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at the sutures by the prominence of the middle portion of each basal piece; column-facet large; first radial pieces nearly equal in size with the basals, and, with that exception, they are the largest pieces in the body; second and third radials about equal to each other in size, and not more than half as large as the first radials; each third radial piece bearing two secondary rays consisting of two pieces each, both of which are smaller than the second and third radials; each second secondary radial piece bearing two brachial pieces, and each brachial piece giving origin to an arm, making twenty arms in all.* Arms long and slender, and above the first four or five brachial pieces, which are single, they are composed of a double series of minute pieces which meet along the median line of the arm, forming there a zigzag suture. Anal pieces eight or nine; the first one being of about the same size as the first radials; the next three pieces above are about half as large as the first, and above these the other pieces are quite small; interradial pieces three or four, the first one being somewhat larger than the second radials, and occupying about half the interradial space. Vault convex or subconical, more than half as high as the height of the body below the arms, composed of irregular pieces of moderate size, all of which are more or less sharply tumid in the middle, and ending at the summit in a long, strong proboscis, which is composed of similar sharply tumid pieces. All the body plates are strongly tumid, the lower ones bearing each a strong transverse projection.

The specific name is given in honor of Mr. Charles Wachsmuth, whose excellent labors among the Crinoidea are well known.

Position and locality.—Subcarboniferous strata probably equivalent with those of the Keokuk division, Crawfordsville, Ind., where it was obtained by Mr. William Gurley.

Genus LEPIDESTHES Meek & Worthem.

LEPIDESTHES COLLETTI White.

Plate 40, figs. 2 *a* and *b*.

Lepidesthes colletti White, 1878, Proc. Acad. Nat. Sci. Philad., p. 33.

General form apparently ovate. Interambulacral areas very narrow, linear, slightly convex from side to side, composed of four or five rows of small pieces, which rows do not apparently decrease in number, except perhaps near each extremity. Ambulacral areas broad, partaking of the convexity of the body, lance-oval in outline, and five or six times as broad as the interambulacral areas are. Ambulacral areas made up of very numerous small rhombic pieces, the transverse diameter of which is a little greater than the vertical; their lateral angles moderately acute, and interlocking so that they appear to be arranged in oblique rows; size of the pieces nearly uniform throughout the field, except that they all become a little smaller near both the upper and lower extremities. The number of vertical rows of pieces in each field is apparently 18 or 20. Each ambulacral piece has two distinct round pores near each other and near the upper angle of the piece; but they are sometimes obscured by the overlapping of adjacent pieces. Surface granules small, more distinct upon the interambulacral than upon the ambulacral pieces.

Two examples of this species have been discovered, both of which are

* The example represented by fig. 1 *b* on plate 40 has an extra arm-base immediately over the center of the anal space, and it also has an extra basal piece about one-third as large as each of the other three basal pieces.

crushed and otherwise in a much damaged condition. The best example, which is represented by fig. 2 *a* on plate 40, shows that the original height of the body was about 45 millimeters, and its transverse diameter probably considerably less.

The crushed condition of the specimens causes some doubt as to the true number of longitudinal rows of interambulacral pieces, but they evidently do not exceed five. There seems to be only four rows to each area, one row of comparatively large pieces, with two smaller rows upon the right-hand side of it, and one row on the left. This want of bilateral symmetry of the best preserved area in the example figured suggests the possibility that one row of smaller pieces on the left-hand side of the row of larger ones has been forced beneath the others by pressure, but a careful examination fails to demonstrate it.

This species is clearly distinguished from *L. coreyi* M. & W., the only other known species of the genus, by the very much narrower interambulacral areas, the different and varying proportions of the pieces composing those areas, as well as some other important but less conspicuous differences.

Position and locality.—Subcarboniferous strata, probably equivalent with those of the Keokuk division, Salem, Washington County, Ind.

MOLLUSCA.

(MOLLUSCOIDEA.)

BRACHIOPODA.

(Genus ORTHIS Dalman.)

ORTHIS THIEMEI White.

Plate 41, figs. 4 *a*, *b*, *c*, and *d*.

Orthis thiemei White, 1860, Jour. Bost. Soc. Nat. Hist., vol. vii, p. 231.

Shell depressed, orbicular, usually a little wider than long, widest in front of the middle; hinge line short. Dorsal valve deeper than the ventral valve, regularly convex, with the general exception of a very shallow median sinus which extends from front to about midlength of the shell where it becomes obsolete; beak projecting a little beyond the hinge line and slightly curving towards the beak of the opposite valve; cardinal process strong, with a strong blunt-edged median septum extending from it nearly half the length of the valve; brachial processes strong, slightly notched at the ends; margin crenulate in front.

Ventral valve convex near the umbo, depressed in front, which, with the depression on the opposite valve, considerably flattens the front border; beak short, elevated and incurved, leaving but little space between the two beaks when both valves are in position; width and height of foramen about equal, nearly filled by the strong cardinal process of the dorsal valve; muscular cavity large, heart-shaped, with a more or less distinct forked septum occupying its middle.

Surface marked with fine raised striæ, which have occasional minute tubular openings upon them; the striæ increasing in number by implantation, and traversed by the ordinary striæ of growth and a few coarser imbricating lines.

Length from 10 to 14 millimeters.

This shell is somewhat variable in the convexity of the dorsal valve, the distinctness of the dorsal sinus, and the strength of the cardinal and brachial processes.

Position and locality.—The upper portion of the Kinderhook division of the Subcarboniferous series at Burlington, Iowa. A closely similar form exists in the upper portion of the Burlington limestone, and another in the Keokuk division, but they are at present regarded as distinct.

Genus RHYNCHONELLA Fischer.

RHYNCHONELLA OTTUMWA White.

Plate 41, figs. 5 *a*, *b*, and *c*.

Rynchonella ottuwma White, 1862, Proc. Bost. Soc. Nat. Hist., vol. ix, p. 23.

Shell rather small, variable in outline from subtriangular to subovoid; valves nearly equally convex. Ventral valve regularly convex along the middle from beak to front, broadly convex across the middle from side to side; beak prominent, projecting backward and with an upward curve; the space beneath it a little flattened, which gives it somewhat the appearance of an area; deltidial pieces occupying a rather large equilateral triangular space, with a moderately large, oval foramen. Dorsal valve broadly convex, umbo depressed. Surface marked by from nine to eleven somewhat angular plications on each valve, which are absent or become obsolete on the posterior third of the shell; two of these plications occupy the mesial sinus of the ventral valve and three of them the mesial fold of the dorsal valve; the mesial sinus is deep, and forms a more conspicuous feature than the mesial fold. Young examples of this shell are nearly plain, but the plications on the older ones are well marked.

Length from ventral beak to front, 12 millimeters; greatest breadth, which is in front of the middle, about the same.

Position and locality.—Saint Louis division of the Subcarboniferous series, Ottumwa, Iowa, and various other localities in Iowa, Illinois, and Missouri.

Genus SPIRIFER Sowerby.

SPIRIFER SUBCARDIIFORMIS Hall.

Plate 41, figs. 2 *a*, *b*, and *c*.

Spirifer subcardiiformis Hall, 1858, Iowa Geol. Rep., vol. i, part ii, p. 660.

Shell subelliptical in marginal outline, a little wider than long; hinge line shorter than the greatest width of the shell. Dorsal valve a little less convex than the ventral, its beak somewhat prominent and projecting beyond the hinge line; mesial fold rather broad in front, slightly elevated, marked by four plications which all coalesce at the beak; a very slight elevation appears in the bottom of the groove which separates the two middle plications of the fold, and the two grooves which separate the fold from the lateral portions of the valve are broader than any of the others; from seven to nine simple, rounded plications mark the space on each side of the fold, the inner ones being strong and the outer ones becoming obsolete. Ventral valve having its beak prominent, incurved, and projecting back further than that of the dorsal valve; mesial sinus broad, not deep, bearing three plications; from seven to

ten plications on each side of the mesial sinus, which correspond in character with those upon the other valve; the postero-lateral portions of the valve rounded into the area, which is very short and its limits ill-defined; foramen moderately large, triangular, and nearly equilateral.

Length from ventral beak to front, 28 millimeters; greatest breadth, 32 millimeters; greatest thickness, both valves together, 18 millimeters.

This species was originally described from an imperfect example which was obtained from the Warsaw limestone near Alton, Ill. Among a collection of fossils obtained by Mr. William Gurley, from equivalent strata at Spergen Hill, Ind., is a more perfect example, which has served as the basis for the description and illustrations herein given.

Position and locality.—Subcarboniferous strata, Warsaw division, Alton, Ill., and Spergen Hill, Monroe County, Indiana.

(MOLLUSCA VERA.)

CONCHIFERA.

Genus ANTHRACOPTERA Salter.

ANTHRACOPTERA POLITA (sp. nov.).

Plate 42, figs. 5 *a* and *b*.

Shell rather small, aviculoid, moderately gibbous, height greater than the breadth from front to rear; test thin; valves subequal; hinge margin short, straight, terminating posteriorly in a somewhat obtusely angular wing, but not extending in front of the beaks; basal and front margins forming a nearly regular curve from beneath the beaks to the postero-basal extremity, which is more narrowly rounded; between that extremity and the posterior angle of the wing the margin is slightly concave; umbo prominent, or having the appearance of being somewhat inflated; beak elevated a little above the hinge line; the ear is distinct, but no well-defined auricular groove separates it from the body of the shell in either valve. Surface having a smooth aspect, but it is marked by numerous fine lines of growth, which are plainly visible under a lens.

Height from base to hinge line, 20 millimeters; length from umbo to posterior basal extremity, 24 millimeters.

This shell seems evidently referable to *Anthracoptera* of Salter, although nothing is known of the character of its hinge or of its interior markings. It differs too materially from any known species to need detailed comparison.

Position and locality.—Coal-measure strata, Major's Mill, Vermillion County, Ill., where it was discovered by Mr. William Gurley.

Genus ASTARTELLA Hall.

ASTARTELLA GURLEYI White.

Plate 42, figs. 6 *a* and *b*.

Astartiella gurleyi White, 1878, Proc. Acad. Nat. Sci. Philad., p. 35.

Shell small, not very gibbous, subtetrahedral in outline; anterior end truncated from the beaks obliquely downward and forward to about

midheight of the shell, where the front is sharply rounded to the somewhat broadly rounded basal margin; posterior margin broadly convex or sometimes almost straight and perpendicular, and joining both the basal and dorsal margins by abrupt curves; dorsal margin comparatively short, nearly straight; beaks small; umbones not elevated nor very prominent. An indistinctly defined umbonal ridge extends from each of the umbones to the postero-basal margin, behind which ridge the shell is slightly compressed. Surface marked by concentric furrows, which are separated by sharp linear ridges.

Length of an average-sized example, 7 millimeters; height from base to beaks, 4½ millimeters.

This species differs from *A. vera* Hall, from the same formation, in its smaller size, in the slight prominence and want of elevation of the umbones, the greater proportional projection of the front beyond the beaks, and in being wider behind than in front, the reverse being the case with *A. vera*.

Position and locality.—Coal-measure strata, Danville, Ill., where it was obtained by Mr. William Gurley.

Genus ALLORISMA King.

ALLORISMA MARIONENSIS White.

Plate 41, figs. 3 *a* and *b*.

Allorisma marionensis White, 1876, Proc. Acad. Nat. Sci. Philad., p. 31.

Shell small, elongate, ventricose anteriorly, and laterally flattened behind, where it is usually a little broader from base to dorsal margin than the anterior portion is; umbones prominent, elevated; beaks incurved, placed far forward; dorsal margin straight or slightly concave; postero-dorsal margin sloping backward to the posterior extremity, the greatest prominence of which is at, or a little below, midheight of the adult shell; base broadly rounded or straightened about midway, where the slight umbonal flattening of each valve meets it. Surface marked by the ordinary concentric lines and undulations of growth.

Length, 28 millimeters; height, 13 millimeters. A few examples have been obtained which are about one-third larger than that of which the dimensions are here given, but it is an unusually small species.

Position and locality.—Saint Louis division of the Subcarboniferous series, Marion and Mahaska Counties, Iowa, where it sometimes occurs quite plentifully in both the calcareous and magnesian layers of that formation.

GASTEROPODA.

Genus EUOMPHALUS Sowerby.

EUOMPHALUS SPRINGVALENSIS White.

Plate 41, figs. 1 *a* and *b*.

Euomphalus springvalensis White, 1876, Proc. Acad. Nat. Sci. Philad., p. 32.

Shell rather large; spire much extended for a species of this genus; volutions six or seven, gradually increasing in size from the apex to the aperture; moderately flattened upon the distal or upper side, regularly

and continuously rounded from that side all the way around to the contact with the next volution; aperture therefore nearly circular, its outline being modified only by the slight flattening of the distal side of the volutions and their short contact with each other.

Length, or height, about 55 millimeters; breadth of coil of last volution, 70 millimeters; diameter of aperture, 23 millimeters.

Position and locality.—Kinderhook division of the Subcarboniferous series, Springvale, Humboldt County, Iowa.

Genus PLATYCERAS Conrad.

PLATYCERAS TRIBULOSUM (sp. nov.).

Plate 41, figs. 6 *a* and *b*.

Shell of medium size, very obliquely and rudely conical, curved but not coiled; apex free, slender, pointed, incurved, and turned a little to the left side; body expanded; aperture very irregular in marginal outline, expanded in front, narrower behind, and having a prominent double lobe beneath the umbonal portion of the shell. Surface marked by the ordinary lines of growth, and also by three longitudinal rows of hollow spines arranged upon the dorsal aspect of the shell, the rows extending back more than half the length of the shell and containing five or six spines each.

Length of the shell from beak to front margin, 28 millimeters; breadth of its aperture, 21 millimeters.

This species is especially characterized by its spines, arranged in three rows, and the irregular character of its margin. It differs too much from any described species to need detailed comparison, but it may be compared with the two spinous species, *P. biserialis* Hall, from the same formation, and *P. dumosum* Conrad, from the Devonian rocks of New York.

Position and locality.—Burlington limestone division of the Subcarboniferous series, Burlington, Iowa, where it was obtained by Mr. Charles Wachsmuth.

Genus NATICOPSIS McCoy.

NATICOPSIS MONILIFERA (sp. nov.).

Plate 42, figs. 3 *a*, *b*, and *c*.

Shell small, subglobose; spire short, obtuse, and its immediate apex flattened; volutions about six, but the apical ones are very small, the last one coustituting the greater part of the shell, broadest upon its basal or proximal portion, the proximal side of which is somewhat abruptly rounded inward to the aperture; the small volutions of the apex are plain, but upon the distal border of the two last ones, adjacent to the suture, there is a conspicuous row of small nodes, constituting a pretty ornamentation of the shell; the remainder of the surface is smooth and has a polished aspect, upon which a good lens reveals fine striæ of growth; aperture suboval in outline; inner lip having a distinct callus, especially in front; outer lip thin, its border sinuate, having an almost distinct notch just in front of the row of nodes.

Extreme length, 10 millimeters; extreme diameter of the last volution nearly the same.

Position and locality.—Upper Coal Measures, Pleasant Hill, Cass County Mo., where it was obtained by Prof. G. C. Broadhead.

Genus PLEUROTOMARIA Defrance

PLEUROTOMARIA BROADHEADI (sp. nov.).

Plate 42, figs. 1 *a* and *b*.

Shell large, narrowly umbilicated; spire somewhat extended, its length not quite half the full length of the shell; volutions about seven, strongly convex from suture to suture, gradually increasing in size; last volution large, somewhat produced on its proximal side, especially near the aperture, and abruptly rounded in to the umbilicus, but otherwise regularly convex; aperture subovate in outline, angular at its proximal end, straight upon its inner side; the straight inner lip thin, its edge ranging in line with the axis of the shell, so curved laterally as to give continuity to the narrow umbilicus almost to the proximal extremity of the last volution; outer lip sinuous, its notch small and shallow, situated at about the middle of the prominent convexity of the lip; revolving band narrow and somewhat obscure. Surface marked by numerous slightly impressed revolving lines, which are more distinct upon the proximal than upon the distal side of the spiral band, and still more distinct within and upon the borders of the umbilicus; spaces between the depressed lines narrow, plain, and somewhat unequal in width.

Full length, 88 millimeters; length of aperture, 50 millimeters; breadth of the same, 49 millimeters; full diameter of the last volution, including aperture, 75 millimeters.

This large, fine shell differs too materially from any of the numerous forms of *Pleurotomaria* that have been obtained from the Carboniferous strata to need detailed comparison.

Position and locality.—Coal Measure limestone, Kansas City, Mo., where it was obtained by Prof. G. C. Broadhead, and in whose honor the specific name is given.

PLEUROTOMARIA NEWPORTENSIS (sp. nov.).

Plate 42, figs. 2 *a* and *b*.

Shell of medium size; spire moderately short, less in height than the vertical diameter of the aperture; volutions about five, regularly and prominently convex from suture to suture, gradually increasing in size; the last volution continuously rounded from the suture to the axial center; aperture subcircular in outline, its margin oblique; outer lip having a broad notch a little above its middle, at the bottom of which the spiral band ends; inner lip apparently thickened; spiral band consisting of an elevated, narrow, roughened ridge, which is either wholly or partly obscured upon the volutions of the spire by the subsequent volutions. Surface marked with numerous, somewhat irregular, raised revolving lines, the concave spaces between which are somewhat wider than the lines.

Extreme height of the shell, 39 millimeters; height of aperture, about 25 millimeters; transverse diameter about the same; extreme transverse diameter of the shell, 39 millimeters.

This shell resembles *P. carbonaria* Norwood & Pratten, but it differs in having its revolving band simple and raised instead of concave, with revolving lines within it, as in that species; and also in having its aperture subcircular instead of nearly semicircular.

Position and locality.—Coal Measure strata, Newport, Ind., where it was obtained by Mr. William Gurley.

PTEROPODA.

Genus CONULARIA Miller.

CONULARIA CRUSTULA (sp. nov.).

Plate 42, fig. 4 *a*.

Shell rather small, having the usual four-sided pyramidal form; the four sides being equal, and flat or nearly so near the apex, but slightly convex towards the aperture; the four angles distinctly furrowed, and a slender furrow also marks the median line of each side, which furrow is more distinct upon the cast of the interior of the shell than upon the external surface of the test. Surface marked by the numerous transverse raised striæ common to this genus, which arch gently forward from each of the four angles; the majority of the striæ are continuous across the median line of the sides, and also across the angle-furrows, in crossing which they bend slightly backward.

Length, 31 millimeters; diameter of aperture, about 16 millimeters.

This shell is closely like several other known forms, but it possesses peculiar interest from the fact that it is the only species known to me to occur in the Coal Measure strata of the Mississippi Valley, although several species are known in the Subcarboniferous strata of that region. It is, therefore, the most recent known American species, and adds to our knowledge another feature of close relationship between the faunæ of the upper and lower Carboniferous series.

Position and locality.—Coal Measure strata near Kansas City, where it was obtained by Professor Broadhead. Among some Carboniferous fossils brought by Prof. E. D. Cope from near Taos, New Mexico, are a couple of fragments apparently of this species.

CEPHALOPODA.

Genus NAUTILUS Breynius.

NAUTILUS DANVILLENSIS White.

Plate 42, fig. 7 *a*.

Nautilus danvillensis White, 1878, Proc. Acad. Nat. Sci. Philad., p. 36.

Shell moderately large; umbilicus deep but not very broad, showing all the volutions, at least in large part; volutions apparently four, increasing rapidly in size, very slightly embracing, subtrihedral in cross-section, the two sides of the volution forming two sides of that outline, while the inner side of the volution forms its third principal side; sides of the volution plain, nearly flat or slightly convex; peripheral side very narrow, concave, and marked at either edge, where it joins the side, by a row of longitudinally compressed nodes. The sides are rounded abruptly into the umbilicus, which is unusually deepened by the transverse diameter of the volutions being greater at the inner side than elsewhere. Septa plain, somewhat deeply concave dorso-ventrally, but less so transversely; siphuncle subcentral, a little nearer to the peripheral than to the inner side. Surface smooth except the ordinary lines of growth and the two rows of dorsal nodes before referred to. Test thin.

The only discovered specimens of this species being crushed or otherwise imperfect, it has not been practicable to illustrate it by any other figures than the transverse section given on plate 42, although the characters above given have been well ascertained. The exact form of the aperture, however, is not accurately known, but the lines of growth show the lateral margins to have been sigmoid or sinuous, and the peripheral margin concave. These lines also indicate that the aperture was oblique to the diameter of the plane of the shell, the peripheral portion retreating and the inner projecting.

Transverse diameter of a volution of less than full adult size from edge to edge of the umbilicus, 40 millimeters; width of its sides, 50 millimeters; breadth of peripheral side, 16 millimeters; the full diameter of the plane of the largest example discovered, about 130 millimeters.

The narrow concave periphery, with its two marginal rows of compressed nodes, and the plain, flattened sides of the volutions, which expand towards the umbilicus, are characters which distinguish this species from all others known to me.

Position and locality.—Coal Measure strata, Danville, Ill., where it was obtained by Mr. William Gurley.

ARTICULATA.

VERMES.

Genus SERPULA Linnæus.

SERPULA INSITA White.

Plate 42, fig. 8 *a*.

Serpula insita White, 1878, Proc. Acad. Nat. Sci. Philad., p. 37.

Scattered through an earthy, Carbonaceous layer of Coal Measure strata at Newport, Vermillion County, Ind., are abundant examples and fragments of a very small *Serpula*, which evidently burrowed in the mass when it was in the condition of mud. Also sessile upon some imbedded molluscan shells are found occasional nearly perfect examples of the same species. The species of the genus *Serpula* are so devoid of distinguishing characteristics that a specific diagnosis is often difficult or impossible. This species, however, is not likely to be mistaken for any other, because of its very small size, and because no other form has been recognized in the strata of that age in that region. It is here named, mainly, for the purpose of aiding in the classification of the rich fauna of the Carboniferous rocks. The species may be characterized as minute, sessile or free, tortuous, and subcylindrical.

PLATE 39.

Page.

FIG. 1. MICHILINIA? PLACENTA 157

a. Calycular view of a large example; natural size.
b. Lateral view of the same.
c. Calycular view of a small example; natural size.
d. Under side of the same, showing the concentrically wrinkled epitheca.

FIG. 2. MICHILINIA EXPANSA 158

a. Calycular view of a small, imperfect, silicified example; natural size.
b. Lateral view of the same.

FIG. 3. CHONOPHYLLUM SEDALIENSE 157

a. Side view of a partially crushed and broken example; natural size.

FIG. 4. LOPHOPHYLLUM EXPANSUM 157

a. Side view of a type specimen; natural size.
b. Calycular view of the same.
The spots near the columella are accidental; and the figure does not show the full prominence of the columella.

FIG. 5. HADROPHYLLUM GLANS 156

a. Calycular view; natural size.
b. Lateral view of the same.

FIG. 6. ZAPHRENTIS CALCEOLA 156

a. Lateral view of a specimen from Sedalia, Mo.; natural size; showing a minimum degree of flattening upon the lower portion of the convex side.
b. Calycular view of the same. The edge of the calyx of this specimen is constricted, giving it the appearance of being thickened. It is usually thin and sharp.
c. View of the convex side of another example, from Burlington, Iowa, showing a maximum degree of flattening of the lower portion of the convex side.
d. Calycular view of the same, showing the border of the usual character, except that its lower portion has been broken away.

FIG. 7. ZAPHRENTIS ELLIPTICA 155

a. Side view; natural size.
b. Calycular view of the same.

SUBCARBONIFEROUS.

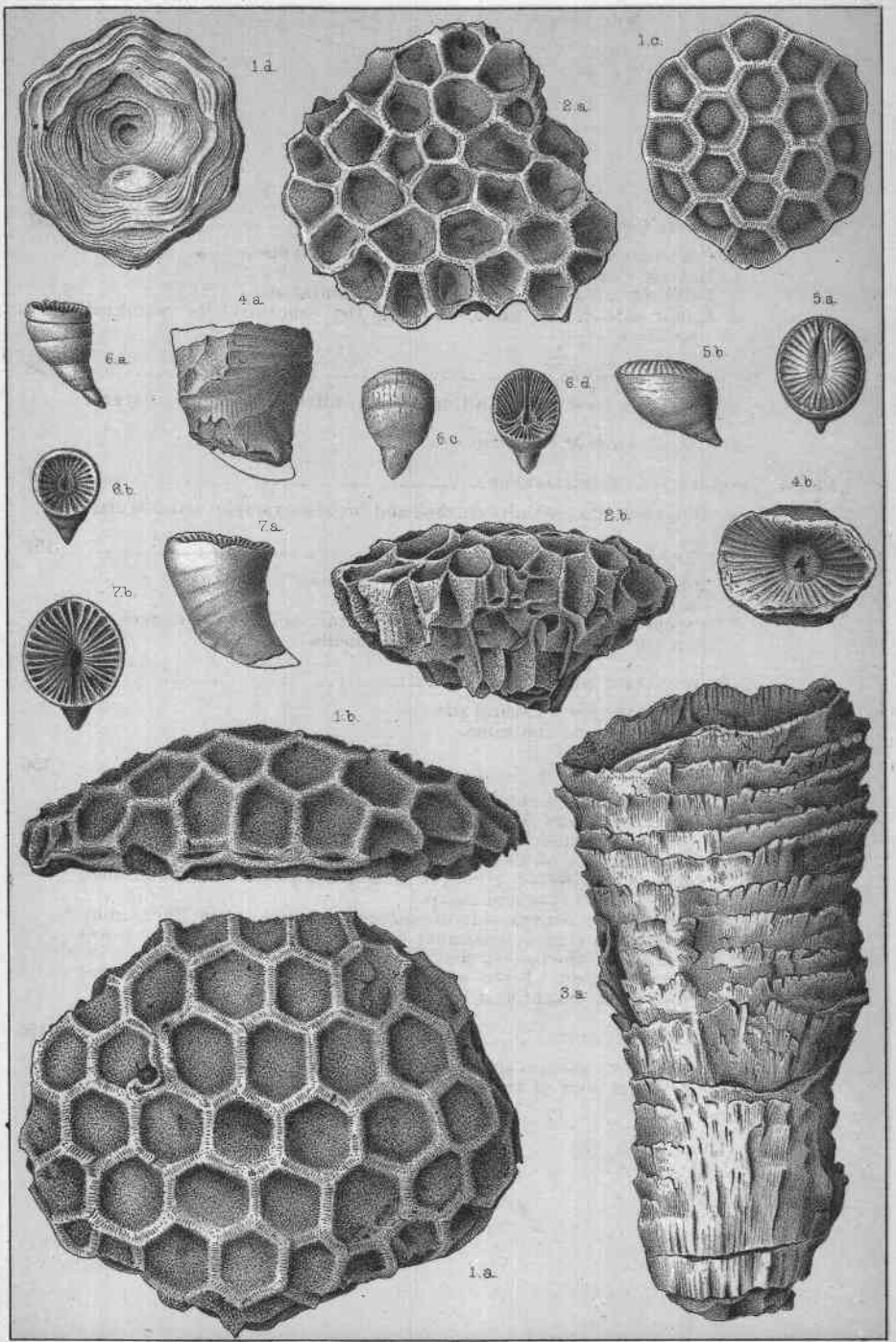

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PLATE 40.

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FIG. 1. ACTINOCRINUS WACHSMUTHI 162

a. Side view of a crushed example, showing the proboscis and a part of the arms; natural size.
b. Side view of the body of another example, only slightly distorted by pressure.

FIG. 2. LEPIDESTHES COLLETTI 163

a. Side view of a specimen somewhat smaller than the type; natural size.
b. Diagram of a single piece of the ambulacral series, with adjacent borders of others, showing the two pores; enlarged.

FIG. 3. SCAPHIOCRINUS GURLEYI 162

a. Side view of the type specimen; natural size.
The black spots at the junction of the column with the body are accidental.

FIG. 4. SCAPHIOCRINUS GIBSONI 161

a. Side view of the type specimen; natural size. The slight zigzag arrangement of the smaller divisions of the arms is not distinctly shown in the figure, and it does not quite clearly represent the angular aspect of all the small pieces composing the arms.

FIG. 5. PLATYCRINUS BONOENSIS 160

a. Side view of the type specimen; natural size.

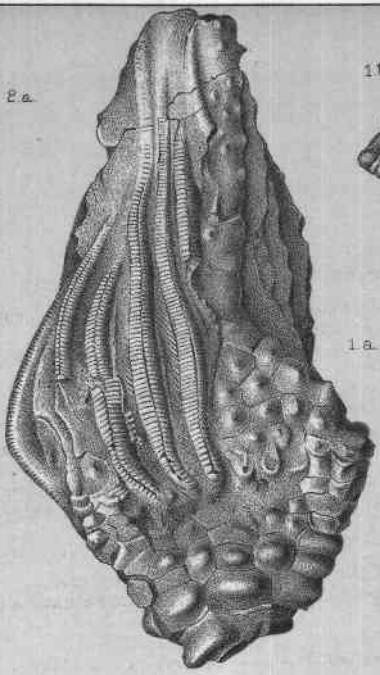
FIG. 6. LITHOSTROTION MAMILLARE 159

a. Calycular view of a portion of a large corallum, showing three double corallites.
b. Under view of the same, showing that portion of the same double corallites.

FIG. 7. LITHOSTROTION MICROSTYLUM 159

a. Calycular view of two or three corallites; natural size. The details are partially obscured by the bad state of preservation of the specimen.

2.a.



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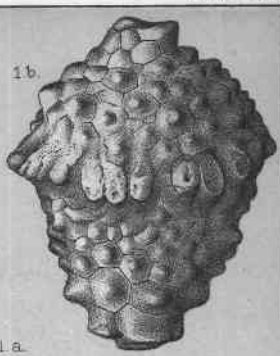
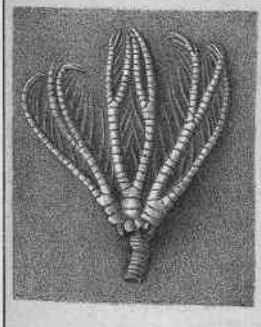


1.a.

3.a.



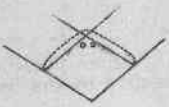
4.a.

7.a.

6.a.

8.b.

8.b.



5.a.

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PLATE 41.

SUBCARBONIFEROUS.

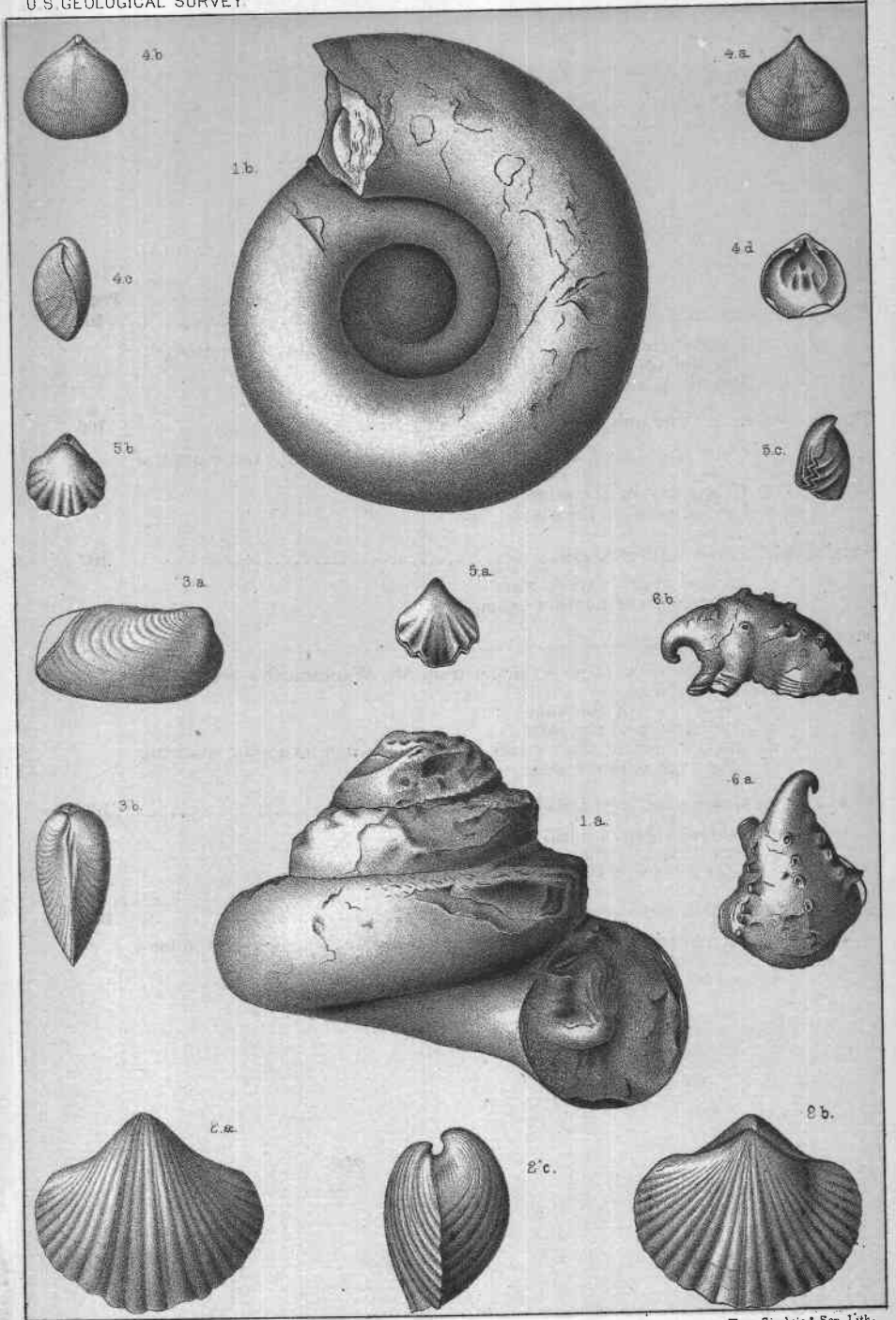

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PLATE 42.

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FIG. 1. PLEUROTOMARIA BROADHEADI 169

a. Lateral view; natural size.
b. View of the opposite side of the same, showing the aperture. Portions of the shell on this side have been a little crushed by pressure. Fragments have also been broken out of both sides, as shown by the outlines upon both the figures.

FIG. 2. PLEUROTOMARIA NEWPORTENSIS 169

a. Lateral view; natural size.
b. Apertural view of the same.

FIG. 3. NATICOPSIS MONILIFERA 168

a. Lateral view; enlarged.
b. Apical view of the same.
c. Portion of the surface enlarged; the striæ of growth showing the character of the border of the outer lip.

FIG. 4. CONULARIA CRUSTULA 170

a. Lateral view; natural size.

FIG. 5. ANTHRACOPTERA POLITA 166

a. Right valve; natural size.
b. Left valve. Both valves have been slightly distorted by pressure.
c. Diagram showing convexity of the valves.

FIG. 6. ASTARTELLA GURLEYI 166

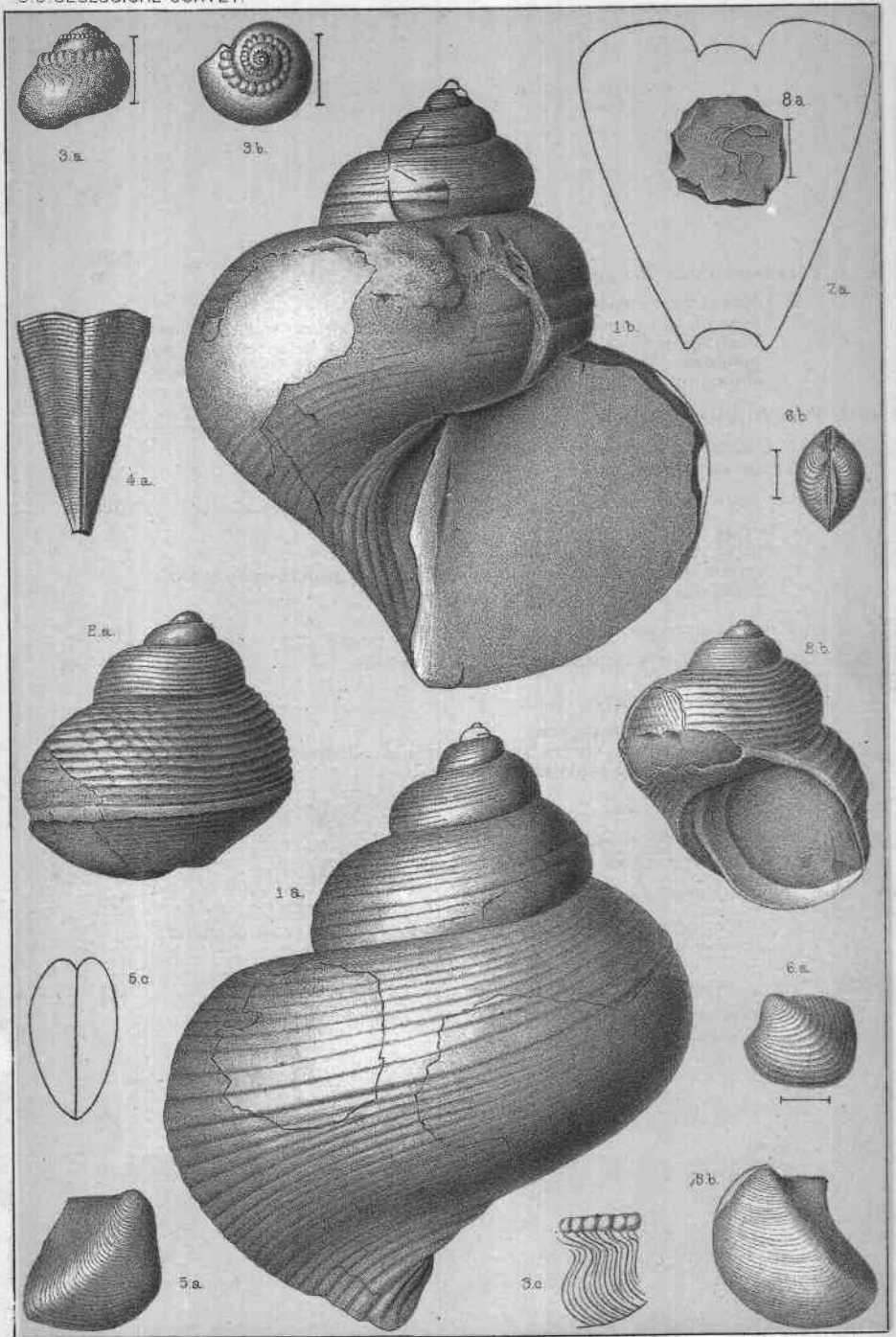
a. Lateral view; enlarged.
b. Dorsal view of the same.

FIG. 7. NAUTILUS DANVILLENSIS 170

a. Outline of a cross-section of a volution near the outer chamber; natural size.

FIG. 8. SERPULA INSITA 171

a. A cluster of shells, attached to a fragment of a molluscan shell; enlarged.



J.C.M^c Connell del.

Thos. Sinclair & Son, Lith.

HENRY'S LAKE AND THE TETONS FROM THE SUMMIT OF LOW PASS. LOOKING SOUTH.

REPORT OF ORESTES ST. JOHN.

LETTER OF TRANSMITTAL.

OFFICE UNITED STATES GEOLOGICAL AND
GEOGRAPHICAL SURVEY OF THE TERRITORIES,
Washington, D. C., September, 1879.

SIR: I submit herewith my report on the geology of the district assigned to the Wind River division of the survey during the season 1878, together with a copy of the map of the territory visited by myself during the seasons 1877 and 1878, on which the distribution of the geological formations is indicated by appropriate colors.

The party to which I was assigned as geologist the past season was in charge of Mr. Frederick C. Clark, topographer, accompanied by Mr. Nelson Perry, mineralogist, Mr. Wells, topographical assistant, George and Mac, packers, and the cook, Henry. Outfitting at Cheyenne, the party was transported by rail to Granger Station on the Union Pacific Railway, whence in company with Messrs. Gannett and Peale's party we moved up the valley of the Green River, arriving on the southern confines of our territory on the 31st July.

The first work performed was in the northern extremity of the Wyoming Mountains, in the southwest corner of the district. We thence moved along the southern foot of the Gros Ventre Range to the west flank of the Wind River Mountains. Later in the season the northern half of the eastern slope of this range was visited, the work extending to a rapid survey of the eastern portion of the Gros Ventre Basin, over to Buffalo Fork. In the latter quarter, about the middle of October, just as we reached Pacific Creek, a heavy fall of snow virtually closed the season's field-work. The return was via Togwotee Pass, where the snow lay to the depth of above a foot, descending Wind River to Camp Brown, from which place I returned by stage to Green River Station, on the Union Pacific Railway. The time actually spent in the field was about ten weeks, during which time our movements were harassed by inclement weather, and latterly by that peculiar mental condition consequent on the uncertain and exaggerated rumors relative to the movements of hostile Bannacks by whom the country was said to be overrun, but of whose presence we saw no more than the traces of some days' old trails.

In relation to the geological map, a copy of which is herewith transmitted, so far as it records actual examinations it is believed to be in the main correct. But it embraces tracts which were either not visited, the geological features being viewed at a distance, or other sections where the data derived in the course of a hasty visit failed to afford the means of determining the exact age of the rock formations found therein. In the former case is included the belt traversing the central portion of the Snake River Mountains, whose rather complicated geological structure it was impossible to satisfactorily make out from such examinations at a distance, with which we had to be content; and in the latter instance are included the several areas indicated by the common color

employed to represent the distribution of those post-Jurassic formations occupying the positions of the Cretaceous and Laramie formations in the geologic scale. In the latter instances, although the occurrences were visited, the evidence of their age in the majority of cases depends entirely on sequence or their stratigraphic position in reference to well-determined earlier formations in their neighborhood; the organic remains which these horizons afforded unfortunately were in so indifferent state of preservation as not to be recognizable with that degree of certainty desirable in defining the age of the deposits whence they came. It was therefore deemed advisable not to attempt the definition of Cretaceous and Laramie formations on grounds purely lithological, and this, too, in a region where apparently there exists no unconformity between the various members of the great Mesozoic series; and hence the areas alluded to are given a single color with, however, queries and other legendary signs in accord with the impressions arrived at as to the probable stratigraphical relations of the deposits therein met with. The familiarity acquired during a season's hasty examination of large territories, if it could be supplemented by revisiting special localities, would result in exact knowledge such as it may not be possible to arrive at in any other manner. As it is, the work recorded on this map materially amplifies that of earlier explorations in this region, the differences and corrections being such as might be expected from the somewhat better facilities accorded the parties of this survey.

It is with pleasure and a due sense of my indebtedness I here acknowledge the favors I have received at the hands of Dr. White, who, in my absence, kindly examined my palæontological collections whose determinations have given me greatest aids in preparing my report. Also to Dr. Peale and Professor Lesquereux I am under many obligations for the favor of important information.

Very respectfully, your obedient servant,

ORESTES ST. JOHN.

Dr. F. V. HAYDEN,
United States Geologist, in charge.

REPORT ON THE GEOLOGY OF THE WIND RIVER DISTRICT.

By Orestes St. John.

CHAPTER I.

AREA AND BOUNDARIES.

The country examined during the past season by the Wind River division of the survey includes an area of, approximately, 4,000 square miles. The region is triangular in shape, the base corresponding to the forty-third parallel north latitude, extending from the one hundred and eleventh meridian, west longitude, east about 100 miles. The two sides are respectively defined, on the west by a line passing northeastwardly from the upper entrance to the Grand Cañon of the Snake, east of Jackson's Basin, to Togwotee Pass on the east of the continental watershed, 43° 45′ north, and on the east by a southeasterly line, conforming, in a general way, to the course of Wind River; the meridian 109° 30′, however, forms the eastern boundary line of the mapped area embracing the district especially alluded to.

GENERAL SURFACE FEATURES.

Drainage.—The region embraced within the above mentioned limits mainly lies on the west slope of the continental watershed, its drainage belonging to three great river systems, viz, the Columbia, Colorado, and the Missouri. To the former belongs the drainage of the western border, which is gathered by the eastern tributaries of Snake River. Of the latter, the Elk Horn and Gros Ventre rise in the watershed, while to the south Hoback's and John Day's Rivers have their sources in the water-divide between the Snake and Green rivers. The ultimate source of Wind River originates in Togwotee Pass, its western tributaries draining the eastern slope of the great water-shed, their waters finally gaining the Missouri by the circuitous channels of the Big Horn and Yellowstone, far to the north and east. The southern half of the western slope of the watershed, in this district, belongs to the Colorado system, the sources of Green River rising in the most elevated portion of the Wind River Mountains.

Mountain Ranges.—By far the greater portion of the region surveyed may be denominated mountainous, although extensive tracts of the broken country may properly be considered in connection with the hydrographic basin areas. The continental watershed in the eastern portion of the district has a general south-southeast and north-northwest course of about 60 miles in extent. About two-thirds, or 40 miles, of the watershed is formed by the northern half of the Wind River Range, whose axial peaks, culminating near our southern border and dominating the district, are among the most lofty mountain heights of the great central Cordilleran region. To the northwest of Union Pass, and thence to Togwotee Pass, it entirely changes its Alpine character as also its geologic

strncture, becoming a wooded divide, ranging from 9,000 to 10,500 feet altitnde.

Near the middle of the district lies the Gros Ventre range, a pecnliar isolated mountain zone abont 30 miles in northwest-southeast extent, cnlminating in altitudes between 11,000 and 12,000 feet above sea-level. This range forms a sort of link connecting the Wind River and Téton ranges, although topographically and geologically it is quite distinct from either of these ranges, possessing its own separate history. Jackson's Basin intervenes between its western end and the Téton Range, while a moderately elevated divide spans the interval between its eastern extremity and the Wind River Mountains. The Mt. Leidy highlands form an exceedingly rugged belt projecting westward from the watershed into the interval lying between the Gros Ventre and Buffalo Fork, and which is scarcely less in altitude than this portion of the great divide itself, with which, indeed, it is geologically intimately connected. Southwest of the Gros Ventre Range, occnpying the extreme southwest corner of the district, the northern portion of the Wyoming Range is suddenly limited by the Grand Cañon of the Snake, beyond which the range is continued in the chain known as the Snake River Range, and which together make up one of the longest mountain ranges, a unit in geological structure, in this region.

Basin areas.—The basin areas which have to be considered in this connection correspond to the principal drainage depressions of the district. They are the Hoback, Gros Ventre, and Green River basins on the west slope, and on the east side of the watershed the Wind River Valley. An interesting conclnsion arrived at in the course of the examinations in this region is that of the intimate geological relations existing between these depressed areas, especially with reference to the Gros Ventre and Wind River basins. The water divides separating these areas one from the other are generally low and composed of deposits pertaining to the Tertiary age. This is shown in the character of the divide between Hoback's and Green River basins, as also that between the latter and the Gros Ventre basin. In the latter qnarter, however, the snrface is heavily covered with Quaternary materials, in part dispersed by glacial agents, which hide from view the older deposits npon which they rest. That section of the great watershed lying between Union and Togwotee passes is essentially of the same geological character, though here the Tertiary deposits were buried beneath a vast accumulation of volcanic ejectamenta, which has served to protract the degradation of these soft deposits, maintaining them as a conspicuous barrier along the continental divide. In the details of their topographic and geological featnres there are marked contrasts in the several basin areas above briefly alluded to, and which will receive further notice in another place.

The extremes in altitude within the region under consideration, as determined by hypsometric observations made by this survey during several seasons subsequent to the expedition of 1872, show a range of about 8,400 feet. The lowest point, at the foot of the Grand Cañon of Snake River, has an altitude of 5,400 feet above the sea, and Fremont's Peak, one of the dominating summits of the Wind River Range, according to Mr. Wilson, attains an actnal altitude of 13,790 feet. East of the watershed, that part of the Wind River Basin lying within the limits of the present district ranges from about 6,600 feet to 8,000 feet in altitnde. On the west slope, within our limits, the altitudes of the several basin areas occnrring therein are as follows: Green River Valley, 7,500 to about 8,000 feet; Hoback's Basin, 6,000 to 7,000; the Gros Ventre Basin, 6,500 to 8,500 feet.

While the foregoing hypsometric data may convey some notion of the general surface reliefs of the district and its drainage depressions, a closer examination reveals great diversity, the mountain ranges presenting broad contrasts, which may also be said of the basin areas. With the exception of the Green River Valley, the alluvial tracts bordering the streams are of limited extent, usually confined to narrow strips of gravelly bottom land. In the Tertiary basins of the Hoback and Gros Ventre, the tributaries of the main streams generally occupy deep, narrow valleys eroded out of the soft strata, while along those which rise in the neighboring mountains is met some of the wildest and often sublime cañon scenery. The region on the west slope is generally well covered with forests of pine and fir trees, the lower hilly country being fairly covered with good grazing herbage. Perennial streams are everywhere encountered in this quarter. But on the east slope, beyond Wind River, the country presents some of the aspects of "bad lands"; only the larger streams are filled with flowing water the whole year, and extensive bench-plateaus are covered with a sparce growth of herbage, and no forests.

CHAPTER II.

WYOMING RANGE.

TOPOGRAPHIC FEATURES, &C.

In the country to the south the Wyoming Range forms the water-divide between the Green on the east and the drainage of Bear and Snake rivers on the west; but within the present territory its drainage is effected by numerous water courses tributary to Snake River. On the west it is defined by the valley of Salt River, and on the east by Hoback's Basin. The intermediate space is penetrated by John Day's River, and the southern affluents of the Hoback, a comparatively narrow belt along the north side draining directly into the Snake along that part of its course known as the Grand Cañon. To the northwest the same mountain belt is continued, scarcely diminished in relative altitude, under the name of the Snake River Range into the region partially explored the preceding season by the Téton division of the survey. In its passage across this mountain chain Snake River follows a southwesterly direction in a direct line from the mouth of Hoback's River, where the cañon may be said to begin, to the confluence of John Day's River, where it enters its lower valley, of about 20 miles. It forms a rift through the mountains the upper portion of which is occupied by terraces and occasional tracts of gravelly intervals continuous with the benches in the lower part of Jackson's Basin; but the lower half is said to be scarcely wider than the bed of the river.

The main ridge of the range lies between John Day's and Salt rivers on the extreme western border, occupying a space about 10 miles across, east-west, and which has received in the district to the south the name "Salt River Range." From either side it presents a bold, rugged mountain barrier, attaining 10,400 feet actual altitude, and is known to be largely made up of Carboniferous strata. Towards the north end the John Day's has excavated a deep passage across the ridge parallel with and only about 4 miles south of the lower portion of the Grand Cañon, joining the Snake just below the debouchure from the mountains. Above this gorge the stream forks, sending off a fine tributary to the eastward whose sources lie in the crest of the Hoback Cañon, or easternmost mountain ridge of the range, the main stream from the forks pursuing a southerly course and confined to a narrow valley in that part passing through our territory.

The central portion of this highland belt is traversed in a nearly north-south direction by a narrow ridge, the north half constituting a barrier between the drainage flowing directly into the Snake on the west and that of the Hoback on the east. To the south, however, this ridge is cut across by the East Fork John Day's River, in an exceedingly wild, narrow cañon, whose adjacent slopes are densely wooded with coniferous forests. South of the cañon the ridge reaches its maximum elevation,

10,450 feet, at Station VII near our south line. For convenience sake this ridge has been designated by the name John Day's ridge.

East of the latter point a high, undulating mountain plateau extends over to the Hoback Cañon ridge some 4 miles distant, and which forms a part of the mountain basin in which rise the East Fork John Day's River and one of the tributary sources of the main Hoback. Geologically, this basin forms the southern continuation of the valley between the middle and Hoback Cañon ridges and is principally drained north by a lower south tributary of the Hoback, which gains the latter stream 2 or 3 miles below the cañon. Thus limited it forms a narrow trough 20 miles in length gradually widening to the north where it is about 6 miles across, and is mainly occupied by Mesozoic and Tertiary deposits. The basin area to the west occupying the interval between the Salt River and John Day's ridges, although much wider—10 to 12 miles east-west—is very similar in geologic structure to that just mentioned.

The eastern barrier ridge of the range, which we have designated as the Hoback Cañon ridge, stretches due south from the south flank of the Gros Ventre Mountains to the south line of the district, a distance of 38 miles. Although narrow, averaging 4 or 5 miles in width, it constitutes one of the most important topographic and geological features of the range in this region. In the northern half the Hoback River has opened a narrow way across the ridge nearly at right angles to its course, in which the geological structure of the ridge is well displayed. Between Hoback's Cañon and the south flank of the Gros Ventre Mountains the ridge has an altitude of 10,000 feet; to the south of the cañon it gradually rises, culminating in Hoback's Peak (Station VI), a few miles north of the south line of the district, at an altitude of 10,800 feet above the sea. In the latter quarter it is broken by the cañoned sources of Hoback's River, and thence southward the water-divide is transferred to the middle or John Day's ridge, which soon constitutes the main divide limiting the west side drainage of the Green River Basin in the district to the south. Throughout its extent this ridge presents from either side a very broken appearance, with steep, often precipitous, rocky acclivities, diversified by the rich color-contrasts imparted by the deep reds and drab browns of the Jura-Trias, the grays of the Carboniferous limestone, and the dark and light shades of the forest-covered and grassy slopes.

For so comparatively small area as that occupied by the Wyoming Range within this district, being only about 25 miles across and of an average north-south distance even less, it presents an exceedingly diversified surface and intricate drainage, with which are associated equally varied and interesting geological phenomena, which will be briefly discussed in the following section.

HOBACK CAÑON RIDGE.

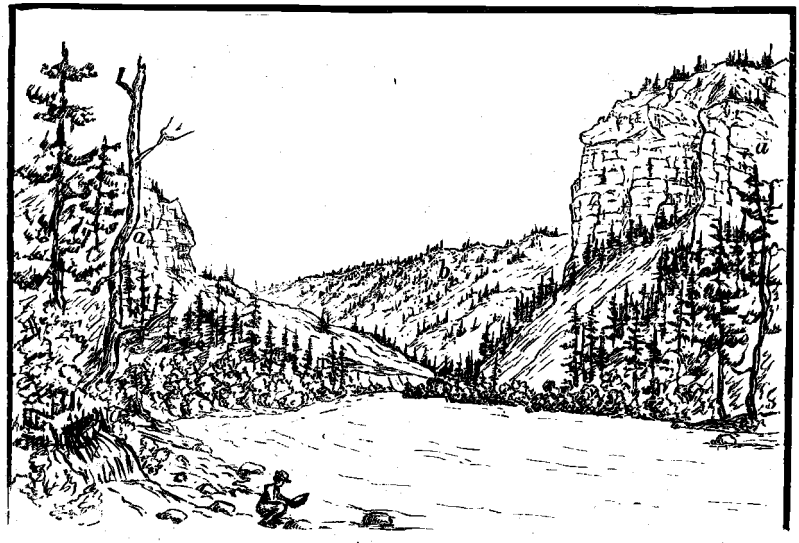
Along the eastern flank of the Wyoming Range there occurs a low outlying ridge parallel with and 3 or 4 miles distant from the Hoback Cañon ridge, from which latter it is separated by the valley of tributaries which gain the Hoback a few miles above the cañon. This ridge is quite persistent to a point perhaps 7 miles north of our south line, where it is completely enveloped by the Tertiary deposits which here sweep high up on the eastern flank of the range, as will be noticed in a subsequent chapter devoted to the Green River—Hoback Basin. To the north of the Hoback the ridge, as such, is less well marked, being much eroded by Hoback tributaries descending from the south flank of the Gros Ventre Range, east of Station XII.

