VIEW OF PART OF THE MERCED CAÑON WITH THE VERNAL FALL, YOSEMITE VALLEY, CALIFORNIA
(From Report on Geological Survey of California by C. J. D. Whitney, State-Geologist)

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CAÑONS

TO the south of Salt Lake and the Mormon Territory lies a dreary series of plateaux traversed by the Colorado river and its tributaries, which bear their burthen of waters into the Gulf of California. Though this region possesses many considerable streams, it is over large areas a kind of desolate wilderness, for instead of irrigating the ground these streams flow in profound gorges, which serve as natural drains to carry off the water which may fall upon the tablelands. Many fabulous tales have been told of these regions, their natural marvels receiving many amplifications as they came to be rehearsed by Indians, trappers, and adventurous wanderers into the far west. In 1857 the Government of the United States despatched an expedition to explore that little known portion of the Continent, and the report published by the expedition in 1861 gave the first trustworthy and detailed account of the Colorado region. The truth turned out to be almost stranger than the fiction. A vast territory was found to be intersected by ravines leading into the main line of gorges of the Colorado. These ravines, or cañons as they are termed, meander over the table-land as rivers do over alluvial meadows; but they are thousands of feet deep—hundreds of miles long, and so numerous that the country traversed by them is said to be impassable, save to the fowls of the air.

The longest and deepest gorge is the Grand Cañon of the Colorado. Its length was set down by Dr. Newberry as about 300 miles; and its walls were described as rising steeply, sometimes vertically, from the margin of the river which filled the bottom of the ravine, to a height of from 3,000 to 6,000 feet—a line of precipice or natural section which has not yet found its equal on any other part of the globe.* Attention has lately been again called to this remarkable gorge by the interesting narrative in Mr. Bell's "New Tracks in North America," and by the fuller details, as yet only partially published, obtained by an exploring party under Colonel Powell, of the United States army. By successive travellers and Government expeditions the gorges of the Colorado had been reached here and there. The surveying party of 1857-58 mapped them out and gave many admirable drawings of them, but declared the river not to be navigable above the Black Cañon. Profiting by previous failures, and by all the information which he could receive from Indians and others, Colonel Powell conceived the bold idea of attempting the descent of the Colorado in boats. After months of toil and danger, he succeeded in forcing the passage of these forbidding gorges, and emerging safely at their further end. From his survey it appears that the Grand Cañon is 238 miles long, and from 2,500 to 4,000 feet deep. But though this is the longest, there are other ravines of hardly inferior dimensions. On the Green River, Col. Powell's party navigated a series 190 miles long. From where the Green River joins the Colorado, they passed through a succession of cañons for a distance of 256 miles before they came to the Grand Cañon.

HEAD OF MERCED AND TUOLUMNE RIVERS (See Geology of the Sierra Nevada in Whitney's Geological Survey of California, pp. 415–419)

Each cañon has tributary cañons: these again have often also their tributaries. In some places the lateral gorges crowd so closely together where they join the main one, that they are divided by perpendicular walls of rock, which seem so narrow at top as hardly to furnish footing for a man, though in reality large enough to support cathedrals. And these walls shoot 2,000 or 3,000 feet above the river, "while rocks and crags and peaks rise still higher, away back from the river, until they reach an altitude of nearly 5,000 feet." They consist to a large extent of brown, grey, and orange-coloured sandstones, gently inclined or horizontal, beneath which marble and granite in some places have been deeply trenched. In some places

* See Dr. Newberry's section of this gorge in NATURE, No. 6, p. 163.

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the walls are so absolutely vertical, that it is impossible to find a pathway between their base and the water. But where, owing to rapids, some portage was necessary, the explorers usually succeeded in carrying their stores, and sometimes even their boats, along the base of the cliffs.

The water of the Colorado River is red and muddy. It receives some tributary streams of clear water, but others are very turbid, particularly one which the expedition appropriately marked as the Dirty Devil. Moreover, after every heavy shower of rain, "cascades of red mud pour over the walls from the red sandstone above, with a fall of hundreds of feet." We await with interest the detailed report which Colonel Powell will furnish of these features of the river.

Dr. Newberry, who described this territory in the report of the former Exploring Expedition above referred to, declared his opinion that, notwithstanding the stupendous scale on which these cañons or ravines had been formed, they were all nevertheless true river-gorges, excavated by the erosive action of running water. Some geologists, as Dr. Foster of Chicago, in his recent work on the Mississippi Valley, have opposed this opinion, and have suggested that "the form and outline of these chasms were first determined by plutonic agency." But Dr. Newberry's explanation has been very generally accepted. He showed that there is nowhere any trace of fracture or disturbance, and that when the Cañon is dry its rocky bottom shows no mark of dislocation. Indeed, when we consider the intricate ramifications of these cañons, so precisely similar to the ordinary outlines of a drainage system over a low flat ground, it seems impossible to conceive of any agency capable of producing such ravines save the streams which flow in them.

