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Beltian stratigraphy and structure in southern part of Ovando quadrangle Montana

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BELTIAN STRATIGRAPHY AND STRUCTURE IN SOUTHERN PART OF OVANDO QUADRANGLE,

MONTANA

BY

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INTRODUCTION

GENERAL STATEMENT

South of Missoula the Upper Wallace limestone is overlain by a series of argillites and quartzites which were carefully measured and named the Missoula group[1] by C. H. Clapp and C. F. Deiss during the summer of 1930. The Missoula group is divided into five formations: Miller Peak, Hellgate, McNamara, Garnet Range, Sheep Mountain. Clapp and Deiss[2] used the original stratigraphic section of Walcott[3] in the Belt Mountains as the type section of the Algonkian rocks in Montana. The Upper Wallace limestone[4] of the Missoula section is correlated with the Helena limestone of the type section, and the Miller Peak argillite[5] of the Missoula section with the Marsh shale of the type section. The Marsh shale is the youngest Beltian formation in the Belt Mountains. Consequently the Missoula group formations above the Miller

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[1] C. H. Clapp and C. F. Deiss: <u>Correlation of Montana Algonkian formations</u>, Geol. Soc. Am., Bull., vol. 42, pp. 673-696 (1931); also Mont. Bur. Mines and Geol., Reprint no. 1 (1932).

[2] Idem: p. 689.

[3] C. D. Walcott: <u>Pre-Cambrian fossiliferous formations</u>, Geol. Soc. Am., Bull., vol. 10, pp. 203-209 (1899).

[4] C. H. Clapp and C. F. Deiss: op. cit., p. 691.

[5] Idem: p. 690.

Peak are not present in the Belt Mountains section.

After the Missoula group was measured and named, Clapp and Deiss, assisted by A. H. McNair, began mapping the Coopers Lake quadrangle, Montana. In this area the Miller Peak argillite overlies the Helena limestone and in turn is overlain by a limestone, above which is a series of interbedded quartzites and argillites. These rocks overlying the Miller Peak were divided by Clapp and Deiss[6] into two formations, tentatively called the Lake limestone and Evans quartzite.

The lateral gradation of the Hellgate, McNamara, Garnet Range, and Sheep Mountain formations of the type Missoula group section into the Lake and Evans formations of the Coopers Lake quadrangle was not studied in detail by Clapp and Deiss. The investigation of this gradation was made by the writer during the summer of 1935 in the attempt to solve the stratigraphic relationships of the Hellgate quartzite in the type section to the Lake limestone in the Coopers Lake quadrangle.

The Lake limestone and Evans quartzite were so named[7] because of their presence on the north slopes of Lake Mountain, in T. 16 N., R. 11 W., and Evans Peak, in T. 18 N., R. 10 W., respectively. When Clapp and Deiss climbed Evans Peak they found that they had mistaken some igneous rocks for the Evans quartzite. For this reason the name Evans quartzite cannot be published, but is tentatively retained by Montana geologists as a field name for the Beltian quartzites and argillites

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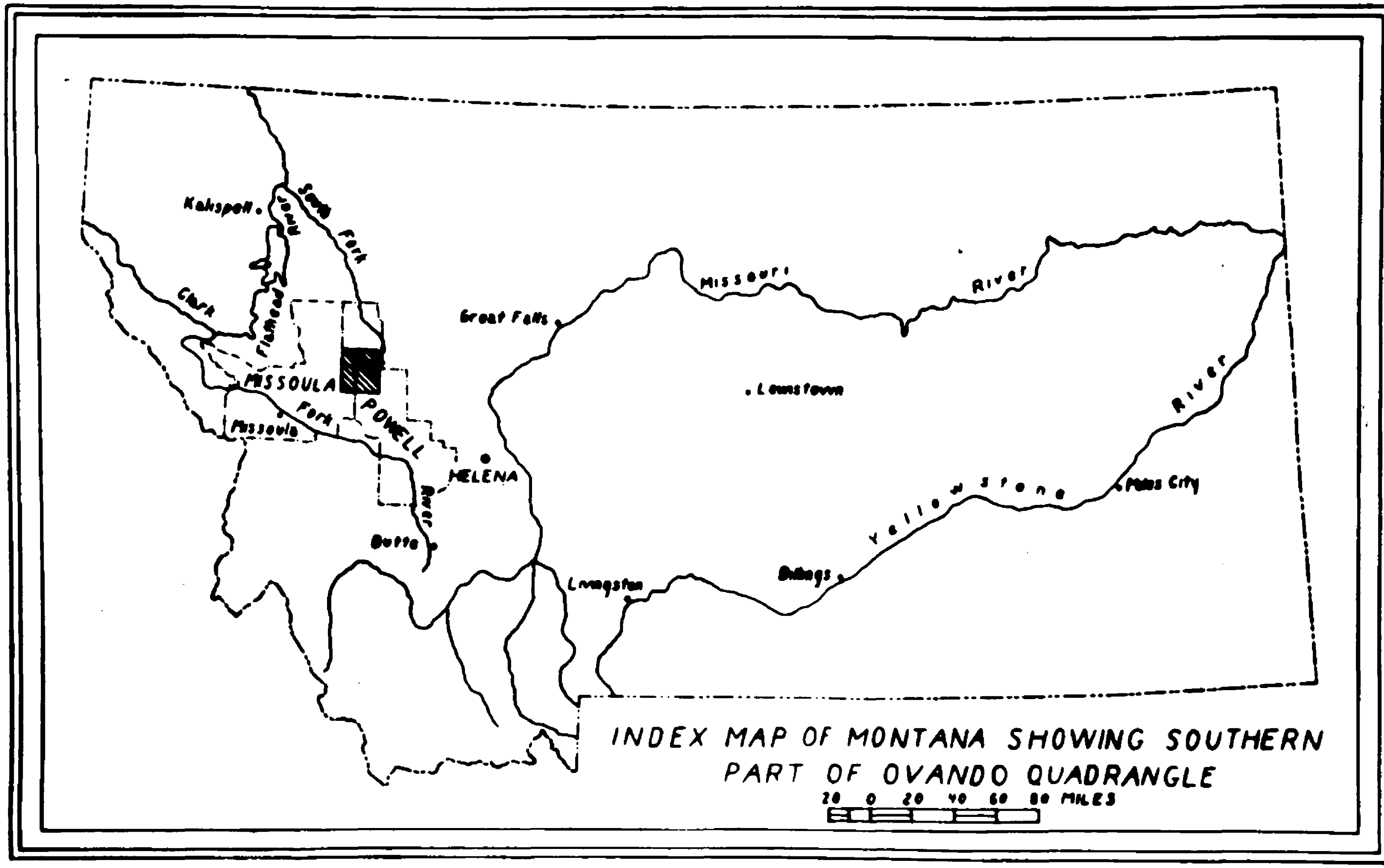
[6] C. F. Deiss: personal communication.

[7] C. F. Deiss: personal communication.

PLATE 1.



INDEX MAP OF MONTANA SHOWING SOUTHERN PART OF OVANDO QUADRANGLE

20 0 20 40 60 80 MILES

overlying the Lake limestone. Consequently the manes Lake limestone and Evans quartzite are here used for the rocks so designated in the field by Clapp and Deiss.

LOCATION OF AREA

The area investigated (Pl. 1) contains 409 square miles, lies between meridians 113°05' and 113°27' west longitude and between parallels 47°01' and 47°17' north latitude, is within Ovando quadrangle, Montana, and includes part of eastern Missoula and western Powell counties.

ACKNOWLEDGMENTS AND FIELD WORK

The field work was done under the auspices of the Montana Bureau of Mines and Geology. The work was made possible by the active interest of the director of the Bureau, President Francis A. Thomson of the Montana School of Mines, and of Professor Charles Deiss of the geology department at Montana State University.

During the greater part of the field season Mr. Donald Duncan acted as field assistant. After the close of the regular season, four extra days were used to obtain further field evidence in the vicinity of Salmon Lake. On this trip Mr. Albert Spaulding assisted.

