THE

VOLCANIC TUFFS OF CHALLIS, IDAHO,

AND OTHER WESTERN LOCALITIES,

BY

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(*Abstract.*)

In a paper recently read before the Academy it was shown that a certain compact, white, almost structureless rock, often porcellanous in texture, occurring abundantly in the Western Territories, and variously styled "trachyte," "rhyolyte," "porphyry," etc., (*e. g.*, at Leadville, Colorado, in the Black Hills of Dakota, etc.), is a sedimentary form of a highly silicious volcanic tuff, probably derived from the finest detritus of trachtyes, rhyolytes, and quartz-porphyries. A series of specimens collected by Prof. NEWBERRY, during the last and previous summers, and kindly put in the author's hands for lithological examination, has furnished the material for the following additional notes on this interesting but neglected group of widespread American rocks.

1. *Coarse pumice-tuff of Challis, Idaho.*

The rock is quite compact, schistose, of a gray color, with dull white spots. The latter consist of pumice in finely fibrous grains, from 1 to 5 mm. in length. Quartz and feldspar are seen in small angular flakes, sometimes reaching 0.5 mm. in length; hornblende commonly in fibrous black fragments, about 1 mm. in diameter; and much biotite, brownish-green, sometimes brownish-black, with greasy lustre, in hexagonal scales, often up to 2 to 3 mm. in size.

The thin sections present under the microscope numerous grains, generally angular, of several minerals, varying in size up to 3 or 4 mm.: pumice in rounded to sub-angular fawn-colored fragments lying at all angles, commonly made up of straight or curved fibres, and often including glassy lenses filled with crystallites: a triclinic feldspar, in clear grains, sometimes including minute globules of glass, and possessing fine lamellation, beautifully striated in polarized light, the remaining traces of crystalline outlines indicating that these grains are all of fragmentary, never of indigenous formation: quartz, in water-clear angular grains, 0.2 to 1.6 mm. long, retaining more frequent and perfect traces of their crystalline forms, their sides being often very ragged, curiously and deeply eroded into rounded indentations, while within occur numerous inclusions of the ground-mass and of scales of biotite, long greenish needles of hornblende, and sub-angular drops of a brownish-violet glass with one or several fixed bubbles of gas; biotite in abundant

irregular scales, 0.2 to 1.3 mm. long, brown inclining to maroon or brownish-yellow, cloudy to opaque, with some dichroism remaining in the striated sections; hornblende in brownish-green, strongly dichroic, fibrous crystalline flakes; opacite, probably magnetite, and ferrite or iron-oxide, in dusty particles or groups in the biotite scales and among the pumice fibres. The fine ground-mass is mainly composed of minute fragments, fibres, scales, etc., of all these minerals; also in large part of solid globules of fawn-colored glass, or of thin and apparently hollow shells, or of fragments of quartz or feldspar coated with a glass crust. Many of these forms are found adhering in curious aggregations or with their sides crushed in.

The general constitution of this rock is similar to that of the volcanic tuff of the El Dorado Cañon, Cal.

2. *Fine green volcanic tuff, of Challis, Idaho.*

A very fine compact rock, with almost the texture of stoneware, with a pale, greenish-gray color, and a very thin parallel lamination. A few minute scales of biotite can be distinguished by the loup. The surfaces of fissures are mottled and spotted with bluish-green and ochreous, brownish-gray films.

The thin sections present the same constitution as that of the coarse variety of the rock, without the presence of pumice, the particles of quartz and feldspar varying in size from 0.06 to 0.25 mm. Biotite is abundant in scales 0.01 to 0.2 mm. in diameter, often of ochreous shades of brownish-yellow and maroon, through partial decomposition, and with curved fibres or wrinkles, as if crushed in by pressure. To its abundance are due the fine lamination of the rock and, in part, its greenish color. The ground-mass largely consists of globules of colorless glass, but in less degree than in the preceding variety, their size varying from 0.006 to 0.01 mm.

3. *Fine white pumice-tuff of Challis, Idaho.*

A very fine compact rock, grayish, with a bronze shade, with a lamination so decided that it inclines to slaty. Under the loup the same constituents are visible as in No. 1.

