CORRELATION OF THE FORMATIONS OF the Laramie Range, Hartville Uplift, Black Hills, and Western Nebraska

G. E. Condra, E. C. Reed, and O. J. Scherer

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BY

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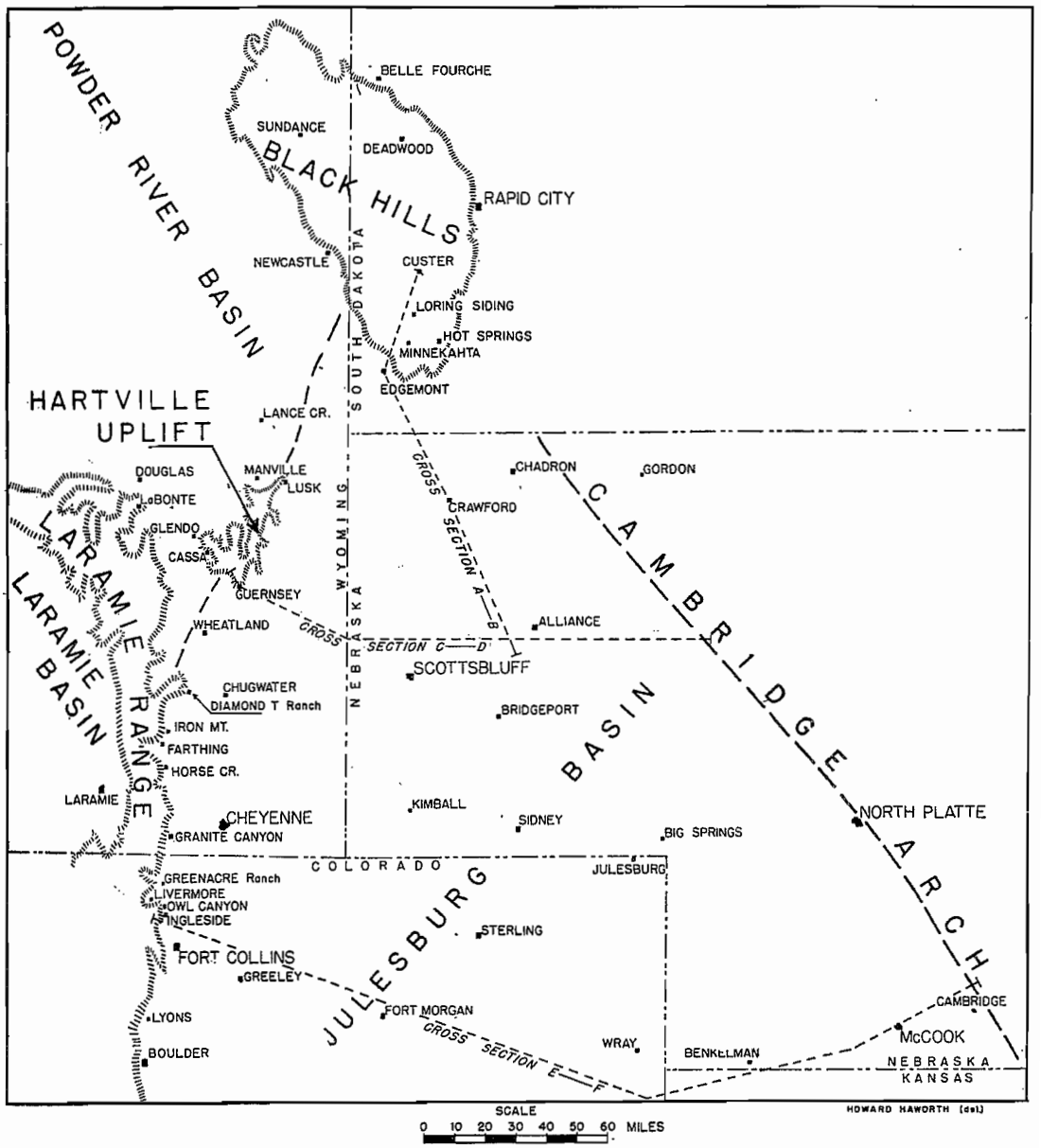

Figure 1.—Generalized map showing locations of major topographic features, sections, and geologic profiles.

Correlation of the Formations of the Laramie Range, Hartville Uplift, Black Hills, and Western Nebraska

G. E. Condra, E. C. Reed, and O. J. Scherer *

One of the main purposes of geological survey is to delimit and describe the formational composition of the land. This purpose is accomplished in various ways, but mainly by the study, comparison, and correlation of formations at their outcrops and by subsurface exploration. In western Nebraska, however, most of the older formations are deeply buried and their study must be made, first at their exposures in the mountains of adjacent states, and later by deep drilling within our state. This procedure has been followed by the Nebraska Geological Survey in the study of outcrops along the Rocky Mountain front, Laramie Range, Hartville Uplift, and the Black Hills, and in the correlation of cuttings and cores of deep wells drilled in the western counties of Nebraska and adjacent areas.

Some of the sedimentary formations which pass under the High Plains carry much ground water from the mountains to our state, some contain thick deposits of gypsum and rock salt in western Nebraska, and some of them are potential sources of oil and gas in Nebraska. Consequently, the occurrence, character, and correlation of these formations, both at their outcrops and in the subsurface, has importance to Nebraska, in response to which condition this bulletin is published.

Major Structural Features.—The principal topographic and structural features referred to in this report are the Laramie Range, Hartville Uplift, Black Hills, Cambridge Arch, and the Julesburg Basin. Their locations are shown by figure 1.

The Laramie Range extends northeastward from the Rocky Mountains proper to west of Glendo, Wyoming, and thence westward to southwest of Casper. The Hartville Uplift and small structures north of it, and the Black Hills, are in line northeastward from the Laramie Range but are separated by small basins. The Cambridge Arch extends southeastward from near the Black Hills through Nebraska and into Kansas where it merges with the Central Kansas Uplift. The area lying between the northern extension of the Cambridge Arch, the Hartville Uplift, and the Laramie Range is known as the Julesburg Basin. This basin is in the Great Plains province.

Pre-Cambrian granite is exposed high in the mountain areas of the region and occurs comparatively high (subsurface) in the Cambridge Arch and very deep in the Julesburg Basin. The oldest sedimentary rocks dip sharply eastward in the east flank of the Laramie Range, passing into the Julesburg Basin, but their dip from the Black Hills and Hartville Uplifts to this basin is variable and less steep. Many of the formations exposed in the mountains pass through the Julesburg Basin, some of them overlapping against the pre-Cambrian formations in the Cambridge Arch.

Geologists and Reports.—Many geologists have contributed to the current knowledge of the geology of the areas considered in this bulletin, but it is generally conceded that most credit for geological study here belongs to N. H. Darton, who, through the years, conducted a comprehensive survey of the region, and named, mapped, and described many of the stratigraphic units. (See

* The authors have received valuable assistance in the preparation of this bulletin from Doctor Carl O. Dunbar, J. E. Upp, M. E. Upson, A. L. Lugn, Anthony Folger, C. T. Jones, and others. The publications of N. H. Darton, S. H. Knight, N. M. Fenneman, H. D. Thomas, W. T. Lee, and W. S. T. Smith, and of the Kansas Geological Society, the U. S. Geological Survey, the American Association of Petroleum Geologists, and the Geological Society of America have been very helpful. Quarry operators and the officials of the Federal Power project at Guernsey, Wyoming, have shown an interest in our study and have assisted in various ways. Howard Haworth and Orville Hansen assisted in drafting the sections. Miss Gladys Davis and Miss Marjorie Ball typed the report.

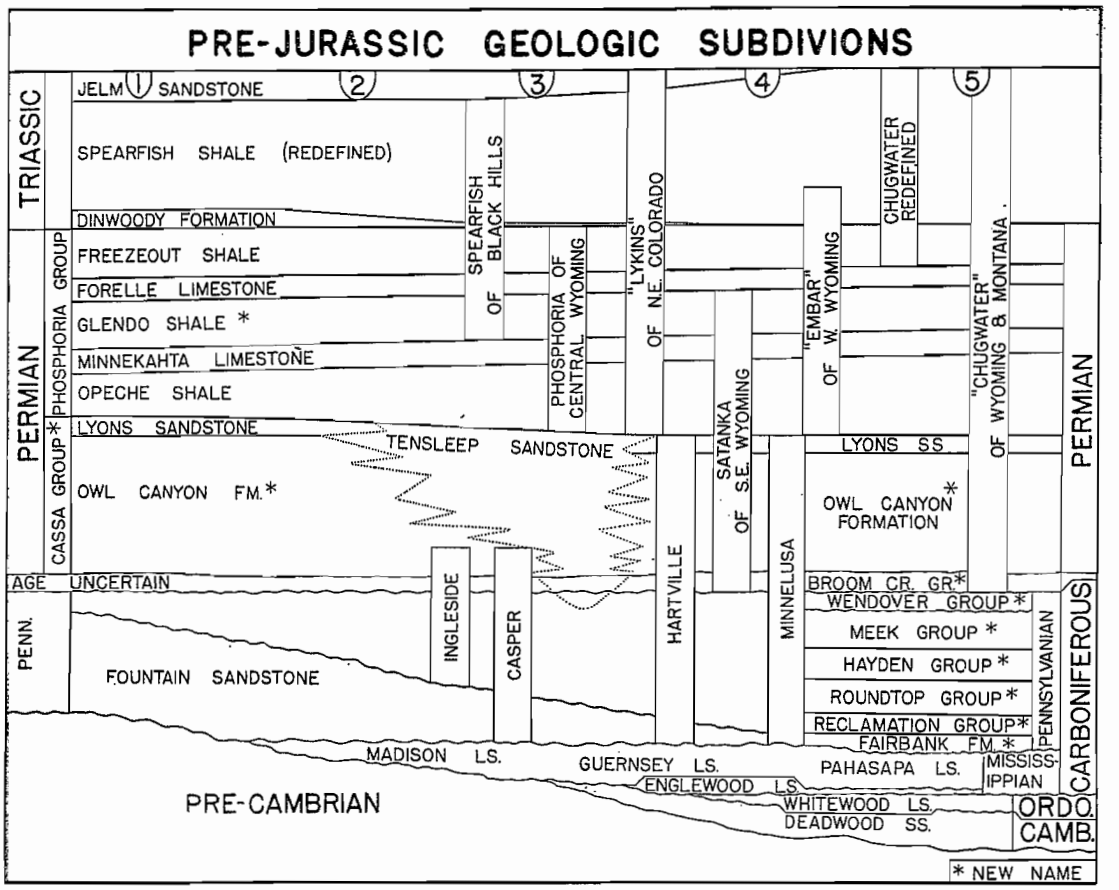

Figure 2.—Generalized cross-section showing usage of geologic terms.

list of references, page 50.) Some of the geological reports on the region are out of print and some are not readily available, and because of this situation, certain data formerly published by Darton, Smith, Lee, Knight, Thomas, Condra, Reed, and others are compiled here for the use of oil geologists in particular.

Confused Nomenclature.—Several geological subdivisions of this region were given different names in various localities before they were correlated regionally. The units of some areas include parts or all of the units of other areas and consequently there is confusion regarding the proper regional usage of certain names. Also some of the formational names were used too comprehensively to designate what we now class as groups, series, and systems of rocks.

Figure 2 is a table of subdivisions of the Pre-Jurassic rocks of the region, and shows the conflicting usage of such names as "Embar," "Lykins," "Chugwater," "Spearfish," "Satanka," and "Minnelusa." It shows that the nomenclature should be clarified. Some of the names with conflicting usage should be redefined and others should be accepted or abandoned according to the rules of priority.

The term Minnelusa has priority over the Hartville. Satanka, Lykins, and probably Embar should be abandoned or redefined. The Chugwater as now used in Wyoming is synonomous with Spearfish redefined. The Freezeout tongue of the Chugwater, by H. D. Thomas (1934, p. 1664), is here designated as a member or a formation, and the Spearfish, named by Darton (1899, p. 387), is redefined to apply to the section between the Phosphoria group and the Sundance, or at places, the section from the Phosphoria to the base of the Jelm formation.

The Tensleep, defined by N. H. Darton (1904, pp. 394–401) from the lower course of Tensleep Canyon located near Tensleep, Wyoming, is here recognized as a sandstone facies of the Cassa group, but some geologists use the term at its type locality to include also sandy beds of Embar age or older. (See figure 2.)

The Dakota group, defined by Meek & Hayden (1862), includes the Lakota sandstone, Fuson shale, and the "Dakota sandstone," but Lee (1927, pp. 37, 39) extended the use of the name Dakota group in Colorado to include also two formations younger than the "Dakota sandstone." The formations of the Dakota group as given by Lee, and now correlated by geologists in the Black Hills and Rocky Mountain areas are the Lakota sandstone (Darton, 1899), Fuson shale (Darton, 1901), Fall River sandstone (Russell, 1927), Skull Creek shale (Collier, 1922), and the Newcastle (Muddy) sandstone (Hancock, 1920). The Skull Creek shale and the Newcastle sandstone are of lower Graneros age.

There has been lack of agreement in the correlation of the above-named formations in eastern Nebraska, the Black Hills, and adjacent areas. However, it appears now, from surface and subsurface study, that the Lakota, Fuson, and Fall River units do persist in these areas, east and west, and that the Skull Creek shale and Newcastle sandstone are not well defined very far eastward in South Dakota and Nebraska. Also, it is believed that the Inyan Kara group of Rubey (1930) is correlative with the Dakota group of Meek & Hayden (1862).

The Dakota group as defined by Lee and by Meek & Hayden includes Upper and Lower Cretaceous formations, which means that it may become necessary eventually to restrict the use of the name to the Lower Cretaceous, i.e., to include the Lakota and Fuson formations. The latter usage would apply to most of the section included by Meek & Hayden in 1862, and the name would have priority over Kootenai (Dawson, 1885), Cloverly (Darton, 1904), and Purgatoire (Stose, 1912). Consequently, when the Dakota group is redefined, we believe that it should embrace the Lakota and Fuson formations, and that the Fall River sandstone ("Dakota sandstone") should be classed as the lowest formation of the Upper Cretaceous in this region. If this classification were made, the Dakota group would correlate in age with part of the Comanche (Hill, 1887) of Kansas, Oklahoma, and Texas.

New Names.—Our study shows that several Pennsylvanian and Permian members and formations of these areas have not been named, but with three exceptions, the opportunity to name them is left to the Geological Surveys of the states in which they are exposed. We name the Reclamation, Roundtop, Hayden, Meek, Wendover, Broom Creek, and Cassa groups; the Fairbank and Owl Canyon formations; and the Glendo member or formation. The type localities of these are as follows:

FAIRBANK FORMATION. — North Platte River bluffs immediately north and northwest of the site of an abandoned village known as Fairbank, in sec. 27, T. 27 N., R. 66 W., Platte County, Wyoming; comprises Division VI (Condra & Reed, 1935) Hartville "formation"; thickness 30 to 100 feet.

RECLAMATION GROUP.—Reclamation Hill, sec. 27, T. 27 N., R. 66 W., Platte County, Wyoming; comprises Division V (Condra & Reed, 1935) Hartville "formation"; thickness 72 to 87 feet.

ROUNDTOP GROUP.—Roundtop Mountain, sec. 22, T. 27 N., R. 66 W., Platte County, Wyoming; comprises Division IV (Condra & Reed, 1935) Hartville "formation"; thickness 149 feet.

HAYDEN GROUP.—Hayden Cliff, sec. 22, T. 27 N., R. 66 W., Platte County, Wyoming; comprises Division III (Condra & Reed, 1935) Hartville "formation"; thickness 120 feet.

MEEK GROUP.—Meek Cliff, sec. 22, T. 27 N., R. 66 W., Platte County, Wyoming; comprises lower 130 feet of Division II (Condra & Reed, 1935) Hartville "formation"; thickness 119 to 130 feet.

WENDOVER GROUP.—Platte River Valley in the vicinity of Wendover, Platte County, Wyoming; comprises upper part of Division

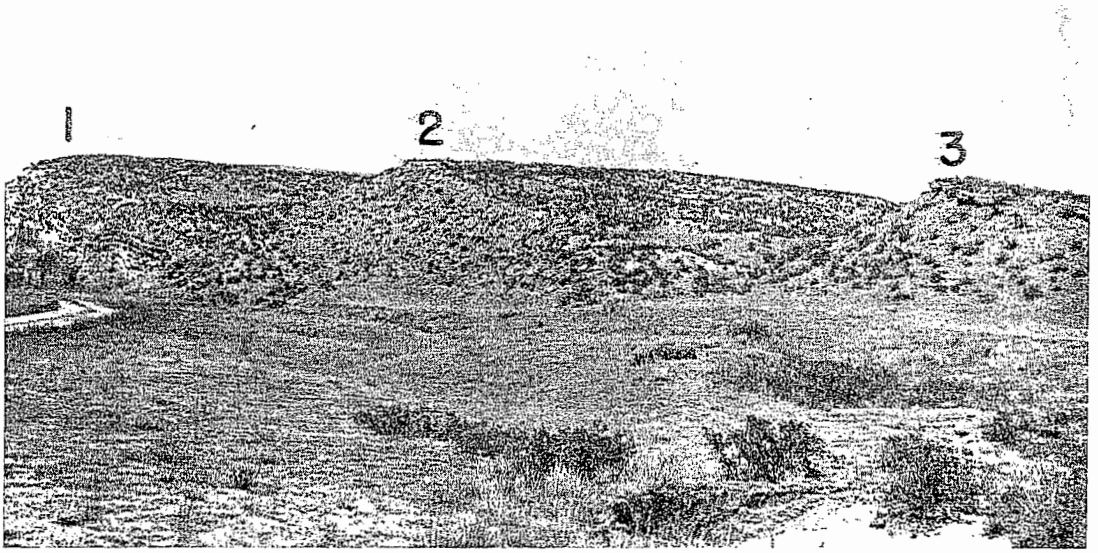

Figure 3.—Hogbacks on limestones of the Phosphoria group, NE of Owl Canyon Store, Colorado: (1) Minnekahta, (2) Forelle, and (3) Ervay (?).

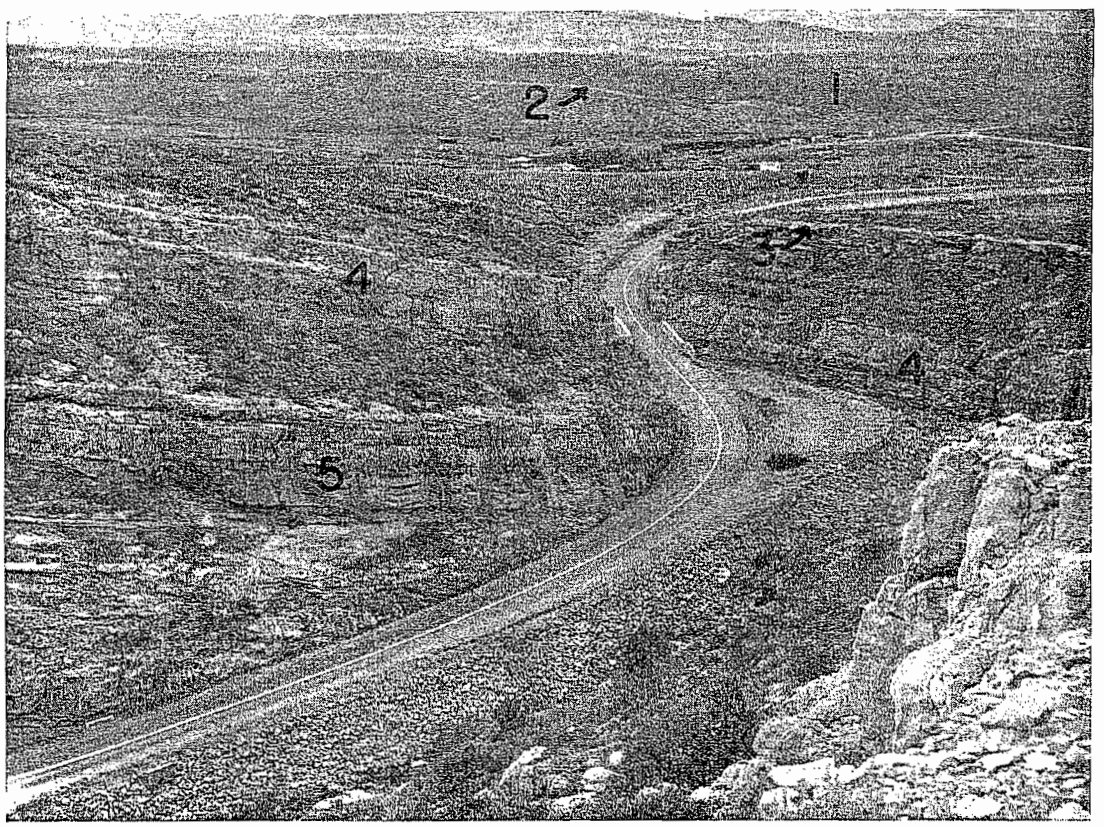

Figure 4.—View northeastward from near head of Owl Canyon. The hogbacks in the far distance are on the lower beds of the Cretaceous; No. 1 is Phosphoria; No. 2 is the Lyons; No. 3 is the top of the Broom Creek (top of Ingleside of old usage); No. 4 is a limestone bed at the top of the restricted Ingleside; and No. 5 is subdivision V (II) 3 of the Ingleside. (See Section No. 1.)

II (Condra & Reed, 1935) Hartville "formation"; thickness 104 feet.

Broom Creek Group.—In Broom Creek Valley, sec. 10, T. 28 N., R. 66 W., Platte County, Wyoming; comprises interval from base of Cassa group to top of Wendover group; thickness 14 to 75 feet.

Cassa Group.—Buckshot Canyon (also called Ragan Canyon), T. 29 N., R. 67 W., 3 miles northeast of Cassa, Platte County, Wyoming; comprises upper 180 feet of Division I (Condra & Reed, 1935) Hartville "formation"; overlain by Broom Creek group; thickness in area of this report, 175 to 328 feet.

Owl Canyon Formation.—Lower part of Owl Canyon, NW¼ sec. 6, T. 9 N., R. 59 W., and NE¼ sec. 1, T. 9 N., R. 70 W., Larimer County, Colorado; comprises that part of the Cassa group below the Lyons sandstone; thickness in area covered by this report, 90 to 275 feet.

Glendo Shale.—In Spring Creek Valley 1 mile south and 2 miles west of Glendo, Wyoming; comprises the interval between the Forelle and Minnekahta limestones; thickness in area covered by this report 43 to 56 feet.

Composite Sections and Cross-Sections.—Several composite sections are used in this report to show the occurrence and correlation of the geologic subdivisions in the flanks of the Laramie Range, Hartville Uplift, and the Black Hills. These are followed by three cross-sections which extend from the mountain areas to the Julesburg Basin and show the correlation of formations in western Nebraska.

The geologic subdivisions listed and described are numbered from top to bottom, that is, from youngest to oldest. This departure from the generally followed practice of numbering units from oldest to youngest in purely genetic studies is believed to be justified because it avoids confusion in reading, because the written sections and graphic sections may be numbered in the order in which they are read and observed and because this system corresponds to the order in which the geological subdivisions are drilled in wells.

THE LARAMIE RANGE IN COLORADO

The following sections numbered 1, 2, and 3, were measured in the monoclinal ridges and the valleys which border the Laramie Range in the area between Owl Canyon, Colorado, and the Wyoming-Colorado line. Generally here the strata dip eastward (figure 3), but are faulted and cross-folded in places.

Section No. 1

This section was measured in the vicinity of Owl Canyon (figure 4) located about 16 miles northwest of Fort Collins, along or near Highway 287. Its upper part is compiled and slightly modified after Lee (1927, pp. 37, 38). The rest of the sections were measured by the authors.

I. Cretaceous System, 5015′–6516′+:
  1. Lance (Laramie) formation, 200′
  2. Fox Hills formation, 1000′+
  3. Pierre shale, 2500′–4000′
  4. Niobrara formation, 250′+
  5. Benton shale, 679′
  6. Dakota group, by Lee, in high monoclinal ridge east of Ingleside, 386′:
    (1) Newcastle (Muddy) sandstone, 40′
    (2) Skull Creek shale, 195′
    } *These are regarded as basal members of the Graneros formation by some*
    (3) Fall River "Dakota" sandstone, 12′
    (4) Fuson shale, 64′
    (5) Lakota sandstone, conglomeratic at base, 75′
    } *Dakota group, by Meek & Hayden*

Unconformity.

II. Jurassic System, in west slope of monoclinal ridge cited above, about 334′:
  1. Morrison beds, green, gray, and maroon shales, sandstone and some limestone, 195′

Unconformity.

  2. Sundance beds, 139′:
    (1) Limestone, blue, brittle, 15′
    (2) Sandstone, gray, 8′
    (3) Shale, gray, sandy, 18′
    (4) Limestone, gray, dense, cherty, conglomeratic at top, 1′
    (5) Shale, pink, 2′
    (6) Sandstone, pink, part ripple marked, 4′
    (7) Shale, sandy, in lower part, 11′
    (8) Sandstone, gray to yellowish, massive, 80′

Unconformity.