The areal geologic mapping was done by the traverse and plane-table methods with a Richard's model of the Brunton compass and an aneroid barometer. Distances and altitudes were checked on the Ovando quadrangle topographic map. All of the roads in the area were traversed by automobile, and the trails were traversed by foot.

Two sections of Upper Miller Peak argillite, Lake limestone, and Lower Evans quartzite were measured in detail. The thicknesses given of all formations are approximate.

PREVIOUS WORK ON BELT SERIES IN MONTANA

During 1859 and 1860 F. V. Hayden[8] investigated the geology of Montana near the headwaters of the Yellowstone and Missouri rivers where Beltian rocks are known to occur. Mr. Hayden later returned to this area and in 1872[9] and 1873[10] called the strata, which are now referred to the Belt series, Lower Silurian. In 1888[11] he referred to Peale's East Gallatin group[12] (Belt) as probably Middle Cambrian. In

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[8] W. F. Raynolds: Report on the exploration of the Yellowstone and Missouri rivers, in 1859-'60, Ex. Doc., no. 77, 40th Congress, 1st session, p. 17 (1868). Mr. Raynolds said: "The report . . . of Professor F. V. Hayden . . . upon the geology of this country, will be found to contain all information upon that branch up to date."

[9] F. V. Hayden, Fifth annual report of progress, U. S. Geol. Surv., Prelim. Rept., Mont., p. 140, 1871 (1872).

[10] F. V. Hayden, Report of progress, U. S. Geol. Surv. Terr., Sixth Ann. Rept., pp. 72-73, 1872 (1873).

[11] F. V. Hayden: Report, U. S. Geol. Surv., Seventh Ann. Rept., p. 86, 1885-'86 (1888).

[12] F. V. Hayden: Report, U. S. Geol. Surv., Sixth Ann. Rept., p. 50, 1885 (1886). Hayden's assistant, A. C. Peale, measured a 2,300 foot section in detail.

1886 W. M. Davis[13] referred the "barren slates" of the Belt Mountains to the Lower Cambrian. In 1891 J. S. Newberry[14] described the Belt rocks near Sulphur Springs and Prickly Pear Canyon as Cambrian.

In 1892 C. R. Van Hise[15], after a review of Beltian literature, said that if the barren slates below the fossiliferous Cambrian were Algonkian, then, in Montana "there is . . . probably two series of Algonkian rocks, one almost completely unaltered, the other thoroughly crystalline."[16]

A. C. Peale, in 1893[17] and in 1896[18], tentatively referred the Belt formation to the Algonkian. He said:

"The possibility that Lower Cambrian fossils may yet be found in the quartzite at the base of the Flathead formation; the absence of organic remains in the Belt formation; the metamorphosed condition of the latter; and the existence of the unconformity between the quartzite and the beds below lead us to refer the latter, for the present at least, to the Algonkian."[19]

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[13] W. M. Davis: Relation of the coal of Montana to the older rocks, U. S. 10th Census, vol. 15, Mining Industries, pp. 697, 700, 702 (1886).

[14] J. S. Newberry: The flora of the Great Falls coal field, Montana, Am. Jour. Sci., 3d series, vol. 41, p. 191 (1891).

[15] C. R. Van Hise, Correlation Papers--Archean and Algonkian, U. S. Geol. Surv., Bull. 86, pp. 282-286 (1892).

[16] Idem: p. 286.

[17] A. C. Peale: The Paleozoic section in the vicinity of Three Forks, Montana, U. S. Geol. Surv., Bull. 110, p. 19 (1893).

[18] A. C. Peale: Description of the Three Forks sheet, Montana, U. S. Geol. Surv., Geol. Atlas, folio 24, p. 2 (1896).

[19] A. C. Peale: op. cit., pp. 19-20.

He had previously[20] referred to the Belt rocks near Gallatin City as probably Huronian.

In 1896 W. H. Weed and L. V. Pirsson[21] described the Belt rocks in the Castle Mountains. They said:

"The Paleozoic rocks of the Castle Mountain area show two distinct and quite different series. The lowest of these is a group of conformable strata, mainly of argillaceous shales or slates, called the Belt formation, from its great development in the ranges of that name. . . . We believe it to be of Algonkian age."[22]

In 1899 W. H. Weed[23] separated the Belt rocks in the Little Belt Mountains into a lower Neihart quartzite and an upper Belt formation.

In 1899 Walcott published his Belt Mountain section[24], and Weed's section[25] south of Neihart. Walcott divided the Belt series into eight formations: Neihart, Chamberlain, Newland, Greyson, Spokane, Empire, Helena, Marsh. The Belt and Cambrian formations are separated by an unconformity, which he discussed in part by these words:

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[20] A. C. Peale: Report, U. S. Geol. Surv. Terr., Sixth Ann. Rept., pp. 172, 174, 1872 (1873).

[21] W. H. Weed and L. V. Pirsson: Geology of the Castle Mountain mining district, Montana, U. S. Geol. Surv., Bull. 139, pp. 26, 31-32 (1896).

[22] Idem: p. 31.

[23] W. H. Weed: Description of the Little Belt Mountains Quadrangle, Montana, U. S. Geol. Surv., Geol. Atlas, folio 56, pp. 1-2 (1899).

[24] C. D. Walcott: Pre-Cambrian fossiliferous formations, Geol. Soc. Am., Bull., vol. 10, pp. 204-208 (1899).

[25] Idem: pp. 208-209.

"I think that an unconformity to the extent indicated is sufficient . . . to warrent our placing the Belt terrane in the pre-Cambrian Algonkian system of formations."[26]

In 1902 Bailey Willis[27] published his Glacier Park section. Willis divided the Belt series (Algonkian) into six formations: Altyn, Appekunny, Grinnell, Siyeh, Sheppard, Kintla. He worked with Stuart Weller and G. L. Finlay.

In 1906 Walcott[28] published sections from the Lewis and Clark, Swan, and Mission ranges. Walcott divided the Belt rocks into the Ravalli, Blackfoot, and Camp Creek series. The Ravalli series[29] is correlated with the strata (Burke, Revett, Saint Regis) above the Prichard and below the Wallace of the Coeur d'Alene series. The Blackfoot series[30] is correlated with "the Newland limestone of the Belt Mountains section, and the Altyn limestone of the Lewis Range section[31], and the Wallace calcareous series of the Coeur d'Alene section of Idaho." The Camp Creek series[32] is correlated with the Greyson, Spokane,

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26 C. D. Walcott: op. cit., pp. 213-215.

27 Bailey Willis: Stratigraphy and structure, Lewis and Livingston Ranges, Montana, Geol. Soc. Am., Bull., vol. 13, pp. 316-324 (1902).

28 C. D. Walcott: Algonkian formations of northwestern Montana, Geol. Soc. Am., Bull. vol. 17, pp. 2-17 (1906).

29 Idem: p. 20.

30 Idem: p. 20.

31 See Willis' Glacier Park section.

32 C. D. Walcott: op. cit. pp. 17-20.

Empire, Helena, and Marsh formations of the Belt Mountains, with the Striped Peak formation of the Coeur d'Alene Mountains, and with the Appekunny, Grinnell, Siyeh, Sheppard, and Kintla formations of the Lewis range. Walcott presented the first Beltian correlation table[33].

Clapp and Deiss later discovered that:

"the part of the Blackfoot limestone which appeared to Walcott to underlie the Camp Creek series is a down-faulted block of Paleozoic limestone, although the section which he measured along the North Fork of the Blackfoot River below Dry Fork is in the Belt series."[34]

From 1903 to 1915 Calkins worked in the Philipsburg quadrangle, Montana,[35] and in and north of the Coeur d'Alene district of Idaho.[36] He divided the Belt series of Idaho and northwestern Montana into six formations: Prichard, Burke, Revett , Saint Regis, Wallace, Striped Peak. Calkin's Philipsburg section, consisting of five formations: Neihart, Pritchard, Ravalli, Newland, and Spokane, was generally used for all geological mapping in western Montana from 1915 to 1930.[37]

Concerning the period from 1921 to 1932 C. H. Clapp stated:

"Following the completion of a reconnaissance of central and eastern Montana in 1920, a reconnaissance survey of the western part of the state was commenced in 1921 for the Montana Bureau of Mines and Geology....

