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NEBRASKA GEOLOGICAL SURVEY

Paper Number 9

PERMO-PENNSYLVANIAN
SECTION OF THE HART-
VILLE AREA OF
WYOMING

By

G. E. CONDRA AND E. C. REED

Conservation & Survey Division
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The Permo-Pennsylvanian Section of the Hartville Area of Wyoming

By G. E. CONDRA and E. C. REED

This report is based on a study of the rocks exposed in the North Platte River Valley in the vicinities of Guernsey, Wendover, and Cassa, and about six miles north of Glendo. The outcrops are in Platte County, eastern Wyoming, 25 to 30 miles or more west of the Nebraska-Wyoming line (Figure 1).

The purpose of this investigation is to establish a detailed section of the Permo-Pennsylvanian beds in the Hartville area as the initial step in their close study throughout the western areas. This study is intended to serve in the correlation of the deeply buried strata of this age in western Nebraska, when they are drilled, and finally in their correlation with the formations of southeastern Nebraska and the Northern Mid-Continent Region generally. Although fossils have been collected quite systematically in this investigation we do not list all of them by species because they are being studied for a faunal report. However, they are used with sufficient detail to erect the age relationship of the major subdivisions of the strata.

The Permo-Pennsylvanian rocks outcrop in southeastern Nebraska and are supposed to underlie the region westward and northwestward to the Rocky Mountains, the Hartville uplift, and the Black Hills. Their best exposures adjacent to western Nebraska are in the Guernsey Hartville uplift, however, scattered outcrops of them occur in the Black Hills, in the Laramie, Big Horn, and other uplifts of Wyoming and along the Rocky Mountain front in Colorado.

The Hartville uplift is an interesting area for geologic investigation. This is true especially in the vicinity of the Guernsey Reclamation project where the Federal Government is building roads and other recreational improvements. The road work recently opened a number of good exposures which were used to advantage in our study. Again, Guernsey Lake was unusually low in the fall of 1934, exposing bed rock that had been obscured for several years. This condition revealed certain small outcrops along the shore line that also served in perfecting the correlation of the small geologic units.

The Guernsey project was built largely with funds assessed against irrigated lands in Nebraska. It supplies supplemental irrigation water and water power for distribution principally in Nebraska. Consequently our state has an economic interest in the Guernsey area. Furthermore Guernsey Lake and the scenic features about it attract many Nebraskans.

The topographic features in the vicinity of Guernsey Lake are of educational interest to tourists and others. We are proposing appropriate

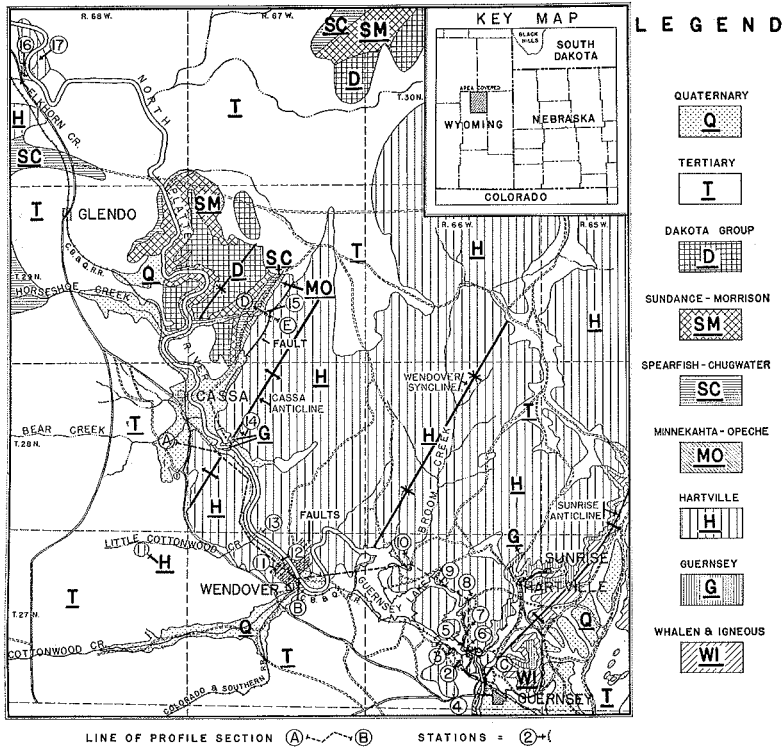


FIGURE 1.—Areal geologic map, Hartville uplift and vicinity, modified after U. S. Geological Survey Folio 91 and Geologic Map of Wyoming.

names for the leading features that should be recognized (Figure 2). The names so used are those of Indian chiefs, explorers, emigrants, railroad builders, irrigationists and pioneer geologists who contributed most in the study of this and adjacent areas. Among the men so recognized are: J. W. Powell, the first Director of the U. S. Geological Survey; F. B. Meek and F. V. Hayden, geologists of the U. S. Geological Survey, responsible for the preliminary investigations in adjacent areas; O. C. Marsh, geologist and paleontologist, especially noted for his Dinosaur studies in the surrounding areas; W. C. Knight, former State Geologist of Wyoming; H. D. Newell and A. P. Davis, former officials of the U. S. Reclamation Service; John C. Fremont, U. S. Army General and explorer; G. W. Holdrege, former general superintendent of Burlington Lines West; and Red Cloud and Spotted Tail, Sioux Indian chiefs.

Other names in the area which are now in usage are Guernsey (the town, the lake, and the dam) for C. W. Guernsey, pioneer of the area who was instrumental in its development and Hartville, for Major Hart,

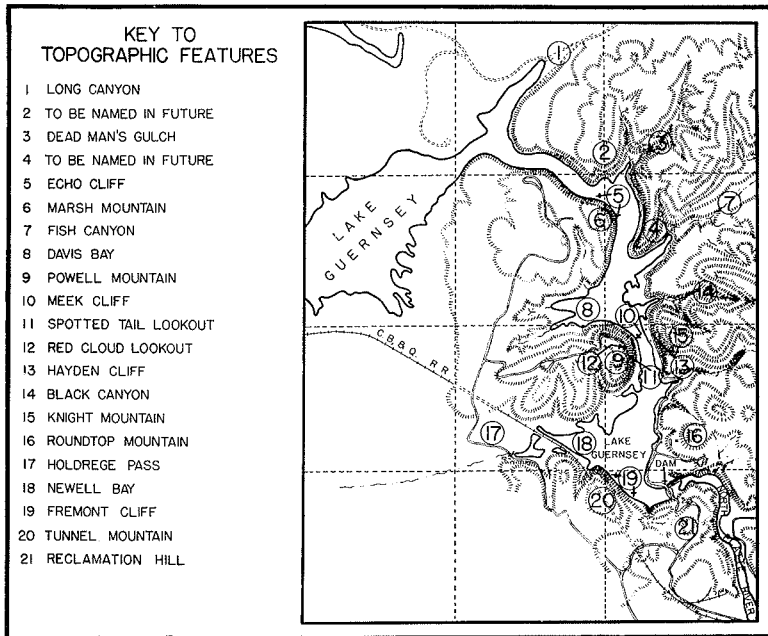


FIGURE 2.—Topographic features, Lake Guernsey vicinity, showing locally accepted names and new names. Numbers 1, 3, 5, 7, 14, 16, and 20 are locally accepted names. The other features are herein named for O. C. Marsh, J. W. Powell, F. B. Meek, and F. V. Hayden, former geologists of the United States Geological Survey; W. C. Knight, former State Geologist of Wyoming; A. P. Davis and H. D. Newell of the United States Bureau of Reclamation; General J. C. Fremont, explorer; G. W. Holdrege, former General Superintendent of Burlington Lines west; Red Cloud and Spotted Tail, Sioux Indian Chiefs.

of the U. S. Army who commanded a detachment of soldiers stationed in the vicinity of the present town of Hartville at an early date.

It is believed that the names Darton, Walter, Meade, and Calvert, should be applied to features of this area at a later date, in honor of N. H. Darton, the leading regional geologist of the area; Elwood Meade, present commissioner of the Bureau of Reclamation; R. F. Walter, chief engineer of the Bureau of Reclamation, engineer-in-charge during the construction of the Guernsey dam; and T. C. Calvert, former chief engineer of the Burlington Railroad.

The naming of cultural features such as trails, drives, camp and picnic grounds, vistas, etc., is being done by the National Park Service in cooperation with the Bureau of Reclamation.

PREVIOUS INVESTIGATION

The most complete report of the geology of the Hartville area is that of Smith¹ who recognizes the *Minnekahta* limestone and the *Opeche* shale and groups the remaining Permo-Pennsylvanian rocks of the area as the *Hartville* formation. Smith does not describe these rocks in detail and we find that some of the thicknesses he assigns to beds are in error.

The Hartville area has come to the attention of various other geologists of the United States Geological Survey, notably N. H. Darton² and W. T. Lee.³ Others who have made investigations in the area include Louis D. Ricketts, Wilber C. Knight, H. M. Chance, S. H. Knight, Henry C. Beeler, Sydney H. Ball, and the geologists of oil companies.

The investigations of the Nebraska Geological Survey in this area began about seven years ago under the direction of the senior author with the assistance of Dr. C. O. Dunbar and members of the Survey. It has continued intermittently since that time and was completed during the fall of 1935.

GENERAL GEOLOGY OF THE AREA

Structure. The Hartville area is a broad uplift, about 12 miles in width and 35 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. The general structural trend is north-northeast. This uplift is composed of two roughly parallel, asymmetric, anticlinal folds separated by a broad, shallow syncline. The folding is modified by some faulting, notably just northwest of Wendover, three miles northeast of Cassa, and north of Guernsey (Figure 1). A series of small gravity faults, with displacements of from one to thirty feet, is seen northwest of Wendover in the North Platte River Canyon (Figure 3). Three miles northeast of Cassa is a large fault which repeats about 200 feet of section (Figure 4). In general these faults trend north-northeast.

The easternmost fold of the Hartville uplift is herein referred to as the *Sunrise* anticline. It is complex in nature and the eastern flank is obscured by the overlap of Tertiary rocks on strata as old as pre-Cambrian in places. From well records, however, it is known that Cretaceous and older rocks are present in regular succession under the Tertiary overlap, on the east. The western fold, herein referred to as the *Cassa* anticline,

¹ Smith, W. S. T., *The Hartville Quadrangle*, Geologic Atlas No. 91, U. S. Geological Survey, 1903.

² Darton, N. H., Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains, Prof. Paper 32, U. S. Geological Survey, 1905, pp. 61-65.

³ Lee, W. T., Correlation of Geologic Formations between East-Central Colorado, Central Wyoming and Southern Montana, Prof. Paper 149, U. S. Geological Survey, 1927, pp. 44-46.

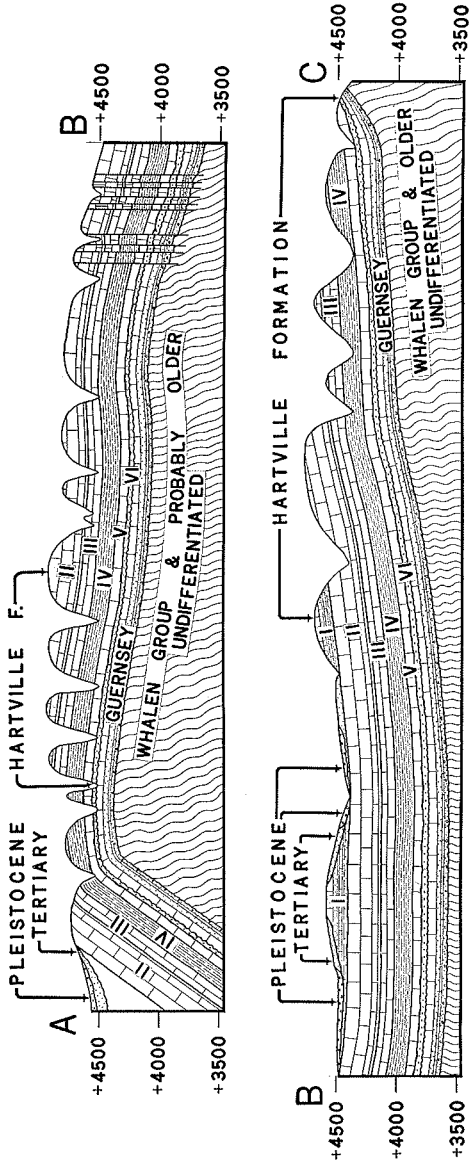


FIGURE 3.—Profile section, North Platte River Valley, from Cassa to near Guernsey, view northeastward.

exhibits a gentle eastern flank and a steeply dipping western flank. Six miles north of Glendo the Pennsylvanian rocks are again brought to the surface in a small anticline.

Stratigraphy. Metamorphic and igneous rocks of pre-Cambrian age are exposed in the crest of the Sunrise anticline. Smith names these ancient gneisses, schists, quartzites, and limestones the *Whalen* group and describes intrusive granite and pegmatite dikes. Ball* 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 those of either series.

The *Guernsey* formation, as defined by Smith, unconformably overlies the *Whalen* group. It consists of conglomeratic quartzite and sandstone in the lower part, and fine-grained, medium to dark gray, dense, massive, often chert-bearing limestone in the middle and upper parts. The formation is exposed in the axial region of the Sunrise anticline and three miles southeast of Cassa where the North Platte River traverses the Cassa anticline.

The *Guernsey* formation is thought to be Mississippian in age, correlative with the *Pahasapa* † of the Black Hills. Its upper surface is deeply channeled and, as a result, the formation varies from 75 to 200 feet in thickness. Evidently a considerable thickness of Mississippian rocks has been eroded from this area. The part remaining probably is Lower Mississippian in age.

Smith gives the name *Hartville* formation to the rocks which unconformably overlie the Mississippian and classes them as Pennsylvanian. This so-called formation is composed of widespread beds of limestone, mudstone, sandstone, and shale which are described in detail later in this report. Its base, according to Smith, is at the well-known erosional unconformity at the top of the Mississippian and its topmost beds are the light colored, massive sandstones which immediately underlie the *Opeche* shale. Smith reports a thickness of 650 to 700 feet for the *Hartville* formation but we find its thickness to be about 930 feet.

The upper beds of Smith's *Hartville* formation probably are Permian in age. This age uncertainty, however, is due to a scarcity of fossil evidence and a lack of agreement among paleontologists regarding the Pennsylvanian-Permian contact.

Opeche shale. This formation overlies the "*Hartville* formation" with apparent conformity and is believed to be Permian in age. It is about 60 feet thick and consists of red sandy shales and sandstones.

* Ball, Sydney H., The *Hartville* Iron-Ore Range, Wyoming, U. S. Geological Survey, Bulletin 315, 1907, pp. 192-194.

† Darton, N. H., Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming, U. S. Geological Survey, 21st Annual Report, Part IV, 1900, pp. 509, 510.