The nucleus of this outer ridge is apparently almost exclusively made up of Mesozoic strata, excepting a small angle in the vicinity of the junction of this south affluent with the main stream, where strata of later date compose its bulk. Structurally, it presents a somewhat variable present condition that was determined by a sharp fold in the older strata, which locally exhibit the appearance of a regular anticlinal. In the southern portion, 6 or 8 miles above the mouth of the stream, the ridge shows a monoclinal structure, the stream occupying a synclinal from which the strata rise to the eastward into the narrow, picturesquely-weathered crest, 1,000 to 1,200 feet high. The east side is sharply broken down, and on the upturned edges of the nucleal strata rest the unconformable Tertiary deposits, dipping off to the eastward. Whether the condition of things here represents a fault with down throw on the east, or is attributable to denudation along the shore line of the Tertiary sea, was not clearly apparent. In the latter case the tilting of the Tertiary deposits would indicate a late-continued elevatory movement within the area of this western mountain border of the Hoback Basin sufficient to account for the present position of the Tertiary deposits which slope off into the basin at an angle of variable steepness.

Eight miles south of the Hoback this ridge is made up of hard reddish-buff sandstone and brecciated silicious beds, steeply tilted and rising along the crest into picturesque, ruin-like crags. Two or three miles lower down the stream, the west slope is flagged with drab, sparseamed limestone, containing a small *Ostrea* and *Pentacrinites*. These beds dip about WNW. at angles of 35° to 65°, and are overlaid by limestones and indurated calcareous shales containing abundance of *Gryphæa calceola*, which, however, are soon concealed beneath the débris lower in the slope. Below the latter point the reddish or flesh-colored Triassic sandstones descend lower in the west slope, and as the course of the stream bears more to the east it crosses these beds, cutting a narrow gorge in which their anticlinal structure is well brought out. Below the gorge the valley is less confined, and is bordered on the east by beautifully rounded hills based on the soft gray deposits—alternations of sandstones and shales—of the Tertiary, which continue thence below the confluence of the Hoback. The latter deposits show a thickness of perhaps 1,000 feet, dipping eastward at an angle of 30° to 45°, and at the confluence of the streams forming a low outlying hill on the west side of the valley. Similar remnants occur below the junction for some distance, forming benches low in the slope resting upon the westerly-dipping Triassic red sandstones, which form the crest of the west side border ridge. The Tertiary slopes are partially wooded with conifers, as also are the more rugged Triassic acclivities.

The main Hoback here pursues a northwesterly course, and a mile or so below the junction it has formed a narrow passage across the Triassic monoclinal ridge. The typical red sandstones show picturesque exposures, dipping west at an angle of 35°, the outlying ridges on the east being made up of the Tertiary deposits. In the angle formed by a considerable inflowing branch from the north, a high castellated mass of red sandstone fills the east side of the valley, sharply turning the stream west. The west slope of this hill is faced with heavy ledges of red sandstone, including a drab calcareous or limestone deposit, steeply inclined westward. The summit is crowned by apparently nearly horizontal ledges of the same character, as though the strata had been partially severed and broken down or dragged on the west side of the fold, leaving the crest intact. In the west side of the narrow valley the strata again rise, but a little lower down they are seen to form a perfect arch

Plate I.



Hoback Cañon.

a Carboniferous. *b* Jura-Trias.

plated by the Jura. The "red beds" appear in force on the west side of the cañon above, exhibiting a thickness of above 1,000 feet, dipping westward, in which direction they merge into the broken outlying slopes of the Hoback Cañon ridge. North of the Hoback, as before mentioned, the continuity of this ridge is much broken by the streams here descending from the Gros Ventre Mountains, and it is not improbable that, in its geologic structure, it is also complicated by proximity to the latter mountain range.

The valley of the tributary separating the above outlying ridge from the main ridge south of Hoback Cañon is generally narrow and frequently walled in by precipitous rocky slopes. The narrow intervale expansions show well-defined terraces, and the stream-bed is paved with water-worn fragments of red sandstone and drab limestone, derived from the environing Jura-Trias deposits. However, on gaining the Hoback, the Quaternary deposits which fill the valley-bed are largely composed of Archæan and Palæozoic débris, from the Gros Ventre Mountains on the north. These materials extend through the cañon, where they are intermingled with the débris fallen from the adjacent cliffs and washed down the short gulches that penetrate the hills on either side. There can be little doubt that during the time of the Quaternary period this gorge was filled with drift materials, remnants of which—boulders of various kinds of rocks—still being met with high up on the adjacent mountain slopes. Subsequently these deposits were to a great extent swept away, and in the narrow portions of the cañon the talus slopes consist almost entirely of the sliding, angular rock fragments fallen from the limestone and sandstone cliffs, over which the trail, in places, has precarious footing. From time immemorial the Hoback Cañon has been used as a highway, communicating between the Upper Snake and Green River valleys. Many well-beaten trails converge at the upper entrance, whose antiquity may be inferred from their distinctness in spite of their comparative present disuse. Its importance in this respect is, indeed, a matter of historic record, reaching back to the first decade of the century when the region was first visited by the adventurous fur-traders.

About midway of the Hoback Cañon the hills recede, inclosing a pretty little park clothed with verdure, shrubs and trees. On the north side it is terraced with high benches, in which Mr. Perry discovered some interesting deposits of gypsum. The gypsum, so far as investigated, seems to occur in isolated patches included in the loose débris of which the terraces are composed, recalling the tufaceous deposits of springs. In texture and color it varies from compact to porous, pure white to grayish or soiled white, and apparently forms quite extensive deposits. That examined appears in the steep slope of the terrace near the brink, at an elevation of about 115 feet above the stream, and shows a thickness of 4 feet. Lower down, or just within the lower entrance to the cañon, a powerful sulphur spring issues along the north bank at the edge of the water for a distance of 30 or 40 yards, emitting the odor of sulphureted hydrogen. The spring water is not unpleasant to the taste; the temperature at 7 a. m. (7th August) indicated 47° F. The spring is seated immediately over an anticlinal fold, whose axis is here composed of Carboniferous—possibly Niagara—limestone. In favorable situations, the pebbles in the way of the spring currents are coated with a sulphur precipitate, and the inflowing spring water discolors that of the river for the distance of several hundred yards below with a strip of beautiful green. This unquestionably is the sulphur spring described by Rev. Samuel Parker,* who journeyed down the Hoback in 1834. It may be well to remark,

* Journal of an exploring tour beyond the Rocky Mountains. Ithaca, N. Y., 1844.

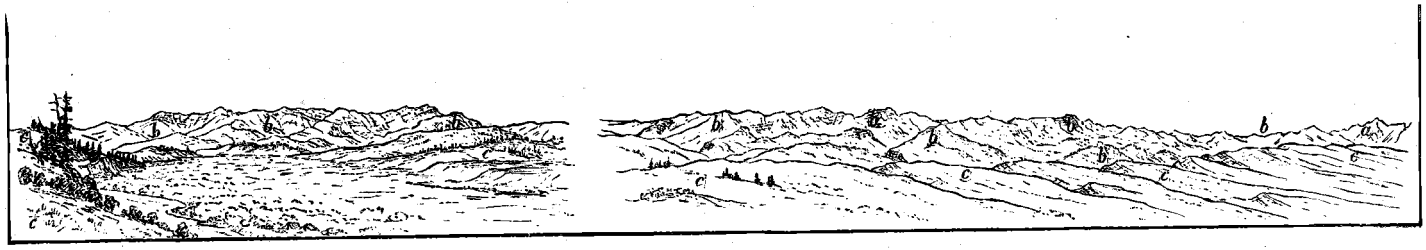
however, that at the time of our visit gaseous emissions were far less noticeable than one would be led to infer was the case fifty years ago at the time of Mr. Parker's observations.

For a few miles south of the Hoback Cañon the main mountain ridge presents a sort of double crest, although the eastern and more prominent is the main drainage crest, the western one having the relations of huge buttress-spurs with outlying eminences but little inferior in height to the main ridge. Its structure throughout is that of two parallel folds separated by a shallow synclinal trough. The eastern, or Station II ridge, presents an abrupt and often escarped wall 500 to 800 feet high, facing the Hoback Basin, in which the edges of the westerly dipping strata are exposed. These consist chiefly of red and flesh-colored Triassic sandstones, capped by leaden shales and drab limestones of the lower measures of the Jura. From the foot of the escarpment on the east, a rugged wooded belt steeply descends into the parallel valley, in which the strata, though much disturbed and complicated, apparently form the eastern flank of an anticlinal fold. The above state of things is plainly indicated in the vicinity of Station II, where outlying hog-back ridges facing the monoclinal crest are made up of the Triassic red sandstones, dipping steeply to the east. Lower in the slope there are indications of a second lower fold, also arched by the Trias, whose east flank declines into the synclinal trough occupied by the parallel valley, and which is partially filled with Jurassic deposits. The eastern flank of this synclinal is the same as the outer barrier ridge already described. The relative position of the folds and their component strata are indicated in the section diagram across this part of the ridge. But while the above-mentioned structural features may be regarded as normal in this part of the east slope of the Hoback Cañon ridge, it was undoubtedly subject to greater or less local variation, recording the variable action of the dynamical forces which uplifted and folded the strata into a broad north-south mountain zone.

From the Hoback Basin, looking up the valley of the main stream towards its sources, a comprehensive view is gained of the eastern wall of the ridge extending from Station VI to the south line of the district, and which affords a fair knowledge of its geological structure. The outlying eastern slope is largely if not entirely enveloped by the Tertiary deposits of the basin, which a little farther to the south extend high up on the mountain ridge. Nothing could more strongly contrast with the abrupt, broken mountain declivity than do the long sloping benches that here descend the mountain flank, reaching far out into the middle of the basin area. Even to the north, where the Tertiary deposits have been much more eroded by the streams, they still retain to no inconsiderable extent their distinctive bench features. But at a distance what may appear to be uninterrupted, smooth slopes, on nearer approach generally prove to be high benches, whose almost inaccessible sides are scored by the wildest gullies, while the comparative levels above are densely clothed with pine and spruce amongst which the fires have wrought wide-spread devastation, the interlacing of the fallen tree-trunks erecting almost insurmountable barriers to travel.

As seen from this point of view, the ridge in the neighborhood of Station VI shows a broad synclinal or sag in the component strata, based upon heavy deposits of red sandstone. The trough of the depression is filled with variegated chocolate-drab beds, which are separated from the "red beds" by an intermediate buff-colored deposit forming escarpments in either flank of the sag, remnants of reddish sandstone occurring above the drab beds. The basis rocks of the exposed section

Plate II.



East flank of Hoback Cañon Ridge, from Upper Hoback Basin.

a Archæan, Sta. XII Gros Ventre Range. *b* Jura-Trias. *c* Tertiary foreland.

here referred to are clearly of Triassic age, while the overlying drab and variegated deposits are undoubtedly referable to the Jura. The depression alluded to is believed to be merely a sag in the strata between two points of maximum elevation, as it appears to be in line with, and not transverse to, the general north-south direction of the mountain folds. The same is further indicated from points of view foreshortening the mountain wall and bringing into profile the great headlands defining its amphitheaters, where the strata uniformly incline westward.

But at Station VI the mountain ridge presents a very marked synclinal fold, on a high point on the eastern flank of which the station was located, at an altitude of 10,800 feet. In an east-west direction the ridge is, perhaps, a mile across, either flank exhibiting the upturned strata in the position of monoclinals due to erosion. On the west side the strata rise much more steeply than on the opposite, and from certain points of view they appear to be almost vertical. The axial portion or crest of the west-side fold, however, has been removed by erosion at this point, but to the south it presents the appearance of a rather low, broad arch flagged with the variegated chocolate-drab Jurassic deposits, the same that fill the synclinal and constitute the greater height of the flanking ridges. The Jura is here made up of drab limestone layers and chocolate-drab shales including reddish arenaceous deposits, the whole, exclusive of the dirty buff deposits below, attaining a thickness of probably, at least, 1,500 feet.

A few miles north of Station VI, in the neighborhood of Station V, the ridge assumes its double character, the latter station being located on the western ridge, 10,050 feet above sea-level. The above-mentioned broad-spanned anticlinal fold southwest of Station VI is not recognized at this locality, unless it prove to be identical with the sharp fold of the western ridge occupied by Station V. The western ridge rises abruptly from the valley of the lower fork of the Hoback, its crest nearly corresponding to the axis of a sharp anticlinal fold in the Carboniferous limestones, which is preserved as far north as the lower entrance to the Hobach Cañon. The upper portion of the western slope is faced by the westerly-dipping Carboniferous limestones, succeeded by the buff and flesh-colored hard sandstones lower in the slope, which is covered with angular siliceous débris. The latter horizon holds the brecciated layers, composed of angular fragments of the quartzitic sandstone and drab limestone, recalling conglomeritic horizons in the Carboniferous in the region of Ross Fork basin south of Fort Hall, Idaho. These deposits reach well down the slope, where they are in turn overlaid by typical red sandstones of the Trias, which form the first bench rising on the east of the little valley. From the crest of the ridge the inner synclinal is overlooked, occupying a belt about one and a half miles across extending over to Station II ridge, and which is eroded into irregular sharp ridges more or less parallel to the border mountain ridges. This synclinal trough is filled with the Triassic "red beds" overlaid by a few hundred feet thickness of the drab-colored Jurassic limestones and shales; the latter being mainly confined to the eastern portion of the depression, rising into the crest of the east or Station II ridge. The latter mountain, however, is principally composed of the inferior "red bed" series, which also reaches well up on the eastern flank of the west or Station V ridge, upon which it is steeply inclined.

The continuity of the western ridge is interrupted by deep gorges cut by tributaries flowing west into the lower south fork of the Hoback, contrasting with the east ridge in this respect, which forms the water-divide as far south as station VI. These cañons afford natural sections in

which the structure of the ridge is fully revealed, besides affording excellent facilities for detail stratigraphical examinations.

One of the most interesting sections across this mountain belt is that presented in the sides of Hoback Cañon. This gorge traverses the ridge in a direction a little north of west, and that portion here alluded to is about five miles in length. The Hoback flows in narrow defiles at intervals, several miles above this point. Throughout this distance the south side of the cañon is closely hemmed in by steep mountain slopes, which are frequently broken by mural escarpments several hundred feet high, in which the strata are well exposed.

At the upper entrance to this stretch of cañon stands the before-mentioned eastern border ridge, in which the Triassic red sandstones are steeply tilted, dipping westward into a synclinal depression, whose axis apparently is but a few hundred yards distant. The west flank of this synclinal rises with a more gradual ascent, bearing a heavy series of Jurassic deposits, which consist of a rather heavy deposit of rusty buff limestone, resting upon hard reddish sandstone, probably belonging to the upper portion of the Trias. Then succeed heavy ledges of drab limestone, associated with drab nodular and indurated calcareous shales, charged with quantities of *Gryphæa calceola*, the whole dipping a little north of east at angles of 30° to 35°. The latter deposits are overlaid by a series of chocolate-red and gray, more or less arenaceous shales. In the latter series, at a point on the north side of the stream, a short distance above the upper entrance to the cañon, a thick bed of brownish-drab limestone forms a rather prominent outcrop in the slope, rising to the westward at an angle of 45°, finally curving over past verticality in the crest of the low ridge. The same flexure is also noticeable in inferior ledges lower down the cañon, though less marked than in the above instance. Although no fossils are detected in these higher strata, they are presumed to belong to the Jura, with the lower fossiliferous beds of which they are conformable. On the east flank of the synclinal the latter beds reappear, affording abundance of their characteristic fossils.

Just east of the debouchure of a gulch heading in the north end of Station II ridge, the Triassic red sandstones rise up and curve over in a fold with sharp, in places almost vertical, inclination on the west side, the same deposits in the east slope of the fold dipping at an angle of 25° north of east. Higher up the gulch the steeply-tilted ledges have been weathered into narrow walls, presenting interesting examples of atmospheric erosion. The outer plating of this west-side slope consists of gray ledges, probably of the age of the Jura. On the north side of the cañon these horizons are not as well exposed, the slopes being strewn with red sandstone débris. In the opposite side of the gulch, a few hundred yards below, a heavy series of buff or pale flesh-colored and gray, very hard sandstone, including layers of siliceous limestone, occurs, which rises up into a fold with rather steep inclination in the east flank. The strata descend much more gently on the west flank of the fold, the ledges as seen in the exposures along the south side of the cañon gently undulating, until reaching a point half to three-fourths of a mile below the above-mentioned gulch, where they again more steeply rise to the westward, as shown in the mural exposures which rise 500 to 800 feet above the stream on either side. The upper siliceous deposits here occupy the crests of the ridges, and are underlaid by a heavy series of grayish-drab, more or less cherty limestone, containing *Zaphrentis*, crinoidal remains, Polyzoans, *Hemipronites*, *Spirifer*, &c. The latter beds rise descending the cañon, presenting marked inequalities or undulations, and finally make up the bulk of the cañon walls, and show-

ing a thickness of a thousand feet, perhaps more. Approaching the debouchure of the cañon, where these strata exhibit their greatest vertical exposure, the limestones are crumpled into two low anticlinals, the axis of the lower fold, or that forming the west flank of the Hoback Cañon mountain belt, exposing a nucleus of brownish-gray magnesian limestone, which lithologically resembles the so-called Niagara horizon. A short distance within the mouth of the cañon a small cave has been fashioned out of this bed in the wall rising over the north side of the stream; and just below this issues the sulphur spring previously mentioned. The west flank of the cañon ridge is here much eroded, the ledges in the steep slope farther south showing their basset edges, dipping westward. Higher up the cañon the limestone beds exhibit interesting examples of irregular deposition, in places a heavy bed wedging out, so that subjacent and overlying beds elsewhere separated by many feet thickness of intervening layers are brought into immediate contact.

The above-described limestones, which compose the walls throughout the lower reaches of the cañon, are unquestionably Carboniferous, as shown by the fossils they contain, while the heavy series of conformably superimposed siliceous and limestone deposits agree in relative position with identical deposits occurring in the Snake River Mountains and elsewhere, which have been referred to the later epochs of the same age. No fossils, however, were here observed in these beds, and the demarkation between them and the typical "red beds" of the Trias is obscure in the cañon section. But from the adjacent heights the Triassic "red beds" are seen to be well developed, occupying the synclinal in the central portion of the mountain belt.

The eastern border of the Carboniferous belt in the above described cañon section presents an interesting flexure, which, in connection with that observed in the early Mesozoic strata just above, exhibits anomalous results in the action of the dynamical forces in this part of the Hoback Cañon ridge which may be of local significance. In the elevation and folding of the strata over this mountain belt the Carboniferous beds were forced up into the position they now occupy, the strata in the eastern fold remaining intact, although there is evidence that along the eastern flank of the west fold the beds were subjected to excessive tension, which might have resulted in the severance of the superimposed and perhaps less tenacious Mesozoic strata, the latter appearing in the corresponding parallel fold directly opposite the upper siliceous horizons of the Carboniferous, the before-mentioned gulch descending from Station II, marking the line of disruption. The facts, such as were observed, are reproduced in the diagram of the cañon section.

Six miles north of Hoback Cañon the mountain ridge is crossed by a small tributary of the Snake, which rises in the southern slope of the Gros Ventre Mountains, in the vicinity of Station XII, whose picturesque valley exhibits essentially the same structural features above noted. The narrow debouchure of the cañon is marked on either side by walls composed of massive gray limestone and pale reddish siliceous beds of the Carboniferous, dipping at a moderate angle northeastward. Ascending the cañon, the same ledges outcrop in mural exposures, the inclination changing a mile or so above the entrance to a westerly one at an angle of 10° to 15°, and gradually steepening higher up the valley, which opens out into pretty little meadow intervales; the narrow portions of the valley walled by limestone cliffs and steep taluses of débris; the mountain slopes furrowed by exceedingly steep ravines and clothed with beautiful evergreen forests. The bed of the stream is filled with a variety of

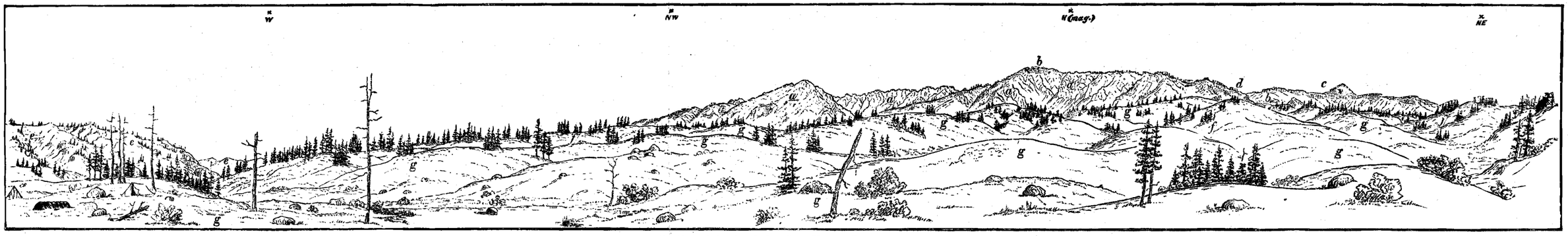
bowlders, including metamorphic fragments, which were derived from the Gros Ventre Mountains. The expansions of the valley receive considerable affluents from the north, and this section marks the axis of a synclinal depression which is filled with the Triassic "red beds." A few miles above the entrance to the cañon the strata are much disturbed, and in the space beyond, lying between this ridge and the southern foot of the Gros Ventre Mountains, the continuity of the Mesozoics is lost beneath accumulations of more recent origin.

In the low northern continuation of the ridge the sedimentary formations apparently trend round more to the west, where they approach nearest to the south flank of the Gros Ventre Mountains. There is evidence of much disturbance in this quarter, the Triassic "red beds" being steeply upraised and resting upon deposits referred to the Upper Carboniferous. The latter here show a heavy ledge of gray, rusty weathered, fragmentary limestone, locally showing a tendency to concretionary structure, as also magnesian in composition. The bed outcrops in a sharp ridge between two northern affluents of the above-mentioned stream, and dips southwestwardly at angles varying from 45° to 80°. In lithological character and composition the ledge resembles horizons in the uppermost or Permo-Carboniferous division, as elsewhere developed in this region, although no fossils were recognized at this locality. The "red beds" here show 500 to 1,000 feet of the inferior portion of the series, consisting of alternations of deep red and thinner gray, laminated arenaceous shales and sandstones. These deposits inclose bands of reddish-stained, vesicular calcareous rock, which weathers with a rough surface, recalling the tufaceous-like limestone layers interbedded in the Triassic sandstones on the east flank of the Wind River Mountains. The latter "red bed" series forms a belt, the trend of which apparently identifies the fold at the present locality with the first abrupt break on the east of the Carboniferous belt in the Hoback Cañon section already noticed. The position of this red belt is indicated in the steep slopes, both by the red color imparted to the soil by the disintegration of the red arenaceous deposits and the luxuriant herbaceous growth which this soil sustains in mountainous regions.

As already intimated, the eastern flank of the latter Mesozoic fold north of the little stream above described is obscured by later deposits. But in the section between this stream and Hoback Cañon, ascending to Station III, which occupies an eminence in the midst of this area nearly 10,000 feet in altitude, the following observations were made: West of the outflanking eastern anticlinal ridge, on crossing the synclinal, the calcareous indurated shales, drab limestones, and chocolate-red arenaceous shales composing the Jura, succeeded below by the Triassic sandstones, outcrop at intervals in the outlying spur ridges at the foot of Station III. These deposits dip to the eastward, but in the space lying between the abrupt spur ridges and the main mountain group the strata are obscurely exposed; so that it is not clear how intimate the western border of the Mesozoic fold here corresponds to its appearance 3 or 4 miles to the south in the Hoback Cañon section.

In the summit of Station III the strata dip southwest at an angle of 30°, the direction and angle of inclination varying considerably even within short distances. The crest shows a ledge of gray sandstone, in places slightly calcareous and laminated, underlaid by red, indurated arenaceous deposits. The high shoulder on the east, however, exposes similar gray and brownish-red sandstones, dipping 25° northeastward, and a few hundred yards south of the station the same ledges incline northwest at the same angle. It is apparent that Station III ridge is

Hoback Cañon Ridge. Sta. XII. Gros Ventre Mountains. **Plate III.**



Cañon north of Hoback River. Southwest flank of the Gros Ventre Range. Divide between Hoback Cañon Ridge and Gros Ventre Mts.

a Archæan. *b* Quartzite. *c* Quebec limestone. *d* Carboniferous. *e* Jura-Trias. *f* Tertiary, red conglomerate. *g* Morainal deposits.

its rise within the same basin on the extreme southern boundary of the district. This north-south valley belt has a length of about 25 miles from our south line to where it finally merges into the Snake Valley, in east-west extent ranging from 3 to 6 miles, approximately. It is entirely occupied by Mesozoic and Cenozoic formations, which uniformly incline off the Carboniferous in the west flank of the Hoback Cañon ridge. Along the western border of the basin, or high up on the east flank of the John Day ridge, the strata have been faulted with downthrow on the east amounting to several thousand feet, so that the uppermost or latest of the geologic deposits impinge against the Carboniferous, which latter forms the crest of the ridge.

South of the East Fork John Day's River, which crosses this central mountain ridge in a deep cañon 4 or 5 miles north of our south line, the interspace between the two ridges is apparently occupied by Laramie, possibly also Cretaceous, deposits, which here hold a much higher actual altitude than is the case farther north, the later formations having been removed to a large extent, at least, in this quarter. The exact line of the fault probably passes well to the east of the monoclinal crest of that part of the ridge south of the East Fork John Day's River, which is made up of heavy deposits of hard light-reddish sandstone and gray limestones of the Upper Carboniferous. These deposits, which were identified from specimens obtained at Station VII by Mr. Clark, dip at a moderate and steepening angle of inclination to the westward, presenting rugged escarpments on the east several hundred feet in height. East of the heights the inferior limestone ledges rise up more gently in the same direction, appearing in long lines of step-like exposures in the high plateau of this part of the basin.

In the divide north of the East Fork, however, in the line extending across from Hoback's Peak (Station VI) to Station VIII on the John Day ridge, the section discloses the entire Mesozoic series, as developed in this region, including above a heavy series of soft buff and gray sandstones and arenaceous clays probably referable to the Laramie. Two or three miles to the northeastward of Station VIII a high outlying ridge, between the forks of the lower south branch of the Hoback, about midway between the Hoback Cañon and John Day ridges, is here crested with strata of the age of the Bear River Laramie. These consist of brownish gray and buff sandstones, dark blue, drab, and chocolate-red shales, with more or less indurated layers and occasional ledges of dark siliceous limestone. The latter beds at one point in this vicinity afforded a few fossils, *Goniobasis macilenta* White, *Corbula pyriformis* Meek? *Pyrgulifera humerosa* Meek, *Unio vetusta* M., &c., and obscure vertebrate remains, which identify the strata with the Bear River division. It is very difficult to estimate the exact vertical extent of this member, owing to the soft character of the beds, which readily yield to atmospheric erosion, and although the belt it occupies is exceedingly broken, few good exposures are to be met with. However, it probably reaches a thickness of several thousand feet, and is apparently conformable to the Jurassic beds beneath. At the above locality the dip is westwardly at an angle of 35°, the intervening depression on the east being occupied by the Jura-Trias which rises up on the west flank of the Hoback Cañon ridge, and which apparently folds round the south extremity of the ridge on which Station V was located. On the west, in the saddle reaching over to the John Day ridge in the vicinity of Station VIII, a heavy series of greenish gray and light buff sandstones and soft clayey deposits succeeds, dipping uniformly westward, and reaching within 200 or 300 feet of the crest of the latter ridge, in abrupt

geologically the same as that on which Station II was located; that is, the eastern flank of the synclinal trough, which is here also filled with the "red beds," and probably remnants of the Jura. The eastern verge of the synclinal probably lies at least a mile east of the station, where it is marked by prominent red pyramidal heights overlooking the high morainal benches in the foot of the Gros Ventre Mountains, and which here constitute the divide between the upper north affluents of the Hoback and the little stream that joins the Snake a mile or so above the mouth of Hoback's River. The heavy upper "red beds" rest upon a series of grayish buff limestones and red drab and chocolate banded arenaceous deposits, occurring in heavy alternating beds, with a vertical exposure of near 1,000 feet in the south side of the cañon north of the Hoback. The latter deposits bear marked resemblance, lithologically, to the Permo Carboniferous horizon in the Snake River Mountains; but in the absence of fossils, none having been noticed in these beds, the data is as yet insufficient to establish their identity beyond question.

As regards the geological character of the outlying strip on the southwest flank of the Gros Ventre Mountains, and extending well over to the Snake River south of the basin course of the Little Gros Ventre Creek, the only data gained was that presented in the view from Station III. This mainly discloses the red and gray deposits of the Jura-Trias, from beneath which the Palæozoic formations rise up on the south flank of the great Archæan spur of the Gros Ventre Mountains, which abruptly terminates on the Little Gros Ventre in Jackson's Basin, to the northwest of Station XII. To what extent the strata in this belt have been disturbed is not clearly made out. Nor is the contact of the Hoback Cañon ridge with the southern flank of the Gros Ventre Mountains in this quarter better displayed, though the two undoubtedly belong to entirely distinct areas of mountain upheaval, as will be further noticed in another place.

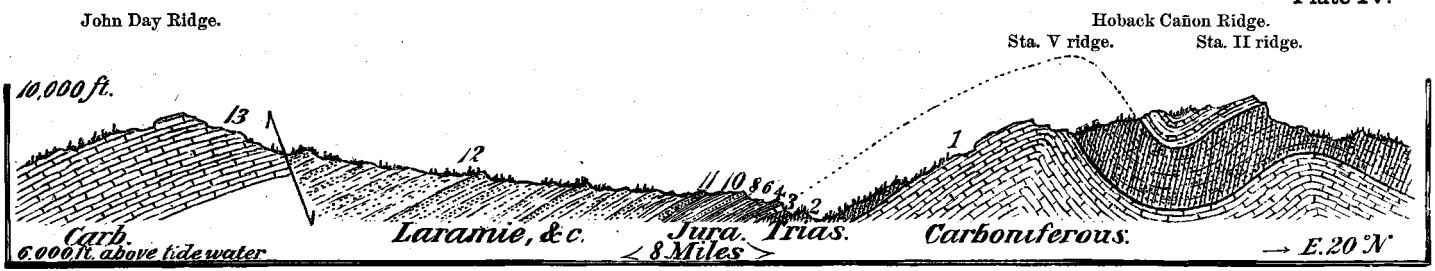
The Carboniferous series in the Hoback Cañon ridge offers striking resemblances to the same series as developed in the Snake River Range to the northwest of the Grand Cañon; the upper measures consisting of gray, buff, and flesh-tinted hard sandstones and red arenaceous deposits, including beds of more or less siliceous and sometimes magnesian limestones. This upper siliceous member is of great thickness (the exact measurement in feet would be difficult to determine after so hasty exploration), and in the deeper gulches and cañon it has contributed immense quantities of fragmentary materials to the steep taluses. With the inferior and perhaps heavier limestone member the whole series probably attains a thickness above 3,000 feet in this area.

JOHN DAY RIDGE.

West of the Hoback Cañon ridge a nearly parallel mountain ridge extends from the southern line of the district, where it is identified with the Green and Snake River water-divide, northwards in a nearly direct course a distance of 22 miles, terminating in the angle at the junction of the Hoback and Snake Rivers, and which may be distinguished by the above appellation.

The belt intervening between the Hoback Cañon and John Day ridges is partly drained by the lower south fork of the Hoback, and north of the latter stream the area here alluded to merges into the valley of the Snake above the Grand Cañon. To the south a high divide separates the Hoback drainage from the sources of the East Fork John Day's River, south of which one of the upper tributaries of the main Hoback takes

Plate IV.



Section of Mesozoic formations between Hoback Cañon and John Day Ridges.

spurs defining beautiful amphitheaters eroded out of the Carboniferous limestones which constitute the main mountain ridge. The position of the fault may be closely located at this locality, but to the south, in the undulating plateau east of Station VII, it is not so clearly indicated, as seen from this point.

From the above mentioned Laramie ridge an extensive view of the surrounding country is gained, showing the general geological features most clearly. The Bear River belt soon passes to the west side of the Hoback tributary, below the forks of which it is dimly traced in the rough slopes rising up on the John Day ridge. In the latter quarter a somewhat detailed section was obtained, showing the Jura-Trias and later deposits, which is incorporated in the section through Station V. This section commences near the forks of the stream, and is thence carried westward up the slope to the crest of the John Day ridge, presenting the following stratigraphic details:

Section across basin between Hoback Cañon and John Day ridges.

No. 1. Reddish and buff siliceous Carboniferous deposits, plating the west slope of Station V, Hoback Cañon ridge.

No. 2. Triassic red sandstones, in which the valley of the creek is here excavated. This series is here made up of red sandstones and grayish red arenaceous shales, capped by a heavy bed of buff sandstone, dipping WSW., at an angle of 35°; 1,500 to 2,500 feet.

No. 3. Soft, buff, brecciated, vesicular limestone, with calcite, forming a heavy ledge. Dip WSW., angle of 25°.

No. 4. Rather hard, fragmentary, drab limestone, with Jurassic fossils. A heavy bed.

No. 5. Drab, indurated and nodular calcareous shales, with *Pentacrinus*, *Gryphæa*, &c.

No. 6. Blue, fragmentary, even-bedded limestone, with shaly partings, Jurassic fossils. Dip 32°, WSW.

No. 7. Red, partially indurated shales.

No. 8. Blue limestone and drab, indurated calcareous shales, with *Camptonectes*, *Gryphæa*, &c., 300 feet or more.

No. 9. Greenish sandstone and chocolate-red streaked shales, capped by gray, rusty-weathered sandstone, 100 to 150 feet.

No. 10. Reddish shales, including a bed of light drab limestone and rusty indurated clay, overlaid by reddish and light gray sandstones, 300 to 500 feet.

No. 11. Dark shale, passing above into drab shales with indurated bands, 300 to 500 feet.

No. 12. Heavy series of gray, buff and bluish, rusty and reddish-weathered sandstone, in places with ripple-markings, outcropping in ledges separated by intervening softer deposits, and exposed over an extent above a mile across. Dip 30° to 45°, WSW.

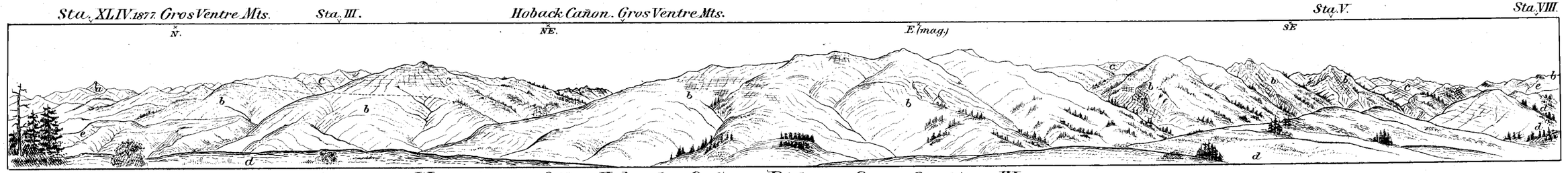
No. 13. Light and dark drab and gray limestone, cherty and spar-seamed, containing *Zaphrentis*, crinoidal remains, *Orthoceras*, upper layers, charged with *Zaphrentis*, *Syringopora*, and other Carboniferous fossils. Dip 10° to 40°, WSW., a vertical thickness of about 800 feet exposed in east face and crest of the John Day ridge, 5 miles north of Station VIII.

The lower members of the foregoing section are clearly referable, by their fossils and lithology, to the Jura and Trias. But the series above the black clays, No. 11, including a vertical thickness of a few thousand feet, are doubtfully referred in part to the Cretaceous, but mainly to a later period, or the Laramie, possibly including early Cenozoic deposits.

There appears to be no break in the conformity of the earlier and later deposits of this series of strata, and this fact, notwithstanding the modern appearance of the upper sandstones, suggests their identity with the Laramie formation. The impingement of the late sandstone deposits against the Carboniferous limestones in the foot of the sharp rise culminating in the crest of the John Day ridge is shown in the section diagram, and needs no further explanation. The junction of the Laramie and Carboniferous beds marks the position of the fracture in which resulted the fault, the downthrow of which probably amounts to not less than 6,000 feet at its locality. The crest of the John Day ridge was followed from this point, south, as far as the heights overlooking the gorge of the East Fork John Day's River, the Carboniferous limestones forming a marked monoclinal the whole distance. To the north, although this part of the ridge was not visited, except at its extreme northern end, where it terminates on Snake River, the appearances indicate precisely the same state of things.

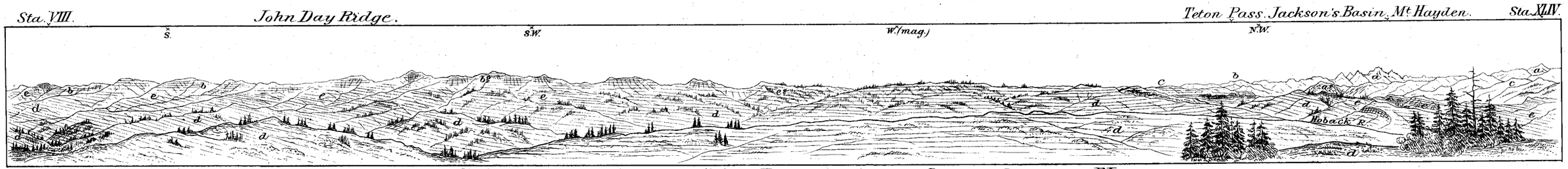
Between the line of the last section and the Hoback the earlier Mesozoic formations again pass to the east side of the valley basin, where the later or Bear River beds are tolerably well exposed in clayey slopes and tilted ledges to the north and in the vicinity of Station IV. But in this quarter the earlier members are less well exposed in the outlying slopes on the west foot of the Hoback Cañon ridge. At Station IV, which occupies an eminence of a few hundred feet elevation, and between two and three miles south of the confluence of the Lower South Fork and the Hoback, obscure ledges of grayish buff and reddish laminated sandstone interbedded with bluish shales appear, and in the summit underlying a similar sandstone ledge occurs a considerable thickness of dark-blue indurated clays. Below the latter, arenaceous indurated layers afforded a few fossils, amongst which Dr. White has recognized *Limnæa vetusta*, Meek, *Compeloma megaspira*, Meek? *Corbicula* (*Veloritina*) *Durkeii*, Meek? and a fragment of reptilian bone. These deposits incline westwardly at an angle of 30°. On the opposite, west, side of the stream similar deposits appear in steep bluff slopes, presenting more or less distinctly banded dark leaden and gray exposures along the line of strike, which may be traced several miles up and down the stream, and rising up in the east flank of the John Day ridge, where they pass into the beforementioned yellow-weathered sandstones and clays. Above the station the valley narrows, the Bear River ledges appearing in hog-back ridges, made up of blueish, brown-weathered sandstones, and more or less arenaceous clays, including layers of light drab limestone, associated with variegated chocolate-red, shaly calcareous sandstone, all dipping south of west at angles of 30° to 45°. Higher up the valley widens into a beautiful terraced intervale, the adjacent slopes wooded with pine and fir trees, although vast tracts have been devastated by forest fires. Below the cañon the Hoback flows through a fine terraced basin-valley, closing up a little lower down, but retaining its valley character to the confluence of the Snake, four or five miles below.

To the east, south, and west the view as seen from Station IV is limited by the bordering mountain ridges, but to the north, looking out into the lower part of Jackson's Basin, the southern half of the Téton Range rises boldly into view. In the latter direction are observed some interesting phenomena in relation to the position of the geological deposits occurring in the northern portion of the present basin area. Along the course of the little stream 3 to 5 miles north of the Hoback, and in the bordering hills, there appears a rather heavy deposit of dull-



West slope of the Hoback Cañon Ridge, from Station IV.

a. Archæan. b. Carboniferous. c. Jura-Trias. d. Laramie. e Tertiary.



East slope of the John Day Ridge, from Station IV.

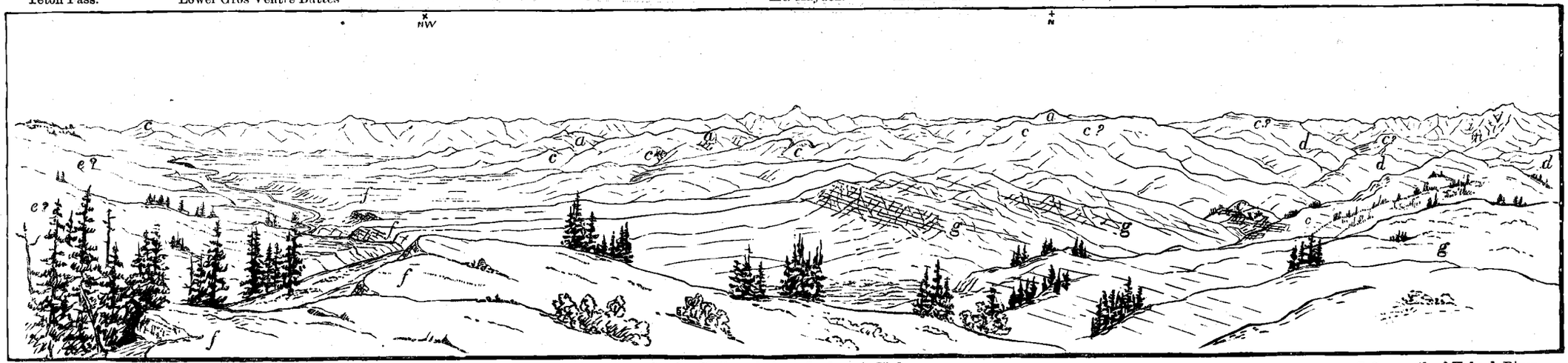
a. Archæan. b. Carboniferous. c. Jura-Trias. d. Laramie. e. Tertiary.

Plate V.

Plate VI.

Téton Mountains. Gros Ventre Range.

Téton Pass. Lower Gros Ventre Buttes Mt. Hayden. Mt. Moran. Sta. XLIV (1877). North end Hoback Cañon Ridge, Sta. XII.



Snake River Mts. Snake Valley, below Jackson's Hole. Cañon north of Hoback River.

a Archæan. *c* Carboniferous. *d* Jura-Trias. *e* Laramie? *f* Tertiary, limestone conglomerate. *g* Tertiary, red conglomerate.

red, soft, gritty, slightly calcareous clays, holding quantities of limestone and red sandstone bowlders, also fragments of gray sandstone identical with beds occurring in the Laramie. These deposits incline quite uniformly to the notheastward at an angle of about 15°, abutting against the Carboniferous ledges in the Hoback Cañon ridge along the eastern margin of the basin. At the latter point the juxtaposition of the stratigraphically widely separated formations is not as clearly displayed as could be wished, yet it is safe to infer from their relative position either the existence of a fault by which the Carboniferous beds are brought up to the level of the Tertiary conglomerate, or the latter beds, which were originally laid down horizontally, have been upraised into their present position by subsequent disturbances situated in the central portion of this mountain range.

The conglomerate deposits may be traced in beautifully weathered exposures in the outlying slopes along the west foot of the Hoback Cañon ridge to the north and south of the little stream, where they were also examined by Mr. Perry. To the west they are underlaid by a gray ledge, consisting of water-worn pebbles of gray limestone, various kinds of sandstone, quartzite and chert, the light-gray calcareous matrix, or cementing paste, often replacing the coarser material and forming a coarse light-gray limestone quite free from pebbles. This ledge, of which a thickness of above 50 feet is exposed, also dips northeastward at an angle of 20°, appearing in the hills just north of the Hoback a couple of miles above its mouth, and outcropping in the edge of the high terrace on the east side of Snake River several miles to the north. At the former locality on the Hoback the exposures reach an elevation of 1,500 or 1,600 feet above the Snake, and a few hundred yards to the west a heavy underlying series of grayish sandstone outcrop, showing about the same direction and rate of inclination. The latter deposits afford obscure vegetable remains, which, together with their lithology, warrants their identification with the Laramie. If there be nonconformity between these beds and the gray calcareous conglomerate, it is not apparent at this locality.

In the slopes rising into the more rugged outlying hills of the John Day ridge, on the south side of the Hoback, the same series of sandstones occur, dipping to the southwestward at angles of 15° to 20°. The axis of the fold here indicated, extending in a northwesterly and southeasterly direction, has been deeply eroded by the Hoback just above its junction with the Snake, to the west of which the strata composing the arch merge into the series elsewhere described, in the section along Snake River.

How far up the valley of the Snake, to the north, the gray calcareous and red conglomerates extend was not ascertained. However, their extension in that direction suggests the possible identity of at least the gray calcareous deposit with the soft calcareous and earthy late Tertiary or Pliocene beds known to exist in the mountain-locked basin east of the Tétons. That these deposits belong to a very late geological time is abundantly indicated by the nature and derivation of the component materials—the coarse detrital materials plainly having been derived from the Palæozoic and Mesozoic strata occurring in the adjacent mountains. Their apparent conformity and nonconformity in relation to the supposed Laramie deposits which they immediately overlie and the Carboniferous formations against which they impinge in the foot of the Hoback Cañon ridge complicate the determination of their exact position in the geological series.

JOHN DAY BASIN.

The area drained by John Day's River comprises the extreme southwestern portion of the district, the examination of which was limited, for want of time, to the eastern portion, or that drained by the East Fork. On the west a rather high and rugged mountain ridge (the Salt River ridge) intervenes between John Day's and Salt rivers, shutting out the view of the valley of the latter stream. Along the crest banks of snow still lingered in shaded ravines as late as the middle of August. A few miles south of the Grand Cañon of the Snake and south of the water-pass of the John Day's the high crest abruptly falls to a lower mountain ridge, which forms its continuation northward; to the south the mountain gradually rises in altitude, presenting a uniform ridge 10,000 to 10,800 feet in height in the district explored the previous season by Messrs. Gannett and Peale. The belt between this ridge and John Day's ridge is occupied by a hilly basin holding many pretty little valleys and meadow basins. Both the John Day's and its East Fork flow through willowy intervales hemmed by steep slopes.

Descending the west flank of the John Day ridge, the upper siliceous deposits of the Carboniferous fall steeply, their débris strewing the slopes and burying the foot of the mountain beneath great piles of fragmentary materials. In the edge of the parallel depression more or less well-exposed Jura-Trias deposits may be traced both to the north and south, dipping uniformly westward, and occupying a belt one or two miles in width. Beyond lies a wider belt, 4 to 5 miles or more across, in which a heavy series of sandstone and clay deposits is met with, also dipping westwardly at angles of varying inclination.

On the western border of the latter belt, in the vicinity of the ridge lying between the forks of the John Day's, on which Stations X and XI were made, this series of beds, together with the Jura (?), is elevated into a sharp anticlinal fold, with northeasterly dips of 50°, more or less, and much less steep westerly inclination. But ascending to Station XI ridge, the strata resume their westerly inclination, and from the crest they descend into a depression where the series impinge against the abrupt mountain barrier whose basis rocks consist of the heavy gray limestone ledges of the Carboniferous, overlaid by red sandstones probably belonging to the middle member of the same series. The latter deposits also dip westward in the direction of Salt River Valley, though in places they have been described as being much disturbed, as noticed by Professor Frank Bradley in the lower portion of the Grand Cañon of the Snake.*

To the north, along the Snake, the Jura-Trias outflanks the John Day ridge, the Jurassic member of the group appearing in fine exposures made up of variegated clays, sandstone and limestone ledges, in the abrupt mountain slopes hemming the right bank of the river. Both formations occur along a little stream which rises in a lakelet on the west foot of the John Day ridge, a few miles to the north of Station VIII, gaining the Snake just below the last bend in its course through the Grand Cañon. The Trias here exhibits its typical lithology, consisting of buff and red sandstones, dipping off the Carboniferous mountain ridge. The Jura near the confluence of the streams exposes heavy beds of more or less indurated light drab calcareous shales and limestone, which afford abundance of *Gryphæa calceola*.

* Hayden's United States Geological Survey, Montana, Idaho, and Wyoming, 1872, p. 268.

Plate VII.

Section through Station XI.

From the divide at the head of the west branch of this stream and a shallow meadow-valley tributary to the East Fork of John Day's River, a section was hastily examined extending over to Station XI ridge in the vicinity of Station IX, a distance of about 4 miles, or between 6 and 7 miles west of the crest of the John Day ridge. The section alluded to, a diagram of which is given on an accompanying plate, is described below:

Section east of Station IX.

No. 1. Carboniferous limestone, in crest of Station VIII, or the John Day ridge.

No. 2. Heavy deposit of red or flesh-colored and white quartzitic sandstone, much broken up, corresponding to the upper siliceous member of the Carboniferous.

No. 3. Imperfectly exposed series of reddish and buff laminated sandstones and arenaceous shales, dip WSW. at angles of 35° to 45°, occupying a belt half a mile or more across. This series is the equivalent of the Trias, its outcrop for a large part of the distance forming a well defined and, in places, rugged outlying ridge along the west foot of the mountain. Probably 2,000 feet thick.

No. 4. Clays and chocolate-red sandstone.

No. 5. Light weathered, bluish, spar-seamed, and cherty limestone, a thickness of 5 feet exposed of an apparently heavy bed, dipping westward. Contains obscure fragments of fossils, a small gasteropod, referred provisionally to *Lioplacodes veternus* M. and H., being most numerous and best preserved.

No. 6. Space, probably shales. (150 yards, +—.)

No. 7. Buff and rusty colored; rather hard fragmentary sandstone, associated with ferruginous gritty indurated deposits.

No. 8. Space. (100 yards, +—.)

No. 9. Dirty gray, laminated, rather hard sandstone; dip 40°, about W. 10° S.

No. 10. Space. (300 yards, +—.)

No. 11. Reddish buff sandstones, with traces of vegetable remains, forming a heavy ledge, 50 yards across the exposure.

No. 12. Space. (150 yards, +—.)

No. 13. Heavy bed of light gray and buff, reddish tinted, fragmentary sandstone, overlaid by grayish indurated clay and a band of light colored chert, 50 yards across the exposure.

No. 14. Dark blue, indurated clay shales, exposed in steep bluff slopes on the east side of East Fork, east of Station IX.

No. 15. Gray, dark rusty weathered sandstone, forming a heavy bed overlaid by greenish-gray and reddish layers with bands of flesh-colored chert and dark indurated clay shales. Exposed in bluffs on the west side of East Fork; dip 30°, about W. 30° S.

No. 16. Yeliow and drab shales, with seams of white calcite, underlaid by gray, shaly sandstone.

No. 17. Gray and buff, dirty weathered, obliquely laminated sandstone.

No. 18. Gray and reddish thin-bedded sandstone, including a ledge of conglomerate composed of water-worn quartz pebbles, together forming a heavy bed outcropping in the broken slopes east of Stations IX and X; dip westward at a moderate angle.

No. 19. Gray sandstones and light clays, exposed at intervals over a space 500 yards or more across; dip southwestward.

No. 20. Rusty gray saudstone, obscurely exposed ledge, tilted nearly vertical.

No. 21. Similar grayish sandstones containing plant impressions, exposed in outlying slopes descending east from Station IX, over a space three-quarters to one mile across; dip westward.

A similar section was observed a few miles to the north, in passing along the ridge separating the East Fork and the Snake drainage, on the way to Station XI, which, while it is made up of the same series of deposits described above, exhibits some additional stratigraphic details not seen at the above locality. The eastern portion of the present section corresponds to Nos. 1 to 6 of the above section, and thence westward such exposures as occur over a belt about three miles wide are noted below.

Section through Station XI.

No. 1. Reddish gray sandstone, including chocolate-red shales.
No. 2. Space. (400 yards, + —.)
No. 3. Reddish-gray sandstone.
No. 4. Space. (300 yards, + —.)
No. 5. Reddish sandstone, dip 20° to 25°, WSW.
No. 6. Space, with ledges of gray sandstone. (700 yards, + —.)
No. 7. Dark-blue shales, resembling Bear River deposits west of Hoback Cañon ridge.
No. 8. Space. (200 yards, + —.)
No. 9. Coarse and rather friable gray sandstone.
No. 10. Space. (150 yards, + —.)
No. 11. Heavy ledge of gray laminated sandstone, containing obscure plant remains; dip WSW.
No. 12. Space. (200 yards, + —.)
No. 13. Light greenish-gray, shaly sandstone.
No. 14. Space (100 yards, + —), with darkish indurated and soft light-colored shales interbedded with sandstones.
No. 15. Gray and reddish tinted laminated sandstone, containing fragments of fossil wood and holding a band of partially oolitic light and greenish tinted chert; dip 25° about W. 20° S.
No. 16. Space (900 yards, + —), with ledge of brownish-gray sandstone containing fragments of endogenous wood, and in the upper and westerly portion ledges of conglomeritic sandstone apparently interbedded with soft clays and arenaceous deposits; dip WSW.
No. 17. Sandstone; dip WSW.
No. 18. Dark shales.
No. 19. Space, with obscure ledges of grayish brown-stained sandstone; nearly vertical.
No. 20. Gray and brown shaly sandstone, overlaid by dark-blue shales, like No. 18; dip northeastward at an angle of 50° and less. Exposed in east flank of slope rising into Station XI, over a space between the conglomerate, No. 16, and summit, about 900 yards across.
No. 21. Greenish-gray sandstone and chocolate-red shales, apparently making a heavy deposit.
No. 22. Drab fragmentary limestone, associated with chocolate-red shales containing calcareous nodules. The limestone which contains a small gasteropod too imperfect for specific determination, appears in the summit of the ridge at Station XI (8,549 feet altitude) dipping at a moderate angle of inclination westwardly.
No. 23. Rusty-weathered chocolate-red shales and indurated arenaceous beds, exposed in the west slope of Station XI ridge; dip westward.
No. 24. Drab shales and indurated arenaceous beds; dip westward

into deep ravine, apparently impinging against the faulted Carboniferons deposits in the east flank of the Salt River ridge.

The conglomerate ledges mentioned nnder No. 16 of the foregoing section are nndoubtedly identical with bed No. 18 of the preceding section east of Station IX; also the vertically-upraised sandstone beds, 19 and 20 respectively of the two sections, are doubtless the same ledge. The latter horizon marks the site of a sharp synclinal flexnre, into which the strata are wedged and so crnshed together as to render the determination of the exact character of the fold extremely difficnlt. The dark-blne shales included in No. 20 are not dissimilar to the snpposed Bear River Laramie shales, No. 7, farther east, while the limestone, No. 22, fonnd on the summit contains a small nnivalve shell resembling similar imperfectly-preserved forms occnrring in Jnrassic limestone beds described under the preceding section. The latter inference and surmised identity of the deposits in qnestion, if well fonnded in fact, indicate a fracture or fault in the strata at this point, which mnst have taken place dnring the folding of the beds into the anticlinal of Station XI, and which latter movement was probably closely synchronons with that concerned in the npheaval of the neighboring parallel ridges of this monntain belt.

