

support of the most ancient and stately of European thrones.

Signed by order and on behalf of the Members of the Alpine Club,

JAMES BRYCE, President.

H. G. WILLINK, Vice-President.

F. O. SCHUSTER, Vice-President.

A. L. MUMM, Hon. Secretary.

Home Office, Whitehall, 29th March, 1901.

Sir,—I am commanded by the King to convey to you hereby His Majesty's thanks for the Loyal and Dutiful Resolution of the Members of the Alpine Club expressing sympathy on the occasion of the lamented death of Her late Majesty Queen Victoria, and congratulation on His Majesty's Accession to the Throne.

I am, Sir, your obedient servant,

CHAS. T. RITCHIE.

A. L. Mumm, Esq., Alpine Club,
23 Savile Row, W.

THE GRAND CAÑON OF THE COLORADO RIVER.

By TEMPEST ANDERSON.

(Read before the Alpine Club, February 12, 1901.)

I HAD long dreamed of a holiday in the Far West, but had always been deterred by the distance and by the length of time involved. However in the spring of 1900 I resolved to make the attempt, so I wrote to my friend Professor Davis, of Harvard, for information. I got the inspiring reply, 'If at all possible come at once and join a small party of geologists who start in a fortnight to explore the Grand Cañon region.' Here was the chance of a lifetime, so I made most rapid preparations, packed my photographic apparatus, and caught the 'Lucania' for New York, where I arrived with two or three days in hand. If I had been a day sooner I should have had time to go to the South and photograph the total eclipse; but it could not be done, so I filled up the time by visiting Washington. I lunched at the mess of the Geological Survey, and heard from several who had just returned the account of their yesterday's eclipse experiences, which were extremely interesting and exciting. The party included such men as Gilbert, the explorer of many parts of

the Far West, and Hague, who surveyed the Yellowstone. All seemed to vie with one another in giving me information which proved most useful in the later part of the journey, though of course while I was in the Cañon district with such men as Davis, Dodge of Columbia, and Gregory of Yale I had no need of extraneous assistance. We took the train *via* Chicago to Flagstaff, on the Santa Fé Railway, a distance of over 2,600 miles, gradually picking up our party of six all told—viz. Barrett at Chicago, and Weatherill, our outfitter, at Flagstaff. The latter is in charge of the Hyde exploration among the Zuni Pueblos, and his knowledge of the country and experience in travelling proved invaluable. At Flagstaff we left the railway and civilisation, and spent twenty-one nights in the open without tents, though in that excessively dry climate this involved no hardship. We eventually came out at Milford, the end of a short branch line of railway south of Salt Lake City. Though the distance as the crow flies did not probably exceed 180 miles we zigzagged about in the desert so much that it was calculated we covered between 600 and 700 miles by various combinations of buggy, saddle and pack horses, and 'pie waggon.' Undoubtedly if the traveller is a good rider a saddle horse is the best mode of conveyance, and occasionally it is necessary to use pack horses, but in most places it is possible, though sometimes difficult, to get a waggon which will serve as a base of supplies from one camping place to another. One of the great troubles is the scarcity of water, and détours have frequently to be made from what would otherwise be the most desirable route in order to obtain it. We often travelled from 30 to 40 miles from one spring to the next.

The district of the Colorado plateaux is continuous on the north with the high plateaux of Utah, and the two together present a succession of strata from the Archæan, in the bottom of the cañon, to the late Tertiary. The depth of strata measured in the escarpments is about 10,000 ft., but as the dip is slightly to the north the actual elevation is only about 3,000 ft. to 4,000 ft. greater to the north. Flagstaff is about 7,000 ft. above sea-level. A series of great faults, or monoclines almost equivalent to faults, run roughly north and south, throwing the Carboniferous strata of the Kaibab plateau, the backbone of the region, several thousand feet higher than they are either to the east or west, where they are deeply covered by newer formations. The Colorado River runs across the district with many windings and zigzags, but in a general direction from north-east to south-west. It has cut for itself

