DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 105

THE LARAMIE AND THE OVERLYING LIVINGSTON FORMATION IN MONTANA

WASHINGTON
GOVERNMENT PRINTING OFFICE
1893

LIBRARY CATALOGUE SLIPS.

Series title.

United States. *Department of the interior.* (*U. S. geological survey*).

Department of the interior | — | Bulletin | of the | United States | geological survey | no. 105 | [Seal of the department] |

Washington | government printing office | 1893

Second title: United States geological survey | J. W. Powell, director | — | The Laramie | and | the overlying Livingston formation in Montana | by | Walter Harvey Weed | with | report on flora | by | Frank Hall Knowlton | [Vignette] |

Washington | government printing office | 1893

8°. 68 pp. 6 pl.

Author title.

Weed (Walter Harvey).

United States geological survey | J. W. Powell, director | — | The Laramie | and | the overlying Livingston formotion in Montana | by | Walter Harvey Weed | with | report on flora | by | Frank Hall Knowlton | [Vignette] |

Washington | government printing office | 1893

8°. 68 pp. 6 pl.

[United States. *Department of the interior.* (*U. S. geological survey*). Bulletin 105.]

Title for subject entry.

United States geological survey | J. W. Powell, director | — | The Laramie | and | the overlying Livingston formation in Montana | by | Walter Harvey Weed | with | report on flora | by | Frank Hall Knowlton | [Vignette] |

Washington | government printing office | 1893

8°. 68 pp. 6 pl.

[United States. *Department of the interior.* (*U. S. geological survey*). Bulletin 105.]

ADVERTISEMENT.

[Bulletin No. 105.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization; and the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (734) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this office has no copies for gratuitous distribution.

ANNUAL REPORTS.

I. First Annual Report of the United States Geological Survey, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Second Annual Report of the United States Geological Survey, 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 62 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883-'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

VI. Sixth Annual Report of the United States Geological Survey, 1884-'85, by J. W. Powell. 1885. 8°. xxix, 570 pp. 65 pl. and maps.

VII. Seventh Annual Report of the United States Geological Survey, 1885-'86, by J. W. Powell. 1888. 8°. xx, 656 pp. 71 pl. and maps.

VIII. Eighth Annual Report of the United States Geological Survey, 1886-'87, by J. W. Powell. 1889. 8°. 2 pt. xix, 474, xii pp. 53 pl. and maps; 1 p. l., 475-1063 pp. 54-76 pl. and maps.

IX. Ninth Annual Report of the United States Geological Survey, 1887-'88, by J. W. Powell. 1889. 8°. xiii, 717 pp. 88 pl. and maps.

X. Tenth Annual Report of the United States Geological Survey, 1888-'89, by J. W. Powell. 1890. 8°. 2 pt. xv, 774 pp. 98 pl. and maps; viii, 123 pp.

XI. Eleventh Annual Report of the United States Geological Survey, 1889-'90, by J. W. Powell. 1891. 8°. 2 pt. xv, 757 pp. 66 pl. and maps; ix, 351 pp. 30 pl.

XII. Twelfth Annual Report of the United States Geological Survey, 1890-'91, by J. W. Powell. 1891. 8°. 2 pt. xiii, 675 pp. 53 pl. and maps; xviii, 576 pp. 146 pl. and maps.

XIII. Thirteenth Annual Report of the United States Geological Survey, 1891-'92, by J. W. Powell, 1893. 8°. 3 pt.

MONOGRAPHS.

I. Lake Bonneville, by Grove Karl Gilbert. 1890. 4°. xx, 438 pp. 51 pl. 1 map. Price $1.50.

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.00.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.00.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. The Copper-Bearing Rocks of Lake Superior, by Roland Duer Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. and maps. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by William Morris Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph Story Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles Doolittle Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. 1 map. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1886. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. and maps. Price $1.75.

XII. Geology and Mining Industry of Leadville, Colorado, with atlas, by Samuel Franklin Emmons. 1886. 4°. xxix, 770 pp. 45 pl. and atlas of 35 sheets folio. Price $8.40.

XIII. Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker. 1888. 4°. xix, 486 pp. 7 pl. and atlas of 14 sheets folio. Price $2.00.

XIV. Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley, by John S. Newberry. 1888. 4°. xiv, 152 pp. 26 pl. Price $1.00.

XV. The Potomac or Younger Mesozoic Flora, by William Morris Fontaine. 1889. 4°. xiv, 377 pp. 180 pl. Text and plates bound separately. Price $2.50.

XVI. The Paleozoic Fishes of North America, by John Strong Newberry. 1889. 4°. 340 pp. 53 pl. Price $1.00.

XVII. The Flora of the Dakota Group, a posthumous work, by Leo Lesquereux. Edited by F. H. Knowlton. 1891. 4°. 400 pp. 66 pl. Price $1.10.

XVIII. Gasteropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1891. 4°. 402 pp. 50 pl. Price $1.00.

XIX. The Penokee Iron-Bearing Series of Northern Wisconsin and Michigan, by Roland D. Irving and C. R. Van Hise. 1892. 4°. xix, 534 pp. 37 pl.

XX. Geology of the Eureka District, Nevada, with atlas, by Arnold Hague. 1892. 4°. 419 pp. 8 pl.

In press:

XXI. The Tertiary Rhynchophorous Coleoptera of North America, by Samuel Hubbard Scudder.

XXII. A Manual of Topographic Methods, by Henry Gannett, chief topographer.

XXIII. Geology of the Green Mountains in Massachusetts, by Raphael Pumpelly, J. E. Wolff, T. Nelson Dale, and Bayard T. Putnam.

In preparation:

— Mollusca and Crustacea of the Miocene Formations of New Jersey, by R. P. Whitfield.
— Sauropoda, by O. C. Marsh.
— Stegosauria, by O. C. Marsh.
— Brontotheridæ, by O. C. Marsh.
— Report on the Denver Coal Basin, by S. F. Emmons.
— Report on Silver Cliff and Ten-Mile Mining Districts, Colorado, by S. F. Emmons.
— The Glacial Lake Agassiz, by Warren Upham.

BULLETINS.

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.
2. Gold and Silver Conversion Tables, giving the coining value of troy ounces of fine metal, etc., computed by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.
3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.
4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.
5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.
6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.
7. Mapoteca Geologica Americana. A Catalogue of Geological Maps of America (North and South). 1752–1881, in geographic and chronologic order, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.
8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.
9. A report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist. T. M. Chatard, assistant chemist. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call. Introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, with a Historical Sketch of the Territorial Changes, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the Higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, with notes on the Geology of the District, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation. A Report on the Region between the Grand and Moreau Rivers, Dakota, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary Fossils and recent forms from American Localities between Cape Hatteras and Cape Roque, including the Bermudas, by William Healy Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Maryland, by George Huntington Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second Contribution to the Studies on the Cambrian Faunas of North America, by Charles Doolittle Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. Systematic Review of our Present Knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel Hubbard Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a Preliminary Study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by J. S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of Fine Solid Particles in Liquids, by Carl Barus. 1886. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by J. S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis. 1887. 8°. 10 pp. 4 pl. Price 5 cents.

41. On the Fossil Faunas of the Upper Devonian—the Genesee Section, New York, by Henry S. Williams. 1887. 8°. 121 pp. 4 pl. Price 15 cents.

42. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist. 1887. 8°. 152 pp. 1 pl. Price 15 cents.

43. Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson. 1887. 8°. 189 pp. 21 pl. Price 15 cents.

44. Bibliography of North American Geology for 1886, by Nelson H. Darton. 1887. 8°. 35 pp. Price 5 cents.

45. The Present Condition of Knowledge of the Geology of Texas, by Robert T. Hill. 1887. 8°. 94 pp. Price 10 cents.

46. Nature and Origin of Deposits of Phosphate of Lime, by R. A. F. Penrose, jr., with an Introduction by N. S. Shaler. 1888. 8°. 143 pp. Price 15 cents.

47. Analyses of Waters of the Yellowstone National Park, with an Account of the Methods of Analysis employed, by Frank Austin Gooch and James Edward Whitfield. 1888. 8°. 84 pp. Price 10 cents.

48. On the Form and Position of the Sea Level, by Robert Simpson Woodward. 1888. 8°. 88 pp. Price 10 cents.

49. Latitudes and Longitudes of Certain Points in Missouri, Kansas, and New Mexico, by Robert Simpson Woodward. 1889. 8°. 133 pp. Price 15 cents.

50. Formulas and Tables to facilitate the Construction and Use of Maps, by Robert Simpson Woodward. 1889. 8°. 124 pp. Price 15 cents.

51. On Invertebrate Fossils from the Pacific Coast, by Charles Abiathar White. 1889. 8°. 102 pp. 14 pl. Price 15 cents.

52. Subaërial Decay of Rocks and Origin of the Red Color of Certain Formations, by Israel Cook Russell. 1889. 8°. 65 pp. 5 pl. Price 10 cents.

53. The Geology of Nantucket, by Nathaniel Southgate Shaler. 1889. 8°. 55 pp. 10 pl. Price 10 cents.

54. On the Thermo-Electric Measurement of High Temperatures, by Carl Barus. 1889. 8°. 313 pp. incl. 1 pl. 11 pl. Price 25 cents.

55. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1886–'87. Frank Wigglesworth Clarke, chief chemist. 1889. 8°. 96 pp. Price 10 cents.

56. Fossil Wood and Lignite of the Potomac Formation, by Frank Hall Knowlton. 1889. 8°. 72 pp. 7 pl. Price 10 cents.

57. A Geological Reconnaissance in Southwestern Kansas, by Robert Hay. 1890. 8°. 49 pp. 2 pl. Price 5 cents.

58. The Glacial Boundary in Western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois, by George Frederick Wright, with an introduction by Thomas Chrowder Chamberlin. 1890. 8°. 112 pp. incl. 1 pl. 8 pl. Price 15 cents.

59. The Gabbros and Associated Rocks in Delaware, by Frederick D. Chester. 1890. 8°. 45 pp. 1 pl. Price 10 cents.

60. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1887–'88. F. W. Clarke, chief chemist. 1890. 8°. 174 pp. Price 15 cents.

61. Contributions to the Mineralogy of the Pacific Coast, by William Harlowe Melville and Waldemar Lindgren. 1890. 8°. 40 pp. 3 pl. Price 5 cents.

62. The Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan; a contribution to the subject of dynamic metamorphism in eruptive rocks, by George Huntington Williams; with an introduction by Roland Duer Irving. 1890. 8°. 241 pp. 16 pl. Price 30 cents.

63. A Bibliography of Paleozoic Crustacea from 1698 to 1889, including a list of North American species and a systematic arrangement of genera, by Anthony W. Vogdes. 1890. 8°. 177 pp. Price 15 cents.

64. A report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1888–'89. F. W. Clarke, chief chemist. 1890. 8°. 60 pp. Price 10 cents.

65. Stratigraphy of the Bituminous Coal Field of Pennsylvania, Ohio, and West Virginia, by Israel C. White. 1891. 8°. 212 pp. 11 pl. Price 20 cents.

66. On a Group of Volcanic Rocks from the Tewan Mountains, New Mexico, and on the occurrence of Primary Quartz in certain Basalts, by Joseph Paxson Iddings. 1890. 8°. 34 pp. Price 5 cents.

67. The Relations of the Traps of the Newark System in the New Jersey Region, by Nelson Horatio Darton. 1890. 8°. 82 pp. Price 10 cents.

68. Earthquakes in California in 1889, by James Edward Keeler. 1890. 8°. 25 pp. Price 5 cents.

69. A Classed and Annotated Bibliography of Fossil Insects, by Samuel Hubbard Scudder. 1890. 8°. 101 pp. Price 15 cents.

70. Report on Astronomical Work of 1889 and 1890, by Robert Simpson Woodward. 1890. 8°. 79 pp. Price 10 cents.

71. Index to the Known Fossil Insects of the World, including Myriapods and Arachnids, by Samuel Hubbard Scudder. 1891. 8°. 744 pp. Price 50 cents.

72. Altitudes between Lake Superior and the Rocky Mountains, by Warren Upham. 1891. 8°. 229 pp. Price 20 cents.

73. The Viscosity of Solids, by Carl Barus. 1891. 8°. xii, 139 pp. 6 pl. Price 15 cents.

74. The Minerals of North Carolina, by Frederick Augustus Genth. 1891. 8°. 119 pp. Price 15 cents.

75. Record of North American Geology for 1887 to 1889, inclusive, by Nelson Horatio Darton. 1891. 8°. 173 pp. Price 15 cents.

76. A Dictionary of Altitudes in the United States (second edition), compiled by Henry Gannett, chief topographer. 1891. 8°. 393 pp. Price 25 cents.

77. The Texan Permian and its Mesozoic Types of Fossils, by Charles A. White. 1891. 8°. 51 pp, 4 pl. Price 10 cents.

78. A report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1889-'90. F. W. Clarke, chief chemist. 1891. 8°. 131 pp. Price 15 cents.

79. A Late Volcanic Eruption in Northern California and its Peculiar Lava, by J. S. Diller. 1891. 8°. 33 pp. 17 pl. Price 10 cents.

80. Correlation papers—Devonian and Carboniferous, by Henry Shaler Williams. 1891. 8°. 279 pp. Price 20 cents.

81. Correlation papers—Cambrian, by Charles Doolittle Walcott. 1891. 8°. 447 pp. 3 pl. Price 25 cents.

82. Correlation papers—Cretaceous, by Charles A. White. 1891. 8°. 273 pp. 3 pl. Price 20 cents.

83. Correlation papers—Eocene, by William Bullock Clark. 1891. 8°. 173 pp. 2 pl. Price 15 cents.

84. Correlation papers—Neocene, by W. H. Dall and G. D. Harris. 1892. 8°. 349 pp. 3 pl. Price 25 cents.

85. Correlation papers—The Newark System, by Israel Cook Russell. 1892. 8°. 344 pp. 13 pl. Price 25 cents.

86. Correlation papers—Archean and Algonkian, by C. R. Van Hise. 1892. 8°. 549 pp. 12 pl. Price 25 cents.

90. A report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1890-'91. F. W. Clarke, chief chemist. 1892. 8°. 77 pp. Price 10 cents.

91. Record of North American Geology for 1890, by Nelson Horatio Darton. 1891. 8°. 88 pp. Price 10 cents.

92. The Compressibility of Liquids, by Carl Barus. 1892. 8°. 96 pp. 29 pl. Price 10 cents.

93. Some insects of special interest from Florissant, Colorado, and other points in the Tertiaries of Colorado and Utah, by Samuel Hubbard Scudder. 1892. 8°. 35 pp. 3 pl. Price 5 cents.

94. The Mechanism of Solid Viscosity, by Carl Barus. 1892. 8°. 138 pp. Price 15 cents.

95. Earthquakes in California in 1890 and 1891, by Edward Singleton Holden. 1892. 8°. 31 pp. Price 5 cents.

96. The Volume Thermodynamics of Liquids, by Carl Barus. 1892. 8°. 100 pp. Price 10 cents.

97. The Mesozoic Echinodermata of the United States, by W. B. Clark. 1893. 8°. 207 pp. 50 pl. Price 20 cents.

98. Flora of the Outlying Carboniferous Basins of Southwestern Missouri, by David White. 1893. 8°. 139 pp. 5 pl. Price 15 cents.

99. Record of North American Geology for 1891, by Nelson Horatio Darton. 1892. 8°. 73 pp. Price 15 cents.

100. Bibliography and Index of the publications of the U. S. Geological Survey, 1879-1892, by Philip Creveling Warman. 8°. 495 pp. Price 25 cents.

101. Insect Fauna of the Rhode Island Coal Field, by Samuel Hubbard Scudder. 1893. 8°. 27 pp. 2 pl. Price 5 cents.

104. Glaciation of the Yellowstone Valley north of the Park, by W. H. Weed. 1893. 8°. 41 pp. 4 pl. Price 5 cents.

105. The Laramie and the overlying Livingston Formation in Montana, by Walter Harvey Weed, with Report on Flora, by Frank Hall Knowlton. 1893. 8°. 68 pp. 6 pl. Price 10 cents.

108. A Geological Reconnoissance in Central Washington, by Israel Cook Russell. 1893. 8°. 108 pp. 12 pl. Price 15 cents.

In press:

102. A Catalogue and Bibliography of North American Mesozoic Invertebrata, by C. B. Boyle.

103. High Temperature Work in Igneous Fusion and Ebullition, chiefly in relation to pressure, by Carl Barus.

106. The Colorado Formation and its Invertebrate Fauna, by T. W. Stanton.

107. The Trap Dikes of Lake Champlain Valley and the Eastern Adirondacks, by J. F. Kemp.

109. The Eruptive and Sedimentary Rocks on Pigeon Point, Minnesota, and their contact phenomena, by W. S. Bayley.

110. The Paleozoic Section in the vicinity of Three Forks, Montana, by A. C. Peale.

In preparation:

— The Moraines of the Missouri Coteau, and their attendant deposits, by James Edward Todd.

— On the Structure of the Ridge between the Taconic and the Green Mountain Ranges in Vermont; and On the Structure of Monument Mountain in Great Barrington, Mass., by T. Nelson Dale.

— A Bibliography of Paleobotany, by David White.

STATISTICAL PAPERS.

Mineral Resources of the United States, 1882, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

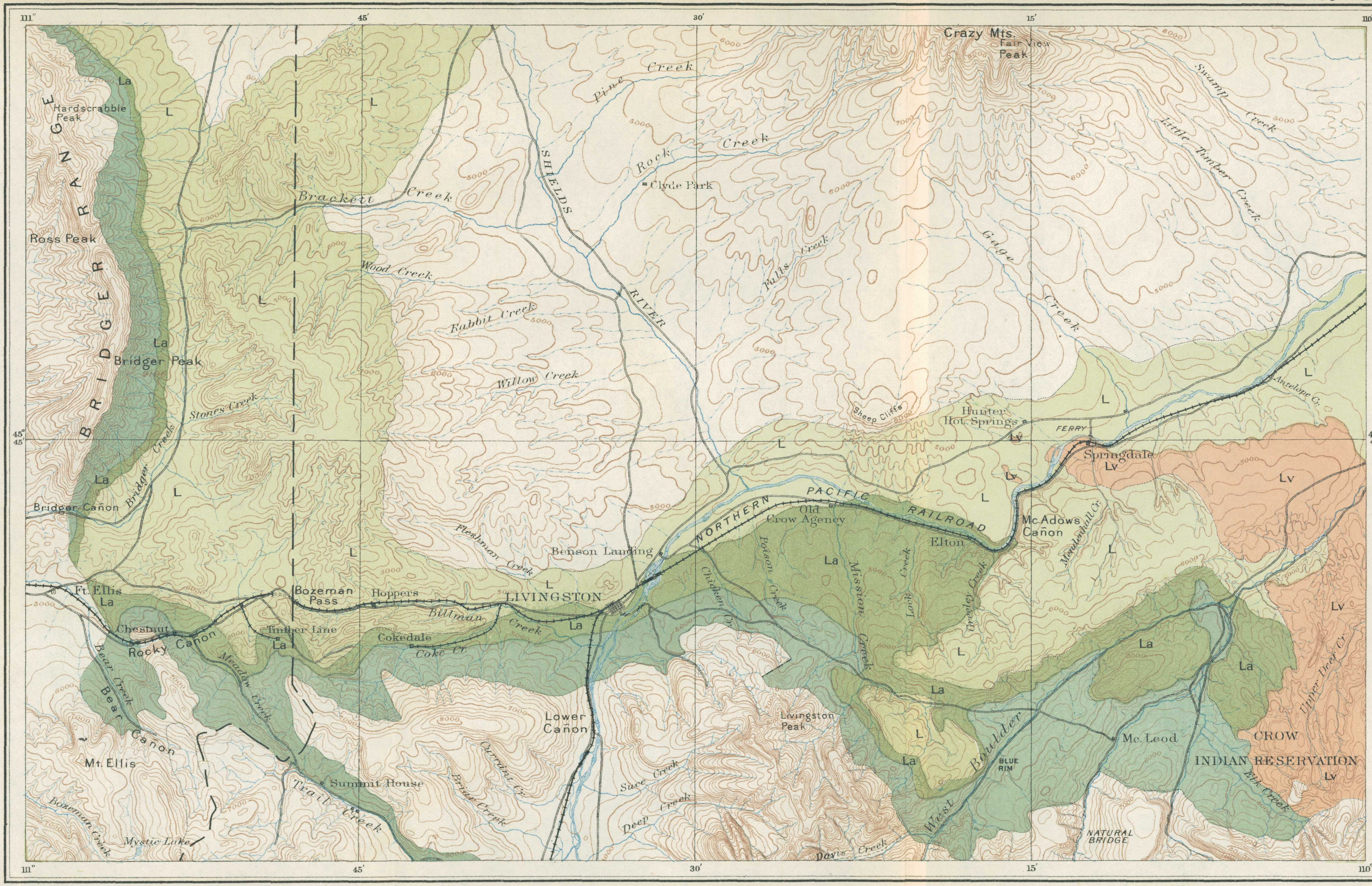
Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°. viii, 813 pp. Price 50 cents.
Mineral Resources of the United States, 1887, by David T. Day. 1888. 8°. vii, 832 pp. Price 50 cents.
Mineral Resources of the United States, 1888, by David T. Day. 1890. 8°. vii, 952 pp. Price 50 cents.
Mineral Resources of the United States, 1889 and 1890, by David T. Day. 1892. 8°. viii, 671 pp. Price 50 cents.
Mineral Resources of the United States, 1891, by David T. Day. 1893. 8°. vii, 630 pp. Price 50 cents.