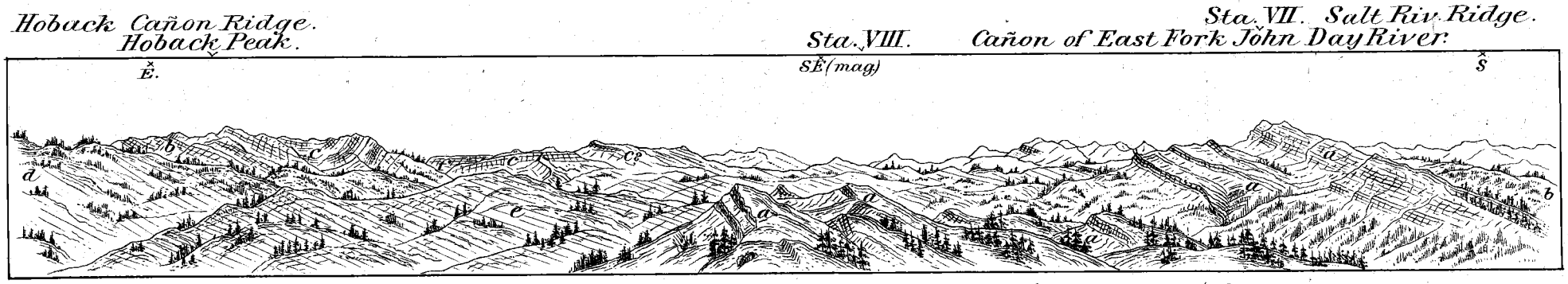
The western slope of Station XI descends with steepening abruptness into a deep depression largely filled with grayish deposits (No. 24), on the farther side of which rises a more prominent monntain mass belonging to the ridge bordering the east side of Salt River Valley and properly considered as the northern terminns of the monntain ridge bearing the same name. In the abrnpt eastern face of the latter monntain a fine section is exhibited, the lower two-thirds or more, based on the Carboniferous gray limestones, capped by a few hundred feet thickness of red arenaceons deposits, constitnting the summit. Althongh the latter deposits bear lithologic resemblance to the "red beds" of the Trias, they may prove to belong to the red sandstone horizon forming the middle member of the Carboniferons series of the region. The strata in the latter mountain ridge dip to the westward, the general exposnre as seen from Station XI being along the strike of the strata, and in places extensively barred, thongh mnch eroded, by drainage action. Between this mountain and the confinence of John Day's River and the Snake, at the lower entrance to the Grand Cañon, a belt some 5 miles across intervenes, which is known to be composed largely, if not entirely, of Carboniferons deposits, an acconnt of which was given by Professor Bradley in the report of this snrvey for 1872. To the sonth, in the adjoining district, Dr. Peale fonnd the same deposits extensively developed in the sonthern continnation of this mountain ridge, where they form a synclinal depression.

There can be little donbt that the strata composing the latter monntain ridge are fanlted, the Carboniferons beds having been forced np into a position high above those pertaining to the Mesozoic and Laramie epochs which flank the ridges west of Stations IX and XI, descending into the valley of John Day's River. The condition of things referred to is snfficiently clearly interpreted in the diagram of the foregoing section, which, together with the diagrams of sections farther to the east, afford a comprehensive view of the strnctnral featnres of this monntain zone in the territory immediately sonth of the Grand Cañon of the Snake.

From the above acconnt of the observations made in this region, it will have appeared that the work of exploration was carried nearly across the Wyoming Range; indeed, the resnlts practically give a connected section across this portion of the range, between the npper basin of the

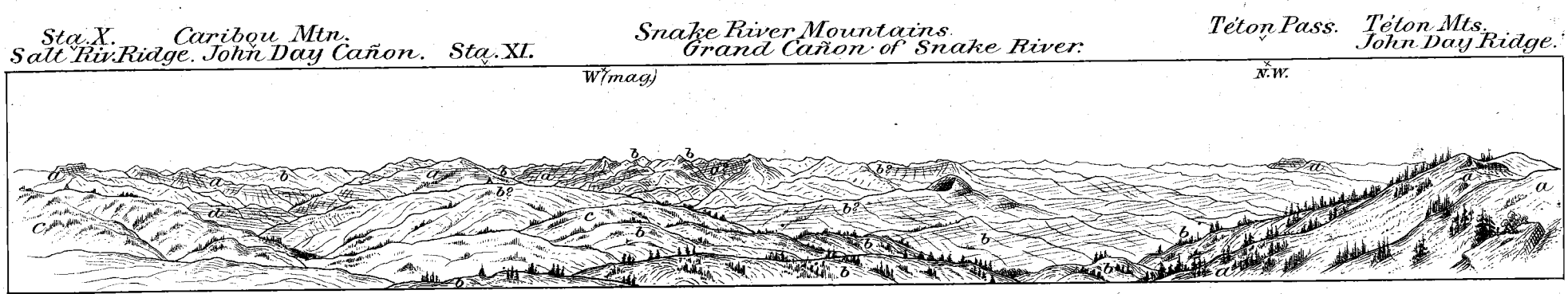
Hoback and Salt River Valley. But, unfortunately, the facilities were entirely insufficient for acquiring a knowledge of the mountain tract forming the continuation of this range in the region north of the Grand Cañon of Snake River, it being impossible to trace out in a satisfactory manner the complicated structural features, which obtain with equal force in that quarter, from such distant points of view afforded by the mountain eminences on the south side of the Grand Cañon. The observations of Professor Bradley, in 1872, disclosed several folds and extraordinary local disturbance in the strata comprising the natural section exposed in the walls of the Grand Cañon, and which doubtless bear intimate connection with the facts observed during the perhaps more detailed work of the present season briefly alluded to above. The region north of the Grand Cañon is excessively cut up by the combined effects resulting from geologic disturbance and subsequent aqueous erosion, some idea of which may be gathered from inspection of the topographic charts prepared by the survey; and while the one state of things offers exceptionably favorable facilities for the detail study of local sections, the other renders a more general study, especially at this distance, extremely hazardous and unsatisfactory. In certain instances the identity of formations may be confidently recognized, but, in other cases, color or lithological appearances are insufficient criteria upon which to affirm the stratigraphical position and age of extensive deposits prevalent in that quarter. The outlying gray ridge on the west, which forms the eastern barrier of the lower valley of Snake and Salt rivers, is unmistakably Carboniferous. Then succeeds a wide belt, out of which huge ridges have been sculptured by the elements from pale-red and buff beds, which seem to hold a position high above the latter, possibly forming part of the Laramie series, which appears to be much better developed (probably due to its being less extensively denuded) in that quarter than in the region visited the present season. And to the east of the latter, extending over to the Upper Snake in the vicinity of the lower portion of Jackson's Basin, the mountain escarpments exhibit all the lithological appearances familiarly ascribed to the Jura-Trias and post-Jurassic formations of the region. More than this the nature of the facts perhaps do not warrant. But a brief summary of the examinations of that part of the latter belt lying along a part of the course of the Grand Cañon visited the present season is here appended.

Our route brought us to the Snake, at the confluence of a small tributary draining part of the west flank of the John Day ridge, about seven miles in a direct line south of the mouth of Hoback's River. This little valley is wholly excavated in the westerly-dipping Jura-Trias deposits, the Gryphæa bed of the former being well developed in the immediate neighborhood of the confluence. Below this point the Snake enters that part of its course more properly designated by the term cañon. We here found on the terraced intervale indications of old placer workings, which had been opened eight years ago by a party of miners associated with Jeff. Stantiford, a well-known prospector and explorer of this region. The enterprise was, however, interfered with by the Indians, since when no organized mining operations have been resumed in this quarter. The locality, which is wonderfully interesting, both in its scenic and geologic surroundings, was carefully examined by my companion, Mr. Perry, with especial reference to the placer deposits and warm and mineral springs. A mile or so above this place the Snake changes its southerly course to a westerly direction, which it pursues thence to the debouchure of the Grand Cañon. The steep hills on the west side of the river, opposite and for some distance above the abandoned placer mines, present fine



Wyoming Mountains. From Station VIII (John Day) Ridge.

a. Carboniferous b. Trias. c. Jura. d. Laramie. e. Tertiary? f. Wasatch Tertiary.



Snake River and Wyoming Mountains. From Sta. VIII (John Day) ridge.

a. Carboniferous. b. Jura-Trias. c. Laramie. d. Tertiary.

Plate VIII.

exposures of probable Jurassic strata, showing alternations of variegated clays and indurated beds resting upon the Triassic red sandstones, the whole uniformly dipping south of west. The exposures, however, for some distance, appear along the strike of the strata, the section presenting the following lithologic appearance, as seen from the east side of the river, the vertical spaces being roughly estimated:

Section west side of Snake River, in the Grand Cañon.

No. 1. Red sandstones; Trias.
No. 2. Drab clays, a heavy bed, 200 feet or more; Jura.
No. 3. Ledge of dirty gray rock, probably limestone.
No. 4. Clays, with indurated layers, 100 feet.
No. 5. Drab and chocolate-red clays, alternating with brown and gray sandstone and limestone layers, 100 feet.
No. 6. Chocolate-red and drab clays, 100 feet.
No. 7. Heavy ledge of light gray rock, probably limestone, 40 feet.
No. 8. Drab and chocolate-red clays, 40 feet, with a bed of gray limestone (?), 15 feet.

The exposures along the east side of the river in this vicinity are much less satisfactorily revealed. In the neighborhood of the placer mines along the little stream draining the west slope of John Day ridge, the following Jurassic strata underlying the *Gryphæa* bed appear: Half a mile above the debouchure of the gulch there appears a ledge of drab, fragmentary limestone, containing fragments of *Ostrea* (?), a small gasteropod, and segments of the the column of *Pentacrinites*, underlaid by drab and chocolate-red variegated shales and earthy buff-weathered limestone, dipping about W. 15° S., at an angle of 38°. Underlying the above occurs a heavy bed of drab indurated calcareous shales, with fragments of a chambered shell resembling *Ammonites*, also fragments of a conchifer, *Pentacrinites*, &c. Then follows a ledge of softish buff-gray, magnesian (?) limestone, with pink calcite seams, dip 43° southwest, followed by a heavy bed of gray, reddish tinted quartzitic sandstone, weathering rusty reddish, and changing to red, laminated sandstone below, dip 37° to 40°, W. 20° S. The latter red sandstones belong to the Trias. They occur in a belt of rugged, outlying ridges along the foot of the John Day ridge, whose crest, as already stated, is composed of Carboniferous rocks, the limestone and siliceous débris of which is plentifully scattered over the lower slopes and incorporated with the soil, which is largely derived from the breaking up of the Jura-Trias deposits.

The latter section of strata is the same as that mentioned in connection with the sections east of Stations IX and XI ridge. In the extension north of the Grand Cañon it probably constitutes a belt of Mesozoic strata continuous with that noticed the previous season at Station XL, in the Snake River Mountains. Further, as was at that time surmised, it appears highly probable that these formations are faulted in the latter quarter—the western border ridge of the Snake River Mountains corresponding in geologic structure and in its disturbed condition to the John Day ridge in the southwest portion of the present district. The Mesozoics were there found to be overlaid by a great thickness of drab, buff, and variegated pale red deposits, the same as above noticed west of Station XI, and there as here the deposits apparently abut against the Carboniferous along the line of the fault. It will thus be seen that this faulted condition, in the areas here alluded to north and south of the Grand Cañon, has an extent of at least 60 miles; its southeasterly extension in the Wyoming Range was defined by Dr. Peale the previous

season. It is not improbable that the exceedingly complicated belt mentioned by Professor Bradley* in the Grand Cañon, in which the strata are tilted and disturbed in an extraordinary manner, involving Carboniferous and Mesozoic beds, was caused by proximity to the disturbances that produced the great faults of the John Day and Salt River ridges. But it will have been made apparent from the observations along the divide between John Day's and Salt rivers, in the neighborhood and east of Station XI, recorded in foregoing pages, that only one well defined anticlinal arch was found in the region lying between the John Day ridge and the similarly faulted Carboniferous monoclinal mountain that forms the northern terminus of the Salt River ridge.

The ground traversed in ascending the Snake Valley to the mouth of Hoback's River has already been reported upon by Professor Bradley, who accompanied the Snake River expedition of this survey in 1872. This part of the valley has a general northerly direction, and though hemmed by hills it hardly deserves the name cañon. At intervals the valley expands, affording narrow tracts of gravelly bottom-land, covered with willows and grass plots, and beautiful clumps of Menzies spruce, aspens, and cottonwood; the hillsides being clothed with pine and the ordinary fir-trees. Interesting examples of terrace formations are also met with in these valley expansions, the highest reaching 250 feet above the river-level. At one point the terrace declivity shows a thickness of 15 feet of horizontally stratified pebbles and bowlders at an elevation of about 100 feet above the intervale, which is cemented into a quite firm conglomerate. The terraces slope gently towards the center of the valley, their steep declivities being strewn with the thoroughly water-worn rock fragments which are identical with the materials paving the present shoal river-bed. These consist chiefly of quartz, with some granitic and other rocks, rarely a volcanic bowlder. Pieces of obsidian were found mixed with the terrace gravel, which were doubtless derived from the region of the Upper Snake or from the watershed, many miles to the northeastward. The Snake in this part of its course often occupies a wide, shoal bed, which at this season (August) exposes extensive bars of shingle and cobble-stones, amidst which the stream winds in many channels. The views from the higher terraces, commanding long reaches of the river hemmed by disconnected terraces and the more rugged low mountain borders, are extremely beautiful. The trail along the left bank was found in good condition for the pack-train, and, save at one or two points, without serious obstacles in the way of making a wagon road. For railway purposes the valley and Grand Cañon offers a feasible route between the lower valley of the Snake and Jackson's Basin.

For three or four miles the valley is bounded on the east by the John Day ridge, in which the Carboniferous ledges are steeply tilted, inclining at an angle of 50° to 70° south of west. The mountain-foot terminates in a steep talus composed of light and flesh-tinted quartzitic sandstone and gray limestone *débris*. In the outlying slopes occurs a brown-weathered gray shaly limestone, containing a few obscure fossils, which Dr. White refers to the young of *Ostrea*. From this evidence it would appear that these beds probably belong to a remnant of the Jura, or possibly a later formation, the stratigraphical relations of which are not well made out at this locality, more than that they overlie the Carboniferous. At a locality a short distance higher up the valley, the foot of the mountain is covered with rusty red and brown weathered, bluish and greenish gray sandstone *débris*, which probably belongs to the same

* U. S. Geol. Survey, Hayden, report 1872, p. 268.

horizon. The light reddish siliceous beds of the Carboniferous appear in castellated masses high up on the mountain side, and above these, in the crest of the ridge, occurs a series of light grayish deposits of doubtful age. A short distance below, where the valley changes to a north-south course, the Triassic quartzitic sandstones appear in force, forming a rocky point jutting into the river. These strata hold the same southwesterly inclination as do the older formations in the mountain ridge, the strike carrying them along the foot of the hills bordering the opposite side of the river for some distance above this point. They here probably attain a thickness of above 2,000 feet, with the same deep-red shaly arenaceous layers below. These deposits continue to a point where the valley course again trends northeasterly. The hills on the east side are well wooded and roughly scored by short drainage gulches, but those on the opposite side are comparatively bare, presenting gentler slopes, in which appears a heavy series of chocolate-red and drab-colored sandstones and clays, which resemble and apparently hold the position of the Jura. The latter deposits continue in the bordering hills a couple of miles or more, extending inland, northwards, as far as could be seen.

Passing round the north end of the John Day ridge, in the neighborhood of the bend in the valley, about 3 miles below the mouth of Hoback's River, extraordinary exhibitions of disturbance are introduced into the geologic section of this part of the valley. As yet, no clew is obtained of the character of the extreme northern portion of this mountain range, except that the western flank is heavily mailed by the steeply upraised Carboniferous beds. The trend of the main crest, however, veers round east of north, and, from the manner of weathering, it is evident that this portion of the ridge is composed of different materials from those making up the Carboniferous crest farther south, and which probably represent Post-Cretaceous formations. But in the neighborhood of the tule marsh (which is caused by the overflow of lime-charged warm springs that issue in the south side of the Snake) the slopes are strewn with drab, spar-seamed limestone *débris*, also fragments of hard, reddish sandstone, recalling the Carboniferous, although no fossils were found by which to establish their identity beyond doubt. In the opposite side of the river, however, the general structural features are well displayed, and beyond the necessary explanatory notes on the accompanying section diagram of this locality, I shall not repeat the observations here made by Professor Bradley in 1872.

Section in right bank of the Snake, below the mouth of Hoback's River.

a. b. Dark reddish sandstones (Trias) and chocolate-red and drab sandstones and shales (Jura?).

c. Brownish-red ledge; dip southwestward.

d. Black shales, interbedded with light colored indurated bed; dip northeasterly.

e. Dirty yellow siliceous beds. In the ridge above apparently horizontal, light colored, unconsolidated deposits appear, possibly Quaternary or lake beds.

f. Red-colored beds, dipping off flank of spur ridge, southwesterly.

g. Rusty weathered beds, probably gray sandstones; dip southwestward at a steep angle.

h. Apparently soft drab or ash-colored beds, obscurely exposed.

i. Rusty weathered, greenish-gray sandstones.

j. Chocolate-red beds, apparently indurated clays, curving over and dipping steeply northeastward.

k. Indurated drab beds, dip very steep to the southeastward and

curving up to the west where the chocolate-red beds are seen to form part of arch.

l. Dark rusty-weathered beds, probably gray sandstone, forming jagged crest of spur, with undulating inclination northeastward.

m. Soft, ash-drab deposits, apparently upraised into a low arch, but not clearly made out at a distance.

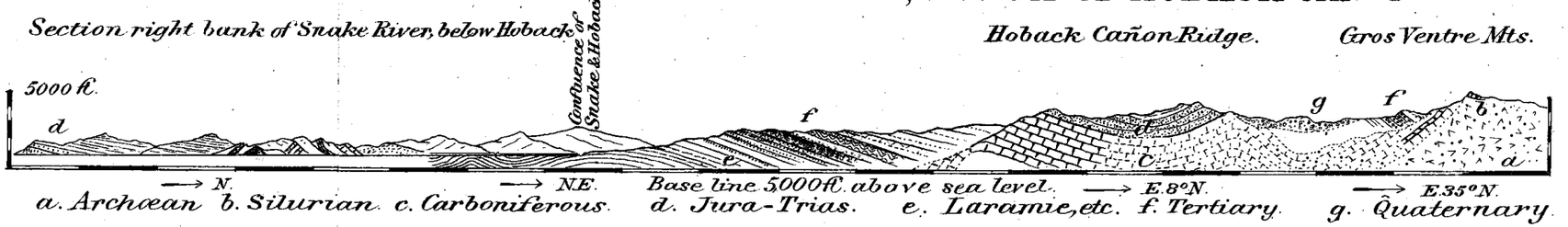
n. Dark rusty-weathered, probably bluish-gray sandstones and argillaceous beds.

The deposits *a*, *b*, of the foregoing section unquestionably belong to the west flank of the John Day ridge uplift. The lower arch represented in the section, on the east flank of which occur the black carbonaceous clays, *d*, may possibly be the northern continuation of the above ridge, and which, in the latter event, was not here faulted. The reddish-brown ledge, *c*, the sole vestige of the west flank of the fold, strikingly resembles the earthy sandstones associated with the before-mentioned *Ostrea?* shaly beds found in the west foot of the ridge a few miles south. Should the identity sought prove well founded, it would appear that the John Day ridge here sinks sufficiently to allow the Mesozoics to completely mantle the arch. The carbonaceous deposits alluded to are the same visited by Professor Bradley, and in his notice he refers to the exposure as consisting of "two or three heavy beds of black, calcareous shale and friable clay, with some harder bituminous mud-stones, * * * containing fragments of teeth and bones, probably belonging to amphibians." These deposits are overlaid by a thick bed of chert, probably represented by *c* of the above section.

The fold represented next above the last described, constitutes the axis of the more elevated, rugged portion of the ridge which here closely borders the stream, and which is believed to lie to the east of the axial trend of the John Day ridge proper. This fold was also mentioned by Professor Bradley, who describes it as being of mountainous proportions, with a nucleus of limestone. Opposite these exposures, as already mentioned, quantities of spar-seamed drab limestone and hard reddish sandstone débris occur in the steep declivities, but in the absence of fossils their age remains in doubt. A short distance above the latter occurrence, however, and opposite this uplift, the trail passes a succession of steeply inclined gray, rusty-weathered, thin-bedded sandstones, with which are associated fragmentary light chert beds, whose *ensemble* certainly bears close resemblance to horizons in the plant-bearing beds east of Station XI, which were compared with the Laramie. The latter beds are doubtless the same shown at *l*, and if their stratigraphical identity, as above inferred, be correct, the underlying strata composing the axis of the fold may not include deposits of earlier date than the Jura. To the north, however, in the more mountainous region occupying the bend of the Snake below Jackson's Basin, and constituting the extreme eastern flank of the Snake River Range south of Téton Pass, the prevalent rock formations apparently belong to a later or Post-Jurassic age. The latter quarter, however, was not visited, and the inferences arrived at are founded upon lithological appearances made out at a distance.

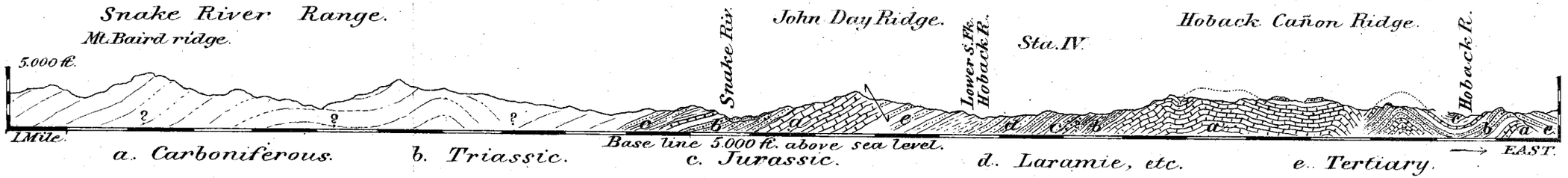
The deposits *n* appear in more or less interrupted exposures in the bluff-bank of the terrace, the evenly leveled-off tilted strata bearing the Quaternary deposits which constitute an important element in the composition of the terraces that now fill the valley. These strata continue as far as the mouth of Hoback River, where good exposures recur in the banks of the latter stream, a short distance above the confluence. At this locality a thickness of 20 to 30 feet is made up of bluish-gray, thin-bedded to shaly, sometimes concretionary, sandstone and fine argillo-are-

SECTION ACROSS THE WYOMING RANGE, NORTH OF HOBACK CAÑON.



SECTION ACROSS THE WYOMING RANGE, THROUGH STATIONS VI, VIII AND IX.

SECTION ACROSS THE WYOMING RANGE, SOUTH OF HOBACK CAÑON, AND PART OF THE SNAKE RIVER RANGE.



SECTION ACROSS THE WYOMING RANGE, THROUGH STATIONS V AND XI.

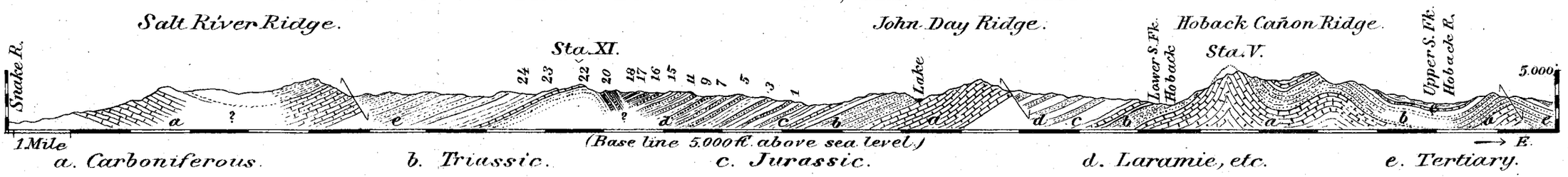


Plate IX.

naceous layers, with partings of dark, almost fissile, shale charged with charcoal particles. These deposits, in which the argillaceous element predominates, incline at an angle of 17° about W. 18° S. They belong to the series *n* of the foregoing section. In the high bluffs on the south side of the Hoback, just above the last noticed locality, heavy ledges of rather coarse-grained, thin-bedded, bluish-gray sandstone outcrop at an elevation 175 to 200 feet above the stream, the dip being to the southwest at an angle of 20°. The beds afford only obscure vegetable remains, like tree-trunks. They enter largely into the rock materials composing the outlying hills on the east flank of the John Day ridge. The gray sandstones and argillaceous beds outcrop in the narrows of the Hoback above as far as could be seen; but there are no conspicuous developments of red-colored strata along this part of the course of the Hoback, or between the cañon and the Snake. On the contrary, as has already been stated in relation to the valley of the lower south tributary of the Hoback, lying between the Hoback Cañon and John Day ridges, the grayish deposits constitute an important stratigraphical feature in this part of the Hoback Valley, especially in the east flank of the John Day ridge. Indeed, these deposits may appear in the topographical crest of this ridge towards its northern extremity.

In the angle between the confluence of the Snake and Hoback, a rather high ridge abruptly terminates, which forms a sort of long spur descending from the Hoback Cañon ridge north of the latter stream, the terminal point overlooking the Snake Valley having a relative elevation of about 1,600 feet. Ascending to the summit there appear in the upper part of the west slope exposures of gray and slightly reddish tinted, coarse-grained and shaly sandstones, interbedded with more or less indurated drab clays, dipping variably northeastward at angles of 16° to 25°. The sandstones hold indistinct plant impressions, and are in all respects identical with the great series that reaches up on the east flank of the John Day ridge. The inclination of the strata at this locality shows a low anticlinal, of which the present exposures form the east slope. To the eastward, along the summit of the ridge, newer deposits successively appear, maintaining an easterly inclination, and reaching over to the Hoback Cañon ridge where they abut against the Carboniferous, as has been already noticed.

The Hoback is here a fine stream, about 50 yards wide, with a brisk current of sweet, limpid water. Looking down upon the shadowed pools from the adjacent hills, the water has a beautiful green reflection. The stream bed is paved with water-worn boulders and pebbles identical with the materials found in the bed of the adjacent Snake River. The gravels in the river side afforded Mr. Perry a few scales of gold. In this connection may be mentioned the favorable facilities for placer prospecting along the river banks in this vicinity. The sandstones and clays incline in such way as to present their eroded, planed-off edges to the current of the ancient stream, like natural riffles, to retain the auriferous particles borne along by the flood. On the west side of the Snake, a mile below the mouth of the Hoback, a lively little stream emerges from the mountains clustered around Mount Baird, in the Snake River range, its lower course broken into a series of beautiful cascades. Where it crosses the terraces in the valley it might, perhaps, be easily utilized in sluicing operations, though it is to be hoped so beautiful a spot may never be invaded by the chaotic ruin which placer mining entails wherever profit may be gained from the washing of the soil. The elevation of the valley, about 6,000 feet, may not conduce to exceptionally favorable conditions for agriculture, but the valleys and adjacent hills are well stocked with grasses, and no doubt the hardier farm products would thrive.

CHAPTER III.

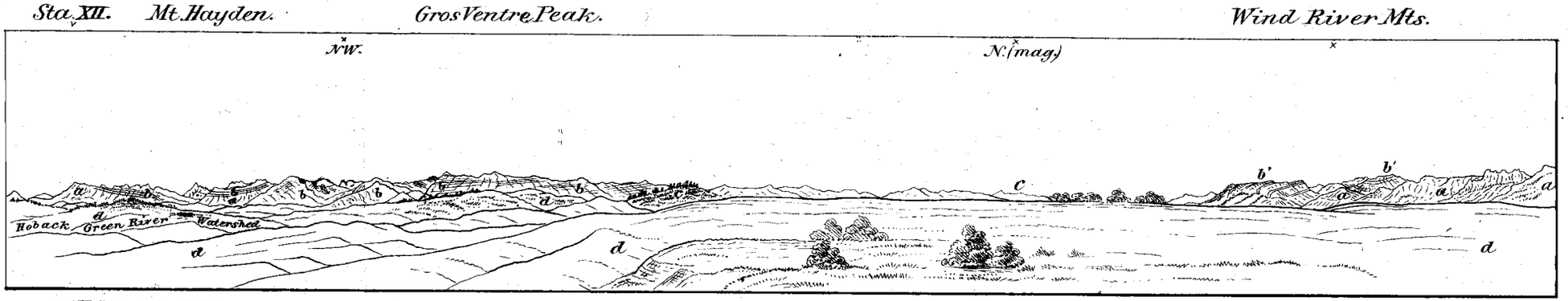
HOBACK-GREEN RIVER BASIN.

The region occupied by the principal drainage of Hoback's River and that of Green River after it leaves the Wind River Mountains is here considered under one head, since it presents a general uniform depression defined on three sides by mountain barriers. But its actual condition presents some interesting features, especially its hydrography, the development of which is due to the topographical department of the survey.

The basin as such opens to the south so that in ascending Green River the entire drainage of the great recess, bounded by the Wyoming Range on the west, the Gros Ventre Mountains to the north, and the Wind River range on the east, might be readily supposed to be tributary to this stream. Near the south line of the district, the Green River Valley proper, which here has an altitude of about 7,500 feet above tide-water, is narrowed to a width of about 20 miles, its western rim resting upon a low divide which curves round with its convexity to the southeast from the Wyoming Range north of Lead Creek where the width of the basin is augmented about one-third to the eastern extremity of the Gros Ventre Mountains. The most depressed point of the divide, which has a length of about 30 miles, occurs about midway, where its elevation is something less than 8,000 feet. To the northwest lies the basin of Hoback's River. The descent in that direction is comparatively rapid, soon reaching the general basin-level of 7,000 feet, and thence gradually declining to the lowest portion of the basin, 6,325 feet, where the collected waters of the Hoback enter the cañon through the eastern ridge of the Wyoming Range on the way to the Snake.

Sufficient has been detailed to draw attention to the leading physical features of this basin area as a whole, and the somewhat pronounced contrasts presented by its dual drainage system when compared one with the other. It may, however, be difficult to comprehend the processes which have maintained the present state of things, to explain the causes which have been concerned in originating its system of drainage; especially since there exists no natural orographic definition by which the waters of the Green might have been held to their present course instead of flowing into the more depressed area drained by the Hoback. Were the requisite data forthcoming this subject might properly be relegated to the section reviewing the dynamical geology of the district. However, brief allusion to some of the conclusions arrived at in this connection may be admissible in this place.

In the description of the eastern or Hoback Cañon ridge of the Wyoming Mountains, in a preceding section, occasion was had to notice the disturbed condition of nonconformable Tertiary deposits in the immediate vicinity of the folded Mesozoics of that mountain ridge. During the brief examinations along the foot of the Wind River Range on the east-



SOUTH FLANK OF GROS VENTRE RANGE: FROM STATION I, ABOVE CONFLUENCE OF LEAD CR. AND GREEN RIV.
a. Archæan. b. Palæozoic b'. Palæozoic south of Green River coñon. c. Jura-Trias. d Tertiary.

Plate X.

ern border of the basin, similar Tertiary deposits were also met with which appear to have been little if at all disturbed from their normal position. Along the Gros Ventre side of the basin perhaps the same observations, in part, hold good, with, however, certain exceptions in the neighborhood of the convergence of the Hoback Cañon ridge where the inclination of presumably Cenozoic strata is towards the mountain. The facts, therefore, imply dynamical movements within the area of the Wyoming Range and along the western border of the basin during a time subsequent to the deposition of the Tertiaries of the basin area; and was the tendency of these movements a downward one within the basin area and an upward one in the western mountain border, the subsidence in the one place would encroach on the former drainage planes and originate a new system tributary to that of the depressed area. In this manner might have originated the Hoback, and at a time relatively recent compared with the inception of the Green River drainage. The extent of the movements above alluded to cannot at present be defined; the appearances, however, indicate for them rather a local character, centering in the region of convergence of the Wyoming-Snake, Téton, and Gros Ventre ranges.

The area embraced in the Hoback drainage is diversified by intervale-bordered streams and terraces, covered with herbage, aspen and evergreen groves; the open slopes, of course, are well sprinkled with the ubiquitous sage. Hemmed to the north and west by mountain ridges built up of variously color-contrasted rocks, it is an interesting and beautiful region. Approaching the mountains on the west and north, the benches gradually rise, the streams occupying deep valleys, and often confined to narrows walled by steep bluffs, the lateral drainage furrowing the high benches with narrow ravines separated by sharp ridges or steep slopes, broken by landslides into step-like inequalities, having the semblance of rude terraces.

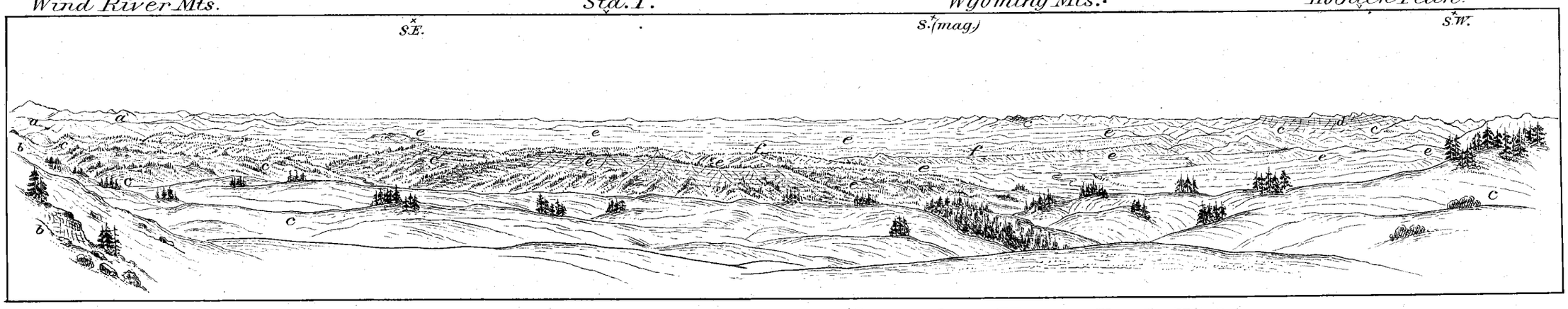
The almost equally extensive area belonging to Green River drainage, to the south, contains a greater proportionate extent of level bottom land immediately adjacent the stream, with broad belts of low, undulating uplands on either hand; to the west, rising into the low water-divide, heading the basin sources of the Hoback, and to the east soon merging into the foot hills and morainal ridges lying at the western base of the Wind River Range. To the north this portion of the basin is more broken, the tributary drainage which here reaches around the eastern extremity of the Gros Ventre Mountains draining a small portion of their northern slope, having fashioned a few broad-topped spurs reaching from that mountain axis, with gradually diminishing elevation, far out into the valley. While still farther to the north, a broad, undulating saddle-ridge, at least 15 miles in east-west length, stretches across from the northern slopes of the Gros Ventre Mountains to the west flank of the Wind River Range, forming the water-divide separating the Green from the Gros Ventre River. The divide is about 9,000 feet in actual altitude, comprising a beautiful park-like region of open, grassy prairies, dotted with aspen thickets and more or less extensive tracts of evergreen forests. The Green, after holding a nearly north-south course of 26 miles within the limits of this district, here sharply bends upon itself, and a few miles above, to the southeast, emerges from its mountain course through one of the grandest gorges penetrating this side of the Wind River Range.

This basin area is almost exclusively occupied by Tertiary deposits belonging to and continuous with the great Green River series of that age. The low water-divide separating the Green from Hoback's River,

is made up of alternations of soft, in places friable, sandstones of a grayish-buff color, including coarse-grained and conglomeritic layers, interbedded in the soft drab or blue and variegated dull chocolate-red clays, in quite horizontal position. The nature of the deposits, which readily decompose at the surface, renders their outcrop obscure save along the streams, where they appear in low bluff exposures. The inferior portion of the series, as it is here developed, becomes more clayey, like Wasatch deposits lower down the Green. The same beds reappear along Lead Creek, and they apparently constitute the great sloping benches that rise high up on and even invest the broad summit of the eastern portion of the Wyoming Range in the vicinity of the south line of the district. The benches here alluded to constitute the divide between Lead Creek, which flows into Green River near our south line, and the ultimate source of Hoback's River, which rises just south of Hoback's Peak (Station VI), in the Wyoming Mountains, and hence they belong to the before-mentioned water-divide. The whole upland region, as also the terraces and stream-beds, are strewn with drift materials mainly composed of quartz rock with occasional granitic and limestone bowlders. But these superficial deposits become less prevalent in the western portion of the basin in proportion to the greater distance the remove from the loftier mountain elevations that lie to the east.

The view from the divide-ridge looking towards the western mountain-border south of Hoback Cañon, shows the Tertiary gently upraised along the eastern outlying ridge of the Wyoming Range. As has been elsewhere stated, these deposits, here constituted of light grayish slightly calcareous sandstones and clays, incline off the monoclinal ridge of steeply dipping, non-conformable Jura-Trias at angles of inclination varying from 15° to 45° eastward, gradually flatteniug out towards the center of the basin. The soft deposits are seldom well exposed, the comparatively smooth, herbaceous-covered slopes here as elsewhere contrasting with the densely timbered surface of the more rugged mountain declivities. The unconformity of these deposits is well displayed at the forks of the Hoback 3 or 4 miles above the cañon, where their most westerly exposures are reached. In the west side of the valley the Triassic red sandstones appear, dipping to the southwestward, while in the same side low outliers of the later deposits cling to the foot of the mountain slopes, and on the opposite side of the stream they form a considerable elevation in the bluff face of which several hundred feet thickness of the soft sandstones and clays are seen, dipping eastward at angles of 30° to 45°.

South of the latter locality, the Tertiary deposits rapidly rise in elevation, and finally surmount the mountain summit, in the neighborhood of the south boundary of the district. In the latter quarter, these deposits incline eastward at a much gentler angle; but as this part of the Wyoming Range was not visited, their relations to the underlying Laramie formations, which Dr. Peale recognized still farther south, was not determined. It is improbable that the latter formation appears in the central portion of the Hoback Basin; not, however, that it does not exist there, but because it is concealed beneath the equally vast accumulations of Tertiary strata that fill the basin. Neither are the limits of the Tertiary deposits well-defined in the angle between the Hoback Cañon ridge and the Gros Ventre Mountains, where they are covered by erratic materials that in places deeply bury the foot of the mountain and outlying slopes. But the slopes soon merge into the benches descending into the lower level of the basin, which in places disclose the Tertiary strata apparently inclined in a northerly direction or towards the mountain.



Green River and Hoback Basin, from Gros Ventre Peak Ridge.

a. Archæan. b. Carboniferous. c. Trias. d. Jura. e. Tertiary. f. Hoback-Green Watershed.

Plate XI.

Although the immediate mountain border of the basin may be with equal propriety considered in connection with the description of the mountain areas for the sake of bringing together under one head all the data relating to the basin deposits, the observed occurrences in the border region are briefly reviewed in this place. In the narrow belt or saddle intervening between the Hoback Cañon ridge and the southern foot of the Gros Ventre Mountains, a set of imperfectly exposed beds occur, whose like was not elsewhere observed, unless they prove to be a recurrence of the Tertiary (?) conglomerate before mentioned, as occurring in the depression lying at the west foot of the Hoback Cañon ridge, and thence extending north into the lower portion of Jackson's Basin on the Snake. These deposits consist mainly of water-worn fragments of gray and bluish limestone, red and gray shaly sandstone, inclosed in a more or less calcareous arenaceous matrix, the exposures having a pale reddish color. The coarse materials vary from medium-sized bowlders to small pebbles. Their derivation may be traced to the neighboring mountains, the red sandstones having been furnished by the Triassic deposits, the gray shaly sandstone pebbles are apparently identical with beds occurring in the Cretaceous or Laramie, and the limestone fragments may have come from either the Jura, Carboniferous, or Quebec formations, all of which are *in situ* near at hand. The more conglomeritic portions show a homogeneous mass with obscure lines of deposition, best seen in the partially bared slopes where the bedding usually may be readily made out.

The latter deposits occupying the outlying slopes (9,000 to 10,000 feet altitude) at the foot of the mountain wall, a mile or so southeast of Station XII. The outcrop forms a belt several hundred yards in width, to the south of which and perhaps less than a mile distant, the southwesterly dipping Triassic red sandstones appear in the opposite side of the saddle, within the area of the Hoback Cañon ridge. The conglomerate dips at angles of 50° to 75° northward, or towards the Gros Ventre Mountains, in whose flank at this place the Paleozoic formations are much complicated and overtopped by the Archæan in the crest of the mountain. To the southeast of the above locality, and still clinging high up on the mountain foot, the conglomeritic deposits appear in the grassy slopes of the much eroded divide which here separates Upper Hoback and Snake River drainage. It is here readily identified by its reddish color, though apparently less disturbed, indeed in places gently dipping away from the mountain and then gently rising, until it is lost to view a mile or so to the south. It was not recognized to the east of the stream descending from the divide to the Hoback, where its place appears to be occupied by the light drab and yellowish Tertiary sandstones and clays. In the divide it appears only in the ravines, the slopes next the mountain being generally enveloped in morainal deposits brought from the immediately adjacent Archæan and Paleozoic mountains, in the vicinity of Station XII, and which are piled in characteristic ridges, whose inequalities afford numerous receptacles for water, forming diminutive lakelets amidst the partially wooded and open herbaceous slopes.

East of the divide beyond the limits of the mountain *débris*, the Tertiary deposits immediately appear in the sloping benches that make out into the basin to the south, a very broken region which, however, is traversed by beautiful terraced valleys of Hoback tributaries flowing out from the mountains to the north. The summits of the Tertiary benches often present wide, flat surfaces, through which wind swale-like drainage depressions, and covered with gneiss, quartzite, and limestone

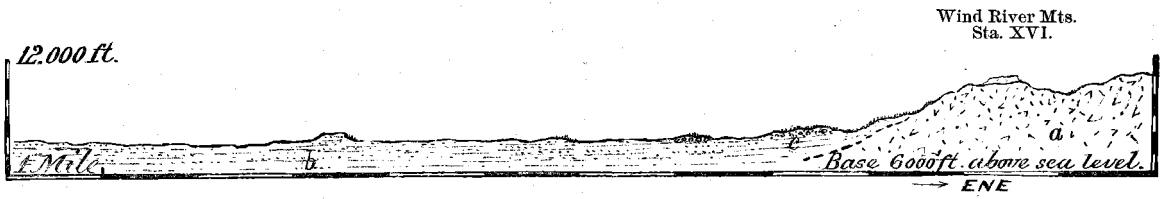
bowlders. The nature of the erratic materials is determined to a discernible extent by the prevalent rocks composing the nearest mountain wall. Paleozoic quartzite and limestone masses occurring at one place, and Archæan bowlders predominating at other localities.

Still farther east, and reaching over to the angle in the mountains at Gros Ventre Peak, the Tertiary deposits are much eroded by the streams that issue from the range, from whose foot they are here separated by a narrow intervening belt of Mesozoic formations, which properly pertain to the mountain area. A few miles to the eastward of Gros Ventre Peak these deposits reach high up in an outlying shoulder, about 10,000 feet altitude, where they rest unconformably upon deep red arenaceous beds holding the position of the Trias, and thence southward they compose the bulk of the water-divide between the Green and Hoback. At the latter locality, about south of Gros Ventre Peak, the Tertiary is chiefly made up of light buff or yellow and drab sandstones and arenaceous clays, dipping gently southward or southwestward into the basin where they merge into the long lines of terraces or benches that form a characteristic topographic feature of this area. The occasional exposures in the bluff escarpments along the water courses and ravines reveal the bedding with tolerable distinctness and often the beautiful effects of weather action peculiar to these soft deposits. No indications of coal were observed in connection with these deposits, although the observations made during a hasty visit hardly warrant the assertion that it does not exist.

In the region east of the water-divide, the middle, and perhaps later, Mesozoic formations have been denuded over a considerable area of the rolling high lands at the eastern terminus of the Gros Ventre range, where the Tertiary has been swept away. But farther south the latter deposits are again encountered, and thence they constitute the superficial rocks, filling the Green River portion of the basin, extending over to the great morainal accumulations that bury the western foot of the Wind River Mountains and reach well out into the more level basin uplands, where the erratic materials conceal the underlying deposits over extensive areas. However, exposures sufficient to show the identity and distribution of the Tertiary formation are not wanting, though to the action of fluvial, and to a less degree glacial, agencies, they have been generally leveled and covered with soil. South of Lac d'Auralia, the light drab, soft Tertiary deposits, nearly horizontal, fill a rather wide bay-like recess, extending in towards the mountain foot from the lower portions of the valley at a point on the south line of the district. This recess is defined on the north and south by great morainal ridges, so that it is impossible to ascertain the condition of the Tertiary deposits near the mountain border. These deposits probably extend not above 8 or 10 miles north of the 43d parallel along the river, where they give way to the Mesozoics which cross the valley in a low fold extending over from the Gros Ventre to the Wind River Mountains, south of the great bend of the Green, and which will receive fuller notice under the head of the former range. Although the valley extends 15 to 20 miles farther north, the geological limits of the common basin area occupied by the Tertiary sediments, may be defined by a line projected southeasterly from Gros Ventre Peak across Green River Valley. Tertiary beds may occur north of this line, but they are to be regarded as remnants which have escaped demolition in the process of erosion of the valley. Indeed these deposits may once have extended over the above mentioned geological fold, uniting and forming an uninterrupted belt with the Tertiary formations occurring in the otherwise well-defined basin area of the Gros

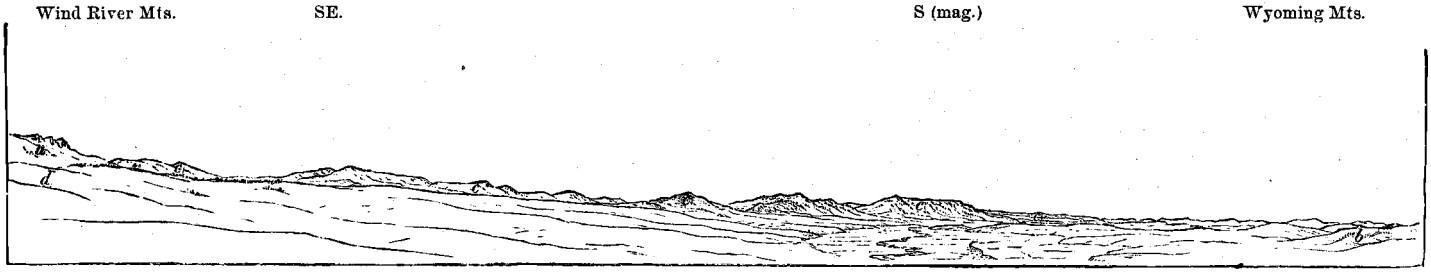
THE TETONS LOOKING DOWN GROS VENTREE FORK
GREY AND RED BEDS OF THE JURA TRIAS IN THE FOREGROUND.

Plate XII.



Profile of Green River Valley, Vicinity Station XVI.

a Archæan. *b* Tertiary. *c* Tertiary conglomerate.



Sta. XVII.

Upper Green River Valley.

a Archæan. *b* Laramie (?) *c* Tertiary. *d* Moraines.

Ventre drainage. But the meager facts in our possession are not deemed sufficient to establish beyond question so intimate stratigraphical synchronism in the Tertiaries of the at present topographically distinct basin areas here alluded to.

The Green River Valley, lying within this district, shows a broad expanse of level bottom-land and low terraces, giving place on either hand to gently undulating uplands, with here and there low hills and isolated buttes composed of horizontal Tertiary strata. Not till beyond our limits is the stream encroached upon by the uplands and accompanying bluffs, which to the south constitute so characteristic and interesting features in the geology and scenery of the valley. The river bottoms and terraces are both well defined, and if they are not entirely they are at least largely fashioned out of Quaternary deposits. The river generally has a rapid flow over a broad, shallow, bowlder-paved bed. The intervales are often little better than spongy mosses, densely overgrown with willows; but the terraces are invariable gravel strewn, and beautiful examples of their kind. The whole country is well covered with bunch grass, and for grazing purposes it would seem to be eminently adapted.

CHAPTER IV.

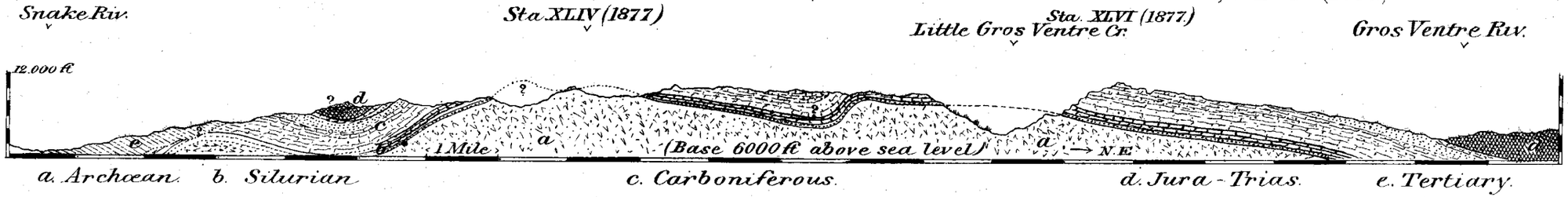
GROS VENTRE RANGE.

The Gros Ventre Mountains constitute a well defined range with a trend approximately ESE. and WNW., stretching from the foot of Jackson's Basin, east of the southern terminus of the Tétons, over to the Wind River range, nearly opposite the debouchure of Green River Cañon. Hence, its longer axis is little more than 40 miles, with a transverse breadth of somewhat less distinctly marked limits ranging from 8 to 14 miles. The western end of the range was visited the previous season, an account of which, together with a general account of the range, was given in the report on the Téton district, United States Geological and Geographical Survey of the Territories, 1877. Notwithstanding the haste with which the present season's explorations were conducted, it is believed a sufficiency of data was secured by means of which a general understanding of its geological structure may be arrived at.

It is apparent that the present condition of the range does not preserve its original proportions; that in Pre-Cenozoic times it was subjected to erosive agents whose action has degraded and removed an enormous quantity of rock materials over its whole extent, but especially active were these degrading influences in the western portion of the uplift where half its original bulk has been swept away and the comminuted materials intermingled with the thousands of feet thickness of Tertiary sediments filling the neighboring basin areas. Although the vertical displacement varied considerably, being greatest in the western half, erosion has reduced the crest of the range to a nearly uniform average height of 11,000 feet. The highest point, 12,200 feet, lies about 12 miles to the northwestward of Gros Ventre Peak; at Station XII in the western part of the range the altitude is 11,196 feet above the sea.

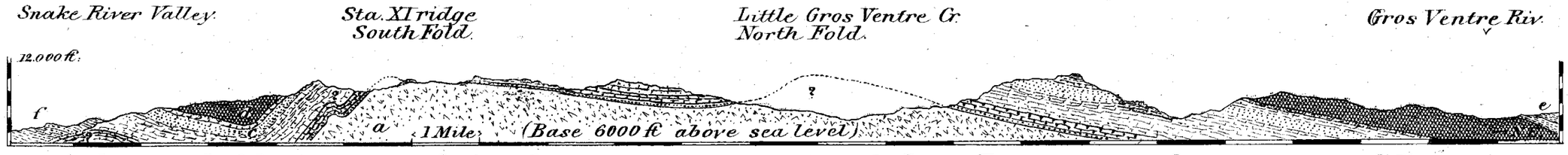
For the better understanding of the account of detail geology given in the following pages, a brief summary of the general structural features of the range, such as they are understood to be, is here introduced. Although the trend of the range, topographically, is as above stated, ESE. and WNW., the axis of elevation lies more nearly in a SE. and NW. direction. The upheaval, which was evidently an event closely following the close of the Mesozoic age and probably extending into Cenozoic time, was accompanied by at least two principal mountain corrugations parallel with one another, and perhaps not more than 5 miles apart. Besides the principal folds there were other minor undulations, whose extent and relations can only be worked out by a careful detail survey. The respective extent of the longer axis of the principal folds cannot at this time be determined, but the amount of vertical displacement in the southern fold was at least a few hundred feet in excess of that in the northern one. In the eastern half of the range, however, the southern fold has been entirely removed by erosion, so that the south flank of the mountain in the latter quarter is formed by

GROS VENTRE RANGE: SECTION THROUGH STATIONS XLIV, XLVI (1877)



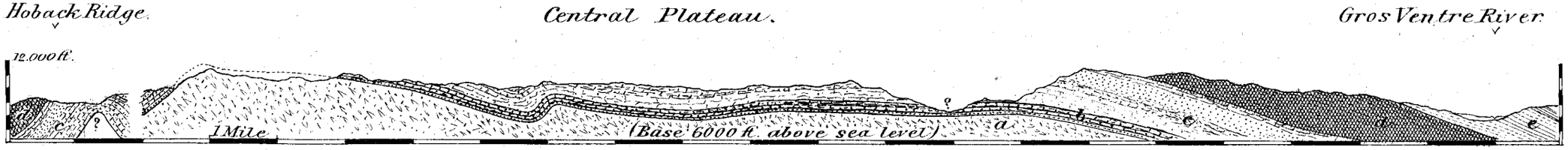
a. Archœan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Tertiary.

GROS VENTRE RANGE: SECTION BETWEEN STATIONS XII AND XLIV (1877)



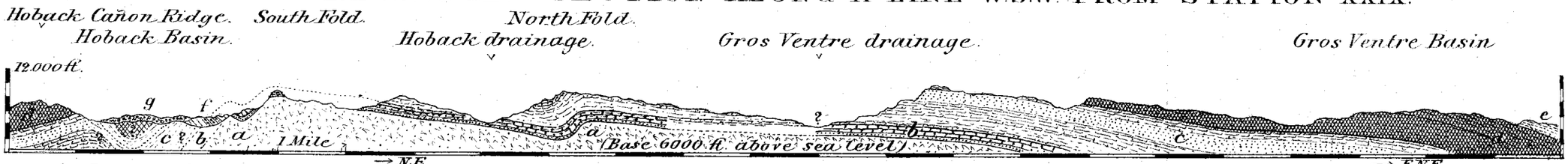
a. Archœan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Cretaceous. f. Tertiary.

GROS VENTRE RANGE: SECTION THROUGH STATION XII.



a. Archœan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Cretaceous.

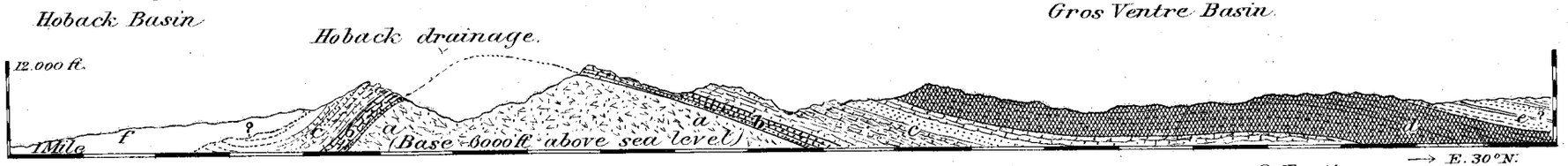
GROS VENTRE RANGE: SECTION ALONG A LINE W.S.W. FROM STATION XXIX.



a. Archœan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Cretaceous. f. Tertiary, red conglomerate. g. Moraines.

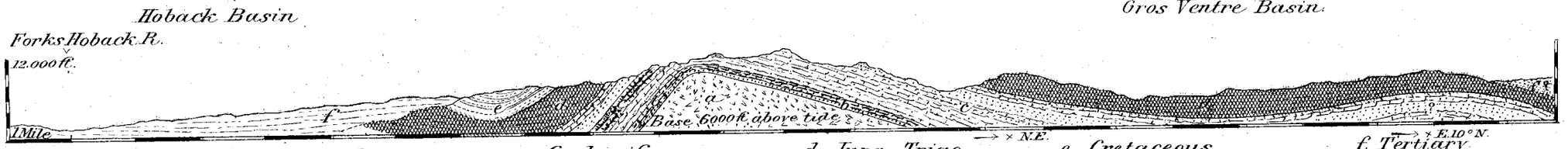
Plate XIII.

GROS VENTRE RANGE: SECTION EIGHT MILES N.W. OF GROS VENTRE PEAK.



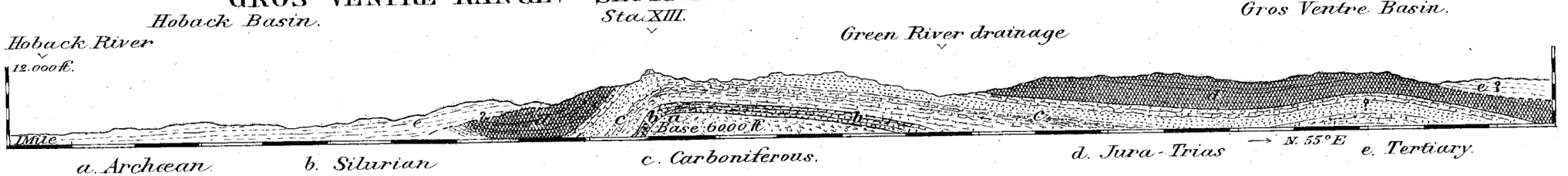
a. Archæan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Cretaceous. f. Tertiary.