III. Triassic System, in lower part of ridge and red valley east of Ingleside, 610′ or less:

III. Triassic System (contd.)
1. Jelm formation, orange colored, cross-bedded sandstone, 60′+
UNCONFORMITY.
2. Spearfish (redefined), consisting of red shales and sands, 550′ or less

IV. Permian System, measured about one mile north of Owl Canyon Store, 495′ or 536′:
(I) Phosphoria group, 227′:
1. Freezeout beds, 47′ or more:
(1) Limestone, gray-red, sandy, 2′
(2) Shale, bright red, with thin gray sandy seams above middle, about 45′
2. Forelle limestone, forms low monoclinal ridge, gray to pinkish, part crinkly, with some red shale, 4′+
3. Glendo shale (new name), 51.5′–56′:
(1) Shale, red, thickness about 44′ near the new gypsum quarry
(2) Limestone, grayish, brecciated, irregular, 2′–4′
(3) Shale, red, sandy, 5.5′–8′
4. Minnekahta limestone, forms monoclinal ridge, thickness 35′ near Owl Canyon Store and 41′ at the Hintz gypsum quarry located one mile north of Owl Canyon store:
(1) Limestone, light gray, crinkly, with gray shale partings, 20.5′
(2) Lime-sand zone, gray in upper part and reddish below, 20′
(3) Limestone, light gray, crinkly, 1′+
5. Opeche shale, 74′–79′:
(1) Shale, lavender, argillaceous to sandy, 1′–2′
(2) Sandstone, red, argillaceous, massive to bedded, 18′–20′
(3) Shale, red, sandy, with gypsum seams, .7′–1′
(4) Shale, red, sandy, with blocky sandstone at top, 2′+
(5) Sandstone, red, argillaceous, massive to bedded, 10′
(6) Shale, red, part sandy, with gypsum seams, 19′+
(7) Gypsum and shale, at new gypsum quarry, 18′–20′:
a. Gypsum, light gray, massive, 1′–1.2′
b. Shale, red, .6′–.9′
c. Gypsum, gray, massive, 1.5′
d. Shale, red, .9′
e. Gypsum, gray, massive, 1.35′
f. Shale, red, gypsiferous, 1.5′–3′
g. Gypsum, light gray mottled, massive, 11.5′ or more
(8) Limestone, gray to yellowish, finely granular, sandy, slightly dolomitic, gypseous, .5′
(9) Shale, red to yellowish gray, 4.5′

(II) Cassa group (new name), 242′–267′:
1. Lyons sandstone, forms low ridge just east of Owl Canyon Store, 21′–26.5′:
(1) Sandstone, pinkish gray to buff, thin-bedded and flaggy to cross-bedded, 15′–20′
(2) Covered interval, 2.5′
(3) Sandstone, yellow gray, calcareous, part cross-bedded, 3.5′
(4) Shale, ash gray, sandy, .35′
(5) Sandstone, gray to yellowish, indurated, 1′
2. Owl Canyon formation (new name), measured in the red valley west of the Hintz gypsum quarry, 221′–240′:
(1) Sandstone, greenish gray to buff, crumbly, with small flakes of mica; top 2′ dark gray, shaly to sandy, weathers buff; combined thickness 11′
(2) Shale, red, sandy, with seven subzones of shaly sandstone, 37.5′
(3) Sandstone, yellow-gray, friable, massive, and red shale, 2.5′
(4) Shale, brick red, part dark red, 4′
(5) Sandstone, yellow-red, quartzitic, .7′–1′
(6) Shale and sandstone, red, loosely indurated, top 3′ shaly, remainder crumbly bedded sandstone, 10′
(7) Sandstone, gray-yellow, massive, .5′–1′
(8) Shale and sandstone, 15.5′:
a. Shale, red, sandy, 5′
b. Sandstone, red, shaly, loosely indurated, 2′–3′
c. Shale, red, 7.5′
(9) Sandstone, yellow-gray-red, massive, base uneven, .5′–7′
(10) Sandstone, red, fine massive to crumbly subzone separated by red shale, 20.3′
(11) Sandstone, yellow-gray, .3′–.5′
(12) Sandstone and shale, red, part crumbly, 4.5′
(13) Sandstone, gray-yellow, calcareous, indurated, 8.7′
(14) Sandstone, red, shaly, crumbly, top .7′ shale, combined thickness 4.5′
(15) Sandstone, yellowish, .5′
(16) Shale, red, sandy, 6.3′
(17) Sandstone, reddish, top yellowish, lower part shaly in places, 3.7′
(18) Sandstone, grayish, top 1′ fairly firm, with very small light colored concretions in lower part, thickness 6′
(19) Sandstone and shale, red, sandy, 2.5′
(20) Sandstone, gray, 3.4′
(21) Sandstone, red, shaly, 1.5′–1.7′
(22) Sandstone, gray-yellow, 2.2′

IV. Permian System (contd.)
(II) Cassa group (contd.)
2. Owl Canyon formation (contd.)
(23) Shale, red, sandy, 3′
(24) Sandstone, yellow-red, massive, 2.5′
(25) Shale, red, sandy, 2.4′
(26) Sandstone, yellow and red, 2.2′
(27) Shale, red, sandy, 8.5′
(28) Sandstone, gray-red, friable, 4′
(29) Shale and sandstone, red, with blue-gray seam at top, 3.5′
(30) Sandstone, red, 1.2′
(31) Sandstone, red, bedded, part shaly, with blue-gray seam at base, 5.5′
(32) Sandstone and shale, red, 11.5′
(33) Sandstone, light gray, stained yellow-red, base uneven, 1.5′
(34) Shale, red, with seam of quartzite at base, 8.3′
(35) Sandstone, largely salmon colored, with shale separations in places, thickness variable, 20′–32′. Average about 26′
3. Limestone member, gray to red stained, sandy, irregular, dense, dolomitic, 3′–6′
4. Sandstone member, gray-yellow to red, top and base usually bedded, some red shale at top; middle cross-bedded; base uneven; thickness 30′–35′, with .5′–1′ of reddish reworked material at base

UNCONFORMITY.

V. Pennsylvanian Subsystem (Ingleside-Fountain beds), exposed in monoclinal ridge west of Ingleside and Owl Canyon Store and in valley west of ridge, measured in Owl Creek Canyon and westward therefrom 681′–737′ or more:
(I) Broom Creek group (in the Ingleside) Permian (?), Pennsylvanian (?), measured in Owl Canyon, about 14′–17.5′
1. Limestone and dolomite; upper part grayish to pinkish, dark speckled, massive, limy, moderately coarsely crystalline, slightly dolomitic, quartzitic-like, largely massive, top uneven; lower part pink to red, massive dolomite, moderately coarsely crystalline, with some silty material; combined thickness 6.6′–7.5′. This division forms large rounded blocks.
2. Sandstone, reddish, forms re-entrant, 1.5′–2′
3. Dolomite, gray to pink, or red, moderately coarsely crystalline, with some silt, part with small geodes, part stylolitic, base uneven, 6′–8′. This division forms large blocks.

UNCONFORMITY.

(II) Main part of Ingleside, age Virgil-Missouri, 132′–142.5′:
1. Limestone, with some silt and sand, 22′–23′:
(1) Siltstone, two or three dolomitic gray to pinkish or reddish zones; top uneven; combined thickness 2′–3′
(2) Siltstone-sandstone, red, dolomitic; part red shale; thickness .5′
(3) Limestone, medium dark gray to reddish, crystalline, dense, fine grained, massive, with fossils and very small geodes, part stylolitic, thickness in canyon, 19′–19.5′
2. Sandstone, gray-yellow, calcareous and indurated at top, largely massive, part cross-bedded, 25′
3. Limestone, pinkish gray at top, medium dark gray below, dense, finely crystalline, stylolitic, massive, part algal, fossiliferous, 18′
4. Sandstone, gray-yellow, thin bedded to massive, 30′+
5. Limestone, medium dark gray to pinkish, in four zones, the third from top being sandy, largely irregularly bedded to massive, dense, crystalline, part geodal with calcite crystals, part sandy, main part arenaceous, with small crinoid joints, and *Bellerophons* at top, 13.5′
6. Sandstones, limestone, and shale, 23.5′–33′:
(1) Sandstone, yellow-red, calcareous, largely massive, part bedded, with small crinoid joints in upper part, base uneven, 18′–25′+
(2) Limestone, light gray to dark gray and pinkish, crystalline, geodal in upper part, with some red pebbly shale and red sand in places; upper and lower surfaces uneven; combined thickness 2.5′–4′
(3) Sandstone, gray-red, 1′–2′
(4) Shale, red, and some arkose, 2′

UNCONFORMITY.

(III) Ingleside (?), Fountain (?), 83′–100′:
1. Sandstone, measured in scarp east of Owl Creek Canyon, yellow-red, largely massive, top uneven, 6′–15′
2. Limestone, best shown in scarp east of canyon, largely light to dark gray, part reddish, dense, irregular lensing to massive, crystalline, locally sandy, 2′–5′
3. Sandstone, yellow-red, friable, upper part massive, lower part bedded, with some arkose near base, about 38′
4. Sandstone, yellow-red, with some grayish pink or red dolomitic lime, 6′–7′
5. Shale, red, and sandstone, red, 20′
6. Sandstone, red to yellowish, massive, with some arkose; concretionary lime at base, combined thickness 5′

V. Pennsylvanian Subsystem (contd.)

(III) Ingleside (?), Fountain (?) (contd.)

7. Arkose, gray-brownish, 1′–2′
8. Dolomite, gray to pink, massive, fine grained, dense, sandy, grades from sandstone to dolomitic lime, thickens eastward, 5′–8′

NOTE: The following part of Section No. 1 is not well exposed in the immediate vicinity of Owl Canyon, but is well shown farther west, at Red Butte located between Livermore and Virginia Dale, i.e., in sec. 19, T. 11 N., R. 70 W., east of the road leading from Highway 287 to Granite Canyon, Wyoming. The butte is capped by (III) 8 or the preceding part of this section. The strata here are nearly horizontal, with a small deformation in the north end of the butte. Section continued downward from zone (III) 8 as follows:

(IV) Fountain beds, 452′–476.5′:

1. Sandstone, gray-red, with limy concretions, 8′–10′
2. Sandstone, red, massive, 15′
3. Sandstone, grayish red, calcareous, 1′
4. Sandstone, yellowish red, limy at base, 19′
5. Sandstone, red, cross-bedded, in slabby layers, 11′
6. Sandstone, gray, calcareous, concretionary, 1′–2′
7. Sandstone, red, massive, quite firm in upper part, not very firm in lower part, 28′
8. Sandstone, grayish red, calcareous, irregular, with nodular subzones, 6′
9. Sandstone, red, calcareous at base, 30′
10. Sandstone, red, 9′
11. Sandstone, gray-red, calcareous, 2′–3′
12. Shale, red, 3.5′
13. Sandstone, gray-red, calcareous, 5′
14. Sandstone, red, 18′
15. Sandstone, gray-red, part limy, 8′
16. Sandstone, gray-red, caps rim-rock, 1′–2′
17. Sandstone, red, shaly, 1′
18. Sandstone, brownish red, massive, 4′–5′
19. Sand and shale, gray-red, forms a re-entrant, 1′
20. Sandstone, grayish red, calcareous, 5′
21. Sandstone, red, loosely indurated, 2′–3′
22. Limestone, gray, impure, 3′–4′
23. Sandstone and shale, largely red with thin grayish layers, 22′
24. Sandstone, forms cliff, top gray and limy, middle and base red and indurated; thickness about 17′
25. Shale, red, sandy, 2.4′
26. Sandstone, yellow and red, 2.2′
27. Sandstone, gray-red, part shaly, part calcareous, 9′–12′
28. Arkose, pink, gray-red, with red shaly layers, slope former, 18′
29. Shale, dark red, micaceous, with arkose layers, 21′–25′
30. Sandstone, pink, calcareous, 1′
31. Arkose layers and pink limy sandstone in red shale, 6.5′
32. Arkose layers and red shale, 6′
33. Sandstone, pink, limy, 2′–3′
34. Arkose, red shale, and sand, 18′–20′
35. Limestone, buff or dark gray, pebbly, a "hump"-former, 2′–2.5′
36. Shale, red above, gray-brown below middle, basal part nodular, thickness 12.5′
37. Limestone, gray-brown, arkosic, 1.9′
38. Arkose, limy, 4′
39. Shale, pink and red, a slope former, 20′
40. Sandstone, upper portion gray and bedded, middle brownish red, basal part pebbly and limy, thickness 8′
41. Shale, red, and grayish arkose, 21′
42. Arkose, light gray, massive, 6′–8′
43. Arkose, grayish, with some shale in places, 10′–12′
44. Shale and sandstone, largely red, conglomeratic at base, 50′ or more

VI. Pre-Cambrian granite

The thin layers of the Fountain part of the above section are better shown at Red Butte than they are in Owl Canyon or at any other place in that vicinity.

The Pennsylvanian is here classified as a Subsystem but many geologists believe that it should be raised to System rank in this country.

The term Sundance, as applied generally, consists of more than a formation, probably a group, and the Morrison is also more than one formation in places.

The designation of the Dakota group, made by Lee (1927) is not fully satisfactory. The group includes formations of both Lower and Upper Cretaceous age as does the Dakota group of Meek & Hayden, but Lee expands the group to include beds that have been classified as Benton in age.

The location of the boundary between the Ingleside and Fountain in this section is a matter of opinion. It lowers northward in the Fountain horizon as the calcareous subzones of the latter thicken in that direction becoming limestones proper. In this manner the Ingleside becomes progressively thicker northward and the Fountain correspond-

ingly thinner, as shown by Sections 1, 2, and 3. The limy layers of the Fountain of Section No. 1 become well defined limestones at the Colorado-Wyoming line.

Some geologists who have studied the formations in this area place the top of the Ingleside and the top of the Pennsylvanian at the limestone member in the lower part of the Cassa group, and some place the Permian-Pennsylvanian contact at the top of the Lyons sandstone, notwithstanding the fact that faunal evidence is lacking to support such correlations. The basal members of the Cassa group are here classed as Permian or Pennsylvanian, and the age of the Broom Creek group is not certain, it being either of Virgil or Lower Permian age. The thick red bed section below the Lyons sandstone is classified as Permian.

We recognize the Freezeout and Forelle tongues of the Phosphoria as members or formations, and give the name Glendo to the shale which lies between the Forelle and Minnekahta limestones. Since the Phosphoria extends into the basal Spearfish of the Black Hills, redefinition of the latter becomes necessary. The Spearfish in this area is restricted to the interval between the Freezeout and the Jelm, and in places where the Dinwoody is present, to the interval between Dinwoody and Sundance. The age of the Phosphoria is Permian, as is evidenced by fossils, but the age of the Spearfish—whether Permian or Triassic—has not been determined beyond question.

Section No. 2

Location about 5½ miles north of Owl Canyon, Colorado.

I. Triassic, well exposed, but not measured
II. Permian System, 438′ exposed:
  (I) Phosphoria group, 198′+:
    1. Freezeout shale, basal part poorly exposed, largely red, about 40′
    2. Forelle limestone, forms low ridge, 6′–8′
    3. Glendo shale, red, 45′
    4. Minnekahta limestone, forms high monoclinal ridge, about 30′
    5. Opeche shale, red shales and sandstone, about 75′
  (II) Cassa group, 240′:
    1. Lyons sandstone, largely gray and cross-bedded, top separated from main part by reddish shale, thickness 20′
    2. Owl Canyon formation, 220′:
      (1) Shale and sandstone, red, and thin grayish sands, 110′
      (2) Sandstone, gray and red shale, 40′
      (3) Shale, red and gray sandstones, 70′
    3. Limestone member and the sandstone member, missing
  Unconformity.
III. Pennsylvanian Subsystem (Ingleside beds), about 100′ of limestones and sandstones exposed in a deep canyon. This part of the section correlates with V (I) and (II) 1 to 3 of Section No. 1 at Owl Canyon. In other words, it includes a thin development of the Broom Creek group and most of the Wendover group, and is of Virgil age, at least in part.

Note: West and northwest of the Greenacre ranch, massive gypsums come into the section at the horizon of the Glendo, Forelle and Freezeout units, making them less regular than at places where the gypsum is absent or poorly developed.

Section No. 3

This composite section was measured in Boxelder Creek Valley north of the Greenacre ranch, which is located about 8 miles north of Owl Canyon. The section from the top of the Dakota group to the Spearfish was made by Lee (1927, p. 29) about 1 mile north of the Greenacre ranch. The section below the Minnekahta limestone was measured by Thompson, Osborne, & Simmons in a canyon in sec. 2, T. 11 N., R. 70 W. (1938, pp. 64, 65). This latter part of the section was inspected and slightly modified by Condra and Scherer.

I. Cretaceous System:
  1. Formations above Dakota group, not measured
  2. Dakota group, about 315′:
    (1) Newcastle sand, 82′
    (2) Skull Creek shale, 118′
    (3) Fall River sandstone, 15′±
    (4) Fuson shale, 25′+
    (5) Lakota sandstone, 75′±
  Unconformity.
II. Jurassic System, 434′:
  1. Morrison beds, 205′
  2. Upper Sundance, missing at an unconformity
  3. Sundance, 229′

III. Triassic System, 572′:
1. Jelm sandstone, 122′
UNCONFORMITY.
2. Spearfish (redefined), about 450′±
IV. Permian System, 378′:
(I) Phosphoria group, 184′ or more:
1. Freezeout shale, top not shown, contains considerable gypsum, thickness uncertain, probably 40′ or more
2. Forelle limestone (?), poorly exposed, gypseous, 8′±
3. Glendo shale, red, with considerable gypsum, 58′ or less
4. Minnekahta limestone, poorly exposed, with considerable shale and some sand, 18′
5. Opeche shale, base not definitely determined, top lavender colored, about 60′
(II) Cassa group, 194′:
1. Owl Canyon formation, largely red sandstones and shale, 155′ or more
2. Limestone, gray, 6′–7′±
3. Sandstone, rusty red, cross-bedded, 32′
UNCONFORMITY.
V. Pennsylvanian Subsystem, about 905.5′:
(I) Ingleside beds, 432.5 or 633.5′:
1. Limestones and sandstones, 165′:
(1) Limestone, gray, dense, blocky to crumbly, with poorly developed Broom Creek beds at top, 40′
(2) Sandstone, rusty red, very fine grained, bedded, 26′
(3) Limestone, 21′:
a. Limestone, gray, dense, massive, 9′
b. Limestone, gray to white, somewhat platy, 4.5′
c. Limestone, gray to white, saccharoidal, 7.5′
(4) Sandstone, rusty pinkish red, bedded to slightly cross-bedded, 13′
(5) Limestones and sandstones, 65′:
a. Limestone, gray to light gray, saccharoidal, 3′
b. Sandstone, pinkish red, bedded, 10′
c. Limestone, bluish gray, dense, massive, 13′
d. Sandstone, pinkish red, bedded to slightly cross-bedded, 21′
e. Limestone, light gray, dense to saccharoidal, with *Bellerophons,* 10′–18′
2. Sandstone, quartzite and arkose, 113.5′:
(1) Sandstone, rusty red, bedded, scattered small limestone pebbles, 20.5′
(2) Quartzite, lavender-red, forms a prominent ledge in canyon wall, 10′
(3) Sandstone, rusty red, with thin irregular zones of arkose, 83′
3. Limestone, light gray, saccharoidal, cavernous, 35′
4. Sandstones, red, friable and arkose, 86′
5. Limestone and shale, 33′:
(1) Limestone, reddish, arenaceous, with *Bellerophons,* 3′
(2) Shale, red, sandy, 10′
(3) Limestone, arenaceous, a cliff-former, 20′
(II) Ingleside (?), Fountain (?), 201′:
1. Sandstones, red, soft, and some arkose and four thin sandy limes, 138′
2. Sandstone, red, friable, platy, 20′
3. Limestone, light gray, sandy, 3′
4. Sandstone, pink to red, part cross-bedded, platy, 40′
(III) Lower Fountain, 272′:
1. Arkose, coarse, 5′
2. Limestone, pinkish, top uneven, with coral remains, 5′
3. Shale, red, with interbedded arkose, 138′
4. Arkose, light gray, pebbly, 10′
5. Shale and sandstone, red, micaceous and arkose, 109′
6. Conglomerate, composed of chert pebbles, with some reworked granite and Mississippian fossils, 5′
VI. Pre-Cambrian granite

NOTE: The Owl Canyon formation is considerably thinner here than in Section No. 1 and the Lyons sandstone is very thin or missing. Two of the thin limestones of the Fountain measured in Section No. 1 are well-defined formations in this section (2) and are classed with the Ingleside.

THE LARAMIE RANGE IN WYOMING

SECTION No. 4

This section was measured in the east flank of the Laramie Range in the canyons located south of Granite Canyon Station, Wyoming. It is south of the Union Pacific Railroad, about 18 miles west of Cheyenne. The beds dip quite rapidly eastward.

According to the Colorado terminology the upper formations of this section would be classed under the Ingleside "formation," but in Wyoming this part of the section plus the equivalent of the Fountain is called the Casper as revised by S. H. Knight (1929). Consequently we use the name Casper for the Pennsylvanian in the Laramie Range, to include the Ingleside and Fountain "formations" in the following sections.

I. Cretaceous, Jurassic, Triassic, Permian, and probably the top of Pennsylvanian, covered by Tertiary and Pleistocene deposits
II. Pennsylvanian Subsystem (Casper beds), about 825′ exposed:
(I) Ingleside beds, 611′–618′:
1. Limestones and sandstones, 180.5′:
(1) Limestone, badly covered in slopes, top eroded, gray, cherty, thickness (?) probably about 20′
(2) Sandstone, red, part quartzitic, about 25′
(3) Limestone, greenish gray to bluish gray, dense, massive, very fine grained, 14.5′
(4) Sandstone, red to pinkish, part quartzitic and slabby, about 20′
(5) Limestone, bluish gray, reddish near base, dense, fine grained, stylolitic, geodal, crinoidal, 14′
(6) Sandstone, badly covered, red, about 20′
(7) Limestone, badly covered, gray, algal, 10′ or more
(8) Sandstone, badly covered, red, about 25′
(9) Limestone and sandstone, 32′:
a. Limestone, gray, dense, massive, about 10′
b. Sandstone, yellow-red, 12′
c. Limestone, gray-pink, 10′
2. Sandstones and quartzites, yellow-red pinkish, and five or six thin limestones, all badly covered, about 112′
3. Limestone, quartzite and shale in quarry located in canyon, 24.5′:
(1) Limestones, lavender to pinkish, dense, micaceous, somewhat arenaceous, 2.5′
(2) Shale, red, micaceous, crumbly, .5′
(3) Quartzite, greenish gray, blocky, 12′
(4) Limestone, gray, dense, massive, fine grained, 7′+
(5) Quartzite, gray, blocky, 2.5′
4. Limestone, gray to yellowish, dense, in massive zones, about 71′
5. Sandstone, exposed in canyon farther south, covered in canyon just south of railroad, 35′:
(1) Sandstone, yellowish, 20′
(2) Sandstone, gray-pink, massive, 15′
6. Sandstones and limestones, red and gray, 35′
7. Limestone, gray-pink, dense, massive to badly covered, about 11′
8. Sandstone, 12′:
(1) Sandstone, gray-yellow, bedded to cross-bedded, 5.5′
(2) Sandstone, reddish, with shale above middle, 6.5′
9. Limestone, gray, dense, massive, sandy near top, with crinoid joints, 12.5′
10. Sandstone and quartzite, 25.5′:
(1) Sandstone, pinkish, quartzitic, bedded to massive, 13′
(2) Quartzite, pinkish, crinoidal, 12.5′
11. Limestones, sandstones and shale, 79.5′:
(1) Limestone, light gray, pisolitic, grades into sandstone, 1′
(2) Sandstone, gray, crumbly, arkosic, 7′
(3) Limestone, gray, dense, massive, with scattered fossil fragments, 2.8′
(4) Limestone, gray, weathers crumbly, forming re-entrant, 2′
(5) Sandstone, reddish, argillaceous, crumbly, 2′
(6) Limestone, gray, dense, massive, 5.3′
(7) Shale, red, sandy, somewhat crumbly, 1.3′
(8) Limestone, gray-pink, dense, massive, upper 1′ conglomeratic, 8.5′
(9) Sandstone, pinkish, 4.5′
(10) Limestone, 14.1′:
a. Limestone, lavender, dense, massive, with scattered fragmentary fossils and sand grains, 9.8′
b. Limestone, pinkish, crumbly, dense, with fossil fragments, 4.3′
(11) Limestone, crumbly, with fossil fragments, 4.5′
(12) Shale, red, limy, .9′
(13) Limestone, pinkish, dense, massive, algal, crinoidal, with scattered fusulines and other fossil fragments, 8′
(14) Sandstone, pinkish, very fine grained, 6′
(15) Sandstone, reddish, faintly cross-bedded, fine grained, 8.5′
(16) Limestone, pinkish, dense, blocky, changes laterally to sandstone, 1.3′
(17) Shale, red, crumbly conglomeratic, 1.8′
12. Limestone, 19.5′:
(1) Limestone, pinkish, dense, blocky, massive, 12′
(2) Limestone, lavender-red, dense, blocky, massive, sandy and conglomeratic in lower part, with scattered crinoid joints and other fossil fragments, 6.5′
(3) Sandstone–limestone, gray-red, blocky, conglomeratic, with fusulines, 1′
(II) Fountain, 214′:
1. Sandstone, red, somewhat coarse grained, cross-bedded, 5′
2. Sandstone, brick-red, fine grained, blocky, 8′
3. Slope on red sandstone and arkose, probably 202′+
III. Pre-Cambrian granite

Section No. 5

This is located in the vicinity of Horse Creek Station and the limestone quarries northwest of the station. The Cretaceous beds are modified slightly after Darton (1905, p. 73); the Jurassic and Triassic measurements are by Lee (1937, pp. 41, 42), modified by Condra. The strata are nearly on edge at and near the quarries.

I. Cretaceous System:
1. Fox Hills formation, exposed near railroad station, quite thick
2. Pierre shale, very thick
3. Niobrara chalk, about 375′ or less
4. Carlile shale, 230′
5. Greenhorn limestone, missing or .25′+
6. Upper Graneros shale, 560′
7. Newcastle sandstone, forms ridge, 50′
8. Skull shale, 150′
9. Fall River "Dakota" sandstone, forms ridge, 20′+
10. Fuson-Lakota beds, 96′

Unconformity.

II. Jurassic system, 245′:
1. Morrison formation (not well exposed), 200′

Unconformity.

