55.1,781 (78.7)

Article XV.—VOLCANIC ASH IN THE BRIDGER BEDS OF WYOMING.

By W. J. Sinclair.

Plates XXXV–XXXVIII.

It has been commonly assumed that the sediments referable to the Bridger stage of the Eocene of Wyoming are normal detrital deposits, and in the reports of the earlier governmental surveys[1] they are referred to as sandstones, shales, marls, limestones, and cherts.

During the past summer it was the writer's good fortune to accompany one of the field parties of the American Museum of Natural History operating, under the leadership of Mr. Walter Granger, in the area of Bridger beds lying north of the Uinta Mountains and west of Green River. This series of exposures extends as far west as Carter station on the Union Pacific Railroad and as far north as the junction of the Big Sandy and the Green. In addition to the routine palæontological work of the party, considerable data of geological interest were secured, including a suite of representative rock specimens from all horizons in the Bridger formation. These have recently been subjected to microscopical examination, with the surprising result that almost the entire Bridger group has been found to be of volcanic origin.

General Features of the Geology.

The Bridger formation in the area studied abuts uncomformably against the northerly dipping Palæozoic rocks of the Uinta Range. Its relations with the underlying Green River group have not been sufficiently investigated, but according to the Fortieth Parallel Survey[2] the Green River shales, a short distance west of Green River, pass with apparently a slight unconformity beneath the softer beds of the overlying Bridger group. On the west, in the vicinity of Carter station, the Bridger beds are said to lie with apparent conformity, but actual unconformity, on the Lower Green River.[3] North

[1] Hayden. U. S. Geol. Survey of Wyoming and Contiguous Territory, pp. 55–58, 1871.
Powell. U. S. Geog. and Geol. Survey, Geology of the Uinta Mts., pp. 40, 45, 167, 1876.
Emmons. U. S. Geol. Exploration of the 40th Parallel, Vol. II, pp. 204, 244, 1877.
King. U. S. Geol. Exploration of the 40th Parallel, Vol. I, p. 394, 1878.

[2] King. U. S. Geol. Exploration of the 40th Parallel, Systematic Geology, Vol. I, p. 395.

[3] Powell. Geology of the Uinta Mountains, p. 63.

of Carter, the stratigraphic relations of the Bridger have not been carefully studied but there is reason to believe that between Carter and Opal it overlaps on the uptilted Wasatch, an erosional unconformity with discordance of dip existing between the two groups.

The Bridger beds are horizontal or nearly so, dipping so slightly toward the southeast that the gradient can be determined only by a series of carefully run levels. Black's Fork and its tributary, Muddy Creek, cut across the northwest portion of the area, exposing the lowermost beds in a line of bluffs extending to the northeast of Carter station. To the southeast, higher and higher levels are exposed in a series of terraces controlled by narrow but remarkably persistent hard beds which have influenced the development of the valleys of the smaller streams tributary to Black's Fork. The uppermost levels, remnants of which are preserved beneath the resistant Pleistocene conglomerate capping the mesas known as Sage Creek Mountain, Henry's Fork Hill, and Henry's Fork Table (the Turtle Bluffs of the Fortieth Parallel Survey map), have been entirely removed by erosion from the region farther north.

Lithologic and Stratigraphic Classification of the Bridger Group.

On a lithologic and faunal basis the Bridger may conveniently be subdivided into three divisions of which the lower, exposed principally along Muddy Creek and Black's Fork, has been determined by Dr. Matthew and Mr. Granger[1] to be in the vicinity of 200 feet thick.

The Lower Bridger.—The Lower Bridger consists of buff and pale green tuffaceous shales and sandstones often containing in enormous numbers the shells of *Goniobasis*, *Paludina*, and *Unio*. Vertebrate fossils are rare and such as are present are aquatic types, mainly crocodiles, fish, and turtles.