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[33] C. D. Walcott: op. cit., p. 18.

[34] C. H. Clapp and C. F. Deiss: Correlation of Montana Algonkian Formations, Geol. Soc. Am., Bull., vol. 42, p. 673 (1931).

[35] F. C. Calkins and W. H. Emmons: Description of the Philipsburg quadrangle, Montana, U. S. Geol. Surv., Geol. Atlas, folio 196 (1915).

[36] F. C. Calkins: A geological reconnaissance in northern Idaho and northwestern Montana, U. S. Geol. Surv., Bull. 384, pp. 7-91 (1909).

[37] C. H. Clapp and C. F. Deiss: op. cit., p. 675.

"During the first two seasons G. S. Lambert, Arthur Bevan, and C. H. Clapp were the geologists. Earl B. Young did some work in 1922. In 1923 Roy A. Wilson, who had previously spent the seasons of 1919 and 1920 in a survey of the Mission Range in connection with his graduate work at the University of Chicago, joined the survey. In 1924 G. S. Lambert compiled from the work of the three seasons a complete geologic map of western Montana, which has not been published....

"From 1924 to 1928, except for some work done by Lambert in 1924, the survey was carried on at odd times by C. H. Clapp, although in the summer of 1925 he worked with J. H. Bradley, Jr., for three weeks in the mountains north of the upper Blackfoot Valley. In 1929 C. H. Clapp accompanied by G. R. Megathlin began a more systematic study of Glacier Park and of the Flathead and Lewis and Clark ranges. . . . In 1930 C. H. Clapp and C. F. Deiss carried a stratigraphic and structural section across the south ends of the Mission, Swan, and Lewis and Clark ranges from Missoula to Helena. C. M. Langton surveyed in detail a small area in the Lewis and Clark Range in the vicinity of Shafer Meadows. In 1931 C. H. Clapp and C. F. Deiss assisted by Andrew McNair nearly completed the geologic mapping of the Coopers Lake Quadrangle north of the upper Blackfoot Valley. In 1932 C. F. Deiss assisted by Andrew McNair, in connection with a stratigraphic study of the Paleozoic rocks, revised the mapping of portions of the Flathead and Lewis and Clark ranges. . . . C. H. Clapp, C. F. Deiss, and Andrew McNair completed the mapping of the northeastern part of the Coopers Lake Quadrangle and revised the reconnaissance mapping of the southwestern part of the Saypo Quadrangle. In both 1931 and 1932 slight revisions were made in the mapping of Glacier Park."[38]

Claude M. Langton and C. H. Clapp[39], in 1932 and 1933, worked in the Sapphire and Bitterroot ranges.

In 1931 C. L. and M. A. Fenton[40] published their Glacier Park section. They divided the Belt series into six formations: Waterton, Altyn,

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[38] C. H. Clapp: Geology of a portion of the Rocky Mountains of northwestern Montana, Mont. Bur. Mines and Geol., Mem. no. 4, pp. 2-3 (1932).

[39] Claude M. Langton: Geology of the northeastern part of the Idaho Batholith and adjacent region in Montana, Jour. Geol., vol. 43, pp. 27-28 (1935).

[40] C. L. Fenton and M. A. Fenton: Algae and algal beds in the Belt series of Glacier National Park, Jour. Geol., vol. 39, pp. 672-676, (1931).

Appekunny, Grinnell, Siyeh, Boulder Pass. The name Boulder Pass is the only new formation name which they introduced. The Boulder Pass formation includes the Sheppard and Kintla formations of Willis as members. The name Waterton was taken from Daly.[41]

In 1931 Clapp and Deiss, after making a stratigraphic section of the rocks near Missoula and tracing the formations from Missoula to Helena, stated:

"The results of this work revealed that all previous correlations were partly correct, but fail to recognize that the argillites and the quartzites separating the Helena and Newland limestones in the Belt Mountains thin to the northwest and west to such an extent that the workers in the western ranges had mapped these limestones as a single formation."[42]

In addition to the eight well-known Beltian stratigraphic sections published from Montana by Walcott[43,44], Willis[45], Calkins[46,47,48],

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[41] R. A. Daly: Geology of the North American Cordillera at the Forty-ninth parallel, Canada Geol. Surv., Mem. 38, pt. I, pp. 50-56 (1912).

[42] C. H. Clapp and C. F. Deiss: op. cit., pp. 676-677.

[43] C. D. Walcott: Pre-Cambrian fossiliferous formations, Geol. Soc. Am., Bull., vol. 10, pp. 204-208 (1899).

[44] C. D. Walcott: Algonkian formations of northwestern Montana, Geol. Soc. Am., Bull, vol. 17, pp. 2-18 (1906).

[45] Bailey Willis: op. cit., pp. 316-334.

[46] F. C. Calkins (and F. L. Ransome): The geology and ore deposits of the Coeur d'Alene district, Idaho, U. S. Geol. Surv., Prof. Pap. 62, pp. 23-25 (1908). The Coeur d'Alene section extends into Montana.

[47] F. C. Calkins: A geological reconnaissance in northern Idaho and northwestern Montana, U. S. Geol. Surv., Bull. 384, pp. 38-41; 58-91 (1909)

[48] F. C. Calkins (and W. H. Emmons): Description of the Philipsburg quadrangle, Montana, U. S. Geol. Surv., Geol. Atlas, folio 196, pp. 3-5 (1915).

Fentons[49], and Clapp and Deiss[50], two well-known sections from Canada have been published by Daly[51], and by Schofield[52].

A correlation table which has not been published was prepared by P. A. Billingsley and J. A. Grimes[53], assisted by other geologists, of the Anaconda Copper Mining Company.

In 1935 Norman E. A. Hinds[54] referred the Belt series, Algonkian, to the Paleozoic. He said:

"Algonkian strata so much more closely resemble those of the Paleozoic than those of the Archean that the time interval represented by them is considered the first period of the Paleozoic."[55]

The Paleozoic age of the Belt series has not yet been proven.

Deiss[56], in 1935, discussed the Cambrian-Algonkian unconformity in

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[49] C. L. Fenton and M. A. Fenton: Algae and algal beds in the Belt series of Glacier National Park, Jour. Geol., v. 39, pp. 672-676 (1931).

[50] C. H. Clapp and C. F. Deiss: op. cit. pp. 677-683.

[51] R. A. Daly: op cit., pp. 49-83.

[52] S. J. Schofield: The Pre-Cambrian (Beltian) rocks of southeastern British Columbia and their correlation, Canada Geol. Surv., Mus. Bull. 2, pp. 79-91 (1914).

[53] C. H. Clapp and C. F. Deiss: op. cit., pp. 677-683.

[54] Norman E. A. Hinds: Ep-Archean and Ep-Algonkian intervals in western North America, Contr. to Paleontology I, Carnegie Inst. Washington Pub. no. 463, p. 6 (1935).

[55] Idem: p. 6.

[56] Charles Deiss: Cambrian-Algonkian unconformity in western Montana, Geol. Soc. Am., Bull., vol. 46, pp. 95-124 (1935).

western Montana. He said:

"The magnitude of the erosion interval and of the unconformity in western Montana is held to be conclusive proof of the pre-Cambrian age of the Beltian rocks, a conclusion widely accepted, but one that, even in recent years, has been subjected to some doubt."[57]

Other reports on the Belt series have been published since 1900, by W. H. Weed[58], N. H. Winchell[59], Waldemar Lindgren[60], Joseph Barrell[61], G. R. Mansfield[62], Edward Sampson[63], Margaret Fuller[64], Arthur Bevan[65],

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[57] Charles Deiss: op. cit., p. 124.

[58] W. H. Weed: Geology of the Little Belt Mountains, U. S. Geol. Surv., Twentieth Ann. Rept. pt. III, pp. 257-461, 1899 (1900).

[59] N. H. Winchell: Notes on the Geology of the Hellgate and Big Blackfoot valleys, Montana (abstract), Geol. Soc. Am., Bull., vol. 15, pp. 576-578 (1904).

