

THE FOSSIL FORESTS OF THE YELLOWSTONE.

BY WALTER HARVEY WEED.

THE name of fossil forest has been so often used to call attention to small collections of prostrate tree trunks of siticified wood that one scarce expects more of the locality bearing this designation in the Yellowstone Park. Yet the name of fossil forest is a most appropriate one for this collection of upright tree trunks, which, seen at a little distance, closely resemble the skeleton trunks of their living relatives near by.

The particular locality to which attention is called, and to which the name of The Fossil Forest is applied, is in the eastern part of that great national pleasure ground, the Yellowstone Park. Although easily reached by a fairly good wagon road, which forms the mail route to the little mining camp of Cooke, Montana, the locality is seldom visited, save by those vandals who have carted away its treasures by the wagon load to be shipped to the dealer in "specimens." The region is a picturesque one; the broad, wide valley of Lamar river, with its great meadows and groves of tall cottonwoods is enclosed by grassy foothills, the slopes dotted with patches of the quaking aspen. The steeper slopes that rise upward to the mural cliffs that face the valley are dark with pines and the picturesque Douglas spruce. To the eastward Soda Butte Valley penetrates the heart of the rugged Sierra, whose high peaks rise in castellated forms. The visitor, disappointed perhaps in the mountain scenery of the park, after travelling the usual route over the dusty roads of the park plateau, will here find mountain views that are sure to fulfil his expectations, while the neighborhood is not lacking in curiosities that in another land would attract visitors from far and wide.

Soda Butte, a cone of hot spring limestone (travertine) that gives its name to the creek flowing by it, is only worthy of notice as a ruin, but the cold springs near by are highly charged with mineral salts and gases, and whether the visitor be bettered in health by a glass of it or not the spring is sure to be remembered by all who have tasted its mal-odorous waters. The only accommodations in this part of the park are to be obtained here, and

though far from luxurious the cabin that serves as mail station is not lacking in the usual frontier comforts. A couple of miles from here is an area of many acres of whitened rocks, where sulphurous gases, still ascending, have formed banks of sulphur, the surface covered by a dark gray crust whose ropy forms resemble scoria and wholly lack the bright primrose color of sulphur, though composed entirely of it.

A few miles beyond is Death Gulch, whose deadly vapors have killed a number of bears, their skeletons and fur lying strewn about its bottom, while other and smaller game occasionally venture in the walls, and, succumbing to its vapors, serve as bait for the next victim. The mortuary interest of this peculiar valley of death overshadows the attention aroused by the beautiful deposits of calcite, an old hot spring deposit and the iris pools of acid chalybeate water near by.

The geological structure of this region is comparatively simple, though the details of its history required patient investigation. Lava flows and great quantities of fragmental volcanic rocks, forming beds of breccia, aggregating thousands of feet in thickness, rest upon the eroded surface of nearly horizontal limestones, carrying Paleozoic fossils. These breccias, which formerly covered the entire eastern part of the park, now form the high and rugged peaks of the Absarokas, and are cut into deep cañons, high plateaus and towering mountain summits. Since their deposition they have been covered with subsequent lava flows, while the last act of the dying volcanic forces filled the valley bottom with basalt. The volcanic breccias, which occur in beds of varying thickness, are composed of fragments of all sizes; they generally show a rude assortment, and are separated by intercalated bands of volcanic tuffs. The rocks are all andesitic and basaltic, but vary considerably in their character. It is in these beds of breccia that the fossil trees occur, their roots imbedded in the tuffs that once formed their soil, and which now contain an abundant and extremely beautiful collection of leaf remains.