Two specimens of Lower Bridger rocks collected in the immediate vicinity of Fort Bridger from layers abounding in shells have been studied by the writer. Both yield a brisk effervescence when treated with hydrochloric acid, showing the presence of considerable calcium carbonate, a characteristic of almost all the Bridger rocks irrespective of horizon. Microscopically examined, the insoluble residue is seen to be composed mainly of highly angular, splintered fragments of glassy sanidine, with a small amount of green hornblende and brown

[1] A report on the faunal horizons of the Bridger group by Dr. W. D. Matthew and Mr. Walter Granger is in preparation. The writer is indebted to their manuscript for the statements regarding the thickness of the beds.

biotite. A considerable quantity of finely divided glass is also present. The glass in the Bridger is frequently devitrified. The glass needles shown in Plate XXXVII, Figure B, from a pumiceous tuff occurring at a considerably higher horizon are in this condition.

The Middle Bridger.—No sharp stratigraphic line can be drawn between the lower and middle subdivisions, although the two are separated sharply enough faunally. The Middle Bridger is magnificently exposed in the escarpment east of Smith's Fork known as the Grizzly Buttes, and also along Cottonwood Creek, Sage Creek, and Henry's Fork, attaining a total thickness of 1175 feet. The rocks of this division are fine grained, greenish tuffs; coarse, gray, pumiceous tuffs; white tuffaceous marls and shales; coarse, cross-bedded, green sandstones, often with basal conglomerates; cherts; limestones and thin beds of lignite.

The pale greenish tuffs are the most extensively developed and contain the best preserved vertebrate fossils. Water-white, splintered grains of sanidine and fragments of glass, sometimes devitrified, make up the bulk of this rock. Considerable green hornblende in narrow, lath-shaped fragments is present, with a subsidiary amount of angular quartz grains and foils of brown biotite. The calcareous component, removable by treatment with acid, is undoubtedly of organic origin and is probably derived from the comminuted shells of *Unio*, of which the disarticulated valves occur throughout these tuffs at various horizons. On weathering, this rock assumes the topographic forms shown in the foreground of Plate XXXVI.

The coarse, gray, pumiceous tuffs are especially well developed a few feet above the prominent bed of white tuffaceous marl shown in the middle distance in Plate XXXV, where they occur in lenticular masses frequently containing rolled pebbles as well as angular fragments of pumice. The pumice grains contain needle-like crystals of hornblende. The glass in the pumice (Pl. XXXVII, Fig. B) is devitrified. The rock is soft and incoherent. Calcareous material is practically absent, pumice in fine powder acting as the cementing substance of the coarser grains. Green hornblende in stubby columns and pale brown mica are abundant. Glassy sanidine and splintered grains of quartz occur in large numbers but the mass of the rock is glass either in the form of pumice or in fine, pale brown needles. This material has apparently accumulated too rapidly to contain much in the way of vertebrate fossils. A skull of *Isectolophus* is the only specimen yet found in it.

Beds of white marly tuff and white, tuffaceous shale occur at four horizons in the Middle Bridger. These white beds (Pll. XXXV, XXXVI) vary in thickness from one to twelve feet and are traceable for long distances as rim rocks in the valley escarpments. Laterally, they cover areas many square miles in extent and have played an important part in the development of the terraces previously mentioned, and have also influenced in a marked degree the development of the valleys of some of the smaller streams.

The marly facies is composed of the shells of fresh-water gastropods of the genus *Planorbis*, but in addition to the calcareous component, there is a large amount of siliceous material of volcanic origin. Fine fragments of glass predominate, with an occasional flake of sanidine and needle of hornblende. Locally, the marl may pass into a pale gray limestone as at the summit of the westerly extension of the Grizzly Buttes, but even in this the volcanic ejecta may be discovered in the insoluble residue remaining after treatment with acid. Highly angular fragments of glassy sanidine, bounded by fracture and cleavage planes form the largest percentage of the insoluble residue, but a smaller amount of hornblende, biotite and quartz is also present, as well as glass in finely divided particles. Lignitic bands, sometimes with a basal layer of fire clay, are frequently associated with the tuffaceous marls, registering a transition from lacustrine conditions to peat bogs (Pl. XXXVIII). Remains of insectivores and other small mammals are found in great abundance in certain of the white layers or at the contact between the white layer and the bed lying immediately beneath, showing that the lakes and ponds in which the marls accumulated were the favorite haunts of the Eocene microfauna.