a gorge or cañon in places over a mile in vertical depth, which presents scenery absolutely without a parallel in the world. The deeper parts of the cañon show almost vertical walls of 1,000 ft. to 2,000 ft., and the width is in some places not much greater, while the parts nearer the surface of the plateaux, which have been longer exposed to denudation, attain a width of 5 or 6 miles, and are weathered out into a series of 'buttes' and pinnacles of the most fantastic shapes, comparable to temples, pagodas, and pyramids of gigantic size. The strata of which they are composed are brightly coloured, the predominant colours being warm reds, yellows, and chocolates, but with an admixture of blues, bright greys, and occasional greens. The strata are almost horizontal in the upper portions, and with a field glass can be traced for many miles in corresponding positions in all the various fantastic outliers, as well as in the actual walls. We descended by a rough trail nearly to the bottom of the cañon, and should have gone further had it not been for the intense heat. As it was we were rewarded by a view of the great unconformity in the opposite wall. Near the bottom the cañon is cut into a large mass of Archæan crystalline rock, the surface of which had obviously been a good deal weathered in remote ages. A series of strata, probably silurian, had very early been deposited unconformably over this nearly horizontally. Later on these had been considerably tilted, and their surface in turn weathered down to an almost horizontal plain, on the top of which the carboniferous strata had been laid down and still remain practically horizontal, and some dykes and intrusive sheets of columnar basalt, of which more hereafter, had then been injected. Later again, probably during the slow upheaval of the whole mass, the present cañon had been excavated by the river, and now we, standing on a suitable point, can see in the opposite wall of the cañon as plainly as if we could touch it the Archæan rocks, the wedge of silurian, the edge of an intrusive sheet, and the horizontal strata above. They are absolutely inaccessible, but truly this is a land of geology by telescope.

We had had a two days' drive from Flagstaff to the cañon, and, after spending two days examining its south bank, we started to make a *détour* to the east, in order to get round to explore the country to the north; and to do this we had to return a day's journey south to Cedar Springs (as there was no other water for many miles), then north-east to a ford over the Little Colorado River, which further north runs in an impassable cañon, and then north along the base of the



T. Anderson, photo.

THE GREAT UNCONFORMITY. GRAND CAÑON.

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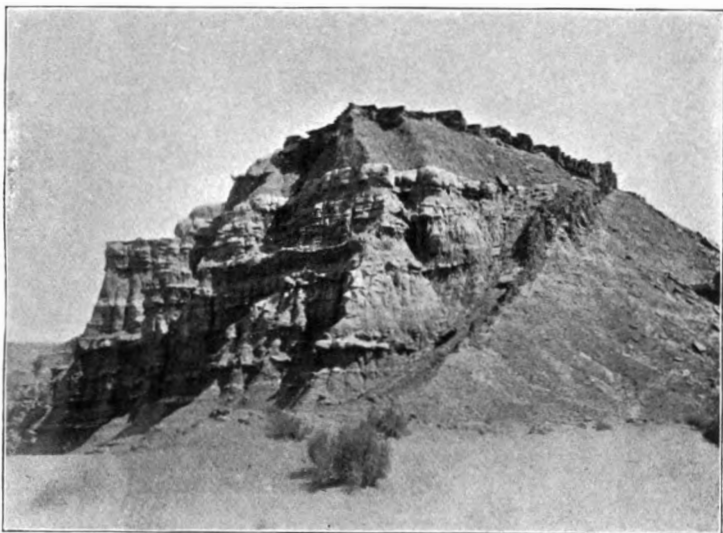
famous Echo Cliffs to Tuba City, and thence to Lee's Ferry, the only possible place for crossing the Great Colorado River. The traveller's routes and camping places in the Arizona Desert are determined almost entirely by the position of the springs, which are few in number, often scanty in quantity, and frequently alkaline and unwholesome. At Tuba City there is a copious spring, and consequently each house has an irrigated garden, which produces vegetables and fruits in abundance. The soil would be everywhere most fertile if only there were sufficient water available.

