plutonic intrusions.

A small basic sill was encountered several hundred feet east of the quartz pegmatite, but was not included on the map. On the tributary of Modesty Creek is found a small outcrop of diorite which stopes its way into the Meagher marble.

EXTRUSIVES

Several small beds of brownish-grey rhyolite, capping the Tertiary gravels, were mapped at the head of Antelope Creek. Large beds of rhyolite, and other types of extrusives occur in lower Lost Creek and Antelope Gulch. The Philipsburg quadrangle shows exposures of andesites in the hills between Lost Creek and Anaconda. An exposure is in the southwest corner of the geologic map. (See Plate 10.)

Later crustal movements tilted the Tertiary gravels and the extrusive beds, exposing these beds to erosion.

METAMORPHISM

The Cambrian and Beltian rocks have all been metamorphosed to an extent that the former shale beds are now argillites, limestones are marbles, and sandstones are quartzites. All fossil evidence has been destroyed as a result of the regional metamorphism. Contact metamorphism is present in varying intensity around all igneous intrusions.

MINERAL RESOURCES

Although one can not go very far without observing an abandoned prospect, there are no deposits which have been proven to be of great economic importance in the area covered by this report. These "diggings" are found in practically every fault zone and along every contact of igneous bodies with limestones and shales. Apparently none of the numerous prospects in the region have been worked for probably several decades, and in this light it seems possible that intelligent geologic prospecting may result in uncovering something of value. Metallic type deposits that have shown varying degrees of success in the Philipsburg Quadrangle are as follows:[2]

A. Deposits filling fissures
   1. Silver-bearing veins in granite
   2. Gold-bearing veins in granite
   3. Silver-bearing veins in quartzite
   4. Gold-bearing veins and sheeted zones in quartzites
B. Replacement deposits related to fissures or to bedding planes
   5. Silver-bearing replacement veins in sedimentary rocks
   6. Silver deposits in bedding planes of calcareous rocks
   7. Gold-bearing replacement veins in sedimentary rocks
C. Replacement deposits of contact-metamorphic origin
   8. Gold-copper deposits
   9. Magnetite deposits
D. Gold placers.

The prospects around the pegmatites were worked presumably for gold or silver, not for the nonmetallic values they might contain. Gold in stream and glacial gravels has been recovered with varying degrees of success in the area. At the present time one prospector is doing intermittent work on the placers in the tributary to Modesty Creek shown in section 27. Also two men operating a dragline, trommel, and sluice boxes are prospecting Spring Gulch for placers. Modesty Creek has seen extensive activity since the late nineties. Ground sluicing and hydraulic mining methods were employed.

The only other evidence of former mining activity observed was an old quarry in the Madison limestone of Lost Creek 1000 feet north of section corner 9, 10, 15, 16.

Lost Creek, Modesty Creek and Racetrack Creek furnish water for irrigation purposes in the Deerlodge Valley. A network of ditches used for placer mining is to be found in sections 22 and 27.