White tuffaceous shales occasionally showing indistinct plant impressions form the greater part of certain of the white layers. In these shales, segregation of the silica has taken place, producing lenticular sheets of black chert varying from a fraction of an inch to several inches in thickness. The chert has been used by the Indians as a source of material for arrow points.

At all horizons in the Middle Bridger massive lenses of coarse-grained green tuff-sandstone are common (Pl. XXXVIII), often with a basal conglomerate of flattened pebbles of greenish tuffaceous shale. Water-worn bones and teeth, *Unio* shells, and thin bands of pebbles are common in the sandstone. Cross-bedded structures are frequently observable. The pebbles in the conglomerate bands are usually black chert and indurated tuff shale, but pebbles of apparently a scoriaceous rhyolite are not uncommon. The finer grains are mainly sanidine, with fragments of black chert and various Bridger shales. A large amount of green hornblende and numerous foils of biotite are present, the latter often preserving more or less perfectly the hexagonal outlines of the cleavage flakes. Glass occurs abundantly in the fine dust which often forms a coating over the coarser grains, acting together with the large amount of calcium carbonate present as the cementing substance of the rock. The highly angular character of the sanidine grains shows conclusively that they have not been subjected to long continued abrasion by the transporting agents, whether wind or water or both, and suggests that these deposits accumulated rather rapidly in the swifter reaches of sluggish streams. An occasional more or less rounded grain is present.

Numerous veins of calcite and gypsum are common in the Middle Bridger, usually forming the capping of small terraces. Cylindrical aggregates of barite, showing a radial structure in cross section, occur in the soft tuffs.

The Upper Bridger.—The Upper Bridger is sharply differentiated from lower levels by its high gypsiferous content. Its thickness may be fixed approximately at 500 feet. Lithologically, the Upper Bridger is composed of red, green and buff gypsiferous tuffs, white tuffaceous marls, and beds made up almost entirely of sanidine grains and glass either in the form of pumice or in fine fragments. Lignitic bands and black cherts similar to those described in treating of the Middle Bridger rocks occur locally. The gypsum in the Upper Bridger either takes the form of large spear-shaped crystals or is distributed through the tuffs as the cementing substance. In certain of the reddish tuffs it occurs in discoidal, worn grains. A large amount of calcium carbonate is present, associated with the gypsum, as well as considerable oxide of iron in the red tuffs. A sample of the latter examined microscopically, after digestion in acid, is seen to be composed of numerous small discs of gypsum and an abundance of a finely divided, pale greenish siliceous material, feebly polarizing, which is probably devitrified glass. Toward the top of the Upper Bridger, beds of fine white tuff occur on both Sage Creek Mountain and the southerly facing escarpment of Henry's Fork Mesa (Turtle Bluffs). These are composed almost entirely of sanidine and glass, but in the specimen shown in Plate XXXVII, Figure A, minute laths of green hornblende and foils of brown biotite are also present although not seen in the figure. The only fossils thus far discovered in the Upper Bridger have been a few fragments of the carapace of a turtle.

The Wyoming Conglomerate.

Although not a part of the Bridger group, the Wyoming conglomerate exercised such an important function in preventing the erosion of the Upper Bridger beds and is in such strong lithologic contrast to the whole Bridger series that a brief description of its principal characters will not be out of place here.