In preparation:
Mineral Resources of the United States, 1892.

The money received from the sale of these publications is deposited in the Treasury, and the Secretary of the Treasury declines to receive bank checks, drafts, or postage stamps; all remittances, therefore, must be by POSTAL NOTE or MONEY ORDER, made payable to the Chief Clerk of the U. S. Geological Survey, or in CURRENCY, for the exact amount. Correspondence relating to the publications of the Survey should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *June, 1893.*



Distribution of
CRETACEOUS FORMATIONS NEAR LIVINGSTON, MONTANA.

SCALE. CONTOUR INTERVALS 200 FT.

L. Livingston — Lv. Livingston Agglomerates — La. Laramie — Montana Colorado

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 105

WASHINGTON
GOVERNMENT PRINTING OFFICE
1893

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE LARAMIE

AND

THE OVERLYING LIVINGSTON FORMATION IN MONTANA

BY

WALTER HARVEY WEED

WITH

REPORT ON FLORA

BY

FRANK HALL KNOWLTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1893

CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
YELLOWSTONE NATIONAL PARK DIVISION.
Washington, D. C., July 18, 1892.

SIR: I take pleasure in transmitting, herewith, a paper by Mr. Walter H. Weed, entitled "The Laramie and the overlying Livingston Formation in Montana," with a report upon their Flora, by Mr. Frank H. Knowlton.

In working out the geology of the Cordillera there are no more important chapters than those that relate to the physical history of the Laramie and the overlying formation. These rocks are well developed in the Yellowstone valley, between the Bridger, Snowy, and Crazy mountains, and Mr. Weed has devoted much time to their study, embodying the results of his investigations in the present paper. He presents most forcible reasons for dividing the great thickness of beds which have heretofore been included in the Laramie into two distinct horizons, restricting the use of the term "Laramie" to the sandstones conformable to the underlying marine Cretaceous, and designating the overlying unconformable beds as "the Livingston formation." The physical conditions shown in the Yellowstone valley are strikingly in accord with those described by Mr. Cross along the Front range in Colorado. It is by such detailed studies that we shall finally arrive at the true geological limits of the Laramie formation.

In the accompanying paper Mr. Knowlton admirably supplements the work of Mr. Weed. He discusses the fossil flora from both horizons in the Yellowstone valley, reviewing all the material obtained since 1871. The two papers taken together form an important contribution to our knowledge of these beds.

I take pleasure in recommending its publication as a Bulletin of the U. S. Geological Survey.

Yours, very respectfully,

ARNOLD HAGUE,
Geologist in Charge.

HON. J. W. POWELL,
Director U. S. Geological Survey.

OUTLINE OF PAPER.

Briefly summarized, this paper gives an account of a series of beds heretofore embraced within the Laramie, and covering the greater part of the state of Montana east of the Rocky mountains. It is shown that the thickness of some 13,000 feet of sandstone shales and conglomerates belong to three formations: the Laramie, the overlying Livingston, and the higher Fort Union beds. The Laramie is briefly described, and an account given of the overlying series of strata composed of water-laid and assorted volcanic material, which are named the Livingston beds. Observations prove that these beds overlie the coal-bearing true Laramie rocks, and that they contain intercalated beds of true volcanic agglomerate. The entire Livingston formation is overlain by a great thickness of beds of fresh-water sandstones, of which the Crazy mountains are formed, which are believed to be of Fort Union age. Stratigraphical evidence is presented to show that the Livingston beds are of post-Laramie age, yet older than and distinct from the Fort Union Eocene. Evidence is given showing an uplift with erosion during the accumulation of the Livingston beds, and after the formation of the Laramie coal beds, and it is shown from the composition of the conglomerates and their relation to the consolidated ejectamenta of explosive volcanic eruptions and from the nature of the overlying beds forming the Crazy mountains, that we have undoubted proof of powerful dynamic movements, accompanied by an eruptive activity following soon after the epoch of the coal-bearing Laramie, and marking the inception of that long period of volcanic action which continued with various interruptions into Pleistocene times, and formed the great volcanic area of the Yellowstone National park.

THE LARAMIE AND THE OVERLYING LIVINGSTON FORMATION OF MONTANA.

By WALTER HARVEY WEED.

INTRODUCTION.

The region of the Great Plains which forms the eastern portion of Montana and the Cordilleran region of the western part of the state, present widely different types of scenery and geological structure. The first is but a continuation of the broad trans-Mississippian plains stretching northward along the eastern front of the Rocky mountains far into Canadian territory. The latter is a complex of mountain ranges, where the folding and faulting of the rocks is both intricate and obscure. It is with a portion of the border line between these two sharply contrasted regions that the present paper deals, a region where the slightly folded rocks of the plains are warped and crumpled upon the flanks of the mountains that form the easternmost portion of the Cordilleran area.

In the foothill country, lying at the base of the mountains south of the Yellowstone river, near Livingston, Montana, a series of water-laid strata, composed mainly of volcanic detritus and overlying the coal-bearing Laramie beds, was observed by the writer in 1890, while studying the geology of the region, in continuation of the work of the Yellowstone park survey. Further exploration proved that the series covers a large part of this region and is separable lithologically and by evidences of unconformity into a distinct formation.

Measured sections of the strata about the Crazy mountains show a thickness of 12,000 feet of fresh water sandstones and clays referred to the Laramie. It is now possible to subdivide this great thickness of beds into Laramie, a higher horizon herein named the Livingston, and the still higher beds of the Crazy mountains, which have not as yet been differentiated into horizons, but probably represent the Fort Union beds of eastern Montana.

These beds present proof of a series of events following the epoch of the coal-making Laramie similar to those described by Whitman Cross,[1]

[1] The Denver Tertiary Formation. Amer. Journ. Sci., vol. XXXVII, April, 1889. Post-Laramie Deposits of Colorado. Am. Jour. Sci., XLIV, July, 1892.

in Colorado, of which the Arapahoe and the Denver beds are the evidence. The importance of this post-Laramie elevation and erosion with accompanying volcanic activity has been strongly insisted upon by Mr. Emmons,[1] and is confirmed by rapidly accumulating evidence observed in different parts of Colorado.[2]

The strata described in the present paper, though differing in many points from those of Colorado, attest a somewhat similar period, and afford the first recognition of the epoch outside of Colorado.

In this part of Montana the orographic movements that produced the Rocky mountain ranges were accompanied by periods of volcanic activity prolonged into late Tertiary time, which resulted in the accumulation of vast quantities of agglomerates, breccia, and lava flows, out of which great mountain ranges have been carved. These volcanic accumulations have been studied for many years in the region of the Yellowstone park and the adjacent country, where they rest upon Archean gneisses, eroded Paleozoic limestones, and Cretaceous sandstone alike, but no definite age could be assigned to the beginning of this long period of disturbance and volcanic activity.

Examinations of the Laramie and post-Laramie strata east of Livingston showed that these beds were several thousand feet thick, and included an intercalation of volcanic agglomerate that represents, in part, the source of the sands and pebbles of the stratified rocks. As the water-laid beds of the series contain determinable plant remains and a scanty fresh-water fauna, they possess decided interest in the light they throw upon the age at which the remarkable series of volcanic eruptions of this region began.

GEOGRAPHY OF THE REGION.

The region in which these formations have thus far been mapped and studied embraces a part of the Rocky mountains and the country eastward. Geographically the region is an interesting one, embracing the headwaters of the Missouri river, and its great tributary, the Yellowstone. The country north of the Yellowstone National park, with that about the headwaters of the Missouri, is a mountainous tract, through which the Yellowstone and the three rivers that uniting form the Missouri, have cut valleys that divide this elevated area into north and south ranges, known as the Snowy mountains and the Gallatin, Madison, and Jefferson ranges. These mountains end abruptly northward in the Yellowstone and in the Three Forks valleys, but the front range of the Rocky mountains is continued north of the Gallatin range by the lesser uplift of the Bridger, which with the lower elevations of Sixteen-mile creek connect the southerly ranges with the Big Belt and Little Belt mountains. The Snowy mountains, which inclose the park

[1] Bull. Geol. Soc. Amer., vol. I, 1890, pp. 245-280.

[2] R. C. Hills, Proc. Col. Sci. Soc., 1890.

upon the north, are encircled by the Yellowstone river, whose broad valley about Livingston is typical of its further course.

North of the Yellowstone river are the Crazy mountains, a strikingly picturesque and rugged group of peaks. They form an isolated mountain mass standing out prominently by themselves, and separated by wide valleys from the front ranges of the Rockies that encircle them on three sides. In the Crazy mountains and the valleys between them and flanks of the adjacent ranges the formations herein described attain their most interesting development. The southernmost part of this region has been called the Bozeman coal field, as it is an area distinguished by the occurrence of the productive Coal-measures of the Laramie lying east of the city of Bozeman. The "field" is adjacent to the Northern Pacific railroad and is situated 50 miles north of the Montana boundary line, embracing the entire foothill country between the Yellowstone river and the mountains to the south, from Big Timber to Livingston, as well as the rugged country westward, forming the Missouri-Yellowstone divide and the foot slopes of the Bridger range. The mountains bounding the field upon the south are steep and rugged peaks belonging to the Snowy range, through which the larger streams have cut deep canyons on their way to the lower country of the plains. The largest of these streams is the Yellowstone river, which, after leaving the Yellowstone park, flows through a couple of picturesque mountain valleys and intervening canyons and emerges from the mountain region at Livingston. West of this point the railroad follows up a small stream to the Muir tunnel, which gives access to the Missouri drainage, the coal-bearing strata forming a belt south of the railroad as far as Rocky canyon, where they turn northward and are continued along the base of the Bridger mountains and the low uplifts that connect this range with the Little Belt mountains.

GENERAL GEOLOGY.

The structural features of the region present several peculiarities of interest. The mountains lying between the National Park and the Yellowstone river, known as the Snowy range, consist in the main of Archean rocks and volcanic accumulations. The northern peaks of the range show Paleozoic rocks dipping steeply to the northward away from the Archean plateaus. The canyons cut by the streams that issue from the mountains show an S-shaped fold parallel to the mountain front, and modified by a tendency to en échelon folding. Faulting of this fold has brought up Archean rocks, which form high and sharp peaks entirely surrounded by Paleozoic rocks. West of Livingston the warping takes the form of a succession of short anticlinal folds arranged en échelon, with a northeast trend, their axes dipping more or less steeply in the same direction. These folds end in the overturn forming Mount Ellis and the south end of the Bridger range. Nowhere is the relation between geologic structure and topographic relief more clearly shown, and the cutting across of the anticlinal folds by the mountain streams clearly reveals the details of their structure.

The Bridger range is a fold involving the Livingston and all earlier rocks, of which the eastern side alone now remains. The low mountains northward show parallel anticlinal folds, running north and south, broken through in the Elk mountains by an extensive intrusion of quartz porphyrite. In the extensive synclinal basin thus inclosed upon three sides by the uplifts of these front ranges of the Rocky mountains, the Crazy mountains, form a magnificent monument of erosion. The main mass of these mountains is formed by a synclinal of post-Laramie strata, in which the sedimentary rocks have been baked and metamorphosed about a great core of igneous rock, from which dikes radiate on every side.[1]

The geology of the Gallatin, Madison and Jefferson ranges, defined by the three forks of the Missouri, is discussed by Dr. A. C. Peale in the text of the Three Forks Atlas sheet of the U. S. Geological Survey.

A number of carefully measured sections were made at different localities, from a study of which and the review of the fossil remains thus far collected, the different terranes have been discriminated. The following section represents the entire stratigraphic series from Cambrian to post-Laramie as developed in the region under discussion.

---

[1] Geology of the Crazy mountains, Montana, J. E. Wolff, Bull. Geol. Soc. Amer., vol. 3, pp. 445-452.

Geological series exposed near Livingston, Montana.

7,000		Livingston beds—sandstones, shales, and conglomerates.
4,700	1,000	Laramie coal-bearing sandstones and shales; leaf remains, and invertebrates.
	1,500	Montana—sandy shales and argillaceous shales.
	1,600	Colorado—argillaceous limestones, with bituminous shales at base.
	600	Dakota—sandstones and conglomerates.
460	-------	Jura: Sandstones. Limestones and shales.
1,900	400	Carboniferous: Quartzites, sandstones, and interbedded limestones.
	1,500	Carboniferous: Limestones, massive, fossiliferous.
450	250	Devonian: Limestones and shales.
	200	Devonian: Limestones—very massive.
835	410	Cambrian: Limestones, generally massive, with limestone conglomerate, alternating with shales.
	425	Cambrian: Soft shales, with interbedded impure limestones and basal quartzite.
		Algonkian schists.

The section is well exposed in the canyon of the Yellowstone, 4 miles south of Livingston.

THE MESOZOIC SECTION.

A detailed section of the strata overlying the Jurassic limestones has already been published by the writer, but is republished herewith in greater detail, in order that the nature of the Laramie and its relations to the underlying Mesozoic and overlying Mission creek beds may be fully understood. It represents the series as exposed near the town of Cokedale, some 10 miles west of Livingston.

This section was measured on the slopes west of the south fork of Cokedale creek, and begins at the point where this stream cuts across the anticline of Canyon mountain and exposes the Jurassic shales and limestones.[1] A section of the strata in this vicinity was made for the Northern Transcontinental Survey, a graphic representation of which is published in the very interesting account of the Bozeman coal field written by Mr. G. H. Eldridge.[2]

Section at Cokedale, Montana.

		Chocolate conglomerate, 400′ above coal-seam horizon.
		Shaly beds; chocolate-colored.
	30	Conglomerate—local and passing into sandstone; volcanic.
LARAMIE.	2	Limestone.
	210	Sandstone, shaly.
	6	Coal (seam worked at Cokedale).
	112	Sandstones.
	20	Sandstone ledge; fissile; crest.
	575	Sandstone; thick beds alternating with thin seams of shale and coal.
	75	Bluff sandstones; massive, white, etc.
MONTANA.	150	Tombstone sandstones.
	1149	*f* shaly beds ... 175 *e* sandy shales; dark gray ... 245 *d* shales and thin layers of sandstone . 315 *c* shaly sandstone ... 40 *b* sandstone shale ... 112 *a* shale ... 262
	25	Sandstone, forming crest ledge of 2′–6′ (25′ near creek); very prominent; pitted, and outcrops marked by pines.
COLORADO.	300	Shaly beds, weathering down to brown earth with intercalated sandstones. { *e* shales 195; *d* sandstone 3; *c* shales 50; *b* sandstone 2; *a* shales 40 }
	30	Sandstone; big ledge, but not showing on summit of hill; conglomerate at top.
	350	Shales; gray; sandy.
	7	Yellow sandstone, fine-grained and fissile, forming striking topographical feature of this depression.
	247	Shales marked by sharply cut gully.
	12	Sandstone ledge; gray, very fissile; massive crop, and not generally a ledge.
	217	Shales.
	10	Sandstone; micaceous; fucoid impressions; forms low hogback ridge.
	455	Shales.
DAKOTA.	60	Quartzite; supposed to be summit of Dakota.
	40	Sandstones; fissile and slabby.
	200	Red or yellow limestone or sandstone, with pebbles.
	8	Quartzite.
	10	Lilac limestone, magnesian, becoming pebbly at base; passing above into red clays.
	25	Dakota conglomerate; forming hogback.
JURASSIC.	105	Shales; dark gray; crumbly and earthy.
	50	Sandstones; indurated, slabby, cross-bedded; white quartz grains, and rusty cement.
	60	No exposure.
	5	Sandstone; fissile and crumbly.
	70	Red shale.
	5	Dark-gray shale.
	40	Limestones, forming lenses in sandstone grit or conglomerate, both carrying broken fossils.
	75	Sandstones.
	200	Myacites beds.
	75	Quartzite; Carboniferous.

JURA.

The base of this section is the belt of impure limestone and shale that overlies the heavy bed of quartzite capping the Carboniferous. These Jurassic limestones and shales contain an abundance of fossils, among

[1] Bull. Geol. Soc. Amer., vol. II, pp. 349–364.

[2] Reports, Tenth Census U. S., vol. XV, Mining Industry, p. 739.

which Gryphea and Myacites are the most plentiful. The rocks are soft shales or impure limestones, readily weathering down so that the beds most frequently form a gulch parallel to the strike, where monoclinal folding prevails. Overlying these beds the strata are sandy, and grade into a coarse crystalline limestone full of fossil fragments and changing rapidly into a very remarkable cross-bedded grit, frequently conglomeratic. This bed has been recognized over large areas of central Montana and is generally a conspicuous ledge outcropping on the slope beneath the Dakota "hogback." The fossils found in it are largely fragmentary, but show *Gryphea, Ostrea stringulata, Camptonectes pertenuistriatus*, and *Rhynconella myrani* in abundance. Between this bed and the Dakota conglomerate there is a series of shaly beds in which no fossils have been found, alternating with sandy strata possessing no marked characteristics. Both sandstones and shales are seldom exposed, but form the slopes between Jura and Dakota ledges. These beds have in the section been assigned to the Jurassic. They correspond in stratigraphic position and lithological character to the freshwater Jura of Colorado, are variegated in color, but in the absence of fossils can not be positively assigned to the Jura.

CRETACEOUS.

The Dakota.—The Dakota forms the most persistent and readily recognizable horizon of the Rocky mountain Mesozoic. In this region it is generally a sandstone usually with a characteristic conglomerate at the base, which, with the associated sandstones, resists weathering and in the upturned strata of the foothills stands out very prominently. This conglomerate is overlain by variegated magnesian limestone, carrying pebbles at the base, and of a prevailing lilac or red tint. These beds grade into soft sandstones succeeded by sandy shales, and these by a thin bed of fine-grained dark-gray limestone, full of gasteropod shells. An examination of these fossils by Dr. C. A. White, together with the stratigraphical position of this limestone, shows it to be equivalent to the fossiliferous Dakota beds of Bear river, recently described by Mr. T. W. Stanton. This is overlain by sandy shales with some carbonaceous markings (but no recognizable plant remains), capped by the dense pink and white finely granular sandstone or quartzite that is assumed to be the top of the Dakota. It is a very hard rock, resists erosion well, but breaks into great cubical blocks, whose débris is abundant on the slopes and in the valley drift.

Colorado group.—Overlying the beds referred to the Dakota there is a great thickness of shales, with interbedded sandstones. The lower part of this series consists of rather dark carbonaceous shales, with lighter arenaceous beds and occasionally sandstones. In their sandy nature and the presence of beds of sandstone, the beds show evidence of the proximity of a shore line. Fossils obtained from these beds by

W. M. Davis prove the Colorado age of the strata. The following species were identified by R. P. Whitfield:

Inoceramus umbonatus M.
problematicus M.
sp ?
undabundris M.
Ostrea congesta.
Gryphea vesicularis.
Exogyra.
Gyrodes depressa M.
Pholadomya Berthoudi (probably *P. papyraceæ*).
Several other species that appear to have no taxonomic value were also found.