[60] Waldemar Lindgren: A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho, U. S. Geol. Surv., Prof. Pap. 27 (1904).

[61] Joseph Barrell: Pre-Cambrian formations of Montana, Jour. Geol., vol. 14, pp. 553-560 (1906).

[62] G. R. Mansfield: Structure of the Rocky Mountains in Idaho and Montana, Geol. Soc. Am., Bull., vol. 34, pp. 263-284 (1923). Mansfield's paper deals entirely with structure.

[63] Edward Sampson: Belt sedimentation and correlation (Abstract), Geol. Soc. Am., Bull., vol. 38, p. 111 (1927).

[64] Margaret Fuller: Stratigraphic boundaries in Glacier National Park (abstract) Geol. Soc. Am., Bull., vol. 38, p. 153 (1927).

[65] Arthur Bevan: Rocky Mountain front in Montana, Geol. Soc. Am., Bull., vol. 40, pp. 427-456 (1929).

and by R. A. Wilson, J. S. Lambert, and C. H. Clapp[66]. In addition Joseph Barrell[67], F. L. Ransome[68], D. F. MacDonald[69,70], W. H. Emmons[71,72], Adolph Knopf[73], Reno Sales[74], and J. T. Pardee and F. C. Schrader[75] have published reports on the mining districts in the region containing the Belt formations.

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[66] R. A. Wilson, J. S. Lambert, and C. H. Clapp: Belt series in Montana (Abstract), Geol. Soc. Am., Bull., vol. 15, pp. 91-92 (1934).

[67] Joseph Barrell: Geology of the Marysville mining district, Montana, U. S. Geol. Surv., Prof. Pap. 57 (1907).

[68] F. L. Ransome (and F. C. Calkins): The geology and ore deposits of the Coeur d'Alene district, Idaho, U. S. Geol. Surv., Prof. Pap. 62 (1908).

[69] D. F. MacDonald: Economic features of northern Idaho and northwestern Montana, U. S. Geol. Surv., Bull. 285, pp. 41-52 (1906).

[70] D. F. MacDonald: Notes on the economic geology of northern Idaho and northwestern Montana, U. S. Geol. Surv., Bull. 384, pp. 92-108 (1909).

[71] W. H. Emmons (and F. C. Calkins): Geology and ore deposits of the Philipsburg quadrangle, Montana, U. S. Geol. Surv., Prof. Pap. 78 (1913).

[72] W. H. Emmons (and F. C. Calkins): Description of the Philipsburg quadrangle, Montana, U. S. Geol. Surv., Geol. Atlas, folio 196 (1915).

[73] Adolph Knopf: Ore deposits of the Helena mining region, Montana, U. S. Geol. Surv., Bull. 527 (1913).

[74] Reno Sales: Ore deposits of Butte, Montana, Trans. Am. Inst. Min. Engr., vol. 46, pp. 3-109 (1914).

[75] J. T. Pardee and F. C. Schrader: Metalliferous deposits of the Greater Helena mining region, Montana, U. S. Geol. Surv., Bull. 842 (1933).

PHYSIOGRAPHY

The map area may be divided into three rather distinct topographic districts: (1) a northern, mountainous district, (2) a southern and south central, rolling district, and (3) a western, hilly district.

The northern district is covered by the southern end of the Swan range. The mountains attain altitudes of 6,000 to 7,000 feet in the southern, and more than 8,000 feet in the eastern and western parts of the district. High cliffs are especially developed on the northern and western slopes. Although the most rugged scenery is in the northern and eastern parts of this district, the central and southern parts have been extensively glaciated.

The southern and south central district is characterized by a glacial topography consisting of numerous moraines, kames, drumlins, and isolated sunken lakes. The glacial deposits are probably several hundred feet thick and are eroded thru to bed rock at only one known place. This is on Monture Hill, three miles west of Ovando. Most of this district is 4,000 feet above sea level, but the northern and northeastern parts rise to 5,000 feet.

The western district is characterized by rounded hills which rise to 5,000 feet above sea level in the southern, and to 6,400 feet in the northern parts of the district. Cliffs are prominent in Blackfoot River Canyon, in the vicinity of Salmon Lake, and just north of Fish Lake. Clearwater River and Trail Creek lie in broad, terraced valleys. Much of the district has been glaciated.

The northeast and northwest corners of the map area are drained by tributaries of the South Fork of Flathead River. Drainage of the remainder of the area, which lies south of the crest of the Swan Range, is controlled by Monture Creek, Cottonwood Creek, and Clearwater River. These streams are tributaries to the Blackfoot River and flow southward, roughly parallel to the strike of the strata. The Blackfoot River flows westward along the southern boundary of the area and is a part of the Columbia River system which drains into the Pacific Ocean.

As high as 7,000 feet above sea level the slopes are heavily forested with small fir and pine trees. These trees are a source of supply for lumber camps near Woodworth. The slopes above 7,000 feet are either rocky or covered with stunted, wind-blown pine, fir, and juniper. Abundant grass provides excellent pasturage for cattle, sheep, and game in all parts of the area. Many of the wide valleys have been, or are being, extensively cultivated.

Roads extend along Clearwater, Blackfoot, and Cottonwood Valleys. Other roads extend from Ovando to Salmon Lake via Woodworth, and from Ovando to Monture Ranger Station near the junction of Spread and Monture Creeks. Trails of the United States Forest Service afford easy access to the greater part of the area.

STRATIGRAPHY

DESCRIPTION OF FORMATIONS

Newland Limestone

The oldest Beltian formation exposed in the map area is the Newland limestone, which, in northwestern Montana, ranges from 2,300 to 5,400 feet in thickness. The formation is composed of blue-gray, light-grey, gray-green, and occasionally dark blue-gray to black dolomitic limestone and calacareous argillite. The argillite weathers light-tan to brown, gray, or in places to red-brown. A few ripple marks and contorted laminae are present. The limestones are interbedded with gray-green and light-brown to dull pale-pink, calcareous sandstone and sandy argillite. The sandstone and sandy argillite weather white, green, or light-tan to buff and dull-red. The Newland limestone is usually more argillaceous than the Helena and Lake limestones.

Spokane Quartzite[76]

The Spokane quartzite overlies the Newland limestone and ranges in thickness from 800 to 5,000 feet. The Spokane formation is composed of purple, red, green, and gray to white-gray argillite and quartzite. The beds weather green, red, purple, gray-green, or light-tan to rusty.

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[76] Most geologists refer to the Spokane as an argillite.

Purple "mud-flake conglomerate" (clay galls)[77], and mud-cracked, micaceous argillite occur in the upper part of the formation.

Helena Limestone

The Helena Limestone lies conformably upon the Spokane quartzite and ranges in thickness from 1,500 to 6,100 feet. The Helena formation is composed of light-gray and dark blue-gray, petroliferous limestone and dolomitic limestone. The laminae are often much contorted. Some oolitic limestone and thin-bedded, calcareous argillite are present. The basal part of the formation contains an occasional bed of light-tan sandstone, and the upper part contains veins of calcite. The beds weather tan, brown-red, white, or blue-gray.

Miller Peak Argillite

The Miller Peak argillite, the basal formation of the Missoula group, is approximately 1,400 to 2,900 feet in thickness. The formation is composed of alternate zones of purple and green, fine-grained, micaceous argillite and quartzitic argillite, and contains an occasional one- to four-inch bed of massive, white, coarse-grained, siliceous quartzite. Beds of light-gray to light purple, calcareous argillite occur in the lower part of the formation. In the upper part the beds become dominantly purple and increasingly quartzitic. The beds weather purple, green, red, or buff. Ripple marks and mud cracks are common.

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[77] W. H. Twenhofel: Treatise on sedimentation, p. 692 (1932).

especially towards the top of the formation.

Hellgate Quartzite

The only exposure of the Hellgate quartzite is in the southwestern part of the map area in Blackfoot Canyon, and only the lower part of the formation is exposed. The Hellgate quartzite in the map area is composed of pink to gray-white, coarse-grained quartzite which weathers pink, light-tan to white, buff, light-gray, or dull-red. Beds of maroon argillite and mud-flake conglomerate are occasionally present.