III. Triassic system, 502′:
1. Spearfish (revised), about 500′
2. Dinwoody sandstone (?), 2′ or more

IV. Permian System, 584′:

(I) Phosphoria group, 250′–256′:
1. Freezeout beds, 102′:
(1) Limestone, gray, gypsiferous limestone and red shale, 8′–10′
(2) Shale, red, about 45′
(3) Limestone, gray-pink, 2′+
(4) Shale, red, and thin layers of red sandstone, 45′
2. Forelle limestone, gray-pink, two beds separated by shale, 8′–12′
3. Glendo shale, 50′+:
(1) Shale, red, 8′–10′
(2) Sandstone, yellowish, 1′+
(3) Shale, red, 39′–40′
4. Minnekahta limestone, gray to purple, fossiliferous, in thin beds, forms conspicuous narrow ridge, 20.5′–25′
5. Opeche shale, base not located, about 67′:
(1) Shale, lavender, 7′–8′
(2) Shale and sandstone, red, about 59′

(II) Cassa group, about 328′:
1. Sandstones, yellow, interstratified with red shales, resembles the Lyons sandstone, 10′–12′
2. Owl Canyon formation, about 275.9′:
(1) Shale, red, arenaceous, crumbly, 21′
(2) Sandstone, red, 14′
(3) Shale, red, with thin sandstones, 18.5′
(4) Sandstone, red, 1.5′
(5) Shale, red, arenaceous, crumbly, 4.2′
(6) Sandstone, red, 9′
(7) Sandstone and shales, 13′
(8) Sandstone, red, ripple marks on top, 2.7′
(9) Shale, red, crumbly, 1.9′
(10) Sandstone, red, 10′
(11) Shale, red, arenaceous, crumbly, 1.3′
(12) Sandstone, red, 1.8′
(13) Shale, red, crumbly, .7′
(14) Sandstone, red, 10′
(15) Shale, red, arenaceous, crumbly, 2.3′
(16) Sandstone, red, shaly, laminated, 2.1′
(17) Sandstone, red, 2′
(18) Shale, red, crumbly, .5′
(19) Sandstone, red, quite massive, 15.5′
(20) Shale, red, irregular, crumbly, .5′
(21) Sandstone, red, massive, 1.4′
(22) Sand, red, separated by thin red shales, 7′
(23) Sandstone, red, massive, 6.8′
(24) Sandstone and thin red shales, 2.6′
(25) Sandstone, red, massive, 3.2′
(26) Shale, and sand, red, a=shale, 1.4′; b=sandstone, .6′; c=shale, 3.4′; total 5.4′
(27) Sandstone, red, massive, upper .5′–.7′ saccharoidal, a foot of red shale .5′ above base; 6.4′
(28) Shale, red, gray layers at top and bottom, 1.4′
(29) Sandstone, white, very fine grained, .8′
(30) Shale, red, with thin sand subzones, crumbly, 7.6′
(31) Sand, gray on top, remainder red, 1′
(32) Shale, red, gray seams at top and bottom, 2.1′
(33) Sandstone, red, bedded, gray at top and bottom, 12′
(34) Shale, red, crumbly, 3.3′
(35) Sandstone, yellow, red and white, .6′
(36) Shale, red, crumbly, 1.9′
(37) Sandstone, red, 1.2′
(38) Shale and sand, red, 24′
(39) Sandstone, red, grayish white, mottled on top, 1.3′
(40) Shale, red, crumbly, .35′
(41) Sandstone, red, .7′
(42) Shales and sands, red, with some gray streaks, 14.7′
(43) Sandstones, red with thin red shale laminae, 5.7′
(44) Shale, red, red sands and six thin gray sand streaks, 42′

IV. Permian System (contd.)
(II) Cassa group (contd.)
3. Limestone, gray, dense to porous, 1.8′
4. Sandstone, red, massive, part cross-bedded, part slightly argillaceous, 38′

V. Pennsylvanian Subsystem (Casper beds), 823′:
(I) Ingleside beds, 613′:
1. Limestone, sandstone and quartzite, 136′:
(1) Limestone, top not well exposed, probably including at top a thin development of the Broom Creek beds, gray, dense to saccharoidal, with large calcite crystals in geodes, about 35′
(2) Covered slope, largely on limestone and some slate and sand, 17′
(3) Limestone, gray, dense, massive to thin bedded, with abundant reddish chert, 30′
(4) Quartzite, red, with limestone pebbles, 6′
(5) Covered slope, probably on sandstone, 6′
(6) Limestone, gray, dense, massive, 7′
(7) Sandstone, red, about 25′
(8) Limestone, badly covered, grayish, 8′–10′
2. Sandstone and quartzite, red to rusty red, largely massive, about 41′
3. Limestone, 112′:
(1) Limestone, gray, dense, with scattered red chert, 30′
(2) Limestone, greenish gray, dense, massive, 10′
(3) Limestone, gray, platy to massive, 20′
(4) Limestone, somewhat covered, gray, dense, massive to platy, probably some quartzite, 52′
4. Quartzite, pinkish brown, 8′
5. Limestone, 17′:
(1) Limestone, mined in short open cut on south side, bluish gray, dense, massive, 8′
(2) Limestone, bluish green-gray, dense, massive, 4′
(3) Limestone, grayish yellow, arenaceous, grades into a quartzite, 5′
6. Quartzite, pinkish near base, becoming gray and limy near top, 12′
7. Limestone, 55′:
(1) Limestone, mined on south side, greenish gray, dense, massive, 25′
(2) Limestone, gray, dolomitic, 30′
8. Sandstone, reddish, 8′
9. Limestone, 32′:
(1) Limestone, greenish gray, dense, massive, 10′
(2) Limestone, reddish gray, mottled, dense, somewhat nodular, 21′
(3) Limestone, bluish gray, dense, massive, with abundant fusulines, 1′+
10. Quartzite, gray, massive, 5.5′
11. Limestone, 34′:
(1) Limestone, gray to pinkish, dense, massive, 9.5′
(2) Limestone, gray, dense, 5.5′
(3) Limestone, gray, dense, massive, part slightly arenaceous, 14′
(4) Limestone, gray to pink, dense, massive, abundant fusulines in lower part, 5′
12. Sandstone, reddish to pink with a thin red shale 1′ above base, 6′
13. Limestone, gray, part saccharoidal, 2.9′
14. Covered slope, probably on sand or on shale, 10′
15. Limestone, 14′:
(1) Limestone, gray-lavender, massive, dense, with small red chert nodules, 5′
(2) Limestone, bluish gray, dense, massive, with numerous crinoid joints, 5′
(3) Limestone, bluish gray, dense, massive, 4′
16. Quartzite, red-pink, 10′
17. Limestone, 26′:
(1) Limestone, the lowest bed mined on south side, greenish gray, dense, massive, 22′
(2) Limestone, greenish gray, dense, 4′
18. Quartzite, limestone and shale, 10.8′:
(1) Quartzite, grayish, 1.5′
(2) Limestone, gray, dense, .8′
(3) Quartzite, light gray, 7.5′
(4) Shale, red, with green limestone pebbles, .9′
19. Limestone, 13′:
(1) Limestone, greenish, dense, massive, stylolitic, 5.5′
(2) Limestone, dark bluish gray, dense, with crinoid joints, 1.9′
(3) Limestone, greenish, dense, massive, stylolitic, 5.5′
20. Quartzite, gray to pinkish, bedded, 31.5′
21. Limestone, dark blue to light gray, dense, with abundant fusulines, 1.5′
22. Quartzite, gray to pink, bedded, 17′
23. Limestone, 10′:
(1) Limestone, bluish to lavender, green mottled, nodular, dense, 8′
(2) Limestone, blue, nodular in a sand matrix, 2′

(II) Fountain beds, best shown in a canyon about 1⅜ miles north of the Horse Creek quarries; consists of sandstones, quartzite and some arkose, all reddish or yellow-red, about 200′

VI. Mississippian (Madison limestone), 22′ according to Lee (1927, p. 41)
VII. Pre-Cambrian granite

Section No. 6

Location is about 1 mile northeast of Iron Mountain station (abandoned), or 3¼ miles northeast of Farthing railroad station. It is west of where the Farthing-Chugwater highway crosses Chugwater Creek. The Cretaceous, Jurassic, and Triassic beds were measured by Lee (1927, p. 43); the Permian and Pennsylvanian beds were measured by Condra.

I. Cretaceous System, about 1725′:
  1. Niobrara formation measured near Iron Mountain, about 4 miles northwest of Farthing station, 325′
  2. Benton shale, measured near Iron Mountain, 1025′:
    (1) Shale, dark, 850′
    (2) Mowry shale, light colored, 75′
    (3) Shale, dark, with a thin limestone, 100′
  3. Dakota group, near Iron Mountain, 375′ or less. Lower bed well shown at location of this section 3¼ miles northeast of Farthing

Unconformity.

II. Jurassic System, 336′:
  1. Morrison beds, badly covered, 220′

Unconformity.

  2. Sundance beds, about 116′:
    (1) Limestone and shale, 10′
    (2) Shale, badly covered, 15′
    (3) Limestone, 1′
    (4) Shale, badly covered, 15′
    (5) Sandstone, gray to yellowish, 75′

Unconformity.

III. Triassic System, probably about 536′:
  1. Jelm sandstone, reddish, 36′
  2. Spearfish formation (redefined) and 2′ or more of the Dinwoody sands (?), at base, 500′

IV. Permian System, 490′:
  (I) Phosphoria group, 198′:
    1. Freezeout shale, 63′:
      (1) Sandstone, 2′–3′
      (2) Red shale and covered slope, 50′–60′
    2. Forelle limestone, gray, with some red shale, about 10′
    3. Glendo shale, red, sandy, 45′
    4. Minnekahta limestone, not well exposed, 10′ or more
    5. Opeche shale, about 70′:
      (1) Shale, lavender, part sandy, 6′–8′
      (2) Shale and sand, red, about 62′

  (II) Cassa group, 292′:
    1. Owl Canyon formation, 256′:
      (1) Sandstone, red with interbedded red shale, 78′
      (2) Sandstone, red, and red shale, 28′
      (3) Sandstone, red, massive, 6′
      (4) Shale, red, sandy, and some red sandstone, 8′
      (5) Sandstone, red, massive, 9′
      (6) Sandstone, red, bedded, 5′
      (7) Sandstone, red, massive, 3.5′
      (8) Shale, red, and sandstone, red, 3′
      (9) Sandstone, red, massive, and some shale, red, 12′
      (10) Shale, red, sandy, bluish gray, in thin layers, top uneven, upper part a lensing mudstone, 13′
      (11) Sandstone, red, massive, two beds each 1′ thick, separated by 1′ of red shale; combined thickness 3′
      (12) Shale, and sandstone, red, 10′
      (13) Sandstone and shale, red, 12′
      (14) Sandstone, gray-red, 1′
      (15) Sandstones and shales, red, 30′
      (16) Sandstone and shale, red, 3′
      (17) Shale and sand, red, 14′
      (18) Sandstone, yellowish, three sandstone zones separated by red shale, 18′+
    2. Limestone, gray, dense, grades into sandstone, below, 3′–7′
    3. Sandstone, yellow-red, indurated, 22′
    4. Shale, transition zones, red, with gray lense of limy sandstone at top, base uneven, 5′–7′

} Age (?)

Unconformity.

V. Pennsylvanian Subsystem (Casper beds), about 391′ exposed:
  (I) Ingleside beds, exposed 391′:
    1. Limestones and sandstones, 163′:
      (1) Limestone, gray, and shale, red and pinkish dolomitic sandstone-limestone, top uneven, 10′
      (2) Limestone, 34′:
        a. Limestone, gray, cherty, top uneven, with reddish shale, 4′
        b. Limestone, gray, massive to bedded, with much bluish to reddish chert, 30′+
      (3) Sandstone, red, indurated, 14′
      (4) Limestone, light gray, 10′
      (5) Sandstone, red, indurated, 9′
      (6) Limestone, yellowish gray, irregular, 14′–15′
      (7) Sandstone, reddish, surface brownish, massive, 15′–16′

V. Pennsylvanian Subsystem (contd.)
(I) Ingleside beds (contd.)
1. Limestones and sandstones (contd.)
(8) Limestone, dark gray, middle light buff, 13′
(9) Sandstone, gray-red, surface brownish, cross-bedded, base very uneven, 6′–10′
(10) Limestone, gray, largely massive, top uneven, 36′
2. Sandstone and limestone, 29′:
(1) Sandstone, gray-red, with some dark gray limestone, 5′
(2) Limestone, gray-red, base uneven, 2′–3′
(3) Sandstone, red, with some gray lime, 12′
(4) Limestone, gray, uneven, 2′–3′
(5) Sandstone, reddish, surface brownish, 4′–6′
3. Limestone, gray, largely massive, 30′
4. Sandstone, red, and some red shale, 20′
5. Limestone, gray, massive, 6′
6. Shale, red, and sandstone, red, 2′–3′
7. Limestone, gray, largely massive, cherty, about 50′
8. Covered slope, largely red sandstone and red shale, about 40′
9. Limestone, grayish, poorly exposed, 8′–10′
10. Covered slope, largely on reddish shales and sands, about 40′, which does not extend to the base of the Ingleside

NOTE: In the exposures at Iron Mountain, located about 4 or 5 miles west of this section, Lee (1927) reports a thickness of 710′ correlated as Ingleside and 215′ as Fountain, making 925′ for the Casper.

SECTION NO. 7

Location is west of the Diamond T Ranch about 12 to 14 miles west of Chugwater, Wyoming. The beds dip moderately to rather steeply eastward.

I. Cretaceous to Permian and top few feet of Pennsylvanian, covered
II. Pennsylvanian Subsystem (Casper beds), top not exposed, 603′:
(I) Ingleside beds, top covered, 363′ exposed and measured:
1. Limestones, not well exposed, measurement not certain, about 36′ or more:
(1) Limestone, gray, dense, with abundant red chert, 12′+
(2) Limestone, grayish, brecciated, 10′–12′
(3) Limestone–mudstone, bluish and gray, 6′
(4) Limestone, bluish gray, dense, blocky, 6′
2. Sandstones and quartzite, 29.5′:
(1) Sandstone–limestone, gray, platy, with red chert in middle, 15′
(2) Sandstone, gray, quartzitic, platy, 7′–10′
(3) Quartzite, pinkish, 4.5′

UNCONFORMITY.

3. Limestone, 63′:
(1) Limestone, blue-gray, dense, 12′
(2) Limestone, gray, pinkish and yellowish, 20′–24′
(3) Limestone, pinkish to red, 5′–6′
(4) Limestone, pinkish to gray, 12′
(5) Limestone–sandstone, gray, 9′
4. Sandstone, quartzite and limestone, 21′:
(1) Sandstone, red, platy, 8.5′
(2) Limestone, bluish, dense, massive, 2′
(3) Quartzite, brownish, platy to blocky, .8′
(4) Sandstone, reddish, 3.8′
(5) Limestone, blue, dense, massive, grades into quartzite, 1′
(6) Quartzite, brown, platy to blocky, 1.5′
(7) Sandstone, red, 3.4′
5. Limestone, 61.7′:
(1) Limestone, three gray, massive ledges, lower ledge locally quartzitic, 8.4′
(2) Limestone, gray, dense, massive, 36′
(3) Limestone, reddish, dense, massive, algal, 8.8′
(4) Limestone, gray, dense, massive, 8.5′:
a. Limestone, gray with red chert, 2.5′
b. Limestone, gray, with abundant red chert, 3.5′
c. Limestone, gray, dense, massive, 2.5′
6. Quartzite, gray, massive, brownish on surface, 4.5′–5′
7. Limestone, 18′:
(1) Limestone, gray, dense, 7′
(2) Limestone, sandy and dolomitic, gray, 4′
(3) Limestone, gray to pinkish, three main ledges, red chert zones in massive parts of ledges, 7′
8. Quartzite, gray, 3′
9. Limestone, 125.5′:
(1) Limestone, gray, massive, dense, with small amount of chert in lower part, 29.5′
(2) Limestone, dark bluish gray, dense, massive, with chert zones, 19.5′
(3) Quartzite, gray-brown, 2.5′–3′
(4) Limestone, bluish gray, dense, massive, with abundant fusulines in middle part, 19′
(5) Limestone, gray, and shale, 4′
(6) Limestone, gray-yellow, dense to chalky, with *Ambocoelia* and *Mesolobus*, 7′
(7) Shale and lime, bedded, dark gray, 4′
(8) Covered slope, with some limestone, 7.5′

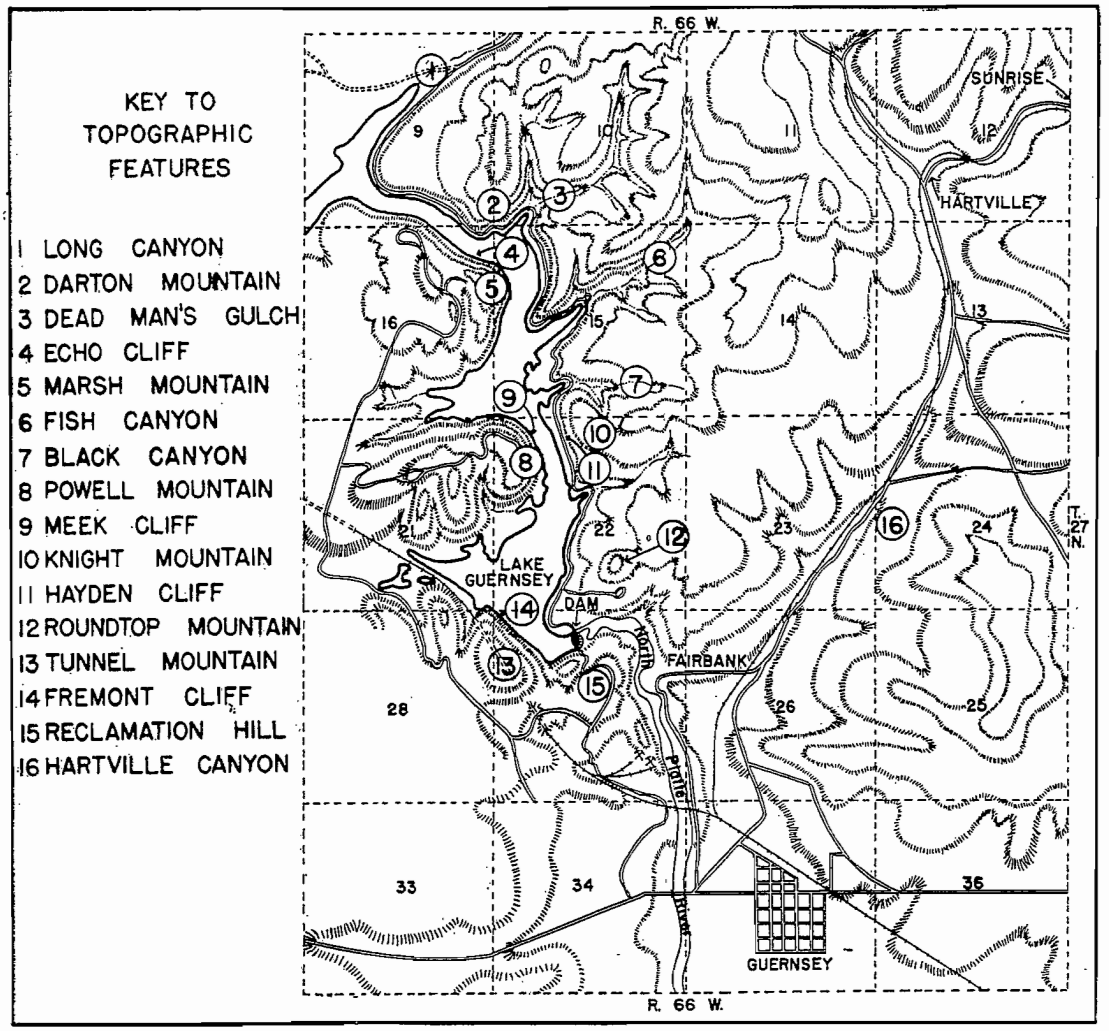

Figure 5.—Topographic features in the vicinity of Lake Guernsey.

II. Pennsylvanian Subseries (contd.)
(I) Ingleside beds (contd.)
9. Limestone (contd.)
(9) Limestone, gray, dense, cherty, with fusulines, 15′
(10) Slope, probably in shale and sand, 8′–9′
(11) Limestone, impure, sandy, badly covered, about 8′
(II) Fountain beds, in badly covered slope, consisting of reddish sands and shales and some arkose, about 240′

Section No. 8

In sec. 5, T. 29 N., R. 72 W., west of the La Bonte postoffice, Converse County, Wyoming; after H. D. Thomas (1940, p. 84); modified by Condra.

I. Cretaceous, Jurassic, and Triassic systems, not measured but about the same as at the Farthing section
II. Permian System, 350′:
(I) Phosphoria group, 175′:
1. Freezeout beds, 37′:
(1) Limestone, gray, 1′+
(2) Shale, red, 7′
(3) Limestone, gray, 3′
(4) Shale, red, 16′–18′
(5) Limestone, gray, gypsiferous, 1′–2′
(6) Shale, gray-lavender, gypsiferous, 6′
2. Forelle limestone, gray, with some bluish and reddish chert, 2′–4′+
3. Glendo shale, 43′:
(1) Shale, gray-red, 18′
(2) Limestone, gray, sandy, (?)
(3) Shale, red, 21′–25′

II. Permian System (contd.)
(I) Phosphoria group (contd.)
4. Minnekahta limestone, 27′:
(1) Limestone, lavender colored, 1′
(2) Limestone, gray, sandy, 2′–3′
(3) Shale, red, with thin limy sands, 4′
(4) Limestone, pink to gray, bedded, 18′
(5) Limestone, yellowish gray, 1′
5. Opeche shale, about 64′:
(1) Shale, lavender, 7′–9′
(2) Sands and shales, red, about 55′
(II) Cassa group, 175′:
1. Owl Canyon formation, 124′:
(1) Sandstone, red, massive to irregular, 13′
(2) Sandstone, yellowish to red, irregular, bedded and massive zones, 9′
(3) Sandstone, gray, cross-bedded, friable, 2′
(4) Sandstone, red, massive, 7′
(5) Sandstone, gray, cross-bedded, friable, with two thin bands of red sandstone, 26′
(6) Sandstone, red, 2′+
(7) Sandstone, yellowish, massive, friable, 12′
(8) Sandstone, gray, cross-bedded, friable, 12′
(9) Covered, but probably sandstone, 8′–10′
(10) Sandstone, yellow-red, largely cross-bedded, about 31′
2. Limestone member, reddish, sandy, 5′–7′
3. Sandstone members, red, with some quartzite, 44′
III. Pennsylvanian Subsystem (Casper beds), about 642′:
(I) Ingleside beds, 469′:
1. Limestone, gray, upper part at horizon of the Broom Creek beds, badly covered and not differentiated, cherty near top, part fossiliferous, 145′
2. Sandstone, red, with red shales and thin limestones, 100′
3. Limestone, gray, massive, 11′
4. Sandstone, red, about 30′
5. Shale, red and sandy limestone, 37′
6. Limestone, gray-red, massive, 146′
(II) Fountain beds, 173′:
(1) Sandstone, red; shale, red; sandy lime; combined thickness about 64′
(2) Sandstone, reddish and firm, and reddish sandstone, basal part reworked, 112′
IV. Mississippian Subsystem, limestone, cherty, 25′
V. Cambrian System (Deadwood sandstone), 15′
VI. Pre-Cambrian granite

NOTE: The Permian-Pennsylvanian beds are badly covered in the stretch between north of the La Bonte postoffice and south and southwest of Douglas. They are well exposed near Glendo, Cassa, and Guernsey.

THE HARTVILLE UPLIFT IN WYOMING

The Hartville Uplift is an interesting area for geological investigation, especially so in the vicinity of the Guernsey Reclamation project where there are good outcrops which the federal road cuts make readily accessible for study. The geologic, hydrologic, topographic, and scenic features in the vicinity of Lake Guernsey are of educational interest to tourists and others (see figure 5). Some of these features were named for well-known geologists and engineers.

Structure.—The Hartville Uplift is 15 to 23 miles in width and 35 to 40 miles in length, extending from Guernsey and Cassa on the south and southwest to the vicinity of Manville and Lusk on the north and northeast. Its general structural trend is north-northeast. The main part of this area is composed of two roughly parallel anticlinal folds separated by a broad, shallow syncline, and is bordered on the east and west by small outlying synclines and folds. The folding is modified by some faulting, notably just northwest of Wendover, 3 miles, northeast of Cassa, and north of Guernsey. A fault, 3 miles northeast of Cassa, repeats about 200′ of section. In general the faults of this area trend north-northeast.

The Sunrise Anticline is the easternmost fold of the main part of the Hartville Uplift. Its eastern flank is obscured by the overlap of Tertiary rocks, but well records show that Cretaceous, Jurassic, Triassic, Permian, and older rocks lie under the Tertiary, dipping away from the uplift. The Cassa Anticline has a general eastern flank and a steeply dipping western flank. The Broom Creek Syncline lies between the Cassa and Sunrise anticlines.

Stratigraphy and Synonomy.—Metamorphic and igneous rocks of Pre-Cambrian age are exposed in the crest of the Sunrise Anticline. Smith (1923, pp. 1, 2) names these ancient gneisses, schists, quartzites, and dolomites the Whalen group and describes the intrusive dikes. Ball (1906, pp. 192–4) reports older and younger series of metamorphosed sedimentary rocks and

states that the intrusive igneous rocks, which penetrate the older series, are believed to be younger than the gneisses and schists.

Smith (1903, p. 2) names the Guernsey formation to include the sedimentary rocks lying next above the Whalen group in this area, but it is believed now that the lower 5′ or more of the Guernsey is the Deadwood sandstone of Cambrian age. The basal part of the limestone next above the Deadwood correlates with the Englewood limestone, and the main body of the massive limestone of the Guernsey is the Pahasapa of the Black Hills.

Smith (1903, p. 13) names the Hartville formation to include the rocks lying between the Guernsey and Opeche formations. He classes this part of the section as Pennsylvanian in age, but it has been known for some time that the Hartville is correlative with Darton's Minnelusa of the Black Hills named in 1900 and with the Casper of Wyoming as redefined by Knight (1934, p. 34). Furthermore, the Hartville-Minnelusa-Casper interval includes two systems of rocks composed of three or four series, six groups, and many unnamed formations and members. Consequently, the terms Hartville, Minnelusa, and Casper do not properly apply as formation names.

As noted before, deep wells evidence the presence of the Triassic, Jurassic, and Cretaceous formations in the east flank of the Hartville Uplift, and show that, with few exceptions, these subdivisions have about the same thickness here and in the east flank of the Laramie Range. The section from near the base of the Pennsylvanian to the top of the Dakota group is exposed northeast of Cassa where the thickness of the divisions above the Cassa group are as follows: Phosphoria about 224′, Spearfish 450′, Sundance 200′, Morrison 100′, and the Dakota group about 300′. The strata here dip southwestward.