The Wyoming conglomerate of the Fortieth Parallel Survey (apparently the same as the Bishop's Mountain conglomerate of Powell[1]) forms the cap rock of Sage Creek Mountain, Henry's Fork Table and Henry's Fork Hill, extending with increasing thickness to the south into the Uinta Mountains. It is a coarse conglomerate of water-worn pebbles and boulders, mainly of Pink Uinta quartzite in a calcareous matrix. It occurs in place in the mesas just mentioned, resting with apparent conformity on the Upper Bridger, but pebbles derived from it are scattered over the entire Bridger area (Pll. XXXV, XXXVI), over the greater portion of which it may have originally extended. Judging from the amount of erosion which has occurred since its deposition, its age may be regarded as probably Pleistocene.

Mode of Accumulation of the Bridger Beds.

With the problem of the origin of the Bridger beds in mind, the writer searched carefully for any trace of material which might be regarded as derived by erosion from an older series, but not the least indication of such detrital deposits has been found. Although pebbles and boulders of all the rocks of the Uinta range occur in the Wyoming conglomerate, not a fragment derived from such sources has been found in place in the Bridger. The conclusion appears to be well established that the drainage from the Uinta Range during this stage of the Eocene did not reach the Bridger area. The volcanic nature of the Bridger sediments appears fully established from the abundance of sanidine grains and glass fragments. The fine grain, high angularity, and great homogeneity of these volcanic products is opposed to the idea that they were transported from a distance by streams, as under such circumstances it seems inevitable that a certain amount of admixture with foreign material must take place. On the contrary, such deposits in the Bridger as are referable to stream action have derived their material entirely from Bridger sources, with the exception of the rhyolitic pebbles noticed above

[1] Powell. Geology of the Uinta Mountains, pp. 169-171.

which may represent the scoriaceous facies of the acid magma from which the Bridger tuffs were derived. Apparently the greater portion if not all of these tuffs were distributed from the eruptive centers by the wind. The location of the explosively erupting vents is at present unknown, but there is no reason to think that they were located in the Uinta Range.

While it is believed that the wind was the principal transporting agent, there is positive evidence that a large part of the Bridger was either deposited in water or worked over by it to a considerable extent within the area of deposition. The tuffaceous shell marls may be regarded as lacustrine. The lakes in which they accumulated were remarkably wide but probably rather shallow, at least locally, and subject to fluctuations in level as shown by the accumulations of lignite which alternate with beds containing fresh water shells. The coarse sanidine sands with basal conglomerates, cross-bedding and bone pebbles are believed to be stream or delta deposits, while the fine grained greenish tuffs with frequent shells of *Unio* and abundant fish and mammal remains may be in large part flood-plain deposits.

That the Bridger accumulated in a base-leveled area may be inferred from the general absence of coarse material such as would be transported by high grade streams. The lack of kaolinization in the sanidine grains might suggest aridity but may mean nothing more than rapid burial and the absence of acidulated waters.

From the large number of fish, turtles and crocodiles in the Lower Bridger and the thin-bedded character of much of the tuff of this horizon it is believed that these beds are largely lacustrine. The Middle Bridger is partly lacustrine as shown by the tuffaceous marls and partly fluviatile as indicated by the cross-bedded sands. Wind blown sands have not been recognized, or, if such exist, the sand grains have not travelled far, as round grains are prevailingly absent. The gypsum in the Upper Bridger indicates aridity, which probably explains the almost entire absence of vertebrate remains. It is believed that these beds were deposited in playa lakes.

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April, 1906.

EXPLANATION OF PLATE XXXVIII.

Detail of one of the white bands in the Middle Bridger exposed in the east bank of Sage Creek at Sage Creek Spring.

1. Pale greenish tuff with narrow veins of calcite and gypsum, base concealed by talus.

2. Impure lignite inclosing lenses of tuff. Average thickness about 2½ inches.

3. Pale greenish tuff, 4½ feet.

4. Buff tuffaceous marl, with numerous shells of fresh water molluscs, 1–1½ feet.

5. Tuff similar to numbers 1 and 3. Thickness about 6½ feet.

6. Tuffaceous marl, locally approaching a limestone, with abundant shells of fresh water gastropods. Thickness about 5 feet.