Lake Limestone

The Lake limestone ranges from 1,500 to 2,100 feet in thickness. The lower part of the formation consists of green-gray and purple, calcareous argillite and micaceous argillite, gray-green, thin-bedded limestone, purple mud-flake conglomerate, and occasional beds of green-white, siliceous quartzite. East of Cottonwood Lake the basal zone of the formation contains a light-green to brown, fine-grained, slightly calcareous sandstone which weathers green, brown, or red-brown. This sandstone thins northward and is absent in the Blind Canyon Creek section. The middle part of the formation is dominantly gray, green-gray, and buff limestone which weathers buff, brown, gray, or orange-red, is banded light- and dark-green, and in places is dolomitic and siliceous. The upper part of the formation is composed of interbedded gray and gray-green limestone and purple and gray-green, calcareous argillite interbedded in places with gray-green argillitic quartzite.

Evans Quartzite

The Evans quartzite ranges from 10,000 to 16,000 feet in thickness. North of Fish Lake and near the head of Dunham Creek the transition zone between the Lake and Evans formations consists of interbedded pink, purple, and white-gray, fine- and coarse-grained, massive limestone, argillitic limestone, and calcareous argillite. The lower third of the Evans quartzite is composed of bright-red, mud-cracked argillite interbedded with red and white-gray quartzite and mud-flake conglomerate at the base. This interval is overlain by a succession of massive, pink, gray, purple, and buff siliceous quartzite; slightly calcareous quartzite; interbedded purple, micaceous, calcareous argillite; green limestone; and sandy quartzite. Overlying these beds is a succession of green, massive sandstone; fissile, shaly sandstone; and a series of exceedingly thick alternating zones of purple and green, micaceous argillite and pink, white, and purple, massive, cross-bedded, siliceous quartzite and sandy quartzite.

DETAILED STRATIGRAPHIC SECTIONS

The sections are arranged geographicall and are given in order from south to north.

Two sections were measured in detail. One of the sections is located east of Cottonwood Lake, the other near the head of Blind Canyon Creek. A 100 foot steel tape was used for measuring the distances, and a Brunton was used for obtaining the strike and dip, bearing, and slope angle. The thickness was computed from these data.

The part of the type Missoula group section quoted is from Clapp and Deiss.[78] Because the Lake and Lower Evans formations are the equivalent of the Hellgate and part of the McNamara formations, only the Miller Peak, Hellgate, and the lower 2,420 feet of the McNamara sections are quoted in detail. The type section of the Miller Peak argillite[79] is the upper part of "the southern flank of Miller Peak." The type section of the Hellgate quartzite[80] is "on the north side of Mount Sentinel, near the tracks of the Chicago, Milwaukee & St. Paul Railway, from a point about 1½ miles east of the railroad station at Missoula, east along Hellgate Canyon for nearly 1 mile." The type section of the McNamara argillite and quartzite[81] is "along the Blackfoot River in the vicinity of McNamara's Landing."

"The following are the formations which comprise the Missoula group:

	Feet
Sheep Mountain	2,300
Garnet Range	7,600
McNamara	3,000
Hellgate	2,200
Miller Peak	2,900
Total	18,000"[82]

[78] C. H. Clapp and C. F. Deiss: Correlation of Montana Algonkian Formations, Geol. Soc. Am., Bull., vol. 42, pp. 673-696 (1931).

[79] Idem: p. 679.

[80] Idem: pp. 679-680.

[81] Idem: p. 681.

82

The following type sections of the Lower Missoula group formations are quoted exactly from Clapp and Deiss.[83]

Type Sections of Lower Missoula Group Formations

	Feet
<u>Lower two thirds of McNamara formation</u>	
"Red, green, and gray fine-grained, dense, thin-bedded argillite. Sandy beds present near top. Mud cracks common in some beds --	630
Maroon, pale green, and gray fine-grained argillite. Many thin beds of very dense, chertlike green argillite. In general red beds coarser-grained than green beds --------	480
Gray and greenish gray argillitic thin-bedded sandstone. Gray weathering --	90
Massive pink-white quartzite and gray sandy quartzite. Ripple marks common in both beds. Rock weathers to thin plates, and to buff color -------------------------------	100
Massive quartzite interbedded with maroon sandy argillite ----	190
Massive pink-white quartzite. Forms talus slopes of small fragments --	75
Massive pink-white quartzite. Forms talus slopes of large blocks. Buff weathering -------------------------------	300

[83] C. H. Clapp and C. F. Deiss: op. cit, pp. 678-681.

	Feet
"Massive to medium-bedded, pink-gray, finely banded quartzite, with quartz veins up to 1 inch in thickness	105
Massive gray-green coarse-grained sandy quartzite. Cross-bedded, ripple-marked, and with many quartz veinlets. Buff weathering	40
Purple to green-gray micaceous sandy argillite, with thin sandy quartzite beds in the upper part. Buff weathering	410
TOTAL	2,420

Hellgate formation

Massive gray-red siliceous quartzite. Weathers variegated gray, buff, and lavender	365
Massive gray and red-gray fine- to coarse-grained finely banded pure quartzite and sandy quartzite. Ripple marks common	280
Massive thick bedded pink-gray quartzitic sandstone. Buff weathering	1,160
Massive gray fine-grained siliceous quartzite. Ripple marks common. Buff weathering	300
Massive red-gray coarse-grained quartzite, with sandy beds up to 3 feet in thickness. Buff and dull lavender weathering	95
TOTAL	2,200

	Feet
"Miller Peak formation	
Purple massive to thin-bedded argillitic sandstone, and some gray argillite. Lavender to maroon weathering ----------	235
Red and purple sandy argillite, with some beds of green and gray argillite. Occasional beds of argillitic sandstone intercallated between argillite beds --------------------	1,440
Pale green-gray argillitic sandstone ------------------------	85
Purple and green-gray sandy, micaceous argillite; weathers to rusty-buff color on joint faces ------------------------	590
Purple sandy thin-bedded mud-cracked siliceous argillite. Occasional beds of finely micaceous argillite and gray sandy argillite. Beds weather dull red-purple with greenish streaks --	550
TOTAL --	2,900
TOTAL THICKNESS OF SECTIONS ------------------	7,520"

Section $2\frac{1}{3}$ Miles East of Cottonwood Lake

The section occurs along the top of a ridge, the lowest end of which begins at a point $2\frac{1}{4}$ miles S. 56°E. of the south end of Lower Cottonwood Lake. The ridge strikes first N. and then N. E. The section was measured along the part of the ridge which strikes N.E. from a point 5,500 feet in elevation near the center of the N.W. $\frac{1}{4}$, sec. 7, T. 16 N., R. 13 W. along a bearing approximately N. 42°E. to the center of the S. E. ¼, sec. 6, T. 16 N., R. 13 W. at an altitude of 6,600 feet.