Montana group.—A satisfactory discrimination between the beds of the Colorado and those forming this group can not be made on paleontological grounds, as few fossils have been collected in the beds assigned to the Montana. The lower thousand feet consists of sandy shales, impure limestones, and occasional thin sandstones, the whole becoming more arenaceous towards the top and grading into thinly bedded sandstones. These latter beds sometimes form bluff exposures, but more often weather out in "tombstone ledges." In the eastern part of the field the dark gray sandy shales are directly overlain by a heavy ledge, of yellow, rather dark, and very massive sandstone, which is thought to be the equivalent of the Fox hills. It is immediately overlain by the whiter, cross-bedded, and somewhat softer massive beds of the Laramie Coal-measures. No fossils have been obtained from this supposed Fox hill sandstone, which may prove to belong to the Laramie.

Those irregular and local elevations of the Cretaceous sea bed that occurred in the region east of the mountains in Canada and northern Montana, and resulted in the accumulation of estuarine and lacustrine deposits, known as the Belly river beds, are not indicated in the rocks of this vicinity. The Montana beds indicate a varying subsidence and the proximity of a low land mass with a gradual shallowing of the waters that resulted in the accumulation of the sandstones and coal seams of the Laramie.

THE LARAMIE FORMATION.

The Laramie, the chief coal-bearing formation of the Rocky mountain region, is well developed in Montana. In the particular area under discussion the strata form a continuous belt stretching westward along the flanks of the Snowy mountains, and northward upon the slopes of the Bridger and Little Belt ranges. Isolated exposures also occur in the mountainous region to the west, which though of small geographical extent, present structural features of much interest.

The area in which the Laramie strata are exposed is the region adjacent to Livingston is shown upon the geological map, Plate I.

The rocks of this formation form a group which is sharply defined both by fossils and physical characters. The beds consist of massive light-colored sandstones, with intercalated shale beds and coal seams near the base, becoming less frequent toward the top. The lower delimitation of the Laramie is assumed to be the dark and heavy bed of massive sandstone, assigned to the Fox hills, found below the lowest workable coal seam and resting directly upon the readily distinguishable and lithologically distinct gray shales and fissile argillaceous sandstones of the Montana group. The upper limit of the Laramie in the region studied is marked by an abrupt change in the composition of the beds and closely resembles in general characteristics that change which has been found so prominently developed in Colorado.

This definition of the Laramie is in accord with the original definition of King, and conforms to the usage of Newberry, Emmons, and Cross, though differing from the limits assigned on theoretical grounds by Prof. White, which are based upon faunal characteristics. The occurrence of marine Cretaceous fossils in the Laramie, showing temporary recurrence of salt-water conditions following a considerable period of coal-making depositions is now a well-established fact.

As exposed at various localities throughout this region the average thickness is 1,000 feet. This is exceeded in the hills north of the Bridger mountains, but is about the thickness throughout the Bozeman coal field. The exposures can not be directly compared, however, since there is proof of a considerable period of erosion following the deposition of the beds of the Laramie group, during which the upper portion of the series may have been in part removed, before the deposition of the Livingston. The sandstones which form the characteristic feature of the group and distinguish it from the underlying formations occur in beds of varying thickness, alternating with gray shales carrying plant remains, and seams of coal. The thicker beds of sandstone are generally massive, but the rocks have a laminated structure, following the cross bedding, and erode into picturesque bluff faces. The shales and coal seams, abundant near the base, become less frequent higher in the series, though a workable coal seam is generally found near the top of the series as exposed throughout the Bozeman field. These coal seams form a prominent feature of the series, and though but three or four of the many seams are of workable thickness and purity, have given an economic importance to the formation that has stimulated exploration and added much to our knowledge of the areas covered by this formation.

In general these coals are valuable fuels, differing materially from the lignites of the plains to the east, and are in ready demand throughout the state. They are mined at a number of localities throughout the Bozeman coal field, but elsewhere in this part of the state have not been commercially developed.

The following section is typical of the lower part of the Laramie throughout this region:

Section of Laramie Coal-measures at the Bowers mine.

Number of bed.	Thickness in feet.	
28	30	Massive sandrock, firm, light gray.
27	½	Coal seam.
26	10	Sandstone, breaking into small angular fragments.
25	1	Shale, dark gray.
24	6	Coal seam.
23	12	Shale, hard and slaty.
22	10	Sandstone, with shelly structure.
21	3	Coal; middle seam.
20	6	Red limestone, very magnesian.
19	3	Sandstone.
18	¾	Coal; called by the miners "upper bastard vein."
17	30	Sandstone, thinly fissile, brown.
16	¾	Coal.
15	10	Sandstone, shaly at top.
14	4	Coal.
13	20	Fissile and leafy sandstone.
12	30	Sandstone, massive, with jointed surfaces rounded.
11	6	Coal; poorly defined; vein 2 or 3 feet; the rest shale.
10	15	Sandstone, massive, brown, much pitted by weathering.
9	2	Coal.
8	3	Sandstone.
7	8	Coal and slate.
6	3	Sandstone, very fissile and soft.
5	10	Sandstone, hard and firm.
4	1½	Coal.
3	3	Shale.
2	18	Sandrock.
1	2	Coal.

The general characters of the formation are very constant in this particular region—though there is a decreasing amount of coal as the strata are followed northward to the Musselshell river, or into the plains region east of the Crazy mountains.

The lithological characters of these Laramie sandstones present few points of especial interest by themselves, but are of importance when compared with those of the overlying formations. The rocks are rarely compacted, or so firmly cemented as to form quartzites; in thin sections they are seen to be typical sandstones, formed mainly of well-rounded grains of quartz, with mica and accessory minerals, all indicating the erosion of Archean rocks. No fragments or minerals of an eruptive nature are found in any of the sections so far examined. No vertebrate remains have been discovered in the Laramie strata of this particular part of Montana. Leaf remains occur abundantly in the shales overlying many of the coal seams, but the rocks are so crumbly and the specimens so difficult of preservation, that few have been brought in. Leaf remains rarely occur in the sandstones.

The perfect stratigraphic continuity of the marine Cretaceous with the Laramie is apparent everywhere. No break occurs and no evidences of unconformity have been observed, up to the top of the formation. The evidences of such a break and unconformity between this and the overlying Livingston formation are given in the description of those beds.

In the clay shales associated with the productive coal seams, Unio remains have been found, the specimens being too poorly preserved for specific determination, and *Corbula subtrigonalis* M. and H. has been identified for me by Dr. White. Fossil plant remains are not uncommon in these shale beds, but the material is too soft to bear transportation, and only a few forms have been brought in. They are discussed at length in Prof. Knowlton's report.

THE LIVINGSTON FORMATION.

Overlying the coal-bearing Laramie strata, there is a series of beds constituting a newly recognized formation, for which the name Livingston is proposed, as it is typically developed in the vicinity of Livingston, Montana. The formation consists of a series of beds, in places aggregating 7,000 feet in thickness, composed of sandstones, grits, conglomerates, and clays, made up very largely of the debris of andesitic lavas, and other volcanic rocks, and including local intercalations of volcanic agglomerates.

DISTRIBUTION.

The accompanying map, Plate I, shows the surface distribution of the Livingston beds in the country about Livingston, the map representing part of the geological atlas sheet bearing that name. The formation attains its greatest development in this region, and in the country immediately north of the area shown by the map—that is, in the region east of the Rocky mountains. But exposures also occur within the mountain region, in the Madison and Jefferson ranges, where they have been mapped and described by Dr. A. C. Peale and indicated upon the Three Forks atlas sheet, and the region drained by Sixteen mile creek, north of the Bridger range, contains a considerable area of these beds. In the Crazy mountains the Livingston is covered by the Fort Union strata, which in this part of the field everywhere overlie and conceal the earlier deposits.

Although the origin of the formation is such that it varies greatly at different localities so that horizons can not be closely defined, there are three general divisions into which the formation may be separated, viz: The leaf beds, the conglomerates, and the volcanic agglomerates. The first two comprise the lower and upper parts of the formation. The third is an intercalation of volcanic ejectamenta that only occurs locally, though attaining a thickness of 2,000 feet in the southeastern part of the region covered by the Livingston beds. The total thickness of the formation approximates 7,000 feet in the region east of the mountains, where the agglomerates are absent. Of this total thickness from 600 to 2,000 feet may be assigned to the lower division.

THE LEAF BEDS.

The strata grouped together under this name embrace the basal portion of the formation up to a point where a decided change in color, mechanical constitution, and general nature appears, and includes the various horizons in which plant remains have thus far been found. A definite upper limitation is not always possible. On the flanks of the Snowy range the intercalated agglomerates form a convenient point at which to draw the line. Elsewhere it is marked by light colored, thinly bedded sandstones, with green or purple shales, which are readily distinguishable in the field, and are arbitrarily assumed to be the base of the conglomerate series.

This lower division of the Livingston deserves a somewhat detailed description, because it is the only portion yielding paleontological remains, and presents, moreover, features of lithological character and mechanical constitution separating it from the Laramie strata that so generally underlie it. The character of these lower beds, as exposed throughout this region is, therefore, quite fully described. In general it consists of a series of sandstones, conglomerates, and shales composed largely of angular or but slightly water-worn débris of volcanic eruptions and ash showers, that rest directly upon the productive Coal-measures. Usually the beds are dark colored and weather into ledges whose appearance suggests a volcanic rock, often breaking down into fine angular débris, forming slopes that support a scanty vegetation. Consisting mainly of sandstone, grits, and conglomerates, the beds vary in coarseness at different localities. Contrasted with the Coal-measure sandstones beneath, the rocks are darker, much harder, well indurated, brittle, and break into fine angular bits, while the Coal-measure sandstones are fissile, light colored, and often crumble into sand on weathering. Their intimate composition presents a striking difference in the nature of the two formations, the Laramie sands being well rounded quartz grains derived from Archean land areas, the materials being well assorted and stratified; the Livingston rocks, on the contrary, being composed of angular or slightly water-worn grains, showing no assorting of the material and consisting mainly of andesitic fragments cemented by fine volcanic ash. Plant remains are abundant at various horizons. The thickness of the leaf beds varies greatly at different localities; it is least in the eastern part of the field and increases westward, reaching a thickness of over 2,000 feet in the vicinity of the Muir tunnel and in the range of hills east of the Bridger mountains.

In the foot slopes of the Snowy range these leaf beds are generally green in color and differ somewhat in character from the beds belonging to this horizon in other localities.

THE BLUE RIM SECTION.

A fine exposure of the lower horizon is seen in the canyon walls of the west Boulder river in the extreme eastern part of the region shown in the map (Pl. I). The rocks occupy a shallow synclinal trough capping gray Cretaceous sandstones, and form picturesque cliffs locally known as the Blue rim. A few miles above these cliffs the river emerges from a canyon with walls of gneiss 2,000 feet high, at the northern end of which the section of upturned Paleozoic rocks is well exposed, and the succession of beds from the base of the Cambrian to the rocks of the Blue rim is clearly revealed.

The following detailed section of the beds is introduced to show the variations of the strata:

Blue rim section.

29. Sandstones of varying nature, color, weathering, and fracture, but of substantially the same rock. Occasional pebbles, but not assorted nor arranged. Cross bedding rare. Lense bedding occasional. In general, the arrangement and appearance of the strata is similar to that of the Yellowstone tuff beds of the Fossil Forest. Jasperized wood occurs, but the trees are prostrate.
28. Sandstone, fine grained, and breaking into slabs.
27. 6′. Shale? a dark brown ferruginous belt, that is unusually persistent.
26. 2′. Shaly rock, crumbly, earthy brown, not unlike ordinary Cretaceous shales.
25. 8′. Tuff-sandstone, very fine grained and green colored.
24. 6′. Sandstone or ash bed; forms lowest ledge of cliff.
23. 20′. Sandstone, gray and breaking into small fragments.
22. 3′. Sandstone, massive, weathering like a Laramie ledge.
21. 30′. Shaly bed, fissile and shaly, dark ferruginous, with carbonaceous material staining surfaces.
20. 1′. Sandstone, rather gray and micaceous.
19. 8′. Shaly sandstone.
18. 3′. Sandstone jointed, gray, hard, and indurated.
17. 25′. Shaly beds, crumbly brown bed, covered by slide of ledge above.
16. 12′. Sandstone, forming persistent ledge, well jointed, very hard, and holding lenses of brown cemented rock in lower part.
15. 1′. Green ledge of crumbly rock.
14. 9′. Shaly rock.
13. 6′. Sandstone, massive.
12. 5′. Shaly brown beds.
11. 3′. Sandstone, massive gray, cross bedded, thickens to north and thins out to south.
10. 12′. Splintery shale, greenish brown.
9. 3′. Sandstone, massive.
8. 8′. Shale, splintery, crumbly, green micaceous.
7. 2′. Limestone, dark blue.
6. 5′. Crumbly brown shale.
5. 3′. Gray sandstone.
4. 5′. Sandstone, green earthy, fracturing.
3. 30′. Massive sandstone, probably Laramie.
2. 20′. Shale, dark gray, carbonaceous, with thin layers of sandstone.
1. 50′. Massive sandstone.

The Blue rim section shows beds of water-laid sandstones and shales at the base, while the sandstone forming the blue cliffs are made of volcanic detritus, the finer-grained rock and the shaly beds being of volcanic ash and showing but little assorting. Plant impressions occur near the top of the section and prostrate tree trunks of silicified wood are seen. The shale belts are peculiarly inconstant, and the brown color is the result of the oxidation of the fine-grained green rocks.

An examination of thin sections of the rocks of the Blue rim section under the microscope, made by Mr. J. P. Iddings, show that the sandstones at the base consist of well-rounded grains of Archean material, mainly quartz, well assorted and quite like the sandstones of the Laramie Coal-measures of other places. Fifty feet above the basal sandstones the rock shows, in thin section, decidedly angular grains of plagioclase, quartz and a little mica, and though but one fragment of andesite is seen in the slide the rock has more the appearance of a volcanic ash than a true sandstone. Still higher in the section the sandstone (No. 16) is formed of rounded grains of Archean material, but above this the rocks show in thin sections a decidedly volcanic nature, consisting of fine fragments of pyroxene andesite and andesitic breccia. The shaly strata are formed of so fine an ash that but little can be distinguished in thin section, but they grade into the coarser beds whose composition is clearly volcanic.

DISTRIBUTION AND CHARACTER.

Followed westward the beds of the Blue rim increase in thickness and include more water-worn material, the tuff beds becoming less prominent. The rocks form picturesque combs along the valley of Little Mission creek and are well exposed where the Blue Rim syncline is cut across by Mission creek above the forks. At this place the rocks consist of brownish ash beds overlain by green fissile sandstones and conglomerates. In the walls of McAdow canyon of the Yellowstone the beds are well exposed and their relation to the coal rocks clearly seen. At this locality the shaly beds are often quite carbonaceous and contain an abundance of plant remains and a few fresh-water shells.

At Livingston fine exposures of the formation occur in the hills north of the town, where the beds dip at 10° northward. The rocks are dark chocolate colored or green sandstones, carrying lenses of fine grained tuff-like rocks, that contain plant remains. Local beds of volcanic débris, showing little if any water-assorting, also occur. In the sag between the two hill tops, an opening has been made on a two-foot seam of impure lignite, overlaid by a thickness of several hundred feet of sandstones that are locally conglomeratic.

A detailed section of the beds of the Livingston formation at Cokedale would be of little value, as the beds vary rapidly from quite fine-grained sandstones to coarse grit, with thin intercalations of conglomerate. Thin sections of the rocks, when seen under the microscope, show a variation in the amount of Archean material present. The rocks immediately overlying the coal are good sandstones, harder than those associated with the coal, but water-laid and formed of assorted water-worn grains. The rocks above change rapidly, however, to coarse-grained sandstones of angular fragments, showing but little assortment. Many of the rocks resemble a fine-grained volcanic agglomerate in the hand specimen, while the finer layers that crumble into small angular bits are volcanic ash beds. There is a noticeable admixture of Archean detritus with the volcanic grains of some of the ledges, but the latter largely predominate and frequently form the entire rock. At some 2,300 feet above the coal the Archean material is very abundant, showing a cessation of the ash showers, but the grits above and those associated with the shales of the Billman creek valley are wholly of volcanic material.

In the exposures of Rocky canyon and vicinity, from which the larger part of the plant remains obtained from the Livingston beds have been taken, the rocks immediately overlying the workable coal seam at the top of the Laramie are dark green or brown and resemble fine volcanic tuffs made up of andesitic débris, overlaid by grits and sandstones, with conglomerate intercalations, at 400 feet above the coal. Leaf remains occur at various horizons, but the collections all come from the lower 500 feet of the formation.

Upon the eastern flanks of the Bridger range, and northward to the Castle mountains, the leaf beds possess the same general characters. Hard sandstones of varying texture and grain, generally dark colored, and rarely conglomeratic, alternate with dark olive brown shales, that are hard and indurated, but crumble into fine angular bits. The conglomerates are composed almost wholly of pebbles of andesitic materials, but pebbles of white, brown, and blue quartzite occur sparingly, together with rounded fragments of coal and normal sandstones. Intercalations of volcanic agglomerate occur on the slopes of the Bridger range at Flathead pass, and farther north, about the headwaters of the Musselshell.

Fine exposures of this lower division of the Livingston occur in the hills drained by Cottonwood creek, where they rest upon the Laramie. The lowest beds are seal brown, very fine-grained sandstones, containing fossil plant remains in abundance, overlaid by coarser, lighter-colored sandstones and grits, which at higher horizons are interbedded with soft shales. In the exposures at the head ot Smith river, near Castle, a few gasteropod shells and Unio remains were found in the finer-grained beds. In this vicinity the first marked change is observed in the beds. Throughout the region north of the Crazy mountains a prominent bed of white calcareous sandstone occurs, interbedded with the dark colored sandstones, grits, and shale beds of the Livingston, about 500 feet above the base. No fossils were observed in this rock in the vicinity of Castle, but near the forks of the Musselshell river this bed is composed of brackish-water shells of Laramie types. The northern portion of the Crazy mountains is composed very largely of Livingston rocks. A section made along Lebo creek east of the mountains showed a total thickness of 7,100 feet of Livingston sediments, in which the lower beds do not form so distinct a division as elsewhere in the neighborhood of the Crazy mountains.

In the mountainous region south of the Gallatin valley the only exposure of the Livingston is in the Madison range, where the beds cover an area of 15 to 20 square miles in the vicinity of Sphinx mountain. They are thus described by Dr. A. C. Peale: "The strata consist of indistinctly bedded volcanic material, mostly andesitic in nature, and of a somber hue. At one or two places conglomerates made up of all sorts of pebbles are seen near the base." The beds rest unconformably upon the eroded edges of all the Cretaceous formations, and are unconformably overlain by the coarse conglomerates assigned to the Eocene. On the eastern flanks of the Jefferson range another exposure of the Livingston occurs. The beds present a somewhat different aspect from those just described, not being so dark in color and showing more distinct evidences of bedding and seemingly more nearly conformable to the underlying Laramie beds with which they are in contact. In the vicinity of the Jefferson canyon they have a dark greenish-gray color, and apparently contain interbedded hornblende andesites, which seem to have been laid down as lava flows. Other beds are conglomerates composed of all sorts of volcanic material, andesites, however, as at other localities, apparently predominating. The period during which they were deposited was undoubtedly one of great volcanic activity.

The water-laid beds of the basal portion of the formation thus far described contain but small and local bodies of conglomerate. In the section which has already been given, made in the vicinity of Cokedale, these beds have been estimated to be 2,400 feet thick. In the Blue Rim section, which does not embrace the entire thickness, there is some 600 feet, and on the Bowlder river, where they are capped by the volcanic agglomerate, the total thickness is not thought to exceed some 700 feet.

THE VOLCANIC AGGLOMERATES.