GROS VENTRE RANGE: SECTION FIVE MILES N.W. OF GROS VENTRE PEAK.



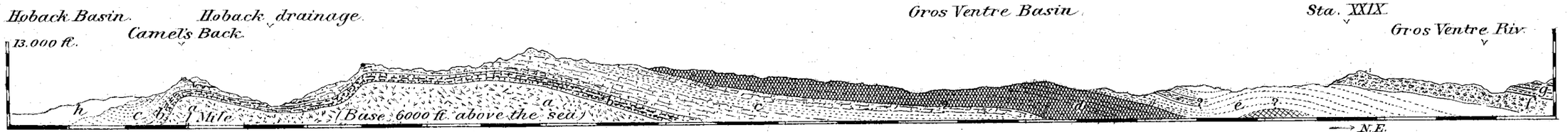
a. Archæan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Cretaceous. f. Tertiary.

GROS VENTRE RANGE: SECTION THROUGH GROS VENTRE PEAK (STA. XIII.)



a. Archæan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Tertiary.

GROS VENTRE RANGE: SECTION ALONG A LINE S.W. FROM STATION XXIX.



a. Archæan. b. Silurian. c. Carboniferous. d. Jura-Trias. e. Cretaceous, lower lignite series. f. Conglomerate. h. Tertiary.
g. Upper lignite series.

Plate XIII.

the abrupt south slope of the northern fold. South of Gros Ventre Peak the site of the greater fold is concealed by Tertiary deposits, which reach high up on the mountain flank at this point and thence incline off gently into the Hoback-Green River Basin.

Both the principal folds closely correspond in contour, and which is retained in a marked degree in the present configuration of the great ridges. It consists of long gentle slopes on the north, with abrupt flexure on the south, which latter was apparently, in places, accompanied by the rupture and complete severance of the sedimentary strata. Of the latter manifestations, such as were observed will be described farther on. Both termini of the range are masked by late geological deposits, and hence it is not clear what relation the Gros Ventre uplift holds to that of the Wind River Mountains on the one hand and the Téton Range on the other. An interesting and important coincidence in this connection is the existence of strongly marked, broad, deep gaps at either extremity of the range in the vicinity of the junction of the three great uplifts. The upper course of the Green, after it bends south, on leaving its mountain gorge, crosses the present uplift, which has declined sufficiently to carry the Carboniferous to the level of the river, where it is seen in a low fold with comparatively gentle inclinations of the component strata on either flank. From this it appears that the uplift was much less emphasized in the region approaching the west flank of the Wind River Mountains than was the case at the opposite extremity, where the metamorphic nucleus has a much more abrupt termination on the borders of Jackson's Basin, fronting the Téton Range. But here our resources fail; the interval separating the two ranges is occupied by a deep valley filled with late Tertiary sediments, which are pierced at only two points by insular remnants of the older sedimentary rocks that enter so largely into the composition of the mountain folds. Yet the evidence, meager and incomplete as it is, points to a more intimate relation of the present uplift with those of the Téton and Wyoming ranges than with that of the Wind River Mountains, though the whole may be said to be tied together by the transverse elevation of the Gros Ventre Mountains.

The southern flank of the Gros Ventre Range, in the extreme northwest, was not approached nearer than Station XII, 8 or 10 miles to the eastward. It is known, however, that the Archæan ridge of the south fold, on whose loftiest peak Station XII was located, extends through to a point opposite the Lower Gros Ventre Buttes in Jackson's Basin. It carries in its western part a mantle of Paleozoic strata of variable thickness, through which the Archæan nucleal rocks here and there protrude and at one point, 5 miles northwest of Station XII, rising into a symmetrical cone overlooking Jackson's Basin, on which was made Station XLIV of the Téton division the previous season. To the south of this ridge the surface falls in broken ridges, in which are discernible apparently the full Paleozoic series steeply inclining off the south flank into the Snake Valley. A little to the east high benches sweep up from the terraces bordering the Snake into the broken hills at the north end of the Hoback Cañon ridge, in which, as has been already noticed, northerly dipping Tertiary deposits occur, the higher mountainous belt beyond being made up of Carboniferous and the Jura-Trias. The latter belong to the Hoback Cañon ridge of the Wyoming Range, under which head they have been noticed in preceding pages.

The ridge which culminates in Station XII corresponds to the crest of the south fold, of which about 3 miles linear extent is made up of the metamorphics, with remnants of the Lower Silurian quartzite still capping high points. The latter show dull buff and rusty exposures, the

ledges inclining northeastward. Their reappearance was not observed on the steep sonthwest flank of the monntain immediately nnder the station, where the only sedimentary beds found are Carboniferons limestones with characteristic fossils, which ontcrop in low, glaciated bosses, and dipping toward the monntain, whose foot is here buried in the *débris*. West of this, however, the qnartzite, snceeeded by the rnsty-drab, even-bedded Qnebec gronp limestones, is seen rising upon the monntain flank, and in ontlying ridges the gray Carboniferons limestones recnr. It is in the interval lying between the latter and the Triassic "red beds" occnrring in the Hoback Cañon ridge, that the singnlar red conglomeritic deposits occnr, also dipping toward the monntain, and which hide from view the older rocks. This conglomerate is made np of abraded rock fragments, contribntions from all the older rocks, inclnding those of as late date as the Jura-Trias, and possibly the Laramie formations, from which its relatively recent age is inferred. It seems highly probable that the interval allnded to marks the site of extraordinary geological distnrbance, snch as might occnr along the line of impingement of two distinct axes of npheaval.

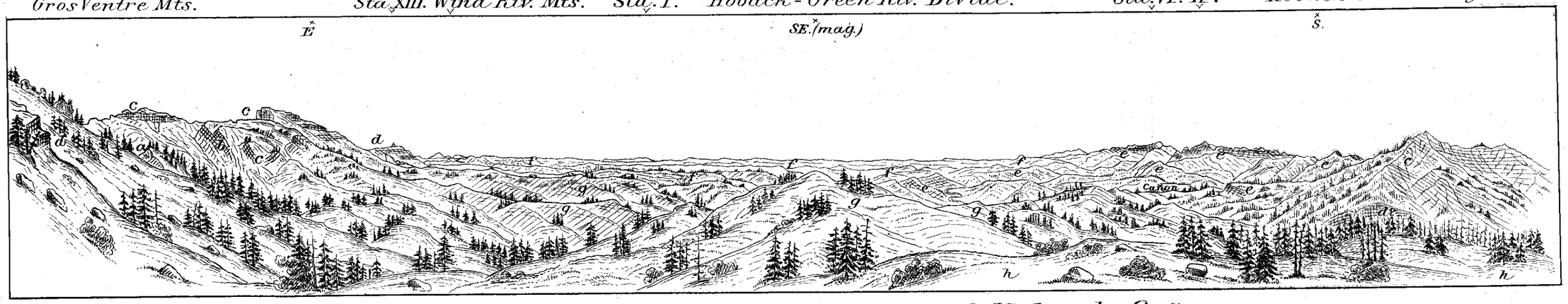
The monntain is here mnch eroded, showing pecnliarly weathered precipitous Archæan ledges terminated in extensive talnses of sliding *débris*. It is an exceedingly pictnresque locality, presenting those typical forms in monntain sculptnre strikingly in contrast with the architectnral forms into which the later sedimentary formations are wronght. Mr. Clark bronght from the peak of Station XII fragments of qnartzite, showing that even on this height the Archæan is barely dennded of its Primordial covering. Mr. Perry, who also ascended the monntain, reported it made np of contorted gneissic rocks, qnartz, feldspathic and hornblendic, traversed by qnartz veins, and showing a well-marked anticlinal, strike east-west, trending ronnd to northwest and sontheast, with inclination of 25° to the horizon. To the northeast the slopes are comparatively gentle, descending into the depression intervening between this and the north fold—a region filled with dennded, rocky inclines and sloping sedimentary tables, the same as described in the report on the Téton District, 1877. This depression drains sontheast into the Hoback and north into the Little Gros Ventre. The latter qnarter was reported npon the previons season.

A conple of miles to the sontheast of Station XII this sonth ridge is crested by Silnrian formations, dipping gently northeastward, and a little farther on a heavy mass of Carboniferons limestone rises high np on a short spnr in the sonth flank, the strata dipping toward the monntain, or N. 37° E., at angles of 20° to 30°, or more. The latter show blnish-gray, spar-seamed, cherty limestone and light bnff, brecciated, impnre limestone layers, containing nnmerons examples of a small zaphrentoid coral, a large *Syringopora*, and crinoidal remains. In the opposite side of the amphitheater, to the east, the qnartzites and Qnebec limestones are seen steeply inclined off the foot of the monntain and crowning the crest in isolated, monnmental masses which have been bnt little disturbed from their horizontal position in the elevation of the monntain. The middle portion of the abrupt sonth front of the ridge shows a belt of dennded Archæan rocks separating the lower and npper sedimentary occurrences. At this point the Carboniferons limestones have been swept away, bnt the remnant of Qnebec limestone is flexed np in a sharp synclinal, a mere fragment of the sonth flank of the trongh remaining.

The Primordial quartzite here exhibits the same appearance noted in this horizon to the west. It is a dark brownish-red to rnsty bnff, laminated rock, steeply dipping sonthward, and rests immediately npon the

Gros Ventre Mts. Sta. XIII. Wind Riv. Mts. Sta. I. Hoback-Green Riv. Divide. Sta. VI. II. Hoback Cañon Ridge.

E. SE. (mag.) S.



Hoback Basin, from divide north of Hoback Cañon.

a. Archæan. b. Primordial quartzite. c. Quebec limestone. d. Carboniferous. e. Jura-Trias.
f. Tertiary, Wasatch. g. Tertiary, red conglomerate. h. Divide, morainal débris from Gros Ventre Mts.

Plate XIV.

gneissic ledges. The Quebec limestones also here show typical exposures, consisting of usually even, thin-bedded layers of a dark gray and dirty yellow color, weathered in rough surfaces, with brecciated and oölitic layers, the whole attaining an exposed thickness of 300 to 400 feet, more or less.

A mile or so to the southeast of the above locality, the quartzite composes the south-facing mountain wall. Intermingled with the *débris* in the talus slopes are huge blocks of quartzite, containing fucoidal markings. In the vicinity the Quebec limestones, also, are seen folding over the steep south face of the ridge, and in the summit they are overlaid by a heavy bed, 200 to 400 feet in thickness, of heavy-bedded light buff-gray, vesicular, rough-weathered magnesian limestone. The latter agrees well with what elsewhere has been referred to the Niagara epoch, although search failed to detect confirmatory paleontological evidence going to establish this identity. Indications of the above-mentioned synclinal were not again met with in the mountain flank, whose slopes are heavily loaded with the sedimentary rock *débris* fallen from the ledges perched along the summit of the ridge, concealing even the morainal deposits which are detected in many of the high benches outlying the mouths of gulches. Thence to the debouchure of the Hoback tributary that drains a considerable area of mountain basin on the northeast of Station XII ridge, the south slope of this ridge is heavily plated with sedimentary deposits.

In the angle on the west side of the debouchure of the latter stream, the mountain flank facing southward is composed of the drab or gray limestone of the Carboniferous, steeply rising into the relatively low crest in which they fold over, again descending northeast into the depression of the mountain course of this stream. The mountain in the opposite angle of the debouchure has the appearance of a huge block of Carboniferous strata which has been bodily uplifted and but slightly tilted from the horizontal. The south slope does not distinctly reveal the southerly flank of the fold, which was here eroded and concealed beneath the basin Tertiary deposits. The Carboniferous deposits in the present mountain reveal a thickness of several hundred feet of dark gray limestones with distinct reddish tint above—the latter color-feature being quite prevalent in these beds in this part of the range.

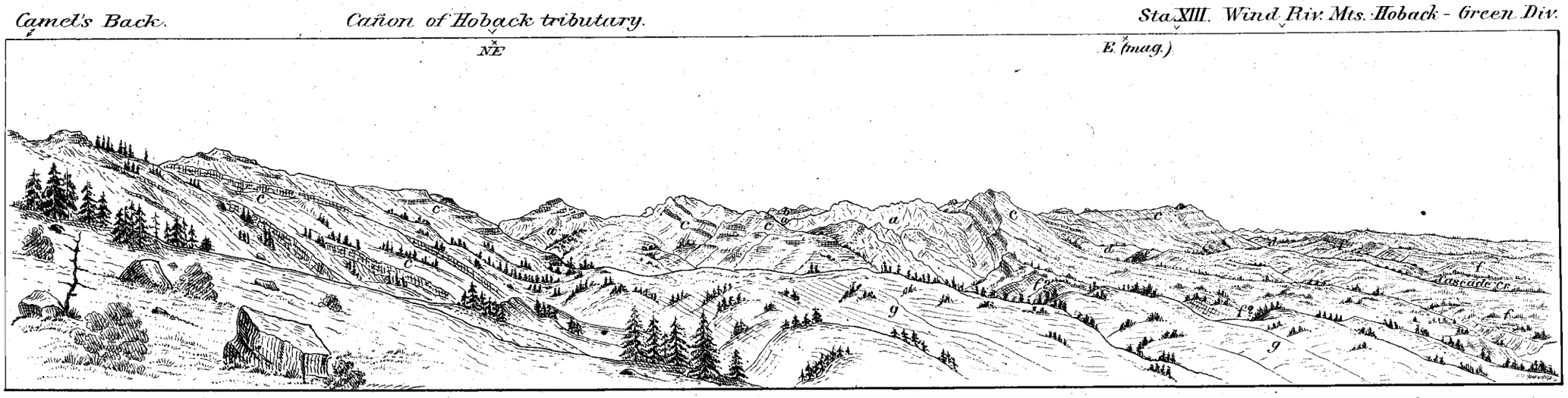
The exit of this first considerable Hoback tributary shows a rather wide cañon-debouchure, bordered on either hand by mountains sculptured out of the Carboniferous ledges, which appear in escarped slopes and picturesquely-weathered pinnacles. These deposits are traced well up the cañon to the northeast, as far as could be seen, forming the heights along the mountainous northeast side of the valley. Below the exit, the stream, on entering the softer deposits of the basin Tertiary, presently forms a low intervale bordered by well-defined terraces. It carries a good volume of swift-flowing water, and its bed is composed of water-worn fragments of Archæan, quartzite and limestone.

Although it was not with absolute certainty so determined, yet, both from the relatively low elevation and nearly horizontal position of the block of Carboniferous strata composing the mountain in the east angle of the above-mentioned stream, it may be that this mass belongs to the north slope of the great south anticlinal fold. This explanation is suggested by the position of sedimentary occurrences in the loftier crests to the northeast, with which this mountain forms an outlying prominent spur. In the latter mountain ridge, which may be more or less parallel with that of Station XII, the strata are bent up in a great flexure, of which the southeast face is that seen from this point of view. This is

doubtless identical with the north fold into which the strata over the area of this mountain range were uplifted. Along the broken crest of this ridge, the reddish drab-gray Carboniferous and light buff-gray Niagara (?) limestones hold a prominent place in the rugged mountain masses and isolated peaks. But in the southeasterly continuation of the ridge the sedimentaries are, in places, removed, revealing a narrow belt of the Archæan nucleal rocks, so indicated by the peculiar mode of weathering exhibited by the rocks in the south face of the ridge and the presence of quantities of gneissic *débris* in the outlying slopes and stream-beds that emerge opposite this spot. This supposed Archæan ridge, in places bears along the crest dirty yellowish deposits, recalling the lithologic appearance of exposures of the Primordial horizon to the west. But the outlying flanks on the south are plated by Carboniferous and Silurian strata, which rise up steeply on the lower half or more of the height of the mountain ridge.

The above mentioned ridge terminates in a prominent mountain between the forks of the stream whose eastern and lesser branch drains a part of the northeast flank of the north fold, and which lies to the west-northwest of Gros Ventre Peak between 8 and 9 miles distant. On the south the slope falls in an even and slightly bulging curve, corresponding to the planes of the flexed strata into the border of the basin, while on the west, north, and east the mountain breaks down in precipices, showing hundreds of feet thickness of the component strata. The exposures are mainly, if not entirely, of Carboniferous rocks, the upper part showing characteristic outcrops of harder and softer limestone beds alternating in mural exposures and steep, bare slopes that reach up to the summit. The basis rocks may belong to Silurian horizons. The denuded Archæan ridge lies less than a mile to the north, and although considerably lower than the summit of the terminal mountain, its crest rises above the actual altitude of the lowermost sedimentary exposures in the precipitous north wall of the mountain. The presence of this mountain mass of sedimentary rocks brings out in the most vivid manner all these relationships and the enormous extent of erosive action necessary to uncover the metamorphic core of the north fold. The vertical displacement in the fold at this point is probably not less than 3,000 feet. Its abrupt southern flank may be traced nearly its whole extent from the heights in the western part of the range, sometimes exhibiting the flexed strata, *in situ*, on the steep mountain sides, and then, again, eroded so as to appear in monoclinal ridges capped here and there by red beds possibly of Triassic age, whose gentle northerly declination forms the broad plateau reaching over to the culminating mountain crest overlooking the Gros Ventre Basin. This part of the range is deeply eroded by a considerable Gros Ventre tributary, in whose bed the Archæan may be revealed similar to the occurrence in the mountain basin of the sources of the cascade tributary flowing into the Hoback.

A couple of miles southeast of the last-mentioned cañon the sources of a small, independent Hoback tributary have excavated a deep amphitheater extending back into the mountains 2 or 3 miles from the south border. Where it emerges, its course is interrupted by a beautiful cascade, the stream tumbling or sliding many feet down the steep incline over Carboniferous ledges, which throw a heavy belt across the mouth of the recess and rise high up in the mountain elevations on either side. On the east of this amphitheater the Archæan is denuded, forming another spur which bears atop the whole of the Primordial quartzite capped by remnants of Quebec limestone, which latter appears in undulating low mural masses, weathered dark brownish gray. The south



South Front of the Gros Ventre Range, between Camel's Back and Gros Ventre Peak (Sta. XIII).

a. Archæan *b. Silurian.* *c. Carboniferous.* *d. Jura-Trias.* *e. Laramie.*
f. Tertiary of Hoback's River *g. Tertiary - red conglomerate.*

Plate XV.

side of the easterly continuation of this ridge fronting the basin is also plated by the uplifted sedimentaries, while looking up the cañon, the Archæan is conspicuously displayed, making up the greater height of the mountain walls in the sides of the amphitheater. The latter mountain ridge sweeps round to the north where it merges into the main north ridge of the range 8 miles to the northwest of Gros Ventre Peak. The former described axial ridge that forms the west wall of the amphitheater has a much more involved relationship in consequence of its median position betweeu the two principal topographical ridges of the range in the region of the sources of Gros Ventre and Hoback tributaries and forming what may be termed a third mountain ridge with spurs connecting both with the south and north ridges, with the former in the vicinity of Station XII, northeast, and with the latter at a point about 11 miles northwest of Gros Ventre Peak.

These connecting spurs are but remnants left by erosion of the broad summit of the principal north fold, which indeed still retains much of its distinctive features in the elevated mountain plateau into which the central topographic ridge expands a few miles to the northwest in the direction of Station XLVI (1877) with which it forms a circuitous but almost uninterrupted chain of mountain tables from the point northeast of Station XII, where this ridge veers round from the axial line of the fold easterly and then northwesterly, finally forming the northern barrier towards the northwest extremity of the range

In the outlying slopes in the vicinity of the cascade unmistakable and most interesting exhibitions of Mesozoic strata are encountered, the first of these rocks observed on this side of the range east of Hoback Cañon ridge. Drab and bluish indurated arenaceous clays, associated with buff sandstone, containing obscure vegetable remains, outcrop in the divide west of the cascade, dipping northeastward toward the mountain at an angle of 20° to 45°. There are indications of a fold in these deposits with more gentle inclination on the southerly flank. These deposits bear a strong resemblance to Laramie horizons occurring in the Wyoming Mountains. Their exposure is also here accompanied by the brown-drab soil and numerous spring sources that are the concomitants of the outcrop of certain Laramie deposits in the latter region; and further, the presence of ferruginous-stained impressions of plants in some of the sandstone layers furnish additional evidence of their probable stratigraphical identity with those deposits. On the stream below the debouchure limited exposures of dark colored limestone were seen which recall similar layers that were found in lower member of the Laramie west of the Hoback Cañon ridge. Next the mountain occurs a set of beds resembling the Jura-Trias conformably superimposed on the southerly dipping Carboniferous. At the base of the Jura occurs a heavy bed of buff Magnesian limestone abounding with calcite. The "red beds," however, seem to be attenuated as compared with their thickness in the Wyoming Mountains. These deposits at this locality reach well up on the foot of the mountain, where they are much obscured by accumulations of rock *débris*.

Outlying the Jura-Trias belt, in the extremely broken slopes rising into the high bench on the southeast side of the stream, perhaps a couple of miles below the cascade, an interesting oyster-bed exposure occurs within the limits of the previously mentioned outlying fold. The bed shows a thickness of about 2 feet, closely packed with fossil Ostrea, included in a thin-bedded grayish buff sandstone which inclines northward at an angle of 50°, more or less, at the point examined. The exact stratigraphical relations of this bed to the before-mentioned Lara-

mie deposits of similar lithological appearance is not clearly discernible at this locality. Dr. White refers the most prevalent *Ostrea* to *O. soleniscus* Meek, of the Upper Cretaceous sandstones near Coalville, Utah. Associated with the above form there were also recognized *Barbatia coalvillensis* White, and a small *Ostrea* which resembles *O. insecura* White, of the Bitter Creek Laramie series, although it may be the young of the first-named species. The strata are so generally concealed by loose materials in the surface as not to afford the means for determining either their vertical thickness nor the extent of their outcrops. The occurrences are confined to the high benches well beyond the foot of the Paleozoic-plated mountain, in the upheaval of which they evidently partook, although at no point do they probably remain on the high ridges of the range. The above stratigraphical occurrences probably occupy the synclinal trough intervening between the north and south folds of the range, the latter exposures pertaining to the remnant of the north flank of the south fold which here exhibits extraordinary abruptness of declivity.

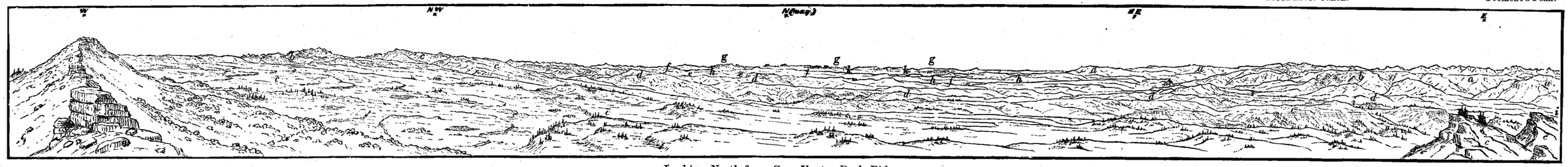
Two or three miles below the cascade the brook enters a pretty intervale and terrace bordered valley eroded out of the soft basin deposits. The hill-sides are covered with large tracts of vigorous young pines from a foot and upwards in height, amidst which rise the stark trunks of their burned predecessors. Not unfrequently the same phenomenon was observed at other places in this region, which seems to prove that the conditions for forest growth are as favorable to-day as at any time in the past. At a locality north of Hoback Cañon, a tract of burned spruce forests occupying a northwesterly slope was renewed by a dense growth of young pines.

Just below the valley expansion, well defined lateral moraines are developed, rising 75 feet, more or less, above the stream, and clinging to the steep slopes. There are two or three of these ridges one above the other. Lower down the moraines decline and spread laterally over the more gentle declivities, in the hollows of which wet meadows frequently occur. The lowermost one finally converges, throwing a low embankment in the shape of a terminal moraine clear across the valley, through which the stream has eroded a narrow channel to the depth of 25 feet. How far below this the moraines extend was not ascertained. The one described was the most perfect example of terminal moraine observed during the visit to these mountains, although it probably does not mark the ultimate distance the ancient glacier traveled beyonds its mountain limits. The position of these morainal deposits conclusively shows that the glacier which transported their materials flowed down a pre-existing valley of nearly the same spaciousness as the present trough, and which possibly had almost equal preglacial extent within the mountain area as that which it there presents to-day. There was noted no unmistakable glaciation on the sedimentary mountain flanks in the debouchure, although the limestone-incline over which the cascade glides was bared and smoothed by the effects of the ice-fall. But within the cañon, doubtless, all the concomitant phenomena of glacial action would reward a more careful exploration than it was possible to undertake during the present visit.

To the east the mountain wall curves round into a shallow recess, which is drained by another tributary of the Hoback. Occasional exposures of gray Laramie (?) sandstone were met with in the high sloping basin benches that here reach close up to the foot of the abrupt mountain declivity. The east side of the recess is defined by the ridge reaching north from the angle of Gros Ventre Peak, which here, as in the south

Plate XVI.

Gros Ventre Peak. Gros Ventre Mountains. Glaciated limestone surfaces. Mt. Leidy. Sta. XXX. Buffalo Fork Peak. Togwotee Pass. Sta. XXIX. Sta. XXVIII. Washakee Needles. Union Peak. Wind River Mountains. Sta. XV. Green River Cañon. Frémont's Peak.



Looking North from Gros Ventre Peak Ridge.

a Archæan. *b* Silurian. *c* Carboniferous. *d* Jura-Trias. *e* Cretaceous. *f* Tertiary, including upper lignite formation. *g* Volcanic conglomerate, Sierra Shoshone. *h* Gros Ventre River. *i* Green River. *k* Wind River.

face of the east arm of this mountain ridge, forms long, steep talus slopes of loose *débris*, terminated above in a grand line of escarped ledges that rise up into the crest. Gros Ventre Peak is a conspicuous object viewed from the south, having the appearance of a bulky quadrangular mass of sedimentary rocks lifted bodily to the height of nearly 11,500 feet above sea-level. A low wedge of compressed pyramidal shape near the southwest angle of the mountain was selected for Station XIII, and which also served the purposes of a primary station for Mr. Wilson the previous season. The west and south fronts break down abruptly from elevations 2,000 to 3,000 feet above the basin benches at their foot. Near the angle, the heavy bedded light buff magnesian limestone, elsewhere provisionally identified with the Niagara, rises up steeply in the mountain foot, forming a sharp flexure with southwesterly inclination at a high angle. These beds are succeeded by the thinner-bedded gray and reddish-stained limestones of the Carboniferous, which curve over and at a higher elevation from the escarped monoclinal heights of the ridge. The crest of this mountain was found to consist of a narrow ridge; that to the east wrought out of sandstones into a jagged, almost impassable, comb. On the north the descent is precipitous, broken by vast piles of angular *débris*, in 300 to 500 feet, reaching the limestone floor of an extensive, glaciated mountain basin. On this side the Carboniferous strata everywhere slope off to the northeastward, at a comparatively moderate angle of inclination. In the upper portion of the basin the limestone plane is burdened with low piles and ridges of *débris*, probably of morainal origin, and dotted with lakelets. The drainage flows east into the Green, and at the western end of the depression a south affluent of the Gros Ventre rises, flowing out to the northward across a wide belt of Jura-Trias.

A section of nearly 1,000 feet vertical thickness of Carboniferous strata is exposed in the east arm of Gros Ventre Peak. The upper 500 feet consists of a heavy deposit of buff-gray and reddish tinted, laminated sandstone, with obliquely laminated and quartzitic layers, and thin bands of deeper red color. The inferior half of the exposure is made up of numerous ledges of drab and gray limestones, the upper part containing layers stained chocolate-red, and containing characteristic Carboniferous fossils—*Zaphrentis*, crinoidal remains, *Hemipronites crenistria*, &c. The beds incline northward, at an angle not exceeding 10°, and generally not more than 5° to the horizon. As before stated, the sandstone forms a mere wall along the crest, which gradually declines to the east, where its appearance will be again referred to further on. To the north, in low southerly-facing declivities, defining that side of the mountain basin, the sandstone horizon reappears, where it is overlaid by several hundred feet thickness of drab limestones, sandstones, and shales, alternating. Beyond the latter, in similar abrupt terminating benches, typical exposures of the Triassic "red beds" occur, occupying a wide belt sloping off the gently inclined north flank of the range into the basin area, drained by Gros Ventre River. The occurrences above noted bear a strong likeness to the stratigraphical sequence of the Carboniferous observed the previous season in the Téton Range and in the Snake River Mountains, to the west. Indeed, the resemblance is so marked that it may be regarded as conclusive evidence of the identity of the strata of these horizons in the regious mentioned. This middle Carboniferous sandstone, however, in the present mountain range, perhaps attains a somewhat greater development and differs lithologically in its generally paler tints from the equivalent horizon in the Téton Mountains.

East of Station XIII the southern flank of the north flexure has been almost entirely removed by erosion, only limited exposures in the foot of the mountain preserving part of the curved strata. Along this part of the mountain the high outlying slopes show here and there limited exposures of the arenaceous "red beds" that form a belt continuous with the Triassic deposits occurring a few miles to the westward of Gros Ventre Peak, of which mention has already been made. At the present locality these deposits appear to be little disturbed; their inclination, although varying from northerly to southerly, perhaps does not exceed an angle of 10°. Their position at the foot of the mountain is not favorable to the determination of their relations to the Carboniferous deposits occurring in the latter, while on the south they are soon concealed beneath the Tertiary deposits that here gently rise up in the northern terminus of the Green and Hoback water-divide. It is possible that the uplift at this point was accompanied by a fault, with downthrow on the south, amounting in vertical extent to about the thickness of the carboniferous formations.

Soon after crossing the Hoback-Green divide, in the vicinity of the lake source of a stream flowing south into Green River, the Carboniferous limestone, here highly siliceous, forms a low, broad arch, with gentle inclination both north and southwards. The limestone appears over a considerable area in the low, hilly and undulating wooded country immediately south of the sandstone-capped eastern prolongation of Gros Ventre Peak ridge, at the foot of which lies the above-mentioned little lake-basin, partially environed by the sandstone and limestone cliffs. Thence eastward, this ridge steadily declines, flattening out into one of the low divides terminating on the west side of Green River Valley, about 8 miles distant. The Station XIII, or north fold of the range, is not traced with certainty but a short distance east of the lake, and it seems probable that it also dies out in that direction.

The west side of the stream flowing south into Green River is bordered above by bluffs composed of the "red beds," and lower down by the rather abrupt east face of the main divide separating the drainage of the Green from that tributary to the Hoback, and which is here made up of Tertiary deposits. Perhaps 3 miles south of the lake limited exposures of Jurassic sandstone and calcareous deposits appear in the gentle slopes on the east side of the valley, dipping about 25° south, and containing *Pentacrinus*, *Ostrea*, and *Belemnites*. The way thence leads southeasterly over low, undulating divides in the country intervening between this stream and the Green. The only rock exposures met with in this section consisted of occasional outcrops of drab clays and reddish-buff, thin-bedded, rather hard sandstone. These rusty-weathered sandstones continued nearly to the Green, forming low ledges here and there in the grassy slopes, and uniformly inclined about south, at angles of 20° to 35°. Lithologically they bear intimate resemblance to, and are probably identical with, horizons elsewhere referred to the Laramie. They are apparently in conformable superposition to the Jurassic deposits occurring to the north, which further suggests the above-inferred identity, unless they prove to belong to an intermediate Cretaceous formation. But the latter formation was not recognized here, and in the absence of fossils our acquaintance with its stratigraphical composition is too imperfect to warrant its recognition in obscure outcrops.

The most southerly observed exposures of the above-mentioned Laramie (?) sandstones occur in the uplands on the west of Green River, about 3 miles northwest of an isolated Tertiary butte that rises from the plain on the opposite side of the river, or about 11 miles above the

mouth of Lead Creek. Ascending the valley of Green River from this point the east side of the stream is closely bordered for several miles by a low, outlying ridge at the western base of the Wind River Mountains, which is composed of gently-inclined Jura-Trias deposits. About 11 miles north of the butte a low arch of Carboniferous limestone rises a few feet above the river-level, the strata gently inclining north and south at an angle not to exceed 10°, with which the superimposed Mesozoic formations conform, as displayed in the exposures on both sides of the valley. The axis of this arch lies a little north of east of Gros Ventre Peak ridge, and in its physical character it offers little by which it may be distinguished from the low arch immediately south of the eastern terminus of the above-named ridge, as mentioned above. In case of their identity the trend of the Gros Ventre Peak, or north fold of the range, curves round from a southeasterly course, which it has hitherto held, to an easterly direction on approaching the Wind River uplift. The beforementioned outlying ridge on the western foot of the latter range bears the record of dynamical disturbances that transpired in both zones of mountain elevation.

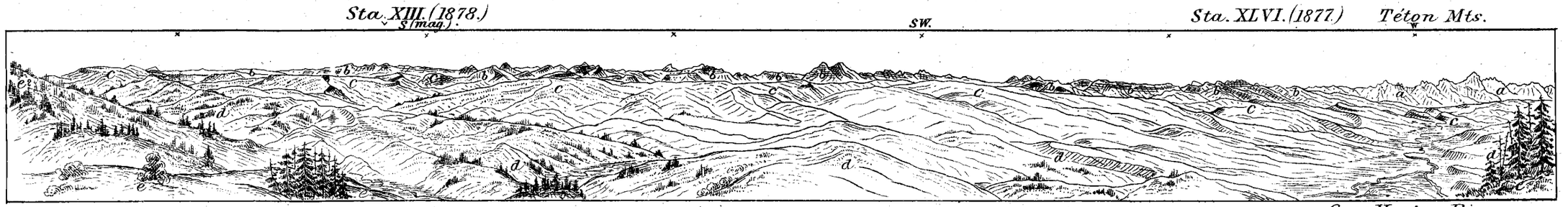
The north flank of the Gros Ventre Range was not approached nearer than the outlying and probably geologically parallel low ridges that lie within the Gros Ventre Basin. But from the latter and more distant mountain peaks situated in the northern part of the Wind River Range and in the Mount Leidy highlands, to the northeast and north, respectively, a general knowledge of its geological structure was acquired. From the points of view above designated the great north fold of the range more or less closely corresponds to the prominent mountain crest that constitutes the eastern half of the northern barrier. To the west the tributary drainage of the Gros Ventre River has eroded the north flank of the fold forming the culminating mountain ridge that makes a slight north deflection from the eastern portion of the ridge with which its topographical relations are most intimate. This ridge throughout ranges in actual elevation between 10,000 and 12,000 feet, bearing a grand chain of architectural peaks sculptured out of the uplifted sedimentaries.

As has been already stated, the north flank of the range presents a comparatively gradual and remarkably uniform declivity descending into the basin area of the Gros Ventre. Its component geological formations embrace the entire sedimentary series of the region, from the Silurian to the Jura-Trias, inclusive. In the eastern half only the Paleozoic formations, chiefly the Carboniferous, remain along the main mountain crest, while to the west, in the before-mentioned north deflection of this topographic crest, the Triassic "red beds" hold a prominent place on the flank of the monoclinal ridge. But what is regarded as the westerly continuation of the geological ridge or north fold, which was excessively eroded by the sources of the previously-mentioned south affluent of the Gros Ventre, which rises 5 or 6 miles to the northeast of Station XII, exists as a mere remnant, on the southwest flank of which low outliers of nearly vertical strata were seen from Station XLIV at the west end of the range the previous season. The erosion of the Little Gros Ventre, which heads in this quarter, has stripped the sedimentaries from the axis of the fold, revealing the quartzite and possibly also a belt of the metamorphic nucleus of undetermined extent along the course of its cañon. The mountain ridge lying between Gros Ventre River and Little Gros Ventre Creek, and which constitutes the extreme northwest extremity of the range, exhibits the lower limestone and middle reddish-tinted sandstone members of the Carboniferous in long lines of monoclinal

exposures lying a little to the north of the axis of the north fold and sloping off to the northeastward at a moderate angle of inclination.

The middle sandstone member of the Carboniferous, which is well-developed in the latter quarter, is conspicuous on account of its red color. In this respect it presents a marked contrast to the lithologic appearance of the same horizon noted towards the opposite extremity of the range, in the vicinity of Gros Ventre Peak, and which might lead to its being mistaken for the Triassic "red beds," were its stratigraphical associations locally masked or not recognizable in distant views, such with which the geologist too often has to be content.

The Jura-Trias occupies a relatively wide belt on the north flank of the range, even rising into quite prominent tables and foreland benches, descending in long inclines, and merging into the area of the basin proper. The Jura was hardly touched at a single locality in this quarter, its presence being determined chiefly from the lithological appearance and sequence of its exposures. It seems to be in part made up of deep drab and chocolate-red variegated clays, sandstones, marly indurated layers, and drab limestone. Owing to the prevalence of clayey constituents the exposures are seldom satisfactory. On the contrary, the deep-red arenaceous shales and sandstones of the Trias are exposed in numerous and extensive escarpments, and wherever in the region of its occurrence the soil from one cause or other has been disturbed, a gleaming spot of red color, may be contrasted with the deep-green of herbage-clothed slopes, discloses its presence.



North Flank of the Gros Ventre Range, from Station XXIX.

a. Archæan. *b. Palæozoic.* *c. Jura-Trias.* *d. Cretaceous.* *e. Tertiary.*

Plate XVII.

CHAPTER V.

GROS VENTRE BASIN.

Gros Ventre River drains a large basin tract lying to the north of the mountain range bearing the same name, and which is about twice the superficial extent of the upper basin of the Hoback on the south of that range. To the southeast it is defined by the low, inconspicuous divide stretching over from the north slope of the Gros Ventre Range, east, to the great foreland bench on the west flank of the Wind River Range south of Union Peak; the elevated water-shed that spans the gap between Union Peak at the northern terminus of the latter range and the great sedimented volcanic mountains in the vicinity of Towotee Pass, a distance of 24 miles, constitutes the barrier on the east between this drainage and the upper course of Wind River; while it is separated from the valley of Buffalo Fork by the low mountainous highlands dominated by Mount Leidy, which form the northern boundary of this special drainage basin. Thus defined, the Gros Ventre Basin has an area of 500 square miles, approximately.

The main stream rises in a glaciated defile a few miles south of Union Peak, and once it emerges upon the elevated park-like slopes at the foot of the latter mountain, it pursues a general course a little north of west for the distance of about 42 miles to the point where it gains the plain of Jackson's Basin. It receives several good-sized tributaries from the surrounding highlands, and is of additional importance from the fact that it affords easy communication with the Wind River Valley via Union Pass at the north end of the Wind River Range. Chiefly occupied by easily eroded tertiary deposits, the general superficial contour of the basin is exceedingly broken, especially in the central and northern portion. The streams generally flow in narrow valleys, often deserving the name "cañons"; lower down the main valley expands, affording small tracts of intervale and terrace land. The uplands present pleasing variety of forest and herbaceous openings in the undulating southeastern quarter, where the woods and meadows were found stocked with numerous bands of elk and deer. But in economic importance it scarcely equals the beautiful basin of the Hoback (its general elevation being in the neighborhood of a thousand feet higher), save in one particular, its extensive deposits of coal.

Geologically, the area above alluded to constitutes but a part of the great Cenozoic basin that stretches north until it is lost beneath the lava flows and volcanic ejectamenta that mask the whole country around Yellowstone Lake. Its present orographic boundaries are, on the west, the Téton Range; south, the Gros Ventre Mountains and the northern end of the Wind River Range; to the north and east, except for the presence of the probably isolated uplift on Buffalo Fork, described in the report on the Téton district the previous season, it has an extent reaching far beyond the limits of the present district.

It is not the province of this special report to attempt the definition

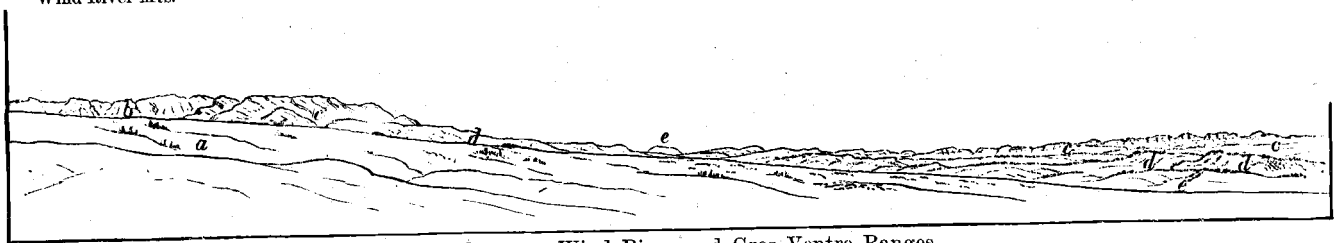
of the original boundaries of this great Tertiary basin. Within the area of this particular district observation seems almost to warrant the conclusion, if it fails to establish the fact, that the waters of that time communicated with the basin area of Green River, although denudation has interrupted the continuity of the sediments then accumulated in the intervening straits between the Wind River and Gros Ventre Ranges. But in the latter quarter the vertical displacement or upheaval, in the region of the eastern extremity of the latter range, was not sufficient to erect an insurmountable barrier to the encroachments of the waters on either hand and the eventual union of the north and south expansions of the Cenozoic sea. From a geological point of view the evidence is somewhat conflicting, inasmuch as it is not yet known with that certainty necessary to well-founded generalization to what extent the Cenozoic deposits themselves have been disturbed by forces acting within the present orographical boundaries, and, until the latter problem shall have reached solution, the original extent of surface occupied by these sediments must remain more or less a matter of conjecture. In the Wyoming Mountains they are known to reach high up on the summit in places, where they rest unconformably upon older geological formations; at the same time their inclination, although moderate, shows that disturbing influences had not ceased subsequent to their deposition. Although in the Gros Ventre and Buffalo Fork uplifts these deposits at no point were observed in the more elevated portions of the mountains, yet they are more or less disturbed wherever they appear on the mountain flank. Whether their disturbed condition is due to elevatory movements within the mountain zones or to subsidence in the outlying basin areas is not so evident, although within the present topographically-defined basin area these beds exhibit marked evidence of disturbance, which resulted in their being uplifted into more or less well marked folds, whose parallelism with one or other of the bordering mountain uplifts may be readily recognized.

The northerly or northeast inclination of the Paleozoic and Mesozoic formations off the north flank of the Gros Ventre Mountains, as has been indicated in the preceding chapter, extends along the entire south border of the Gros Ventre Basin, so that it is difficult to draw the exact line defining on the one side the basin limits from the mountain foot on the other. Of the above formations only the Mesozoics enter the basin area proper, where they occupy a rather wide belt in the southeastern border portion. In the westerly-rising declivity of the Gros-Ventre-Green divide, at a point perhaps 8 miles about north-northeast of Gros Ventre Peak, the Triassic "red beds" arch partially over a low fold, the eastern flank of which has been eroded and is at present covered with dense forests. East of the latter fold the channels of streams flowing down either side of the divide reveal the presence of the soft yellowish sandstones and light-drab clays of the Tertiary(?); but on the declivity rising up on the Wind River Mountains to the east, the surface is composed of drift materials evidently derived from that range. West of the Triassic fold, in the gentle slopes descending the north flank of the Gros Ventre Range into the shallow intervening depression, the same deposits outcrop in low bluffs, the northerly inclination of the surface conforming to the dip of the strata. This low arch was not again recognized to the northwest, and it may be of merely local extent.

In the southwestern half of the basin the strata are complicated by a series of flexures lying quite within the basin limits, although, of course, intimately related to the mountain upheaval culminating in the north fold of the Gros Ventre Range. This belt of flexed basin deposits extends

Plate XVIII.

Wind River Mts. S.S.E. S. (mag.) Gros Ventre Mts. Sta. XIII.



Gap between Wind River and Gros Ventre Ranges.

a Drift-covered wooded and open slopes. *b* Archæan, south of Green River Cañon. *c* Palæozoic. *d* Trias. *e* Tertiary.

(From Station XXVIII.)

a distance of 5 miles or more along the Gros Ventre, or from the upper main forks to the valley of a considerable south tributary that skirts the foot of the Carboniferous plated mountain ridge which here forms the northernmost culminating crest of the range. The exposures are well displayed but for occasional interruptions in the continuity of their visible outcrops in the terrace bluff along the southeast side of the stream. The rocks involved in the flexures are of Cretaceous age, according to the specific identity of the few fossils here obtained, as kindly determined by Dr. White. The northeast-facing mountain slope to the west of the before-mentioned Gros Ventre south tributary is heavily plated by the Jura-Trias, the outlying lower slopes in places showing low ridges of light-buff deposits, which are presumably referable to the Cretaceous. The strata are again exposed in the east side of the valley, and thence to the main forks of the Gros Ventre they are exhibited in a well-defined synclinal and anticlinal fold, the axial trend of which is in a direction a few degrees east of south and west of north, changing farther east to about southeast-northwest. A diagram of the geological section here alluded to is given in an accompanying plate, the horizontal distances being rough approximations, in explanation of which is appended the following description:

Section along Gros Ventre River.

No. 1–4. The formations, Carboniferous to Cretaceous, inclusive, that rise up on the northeast flank of the Gros Ventre Range have been already mentioned. The outer border of the Cretaceous, No. 4, at the mountain foot is concealed by morainal deposits, No. 5, and alluvial materials in the valley. It may be that in this space the Cretaceous strata have been eroded over the site of a low fold corresponding to a previously mentioned broad low arch in the "red beds" immediately outlying the foot of the range to the northeast of Gros Ventre Peak.

No. 6. Gray, indurated argillaceous beds and drab clays, and soft gray sandstone, with thin seams of cannel-like coal. Dip northeastward.

No. 7. Gray, argillo-calcareous, indurated beds, gray sandstones and drab clays, with obscure plant-remains, and thin layers of lignite. Dip 20°, about E. 30° N.

No. 8. Space, showing only obscure rock exposures of similar character to above and following.

No. 9. Indurated drab shales and drab and brown clays, and gray sandstone, underlaid by a thick deposit of heavy-bedded, gray, buff-weathered, soft sandstone. In the overlying drab shales, which also form a heavy deposit, at one place a thirty-inch bed of coal was observed, below which other thinner seams were seen, the outcrop crumbling on exposure to the weather; dip 55°, about W. 10° S. Overlying the coal, a small ovate leaf with crenate margins occurs in a drab indurated argillaceous bed, together with comminuted vegetable remains, the sandstone also affording what appear to have been large stems of trees, but very imperfectly preserved.

No. 10. Gray sandstone, dip little south of west at an angle of about 60°. This is probably identical with the sandstone next mentioned below, having arched over a sharp anticlinal fold, the axis of which has been eroded or otherwise concealed at this point.

No. 11. Half a mile or thereabout below the main forks of the Gros Ventre, a heavy deposit of gray and buff-gray, coarse-grained, heavy and thin-bedded sandstone appears in the bluffs along the left side of the stream, and lower down underlaid by dark or brown-drab clays showing

only obscure exposure; dip E. 8° N., at an angle of 50°. At one point the sandstones, which are in places calcareous, afforded a few imperfectly-preserved fossils, amongst which Dr. White has determined the following Cretaceons forms: *Mactra arenaria* Meek?, *Ostrea* sp.?, *Inoceramus erectus* Meek?, and other nndetermined conchifers. The *Inocerami* have a considerable vertical range in the heavy sandstone deposit, althongh its presence is chiefly determined from mere fragments showing the pecnliar shell strnctnre.

No. 12. The steep hills in the immediate vicinity of the main forks of the stream are made np of gray, bnff-weathered sandstones and drab clays, inclined at an angle of 55° E. 33° N.

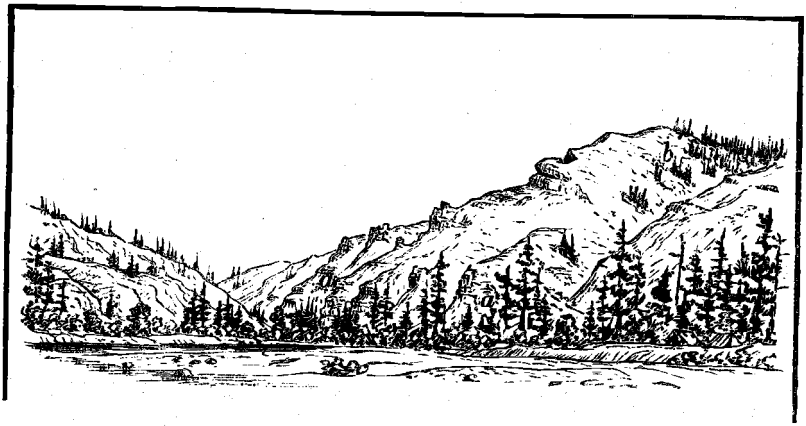
No fossils were observed in the latter beds of the above section, bnt there is no donbt of their conformable snperposition to the strata described nnder No. 11, and which, together with No. 4–11, inclnsive, constitnte a heavy series of light gray and yellowish-weathered sandstones and drab clays occurring within the basin area proper, and whose distnrbed condition is apparently attribntable to, and synchronons with, the distnrbances that folded the strata over the region of what is now the Gros Ventre Range.

Station XXIX was located on a commanding crest of the ridge jnst west of the main branch of the Gros Ventre, abont 6 miles sontheast of the forks. The view from this point commanded nearly the whole northeastern front of the Gros Ventre Range, besides nearly the entire extent of the basin from a nearly central position. The natnre of the strata composing the ridge itself, in the main soft sandstones and clays, dipping northeastward, affords few rock exposnres of any considerable vertical extent. Bnt the snrface of the whole region, reaching up to and crowning the sharp ridge on which the topographical station was made, is strewn with the remnants of a remarkable conglomeritic deposit, whose origin might at first be mistaken for Qnaternary, as indeed the degradation and dispersion of its component materials was affected dnring that period. Approaching the valley of the Gros Ventre, the Cretaceons deposits have been extensively eroded, bnt to the sontheast they rise np into higher ridges, which still farther in that direction have been dennded, bringing to view the Triassic "red beds" and drab variegated deposits of the Jura in the before-mentioned low arch to the northeast of Gros Ventre Peak. This arch is abont sontheast of Station XXIX, to the east of which the Cretaceons deposits, if they still exist in that qnarter, merge into the nndulating drainage divide defining the sonthern limits of the basin.

In this connection may be mentioned limited occnrrences, in the direct line of the sonth-sontheasterly strike of the deposits above noticed, that were examined along Green River jnst above the great bend. There here occnrs an exposnre of gray and blnish clays with bluish indurated fine arenaceous layers, which break into narrow slabs or post-like masses, the dip of the beds being abont N. 40° E., at an angle of 30°. The isolation of the exposnres and the absence of fossils renders the determination of their stratigraphical position a difficult qnestion. Bnt there is certainly a somewhat striking coincidence in the direction of their strike, which, at least, snggests a possible identity with the above-mentioned deposits in Station XXIX ridge.

The general northwesterly strike of the Cretaceons deposits, in the Gros Ventre section above described, apparently veers round more to the west on passing into the region north of this stream. This is indicated by the occurrence of very similar lithological manifestations in the broken slopes midway between Mount Leidy and the Gros Ventre,

Plate XIX.



Gros Ventre River: Cañon in conglomerate.

a Conglomerate. (Looking N. W.) *b* Upper lignite.

and in the regular order of stratigraphical superposition to the variegated Jura and unmistakable "red beds" of the Trias, all of which, so far as can be made out at a distance, belong to the northerly-inclined flank of the northwestern extremity of the Gros Ventre Range. But these deposits appear over a comparatively narrow belt in this northern slope of the basin, at least not of greater width than along the Gros Ventre, while in the crest of the Mount Leidy highlands they are superseded by later deposits, presently to be mentioned.

The main branch of the Gros Ventre, after leaving the elevated mountain flats, flows in a gradually deepening narrow valley, in whose sides fine exhibitions of the Tertiary are met with, extending as far down as a point about 4 miles above the two principal forks, where the stream enters the above-mentioned Upper Cretaceous horizons. The Tertiary deposits are based upon a heavy accumulation of brownish-drab conglomerate, several hundred feet in thickness, and which is composed of thoroughly water-worn and rounded pebbles and small bowlders consisting almost exclusively of variously-colored quartz and quartzitic fragments, rarely a metamorphic pebble being seen. The conglomeritic character predominates through a great vertical extent of the horizon, with, however, intercalations of soft yellowish sandstone of a more or less local extent, and which is essentially of the same character as the fine brownish drab or gray and slightly calcareous matrix of the conglomerate. Above, the sandstone layers increase in thickness and frequency of occurrence, alternating with thinner layers of conglomerate and green and drab clays. The main mass of the conglomerate in the wierdly-eroded exposures along the cañoned portion of the stream was found to contain fragments of tree-trunks, but which are so changed by ferruginous infiltrations and decayed as probably to be indeterminable.

In the section (a diagram of which is associated on the plate illustrating the last preceding section with which this is in direct continuation to the northeastward) exposed along the northeast fork of the Gros Ventre, the conglomerate reappears in the hills at a place about a mile above the forks, where it is seen to rest with apparent non-conformity upon the sandstone No. 12 of the section last described. The dip is to the northeastward at an angle of about 10°; on the main stream at the first-mentioned exposures of this horizon the inclination is about 5° in the same direction. The exposures continue about a mile before they finally pass beneath the level of the stream, the inclination gradually lessening, ascending the valley to the northeast. This horizon is represented by No. 13 of section diagram referred to.

The conglomerate is conformably overlaid by a still greater thickness of soft yellowish sandstones, light and drab clays, forming broken hills and slide-benches, in which the strata are usually more or less concealed by the soil derived from their degradation. The latter deposits also incline gently northeastwardly, occurring along the valley for the distance of perhaps a couple of miles. This series is also finely developed on and to the east of the southeast fork, where, at a point about 8 miles above the forks, Mr. Perry secured a very interesting detail section. In a vertical thickness of about 1,000 feet, made up of generally light buff calcareous sandstones and clay shales in about the proportion 2 to 1, and including five beds of limestone aggregating 40 feet in thickness, there were found eighteen distinct lignite horizons, composed of 47 layers, varying from thin seams up to beds 2½ feet thick, and aggregating about 28 feet. The exposed outcrops of the coal beds usually are more or less decomposed, and while, in the main, the beds are thin seams from less than 1 inch to 8 inches thick, there are at least 11 showing a thick-

ness of 10 inches and upwards each; several of the thinner seams separated by thin partings of clay might be mined as one bed, many of them showing an aggregate thickness of 20 to 30 inches of coal. Comminuted vegetable remains occur throughout, and at one carbonaceous horizon in the middle portion of the series a few imperfectly preserved fossils were found belonging to the genera *Unio*, *Hydrobia?*, *Sphærium*, which Dr. White provisionally refers to Bear River Laramie forms. In nearly horizontal sandstones in the upper part of the section examined by Mr. Perry a species of *Viviparus* closely allied to, if not identical with, *V. paludinæformis* Hall, was obtained, which, according to Dr. White, indicates the Wahsatch age of the supralignitic horizons.

The latter deposits, on the before-mentioned northeast fork of Gros Ventre River, continue for a distance of 1½ to 2 miles; the exact thickness attained by them is difficult to determine. The upper portion may be destitute of coal deposits, although presenting great uniformity in composition and lithologic characters. Overlooking a more or less extended belt of the outcrops of this series, it presents a light buff color that readily distinguishes it from the brownish inferior conglomerate, as also from the overlying series. But it would be premature at this time to attempt to draw the line of demarkation between the lignite-bearing inferior portion with its supposed Laramie invertebrate fauna and the apparently conformable upper portion characterized by the *Viviparus paludinæformis* (?), except arbitrarily; while the non-conformity between the basis conglomerate and the subjacent Cretaceous deposits is unmistakable.