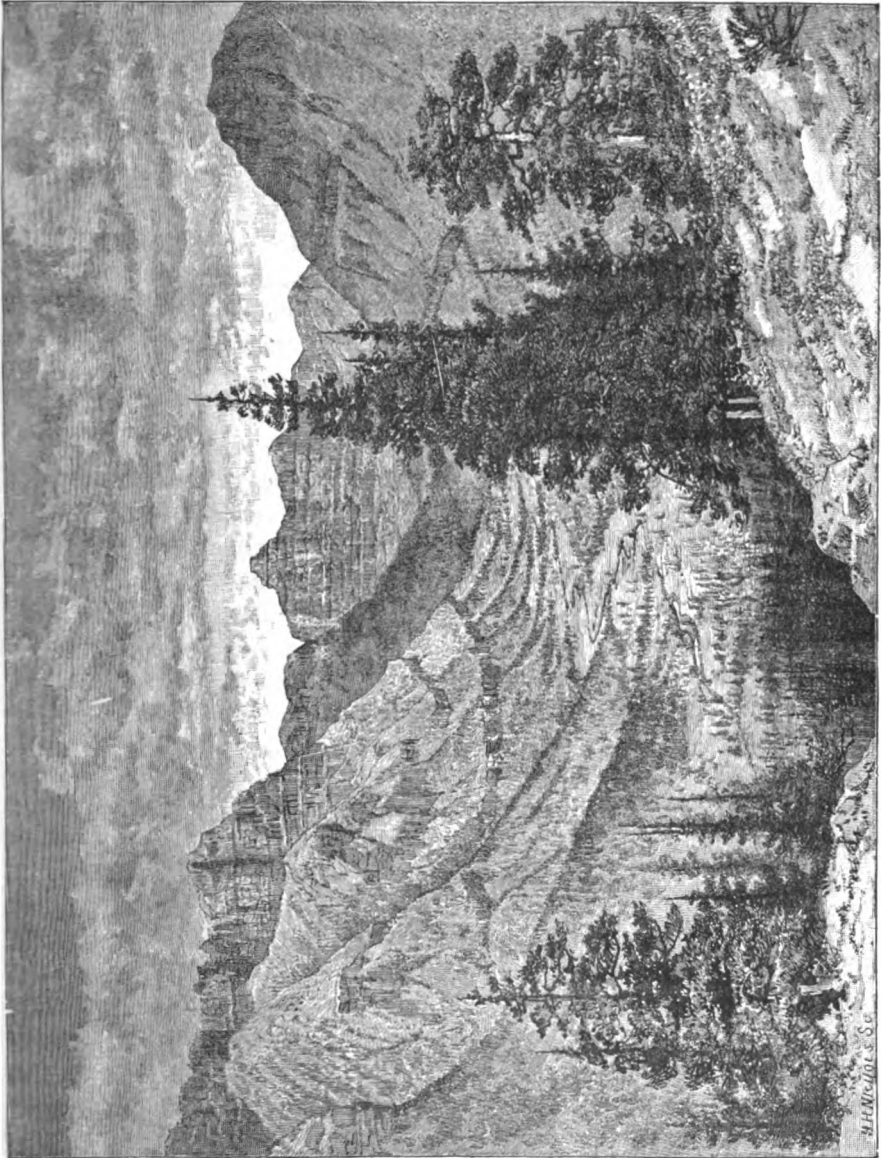
The particular locality designated as the fossil forest, for fossil trees occur at many other places as well, is the bluff wall on the west side of the Lamar Valley opposite the mouth of the Soda Butte Creek, a bare exposure of the breccia rocks and tuffs some 1600 feet in height, where the weathering of the rocks has left the tree trunks standing out in bold relief. When first discovered in

1878 the beds of breccia contained great quantities of agate, amethyst and chalcedony, but these minerals are now rarely seen, having been carried away by visitors in search of "specimens." In recent years even the fossil trees themselves have been taken away when small enough to be readily transported. The discoverer of this interesting feature of wonderland was Mr. W. H. Holmes, who made a brief study of the geology of the region for the Hayden Survey in 1878, and published a graphic account in the twelfth annual report of the survey. The accompanying plate, showing the breccia mountains and the valley of Soda Butte creek, east of the Fossil Forests, is from a drawing by this versatile artist and geologist.