The White River and Arikaree groups of the Tertiary completely surround the Hartville Uplift, overlapping against the older rocks, and must have covered the area with a much greater thickness of sediments than is now present, the North Platte River and its tributaries having cut through the Arikaree and White River rocks and into the older rocks.

The Hartville area has been studied by several geologists of the United States Geological Survey as by W. S. T. Smith, N. H. Darton, Sidney H. Ball, and W. T. Lee. Also, geologic study has been made here by Louis D. Ricketts, Wilber C. Knight, H. M. Chance, S. H. Knight, Henry C. Beeler, and by many oil company geologists.

Geological investigation by the Nebraska Geological Survey began in this area in 1928 under the direction of the senior author, assisted by Dr. Carl O. Dunbar, M. E. Upson, J. E. Upp, and C. E. Busby, and this study has continued intermittently to the present. A report on the stratigraphy of the area was made by Condra & Reed in 1935, and detailed sections of the region by Condra, Reed, and Scherer were published in the 1940 Guide Book of the Kansas Geological Society.

We do not know definitely where to place the Permian-Pennsylvanian contact in the Hartville area, whether at the top of Condra & Reed's (1940, p. 75) Division II or at the top of their Division IC. No fossils were found in Division IB and those found in the upper part of Division IC are not diagnostic of either the Permian or Pennsylvanian. However, lithologic evidence favors the inclusion of Division IC with the Pennsylvanian as correlated in the Laramie Range and the Black Hills. Consequently we class Division IC under the Broom Creek group, Permian, Pennsylvanian (?). This leaves Division IB as probably basal Permian, correlated provisionally as the lower part of the Cassa group.

The basal beds of Owl Canyon formation of the Cassa group change facially between La Bonte and the Cassa section and even more between the Cassa and Broom Creek sections. This gradation northward is shown by the development of siltstones which change to limestones. The lower part of the Owl Canyon formation becomes thin siltstones and limestones interstratified with sandstones in the Hartville area.

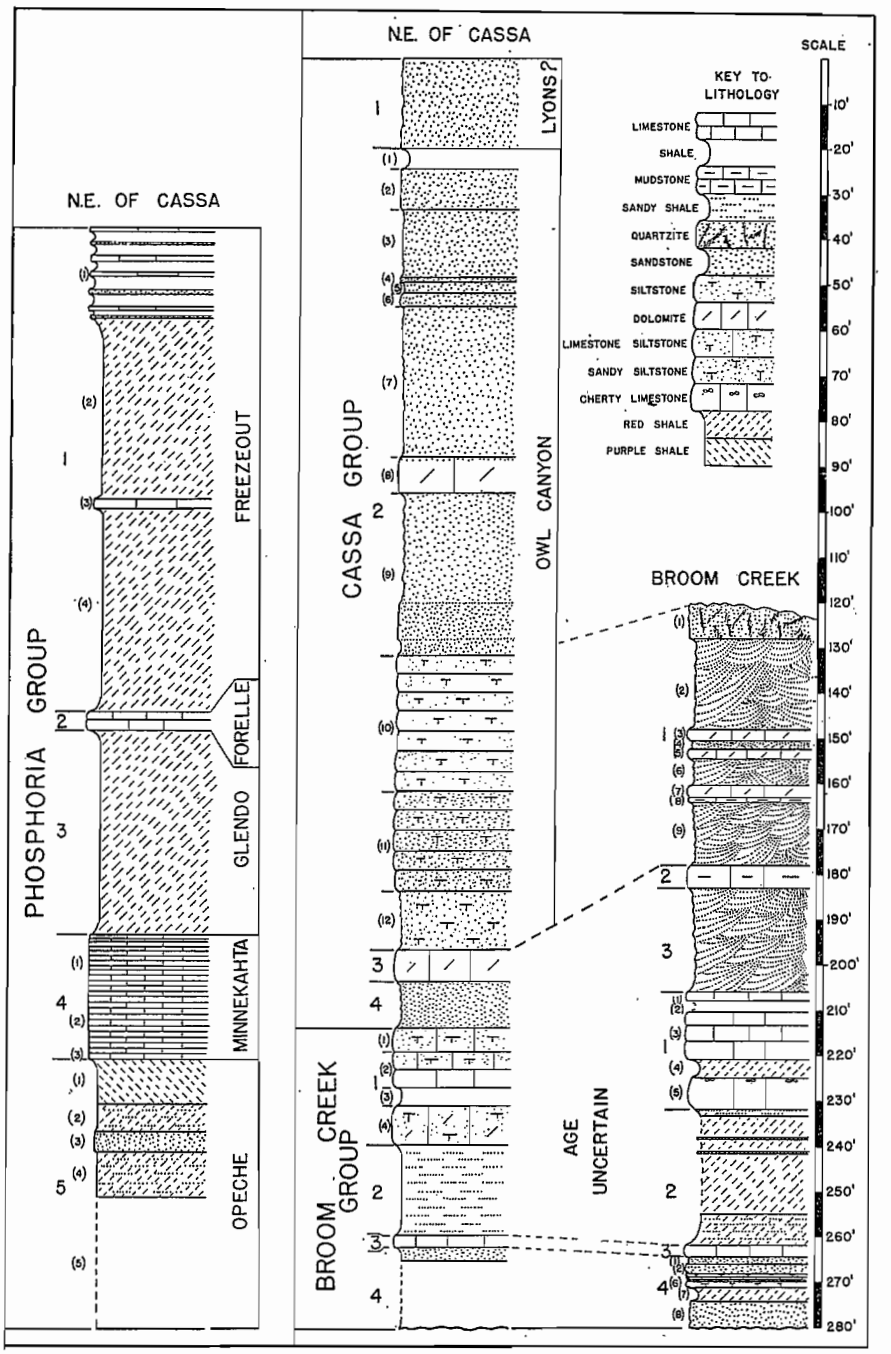

Figure 6.—Composite columnar section of the Phosphoria, Cassa, and Broom Creek groups measured 3 miles northeast of Cassa and on Broom Creek, northwest of Lake Guernsey.

The calcareous marine facies of the lower part of the Owl Canyon formation grades westward into sandstone in the section about 8 miles southwest of Douglas. The Broom Creek group and probably the upper part of the Wendover group become sandstone at points farther west and northwest in Wyoming. The Tensleep sandstone, which is the sandstone facies of the Cassa group and some older beds, becomes quite thick in the Casper, Wind River, and Bighorn mountains.

Section No. 9

Location is about 3 miles northeast of Cassa, Platte County, Wyoming; in sec. 28, T. 29 N., R. 67 W. Upper part of section after Darton (1905, p. 62), (1903, pp. 1-4); rest of section measured by Reed and Condra.

I. Tertiary System, surrounds the uplift, 1000′+
  1. Ogallala beds, missing here
  2. Arikaree group, largely sands, surrounds uplift, consisting of Monroe Creek and Harrison beds, combined thickness 600′±
  3. White River beds, consisting of Chadron sand 60′±, and Brule clay 400′ or less

II. Cretaceous System:
  1. Lance formation, in Powder River Basin northwest of Hartville Uplift, missing here
  2. Fox Hills shale, in Powder River Basin northwest of Hartville Uplift, missing here
  3. Pierre shale, eroded from this area; very thick in Julesburg Basin east of uplift
  4. Niobrara, eroded here, thickness in Julesburg Basin east of uplift, about 300′ or more
  5. Carlile, not exposed here, thickness east of uplift
  6. Graneros shale, basal 120′+ exposed northwest border of uplift; total thickness penetrated in wells east of uplift, about 800′+
  7. Dakota group, 250′–300′ exposed

  Unconformity.

III. Jurassic System, measured near Cassa, 300′+:
  1. Morrison formation, 100′+
  2. Sundance formation, 200′+

  Unconformity.

IV. Triassic System, 450′:
  1. Jelm formation, not present
  2. Spearfish formation (redefined), measured near Cassa, consists of red shales and sands, about 450′ or less

V. Permian System, northeast of Cassa (figure 6), about 505′:
  (I) Phosphoria group, 222.75′:
    1. Freezeout shale, consisting of red shales, thin limes, and some gypsum, 82′–86′ northeast of Cassa
    2. Forelle limestone (?), two gray to pink limes separated by red shale, 4′ or more. The Forelle may be one of the limes in above.
    3. Glendo shale, red, part sandy, 45′+
    4. Minnekahta limestone, northeast of Cassa, 27.75′:
      (1) Limestone, yellowish gray, argillaceous, thin bedded, 12.5′
      (2) Limestone, dark gray to purple-red, thin bedded, 14′
      (3) Limestone, gray, blocky, separated by thin red shales, 1.25′
    5. Opeche shale, about 60′:
      (1) Sandstone, dark red to purple, argillaceous, massive, 10′
      (2) Shale, brick red, sandy, massive, 6.5′
      (3) Sandstone, gray to pink, calcareous, 4.7′
      (4) Shale, red, sandy, some thin sandstones at top, 10′
      (5) Covered slope and red sandy shale, 29′
  (II) Cassa group, 215.8′:
    1. Sandstone (in horizon of the Lyons sandstone), yellow-buff, massive, variable, thin bedded at top and base, 20′
    2. Owl Canyon formation, 178.8′:
      (1) Shale, medium gray, weathers yellow-buff, in part filled with small brown iron concretions, badly covered in lower 3′, forms re-entrant, 4.8′
      (2) Sandstone, yellow-buff, occasionally blotched with red, iron stained on surface, finer grained than above, in three beds separated by thin shale partings, poorly exposed, 9′
      (3) Sandstone, red, streaked with dark red, massive, soft, with a more resistant layer 2.2′ below the top, 15.2′
      (4) Sandstone, red, mottled with light gray, forms a rounded ledge, .8′–1′
      (5) Sandstone, red, massive, soft, 2.8′
      (6) Sandstone, red, fairly hard, forms a ledge, 3′
      (7) Sandstone, red, argillaceous and covered slope, 33′
      (8) Limestone, medium gray to lavender, firm or dense, dolomitic, slightly silty, sandy at top, 8′
      (9) Sandstone, red, friable, badly covered in base of slope, 36′
      (10) Siltstone, light gray to pink and red stained, calcareous, massive, heterogeneous, grades from limestone to sandstone, interstratified with sand, locally cavernous, with angular cobbles of limestone-siltstone, 30′
      (11) Siltstone-sandstone, gray, with limestone cobbles, 22′
      (12) Sandstone-siltstone, pink to red, calcareous, massive, with scattered limestone cobbles, forms slight re-entrant, 14′

V. Permian System (contd.)
(II) Cassa group contd.)
UNCONFORMITY.
3. Limestone member, gray, massive to thin bedded, slightly dolomitic, 7′
4. Sandstone member, red, soft, with some siltstone pebbles and limestone breccia, 10′, underlain by 5.5′ of grayish red siltstone; combined thickness, 15.5′
(III) Broom Creek group (age ?), measured in Buckshot Canyon, 66.5′:
(1) Siltstone, grayish red, 5.5′
(2) Limestone, light gray, silty, dolomitic, 8.5′
(3) Shale, gray-red, mottled, with sandy seams, 4′
(4) Limestone, light gray, silty, dolomitic, massive, 8.5′
(5) Sandstone and shale, red, poorly exposed, 19.5′
(6) Limestone, gray-red, dolomitic, with some pebbles, 2.5′
(7) Sandstone, red, soft and covered slope, 18′
UNCONFORMITY.
VI. Pennsylvanian Subsystem:
(I) Wendover group, exposed in Buckshot Canyon, but not measured (see next section, No. 10)

SECTION No. 10

Measured by Condra and Scherer on Broom Creek just northwest of where it is crossed by the Hartville-Glendo road. This section is about 5½ miles northwest from the junction of the Hartville and Guernsey roads in Long Canyon and 16 miles from the Platte River bridge northeast of Glendo (figure 6). It is in the west half of sec. 10, T. 28 N., R. 66 W., on the Broom Creek Syncline.

I. Permian System, top removed by erosion, about 86.5′ exposed:
(I) Cassa group, largely removed by erosion, 86.5′ remaining:
1. Owl Canyon formation, lower part, 58.5′:
(1) Quartzite, reddish, caps upland, 8′ or more
(2) Sandstone, red, irregular, 20′
(3) Limestone, dark pinkish gray, dolomitic, resembles sandstones, surface rough, forms large blocks, 2.5′
(4) Sandstone, red, cross-bedded, 2′
(5) Limestone, pinkish gray, dolomitic, resembles sandstone, forms large rounded blocks, 2′
(6) Sandstone, red, cross-bedded, 6′
(7) Limestone, dark pinkish gray, dolomitic, resembles sandstone, surface rough, forms large rounded blocks, 2.8′
(8) Mudstone, gray, bedded, 1.2′
(9) Sandstone, red, massive, cross-bedded, surface rough, 14′
2. Limestone-mudstone member, gray, mudstonelike, part shaly, 5′±
3. Sandstone member, red, massive, part cross-bedded, with pebbles near base, 20′–23′
UNCONFORMITY.
(II) Broom Creek group, age (?), 75′:
1. Limestone, 26′:
(1) Limestone-mudstone, gray, 2′
(2) Shale and covered, 2.5′
(3) Limestone, bluish gray, massive to bedded, 10.5′
(4) Shale, gray, 4′
(5) Limestone, gray, with reddish tint, some gray to reddish chert and pebbly at top, with a few brachiopods and crinoid joints, 7′
2. Sandstone, gray, red, and pink; and gray, red, and greenish gray shales, all badly covered, about 30′
3. Limestone, gray-yellow-red, irregular, dolomitic, 2.5′±
4. Sandstone, shale and some limestone, thickness 16.5′:
(1) Sandstone, gray to pink, friable, 1.6′
(2) Sandstone, red, shaly to sandy, jointed, geodal, 2.6′
(3) Siltstone, red, calcareous, pitted, .6′
(4) Limestone, light gray, dense, pitted, weathers buff, with some crinoid joints, .8′
(5) Shale, medium gray to red, with thin silty lenses, .3′
(6) Siltstone, gray-yellow, calcareous, 1.4′
(7) Shale, red, sandy, laminated, with .3′ red-gray sandstone at top, 3′
(8) Sandstone, red, friable, thin bedded to massive, 6′

II. Pennsylvanian Subsystem, 23.9′ exposed:
(I) Wendover group, 23.9′ exposed:
1. Limestone-sandstone, upper part Division II of Condra & Reed (1935), gray, upper surface uneven, 8′
2. Shale, lavender, sandy, .8′–.9′
3. Limestone, gray to buff, irregular to massive, with two or three seams of red chert in upper 3′; rises northwestward on bed of Broom Creek

Discussion.—The few fossils found in the Broom Creek beds of this section are not

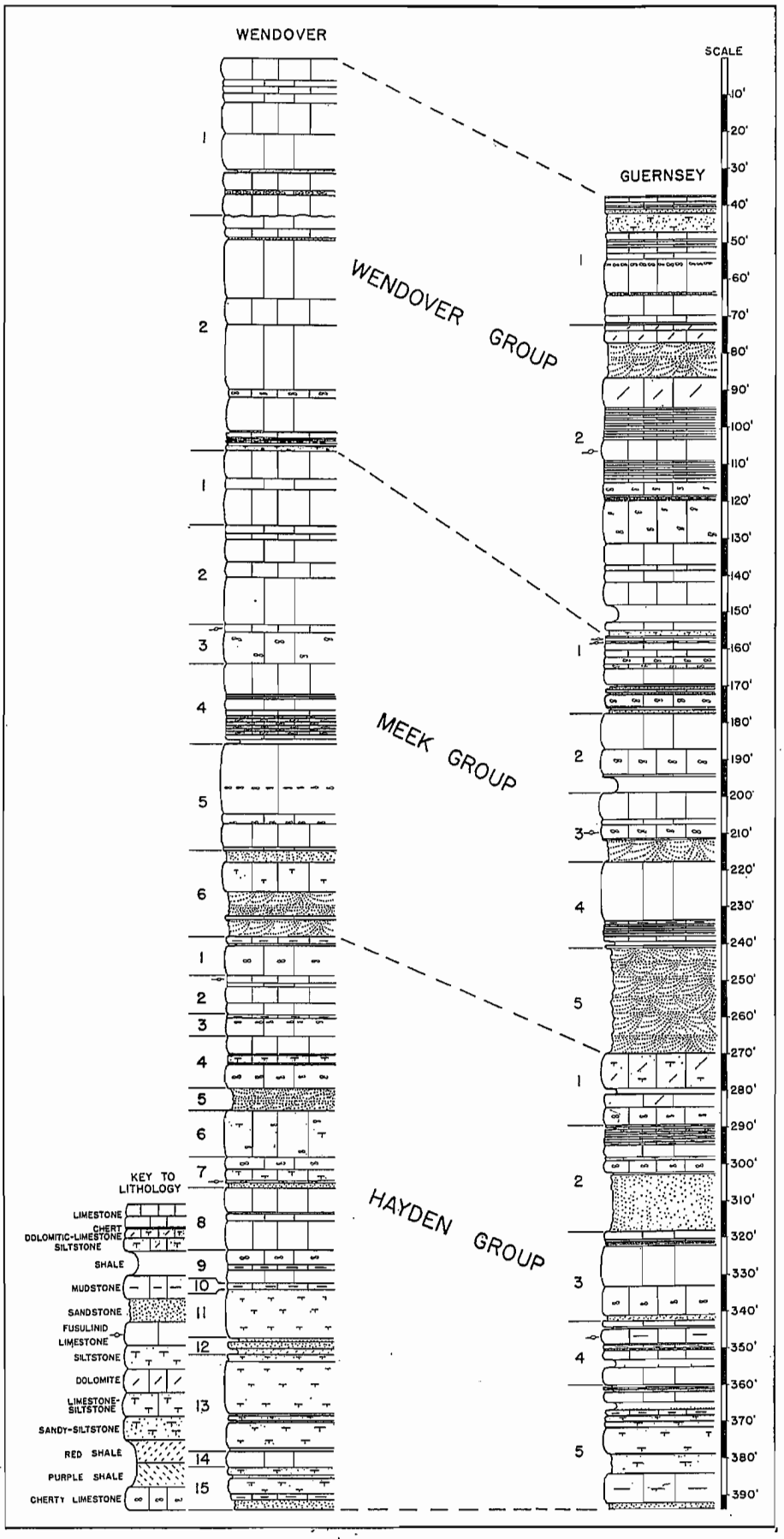

Figure 7.—Composite columnar sections of the Wendover, Meek, and Hayden groups near Wendover and Guernsey.

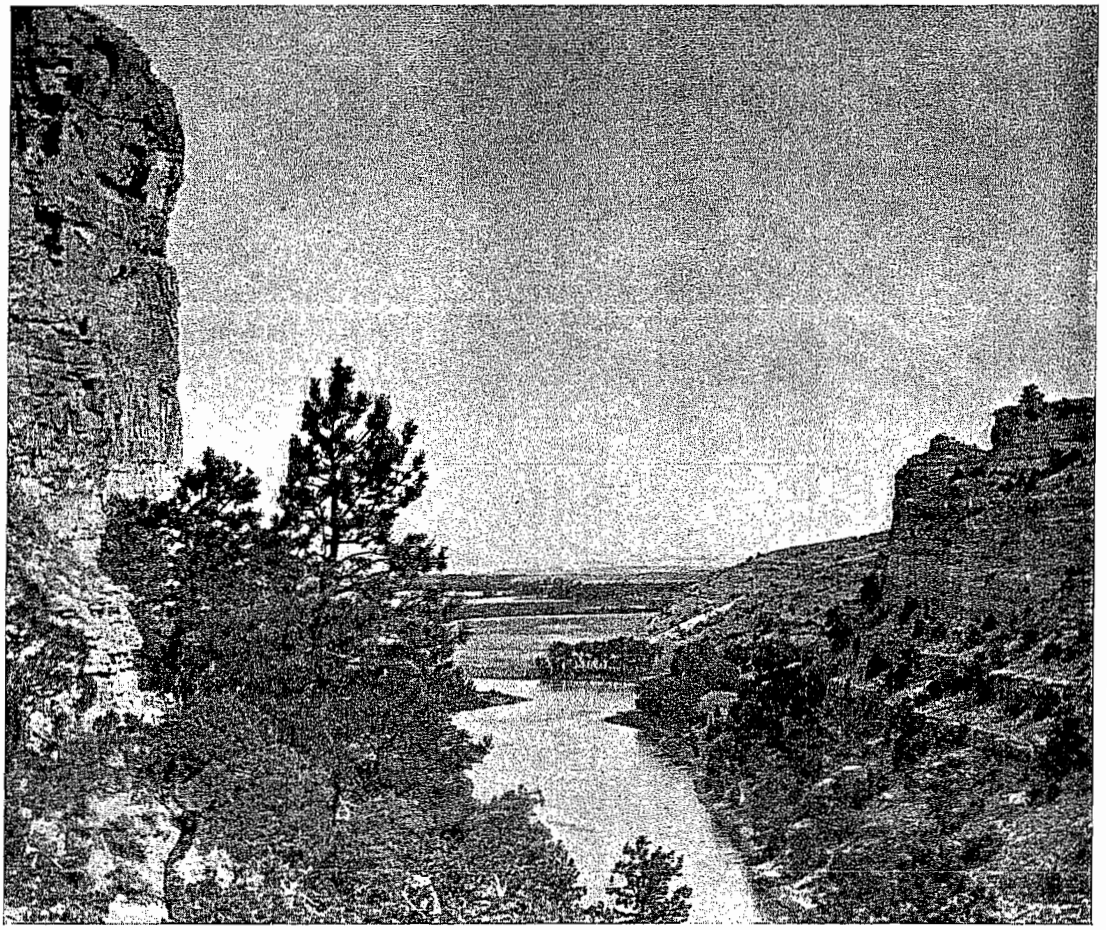

Figure 8.—View west-northwest, North Platte River Canyon, 6 miles north-northwest of Glendo, showing from top downward: Wendover, Meek and Hayden groups, and upper part of Roundtop group near river level.

diagnostic of either the lower Permian or the upper Pennsylvanian. Hence the age of the beds in this horizon is not certain, and is so classed in the hope that future study may solve the problem of the Permian-Pennsylvanian contact at this place.

The quartzite at the top of the Broom Creek section occurs also in the Cassa section (No. 9) and is well developed in the area northwest of Glendo. It becomes quite thick about 8 miles southwest of Douglas, where its top is about 34′ higher in the section than on Broom Creek, and lies next below the Opeche formation. No. 1 of the Wendover group near Cassa grades to quartzite northwestward.

The Broom Creek section corresponds to subdivisions 2 to 12 of Section No. 9 and close correlation of the members of these sections is shown by their comparison in several thin dolomitic limestones which appear in the lower part of the Broom Creek formations, representing a facial change contrasting with the sandstone facies of this formation at Horse Creek and Farthing stations and the shaly-sandstone facies at Owl Canyon. All or nearly all of the Owl Canyon formation grades to quartzitic sandstone from the Cassa and Broom Creek stations to the mountains southwest of Douglas.

Wendover Group.—This group underlies the Broom Creek beds and overlies the Meek group. It consists of limestones interbedded with sandstones, mudstones, and shales. At its base is a sandstone which probably marks an unconformity.

The group outcrops widely in the Hartville area forming cliffs in the canyon walls (figure 7). It is prominently exposed in the Platte River Canyon northwest of Wendover, in Platte River Canyon (figure 8) 6 miles north-northwest of Glendo and in the highest upland bordering Lake Guernsey, located northwest of Guernsey.

Section No. 11

Measured by Condra and Reed in the Platte River Canyon northwest of Wendover, Wyoming.