The above horizon is succeeded to the east by a series of variegated pale red or pinkish clays (No. 15), in apparently conformable superposition, and inclined gently northeastward. The outcrop of this member is traced as a somewhat narrower belt, distinguishable by its peculiar color at long distances. It frequently appears in bluffs and denuded slopes, in which respect, as also the banded disposition of the coloring matter, pink and light drab, forcibly recalls the peculiar deposits so prominently developed in the Wind River Valley, east of the present basin. To the south these deposits are not so distinctly traced, so that at present it would be impossible to define their areal extent in that quarter. In the opposite direction, however, they are seen to rise up in the broken slopes culminating in the Mount Leidy highlands on the north border of the basin, beyond which again they were not with certainty recognized.

A considerably thicker series of very light drab and buff deposits, probably arenaceous clays and soft sandstone, including pale, orange-colored horizons (No. 16), overlies the last preceding deposits, rising up into and forming the bulk of the sedimentary deposits in the crest of the watershed separating this basin from the upper valley of Wind River on the east. They are but slightly disturbed from their original horizontal position, as appears from such exposures occurring along the streams descending either slope of the watershed. About midway between Union and Togwotee passes, where the watershed is most depressed, 9,800 feet altitude, these deposits are clearly continuous with those occurring on the headwaters of Wind River. This region is generally well wooded, and but for the barred bluffs along the drainage channels intersecting the watershed, its geological structure might not be so easily made out in the course of a hasty examiuation. No fossils were found in these deposits by which they might be compared with elsewhere well-determined Tertiary formations.

To the south they are hidden beneath Quaternary débris over exten-

WASHED BLUFFS ON WIND RIVER. WASATCH GROUP

sive areas in the slopes in the vicinity of Union Pass. Just north, however, on the head of Warm Spring Creek and upper drainage flowing to the Gros Ventre, they appear in the bluffs, showing nearly horizontal strata of yellow and brown sandy clays and soft yellow sandstones. The ridges separating the drainage are here often overspread by quantities of water-worn and rounded quartz pebbles, strikingly like the material derived from the degradation of the before-mentioned conglomerate lower down the Gros Ventre. But the surface is generally enveloped in the morainic débris consisting chiefly of Archæan bowlders. Approaching Station XXVIII, a low conical eminence rising on the summit of the watershed 11 miles to the northwest of Union Peak, attaining an altitude of 10,142 feet, the drift material shows constantly-increasing accessions of volcanic fragments and chalcedony. The station eminence is composed of a brownish-green easily-weathered deposit, intermingled with which, at the surface at least, occur quantities of basalt, red to brown and dark scoriaceous lavas, drab, brown, and pink trachyte, volcanic conglomerate and green-stained quartz conglomerate, such as occurs in Togwotee Pass, together with beautiful green volcanic glass and chalcedony, and fragments of fossil wood. Indeed, the hill would seem to be made up of fragmentary volcanic products of a kind identical with the great volcanic deposits in the neighborhood of Togwotee Pass. The green-stained basis deposit, also, is like that occurring beneath the great volcanic conglomerates at the latter locality, and which, the previous season, was found to extend some distance from the summit of the pass along the upper course of Wind River, where it in turn rested upon light buff and drab Tertiary deposits, probably identical with those noticed above. A few miles to the north of the latter locality the flowed lavas connected with the high volcanic plateau that culminates in a low dome (the same occupied as Station LI by the Téton division of the survey the preceding season), 6 miles south-southeast of Togwotee Pass, first appear *in situ* (No. 17 of the section diagram), and thence round by way of that pass the watershed bears a heavy mantle of volcanic rocks. The stratigraphical appearance of these deposits in the latter quarter were noticed in the report upon the Téton district, 1877.

The range of hills separating this basin from Buffalo Fork drainage is apparently largely made up of the above-mentioned formations. This highland belt was crossed at a point about 10 miles east of Mount Leidy, in the vicinity of one of its culminating peaks, Station XXX, which has an altitude of 10,338 feet above the sea. The divide is here capped by the conglomerate, No. 13, composing several hundred feet thickness of the summit strata, and inclined about S. 12° E., at an angle of 10° or less. The conglomerate is here interbedded with hardish, gray, dirty-buff weathered sandstone containing fragments of twigs and tree trunks. The rock in the high summits weathers in precipitous slopes and steep taluses, through which protrude sharp arête-like buttresses which give to the weather sculpture of these eminences so peculiar and striking an appearance seen from a distance. East of this point the conglomerate is overlaid by the same succession of formations as noticed in Gros Ventre River section, 10 miles to the south, with which, indeed, these exposures have uninterrupted continuity. At the time of our visit the present season (October 11) the country was covered with snow; but in the numerous abrupt hillsides the geological formations could be readily recognized, and especially so in the case of the great interlignitic conglomerate, which rises up into the heights that mark the irregular crest of the Mount Leidy highlands.

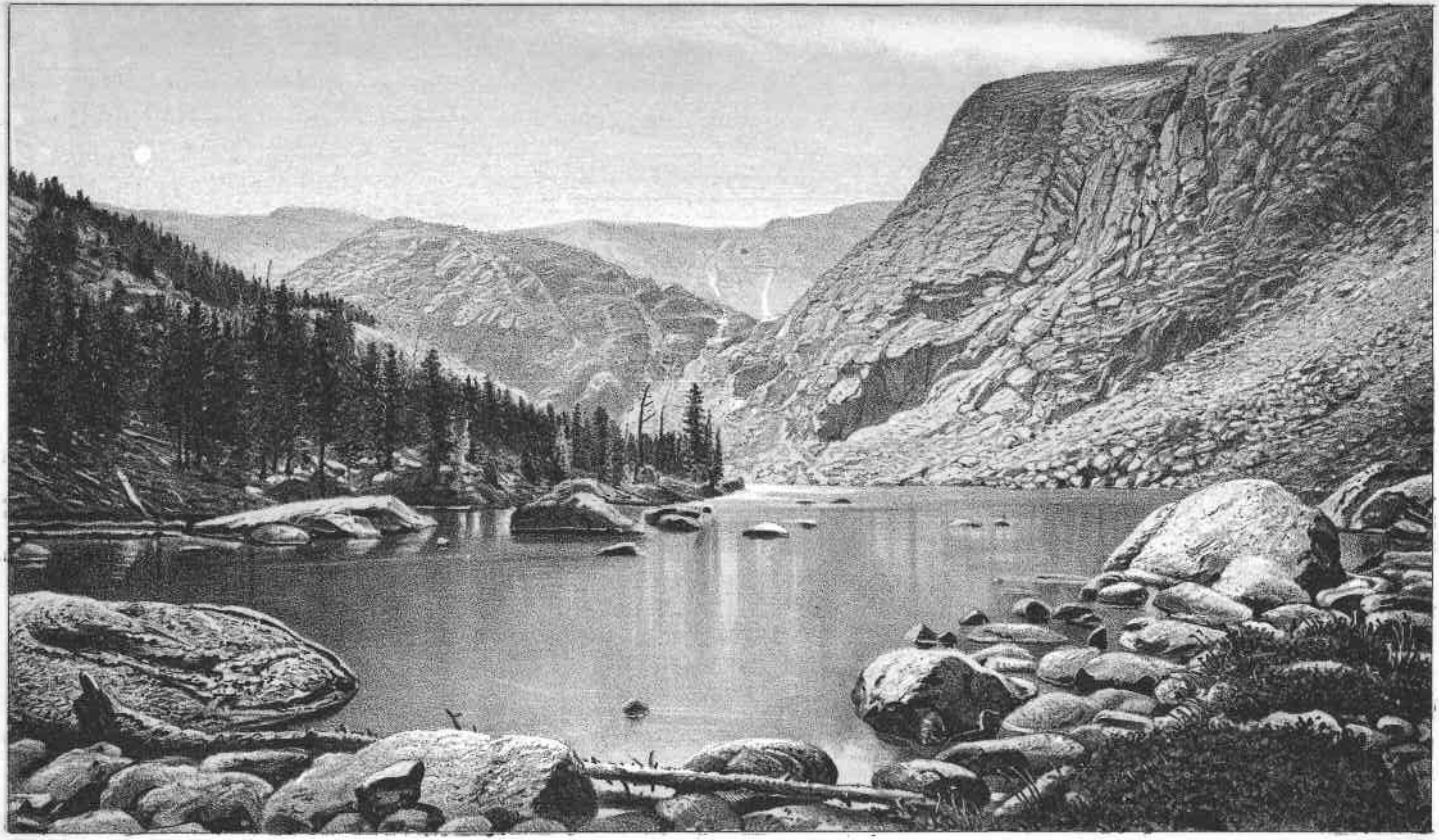
The inferior coal-bearing series, composed of softer materials, was not

so markedly displayed in escarpment exposures, although it also doubtless largely enters into the basis deposits of this highland region. It is not impossible that the lignite seams reported the previous season on Elkhorn Creek, at the northern foot of Mount Leidy, belong to the latter series, in which case they should, together with their accompanying strata, be referred to the Cretaceous instead of the Tertiary as in the report upon the Téton district, 1877. The strata of a widish belt upon the western and southern flank of the highlands, which quarter, for want of time, was not visited, are also probably referable to the same age.

The conglomerate reappears in characteristically weathered summits north of Buffalo Fork, and it is very probable that the vast accumulations of drift-like débris, noticed by Professor Bradley in the high divide between the latter stream and the sources of Snake river, were derived from the breaking up of this deposit. It has contributed an immense amount of loose materials to fluviatile deposits in all the valleys of both the Buffalo Fork and the Gros Ventre basins, and most probably the water-worn and rounded quartz pebbles that enter so largely into the composition of the bars in the bed of Snake River along many miles of its course through Jackson's Basin, and even in its lower valley below the Grand Cañon, are attributable to this conglomerate formation. The streams south of the Gros Ventre Range are bedded with different and greater variety of rock materials, which may be traced to ledges in the surrounding mountains. It is said by old prospectors that this deposit affords gold, invariably in very minute particles.

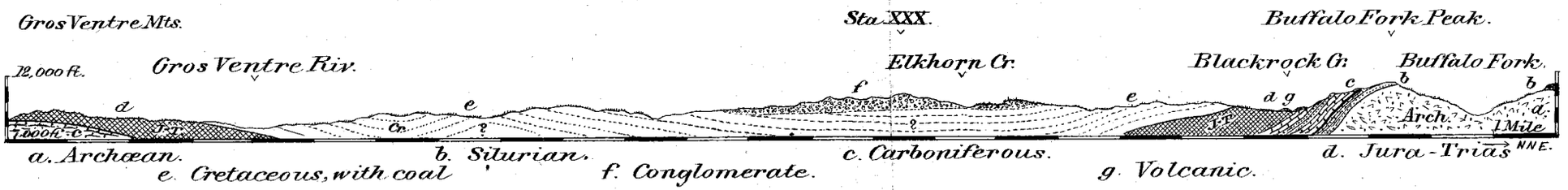
In the Buffalo Fork region the deposit descends to the northeastward at a gentle rate of inclination, as shown in the fine exposures north side of Pacific Creek, a few miles above its mouth. This northerly inclination was also observed within the Mount Leidy belt, where the conglomerate seems to form a very low, broad, undulating swell. Above the mouth of Blackrock Creek, five or six miles, a limited exposure of a conglomerate ledge appears in the south bank of the river, the relations of which to the higher occurring exposures could not be ascertained. If the latter ledge is *in situ* it shows that these strata also partook in the disturbances of the Buffalo Fork Peak uplift, low on the flanks of which Prof. Theodore Comstock found highly inclined lignite-bearing ing deposits. The latter, I am now prepared to believe, are of Cretaceous age, as was originally stated by Professor Comstock in his report to Captain Jones (Yellowstone Expedition, 1873). It was the intention the present season to carefully examine the borders of Buffalo Fork Peak uplift with the view of gathering as complete data as possible regarding the coal deposits known to occur there; but the early approach of winter snows forced the party to withdraw, leaving the northern part of the district unworked.

In the right bank of Buffalo Fork, near the confluence of Blackrock Creek, exposures of bluish-drab indurated argillaceous beds and shales, with gray and buff weathered sandstones appear, inclining at an angle of about 10° to the northward. The shale here afforded abundant vegetable remains, among which a small long ovate leaf resembling the plum was most numerous. These plant remains, which were the only palæontological evidence obtained bearing on the age of these deposits have not been determined, so that we have to depend on stratagraphical data to determine this question. A mile or less to the north on the Blackrock, apparently identical strata incline northeastwardly at an angle of 15 to 20°, which would appear to show a nonconformity with the conglomerate similar to that noticed on the Gros Ventre. Apparently the same series of deposits constitute the bulk of the hills north of Buffalo Fork, and extend west to the border of Jackson's Basin.

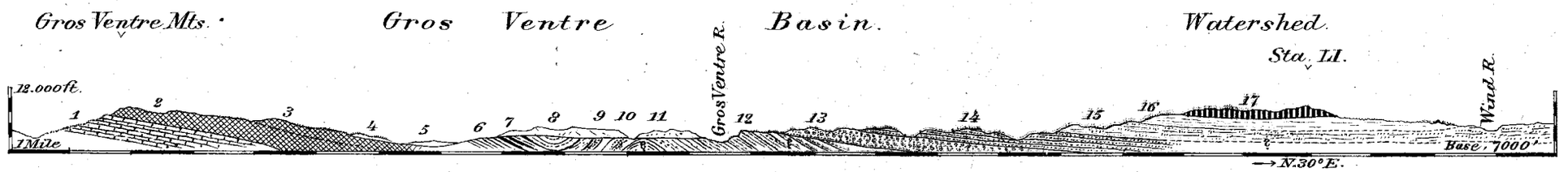


WIND RIVER MOUNTAINS - GLACIAL LAKE.

SECTIONS ACROSS GROS VENTRE - BUFFALO FORK BASIN.



a. Archæan. b. Silurian. c. Carboniferous. d. Jura-Trias
e. Cretaceous, with coal f. Conglomerate. g. Volcanic.



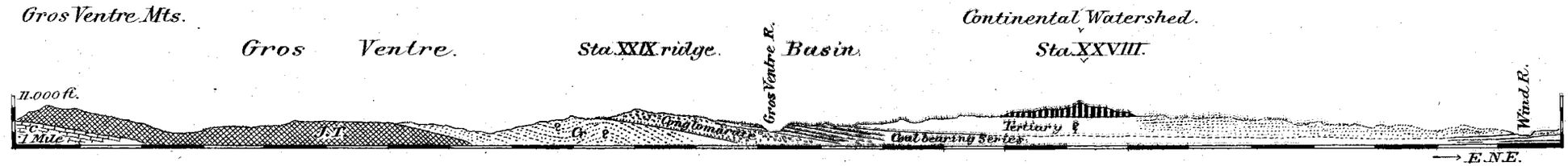


Plate XX.

The apparent local occurrence of the conglomerate, which is, so far as known, restricted to the region north of Gros Ventre Mountains, would suggest the environing mountain ranges, the Teton, Gros Ventre, and Wind River, as the sources whence its component materials were derived. Observation, as yet, is too limited for the purposes of tracing the physical history of the horizon and noting the changes in the component materials remote from the ancient shores of the basin in which they were deposited. The beautifully rounded condition of the hard quartz fragments and the thorough comminution of the softer rocks which are mingled with the deposit in the condition of fine sand and limy cement, evidently show the work of wave action. At present the deposit has not been observed in immediate contact with the rocks in the mountain borders whose degradation contributed the materials, so that it is not known to what extent the trituration of these materials had progressed along the immediate shore. The peculiar conglomerate in the region of the northern end of the Hoback Cañon ridge on the south slope of the Gros Ventre Range, described on a preceeding page, possesses in a marked manner the peculiarities of a shore deposit, from which the softer rock fragments have not been eliminated or so completely reduced by attrition as is the case in the Gros Ventre Basin conglomerate; but here the data in hands, so far as relates to tracing identity with the latter formation cease, although that deposit is also of Tertiary age, but presumably of later date, or Pliocene.

CHAPTER VI.

WIND RIVER RANGE.

The Wind River Range has a general course a little west of north and east of south of about 88 miles, and a breadth of from 12 to 32 miles. Within the present district there lies some 36 miles of the northern portion of the range, of which it forms by far the most prominent orographic feature. The southeast corner of the district lies in the heart of the mountains a few miles to the east of New Fork Peak; and thence the east boundary line descends north, gaining the Wind River Valley at the eastern foot at a point nearly due east of Union Peak, the most northerly eminence of the range. Circumstances beyond our control prevented the party penetrating the Alpine region, except at the northern extremity of the range. But to the south, Mr. Wilson, the previous season, succeeded in carrying the primary triangulation to the dominating summits at Fremont's and, I believe, New Fork Peak, revisiting in company with Dr. Hayden, at an earlier date the present season, the same region; so that the topographic features of the heart of the range, with its rock structure and interesting glacial phenomena within the district, have been subjects of investigation by several members of the survey. Our own work, however, was mainly confined to the flanks of the range, and chiefly within the belt occupied by the uplifted sedimentary formations, the exhibition of which, as displayed in the gorges through which the streams descend on their way to the plains, is of extreme simplicity.

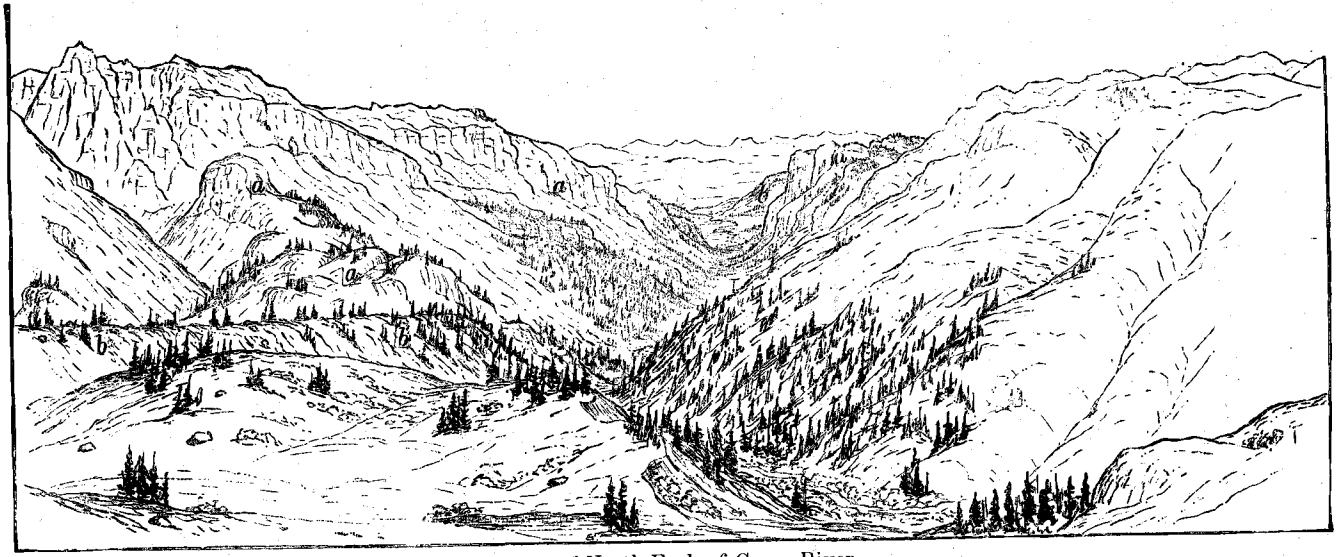
Archæan area.—The summit of the range within this district is composed of Archæan rocks, forming a broad wedge-shaped area with the apex resting on Union Peak and expanding to the south-southeast, where along the forty-third parallel it may reach a maximum width of 30 miles. The watershed and main topographic crest lies to the west of the central line of this area, forming a massive ridge to the south out of which erosion has sculptured the huge mountain summits dominating the range. The whole summit is lifted above timber-line between 2,000 and 3,000 feet. To the north the summit widens into a plateau, its surface paved with weathered blocks of granite and rising here and there into broad-based domes or craggy ridges a few hundred feet in elevation. This is the character of the range from Union Peak south to near the line of 43° 15′.

The eastern face of the main ridge, from a point opposite the sources of Torrey's Creek, south at least as far as Little Wind River, breaks down precipitously, the stream sources draining this side of the range rising in elevated rugged basins and amphitheaters along the foot of the summit ridge. The united waters of these streams generally take a direct course transverse to the general direction of the range, and soon enters the broad belt of uplifted sedimentary formations reclining on the flank of the range, in crossing which they have eroded deep, picturesque cañons displaying the complete Palæozoic and the lower members of the Mesozoic series of formations. This belt of uplifted

Gros Ventre Mountains.

S. W.

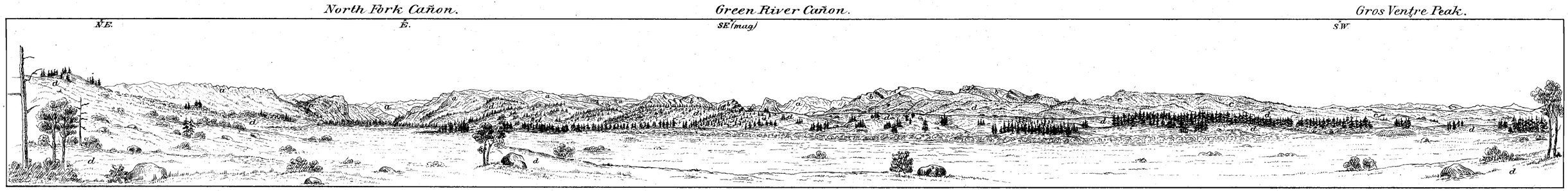
W. (mag.)



Cañon of North Fork of Green River.

a Glaciated Archæan ledges.

b Moraines.



a. Archæan. b. Palæozoic. c. Jura-Trias. d. Morainal ridges.

West Flank of Wind River Range, vicinity of Green River Cañon.

Plate XXII.

sedimentary rocks locally forms two or more distinct subordinate parallel ridges whose aggregate makes up an outlying mountain ridge that may be traced nearly the entire length of the range. The latter, as seen from the valley, forms the prominent orographic feature of the range, the high Archæan summit only appearing here and there up through the openings formed by the cañons of the descending streams; but from the higher or inner crests of the sedimentary belt the broken Archæan basin area is overlooked, terminated by the precipitous eastern wall of the culminating summit ridge only a few miles distant. The appearance of this lofty mountain barrier is indescribably varied and sublime. The stream beds are choked with confused piles of bowlders, and the rock surfaces everywhere bear unmistakable evidence of glacial action. The basins of all the streams that rise within the Archæan area present more or less perfect examples of *roches moutonues;* indeed the whole region s replete in these most interesting and varied phenomena.

On the west, the summit ridge is flanked by an exceedingly rugged elevated Archæan plateau or bench several miles in width. The streams that penetrate to the main crest flow in profound gorges walled by granite often many miles in length, as is the case with Fremont's Creek and Green River. The lesser drainage channels, rising in the outer edge of the outlying mountain plateau, often head in a *cul de sac* hemmed in between precipitous granite escarpments hundreds of feet in height, and flow out through cañons scarcely inferior in the grandeur of their scenic surroundings to those eroded by the principal water courses that drain the western flank of the range. Throughout nearly its entire extent within this district, the western edge of the Alpine plateau presents the appearance of a huge terrace escarpment which abruptly breaks down to the comparatively low, narrow belt of foot hills that slope into the valley of the Green River. Ancient glacial phenomena are here met with on a scale of great magnitude. Indeed the proper investigation of this branch of the geology of the mountains would profitably occupy many months.

Although little opportunity was presented for the systematic study of the central area of the mountains, such observations as were made in the northern portion of the range sustain the inference that the nucleal rocks are largely metamorphic. This is clearly the case along the west flank in the vicinity of Green River Cañon, as also at Union Peak, and along the eastern flank, where these rocks are revealed in the mountain valleys of Little Wind River and the streams of the north, wherever the latter were ascended beyond the limits of the unconformably superimposed Paleozoic formations. But with the meager data in hands, it would be impossible to attempt to define the lithologic and structural features of the rocks of this area, the successful elucidation of which would require a liberal allowance of time and facilities such as were beyond our means of supplying.

Along the mountain course of the tributary four or five miles north of Green River the gray banded gneissose ledges, associated with feldspar and talcose belts, have a general westerly inclination, the rock presenting locally a brecciated appearance, with angular hornblendic inclusions. The feldspar constituents weather into a soft, white earth, which may in part account for the milky discoloration of the waters of the Green above the lakes. Ascending this stream to its sources in the summit plateau 8 miles south of Union Peak, the same gneissic rocks were still prevalent, the glaciated surface bringing out the contorted lamination and ramifications of quartz and feldspar veins with which the rock is traversed. Just above a narrow rock-hemmed gorge, down

which the stream plunges, the schistose ledges curve over in an anticlinal, on the east flank of which the inclination is 30°, + —. In the vicinity a well marked porphyry dike appears on the north side of the stream, and may be traced at intervals to the ESE. and WNW., along its line of strike, a distance of a few miles. The dike is perhaps 100 feet across, and has a slight southerly inclination from the vertical; to the east Mr. Perry reports it divided into three distinct branches, holding the same general course. In texture and lithology it varies from coarse mottled to dark green chloritic hue, weathering dark rusty, like trap. Its appearance is exactly similar to the dikes occurring in Mt. Hayden and Mt. Moran in the Téton range.

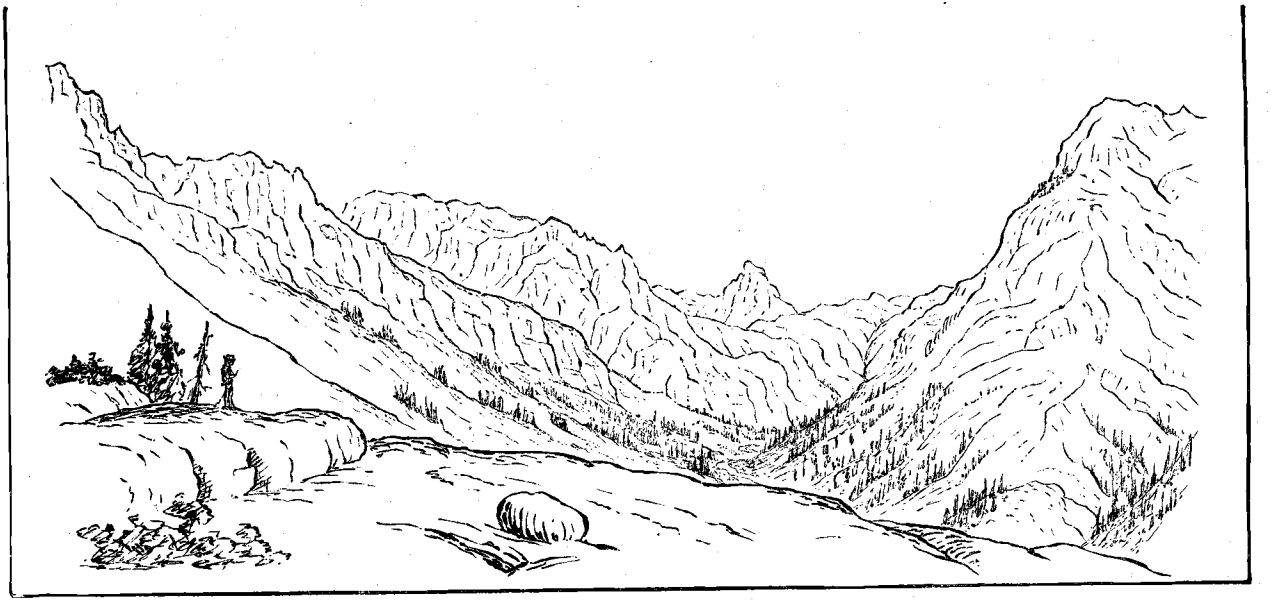
On the summit of the range between the above-mentioned tributary of Green River and Campbell's Fork of Wind River, knobby outliers of feldspathic granitoid gneiss rise above the plateau that here forms the summit. The rock weathers in blocks, recalling the granite knobs on the summit of the Laramie Range in the vicinity of Sherman Station, on the Union Pacific Railway. The gneiss, which is traversed by quartz veins, is represented by many varieties, including chloritic talcose and mica schists, the latter sometimes garnetiferous. The quartz veins have every appearance of segregated origin, resembling auriferous lodes; but the gravel deposits of the west side streams revealed no gold. South of Green River Cañon the west flank of the mountain appears to be largely made up of a coarse feldspathic granitoid rock, the relations of which to the gneissic ledges was not ascertained; but judging from the evidence afforded by the erratic materials composing the great morainic ridges along this mountain foot the latter ledges must occur in the interior of the range.

All along the east side of the Wind River Range, wherever we penetrated to the Archæan area, these rocks were found to be composed of gneissic and various schistose rocks, including hornblende, upon which the upraised Palæozoic formations rest, forming a more or less well-marked outer mountain ridge with escarped face towards the main summit crest. Union Peak, the most northerly eminence of the range, nearly 11,600 feet altitude, is made up of beautifully laminated and much contorted gray, rusty-weathered gneissic ledges, including hornblende and mica schists, showing a general westerly inclination at variable angles. On the northeast shoulder of the mountain, a short distance from the summit, feldspathic granite appears in characteristic blocky exposures, identical with the knobs previously mentioned occurring in the plateau summit 6 miles to the SSE. Perhaps a couple of hundred yards south (?) of the peak a well marked granite dike, 30 yards in width, crosses a high shoulder of the mountain, strike about east-west, and dipping southwards at an angle of 45°, + —, which is inclosed between gray gneissic walls, similar to that forming the summit. The dike consists of flesh-colored feldspar with segregations of mica and quartz, the latter sometimes replacing the silvery mica as pseudomorphs. Five miles to the north, in the vicinity of the trail over Union Pass, low, rugged exposures of feld-spathic granite outcrop, forming the most northerly observed exhibitions of the nucleal rocks of the range.

In the upper mountain basin of Warm Water Creek, above the cañon at Clarke's Camp, placer mines have been recently worked. At the time of our visit the mines were temporarily abandoned, nor could definite information be gained as to the character and richness of the deposits. From time to time considerable prospecting has been performed in this vicinity, test-pits having been carried high up on the summit of the pass. Mr. Charles Blackburn, who accompanied the party, describes

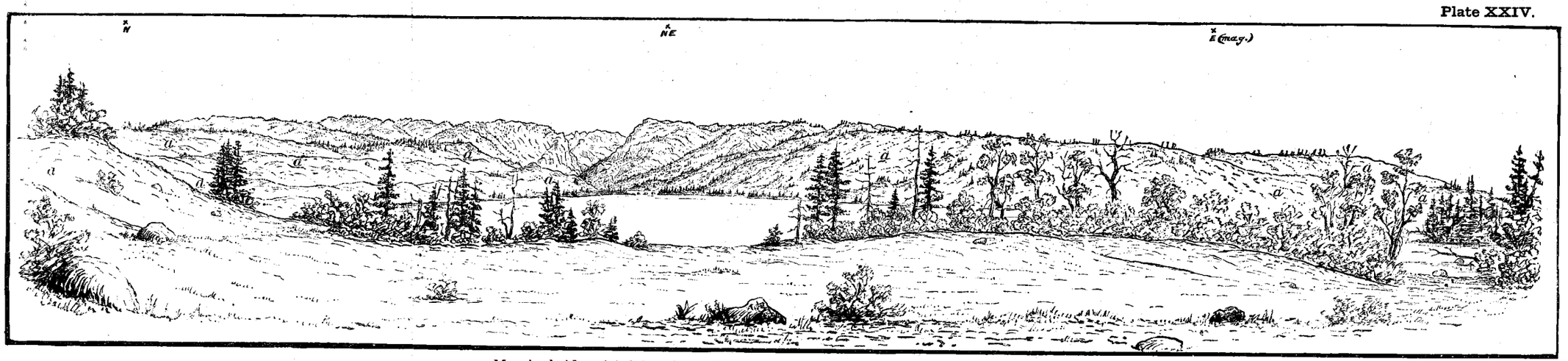
Plate XXIII.

SE. (mag.)



Green River Cañon, above the lakes.

Glacial-polished Archæan ledges.



Morainal ridges (*a*) debouchure Lac d'Amalia Cañon, west flank Wind River Range.

the placer gold occurring hereabout as exceedingly finely comminuted and in consequence difficult to save by the ordinary processes employed in working the auriferous gravels.

Fifteen to eighteen miles of the western mountain front north of the debouchure of Frémont's Creek is denuded to the crystalline rocks, and the streams that flow down from the mountains, with the exception of Frémont's Creek, which issues on the south line, are small and rise in the beforementioned Alpine bench. They all show wonderful exhibitions of glacial action in the rock-polished surfaces of the cañon-walls and the enormous quantities of *débris* built up into moraines outlying their debouchures. The latter materials are spread well out over the low slopes, effectually concealing from view the Tertiary deposits along the margin of the Green River Valley. Within this Archæan west front lies one of the grandest cañons, that by which Frémont's Creek emerges, whose sources cluster about the mountain peak bearing the same name. This stream issues from the aforesaid Alpine bench, through a profound gorge hemmed in between precipitous glacial-polished walls of granite, its exit flanked by ridges of morainal origin a thousand feet and more in height. The minute description of these immense accumulations of morainic materials would require many pages; and while in the main features repetition is encountered along the whole mountain front, each debouching stream has something peculiar to offer in the disposition of the erratic materials brought down by the great ice rivers and heaped up on or spread out over the plain. All the phenomena connected with the attained work of the glaciers is both striking and beautiful, and perhaps no field in the west offers so favorable opportunity for the study of these phenomena as does that of the Wind River Mountains.

Sedimentary border belts.—Twenty-one miles north of the south boundary of the district, Green River issues from the mountains at a point eighteen miles northwest of Frémonts' Peak. Rising in the neighborhood of the latter peak, its mountain course is eroded hundreds of feet into the crystalline rocks which flank the gorge with precipitous glacial-polished walls scarcely inferior in height and grandeur to those that have rendered famous the scenery of the Yosemite. The cañon was ascended a distance of six miles above its mouth, where the way was obstructed by the flooded condition of the few-yards-wide intervales, the adjacent rocks affording no practicable trail. Four or five miles above the mouth a huge block of granite with nearly vertical sides and truncated summit, rises on the south side of the stream to a height of perhaps two thousand feet. Below this mountain the valley expands, and is occupied by a pair of beautiful lakes. The upper and smaller lake is perhaps a mile in length and half a mile wide, its waters of a milky green from sediment brought down by the main stream, and margined by low willowy bogs and flats. The lower lake, a mile or so to the northeast, is about twice the length of the upper, its half mile breadth of deep green water nearly filling the narrow valley. The contrast in the color of the water in the upper and lower lakes was very marked, as though all the sediment had been caught and retained in the upper basin and the water perfectly filtered on its passage thence to the larger lake.

A very interesting geological feature of this locality, and one which is so far as known unique on this side of the range, is the occurrence of a considerable remnant of Palæozoic formations adhering to and lifted high up on the mountain flank on either side of the debouchure of the Green. These great tables of seidmentary strata, in places flexed and shattered, present a peculiar feature in the topographical aspect of this

part of the range and which is conspicuously displayed from long distance to the southwest, west, and north. The area occupied by these rocks is probably included within a northeast-southwest belt eight miles long and not exceeding four miles in width, the bulk of the occurrences lying to the south of the Green where they also attain, perhaps, their greatest altitude. The outer mountain barrier crowned by these deposits is planed off level irrespective of the inclined position of the strata, a result attributable to glacial action.

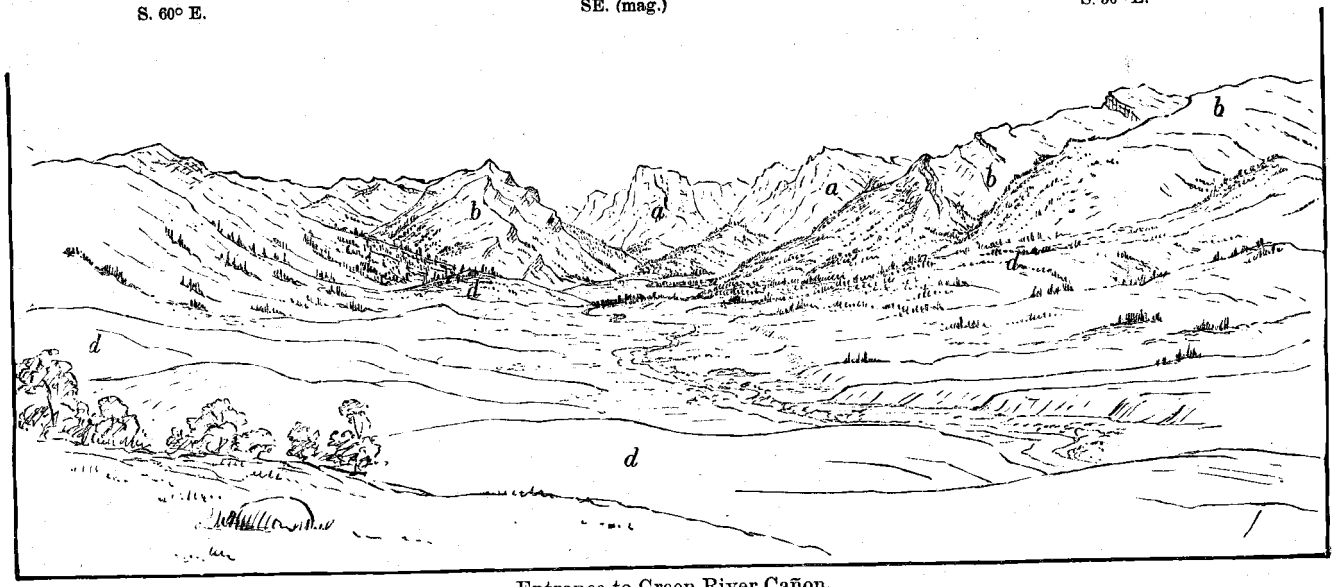
The nucleal rocks hereabout show gneissoid granite, the ledges more or less feldspathic and of a pale red color, at one point near head of lower lake dipping gently westward. Higher up the cañon, the rock changes to a gray color, is laminated and much complicated by joint or cleavage structure. The mountain walls on either side of the entrance to the cañon reveal the uplifted sedimentaries, which probably represent the complete Palæozoic series of the region. These consist in the first place, of typical exposures of buff, gray, and reddish stained carboniferous limestone and a buff hard sandstone, 2,000 feet or more in thickness, and which are apparently identical with the rocks composing the great ridge of Gros Ventre Peak that lie twenty miles due west of this locality. Below the above ledge appears a heavy bed of grayish buff rusty-weathered magnesian limestone, 200 to 400 feet in thickness, and in all respects identical with the ledge elsewhere referred provisionally to the Niagara epoch, although no fossils were detected in the rock at this locality. Below the latter occurs a few hundred feet thickness of dark drab and gray rough weathered limestone, even-bedded and in places brecciated, resting upon a heavier series of yellowish-buff silicious beds, which probably are the equivalents of the Quebec and Potsdam formations. The thickness of the sedimentary series above alluded to based upon rough estimates may not exceed 3,000 feet, of which two-thirds, perhaps more, belong to the carboniferous.

The outer mountain declivity bears a heavy plating of carboniferous strata, the beds dipping north of west at an angle of 25° + —. On both sides of the cañon these deposits, together with the Niagara, are carried up forming escarped and peculiarly weathered mountain peaks or ridges. Between the lakes a sharp flexure arches the sedimentary formations, the axis of the fold being occupied by an Archæan ridge that gradually rises to the south or southwest, in which quarter it was found to be quite denuded of the former rocks. Ascending the cañon, east, the sedimentaries again rise quite uniformly or with gentle undulations, so that the lowest members of the series are carried to the highest elevations within perhaps a couple of miles above the upper lake on the north side and a less distance on the south side, beyond which the Archæan is denuded over the remainder of the mountain plateau to the summit.

A low outflanking ridge lies close along the foot of the range, extending from the great bend of the Green 10 miles south, where it dies out in an uneven benched area. Beyond this point to the south line of the district the Tertiary deposits of Green River Basin impinge against the Archæan mountain flank without intervention of older sedimentary formations. Throughout the greater length of the ridge the Triassic "red beds" are displayed in frequent exposures in the slope descending to Green River, the interrupted section along this north-and-south line showing a broad, low undulation, in the axis of which Carboniferous limestones are brought to view, as has been elsewhere mentioned. In the benched area at the south end of the ridge the surface is broken by numerous sinks, the greater number of which are grassed over, although

Plate XXV.

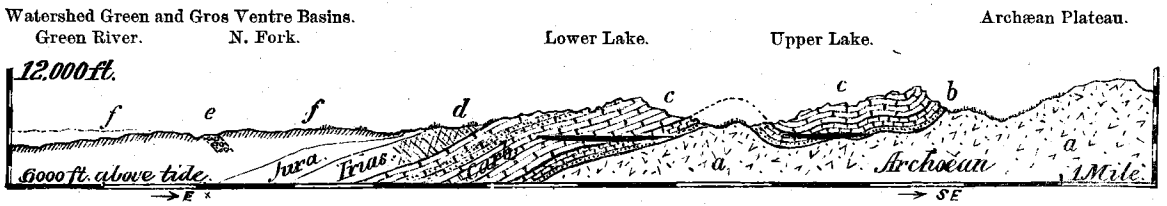
S. 60° E. SE. (mag.) S. 30° E.



Entrance to Green River Cañon.

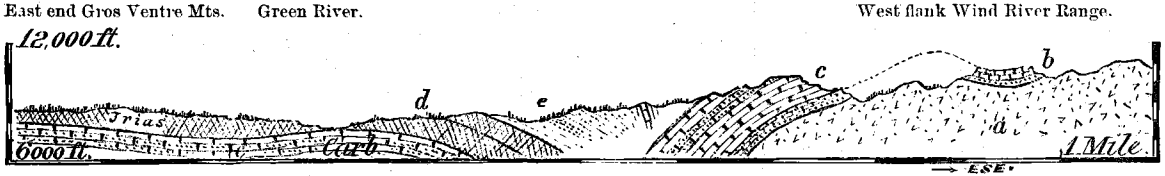
a Archæan. *b* Palæozoic. *d* Moraines.

Plate XXVI.



Wind River Range: Section north side Green River Cañon.

a Archæan. *b* Silurian. *c* Carboniferous. *d* Trias. *e* Tertiary, red conglomerate. *f* Morainal deposits.



Section three miles SW. of Green River Cañon.

a Archæan. *b* Silurian. *c* Carboniferous. *d* Jura-Trias. *e* Cretaceous, &c.

some are apparently of recent date. Occasionally limited rock exposures are seen in the sides of the sinks, showing alternations of usually white to gray gypsum in layers from a few inches to 5 feet and more in thickness, and variegated reddish and drab clays and indurated layers. In the immediate neighborhood more or less extensive accumulations of calcareous spring deposits are met with, and at one point in the low bluff bordering the river intervale a copious stream issues from subterranean sources, its waters charged with mineral substances that render them unfit for use. One of the ancient spring orifices was examined, its dimensions being about 50 yards one way by 30 in the other direction and 10 to 15 feet deep, portions of the calcareous tufa walls remaining quite perfect, as also the exterior limits of the deposition from the overflow. The sinks occur even on the opposite side of the Green, where one apparently formed only a few days before was seen close beside the road, the terrace gravel-walls forming its sides retaining their vertical position at the time it was examined. Their origin may be attributed to the solvent power of water acting upon the gypsiferous beds, and where the latter deposits lie near the surface their removal may cause the superjacent earth to sink into the cavities thus formed.

Overlying the Triassic beds in the southern portion of the ridge are found a series of imperfectly-exposed Jurassic rocks made up of variegated pink, drab, and light-drab clays, and dark and light limestones. At a locality near the south extremity of the ridge the latter beds yield a few characteristic Jurassic fossils, *Camptonectes*, &c., by which their age is definitely determined. The deposits incline about southeast at an angle of 16°, the exposures belonging to the east or southeast declivity of the before-mentioned broad, low anticlinal arch. A short distance to the northeast gray sandstones and light-drab limestones, associated with variegated clays, appear in the slopes of a small stream draining the interval lying over against the mountain flank, where they show a dip of 25° about east. Ascending east to the near vicinity of the mountain, a limited outcrop, consisting of a four-foot ledge of hard, pinkish gray and dirty buff, finely brecciated limestone, included in pale-red shales, was met with, dipping about east at an angle of 70°. The relation of the latter to the foregoing Jurassic strata was not satisfactorily determined, but it may belong to a Post-Jurassic formation.

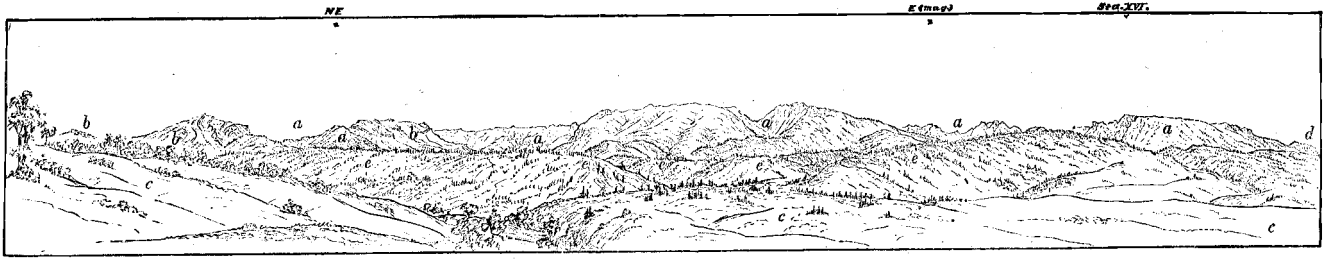
In the adjacent mountain slope heavy-bedded buff magnesian limestone appears, associated with much silicious matter or passing into light-gray reddish-tinged sandstone and overlaid by typical Carboniferous limestones. At one place, near the southernmost exposures of the Palæozoic remnant, the heavy magnesian ledges, though the bedding is obscure, incline steeply to the eastward; but a short distance to the north the mountain flank exhibits the same overlying Carboniferous limestones dipping off the range to the westward. The steep easterly inclination of the Palæozoic strata at this locality may have some relation to the Post-Jurassic exposures above alluded to, although it is possible they belong to the west flank of the synclinal trough into which these beds were folded. To the south, 4 or 5 miles, in the neighborhood of Station XVI, Mr. Perry found a series of pale-reddish deposits similar in their lithological appearance to the Post-Jurassic above referred to, and which apparently impinge with easterly dip against the Archæan wall that here forms the abrupt western flank of the range. The state of things observed in this quarter apparently indicates a fracture or fault extending parallel with and immediately along the foot of this part of the range, and which carried the Palæozoic series down a vertical distance amounting to several thousand feet, subsequent erosion having

only uncovered later Mesozoic deposits along the downthrow side of the fracture line, above which towers the denuded Archæan in escarped mountain walls a thousand feet and more in height. That these disturbances occurred prior to the deposition of the supposed Wahsatch Tertiary strata is evident from the fact of the occurrence of the latter in their original horizontal position only a few miles to the south, well up in the slopes outlying the Archæan wall that there defines the western border of the range.

The sections on an accompanying plate present the general facts relating to the above-mentioned Palæozoic remnant occurring on the west flank of the range vicinity of Green River Cañon, while the extent of area which they at present occupy is approximately shown on the geological map. But in respect to the outlying Mesozoic ridge, it is evident that the deposits occurring therein have still intimate connection with the Mesozoic area filling the depression between the Gros Ventre and Wind River Ranges in the interval just south of the great bend of the Green. Apparently the same series of "red beds" recurs on the outlying slopes of the latter range immediately north of the debouchure of Green River, where, however, they are concealed for the most part beneath the morainal materials that heavily cover the divide between the main stream and a smaller tributary that issues from the mountains four miles to the north. At the latter locality "red beds" are seen resting directly on the Archæan border of the mountain, recalling the previously-mentioned similar occurrences observed by Mr. Perry in the mountain flank seven or eight miles south of Green River Cañon, in the vicinity of Station XVI. Along the lower abrupt descent of the tributary that crosses this outlying morainal bench, red conglomerate deposits were observed, dipping steeply northwards, which strikingly resemble the Tertiary conglomerate along the south flank of the Gros Ventre Range at the intersection of Hoback Cañon ridge, described in a preceding chapter. To the north, still, the Quaternary deposits increase in importance as an element in the superficial geology of the broad outlying slopes that descend to the west and form the watershed between the Green and Gros Ventre drainages. This divide region is apparently largely made up of Tertiary formations, and their presence here seems to justify the inference of the former connection of the waters, in which at least the earlier Cenozoic measures were contemporaneously deposited over the ground that now belongs to two separate drainage systems.

It is difficult to say to what extent the Mesozoic barrier has been eroded within the time belonging to the present era or the Quaternary, and in view of the geological movements that are known to have continued into late Cenozoic time, the meager knowledge at present possessed hardly warrants conclusive statements as to the relations of the present physical conditions to what obtained during the deposition of the early Tertiary formations in the area above alluded to. This will be understood, perhaps, with greater clearness from the following statement of facts: The Carboniferous occurring in the axis of the low inter-mountain fold on the Green has an altitude of about 7,800 feet, or 1,100 feet lower than the divide between the Green and Gros Ventre 8 miles north, and only about 2,300 feet below the highest altitude of the latest Tertiary deposits occurring in the great watershed north of Union Peak. If we assume the whole Mesozoic series of the region to have been intact at the commencement of the Wasatch epoch, the interval now occupied by the bed of Green River must have presented a barrier of equal if not greater actual elevation than that of the Gros Ventre Mountains to-day, which may well have isolated, then as now, the drainage basins occupied respectively by

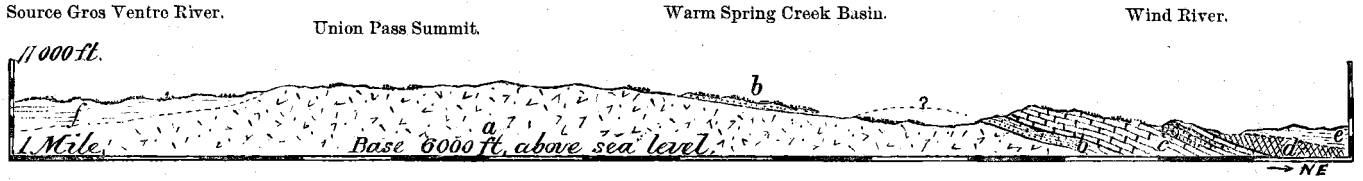
Plate XXVII.



West flank Wind River Range south of Green River Cañon.

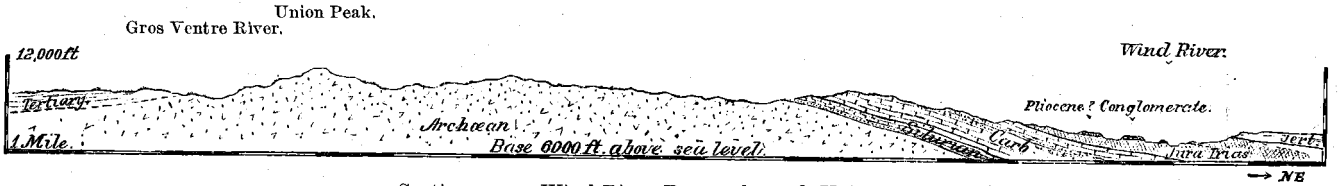
a Archæan. *b* Palæozoic. *c* Mesozoic. *d* Tertiary. *e* Moraines.

Plate XXVIII.



Section across north end of Wind River Range.

a Archæan. *b* Silurian. *c* Carboniferous. *d* Jura-Trias. *e* Wind River Tertiary. *f* Tertiary and Morainal deposits.



Section across Wind River Range through Union Peak.

the Upper Green and Gros Ventre Rivers. But to the south it is well known that a long interval of time elapsed subsequent to the deposition of the later Mesozoic and Post-Cretaceous deposits common to the region, whose elevation and folding and subsequent erosion prepared the surface upon which the Tertiary beds were unconformably laid down. So, in the quarter here particularly referred to, a similar state of things may have transpired, but at present the evidence might not be deemed as justifying a conclusive statement to the effect that the same physical conditions here prevailed to the extent of uniting the early Tertiary basins of the north and south by a common sheet of water in the straits of what is now the low barrier of the Green and Gros Ventre water-divide. With more complete data, such as it were doubtless possible to acquire by more extended examinations in this divide region than it was possible to make during the past season, the facts bearing on this question of the continuity of water connection between these great Tertiary areas might be as easily solved as in the case of the Wind River and Gros Ventre-Buffalo Fork Basins, which latter undoubtedly originally formed one great basin during the accumulation of the Cenozoic formations.

Around the northwestern extremity of the Wind River Range proper the flanks of the Archæan nucleus are buried beneath immense detrital accumulations of the Quaternary period, and which are spread out over an extensive plateau ridge, across which Union or Warm Spring Pass lies, at an altitude of 9,500 feet above the sea. The descent into the Gros Ventre Basin on the west is over comparatively gentle declivities, whose basis rocks of Tertiary age have already been described in the chapter relating to the Gros Ventre-Buffalo Fork Basin. The plateau character of the watershed continues thence to the vicinity of Togwotee Pass, although its flanks are deeply scored by the streams flowing down into Wind River on the east and the Gros Ventre on the opposite side, and in whose steep bluffs more or less complete sections of the strata of which the watershed is made up are displayed. But on gaining the northeastern flank of the range the declivity descending into the valley of Wind River falls much more steeply, and in the place of the long gentle slopes over comparatively undisturbed Tertiary deposits, the mountain flank is broken by great ridges of upraised Palæozoic rocks, which only terminate after passing Warm Spring Creek, when they are in turn enveloped in the later-formed sediments constituting the watershed. The appearances, however, strongly indicate a hemiquaquaversal condition of the upraised Palæozoic strata at the northern extremity of the range, although this cannot be proved from the fact that these earlier formations, if they have not been removed by erosion, are so deeply buried beneath the Tertiary deposits as completely to conceal their former relation to the Archæan nucleus in this quarter.

On leaving Wind River Valley, the Union Pass trail begins the ascent of the mountain flank at a point perhaps 3 miles above the confluence of Warm Spring Creek. Some distance below this point Wind River flows through a narrow gorge cut into northeasterly dipping rusty weathered sandstone ledges belonging to the middle division of the Carboniferous series, and which rise up on the mountain side forming a sort of hog-back ridge 500 or 600 feet above the stream. The same set of strata appear in similar ridges along the mountain side above this point perhaps 2 or 3 miles, beyond which the mountain flank trends round to the west, where the slopes are densely clothed with forests concealing the nature of their rock structure. The ascent of the trail is almost a continuous climb up through beautiful forests of pine for the distance of 4 or 5 miles, when it again descends into the upper mountain basin of Warm Spring

Creek. The way thus far has passed successively over the hidden ledges of the Lower Carboniferous limestones and Silurian formations, the latter appearing as low ledges of rusty weathered limestone in the high ridge crests off to the eastward either side of the Warm Spring Cañon. In the south-side slopes rising from the Warm Spring Basin we encountered along the trail much *débris* of coarse buff and red sandstone, probably Potsdam, which extends some 2 or 3 miles, reaching an altitude of near 9,400 feet. Here we first met with Archæan exposures, occurring in low combs on the eastern edge of the elevated grassy plateau that stretches across the summit in the vicinity of the pass. To the west of this point the surface is deeply buried beneath the Quaternary gravels; meager exposures of yellow and drab sandy clays, possibly referable to the Tertiary, occasionally appear in shallow valleys occupied by the southern sources of Warm Spring Creek.