Next to the Grand Cañon the most striking feature of the district is the cliffs; every plateau ends towards the south in a range of cliffs, not indeed accurately south, but with numerous promontories and recesses, often many miles in extent, and each cliff is the outcrop of one or more geological formations. The range which comes next on the top of the Carboniferous plateau in which the cañon is excavated is the Vermilion Cliffs, which are of the Triassic age and extend from Lee's Ferry first south and then west, forming the edge of the Pariah Plateau and further on the Kanab Plateau. They are in places a thousand feet or more in height, and weathered into shapes almost as fantastic as the cañon walls. For many miles about Jacob's Pools, and again near Kanab, they had at the base a layer of blue clay, which contrasted finely with the red rocks above. Further north again, as we approached the Valley of the Virgen, there were dazzlingly white cliffs of Jurassic age. Each of these formations seems to have its characteristic mode of weathering, which sufficiently distinguish them even at a distance of many miles, though of course there is a family likeness. The cause of their fantastic forms must be sought in the peculiar circumstances under which denudation has acted. The region is one of the driest in the world—so dry that there is no vegetation in most places to protect the underlying rocks. Then the sun beats with intense power, and obviously is likely to render the baked surface of different hardness from the deeper portions, and the rapid alternate heating and cooling sets up differential expansion between the various layers, which is often enough to shiver the hardest crystal, while the few rain storms are apt to be tropical in their violence. Add to this that there appears here to have been no ice age to smooth down weathered crags, and I believe we have the explanation of the extraordinary scenery.

No description of the plateaux would be complete without allusion to the volcanoes, and volcanic rocks are almost every-

where in evidence. The first we saw was Mount San Francisco, near Flagstaff. It is a magnificent mountain of nearly 13,000 ft., standing prominently out alone from a plateau not above 7,000 ft. high, and though surrounded at its base by numerous parasitic cones it is so immeasurably the larger that they do not sensibly interfere with the general effect. It is pointed, and had a good deal of snow on its northern face. It appears to be an old volcano in a stage of denudation comparable to Mont Dore, in Central France, and, like it, associated with a great number of small 'puys,' reminding me much of those in Auvergne, though, unlike them, they appeared to almost surround the mountain. I had often wondered whether the chain of Puys in Auvergne received their supply of ejecta from a fissure or fissures which communicated deep down in the earth's crust with that which ages before had supplied Mont Dore, or whether the source was altogether separate, and their proximity the result of accident, and it was very interesting to see here a very similar case in which the newer puys surrounded the older pile, and were obviously part of the same system. I was very anxious to try an ascent, and to explore the district, and feel sure that in some of the gullies there must be springs, or at any rate water from the melting snow, where a camp could be pitched as a base for excursions. Unfortunately my friends had barely time to see the cañon, and could not include a detailed examination of the mountain in their programme.

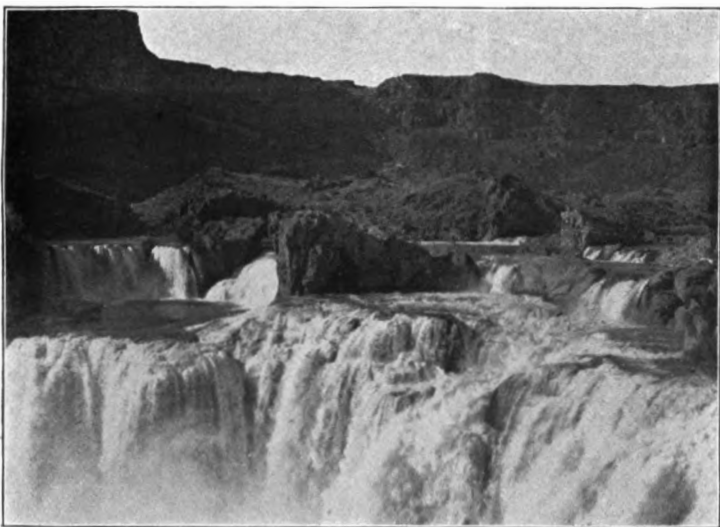
Then on the north of the Grand Cañon and a little more to the west are Mount Trumble and Mounts Logan and Emma, which are all volcanic. We ascended Trumble, and found it much denuded, like Francisco, and, like it, surrounded with an array of recent-looking cinder cones, from which flow several basaltic lava streams, some old and now capping ridges and hills, others quite recent-looking. One of the cones, Vulcan's Throne, described by Dutton, is close to the brink of the cañon, so near that it seems odd that the lava did not find its way out into the bottom of the cañon, especially as intrusive sheets of what must have been at the time liquid basalt have been able to insinuate themselves among the strata composing its wall. It would appear that these sheets and dykes are of very different ages. Some of those in the walls of the cañon are obviously older than the date of the cutting of the cañon and the formation of the present surface features, and the same may be said of such dykes as that shown in the annexed figure, while some of the lava flows are so recent that they actually cascade down the



T. Anderson, photo.

Swan Electric Engraving Co.