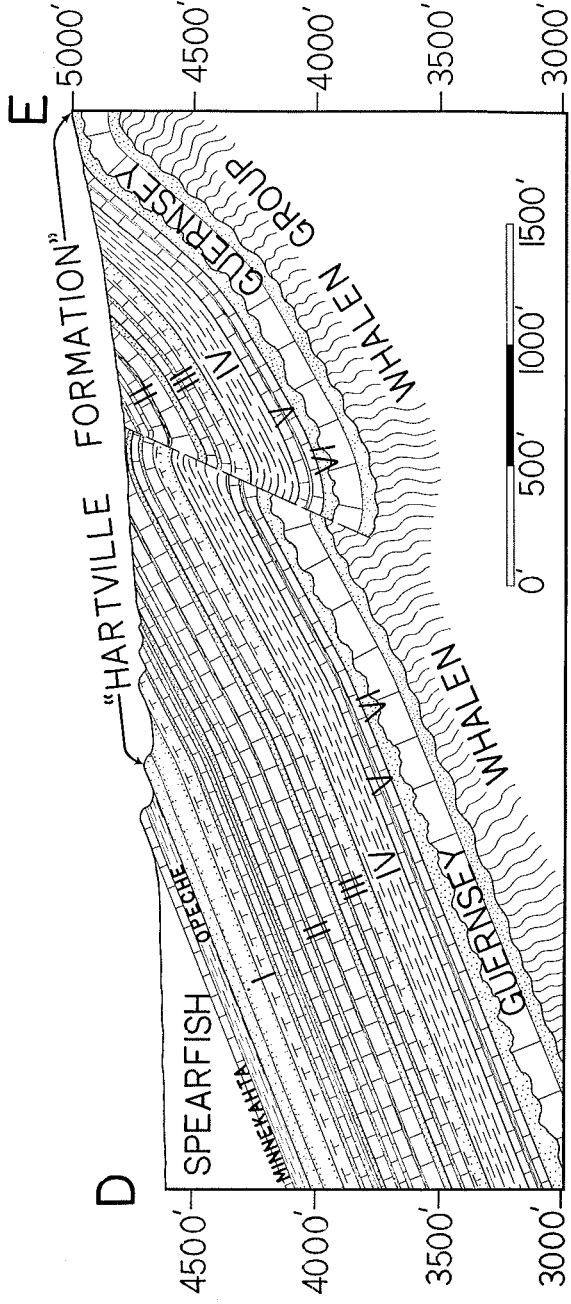


FIGURE 4.—Profile Section in ravine three miles northeast of Cassa, view northeastward.

Minnekahta limestone. Next above the Opeche shale, is this gray to purple-gray, thinbedded, platy limestone. It is thought to be a Permian formation. The Minnekahta limestone and Opeche shale outcrop in a narrow strip northeast of Cassa and are considered to be present beneath the overlapping Tertiary rocks around the Hartville uplift.

The *Spearfish* formation of Triassic age, the *Sundance* formation of Jurassic age, the *Morrison* formation of doubtful Lower Cretaceous age, the *Dakota* group and the *Graneros* shale, both of Cretaceous age, occupy the synclinal area north of Cassa. No doubt, all of these formations, and at places, younger Cretaceous beds, flank the older rocks about the uplift.

The Spearfish, reported to be about 450 feet thick, consists of red sandstones and shales with some thin limestones and gypsum beds in the lower part. The Sundance formation, about 200 feet in thickness, is largely buff colored sandstone. The Morrison formation, composed of varicolored clay shale and a thin limestone, has a thickness of about 100 feet. The Dakota group, 250 to 300 feet thick, consists of massive sandstones and shales. The Graneros shale, composed of gray, flaky shale, containing concretions and sandstones near the top, is exposed in a maximum thickness of about 120 feet.

Evidence from deep wells shows that there is a regular sequence of post-Graneros Cretaceous (Greenhorn, Carlile, Niobrara, Pierre, and Fox Hills) in the eastern flank of the Hartville uplift and that these beds dip rapidly eastward.

Tertiary Rocks. These rocks completely surround the Hartville uplift, overlapping against the older formations. They previously covered the uplift, to a large extent.

The Tertiary here is represented principally by the Brule and Arikaree formations, as defined by Darton.* Subsequent to their deposition, the North Platte River and its tributaries have cut through them and into the older rocks.

THE PENNSYLVANIAN AND PERMIAN ROCKS

The Pennsylvanian and Permian rocks of this area were classified by Smith as the Hartville formation, the Opeche shale and the Minnekahta limestone. They have an aggregate thickness of about 1,017 feet.

The so-called Hartville formation is found to consist of two or more series, six or more groups, and a number of persistent formations and members. The groups are not herein named but are referred to as divisions I, II, III, IV, V, & VI, numbered from top to base.

A study of geologic literature concerning the Northern Rocky Mountain region and its outliers suggests that the Casper, Ingleside, Tensleep, Amsden, Wyoming, Minnelusa, and other formations are, at least in part,

* Darton, N. H., Professional Paper 32, U. S. Geological Survey, 1905, pp. 170-178.

equivalent to the Hartville formation. A careful study of the type sections represented in these so-called formations should be made before final correlations of their subdivisions are attempted.

The six major subdivisions of the "Hartville formation" are now described, from the oldest upward.

DIVISION NUMBER VI

(Figure 5)

This division immediately overlies the Guernsey formation with marked erosional unconformity. It is well exposed in the Platte Canyon, east of the Guernsey dam (Station 1, Figure 1) and three miles southeast of Cassa (Station 14), where the North Platte River and its tributaries traverse the Cassa anticline. It persists along the eastern edge of the Hartville uplift from a point one mile northwest of Guernsey to within a few miles of Lusk, a distance of about 35 miles.

The division consists of red, medium-grained quartz sandstone, often quartzitic, locally calcareous, with occasional erratic limy areas. It does not appear to be arkosic. Because of its uneven base, the thickness of this division varies greatly, averaging about 50 feet and locally aggregating 100 feet or more.

Some fossils occur in the basal part of Division VI. They consist of fragmentary material that may have been reworked from the underlying Mississippian. The age of the Division, though not well proved, is thought to be Lower Pennsylvanian, probably Cherokee or older.

DIVISION NUMBER V

(Figures 5 and 6)

This division consists of interbedded limestones and shales. It lies upon Division VI with some local unconformity which may be largely depositional. Its thickness is about 87 feet in the vicinity of the Guernsey dam, and 72 feet at Station 14 three miles southeast of Cassa. Its best exposures are found at the Guernsey dam spillway and in the canyon wall eastward, also between the power plant and the south end of the dam. The composite section is as follows:

1. Limestone, dark gray, with red blotches, calcite-veined, sub-conchoidal fracture, with some crinoid joints and other fossils, weathers light gray and rounded, 3' 11".
2. Shale, dark maroon with green "polkadot" mottling, irregularly thin-bedded; scattered limestone nodules 1" to 5" in diameter, fossiliferous in part, with *Derbya crassa*, *Linoproductus prattenianus*, *Dictyoclostus portlockianus*; exposed at road level at north end of the dam; thickness 2' 4".
3. Limestone and shale seam, about 3' 6":
 - (1) Limestone, in two or three beds, gray to dark gray, hard, blocky, jointed, contains *Marginifera*, tends to weather light gray with pink stain, 2' 6" to 3'.

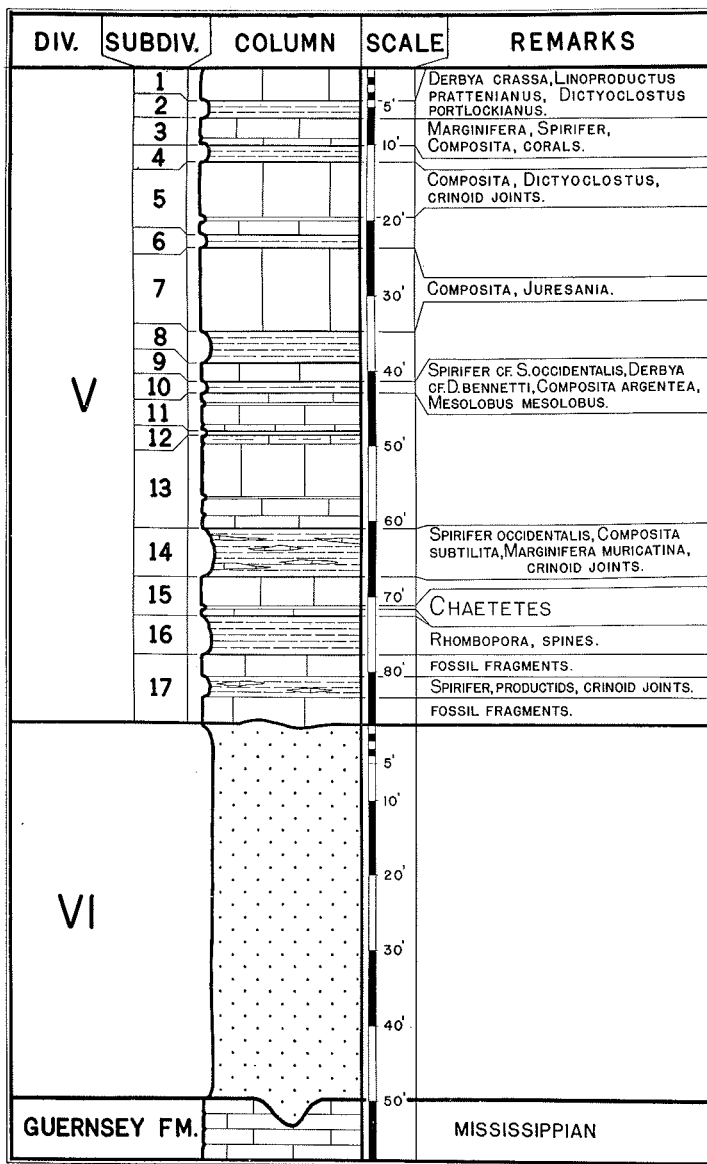


FIGURE 5.—Composite columnar section showing Divisions V and VI of the "Hartville formation", measured at the Guernsey dam (Station 1) and in the canyon walls east of the dam.

- (2) Shale, maroon with green "polkadot" mottling, subfissile, with some gray limy seams containing crinoid joints, *Marginifera*, *Spirifer*, *Composita* and small rugose corals, 1" to 3".
- (3) Limestone, maroon with dark gray blotches, hard, dense, in part nodular, 7" to 8".
4. Shale, reddish to maroon with green "polkadot" mottling, 2' to 2' 6"; contains green-gray limestone nodules in upper 6" to 10".
5. Limestone, about 9' 9":
 - (1) Limestone, light gray, red-stained, geodal, pitted, stylonitic, top uneven, massive, with crinoid joints, *Composita*, and *Dictyoclostus*, 7' 6"; upper surface irregular.
 - (2) Limestone, light green-gray with red blotches, slightly argillaceous, somewhat nodular, 3".
 - (3) Limestone, greenish-gray to dark maroon or purplish, massive in upper 1' 6"; argillaceous and irregularly thin-bedded in lower 6", aggregate thickness about 2'.
6. Shale, maroon with green "polkadot" mottling, platy in upper 3"; middle part massive; lower 6" nodular; combined thickness, 1' 6".

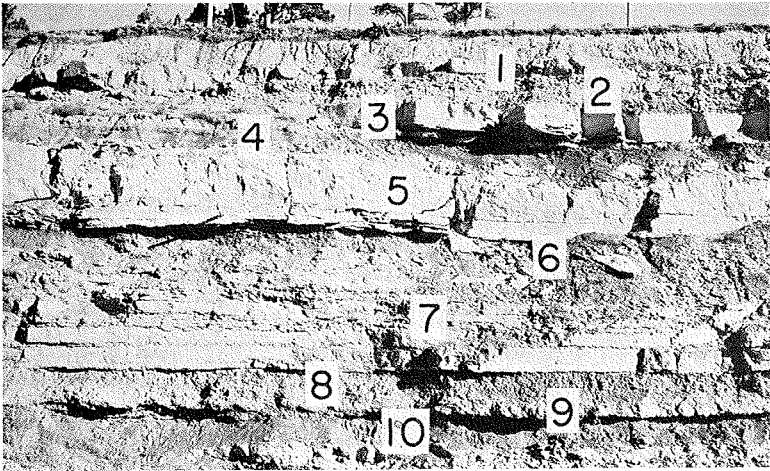


FIGURE 6.—View of the upper part of Division V, in the canyon wall above the Guernsey Dam spillway, looking northward. The numbers refer to the subdivisions of the columnar section (Figure 5).

7. Limestone, dark gray to purple, with greenish-gray "polkadot" mottling, sharp and uneven fracture, with crinoid joints, *Composita*, and *Juresania*, 11' 3". This is well exposed at the road level at south end of dam.
8. Shale, greenish-gray and maroon mottled, nodular, forms a reentrant, 4' 2".
9. Limestone, dark gray with some maroon, occasionally geodal, blocky, dense, weathers light gray to buff and slightly rounded, 2' 6".
10. Limestone, light gray, impure, weathers white and chalky, with laminated dark gray shale in wavy seams, contains *Spirifer* cf. *S. occidentalis*, *Derbya* cf. *D. bennetti*, *Composita argentea*, *Mesolobus mesolobus*, 1' 5".
11. Limestone, with some shale, 5' 2":

- (1) Limestone, dark gray, dense, subconchoidal fracture, top irregular, 1' 6".
 - (2) Shale, maroon, subfissile to laminated, 1" to 2".
 - (3) Limestone, gray to dark gray, sharp fracture, blocky, jointed, weathers reddish with light gray spots, 2' 9".
 - (4) Limestone, maroon speckled with gray, dense, rather blocky, 9". This is capped by red shale seam.
12. Shale, maroon and gray, forms a reentrant, 1" to 3".
13. Limestone, 12' 5":
- (1) Limestone, gray, impure, nodular, weathers light gray and maroon, 1' 2".
 - (2) Limestone, dark gray, dense, sharp and uneven fracture, some solution pitting, a single massive bed, weathers light gray, 7' 7".
 - (3) Limestone, reddish, massive to nodular, with a thin red shale at the top, 3' 8".
14. Shale, reddish, nodular, with limy seams containing *Spirifer occidentalis*, *Composita subtilita*, *Marginifera muricatina*, and crinoid joints, 6' 6".
15. Limestone, 5' 2"-5' 6":
- (1) Limestone, dark gray, dense, massive, 3' 6" to 4'.
 - (2) Shale, reddish, fossiliferous with *Chaetetes* near the top, 2"-1'.
 - (3) Limestone, reddish, dense, with bryozoa, productids, and crinoid joints, 1'.
16. Shale, red with greenish-gray mottling, nodular, with *Rhombopora* and spines, forms a reentrant, 4' 6" to 6'.
17. Limestone, and shale, 9':
- (1) Limestone, dark gray and red blotched, grading to nodular limestone, with fossil fragments, 3'.
 - (2) Shale, reddish, calcareous, with nodules and seams of limestone, contains productids, *Spirifer*, crinoid joints, etc., 2' 10".
 - (3) Limestone, red-stained, granular, weathers with rough surface, with fossil fragments, 3' 2". The base of this bed is located about 50 feet above the river level just east of the dam.

Discussion. Division V is badly covered by debris at Station 14 three miles southeast of Cassa, and the details of the smaller subdivisions are not obtainable. The division as a whole, however, is similar to the section at the dam and it forms a prominent bench. In the canyon walls at the dam and for a distance of a quarter of a mile below, the subdivisions continue with remarkable persistence, dipping gently westward. A ravine one-half mile north of the dam cuts into the upper beds of this division where they are found to be identical with the section at the dam. Along the Sunrise-Manville road, 26 miles north-northeast of Sunrise and eleven miles south of Manville, Division V measures 75 feet and is represented by 40 feet of limestones and shales, similar to those at the dam, underlain by 35 feet of red shale which rests upon the red sandstone of Division VI. The age of this division, as indicated by the fossil content, is Marmaton or older.