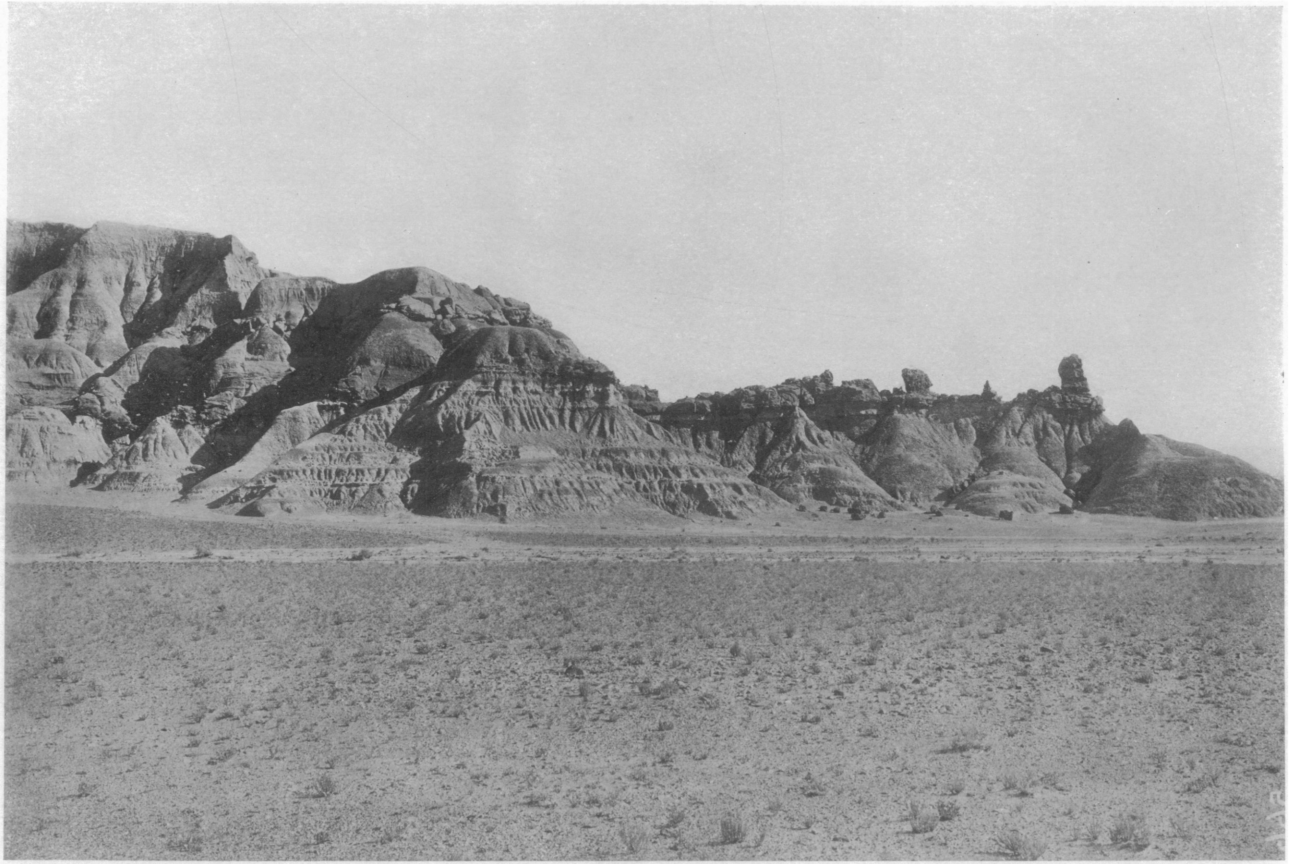
7. Impure lignite with obscure traces of plant remains. Thickness variable but seldom in excess of 2½ inches. The lignite grades into lignitic tuff with calcite and gypsum veins and this finally into a black chert occurring in lenses of varying thickness. Total thickness, excluding lignite, about 15 inches.