A BUTTE WITH VOLCANIC DYKE.



T. Anderson, photo.

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SHOSONE FALLS. SNAKE RIVER.

walls of the Toroweap valley and into the deeper parts of the cañon itself.

Further north again along the Hurricane Ledge, and especially near where it crosses the valley of the Virgen, are many cinder cones and flows of basaltic lava, some old, some modern. It was heart-rending to be obliged to leave them unexamined in order to keep up with the party, but there was no help for it; their time was exhausted. I must not be thought ungrateful. Without my friends' assistance I should never have made this most interesting excursion, and I must not for a moment be considered as in the slightest degree blaming them for their haste, which was inevitable. But to the lover of volcanoes it was like being called away from a feast before the grouse was reached.

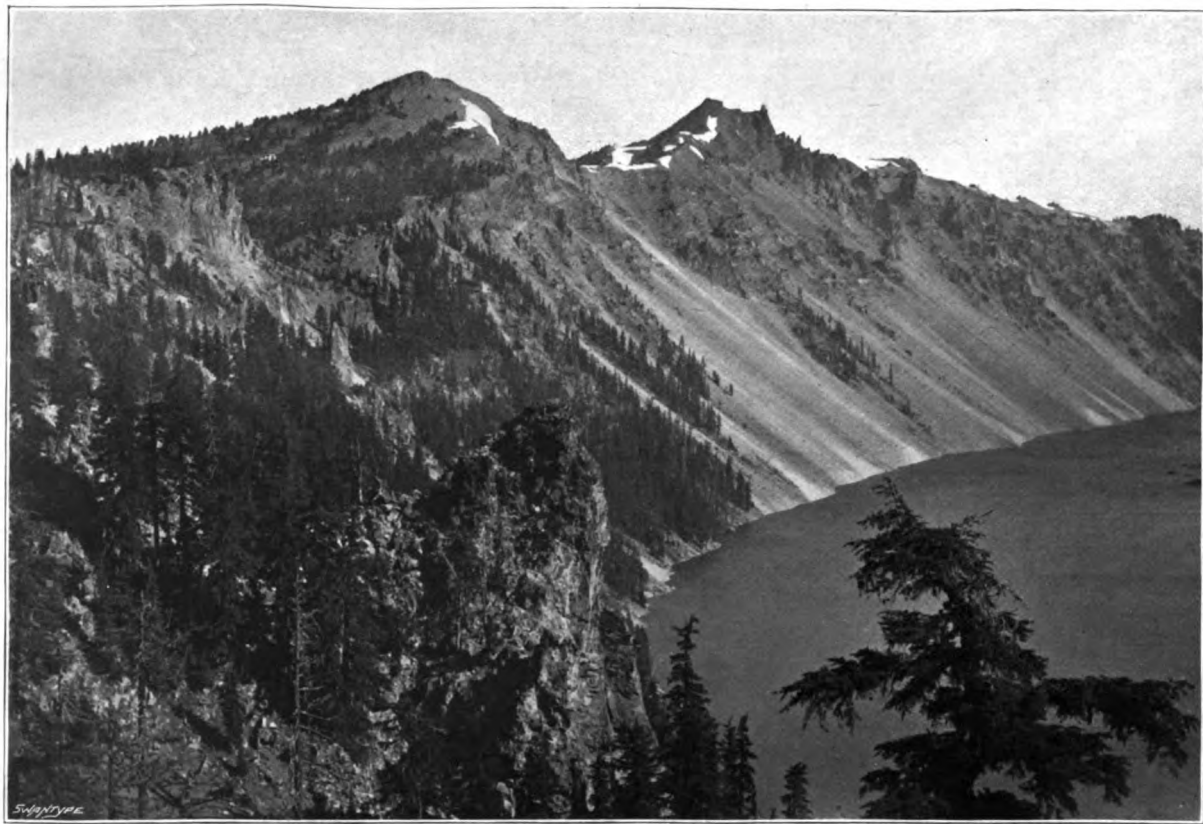
The climate, as already mentioned, is very hot and dry. During the day the solar radiation is intense, owing to our being without the protection of a layer of 7,000 ft. or more of the densest portion of the air, and the temperature of the air is often 100° or more; but directly the sun sinks radiation is for the same reason very active, and the temperature sinks rapidly to 40° or 50°, or even lower, but the air is so dry that no inconvenience is felt. We slept the whole time without tents, and enjoyed to the full each night the marvellous brilliancy of the stars or moon as the case might be. The clearness extends far down towards the horizon. We saw Mercury on three nights with the naked eye, a sight which might not be witnessed in a lifetime in England.