DIVISION NUMBER IV

(Figure 7)

The beds of this division overlie Division V conformably and dip gently to the west, in the Guernsey Lake vicinity and for a distance of about 35 miles north-northeastward. They outcrop along the lower slopes of the canyon walls immediately above the dam and northward for a distance of $1\frac{3}{4}$ miles along the east shore of Guernsey Lake to Fish Canyon (Station 8). The upper beds are exposed at the west end of the Burlington Railroad tunnel (Station 3) thence eastward to the dam, and again at the mouth of Little Cottonwood Creek (Station 13). The complete thickness of the division is exposed in the slopes of the North Platte River canyon and in the surrounding hills, three miles southeast of Cassa (Station 14), where the beds are almost horizontal.

The lower part of this division is well shown north of the dam (Station 5) and the middle and upper parts are well exposed in Fish Canyon (Station 8). The composite section of these stations has a thickness of about 153 feet, as follows:

1. Shale and some mudstone, 22' 5":
 - (1) Shale, greenish-gray, sandy, 3".
 - (2) Mudstone, gray and purple-red mottled, massive, forms a rounded ledge, 1' 8".
 - (3) Shale, maroon, sandy, massive, 2' 6".
 - (4) Mudstone, greenish-gray to light gray, with some maroon streaks, 2' 4".
 - (5) Shale, red, sandy, 2".
 - (6) Mudstone, red, with a few green "polkadot" mottlings, a single bed, 7".
 - (7) Shale, red, massive, 5".
 - (8) Mudstone, red, with green "polkadot" mottling, a single bed, 6".
 - (9) Shale, red, massive, in part poorly exposed, 14'.
2. Limestone, separated by shale, 1' 3":
 - (1) Limestone, greenish-gray and red mottled, argillaceous, very fossiliferous with *Spirifer rockymontanus*, *Composita subtilita*, *Neospirifer*, *Linoproductus*, *Allorisma*, etc., 6".
 - (2) Shale, red, 1".
 - (3) Limestone, gray, stained red, impure, fossiliferous, 8".
3. Shale, brick red, with some greenish-gray "polkadot" mottling, occasionally nodular calcareous material, 16'. The lower 6" of this zone is often dark gray, with *Composita*, *Linoproductus*, and *Marginifera*.
4. Limestone, separated by shale, 1' 3":
 - (1) Limestone, greenish-gray, with some red mottling, impure, with fusulinids, *Marginifera splendens*, *Composita subtilita*, *Spirifer* cf. *S. occidentalis*, *Mesolobus mesolobus*, *Allorisma*, etc., 4".
 - (2) Shale, pink and gray mottled, 3".
 - (3) Limestone, similar to 4 (1), 8".
5. Shale, 7' 6":
 - (1) Shale, brick red, mottled with greenish-gray "polkadots", occasional nodular calcareous material, massive, 5'.
 - (2) Nodular pebble zone, greenish-gray, calcareous, locally developed as an impure limestone, 6".

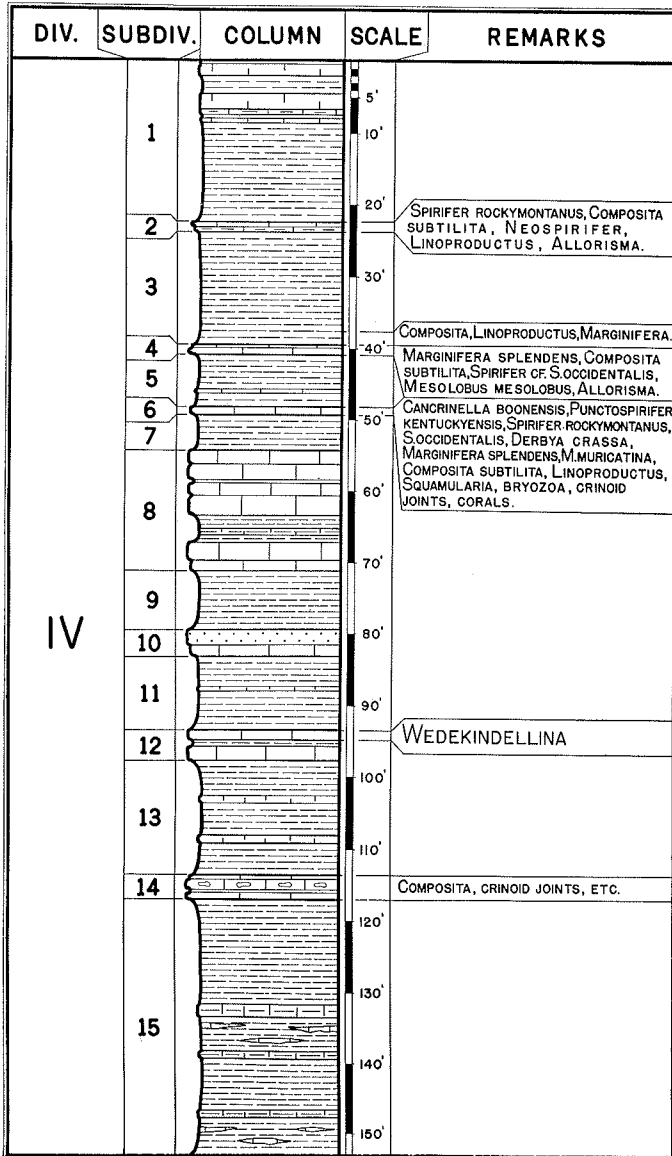


FIGURE 7.—Composite columnar section of Division IV, in the vicinity of Lake Guernsey. Subdivisions 1-14 were measured at Station 8 and 14 and 15 at Station 5.

- (3) Shale, red, massive, 2'.
6. Limestone, greenish-gray, impure, slightly nodular, 1', with crinoid joints, bryozoa, rugose corals, *Cancrineilla boonensis*, *Punctospirifer kentuckyensis*, *Spirifer rockymontanus*, *S. occidentalis*, *Derbya crassa*, *Marginifera splendens*, *M. muricatina*, *Composita subtilita*, *Linoproductus*, *Squamularia*.
7. Covered slope, probably red shale, 5'.
8. Limestone, with shale below the middle, forms a prominent bench, 17':
- (1) Limestone, medium light gray, slightly silty, a single bed, weathers light gray, 1' 10".
 - (2) Shale, red sandy, 2".
 - (3) Limestone, gray, maroon-streaked at top and base, silty, a single bed, weathers light gray to light buff, 2' 2".
 - (4) Shale, red above, greenish-gray below, laminated, forms a slight reentrant, 6".
 - (5) Limestone, gray, silty, shattered, irregularly to heavy-bedded, weathers light buff, 1' 9".
 - (6) Limestone, gray, silty, massive, weathers gray to buff, 2' 8".
 - (7) Shale, greenish-gray, purple to red banded, calcareous, thin-bedded, forms a reentrant, 2'.
 - (8) Mudstone, greenish-gray, in two beds separated by a thin red shale, 10".
 - (9) Shale, red, massive, forms a reentrant, 1' 2".
 - (10) Siltstone, gray, calcareous, laminated to massive, weathers light yellowish to buff, 2' 6".
 - (11) Limestone, gray, pink-stained, silty, weathers light gray, a single bed, 1' 6".
9. Shale, red, with greenish-gray "polkadot" mottling, massive, not well exposed, 8' 6".
10. Quartzitic sandstone and silty limestone, 3' 9":
- (1) Sandstone, light gray to pink, quartzitic, breaks in sharp angular blocks, 2' 1". In Fish Canyon (Station 8) this bed is deeply weathered to a friable sandstone but farther to the south it is typically hard and quartzitic.
 - (2) Limestone, gray, silty, heavy-bedded, weathers light gray, 1' 8".
11. Shale, with a thin mudstone near middle, 10' 2" to 10' 6":
- (1) Shale, dark red, sandy, massive, with some nodular calcareous material, 4' 4".
 - (2) Mudstone, dark gray to purple, with greenish-gray "polkadots", 4" to 8".
 - (3) Shale, red, mottled with greenish-gray "polkadots", massive, some nodular calcareous material, 3' 6".
 - (4) Shale, red, flaky to platy, thinbedded to laminated, 2'.
12. Limestone, separated by shale, 3' to 4' 2":
- (1) Limestone, medium dark gray, dense, occasionally geodal, some dark gray chert with *Wedekindellina*, a single bed, 10" to 1' 2".
 - (2) Shale, maroon with gray mottling, with some nodules and seams of impure limestone, forms a reentrant, 10" to 1' 2".
 - (3) Limestone, greenish-gray to dark gray, dense, blocky, jointed, fossiliferous, fusulinids in upper crust, 1' 3" to 1' 4".
13. Shale and mudstone, 16':
- (1) Shale, maroon, with many red and gray mottled calcareous nodules, 3' 6".
 - (2) Shale, maroon, with greenish-gray "polkadot" mottling, massive, 1' 6".

- (3) Mudstone-siltstone, reddish-brown, ferruginous, forms a ledge, 1' to 1' 6".
- (4) Shale, red and gray mottled, sandy, massive, part covered, 4' to 4' 6".
- (5) Mudstone-limestone, gray, red-stained, silty, shattered, 1'.
- (6) Shale, red with some gray mottling, massive, 4' 6".
- 14. Limestone and shale, 3' to 3' 3":
 - (1) Limestone, medium dark gray, with maroon areas, nodular, weathers platy, 4" to 7".
 - (2) Limestone, greenish-gray, dense, jointed, with red chert filling the joints and along top surface; crinoid joints, brachiopods, etc.; 1' 6" to 1' 8".
 - (3) Shale, maroon and gray, with calcareous seams, 4" to 6".
 - (4) Limestone, gray and maroon-streaked, fossiliferous, *Composita*, crinoid joints, etc., 9" to 10".
- 15. Shale and mudstone, about 36':
 - (1) Shale, brick red, argillaceous, with some calcareous material, 15'.
 - (2) Mudstone-limestone, gray and gray to red mottled, shattered, irregular, probably not persistent; with crinoid joints and fossil fragments, 1'-2' 6".
 - (3) Shale, brownish-red, with occasional calcareous layers and nodules, 5'.
 - (4) Mudstone-limestone, gray, highly shattered, irregular, 10" to 1'.
 - (5) Shale, red, massive, with much nodular calcareous material, 7' 6".
 - (6) Mudstone-limestone, reddish-gray, dense, weathers rounded, 1' or less.
 - (7) Shale, chocolate-gray, with seams and nodules of calcareous material in the middle part, 5'.

NOTE: Subdivisions 1 to 14 were measured at Station 8, and 14 and 15 at Station 5.

Discussion. Division number IV forms a red shale slope wherever it is exposed. Its thickness measures 153 feet in the vicinity of Guernsey Lake and about 150 feet three miles southeast of Cassa. The upper 50 to 60 feet of the division is exposed 6 miles north-northeast of Glendo but not in condition for accurate measurement. Its upper 15 feet outcrops at the mouth of Little Cottonwood Creek (Station 13), where the rocks are locally high.

The thin members of this division are very persistent in the vicinity of the Guernsey Lake and in the upland north of Sunrise where numbers 8, 10, and 14 form benches in the shale slope, and are excellent key beds.

This division belongs quite low in the Pennsylvanian, as evidenced by the presence of *Mesolobus mesolobus*, *Wedekindellina* and other fossils of Des Moines age.

DIVISION NUMBER III

(Figure 8)

This division consists of interbedded limestones, calcareous siltstones and sandstones with minor amounts of mudstone and shale. Limestone forms about 55 per cent of the total thickness, calcareous siltstones and sandstone about 30 per cent, and 15 per cent is mudstone and shale.

These beds outcrop in the lower parts of the canyon walls of Lake Guernsey, dipping gently to the west. They are buried in the Broom Creek syncline and again emerge just below the mouth of Little Cotton-

wood Creek, rising to the west. They occur in the lower parts of the Platte River canyon walls from the mouth of Little Cottonwood Creek to within two or more miles of Cassa, where they are again found to dip westward. Six miles north-northwest of Glendo folding again brings these beds to the surface.

Measured sections of Division III are herein submitted for three localities: (1) the Lake Guernsey vicinity; (2) the North Platte River canyon between Wendover and Cassa; and (3) the North Platte River canyon six miles north-northwest of Glendo.

Lake Guernsey Vicinity. In the vicinity of Lake Guernsey Division III is 120 feet thick. The detailed description of these beds, measured at Station 3, is as follows:

1. Limestone, some shale and mudstone, 19' 6" to 19' 10":
 - (1) Limestone, medium light gray, silty, massive, with scattered nodules of yellow chert, 9'.
 - (2) Shale, medium dark gray, calcareous, with a thin mudstone 4" below the top, forms a reentrant, 1' 8".
 - (3) Limestone, medium dark gray, silty, weathers light gray, becomes very argillaceous in basal part, 3' 6".
 - (4) Limestone, medium light gray, massive, with nodules of yellow chert at top and base and scattered throughout, 5' 4".
2. Mudstone and limestone, 13' 4":
 - (1) Mudstone, medium dark gray, with pink calcite areas, forms reentrant, 9".
 - (2) Shale, medium dark gray, calcareous, forms a reentrant, 7".
 - (3) Limestone, medium dark gray, lithographic with seams of yellow chert, upper part weathers yellowish-brown, 10".
 - (4) Mudstone, ochre to buff, thinly laminated, platy, forms a reentrant, 3' 6".
 - (5) Limestone, medium light gray, lithographic, shattered, weathers light gray to buff, some brachiopods, poorly exposed, 3'.
 - (6) Siltstone, light gray, calcareous, weathers buff, argillaceous in lower part, base uneven, 1'.
 - (7) Mudstone, medium light gray to yellow-buff, with bands of yellow chert, lower foot shaly, 3' 2".
 - (8) Shale, medium dark gray, laminated, sub-fissile, forms a reentrant, 6".
3. Sandstone, medium gray, fine grained, calcareous, weathers yellow-buff with occasional rusty brown stain on exposed surfaces, top dense and carries shark remains, 14' 6".
4. Limestone, with thin sandstone at base, 21' 8" to 23':
 - (1) Limestone, medium light gray, stylolitic, fossiliferous, weathers very light gray, base very uneven, 8" to 2'.
 - (2) Limestone, medium light gray, silty, lithographic, massive, weathers light gray to buff, breaks in small angular blocks; a ½" seam of red, platy shale at the top, 12'.
 - (3) Limestone, medium light gray, silty, in part lithographic, some geodes, separates in five beds with argillaceous partings which carry nodules of red chert; reddish in upper 3" with a 1" to 2" seam of dark gray shale at the top; combined thickness, 7' 6".

- (4) Sandstone, medium light gray, laminated to cross-bedded, weathers yellow-buff, clay pebbles in lower part, base uneven and irregular, 1' 6". This unit is the upper part of a two-fold bed.
5. Limestone, shale, and mudstone, 8' 1":
- (1) Limestone, light and dark gray mottled, weathers light gray, forms the lower part of a two-fold bed, 1' 6".
- (2) Shale, medium dark gray, sandy, sub-fissile, weathers reddish, 7".