Beds of consolidated volcanic ejectamenta form the mountains of the western part of the Crow Indian reservation and terminate the Bozeman coal field at the Boulder river. These agglomerate beds rest directly upon the lower beds of the Livingston formation, and thinning out westward are overlain by the upper part of the same formation, capped in turn by the great thickness of sandstones and clays forming the Crazy mountains.

The volcanic agglomerate attains its maximum development in the region drained by the Boulder river. This stream is a clear mountain torrent, heading in the high plateaus and peaks north of the Yellowstone park, and emptying into the Yellowstone river at Big Timber. In its lower course below the forks the valley is cut in the volcanic agglomerates, which weather into castellated knobs and mural faces, adding much to the picturesqueness of the scenery. At the forks of the stream the Laramie Coal Measures dipping northward are overlain by the dark-colored rocks of the Livingston formation, readily distinguishable by their color, fracture, and weathering. The upper parts of this section are cross bedded, poorly assorted sandstones, very clearly of shallow water formation. The grains are angular, but little water worn, though not less so than the rocks of the Blue Rim. A careful examination shows at a number of localities a decided unconformity between the beds at the top of the series and the overlying agglomerates. At other localites there is an apparent gradation of the water-laid strata into the fine breccias, so that the section shows distinctly water-laid beds capped by a series of strata in which those beds alternate with beds showing no traces of such action. The latter become more frequent in ascending the series until the rocks are all fine-grained breccias that pass rapidly into the coarse volcanic agglomerates made up of large angular fragments of andesitic lavas. The agglomerate beds are very light colored, possessing in a general view a warm gray tint. The fragments composing them are of various tints of gray, brown, lilac or green, the last color often predominating. There is a rude bedding brought out by the rapid weathering of fine-grained material forming thin intercalations rarely more than a few inches thick. The agglomerate fragments range in size from minute particles up to blocks four feet in diameter, though seldom so large as the latter. The lavas from which the agglomerates are formed are all andesitic, the rocks possessing but slight variations in character. Augite-andesite is often conspicuous, the large augite phenocrysts being very abundant. In several large blocks of basic-looking andesite large isolated hornblende prisms were noticed. As a whole the rocks though so light colored, are decidedly basic and in thin section are seen to be pyroxene-andesite.

These agglomerates represent the products of explosive volcanic action from a vent on the shore or in the shallow water of the lake whose sediments formed the Livingston beds. The flanks of the cone built up of this volcanic débris were covered by the lake waters in the subsidence that caused the deposition of the great thickness of sandstones and clays that form the Crazy mountains.

DISTRIBUTION.

In the valley of the lower course of the Boulder river the total thickness of agglomerate interbedded between the Livingston rocks is estimated to be at least 2,000 feet. The beds dip at a low angle downstream and are seen to be overlain by sandstones and purple clays a few miles above Big Timber, frequent sections being exposed in lateral stream cuttings.

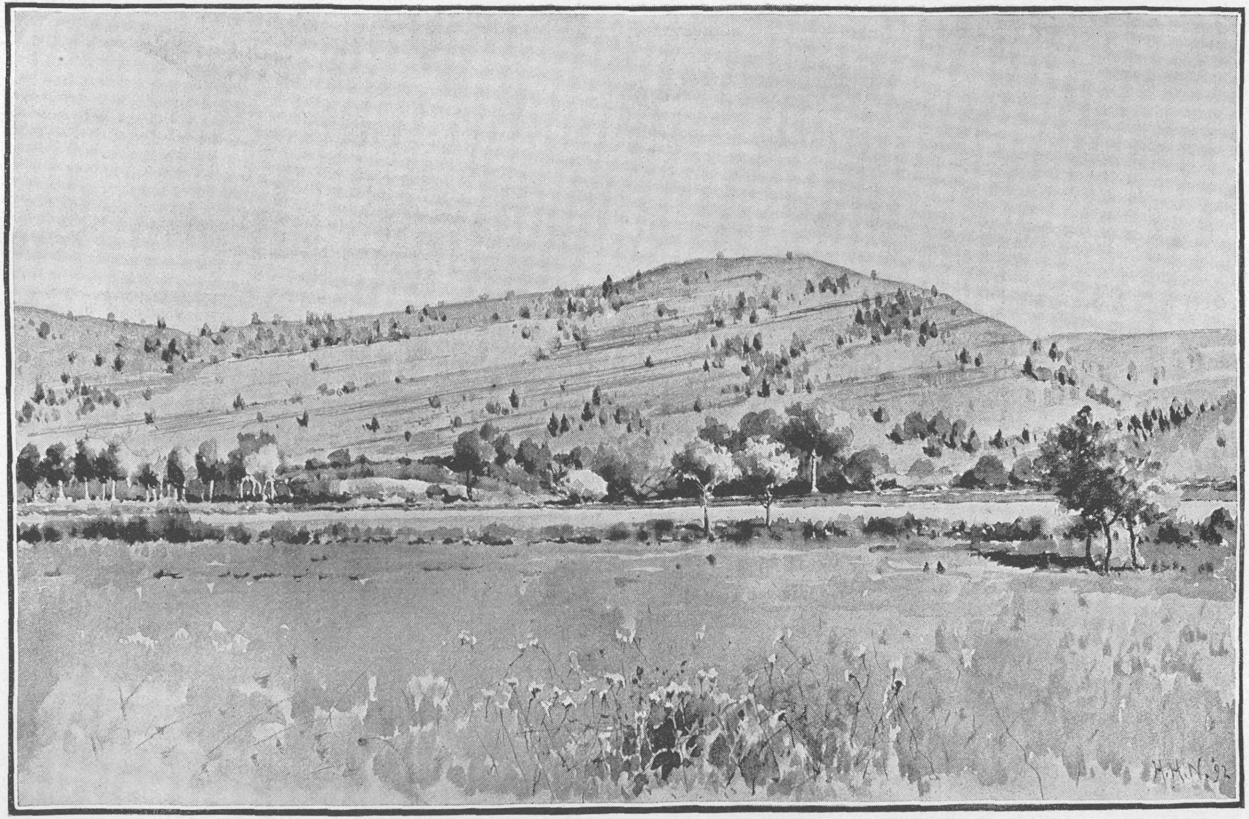
East of the Boulder river these agglomerates form the highly accidented country of the Crow reservation, where they rest upon upturned and eroded Mesozoic rocks. In this region a thickness of over 2,000 feet was observed in a canyon where the underlying rocks were not exposed to view. A portion of this breccia is, however, believed to represent subaerial accumulations deposited contemporaneously with the water-laid strata that cover the agglomerates near Big Timber.

Followed westward from the Boulder river the agglomerates are exposed as far as McAdow canyon and Hunter's hot springs. In the hilly country between the Boulder and Yellowstone rivers the agglomerates are of little moment in the topography; gentle grassy slopes fall off gradually to the broad cobble-covered terrace flats that border the Yellowstone river. In this region exposures must be sought in the rocky walls of the little canyons cut by the branching headwaters of Mendenhall and Antelope creeks. These exposures show a gradual thinning out of the agglomerates to the north.

In the bold bluffs facing the river near Springdale, a railroad station 25 miles east of Livingston, the rocks dip at an angle of 15° eastward, showing the influence of the McAdow canyon folding. The Springdale bluff shows a thickness of about 700 feet of breccia, resting upon typical Livingston beds and covered by the purple clays and lilac sandstones that prevail eastward. The cliffs are some 200 feet high, formed of light-colored agglomerates that, when seen at a little distance, closely resemble ordinary sandstone. The base of the section consists of dark tufaceous sandstones resting upon the water-laid beds of the Livingston series. The lowest ledge of the Springdale bluff is a very hard and dense, almost black, sandstone, very brittle, and breaking into angular débris. It is immediately overlain by a ledge locally characteristic of the base of the breccia. This rock is full of dark brown, round concretions, 1 to 2 feet in diameter, that resemble cannon balls. The "cannon ball" bed is overlaid by beds of fine volcanic material resembling a coarse and poorly assorted volcanic ash showing no evidence of water action. These ash beds are in turn overlain by a second cannon-ball ledge in which the concretions are much smaller. Above this last bed fine-grained agglomerates and very coarse agglomerates alternate in rapid succession and without persistence of horizon. The fragments composing these agglomerates of the Springdale block are andesitic lavas identical with those forming the beds of the Boulder river; green, brown, lilac and gray in color and varying in size from fine lapilli to blocks of 5 feet across (see Pl. II).

In the bluffs of Mendenhall creek east of Springdale station the same rocks are exposed underlain by the cannon-ball beds and resting upon the earthy brown and splintery shales and sandstones of the Livingston series. East of Mendenhall creek the agglomerates are covered by the overlying sandstones.

The most northern exposure of the agglomerates yet found is near



TILTED AGGLOMERATE BEDS NEAR SPRINGDALE, MONTANA.

that local health resort, Hunter's hot springs, some 3 miles north of the Yellowstone river. In this interval the agglomerates thin out rapidly, and in the section exposed by the creek a mile west of the hot springs, just south of the wagon road, the conglomerate is but 25 feet thick and rests unconformably upon the sandstones beneath. The upper surface is uneven and covered by the lilac sandstones and purple shales that usually are above it. (See fig. 1.) There is a general de-

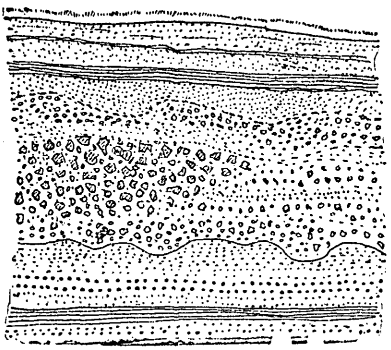


FIG. 1.—Diagrammatic section at Hunter's Hot Springs.

crease in the size of the fragments, as well as the thickness of the beds, from the Boulder river northward. In the area thus far mapped and studied the volcanic agglomerates cover about 75 square miles. They also extend over a larger area in the western portion of the Crow Indian reservation.

Small and local intercalations of volcanic ejectamenta showing no assortment or rounding by the action of water, occur, however, at a number of localities in the lower part of the Livingston formation. Such accumulations are prominent in the vicinity of Flathead pass, and at the head of Smith river, near the mining camp of Castle. The beds exposed east of the Crazy mountains frequently consist of finer grained material, which, in thin section under the microscope, is seen to be a good pyroclastic rock. The areas of Livingston rocks in the Madison range and along the Jefferson river, described by Dr. A. C. Peale, also consist in part of true volcanic accumulations, the latter exposure showing interbedded lava flows.

RELATIONS TO LEAF BEDS.

A gradual increase in the thickness of the beds is noted in tracing the thinning out of the agglomerates, and the thickness at Cokedale corresponds approximately to that of both the agglomerates and underlying beds together of the eastern localities. It is supposed that in a general way the deposition of the subaerial agglomerates was synchro. nous with the formation of littoral deposits of débris washed down from the slopes of the neighboring volcano, making beds of a somewhat higher horizon than those beneath the agglomerate. At the same time there was a shore to the westward supplying Archean débris which mixed with volcanic particles appears in increasing quantity as the rocks are followed westward from the Boulder.

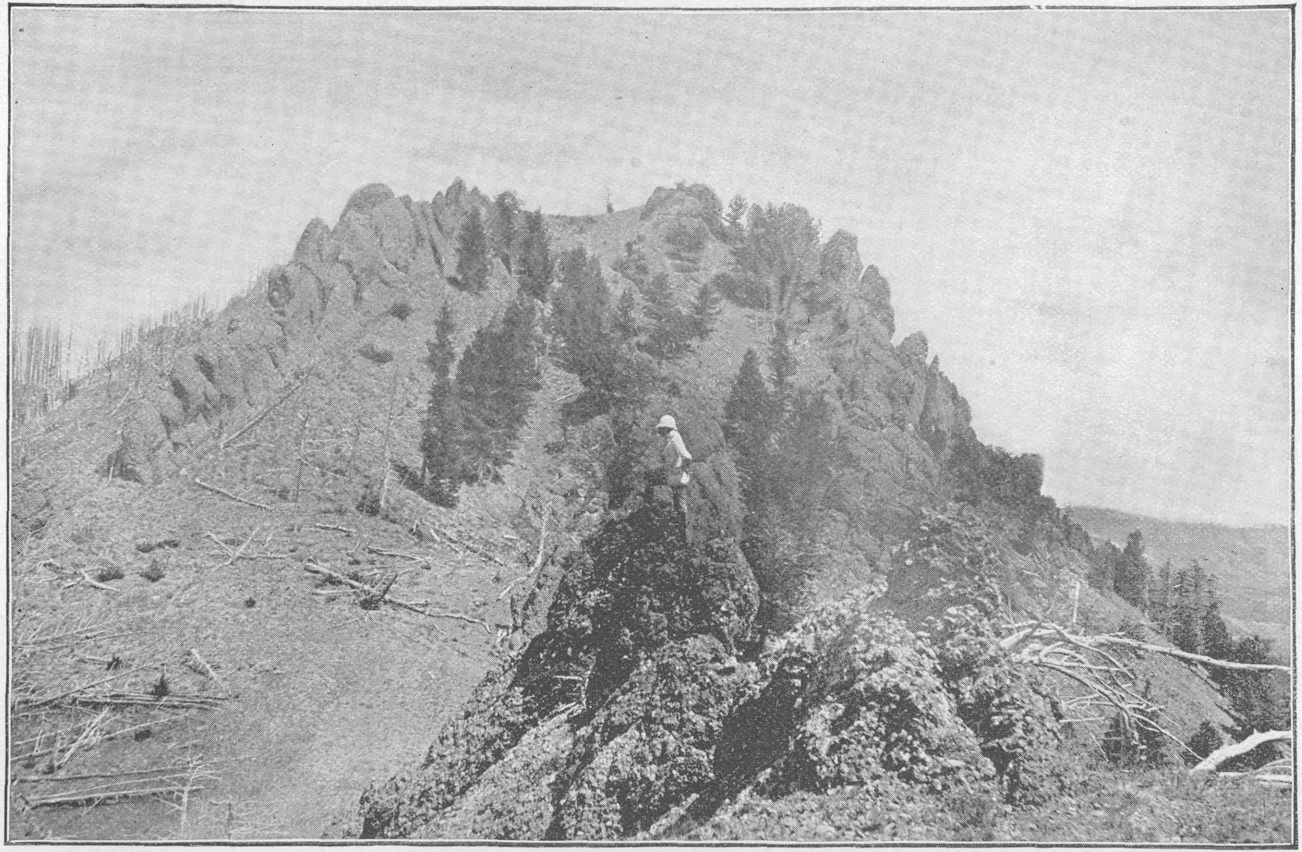
LIVINGSTON CONGLOMERATES.

The upper portion of the Livingston is for convenience designated by this name, as the conglomerates form the most important and often the most conspicuous beds of this part of the formation.

Overlying the leaf beds and volcanic agglomerates there is a series of shales and interbedded sandstones and grits that form a prominent part of the formation wherever the upper portion is exposed. In the eastern part of the region the sandstones are fine and uniform in grain, making an excellent building stone in the vicinity of Big Timber. Traced westward these beds are easily recognized by their red soils that form the terrace flats to the south of the Yellowstone river as far as Springdale. Beyond here they form the low hills and the country north of Livingston. It is in these same shales that the valley of Billman creek has been cut, and they have also afforded the material out of which the long strike valley east of the Bridger mountains has been eroded. In the extension of these beds westward there is a general persistence of character of the shales themselves, but on the other hand the thin beds of "freestone" of the east change in character, become coarser, and in the Billman creek valley form lenticular bodies of coarse and illy assorted grits and conglomerates. Northward the open valley of Flathead creek and the synclinal basin north of the Shields river valley are both eroded in this part of the Livingston formation. The exact nature of the soft clayey shales it is difficult to make out; they crumble readily, are sometimes quite micaceous, and change from green to red on weathering. Thin sections of the associated sandstones show them to be made of volcanic material, grains of andesitic breccia forming a considerable part of the mass. This series of beds has thus far failed to yield any fossil remains.

Overlying the series of purple shales just described, the rocks are chiefly sandstones and conglomerates. They do not form a distinct conglomerate bed throughout the field, but rather a series of sandstones and silty shales holding intercalated beds of conglomerate, the latter rocks becoming more prominent toward the west, and attaining their maximum and most prominent development along the eastern front of the Bridger range. That they form a true part of the series is indicated by their composition and by the gradual transition of the underlying beds into the conglomerate series. Because of their coarser nature a study of the pebbles is more easily made in these beds, and this has been most feasible in the exposures of the western part of the field.

Near Hunter's hot springs the monoclinal ridges back of the hotel are formed of sandstones belonging to this horizon that include lentic-



CONGLOMERATE BEDS FORMING ANTICLINAL RIDGE BETWEEN BRACKETT AND FLATHEAD CREEKS.

ular intercalations of conglomerate, in which, besides the usual variety of volcanic rocks, gneiss, quartzite and limestone pebbles were recognized. These ledges are overlain by sandstones and purple clays that represent the higher part of the formation. At the mouth of Shields river the sandstones interbedded with the purple and green clays are dark and greenish in color and contain conglomerate layers with quartzite and limestone pebbles.

From Big Timber westward the grains forming these rocks become very slightly coarser and in the high hills east of the Bridger range become conglomerates. These hills are separated from the mountains by a long strike valley cut in the purple shales and drained by Bridger and Brackett creeks. The cliffs east of these creeks show a thickness of over 2,000 feet of sandstones, conglomerates, and sandy shale. Several detailed sections were made, but are of little general interest, save to show the proportion of conglomerate. Brown earthy-colored sandstones grade rapidly into conglomerates and alternate with gray, silty, incoherent clay shales. The rugged ridge separating Brackett creek from the flat valley to the north is formed by a sharp anticlinal uplift of these conglomerates. Plate III shows the ledges on the summit of the ridge. The importance which attaches to these conglomerates arises from the light they throw upon the relation of the Livingston formation to the Laramie, and to the post-Laramie movements which elsewhere had been found to be so important. The large size of the pebbles of the conglomerate permits a ready recognition of their lithological nature, and this upon examination proves to be of the greatest interest. In the cliffs east of Bridger creek and the ridges cut by Brackett creek, the conglomerates of the series occupy a very prominent part of the formation. The accompanying illustration (Pl. IV) shows the size and well-rounded character of the pebbles forming the conglomerates. It is reproduced from a photograph. Sections made near Stone's creek and on Brackett creek show a thickness of 2,000 feet of very coarse sandstones and conglomerates in which a large number of pebbles are noted that are not of volcanic origin. In both these sections the conglomerates contain pebbles of granite, quartzite of various colors, limestones showing chert and carboniferous fossils, and cretaceous shales and sandstones. The volcanic rocks also show a wide variety; whereas the pebbles of the lower beds show but little variety of the andesite, those of the higher strata exposed at Bridger and Brackett creeks contain olivine porphyrite, hornblende-porphyrite, pyroxene-andesite, quartz diorite, and dacite. The first of these rocks is unknown elsewhere in this region. The dacite occurs as an intrusion in the Laramie Coal-measures.

There is some evidence that may prove sufficient cause for a separation of these conglomerates and silts from the Livingston formation and their recognition as the base of the Fort Union group.

MATERIALS COMPOSING THE LIVINGSTON.

The peculiar appearance of the rocks overlying the coal beds of the Bozeman coal field was noticed by the geologists of the Hayden Survey,[1] but the volcanic nature of the pebbles was first established by the geologist belonging to the Northern Transcontinental Survey, by whom descriptions of the conglomerates were published.[2]

The general appearance of the coarse sandstones of the lower part of the formation suggests the volcanic nature of the materials composing them. In the hand specimen particles of andesite are frequently distinguishable, and the opaque white feldspars derived from the andesites are always a conspicuous feature of the rocks. The conglomerates of the leaf beds, though always of merely local development, are frequently prominent parts of the outcrop. The pebbles of these conglomerates are almost wholly andesitic in character, the rare exceptions being a few pebbles of quartzite found at a few localities at this horizon.