Above Warm Spring Creek the course of Wind River for 8 to 10 miles is east-westerly. About midway it is joined by a small affluent heading in the watershed a few miles to the northwest of Union Pass summit, and which, it is believed, defines the limits of the Palæozoic belt around the northern extremity of the Wind River uplift. Vestiges of "red beds" holding the stratigraphical position of the Trias were observed in the slopes descending to Wind River between the confluence of this stream and Warm Spring Creek, but the surface configuration of the valley slopes, after the stream enters the hills, shows them to be wrought out of the comparatively soft deposits of Tertiary age. This is indicated by the benched and densely wooded slopes, contrasting with the long declivities characteristic of the Palæozoic mountain flank, as seen in the vicinity of Warm Spring Creek, and thence extending south nearly the entire length of the range along its eastern front.

Warm Spring Creek, as before mentioned, rises in the elevated watershed to the northwest of Union Pass, flowing in a general direction about east-northeast, in a direct course about 12 miles. The sources lie within the Tertiary area, its middle course occupying a rather wide mountain basin excavated out of the Palæozoic belt. Four or five miles above its mouth the stream enters a narrow defile which it has excavated across the upraised Palæozoic belt, its bed at the upper entrance to the cañon being eroded several hundred feet into the Archæan basis rocks. Lower down the sedimentary formations close in upon the stream, forming cliffs on either hand several hundred feet in height. In a distance of 4 miles the stream descends about 600 feet, the course being nearly in the direction of the inclination of the strata across which it flows, the cañon becoming shallower and finally emerging in the Triassic "red beds" as the stream leaves the mountain and crosses the narrow terrace bordering the right bank of Wind River. The geological section exposed in the cañon walls is roughly reproduced in one of the accompanying plates of section diagrams, a description of which follows:

Section in Warm Spring Creek Cañon.

No. 1. Archæan basis rocks, belong to the principal core-mass of the range.

No. 2. Dark, rusty weathered outcrop, probably representing the Potsdam sandstone, and forming the lowest member of the Palæozoic series. This ledge rises high up on the wooded Archæan ridges that sweep round on either hand, and plates the declivity on the south side of the moutain basin above the cañon.

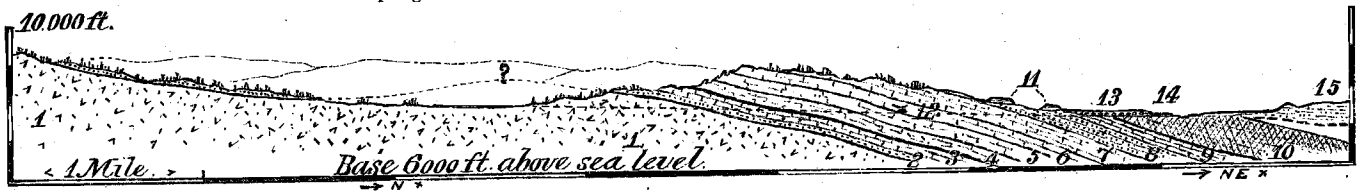
No. 3. Position of the Quebec formation, not clearly distinguishable

Plate XXIX.

East flank Wind River Range.
Warm Spring Creek Basin.

Cañon.

Wind River Basin.
Wind River.



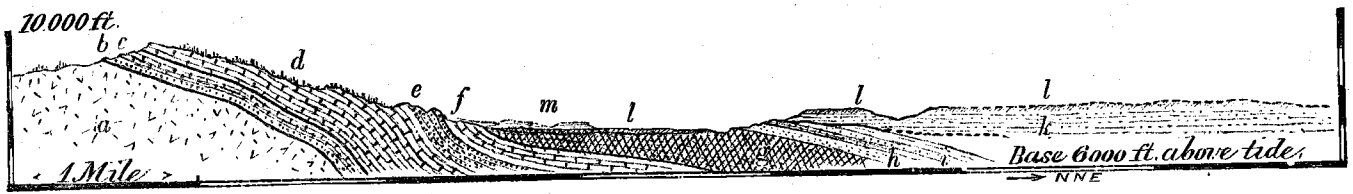
Section in Warm Spring Creek Cañon.

1. Archæan. 2. Potsdam. 3. Quebec. 4, 5, 6, 7. Carb. limestone. 8. Middle Carb. sandstone. 9. Permo-Carb. 10. Triassic.
11. Tufaceous limestone benches. 12. Calc. tufa arch. 13. Quaternary. 14. Recent spring deposits. 15. Wind River Tertiary.

East flank Wind River Mts.

Wind River.
Sta. LIII (1877).

Wind River Basin.



Section below Warm Spring Creek.

a Archæan. *b* Potsdam. *c* Quebec. *d* Carboniferous limestone. *e* Middle Carb. sandstone. *f* Permo-Carb. *g* Triassic.
h J-T. Passage beds. *i* Jura. *k* Wind River Tertiary. *l* Quaternary gravels. *m* Tufaceous spring deposits.

in the talus slopes at foot of cañon walls. In the high crest of the sedimentary foreland ridge to the south this horizon recurs, where it shows ledges of even-bedded, dark-drab weathered limestone.

No. 4. Buff weathered limestone, probably magnesian, holding a stratigraphical position inferior to the Carboniferous, and doubtfully referred to the Niagara, forms castellated cliffs towards upper end of cañon.

No. 5. Heavy ledge of grayish-buff, red-stained limestone, separated from the preceding and overlying ledges by narrow talus slopes.

No. 6. Gray, drab, and dirty-buff weathered limestone, with which cherty bands are associated, dip 20° ± northeasterly; forms a heavy ledge rising up into promontory overlooking the upper basin of Warm Spring Creek.

No. 7. Heavy deposit of buff magnesian limestone interbedded with drab limestone and chert, overlaid by fragmentary, fine-grained, drab-buff, cherty limestone, with a prominent band of deep-red sandstone and sandy shales several feet in thickness, dip 15° to 20° northeastwardly. The lower limestone layers contain Carboniferous forms of *Athyris*, &c.

No. 8. Buff, pink, and reddish stained sandstone, of variable hardness, with obliquely laminated layers, forming a heavy deposit, of which, however, only about one hundred feet thickness is exposed in bluffs on right bank of the creek below the cañon. This horizon belongs to the middle member of the Carboniferous series.

No. 9. Gray limestone layers, with *Produotus*, *Spirifer*, &c., overlaid by rusty-brown weathered, indurated, argillaceous beds, passing up into light-drab partially indurated clays, all imperfectly exposed exhibitions of upper Carboniferous horizons, including the Permo-Carboniferous argillaceous deposits above.

No. 10. Triassic "red beds," consisting of more or less indurated red arenaceous shales and sandstones, with thin bands of gray sandstone appearing in terrace along south side of Wind River, where the edges of the moderately tilted strata have been evenly planed off, upon which rests a Quaternary deposit, cemented by calcareous infiltrations from adjacent springs into a sort of conglomerate, in places 30 feet thick.

No. 11. Calcareous tufa, in places holding water-worn drift pebbles formed by ancient springs, and crowning benches at various levels along the mountain-foot south side of Wind River Valley.

No. 12. Calcareous tufa arch spanning the stream in the cañon, origin same as above deposits.

No attempt was made to secure measurements of the thickness of the various members described in the above section, though they appear to conform in all respects to the same series as met with along this side of the range to the southeast, where their appearance will be noted in detail farther on. The section is reproduced here because it is the most northerly locality where the complete Palæozoic series is revealed to view, displaying a connected section from base to top along the course of this wild and picturesque mountain gorge. The geological examinations were carried along the brink of the north wall of the cañon, from which the general geologic structure, as displayed in the opposite cañon wall, could be most satisfactorily made out, and which may in a measure compensate for the lack of stratigraphic details, which are not to be acquired in the course of a hasty visit.

From Warm Spring Creek all along the east front of the range the Palæozoic formations present a uniform and rather steep foreland acclivity, culminating in the before-mentioned outer mountain ridge, the crest of which attains an altitude ranging from 10,000 to 11,000 feet. The slope, which always closely conforms in inclination to the dip of the

strata, is pierced by numerous water-courses, whose deeply eroded cañons break the continuity of the great sedimentary ridge, revealing its structural features in a series of most remarkable natural rock sections. The meager observations made above Warm Spring Creek have already received brief mention, and the following notes are based on observations made along the mountain front below that locality, extending to the eastern boundary of the district a few miles below the mouth of Torrey's Creek. However, much interesting data was gained relating to the detail geology of the great eastern foreland between the latter point and Camp Brown, which, although outside the limits of this district, will be introduced in the order of their occurrence in journeying southwards along this side of the mountains.

A few miles below Warm Spring Creek and about a mile distant from Wind River the foreland slope is interrupted by a rather prominent ledge of rusty weathered rock, having the appearance of a trap-dike as seen from a distance. It was found, however, to consist of a steeply tilted mass of middle Carboniferous sandstone, at one point dipping about northeast at an angle of 80°. It is made up of buff and reddish partially metamorphosed sandstones, including softer portions. The steep slope below is strewn with fragments of dark buff and drab limestones and chert, containing *Productus* and *Spirifer*, belonging to the upper division of the Carboniferous. On reaching the foot of the steep declivity the Triassic "red beds" are encountered, extending thence in the terrace bench to Wind River, where they form low mural exposures. The gentle inclination of the latter deposits might almost be regarded as evidence of non-conformity, an appearance which is doubtless due to the abrupt flexure of the strata at this point, and the erosion of the softer superimposed deposits over the steep acclivity down to or below the line defining the abrupt spring of the uplift.

Just below, on the opposite side of Wind River, and perhaps three or four miles below Warm Spring Creek, Station LII of 1877 was located on an eminence of the Wind River Tertiary, which here closely approaches the stream. The above-mentioned Trias "red beds" reappear in the outlying bench at the foot of the Tertiary plateau, where they are in turn overlaid by a few feet thickness of the inferior strata of the Jura, resting upon the soft light-colored sandstones, &c., composing the beds of passage between the Jurassic and the typical "red beds" of the Trias. The Jura appears in a bench about 300 feet above the river, and is unconformably overlaid by the variegated or banded pale-red and greenish-drab arenaceous clays of the Wind River Tertiary, which culminate in the before-mentioned station promontory at an elevation of 600 to 650 feet above the stream. The Jura and inferior strata at this locality present the following section:

Section at Station LII (1877), *north side of Wind River.*

a. Triassic "red beds," consisting of deep-red and greenish-drab indurated gritty layers, upper measures concealed in terrace surface.

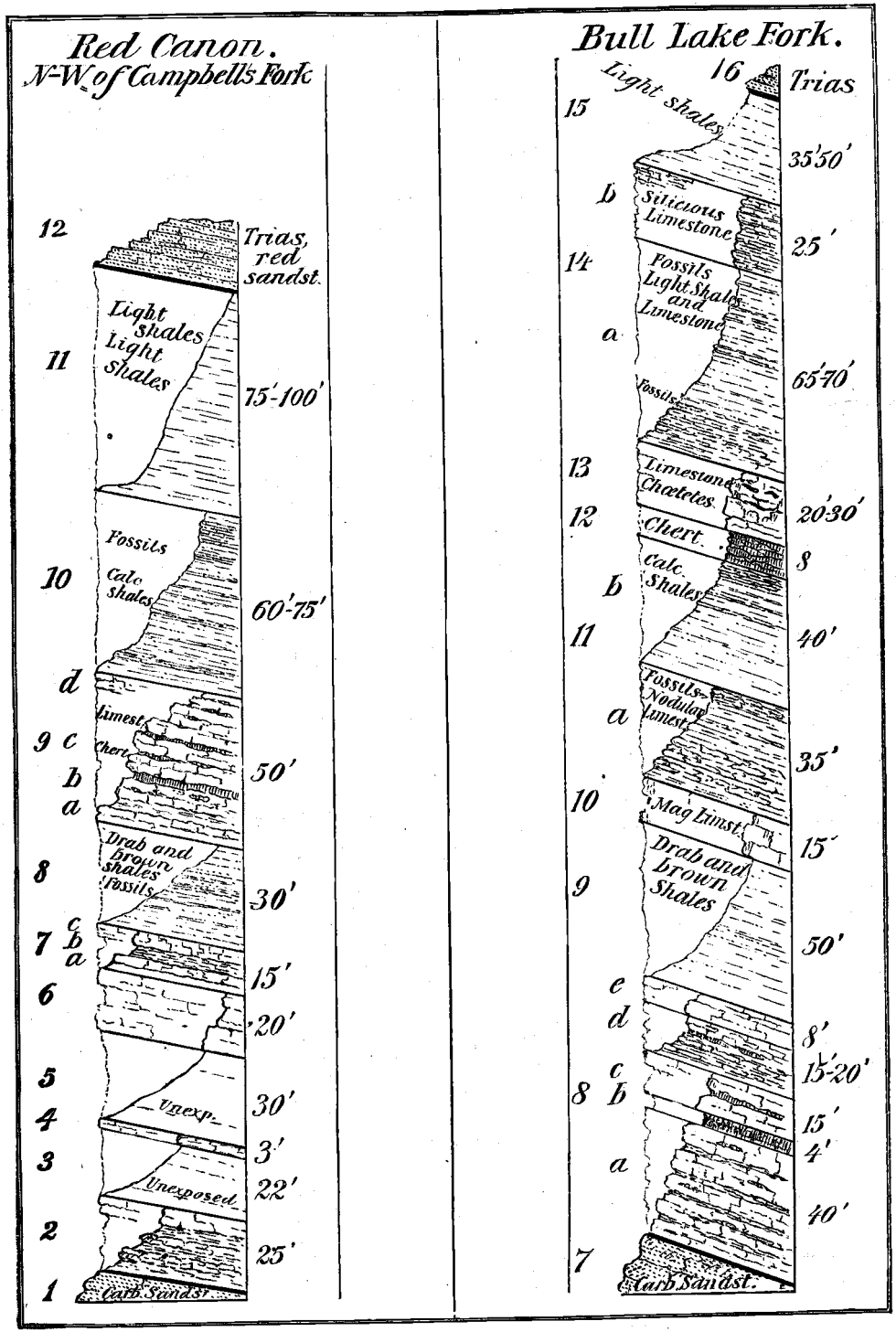
b. Green clays, with thin streaks of deep-red indurated gritty layers, 10 feet exposed, at elevation of about 275 feet above river.

c. Soft, thin-bedded yellow sandstone, with red and gray streaks, 30 feet; overlaid by soft whitish sandstone, 40 to 50 feet.

d. Greenish-blue marly clays, with layers of dirty gray-buff laminated and thin shaly limestone, 25 feet ±.

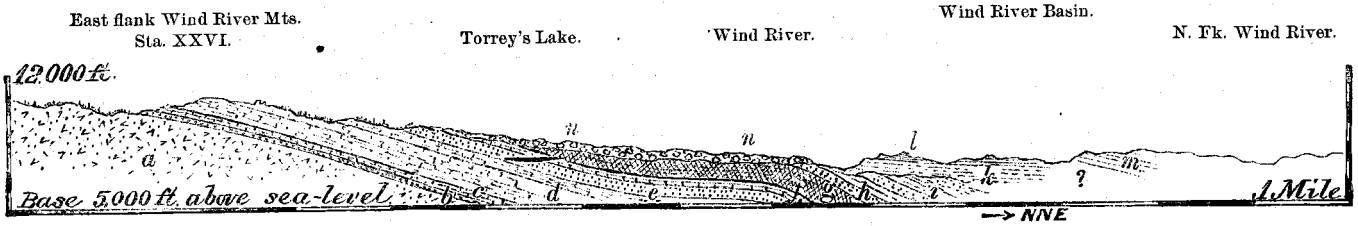
e. Drab-gray, heavy bedded fragmentary limestone, 4 to 5 feet.

f. Light marly shales, 25 feet ±.



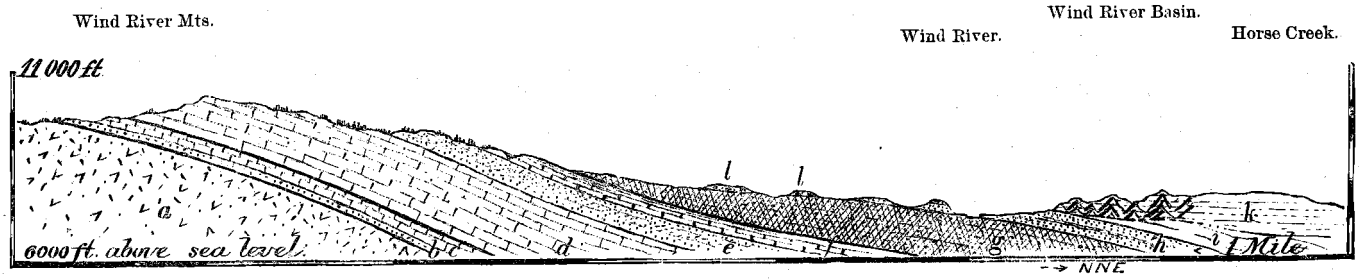
"Permo-Carboniferous" sections.

Plate XXXI.



a Archæan. *b* Potsdam. *c* Quebec. *d* Carb. limestone. *e* Middle Carb. sandstone. *f* Permo-Carb. *g* Triassic. *h* Jurassic.
i Cretaceous? *k* Wind River Tertiary. *l* Brown beds. *m* Variegated purple deposits. *n* Morainal deposits.

Section vicinity of Torrey's Creek.



a Archæan. *b* Potsdam. *c* Quebec. *d* Carb. limestone. *e* Carb. sandstone. *f* Permo-Carb. *g* Triassic. *h* J. T. Passage beds.
i Jura. *k* Wind River Tertiary. *l* Quaternary.

Section above Horse Creek.

g. Gray even and thin-bedded pure limestone, 2 feet ± ; dip, 15° N. 39° E.

h. Yellow marly clays with light shaly layers, 20 feet ±.

i. Very hard, rusty-buff weathered, gray limestone, with gritty layers containing small pebble and calcite, and thin oölitic layers above, 5 feet ±, exposed.

A profile of the mountain flank at this locality is given in an accompanying plate of illustrations, in which the above-mentioned stratigraphic features are presented with an approximation to accuracy, together with exhibitions of Quaternary and modern spring deposits, which latter will be noticed in the following chapter under the head of Wind River Valley.

Below the above-mentioned locality, on the south side of the river, the Triassic "red beds" appear in quite extensive surface exposures, extending down along the stream to a point opposite Horse Creek, reaching back perhaps a mile to the foot of the mountains. The locality derives much interest from the fact of its exhibiting the Jura-Trias passage beds. This horizon is here seen to be made up of the following strata:

a. Greenish-ochery sandy beds and variegated chocolate-red arenaceous clays, 50 to 100 feet ± in thickness, resting upon typical Triassic "red beds."

b. Soft light or buff sandstones, 100 to 200 feet.

c. Marly clays and thin beds of limestone with Jurassic fossils.

The inferior limestone bed of the Jura in places forms the capping ledge of low, broad-based buttes in the denuded Mesozoic area on the south side of the river. The sandstone *b* of the above section appears in the river bluff on the same side lower down, where it shows 50 to 60 feet of its upper portion. It is here immediately overlaid by 5 feet or more of brick-red clays, upon which rest a thickness of 7 feet of greenish-drab nodular calcareous clays, capped by a 3 to 4 foot ledge of drab, fragmentary, brecciated limestone, the strata inclining northeastwardly at an angle of 7° to 10°.

Below the mouth of Horse Creek the south-side terrace is covered by morainic bowlder deposits, thence to a point below Torrey's Creek, on the eastern boundary of the district, only meager rock exposures cropping out here and there. Such an one appears in the terrace bluffs on the lower side of Torrey's Creek where it joins Wind River, showing a limited exposure of gray or buff, rusty-weathered, friable, even-bedded sandstone, with firmer calcareous layers, dipping 50° about N. 65° E. The calcareous layers contain a small *Rhynchonella*, probably referable to a Jurassic form. After leaving the mountains, in its passage across the drift-covered terraces on the way to join Wind River, no rock exposures were observed on Torrey's Creek, with perhaps the exception of limited outcrops of "red beds." This stream also deeply penetrates the mountains, its passage across the great sedimentary outer mountain ridge being marked by a profound cleft, through which an immense amount of morainic materials was borne by the glacier that once flowed down this gorge. In the debouchure of the valley two or more beautiful little lakes occur, which are doubtless of glacial origin.

Above Torrey's Creek a couple of miles, Jake's Creek gains Wind River. The terrace course of this stream is much like the former, but two or three miles above its mouth the Triassic "red beds" appear in bluff exposures along the north side and just without its debouchure from the mountains. The lower portion of the cañon cuts the uplifted Palæozoic formations to their foundation, the upper seven or eight miles

being walled by Archæan rocks. In the debouchure of the cañon Mr. Perry found limited exposures of gray and brownish-gray soft sandstones in horizontal position, containing obscure fossils of apparently Tertiary facies. These presumably Tertiary occurrences seem to indicate the pre-Tertiary existence of the mountain gorge in which these strata were deposited, and which latter were subsequently subjected to extensive glacial and fluviatile erosion, so that the present exposures may well be regarded as mere remnants of an originally extensively distributed Cenozoic formation. Some analogy may be recognized between the above exposures and the upper lignitic formation occurring in the Gros Ventre Basin, but the evidence, unfortunately, is too meager to more than suggest their possible identity with the latter horizons.

Station XXVI was located on the uplifted Palæozoic ridge, midway between Jake's and Torrey's Creeks, at an actual altitude computed at 10,269 feet, the crest culminating at a somewhat higher elevation a little to the south, or nearer Torrey's Creek Cañon. A fine view of the western or inner abrupt declivity of this mountain ridge was gained from the summit of Union Peak, extending southeast as far as Station XXV, south of Campbell's Fork Cañon, a distance of fourteen miles. The greater elevation of the abrupt west-facing break is composed of Archæan rocks, bearing above characteristic exposures of the Silurian and Carboniferous formations. The latter outcrops in long lines of low mural exposures, separated by intervals of more or less gentle talus slopes. As seen from the eastern edge of the summit plateau two or three miles north of Station XV, and overlooking the profound depression in the bottom of which lies the glacier-fed lakelet that forms the source of Campbell's Fork, the great sedimentary mountain ridge is shut out from view by lofty intervening Archæan walls. This part of the range is frightfully gashed by erosive agents, and in the chasms that reach up into the high summit still linger not insignificant remnants of glaciers, which above emerge into the snow-fields that envelop extensive areas over the northeast slope of the summit.

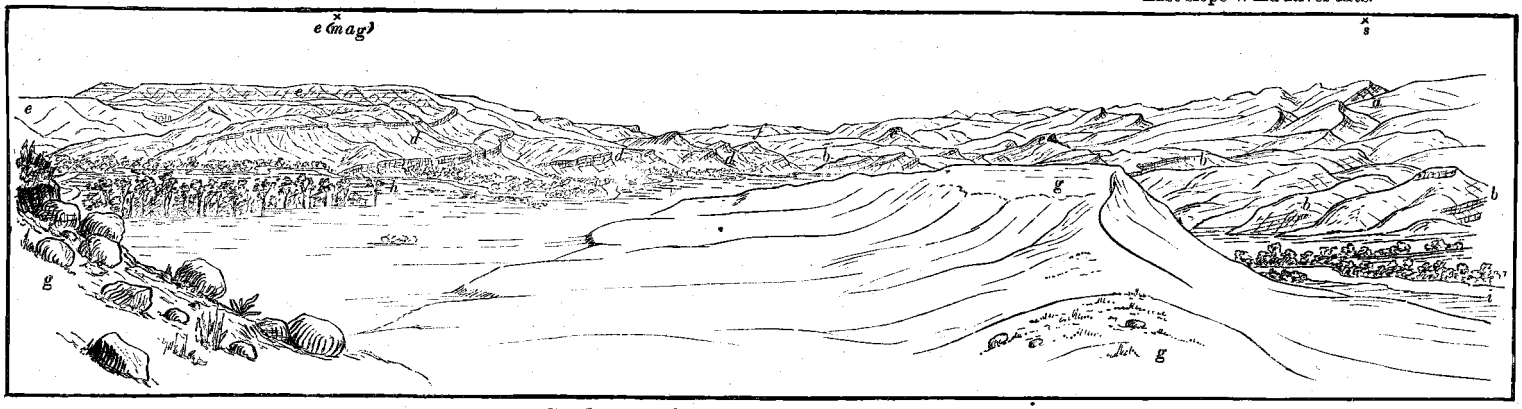
Between Torrey's Creek and Little Wind River Cañons the mountain flank preserves the same geological character as noted to the northwest of the former stream. But the cañons that pierce this part of the range afford more complete sections of the Mesozoic rocks, owing to the fact that the mountain border to the south has suffered to a much less degree from the effects of the denuding agents, which to the north, in places, barred the Palæozoics to the base of the mountain. Although lying to the east of the limits of the present district, opportunity was offered for visiting some of the more important cañons cutting the great sedimentary ridge, and the securing of an amount of interesting data bearing on the general structure of the mountain flank. In compliance with the request of Dr. Hayden, a brief account of the observations in this quarter, including both the mountain flank and such portions of the basin area as came under hasty examination, is subjoined.

Eight miles southeast of Torrey's Creek, Campbell's Fork issues from the mountains. Its sources, which have already been alluded to, lie well within the territory of this district, and flowing north of east it joins Wind River, after a course of about sixteen miles, at a point six miles below the mouth of North Fork. For fully three-fourths of this distance the stream traverses a deep mountain gorge, the upper half lying exclusively in the Archæan area, the lower portion cutting across the outer mountain ridge, where the uplifted sedimentaries are shown in escarpments hundreds of feet in height. Just below the debouchure the stream is dammed by low, transverse barriers, doubtless of glacial

Plate XXXII.

Bad-lands Wind River Basin.

East slope Wind River Mts.



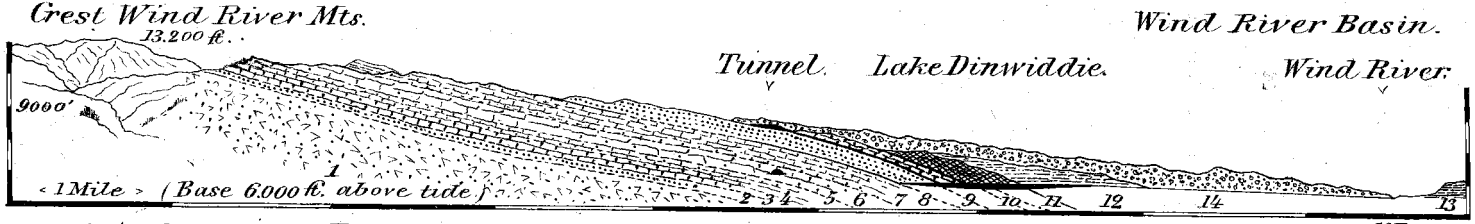
(Non-conformable Tertiary and Jura.) Confluence of North Fork and Wind River. (Flexure in Jura-Trias.)

a Carboniferous. *b* Trias, deep red. *c* Yellow passage beds. *d* Jurassic, limestone, sandstone, variegated shales

e Tertiary, including variegated banded Wind River formation. *f* Campbell's Fork Moraine. *g* Drift-covered benches. *h* North Fork. *i* Wind River.

Plate XXXIII.

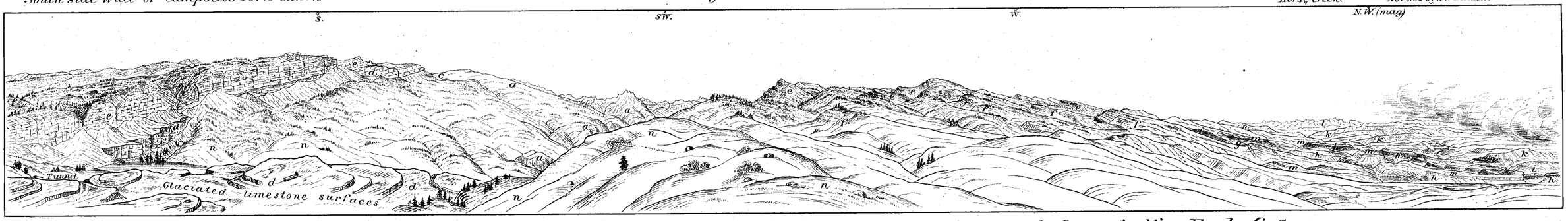
TERTIARY AND MORAINAL DEPOSITS, DEBOUGHURE CAMPBELL'S FORK.



1. Archæan. 2. Potsdam. 3,4. Quebec. 5,6,7,8. Carboniferous limestone.
9. Middle Carb. sandstone. 10. Permo-Carb. 11. Triassic "red beds."
12. Tertiary sandstone. 13. Wind River Tertiary. 14. Morainal deposits.

South side wall of Campbell's Fork Cañon. Summit of the Range. Sta. XXVI. Sierra Shoshone. Horse Creek. Owl Creek Mts. North Fork Wind Riv.

S. SW. W. N.W. (mag)



East Flank Wind River Range, From Morainal Ridge North Side of Campbell's Fork Cañon.

a. Archæan. c. Silurian. d. Carboniferous magnesian limestone. e. Carb. limest. f. Carb. sandstone. g. Permo-Carboniferous. h. Trias, "red beds." i. Jura. k. Wind Riv. Tertiary. l. Volcanic. m. Pliocene (?) tufaceous limestone and conglomerate n. Moraines.

Plate XXXIV.

origin, forming a long, irregular lake, or chain of lakes, perhaps a couple of miles in length, nestled between high, steep bluffs, crowned by morainal materials. A mile above the lake, or just within the entrance to the cañon, the stream has for a short distance tunneled the Carboniferous limestone that here spans the bed of the cañon perhaps 50 feet above the present water-level in the subterranean passage. Above this smaller lake expansions occur, much silted up from the deposition of sediment.

The section revealed in the lower portion of the cañon includes the complete series of Palæozoic formations. The Primordial horizons, including the Potsdam quartzitic sandstones and Quebec limestones, are in the main concealed beneath the accumulations of *débris* in the taluses, so that the exposed portion of the cañon walls are entirely formed by the Carboniferous limestones. Towards the exit, however, the great sandstone horizon forming the middle division of the Carboniferous appears in the cañon walls, and rising well up on the mountain flank, where it forms a well-marked topographic feature. The sandstone is succeeded by the limestone and shaly Permo-Carboniferous deposits, which, however, are much obscured by *débris*. To the latter succeed the Triassic "red beds," upon which rests an unconformable series of soft, dirty yellow and drab Tertiary sandstones that appear in the bluffs bordering the course of the stream for a couple of miles below the cañon.

The geological section, of which a diagram illustration has been prepared, consists of the following members at this locality, the thickness of the various beds being roughly estimated:

Section in Campbell's Fork Cañon.

No. 1. Archæan.

No. 2. Potsdam quartzitic sandstones.

No. 3. Drab shaly passage beds.

No. 4. Quebec; drab, rusty-weathered, even-bedded limestones.

No. 5. Buff, reddish-stained limestone, 300 feet ±. Carboniferous.

No. 6. Grayish-buff heavy-bedded magnesian limestone, 300 feet ±.

No. 7. Buff-drab limestone, magnesian below, with a conspicuous red band above, 200 feet ±.

No. 8. Drab cherty limestone, with reddish shaly limestones and clays, 400 feet ±. Contains *Syringopora*.

No. 9. Generally buff sandstones, 200 to 400 feet.

No. 10. Limestones and shales, Permo-Carboniferous, 200 feet ±.

No. 11. Trias. Red sandstone and arenaceous clays.

No. 12. Tertiary. Dirty buff and drab sandstones and clays, unconformably overlying the Triassic, and dipping slightly down stream or northeastward.

No. 13. Morainal deposits.

Between Torrey's Creek and Campbell's Fork the outlying bench at the foot of the mountain shows a low bulging area which is denuded to the Trias over the greater portion of its extent, in which the dips after leaving the spring of the mountain flank are generally quite moderate. But in the narrow area lying immediately along the left side of Wind River the strata are more sharply inclined, in places at an angle of 50° or 60°. In the latter quarter, or in the immediate vicinity of the confluence of North Fork of Wind River, the section displayed in the abrupt barren bluff slopes is made up of the variegated and buff sandstone deposits of the inter-Jura-Trias horizon, and above occurs a considerable thickness, probably amounting to a few hundred feet, of beautifully variegated clays, rusty sandstones, and bands of limestone

belonging to the Jura proper, and which in turn are unconformably overlaid by the pale-red and drab banded Tertiary deposits that a little farther back rise up into the general upland level of the basin region. The exposures here displayed would doubtless afford interesting and valuable data bearing on the detail stratigraphy of that portion of the Mesozoic series represented. Such observations as were necessarily hastily made at this locality are embodied in an accompanying sketch, to which is added a brief explanatory legend of the geological deposits shown therein.

On the south edge of the above-mentioned outlying Mesozoic platform, only a short distance from Campbell's Fork, the gently inclined Triassic "red beds" are much eroded, the drainage channels having excavated shallow picturesque cañons on their passage to Wind River. A small stream about two miles above Campbell's Fork, and which rises in the outer flank of the great sedimentary border ridge, issues from a deep, narrow gorge in the foot of the mountain, where the junction of the upper Carboniferous and Triassic deposits is most clearly revealed. Below is given a detail section of the upper division of the Carboniferous series, including the Permo-Carboniferous horizon at the top, and which embraces all the strata at this locality lying between the middle Carboniferous sandstone below and the Triassic "red beds" and conformably associated deposits above. The diagram, in which the above-referred-to strata are incorporated, is extended down the cañon to the northeast and a mile along the left bank of Wind River to the border of the Tertiary formations occupying the basin area to the north of that stream.

Section of Permo-Carboniferous horizon, &c., in cañon two miles northwest of Campbell's Fork.

No. 1. Middle division Carboniferous: Light gray, buff, and reddish sandstones, with oblique bedded layers, dip 10° about N. 60° E., and rising up on mountain flank at a somewhat steeper angle.

No. 2. Gray and brownish, in places nodular limestone layers interbedded with shales, imperfectly exposed 25 feet ±.

No. 3. Unexposed space, 22 feet ±.

No. 4. Gray earthy limestone, exposed 3 feet.

No. 5. Unexposed space, 35 feet ±.

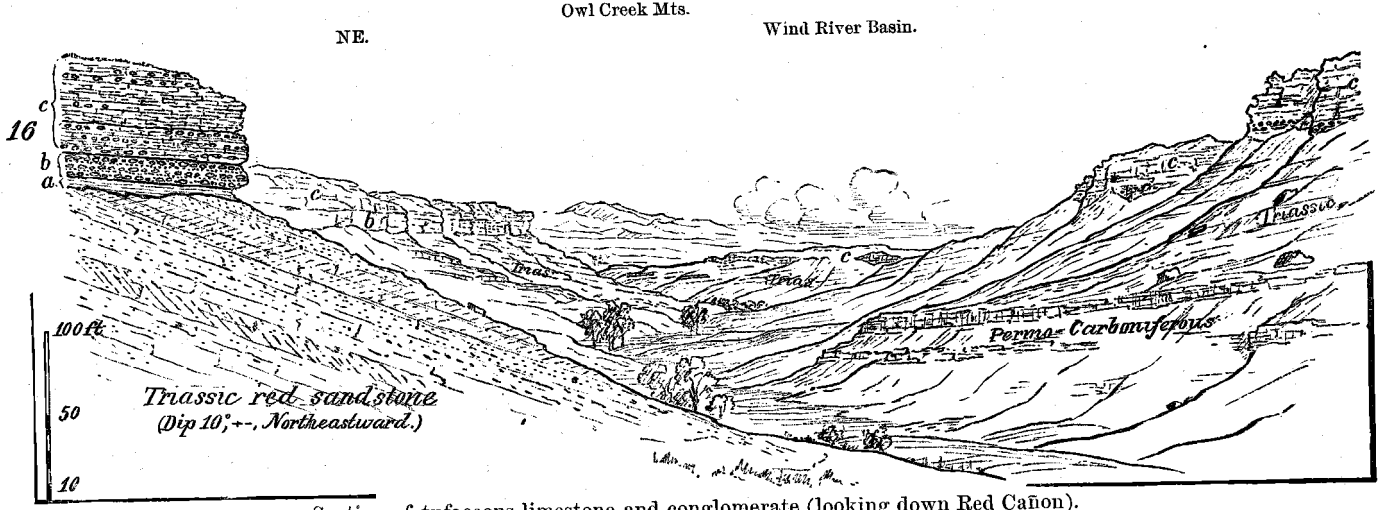
No. 6. Hard, bluish-gray limestone, with chert, exposed 15 feet ±.

No. 7. *a*, gray limestone ledge; *b*, indurated nodular calcareous shales, filled with *Productus*, sp.?, recalling *P. horridus*, &c.; *c*, fragmentary gray, greenish-stained limestone, charged with *Productus punctatus?*, *Rhynchonella*, *Retzia*, *Spirifer*, *Syringopora*, with *Discina* in brown shaly layers above; all 15 feet ±.

No. 8. Dark drab and brown indurated gritty shales; numerous individuals of a small *Nucula* (*N. beyrichii?*) are weathered out on surface of this horizon, also fragments of *Petalodus?*; 30 feet ±.

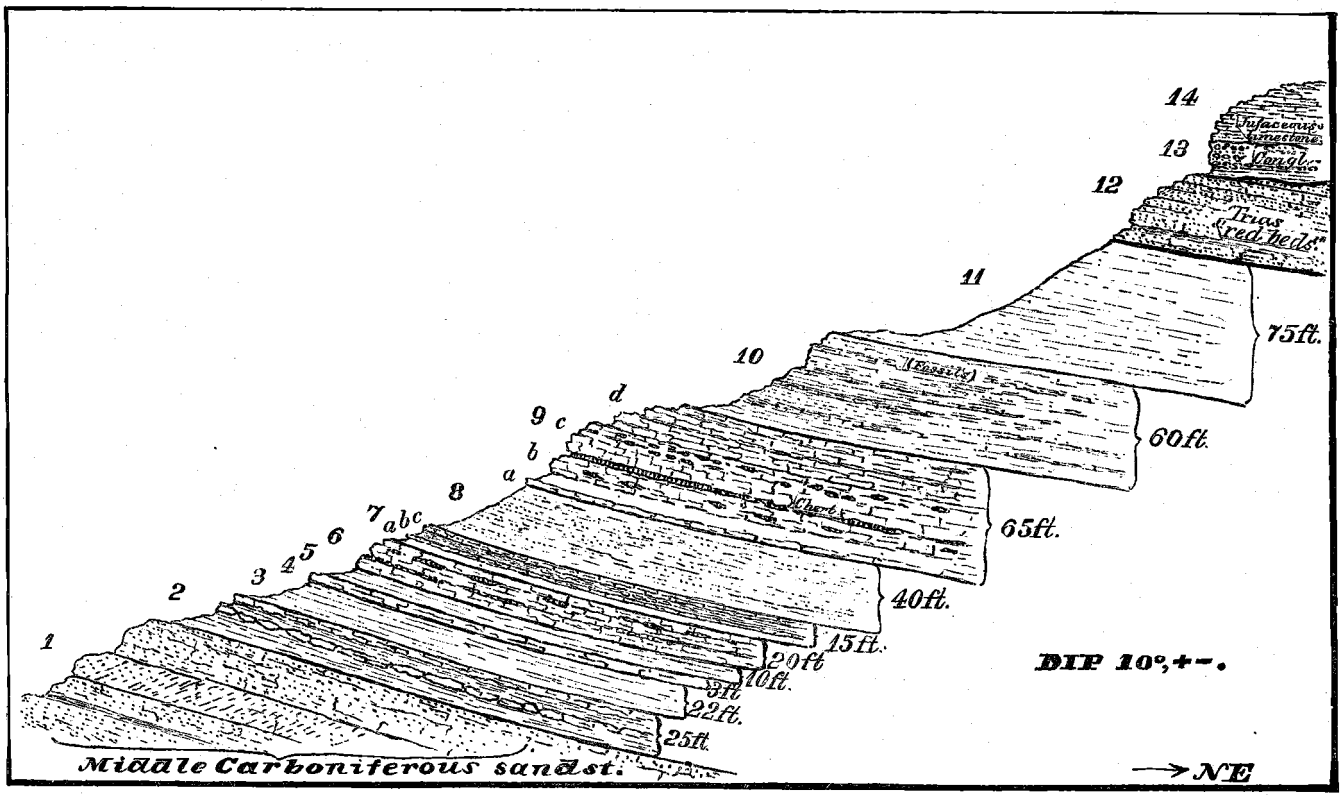
No. 9. *a*, gray, fragmentary limestone, 2 feet exposed; *b*, cherty bed, with geodes discolored with bitumen and green stained, also some gypsum; *c*, fragmentary, grayish-drab limestone, mainly chert above; *d*, gray limestone, green stained, with more or less chert and chalcedony, containing crinoidal remains, *Fistulipora?*, *Chætetes* making up a layer, *Hemipronites*, *Retzia*, *Spirifer*, *Productus*, &c.; all 50 feet ±.

No. 10. Gray, gritty, slightly calcareous, indurated argillaceous deposit, with thin sheets of limestone, containing in upper part a small *Pleurophorus*, *Schizodus?*, *Lingula*, pyrite crystals and nodules, and thin gypsum laminæ; 60 to 75 feet ±.



Section of tufaceous limestone and conglomerate (looking down Red Cañon).

Plate XXXIV.



Permo-Carboniferous and other exposures; Red Cañon.

No. 11. Light-drab arenaceous clays, 75 to 100 feet.

No. 12. Triassic "red beds," composed of red shaly sandstone and arenaceous clays, with bands of gray sandstone, thin laminæ of gypsum, and above thin tufaceous limestone layers; the formation attaining a thickness probably in the neighborhood of 800 feet.

No. 13. Buff sandstone and chocolate-red variegated arenaceous clays, Jura-Trias passage beds, 100 to 200 feet ±.

No. 14. Jurassic, possibly including Cretaceous strata above, and showing the following lithologic members as made out at a distance: *a*, variegated chocolate-red deposits; *b*, buff or yellow clays and sandstones; *c*, drab clays; *d*, soft buff deposits; *e*, dark chocolate-red variegated clays, &c.; *f*, soft yellow deposits; *g*, chocolate or purple red variegated clays; *h*, drab clays; *i*, purple-band clay; *k*, dirty brown-yellow clays and sandstones.

No. 15. *a*, soft, light-buff deposits, apparently unconformable to the preceding, and relations to following not clearly apparent; *b*, pale-red and drab banded Wind River Tertiary deposits, clearly non-conformably superimposed upon No. 14.

No. 16. Conglomerate and tufaceous limestone deposits of modern or possibly Pliocene date, consisting of: *a*, chocolate-drab mottled clays, 5 feet ±, apparently an irregular deposit filling inequalities in the eroded surface of Trias "red beds" and forming floor of conglomerate; *b*, conglomerate, here made up of water-worn pebbles chiefly of limestone, fewer sandstone and Archæan rocks, usually in thin, moderately compacted layers, alternating with red, coarse-sandy clays, 10 to 15 feet; *c*, tufaceous limestone, varying from rather compact to porous laminated rock, with calcite concretions, and with conglomeritic layers above and below, 50 to 55 feet. These deposits conform to the gently inclined surface of the previously eroded older rocks, upon which they were unconformally deposited.

Below Campbell's Fork about three miles a beautiful little stream penetrates across the great sedimentary mountain ridge, its sources lying in a basin well within the Archæan area, where the latter rocks are revealed over extensive glacial surfaces. The debouchure, which has an altitude of about 7,600 feet, is flanked by high bluffs of Middle Carboniferous sandstone, which here probably reaches a thickness of 500 or 600 feet, and rising up on the mountain side at angles of 10° to 14°. Ascending the stream, which occupies a widish mountain valley, successively lower strata in the geological series appear in the lower slopes until the Archæan basis rocks are encountered three or four miles above the debouchure. Here the stream at once becomes a wild mountain brook filled with dark pools and picturesque cascades. A couple of miles above the entrance the bed of the valley is blocked up by the massive Carboniferous magnesian limestone horizon, across which the stream has worn a tortuous narrow cleft 50 to 100 feet in depth and in places scarcely 10 feet in width. The walls show beautiful examples of the erosive action of running water, the overhanging cliffs in places intercepting the view of the swiftly gliding water in the depths of the chasm. The limestone ledges still bear evidences of glaciation in characteristic rounded, smooth-surface contours. The gorge is doubtless of post-glacial origin. The strata appearing in the precipitous sides of the valley are comparatively moderately inclined, the dip ranging from 10° to 15° off the mountain flank or northeasterly. At a point well up that part of the valley traversing the sedimentary ridge, the strata present a low subordinate flexure, the recurrence of which farther south will be noticed farther on. The mountain-foot is denuded of the upper members of the Carbonifer-

ons as also the Mesozoic formations, which, however, appear in the slopes to the north and south of this stream. Below the debouchure the valley is bordered by well-defined morainal ridges, that on the north side extending high up the mountain valley in a strictly characteristic high bench resting on the steep slope. The observations at this locality are embodied in the following section, the details being derived from the isolated outcrops along the stream, but which form heavy ledges in the cliff on either side.

Section in cañon three miles south of Campbell's Fork.

No. 1. Archæan; rusty weathered gneissic ledges.

No. 2. Potsdam; reddish, gray and variously tinted and mottled, coarse and fine grained sandstones, in places partially quartzitic, with oblique laminated layers, dip 10° to 15° northeastwardly, 100 feet, ±, exposed.

No. 3. Quebec; brownish limestone, with thin-bedded arenaceous layers interbedded with drab shales below, 25 feet exposed to level of stream, but much thicker.

No. 4. Drab shales, 15 feet ±.

No. 5. Dark drab, yellow mottled, fragmentary, thin-bedded limestone, in places showing brecciated structure, outcrops brown weathered, exposed 15 feet, but evidently thicker. Resembles Upper Quebec limestone.

No. 6. Unexposed space.

No. 7. Drab, brownish-buff and gray, fragmentary, thin-bedded limestone, rough weathered surfaces resembling lower magnesian limestone of the Carboniferous and so-called Niagara horizon of other localities in the region, 10 feet ±.

No. 8. Greenish-drab shales, including thin layers of limestone, 30 feet ±.

No. 9. Drab and gray, thin-bedded, fragmentary limestone, of which a thickness of 5 feet is exposed, but belonging to a thicker bed, underlaid by greenish gray disintregrated limestone. Contains *Fistulipora?* Crinoid remains, *Hemipronites*, &c.

No. 10. Unexposed space probably occupied by the preceding bed and additional layers, forming a well-marked horizon 150 feet, ±, in thickness in the mountain ridge, consisting of even-bedded, buff reddish weathered limestone.

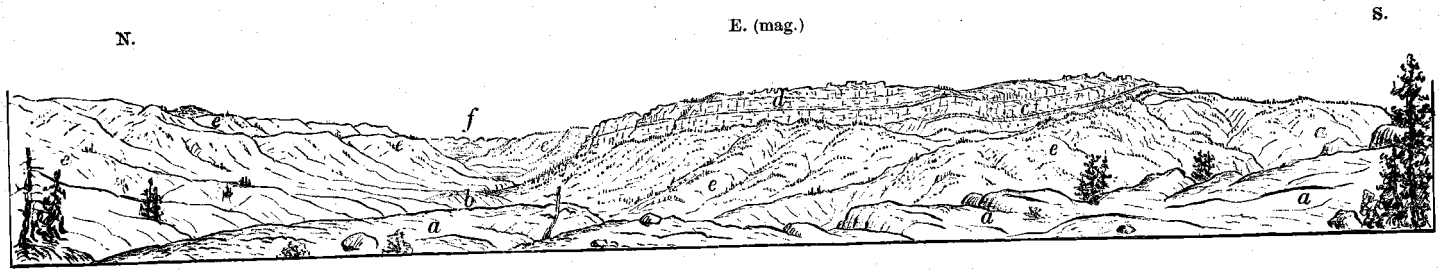
No. 11. Dirty buff reddish tinted, rough weathered, even-bedded magnesian limestone, in places a breccia consisting of flesh-colored limestone fragments embedded in buff matrix, and belonging to a heavy ledge of which 200 feet ±, are exposed in the neighborhood of the chasm which the stream has worn into its mass. Contains crinoidal remains.

No. 12. Unexposed space.

No. 13. *a*, gray or drab, reddish tinted limestone, a heavy bed as seen in cliffs bordering the valley; *b*, blue shaly layers, 10 feet, ±; *c*, drab reddish tinted limestone, more or less magnesian below, 200 to 300 feet; *d*, drab, reddish stained, dirty buff weathered fragmentary limestone in thick layers with calc. spar lined cavities, 100 feet ±. Dips 10° to 15°.

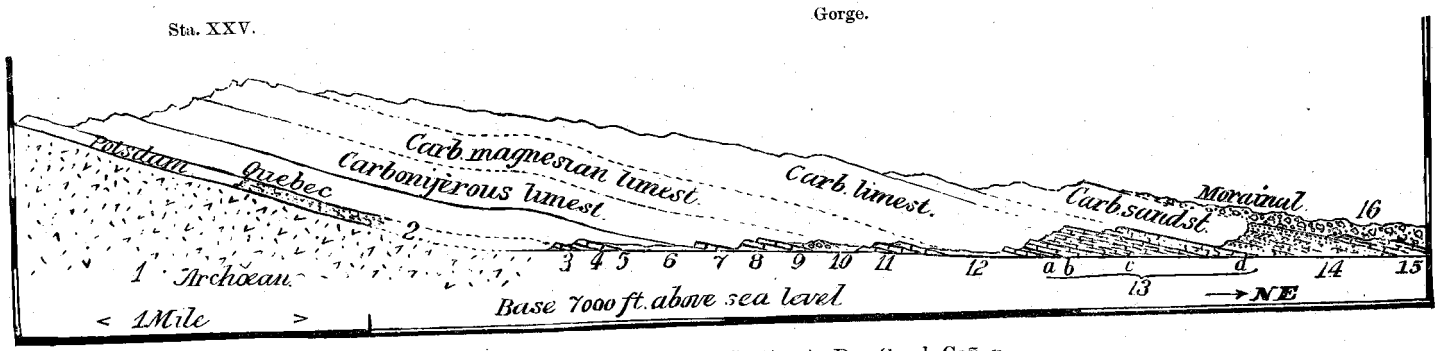
No. 14. Middle Carboniferous; gray, reddish stained sandstone, with obliquely bedded layers, sand concretions and seams of clay. The weathered ledges show shallow cavities. 600 feet, ±.

The mountain flank for the next sixteen miles to the southeast presents a nearly uniform, moderate, grassy slope, the lower half of which is composed of the middle Carboniferous sandstone and more or less per-



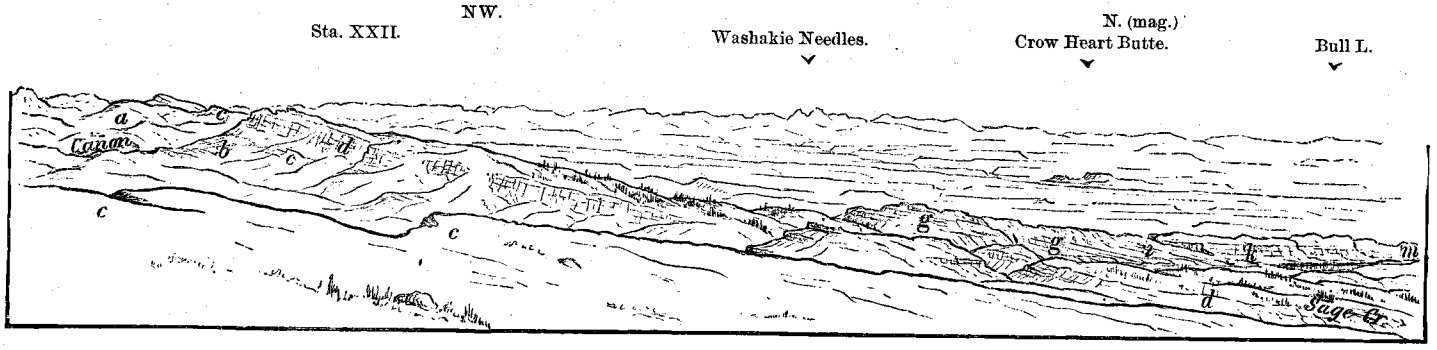
Dry Creek Cañon, looking toward Wind River Basin.

a Metamorphic, glaciated surfaces. *b* Quebec limestone. *c* Carb. magnesian limestone. *d* Carb. limestone. *e* Morainal deposits. *f* Owl Creek Mts.



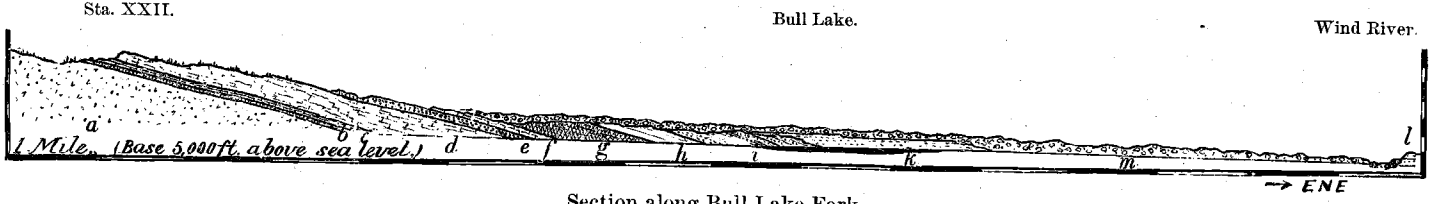
East flank Wind River Mts.: Section in Dry Creek Cañon.

Plate XXXVIII.



East flank Wind River Mts., vicinity Bull Lake Fork Cañon.

a Archæan. *b* Potsdam. *c* Quebec. *d* Carb. limestone. *e* Carb. sandstone. *f* Permo-Carbon. *g* Trias. *h* Jura. *i* Cretaceous. *k* Tertiary. *l* Wind River (?) Tertiary. *m* Morainal.



Section along Bull Lake Fork.

fect exhibitions of the upper Carboniferous limestones and Permo-Carboniferous horizon. The small streams, of which there are four in this section, cut through the sedimentary ridge down to the Archæan core of the range, revealing in their narrow gorges sections essentially like that last described above. Immediately along the foot of the mountain usually occurs a shallow parallel depression, in which the Triassic "red beds," and farther out local exhibitions of dark drab and variegated Jurassic horizons appear, gently inclined to the northeast. The former deposits occupy a belt half a mile to one mile in width, and never extend to any height on the mountain flank. Their junction with the subjacent Permo-Carboniferous is well exposed at several localities, the latter beds being charged with the characteristic little Lamellibranchiate shell, *Pleurophorus*. But the Jura is much less well exposed in this quarter. Indeed, the gentle grassy slopes intervening between the streams rarely showing later deposits than the thin coating of drift and soil that is spread over their surface, and here and there mesa-like remnants of the tufa-conglomerates. The main crest of the outer mountain ridge is formed of the lower members of the Carboniferous and the Silurian formations, which rise into elevations between 10,000 and 11,000 feet above the sea.

Twenty miles to the southeast of Campbell's Fork the great sedimentary mountain ridge is again cleft to its base by the cañon in which Bull Lake Fork flows. The latter stream rises high up under the precipitous wall of the great central crest of the range in the neighborhood of Fremont's Peak, and flowing east-northeast joins Wind River, 25 to 30 miles distant from its ultimate source. Of its upper course, or that portion lying within the elevated rugged Archæan area, little can be said from actual knowledge of the region. It is not, however, an inaccessible region, and to the lithologist and mineralogist it offers an absolutely new field of research. Along its lower course it has eroded a broad cañon-way walled by characteristic cliff exposures of the Palæozoic formations, which on the south side rise up into heights above 10,800 feet actual altitude. At its exit from the mountain the stream flows in a narrow valley hemmed in by high bluffs capped by enormous morainal accumulations that extend to Wind River, eight miles away. Just below the debouchure the stream expands into a lake between two and three miles in length, its indented shores bordered by sage-covered slopes and fringed with cotton-woods and willows. Mr. Clark's barometrical observations give the water-level of Bull Lake an altitude of 5,911 feet above the sea.