These volcanic agglomerates, which, as has been mentioned, characterize this region, attain a thickness of several thousand feet in this vicinity, and are here for the most part horizontal. At certain localities, of which the fossil forest is the best known, these bedded volcanic rocks are full of upright fossil tree trunks.

Turning aside from the wagon road before reaching Soda Butte creek and crossing the grassy footslopes, the detritus from the little ravine that drains the cliffs attracts attention by the large amount of fossil wood, agate and chalcedony which it holds. Reaching the steeper slopes at the base of the cliffs the rocks are concealed beneath the abundance of flowers and grass, but sections exposed in the ravine show fine-grained beds of volcanic ash and agglomerates, in which leaf remains were found, but no tree trunks. Above these grassy slopes the steep surface of the bare buttress ridges that lead to the cliffs above are strewn with broken tree trunks and wood. Some 500 feet above the valley the fossil trees are numerous. Trunks and fragments of trees were found in great numbers and in all conceivable positions. In most cases the woody structure is well preserved, and the trunks resisting the weathering that causes the enclosing rocks to crumble away, stand out in pillars of varying heights. Cross fractures produce a tendency to break in sections on whose surfaces weathering has brought out the annual rings. Often the trees have been replaced by casts of chalcedony or agate, and frequently the trunks are hollow and lined with quartz and amethyst crystals. The large size and fine state of preservation is especially noteworthy. Upright trunks rise from a ledge as broken columns of varying heights. As these trunks break into sections by cross-fractures it is not often that they attain

any great height, the rock wearing away but little more rapidly than the trees themselves.



In many instances the roots are exposed and may be seen penetrating the solid rock that once formed the surface soil. The

largest upright trunk is an old stump 10 feet across and some 12 feet high. The woody structure is not so well preserved as is the case with the smaller trees, but microscopic sections show it to be coniferous. The bark is without structure, four inches thick and retains the outer surface quite perfectly. Prostrate tree trunks are of frequent occurrence, sometimes as much as 50 feet long and 5 to 6 feet in diameter. The higher parts of the cliff show an abundance of trunks, often 20 to 30 feet high, their roots imbedded in the fine-grained rocks, their branchless and battered trunks enclosed in the coarse breccias or agglomerates that form so large a part of the rock series. A careful study of the rocks has shown that they are all the products of explosive volcanic action or of mud flows of volcanic dust or ashes. Fine-grained shaly beds of light brown, grayish or bright green tints alternate with coarse agglomerates of non-assorted angular fragments of basaltic lavas.

The history of these buried forests is that of the volcanic agglomerates of the region, and has only been made clear by a careful study of the region for many miles to the eastward. Some forty-five miles in that direction the bedded volcanic rocks lose their persistent horizontality; are cut by massive dikes that weather out in great walls miles in extent. A high but flat-topped mountain in the rugged, almost impassable country about the head of Crandall creek has proved to be the key that unlocks the secrets of the past ages. It is the heart or core of an old volcano, and the mountain, with the neighboring country, as far away as the Fossil Forests, is indeed a dissected volcano, once rivalling Etna in size. The detailed evidence, which has been carefully worked out by the Yellowstone Division of the Geological Survey, shows that the region was once a country of hills and valleys, in which granites and Paleozoic limestones were exposed as the result of long-continued erosion. In the eastern part of this region volcanic forces found an outlet in a break through the limestones, and explosive eruptions covered the country with a heavy mantling of ashes and lapilli, and about the vent built up a cone of coarser material, the blocks of ejected lava and bombs cast out of the volcano's throat.

Lava flows succeeded, and were in turn covered beneath more volcanic *débris*, and thus a great cone was built up that the observed facts show must have been some 10,000 feet higher than the summit of the present mountains,—a great volcano, yet not larger than those of the present day.