After leaving the Grand Cañon district I visited the Salt Lake of Utah, and saw the wonderful terraces formed by the old shore lines of the ancient Lake Bonneville, so graphically described by Gilbert.

After this I went to the Snake River basalts. These lava beds cover the country for hundreds, perhaps thousands, of square miles to a depth of several hundred feet, and appear to have been the result of eruptions through fissures in the earth's crust, and not to have been ejected from one single habitual vent. I visited the Shosone Falls, the so called Niagara of the West, where the Snake River has cut for itself a new cañon through several hundred feet of the basalt, and well into the Archæan rock on which it rests. The falls themselves pour into a chasm 180 ft. deep excavated in the older rock. There is a most interesting deserted cañon with a series of dry waterfalls in it parallel to what is now the main stream. The Snake River basalts reminded me strongly of similar beds in Iceland, where the fissures are still visible and can

be traced for miles under the bases of rows of small craters. Here the presence of fissures is more a matter of inference. It would have been very interesting to have searched for some, but my outward railway ticket had only one more day to run. (Moral : Confound railway tickets !)

The Crater Lake in Oregon was perhaps after the Grand Cañon the most striking single thing I saw. The Cascade range of mountains is a continuation north of the Sierra Nevada, and runs parallel to the Pacific Coast from Mexico to far up into British Columbia. Beginning with Mount Shasta, in California, it is studded at intervals of from 20 to 100 miles with magnificent pointed mountains, all old volcanoes more or less denuded, and varying from 9,000 ft. to 15,000 ft. in height. They are all snow-capped, and, as they tower several thousand feet above anything in their respective neighbourhoods, are very striking features in the landscape. Among them may be named Mounts Pitt, Hood, Rainier, and St. Helens, and the Crater Lake occupies a place in the series north of Mount Pitt. The Crater itself is about 8 miles by 6 miles, and is surrounded by almost precipitous cliffs rising about 2,000 ft. above the level of the water, which is itself about 2,000 ft. deep in parts. The highest point of the rim is about 8,000 ft. There seems no reason to doubt that the Crater Lake is the basal wreck of a great volcanic pile, comparable to Shasta, which has been in comparatively recent geological times destroyed by an explosion or explosions comparable to that which destroyed Krakatoa in our own day. The country round is thickly covered with debris, apparently the result of the explosion, though not recent enough to be uncovered by vegetation. Since my return I find it has been supposed that the lake has been formed by a volcanic subsidence, and not by an explosion or explosions. Not having seen the Hawaiian craters—some of which are supposed to have been so formed—I am not able to compare them, but I have seen many volcanic subsidences in Iceland with which this crater had nothing in common, while I was strongly reminded of the Crater Lakes of the Eifel, and of the craters of Monte Somma, and the Cañadas at Teneriffe, all of which are recognised as explosive. Moreover there are structures at the crater lake which appear inconsistent with any other theory than that of explosion. At the place in question the lip of the crater almost to its edge is composed of volcanic beds dipping outwards in the usual way, and evidently undisturbed, while the lip itself is formed of a mass of volcanic agglomerate of quite different texture, and composed of frag-