(I) Wendover group, 106′:

1. Limestone, 41′:
   (1) Limestone, medium gray, silty, thin bedded, weathers light gray; with a massive 1′ bed at top; combined thickness 5.5′
   (2) Limestone, gray to pinkish, argillaceous, nodular, 1.6′
   (3) Limestone, light gray, silty, locally sandy-friable, part geodal, weathers to pinkish, 2′
   (4) Limestone, light gray, silty, black, with fossil casts, 2.4′
   (5) Limestone, light gray to pink, sandy, irregular, uneven base, 8′
   (6) Limestone, medium gray, massive, silty, geodal part cavernous, weathers brownish gray to pink stained, 9′
   (7) Shale, red, sandy, irregular at top and base, 1′
   (8) Limestone, light gray, locally pink stained, massive, silty, geodal throughout, with dark gray chert in lower part; breaks into small angular blocks, 4′–4.5′
   (9) Chert, medium gray, pink or lavender; bedded, with irregular uneven base, 1′–1.4′
   (10) Limestone, light gray, silty, part geodal, with pebbles locally, base uneven indicating a local unconformity, 5.5′
2. Limestone, 65′:
   (1) Limestone, gray to pinkish, silty, dense, massive, upper part shattered, basal part geodal, 3.4′
   (2) Limestone, light gray, silty, slabby to shattered, 2.3′
   (3) Sandstone, medium gray to buff, laminated to cross-bedded, locally stained rusty brown at surface, thickens northwestward, .2′–4′
   (4) Limestone, medium gray, massive, silty, geodal, cavernous locally, upper part shatters into small blocks, weathers light gray to buff, 15′
   (5) Limestone, gray, massive, silty, weathers light gray, with many fusulinid-like, calcite-filled pits in upper part, 7′. This seems to be the *Triticites cullomensis* zone.
   (6) Limestone, medium gray, silty, weathers light gray to yellow-buff, breaks into small angular pieces, 16.5′
   (7) Limestone, grayish to medium dark gray, massive, slightly silty, with gray to pink chert and silicified brachiopods in upper part, 2′
   (8) Limestone, red, silty, thin bedded to slabby, with small geodes, 7.8′
   (9) Shale, massive, medium gray above, red below, .2′
   (10) Limestone, dark gray, two or three beds, upper layer black, 1.2′–2′
   (11) Mudstone, limestone, shale, interbedded, medium gray, with some red chert, 2.2′–3.3′
   (12) Siltstone, gray to brownish gray, thin bedded to slabby, grades into limestone, pebbly conglomerate locally, 1.2′–1.5′

(II) Meek group, 130.5′:

1. Limestone, 19′:
   (1) Limestone, medium dark gray, fine grained, massive to bedded, with scattered geodes, crinoid joints and brachiopods in upper part, 7′
   (2) Limestone, as above, but dark gray with a reddish cast, 3′
   (3) Limestone, dark gray and light gray mottled (dark gray lenselike areas bordered with lighter gray), fine grained, massive to medium bedded, about 9′
2. Limestone, part silty, 29′:
   (1) Limestone, light gray, silty, weathers pinkish, shattered, 2.2′
   (2) Limestone, medium dark gray, very fossiliferous, 1′–2′
   (3) Limestone, light gray, silty, massive, weathers light gray to pinkish, breaks into small angular blocks, 6′
   (4) Limestone, medium dark gray, a heavy ledge, with brachiopods, 4′
   (5) Limestone, medium gray, silty, weathers light gray to buff, breaks into small angular blocks, 12′
   (6) Mudstone, medium dark gray to purplish, platy to slabby, weathers as a conspicuous red zone, forms a reentrant, 2.8′

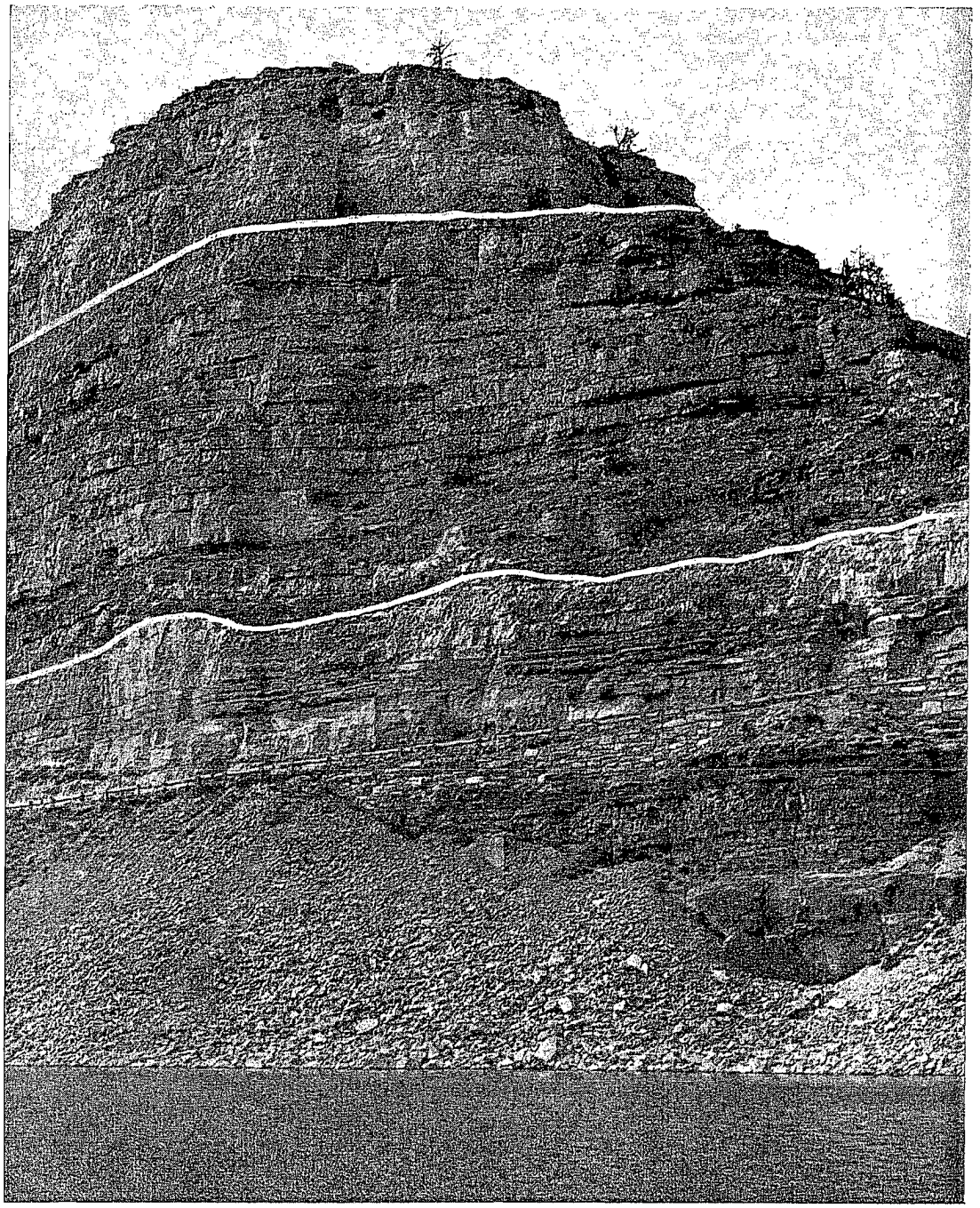

Figure 9.—Exposure of the Wendover, Meek, and Hayden groups in cliff east of mouth of Long Canyon. The lower 70′ of the Wendover group is shown above the upper white boundary line. The Meek group occurs between the white lines and most of the Hayden group below the lower white line. (Photo by R. W. Hufnagle.)

3. Limestone, 10′:
   (1) Limestone, medium dark gray, forms a prominent blocky cap to underlying bed, with *Triticites exiguus,* brachiopods and crinoid joints, 2′+
   (2) Limestone, medium dark gray, massive, weathers medium gray with a few geodes, occasional red chert nodules and brachiopods, 8′
4. Limestone, largely silty, 21.5′:

(II) Meek group (contd.)
4. Limestone (contd.)
(1) Limestone, medium gray, silty, massive, forms small angular blocks, 8′
(2) Limestone, medium dark gray, slightly silty, blocky, .7′
(3) Limestone, medium gray, silty, slabby, weathers light gray, .5′
(4) Limestone, medium dark gray, massive, with some brachiopods, 3′
(5) Limestone, gray, silty, massive, breaks into small regular blocks, 1.6′
(6) Limestone, medium dark gray, very crinoidal, in .5′–1′ beds separated by lenticular layers of red chert, 6′
(7) Shale, dark gray, massive, calcareous, 1.2′
5. Limestone, in part silty, with some chert, 27.6′:
(1) Limestone, medium dark gray, grades downward and laterally to a silty limestone, with a discontinuous lenticular bed of yellow chert 7′ above the base, 18′
(2) Limestone, dark gray, weathers medium dark gray, with lenticular beds of red chert at base and red chert nodules throughout, 2.6′
(3) Limestone, as above, but chert-free and massive, 6′
(4) Limestone-mudstone, dark gray, platy to slabby, weathers medium gray, forms a re-entrant, 1′
6. Sandstone, with some limestone, 23.5′:
(1) Sandstone, gray, laminated to cross-bedded, weathers light gray to buff, often rusty brown stained, locally contains brownish to pink chert along joint planes, 3.5′–4′
(2) Limestone, medium gray, silty, slabby to massive, weathers light gray, often pink stained in middle and lower part, 7.5′
(3) Sandstone, medium gray, thin bedded to cross-bedded, weathers light gray to buff, upper 1.5′ massive, 6.5′
(4) Limestone, dark gray, rough surfaced, minutely stylolitic, a single bed, 9–1′
(5) Sandstone, gray, laminated to cross-bedded, weathers yellow-buff to light gray, 4.6′

The Wendover and Meek groups are well exposed in the vicinity of Lake Guernsey (figure 9) where the following section was measured.

(I) Wendover group, 117.1′:
1. Limestone, 35′:
(1) Limestone, gray, silty, dolomitic, weathers light gray, a single bed, .5′–.6′
(2) Limestone, gray, silty, dolomitic, weathers light gray to gray, one bed capped by a shale seam, contains casts of small gastropods and pelecypods, 1.3′
(3) Limestone, gray, firm, dolomitic, jointed, weathers light gray, some calcareous geodes, a single bed, 1′
(4) Limestone, gray, dolomitic, shattered, weathers pinkish, .7′
(5) Limestone, medium light gray, dolomitic, a single bed, .5′
(6) Sandstone, light gray, fine grained, laminated to cross-bedded, weathers pinkish with a dark rusty brown-stained surface, 1.35′
(7) Sandstone-siltstone, transitional from a pinkish, shattered, calcareous siltstone in the lower part to a massive, yellow-buff sandstone in the upper; irregular, uneven base, 5′
(8) Limestone, light gray, dolomitic, silty, thin bedded to shattered, weathers yellowish buff, 2′
(9) Limestone, pinkish, dolomitic, silty to argillaceous, nodular, with a thin seam of red shale at the top, .5′–.8′
(10) Limestone, gray, dolomitic, silty, geodal, weathers light gray, in three beds (upper bed, .8′, middle bed, .7′, lower bed, 1.5′), combined thickness 3′
(11) Siltstone-sandstone, pink to red with gray bands, calcareous, laminated, friable in upper part, 1.5′–1.8′
(12) Limestone, medium light gray, dolomitic, silty, massive, in part pebbly, occasionally cavernous to knotty, weathers light gray to brownish; includes .2′–.5′ bed of pinkish chert, 1.7′ below the top; combined thickness 8.5′
(13) Chert, medium light gray, pink to lavender, uneven base, quite persistent, .4′–1′
(14) Limestone, medium light gray, dolomitic, sandy, massive, pebbly in upper part, weathers dirty gray to pinkish, 5′
(15) Limestone, medium light gray, dolomitic, silty, massive, weathers pinkish, 2′
(16) Siltstone, red, calcareous, argillaceous, uneven base, 0′–.5′

(I) Wendover group (contd.)
2. Limestone, 72.5′:
(1) Limestone, medium light gray, dolomitic, silty, weathers pinkish gray, highly shattered to small blocks, 1.25′–2′
(2) Dolomitic limestone, medium light gray, silty, massive, 3′–3.3′
(3) Sandstone, light gray, calcareous, laminated to cross-bedded, weathers buff, with rusty brown-stained surface, very persistent but variable in thickness, 4′–12.5′, average 9′
(4) Dolomite, medium light gray, crystalline, massive, with a reddish band at the base, 7.8′
(5) Limestone, medium light gray, dolomitic, silty, thin bedded to platy, weathers yellowish buff, contains some geodes, 8.3′
(6) Limestone, medium light gray, dolomitic, silty to argillaceous, massive with *Triticites cullomensis,* 5.6′
(7) Limestone, medium light gray, dolomitic, silty, geodal, thin bedded, platy, 5.6′
(8) Limestone, medium dark gray, heavy bedded, weathers rough surface, yellow to rusty brown chert, along joint planes, crinoid stems and fossil fragments, 3.3′–3.5′
(9) Limestone, medium light gray, silty to argillaceous, platy, .5′
(10) Chert, yellow to rusty brown, an irregular bed, .5′–.8′
(11) Limestone, medium light gray, argillaceous, forms a slight re-entrant, .3′
(12) Limestone, medium dark gray, light gray, mottled, massive, weathers rough surfaced, some spongy brown chert along joints, 9′–11′
(13) Limestone, medium light gray, dolomitic, silty, lithographic, weathers yellowish gray, some geodes, breaks into small angular blocks, 5.5′
(14) Limestone, pink to reddish, silty to argillaceous, crinoid joints and fragmentary fossils, 1.5′
(15) Limestone, poorly exposed, 3′
(16) Limestone, light gray, platy, in part geodal, weathers yellow-buff, some crinoid joints and other fossil fragments, 6′
3. Shale, limestone, mudstone, and sandstone, 9.6′:
(1) Shale, dark gray to purple, thin bedded to platy, weathers brownish gray, with cone-in-cone calcium carbonate in vertical joints, forms a re-entrant, 4.8′
(2) Limestone, dark gray, blocky, fossiliferous (small brachiopods), with yellowish brown chert nodules along the top and chert in pancakelike nodules, .5–.7′
(3) Sandstone-siltstone, medium light gray, calcareous, laminated to cross-bedded, weathers yellowish buff, 1.5′
(4) Mudstone, gray to reddish, shaly, weathers out in small pieces, forms a re-entrant, .5′

(II) Meek group, 109.4′:
1. Limestone, mudstone, shale, and sandstone, 20.9′:
(1) Limestone, dark gray with a reddish cast, fine grained, weathers with a smooth surface, with *Triticites pygmaeus,* .9′
(2) Mudstone, medium light gray, weathers light buff, some fusulinids, .4′–.5′
(3) Limestone, dark gray, massive, stylolitic, weathers rough surfaced; with .2′ lenticular bed of yellowish brown chert in lower part; separates in three beds, 5.5′
(4) Shale, not well shown, .1′–.2′
(5) Limestone, medium dark gray, weathers with smooth surface; with a lenticular bed of yellow-brown chert in middle part; contains crinoid joints and brachiopods, 1.2′
(6) Limestone, medium dark gray, rough surfaced, some brachiopods, orange-yellow spongy chert along joint surfaces, 4′
(7) Shale, medium light gray, calcareous, with lenticular dark gray mudstone, forms a re-entrant, .6′
(8) Sandstone and limestone, a twofold bed, upper half is cross-bedded brown-stained sandstone and lower half is medium dark gray, silty limestone, 1.5′
(9) Sandstone, light gray, fine grained, argillaceous, calcareous, weathers light gray to white, forms a re-entrant, .8′
(10) Limestone, medium dark gray, rough surfaced, massive, stylolitic near base, some yellow-brown spongy chert on exposed surface, with fusulinids *Chonetes granulifer, Marginifera, Meekella,* and *Linoproductus,* thickness 3.25′
(11) Siltstone-limestone, medium light gray, blocky, weathers brownish, .35′

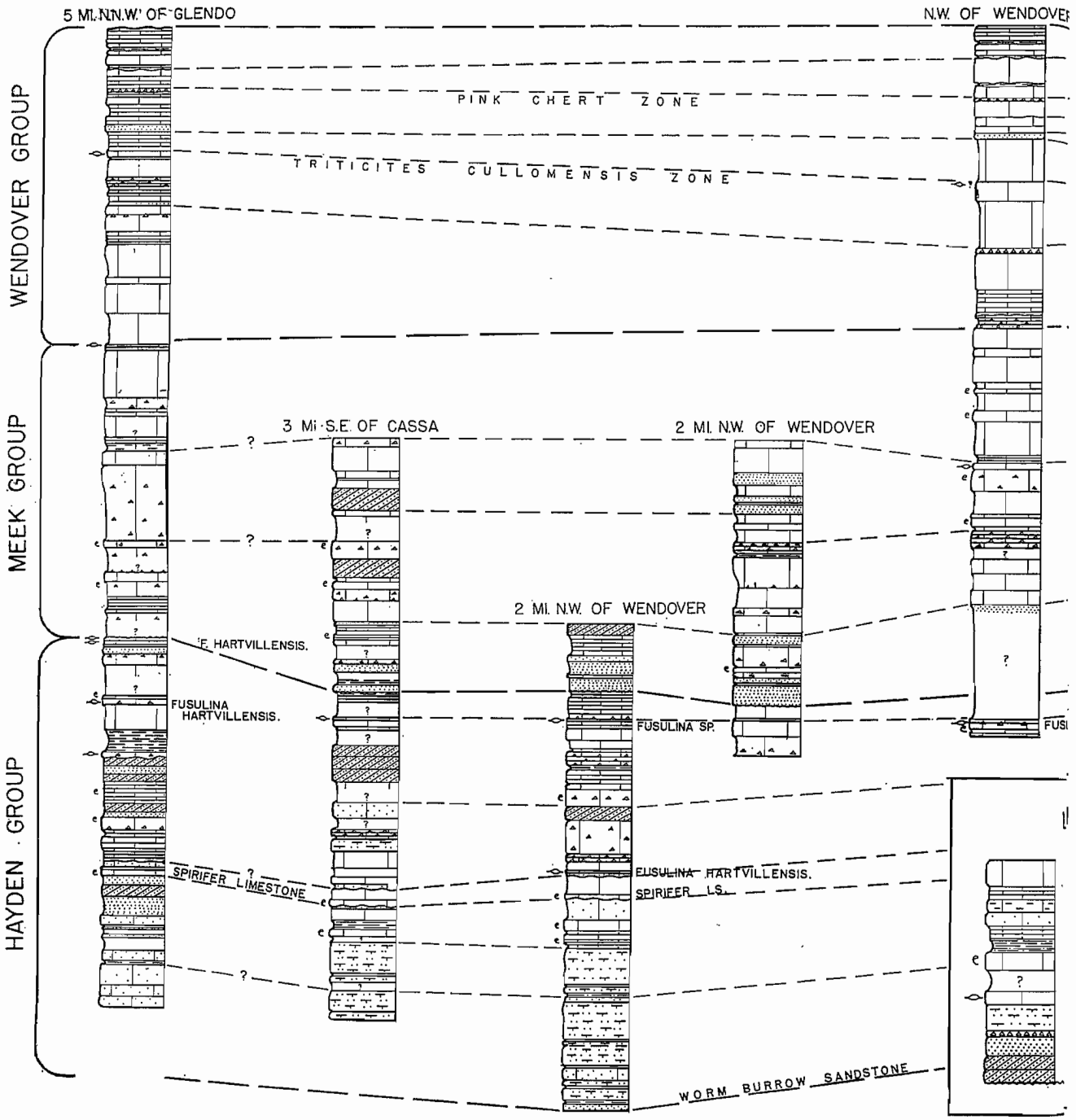

Figure 10.—Correlation table of Wendover, Meek, and Hayden groups in the Hartville Uplift.

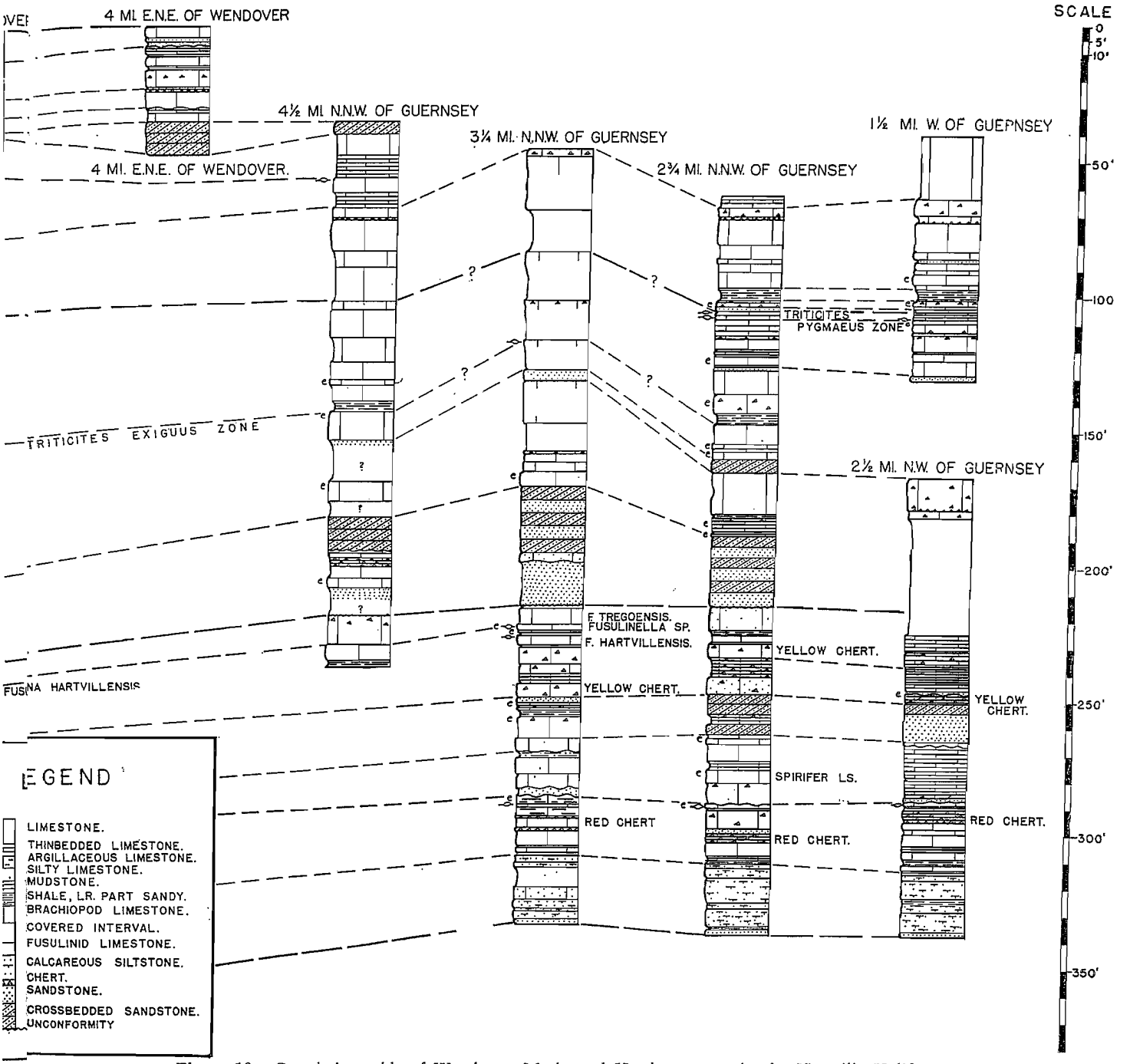

Figure 10.—Correlation table of Wendover, Meek, and Hayden groups in the Hartville Uplift.

(II) Meek group (contd.)
- (12) Shale, medium light gray to reddish, calcareous, with some lenticular bands of mudstone, forms a re-entrant, .5′–.7′
- (13) Sandstone, medium light gray, fine grained, laminated to cross-bedded, weathers buff with rusty brown-stained surface, 1′

2. Limestone, 19.5′:
   - (1) Limestone, medium dark gray, stylolitic, massive, rough surfaced, 9′; with crinoid joints, rugose corals, *Composita, Marginifera, Linoproductus,* and *Neospirifer.*
   - (2) Limestone, medium dark gray, massive, surface coated with spongy yellow-brown chert, carries small rugose corals 1′–2.5′ above the base, 6.5′
   - (3) Limestone, medium dark gray, blocky, very fossiliferous (brachiopods), .5′
   - (4) Shale, medium dark gray, calcareous, platy, weathers reddish, forms a re-entrant, 4′
3. Limestone, and a mudstone, 18′:
   - (1) Limestone, medium light gray, shattered, weathers yellowish buff, poorly exposed, 7′
   - (2) Limestone, medium dark gray, argillaceous, irregularly thin bedded, weathers reddish at top, carries brachiopods and small rugose corals in upper part, 1.5′
   - (3) Limestone, medium dark gray, rough surfaced, yellow-brown chert coating on exposed surfaces, with fusulines, *Hustedia, Marginifera splendens, Composita subtilita, Linoproductus, Dictyoclostus, Neospirifer triplicatus,* etc.; 4′. The basal .5′ of this subdivision locally grades to a cross-bedded siltstone.
   - (4) Sandstone, medium light gray, fine grained, slabby to cross-bedded, weathers light gray with rusty brown stain, thickens eastward, 4.5′–5.5′
4. Limestone and shale, 23′–23.5′:
   - (1) Limestone, medium dark gray, massive, rough surfaced, occasionally cavernous, 15.8′
   - (2) Mudstone, gray and pink mottled, nodular, and shale, dark gray, forms a re-entrant, .7′–1′
   - (3) Limestone, medium dark gray, thin bedded, weathers gray to yellowish, carries *Wellerella* and *Composita;* much dark gray chert in upper 2′ occurring as lenticular beds and eratic nodules; basal .7′ separates as a shaly, rounded bed; 5.25′
   - (4) Shale, medium dark gray, dense, very calcareous, forms re-entrant, 1′
   - (5) Limestone, medium dark gray, rough surfaced, a single bed, .6′–.8′
5. Sandstone, medium light gray, laminated to cross-bedded, weathers yellowish buff, often dark brown stained, 25′–27′

UNCONFORMITY.

Discussion.—The Wendover and Meek groups outcrop extensively in the area of the Hartville Uplift, forming precipitous canyon walls. They occur in the higher parts of the canyons in the Lake Guernsey vicinity, dipping gently westward. At the mouth of Broom Creek only the upper beds of the Wendover are exposed. They and the Meek beds rise out of the Broom Creek Syncline near the town of Wendover, occur high in the canyon walls near the axis of the Cassa Anticline, and then dip sharply westward on the west-northwest flank of the Hartville Uplift.

The presence of *Tricities cullomensis,* about 40′ to 56′ below the top of the Wendover beds, suggests a general correlation of that horizon with the Lecompton-Preston interval in the Nebraska-Kansas area. *Tricities pygmaeus* is found near the top of the Meek group in the vicinity of Lake Guernsey and *Tricities exiguus* occurs a little lower in the section near Wendover. These fusulines are representative of the Missouri and Virgil series in southeastern Nebraska and Kansas and it is notable that they have the same relative positions in the Hartville area as in the Nebraska-Kansas section.

Two prominent and easily recognized chert horizons occur in the Wendover group. The upper of these, a pink chert bed, is found about 22′ below the top of the group north of Glendo, 26′ below Wendover, and 24′ below the Broom Creek section. A brown chert bed, lying lower in this group, occurs widely in the area.

The uppermost 35′ of the Wendover division contains two irregular contacts suggestive of disconformity and the possibility that the beds at this upper horizon may be

of Permian age. However, the fossils collected from them are not sufficiently diagnostic to settle the question of age.

Des Moines Series.—The separation of the Pennsylvanian Subsystem into series in this area is based primarily upon the faunal content of the strata and secondarily upon the lithology and disconformities. The Meek and Hayden groups are separated by unconformity (figure 10). The fossils found above this unconformity are of Missouri age; those of the Hayden, Roundtop, and Reclamation groups are diagnostic of the Des Moines or Middle Carboniferous, and those in the base of the Fairbank formation are redefined Mississippian species.

Hayden Group.—This group is well exposed in Powell Mountain, Knight Mountain, and high in the cliffs along the north side of Lake Guernsey from Fish Canyon westward. The type locality is Hayden Cliff of Knight Mountain. Its subdivisions are shown in the following section.