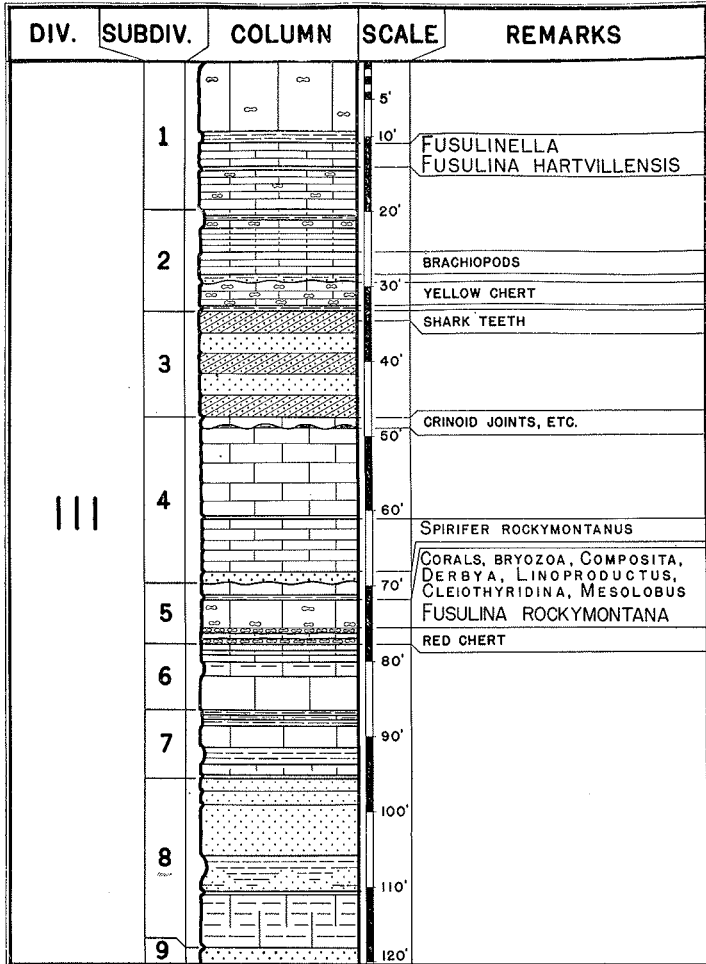


FIGURE 8.—Composite columnar section of Division III in the vicinity of Lake Guernsey. The measurements were made at the west end of the Burlington Railroad tunnel (Station 3).

- (3) Mudstone-limestone, medium dark gray; carries crinoid joints, fusulinids, horn corals, bryozoa, *Composita*, *Derbya*, *Linoproductus*, *Cleiothyridina*, and *Mesolobus*; contains dark gray and red chert in lenticular and oval bodies in the lower 2' 8" with some seams of shale; thickness, 4'.
- (4) Chert, dark gray and red, in a lenticular and irregular bed, with dark gray laminated shale above and below, 4".
- (5) Mudstone, medium dark gray, silty, 1'.
- (6) Chert, red to pink to light gray, in an irregular cavernous and geodal bed, 8".
6. Limestone, 9':
 - (1) Limestone, medium light gray, silty, weathers light gray, laminated in middle part, geodal in middle and lower part, 2' 6".
 - (2) Limy-silty-shaly zone, light gray, heterogeneous, weathers pinkish, forms a reentrant, 2'.
 - (3) Limestone, light greenish-gray, geodal, massive, weathers light gray to yellow-buff, 4' 6".
7. Shale, mudstone, and limestone, 8' 6" to 9':
 - (1) Shale, dark bluish-gray, breaks in tiny pieces, forms a reentrant, 6" to 8".
 - (2) Mudstone, light greenish-gray, silty, weathers light gray above and pinkish below, 6" to 8".
 - (3) Shale, red, with some green-gray mottling, very sandy, breaks in tiny pieces, forms a reentrant, 9" to 1'.
 - (4) Limestone, light greenish-gray, silty, geodal, blocky, weathers light gray to yellowish, 2' 10".
 - (5) Shale, medium dark gray to purplish, part nodular, becomes very sandy at base, forms a reentrant, 2' 3".
 - (6) Mudstone-limestone, medium light gray, a single bed, 1' 8".
 - (7) Shale, red and green-gray mottled, sandy, 2" to 3".
8. Siltstone above, mudstone below, 22' 10":
 - (1) Siltstone, greenish-gray and red mottled, calcareous, often weathers in small vertical columns, 1' 8".
 - (2) Siltstone, reddish-brown, calcareous, massive, 1' 8".
 - (3) 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'.
 - (4) Shale to siltstone; grades from a red, nodular shale in the upper part to a greenish-gray calcareous siltstone in the lower part, 5'.
 - (5) Mudstone-limestone, greenish-gray, massive, weathers light gray to buff, softer and more shaly in upper part with a thin dark gray shale at the top, thickness 7' 6".
9. Sandstone, light greenish-gray, fine grained, calcareous, weathers light gray to buff, with small vertical worm tubes in upper part, 1' 8".

NOTE: The base of the above section occurs 13 feet above the level of the railroad track at the west end of Tunnel No. 1. (See Figure 9.)

Northwest of Wendover. At the mouth of Little Cottonwood Creek (Station 13) the beds of Division III are well shown. They are about 160 feet in thickness and are described as follows:

1. Limestone, with some mudstone at top, 10':
 - (1) Mudstone, dark gray, thinbedded, platy, with 4" of dark shale at base, forms a reentrant, 2' 4".

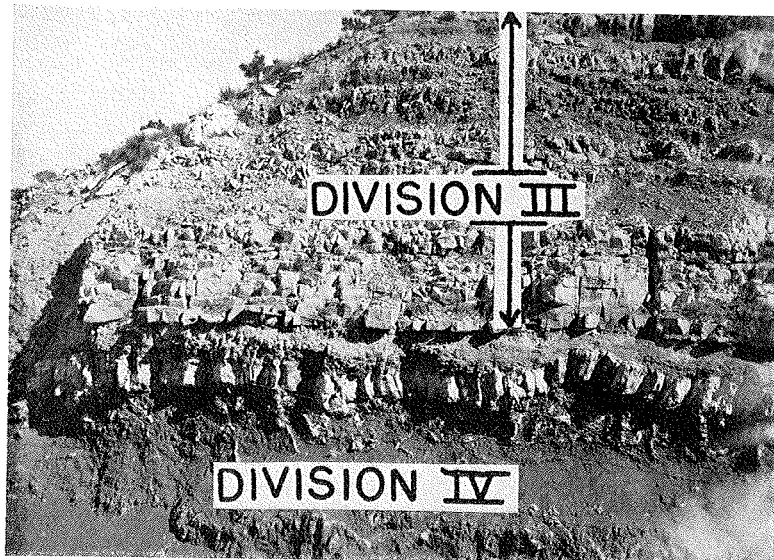


FIGURE 9.—North side of cut at west end of Burlington Railroad tunnel (Station 3), showing the contact between Divisions III and IV. Subdivisions 8 and 9 of Division III and the upper ten feet of Division IV are shown.

- (2) Limestone, medium gray, silty, lithographic, thinbedded to slabby, weathers light gray, with a 2' blocky bed at base, containing red chert nodules, 7' 8".
2. Limestone, 10' 3":
 - (1) Limestone, medium dark gray, upper 7" weathers platy and contains *Fusulina hartvillensis*, 2' 1".
 - (2) Limestone, medium dark gray, dense, slightly silty, blocky, 1'.
 - (3) Limestone, medium dark gray, heavy-bedded, rough-surfaced, 4' 3".
 - (4) Limestone, medium gray, massive, weathers light gray, shattered, 3'.
3. Limestone and chert with some shale and mudstone above, 8' 3" to 9':
 - (1) Mudstone and shale, dark gray, thinbedded, forms a reentrant, 7" to 1' 1".
 - (2) Limestone, medium gray, silty, thinbedded, with thin lenticular beds of red to yellow chert 1' 9" below top and 8" above base, 4' 8".
4. Limestone, 13' 1" to 13' 5":
 - (1) Limestone, medium dark gray, slightly silty, lithographic, weathers brownish-gray, in three beds, 4' 9".
 - (2) Shale and mudstone, dark gray, thinbedded, forms a reentrant, 4".
 - (3) Limestone, medium gray, lithographic, silty, massive, weathers light gray to buff, breaks in small angular blocks, 1' 11".
 - (4) Chert, yellow, in a lenticular bed, 1" to 5".
 - (5) Limestone, medium dark gray, shattered, with some brachiopods and with "niggerheads" of yellow chert in middle part, 6'.
5. Sandstone, gray, thinbedded to cross-bedded, weathers buff to rusty brown-stained, thickens northwestward, 4' 6" to 8'.

6. Limestone, medium gray, silty, massive, weathers light gray, shattered, with scattered nodules of red chert, 11' to 13'.
7. Limestone, with sandstone at base, 14' 6" to 14' 9":
 - (1) Limestone, dark gray, thinbedded, interbedded with thin beds of dark gray to red to yellow chert, 3'.
 - (2) Limestone, medium light gray, silty, massive, 3'.
 - (3) Limestone, medium gray, slightly argillaceous, with *Fusulina cf. rocky-montana* and *Fusulina hartvillensis*, and scattered nodules of yellow chert, a single bed, 5" to 8".
 - (4) Sandstone, medium gray and argillaceous above, pinkish to red below, with an irregular uneven base, 1' 4".
8. Limestone, largely silty, 15' 9" to 16' 3":
 - (1) Limestone, medium gray, silty, massive, weathers light gray, shattered, 6' 9".
 - (2) Limestone, dark gray, rough-surfaced, uneven and gradational at base, with some brachiopods, separated from (1) by a thin gray shale, 1' 6" to 2'.
 - (3) Limestone, medium gray, weathers gray to brownish-gray, silty, massive, lithographic, 7' 6".
9. Limestone separated by mudstone, 9':
 - (1) Limestone, medium dark gray, heavy-bedded in upper part, slabby in middle and silty at base, with some brachiopods and occasional "nigger-heads" of yellow chert, 3' 10".
 - (2) Mudstone, dark gray, weathers medium gray to pinkish, irregularly thinbedded, locally weathers shaly, forms reentrant, 1' 6".
 - (3) Limestone, medium dark gray, rough-surfaced, crinoidal, in 3 beds (upper 2 feet thick, middle 1 foot, lower 8 inches), 3' 8".
10. Mudstone and shale, medium dark gray, weathers pinkish, forms reentrant, thinbedded to platy, 1' 8".
11. Siltstone, brownish-gray, stained and streaked with pink, massive, calcareous, 12' 8". To the northwest the upper part of this zone is a cross-bedded sandstone.
12. Shale and sandstone, 4' 2" to 5' 3":
 - (1) Shale, dark gray to purple, sandy, massive, forms a reentrant, 1' 1".
 - (2) Sandstone, dark red, fine-grained, calcareous, 1' 11".
 - (3) Shale, red, sandy, massive, forms a reentrant, 1' 2" to 2' 3".
13. Siltstone and sandy shale, 25' 2":
 - (1) Siltstone, gray and red mottled, calcareous; upper half weathers in small vertical columns; lower half shaly and nodular, 1' 8".
 - (2) Siltstone, medium gray, weathers pink, calcareous, massive, streaked with dark red and gray at top and base, 13' 6".
 - (3) Shale, red, sandy, massive, forms reentrant, 6".
 - (4) Siltstone, pink, calcareous, a single bed, 1' 6".
 - (5) Shale, dark red, massive, forms a reentrant, 4".
 - (6) Siltstone, pink, calcareous, massive, 6' 8".
 - (7) Calcareo-argillaceous zone, red to purple, nodular, forms a reentrant, 1'.
14. Limestone, medium gray, weathers light gray, silty, geodal throughout, massive, in part cavernous, 4' 4".
15. Siltstone and shale, 8' 8":
 - (1) Siltstone, gray, weathers light gray to buff, calcareous, a single bed, 2'.
 - (2) Calcareo-argillaceous zone, purple and gray mottled, nodular, 1'.
 - (3) Siltstone, medium gray, weathers gray to buff, calcareous, massive, 4'.

- (4) Mudstone, purple and gray mottled, argillaceous, forms reentrant, 1' 8".
16. Sandstone, light gray to greenish-gray, occasionally pink stained, fine-grained, with small vertical worm-tubes in upper part, 2' 3".

NOTE: Next below are found about 15 feet of the red shales of Division IV down to the level of the railroad track.

Northwest of Glendo. Six miles north-northwest of Glendo the beds of this division are exposed in the North Platte River canyon just north of the mouth of Elkhorn Creek. They are 132 feet or more thick, described as follows:

1. Limestone above, shale below, 3' 7" to 3' 8":
 - (1) Limestone, medium dark gray to dark gray, in three rather blocky beds (upper bed 10", middle 1' 6", lower 1'), many small fusulinids (*Fusulina hartwillensis*) in middle and upper beds, 3' 4".
 - (2) Shale, medium gray, weathers brown, purple-red at top, forms a reentrant, 3" to 4".
2. Sandstone, medium gray, fine-grained, laminated to cross-bedded, rusty brown stained on surface, 2' 3".
3. Limestone, largely massive, 27' 3":
 - (1) Limestone, medium gray to dark gray, rough surfaced, a heavy single bed, with a lenticular bed of brown chert at top, 4'.
 - (2) Poorly exposed, appears to be silty limestone, yellow-buff, shattered, 11'.
 - (3) Limestone, dark gray, upper part blocky, contains brachiopods, 1'.
 - (4) Limestone, gray to purplish, locally weathers brownish-gray, surface coated with dark brown ferruginous material, some light gray to pink chert in joint planes, pure above and silty below, fusulinids on top, 2' 3".
 - (5) Limestone, medium gray, weathers light gray, silty, lithographic, massive, jointed and shattered, 9'.
4. Shale, medium dark gray, platy, with some interbedded layers of dark gray mudstone, forms a reentrant, 8'.
5. Limestone, medium dark gray, rough surfaced, with some brachiopods and a few fusulinids, nodules of yellow-brown chert in middle part variable in thickness and uneven at base, 1' 6" to 2' 6".
6. Sandstone, separated by a limestone, 21' 2":
 - (1) Sandstone, medium gray, thinbedded to cross-bedded, soft, friable, weathers light gray to yellow-buff, 8'.
 - (2) Limestone, brittle, platy, *Mesolobus mesolobus*, *Marginifera splendens*, *Ambocoelia planoconvexa*, 8'.
 - (3) Sandstone, medium gray, soft, friable, weathers light gray to yellow-buff, thinbedded to platy and pink-weathering in lower 2', combined thickness, 5'.
7. Limestone, heavy bedded above, thinbedded below, 17' 10":
 - (1) Limestone, medium dark gray, rough surfaced, a single heavy bed, with a few productids on top and nodules of yellow chert 3" to 6" above base, 4' 4".
 - (2) Limestone, silty; upper part pinkish to brown, slabby; lower part weathers light gray, shattered; forms a slight reentrant, 2' 6".
 - (3) Limestone, dark gray to reddish, massive, rough surface, 4'.
 - (4) Limestone, red, silty, slabby to thinbedded, irregular base, 5'.
 - (5) Mudstone and shale, medium gray, thinbedded, weathers buff, reentrant, 2'-2' 8".

8. Limestone, medium dark gray, rough surfaced, with some fossils including *Spirifer rockymontanus*, in two beds (upper bed blocky, 9"; lower bed a single heavy bed, 2' 3"), 3'.
9. Sandstone, 14' 4":
 - (1) Sandstone, medium gray, with many small reddish brown iron concretions, massive, weathers brown to buff, 3' 4".
 - (2) Sandstone, light gray, soft, friable, thinbedded to cross-bedded, weathers buff, dark brown stained surface in upper part, 11'.
10. Siltstone, covered slope and some shale, 17' 3":
 - (1) Siltstone, medium gray, weathers brown to buff, calcareous, with light gray to pink chert filling the joints, 3' 6".
 - (2) Shale, greenish-gray, deeply weathered brownish, sandy, 8".
 - (3) Siltstone, light gray, calcareous, blocky, weathers brownish-gray, 8".
 - (4) Covered slope, 1' 8".
 - (5) Siltstone, light gray, a single bed, weathers brownish-gray, 1' 6".
 - (6) Covered slope, 4' 3".
 - (7) Siltstone, medium gray, massive, weathers light gray, with pink and red chert filling the joint planes, 3' 9".
 - (8) Calcareo-argillaceous zone, medium gray, nodular, weathers pinkish to yellowish, 1' 3".
11. Limestone, medium gray, weathers light gray, silty to clayey, in three beds (upper bed 7' 6", middle 4', lower 4'), separated by thin shales, 15' 6".
12. Covered slope to valley floor, 75'; upper part on Division III and the middle and lower parts on Division IV.