	Feet
<u>Lower Evans formation</u>	
Quartzite: pink, white, gray, massive, coarse-grained, siliceous, sandy; weathers pink, white, or gray, and to rounded edges. Interval largely covered ----------------	40
Quartzite: pale-purple, pink, massive, coarse-grained, siliceous, sandy; weathers purple, banded-pink, Interbedded with light-brown, coarse-grained quartzitic sandstone. Occasional bed of dull-purple argillite ----------------	746
Quartzite: pink, gray, buff, massive, coarse-grained, argillitic, sandy. Several beds of pale-purple, more massive quartzite; weathers gray-white. Upper 188 feet of interval contains an occasional bed of dull-purple, micaceous argillite --	475
Quartzite: gray, pink, purple, massive, coarse-grained, argillitic; weathers gray-white or banded-pink. Zones up to 5 feet thick of bright-red, fine-grained, micaceous argillite --	72
Quartzite: pink, gray, buff, pale-purple, massive, coarse-grained, sandy, ripple-marked; weathers gray-white, buff, pink. Bright-red, micaceous, mud-cracked argillite. Quartzite is not banded-pink ----------------------------	127

	Feet
Quartzite: gray, buff, massive, coarse-grained, sandy, argillitic; contains streaks of purple argillite and laminae, ½ inch apart, of pink quartzite. Bright-red, micaceous argillite. All beds weather banded-pink, light-gray, buff, or brown --	57
Covered Interval --	229
Argillite: dull- and bright-purple, bright-red, thin-bedded, shaly, fine-grained, micaceous, mud-cracked. Gray and pale-purple, coarse-grained argillitic quartzite; contains purple and red laminae ----------------------------	35
TOTAL THICKNESS OF MEASURED EVANS FORMATION ----------	1,781

Lake formation

Limestone: gray, green, massive, coarse- and fine-grained, dolomitic, siliceous; weathers gray, buff, or in places to dull-purple. The coarse-grained rocks contain laminae and flakes of purple argillite ---------------------------	88
Limestone: gray, dolomitic. Interval largely covered --------	173
Limestone: gray-green, massive, dolomitic, siliceous; weathers buff, brown, or in places to gray ------------------------	72
Limestone: green, gray, buff, fine-grained, argillitic. Interval largely covered ---------------------------------	432
Limestone: gray, thick- and thin-bedded, fine-grained; weathers gray, buff, brown, or in places to orange-red ---	242

	Feet
Argillite: light-green, massive, fine-grained, in places siliceous. One 4-inch bed of white, massive, coarse-grained, siliceous quartzite --	72
Argillite: green-gray, massive, slightly sandy, quartzitic; contains an occasional lamina of dull-purple argillite. Float of yellow-brown, fine-grained sandstone ------------	78
Argillite: green, in places dull-purple, thick- and thin-bedded, fine-grained, slightly micaceous. Occasional zone of green, thin-bedded, fine- and coarse-grained limestone in lower 75 feet of interval. Upper part of interval contains float of light-green and brown, fine-grained sandstone; weathers green, brown, or red-brown ---	318
TOTAL THICKNESS OF LAKE FORMATION ------------------	1,475

Miller Peak formation

Argillite: light-green, gray, coarse-grained, quartzitic. Interval largely covered ----------------------------------	178
Argillite: dull-purple, light-green, fine-grained, micaceous; weathers brown, green, or purple. Occasional bed of purple, massive, laminated argillitic quartzite. Mud cracks occur in upper and middle parts of interval -------	215
Argillite: purple, thin-bedded, micaceous; contains an occasional ripple mark and mud crack. Basal zone of green, gray, thin-bedded, coarse-grained argillitic quartzite.	

	Feet
Middle part of interval contains white and pale-purple, massive, coarse-grained, siliceous quartzite ------------	130
Argillite: purple, thick- and thin-bedded; contains laminae of light dull-purple, coarse-grained argillite. Gray to white, coarse-grained, siliceous argillitic quartzite -----	74
Argillite: purple, massive. Light-gray argillitic quartzite; contains purple argillite streaks. Two beds, one at top of interval and one 75 feet below top, of purple-white, coarse-grained, siliceous quartzite --------------------	484
Argillite: green, fine-grained; weathers green or brown. One bed of purple, micaceous argillite in upper part of interval --	325
Argillite: purple, light- and dark-green, thin-bedded, micaceous; shows an occasional mud crack and ripple mark. Purple-gray, massive, fine-grained quartzitic argillite; contains laminae and flakes of dull-purple argillite. Occasional bed of light-purple, massive, coarse-grained, siliceous quartzite -------------------------------------	159
TOTAL THICKNESS OF MEASURED MILLER PEAK FORMATION ---	1,[illegible]
TOTAL THICKNESS OF THE SECTION -----------------	4,821

Section Near Head of Blind Canyon Creek

The base of the section is on the north side of an unnamed creek which enters Blind Canyon Creek from the east at the point at which Blind Canyon Creek turns from a north to a west direction. The section was measured from a point 6,950 feet in elevation near the center of the N. E. $\frac{1}{4}$, sec. 14, T. 17 N., R. 14 W. along a bearing approximately N. 75° E. to the Clearwater--South Fork of Flathead Divide at an elevation of 7,500 feet, and then east along the divide to the south boundary of the S. E. $\frac{1}{4}$, sec. 13, T. 17 N., R. 13 W. at an altitude of 7,300 feet.

	Feet
<u>Evans formation</u>	
Argillite: bright-red, thick-bedded, fine- and coarse-grained, mud-cracked. Red and white-gray, massive, coarse-grained quartzite; contains flakes and mud-cracked laminae of bright-red and purple argillite --------	93
TOTAL THICKNESS OF MEASURED EVANS FORMATION --------	93
<u>Lake formation</u>	
Covered Interval --	43
Limestone: gray and light-green, thick- and thin-bedded, siliceous; weathers buff. Many beds of light-green, massive argillitic quartzite; contains laminae of dull-purple argillite. Purple, thin-bedded argillite. Interval largely covered --------------------------------	66

	Feet
Limestone: light-green, in places gray, massive, coarse-grained, siliceous. Light-green argillitic quartzite. Purple, thin-bedded argillite; becomes brighter and red in upper interval ----------	214
Covered Interval ----------	101
Limestone: gray, gray-green, siliceous; weathers gray, buff, brown, or in places orange-red. Upper part of interval is more siliceous than lower part ----------	173
Limestone: gray; weathers gray, buff, brown, or in places orange-red. Upper part of interval contains an occasional bed of gray-green, massive, coarse-grained, quartzitic limestone; weathers gray and light-green ----------	347
Limestone: gray. Interval largely covered ----------	125
Limestone: gray; weathers light-gray, buff, or orange-red ----	257
Limestone: gray; Interval largely covered ----------	138
Limestone: gray, thick- and thin-bedded; weathers buff or gray ----------	41
Limestone: green, thick- and thin-bedded. Interval largely covered ----------	34
Limestone: light- and dark-green, gray, argillitic; weathers green, buff, gray, or in places brown. One 18-inch bed of gray and blue-gray, contorted limestone in middle part of interval ----------	152
Limestone: light- and dark-green, dull-purple, thick- and thin-bedded, quartzitic. Calcareous, micaceous	

	Feet
argillite. All beds weather green, purple, light-brown to light-red, or in places white-green	108
Covered Interval	192
Limestone: light-green, fine- and coarse-grained, ripple-marked	19
Quartzite: light-green and dull-purple, coarse-grained, argillitic; weathers light-green or red. One 4-inch bed of white, coarse-grained, siliceous quartzite. Purple, massive, slightly micaceous, calcareous argillite in lower part of interval; weathers purple, light-brown, or red	19
Limestone: light-gray, light-green, gray-green, light-purple, thick- and thin-bedded. Occasional bed of green and purple, calcareous argillite and quartzite. Bed, 2 feet thick, of dark-gray, contorted appearing limestone 39 feet above base of interval. All beds weather green, gray-green, or purple. No purple argillite seen in upper 46 feet of interval	135
Limestone: dark-gray and blue-gray, massive, contorted; weathers gray, buff, brown, or in places red-brown	8
Argillite: light-green, bright-purple to red, fine-grained, mud-cracked, ripple-marked, micaceous. Interbedded with green limestone and light-green, slightly red-white, massive, coarse-grained, siliceous quartzite. Two 18-inch beds of dark-gray and blue-gray, massive, contorted limestone in upper part of interval	44

	Feet
Limestone: light-green. Calcareous quartzite and micaceous argillite	18
Quartzite: purple-gray, gray, massive, coarse-grained, argillitic; contains laminae of dull-purple, slightly calcareous, micaceous argillite; weathers purple	22
Limestone: light-green, thick- and thin-bedded; weathers green or in places brown-red; shows good ripple marks in lower part of interval. Interbedded with light-green, slightly calcareous quartzite and micaceous argillite. Occasional bed of green-white, coarse-grained, siliceous quartzite	11
TOTAL THICKNESS OF LAKE FORMATION	2,099

Miller Peak formation

Argillite: bright- and dull-purple, fine-grained, micaceous. Purple-gray quartzite; contains argillite laminae	11
Argillite: dull-purple, and light-green, thin-bedded, fine-grained, mud-cracked, micaceous; weathers light-green or in places red-brown. Purple-gray, coarse-grained quartzite; contains laminae of purple to red argillite. One 2-inch and two 4-inch beds of purple-white, coarse-grained, siliceous quartzite. Two zones, each 1 foot thick, of light-green, thin-bedded, calcareous argillite	152
TOTAL THICKNESS OF MEASURED MILLER PEAK FORMATION	163
TOTAL THICKNESS OF THE SECTION	2,433

CORRELATION OF FORMATIONS

The Hellgate quartzite conformably overlies the Miller Peak argillite west of the Mission thrust near Blackfoot Canyon (Pls. 2 & 3). In this place the Hellgate quartzite was probably 2,000 feet in thickness before the upper part was removed by erosion. The former thickness of 2,000 feet is indicated by the 2,200 feet of the Hellgate formation in the type section[83] and by "the persistence and the uniform thickness"[84] of the Missoula group formations over northwestern Montana[85].