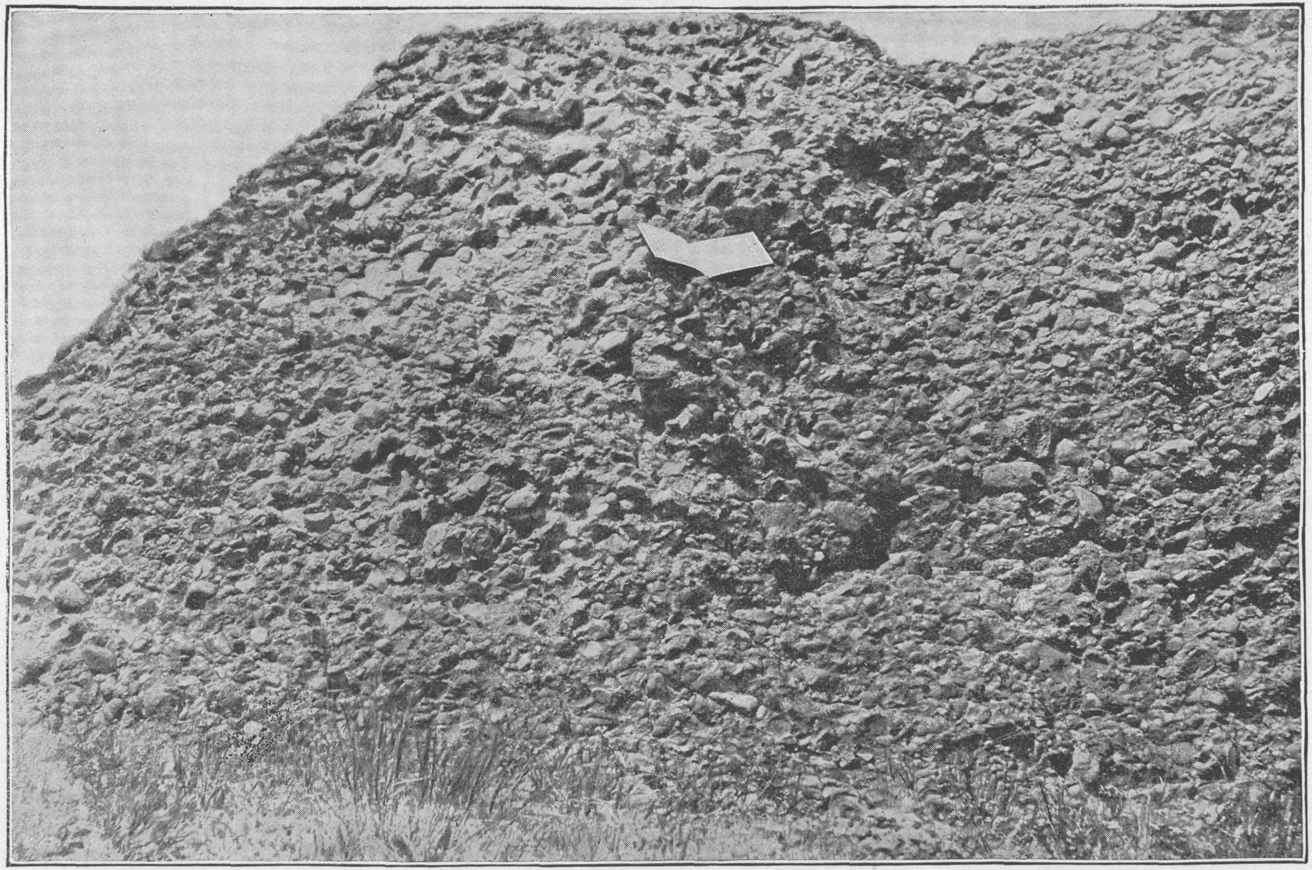
Microscopic examinations of the rocks show a mixture of volcanic with archean material. The character of the rocks of the Blue rim section has already been stated. That of the strata in the vicinity of Cokedale is typical of this formation generally. The lower 1,000 feet of beds show an admixture of andesitic débris with Archean material, the latter being much more abundant than in the rocks of the Blue rim, but in widely varying quantity at different horizons. Many of the Cokedale rocks show no assortment of the grains, as there would be if there had been wave action during their deposition, and they probably represent ash showers. The andesites are all of types represented by the intercalated volcanic agglomerates, described later. Thin sections kindly examined for me by Mr. Whitman Cross show the rocks overlying the coal near the Chestnut mine to be composed of fine to coarse andesitic débris but little different from that seen in thin sections of rocks from the same horizon north of the Crazy mountains.

The conglomerates of the upper part of the formation show a much wider variety in composition. Inconspicuous features in the exposures east of Livingston, they form the high hills east of the Bridger range, where they attain their greatest development and become less and less prominent parts of the formation northward. In the hills just mentioned the conglomerates consist of well-rounded pebbles up to 10 inches in diameter, which, though chiefly of volcanic rocks, are of many types, and include moreover a conspicuous proportion of other rocks. Microscopical examinations show the following variety of igneous rocks:

Olivine-porphyrite.
Hornblende-porphyrite.
Pyroxene-andesite.
Quartz-diorite.
Dacite (or rhyolite?).

[1] Dr. A. C. Peale, Ann. Rept. U. S. Geol. and Geog. Survey, 1871, pp. 49, 173; idem, 1872, pp. 25, 112.

[2] Waldemar Lindgren, vol. xv, Tenth Census U. S., p. 725.



CONGLOMERATE BEDS SHOWING SIZE AND ROUNDING OF PEBBLES.

Pebbles of Archean, gneisses, and quartzites also occur, together with limestones showing Paleozoic fossils and Dakota conglomerate.

FOSSIL REMAINS OF LIVINGSTON FORMATION.

The fossils of the Livingston formation consist of plant remains, found most abundantly in the southern exposures, throughout the Bozeman coal field, and a meager molluscan fauna most abundant in the extreme northern portion of the Crazy mountain country.

FOSSIL FAUNA OF THE LIVINGSTON.

The molluscan remains are of two kinds, fresh-water and brackish-water forms. The former occurs together with leaf remains in the cliffs of McAdow canyon of the Yellowstone and at the headwaters of Smith river. At the first locality *Unio* remains, specifically indeterminable, and fragmentary gastropods have been collected. At the head of the south fork of Smith river a small collection of fossils was obtained from the black calcareous shales of the formation, but the shells have been deformed by the flexing of the strata. Unio remains are abundant, but can not be preserved. The other shells brought are abundant and have been examined for me by Mr. T. W. Stanton, who reports as follows: "The fosssils from this locality are very imperfectly preserved and the identifications are too doubtful to be of value. All that can be said of them is that they are fresh-water forms having some resemblance to species from the Fort Union bed near Fort Union and at the mouth of the Yellowstone, as follows:

1. *Goniabasis tenuicarinata* M and H.
2. *Goniabasis nebrascensis* M and H.
3. A third form represented by a single mold resembles *Thaumastus limnæiformis* M and H, a land shell."

In the region northeast of the Crazy mountains, drained by the Musselshell river, a bed of limestone full of shell remains occurs, interbedded with the Livingston sandstones and conglomerates, a few hundred feet above the base of the formation. The species obtained from this bed, are thus described by Mr. Stanton: "The three species and one variety in this lot are all brackish-water forms, and were all originally described from the Judith river beds near the mouth of Judith river. The Corbicula and the Corbula have been found in the Laramie of the valley of Bitter creek, southern Wyoming, and the Corbula ranges well down in the marine Cretaceous. There is no doubt that these fossils came from the Laramie.

1. *Ostrea subtrigonalis* M. and H.
2. *Corbicula cytheriformis* M. and H.
3. *Corbula subtrigonalis* M. and H.
4. *Corbula subtrigonalis*, var. *perundata*, M. and H.

The horizon from which these brackish-water forms were obtained is below that at which the fresh-water mollusks were found

FOSSIL FLORA OF THE LIVINGSTON FORMATION.

The abundance of fossil plant remains in both the true Laramie and the Mission creek formations has already been noted. Collections were made from both horizons as early as 1871 by Dr. A. C. Peale and other members of the Hayden Survey, and together with further collections made in 1872 and 1878 were submitted to Prof. Leo Lesquereux. In subsequent years the collections were largely increased by Dr. Peale, Prof. F. H. Knowlton, and the writer. At my request a careful revision of this work, together with a study of all other material from the same region, was undertaken by Prof. Knowlton, and his report is a very important contribution to the paleobotany of the Laramie. This work not only describes and tabulates the species collected from the Laramie Coal-measures and those from the Livingston formation, but it clears up the confusion resulting from the mixing up of collections from various horizons and localities described in the early reports of the Hayden Survey, a work so frequently referred to in the literature of the Laramie. As many of Lesquereux's type species of Laramie plants were in these collections, the importance of a careful separation of collections from different localities and horizons will be readily appreciated. This necessitated a careful examination of each specimen of the Hayden collections. This has been done by Dr. A. C. Peale, by whom most of the specimens were obtained. This has shown that fossil plant remains from both the Laramie Coal-measures and the Livingston formation were placed together, and with specimens from the volcanic rocks of the Yellowstone park were described as Laramie species. The latter have been separated out and the specimens from each locality and horizon in the Bozeman district discriminated. The collections studied by Prof. Knowlton are from five different localities and represent two horizons, viz, first, Laramie Coal-measures, and, second, the Mission creek formation. The first includes the specimens labeled Bear creek, Fir canyon, and Fort Ellis, Chestnut and the Craig and Horr mines (Cinnabar field). The specimens labeled Hodgson coal mine, Flathead pass, Mission creek and Bear creek (Madison valley) are from the lower portion of the Livingston formation, and can be readily distinguished by their volcanic matrix from the specimens obtained from the Laramie rocks.

In the accompanying report Prof. Knowlton has shown the similarity of the flora of the Livingston beds with that of the Denver formation, and the table of distribution and the relative abundance of certain species show quite clearly that the flora of the Livingston is distinct both from that of the Laramie and that of the Fort Union formation.

UNCONFORMITY BETWEEN LARAMIE AND LIVINGSTON FORMATIONS.

Unconformity between these two formations has been observed by Dr. A. C. Peale in the vicinity of Sphinx mountain in the Madison range. At this place an area of Livingston beds, representing the lower part of the formation, rests in marked angular unconformity upon the Dakota, and all later formations including the Laramie. An uplift, followed by an erosion of about 3,000 feet of strata at the close of the Laramie and before the deposition of the Livingston, is quite clearly evidenced. Throughout the region east of the mountains examined by the writer, the Livingston beds have not been found resting upon strata older than the Laramie. Considerable variations in the thickness of the latter are believed, however, to be in part due to a period of erosion preceding the deposition of the Laramie.

Undoubted proof of unconformity between the two formations is, however, afforded by the pebbles of the conglomerates of the Livingston. The Cretaceous section up to and including the Laramie affords proof of considerable oscillation of sea and land, but there is good ground for believing that the earlier sediments of this age were nowhere elevated and subject to erosion. The sandstone and conglomerates of the Laramie all indicate their derivation from Archean land. No fragments of other rocks have yet been observed. In the Livingston, on the contrary, there are pebbles from all earlier rock masses, indicating very clearly the erosion of adjacent land masses consisting in part of upturned sedimentary rocks and forming the record of a period of erosion of 6,000 feet or more of strata. The conglomerates contain pebbles referable by fossils or lithological peculiarities to the Laramie, Montana, Colorado, Dakota, Jurassic, and Carboniferous, together with others of limestone that may be Cambrian, and a variety of quartzites and gneisses that are probably Archean. This lithological proof of a great unconformity is in itself a sufficient cause to disregard the apparent conformity of the two formations in the region east of the uplifts of the Front ranges. It is evident moreover that the slight erosion of this region, and the horizontal attitude of the strata during the erosion interval, would necessarily make an unconformity less marked and much harder to detect in this region than nearer the shore line where the coarser sediments and the greater uplift and erosion all reduce the unconformity more apparent.

THE FORT UNION FORMATION.

In the Crazy mountains and the broken plains country to the east the Livingston is overlaid by a series of beds, believed to be a distinct formation, corresponding in stratigraphic position and fossil contents to the beds exposed along the Missouri river at the mouth of the Yellowstone, so long known in geological literature as the Fort Union beds. A detailed description of this formation will not be given here, as it will be discussed in another paper. The formation consists of rather massive, cross-bedded sandstones, with gray, silty shales and local lenses of impure limestone. In lithological habit and general field appearance the formation is easily distinguished from either the Laramie or Livingston rocks, and its fossil contents consist wholly of land and of fresh-water mollusks, and of plants characteristic of the Fort Union of the Missouri river. A measured thickness of 4,000 feet was observed overlying the Livingston, on Labor creek east of the Crazy mountains. The rocks of this formation have never been found west of the foothills of the Rocky mountains, but cover the greater part of the plains to the eastward.

AGE OF THE LIVINGSTON FORMATION.

The different views held by geologists upon the age and relations of the Laramie group, are due to a fundamental difference in the definition. The name was originally applied by King to the series of conformable sediments ending the marine Cretaceous.[1]

A very much wider significance was given to the term Laramie by Dr. White, who correlated the various lignite-bearing strata of the Rocky mountain region, under the name Laramie group. Thus defined the name included formations which further researches show to be distinct in both stratigraphic relations and paleontological remains.[2] It is evident also that collections of fossils from this heterogeneous group of strata, having been described as from the Laramie group, have made the so-called Laramie flora and fauna an unreliable criterion, by which to distinguish true Laramie from post-Laramie strata.

The facts of stratigraphy and of lithology herein presented demand the recognition of the importance of the interval between the Laramie and the Livingston deposits. The importance of this interval is also shown by the plant remains of the two formations, which present such differences and biological development as fully sustain the deductions from stratigraphical evidences. It should be stated, however, that it is only now, since the thorough revision of the flora of the so-called Laramie, in which the collections from the Denver and the Fort Union have been separated, that such evidence is of value.

Unfortunately, the known molluscan remains do not aid us in determining the importance of this erosion interval, because the invertebrate fauna of the Laramie is as much in need of revision as the fossil flora. It has been repeatedly stated, by eminent paleontologists, that sedimentation has been continuous and uninterrupted from the beginning of the Laramie to the end of the beds called Fort Union, which are, in this paper, separated from the Livingston as a higher series. The fossil fauna has been said to be the same from base to top throughout this series. A careful tabulation of species from different horizons shows, however, that this is not true in the collections made from the vicinity of the Crazy mountains.

The oyster bed, found in the Livingston, clearly shows an interval of

---

[1] Rep. Fortieth, Par. Survey, vol. I, p. 331.

[2] The Denver Tertiary Formation; Am. Jour. Sci., April, 1889. Post-Laramie Deposit of Colorado; Am. Jour. Sci., July, 1892.

quiet, succeeding the formation of the sandstones and grits of volcanic material, during which the beds were covered by brackish waters.

The fresh-water invertebrate fossils, at higher horizons, seemingly indicate a change in the character of the waters, and the final recession of the sea. The fossils of the oyster bed are, however, indentical with forms characteristic of the Coal-measures of the Laramie, underlying the Livingston in this same region, and therefore they can not be used as an argument for the separation of the two formations, but clearly show the existence of a Laramie fauna in brackish waters, after the deposition of several hundred feet of Livingston beds. It should be stated, however, that none of the conglomerates of the formation, in the region in which the oyster bed is found, contain pebbles indicating unconformity. It is indeed possible that these beds are incorrectly assigned to the Livingston, and should be classed as Laramie.

As the stratigraphical evidence herein presented shows an uplift, followed by a period of erosion after the deposition of the Laramie Coal-measures, and before the Livingston period, and the plant remains show a flora distinct from the Laramie flora, and allied to that of the Denver beds of Colorado, the Livingston beds are clearly to be assigned to the post-Laramie.

The facts discovered make it necessary to limit the use of the term Laramie to the original definition, which applied the name to the strata ending the sequence of conformable sediments of Cretaceous age; this leaves no alternative but to call the Livingston beds post-Laramie. Such a designation will, of course, be questioned by those using the term Laramie in a broader sense. The great thickness of beds overlying the Livingston formation, aggregating some 8,000 feet of strata and forming the Crazy mountains, has thus far proved too barren in fossils to assign positively any definite age to the strata. Upon lithological grounds and from its stratigraphical position it is regarded as an equivalent of the Fort Union strata of eastern Montana. This is supported by the leaf remains obtained from the beds.

CANADIAN NOMENCLATURE.

In the northward extension of the Great Plains and the foothills of the Rocky mountains into Canadian territory, the careful work of the geologists of the Canadian Geological Survey has added much to our knowledge of the Cretaceous terranes. Both Dr. Dawson and Mr. Tyrrell have subdivided the great thickness of strata found overlying the Montana group into series stratigraphically distinct. Though the term Laramie group is retained for the entire thickness, Tyrrell states clearly that the lower of the two series into which he divides the strata (*i. e.*, the Edmonton beds) is alone entitled to that name. The overlying Paskapoo series he considers distinct, and though there is no apparent break or unconformity between them and the Edmonton, the flora and fauna indicate an Eocene age. These beds are probably identical with the Fort Union group of Montana.

The Edmonton is described by Tyrrell as the most characteristic series of the Northwest territory, for although its thickness never exceeds 700 feet the strata are horizontal and overlie a great extent of country. They consist of whitish or light gray clays and soft clayey sandstones weathering rapidly and into rounded outcrops. The beds are frequently seamed with layers of ironstone whose nodules cap pinnacles cut in the soft sandrock. It is essentially a coal horizon and of considerable economic importance. The fossil fauna and flora includes a number of brackish-water shells, and dinosaurian remains and plant remains closely related to the Belly river, and of unquestioned Laramie types.

The Paskapoo beds include all the rocks generally ascribed in this part of Canada to the Laramie that overlie the Edmonton series. A thickness of 5,700 feet is exposed on the outer edges of the foothills. The rocks are light gray or yellow sandstones weathering brown, thickly bedded and cross bedded with light blue gray or olive sandy shales, holding intercalations of hard lamellar sandstones, and rarely lenses of blue concentric weathering limestones. The whole series is characterized by the presence of land and fresh-water shells, and a flora of Fort Union type.

Mr. Tyrrell says the Rocky mountain uplift began after the deposition of the Edmonton Laramie, the plains gradually sinking beneath the level of the fresh-water lake. The distinction between the Fort Union and the coal-bearing Laramie has been strongly insisted upon by Newberry, by whom the Fort Union with its wholly distinct flora was regarded as Eocene. That no unconformity has been recognized between the two in the region of the Great Plains is to be expected, but the collections of Prof. L. F. Ward from near Glendive, on the lower Yellowstone river, seem to show the absence of the Laramie as defined in this paper at that locality, the Fort Union resting directly upon Fox hill strata. The interpolation of the Livingston series and the great unconformity it shows, between the coal-bearing Laramie and the Fort Union, seems to be good and sufficient grounds for the adoption of Prof. Newberry's divisions, and places us in accord with the results of recent work in Colorado, so fully described by Cross and Hill in their recent publication.

POST-LARAMIE VOLCANIC ERUPTIONS.

The rocks described as parts of the Livingston formation all suggest the importance and extent of the volcanic activity that followed the coal-making period of the Laramie. The water-laid sediments and the terrestrial accummulations of breccias and agglomerate both clearly show the proximity of volcanic centers. These rocks have now been identified over parts of a large area of the Rocky mountain front in Montana and show that the eruptions were not merely local in character. At only one locality, observed by Dr. A. C. Peale, near the Jefferson river, have interbedded lava flows been observed. The deposits generally seem to indicate a period of volcanic outbursts, rather than profound intrusions or extensive outflows of later ages. This volcanic activity became the most important feature of Tertiary time in this region and profoundly modified the topography, which is today largely due to the breccias and lavas of that age. The importance of the Livingston rocks is apparent when it is considered that the volcanoes of that period were the ancestors of the great volcanoes of Tertiary time, and the definite establishment of the stratigraphical position of the earliest records of this activity is the foundation for the study of the order of succession of the volcanic rocks of the region and the geological history which they record.