SECTION No. 12

The Des Moines Series, measured in the vicinity of Lake Guernsey, about 417′:

I. Pennsylvanian Subsystem, 386′–456′:
(I) Hayden group (figure 7), 121.5′:
1. Limestone, 20′:
(1) Limestone, medium light gray, silty, massive, dolomitic, with scattered nodules of yellow chert, 9′
(2) Shale, medium dark gray, calcareous, with thin mudstone, .4′
(3) Limestone, medium dark gray, silty, slightly dolomitic, argillaceous in basal part, 3.5′
(4) Limestone, medium light gray, slightly dolomitic, massive, nodules of yellow chert, 5.5′
2. Mudstone, limestone, sandstone, shale, 28′:
(1) Mudstone, medium dark gray, with pink calcite areas, .75′
(2) Shale, medium dark gray, calcareous, .6′
(3) Limestone, medium dark gray, lithographic, with seams of yellow chert, .85′
(4) Mudstone, ochre to buff, thinly laminated, platy, 3.5′
(5) Limestone, medium light gray, lithographic, brachiopods, 3′
(6) Siltstone, light gray, calcareous, argillaceous in lower part, base uneven, 1′
(7) Mudstone, medium light gray to yellow-buff, with bands of yellow chert, 3.15′
(8) Shale, medium dark gray, laminated, subfissile, .5′
(9) Sandstone, medium gray, fine grained, calcareous, 14.5′
3. Limestone and thin sandstone, 23′:
(1) Limestone, medium light gray, stylolitic, fossiliferous, base very uneven, 2′
(2) Limestone, medium light gray, silty, lithographic, massive, seams of red platy shale at top, 12′
(3) Limestone, medium light gray, silty, in part lithographic with argillaceous partings which carry nodules of red chert, 7.5′
(4) Sandstone, medium light gray, laminated to cross-bedded, base uneven and irregular, 1.5′
4. Limestone, mudstone, chert, and shale, 17′:
(1) Limestone, light and dark gray mottled, 1.5′
(2) Shale, medium dark gray, sandy, subfissile, weathers reddish, .5′
(3) Mudstone-limestone, medium dark gray; carries crinoid joints, fusulinids, horn corals, bryozoa, *Mesolobus* and other brachiopods; contains dark gray and red chert, 4′
(4) Chert, dark gray and red, lenticular, irregular, with dark gray laminated shale, .35′
(5) Mudstone, medium dark gray, silty, 1′
(6) Chert, red to pink to light gray, in an irregular cavernous and geodal bed, .65′
(7) Limestone, medium light gray, silty, laminated in middle part, 2.5′
(8) Shale, limy, light gray, limy-silty, heterogeneous, 2′
(9) Limestone, light greenish gray, geodal, massive, 4.5′
5. Shale, mudstone, and limestone, 33.5′:
(1) Shale, dark bluish gray, breaks in tiny pieces, forms a re-entrant, .5′–.7′
(2) Mudstone, light greenish gray, silty, .5′–.7′
(3) Shale, red, with some green-gray mottling, very sandy, forms a re-entrant, .75′–1′
(4) Limestone, light greenish gray, silty, geodal, blocky, 2.8′
(5) Shale, medium dark gray to purplish, part nodular, becomes very sandy at base, 2.2′

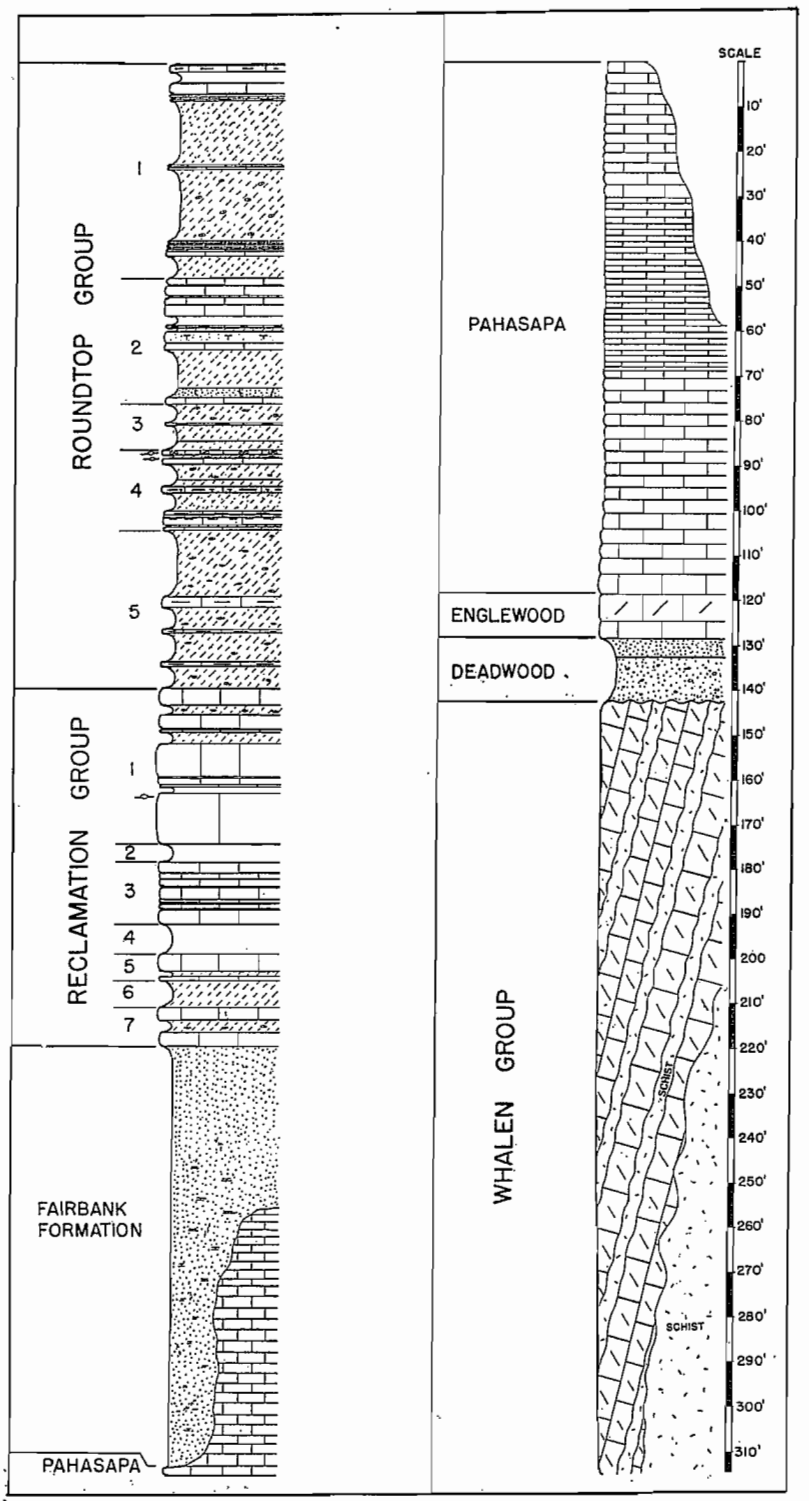

Figure 11.—Composite columnar section of Roundtop and Reclamation groups, Fairbank, Pahasapa, Englewood, and Deadwood formations, and the Whalen group in the vicinity of Guernsey.

I. Pennsylvanian Subsystem (contd.)
(I) Hayden group (contd.)
5. Shale, mudstone, and limestone (contd.)
(6) Mudstone - limestone, medium light gray, 1.6′
(7) Shale, red and green-gray, mottled, sandy, .2′
(8) Siltstone, greenish gray and red mottled, calcareous, 1.6′
(9) Siltstone, reddish brown, calcareous, massive, 1.6′
(10) Siltstone, grades from a light gray to greenish gray in upper half, through greenish gray and red mottled, to reddish in lower part, calcareous, massive, shaly at the base, 7′
(11) Shale-siltstone, grades from a red nodular shale in the upper part to a greenish gray calcareous siltstone in the lower part, 5′
(12) Mudstone - limestone, greenish gray, massive, with dark gray shale at top, 7.5′
(13) Sandstone, light greenish gray, fine grained, calcareous, with small vertical worm tubes in upper part, 1.7′. This sandstone with its worm tubes occurs widely in the Hartville Uplift.

(II) Roundtop group. Measured in Roundtop and Knight mountains and at Fish Canyon (figure 11), 142.5′:
1. Shale, mudstone, and thin limestones, 48′:
(1) Shale, light greenish gray, sandy, finely micaceous, .25′
(2) Mudstone, gray and purple-red mottled, calcareous, massive, forms a rounded ledge, 1.65′
(3) Shale, maroon, massive, 2.5′
(4) Mudstone, greenish gray to light gray, with some maroon streaks, calcareous, 2.35′
(5) Shale, red, sandy, calcareous, .15′
(6) Mudstone, red with a few green "polka dot" mottlings, calcareous, .6′
(7) Shale, red, massive, .4′
(8) Mudstone, red, with green polka dot mottlings, calcareous, .6′
(9) Shale, red, in part green-gray mottled, calcareous, sandy, massive, 14′
(10) Limestone, light gray to greenish gray with some red mottling, argillaceous, *Spirifer rockymontanus, Composita subtilita, Neospirifer, Linoproductus, Allorisma,* .5′
(11) Shale, red, calcareous, arenaceous, .1′
(12) Limestone, gray, stained red, impure, fossiliferous, .65′
(13) Shale, brick red, with some greenish gray polka dot mottlings, calcareous, with fragmentary fossils and nodular calcareous material. The lower .5′ is often dark gray, with *Composita, Linoproductus* and *Marginifera,* 16′.
(14) Limestone, greenish gray to medium dark gray with some red mottlings, argillaceous, fusulinids, *Marginifera splendens, Composita subtilita, Spirifer* cf. *occidentalis, Mesolobus mesolobus, Allorisma,* etc., .35′
(15) Shale, pink and gray mottled, very calcareous, sandy, .25′
(16) Limestone, greenish gray to pinkish, argillaceous, fossiliferous, .65′
(17) Shale, brick red, mottled with greenish gray polka dots, massive, .5′
(18) Limestone, greenish gray, nodular, pebbly, impure, .5′
(19) Limestone, greenish gray, slightly argillaceous and nodular, with crinoid joints, bryozoa, rugose corals, *Cancrinella boonensis, Punctospirifer kentuckyensis, Spirifer rockymontanus, S. occidentalis, Derbya crassa, Marginifera splendens, M. muricatina, Composita subtilita, Linoproductus, Squamularia,* etc., 1′
(20) Covered slope, on red shale, 5′
2. Limestone and shale, 29′:
(1) Limestone, medium light gray to pinkish, slightly silty, 1.85′
(2) Shale, pinkish gray, calcareous, sandy, .15′
(3) Limestone, light gray, maroon streaked at top and base, silty, 2.15′
(4) Shale, red, slightly calcareous above, greenish gray and very calcareous below, laminated, .5′
(5) Limestone, medium dark gray, dense, geodal, 1.75′
(6) Limestone, gray, silty, massive, 2.65′
(7) Shale, greenish gray, purple to red banded, calcareous, silty, thin bedded, 2′
(8) Mudstone, greenish gray, calcareous, two ledges separated by a thin red shale, .7′
(9) Shale, red, massive, forms a re-entrant, 1.1′
(10) Siltstone, gray, calcareous, laminated to massive, 2.5′
(11) Limestone, gray, pink stained, silty, 1.5′
(12) Shale, red, with greenish gray polka dot mottlings, massive, 8.5′
(13) Sandstone, light gray to pink, quartzitic, 2.1′

I. Pennsylvanian Subsystem (contd.)
(II) Roundtop group (contd.)
2. Limestone and shale (contd.)
(14) Limestone, gray, silty, 1.6′
3. Shale and thin mudstone, 10.5′:
(1) Shale, dark red, sandy, massive, with some nodular calcareous material, 4.35′
(2) Mudstone, dark gray to purple, greenish gray polka dots, .35′–.65′
(3) Shale, red, greenish gray polka dot mottlings, massive, 3.5′
(4) Shale, red, flaky to platy, thin bedded to laminated, 2′
4. Limestone, shale and mudstone, 19′:
(1) Limestone, medium dark gray, dense, occasionally geodal, some dark gray chert, *Wedekindellina,* .85′–1.2′
(2) Shale, maroon and gray mottled, nodules and seams of impure limestone, .9′
(3) Limestone, greenish gray to dark gray, dense, blocky, fossiliferous, fusulinids in upper crust, 1.4′
(4) Shale, maroon, with many red and gray mottled calcareous nodules, 3.5′
(5) Shale, maroon, greenish gray polka dot mottled, massive, 1.5′
(6) Mudstone-siltstone, reddish brown, ferruginous, 1′–1.5′
(7) Shale, red and gray mottled, sandy, massive, 4′–4.5′
(8) Mudstone-limestone, gray, red stained, silty, shattered, 1′
(9) Limestone, medium dark gray with maroon mottlings, nodular to platy, .35′–.6′
(10) Limestone, greenish gray, dense, jointed, red chert along top, crinoid joints and brachiopods, 1.6′
(11) Shale, maroon and gray, calcareous seams, .35′–.5′
(12) Limestone, gray and maroon streaked, fossiliferous, .8′
5. Shale and mudstone, about 36′:
(1) Shale, brick red, argillaceous, calcareous nodules, 15′
(2) Mudstone-limestone, gray to red mottled, fossiliferous, 1′–2.5′
(3) Shale, brownish red, occasional calcareous layers and nodules, 5′
(4) Mudstone-limestone, gray, .85′–1′
(5) Shale, red, massive, calcareous nodules, 7.5′
(6) Mudstone - limestone, reddish gray, dense, 1′
(7) Shale, chocolate-gray, with calcareous nodules in middle, 5′

(III) Reclamation group (figure 11), measured in vicinity of federal power dam, 82′:
1. Limestone and shales, 36′:
(1) Limestone, dark gray and red mottled, subconchoidal fracture, 3.9′
(2) Shale, dark maroon and green polka dot mottled, thin bedded, containing scattered limestone nodules, .1′–.4′ in diameter, with *Derbya crassa, Linoproductus prattenianus, Dictyoclostus portlockianis,* 2.25′
(3) Limestone, gray to dark gray, dense, blocky, two or three beds, 3′
(4) Shale, maroon, polka dot mottled, subfissile, with crinoid joints, *Marginifera, Spirifer, Composita,* and small rugose corals, .25′
(5) Limestone, maroon, dark gray mottled, dense, .7′
(6) Shale, reddish to maroon with green polka dot mottlings, contains green-gray limestone nodules in upper .5′, thickness 2.5′
(7) Limestone, light gray, red stained, geodal, pitted, stylolitic, top uneven, massive, with crinoid joints, with *Composita, Dictyoclostus,* etc., 7.4′
(8) Limestone, light green-gray and red mottled, slightly argillaceous, somewhat nodular, .25′
(9) Limestone, greenish gray to dark maroon, massive in upper 1.5′; argillaceous and irregularly thin bedded in lower .5′, thickness 2′
(10) Shale, maroon and green polka dot mottled, 1.5′
(11) Limestone, dark gray to purple, with greenish gray polka dot mottlings, with fusulines, *Composita,* and *Juresania,* 11.25′
2. Shale, greenish gray and maroon mottled, with nodular lime, forms re-entrant, 4.2′
3. Limestone and shale, 14.3′:
(1) Limestone, dark gray, with some maroon, some geodes, dense, blocky, weathers gray-buff, 2.5′
(2) Limestone, light gray, impure, weathers white and chalky, with dark gray shale in wavy seams, contains *Spirifer* cf. *occidentalis, Derby* cf. *bennetti, Composita argentia,* and *Mesolobus mesolobus,* 1.5′
(3) Limestone, dark gray, dense, top irregular, 1.5′
(4) Shale, maroon, subfissile to laminated, .2′

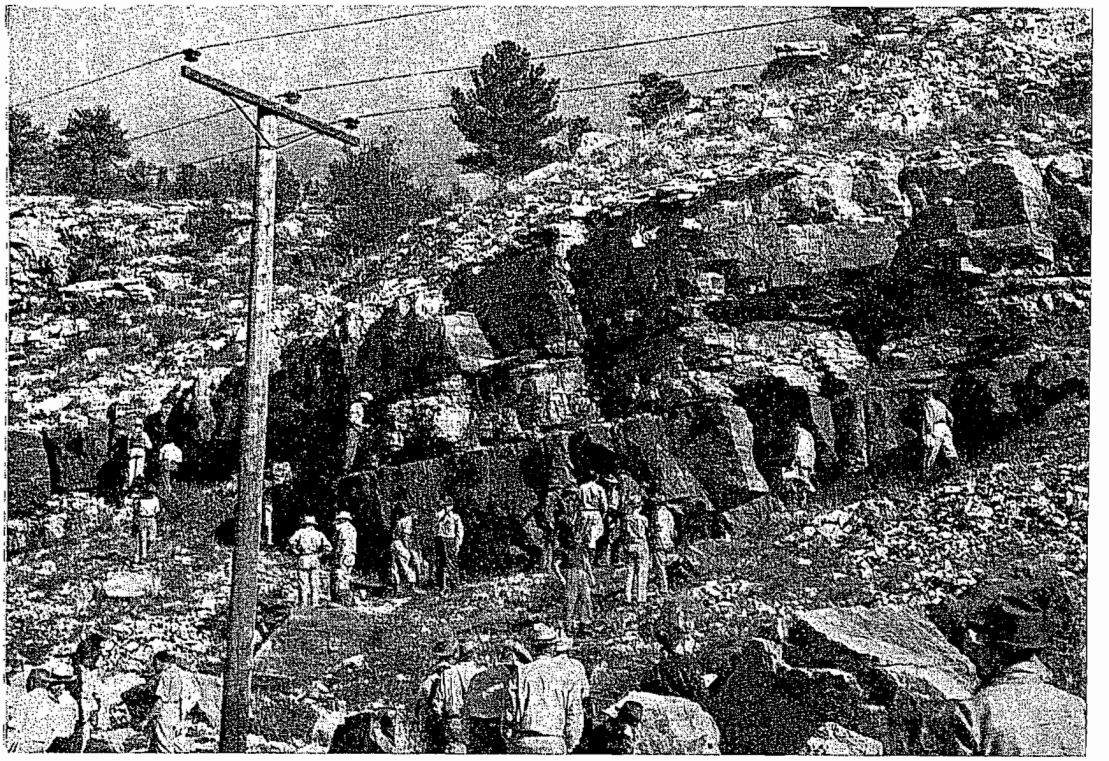

Figure 12.—Part of the "Minnelusa formation," exposed in Warm Brook Canyon, northwest of Hot Springs.

I. Pennsylvanian Subsystem (contd.)
(III) Reclamation group (contd.)
3. Limestone and shale (contd.)
(5) Limestone, gray to dark gray, blocky, jointed, with sharp fracture, weathers reddish with light gray spots, 2.8′
(6) Limestone, maroon, speckled gray, dense, rather blocky, capped by a red shale seam, forms re-entrant, .8′
(7) Shale, maroon and gray, .25′
(8) Limestone, gray, impure, nodular, weathers light gray and maroon, 1.15′
(9) Limestone, reddish, massive to nodular, with red shale seam at top, 3.6′
4. Shale, reddish, nodular, with limy seams containing *Spirifer occidentalis, Composita subtilita, Marginifera muricatina,* and crinoid joints, 6.5′
5. Limestone and shale, 6′:
(1) Limestone, dark gray, dense, massive, 4′
(2) Shale, reddish, with chonetes near top, 1′
(3) Limestone, reddish, dense, with bryozoa, crinoid joints, and productids, 1′
6. Shale, red, with greenish gray mottlings, nodular, with *Rhombopora* and spines, forms re-entrant, 6′
7. Limestone and shale, 9′:
(1) Limestone, dark gray-red blotched, grades to nodular lime, with fossil fragments, 3′
(2) Shale, reddish, with nodules and seams of limestone, contains productids, *Spirifer,* crinoid joints, etc., 2.8′
(3) Limestone, red stained, granular, weathers with rough surface, contains fossil fragments, 3.2′

(IV) Fairbank formation, or lower tongue of the Fountain (figure 11), measured in canyon below power dam, i.e., east of Reclamation Hill; base very uneven, consists of red sandstone or quartzite, which is locally calcareous, thickness 30′–100′, average about 60′

II. Mississippian Subsystem (Guernsey formation) (figure 11), 210′ or less:
1. Pahasapa limestone, gray, massive, fossiliferous, top excessively eroded, thickness 70′–200′
2. Englewood limestone, brownish, 5′–10′

III. Cambrian System (Deadwood sandstone) consists of brownish quartzitic sandstone, 5′–10′+

UNCONFORMITY.

IV. Pre-Cambrian (Whalen group), exposed in the banks and bed of the Platte River just southeast of the power dam, composed of schists, granite, and dolomite. The dolomite is well shown on the bed of the river. It is very thick and dips at a high angle.

BLACK HILLS OF SOUTH DAKOTA AND WYOMING

In this region the Cretaceous, Jurassic, Triassic, and Permian outcrops are less covered by Tertiary and Pleistocene deposits than they are in the Hartville Uplift, but the Pennsylvanian and Mississippian beds are not so well shown as near Guernsey, Wyoming. Darton named and described most of the formations of this region. His latest and most concise description of the area is found in U. S. Geological Survey Professional Paper No. 32.

Section No. 13

This composite section was measured in the vicinities of Hot Springs (figure 12) and Loring Siding. The measurements of the Cretaceous, Jurassic, Triassic, Mississippian, and Cambrian beds are after Darton (1905, p. 25). The Permian and Pennsylvanian parts of the section were measured by the authors.

I. Cretaceous System, exposed between Hot Springs and Edgemont and southward into Nebraska, about 3600′:
  1. Pierre shale, 1200′ or more
  2. Niobrara chalk, 225′ or less
  3. Carlile formation, 500′–750′
  4. Greenhorn limestone, 50′
  5. Graneros shale, 900′–1000′
  6. Dakota group, in high monoclinal ridge east of Hot Springs and northeast of Edgemont, 250′–400′:
    (1) Fall River, "Dakota" sandstone, 35′–150′
    (2) Fuson shale, 30′–100′
    (3) Minnewaste limestone, 5′ or more
    (4) Lakota sandstone, 100′–350′, average about 200′

II. Jurassic System, east of Hot Springs, average about 400′:
  1. Morrison formation, 0′–150′
  2. Unkpapa sandstone, 0′–250′
  3. Sundance formations, 60′–400′

III. Triassic System, 400′:
  1. Spearfish (revised), forms floor of the Red Valley north of Hot Springs and around the Black Hills, consists of red shales and sands, 400′ or less

IV. Permian System, measured north and west of Hot Springs and northeast of Minnekahta, 332.35′:
  (I) Phosphoria group, 210.7′:
    1. Freezeout shale, red, with thin limes and gypsum, 50′–60′
    2. Forelle limestone, gray, gypseous, 4′±
    3. Glendo shale, red, with some gypsum in places, 50′±
    4. Minnekahta limestone, well exposed and typical, 35′±
    5. Opeche shale, about 61′:
      (1) Shale, lavender, largely massive, sandy in places, 10′±
      (2) Shale, red, sandy, 31′
      (3) Sandstone, red, blocky, 2′
      (4) Shale, red, sandy, 18′
  (II) Cassa group, 121.65′:
    1. Owl Canyon formation, upper part of "Minnelusa," measured in Warm Draw west of Hot Springs, 92′:
      (1) Sandstone, red, blocky, with shaly reentrant, 6.25′
      (2) Shale, red, sandy, 2.25′
      (3) Sandstone, red, blocky, 1.35′
      (4) Shale, red, sandy, 1.7′
      (5) Sandstone, red, blocky, 1.35′
      (6) Shale, red, sandy, 1.25′
      (7) Sandstone, red, blocky, .7′
      (8) Shale, red, somewhat sandy, badly covered, 4.8′
      (9) Sandstone, red, blocky, 2.35′
      (10) Shale, red, sandy, 2.6′
      (11) Sandstone, red, blocky, 1.5′
      (12) Shale, red, sandy, 15.75′
      (13) Sandstone, red, blocky, 2.75′
      (14) Shale, reddish, sandy, 5.15′
      (15) Sandstone, red, blocky, 5.25′
      (16) Shale, red, sandy, 1.7′
      (17) Sandstone, red, blocky, 5.6′
      (18) Shale, red, sandy, with thin platy gray sandstone, 1.5′
      (19) Sandstone, red, blocky, .6′
      (20) Sandstone, and argillaceous sands, 3′
      (21) Sandstone, red, blocky, 1.25′
      (22) Sandstone, red, shaly, platy, 1.5′
      (23) Sandstone, red, massive, 4.35′
      (24) Shale, and some sand, red, badly covered, 18.5′

    Unconformity.

    2. Limestone member, best exposed in Warm Draw, in west limb of anticline, gray, buff, pink or red mottled, irregular, top uneven, dolomitic, part conglomeratic or brecciated, 3′–11′

IV. Permian System (contd.)
(II) Cassa group (contd.)
3. Sandstone member, gray-red, massive, friable, thickness about 20′+ in limbs of anticline and 16′–18′ in crest of anticline

UNCONFORMITY.