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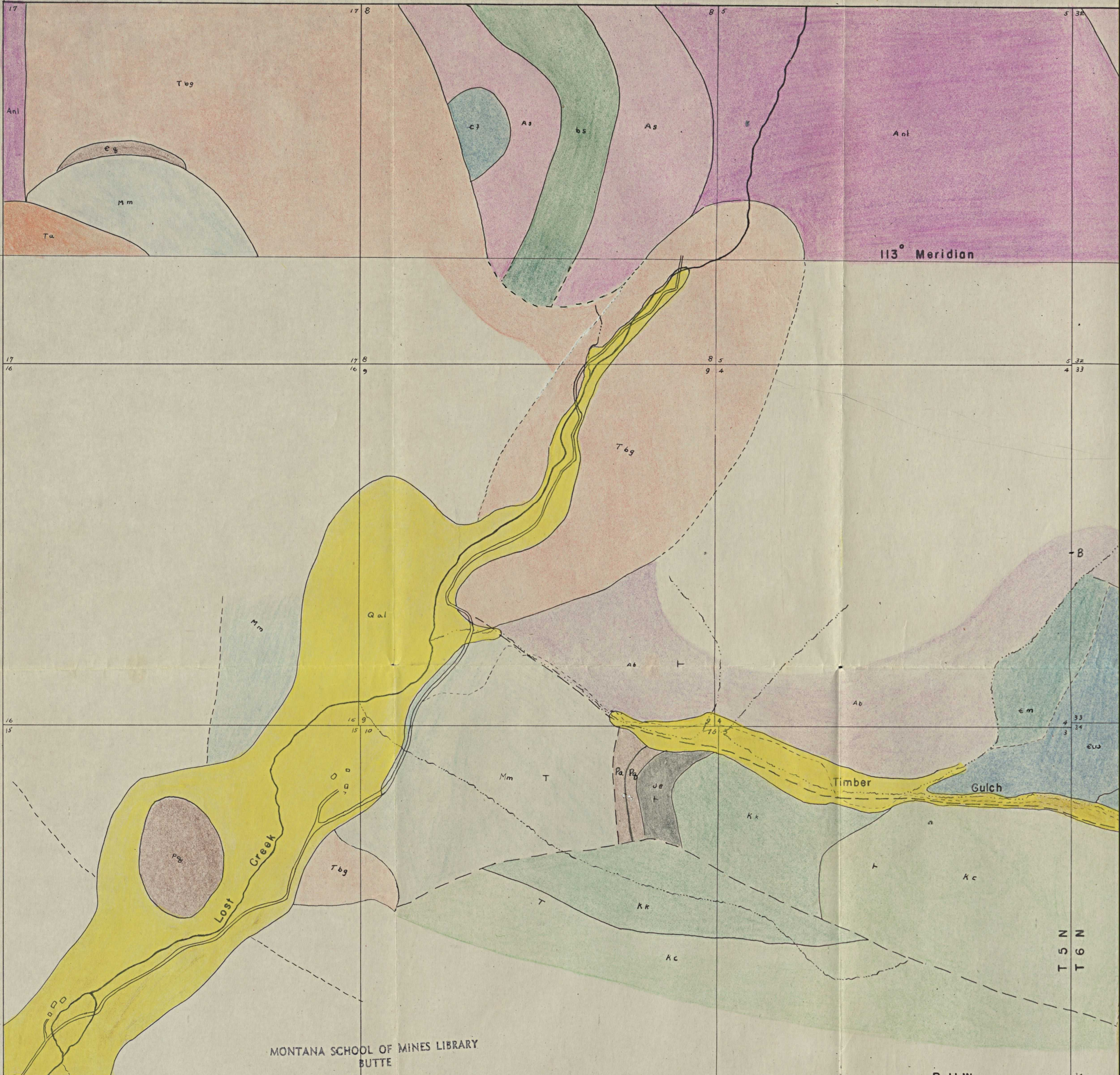


GEOLOGIC MAP

OF THE

LOST CREEK – MODESTY CREEK AREA

DEERLODGE COUNTY MONTANA

OCT. 1947

R.L. POTT & H.B. NICKELSON

SCALE = 1=1000

LEGEND

CENOZOIC	Quaternary	Recent	Alluvium	Qal
		Pleistocene	Moraines	Qm
	Tertiary	Eocene Miocene	Gravels	Teg
MESOZOIC	Cretaceous	Upper	Colorado fm.	Kc
		Lower	Kootenai fm.	Kk
	Jurassic		Ellis fm.	Je