The thin sections show a close relationship to those of No. 2. A little hornblende is present. Biotite occurs in distinct scales, sometimes hexagonal, not so minutely dispersed as in No. 2, generally 0.01 to 0.1 mm. in diameter. The fragments of quartz and feldspar, as a rule, present their longer axes in the schist-plane, varying from 0.03 to 0.22 mm. in length. The glass inclusions in the quartz, range from 0.002 to 0.037 mm. The ground-mass appears to be mainly composed of pumice, more or less altered, in very minute fibres and particles.

This rock strongly resembles the tufa of the lignite beds near Osarisawa, Akita, Japan.

4. *Pumice-tuff, Moore Station, Pancake Range, Moray, Nevada.*

This rock is decidedly schistose, cream-colored, nearly white, of a fine grain, intermediate between Nos. 1 and 2, most of the constituents being the same as in No. 1 and less than 0.5 mm. in diameter, though occasional grains of pumice, gray and red obsidian, and perfect crystals of quartz, may reach from 2 to 8 mm. in length.

In the thin section the constituents are found disposed with great regularity ; pumice, with its fibres often curved, as if crushed while still soft and plastic: quartz: triclinic feldspar, possibly sanidine: magnetite: ferrite: biotite, salmon-colored, sometimes very cloudy: and volcanic glass in cellular network, often full of gas bubbles, elongated and distorted. In the ground-mass, globules of glass and fibres and threads of pumice largely predominate.

The pumice in all these tuffs is not perfectly isotrope between the crossed nicols, but presents innumerable, though exceedingly minute glittering points, apparently crystallites formed by incipient devitrification. A few minute sphærulites were also detected.

5. *Stratified Rhyolyte-tuff, Tempiute, Nevada.*

A snow-white kaolinic variety, related to the preceding, which appears to consist principally of pumice. A few grains of black obsidian and red quartzite occur, the latter also as a somewhat rounded pebble, 34 mm. in length.

The thin section, transverse to the schist-plane, presents an interesting structure, made up of granular layers alternating with others possessing strong fibration.

The material of the former is mostly like that of No. 4: feldspar is sparsely scattered : quartz fragments abound, with the usual glass inclusions, and with sides deeply eroded and indented: also magnetite, ferrite, and minute colorless particles of a polarizing mineral, perhaps augite, in a predominant ground-mass of particles and fibres of pumice and glass, rich in dark gas-bubbles.

The alternating fibrous laminæ consist of a true rhyolyte material, salmon-brown, with a marked fluidal structure around the few quartz-grains, and displaying in spots, and especially next the junction with granular material, the constituent pumice-fibres whose partial interfusion or cohesion seems ordinarily to have produced the solid laminæ.

The arrangement of the glass fibres in parallel planes may have been produced by sorting in the air during their fall, or by later superincumbent pressure while still hot and plastic, or it may be in some instances by the influence of overflowing lava-sheets. The cohesion produced by such downward pressure and interfusion has produced a structure which can hardly be distinguished from that of many obsidians and rhyolytes.

6. *Fine white pumice-tuff, from mouth of Bill Williams' fork of Colorado River, Arizona.*

A compact white schist, with almost the fine texture of No. 3, traversed in places by brown curved impressions, apparently produced by rootlets.

The thin section mainly exhibits a very finely felted mass of short, straight fibres of pale brownish pumice. Besides these only a very few black particles of magnetite, feldspar, etc., were distinguished.

7. *Fine brownish pumice-tuff, from last locality.*

A brownish variety of the preceding, with abundant minute black particles. The slaty lamination is decidedly marked, with slight adherence over many planes at which the rock breaks easily, presenting remarkably flat surfaces.

The constitution displayed in the thin section is similar to that of the preceding specimen. Minute glass globules are abundant, and also more numerous angular particles of other minerals: colorless feldspar (sanidine?) showing cleavage: brownish and greenish augite: brownish and dichroic fibres of hornblende, and black particles of magnetite.

8. *Stratified pumice-tuff, from Black Mountains, Colorado river, Arizona.*

A coarser stratified tuff with brown and white layers, in which grains of pumice, obsidian, glassy feldspar, and quartz reach a diameter of 1 to 5 mm.

The thin section is rich in pumice in all its fibrous, curving, and reticulated forms, and in minute globules, threads, and shreds of volcanic glass: angular grains of finely lamellated plagioclase, water-clear quartz, and sanidine with well marked cleavage and often zonal structure: particles of biotite, hornblende, magnetite and ferrite: abundant grains of augite, angular to rounded, sometimes retaining its optical characteristics in spots, but mostly decomposed and isotrope, colorless, brownish-yellow, light to deep maroon, etc., finely granular, thready, or fibrous, and more or less darkened by opacite even to complete opacity.