NOTE: The lower 30 feet or more of the division down to and including the worm-burrow sandstone, which marks the base in the Guernsey Lake vicinity and above Wendover, is covered here.

Discussion. The rocks of Division III are generally well-exposed and a number of the thin members persist in the entire area. Chart A illustrates the correlation of a number of measured sections of this interval.

Many of the limestone beds show little change in character and thickness between stations. The impure limestones, calcareous siltstones, and sandstones, however, evidence considerable lateral gradation and some variation in thickness.

Two prominent chert horizons persist in the entire Guernsey Lake vicinity. These are an upper yellow chert 2 (7), and a lower red chert, 5 (5) (Guernsey Lake Section). The "worm-burrow" sandstone, at the base of this division, occurs with remarkable persistency in the Lake Guernsey vicinity and again at the mouth of Little Cottonwood Creek.

Irregular and uneven contacts, as well as cross-bedded sandstones, are suggestive of some disconformity within this division. Two uneven contacts, in the middle part of Division III, are widespread in occurrence.

Fossils of Des Moines series age occur throughout, notably *Mesolobus mesolobus*, *Spirifer rockymontanus*, and *Fusulinella*.

DIVISION NUMBER II

(Figure 10)

Division II, immediately overlying Division III, consists of limestone, with some interbedded sandstones, mudstones and shales. The top is marked by a change from dominant limestone, below, to red shales and sandstones with some interbedded limestone, above. At the base, in the Lake Guernsey vicinity, is a thick sandstone which probably marks a disconformity. This sandstone becomes less prominent northwestward.

This division outcrops extensively in the area of the Hartville uplift, forming precipitous canyon walls and prominent mountains. It occurs in the higher parts of the canyon walls in the Lake Guernsey vicinity, dipping gently westward. At the mouth of Broom Creek only the upper beds are exposed. They 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.

Lake Guernsey Vicinity (Figure 11). In the vicinity of Lake Guernsey Division II measures 225 feet and consists of the following beds:

1. Limestone, sandstone, and siltstone, 10' 3":
 - (1) Limestone, gray, silty, weathers light gray, a single bed, 6" to 7".
 - (2) Limestone, gray, silty, weathers light gray to gray, one bed capped by a shale seam, contains casts of small gastropods and pelecypods; thickness 1' 3".
 - (3) Limestone, gray, hard, jointed, weathers light gray, some calcareous geodes, a single bed, 1'.
 - (4) Limestone, gray silty, shattered, weathers pinkish, 8".
 - (5) Limestone, medium light gray, a single bed, 6".
 - (6) Sandstone, light gray, fine-grained, laminated to cross-bedded, weathers pinkish with a dark rusty brown-stained surface, 1' 3".
 - (7) Siltstone-sandstone, transitional from a pinkish, shattered, calcareous siltstone in the lower part to a massive, yellowish-buff sandstone in the upper part; irregular and uneven base; 5'.
2. Limestone, 15' 6" to 16':
 - (1) Limestone, light gray, silty, thinbedded to shattered, weathers yellowish-buff, 2'.
 - (2) Limestone, pinkish, silty to argillaceous, nodular; with a thin seam of red shale at the top; 6" to 9".
 - (3) Limestone, gray, silty, geodal, weathers light gray, in three beds (upper bed 10", middle bed 3", lower bed 1' 6"), 3'.
 - (4) Siltstone-sandstone, pink to red with gray bands, calcareous, laminated, friable in upper part, 1' 6" to 1' 8".
 - (5) Limestone, medium light gray, silty, massive, in part pebbly, occasionally cavernous to knotty, weathers light gray to brownish; includes a 2" to 6" bed of pinkish chert 1' 9" below the top; combined thickness 8' 6".
3. Chert, medium light gray, pink to lavender, uneven base, quite persistent, 5" to 1'.
4. Limestone, uneven at top and base, 7' to 7' 4":

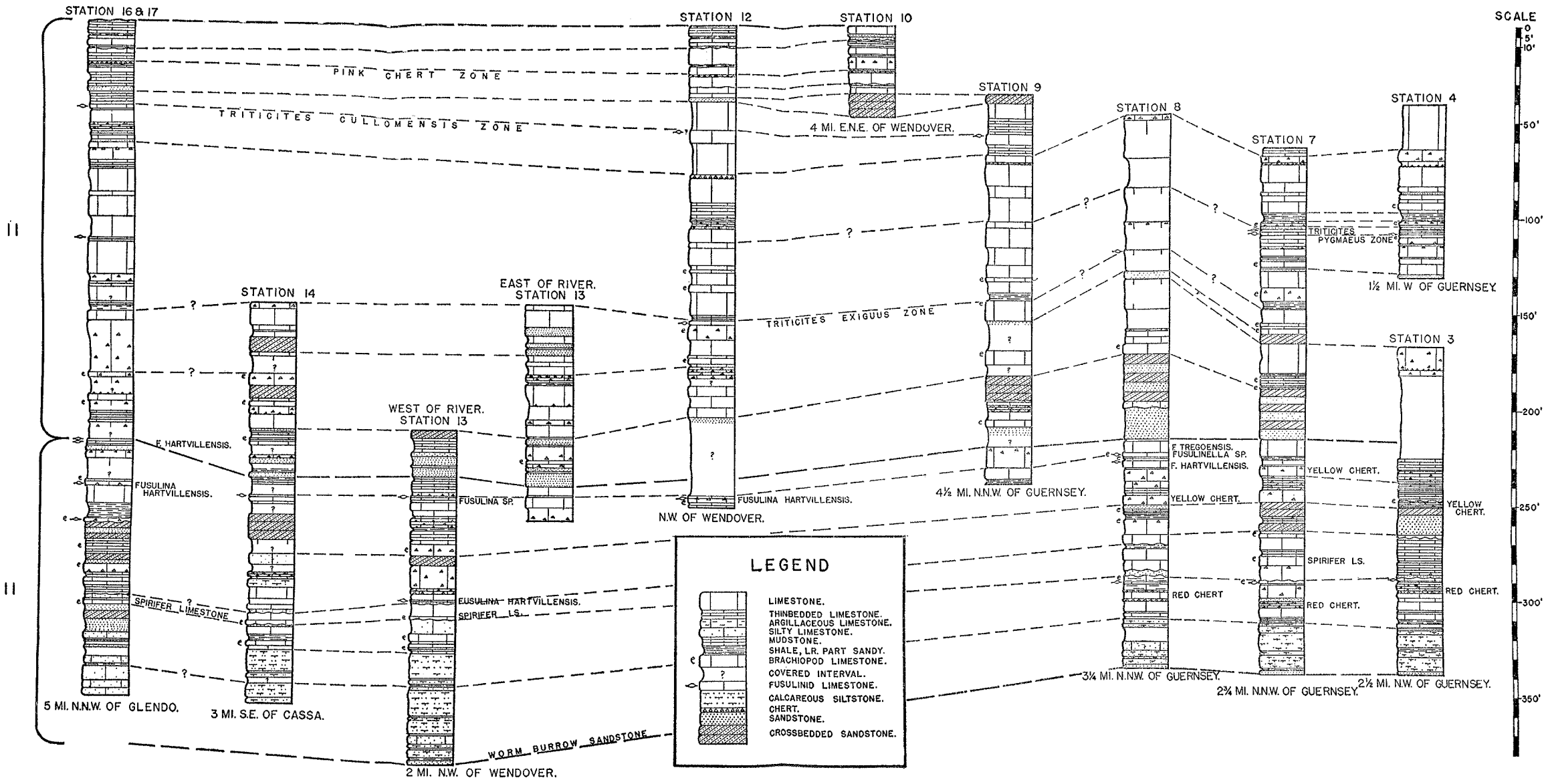


CHART A.—Correlation table of Divisions II and III, Hartville uplift and vicinity.

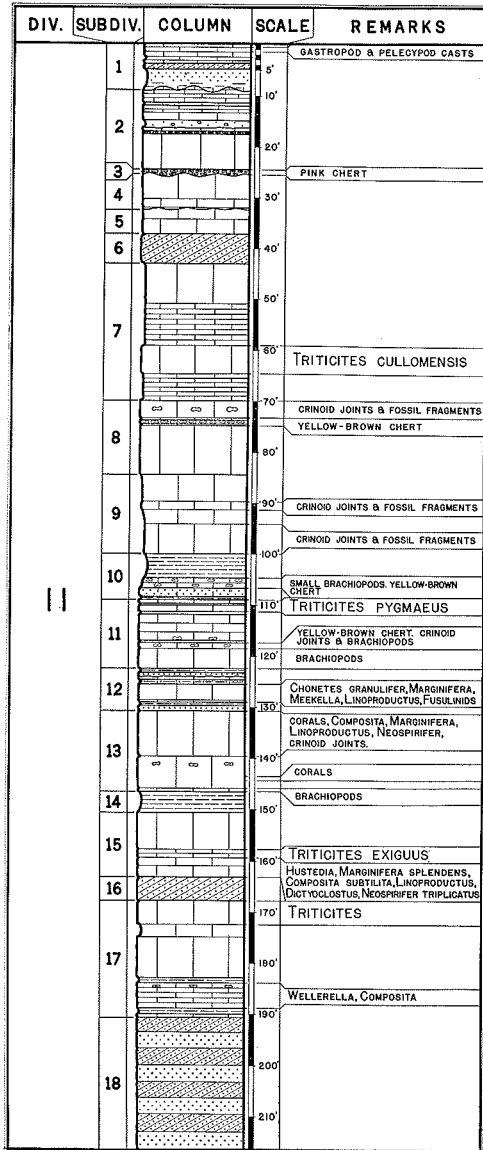


FIGURE 10.—Composite columnar section of Division II in the vicinity of Lake Guernsey. Subdivisions 1-6 were measured at Station 10, 6-8 at Station 9, 8-18 at Station 7.

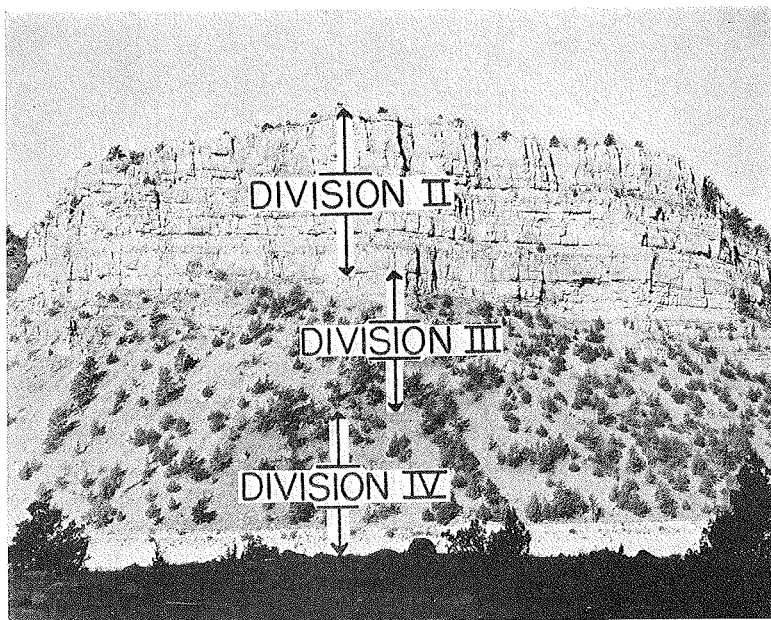


FIGURE 11.—View of Meek Cliff, looking westward, Lake Guernsey in the foreground. This cliff is 380 feet in height. Subdivisions 8-18 of Division II are shown in the upper part of the canyon wall. Division III is partially covered by talus and Division IV entirely covered.

- (1) Limestone, medium light gray, silty, massive, pebbly in upper part, weathers dirty gray to pinkish, 5'.
- (2) Limestone, medium light gray, silty, massive, weathers pinkish, 2'.
- (3) Siltstone, red, calcareous, argillaceous, uneven base, 0-4".
5. Limestone, 4' 3" to 5' 4":
 - (1) Limestone, medium light gray, silty, weathers pinkish-gray, highly shattered to small blocks, 1' 3" to 2'.
 - (2) Limestone, medium light gray, silty, massive, 3' to 3' 4".
6. Sandstone, light gray, calcareous, laminated to cross-bedded, weathers buff with rusty brown-stained surface, very persistent but variable in thickness, 4' to 12' 6".
7. Limestone, 27' 2":
 - (1) Limestone, medium light gray, silty, massive, with a reddish band at the base, 7' 10".
 - (2) Limestone, medium light gray, silty, thinbedded to platy, weathers yellowish-buff, contains some geodes, 8' 4".
 - (3) Limestone, medium light gray, silty to argillaceous, massive, with *Triticites cullomensis*, 5' 6".
 - (4) Limestone, medium light gray, silty, geodal, thinbedded to platy, 5' 6".
8. Limestone, forms top of more precipitous cliff, 13' 9" to 15' 9":

- (1) Limestone, medium dark gray, heavy-bedded, weathers rough surfaced, yellow to rusty brown chert along joint planes, crinoid stems and fossil fragments, 3' 4" to 3' 8".
 - (2) Limestone, medium light gray, silty to argillaceous, platy, 6".
 - (3) Chert, yellow to rusty brown, an irregular bed, 6" to 10".
 - (4) Limestone, medium light gray, argillaceous, forms a slight reentrant, 3".
 - (5) Limestone, medium dark gray mottled with light gray, massive, weathers rough surfaced, some spongy brown chert along joints, 9' to 11'.
9. Limestone, silty, 15' 10":
- (1) Limestone, medium light gray, silty, lithographic, weathers yellowish-gray, some geodes, breaks in small angular blocks, 5' 4".
 - (2) Limestone, pink to reddish, silty to argillaceous, crinoid joints and fragmentary fossils, 1' 6".
 - (3) Limestone, poorly exposed, similar to 9 (1), 3'.
 - (4) Limestone, light gray, platy, in part geodal, weathers yellow-buff, some crinoid joints and fossil fragments, 6".
10. Shale, cherty limestone and sandstone, 8' 11":
- (1) Shale, dark gray to purple, thinbedded to platy, weathers brownish-gray, with cone-in-cone calcium carbonate in vertical joints, forms a reentrant, 4' 9".
 - (2) Limestone, dark gray, blocky, fossiliferous (small brachiopods), with yellowish-brown chert nodules along the top and chert in pancake-like nodules 6" to 8" above the base; separates in four beds, 2' 2".
 - (3) Sandstone-siltstone, medium light gray, calcareous, laminated to cross-bedded, weathers yellowish-buff, 1' 6".
 - (4) Mudstone, gray to reddish, shaly, weathers out in small pieces, forms a reentrant, 6".
11. Limestone, 13' 6":
- (1) Limestone, dark gray with a reddish cast, fine-grained, weathers with a smooth surface, with *Triticites pygmaeus*, 10".
 - (2) Shale, medium light gray, calcareous, with lenticular limy seams, 2" to 3".
 - (3) Limestone, dark gray, slightly argillaceous, with *Triticites pygmaeus*, a single bed, 1' 3".
 - (4) Mudstone, medium light gray, weathers light buff, some fusulinids, 5".
 - (5) Limestone, dark gray, massive, stylonitic, weathers rough-surfaced; with a 2" to 3" lenticular bed of yellowish brown chert in lower part; separates in three beds, 5' 6".
 - (6) Shale, not well shown, 2".
 - (7) 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".
 - (8) Limestone, medium dark gray, rough surfaced, some brachiopods, orange-yellow spongy chert along joint surfaces, 4'.
12. Shale, sandstone, and limestone, 8':
- (1) Shale, medium light gray, calcareous, and lenticular dark gray mudstone, forms a reentrant, 7".
 - (2) Sandstone and limestone, a two-fold bed, upper half is cross-bedded brown-stained sandstone and lower half is medium dark gray, silty limestone, 1' 5".
 - (3) Siltstone, light gray, argillaceous, calcareous, weathers light gray to white, forms a reentrant, 9".