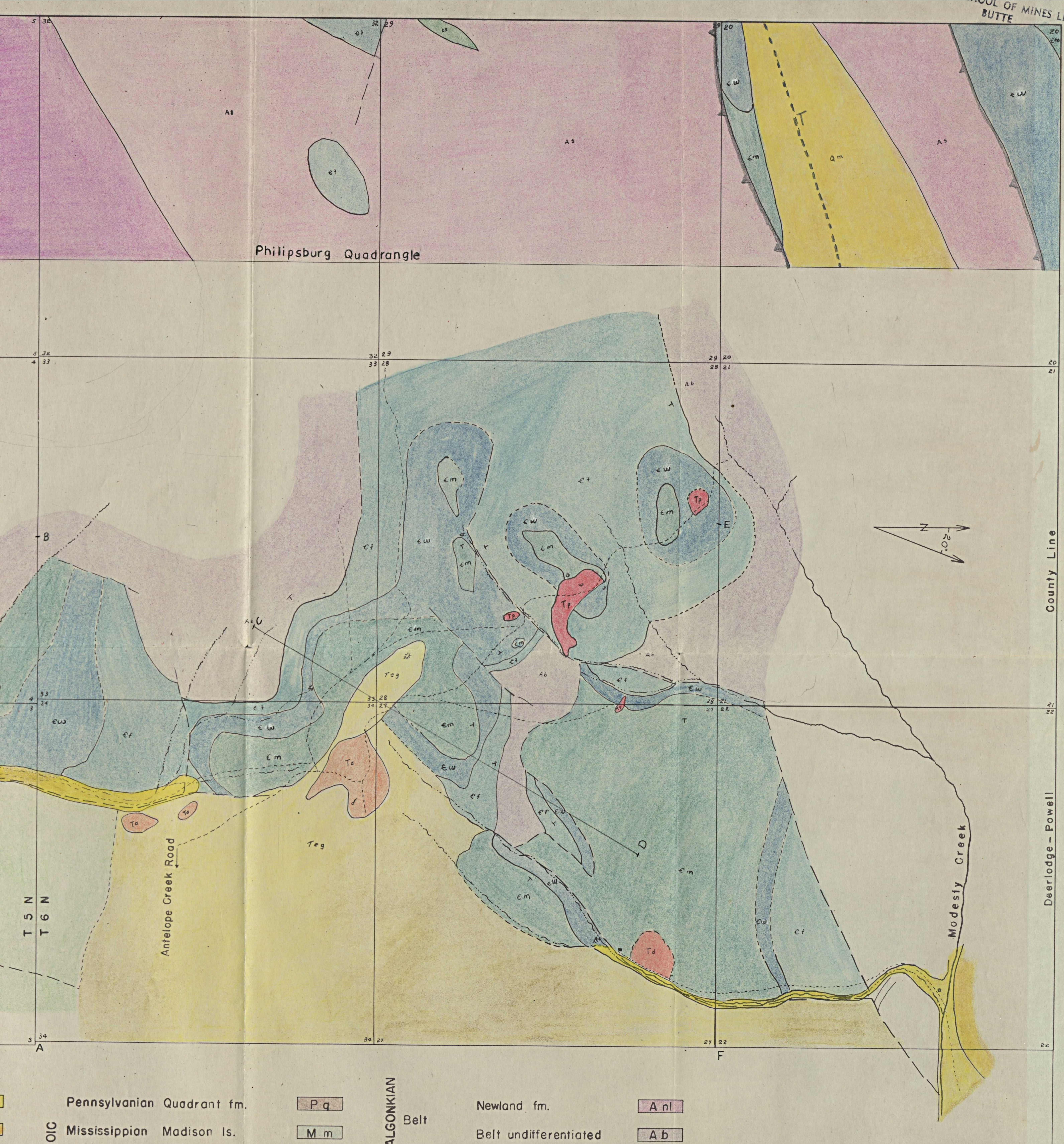
PALEOZOIC

Pe

Mi

Ca

Be



PALEOZOIC	Pennsylvanian	Quadrant fm.	Pq			
	Mississippian	Madison ls.	Mm			
	Cambrian	Meagher ls.	Єm			
		Wolsey sh.	Єw			
		Flathead qtz.	Єf			
	Belt	Spokane fm.	As			
ALGONKIAN	Belt	Newland fm.	Anl			
		Belt undifferentiated	Ab			
		Granite-biotite	Tbg			
	Tertiary	Pegmatite	Tp	Basic sill	bs	
		Andesite	Ta	Jeep road		
		Diorite	Td	Fault		