9. *Basalt-tuff, or peperino, Chinati Mts., Texas.*

A fine-grained olive-green rock, with white streak, friable to arenaceous, with barely perceptible schist structure in the specimen. Under the loup, minute granules of feldspar, quartz, etc., are distinguishable, rarely 1 mm. in diameter, embedded in a grayish-green cement.

In the thin section the constituents are very much the same as in No. 8, with the exception of hornblende, and all the grains are in large part rounded. A few elongated rounded grains of a basaltic lava are also included, highly microcrystalline with minute ledge of plagioclase scattered through a reddish-brown opaque base.

This specimen, and perhaps the preceding, represents the basic division of the tuffs, being ejections from an eruption of basaltic lava, though naturally composed of its more fluid, glassy, and acid scoria.

From these facts it may be concluded that enormous masses of volcanic tuffs of widely varying character are dispersed throughout these regions in the West, to an extent which could hardly be appreciated from the meagre references in our present petrographical literature.

In his discussion of the rhyolytes of the fortieth parallel, ZIRKEL remarks: *

"The foregoing descriptions show in what abundance those fibrous bodies in which the fibres are not grouped radially around a centre, as in sphærulites, but arranged axially along a longitudinal line, are disseminated through these rhyolites. ....These axiolites usually consist of distinct, uniformly thin fibres, or of wedge-like particles....We see in the arrangement of the fibres in these rhyolites four different types: *a*, centrally radial: *b*, longitudinally axial: *c*, parallel: *d*, confused and orderless. The development of fibres is, indeed, a phenomenon very characteristic of rhyolites, etc., etc."

A comparison of these facts with those presented in my examination of these tuffs appears to me significant, not of the development of fibration, etc., in a fused mass, but of the fragmental origin of at least many rhyolytes, obsidians, etc., as suggested in the study of No. 5. The evidence of the hot and plastic condition of the fibres and drops of volcanic glass, with the occasional exception of a cooled outer shell, for a long time after their fall, and of a tendency to the growth of microliths, sphærulites, etc., within them, may offer another mode of origin for the formation of axiolites and sphærulites. The anomalous presence of augite in a quartzose rock like rhyolyte, to which Zirkel calls attention in the same passage, may also find explanations in the varied intermixture of minerals which prevails in many tuffs, rather than by indigenous development within an acid lava.

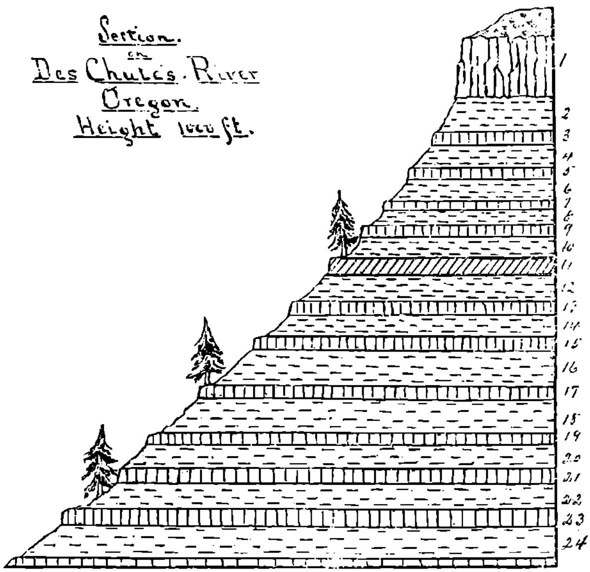
Dr. NEWBERRY said that he had no doubt that Mr. Julien was quite correct in regard to the genesis of the peculiar rocks which he had described. He had collected the specimens and was able to supply some facts in regard to their mode of occurrence. They belong to a series of rocks, plainly volcanic, but of which the history has not been given by those who have studied the volcanic rocks of the West. The circumstances of this occurrence are briefly these: over a great belt not less than one thousand miles wide, in some places, viz., from the crest of the Sierra Nevada to the eastern foothills of the Rocky Mts., and with a north and south extension of thousands of miles in British Columbia, the United States and Mexico, we have an extraordinary display of the products of volcanic action. This is the great silver belt of the world, and is also rich in mines of gold, copper, lead, etc.

* U. S. Geol. Expl. 40th Par., VI, Microsc. Petrog., pp. 201–205.