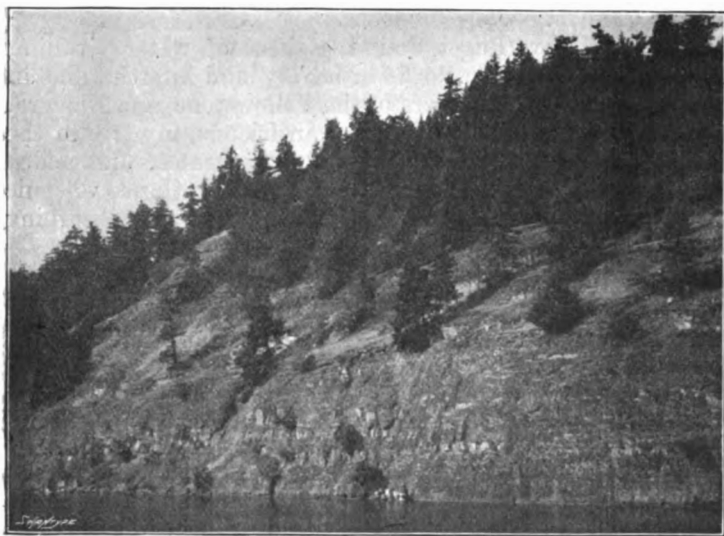
T. Anderson, photo.

CRATER LAKE, OREGON.

Swan Electric Engraving Co.

ments the angles of which appear a good deal rounded. This mass lines the inside of the crater for some depth, and ends in a vertical precipice facing towards the lake. Its presence appears conclusive proof that the crater was formed by more than one explosion, and that some of the materials blown out in the earlier stages fell back and became consolidated, and were not completely removed in the later stages of the eruption. The little island in the lake with its small crater is also a typical cone such as generally forms in a big crater during the cessation of an explosive eruption.

Crater Lake is rather an inaccessible place. A visit to it



ON PUGET SOUND.

involves a journey of about 100 miles each way to and from Ashland, the most convenient railway station. The road, or trail, for in places it scarcely deserves the title of road, runs almost all the way through primeval forest. It passes on the way Pelican Bay, on Klamath Lake, where is a lodge, a charming resort for fishermen, hunters, and naturalists. At Pelican Bay Mount Pitt looks temptingly near, and I determined to make an attempt on it. I got a man who said he knew the way to the foot, and we started with a saddle horse each, and a pack-horse with blankets and two days' provisions. We followed a trail where there had once been a waggon track through the woods, and, though it was

much obstructed by fallen timber, reached without much difficulty a lake where we bivouacked. We could get glimpses of the mountain, and it looked not more than 2 or 3 miles distant. There was one arête which seemed easy, if only we could get to its foot. We started through trackless forest much obstructed by fallen trees, and in some places by dense undergrowth. At last we reached a place where we got a more open view, and thought we must have struck our ridge. We toiled up among big rocks, and, when it was too late, found we had struck the wrong ridge, and reluctantly turned back. It was too late to try the other. If I had had a companion accustomed to climbing we could have done better.

Later on I saw Puget Sound, a sheet of water rivalling some of the Norwegian fjords in beauty and interest, and in returning visited the geysers of the Yellowstone, and Niagara. Thus, thanks mainly to my American friends, my trip to the Far West was very successful and pleasurable, and added largely to my practical acquaintance with those volcanic phenomena which have always had for me an absorbing interest.

THE INFLUENCE OF HIGH ALTITUDES IN MOUNTAINEERING.

By MALCOLM L. HEPBURN, M.D., F.R.C.S.

(Read before the Alpine Club, April 2, 1901.)

THERE is nothing more humiliating to the feelings than to try to assume the position of being an authority on any particular subject, be it scientific or otherwise. I can hardly describe the sensations nor show in how many various ways they can be brought about, but I would invite those who are not familiar with them to try the experiment of working in any way they please at some special subject, preferably one about which they fondly hope little is known and few people have written.

Under these circumstances you can readily understand that when our Secretary asked me to read a paper on the influence of high altitudes in mountaineering, I consented to do so with some degree of reluctance. Two other reasons made me hesitate. One is, that, having no personal experience or physiological discoveries to place before you this evening, there are many here far better fitted than I am to unravel this complex problem; and I feel, in this age of original