(III) Broom Creek group, age Permian (?), Pennsylvanian (?), 28′:
1. Limestone, 21′:
(1) Limestone, top yellowish, middle and lower parts gray to buff, massive, dense, fossiliferous, with thin chert zones, brecciated locally in basal part; combined thickness 12′
(2) Limestone, not persistent, 2′–3′
(3) Sandstone-limestone, gray, yellow or reddish, soft to firm, massive, part calcareous, like limestone in places, with large breccia, 6′+
2. Shale, 7′:
(1) Shale, red, not persistent, 0′–1′+
(2) Shale and sandstone, red to yellowish, massive, with limestone breccia, 5′±
(3) Shale, reddish, not persistent, 0′–1′+

V. Pennsylvanian Subsystem, about 560′ in southern Black Hills, 263′ exposed in Hot Brook Canyon west of Hot Springs:
(I) Wendover-Meek groups, about 210′:
1. Limestone, dolomite and sandstones, 85.75′:
(1) Limestone, gray to yellowish, irregular to massive, veined, 6′+
(2) Sandstone, reddish, irregular to massive, basal 3′ bedded forming a reentrant; thickness 30′–36′
(3) Dolomite, massive, gray, dense, one bed, .75′–1′
(4) Sandstone, red, massive, 8′
(5) Limestone, gray to pinkish, dolomitic, uneven, .25′–1′
(6) Sandstone, red, soft, crushed on arch, 8′–9′
(7) Dolomite, gray, massive, one bed, 1′–1.25′
(8) Sandstone, red, massive, bedded at base, 6′+
(9) Dolomite, gray, fine textured, massive, or three massive beds, 6.5′
(10) Sandstone, red, massive, 8′
(11) Dolomite, gray, 3′
2. Sandstone, 39.5′:
(1) Sandstone, red, massive to irregular, with thin shale seams, basal 1′ gray, uneven, 27′
(2) Sandstone, red, not very firm, 7′
(3) Sandstone, gray, massive, friable, 2.5′
(4) Sandstone, reddish, massive, upper .4′ separated from rest of division which has fossil-like markings on upper surface; combined thickness, 3′
3. Shale, red, argillaceous, and some gray-red sands at top and base, 12.75′
4. Sandstones, mudstones, dolomite, and thin black shales, 20.5′:
(1) Mudstone, gray, probably dolomitic, .35′
(2) Sandstone, red, loose, 2.7′
(3) Shale, black, fissile, 2′±
(4) Mudstone and sandstone consisting of gray limy mudstone and gray-red sand below, combined thickness 7′
(5) Shale, black, .75′
(6) Dolomite, gray, 1′
(7) Sandstone, reddish, with layers of dolomitic limestone and a thin black shale above middle, 3′
(8) Sand, reddish, 1.5′
(9) Shale, black, .25′
(10) Sand, 1.5′
(11) Shale, black, .4′
5. Sandstone and shale, 52′:
(1) Sandstone, gray-red, irregular, pebbly and cherty in top portion, basal 3′ massive, combined thickness 30′
(2) Sandstone, gray-red, massive, 2′
(3) Shale, gray to black, middle indurated, 1′+
(4) Sandstone, gray-tan, massive, bedded and gray above, 15′–16′
(5) Shale, gray to nearly black in flanks of anticline, black and fissile in arch, 2′–3′

UNCONFORMITY.

Des Moines Series.—The upper 52.5′ of this series are exposed at pump station in Hot Brook Canyon west of Hot Springs; thickness exposed in southern Black Hills, 350′.

(II) Hayden group, the upper 52.5′ of the group is exposed near Hot Springs as follows:

NOTE: The middle and lower beds of the Hayden group are poorly exposed in Beaver Canyon, located northwest of Wind Cave [see section by Darton (1905, p. 9)] and some of its zones outcrop north of Argyle and at various places near Loring Siding. However, faulting and folding at these places make it difficult to determine the exact relations of the beds. One of the best places to study the middle and lower parts of the group is in sec. 34, T. 5 S., R. 4 E., located about three-quarters of a mile northeast of Loring Siding where the composite section is continued, measured from the hilltop downward.

1. Sandstone, reddish, massive, top uneven, 12′
2. Shale, gray to black, .5′

(II) Hayden group (contd.)

3. Dolomite, top uneven, gray, part uneven and pitted, with thin chert bodies at top, and .3′ blue shale 1.5′ below top; 11.5′
4. Coal and shale, black, .5′–1′
5. Dolomite, gray, 6′
6. Dolomite, gray, 4.5′
7. Shale, black, .6′–.75′
8. Mudstone or dolomite, gray, top uneven, beds lensing, 8′–9′
9. Shale, black, .5′
10. Dolomite, gray, 6′ exposed
11. Covered to creek bed at railroad underpass, 5′

NOTE: The lower 48′ of the group and the rest of the Pennsylvanian section are exposed near Loring siding as follows:

12. Slope, with some sandstone above and largely gray to brownish cherty limestone below, about 45′
13. Sandstone, about 2′–3′

(III) Roundtop group, 177′:

1. Covered on shale and thin layers of sandstone and cherty limestone, about 35′
2. Limestone in railroad cuts southwest of Loring station, gray; upper part massive, with fusulines, *Bellerophons,* and brachiopods, 6′; lower part not so firm, with bedded seams of shale, gray to purple, 6′, combined thickness 12′. This member is very well exposed at top of railroad cut southwest of Loring, above railroad cut northeast of Loring and in valley outcrops 1 mile or more east of the latter. The subdivisions that follow are well shown in railroad cuts southwest of Loring and at other places.
3. Mudstone, limestone, and shale, 5′:
   (1) Mudstone, gray, limy, bedded shale, 3′
   (2) Limestone, gray to brownish, massive, 1′
   (3) Shale, dark gray, with red-stained nodular fossiliferous limes, 1′
4. Limestone, 3.4′:
   (1) Limestone, gray to brownish, red stained, some chert, with crinoid joints, fusulines and brachiopods, 1.35′
   (2) Shale, lavender, fossiliferous, 1.35′
   (3) Limestone, grayish, nodular, stained, lavender with fusulines, .7′
5. Limestones and shales, 22.2′:
   (1) Shale, lavender, fossiliferous, 1.35′
   (2) Limestone, gray mottled, red, with shale partings, 3′
   (3) Shale, lavender, limy, nodular, fossiliferous, 1.8′
   (4) Limestone, light gray, dolomitic, .8′
   (5) Shale, lavender, nodular, 1′
   (6) Limestone, grayish, lavender stained, dolomitic, 1′
   (7) Shale, grayish, .5′
   (8) Shale, grayish, .5′
   (9) Limestone, grayish, crystalline, 2.2′
   (10) Limestone and shale, gray-lavender, 3′
   (11) Limestone, yellow-gray, massive, cherty, 4′
   (12) Shale and nodular lime, dark gray, 3.5′
6. Limestone, gray to dark gray, becomes slabby and mudstone-like below, 12.5′
7. Mudstone, dark gray, calcareous, separated by shale seam, locally solid like 6 above, 10′. This is well shown in railroad cuts northeast of station. The following beds of the Roundtop group were measured at and near the railroad cut northeast of Loring.
8. Shale, gray, and red, 3′
9. Limestone and mudstone, all dark gray, 14′
10. Shale, red, 14′
11. Limestone, gray to yellowish, massive, in two or three beds, 5′+
12. Shale, top .5′ gray, rest lavender to red and nodular, with *Mesolobus* and other fossils, combined thickness 10.5′. The best outcrop is southeast of Loring, in sec. 34, T. 5 S., R. 4 E.
13. Limestone, gray, red stained, shattered, 1.4′

IV. Reclamation group, measured in valley side west of railroad and highway about three-quarters of a mile northeast of Loring siding, thickness about 48.5′:

1. Sandstones, limes, and thin shales, badly covered, gray, about 10′
2. Limestone, dark gray, with red chert, 3′
3. Shale, red, nodular, 3′+
4. Limestone, light gray, brecciated, with red chert, 3′
5. Covered slope, probably on nodular red shale, 2′–3′
6. Limestone, largely gray, part variegated red, arenaceous, with shale seams, 18′
7. Limestone, gray, locally reddish, fine textured, regular to irregular, forms large flat blocks, 1.5′
8. Limestone, gray-red, nodular, in a red shale matrix, 1′
9. Limestone, greenish to bluish gray, locally fossiliferous, stained reddish locally, dense, massive, with small calcite veins and a few geodes, top uneven in places, 6′

V. Fairbank formation, measured below the Reclamation beds three-quarters of a mile northeast of Loring siding, about 24′ exposed:

1. Shale, red, 1.5′±

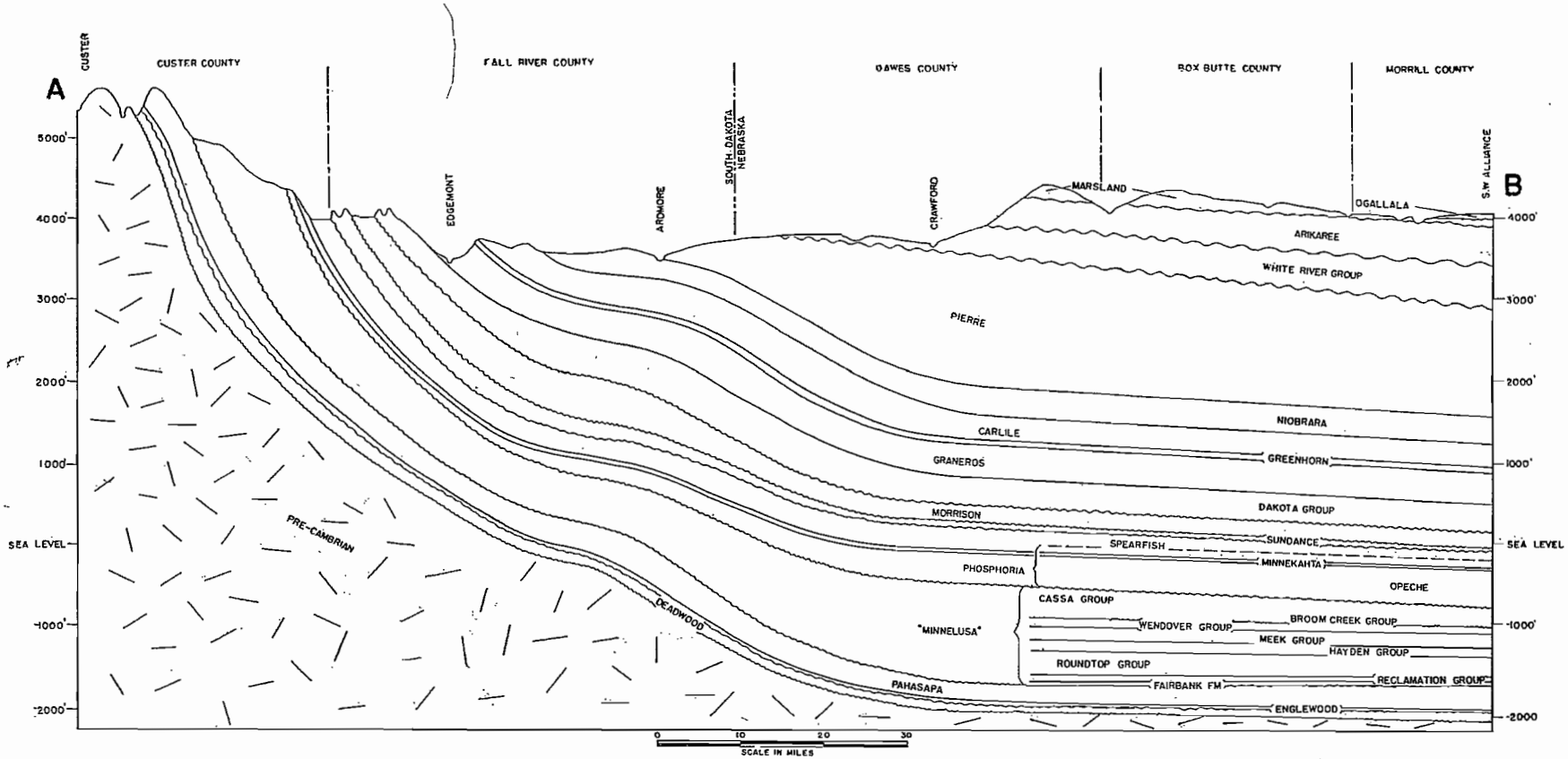

Figure 13.—Geologic profile from the vicinity of Custer, South Dakota, to a point about 10 miles southwest of Alliance, Nebraska.

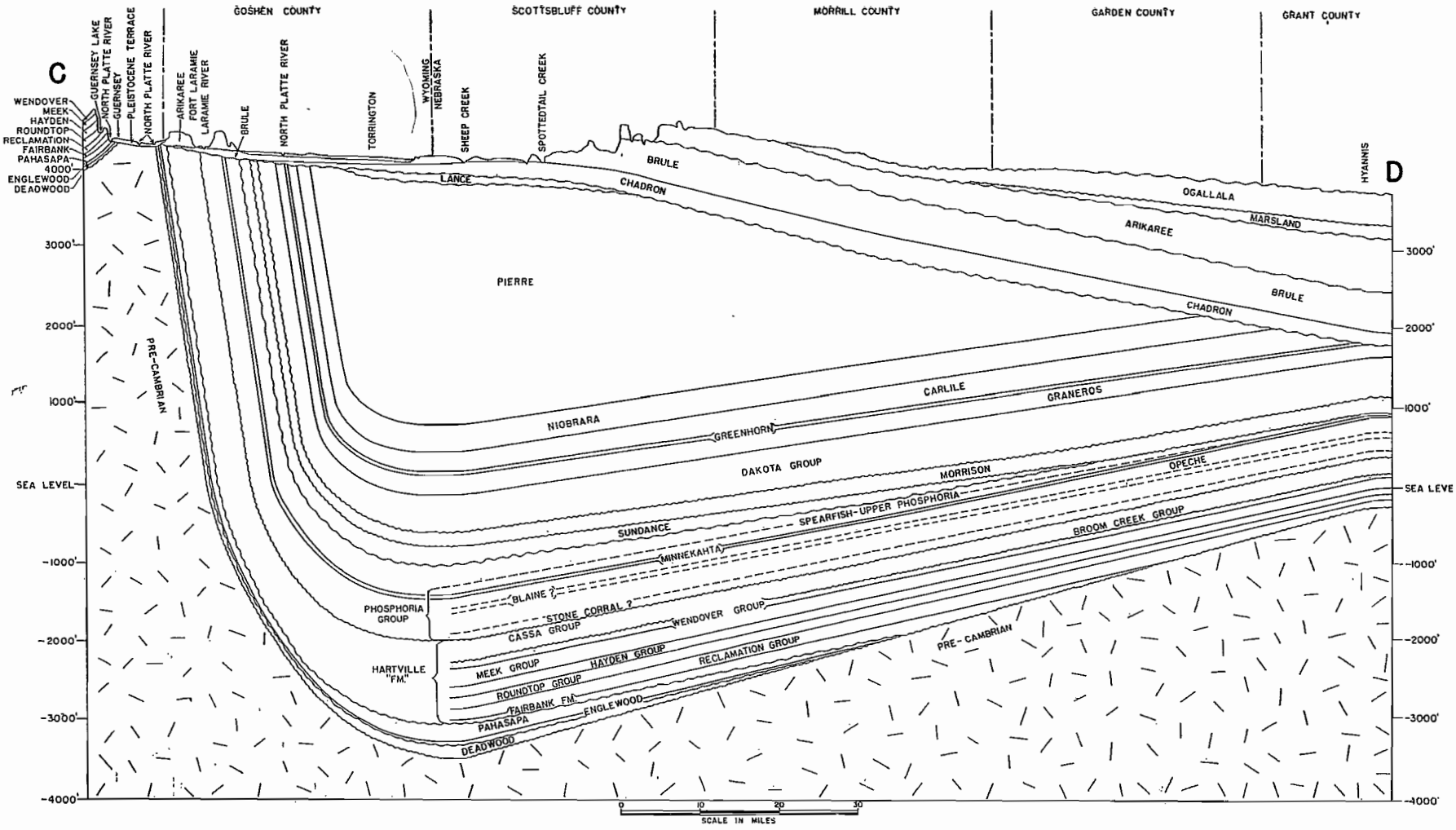

Figure 14.—Geologic profile from vicinity of Guernsey, Wyoming, to near Hyannis, Nebraska.

V. Fairbank formation (contd.)
   2. Nodular limy material, stained reddish, 0′–.5′
   3. Sandstone, gray, stained red, friable to hard, 1′–2′
   4. Sandstone, red, largely massive, with some gray near top, 15′–20′ or more exposed

UNCONFORMITY.

VI. Mississippian Subsystem, near Wind Cave and elsewhere in southern Black Hills, about 300′ or less:
   1. Upper Mississippian, missing
   2. Pahasapa limestone, 225′ or less in the southern Black Hills. This thins southward towards Lusk and Guernsey. It is said to be of Burlington-Keokuk age.
   3. Englewood limestone, exposed at junction of highways northwest of Wind Cave, thickness here about 30′. This formation is thought to be Kinderhookian or Lower Mississippian in age. It is gray to pinkish, slabby, dolomitic, forms large blocks, and is quite fossiliferous.

VII. Devonian and Silurian beds, missing

VIII. Ordovician System, missing in the southern hills, represented by the Whitewood formation in the northern Black Hills

UNCONFORMITY.

IX. Cambrian System (Deadwood), about 400′ thick in the northern Black Hills, thinning southward to 30′–100′ near Wind Cave. The age is thought to be Upper Cambrian and the thinning southward is said to be due to truncation.

UNCONFORMITY.

X. Pre-Cambrian, consisting of metamorphic rocks such as schist, gneiss, and granite

Discussion.—If our correlation is correct, the Meek-Hayden interval is more sandy, relatively more dolomitic and less fossiliferous in the Black Hills than it is in the Hartville area. The contact between the Meek and Hayden groups is marked by local unconformity in the Black Hills, but the contact between the Roundtop and Reclamation groups is not well shown, due to poor exposures. The Reclamation group and the Fairbank formation encircle the Black Hills region without much facial change. In general, however, the rest of the Pennsylvanian becomes more sandy and not very fossiliferous northward in this region.

CROSS-SECTIONS FROM THE MOUNTAINS OF SOUTH DAKOTA, WYOMING, AND COLORADO TO WESTERN NEBRASKA

The relationship of the outcropping formations in the Black Hills, Hartville, and Laramie Range to the subsurface and surface formations of western Nebraska is shown by the accompanying cross-sections designated as figures 12, 13, and 14, and the locations of these cross-sections are indicated by figure 1. To show the required detail it has been necessary to exaggerate the vertical scale used in these sections with the result that there is some distortion in areas of steeply dipping rocks. Furthermore, the sections do not attempt to show details of local structure and it is very probable that structural traps, favorable for oil accumulation, may exist along the lines of the cross-sections. Therefore, the cross-sections are of value primarily in showing regional structure and the thickness, persistence, and correlation of stratigraphic units. The study of the samples from deep wells of western Nebraska and adjacent areas has been used as a basis for the subsurface correlation.

CROSS-SECTION A-B (FIGURE 13)

This section extends from the vicinity of Custer, South Dakota, in a southeasterly direction to a point about 10 miles southwest of Alliance, Nebraska. The pre-Tertiary formations dip under the area south of the Black Hills. They are partially uplifted over a structurally high area near Ardmore, South Dakota, and then continue to lower rather gently into the northeastern part of the Julesburg Basin. The southern part of this cross-section tends to parallel the northeastern edge of the Julesburg Basin and does not cross the deepest part of the basin in the panhandle section of Nebraska. The thickness of the pre-Cretaceous rocks shown in the southern half of the section is theoretical owing to the fact that drilling in this area has not reached sufficient depth to explore all of the sedimentary rocks.

Consequently, there is no subsurface information along this cross-section concerning Lower Pennsylvanian and older rocks;

however, we believe that the Cambro-Ordovician and Mississippian formations and the Fairbank formation and Reclamation, Roundtop and Hayden groups of the Pennsylvanian are present in the subsurface. The Meek group has been drilled in part near Chadron, Nebraska (Palmer No. 1 well), as well as the higher subdivisions. The interval between the Cassa group and the Minnekahta limestone, which is classified as Opeche shale on the outcrop, thickens to about 355′ near Chadron and includes several zones of gypsum, anhydrite, and salt which are believed to correlate with the Blaine and Stone Corral formations of the Cimarron group of Kansas and Oklahoma.

In the light of present information, it is impossible to separate the upper part of the Phosphoria group from the overlying Spearfish formation. This part of the section is grouped together as Phosphoria-Spearfish. Only about 60′ of red-bed section above the Minnekahta was drilled near Chadron but this interval is believed to thicken to some extent southeastward.

The Sundance formation is quite well developed in this cross-section, but shows an eastward thinning. The Morrison persists with approximately the same thickness throughout the area as do the various formations of the Cretaceous. The Pierre shale, however, shows definite truncation as the result of post-Cretaceous–pre-Tertiary folding and erosion. The Tertiary rocks are well represented in the southern part of the cross-section and rest upon the Cretaceous with considerable unconformity.

Cross-Section C-D (Figure 14)

This section extends in a southeasterly direction from the vicinity of Guernsey, Wyoming, following the general course of the North Platte Valley to the Wyoming-Nebraska line where it continues due east to the vicinity of Hyannis, Nebraska. The pre-Tertiary formations dip steeply under the area immediately east of the Hartville Uplift and then rise gently eastward toward the crest of the Cambridge Arch which is thought to occur in the general vicinity of Hyannis. The cross-section traverses the Julesburg Basin from west to east.

The pre-Cretaceous rocks have not been drilled along the line of this cross-section except at the eastern end, therefore the thickness of these subdivisions in the deeper parts of the basin is in part conjectural and in part based on the thicknesses drilled near Agate, Nebraska, about 27 miles north of this cross-section. Pennsylvanian rocks rest on pre-Cambrian granite at the eastern end of the cross-section but pre-Pennsylvanian Paleozoic formations are believed to be present in the deeper parts of the Julesburg Basin and are known to outcrop in the Hartville Uplift. The deep well near Agate (Union Oil Company of California–Agate 15 No. 1) drilled about 120′ of the Meek group at the bottom of the well and probably did not reach the "Leo" horizon of the Lance Creek Field. Three hundred sixty-five feet of dolomitic limestones, salt, anhydrite, and red shales, believed to correlate with the Cassa and Broom Creek groups, and about 535′ of red beds, salt, and anhydrite between the base of the Minnekahta limestone and the top of the Cassa group were drilled near Agate. Here, again, it is difficult to separate the Phosphoria from the overlying Spearfish formation and they are grouped together, about 280′ of Phosphoria-Spearfish above the Minnekahta horizon having been drilled near Agate. The Sundance formation shows an eastward thinning and is believed to be absent at the eastern end of this section although the Morrison and the Cretaceous formations persist with no great changes in thickness. The Pierre shale is truncated and the Cretaceous-Tertiary unconformity is marked. The eastern part of the cross-section shows that the Cambridge Arch was a positive area during several periods in geologic history and the absence of the younger Cretaceous formations over the top of the arch, where the thickness of the overlying Tertiary sediments is a maximum, is significant.

Cross-Section E-F (Figure 15)

This section extends from the Rocky Mountain Front, northwest of Fort Collins,

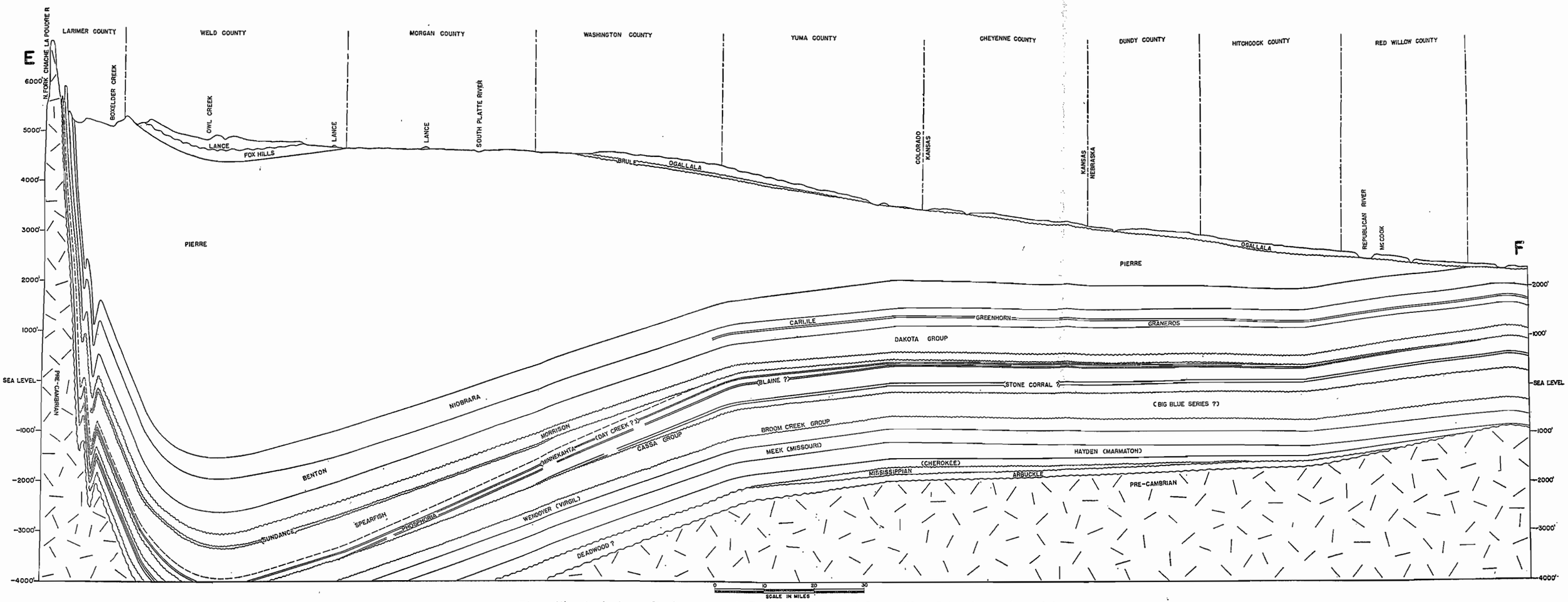

Figure 15.—Geologic profile from Laramie Range, northwest of Fort Collins, Colorado, to the vicinity of Cambridge, Nebraska.

Colorado, east-northeastward to near Wray, Colorado, and thence east-northeastward to the vicinity of Cambridge, Nebraska, traversing the deeper part of the Julesburg Basin. The pre-Tertiary rocks dip very sharply eastward into the Julesburg Basin, then rise gradually eastward on to the Cambridge Arch, showing a flattening of dip near the Colorado-Kansas-Nebraska line which is probably a reflection of the northeast nosing of the Las Animas Arch of Colorado.

The pre-Cretaceous formations in the deeper parts of the Julesburg Basin have not been drilled but deep wells in northeastern Colorado and southwestern Nebraska give good control on these formations in the eastern part of the section where four wells reached rocks of pre-Cambrian age. Rocks of Cambro-Ordovician and Mississippian age are probably present in the subsurface of most of the area traversed by this section but the Mississippian seems to be absent near Trenton, Nebraska, and eastward, and the Pennsylvanian rests on the pre-Cambrian over the top of the Cambridge Arch, northwest of Cambridge, Nebraska. The groups of the Pennsylvanian and Permian persist through the cross-section and their correlation may be continued eastward across southern Nebraska to their outcrop areas. The Sundance may be present in much of the deeper part of the basin but is believed to be absent or very thin eastward. The Morrison, as well as the Cretaceous formations, persists throughout the cross-section although the uppermost Cretaceous formations show truncation by post-Cretaceous–pre-Tertiary erosion. The Tertiary is represented by the Fort Union in the deeper parts of the basin and by a thin representative of the White River group farther eastward which is overlapped by Ogallala group sediments.