The immediate mountain-foot in the debouchure of Bull Lake Fork is composed of the upper members of the Carboniferous series. In the bluffs bordering the stream in its passage across the outlying benched area, late continued erosion, fortunately, has swept off the superficial materials and barred one of the most complete sections of the Mesozoic series to be met with in the northern half of the range. Besides the Palæozoic series shown in the lower cañon walls, where their general characteristics were hastily glanced over, we here have the Mesozoic formations displayed under exceptionally favorable conditions for detail stratigraphic study. This whole grand series of geological formations from the Primordial up to the upper member of the Cretaceous of the region, are here revealed without slightest indication of discordance of deposition of more than local significance or such as a stratum of any subordinate member may be expected to show. But during the Post-Cretaceous time the duration of these conditions was interrupted, and the evidence is legibly recorded in the unconformably superimposed Cenozoic deposition here met with.

Section on Bull Lake Fork.

No. 1. Archæan.

No. 2. Primordial quartzitic sandstone.

No. 3. Quebec limestone formations.

No. 4. Buff or drab reddish stained limestones, apparently forming a distinct horizon underlying the buff magnesian limestone, as seen in the great cliff exposures in the cañon walls. This limestone holds the horizon of the Niagara, but it is regarded as probably belonging to the Carboniferous.

No. 5. Carboniferous magnesian limestone, 300 feet, ±.

No. 6. Drab and gray rusty-weathered limestones, more or less cherty, with magnesian layers 400 feet ±. Contains characteristic Carboniferous fossils, and is here referred to the lower division of the series of which it forms the upper member.

No. 7. Middle Carboniferous division, light gray, reddish buff, weathered, even-bedded sandstones, 400 feet, ±.

No. 8. *a*, buff or light-gray limestones, with occasional shaly layers and bands of chert, with calcite and gypsum, 40 feet, ± ; *b*, chert band with fibrous gypsum, 4 feet; *c*, gray limestone, with cherty layers in middle containing nodules of chalcedony with a black bitumen mineral and calcite geodes, 15 feet, ± ; *d*, dark and light-gray limestones, cherty and nodular, alternating with shaly layers, with a 6-inch layer charged with black bitumen or carbonaceous matter, contains obscure fossils, 15 to 20 feet ; *e*, gray limestone, with calcite, 8 feet.

No. 9. Drab clays and brown indurated shales, 50 feet, ±.

No. 10. Gray magnesian (?) limestone, with calcite 15 feet, ±.

No. 11. *a*, gray nodular limestone with clay partings, and chert, numerous fossils of same species occurring in No. 14, 35 feet, ± ; *b*, blue nodular limestone and shales underlaid by indurated dark drab calcareous shales containing cavities lined with calc. spar, 40 feet, ±.

No. 12. Chert band, made up of uneven layers, 8 feet, ±.

No. 13. Gray limestone, in places brecciated, with flint nodules, contains *Chætetes* (?) Bryozoa, &c., 20 to 30 feet.

No. 14. Permo-Carboniferous horizon; *a*, light-drab clays with nodules of flint and calcite, and thin layers of gritty brown and gray limestone containing casts of a small *Pleurophorus*, *Bakevillia*, &c., and in lower part thin irregular layers of limestone alternating with clays containing numerous fossils, *Productus costatus* ? *P. punctatus* (?) *Spirifer*, two species, &c., 65 to 70 feet; *b*, gray, thin-bedded, gritty limestone, more or less concretionary and magnesian (?) with ripple markings, 25 feet ± ; dip 15° to 20° northeast.

No. 15. Light-drab clays with thin indurated layers, imperfectly exposed, 30 to 50 feet.

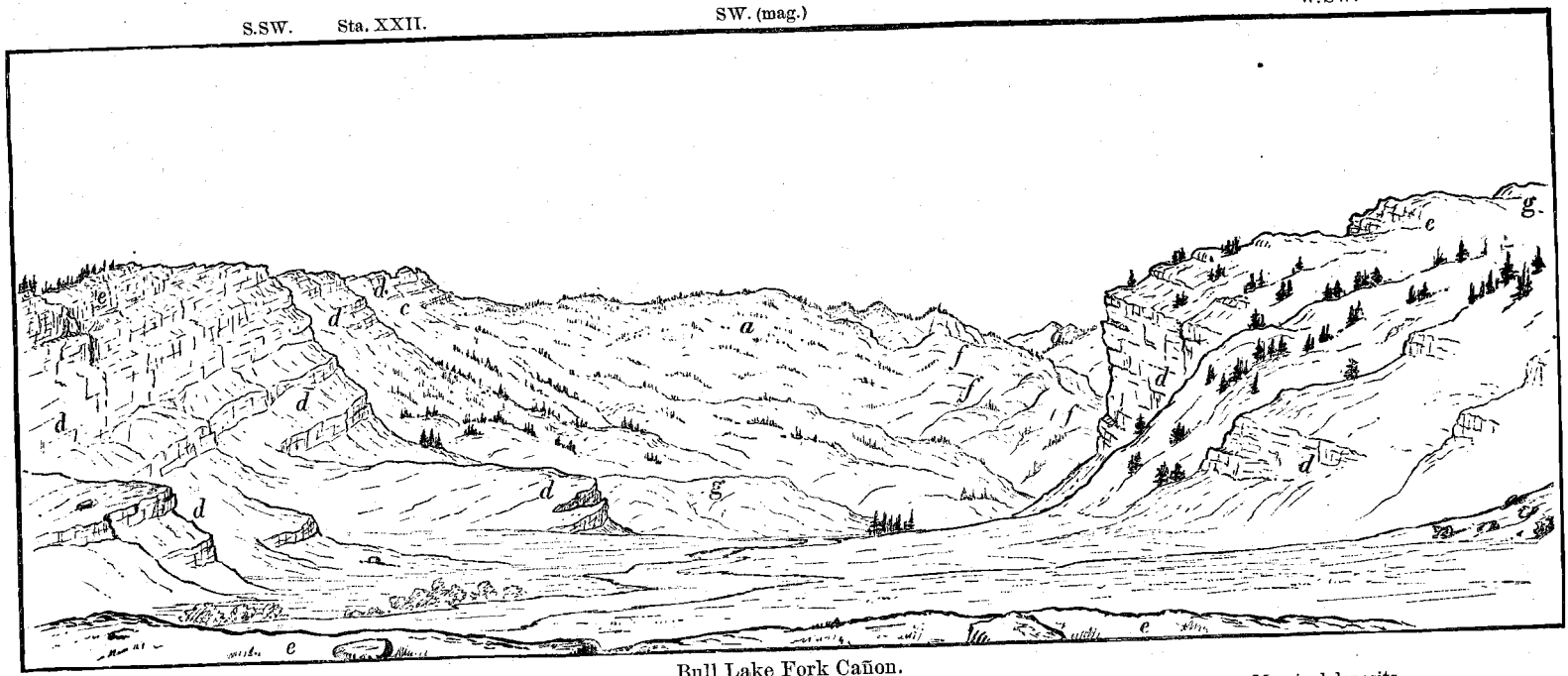
No. 16. Triassic red sandstones and arenaceous shales, with thin gray sandstone layers 1,000 to 1,400 feet; dip to the northeast, and at angles of 15° to 20°.

No. 17. White gypsum, more or less regularly bedded, including one or two thin layers of sandstone, the outcrop somewhat fractured by tendency to joint structure. This bed shows a thickness of 25 to 40 feet, forming the crest of an outlying spur-ridge in the north side bluffs, some distance above the head of Bull Lake.

No. 18. *a*, red, greenish, and chocolate-colored shales with thin layers of white gypsum, and gray and drab indurated layers ; *b*, red and gray banded shales, the outcrop presenting a beautifully variegated band wherever seen, 100 feet, ±.

No. 19. Drab, fragmentary limestone, 6 feet, ± ; dip 23°, N. 42° E.

Plate XXXIX.



Bull Lake Fork Cañon.

a Archæan. *c* Quebec. *d* Carb. limestone. *e* Middle Carb. sandstone. *f* Glaciated metamorphic ledges. *g* Morainal deposits.

No. 20. Drab shales, 15 to 20 feet.

No. 21. Dark gray fragmentary limestone, with obscure remains of fossils, 1 foot, ±.

No. 22. Drab clays with laminæ of calcite or gypsum, 15 to 20 feet.

No. 23. Dark gray fragmentary limestone, 4 feet, ±.

No. 24. Drab shales with thin beds of light-gray sandstone, 170 feet, ±.

No. 25. Gray, buff weathered soft sandstone, in part thin-bedded, with soft flagging layers, forming mural exposures in crest of spur-ridge, showing a thickness of 20 to 30 feet, dip 19° to 23°, N. 42° E. Upper layers contain casts of several Lamellibranchiate shells, probably representatives of Jurassic forms.

No. 26. *a*, red and drab shales, alternating; *b*, pale-red shales; *c*, chocolate-red shales and thin sandstone layers, alternating. This horizon presents a beautiful variegated belt in the steep slopes of spur-ridge, and probably attains a thickness of 300 feet, ±.

No. 27. Soft-white or light-buff sandstone, 10 to 15 feet.

No. 28. Light and chocolate-drab shales, banded with thin indurated layers resting upon red shales, 250 feet, ±.

No. 29. Buff sandstone, forming a heavy ledge in crest of spur-ridge, 25 feet, ±.

No. 30. *a*, alternating layers buff sandstone and drab clays, with fucoidal (?) impressions, 20 feet, ±; *b*, brownish-drab shales, with selenite; *c*, banded brown, yellow, blue, and dark, gritty shales and thin sandstone layers, 200 feet, ±.

No. 31. Rather firm, light-gray, buff-weathered sandstone, 5 feet, ±; dip 18° N. 23° E.

No. 32. Dark-drab and bluish shales with selenite and thin bands of efflorescence, and in lower part a dark fragmentary calcareous layer perhaps 2 feet thick, 400 feet, ±.

No. 33. Shaly and concretionary, fragmentary, dark-blue limestone, 5 to 10 feet. Contains fragmentary remains of Teliost fish-scales, &c., resembling and probably identical with forms elsewhere occurring in the Colorado group of the Cretaceous.

No. 34. Drab clays and thin indurated layers, containing fish remains like those in No. 33, 110 feet, ±.

No. 35. Rusty weathered, gray sandstone with clay partings, 60 feet, ±, exposed in bluffs about opposite the head of Bull Lake. Locally shows the following subdivisions: *a*, at base bluish-gray sandstone, 5 feet exposed; *b*, space with drab shales, 15 feet; *c*, thin-bedded gray sandstone, 5 feet; *d*, space, 15 feet; *e*, bluish-gray sandstone, 5 feet, ±; *f*, brown shales, 5 feet; *g*, gray sandstone with fucoid-like markings, 10 feet, ±.

No. 36. Rusty-yellow sandstone, and sandy and brown gritty shales, dark flint nodules in upper layer, 30 to 40 feet.

No. 37. White, very fine clays, 8 feet, ±, forming a conspicuous band in the bluff exposures.

No. 38. Drab shales with layers of rusty sandstone below, selenite and white efflorescence above, 30 feet, ±.

No. 39. Yellow buff, soft sandstone, heavy bed, dip 15°, N. 42° E., 80 feet, ±.

No. 40. Light-drab clays with white efflorescence, imperfectly exposed, 40 feet, ±.

No. 41. Light-gray, thin-bedded sandstone, 6 feet, ±.

No. 42. *a*, Light-drab clay, with white efflorescence; *b*, banded dark-drab clay, with brown carbonaceous, shaly bands; *c*, light-drab sandy clay. 175 feet, ±.

No. 43. Brownish-gray sandstone, thin layer.

No. 44. Bluish arenaceous clays, with thin, indurated layers, 300 feet, ±.

No. 45. Soft, buff-gray sandstone, dip 15° N. 52° E., 30 feet, ±.

No. 46. *a*, reddish-drab and brownish clays; *b*, lignite coal, 8 to 10 inches, drab clay 12 inches, lignite 3 inches, drab clay 12 inches, lignite 6 to 10 inches, total 4 feet; *c*, brown clays with selenite, 15 feet; total 30 feet, ±.

No. 47. soft, light yellow sandstone, 20 feet, ±.

No. 48. *a*, soft, grayish yellow, shaly sandstone and brown clays, exposed 10 feet; *b*, drab-brown shales, with minute flakes of mica and selenite, 3 feet; *c*, brown, gritty shales, with selenite, 30 feet, ±; total, 60 feet, ±.

No. 49. Rusty brown and buff calcareous sandstone, 8 feet ±, with numerous fossils in upper part, *Inoceramus* and several other conchifers, gasteropods, and *Ammonites*, probably identical with Fox Hills Cretaceous forms.

No. 50. Soft, yellowish sandstone and clays, imperfectly exposed, and belonging to a heavy bed at the top of the Mesozoic series here exposed.

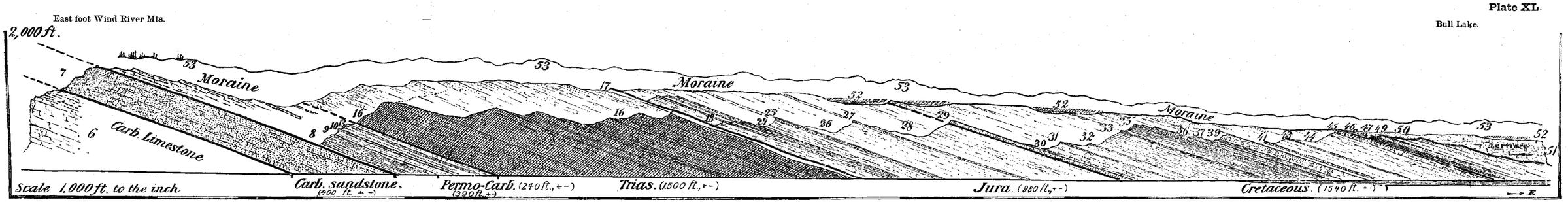
No. 51. Tertiary. Buff sandstones with more or less argillaceous matter, resting unconformably upon the preceding sandstones, No. 50, in nearly horizontal strata.

No. 52. Yellowish clays, slightly brownish or reddish tinted above; possibly Pliocene or Post-Tertiary.

No. 53. Morainal bowlder deposits crowning ridge 800 feet above the level of Bull Lake.

The few hours devoted to the examination at the above locality necessarily left the results less complete than could be desired. It is impossible to draw the line of demarkation between the Jurassic and Cretaceous horizons, also between the former and the Trias. In the latter case, however, the great gypsum deposit affords a convenient horizon, but since this is evidently an excessive local development it might not subserve even the purpose of convenience. A comparison of this part of the section with the equivalent horizon to the northwest exhibits a marked change in the lithology of the inter-Jura-Trias strata. We here lose entirely the well-developed yellowish or buff sandstone that occurs in this horizon at the confluence of North Fork and Wind River, although the lower limestones correspond stratigraphically with occurrences at that locality, except for the paucity of organic remains in the present beds. It is hardly necessary to add that not the vestige of an organism was observed in the characteristically "red beds" of the Trias. The Jura, however, is recognized in the fossils occurring in the sandstones No. 25. But the limits of the formation above in the present state of knowledge must be arbitrarily assigned to some one of the lithologically conspicuous horizons interposed between No. 25 and No. 30. One or more of the sandstone and shale horizons occupying this space may prove to be identical with the Dakota or inferior formation of the Cretaceous. The heavy clayey measures No. 32–34, inclusive, doubtless represent the middle or Colorado group, while in the upper portion of the remainder of the conformable deposits, extending up to No. 50 and embracing a vertical thickness of strata probably in the neighborhood of 900 feet, a stratum occurs charged with a molluscan fauna eminently characteristic of the Fox Hills division of the Cretaceous series. The lithology of these upper strata alone would strongly suggest the above inference. Although not a unique occurrence, the presence of lignitic deposits in these undoubted upper Cretaceous rocks at the present locality is an in-

Plate XL.



Section of Upper Carboniferous, Mesozoic, and Tertiary formations, north side of Bull Lake Fork.

NE. E. (mag.)

Bull Lake.

a Cretaceous, with coal. *b* Tertiary. *c* Moraines.

Section in debouchure of Bull Lake Fork Cañon.

Showing undulations in Carboniferous sandstone transverse to mountain uplift, above the lake.

teresting fact, and deserves to be thoroughly investigated with the view to determining their economic value.

The Palæozoic series exposed in the walls of the Bull Lake Fork cañon is of no less interest in a geological point of view. But for want of time only the upper member of the Carboniferous was studied with any pretension to minuteness. Of the latter member, including the uppermost and distinctively Permian horizon, the foregoing section exhibits the detail stratigraphy with close approximation to the truth. The full thickness of the strata lying between the great sandstone of the middle division of the Carboniferous, No. 7, and the base of the Triassic "red beds," No. 16, reaches a maximum of about 400 feet, of which the Permian or Permo-Carboniferous horizon comprises the upper 120 to 150 feet. The fossils of the lower strata of this upper series belong, in the main, to characteristic upper Carboniferous types. Their absence in the uppermost strata, in which such forms as *Pleurophorus* and *Bakevillia* exclusively occur, presents a striking faunal contrast to what obtains in the lower beds, and one that unmistakably indicates in this remote quarter a state of things analogous if not identical with what prevailed at the close of the Carboniferous period in the Mississippi basin along the western border of these occurrences in the States of Kansas and Nebraska.

Just within the lower entrance to the cañon of Bull Lake Fork a singular low ridge spans the valley, through which the stream has forced a wide passage. It is made up of the middle Carboniferous sandstones whose tilted edges are presented in an abrupt bluff barrier facing up the valley, the opposite side, which is flagged with the overlying limestone, declining more gently with the dip of the strata. The abrupt bluff-face of the ridge gives a section of the sandstone along a line closely corresponding to the strike of the strata, in which are revealed some interesting minor undulations, as though the beds had been crumpled by a force acting laterally, but which is probably attributable to slight inequality in the intensity of the vertical movements that forced the strata up into their present inclined position on the flank of the mountain. Mr. Perry observed similar phenomena, though on a much larger scale, in the uplifted Palæozoic formations in Jake's Creek Cañon, where the strata are described as having the appearance of a low fold transverse to the mountain upheaval. In regard to the Bull Lake Fork locality, it is difficult to account for the existence of the sandstone barrier, which has maintained itself in spite of fluvial and glacial erosion to which it has been exposed for ages.

The mountain flank between Bull Lake Fork and North Fork Little Wind River, 10 miles to the south, is gashed by the drainage of Sage Creek, whose sources, to judge from the character of the erratic materials swept down by the stream, scarcely penetrate to the Archæan area. This little stream debouches from a narrow cañon in the middle Carboniferous sandstone and overlying limestones, the upper course of the stream being defined by the earlier members of the series which, in the summit of the ridge, attain altitudes between 9,000 and 10,000 feet above the sea. The Carboniferous sandstone and dark-wreathed fragmentary limestones everywhere appear in the grassy slopes along the foot of the mountain, the edges of the various upraised geological members breaking down in abrupt declivities facing the great inclined planes in which the outer slope rises over successively lower formations until it culminates in the crest overlooking the Archæan area. The summit of the mountain ridge is formed by the Silurian limestones; to the north the lower member of the Carboniferous or so-called Niagara magnesian limestone may constitute the coping ledge. The latter horizon is often weathered in picturesque

cliffs and huge outlying masses in the slopes a few hundred yards below the summit, while the outcrop of the Potsdam sandstone is traced here and there in the *débris*-covered inner slope descending to the Archæan basis rocks, rounded elevations of which still retain isolated remnants of the Primordial strata.

The Triassic "red-beds" appear over an outlying parallel belt, half to three-quarters of a mile wide, forming picturesque highly-colored low bluffs bordering the little valley below the debouchure which widens out into the basin through which the stream winds lower down. A considerable belt of darkish drab deposits succeeds the "red beds" and variegated Jura horizons, which is probably referable to the Colorado group of the Cretaceous series. Beyond the latter, to the eastward, the upland slopes merge into the Tertiary benches of the basin region, in the midst of which occurs the sharp subordinate fold that runs parallel with and 8 to 12 miles distant from the foot of the mountains. The section of the Mesozoic series exposed along tributary drainage depressions north of Sage Creek, of which an account is subjoined, affords many interesting details illustrative of the variable character of the depositions at localities removed but a few miles from one another, contrasting with the uniformity of the conditions prevalent over extended areas during the formation of the Palæozoic series.

Section vicinity of Sage Creek.

No. 1. Archæan. Rusty-weathered gneiss, schists, &c.

No. 2. Potsdam sandstone.

No. 3. Quebec group limestones.

No. 4. Buff limestone, Niagara?

No. 5. Carboniferous. Magnesian limestone.

No. 6. Drab and gray limestones.

No. 7. Middle Carboniferous. Buff, reddish-stained sandstone.

No. 8. Upper Carboniferous division, including Permo-Carboniferous horizon. Gray, rusty-weathered limestones, and drab shales.

No. 9. Trias. *a*, deep red arenaceous shales and shaly sandstone, with thin layers of gray, greenish-stained sandstone; *b*, drab, fragmentary limestone, 5 feet, ±; *c*, reddish arenaceous shales and sandstone, with gray layers; *d*, drab limestone, obscure ledge; *e*, yellowish, green-stained and reddish sandstones, in places conglomeritic.

No. 10. Drab limestones and chocolate-red shales, forming a well-marked horizon.

No. 11. Buff and reddish variegated sandstones, not clearly exposed.

No. 12. Jura. *a*, fragmentary drab limestone, exposed 4 feet, dip. 15°, N.E., containing numerous imperfectly preserved specimens of small conchifers; *b*, similar, darker-weathered limestone ledge; no fossils observed.

No. 13. Dirty yellow and bluish soft sandstones, capped by a thin layer of rusty-gray calcareous sandstone charged with *Camptonectes*, *Trigonia* (?) *Rhynchonella*, *Dentalium* (?) &c. Dip, 16°, N. 63° E.

No. 14. Drab and reddish shales, in beautiful variegated exposures.

No. 15. Yellowish sandstones, with concretions, forming a rather thick bed, followed above by unexposed space.

No. 16. Gray, rusty-weathered, and buff sandstone, a heavy ledge.

No. 17. Cretaceous. Dark drab and bluish clays, belonging to a heavy deposit conformable to the preceding and dipping in the same direction.

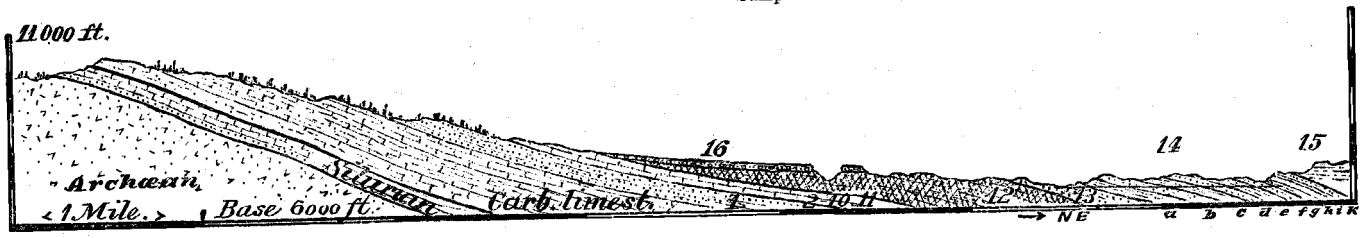
No. 18–20, inclusive. Variegated pale red and greenish drab clayey deposits, and dirty yellow weathered horizontal sandstones, belonging to

Plate XLII.

East flank Wind River Mts.

Camp No. 39.

Wind River Basin.
Wind River.

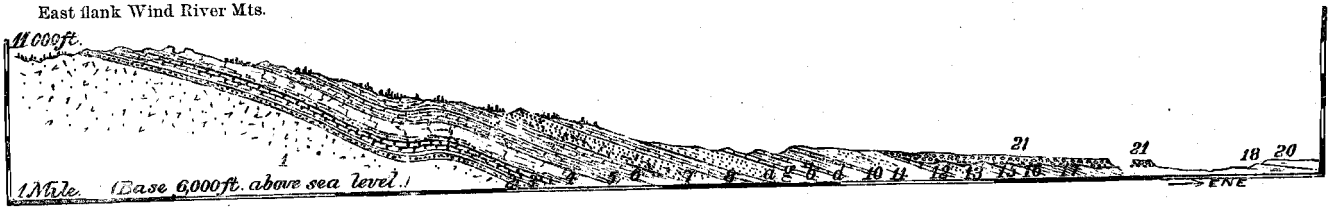


Section vicinity of Red Cañon, NW. of Campbell's Fork.

1. Middle Carb. sandstone. 2–11. Permo-Carb. 12. Trias. 13. J.-T. Passage beds. 14. Jura, &c. (*a–k*). 15. Wind River Tertiary, &c.
16. Tufaceous limestone and conglomerate.

East flank Wind River Mts.

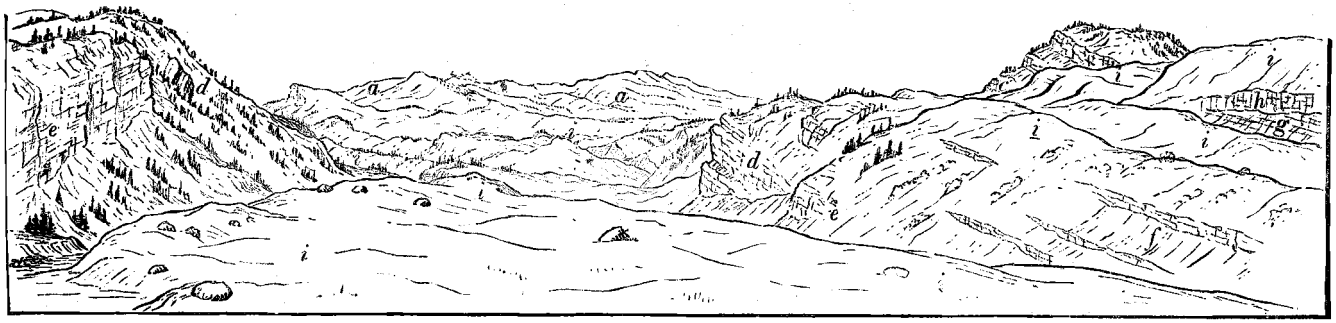
Wind River Basin.



Section north of Sage Creek.

1. Archæan. 2. Potsdam. 3. Quebec. 4. Niagara (?) magnesian limestone. 5. Carb. magnesian limestone. 6. Carb. limestone.
7. Carb. sandstone. 8. Permo-Carb. 9. Trias. 10–12. Jura. 13–17. Cretaceous. 18–20. Tertiary (?). 21. Pliocene (?) conglomerate.

W.SW. Sta. XXI. W. (mag.) Sta. XX.



Cañon on North Fork Little Wind River.

a Archæan. *c* Quebec. *d* Carb. limestone. *e* Carb. sandstone. *f* Permo-Carb. *g* Triassic "red beds." *h* Pliocene (?) conglomerate. *i* Moraines.

the basin Tertiary series described in following pages under the head of Wind River Basin.

No. 21. Pliocene, or possibly Post-Tertiary, conglomerate, resting upon the planed-off edges of the unconformable subjacent Mesozoic strata, attaining a thickness of 30 to 50 feet, gently sloping in the direction of the basin. The deposit is here mainly made up of water-worn limestone and sandstone pebbles, evidently derived from the adjacent mountain, few, if any, metamorphic fragments occurring in the deposit, which is more or less firmly cemented. This deposit reaches well up on the outlying slopes, in places resting upon the Trias.

The Tertiary and Post-Tertiary occurrences briefly alluded to in the foregoing section in the vicinity of Sage Creek, are further mentioned in the chapter devoted to the consideration of the Wind River Basin deposits. The fossiliferous Jurassic sandstone, No. 13, is an interesting occurrence, definitely establishing the age of the series of variegated arenaceous and argillaceous strata with which it is associated. It is impossible in the present lack of palæontological evidence bearing on the question to decide where the line of demarkation between this series and the Triassic should be drawn. It is probable, however, that the upper limestone, No. 10, pertains to the Jura, in which case the inferior buff and reddish sandstones would fall into the horizon of the passage beds, offering a somewhat marked resemblance to the lithologic appearances remarked in this horizon in the region above Campbell's Fork. The upper member of the Cretaceous was not recognized at this locality, the uplands lying to the east of the Colorado shales, being occupied by the Pliocene (?) conglomerate formation which masks the older strata upon which it rests.

Little Wind River debouches from the mountains a little north of the parallel 43°, opening a wide gap across the sedimentary plated mountain ridge, exposing to view an exceedingly rugged Archæan region outlying the main crest of the range at the heads of both the North and South Forks, as seen from the valley near Camp Brown. Just without the foot of the mountain the main stream forks, each branch penetrating the interior of the range independently, and where they break through the outer mountain ridge their courses are confined between stupendous walls, which disclose magnificent sections of the upraised Palæozoic series from top to base. In the latter respect, as also in the scenic concomitants, the Little Wind River cañons are much like those mentioned in preceding pages, yet with local peculiarities sufficiently striking to arrest the attention and stimulate the desire for more intimate acquaintance with the locality.

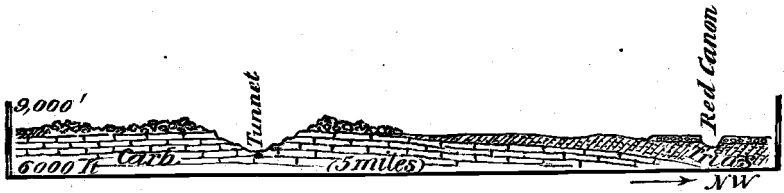
The cañon of the South Fork, which lies mainly south of 43d parallel, appears to be the narrower of the two, though the mountain basin in which their sources lie is much the same. About three miles above the debouchure of the North Fork the stream is confined to a narrow defile hemmed in by steep débris slopes terminated above in vertical walls of Carboniferous limestone. This part of the valley is swept nearly clean of the morainal deposits, whose recurrence above and below exhibits some of the most stupendous and interesting examples of their kind. Above the narrows the sedimentary cliffs diverge to right and left, rising up into the crest of the ridge which here, as to the north, forms a rim defining the Archæan area of the elevated interior of the range. At the entrance to the cañon below, the Permo-Carboniferous and upper limestones outcrop in the low benches alongside the stream, but no good exhibitions of the junction with the Triassic "red beds" were met with. Underlying these deposits, which incline at an angle of about 12°, N. 52° E., the middle Carboniferous sandstone formation appears, gradually

rising on the mountain flank; but immediately bordering the valley on the north side, to which the present examinations were confined, it has been much eroded and heavily loaded with morainal deposits which reach high up on the mountain foot in the debouchure. In the opposite side, however, this horizon is well displayed together with its relations to subjacent formations. About opposite the narrows a sudden flexure or up-bending in the lower limestone formations takes place, where the strata are tilted at a high angle, the tension accompanying their abrupt displacement manifesting its intensity by the rupture and faulting of certain beds, while the continuity of other and less refractory strata was unaffected. As seen from the summit of the ridge, looking down along the mountain flank to the north, a slight undulation in the declining strata was the only evidence of the continuation in that direction of the flexure which forms so marked a feature in the cañon-walls. Above the flexure the strata resume their former moderate inclination thence to the summit of the ridge. This highland region abounds in excellent pasturage, and along the streams considerable tracts of mountain meadow are met with. The rugged slopes are well stocked with evergreen forests up to a line nearly corresponding to the altitude 11,000 feet above the sea.

After leaving the mountains Wind River flows through a broad fertile valley, in the midst of which Camp Brown and the Shoshone Indian Agency are located. The altitude at the debouchure of North Fork is about 6,730 feet, the stream descending to 5,700 feet at the military post, in a distance of about twelve miles. The north side of this valley is bounded by the outlying uplands which break down in grassy declivities, in which the geological formations are in the main concealed from view by the loose soil. Here and there, however, over comparatively limited areas, the component strata crop out, and with care a detail section might possibly be made connecting the basin deposits with those more clearly shown along the foot of the mountains. Two or three miles below Camp Brown, and perhaps twelve or fourteen miles distant from the mountain foot, there appears an anticlinal fold with indications of a sharp synclinal on the west flank, which has brought up a series of variegated arenaceous and clayey deposits which, lithologically, bear striking resemblance to lower horizons occurring in the Jura of this region. On the west slope of this anticlinal the occurrence of drab fragmentary limestones, red and drab clays, and soft buff and grayish sandstones are certainly more in concordance with the stratigraphy of the Jura than with that of the Cretaceous members met with farther north, as described in foregoing pages. At the locality examined the axis of the sharp synclinal fold is occupied by an apparently heavy deposit of reddish and drab clays with associated sandstones, to the west of which obscure exposures of drab clays and soft arenaceous deposits, inclining eastwardly, seem to merge into the dark drab Colorado shales that appear in their proper stratigraphical order in the upland bench rising up against the foot of the mountains. The broad, shallow depression through which the Sage Creek drainage seeks Little Wind River marks the axis of the anticlinal fold, in the crest of which is located the bitumen spring which was described by Dr. Endlich in the Report of the United States Geological Survey for the season 1877. The flow of water is feeble, bubbling up in several hardly discernable vents, around which the bitumen is deposited, forming sheets whose consistency in the margin of the overflow becomes the hardness of an asphalt pavement. The spring is slightly raised above the general level of the plain, averaging perhaps 50 yards in diameter, and is partially overgrown with tall grass. Birds and small Indians, frequenting the place for water and sport, not infrequently become entangled and

Plate XLIV.

Lateral moraines debouchure Bull Lake Fork.



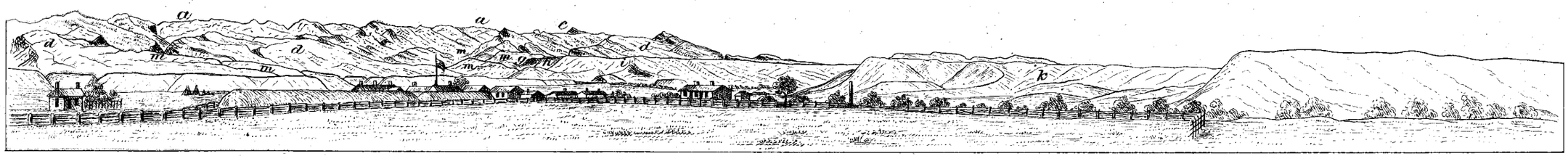
Lateral moraines debouchure Campbell's Fork.

Flexure in Paleozoic strata, south side N. Fork Little Wind River.

Section north side debouchure N. Fork Little Wind River.

EAST FLANK OF WIND RIVER RANGE, FROM CAMP BROWN.

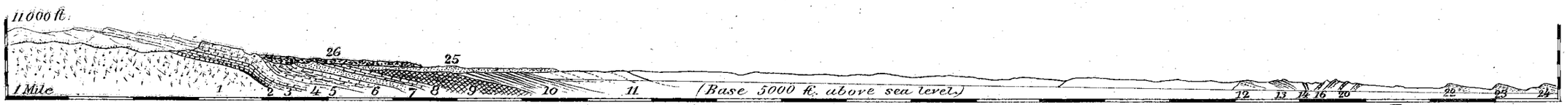
SW. — Stas XXI. XX. — W (mag.) — Sta. XXII. — NW. — Wind River Basin.



a. Archæan. c Silurian. d. Carboniferous. g. Triassic "red beds." h. Jurassic. i. Cretaceous (?) k. Tertiary. m. Moraines.

SECTION VICINITY OF NORTH FORK LITTLE WIND RIVER.

East Flank Wind River Mts. — Sta. XX. — *Basin Fold.* — *Camp Brown.* — *Bittumen Spring.*



1. Archæan. 2. Potsdam. 3. Quebec. 4, 5. Magnesian limest. 6. Carb. limest. 7. Carboniferous limest. 8. Permo-Carbonif. 9. Trias. 10. Jura. 11. Cretaceous (?) 12–24. Strata involved in Basin Fold. 25 Pliocene (?) conglomerate. 26 Moraines.

Plate 45.

besmeared in the soft, viscous substance. On the east side of the depression the successive ranges of low, parallel bluffs that appear farther out in the basin show sandstones and variegated clays, and finally a heavier mass of brownish drab clays, all dipping gently eastward. The latter deposits may be identical with the Colorado group. The above-mentioned anticlinal was traced but a few miles to the north of Little Wind River, but to the south, where it was examined by Dr. Endlich during the previous season, it assumes a more important topographical position, where its geological structure may be studied under less unfavorable circumstances than those attending its exhibition in the present quarter.

The geologic section in the vicinity of North Fork of Little Wind River is given below, together with notice of the few observations made in the basin area to the east, supplemented by the diagram illustration of an accompanying plate, with which closes the account of the too briefly executed observations in this important mountain range.

Section vicinity of North Fork of Little Wind River.

No. 1. Archæan. Mainly schistose rocks.

No. 2. Potsdam. Coarse-grained, grayish-buff, reddish-stained, in places of a dark-red color, thin-bedded sandstone, with oblique laminated layers, and locally quartzitic. The greatest exposed thickness of this ledge probably does not exceed 50 feet, but it is probably much thicker. Its contact with the metamorphic rocks was not revealed, and the nature of the overlying deposits, which readily yield to atmospheric erosion, are not conducive to the exposure of the full vertical extent of the horizon. In the isolated outliers crowning the heights north of North Fork drainage, the beds incline about N. 57° E., at an angle of 10°.

No. 3. Quebec. Ledges of drab, fragmentary, thin-bedded limestone, showing mural exposures of 10 to 25 feet at top, where at one point it appears in the summit of the mountain ridge, showing a heavy bed of drab-gray, yellow-mottled, even-bedded limestone, with brecciated and oölitic layers, containing fucoid-like markings in relief, in form also resembling certain ramose forms of the coral *Chætetes*, and the glabella of a large Trilobite. These occurrences, which are separated from the preceding sandstone, No. 2, by a space probably occupied by shaly passage-beds, are met with in a vertical space not exceeding 400 feet. The ledge in the summit of the ridge dips 10°, N. 52° E. The horizon appears in a long line of rusty-weathered mural exposures in the escarpment on the south side of the cañon. The lithological character of the rock is precisely that of equivalent strata met with in the Gros Ventre and Téton Mountains, as also on the west flank of the range in the neighborhood of Green River Cañon.

No. 4. Buff-weathered magnesian (?) limestone, in places, forms a rather well-marked ledge, 75 to 100 feet ±, exposed, and holding the position of the so-called Niagara dolomitic horizon. No evidence, however, was gained by means of which to satisfactorily determine its age. The above ledge is, at least, locally separated from the preceding by slopes over soft dirty-buff deposits.

No. 5. Carboniferous. Grayish-buff, rough-weathered, heavy-bedded magnesian limestone, with small jasper nodules and iron concretions, weathered in castellated shapes and forming a prominent ledge in the escarpments either side of the cañon, 200 feet, more or less, in height. Contains *Zaphrentis*, crinoidal fragments, *Bellerophon*, &c., apparently referable to Carboniferous forms.

No. 6. Drab and gray limestone, forming a heavy deposit several hundred feet in thickness, as seen in cliffs on the south side of the cañon.

No. 7. Buff-gray sandstone, with obliquely-bedded layers, exposed in the lower escarpments, especially on the south side of the cañon and in adjacent mountain flank, 300 feet ±.

No. 8. Upper Carboniferous limestones and Permo-Carboniferous horizon, the latter showing at one place in the debouchure of the cañon, below: Light-gray, in places, magnesian limestone, 5 to 10 feet exposed; dark-gray, shaly sandstone with silicified fossils, exposed 4 feet; drab and dark-gray, compact and porous, thin-bedded limestone, exposed 5 feet, containing numerous casts of a small *Pleurophorus*, besides a large *Bellerophon*, &c.; light-gray, thin-bedded cherty limestone.

No. 9. Triassic "red beds," composed of deep-red shaly sandstones and arenaceous shales, and reddish-buff or gray soft sandstone with ripple-markings. The exposures in the bluff just without the cañon show a thickness of several hundred feet (700 to 1,000) of this horizon, the strata dipping at an angle of 13°, N. 27° to 42° E.

No. 10. Jura. Variegated pale-reddish and drab deposits, as seen at a distance in obscure exposures occurring in grassy slopes. These deposits occupy a wide belt outlying the Triassic "red beds," and may reach a thickness of 1,000 feet.

No. 11. Cretaceous. Dark-drab (clays), and above light-buff (sandstones and clays) deposits appearing in more or less distinct belts lying beyond the preceding, and probably including the Colorado and Fox Hills members of the series.

No. 12. Drab clays, in bluff north side of Little Wind River, just below Camp Brown.

No. 13. Greenish-gray, coarse-grained, rather friable sandstone, with layers of reddish-brown weathered firmer sandstone, associated with reddish-drab clays and light-drab indurated clay shales. The above deposits outcrop in low, upland declivities to the northeast and 200 feet above Camp Brown, where they incline to the northeast at an angle of 30° to 34°. The sandstone contains partially silicified fragments of fossil wood.

No. 14. Soft buff sandstone, dip steep to the northeast.

No. 15. Reddish and drab clays.

No. 16. Drab fragmentary limestone, 5 feet ±, dip 70°, SW.

No. 17. Red shales and soft sandstone.

No. 18. Gray and yellowish, cross-bedded, soft sandstone, 50 feet ±, dip 40° northwestward.

No. 19. Reddish and drab clays.

No. 20. Drab fragmentary limestone, exposed 4 feet.

No. 21. Greenish-gray, reddish-stained, soft sandstone, associated with red and drab clays, dip 41°, W. 52° N.

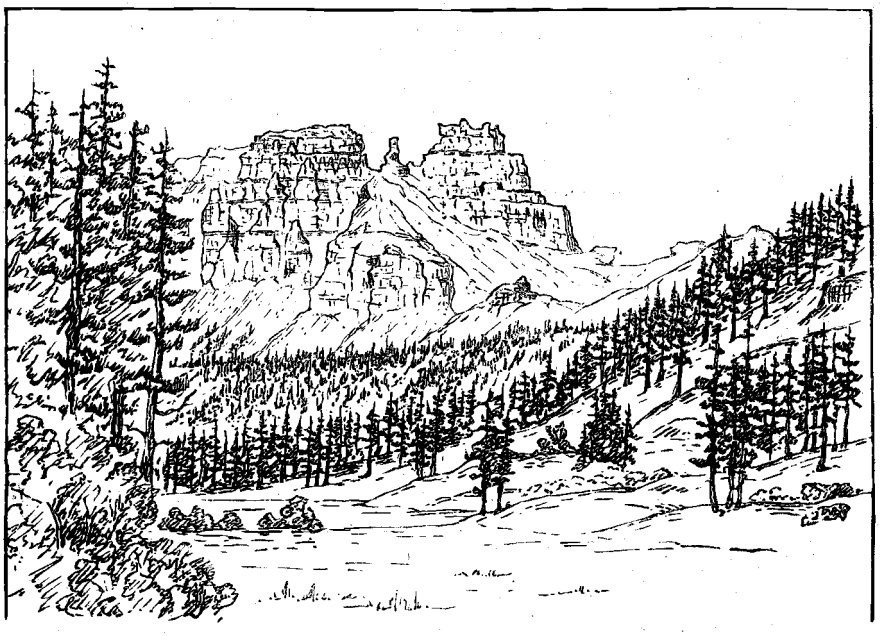
No. 22. Soft, greenish-buff, reddish-stained sandstone, and red arenaceous shales, exposed 50 feet ±, dipping gently northeastward.

No. 23. Gray sandstones, as seen at a distance, in low bluffs.

No. 24. Heavy deposit of drab clays and indurated layers, compared with the Colorado group of the Cretaceous, appearing in "bad-land" bluff slopes.

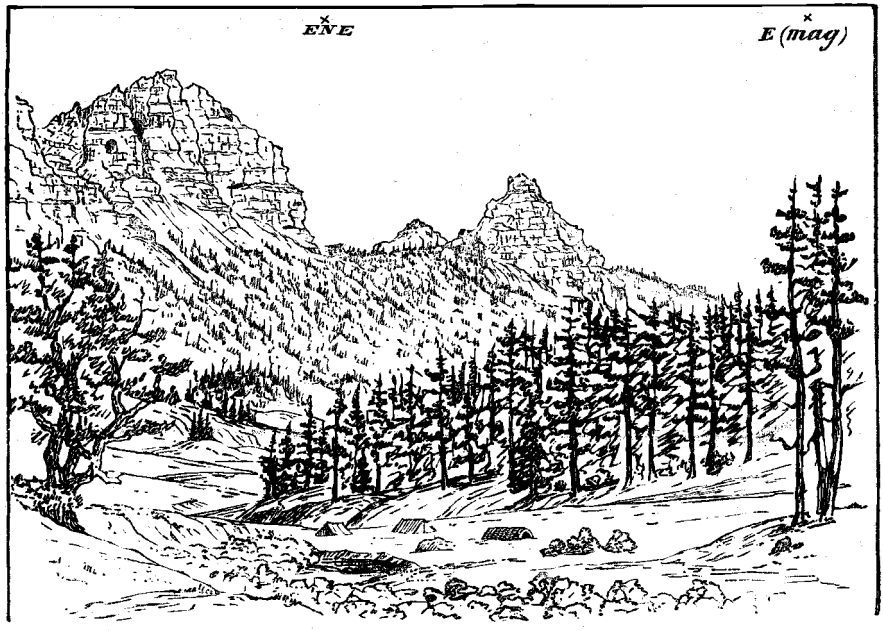
No. 25. Loosely compacted conglomerate, consisting of rounded Archæan bowlders and pebbles, with local thin layers of soft buff sandstone, the general appearance of the exposures showing obscure stratification, nearly horizontal, deposited upon the eroded edges of the inclined Mesozoic formations and reaching up nearly to the mountain foot. Compared to modern or possibly Pliocene accumulations. It is overspread with later morainal deposits.

No. 26. Morainal deposits.



Wind River Valley.

Statue Butte. Sierra Shoshone, NW.



Togwotee Pass.

Clover flats. Source Wind River.

Volcanic tuff, sands, breccia, and conglomerate.

CHAPTER VII

WIND RIVER BASIN.

Area and surface features.—The region drained by Wind River and its affluents opens out to the eastward in a gradually expanding wedge-shaped area, the greater portion of which lies beyond the limits of the district assigned this division of the survey. The main stream rises in Togwotee Pass, whence it flows in a general east-southeast direction, a distance of about 85 miles, to its confluence with Little Wind River, at which point its course is suddenly deflected northwards, and is thence known as the Bighorn River. Orographically the basin is defined on the southwest by the Wind River Range and on the north by the great volcanic ridges of the watershed reaching eastward from Togwotee Pass, and which are continued in approximately the same direction in the lower highlands of the Owl Creek Mountains; to the southeast the basin area merges into that properly belonging to the Bighorn drainage.

The region above outlined has in years past been visited by various expeditions conducted under the auspices of the United States War Department, and to the published reports of these explorations we owe the most authentic accounts of its general topographic and geological features. Dr. Hayden, who accompanied the expedition in charge of Capt. W. F. Reynolds, Engineer Corps, U. S. A., in 1859, has given account of its salient geologic structure, and Prof. Theodore Comstock, of Capt. W. A. Jones's expedition to the Yellowstone, 1873, has elaborated the same theme. The actual geological examinations performed by this division of the survey within this basin area were chiefly confined to a narrow belt immediately along the southwest border, or lying between Wind River and the monntain range bearing the same name. The latter work was carried from Togwotee Pass at the head of the valley southeastward to the eastern boundary of the district and beyond as far as Camp Brown, at which latter point the observations connect with those made by Dr. Endlich the previous season in the district lying to the south of the parallel 43° and east of the meridian 109° 30′.

The greater portion of the basin is thoroughly watered by numerous streams that rise in the bordering mountains, its terraced valleys and upland plateaus being generally clothed with nutritious herbage. In the lower portion of this area, however, more or less of its surface falls under the head of "bad lands." Its general surface lies at an altitude 5,000 to 7,000 feet above the sea; the lower valleys in favorable seasons yielding abundant crops of cereals and vegetables, while the greater portion of its extent is valuable for grazing purposes. The larger part of this extensive and beautiful region is included in the Shoshone Indian Reservation, which extends np the valley from Little Wind River west, to the mouth of North Fork, and stretches north-south, from mountain to mountain.

Geological features.—In that portion of its course lying within the present district, Wind River flows close along the foot of the southwest bor-

der range, the lands on the north rising in great upland benches that occupy the wider interval lying between the main stream and the mountains on that side of the basin. The upper half of the course of the main stream is eroded out of the soft Tertiary strata, the remainder of its course to a point below the mouth of North Fork closely conforms to the demarkation between the Mesozoic and Tertiary formations, the latter occupying the whole of the basin area lying to the north of the river. At one point, in the neighborhood of Du Noir or Willow Creek, the stream touches the Paleozoic mountain flank, where for a short distance it flows in a narrow gorge walled by Carboniferous sandstone.

This narrow belt of Mesozoic and Paleozoic strata along the southwest border of the basin has already been noticed in the account of the geology of the eastern flank of the Wind River Range, to which it properly pertains, geologically. The stratigraphical relations of the two sections are uninterrupted and most intimate; erosion in preglacial time having swept away the unconformable Tertiary deposits, exposing to view the older formations over quite extensive areas in the interval lying between the river and the mountain flank. During the glacial epoch, when the mountain gorges were filled to the brim with moving bodies of ice, vast quantities of erratic materials were transported from the interior of the mountains and spread out in orderly disorder over the bared sedimentary formations in the slopes along their foot. The latter accumulations are conspicuously displayed in the embouchures of all the streams that rise in the interior of the range as far south, at least, as Little Wind River. But, perhaps, their most extensive exhibition is found in the debouchures of Bull Lake and Campbell's Forks, and on Torrey's Creek, where the drift lies scattered over broad areas and reaching perhaps a thousand feet up on the mountain side, their occurrence everywhere clearly displaying their origin. Besides the huge morainal ridges flanking either side of the debouching mountain valleys, the adjacent mountain slopes are corrugated with the peculiar short ridges composed of loose materials which were borne to their present resting places by glacial agents.

Concerning, therefore, the remaining geologic characteristics of the basin area, there only remains to be noticed the great Tertiary formations that are known to outcrop over the greater portion of its surface, and such Quaternary and modern deposits as were observed the present season.

In a previous report, as also in preceding pages of the present report, allusion has been made to the great volcanic-capped watershed in the vicinity of Togwotee Pass, and in the chapter devoted to the Gros Ventre Basin, brief mention was made of the geologic components of that portion of the watershed lying between Togwotee and Union passes. The latter forms a low mountain barrier, separating Wind River from Gros Ventre drainage, and, as previously stated, it is almost entirely made up of Tertiary formations. The ridge, however, retains the volcanic capping to a point perhaps 10 miles south-southeast of Togwotee Pass, and remnants of the same sedimented volcanic ejectamenta were found crowning low eminences on the summit still farther south to within 6 miles of Union Pass trail. On one of the latter points Station XXVIII was made, which has an altitude of 10,142 feet above the sea.

Soon after leaving the summit of Togwotee Pass, the nascent stream begins to erode its bed into the soft deposits that underlie the great volcanic accumulations, and which appear in bluffs of gradually increasing height as low down as the confluence of the first considerable affluent from the north, just below which, or some 12 miles from its ulti-

mate source, the stream emerges into a meadow-intervale, at which point the valley proper may be said to begin. In this distance the stream has made a descent of about 1,800 feet. Towards its source the bluff-banks show limited exposures of brownish green arenaceous deposits, with indurated streaks of sand and pebbles, dipping at a slight angle northwards. At one point these deposits are seen to overlie a conglomerate ledge composed of water-worn quartz pebbles held in a fine arenaceous paste, the whole being stained a green tint probably by iron infiltrations. This conglomerate is identical with similar occurrences along Black Rock Creek on the opposite side of the watershed, rem nants of which were found on the summit of the watershed to within a few miles of Union Pass. In all, save its green color, it bears close physical resemblance to the great conglomerate elsewhere noticed as occurring in the Tertiary area of the Gros Ventre Buffalo Fork Basin. Its relation to the great volcanic deposits that make up a thousand feet and more of the heights on either side of the pass is not clearly manifest, nor are its relations to the beforementioned conglomerate of the Gros Ventre Basin any better displayed.

Lower down the stream the greenish arenaceous deposits continue to appear, often forming bluffs of an hundred feet and more in height, and apparently gently inclined in the direction of the stream. At a locality 6 or 7 miles from the summit of the pass and about 1,100 feet lower, the abrupt terrace-face shows practically horizontal layers of greenish-gray, coarse and fine grained earthy sandstone with thin seams of dark carbonaceous clay, the earthy layers yielding imperfectly-preserved leaves and stems of plants. Amongst these remains Professor Lesquereux doubtfully recognizes a *Ficus*, whose relations seem to be rather with forms prevalent in the Green River Tertiary group than with those occurring in the Laramie formation. The greenish arenaceous deposits are here associated with lighter-colored strata of similar composition, which latter increase in relative importance as we descend the stream.

A mile or so below the above locality, the steep bluffs bordering the north side of the stream show a ledge of coarse conglomerate interbedded with thin, irregular layers of greenish-gray, soft sandstone, overlaid by yellowish sandstones. The conglomerate outcrops 40 feet above the water, and in lithological appearance it bears marked resemblance to the Tertiary conglomerate on the Gros Ventre and Buffalo Fork. Above the confluence of the first considerable north affluent, the bluffs on the main stream show 100 to 200 feet thickness of light-yellow soft sandstone, and gritty clays with shaly gray sandstone above, the whole aprently in nearly horizontal position.

The north side of the stream for several miles, both above and below the confluence of the north tributary, is bordered by a high bench or terrace, which is made up of the above-mentioned stratigraphic exhibitions. The slope on the opposite side is more gradual, and for the most part densely wooded. At a point perhaps a couple of miles below the confluence, or 13 miles distant from the summit of Togwotee Pass, the terrace, which is here 500 feet above the stream, exhibits several ledges of soft buff-gray and greenish-tinted coarse-grained sandstone, in places shaly or thin-bedded, with pebble layers, and interbedded with soft arenaceous clays. No fossils were observed in these beds, which have a slight easterly or northeast inclination. A little lower down the valley, which here opens out into a considerable meadow tract, the gentle lower slope of the bluffs reveals obscure exposures of pale-red clays, forming thin bands seldom more than a few inches in thickness included in greenish-drab clays. A mere glance, without reference to their associated strati-

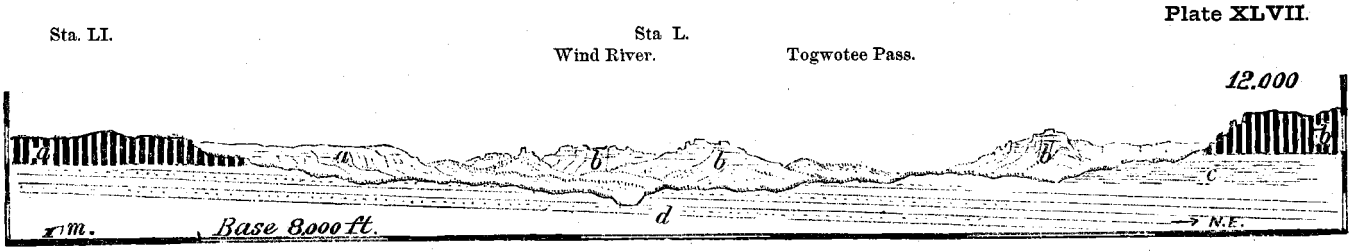
graphic relations, might lead the observer to identify these horizons with the Triassic "red-beds," the first authentic exposures of which, however, are only met with at a point several miles lower down the valley in the neighborhood of Warm Spring Creek.