It may be of interest in this connection to refer briefly to other occurrences of volcanic rocks in the Cretaceous. The presence of conglomerates formed of volcanic pebbles in what is here designated the Livingston series was noted by Lindgren while studying the relations of the coal beds to the older rocks for the Northern Transcontinental Survey.[1] In his later paper on eruptive rocks from Montana,[2] he states: "The character of the subaerial masses accompanying these eruptions is not well known; only a few conglomerates in the Laramie give some hint as to their nature. In the case of a volcanic conglomerate at the coal fields of Bozeman, the horizon could be determined to be 2,200 feet above strata in which fossils of the Fort Benton group were found. This conglomerate consists of pebbles of hornblende-andesite, to which consequently no later age than lower Laramie can be assigned."

In a conglomerate about 1,000 feet above Cretaceous No. 2, in the Highwood mountains, dacites and andesites were found by the same observer. Augite-andesite pebbles form a conglomerate exposed on Sixteen-mile creek, and considered by Lindgren to be Laramie.

In Canada Dr. Dawson has described the occurrence of volcanic agglomerates similar to those of Montana interbedded in a series of strata overlying the Kootanie coal seams, and referred to the Dakota. These agglomerates occur at a horizon about 3,350 feet above the Kootanie coal seams, and consist of "volcanic rocks chiefly, if not entirely, fragmental, forming an agglomerate of varying coarseness, frequently so fine as to be designated a volcanic ash." For the most part they are grayish green or purple, and toward the base weather easily, forming rounded crumbling masses. This description is equally applicable to the agglomerates of the Bozeman coal field. In the general geology of his report, Dr. Dawson alludes still further to the volcanic agglomerates: "The volcanic ash beds and agglomerates of the Cretaceous in this region are evidently due to a local eruption which had its center in the latitude of the Crow Nest pass. These volcanic rocks have, however, been traced north and south from this point over

[1] Tenth Census, vol. XV, p. 725.
[2] Proc. Cala. Acad. Sci., ser. 2, vol. III, p. 51.

a total length of 45 miles, and may probably have at one time had as great an extension east and west, though this has subsequently been diminished by the folding together of the beds. The volume of strata between the coal-bearing horizon and the base of the volcanic rock is estimated approximately at 3,350 feet in the Crow Nest pass, and 2,400 feet on South Kootanie pass. The volcanic rocks themselves are 2,200 feet thick at Crow Nest pass and thin rapidly to the north and south. Dakota plants are found a few hundred feet below these volcanic rocks."

SUMMARY.

The facts presented in this paper are believed to be an important contribution to our knowledge of the orographic and structural geology of the Rocky mountains. The post-Laramie movements that formed so important a part of the mountain building period in Colorado are herein shown to have this parallel in Montana and to accord with the observations made in Canada by Dawson and Tyrrell.

The facts which have been presented may be summarized as follows:

First. The coal-bearing Laramie terminated the succession of conformable cretaceous sediments.

Second. The beds overlying the Laramie Coal-measures give evidence in their pebbles of an unconformity with them and are distinguished by a remarkable change in their composition. To this series of beds the name Livingston formation is applied. It consists of sandstones, conglomerates, and shales, formed chiefly of andesitic volcanic material, with an admixture of Archean débris near the shore line. The beds show very little assorting by water action, the fragments are angular, and the lower part of the series is decidedly tufaceous, being frequently a fine volcanic agglomerate. These beds are consolidated, water-laid sediments formed of cinders, lapilli, and other ejectamenta of explosive volcanic eruptions. This material fell directly into the lake waters or was washed into them from the slopes of the volcano. The abundant plant remains of this formation are discussed at length in Prof. Knowlton's report.

Third. Volcanic agglomerates are intercalated in the Livingston formation. They are unmistakably subaerial deposits of coarse volcanic ejectamenta, compactly cemented by fine-grained ash and rudely bedded. They represent the material forming the flanks of a post-Laramie volcano, whose northern base was subsequently covered by the waters of a lake whose sediments form the rocks of the Crazy mountains.

The lower division of the Livingston beds is thinnest on the Boulder river, where the agglomerates are thickest, increases in thickness as the latter thins out, and attains a maxium development on the Missouri-Yellowstone divide, where the agglomerates are farthest away.

It is believed that the Livingston series and the volcanic agglomerates are the record of volcanic eruptions which began after the close of the coal-making Laramie and were attended by an uplift of considerable extent. Erosion of the volcanic slopes supplied the rounded pebbles and sands, while ash showers formed the coarser tufaceous rocks. In the eastern part of the Bozeman coal field the quantity of ejected material being greatest as nearer the source, the shallow waters were soon filled and the formation of the agglomerates began. Such gradual shallowing and filling are clearly indicated in the beds beneath the agglomerates. An examination of thin sections of the rocks forming the lower part of the Mission creek formation shows them to be composed of the same andesitic material as the agglomerates.

The rocks of this formation generally rest directly upon the Laramie Coal-measures in apparent conformity. The direct unconformity of the Livingston beds observed at Sphinx mountain and the positive proof of a great unconformity and subsequent erosion afforded by the composition of the conglomerates of the series show that the epoch of the coal-forming Laramie was terminated by an uplift of considerable extent. The land area resulting from this elevation was exposed to erosion during a prolonged period, in which a thickness of 4,600 feet of Mesozoic beds was removed and the Paleozoic limestones were exposed to denudation. The Livingston beds were deposited during this period of erosion. The lowest beds of the series in which no pebbles of sedimentary rocks have been detected may represent the area deposits following elevation. They certainly evidence a time of intense volcanic activity. The source of volcanic material is probably to be found in the volcanic outbursts of the Boulder river on the east and of the Flathead pass country to the north.

The recognition of the Fort Union formation above the Livingston is also believed to be an important discovery. This formation has long been a cause of controversy, and has by many been excluded from the Laramie. As its molluscan fauna is wholly fresh water, and, as such, is of little value in determining its age, the fossil flora has been relied upon for its discrimination, and this is clearly Eocene. The stratigrapic relations herein detailed seem to confirm this view.

ANNOTATED LIST OF THE FOSSIL PLANTS OF THE BOZEMAN, MONTANA, COAL FIELD, WITH TABLE OF DISTRIBUTION AND DESCRIPTION OF NEW SPECIES.

By F. H. KNOWLTON.

The first collection of fossil plants from what is now very generally known as the Bozeman coal field was made in 1871[1] by the members of Dr. F. V. Hayden's party while they were encamped at Fort Ellis, preparatory to beginning their memorable exploration of the Yellowstone national park. The actual collecting was done by Dr. A. C. Peale, Mr. Joseph Savage, and Mr. W. H. Holmes. The specimens, as I am informed by Dr. Peale, were all obtained on the same day and from the same vicinity, although not all at exactly the same spot. As the country was at that time new and unsettled, the nearest fixed point was the military reservation of Fort Ellis, and the specimens were labeled by the various collectors as follows: "Six miles above Spring canyon (now known as Rocky canyon), near Fort Ellis, Montana"; "above Spring canyon, near Fort Ellis," and "near Fort Ellis, above coal." The fact that there were three kinds of labels lead Prof. Lesquereux, to whom the specimens were submitted for examination, to suppose that they came from quite different localities, but in his published account[2] he referred them to the same horizon. Most of these specimens are fortunately still preserved in the collections of the U. S. National Museum, and it is therefore possible to correlate them with considerable certainty with the recent collections made in the same region.

The specimens of this first collection may be very readily separated into two groups by the character of the matrix in which they are preserved. The first consists of a very hard, dark metamorphic shale, breaking across the plane of stratification, and therefore rarely affording perfect impressions. The other is a lighter colored, but very coarse, hard sandstone not well suited for the preservation of the details of nervation.

The exact spot from which the original specimens in dark metamorphic shale were obtained has been revisited by Dr. Peale and myself

[1] Hayden's Ann. Rept., 1871, p. 296. [2] Hayden's Ann. Rept., 1872, p. 404.

and a considerable collection gathered, which contains nearly all of the species known, from a comparison of the types in the National Museum, to have come from there. It is the locality now known as Hodson's coal mine, and is on Meadow creek, about 12 miles southeast of Bozeman.

The precise point at which the specimens preserved in the coarse sandstone were obtained has not been rediscovered, as they were collected in 1871 by Messrs. Holmes and Savage, who have never revisited the place. There is, however, little reason to doubt but that it is the same horizon as that at which plants in exactly similar material have been obtained in recent years at the mouth of Bear canyon and near the mouth of Fir canyon. If this supposition be true, and there is no reason to suppose the contrary, as it can be traced continuously from the mouth of Bear canyon to the Meadow creek locality, this horizon is a little lower than the former or the one containing the dark cross-bedded shales.

Following is an enumeration of the material which has furnished the basis for the present paper, with a statement of localities and collectors:

The original collection of 1871, embracing forty specimens and twenty species preserved in the U. S. National Museum.

Timber line, Gallatin county, Montana. Collected by Dr. A. C. Peale, August 30 and and 31, 1883. A few nearly indeterminable fragments.

East side of Bridger range, 8 or 10 miles north of Bridger canyon, Gallatin county, Montana. Collected by Dr. A. C. Peale, August 9, 1885. Fragments determinable generically only.

East side of Bridger range, half mile north of Flathead pass, Gallatin county, Montana. Collected by Dr. A. C. Peale, August 28, 1885. Contains only three species.

Bear canyon, half mile above its mouth and 6 miles southeast of Bozeman, Gallatin county, Montana. Collected, August 25, 1886, by Dr. A. C. Peale. This is the coarse sandstone mentioned above and contains fragments of five or six species.

Near head of Fir canyon (north side), 8 miles east of Bozeman, Gallatin county, Montana. Collected by Dr. A. C. Peale, July 23, 1887, and September 28, 1888. Embraces about a dozen species.

Stone quarry on the road to Meadow creek and about half mile above its mouth. Collected by Dr. A. C. Peale and F. H. Knowlton, September 27, 1888.

Hodson's coal mine on Meadow creek, 12 miles southeast of Bozeman, Gallatin county, Montana. Collected by Dr. A. C. Peale, August 16, 1888, and by Dr. Peale and F. H. Knowlton September 28, 1888.

Mouth of Fir canyon, east side of East Gallatin river, 4 miles southeast of Bozeman, Gallatin county, Montana. Collected by F. H. Knowlton, July 3, 1888.

Between middle and north branches of Bear creek, east of Madison valley, on the east side of the Madison range. Collected by Dr. A. C. Peale August 20, 1889. This is really extralimital, but is included because it is the only other lot of plants from this part of Montana, and is moreover in material similar to that from Hodson's coal mine, and also contains some of the same species.

Horr and Craig mines, Cinnabar mountain, Montana. Collected by W. H. Weed July 17 and 18, 1890.

Near Little Mission creek and east of Mission creek. Collected by W. H. Weed, August 22, 1890.

ANNOTATED LIST OF SPECIES.

ANEMIA SUBCRETACEA (Sap.) Ett. and Gard.

Gymnogramma Haydenii Lx.

Only two or three small fragments observed.

ASPIDIUM LAKESII (Lx.) Kn.

Plate II, figs. 1–4.

Lathræa arguta Lx. Hayden's Annual Report, 1869, p. 96.

Sphenopteris eocenica Ett. Eoc. Fl. d. Mont. Prom., p. 9, Pl. II, figs. 5–8; Hayden's Annual Report, 1872, p. 376.

Sphenopteris Lakesii Lx. Tert. Fl., p. 49, pl. II, figs. 1, 1*a*.

Sphenopteris membranacea Lx. Hayden's Annual Report, 1873, p. 394; Tert. Fl., p. 50, pl. II, figs. 2, 2*a*, 3, 3*a*.

Habitat.—Between middle and north branches of Bear creek, east ot Madison valley, on the west side of the Madison range, Montana. Collected by Dr. A. C. Peale August 20, 1889.

As stated in the list of localities this material is not from the Bozeman coal field proper, but is included on account of the fact that it is the only other lot of plants from this part of Montana, and moreover possesses exceptional biological interest. It is undoubtedly of same age as the Hodson's coal mine material. The form to which these specimens are referred occurs in great abundance in the Denver beds ot Colorado and may be regarded as one of the most characteristic species of that formation. The collections from Colorado contain hundreds of specimens, but strangely enough not one has been found in fruit, and it is therefore of great interest to find the fruiting specimens and be able to settle definitely its systematic position. In absence of the fruit it was referred to the genus Sphenopteris by Lesquereux, but the fortunate finding of these fragments in fruit, as shown in Figs. 1, 2, 3, of Pl. VI, makes necessary their reference to the genus Aspidium.

The complete description of this species in the light of all known material is reserved for a subsequent publication, but in order to show that the Montana specimens agree in matter of outline and nervation with those from Colorado, a single specimen is figured (Pl. VI, Fig. 4) from near the Douglas coal mine at Sedalia, Colo.

EQUISETUM (?)

A minute fragment of doubtful identity.

ABIETITES DUBIUS Lx.

Lesquereux, Tert. Fl., p. 81, Pl. VII, Fig. 24; *non* Figs. 20, 21, 21*a*.

The specimens upon which this species was founded are preserved in the U. S. National Museum. After a careful study of them, together with all material since obtained from the same region, I have divided the species as defined by Lesquereux, a part going to *Sequoia Reichenbachi* Gein. (q. v.), and the small, rather doubtful remaining ones are retained under *A. dubius.*[1]

Abietites setiger Lx., described at the same time, is to be dropped. Schenck (Zittel's Handb. d. Pal., vol. II, p. 350) was the first to suggest that the fragment upon which this was founded was probably nothing but the roots of some plant, and an examination of the type specimens in the U. S. National Museum abundantly confirms this view.

SEQUOIA REICHENBACHI Gein.

Abietites dubius Lx., ex. p., Lesquereux, Tert. Fl., p. 81, pl. VI., figs. 20, 21, 21*a*.

Sequoia Reichenbachi is essentially a Cretaceous species and enjoys a very extensive vertical and areal distribution. It first appeared in the extreme upper Jurassic, is abundant in the Kootanie and Potomac formations and other lower and middle Cretaceous deposits, and is also found in the lower or true Laramie and the post-Laramie of Colorado and Montana.

The National Museum contains several specimens under this name from Spring canyon (Hodson's coal mine), although it does not appear in any of Lesquereux's publications, as found at this place. The recent collections also contain a number of fine specimens. They are distinguished from *Abietites dubius* Lx., by the smaller, more arched and very acute leaves, which were clearly sharply angled. I have referred here Figs. 20, 21, 21*a*, pl. VII, of Lesquereux's *Tertiary Flora*, there called *Abietites dubius.*

TAXODIUM DISTICHUM MIOCENUM Heer.

Heer, Mioc. Balt. Fl., p. 18, Pl. II; III, Figs. 6, 7; XIV, Figs. 24–28; XV, Fig. 1*a*; Flor. foss. arct., V, Pt. II, p. 33, Pl. VIII, Fig. 25*b*; IX, Fig. 1; Lesquereux, Tert. Fl., p. 73.

Taxodium dubium Heer. Lesquereux, Hayden's Annual Report, 1872, p. 389; 1873, p. 409.

Several specimens of this widely distributed species were found in the Hodson's coal mine material. One of them is a large, well preserved specimen, which makes the determination very satisfactory.

GINKGO ADIANTOIDES Ung.

Represented by several fine specimens.

---

[1] For full discussion of the conifers of the Bozeman coal field, see forthcoming Monograph on the Laramie and allied formations, in preparation.

THINNFELDIA POLYMORPHA (LX.) Kn.

Plate I, Figs. 1–4.

Salisburia polymorpha Lx. Am. Jour. Sci., 2d ser., vol. XXVII, 1859, p. 362; Hayden's Ann. Rept., 1872, p. 404; Tert. Fl., p. 84, Pl. LX, Figs. 40, 41; Knowlton, Proc. Biol. Soc. Wash., Vol. VII, p. 153.

Leaves cuneiform or long wedge-shaped, narrowed from above the middle downward into a strong thick petiole and rounded, erose or irregularly lobed or cut at apex; margin entire or more frequently strongly irregularly undulate or toothed; mid-vein very strong, continuing to the apex or in some cases nearly or quite vanishing just below the point; veins thin, close, simple, emerging at an acute angle from the mid-vein, thence running with slight curve to the margin.

The leaves of this species are very large, measuring in some instances fully 30^{cm} in length and $9–11^{cm}$ in width. The smallest specimen (Fig. 4), which may not be complete, is 10^{cm} in length by 3^{cm} in width, but most of the specimens, of which there are numerous fragments, are fully as large as the maximum size given above. They were provided with a strong thick petiole, as in Fig. 3, at least 3^{cm} long and 3^{mm} in diameter. In outline the leaves are long wedge-shaped at base, and rounded or variously, irregularly lacerate-toothed at the apex, as seen in Figs. 1 and 2. The margin, perhaps best seen in Fig. 2, is irregularly undulate, or in some cases, as in Fig. 4, slightly toothed. The mid-vein or rib is very thick and prominent, sometimes running clear to the apex, as in Figs. 2 and 4, while in others it vanishes just below the apex, as in Fig. 1. The lateral veins emerge at a very acute angle and are close, fine and only slightly curved in running to the border.

The name of *Salisburia polymorpha* was first given by Lesquereux[1] to some fragmentary specimens collected by Dr. John Evans at Nanaimo, Vancouver island. It was not described in this publication, the only statement being that, besides several species of dicotyledons, there was also "a very fine Salisburia, very variable in the outline of its leaves and named *Salisburia polymorpha* (Lesq.), distinctly related to *Salisburia adiantoides* (Ung.), found in the Pliocene of Italy." Lesquereux's next mention of this species was in Hayden's Sixth Annual Report (1872), when he identified as belonging to it certain fragmentary specimens obtained by Dr. A. C. Peale and Mr. Joseph Savage from "six miles above Spring canyon, near Fort Ellis, Montana," which locality is the same as that now known as Hodson's coal mine. He alludes to the Vancouver specimens, and states that they had been "described and figured for a final report, which was delivered to Dr. Evans but was never published." This report still remains, so far as known, unpublished, and therefore the Vancouver specimens are still without description or fig-

[1] Am. Jour. Sci., 1859, p. 362.

ures, existing only in name. The Spring canyon (or Hodson's coal mine) specimens were more fully described and illustrated, under the name of *Salisburia polymorpha*, by Prof. Lesquereux in his Tertiary Flora, where he states that he is not quite positive that they are actually the same as those from Vancouver, a view that, in the light of the present large series, is likely to prove correct. But in absence of either descriptions, drawings or specimens from Nanaimo, it is manifest, that according to the laws of nomenclature, the name must be permanently associated with the specimens first actually described, and it therefore falls to the Montana specimens. If subsequent investigation shows that the Nanaimo specimens are actually the same as those from Montana, they will of course take this name, but if they represent a good species of Salisburia (or Ginkgo) allied to *S. adiantoides*, as Lesquereux has said, they must receive a new name.

Some of the forms of this species seem at first sight strongly to resemble certain forms of Ginkgo, as Fig. 4, and in absence of a series for study Prof. Lesquereux was undoubtedly justified in supposing them to represent leaves of this genus. But when a considerable number of specimens are examined it is seen that they do not agree closely with Ginkgo, although it is possible that they are in some way connected with it. Four leaves of Ginkgo that have been identified as *G. adiantoides*, are found in beds of nearly the same horizon, but not actually associated in the same place. As these leaves can not be received in Ginkgo, I have thought best to place them under the somewhat miscellaneous genus of Thinnfeldia, which, according to recent views, seems best characterized to contain them. The genus Thinnfeldia should be placed according to the latest authorities among the conifers, a view which the present specimens undoubtedly confirm, but it has been shifted about from place to place. Thus Schenk at one time regarded it as belonging to the Cycadaceæ; while Saporta, Schimper, and at first Nathorst, would place it among the ferns, a position which some of the forms included under it would undoubtedly demand, for there are, judging from the published drawings, some true ferns. On the other hand, Ettingshausen and Nathorst, in his later views, would put this genus among the conifers, the former writer supposing it to be allied to the genus Phyllocladus.

The species under consideration is found in company with and is undoubtedly related to the following species, which in turn, is very closely related to *T. Lesquereuxiana* of Heer from the Atane beds of Greenland. Heer identified with his species Lesquereux's *Phyllocladus subintegrifolius* from the Dakota group of Kansas and placed it, under the heading *Incertæ sedis*, after the ferns. Whatever may be the disposition of the various species of Thinnfeldia, for this genus seems to be in need of revision, I am convinced that the Montana specimens under consideration belong to the conifers and are not far removed from the genus Phyllocladus.