- (4) Limestone, medium dark gray, rough-surfaced, massive, stylonitic near base, some yellow-brown spongy chert on exposed surface, with fusulinids, *Chonetes granulifer*, *Marginifera*, *Meeckella*, *Linoproductus*, thickness, 3' 3".
- (5) Siltstone-limestone, medium light gray, blocky, weathers brownish, 4".
- (6) Shale, medium light gray to reddish, calcareous, with some lenticular bands of mudstone, forms a reentrant, 7" to 8".
- (7) Sandstone, medium light gray, fine-grained, laminated to cross-bedded, weathers buff with rusty brown-stained surface, 1'.
13. Limestone, 15' 6":
- (1) Limestone, medium dark gray, stylonitic, massive, rough surfaced, 9'; with crinoid joints, rugose corals, *Composita*, *Marginifera*, *Linoproductus*, and *Neospirifer*.

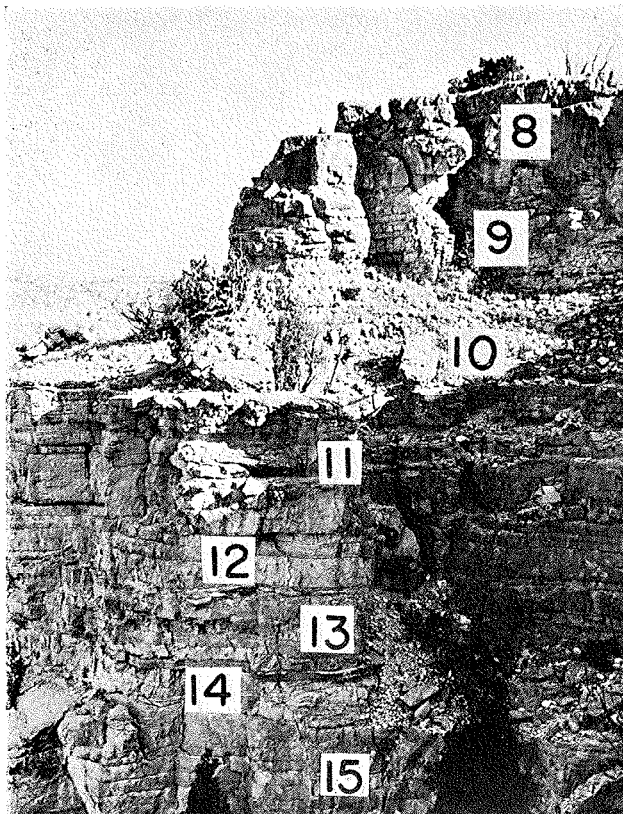


FIGURE 12.—View northward at top of Hayden Cliff (Station 7). Subdivisions 8-15 of Division II are shown.

- (2) Limestone, medium dark gray, massive, surface coated with spongy yellow-brown chert, carries small rugose corals 1' to 2' 6" above the base, 6' 6".
- (3) Limestone, medium dark gray, blocky, very fossiliferous (brachiopods), 6".
- 14. Shale, medium dark gray, calcareous, platy, weathers reddish, forms a reentrant, 4' 3".
- 15. Limestone, 12' 9":
 - (1) Limestone, medium light gray, shattered, weathers yellowish-buff, poorly exposed, 7' 3".
 - (2) Limestone, medium dark gray, argillaceous, irregularly thinbedded, weathers reddish at top, carries brachiopods and small rugose corals in upper part, 1' 6".
 - (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.; thickness, 4'. The basal 6" of this subdivision locally grades to a cross-bedded siltstone.
- 16. Sandstone, medium light gray, fine grained, slabby to cross-bedded, weathers light gray with rusty brown stain, thickens eastward, 4' 6" to 5' 6".
- 17. Limestone, 23' 2" to 23' 8":
 - (1) Limestone, medium dark gray, massive, rough surfaced, occasionally cavernous, 15' 9".
 - (2) Mudstone, gray and pink mottled, nodular, and shale, dark gray, forms a reentrant, 8" to 1'.
 - (3) Limestone, medium dark gray, thinbedded, weathers gray to yellowish, carries *Wellerella* and *Composita*; much dark gray chert in upper 2' occurring as lenticular beds and erratic nodules; basal 8" separates as a shaly, rounded bed, thickness 5' 3".
 - (4) Shale, medium dark gray, dense, very calcareous, forms reentrant 11" to 1'.
 - (5) Limestone, medium dark gray, rough surfaced, a single bed, 7" to 8".
- 18. Sandstone, medium light gray, laminated to cross-bedded, weathers yellowish-buff, often dark brown stained, 25' to 27'.

NOTE: Beds number 1 to 6 were measured at Station 10, 6 to 8 at Station 9, and 8 to 18 at Station 7 (Figures 12 and 13).

Northwest of Wendover. The entire thickness of this division is seen in the North Platte River canyon between Wendover and the mouth of Little Cottonwood Creek. Here the westward rise of the strata brings successively older beds above the river level. In this locality about 235 feet of Division II was measured, as follows:

- 1. Limestone, 11' 6":
 - (1) Limestone, medium gray, silty, thinbedded to slabby, weathers light gray, with a thicker bed, one foot in thickness, at the top, 5' 6".
 - (2) Limestone, gray to pinkish, argillaceous, nodular, slight reentrant, 1' 8".
 - (3) Limestone, light gray, in part geodal, silty, locally sandy and friable, weathers pink, 2'.
 - (4) Limestone, light gray, silty, rather blocky, some fossil casts, 2' 4".
 - (5) Limestone, light gray to pink, sandy, irregular, uneven base, 7"-11".
- 2. Limestone, with a thin red shale below the middle, 13' 8" to 14' 6":

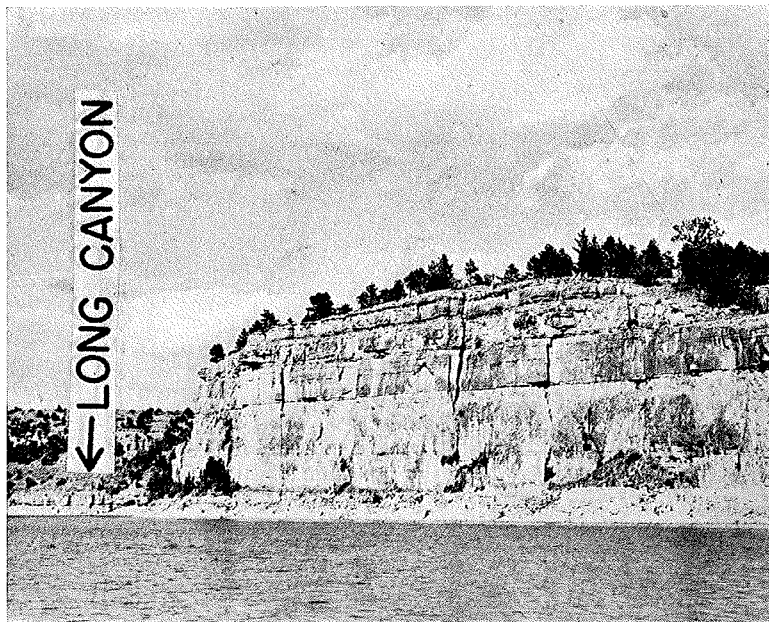


FIGURE 13.—Cliff below the mouth of Long Canyon, view northward. The rocks exposed are those of Division II with subdivision 7 at the top.

- (1) Limestone, medium gray, silty, geodal, in part cavernous, massive, weathers brownish-gray to pink-stained, 9'.
- (2) Shale, red, sandy, rather irregular at top and base, forms reentrant, 8" to 1'.
- (3) Limestone, light gray, occasionally pink-stained, silty, geodal throughout, with some dark gray chert nodules in lower part, breaks into small angular blocks, massive, weathers light gray to yellowish-buff, 4' to 4' 6".
3. Chert, medium gray to pink to lavender, bedded, irregular uneven base, 1' 2" to 1' 5".
4. Limestone, light gray, silty, in part geodal and knotty, locally pebbly, weathers pinkish-gray, irregular uneven base, 5' 6".
5. Limestone, 5' 8":
 - (1) Limestone, gray, silty, hard, massive, weathers light gray, upper part pinkish and shattered, lower part geodal, 3' 4".
 - (2) Limestone, light gray, silty, slabby to shattered, 2' 4".
6. Sandstone, medium gray to buff, often stained rusty-brown on exposed surface, laminated to cross-bedded, thickens to the northwest, 2" to 4'.
7. Limestone, 38' 6":
 - (1) Limestone, medium gray, silty, geodal, massive, locally cavernous, weathers light gray to buff, upper part shatters in small blocks, 15'.
 - (2) Limestone, gray, silty, massive, weathers light gray, with many fusulinid-like, calcite-filled pits in upper part, 7'.

- (3) Limestone, medium gray, silty, weathers light gray to yellow-buff, breaks in small angular pieces, forms a reentrant, 16' 6".

NOTE: The beds below this subdivision form more precipitous canyon walls than those above.

8. Limestone, with chert at top, about 15':
 - (1) Chert, medium gray to light pink, weathers brownish, with some silicified brachiopods, locally grading to quartzitic siltstone, 2'.
 - (2) Limestone, gray to medium dark gray, slightly silty, massive, geodal, 13'.
9. Limestone, red, silty, with small geodes, thin-bedded to slabby, 7' 10".
10. Shale, limestone and mudstone with chert, 4' 10" to 7':
 - (1) Shale, medium gray above, red below, massive, 2".
 - (2) Limestone, dark gray, occasionally red-stained, in two or three beds, upper layer blocky, 1' 3" to 2'.
 - (3) Mudstone, limestone, and shale, interbedded, medium gray, thinbedded, with some red chert in lenticular discontinuous beds at top and base, 2' 3" to 3' 4".
 - (4) Siltstone, gray to brownish-gray, thinbedded to slabby, in places grades to a limestone pebble conglomerate, 1' 2" to 1' 7".
11. Limestone, 19':
 - (1) Limestone, medium dark gray, fine-grained, scattered geodes, massive to bedded, with brachiopods and crinoid joints in upper part, about 7'.
 - (2) Limestone, as above, but dark gray with a reddish cast, about 3'.
 - (3) Limestone, dark gray and light gray mottled (dark gray lense-like areas bordered with lighter gray), fine-grained, massive to medium-bedded, about 9'.
12. Limestone, in part silty, 25' 3" to 26' 3":
 - (1) Limestone, light gray, silty, weathers pinkish, highly shattered, 2' 3".
 - (2) Limestone, medium dark gray, very fossiliferous with brachiopods and crinoid joints, 1' to 2'.
 - (3) Limestone, light gray, silty, massive, weathers light gray to pinkish, breaks in small angular blocks, about 6'.
 - (4) Limestone, medium dark gray, with brachiopods, a heavy single bed, 4'.
 - (5) Limestone, medium gray, silty, weathers light gray to light buff, breaks in small angular blocks, 12'.
13. Mudstone, medium dark gray to purplish, platy to slabby, weathers as a conspicuous red zone, forms a reentrant, 2' 10".
14. Limestone, 10' 1":
 - (1) Limestone, medium dark gray, with *Triticites exiguus*, brachiopods and crinoid joints in upper part, forms a prominent blocky cap to underlying bed, 2' 1".
 - (2) Limestone, medium dark gray, massive, weathers medium gray, with some brachiopods, a few geodes, and occasional red chert nodules, 8'.
15. Limestone, mostly silty, 13' 9":
 - (1) Limestone, medium gray, silty, weathers light gray to light buff, massive, breaks in small angular blocks, 8'.
 - (2) Limestone, medium dark gray, slightly silty, blocky, 8".
 - (3) Limestone, medium gray, silty, slabby to shattered, weathers light gray, 6".
 - (4) Limestone, medium dark gray, massive, weathers medium gray, containing some brachiopods, 3'.
 - (5) Limestone, gray, silty, massive, weathers light gray, breaks in small angular blocks, 1' 7".

16. Limestone, medium dark gray, weathers dark gray to medium gray, very crinoidal, in 6" to 1' beds separated by lenticular beds of red chert, 6'.
17. Shale, dark gray, calcareous, massive, 1' 2".
18. Limestone, in part silty, with some chert, 27' 8":
 - (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' 8".
 - (3) Limestone, as above, but chert-free and massive, 6'.
 - (4) Limestone-mudstone, dark gray, platy to slabby, weathers medium gray, forms a reentrant, 1'.
19. Sandstone, with some limestone, 23' to 23' 8":
 - (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' 4" to 4'.
 - (2) Limestone, medium gray, silty, slabby to massive, weathers light gray, often pink-stained in middle and lower part, 7' 6".
 - (3) Sandstone, medium gray, thinbedded to cross-bedded, weathers light gray to buff, upper 1' 6" massive, 6' 6".
 - (4) Limestone, dark gray, rough-surfaced, minutely stylolitic, a single bed, 11" to 1'.
 - (5) Sandstone, gray, laminated to cross-bedded, weathers yellow-buff to light gray, 4' 8".

NOTE: In the above section, beds 1 to 16 were measured between Wendover and a point 1 mile northwest of Wendover and beds 16 to 19 were measured high in the canyon wall opposite the mouth of Little Cottonwood Creek.

Northwest of Glendo (Figure 14). In this locality Division II is 217 feet in thickness, showing the following succession of beds:

1. Limestone, generally slabby, 13' 3" to 14' 3":
 - (1) Limestone, medium light gray, silty, slabby to thin-bedded (3" to 6" beds), weathers light gray, 5' 6".
 - (2) Limestone, gray, jointed, silty, weathers light gray to yellow-buff, 1' 6".
 - (3) Shale, medium gray, calcareous, nodular, weathers pink to buff, reentrant, 1'.
 - (4) Limestone, medium gray, silty, blocky to jointed, weathers light gray, 1' 9".
 - (5) Limestone, medium gray, silty, massive, weathers light gray to yellow-buff, sandy and rounded at top, 3' 6".
 - (6) Limestone, medium gray, silty, minutely shattered to slabby, weathers light gray, irregular uneven base, 1' to 2'.
2. Limestone, 6' to 7':
 - (1) Limestone, medium gray, silty, locally pebbly, massive, weathers light gray, 2' to 3'.
 - (2) Limestone, medium gray, geodal, irregularly thinbedded, weathers light gray, 4'.
3. Chert, medium gray to slightly brownish, bedded to thinbedded, irregular base, 1' 6".
4. Limestone, 11' 5":
 - (1) Limestone, gray, silty, jointed and minutely shattered, massive, weathers light gray, somewhat irregular base, forms slight reentrant, 10".