East of Fish Lake, six miles north of Blackfoot Canyon, the Lake limestone conformably overlies the Miller Peak argillite and may be 1,000 feet in thickness. Poor exposures prevented the measuring of a section in this vicinity, but farther north, 10 miles from Blackfoot Canyon and 2½ miles east of Lower Cottonwood Lake, a section was measured in detail. In this section the Lake limestone lies conformably upon the Miller Peak argillite, is 1,475 feet in thickness, and is argillaceous and arenaceous in the lower part. On the north slope of Lake

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[83] C. H. Clapp and C. F. Deiss: op. cit., p. 679.

[84] Charles Deiss: Cambrian--Algonkian unconformity in western Montana, Geol. Soc. Am., Bull., vol. 46, p. 97 (1935).

[85] This statement may seem to be contradictory after having given the thickness of the Miller Peak argillite as 1,400 to 2,900 feet, but Clapp and Deiss stated in Montana Algonkian formations (pp. 690-691) that the Miller Peak is about 1,400 feet thick from Prickly Pear Creek to Salmon Lake and is 2,900 feet in thickness in the Missoula section.

Mountain, 16 miles east of the Cottonwood Lake section, the Lake limestone[36] lies conformably upon the Miller Peak argillite, is approximately 1,500 feet in thickness, and is argillaceous and arenaceous in the lower part. Because limestones are deposited more slowly than sands, this change from 2,000 feet of Hellgate quartzite to 1,500 feet of Lake limestone is interpreted as indicating contemporaneous deposition of these two formations. Unfortunately a transition zone, which may have been present in the map area, between the Hellgate and Lake formations has been removed by erosion. Contemporaneous deposition of the Hellgate quartzite and Lake limestone also seems to be indicated by the uniform thickness and lithological character of the underlying Miller Peak argillite, and by the thick transition zones between the Miller Peak and Hellgate and between the Miller Peak and Lake formations.

In the section east of Cottonwood Lake the basal zone of the Lake formation contains much float but no outcrops of light green and brown, fine-grained, slightly calcareous sandstone. This sandstone thins northward and is absent five miles to the north in the Blind Canyon Creek section. The lower part of the Lake formation contains numerous beds of calcareous argillite and, in places, quartzite. These beds are most prominent in the lower 470 feet of the formation in the Cottonwood Lake section and in the lower 250 feet in the Blind Canyon Creek section. The argillaceous, arenaceous, and quartzitic beds in the lower part of the Lake formation may indicate interlapping of the

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[36] C. F. Deiss: personal communication.

Hellgate quartzite and the Lake limestone but no definite conclusion can be made.

Near the head of Blind Canyon Creek, five miles north of the Cottonwood Lake section, the Lake limestone has increased in thickness to 2,100 feet. This increase in thickness of the Lake limestone appears to be partly compensated by the northward thinning of the lower beds of the overlying Evans quartzite.

The transition zone between the Lake and Evans formations is rather thin but no break in sedimentation is apparent.

The Evans quartzite in the Coopers Lake and Ovando quadrangles shows a similar sequence of quartzites and argillites, and is lithologically similar to the McNamara and Garnet Range formations in the type Missoula group section. In these quadrangles the Evans quartzite is tentatively correlated with the McNamara and Garnet Range formations of the type Missoula group.

STRUCTURE

The area lies within the northern geologic division[87] of western Montana. The rocks strike N. 40°W. and dip 10°--45° N.E., in general, and have been broken by one normal strike and four thrust (reverse) strike high-angle faults.