Upon the lower and gentle slopes of this volcano vegetation flourished and forests grew up, until explosive eruptions of unusual violence buried them beneath an accumulation of ejected material. In eruptions of the active volcanoes of to-day that have been studied, similar cases are not uncommon. The eruption of Krakatoa in 1883, and of Tarawera, New Zealand, in 1886, were of this nature. The trees, stripped bare of leaves and limbs by the violent winds that accompany these eruptions, were buried beneath the mud showers and streams, and by the later fall of stones and great blocks of lava. In such a way the forests that first grew upon the flanks of the great Crandall creek volcano were buried beneath the ashes, muds, and *débris* of the eruption.

In a period of quiet succeeding, a new forest flourished and grew up, only to be in turn buried beneath the showers of rocks; and this was repeated until there were, as the cliffs now show, no less than ten or more buried forests, one upon another.

Since the dying out of the volcano, wind and rain and frost have carried away the cone and laid bare the plug of lava that filled the heart of the old volcano, and its flanks now form the mountain ridges, peaks, and plateaux of the present country. It is only about the flanks of the old volcano that fossil trees are found, as it was only there that vegetation flourished in the intervals between the greater explosions of the vent. To-day the streams have cut deep cañons in the volcanic rocks, and again exposed the underlying limestones and granites to view.

The trees thus buried have been beautifully preserved. Prostrate trunks and upright trunks alike are as perfect in form as the day they were imbedded in the rocks. By what process has the soft and perishable woody tissue been converted into stone is a question often asked. If a piece of the petrified wood be ground down until it is almost transparent and examined under a microscope, it will be found to show every detail of the woody structure as perfectly as a slice from the wood of a modern tree, yet the material is wholly silica. It is evident the process of transformation has been a most thorough and, we are led to believe, a slow one. The actual silicification of pine wood about the present hot springs of the Park has led to a belief that it was by a similar agency that the petrification of these forests was accomplished. This is not, however, the case. The rocks about them do not show the alteration produced by hot waters, but rather the infiltration of sur-

face waters, which, charged with silica derived from the readily soluble minerals, found an easy passage through the porous rocks. The rotting wood wetted by these waters produced a chemical precipitation of the silica, particle by particle, until the entire trunk was fossilized, and the centre often filled by the beautiful crystals of limpid quartz or amethyst now so often found. Not only were the trees thus silicified, but the seams and crevices of the rocks were filled with silica, and, later, by calcite from the percolating waters.

The geological importance of the Fossil Forests lies in the light the trees and leaf remains throw upon the nature of these ancient forests. The leaf impressions, so abundant in certain layers, show a wide variety of trees of types referred to the Miocene age, so that they afford evidence, which a study of other features of the geology of the region confirms, of the time at which this volcano was active. The leaf remains are often quite beautiful, the dark-brown color showing in most pleasing contrast to the bright-green tint of the rock itself. Delicate ferns flourished beneath great conifers, and tulip trees, walnuts, maples, and other congenitors of living species formed great forests.

A large collection of plant remains from this region has been made, and is in the hands of Prof. L. F. Ward, of the U. S. National Museum, for examination, so that an interesting account of the flora of this olden time may be expected soon.

CONTRIBUTIONS FROM THE MINERALOGICAL LABORATORY OF COLUMBIA COLLEGE.

BY A. J. MOSES AND L. MCL. LUQUER.

ALABANDITE FROM TOMBSTONE, ARIZONA.

ACCORDING to the description of Mr. Staunton, the Superintendent of the Tombstone Mining Company, a mineral, which we have determined to be the manganese sulphide alabandite, was found in April, 1891, "in the footwall of the Lucky Cuss fissure-vein in a pure white, strongly crystalline limestone. The mineral was found by following a body of oxide of manganese and lime spar ore which gradually merged into it, reaching a point where there was little else, and this afterwards gradually merging into the sulphides of iron, zinc and copper, with still a small amount