8. White tuffaceous shale with imperfect plant impressions. Thickness about 4½ feet.

9. Yellow tuff-sandstone. Top covered by an alluvial deposit (10) with pebbles derived from the Wyoming conglomerate.

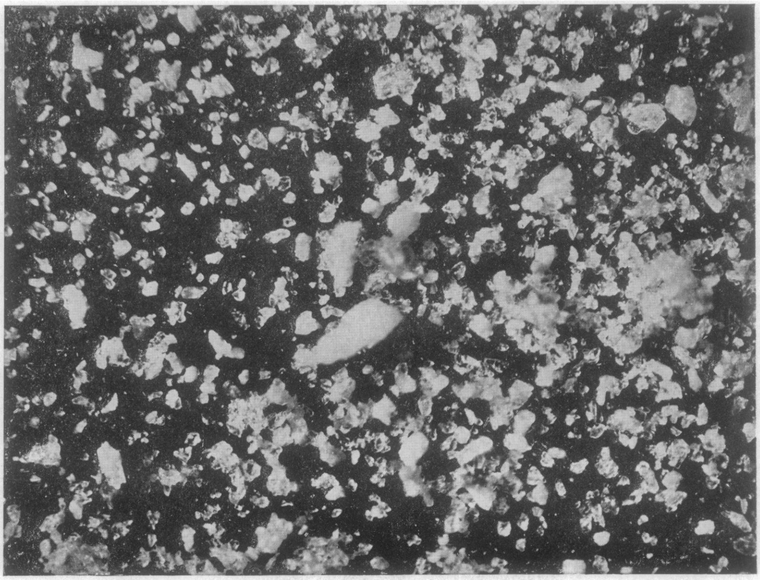
Henry's Fork Hill.

Tuffaceous marl band shown in middle distance (✠).

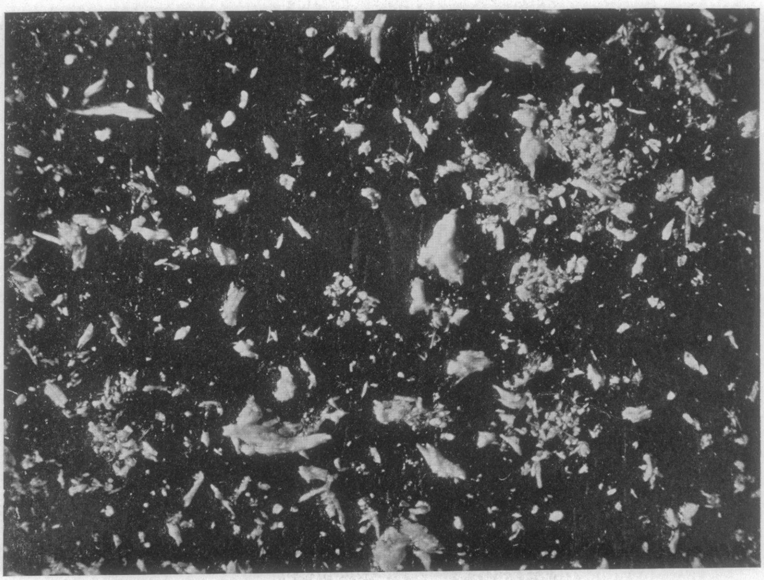


GRIZZLY BUTTES EAST.

A bed of coarse, green tuff-sandstone caps the promontory on the right.
Wyoming conglomerate pebbles in foreground.



A.



B. Photo-micro by G. Van Ingen.

BRIDGER TUFFS.

A.—Sanidine tuff from the Upper Bridger, showing abundant sanidine grains and glass fragments.
B.—Pumice from a Middle Bridger Tuff. The grains are composed of a pale brown devitrified glass.
Both figures are enlarged eighteen diameters.

SAGE CREEK SPRING.

Detail of one of the white layers.