Deep Wells Studied.—The details of the foregoing cross-sections are based in part on a study made by Reed and others of a number of deep wells in western Nebraska and adjacent areas. Most of these wells occur along the line of the cross-section or relatively close to the line of the section. Details of this subsurface study will be the subject of subsequent publications because it is impractical to include them here. The principal wells used in correlation are as follows:

J. M. Huber Corporation—Morgan No. 1.—C SW SW sec. 32, T. 35 N., R. 56 W., Sioux County, Nebraska; elevation 3992′; total depth 3999′.

Union Oil Co. of California—Agate 15 No. 1.—C NW SE SE sec. 15, T. 28 N., R. 55 W., Sioux County, Nebraska; elevation 4705′; total depth 6846′.

Felmont Corporation—Kinion No. 1.—SE SE sec. 21, T. 27 N., R. 55 W., Sioux County, Nebraska; elevation 4745′; total depth 6599′.

Stephens Oil Co.—Palmer No. 1.—SW NW sec. 1, T. 33 N., R. 50 W., Dawes County, Nebraska; elevation 3450′; drilling suspended.

William Erbe et al.—Pinney No. 1.—NW NW sec. 13, T. 32 N., R. 52 W., Dawes County, Nebraska; elevation 3655′±; total depth 3185′.

C. L. Price et al.—Hall No. 1.—SE SE SE sec. 10, T. 23 N., R. 49 W., Morrill County, Nebraska; elevation 4100′±; drilling suspended.

Byrd and Frost, Inc.—Abbott No. 1.—C NE NW sec. 22, T. 24 N., R. 38 W., Grant County, Nebraska; elevation 3775′; total depth 4040′.

Fairey Petroleum Co.—McCulley No. 1.—SE SE sec. 35, T. 23 N., R. 58 W., Scotts Bluff County, Nebraska; elevation 4000′±; drilling suspended.

Indian Territory Illuminating Oil Co.——Vorce No. 1.—Sec. 28, T. 1 S., R. 49 W., Washington County, Colorado; elevation 4360′; total depth 7000′.

Indian Territory Illuminating Oil Co.—Strangways No. 1.—C NW SW sec. 21, T. 2 S., R. 43 W., Yuma County, Colorado; elevation 3597′; total depth 5595′.

C. L. Price et al.—Carter No. 1.—SW NE SW sec. 35, T. 2 N., R. 32 W., Hitchcock County, Nebraska; elevation 2795′; total depth 4464′.

Red Willow Oil and Gas Co.—Watkins No. 1.—Sec. 13, T. 5 N., R. 26 W., Frontier County, Nebraska; elevation 2360′; total depth 3423′.

Phillips Petroleum Co.—Andrews No. 1.—Sec. 3, T. 2 S., R. 42 W., Yuma County, Colorado; elevation 3443′; total depth 5130′.

REGIONAL CORRELATION

This is a summary review of the correlation of the stratigraphic units from pre-Cambrian to Tertiary inclusive — in the areas considered in this report. The sequence of treatment is from the oldest rocks upward, in the order of their development, as follows:

1. Pre-Cambrian. — Occurrence general, buried or exposed; surface peneplained. Materials: metamorphics and intrusives. Thick dolomites occur in this horizon at Guernsey, and small bodies of the kind are found at places in the Black Hills and the Laramie Range.

2. Cambro-Ordovician.—Upper Cambrian rocks (Deadwood sandstone) occur in all areas of this report, and yet older formations of this period are found in central and western Wyoming.

Ordovician rocks outcrop in the vicinity of Deadwood, where they are known as the Whitewood (above) and the equivalents of the Pottsville and Simpson below. According to R. A. Carmody and others, these formations have been drilled in deep wells north of the Black Hills.

Although beds of Ordovician age are not known from the southern Black Hills, Hartville Uplift and Laramie Range, the Arbuckle limestone of this age has been drilled in eastern Colorado and it may extend to the southern part of the Julesburg Basin.

3. Silurian System.—Missing.

4. Devonian System.—Probably missing, but present in the subsurface of the tablelands north of the Black Hills and in western Wyoming and central Montana.

5. Mississippian Subsystem.—The Englewood formation or lower Mississippian is in the Black Hills, Hartville Uplift (near Guernsey) and probably northwestern Nebraska, but has not been found in the east flank of the Laramie Range. The Pahasapa-Guernsey-Madison-Leadville horizon of Osage age occurs in all areas covered by this report.

Younger Mississippian rocks were described by C. C. Branson (1937, pp. 650–60) from the Wind River Mountains under the name Sacajawea formation. Beds of this age are thought to underlie Wyoming and South Dakota at points northwest and north of the Black Hills.

6. Pennsylvanian Subsystem.—In most of Pennsylvanian time the region under consideration was occupied by the sea bordered by a granite highland on the southwest. The basin received arkosic wash from the highland, making the Fountain beds and marine and continental deposits farther seaward, building what we now call the Fairbank formation and the Reclamation, Roundtop, Hayden, Meek, and Wendover groups of rocks. The shorelines advanced and retreated with some regularity, causing the belts of sedimentation to shift correspondingly, producing thereby the so-called interfingering of the two types of deposits.

The Fairbank formation is of Lower Fountain age. The Fairbank formation, or basal tongue of the Fountain, extends from near the Horse Creek section northward to and beyond the Black Hills, and under the Powder River Basin, and probably under most of the northern part of the Julesburg Basin. The Bell sandstone, an oil horizon in the Powder River Basin, is equivalent to this formation.

The Reclamation group is well developed at the type locality. In some places its lower beds are missing, owing to a lack of calcic deposition, and at these places, as near Willow Springs ranch, located about 11 miles south of Manville, Wyoming, the upper part of the Fairbank formation is found to be correspondingly thicker. The zone missing in these places is the one which in normal development carries the coral known as chaetaetes, which is very abundant in the Fort Scott limestone of southeastern Kansas. Because of the presence of this fossil, some geologists have suggested that the Reclamation beds may be of Marmaton age. However, this fossil is not generally diagnostic of Fort Scott age.

The other Pennsylvanian groups extend southward from the Black Hills as follows: Roundtop group to Granite Canyon, Wyo-

ming; Hayden group to the Boxelder Creek section in Colorado; Meek group to beyond the Boxelder Creek section, and the Wendover group to beyond Owl Canyon, Colorado.

7. **Permian System.**—This system contains marine, continental red-bed, and evaporite deposits. The Broom Creek group, which is classed provisionally as age uncertain, occurs in all areas of the region. It is poorly developed in the Laramie Range, but is quite well shown in the Hartville and Black Hills areas, and probably extends under western Nebraska.

The Cassa group is very persistent but marked by facial changes. Its basal sand and the thin limestone next above extend from the Owl Canyon section of Colorado to the Hot Springs section of South Dakota. To the south, the Owl Creek formation consists of red shales and sands, which grade northward into red sands and some shale. The lower part of this formation (I, B) becomes sands, mudstones, and thin dolomitic limes in the Broom Creek section and changes back to less lime in the southern Black Hills.

The Lyons sandstone at the top of the Cassa group is said to pinch out in northern Colorado, but stone of this type and in this stratigraphic position appears at places farther north, as at the La Bonte section, the Cassa section, and in the western part of the Black Hills. The Cassa group grades northward and northwestward into a sandstone facies, i.e., into the Tensleep sandstone, which in this zone is of Permian age. And it appears that at places in the west prong of the Laramie Range a lower zone of the Tensleep is the sandstone facies of the Broom Creek and yet older beds.

The Phosphoria group is well defined in western Wyoming, but becomes less cherty eastward past the Rattle Snake Mountains and along the Laramie Range. The Opeche shale, the Minnekahta limestone, Glendo shale, Forelle limestone, and Freezeout shale of this group occur in the Laramie Range, Hartville Uplift, and the Black Hills and probably for considerable distances under western Nebraska.

8. **Triassic System.** — The correlation usually made of units of this system is not satisfactory to all geologists. The Dinwoody formation at the base of the system is classed by some as Permian and by others as Triassic. Faunal evidence, however, seems to indicate its Triassic age. Then if this is conceded, and since the Dinwoody extends to below the Spearfish in the east flank of the Laramie Range, it must be decided that the Spearfish is of Triassic age and not Permian.

The Jelm sandstone is at the top of the Triassic in the southern part of the Laramie Range. The Alcova limestone is at the top of the system in Central Wyoming, underlain by the Jelm which overlies the Spearfish which is the widely persistent formation of the system in this region. No physical break occurs between the Phosphoria and Spearfish in the areas except where the thin finger of the Dinwoody is found. The Spearfish (redefined) is unconformable with the Sundance of Jurassic age in the Black Hills and Hartville Uplift. Occurrence of the Triassic beds:

1. Alcova limestone, missing in this region, but present in central Wyoming.
2. Jelm sandstone, in the southern section of the Laramie Range and widespread in central Wyoming, Utah, and New Mexico.
3. Spearfish (redefined), persistent in all sections and cross-sections of the region and wide occurrence westward.

9. **Jurassic System.**—This system consists of several formations, some of which have restricted range. The Sundance and Morrison groups, however, occur in all areas of this region.

10. **Cretaceous System.**—The Cretaceous formations from the Lakota to the top of the Pierre shale persist in this region, but some of them have considerable range in thickness. In eastern Nebraska the Lakota sandstone, Fuson shale, and "Dakota" sandstone constitute the Dakota group, but in Colorado and Wyoming, as defined by Lee (1927), the Dakota group is composed of

what we now call the Lakota, Fuson, Fall River sandstone, Skull Creek shale, and the Newcastle (Muddy) sandstone. Skull Creek and Newcastle are Graneros, however, and not Dakota. In the western area the name Fall River is used for the "Dakota" sandstone and the name Dakota is applied to the group. The Newcastle or Muddy sandstone and the Skull Creek shale do not extend to eastern Nebraska, and at a few places in the Laramie Range, the Lakota, Fuson, and Fall River unite practically as a single formation, but generally all subdivisions of the Dakota group are distinct units throughout the areas of this region.

The Fox Hills and Lance formations are restricted in range to small areas in this region; they occur widely north and northwest of the Black Hills. The Cretaceous section between the middle Graneros and the top of the Pierre shale becomes quite sandy in the Powder River Basin west of the Black Hills and Hartville Uplift, where the formations of this interval are known as the Newcastle sandstone, Mowry shale, Frontier formation, Niobrara formation, and the Mesaverde formation, above which are the Steele shale, Fox Hills formation, and the Lance formation.

11. Tertiary System.—The principal subdivisions of the Tertiary in this region are the White River group (Oligocene), Arikaree and Hemingford groups (Miocene), and the Ogallala group (Pliocene). Formations of Eocene age occur widely in eastern Wyoming, southeastern Montana, North Dakota, and northwestern South Dakota, but they have not been found in this region, unless the upper part of the section classed as Lance in the Goshen Hole of Wyoming and western Nebraska may prove to be of this age.

The Monroe Creek and Harrison formations of the Arikaree group are exposed in the High Plains from Pine Ridge southward, in Dawes and Box Butte counties of Nebraska, and through Wyoming and parts of Colorado. The Hemingford group is found above the Arikaree at places in northwestern Nebraska and locally in adjacent parts of Wyoming, and the Ogallala group, consisting of the Valentine, Ash Hollow, Sidney, and Kimball formations, occupies much of the surface in an area lying southeast of a line between Hay Springs, Alliance, and Broadwater in Nebraska, and Pine Bluff in Wyoming. The Ogallala group has been erroneously mapped at places west of this line, both in Wyoming and Colorado.

RELATION OF THE PENNSYLVANIAN AND PERMIAN OF WESTERN NEBRASKA TO THOSE OF KANSAS

Correlation of the Pennsylvanian and Permian formations of the Northern Mid-Continent Region with rocks of similar age in the outcrop areas of the Black Hills, Hartville Uplift, and Rocky Mountain Front is difficult from a study of surface exposures alone because of facial changes which occur in the subsurface between these outcrop areas. Therefore, a study of the samples from deep wells drilled in central and western Nebraska must be relied upon to bridge the gap between the eastern and the western outcrops. The accuracy of correlations based on this type of study is dependent upon the condition of the samples studied and the distance between wells where samples of the Pennsylvanian and Permian are available for study. Therefore, the conclusions regarding correlation reached at this time are subject to revision as further drilling will make available more material for study. The present interpretation of correlation is shown in figure 16.

The Cherokee group of shales and sandstones is believed to correlate with the Fairbank formation and the Reclamation and Roundtop groups of the Colorado-Wyoming-South Dakota section. Fossil evidence in the Reclamation and Roundtop groups is somewhat contradictory. Presence of *Wedekindellina* is more suggestive of Cherokee age than any younger group, yet the persistent occurrence of *Chaetaetes milleporaceous* near the base of the Reclamation group is suggestive of the Fort Scott horizon of the Northern Mid-Continent. There is little or no question as to the correlation of the Fairbank, Reclamation, and Roundtop, as well as the overlying Hayden group, with the Des Moines series.

The opinion has been expressed by several

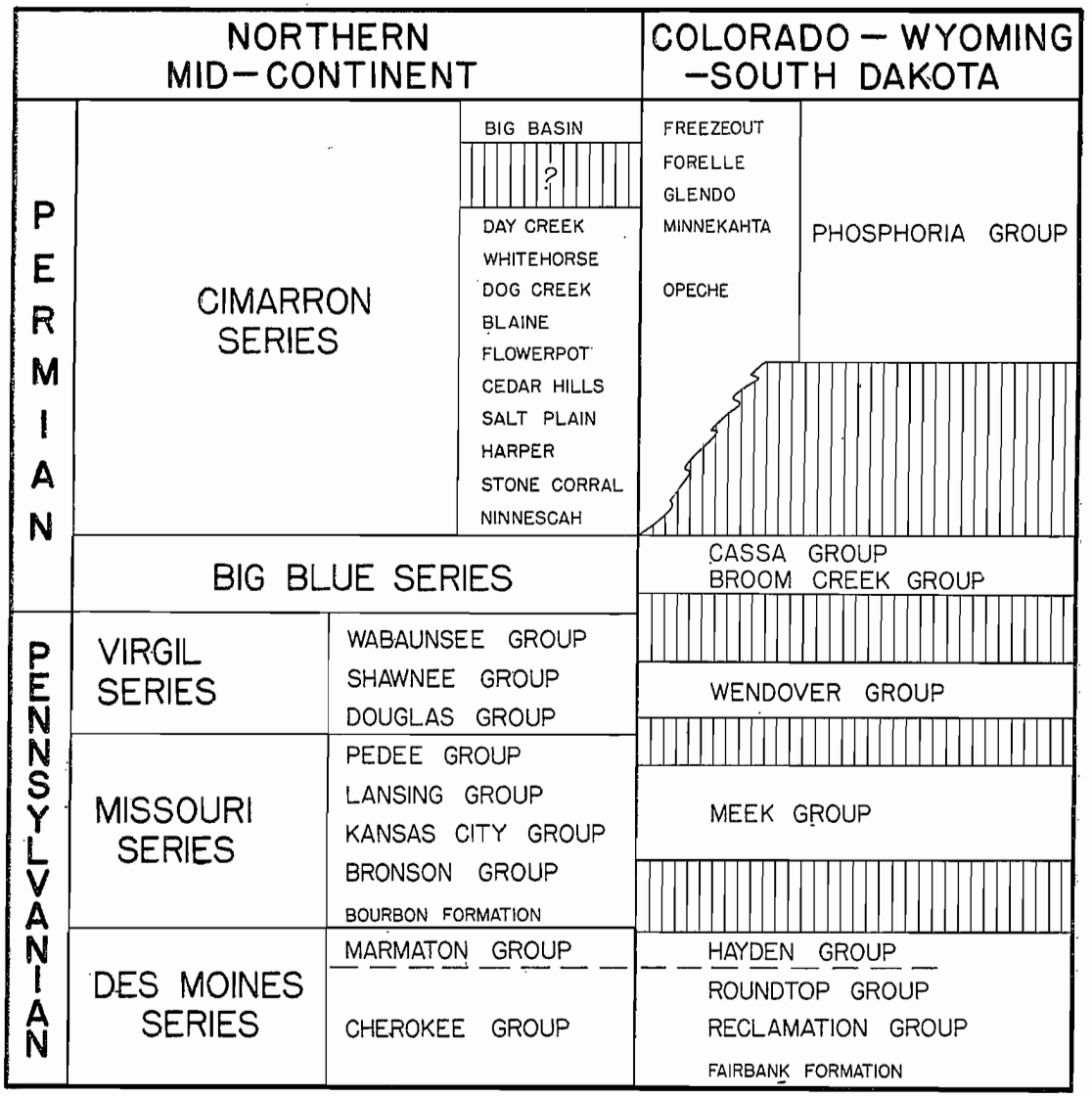

Figure 16.—Tentative correlation chart of Permian and Pennsylvanian stratigraphic nomenclature.

geologists that the Fairbank formation may be equivalent to the Sacajawea formation of Chester age but there is no evidence to this effect in the area covered by this report. The only Mississippian fossils found in the Fairbank formation occur in chert fragments which obviously have been reworked from the underlying Pahasapa limestone and the presence of Pennsylvanian brachiopods, corals, and fusulines in the Reclamation group precludes any possibility of that or any overlying group being as old as Chester.

The Hayden group is believed to correlate with the Marmaton group, although here again the fossil evidence is not conclusive. The fusulinids of the Hayden group are believed by some to have a distinct Cherokee aspect although the same species are not common to both the Rocky Mountain and Northern Mid-Continent areas. In tracing the Marmaton group westward through the subsurface it is noted that the shale and thin limestone phase as represented by the Marmaton tends to become more limy westward and the logical conclusion from present subsurface studies is that it grades into the Hayden group. There is, of course, no

question of the Des Moines series age of the Hayden group.

As noted before, the fusulinids and macrofossils of the Meek group clearly indicate a correlation with the Missouri series and the presence of *Triticites exiguus* and *Triticites pygmaeus* in the Meek group indicates a correlation with the Lansing and Kansas City groups. This correlation is substantiated by subsurface studies. There is no direct evidence that the Bourbon formation and the Bronson group are or are not represented in the Meek group and there is a possibility that the Des Moines-Missouri series unconformity represents a larger hiatus in the northwestern outcrops than is represented in the Northern Mid-Continent. The basal sandstone zone of the Meek group is believed to correlate with the "Joss sand" of the Lance Creek field.

Fossil evidence and subsurface study indicate that the Wendover group is correlative with the Virgil series. The presence of *Triticites cullomensis* in the upper part of the Wendover group suggests that the Wabaunsee group of the Virgil series is very thin or absent in the western outcrops and that the Pennsylvanian-Permian unconformity is of increasing importance westward. This is substantiated by subsurface evidence that the Wabaunsee becomes increasingly thinner westward in Nebraska and is either absent or very thin west of the central part of the state. The "Leo sand" of the Lance Creek field is believed to correlate with the basal part of the Wendover group.

The precise correlation of the Broom Creek and Cassa groups is in question. No fusulines have been collected by the writers from these groups and, as noted before, the brachiopod fauna in the Broom Creek group could be of Upper Pennsylvanian or of Big Blue Series Permian age. Subsurface study indicates that a dolomitic limestone bed at approximately the position of the Herington limestone toward the east may be traced westward with some certainty, apparently correlating with horizons in the upper part or near the top of the Cassa group. Further drilling at closer intervals in central and western Nebraska may furnish the information necessary to substantiate this correlation. The "Converse sand" of the Lance Creek field appears to correlate with the Lyons sandstone at the top of the Cassa group but this sandstone apparently thins and disappears southeastward, not being noted in most of the western Nebraska wells. The Lyons sandstone may be correlative with the Cedar Hills sandstone of the Cimarron.

There is much difference of opinion regarding the correlation of the formations of the Phosphoria group with the formations of the Cimarron series of the Kansas-Oklahoma area. We believe that the Minnekahta is correlative with the Day Creek, that the gypsiferous zone of the Opeche shale is correlative with the Blaine, and that the Stone Corral is not represented in the western outcrop area unless it may be one of the units of the Cassa group. The J. M. Huber Corporation—Morgan No. 1 well (C SW SW sec. 32, T. 35 N., R. 56 W., Sioux County, Nebraska), the Stephens Oil Company—Palmer No. 1 well (SW NW sec. 1, T. 33 N., R. 50 W., Dawes County, Nebraska), and the Union Oil Company of California—Agate 15 No. 1 well (C NW SE SE sec. 15, T. 28 N., R. 55 W., Sioux County, Nebraska) furnished important evidence regarding this problem. The most persistent and easily identified member of the Phosphoria group is the Minnekahta limestone which can be traced from the outcrop areas into the above-mentioned wells without great difficulty, occurring 88′ above the top of the Cassa in the Morgan well, 355′ above the Cassa in the Palmer well, and 535′ above the Cassa group in the Agate well. This shows that there is a southward thickening of the section represented by the Opeche shale in the Black Hills. In the Morgan well, where the Opeche is relatively thin, only one gypsum-anhydrite zone was drilled and we believe that this zone is equivalent to the gypsum zone of the Opeche in the southwestern Black Hills and is correlative with the Blaine. In the Palmer and Agate wells a lower gypsum-anhydrite section appears near the base of the interval in question which may correlate with the Stone Corral. Salt is common to the red-bed section between these two gypsum-anhydrite zones.

Therefore, it appears that the lower formation of the Phosphoria thickens southeastward and is equivalent to the portion of the Cimarron which underlies the Day Creek dolomite in the Kansas section.

The upper beds of the Phosphoria formation seem to lose their identity in the subsurface of western Nebraska and we find it necessary in some areas to correlate the red-bed interval above the Minnekahta as Spearfish-Phosphoria.

The suggestion made by some that the Minnekahta is equivalent to the Blaine does not seem tenable because it presupposes that the Forelle or other upper limestone member of the Phosphoria persists eastward, becoming the Day Creek of Kansas, and that the Minnekahta changes facially to a gypsum-anhydrite. All of our field evidence indicates that the Forelle and other upper Phosphoria limestones show a marked tendency to grade to gypsiferous zones eastward while the Minnekahta persists with no evidence of facial change. Nor is it likely that the Minnekahta is equivalent to the Stone Corral because this horizon in the south-central Nebraska wells seems to correlate rather definitely with a gypsum-anhydrite zone found in the northwestern Nebraska wells located 350′ to 450′ below the Minnekahta.

OIL AND GAS POSSIBILITIES

Many of the formations that produce oil and gas in the adjoining states of Wyoming, Colorado, and Kansas are known to occur in the Julesburg Basin region of western Nebraska. The finding of commercially important accumulations of oil and gas in this region where these formations occur under favorable structural and stratigraphic conditions is possible. Surface formations in much of the area are Tertiary and Pleistocene in age and may not faithfully reflect structure of the more deeply buried rocks. Possible producing horizons in western Nebraska include the following formations from youngest to oldest.

(1) Tertiary formations—some scattered production in Wyoming in which the oil is believed to have migrated into White River (?) Tertiary formations from underlying sources; perhaps not an important possibility in Nebraska.

(2) Sandy zones in the Pierre shale or equivalents, such as the Shannon sandstone of the Powder River Basin fields and the Hygiene sandstones of northeastern Colorado, have not been definitely identified in the subsurface of western Nebraska to date but may occur in the deeper parts of the Julesburg Basin.

(3) The Wall Creek sands of the Frontier formation, which produce in parts of the Big Horn Basin, Powder River Basin, and Sweetwater Basin fields of Wyoming, appear to grade laterally to a less sandy phase eastward and are not expected to be represented in Nebraska.

(4) The Newcastle or Muddy sandstone of the Graneros, which produces in places in the Powder River Basin, Laramie Basin, Sweetwater Basin, and northeastern Colorado fields, is believed to be present in the subsurface of much of the Julesburg Basin of western Nebraska and may yield oil and gas where present under favorable structural conditions.

(5) The Dakota group of sandstones and equivalents which produce in some fields in the Big Horn Basin, Powder River Basin, Laramie Basin, Sweetwater Basin, and northeastern Colorado are known to be present in the subsurface of western Nebraska with possibilities of production under favorable conditions.

(6) Sandstone zones in the Morrison formation which yield some oil and gas in the Powder River, Laramie, and Sweetwater Basin fields of Wyoming are known to be present in the subsurface of the area in question.

(7) Sandstone zones in the Sundance which produce in the Powder River, Laramie, and Sweetwater Basin fields of Wyoming are known to occur in the western part of the Julesburg Basin region of Nebraska and are believed to have possibilities where present under favorable conditions.

(8) The Permian sandstones, limestones, and dolomites, which include the "Embar" and possibly some of the "Tensleep" production in the Big Horn Basin Field, the "Converse sand" and "Tensleep" in the

Powder River, Laramie, and Sweetwater Basin fields, and the Permian dolomite production of western Kansas, are known to be present in part in the subsurface of western Nebraska with possibilities of production in favorable areas.

(9) The Pennsylvanian producing horizons, such as a part of the "Tensleep" production of the Big Horn Basin, the "Joss," "Leo," and "Bell" sands of the Laramie Basin, and the Topeka, Lansing, and Kansas City of central Kansas, are known to be present in the subsurface of western Nebraska with possibilities of production under favorable conditions.

(10) The Mississippian, which produces to a small extent in the Big Horn Basin and central Kansas, is absent over the top of the Cambridge Arch but is believed to be present in the deeper parts of the Julesburg Basin area of western Nebraska.

(11) The Viola and Simpson of the Upper Ordovician, which produce oil in Kansas, are believed to be present in the subsurface in the deeper parts of the Julesburg Basin of western Nebraska.

(12) The Cambro-Ordovician Arbuckle limestone, an important producer in central Kansas, and the Cambrian Reagan sandstone are believed to be present in the deeper parts of the Julesburg Basin.

The possibilities of securing production in the sandstone zones enumerated above depend largely upon the finding of suitable structural or stratigraphic traps in areas where good oil source beds occur in close association with the reservoir rock. In the case of the limestone or dolomite horizons it is also necessary that relatively good porosity has been developed in the reservoir rocks.

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