Throughout all the Palæozoic and Mesozoic ages this country was an unbroken, though not entirely unwarped, sub-marine or sub-aerial plateau, where the most continuous and extensive series of sedimentary rocks was deposited of which we have any knowledge. At the close of the Jurassic age the western portion of this region was folded up, to form the great chain cf the Sierra Nevada and Cascade Mts., and along this line of fracture numerous volcanic vents were established—Lassen's Butte, Mt. Shasta, Mt. Hood, Mt. Baker, etc.—which have continued in intermittent activity to the present day. In tertiary times the plateau east of the Sierra Nevada was broken up by a series of north and south fractures, resulting in the formation of the remarkable system of meridional mountain ranges which constitute the chief topographical features of the district. These mountain ranges are composed of blocks of Palæozoic limestones and sandstones—now converted into marble and quartzites—set up on edge or at a high angle, or of volcanic materials which have welled up through some of the fissures. Along the lines of fractures are great numbers of hot springs, the representatives of thousands more which existed in former days, and to which we owe the great system of fissure veins of this country :—hot water charged with mineral matter gradually depositing this and filling the channels through which it flowed.

The volcanic rocks which have been poured out in so many places exhibit a great variety of physical and chemical characters, but have been grouped by RICHTHOFEN and ZIRKEL into five species—propylyte, rhyolyte, trachyte, andesyte and basalt. Capt. DUTTON, who has given great attention to the volcanic rocks of the West, has distinguished a larger number of kinds and has adopted a different classification. Aside from these massive rocks there is another group which constitutes a marked feature both in the topography and geology, and these are those which have been made the subject of Mr. JULIEN'S paper. They are generally soft in composition, often highly colored—white, red, blue, green, gray, or yellow—more commonly white, red or gray. They are often quite local and usually occupy the lowlands, frequently underlying much of the level surface between the mountain ranges; and the best exposures are seen in the banks of streams which have cut these lowlands. There they are shown to be often horizontally bedded and sometimes interstratified with lacustrine sediments and sheets of basalt. Typical exposures of these rocks may be seen at Eureka, Nevada, where houses and cellars are excavated in the soft material which forms the sides of the valley ; at Challis, in the banks of Salmon River and Garden Creek, whence the specimens described by MR. JULIEN came, and in the cañons of the Des Chutes and its tributaries in Oregon.

Economically these rocks have considerable importance, as they are extensively used in place of fire-brick for lining lead-smelting furnaces, being very refractory, and easily dressed into shape with an old axe.



The above section represents the filling of some of the fresh water lakes which formerly existed in Oregon just east of the great volcanic cones of the Cascade Mountains. Numbers 1 and 11 represent sheets of basalt, the even numbers softer tuffs and beds of diatomaceous earth, the odd numbers consolidated conglomerates of volcanic materials called "concrete" in my notes.

The study of a large number of outcrops of this series of rocks from Southern Arizona to the Columbia River, has convinced me that they are generally volcanic ashes which have been washed down and more or less perfectly stratified in bodies of water which formerly occupied the intervals between the mountain ranges of the great basin. On the Des Chutes a section of more than 1000 feet shows 25 alternations of strata, many of which are examples of the rocks in question. Here they are interstratified with beds of tripoli, composed of fresh-water diatoms and layers of basalt. Some of the ash beds are almost entirely composed of lapilli of soft cottony pumice, others are finer, grey, red, white, etc., and contain the trunks of coniferous trees, and in some instances are pierced with holes which represent the stems of upright plants, thickets of which were buried by the descending showers or rapidly accumulating sediment of volcanic ash. Here the source of the materials is to be sought in the line of great volcanic vents which crown the summit of the Cascade Mountains, and from which, at intervals, were emitted either floods of lava, poured down on to the plain along the eastern border of the range, or showers of ashes which, borne inland by the prevailing westerly winds, fell on forest, savannah and lake, temporarily destroying animal and vegetable life, and forming, when falling or washed into water basins, strata which alternate with fossil-beds, the accumulations of quieter times. In other places these tufaceous deposits were washed from all the highlands into the valleys, forming local masses of considerable thickness without the intercalated beds mentioned above.

The accompanying section, copied from my report on the geology of Northern California and Oregon (Pacific R. R. Report, Vol. VI, Geology, p. 47), will illustrate the deposition of these tufaceous rocks in the lake basins where they are interstratified with the fossiliferous beds.