But if cañons are merely the results of ordinary river erosion, why do they not occur everywhere? To such a question we may reply that river-ravines do occur everywhere, but it is only where the special circumstances which favour the formation of such ravines are most fully developed that they grow into the depth and length of cañons. What then are these special circumstances?

If we watch what takes place along the course of the rivers of this country, we can mark two kinds of erosion distinctly at work. First there is the river, grinding down the sides and bottom of its channel by sweeping along sand and shingle; and, secondly, there is the action of rain, springs, and frosts perpetually loosening the sides of the water-course, and sending the débris into the river which sweeps it away. If the river were not interfered with by these other subaërial agents, it would in time dig out for itself a gorge with more or less precipitous sides. But in proportion as these agents come into play, the ravine-like character passes into that of a valley with sloping sides. Where river erosion predominates we have ravines, where it is modified by rains and springs, but especially by frosts, we have valleys. Many of our rivers run both through gorges and along valleys, the changes in the nature of their banks being determined by corresponding changes in the nature and grouping of the rocks of which these banks consist, and the greater or less facility with which the rocks have been worn away by the one form of denudation or the other. The conditions needful for the formation of cañons, therefore, appear at present to be chiefly these:—1st. The erosive power of the streams must be greatly in excess of that of the other forms of atmospheric denudation. The rainfall must be small, or, at least, so equally distributed over the year as to reduce pluvial action to a minimum. Frosts must be equally rare and unimportant. The main streams drawing their supplies of water from a distance, either from melted snow or abundant rainfall in the upper parts of their basins, must be maintained in sufficient volume to keep their channels full, either for the whole, or a good part of the year. 2nd. There must be a considerable uniformity in the character of the rock which the stream has first to cut through. It is not necessary that the rock should be soft, but it should preserve for a long distance, and present to the erosive action of the river, the same kind of geological texture and structure. Hence, horizontal or gently undulating strata, as of sandstone, or limestone, offer the greatest facilities for the erosion of cañons, as we know they do in our own country for the formation of ordinary river-ravines. When once the river has excavated its channel so deep that it cannot quit it, the nature of the rock may vary indefinitely without materially altering the aspect of the cañon. Hence on the Colorado, while the upper and chief part of the cañon has been cut through flat sandstone, limestone, and other strata, the lower portion has been excavated in marble and even in granite. 3rd. The country must be sufficiently elevated above the sea, either originally or by subsequent upheaval, to permit of a considerable declivity in its river-channels. The slope must be sufficient, not merely to let the water run off, but to give rise to currents strong enough to sweep along sand and gravel, and to excavate pot-holes. It is by the ceaseless grinding of such detrital material along the bottom of the river that the ravine is slowly deepened. Geologists, although they have constantly recognised this action, have not, perhaps, been always fully aware of its rapidity and extent, partly, no doubt, from the want of reliable data as to the nature and amount of the detritus pushed by rivers along the bottom of their beds. Messrs. Humphreys and Abbot computed that the Mississippi annually pushes into the Gulf of Mexico 750,000,000 cubic feet of gravel and sand, "which would cover a square mile about twenty-seven feet deep." The writer of the present paper was surprised a few years ago to find that the Rhine, after escaping from all its ravines and entering the low country about Bonn, retained force enough to drive along shingle upon its bed. By laying the ear to the bottom of a boat floating down mid-channel, it was easy to hear the grating of the stones as they rolled over each other. Hence we see that a river, which may be perfectly navigable by steamers, may yet have rapidity enough to scour its bed with coarse shingle. The scour will, of course, be greater in proportion to the narrowing of the breadth of the stream and the increase of the slope.

It is mainly this eroding action which, so far as we know at present, has carved out the cañons of the Colorado. These wonderful ravines, meandering as ordinary rivers do, have sunk inch by inch into the country, retaining their original curves and windings, though continually increasing in depth. Unassisted, or aided but feebly, by the other subaërial agents, which, in such a country as ours, tend to break down the walls of ravines; and undisturbed by the inequalities of surface so characteristic of regions that have been under the influence of glacier-ice,* the rivers, probably once much fuller than now, have been allowed to dig out their gorges through the table-lands of the Colorado, and to convert a tract of country, originally, perhaps, green and well-watered, into a dreary desert, intersected by a network of profound impassable ravines.

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SCIENTIFIC SERIAL

Revue des Cours Scientifiques, February 19.—This number contains a list of subscribers to the Sars Fund; also a lecture delivered at the Sorbonne by M. A. Cazin, on "Motive Power," in which are described the laws obtaining in regard to those natural forces which are already made available as sources of motive-power and the application of some other forces which may probably be turned to account in the same way as science progresses; for instance, the application by M. Mouchot and Ericsson of solar heat for working a steam engine is especially mentioned as worthy of consideration; and the application of the force of tides suggested by M. Tommasi.

* The absence of any trace of glacial action on the Pacific slope is noted by Whitney (Proc. Acad. Nat. Sciences, California, iii. 272), and by Foster ("Mississippi Valley," p. 358).

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