Certain of the smaller fossil leaves, as Fig. 4, have a strong resemblance to certain living species of Phyllocladus, as for example *P. rhomboideus* Rich., from Tasmania, which is irregularly toothed or lobed on the margin but is larger and more regularly wedge-shaped at apex. The rachis is much the same in both. It is possible that it may be connected with other living species of Phyllocladus, but the limited herbarium at my command will not admit of further comparisons.

THINNFELDIA LANCEOLATA n. sp.

PLATE V, Fig. 5.

Leaves long-lanceolate, tapering gradually below into a thick petiole and above into a long, slender acuminate apex; margin entire or slightly undulate-crenate, especially above the middle; mid-vein very strong in the lower portion, gradually becoming thinner above and vanishing below the apex; veins numerous, close, simple or rarely forked; at an acute angle of divergence, running straight to the margin.

This species is well represented by the very perfect specimen figured (Pl. V, Fig. 5), as well as by several smaller less perfect fragments. It has a length of 31^{cm} and a width in the middle of 4^{cm}. The midrib at the base is very strong and thick and was evidently extended into a thick petiole, which is now broken. Another specimen of exactly the same shape is only about 25^{cm} long and 3^{cm} wide, but has neither the apex or base preserved. The midrib is very pronounced in the lower half of the leaf, but becomes gradually thinner until it vanishes in the upper fifth of the leaf. The nerves emerge from the midrib at a very acute angle. They are close, parallel and rarely, possibly never, forked.

This species is found associated in the same beds, and even on the same pieces of matrix, with the preceding, and is evidently closely related to it. The thick, prominent midrib and the numerous close veins emerging at an acute angle from it, are the same in both species, but the present species is readily distinguishable by its lanceolate form, with nearly entire margins and long acuminate apex. It is possible that they may represent leaves from different parts of the same tree, or of the same species under different circumstances, for as is well known, many living trees exhibit such striking differences in form and size of foliage as almost to preclude the probability of their belonging to the same species. But as both forms can be so readily separated by the characters pointed out above, and particularly as no intermediate forms have been detected, it is thought best, provisionally at least, to describe them as distinct.

The only described species of Thinnfeldia with which this form seems to be related is *T. Lesquereuxiana* Heer (Fl. foss. arct., VI, Abth. 2, p. 37, Pl. XLIV, Figs. 9, 10; XLVI, Figs. 1–12), with which Heer has also identified the *Phyllocladus subintegrifolius* of Lesquereux (Cret. Flora, p. 54, Pl. I, Fig. 12). It, however, differs by its much larger size and in being always pointed at apex and quite entire. It is not improbable, however, that they may be more closely related than the present specimens permit of deciding.

There are several living conifers with which this species is undoubtedly related, and were it not for the fact that it seems to be related to the preceding form (*T. polymorpha*), it might perhaps best be described under the name of the living genus. This living genus is Podocarpus, of the tribe Podocarpeæ. The species which it most resembles is *P. macrophylla* Wall., from tropical India, which has lanceolate leaves 6 to 8 inches in length and a little more than one-half inch in width, and of exactly the same shape as the fossil leaves. It has also a strong midvein with close, divergent, lateral veins, as in the fossil. *P. Rumphii*, from New Guinea, is also quite like the fossil species, as is *P. leptostachya* Bl., from Borneo, and *P. salicifolia*, from the island of St. Martha.

PHRAGMITES ALASKANA Heer.

The specimen referred by Lesquereux to this species is in the U. S. National Museum collection, and the newly obtained material agrees exactly with it.

CAULINITES SPARGANIOIDES Lx.

The fragments which Lesquereux had from this place were referred with considerable doubt to this species. The specimens in the latter collections are similar to those seen by Lesquereux, but the question as to whether they or any of them really represent the species under consideration is unsettled.

POPULUS MUTABILIS, var. ovalis Heer.

Not observed in the recent collections.

POPULUS LÆVIGATA Lx.

Only a single specimen, which is of the same character as that figured by Lesquereux from Rock creek, Laramie plains, being, however, much smaller.

POPULUS cf. ARCTICA Heer.

Plate II, Figs. 7–9.

Leaves broadly reniform with rounded lobes, a heart-shaped or slightly wedge-shaped base and very rounded apex; 5-nerved from the apex of the petiole, the nerves all of the same strength.

Habitat.—Near mouth of Bear canyon, 6 miles southeast of Bozeman, Montana. Dr. A. C. Peale, collector.

As will be seen from the figures the three leaves here referred provisionally to this species differ considerably among themselves, and there may possibly be two species, although probably not. Two of them

(Figs. 8, 9, of Pl. VI) are clearly similar. They have a very rounded outline, with a distinctly heart-shaped base. The five nerves, which are of nearly equal strength, all, or usually, arise from the apex of the petiole and do not arch much in passing to the borders. The other leaf (Fig. 7) has the same rounded outline, being as broad as or broader than long, but is wedge-shaped at base. The nerves are five in number, as in the others, and they diverge from the apex of the petiole in the same manner, but as the leaf is narrower the nerves have a more acute angle. In all the leaves it is a noticeable fact that the five nerves divide the leaf into approximately six equal parts, thus making a wider angle in the broad leaves than in the wedge-shaped one. The branching of the nerves, as far as it is possible to make it out, is the same in all. The further fact that they all occur at the same place and even on the same piece of matrix is suggestive of their belonging to the same species.

The question of their identity with *P. arctica* Heer is quite another thing. They can hardly be regarded as typical *P. arctica*, and yet they do not differ greatly from a few that have been figured as belonging to this species. Heer, Fl. foss. arct., Vol. I. Pl. V, Figs. 3, 4; Pl. XXI, Fig. 14; *op. cit.*, Vol. III. Mioc. Pfl. v. Grönl., Pl. II, Fig. 20*a*; *op. cit.*, vol. IV, Beiträge z. foss. Fl. Spitzb., Pl. XXXII, Fig. 3; Lesquereux, Tertiary Flora, Pl. XXIII, Figs. 1, 4, etc., while not absolutely similar, are very suggestive. In absence of sufficient material to make out a fuller description it has been thought best to leave them as above.

POPULUS? PROBLEMATICA n. sp.

Plate VI, Figs. 5, 6.

Fruiting ament long peduncled, the peduncle rather thick; capsules oblong, rounded at apex, pediceled.

Habitat.—Head of Fir canyon (north side) 8 miles east of Bozeman, Montana. Dr. A. C. Peale, collector.

The best preserved specimen (Pl. VI, Fig. 5), appears to have had a shorter peduncle than the other (Fig. 6), but it is partly obscured by the matrix and its full length can not be ascertained. The capsules at the base of this ament are long pediceled, but the pedicels become gradually shorter toward the apex of the ament and the capsules also become smaller. The other specimen (Fig. 6) is very obscure and the figure of it is in a measure conventional. It has a long, naked basal portion, and the capsules, if they be such, are more closely oppressed to the axis than in the best preserved specimen. It appears to have been in a younger state than the other at the time of its fossilization. It is also possible that it (Fig. 6) is not the same species as the other, for as remarked above, it is so obscure that it is made out with great difficulty.

It is with a good deal of hesitation that these aments are described under the name of Populus. As they occur at the same place, and one of them actually on the same stone with specimens of *Thinnfeldia polymorpha*, the first thought is that they represent fruiting aments of this species, a view further supported by the fact that no leaves of Populus have been detected in this bed. A careful consideration, however, fails to develop other than negative support for this theory, for the aments that have been described for similar forms differ widely. Thus the aments described as belonging to Ginkgo in the various volumes of Heer's Arctic Flora are entirely different. The nearest approach to it is *Czekanowskia setacea* Heer,[1] which has pediceled fruits not unlike Fig. 5. But the leaves of this genus, which have sometimes been found attached to branches bearing the fruits, are entirely different from anything that has ever been found in the Bozeman coal field. There is, therefore, very little reason for supposing that these aments belong to this genus.

On the other hand, these aments have a decided resemblance to the mature fruiting aments of certain living species of Populus. They are for example very like *Populus monolifera* Ait., and more particularly *P. Fremonti*, Wats., var. *Wislizeni* Wats., from the state of Chihuahua, Mexico, as preserved in the herbarium of the U. S. National Museum. The living species mentioned have long aments with the large capsules pediceled as in the fossil and they decrease in size from above downward in the same manner.

While no leaves of Populus have so far been obtained in the same beds with these aments, no less than three well-marked species have been found in other parts of the Bozeman coal field, thus showing that this genus was undoubtedly present. It is, however, open to question, and it is to be understood as a merely provisional name awaiting the possible discovery of new and more decisive material.

SALIX ANGUSTA Al. Br.

The recent collections contain a great number of leaves or fragments of leaves which seem to be the same as those so identified by Lesquereux, but they are mostly without nervation and therefore in doubt.

QUERCUS CHLOROPHYLLA Ung.

The specimens referred by Lesquereux are in the Museum collection and are found to have come from the coarse sandstone layer. They are very obscure with very little nervation. The specimens in the recent collection are also in the coarse sandstone and are equally obscure. They are, however, the same as those referred by Lesquereux to this species.

QUERCUS CASTANOPSIS Newberry.

This determination is based on a single fairly well-preserved leaf, and can not therefore be regarded as of much value.

[1] Fl. foss. arct., VI, Nachträge z. Jura Fl. Sibiriens p. 18, Pl. VI, Fig. 15.

QUERCUS GODETI? Heer.

The specimens referred by Lesquereux to this species are in the Museum collection, while the later collections do not contain it.

QUERCUS ? FRAXINIFOLIA Lx.

No additional specimens of this species have been seen.

QUERCUS ELLISIANA Lx.

The most abundant species of oak found in the collections.

Quercus Pealei Lx., was founded upon a single leaf from Spring canyon. This specimen is fortunately preserved in the U. S. National Museum, and after some consideration I have decided to reduce it to *Q. Ellisiana.* Lesquereux in his last mention of *Q. Pealei* (Tert. Fl., p. 156) said: "This small leaf * * * may be referable to the former species." It comes from the same beds, and is the only one ever obtained. At first sight the nervation may appear quite unlike the typical *Q. Ellisiana*, but by comparing all the figures and recent specimens it is found that the position and direction of the lowest pair of secondaries depend upon the shape of the leaf, and the narrower examples of *Q. Ellisiana* have the same character.

JUGLANS RUGOSA Lx.

A number of good specimens obtained.

JUGLANS DENTICULATA Heer.

No specimens observed in the recent collections, and none of those referred to this species by Lesquereux are in the Museum collection.

JUGLANS RHAMNOIDES Lx.

The specimens referred to this species by Lesquereux are also missing, and none that could be regarded as similar have since been found.

PLATANUS GUILLELMÆ Göpp.

A number of well preserved leaves were found which seem clearly to belong to this species. They are evidently closely allied to the following species, as pointed out by Lesquereux,[1] and have usually been found associated with it. They probably represent a single variable species.

PLATANUS ACEROIDES Göpp.

None of the recent material contains specimens that seem to belong to this form, and its presence is based on Lesquereux's determination

[1] Tert. Fl., p. 183, et seq.

and upon a single broken specimen in the Museum collection under the name *Quercus platanoides*, now regarded as a synonym of *P. aceroides*.

FICUS AURICULATA Lx.

The recent collections contain nothing but a number of fragments that are doubtfully referred to this species, while the type specimens are missing.

FICUS TILIÆFOLIA Al. Br.

This species enjoys precisely the same status as the former.

FICUS PLANICOSTATA Lx.

The recent collections embrace a number of well preserved leaves that are referred with much certainty to this species.

CINNAMOMUM SCHEUCHZERI ? Heer.

The specimens in the collection of 1872 were doubtfully referred by Lesquereux to this species. They are preserved in the Museum collection and agree exactly with a number in the late collections. They are, however, not sufficient to settle the real question of their identity.

CINNAMOMUM ELLIPTICUM n. sp.

Cinnamomum polymorphum Al. Br., Lesquereux, Tert. Fl., p. 221, pl. XXXVII, fig. 10 [non fig. 6].

Cinnamomum Rossmässleri Heer, Lesquereux, Hayden's Ann. Rept., 1872, p. 379.

Leaf of medium size (about 9^{cm} long and 4^{cm} broad), long-elliptical in outline, apparently rounded above to a short acumen (broken), and below to a rounded, slightly wedge-shaped base; lateral nerves thick, as prominent as the midrib, ascending to near the upper extremity, branching outside; midrib sparingly branched above the middle.

Habitat: Hodson's coal mine on Meadow creek, 12 miles southeast of Bozeman, Montana.

It is with some hesitation that this species is described as new to science. It depends upon a single well preserved leaf and a number of more or less doubtful fragments. This nearly perfect specimen was described by Lesquereux as *C. polymorphum*, Al. Br., and is the only specimen upon which the presence of this abundant European species in American strata rests. In the discussion regarding *C. polymorphum*, Lesquereux says: "In the leaves[1] which I refer to this species, the surface is coarser cut by deeper nervils, the midrib more divided than in *C. affine*.[1] But the essential characters of *C. polymorphum* are not sufficiently distinct upon our specimens, none of them having the upper part of the

[1] The other one of the two so referred is now placed under *C. affine* Lx. F. H. K.

leaves or the acumen preserved, and the areolation and fibrillæ of the borders being obsolete. Therefore we may have in the two leaves referred here to *C. polymorphum* mere varieties of *C. affine*, and thus it may be that all the American Cinnamomum leaves represent only one species."

A careful comparison of the many published figures of *C. polymorphum* does not show any that agree satisfactorily with the one under discussion. It is for example much nearer to *C. Rossmässleri* Heer[2] with which Lesquereux appears at first to have identified it. It is also less like *C. affine* than he supposed it to be.

LITSEA WEEDIANA n. sp.

Tetranthera sessiliflora Lx. ex. p. Lesquereux, Tert. Fl. p. 217, pl. XXXV. fig. 9.

Leaf sessile?, entire, oblong-lanceolate in outline, broadest below the middle from which point it tapers upward gradually, then rather abruptly, into a sharp-pointed apex, and downward into a rounded heart-shaped base; midrib straight; secondaries about 6 or 7 pairs, subopposite, camptodrome, lowest pair emerging from just above the apex of the petiole at a more acute angle than the upper ones, joining the second pair just above the middle of the leaf; just below the first prominent pair of secondaries is a pair of thin veins that arch along near the lower margin of the leaf and unite with a branch of the first pair at about the middle of their length; cross nervation at right angles to the midrib.

Habitat: Hodson's coal mine on Meadow creek, 12 miles southeast of Bozeman, Montana.

The specimen of this species figured in the *Tert. Fl.* pl. XXXV, fig. 9, as *Tetranthera sessiliflora* was said by Lesquereux to have come from Evanston, Wyoming. Fortunately this specimen is still preserved in the U. S. National Museum collection (No. 305). A glance at the matrix shows conclusively that it could not have come from any known horizon at Evanston, and on referring to the Museum catalogue it is found properly recorded from "Spring canyon, Montana." The Museum contains another very perfect specimen (No. 834) of this species from the same place recorded under the name of Cassia, and the recent collection also affords another fine leaf, both of which agree perfectly with the one figured in the *Tert. Fl.*, loc. cit.

These leaves differ markedly from *Litsea* (*Tetranthera*) *sessiliflora* in being apparently sessile, in being broadest much below the middle, with a heart-shaped base and in having 6–7 pairs of secondaries with a single pair of thin veins below the lowest prominent pair. I have therefore regarded them as new to science and have named the species in honor of Mr. Walter H. Weed of the U. S. Geological Survey, who has done so much to unravel the intricate geology of this region.

[1] Fl. Tert. Helv. II, pl. XCIII, fig. 15.

LAURUS SOCIALIS Lx.

A number of fairly well preserved leaves are referred to this species.

FRAXINUS DENTICULATA HEER.

Several leaves with dentate margin are referred with considerable certainty to this form. It is, however, not well characterized.

ANDROMEDA GRAYANA HEER.

Probably the most abundant species from this locality.

ANDROMEDA AFFINIS Lx.

This species was first described by Lesquereux in Hayden's Annual Report, 1874, p. 348. It is there said to have come simply from "Spring canyon," without indication of the state or territory, and is included with the plants of the Dakota group. The type specimen is preserved in the U. S. National Museum where it was found among the specimens from Spring canyon, Montana, from which place it undoubtedly came as shown both by its original number and by the matrix in which it is preserved. In the Cretaceous and Tertiary Floras, p. 60, it is described among the Dakota group plants, an error which is also perpetuated in the final Flora of the Dakota Group, Monograph U. S. Geological Survey, XVII, p. 118.

NYSSA LANCEOLATA Lx.

The original specimens from Spring canyon that were referred by Lesquereux to this form are missing and none of the recent material contains it.

CORNUS RHAMNIFOLIA O. Web.

The specimens in the 1872 collection were preserved in the coarse sandstone and as they are very obscure they were with doubt referred to this species. The material from the mouth of the Bear canyon contains one or two leaves that have been referred here, although they are so obscure as to render their identification doubtful.

LEGUMINOSITES CASSIOIDES Lx.

A number of specimens are referred with certainty to this form as determined by Lesquereux's identification of the 1872 material.

CISSUS TRICUSPIDATA ? Lx.

Doubtfully referred to this species.

RHAMNUS RECTINERVIS Heer.

There are no specimens in the recent collections that can be referred to this form and the type specimens are also missing.

RHAMNUS SALICIFOLIUS ? Lx.

A number of fragments are doubtfully referred here.

CELASTRINITES LÆVIGATUS Lx.

The types of this species are preserved in the National Museum and are the only specimens ever found.

DOMBEYOPSIS PLATANOIDES Lx.

The types of this species are also to be found in the National Museum, and one or two fairly good additional specimens have been found.

NELUMBO.

A very obscure fragment doubtfully referred as above.

DISCUSSION OF TABLE.

Before passing to a consideration of the table it may be well enough to call attention to several points which would seem worthy of more consideration and weight than has usually been given them in many discussions of this kind, and in doing this I can hardly do better than quote from a recent paper by Prof. Fontaine.[1]

[1] Fossil plants from the Great Falls coal field, Montana. Proc. U. S. Nat. Mus. 1892, vol. xv, p. 489.

Table showing distribution of plants in the Bozeman coal field.

	Hodson's coal mine (Liv.).[1]	Flathead pass (Liv.).	Quarry, Chestnuts (Liv.).	Mission creek (Liv.).	Head of Fir Canyon (L.).[2]	Mouth of Fir Canyon (L.).	Mouth of Bear Canyon (L.).	Craig & Horr mines (L.).	Laramie (coal-bearing).	Denver.	Carbon and Evanston.	Fort Union.	Eocene (Alum bay, etc.).	Green River group.	Miocene.	Pliocene.	Remarks.
Anemia subcretacea (Sap.) Ett. & Gard.					×			×	×	×			×				
Aspidium Lakesii (Lx.) Kn									× ?	×							
Equisetum ?				×													
Abietites dubius Lx	×			×	× ?			× ?	×								
Sequoia Reichenbachi Gein			×						×								
Taxodium dist. miocenum Heer	×										×	×		×	×	×	
Ginkgo adiantoides Ung				×								×	×		×	×	
Thinnfeldia polymorpha (Lx.) Kn					×												
Thinnfeldia lanceolota, n. sp					×												
Phragmites alaskana Heer	×	×	×									×		×	×		
Caulinites sparganioides Lx			×						×		×						A true Laramie species.
Populus mutabilis ovalis Heer	×								×		×				×		
Populus lævigata Lx	×									×							
Populus ? problematica, n. sp					×												
Populus cf. arctica Heer						×											
Salix angusta Al. Br	×	×			×								×		×	×	Tertiary, mainly Miocene.
Quercus chlorophylla Ung						×											
Quercus castanopsis Newb	×											×					
Quercus Godeti ? Heer	×																
Quercus ? fraxinifolia Lx						×	×										
Quercus Ellisiana Lx	×					×											
Juglans rugosa Lx	×								×	×	×	×	×	×	×		Has a wide distribution.
Juglans denticulata Lx	×									×	×			×	×		
Juglans rhamnoides Lx	×								×	×	×						
Platanus Guillelmæ Göpp	×				×		×			×							Miocene outside of United States; true Laramie in United States.