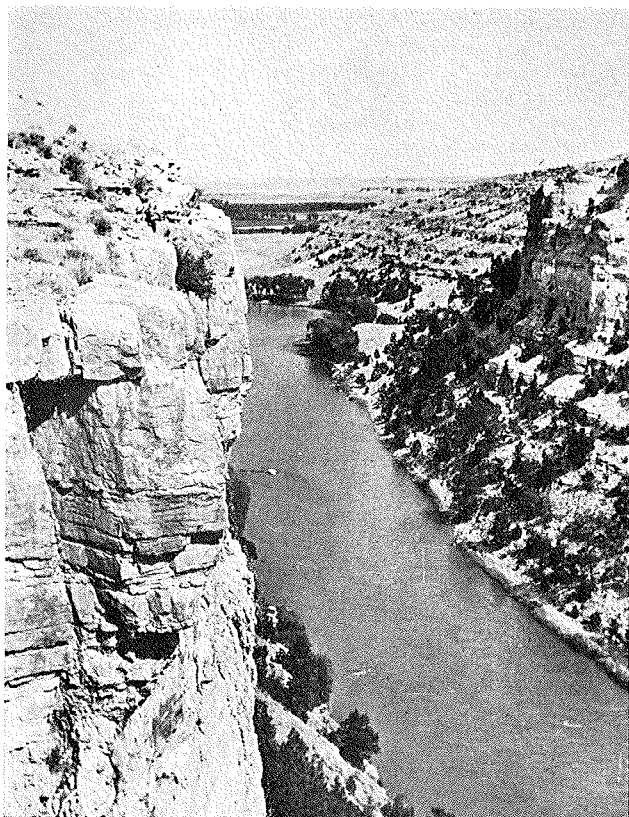


FIGURE 14.—View northward, North Platte River Canyon 6 miles north-northwest of Glendo. Subdivision 8 of Division II forms top of canyon, Division III in lower slopes, top of Division IV near river level.

- (2) Limestone, gray, silty, weathers light gray, pinkish and pebbly on top, 1' 2".
- (3) Limestone, medium gray, silty, geodal, massive, weathers light gray, 2' 6".
- (4) Limestone, medium gray, silty, some small geodes, thinbedded and jointed, weathers yellow-buff, forms a slight reentrant, 4' 5".
- (5) Limestone, gray, silty, irregularly thinbedded, weathers light gray to yellow-buff, with large geodes at the base, 2' 6".
5. Sandstone, light gray, rusty brown-stained on surface, cross-bedded in upper 1' 6", massive below, weathers light buff, 2' 6".
6. Limestone, 16':
 - (1) Limestone, medium gray, silty, many geodes, irregularly thinbedded and jointed, weathers light gray to yellow-buff, 6' 9".
 - (2) Limestone-mudstone, medium gray, occasionally pinkish, shaly in lower part, many *Triticites cullomensis*, forms slight reentrant, 2'.

- (3) Mudstone, medium dark gray, shaly above, weathers yellow-buff below, forms a reentrant, 9".
- (4) Limestone, deeply weathered yellow-buff, silty, slightly argillaceous, jointed and shattered, large geodes at top, weathers rounded, 6' 6".
- 7. Limestone, mudstone and sandstone, in thin beds, 9' 8" to 10' 1":
 - (1) Limestone, gray, silty, with thin seams of dark brown to yellow chert, thinbedded, weathers medium gray, 3' to 3' 3". These chert seams weather out as light buff mushroom-like remnants on top of exposed layers.
 - (2) Interbedded mudstone and shale, medium gray, thinbedded, occasionally weathered buff, forms a reentrant, 2' 5".
 - (3) Limestone, medium gray, silty, slabby, weathers light buff, 4" to 5".
 - (4) Limestone, gray, silty, rather blocky, weathers medium gray, 5" to 6".
 - (5) Limestone, gray to pinkish, silty, shattered, forms slight reentrant, 2'.
 - (6) Sandstone, yellow-buff to pinkish-gray, friable, rounded, 1' 6".
- 8. Limestone, heavy-bedded to massive, forms top of precipitous cliff, 25' 6":
 - (1) Limestone, medium dark gray, rough-surfaced, with some yellow to brown chert in lenticular aggregates at the base, in a single heavy bed, 3'.
 - (2) Shale, medium gray, calcareous, forms a reentrant, 2".
 - (3) Limestone, medium dark gray, rough-surfaced, massive, with brown chert on top, 6'.
 - (4) Shale, medium gray, calcareous, forms slight reentrant, $\frac{1}{4}$ " to $\frac{1}{2}$ ".
 - (5) Limestone, medium dark gray, in two beds (upper 1' 8", lower 8"), 2' 4".
 - (6) Calcareous-argillaceous zone, gray to buff, forms slight reentrant, 4".
 - (7) Limestone, medium dark gray, rough-surfaced, single bed, 1'.
 - (8) Limestone, as above, but slabby to irregularly thinbedded, 11".
 - (9) Limestone, medium gray to light gray, massive, becomes silty and weathers light gray to yellow-buff in middle and lower part, 11' 9".
- 9. Limestone, medium dark gray, massive, upper two feet set off as a separate bed by a thin seam of gray shale, 13'.
- 10. Limestone, 34':
 - (1) Limestone, medium gray, silty, massive to slabby; cavernous 2' 6" to 3' below top; grades to a more silty, yellow-buff limestone; separated from bed 9 above by a thin gray shale; 11'.
 - (2) Limestone, medium gray, silty, badly shattered, weathers light gray to light yellow-buff, cavernous in lower 4', with occasional yellow chert "niggerheads", the upper 2 feet weathers slabby and contains some fusulinids, 23'.
- 11. Limestone, thinbedded to massive, shaly in lower part, 15' 4":
 - (1) Limestone, gray, silty, thinbedded and shattered, weathers yellow-buff, 2' 4".
 - (2) Limestone, gray, silty, massive, shattered, weathers yellow-buff, 8'.
 - (3) Limestone, medium dark gray, slightly silty, weathers slabby, 2'.
 - (4) Calcareo-argillaceous zone, gray, weathers pinkish-gray, very crinoidal, forms a reentrant, 3'.
- 12. Limestone, massive, 32' 6":
 - (1) Limestone, medium gray, rough surfaced, pure above and silty below, massive, 5'.
 - (2) Limestone, medium gray, massive, weathers light gray to buff, with scattered nodules of yellow chert, silty in middle and lower part, 27' 6".

13. Limestone, largely chert-bearing, fossiliferous at top, 19' 9" to 20' 9":
- (1) Limestone, medium dark gray, a single heavy bed, containing some brachiopods, occasional gray to yellow chert nodules in middle part, 2' 3".
 - (2) Limestone, gray, silty, weathers light gray to yellow-buff, much red and yellow chert in nodules, highly shattered and poorly exposed, 9'.
 - (3) Limestone, medium dark gray, rough-surfaced, a single heavy bed, with dark gray to reddish chert in masses along top, 3' to 4'.
 - (4) Limestone, medium gray, silty, massive, with scattered "niggerheads" of yellow chert in upper part, chert occasionally fossiliferous, 5' 6".
14. Limestone, silty, thinbedded above, massive below, 14' 9":
- (1) Limestone, medium dark gray, silty, slabby, with a 1" to 2" yellow-buff shaly zone 9" above base; basal 9" very crinoidal, 5'.
 - (2) Limestone, medium gray, massive, highly shattered, weathers yellow-buff, with scattered nodules of yellow to brown chert, poorly exposed, 9' 5".

NOTE: Beds number 1 to 8 were measured in the upper part of the canyon wall at station 17, and 8 to 14 were measured at station 16.

Discussion. This is the most widespread and best exposed division of the "Hartville formation". It persists over the entire area and many of its members may be traced for long distances. The correlation of a number of measured sections of parts of this interval is shown in Chart A.

Two prominent and easily recognized chert horizons have wide occurrence. The upper of these, a pink chert bed, occurs 22 feet below the top north of Glendo, 26 feet below the top near Wendover, and 24 feet from the top in Broom Creek (Station 10). A brown chert bed, number 8 (3) of the Lake Guernsey section, 8 (1) northwest of Wendover, and 8 (3) north of Glendo, is present wherever this interval outcrops.

The uppermost 35 feet of this division contains two irregular contacts suggestive of disconformity (Figure 15). There is some possibility that these upper beds may be Permian in age. The fossils collected from this interval are not sufficiently diagnostic to settle the question of age. Consequently these upper beds are grouped with the underlying known Pennsylvanian because of similarity of lithology.

The fossils of Division II, with the exception of the uppermost part of doubtful age, are Virgil and Missouri Series Pennsylvanian. It is interesting to note that the various species of *Triticites* are found in the same relative position in the geologic column as in the Northern Mid-Continent region.

DIVISION NUMBER I

(Figure 16)

A group of sandstones, shales, and limestones, with a total thickness of about 280 feet immediately overlies the limestones of Division II and is herein referred to as Division I. This group of beds outcrops (1) in the middle synclinal area between Broom Creek (station 10) and Wendover

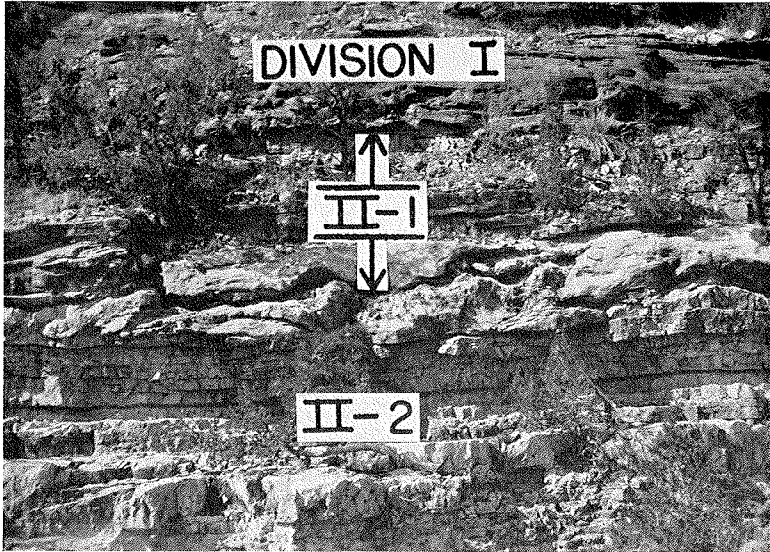


FIGURE 15.—East wall of Broom Creek Canyon at Station 10, showing the contact between Divisions I and II and the irregular base of subdivision II-1.

(station 11), (2) along the western flank of the Hartville uplift northeast of Cassa (station 15), and (3) in the uplands east of the Platte River canyon 6 miles north of Glendo (station 17).

The entire thickness of this division is seen only at Station 15, northeast of Cassa, where it underlies the Opeche shale. The lower 140 feet is exposed in the Broom Creek vicinity and 140 feet of the lower part of the division was measured north of Glendo. In the latter locality, where the base of this division is most clearly seen, its contact with the upper beds of Division II is uneven and suggestive of unconformity. Moreover, many of the interbedded limestones of Division I contain pebbles and angular blocks of limestone which are similar, lithologically, to the rocks of Division II and may have been derived therefrom.

The limestone beds of the lower part of Division I are quite persistent and preserve their characteristics in all outcrops. At Station 17, six miles north of Glendo, red quartzites mark the upper part of the exposed section. These quartzites are dissimilar to any beds of Division I within the confines of the Hartville uplift. It appears probable that the section is more sandy and less calcareous in a northwest direction and that these quartzites represent a change in facies. W. T. Lee* records a

* Lee, W. T., Correlation of Geologic Formations Between East-Central Colorado, Central Wyoming and Southern Montana, Prof. Paper 149, U. S. Geological Survey, 1927, p. 46.

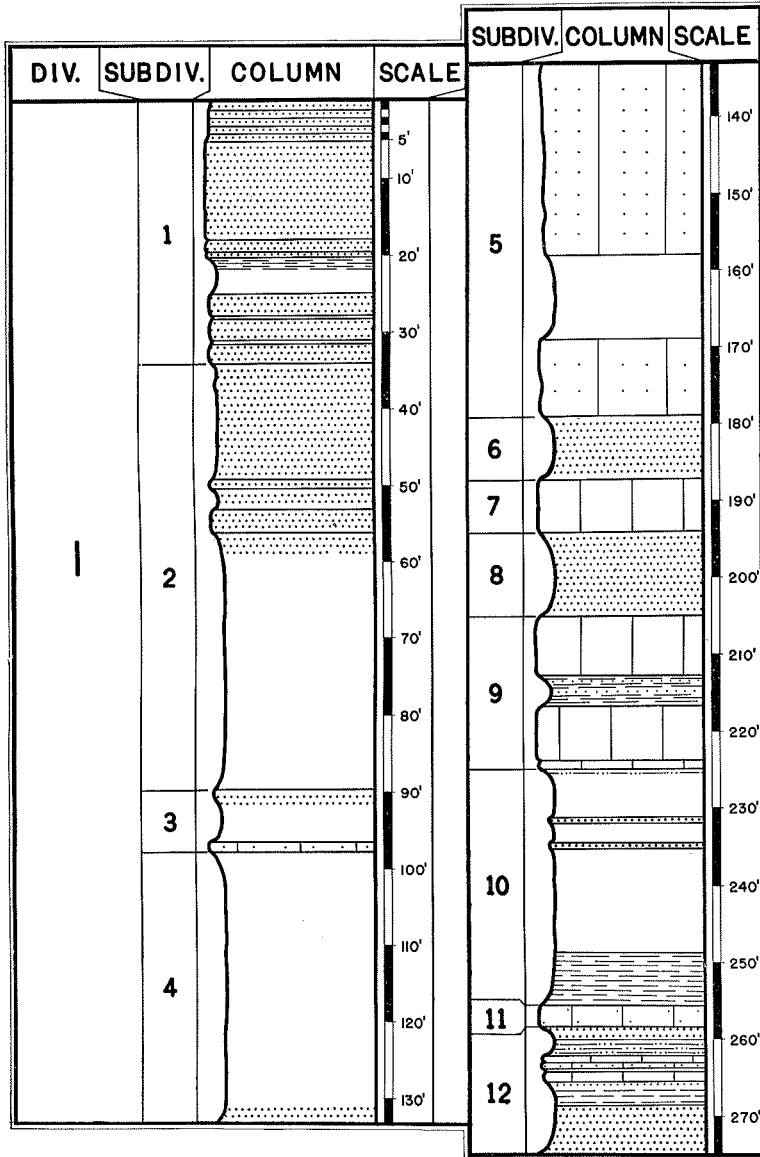


FIGURE 16.—Composite columnar section of Division I, measured in ravine three miles northeast of Cassa (Station 15).

series of red quartzites immediately below the Opeche shale, southwest of Douglas, Wyoming.