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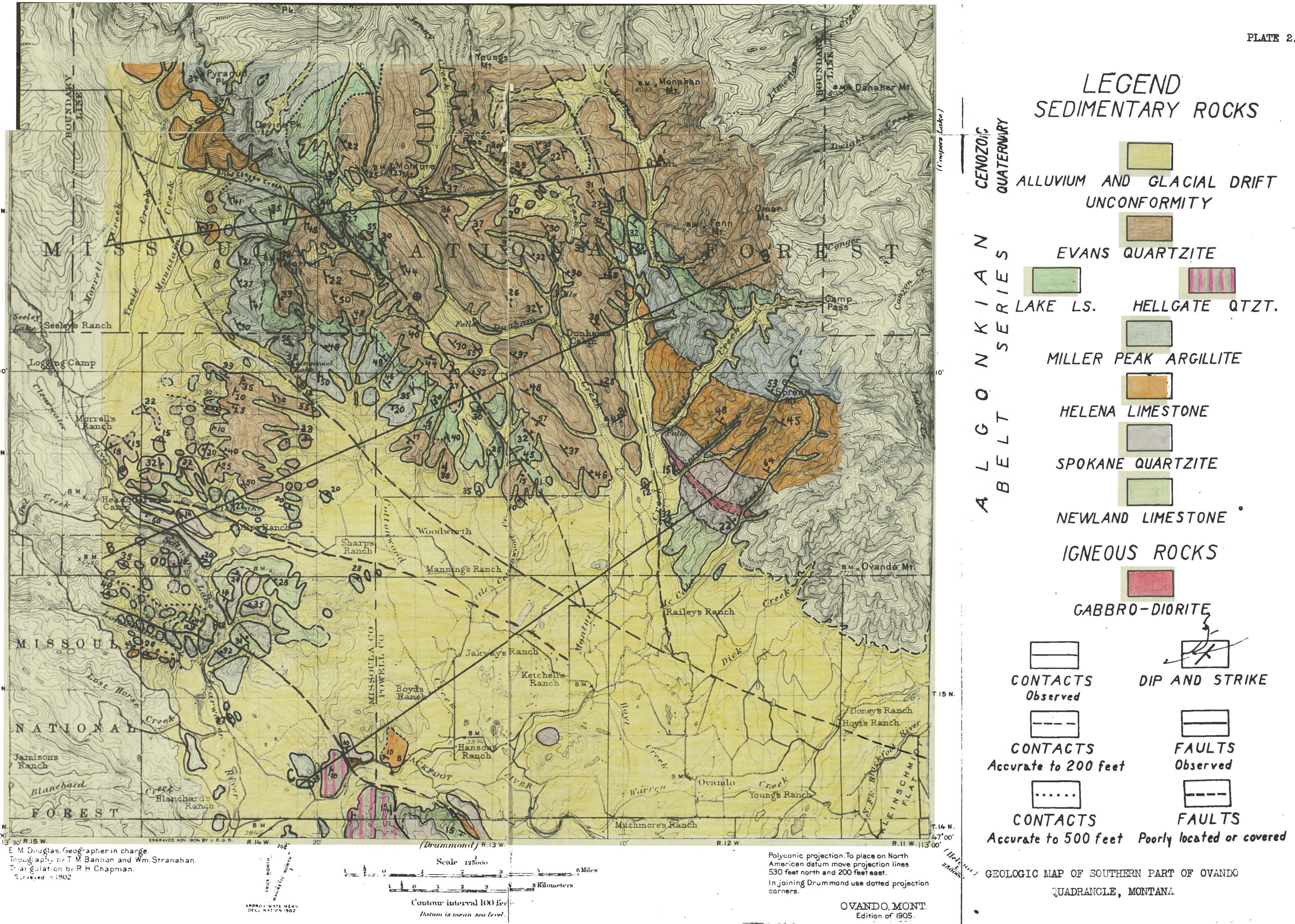
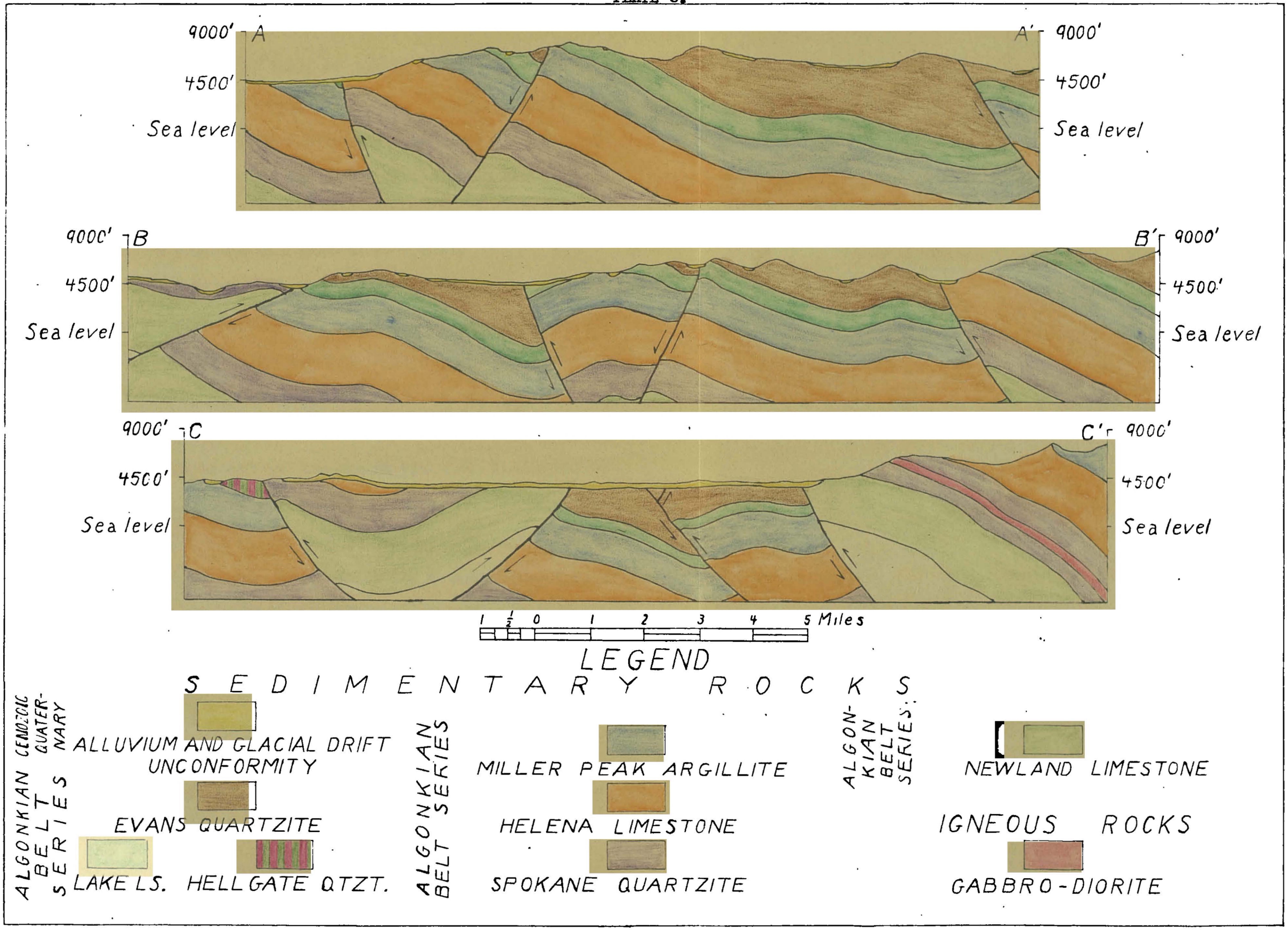
[87] C. H. Clapp: Geology of a portion of the Rocky Mountains of northwestern Montana, Mont. Bur. Mines and Geol., Mem. no. 4, pp. 17-18 (1932).

PLATE 2.



GEOLOGIC MAP OF SOUTHERN PART OF OVANDO QUADRANGLE, MONTANA

PLATE 3.



STRUCTURE SECTIONS OF SOUTHERN PART OF OVANDO QUADRANGLE, MONTANA

The Mission thrust dips 55°N.E., strikes N. 60°W., and crosses the southwest corner of the map area (Pls. 2 & 3). The fault is plainly exposed at the south end of Salmon Lake where the Newland limestone, on the north side of the thrust, has been upthrown against the Miller Peak argillite. At Blackfoot Canyon the Spokane quartzite has been upthrown against the Hellgate quartzite (Pls. 2 & 3).

At Fish Lake, five miles west of Woodworth, a thrust fault, which strikes N. 75°W. and dips approximately 40°S.W., has upthrown the Spokane quartzite against the Lake limestone (Pls. 2 & 3). Because the fault line is covered by glacial drift and alluvium, the fault has not been accurately located.

Between the Mission thrust and the one at Fish Lake is a syncline in which the Newland, Spokane, and Helena formations are exposed (Pls. 2 & 3). Apparently the transition zone in which the quartzite of the Hellgate formation on the south graded laterally into the limestone of the Lake formation on the north lay within this syncline. Unfortunately this transition zone has been eroded from the syncline.

The Swan thrust, which strikes N. 60°W. and dips 70°N.E., extends from the North Fork of Blackfoot River to approximately two miles west of Cottonwood Lake. The fault there apparently turns northward and strikes N. 30°W. to the northwest corner of the map area (Pls. 2 & 3). The fault line is covered by glacial drift and alluvium, but the fault has been fairly accurately located in Cottonwood Valley. The extension of the Swan thrust southeast of Cottonwood Valley was plotted from

Morrell Mt.

Monture Mt.

Figure 1. Semicyclorama south and east from ridge top on southwest side of Blind Canyon Creek. Miller Peak argillite--Evans quartzite contact along a normal fault dipping at right angles to fault-line. The fault appears to be a thrust because the ridges on either side of the fault are at right angles to each other.

C. H. Clapp's[88] map of a portion of northwestern Montana.

A normal fault, the ends of which appear to lie against the Swan thrust (Pls. 2 & 3 and Fig. 1) is well exposed along Blind Canyon Creek and near the head of the first southward flowing stream west of Dunham Creek. The fault dips 70°S.W. and strikes in general N. 45°W. The southwestern side has slipped downwards. The throw reaches a maximum of approximately 2,500 feet but diminishes to almost nothing at each end of the fault.

Dioritic intrusives, too small to map, occur near the normal fault in sec. 22, T. 17 N., R. 14 W. and in sec. 22, T. 16 N., R. 13 W. Such occurences are common[89] in northwestern Montana.

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[88] C. H. Clapp: op. cit., See geologic map at end.

[89] Idem: p. 27.

A thrust fault, which strikes N. 10°--25°W. and dips 60°N.E., extends along Monture Creek Valley (Pls. 2 & 3). From north to south the Newland, Spokane, Helena, Miller Peak, Lake, and Evans formations east of the fault have been upthrown against the Evans formation to the west. The southern end of the fault appears to lie against the Swan thrust (Pls. 2 & 3).

Much of the area, especially in the south and west and at the head of Lodgepole Creek, has been covered by Pleistocene glacial drift, probably of two stages, and by Recent aluvium (Pls. 2 & 3).

CONCLUSIONS

1. The Lake limestone is tentatively correlated with the Hellgate quartzite, and the Evans quartzite with the McNamara and Garnet Range formations.

2. The Lake limestone to the north apparently replaces the Hellgate quartzite.

3. Deposition of the Lake limestone and Hellgate quartzite appears to have been contemporaneous.

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