Platanus aceroides Göpp			× ?							×	×	×	×	×	×	×	Miocene species outside of United States.
Ficus auriculata Lx	×									×							Mainly a true Laramie species.
Ficus tiliæfolia (Al. Br.) Heer	× ?								×	×	×	× ?		×	×	×	Largely Miocene outside of United States; typical in California Miocene.
Ficus planicostata Lx	×			×					×	×			×				Mainly a Denver species.
Cinnamomum Scheuchzeri? Heer.	×																
Cinnamomum ellipticum n. sp	×																
Litsea Weediana n. sp.	×																
Laurus socialis Lx			×								×		×				Type from the Laramie.
Fraxinus denticulata Heer	×								× ?		×				×		Mainly a Miocene species.
Andromeda Grayana Heer	×				×			× ?							×		
Andromeda affinis Lx	×				×												Distribution by error; all Dakota group.
Nyssa lanceolata Lx.	× ?									×							Denver only outside of Bozeman coal field.
Cornus rhamnifolia O. Web.							×										Identification doubtful; distribution omitted.
Leguminosites cassioides Lx					×			×						× ?			
Cissus tricuspidata? Lx.				×					×	×							Identification doubtful.
Rhamnus rectinervis Heer	×								×	×	×				×		
Rhamnus salicifolius? Lx.	×								×								
Celastrinites lævigatus Lx.	×																
Dombeyopsis platanoides Lx					×												

[1] LIV = Livingston beds.

[2] L = Laramie beds.

After discussing at some length the facies of the Great Falls flora Prof. Fontaine says: "In this connection I will repeat an opinion expressed before. In determining the age of an unknown group of fossil plants, greater weight, as evidence of age, ought to be assigned some plants than others. These are the plants whose fossils have marked and salient features, that permit them to be identified without danger of error. An example of this kind is *Frenelopsis*, especially *F. parceramosa* of the Potomac flora. Where these are fully established and at home in a formation, as would be shown by their general distribution and the abundance of fossil specimens that they afford, they ought not to be considered as units in a sum total to establish a percentage. Their evidence would thus be neutralized by that of other units which are newcomers or belated survivors. This is especialy true of floras in a critical stage of evolution, and which contain a considerable number of newcomers and survivors. The Potomac flora was one of this character, in which Jurassic types were being cast out and Cretaceous ones introduced."

The Bozeman coal field presents a problem somewhat similiar to that of the Great Falls coal field and remotely of the Potomac formation. That is, the fossil plants play an important role in confirming the results of stratigraphy. But as Fontaine has said we should not take absolute percentages but should take into account the species which may be identified with absolute or at least reasonable certainty, and also their relative abundance. Several European species were identified by Lesquereux with hesitation in this flora, such as *Quercus Godeti*, *Cinnamomum Scheuchzeri*, *Rhamnus salicifolius*, etc., and it would manifestly be not only unwise but probably absolutely wrong to attach much weight to the foreign distribution of species of so doubtful a status. Such determinations are especially hazardous when, as in the present instance, the specimens are fragmentary or preserved in a matrix which will not retain the essential nervation.

Again, it would seem well to use with caution evidence derived from a single specimen of a species, no matter how certain its identification might be. It may be a waning type or a newly introduced one. The force of this argument, however, is somewhat reduced by the fact that, unless the exploration of the beds has been very thorough, we can never be certain that the specimens seen are a fair and full representation of everything found at that place. There is always the possibility that the next blow of the hammer may have revealed an abundance of what is now considered rare or perhaps represented by a single specimen.

Lesquereux, in his original consideration of this flora, referred it to the lower lignite[1] or true Laramie. Prof. Ward, on the other hand, inclined to regard it as belonging to the Fort Union[2] beds, but he in-

[1] Hayden's Ann. Rept., 1872, p. 409.

[2] Synopsis of the Flora of the Laramie group, p. 441.

cluded with the Bozeman coal field the somewhat indefinite localities in or near the Yellowstone National park, known as Yellowstone lake, Elk creek, and Snake river, therefore attaching undue weight to species common to these places and the Fort Union beds. The specimens that Lesquereux examined from these localities are fortunately nearly all preserved in the National Museum, and from a study of the matrix in which they are preserved, together with the recollections of Dr. A. C. Peale, who either collected them personally or was with the parties when they were obtained, we are able to arrive at a pretty definite conclusion as to their position. Those from the "Snake river," or rather from the "Divide between Snake river and Yellowstone lake," were collected by Dr. Hayden's party in 1871, and are from strata resting directly upon the Fox hills, therefore probably true Laramie. This view is confirmed by the present members of the U. S. Geological Survey connected with the Yellowstone park division. This is the type locality for *Gymnogramma Haydenii* or *Anemia subcretacea,* as it is now called.

The specimens from the Yellowstone lake were obtained during the same season by Dr. Hayden himself, and come from the west side of the lake, probably not far from Stevenson's peak. The material is the brittle shales, characteristic of what is known as the Volcanic Tertiary of that region. *Equisetum limosum?* Linn., was identified from this place.

The specimens from Elk creek were obtained by Dr. Peale, who is able to locate the spot very definitely on the present map of the Yellowstone park. They came from the foot of low bluffs just above (N. W.) the trail to Pleasant valley. That is, they came from the base of Crescent hill, about one mile above Yancey's. Several specimens were obtained here, among them *Platanus nobilis* or *Aralia notata,* as it was called by Lesquereaux, the species which Prof. Ward seems largely to have relied upon to establish their connection with the Fort Union beds.

Having disposed of the localities clearly confounded with the Bozeman coal field, we may turn to a consideration of the table of distribution. This table embraces 44 more or less satisfactory species, which composes the flora of these beds. Of this number 5 are regarded as new to science, and are, therefore, dismissed as having, in themselves, no diagnostic value or at most only negative value. Of the remaining, 11 species have so far never been found outside of these beds, thus leaving 28 species having a distribution, and upon which we must largely rely for comparison. Of these 28 species no less than 22 are confined to the Livingston beds, while only 2 are confined to the Laramie proper, and 4 are found in both Livingston and Laramie beds. With this distribution of species within the Bozeman coal field in mind, we may pass to a comparison with other floras.

Of the 28 species only 7 have been found in the Fort Union beds.

These are *Ginkgo adiantoides*, *Phragmites alaskana*, *Juglans rugosa*, *Platanus aceroides*, and *Taxodium distichum miocenum*, which are positively identified in the two horizons, and *Quercus castanopsis*, which depends upon a single broken leaf from Hodson's coal mine, and *Ficus tiliæfolia*, found only in fragments in both places. Of the first four species, *Ginkgo adiantoides* has a very wide distribution outside of the United States in the Miocene and Pliocene of Europe. *Juglans rugosa* was originally described[1] from Marshall's mine, near Denver, Colorado, and is also especially abundant in the Denver formations at Table mountain, Golden, Colorado. It has a wide distribution in the United States and has also been found in the English Eocene at Alum bay Isle of Wight.

Of the 22 species of the Livingston beds having a distribution outside of this area, we find that 4 species (*Populus lævigata*, *Juglans denticulata*, *Ficus auriculata* and *Nyssa lanceolata*) are confined exclusively to the Denver beds of Colorado; 3 species occur in the Denver and later formations; 3 species in Tertiary beds; 10 species in Denver and Laramie, and only 2 species (*Sequoia Reichenbachi* and *Rhamnus salicifolius*) in Laramie exclusively. That is, no less than 17 of the 22 species are found either exclusively in the Denver or have their greatest development in this formation.

Of the 4 species (*Abietites dubius*, *Salix angusta*, *Platanus Guillelmæ* and *Andromeda Grayana*) found in both Livingston beds and Bozeman-Laramie, *Abietites dubius* is of doubtful status, being questionable in the Bozeman-Laramie; *Salix angusta* is a common European Eocene and Miocene species and is not found in the Laramie outside of the Bozeman coal field; while the other two are clearly identified in both horizons.

The two species found in the Bozeman-Laramie exclusively are *Anemia subcretacea* and *Quercus chlorophylla*, the first depending on a few fragments and the second upon a single specimen.

As the localities of Carbon and Evanston, Wyoming, are still open to question as to their age, it has been thought best to keep up the distinction by placing them in a separate column. They were regarded by Lesquereux as belonging to his Upper Lignitic, and therefore possibly belong to what has since been differentiated as the Denver group, to which they have been referred in the above tabulation, although Dr. C. A. White[2] would probably regard them as true Laramie, as he considers the Arapahoe and Denver formations as contemporaneous with the upper part of the Laramie, *where it is complete*. A more thorough study of these localities in the light of present knowledge would undoubtedly be productive of important results.

The only group which it remains seriously to consider is the true Laramie or coal-bearing series of strata, the Lower Lignitic of Les-

[1]Hayden's Ann. Rept., 1869, p. 96.
[2]Bull. U. S. Geol. Survey, No. 82, p. 150.

quereux as typified at Raton mountains, New Mexico, Point of Rocks, and Black buttes, Wyoming, etc. Of the 28 species taken as the basis of comparison in the Bozeman coal field 14 have been found in the Laramie proper. This, it is to be understood, is the absolute number, of which several, from one cause or another are doubtful; thus, excluding the 2 species found only in the Laramie of both areas, and at least 5 of the 10 species above pointed out as common to the Denver and Laramie, we have no more than 6 or 7 of the 28 species belonging, in numbers worthy of much consideration, to the Laramie.

From these considerations it appears, beyond question, that the flora of the Livingston formation finds its nearest relationship with the flora of the Denver beds of Colorado. This result appears to differ from the results obtained by a preliminary study of this flora as set forth in a short paper published in July, 1892, on the *Fossil Flora of the Bozeman Coal Field.*[1] In that paper it was stated that an equal number of species were common to the Bozeman flora, and the Denver and Laramie of other parts of the United States. This statement was based on the distribution of the Laramie plants as contained in the books, which were published before the Denver beds had been separated as a distinct series, and when it was consequently impossible to tell exactly where a species came from, when as at Golden, Colorado, both formations are present, and both plant-bearing. Since that time much labor has been expended on a thorough revision of the Laramie and allied floras, based upon most of the original material, together with extensive recent collections. The result of this has been to fix definitely the distribution of a large number of the species, the horizon of which were before loosely given or often wholly unknown. This modification of our knowledge of distribution had made possible the above corrections in the working out of the affinities of the Bozeman flora.

NOTE.—Since the foregoing paper was written Mr. W. H. Weed has submitted to me a small collection of fossil plants obtained by him at the foot of the Crazy mountains, on Big Timber creek, Park county, Montana. The collection numbers nine specimens which I have been able to identify as follows: A single specimen each of *Sequoia Langsdorfii* Heer, and *Populus genatrix* Newberry, and four specimens of *Ulmus speciosa?* Newberry, with fragments of a *Platanus* (possibly *P. nobilis*), a *Phragmites* and *Ulmus* sp.

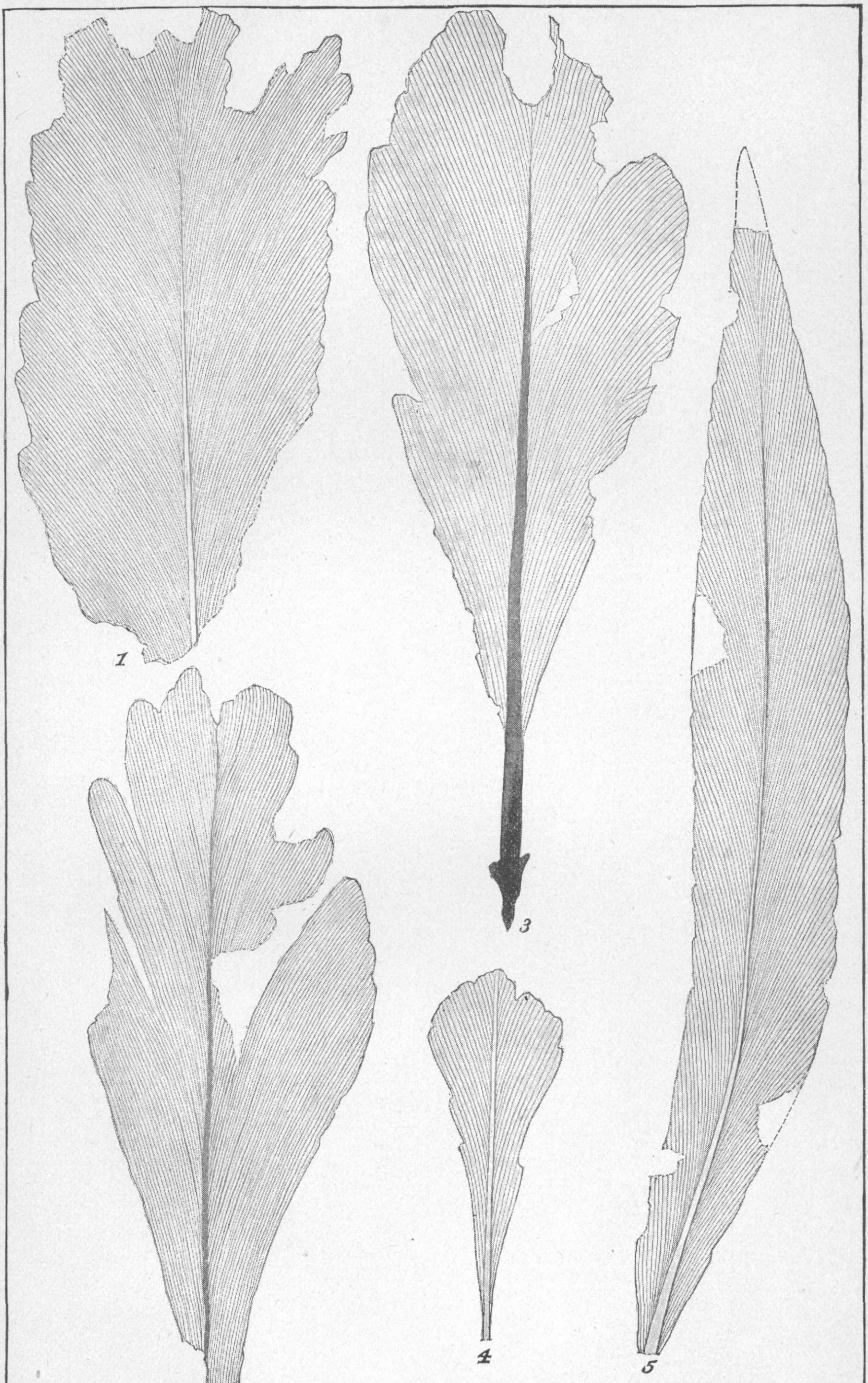
Sequoia Langsdorfii has been abundantly found in, but is not confined to, the Fort Union group, while *Populus genatrix* and *Ulmus speciosa* are typical Fort Union plants. While it is manifestly unsafe to place much dependence in such meager data all the species identifiable belong to or are found in the Fort Union group.

[1] Proc. Biol. Soc., Wash., vol. VII. pp. 153, 154.

Plate V.

Figs. 1–4. *Thinnfeldia polymorpha* (Lx.) Kn.
From head of Fir canyon, 8 miles east of Bozeman, Montana.

Fig. 5. *Thinnfeldia lanceolata* n. sp.
From head of Fir canyon, 8 miles east of Bozeman, Montana.



FOSSIL PLANTS FROM THE LARAMIE AND OVERLYING LIVINGSTON FORMATION OF MONTANA.

Plate VI.

Figs. 1–3. *Aspidium Lakesii* (Lx.) Kn.

From point between Middle and North branches of Bear creek, east of Madison valley, Montana.

Fig. 4. *Aspidium Lakesii* (Lx.) Kn.

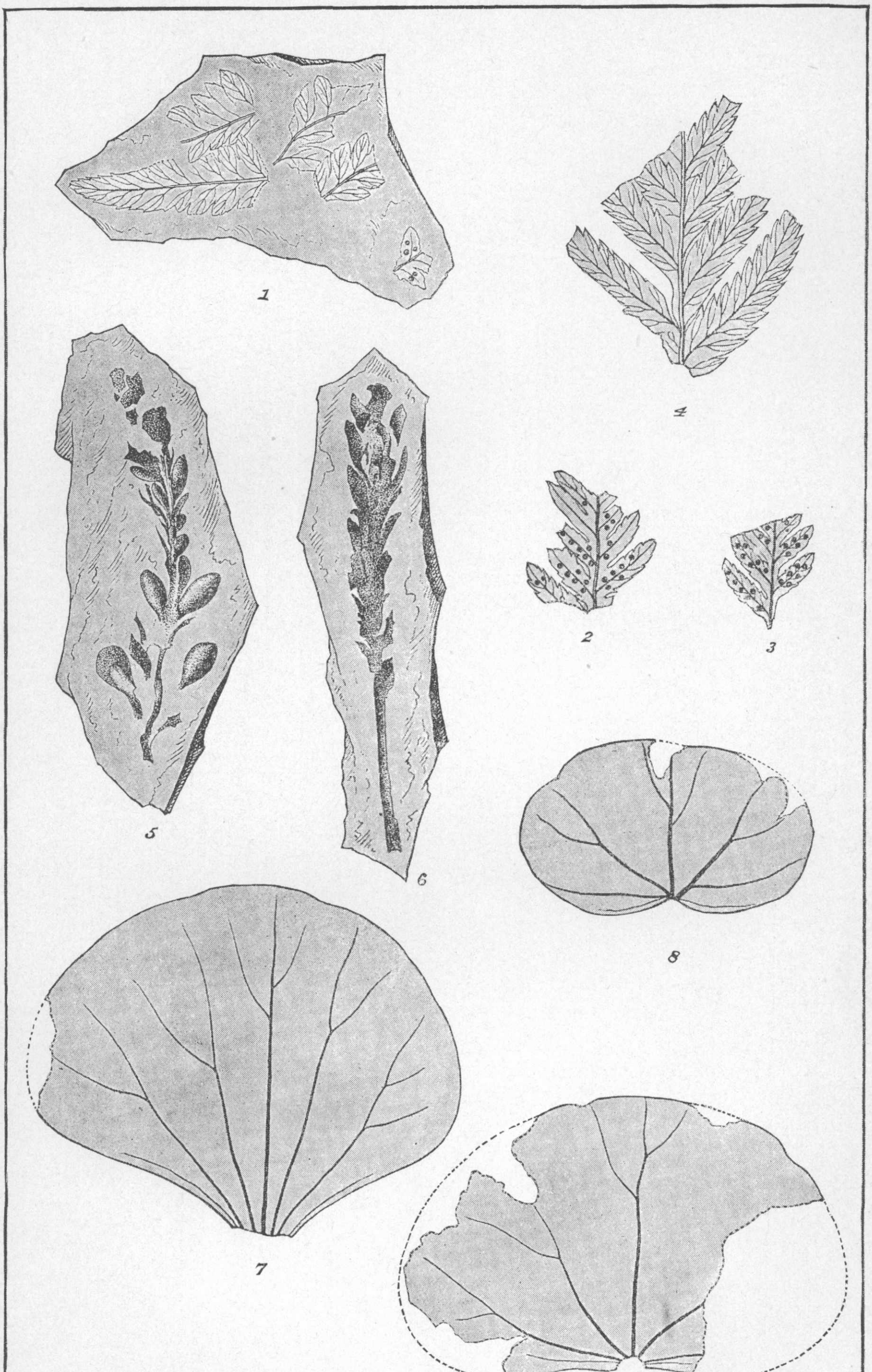
From Quarry No. 2, 3,000 feet east of the Douglas coal mine, Sedalia, Colorado. (Introduced for comparison.)

Figs. 5, 6. *Populus ? problematica* n. sp.

From head of Fir canyon, 8 miles east of Bozeman, Montana.

Figs. 7–9. *Populus* cf. *arctica* Heer.

From near mouth of Bear canyon, 6 miles southeast of Bozeman, Montana.



FOSSIL PLANTS FROM THE LARAMIE AND OVERLYING LIVINGSTON FORMATION OF MONTANA.

INDEX.