Northeast of Cassa. The full thickness of Division I is exposed at Station 15 in the region northeast of Cassa. This section is graphically shown in Figure 16. Partial sections of this division were measured at Station 10, 4 miles east of Wendover, and at Station 17, 6 miles north of Glendo. A section of the beds of Division I, exposed in a ravine three miles northeast of Cassa, is as follows:

1. Largely yellow-buff sandstone, forming a low hog-back ridge, 33' 10":
 - (1) Sandstone, yellow-buff, friable, thin-bedded, 5'.
 - (2) Sandstone, yellow-buff, friable, massive, 12' 10".
 - (3) Sandstone, as above but containing many small brown iron concretions, 1' 6".
 - (4) Sandstone, yellow-buff, friable, massive, 8".
 - (5) Shale, medium gray, weathers yellow-buff, in part filled with small brown iron concretions, badly covered in lower three feet, forms reentrant, 4' 10".
 - (6) 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'.
2. Sandstone, red, soft, with some more resistant beds, 55':
 - (1) Sandstone, red, streaked with dark red, massive, soft, with a more resistant layer 2' 2" below the top, 15' 2".
 - (2) Sandstone, red, mottled with light gray, forms a rounded ledge, 10" to 1'.
 - (3) Sandstone, red, massive, soft, 2' 10".
 - (4) Sandstone, red, fairly hard, forms a ledge, 3'.
 - (5) Covered, except for upper 5 feet which is sandstone, red, shaly, soft, 33'.
3. Poorly exposed interval, 8':
 - (1) Sandstone, yellow-buff, friable, massive, 1' or more.
 - (2) Covered interval, 6'.
 - (3) Limestone, medium gray to lavender, hard, slightly silty, 1'.
4. Covered interval with red friable sandstone at base, 36'.
5. Siltstone, massive, 52':
 - (1) Siltstone, light gray to pink and red-stained, calcareous, very massive, heterogeneous, grades from limestone to sandstone, with occasional included angular cobbles of limestone and siltstone, locally cavernous, 30'.
 - (2) Siltstone, as above, but including more limestone cobbles, 22'.
6. Siltstone-sandstone, pink to red, calcareous, massive, with scattered limestone cobbles, heterogeneous, forms slight reentrant, 14'.
7. Limestone, forms a prominent ledge, 7':
 - (1) Limestone, medium light gray, occasionally pink-stained, slabby to thin-bedded, 1' 6".
 - (2) Limestone, medium light gray, massive, part geodal, 5' 6".
8. Sandstone, red, soft, with some included siltstone pebbles and limestone boulders (small), 10'.
9. Limestone in two heavy beds separated by shale, 26' 8":
 - (1) Limestone, medium light gray, pink-stained, silty, slabby to thin-bedded, 14'.
 - (2) Shale, red and gray mottled, with occasional sandy seams, 4'.

- (3) Limestone, medium light gray, silty, massive, weathers light gray, 8' 8".
- 10. Covered interval, probably soft red sandstone and shale, 18' 6".
- 11. Limestone, light gray, pink-stained, some small limestone pebbles, forms ledge, 2' 6".
- 12. Sandstone, red, soft, massive, lower 15' covered, 18'.

NOTE: The top of Division II is exposed next below bed No. 12, at this station.

Broom Creek Section. In the lower part of Broom Creek (station 10) the lower 140 feet of Division I are exposed. This region is generally synclinal and the attitude of the beds is almost horizontal. The following beds correlate with beds 5 to 12 inclusive, of the preceding section:

- 1. Siltstone, forms rounded hills, 53' 6":
 - (1) Siltstone, pinkish-gray, very calcareous, heterogeneous, grades from limestone to sandstone, very massive, in part cavernous and geodal, with some red to pink calcareous sandstone on top, 24' 6".
 - (2) Covered interval, 11'.
 - (3) Siltstone, pinkish-gray, very calcareous, very massive, heterogeneous, 10'.
- 2. Limestone, light gray, stained pink, very silty, rather heterogeneous, massive, 7'. (Correlates with No. 7, northeast of Cassa.)
- 3. Covered slope, 11'.
- 4. Limestone, (Correlates with No. 9, northeast of Cassa), 19' 6":
 - (1) Limestone, medium gray, weathers light gray, silty, massive, locally contains angular cobbles of limestone, 7' 6".
 - (2) Covered interval, probably shale and sandstone, 4'.
 - (3) Limestone, medium gray, weathers light gray, geodal, a heavy bed except for basal 8" which separates as a singly blocky bed, 8'.
- 5. Sandstone and shale, soft, with some more resistant layers, 30' 9":
 - (1) Shale, greenish-gray, very sandy, lower 5' covered, 6' 6".
 - (2) Sandstone, pink and gray mottled, calcareous, fine-grained, forms ledge, 6".
 - (3) Covered interval, probably soft sandstone, 2' 9".
 - (4) Sandstone, green-gray, calcareous, fine-grained, forms a rounded ledge, 6".
 - (5) Covered slope, probably soft sandstone, 13' 6".
 - (6) Shale, red, slightly sandy, platy, 7'.
- 6. Limestone, light gray, speckled with black, pink-stained, irregular in texture, forms a prominent ledge, a single bed, (Correlative with No. 11, northeast of Cassa), 2' 4" to 2' 7".
- 7. Sandstone, shale, and some limestone, 16':
 - (1) Sandstone, gray to pinkish, soft, friable, 1' 8".
 - (2) Sandstone, shaly, to sandy shale, red, jointed, geodal, breaks out in long angular pieces parallel to bedding, 2' 4".
 - (3) Siltstone and limestone, often exposed as a ledge, 3':
 - a. Siltstone, red, calcareous, pitted, a single bed, 8".
 - b. Limestone, light gray, weathers light buff, hard, pitted, with some small crinoid joints, a single bed, separated from a. above by a thin shale, 9".
 - c. Shale, medium gray to red, with thin silty lenses, 2" to 3".
 - d. Siltstone, yellowish-gray, calcareous, a single bed, 1' 4".
 - (4) Shale, red, sandy, laminated, breaks out in small flat pieces, contains a 2 to 4 inch bed of red and gray soft sandstone at the top, 3'.

(5) Sandstone, red, friable, thinbedded to massive, 6'.

NOTE: The uppermost beds of Division II occur next below bed 7 (5) in this locality, rimming the small canyon of Broom Creek.

Northwest of Glendo. The lower 140 feet of Division I is in the upland east of the North Platte River canyon (station 17), six miles north-northwest of Glendo. Here the beds are dipping gently to the southeast. The section is as follows:

1. Quartzites and covered slope, 26':
 - (1) Slope covered to hill top where red medium-bedded quartzite is exposed, 8'.
 - (2) Quartzite, pink to red, hard, in upper foot, with covered slope below, 18'.
2. Quartzite, red, massive to cross-bedded, locally grading to sandstone, forms a small cliff along hill-side, 20'.
3. Covered slope, 27'.
4. Sandstone, 11' 3":
 - (1) Sandstone, red to pink, weathers dark reddish-brown, quartzitic, forms a resistant ledge, 4' 6".
 - (2) Sandstone, pink, friable, massive, forms a reentrant, 4' 3".
 - (3) Sandstone, pink, with some gray mottling, hard, calcareous, conglomeratic (limestone pebbles, $\frac{1}{2}$ " to 6" in diameter), irregular uneven base, 2' 6".
5. Limestone, forms a ledge, (probably correlative with No. 7, northeast of Cassa), 5' 8" to 6':
 - (1) Limestone, medium gray to light gray, separates in 2" to 6" beds, 3'.
 - (2) Limestone, medium light gray, weathers light gray, silty, breaks in small angular pieces, forms a slight reentrant, 8" to 1'.
 - (3) Limestone, medium light gray, weathers light gray, geodal in part, massive except for basal 4" which is a gray to pink blocky bed, 2'.
6. Poorly exposed reentrant: upper foot is medium gray shale, grading to red at the top; underlain by a foot or more of a heterogeneous mixture of fine-grained pink sandstone and pebbles and cobbles of limestone; lower part covered, 4' 9".
7. Limestone, light gray to pinkish, massive, in part geodal, with angular pebbles and cobbles of limestone and chert; lower foot pink in color and occurs as a separate bed (probably correlative with No. 9 (1), northeast of Cassa), 6' 6".
8. Sandstone, shale, and silty limestone, 6':
 - (1) Sandstone, light gray and brown mottled, soft, friable, forms a reentrant, 8".
 - (2) Sandstone, pink to light gray, fine-grained, in part cross-bedded, 1'.
 - (3) Shale, medium gray with some yellow ferruginous bands, sandy, reentrant, 1'.
 - (4) Limestone, light gray to pink, very silty, 6".
 - (5) Sandstone, pink to red, friable, thinbedded, forms a reentrant, 2' 9".
9. Limestone, probably correlative with No. 9 (3) northeast of Cassa, 4' 8" to 5' 2":
 - (1) Limestone, light gray to pinkish, very silty, slabby, 1' to 1' 6".
 - (2) Limestone, purple to red, in part light gray, massive, scattered geodes, occasional nodules of red chert, sandy at top, silty throughout, uneven base, 3' 8".

10. Covered slope; upper 3' contains angular pieces of limestone and chert in a silty-limy-sandy matrix, pink in color and massive, 19' 6".
11. Limestone, purple, red, and light gray, irregularly pebbly, uneven base, forms a ledge (correlative with No. 11, northeast of Cassa), 3'.
12. Sandstone, 4' 6" to 5' 10":
 - (1) Sandstone, red, massive, friable, with a 10" pink and gray calcareous sandstone bed 1' to 2' below the top, 3' 10" to 4' 10".
 - (2) Sandstone, red to purple, pebbly, calcareous, with some small geodes, base uneven, more resistant than above, 8" to 1'.

Discussion. The thin members of Division I are generally persistent, especially those in the lower part. Six miles north-northwest of Glendo, however, there are red quartzites at the top of the section which are different from any part of this division in the region between Guernsey and Cassa. The rocks numbered 1 to 4 in the preceding section are believed to correlate with beds 5 and 6 northeast of Cassa and their difference is thought to be due to lateral gradation. At Station 10 (4 miles east of Wendover) this interval consists of beds which are very calcareous and light gray to pink to red in color. This condition suggests a transition from silty limestones and calcareous siltstones to red quartzites. It is interesting to note that this rock at Station 10, although chemically a limestone, is genetically a siltstone.

No fossils were found in Division I. For this reason the authors hesitate to assign it to either the Pennsylvanian or Permian. The change in lithology from the dominant limestones of Division II, below, to the red bed and limestone type of Division I, above, suggest that Division I of the so-called Hartville formation may belong to the Permian. Where the contact between Division I and II is clearly seen there is some evidence of unconformity and pebbles and cobbles of limestone, which may have been derived from Division II, are sometimes found in Division I.

MINNEKAHTA LIMESTONE AND OPECHE SHALE

The Minnekahta limestone and Opeche shale are exposed only along the west-northwest flank of the uplift. Here the beds dip westward at 20 to 25 degrees. The Minnekahta limestone forms a pronounced low "hog-back" ridge which is separated from the higher topography of the "Hartville formation" by a narrow valley formed on the Opeche shale outcrop.

The detailed section of these beds, measured at Station 15 (3 miles northeast of Cassa), is as follows:

1. Minnekahta limestone, 27' 9":
 - (1) Limestone, yellowish-gray, argillaceous and silty, thin-bedded, less resistant than underlying beds, 12' 6".
 - (2) Limestone, dense, 13':
 - a. Limestone, medium dark gray to purplish-red, very dense, platy, in thin 1½" to 8½" beds, 1' 10".

- b. Limestone, as above, a single bed, 1' 3".
- c. Limestone, dark gray to purplish-red, dense, platy, thinbedded, 9' 11".
- (3) Limestone, two beds, separated by shale, 2' 3":
 - a. Limestone, dark gray to purplish-red with light gray bands, thinbedded, 1'.
 - b. Shale, red, calcareous, 1" to 2".
 - c. Limestone, gray, dense, weathers light yellowish-gray, 1' 1".
- 2. Opeche shale, 60':
 - (1) Sandstone and sandy shale, 16' 6":
 - a. Sandstone, dark red, slightly argillaceous, soft, massive, 10'.
 - b. Shale, brick red, sandy, massive, 6' 6".
 - (2) Sandstone, 4' 8":
 - a. Sandstone, light gray to pink, slightly argillaceous, calcareous, lower foot reddish and very argillaceous, 3'.
 - b. Sandstone, gray, often pink-stained, relatively hard, transitional at base, forms a rounded ledge, 1' 8".
 - (3) Shale and sandstone, about 39':
 - a. Shale, red, slightly sandy, some thin beds of gray to red sandstone in upper part, 10'.
 - b. Covered slope, about 29'.

Discussion. The above-described beds are very similar to the Minnekahta limestone and Opeche shale of the Black Hills region, where they are believed to be Permian in age.

The contact between the Minnekahta limestone and overlying Spearfish formation is transitional. It is probable that the lower part of the Spearfish is Permian in age and that the Permian-Triassic contact occurs within the Spearfish formation as now defined.

REGIONAL CORRELATION

The Minnekahta and Opeche formations of this area are identical, lithologically, to the units bearing the same names in the Black Hills, where they have been determined as Permian in age. It appears that the Minnelusa formation of the Black Hills is correlative with the "Hartville formation". At Loring Siding, in the southwestern part of the Black Hills, all of the above described divisions of the "Hartville formation" were observed to be present, overlying the Pahasapa limestone, and overlain by the Opeche shale.

Unfortunately no fossils were found in Division I of the "Hartville formation" and, as far as we know, it may be either Pennsylvanian or Permian in age. In some localities the contact between Divisions I and II appears to be unconformable and some of the beds in Division I include fragments and angular blocks of limestone which seem to have been derived from the limestones of Division II.

Divisions II, III, IV, and V are fossiliferous and certainly Pennsylvanian in age. Missouri and Virgil series fossils were found in Division

II. The presence of *Triticites cullomensis*, 44 feet below the top at Station 17 and 56 feet below the top at Station 9, suggests a general correlation of that bed with the Leocompton-Emporia interval, in the Nebraska-Kansas area. *Triticites pygmaeus* occurs 107 feet below the top in the vicinity of Lake Guernsey and *Triticites exiguus* was found 154 feet below the top, near Wendover. These fusulines are representative of the Virgil and Missouri series, in southeastern Nebraska. It is notable that all three of these forms preserve the same relative positions in the Hartville area as in the Nebraska-Kansas area.

Fusulina hartvillensis, *Fusulina tregoensis*, *Fusulina* sp. (similar to *F. rockymontanus*) and *Fusulinella* sp. occur in Division III. These species are thought to belong to the Des Moines series of the Mid-Continent Region. The lithologic similarity of Divisions II and III suggests that no great time interval occurred between the deposition of these two subdivisions.

Division IV is of Des Moines age. The presence of *Wedekindellina* sp. near the middle of this division suggests Cherokee age and the lithology is generally similar to that of the Cherokee in other areas. Division V may be Cherokee or older. As stated before, the marked erosional unconformity at the base of Division VI and the slight irregularity at its top suggests that Division VI is Pennsylvanian rather than Mississippian in age. It might be held, however, that the Mississippian-Pennsylvanian break is at the top of Division VI. The contact between Divisions V and VI shows relief of several feet in places but this feature may be entirely depositional and is not conclusive evidence of an important unconformity.

CONCLUSIONS

1. The Minnekahta and Opeche formations of the Hartville area are of Permian age.
2. The "Hartville formation" has a thickness of about 930 feet in this area instead of 650 feet, as previously reported. It includes six major subdivisions, each with group ranking.
3. Division I ("Hartville formation") is Permian in age.
4. Division II, for the most part, is correlative to the Virgil and Missouri series of the Pennsylvanian.
5. The fusulines of Division III suggest a correlation with Marmaton group.
6. Division IV seems to correlate with Cherokee beds of the Mid-Continent Region and Division V seems to be Cherokee or yet older Pennsylvanian.
7. The stratigraphic relationships of Division VI suggests lower Pennsylvanian age.

8. The six divisions of the so-called Hartville formation are persistent in the entire area and their units are traceable for considerable distances.
9. Much of the "Hartville formation" is of Des Moines age.

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