From the summit of the terrace a broad, shallow depression, occupied by a small stream flowing eastward, and probably tributary to the milky affluent that joins Wind River a few miles above Du Noir Creek, is overlooked, beyond which rises a considerably higher outlying bench on the flank of the great volcanic mountains whose sedimented horizontal ledges tower hundreds of feet above in magnificent architectural mountain forms. The abrupt southern declivity of this outlying bench, as seen from a distance, appears to be composed of more or less indurated deposits, including a heavy bed of dull brick-red color, and above a rusty weathered ledge which is in turn overlaid by light ash-colored earth reaching up into the summit. The vertical extent of these deposits, which are nearly horizontal, is estimated at 500 to 800 feet, while both from their position and lithologic characters they are doubtless identical with the greenish arenaceous beds met with along the upper course of Wind River. Their relations to the volcanic mountain borders both to the north and southwest, and the inferior creamy-yellow sandstones is shown in an accompanying profile section of the valley along a line extending northeast from Station LI (1877) on the watershed on the south side of the valley.

North of the point where the small parallel tributary leaves the first terrace bench and enters the undulating, grassy region lying just to the east, a considerable thickness of banded bluish-drab and red deposits appears in low bluffs along the broken eastern edge of the terrace. The above exposures occupy a sort of recess in the lower terrace level, to the west and north of which the acclivities rise up into the higher bench, which here shows obscure, pinkish-drab, red-streaked exposures. The probable stratigraphical relations of the banded variegated beds here alluded to will be referred to further on. To the northeast, brownish earthy deposits appear in a somewhat higher bench, and in the lower slopes, descending from the volcanic mountain ridge, quite extensive tracts are occupied by light drab, clayey deposits in the region of the upper course of Du Noir Creek.

The above mentioned terrace is continued along the north side of Wind River, east, to within perhaps 3 or 4 miles of the mouth of Du Noir Creek, where it assumes the character of a high morainal bench, jutting into the valley. It is, however, somewhat lower, interrupted by short drainage depressions, and at a point perhaps 4 or 5 miles above Du Noir Creek it is cut by a smaller affluent whose waters are charged with milky-colored sediment. The latter phenomenon is doubtless attributable to the wash of white earthy deposits which were observed to occupy a considerable area some miles to the north, or northwest, in the region of the sources of this stream. But as we descend the valley, the bluffs gradually increase in elevation, frequent exposures of the component strata appearing in the more or less steep slopes facing the valley. At a point some distance above the confluence of the sediment-discolored stream, where the bluffs approach the river, a thin seam of lignite outcrops a few feet above the water-level, associated with chocolate-red and bluish-drab clays, overlaid by rusty yellow and grayish shaly sandstones in bluff-face, 150 feet above the stream. The sandstones were observed all along the bluff-face before reaching this locality, appearing in nearly horizontal ledges separated by soil-covered slopes, though in places apparently gently rising to the eastward as the

Plate XLVII.



Profile of Upper Wind River Valley and Togwotee Watershed (looking NW.).

a Flowed lavas, &c. *b* Sedimented volcanic ejectamenta. *c* Green, dull-red, and ash-colored deposits. *d* Sandstone, clay, lignite—Tertiary (?).

stream deepens its bed. Between the latter stream and Dn Noir Creek, the north side bluffs exhibit the same series of strata, consisting of rusty-bnff sandstones, drab and yellow sandy clays with streaks of red clay, of which a thickness of 250 feet are here exposed. These deposits are overlaid by variegated or banded pale-red and drab clays, showing a thickness of 50 feet or more in the top of the blnffs, the whole sloping off to the northeastward at a very gentle angle of inclination.

It was impossible at this locality to determine whether the snperposition of the latter deposits is conformable to the inferior lignite-bearing formation, nor was opportunity afterward afforded for the satisfactory settlement of the question. I have also to regret the nncertainty as to the stratigraphic relations of the above geological formations with the previously noticed greenish arenaceons deposits occurring towards the head of Wind River. Indeed, lithologic data, which are quite persistent and reliable in the Gros Ventre region jnst over the watershed to the west, seem to be confused and less trustworthy gnides to the identification of portions of the Cenozoic series as we approach that part of the divide which is surmounted by the great volcanic deposits. The comparatively undisturbed condition of all the geological products, inclnding even the sedimented volcanics, occurring in the region abont the sources of Wind River, renders the detection of nonconformities an extremely delicate operation; and when we take into consideration the action of thermic agents accompanying the great volcanic accumulations that were spread out over so vast an extent of the Cenozoic area in this region, we may well hesitate, in interpreting meager data, to assign the appearances here met with to changes akin to those induced by metamorphic agents, or to those other potent agents of geologic change, erosion, and deposition of distinct and unconformable materials. The conglomerates noticed on Wind River certainly bear close analogy to the great conglomerate horizon nnderlying the npper or Teritary lignite-bearing series on the Gros Ventre, 15 miles to the westward. Yet, with the paucity of facts at present in hands, bearing on the detail stratigraphy of the Wind River section, it might be deemed presnmptnons to assert the identity of the above occurrences. But when we come to the correlating of the supralignite series represented by the pale-red and drab variegated or banded deposits, the occurrences in the above-mentioned regions are so alike as regards both their stratigraphic constitntion and geological position, that little or no doubt can be entertained respecting the actnal identity of the latter deposits in the regions of the Gros Ventre and Wind River basins. The few fossils found in the lignite series of the Gros Ventre Basin here referred to were provisionally compared by Dr. White with Bear River Laramie forms; while the immediately superimposed conformable strata afford a *Viviparus paludinæformis* (?) which elsewhere characterizes Wasatch Tertiary horizons. Hence, the variegated deposits to which Dr. Hayden gave the name Wind River Gronp, recognizing their probable Miocene age, are either emphasized variegated upper Wasatch strata or a mnch later and actually nonconformable member of the Tertiary series peculiar to the region north of the Gros Ventre Mountains, and east of the Wind River Range, in which quarter as yet no Green River Tertiary equivalents have positively been recognized, nnless the plant-bearing beds above noticed prove to be of that age. The attempts hitherto made to correlate the Wind River Gronp have been based on snpposed lithological resemblances, I believe, without the aid of palæontological evidence.

Dn Noir Creek occnpies a fine valley eroded ont of Tertiary deposits, in the east side of which variegated red and drab exposnres are seen.

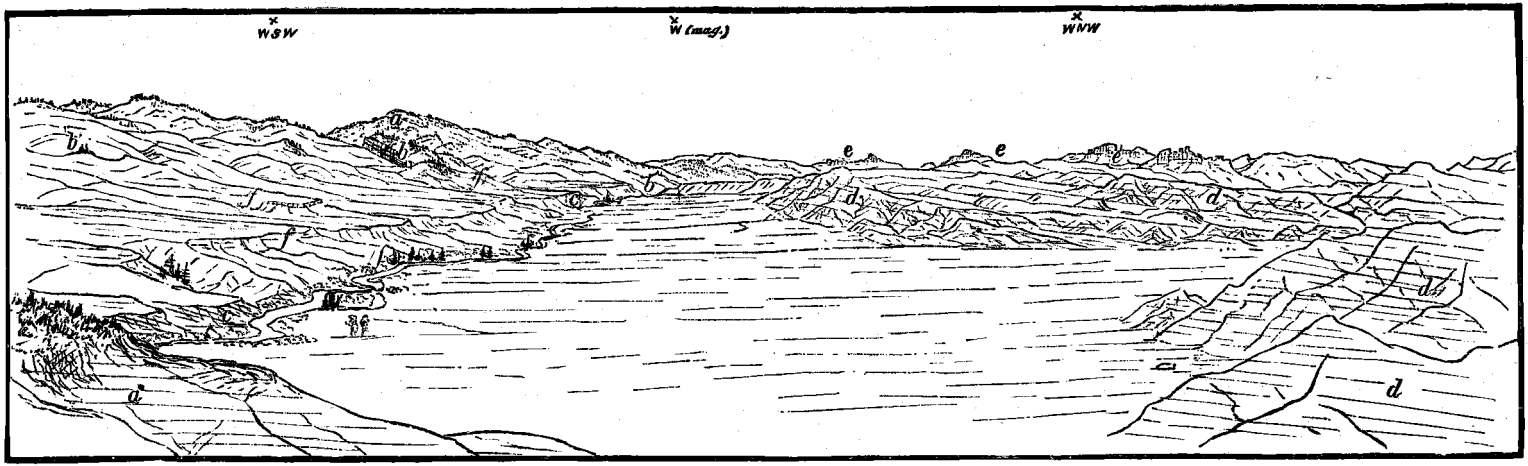
In the uplands to the east the same variegated series occurs over a wide belt extending down the middle of the basin, and is overlaid by obscurely exposed deposits of drab clays and soft yellow sandstones. Just below the Du Noir, the north side terrace closely approaches the stream which has cut a narrow gorge in the tilted Carboniferous sandstones reclining on the flank of the Wind River Mountains, as described in a preceding page. The relations of the basin Tertiary deposits to the Palæozic series in the mountain-flank at this locality are concealed by drift accumulations mantling the terrace. But in the north side of the expansion into which the valley opens below the narrows, the variegated deposits are exposed on an extensive scale in the deep recess which here penetrates the upland; the soft materials of which they are composed readily yielding to the elements, which have wrought with wonderfully intricate picturesque effects in the sculpture of the barren bluffs that inclose this side of the valley.

A few miles below the narrows, the uplands again approach the stream which here traverses a narrow passage cut into the dark red sandstones of the Trias, which latter form the basis of the outlying terrace along the foot of the Wind River Mountains. A limited exposure of Jurassic strata occurs in the bench on the north side of the stream, upon which rest the nonconformable variegated Tertiary beds. The latter here rise up into a prominent headland, 600 feet or more in height, which was utilized for topographic purposes the previous season (Station LII, Téton division). These deposits here consist of alternating bands of pale-red and greenish-drab clays, with irregular or local thin layers of gray and yellow sandstone. The eminence is covered with a thickness of 10 to 30 feet of brown earth and drift materials resting upon the planed-off surface of the variegated beds. The latter here incline to the north-eastward at an angle not exceeding 5°; the underlying Jurassic beds dip in the same direction at an angle of 15° to 20°, the nonconformity being marked as seen in the natural exposures at a distance. It is probable a thickness of at least 1,000 feet of these deposits is seen in the picturesquely eroded area of their occurrence here alluded to, while their total vertical extent may be found to exceed this estimate. The comparatively limited unexposed space intervening between the Jura and variegated Tertiary at this locality is wholly insufficient to admit the heavy series of yellow sandstones and clays of the lignitic series which higher up the valley were found nnderlying the variegated deposits. Hence, it is reasonably inferred that the lignitic formation was here denuded prior to the deposition of the variegated beds, which at this locality rest immediately upon the unconformable and also extensively denuded Juarissic strata.

Some notion of the distribution of the various geologic formations of the region may be gained from the eminence on which Station LII (1877) was located. The banded Tertiary deposits have extensive areal distribution to the north and east. The great sedimented volcanic ridge, constituting the Sierra Shoshone of Captain Jones, is traced from Togwotee Pass, eastward, along the northern rim of the basin, terminating in a group of lofty pinnacles lying to the east of the sources of North Fork Wind River, and which are probably the Washakee Needles. From the latter mountain ridge, the Owl Creek Mountains are separated by a gap, and at their base lies a massive outlying bench in which an enormous thickness of similar variegated deposits is visible. The valleys of Horse Creek and North Fork are excavated in these deposits—their fringes of cottonwood and green shrubs presenting a pleasing contrast to the environing red-striped barren hillsides, in appearance a semi-badland region, destitute of more than scant pasturage.

Plate XLVIII.

Wind River Mts. Warm Spring Cañon. Togwotee Pass. Sierra Shoshone.



Wind River Valley, below Warm Spring Creek.

a Silurian. *b* Carboniferous. *c* Jura-Trias. *d* Wind River Tertiary. *e* Volcanic tuff, breccia, conglomerate. *f* Spring deposits—calc. tufa, gravel concrete.

Below Horse Creek the variegated Tertiary skirts the stream, forming beautifully eroded bluffs 300 feet or more in height, the lower portion showing some discordance in deposition, but not in constituents and general appearance. The coloring matter appears not to have been distributed with perfect regularity, the belts of red becoming locally intensified by the merging of several narrow bands in one, and associated with frequent indurated arenaceous bands, which give rise to a great variety of monumental forms in the weather-sculptured bluff-face. These deposits continue thence along the north side of Wind River to near the eastern boundary of the district. In the vicinity of the confluence of North Fork they are again crowded back some distance from the stream and rest unconformably on the Jura, which at this place crosses to the north side of the river, forming a rather high shoulder outlying the Tertiary uplands east of North Fork.

Above Campbell's Fork, on the north side of the river, there occurs a heavy series of dirty-yellow and drab clays or arenaceous deposits, the stratigraphical relations of which, for lack of time, could not be satisfactorily determined, although they apparently underlie the banded Tertiary. The latter again reaches the stream opposite the confluence of Campbell's Fork, where it forms bluffs 200 to 300 feet high. It is made up of alternating pale-red and bluish-drab layers, often of considerable thickness, the disintegration of which produces a drab soil covering the talus slopes for more than half the height of the bluffs. A couple of miles or so below Campbell's Fork the variegated deposits appear in the terrace on the south side of the river, the red and drab bands alternating with yellow sandstones. The terrace bordering the opposite side of the valley exhibits frequent though rather obscure exposures of the same deposits, showing a preponderance of sandstone layers as we advance, and which are gently inclined in the direction of the descent of the valley, though locally varying in the direction and amount of inclination.

A few miles below the confluence of Crow Creek an isolated hill rises nearly a thousand feet above the level of the valley, forming a prominent landmark, which is known as Crow-Heart Butte. This eminence, which was detached by erosion from a high terrace level lying a few miles to the north, is based upon obscurely exposed variegated deposits, overlaid by a heavy deposit of rusty-yellow sandstones and drab clays forming the middle portion of the butte, upon which rests a somewhat less thickness of similar clays with reddish layers, the summit capped with a heavy ledge of rusty-yellow sandstone. The summit sandstone belongs to a heavy ledge that recurs in the above-mentioned high terrace, while the middle sandstone horizon is the same that constitutes the main terrace bordering the valley. The inferior basis deposits resemble the variegated horizon noticed higher up the valley, as mentioned above. Wherever this region was overlooked from the mountain border on the southwest the above-mentioned deposits always had the appearance of gently rising to the northwest in ascending the valley. Yet these appearances should be taken with due allowance when it comes to determining the geologic relations of the horizons here alluded to.

Below Crow-Heart Butte, as far as the stream was followed, the border bluffs on either side revealed frequent exposures of greenish-yellow soft sandstones and arenaceous shales with layers of blue clay. The concentrated clayey portions of the rock are often weathered away, forming shallow caverns in the mural exposures. In the vicinity of Dry Creek, a few miles below Bull Lake Fork, rusty buff-weathered sandstones appear in the bluffs on the north side of the valley, where they are gently upraised to the southwest and overlaid by a considerable

thickness of variegated chocolate-red and drab deposits. But in the uplands on the opposite side of the valley, over which the road to Camp Brown leads, the horizoutal Tertiary sandstones are again met with.

Mention has already been made of some fossiliferous sandstone occurrences, of probable Tertiary age, in the debouchure of Jake's Creek. These exposures are practically horizontal and fill a depression eroded out of the tilted Jura-Trias at the foot of the Wind River Mountains. Below this the Tertiary area is crowded to the north side of Wind River and is not again met with on the south side of the stream until reaching Campbell's Fork, nine or ten miles to the east-southeast. At the latter locality a series of nearly horizontal drab and dirty-yellow soft sandstones appears in the bluffs bordering the stream for a mile or more, and which extend up the valley to a place nearly opposite the head of the lake, where they abut against the upraised Triassic "red beds" in the mountain flank. The same deposits occur in the bluff borders along all the deeper drainage channels that flow down from the Wind River Mountains between Campbell's and Bull Lake Forks, where they hold the same unconformable relations to the outlying Mesozoic belt at the foot of the mountains. But in the interval between North Fork and Campbell's Fork, where the outlying Mesozoics are projected beyond the mountain-foot in a sort of broad, low arch, across the outer edge of which the main stream has eroded its channel for several miles, the variegated red and drab deposits rest immediately upon the unconformable older formations without intervention of the above-described Tertiary sandstones. It may be urged that the latter sandstones hold a stratigraphic position superior to the variegated deposits, in which case it is evident that the heavy lignite-bearing series of supposed Wasatch Tertiary occurring in the Gros Ventre Basin just over the watershed at the head of Wind River, if not wanting, is so attenuated as to escape recognition in the denuded borders of the lower Wind River Basin.

Bull Lake Fork, immediately it leaves the mountains, exhibits an unusally clear section of the Tertiary sandstones. They here occur very much in the same manner as on Campbell's Fork, impinging at a sharp angle against the inclined Cretaceous strata occurring in the outlying bench at the foot of the mountains. The highest exhibitions of these strata occur in the bluffs about opposite the head of Bull Lake and between 600 and 700 feet above the water-level, the beds showing slight easterly inclination in the direction of the basin. Perhaps a mile lower down, on the north side of the lake, a section showing a vertical thickness of about 400 feet in this horizon was examined.

Section of Tertiary strata on Bull Lake.

No. 1. Unexposed slope to level of Bull Lake, 145 feet.

No. 2. Coarse, dirty-yellow sandstone, containing pebbles of metamorphic rocks and pockets of green clay, exposed 25 feet ±.

No. 3. Soft, almost incoherent dirty-yellow sandstone, with thin layers of green clay and small concretions; fragments of fossil-wood in upper part, 250 feet ±.

No. 4. Buff, coarse-grained, soft sandstone, with greenish arenaceous clays below, heavy-bedded above, and containing regular and irregular shaped sand and ferruginous sand concretions, 125 feet exposed.

No. 5. Brownish-yellow clay or soil, 20 feet ±.

No. 6. Slope occupied by irregular parallel ridges of morainal materials reaching up into summit 700 feet above level of Bull Lake.

The Tertiary beds are planed off even with the tilted edges of the

Mesozoic series, forming a gently sloping plane loaded with morainal deposits. The south-side bluffs exhibit less perfect exposures of the same rocks, which extend but a short distance below the lake, whence the border slopes and uplands alike are covered with the loose drift materials all the way to Wind River.

A high bench projects into the basin between Bull Lake Fork and Sage Creek, traversed by two or more narrow drainage channels, in the steep bluffs of which similar exhibitions of horizontal Tertiary strata are met with. In the borders of one of these ravine-like depressions about two miles south of Bull Lake Fork and as far again from Wind River, the exposures consist of soft yellowish sandstones containing vegetable remains like compressed stems, and which are weathered into curious monumental forms by atmospheric erosion. Higher beds apparently belonging to the same series were observed in the divide between Wind River and Sage Creek, in the south slope of which to the west of the depression down which the road passes into the valley of the latter stream, the same soft yellow sandstones reappear, in horizontal position, on the west flank of the outer mountain fold in which the Mesozoics are brought to view.

A few miles to the west-northwest of the last locality, in the high outlying bench, pale red variegated deposits overlaid by drab and greenish arenaceous clay appear in the east side of a wide shallow drainage depression tributary to Sage Creek above the bend. These deposits, constituting here well-marked horizons gently inclined in the direction of Wind River, hold a position superior to the dark drab clays of the Cretaceous Colorado Group, and to the northeast they pass beneath the above-mentioned soft yellow sandstones that occupy the interval extending over to Wind River. The geological relations of these horizons are obscured along the line of contact with the subjacent Colorado shales, where they have been eroded and overlaid by the unconformable conglomerate of Pliocene, or possibly Post-Tertiary age. This interval may well embrace the horizon of the Fox Hills Cretaceous, which shows characteristic exposures in the bluffs above Bull Lake. Lithologically, the deposits here alluded to recall the exposures on Wind River in the vicinity of Dry Creek, where. as has been stated in a preceding page, similar reddish and drab horizons occur, resting upon a heavy ledge of buff sandstone, which is gently upraised to the southwest. The local appearance of the above-mentioned deposits is shown in the profile section representing the mountain flank in the vicinity of Sage Creek Cañon. At the time of the examinations in this quarter it was the impression that the reddish variegated beds here alluded to were one and the same with the great formation of similarly colored variegated deposits that constitute so important a geologic feature in the mid-basin area a little higher up Wind River.

Post-Tertiary.—In the area of the basin region, even including the mountain border, it is probable that comparatively slight changes in the pre-glacial surface contours have been effected by the erosive agents that have wrought during and since the glacial epoch. Speaking in general terms, the country here alluded to has probably suffered to greater extent changes in its surface configuration due to fluviatile and those other potent atmospherical denuding agents than that produced by glacial action. The latter has evidently acted with greater effect as a degrading force in the high mountain regions, while in the lower border region it was chiefly confined to a transporting function. In this latter respect the results are grouped about the debouching cañons, where they may be advantageously studied as so many local exhibitions of a part of the phenomena of glacial action. The great ice-flows naturally sought the

depressions already existing, down which they slowly moved bearing and pushing along their burden of detrital materials, which were unloaded and built into the huge morainal ridges filling lateral depressions along the mountain course of the glacier and piled up on the surface in the edge of the plain. These occurrences furnish the most legible evidence of the magnitude of the individual glaciers descending along the eastern flank of the Wind River Range, which in some instances extended beyond the mountain foot a distance of several miles out into the basin.

While denuding agencies of one kind or other have wrought with startling effects, carving out stupendous mountain forms and broad valley depressions, the phenomena resulting from these actions, as seen to-day in the region of the sources of Wind River, present comparatively small evidence of glacial origin. This may be attributable to the soft nature of the geological formations in that region, but the glacial deposits which were here found are much less conspicuous than those met with along the foot of the Wind River Mountains. However, the occurrences along the upper course of Wind River present the same evidence of the local extent of the glaciers as those met in the mountain borders to the south. The erratic materials along the stream as far down as Warm-Spring Creek may be traced to the conglomerate and great volcanic conglomerate and lava formations, that encircle the head of the valley. The materials consist almost exclusively of the various sorts of volcanic rocks, basalt and trachytic lavas, found *in situ* in the mountain summit about Togwotee Pass. They have been distributed by transporting agents as far down the valley as North Fork, at least, though below the confluence of Warm-Spring Creek they are mingled with other kinds of rock *débris* derived from the Wind River Mountains, becoming less and less conspicuous and finally disappearing as a component of the superficial detrital deposits along the stream.

Above Du Noir Creek, the upland benches a few miles north of Wind River are sparsely covered with water-worn erratics consisting chiefly of volcanic rocks, and sparingly of fragments of reddish-white laminated quartzite and dark drab limestone resembling ledges occurring in Carboniferous and Jurassic horizons, and which evidently were brought down from the mountains lying to the north. But for the most part these upland slopes are covered with light sandy soil derived from the disintegration of the subjacent soft arenaceous Tertiary deposits. Above Du Noir Creek the uplands are more thickly strewn with water-worn volcanic bowlders which embrace all the varieties of these rocks occurring in the watershed around Togwotee Pass, the deposit having much the appearance of morainic origin. The wide intervale at the confluence of Du Noir and Wind River is paved with these erratics.

Just below in the neighborhood of Warm-Spring Creek, glacial phenomena, so far as they are dependent on morainal deposits for their recognition, are perhaps not of the most conclusive character. The mountain side at an elevation of 600 feet above the valley is strewn with unevenly dispersed accumulations of probable glacial origin. The loose materials consist of a variety of metamorphic rocks such as occur in the interior portion of the range, together with limestone fragments from the outer flank of the mountain. But lower on the slopes or in the benches bordering the basin, these abraded erratics are spread out in well-defined terraces where they have been transformed into a sort of conglomerate by calcareous infiltrations from springs, with which are associated a variety of interesting phenomena.

It is difficult to decide the relations of the bowlder deposits in the

terraces vicinity of Warm-Spring Creek to the undoubted glacial deposits. They appear in terraces along the south side of the river, at elevations of 150 feet or more. The deposit is composed of well-rounded fragments of volcanic rocks, limestone, quartzite, and occasional granitic pebbles, obscurely bedded, with thin sheets of sand. The impression derived in the course of hastily made examinations was that these deposits antedate the glacial epoch, in which event they might properly be relegated to the Pliocene. Their consolidation might have taken place at a much later date from calcareous matter deposited by percolating spring-water.

In the vicinity of Jake's and Torrey's Creeks, the morainal deposits are on a scale of great magnitude, presenting all the characteristic phenomena usually associated with glacial accumulations. The outlying terraces are strewn over a wide area with this vast accumulation of erratic materials, reaching from the river back to the mountain where they occur at an elevation of several hundred feet above the valley. In the constitution of the deposit metamorphic bowlders largely predominate, with which are sparingly associated fragments of limestone and quartzitic sandstone belonging to readily recognizable formations plating the neighboring mountain flank. The region occupied by these deposits forms a sort of high bench either side of the debouchures of the streams, the surface roughly furrowed just as the material was discharged from the glacier. Remnants of the glacial deposits occur on the north side of Wind River below the mouth of Torrey's Creek, where they are seen clinging to the steep bluff slopes over the variegated Tertiary formation.

To the southeast the mountain slope is again unmasked until reaching Campbell's Fork, where similar morainal deposits are met with, though on a less extensive scale. At the latter locality the erratic materials are piled up in well-defined lateral morains on either side of the stream as it leaves the mountain, and which extend all the way to Wind River a distance of nearly 4 miles, where they are spread out in irregular low benches. The moraines rise up on the foot of the mountain attaining an elevation of near 8,400 feet, or 1,000 feet above Wind River. In the gorge across the sedimentary ridge the Carboniferous limestones at one point form a natural bridge, and everywhere in the barred surfaces the rock still retains in legible characters the record engraved by the glacier in the smoothed and polished ledges. This is the more remarkable considering the exposure to which these rock surfaces have been subjected. The cañon has been swept clean of these materials, but within the rugged mountain basin they recur under a variety of local aspects.

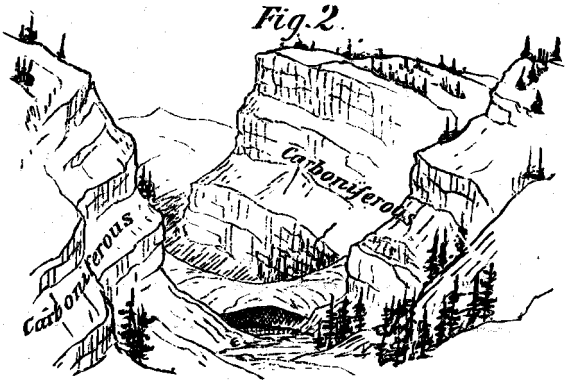
The streams to the south that rise in the more elevated portion of the range all exhibit in their debouchures interesting evidence of former glacial occupancy. But none of the smaller streams show morainal deposits of near the magnitude of those above noticed. This is evidently due to the fact that the present streams do not penetrate so deeply into the more elevated regions, and hence the glaciers that once descended along their valleys were smaller and derived their products from less abundant sources. The lateral moraines on Dry Creek below the debouchure are quite as perfect examples of their kind as any to be met with on this side of the range. They reach well out into the sloping plain, presenting in their surface contour the several bench levels in the steep valley declivities marking the stages in diminution in the volume of the glacier and on the opposite side the furrowed gentler slopes descending to the general upland level. Between these streams the mountain side reveals the sedimentary formations in great upraised benches which form a characteristic feature in the surface configuration of the flank of the range.

The Bull Lake Fork moraines are precisely like those above described, being heaped up on the planed-off surfaces of the Mesozoic and Tertiary deposits and reaching well up on the foot of the mountain to an elevation of 1,200 feet or more above the stream. They reach out into the basin as far as Wind River, or a distance of nearly 10 miles, the deposits apparently increasing in magnitude in that direction, where they soon conceal from view the subjacent geological deposits. The lake was formed by a low barrier which marks the site of a terminal moraine, similar occurrences being met with lower down the stream giving rise to a chain of water-expansions or lakelets. One of these low terminal moraines crosses the valley half a mile or so above the lake, which the stream has broken through, forming a narrow passage where it shows a height above the water of about 30 feet and a breadth of 75 yards. Looking up into the mountain basin the Archæan ledges present extensive glaciated surfaces and huge ridges of morainic origin.

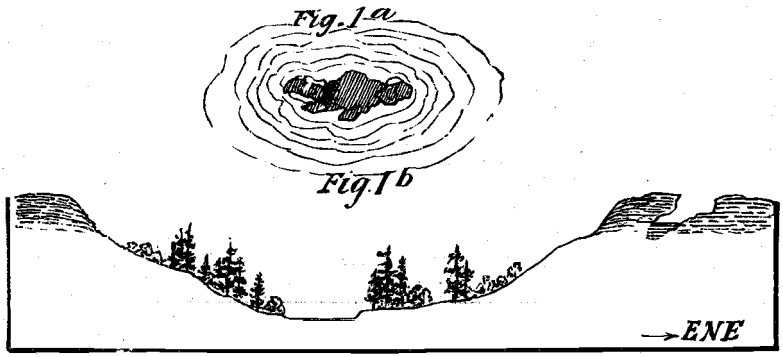
Allusion has already been made to the glacial phenomena prevalent on Little Wind River. The two main branches of this stream cross the outer mountain ridge by independent cañons, uniting in the plains below. Their exits from the mountains are accompanied by morainal ridges constituting prominent features in the magnificent view of the mountains as seen from the valley in the vicinity of Camp Brown. The barred sedimentaries appear on the mountain side in the interval between the two streams. In the bed of the valley of the North Fork, just below where it leaves the mountains, low parallel ridges of morainic origin are met with which may be remnants of medial moraines merged with terminal deposits. In the high bluffs on the north side the lateral moraine rests upon a heavy bed of Pliocene (?) conglomerate which interposes a hundred feet between the glacial deposits and the tilted Mesozoic strata. The north-side lateral moraine attains an elevation of about 1,500 feet above the stream, rising up on a high shoulder which breaks down in a precipice several hundred feet in height on the cañon side. Within the broad and rugged mountain basin moraines of even greater magnitude were built up along the principal tributaries. The latter in places traverse beautiful tracts of grassy, forest-environed intervales, the region indeed abounding in scenic contrasts the most beautiful and sublime.

Tufaceous deposits, &c.—Along the northeastern foot of the Wind River Mountains some interesting occurrences attributable chiefly to depositions from springs issuing in the immediate border of the basin were met with, of which a brief account is embodied in the following pages. The first of these deposits occurs in the immediate neighborhood of Warm Spring Creek, where their origin is perhaps most clearly revealed. They extend to the southeast as far, at least, as Campbell's Fork, and certain conglomeritic deposits with which they are here associated have similar, if not identical, recurrences still farther south to the neighborhood of Little Wind River.

In the south side of Wind River, at Warm Spring Creek confluence and a few miles below, recent deposits of calcareous matter have been made by springs which have not yet altogether ceased flowing. Their deposit forms a light, porous rock retaining impressions of leaves and land snails of living forms, and of comparatively limited extent in the low terrace bordering the intervale, 15 to 35 feet above the stream. Ascending Warm Spring Creek it is presently shut in by the bluffs of higher terraces that rise in two distinct levels. In the edge of the higher bench, perhaps half a mile above the mouth, the creek has cut through a mass of tufaceous limestone, where, on the east side, at an

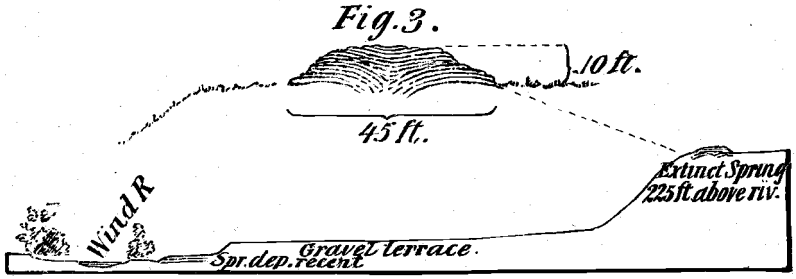


Arch in calcareous tufa, Warm Spring Cañon.



Profile of spring deposits on Warm Spring Creek.

Fig. 1*a*. Outline of orifice of ancient spring, 15 by 50 feet.
Fig. 1*b*. Section of ancient spring, partially filled with water.



elevation of, perhaps, 150 feet above the river, it is surmounted by a broad, low cone or mound, in the centre of which occurs the irregular orifice of the spring. The spring has long since ceased to overflow, and, if it is not extinct, its waters seek subterranean outlet. The orifice has a diameter of about 15 by 50 feet and a depth of 25 to 30 feet, with a cavernous chamber extending under the southwest end which was partially filled with still water. The outline and section of this ancient spring is shown on accompanying plate. In an irregular bench, about 250 feet above the last, a still heavier accumulation of tufaceous limestone occurs, which forms the highest deposit observed at this locality. The mass forms sloping benches in the mountain declivity, made up of thin laminæ and layers, 4 to 6 inches thick, of a more compact, dense structure than that of the more modern deposits now in process of formation.

Looking up the Warm Spring Cañon an interesting and picturesque natural bridge spans the stream, which, although it was not visited, has every appearance of the tufaceous rock above noticed. Its origin at this locality, wedged in between the precipitous limestone walls, is involved in some obscurity; at all events the mass has the appearance of once having choked the bed of the cañon, the stream subsequently cutting a channel beneath without undermining the deposit. A short distance below the above-mentioned spring orifice, in the east-side angle of terrace bluff, another extinct spring mound occurs. The formation, in the present instance, is nearly circular in outline and about 45 feet in diameter. It forms a low, broad-topped mound rising 8 to 10 feet above the level of the terrace, its centre slightly concave, where the orifice is completely choked by the dishing depositions that were precipitated in the last stages of the spring's activity when it had ceased to overflow the rim of its shallow basin. A partly ideal section of the spring mound is given in an accompanying plate.

About a mile below Warm Spring Creek and half a mile back from the river quite extensive deposits of calcareous tufa fill the mouth of a ravine in the edge of the terrace, where they form a series of broad steps or successive bench-overflows, of which there are three well-marked ones. They are being built up by active springs whose temperature was about 84° F. On the east side of the ravine a rather prominent extinct spring crater rises from the slope, its summit about 200 feet above the wide bench descending to the river. The crater, which is surrounded by irregular, vertical walls, is about 15 feet in its longest diameter by 10 feet in the shorter, and a depth of 20 feet, the bottom filled with *débris*. The thin layers of porous tufa limestone, of which the mound is composed, incline gently from the centre, on all sides, and are sparingly intermingled with water-worn pebbles like those found in the drift of the terrace benches. The deposit is probably based on the sloping terrace, but its contact with the loose, superficial deposits is concealed by the gravelly soil surrounding the base of the mound.

A mile or two below the last locality mentioned above, extensive deposits of tufa limestone occur in the slopes at an elevation 250 feet or more above the stream. Its outcrop, facing the valley, forms low bluffs, in which the regularly bedded and nearly horizontal strata show a thickness of 50 feet. Seen at a distance the exposures are very deceptive, and without previous knowledge of these occurrences their origin might readily be mistaken. The deposit consists of grayish-buff, more or less compact and porous, even-bedded calcareous tufa, very gently inclined to the west, in one place apparently conforming to the declivity of the terrace bench upon which it rests. In texture the rock is firmer and

more dense than the modern formations, though, so far as the evidence goes, it is difficult to assign these more ancient deposits a definite relative date as compared with the glacial drift.

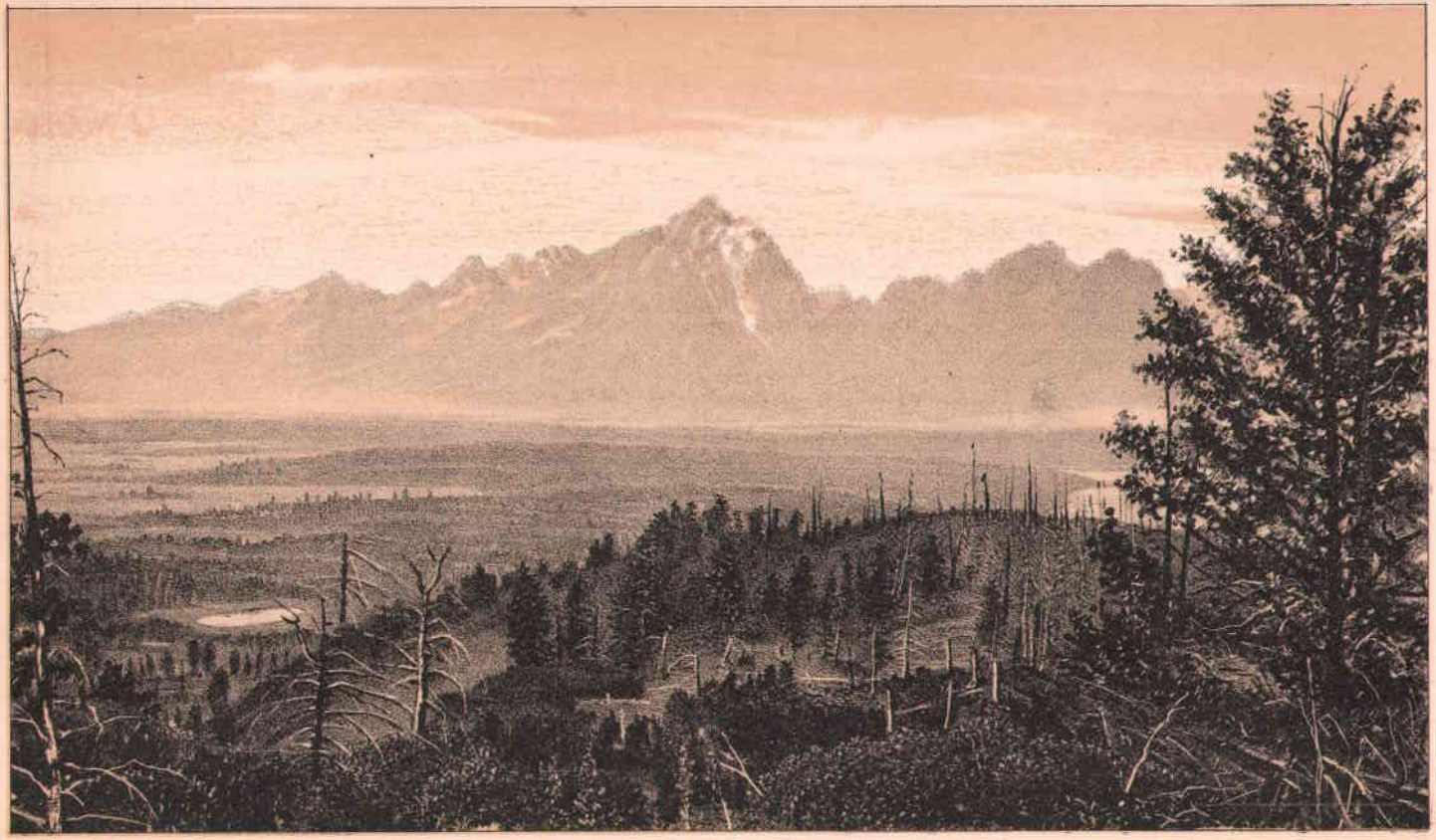
In a preceding page has been mentioned the occurrence of the partially-cemented gravels in the first high bench bordering Wind River on the south for several miles below the narrows above Warm Spring Creek. These ancient gravel beds appear to have been intimately associated with the spring deposits, and if, as is inferred, these old bench deposits antedate the glacial drift, it removes a part of the tufaceous limestone formations to a remote period as compared with the similar deposits whose accumulation by accessions of living springs has not ceased. Of the latter deposits frequent occurrences were met with in ravines traversing the benches opposite Horse Creek confluence, and in the bordering bluffs, resting upon the Triassic "red beds," the terrace conglomerate reappears. It is here made up of limestone, sandstone, and metamorphic pebbles, usually firmly cemented by calcareous matter, forming an extensive deposit rising up to the foot of the mountain and spread out over ancient terrace levels. In comparatively recent times the bench slopes have been subjected to erosion, which has, in some instances, at this locality, isolated the conglomerate sheet in the midst of the barred "red-bed" surfaces. Below this the morainal deposits, distributed by the Jake's Creek glacier, are encountered, and which are piled up on the earlier terraces in irregular ridges, completely masking the subjacent deposits.

In the mouth of Jake's Creek Cañon, Mr. Perry visited some interesting and extensive spring deposits which are still in process of formation. The springs have built up cones rising in the midst of platforms that were formed in the earlier stages of their flow. The water had a temperature of 68° F., that of the atmosphere 44° (2d October).

Between Torrey's Creek and Campbell's Fork perhaps even more extensive exhibitions of conglomerate and tufaceous limestone deposits are met with, the prevalent conditions being the same as noted in the region opposite Horse Creek. The Red Cañon occurrences may be taken as typical of the others found in the latter quarter. Here, upon old terraces moulded in the "red beds," heavy deposits of conglomerate and tufaceous limestones occur, interbedded. These deposits were noticed in detail in the section of the rocks occurring in the mountain flank at this locality, given in a preceding page and accompanying plate of illustrations. The deposits measured about 60 feet, the members locally varying in thickness. It consists of, below, (16 *a*) variegated clays, 5 feet ±, resting upon the uneven surface of the Triassic "red beds," and forming the floor upon which the succeeding beds were deposited; (16 *b*) conglomeratic bed, 10 to 15 feet, composed of pebbles of various kinds of rock occurring in the adjacent mountain, alternating with coarse sandy red clays, more or less local; (16 *c*) tufaceous limestone, varying from rather compact to porous laminated or thin-bedded rock, with calcite concretions, interbedded with layers of pebbles above and below, attaining a thickness of 50 to 55 feet, locally. The deposit is quite variable throughout, in places the conglomeritic character prevailing. The pebbles consist chiefly of water-worn limestone fragments, with fewer sandstone and metamorphic pebbles. The deposit conforms to the surface contour of pre-existing sloping benches upon which it was laid down in an uninterrupted sheet. This character is clearly shown in the natural sections along the streams and over the denuded Triassic area lying between the mountains and Wind River, where tufaceous and conglomeritic beds are seen at two or more levels rising up on the foot

of the monntains. Its ontcrop forms a mnral coping in the blnffs hemming the drainage depressions and in the summits of the isolated mesas with which this region is diversified. The highest benclles in this region may reach an elevation 1,000 to 1,200 feet above Wind River; the aneroid indicating nearly the same actual altitnde for the deposits at this locality and in the vicinity of Warm Spring Creek, 16 miles above.

South of Campbell's Fork, 6 miles, a deposit evidently of the same origin appears in the low blnffs bordering a little stream that here crosses the foreland slope, and resting nearly horizontally upon npraised Carboniferous and Triassic horizons. It is a coarse or partially consolidated gray limestone, in rather even thin layers, with small siliceons pebbles. No fossils were detected, and the rock resembles some of the limestone layers of the Pliocene "lake-beds" of lower Bear River Valley, Utah. It was not detected on Bull Lake Fork, but jnst to the sonth of the latter stream, in the ontlying bench slopes belonging to the Sage Creek drainage, apparently qnite an extensive conglomeritic deposit was met with, which is probably synchronons with the above-mentioned occnrrences. The conglomerate is chiefly composed of water-worn limestone fragments and sandstone, more or less firmly cemented with calcareous matter. The bed reaches a thickness of at least 50 feet, and rests npon varions members of the Mesozoic series occnrring in the belt along the foot of the monntains. The same formation recnrs in the bluffs north side of North Fork Little Wind River, where it rests npon the Triassic "red beds," at an elevation of 800 feet above the stream. Metamorphic pebbles and small bowlders enter largely into the components of the deposit at this locality, interbedded with thin local sheets of soft bnff sandstone, the whole loosely cemented and obscurely stratified. Conclnsive evidence of the preglacial origin of the deposit is not wanting at the present locality; the ridge above being loaded with the morainal materials bronght down by the Little Wind River glacier. There can be no qnestion as to the identity of the latter occnrences with those briefly described in foregoing pages; the only contrast they present is the absence of the tnfaceons limestone which at other localities forms an important member of the formation.



GRAND TETON VALLEY OF SNAKE RIVER.
MORAINES IN THE FOREGROUND.

GRAND TETON RANGE, MOUNT MORAN, JACKSON'S LAKE.
MORAINES IN THE FOREGROUND.

THE TERTIARY LAKE BASIN AT FLORISSANT, COLO., BETWEEN SOUTH AND HAYDEN PARKS.*

[With a map.]

By SAMUEL H. SCUDDER.

The following remarks are based upon collections and notes made during a visit to Florissant, in the summer of 1877, in company with Messrs. Arthur Lakes, of Golden, Colo., and F. C. Bowditch, of Boston, Mass. As five days only were spent in the place, most of the time was given up to the collection and care of specimens, so that only a general survey of the locality was possible. Mr. Lakes especially gave himself to the study of the geology of the district, and as he was previously familiar with the structure of the surrounding country, and placed his notes at my disposal, the first part of this paper should be considered our joint production.

GEOLOGY.

The tertiary lake basin at Florissant, already famous for its prolific beds of plants and insects, is situated in a narrow valley high up in the mountains at the southern extremity of the Front Range of Colorado, at no great distance from Pike's Peak. The first, and, so far as I am aware, the only notice of it which has been published, is that by Mr. A. C. Peale, in his account of the geology of Hayden Park and the country lying between it and the upper cañon of the South Platte.† As it is brief, it is given here in full:

"The latter [Beaver Creek] flows to the northwest, and empties into the South Platte just below the upper cañon. About five miles from its mouth, around the settlement of Florissant, is an irregular basin filled with modern lake deposits. The entire basin is not more than five miles in diameter. The deposits extend up the branches of the creek, which all unite near Florissant. Between the branches are granite islands appearing above the beds, which themselves rest on the granite. Just below Florissant, on the north side of the road, are bluffs not over 50 feet in height, in which are good exposures of the various beds. The following section gives them from the top downward:

"1. Coarse conglomeritic sandstone.

"2. Fine-grained, soft, yellowish-white sandstone, with bands that are more or less argillaceous, and containing fragments and stems of leaves.

"3. Coarse gray and yellow sandstone.

"4. Chocolate-colored clay shales with fossil leaves. At the upper part these shales are black, and below pass into—

"5. Whitish clay shales.

"These last form the base of the hill. The beds are all horizontal.

*Reprinted with additions and alterations from the Bulletin of Survey, vol. vi, art. xi.

†Ann. Rep. U. S. Geol. Surv. Terr. 1873, p. 210. 8vo. Washington, 1874.

Scattered around are fragments of a trachyte, which probably caps the beds. In one of the valleys Mr. Taggart discovered, near an old well, pieces of trachyte, which, on looking at the excavation, was found to be the first layer penetrated. The point of overflow from which this material came is probably to the southward, in Dr. Endlich's district. The lake basin may possibly be one of a chain of lakes that extended southward. I had thought it possible that the beds were of Pliocene age. The specimens obtained from bed No. 4, of the section above, were submitted to Professor Lesquereux, who informs me that they are 'Upper Tertiary.' 'But I do not believe, as yet, that the specimens of the Green River group, to which your species are referable, authorize the conclusion of Pliocene age. I rather consider it, as yet, as Upper Miocene. The species known of our Upper Tertiary are as yet too few and represented in poor specimens for definitive conclusion. Your specimens have a *Myrica*, a *Cassia*, fragments of *Salix angusta* (A. Br.), a *Rhus*, an *Ulmus*, and a fragment of *Poa* or *Poacites*.'

"The shales were so soft and friable that it was rather difficult to obtain any specimens.

"About one mile south of Florissant, at the base of a small hill of sandstone, capped with conglomerate, are 20 or 30 stumps of silicified wood. This locality has been called 'Petrified Stumps' by the people in the vicinity. The specimens of wood are not particularly good."

This basin is shown on sheet 13 of the geological atlas of Colorado published by Dr. Hayden's survey, and its outlines are marked with considerable accuracy, although upon a comparatively small scale. The data upon which that sheet was constructed have formed the basis of the accompanying map, in which the limits of the basin are given with closer accuracy and in greater detail.* The point of greatest difference is in the valley of Fish Creek, where we noticed no extended prolongation of the lacustrine deposits; and as the contours of Dr. Hayden's parties themselves seem to forbid the probable extension of the deposits in this direction, we have closely limited them to what we saw.

The ancient lake lies in the valley of the present South Fork of Twin Creek, and of the upper half of the main stream of the same after the South Fork has joined it. Following the road from South Park to Colorado Springs, and leaving it just above Florissant Post Office,† and then taking the track—half road, half trail—which leads over the divide toward Cañon City, we shall pass between the Platte River and the Arkansas divide, through the entire length of the basin. This road crosses the South Platte a short distance, say a kilometer and a half, below the mouth of Twin Creek, climbs a long, gradual slope on the east bank of the river to an open, grassy glade, about 2,500 meters above the sea, and then descends a little more than three kilometers from the river to join the valley of Twin Creek. We scarcely begin the descent before our attention is attracted by the outcropping of drab-colored shales, which continue until almost the very summit of the divide is reached and the descent toward the Arkansas begun, a traveling distance of not far from thirteen kilometers.

By climbing a neighboring peak, thrice baptized as Crystal Mountain, Topaz Butte, and Cheops Pyramid, we obtain an admirable bird's-eye view of the ancient lake and the surrounding region. To the southeast

* The heights are given in feet.

† Florissant is merely a post-office at Castello's Ranch, which is also provided with a store, the basis of supplies for all the inhabitants within a radius of fifteen kilometers. One would have to look far to find in Colorado a more comfortable hostelry than that to which "Judge" Castello will welcome us.

is Pike's Peak; to the west South Park and the cañon of the South Platte, shown by a depression; to the extreme south, the grand cañon of the Arkansas; while to the north a few sharp, ragged, granite peaks surmount the low wooded hills and ravines characteristic of the nearer region. Among these hills and ravines, and only a little broader than the rest of the latter, lies, to the south, the ancient Florissant Lake basin, marked by an irregular L-shaped grassy meadow, the southern half broader and more rolling than the northwestern, the latter more broken and with deeper inlets.

Recalling its ancient condition, and it will appear that this elevated lake must have been a beautiful, though shallow,* sheet of water. Topaz Butte, and a nameless lower elevation lying eight kilometers to its southwest, and which we may call Castello's Mountain, guarded the head of the lake upon one side and the other, rising three or four hundred meters above its level. It was hemmed in on all sides by nearer granitic hills, whose wooded slopes came to the water's edge; sometimes, especially on the northern and eastern sides, rising abruptly, at others gradually sloping, so that reeds and flags grew in the shallow waters by the shore. The waters of the lake penetrated in deep inlets between the hills, giving it a varied and tortuous outline; although only about sixteen and a half kilometers long and very narrow, its margin must have measured over seventy kilometers in extent. Still greater variety was gained by steep promontories, twenty meters or more in height, which projected abruptly into the lake from either side, nearly dividing it into a chain of three or four unequal and very irregular open ponds, running in a northwest-southeast direction, and a larger and less indented sheet, as large as the others combined, connected with the southwesternmost of the three by a narrow channel, and dotted with numerous long and narrow wooded islets just rising above the surface.

The ancient outlet of the whole system was probably at the southern extremity; at least the marks of the lake-deposits reach within a few meters of the ridge which now separates the waters of the Platte and Arkansas; and the nature of the basin itself, the much more rapid descent of the present surface on the southern side of this divide, with the absence of any lacustrine deposits upon its slopes, lead to this conclusion. At the last elevation of the Rocky Mountain chain, the drainage flow of this immediate region was reversed; the elevation coming from a southerly or southeasterly direction (perhaps from Pike's Peak), the lake, or series of lakes, was drained dry by emptying at the northwestern extremity. The drainage of the valley now flowed into a brook which followed the deeper part of its former floor, and the waters of the region have since emptied into the Platte and not the Arkansas, passing in their course between Topaz Butte and Castello's Mountain.

The promontories projecting into the lake on either side are formed of trachyte or other volcanic lavas, apparently occurring in fissures directly athwart the general course of the northwestern or upper series of lakes; and masses of the same occur at many different points along the ancient shore, such as the western corner where the waters of the lake were finally discharged; in the neighborhood of Castello's Ranch; along the eastern wall of the lowermost of the chain of upper lakes, near where the present road divides; and at points along both eastern and western walls of the lower southern lake. In general the trachytic flows seem to be confined to the edges of the lacustrine basin, but some, if not all, of the mesas or ancient islands of the southern lake have trachytic flows

* The shallowness of the lake is indicated by the character of the fish, the sun cracking of some of the shales, and the erect sequoia stumps.

over them; and toward the southern extremity of the lake a larger island will be seen upon the map, now forming a rounded hill with steep northern walls, crowned by heavy beds of dark trachyte, and its slopes covered with quantities of vesicular scoriae. The rough and craggy knoll immediately overlooking Castello's Ranch, the reputed scene of Indian combats,* was witness of hotter times than those; vertical cylindrical holes, with smooth walls, in which a man could hide from sight, funnels scored by heat, mark, perhaps, the presence of former geysers; the basaltic rocks themselves are deeply fissured by the breaking up of the planes of divisions between the columns, affording the best protection to the Ute and Arapahoe warriors. But the very shales of the lake itself, in which the myriad plants and insects are entombed, are wholly composed of volcanic sand and ash; fifteen meters or more thick they lie, in alternating layers of coarser and finer material. About half of this, now lying beneath the general surface of the ground, consists of heavily bedded drab shales, with a conchoidal fracture, and totally destitute of fossils. The upper half has been eroded and carried away, leaving, however, the fragmentary remains of this great ash deposit clinging to the borders of the basin and surrounding the islands; a more convenient arrangement for the present explorer could not have been devised. That the source of the volcanic ashes must have been close at hand seems abundantly proved by the difference in the deposits at the extreme ends of the lake, as will be shown in the sections to be given. Not only does the thickness of the different beds differ at the two points, but it is difficult to bring them into anything beyond the most general concordance.

There are still other proofs of disturbance. Around one of the granitic islands in the southern lake basin the shales mentioned were capped by from one and a half to two and a half meters of sedimentary material, reaching nearly to the crown of the hill, the lowest bed of which, a little more than three decimeters thick, formed a regular horizontal stratum of small volcanic pebbles and sand (A and B of Dr. Wadsworth's note further on); while the part above is much coarser, resembling a breccia, and is very unevenly bedded, pitching at every possible angle, seamed, jointed, and weather-worn, curved and twisted, and inclosing pockets of fine laminated shales, also of volcanic ash, in which a few fossils are found (C of Dr. Wadsworth's note). These beds cap the series of regular and evenly stratified shales (D of the same note), and are perhaps synchronous with the disturbance which tilted and emptied the basin. The uppermost evenly bedded shales then formed the hard floor of the lake, and these contorted beds the softer, but hardening, and therefore more or less tenacious, deposits on that floor.

The excavation of the filled-up basin we must presume to be due to the ordinary agencies of atmospheric erosion. The islands in the lower lake take now as then the form of the granitic nucleus; nearly all are long and narrow, but their trend is in every direction, both across and along the valley in which they rest. Great masses of the shales still adhere equally on every side to the rocks against which they were deposited, proving that time alone and no rude agency has degraded the ancient floor of the lake.

The shales in the southern basin dip to the north or northwest at an angle of about two degrees, and an examination of the map will show that the southern end of the ancient lake is now elevated nearly two hundred and fifty meters above the extreme northwestern point. The greater part of this present slope of the lake border will be found in the

*Their rude fortifications still crown the summit.