GEOLOGY OF THE GRAND CAÑON.

Tertiary history of the Grand Cañon district. By CLARENCE E. DUTTON. (Monographs U.S. geological survey, ii.) Washington, *Government printing-office*, 1882. 264 p., 42 pl. 4°. Atlas, 23 sh. f°.

THIS work is the second in numerical order, though the first in date of publication, of the monographs of the U. S. geological survey. It is not a geological report in the generally accepted sense of the term, but deals strictly with the physical problems displayed by the Grand Cañon district, and, as its title indicates, principally with that part of its history embraced in the tertiary period, of which the distinguishing feature in this region is denudation on a stupendous scale.

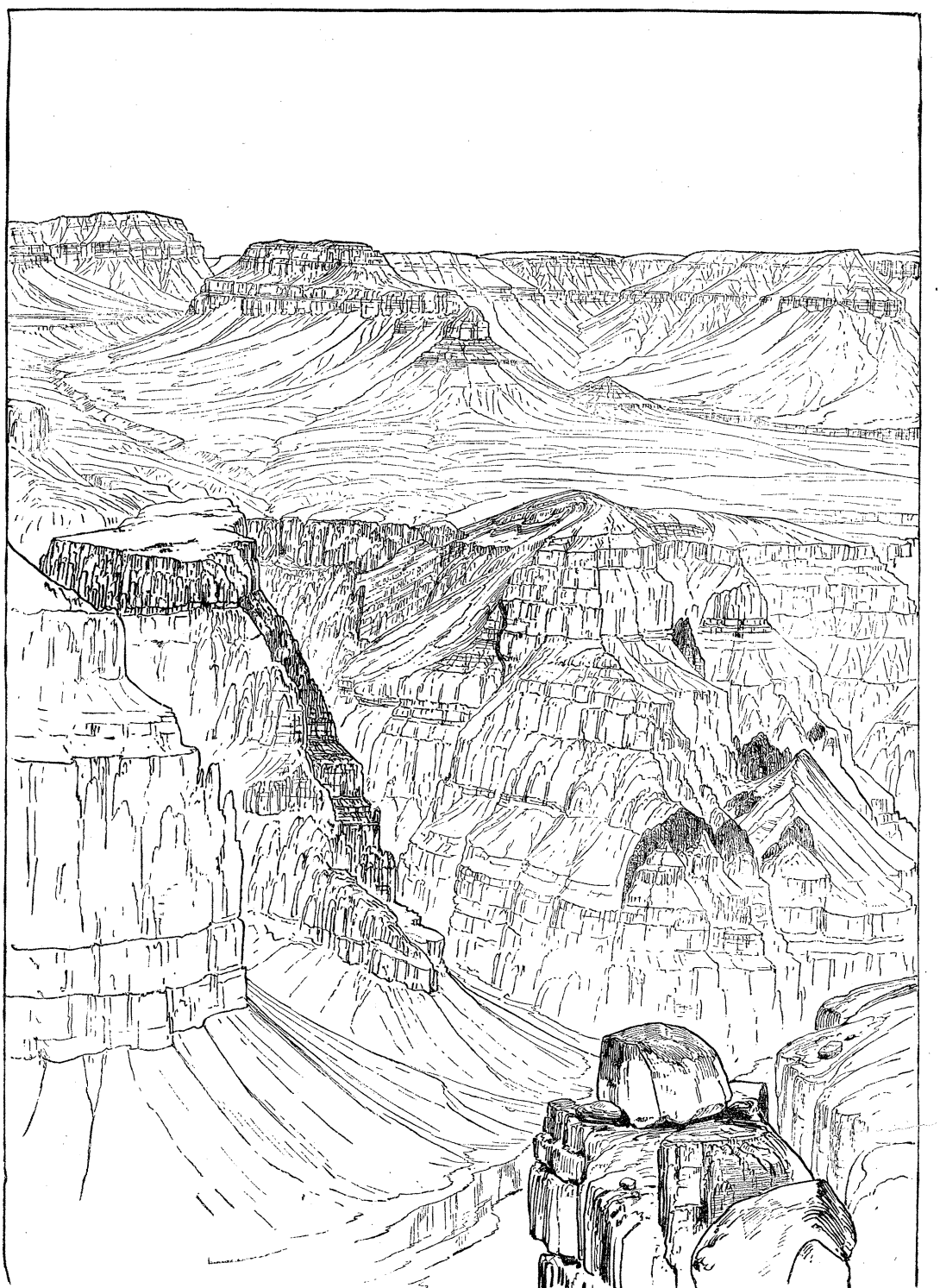
The first geological exploration of the Grand Cañon of the Colorado is due to Major Powell; and for several years his name was closely associated with the progress of discovery in this field. Finding himself, however, unable to continue the work, it was delegated to Capt. Dutton, who had already become familiar with some parts of the district; and the present monograph is the best possible evidence that Major Powell has found no unworthy successor in his investigations.

Capt. Dutton writes as one in love with his subject; and it would indeed be surprising if any geologist who has had the privilege of studying this region were otherwise than enthusiastic in regard to it. A large part of the western territory is such that the geologist who runs may read; that even from the windows of the railway more facts may be gleaned in a day's journey than could be certainly arrived at by months of study in a wooded country, or one mantled by the northern drift. In addition to these advantages, common to vast tracts, the Grand Cañon presents the most striking river-section in America, and perhaps in the world. In such a field a more complete knowledge of the problem is possible, and a closer and more logical method in its treatment admissible, than elsewhere, — circumstances fully taken advantage of in the present report.

The high plateaus of southern Utah descend to the south in a succession of gigantic terraces, composed in succession of the eocene, cretaceous, triassic, and Permian formations, till the summit of the carboniferous is eventually reached. This forms a wide platform, with some approach to regularity of surface, but drops at length in an escarpment of great cliffs to the desert and sierra regions of the farther south and west. The terrace country has a width of from thirty to forty miles, with a length of about one hundred, and forms, as it were, a giant stairway, leading down from the high plateaus, with an elevation of over ten thousand feet, to the carboniferous platform, five thousand feet or more lower. The whole rock series has a preponderant northward dip of an extremely regular character, which seldom exceeds two degrees, and is generally less than one degree, in amount. The carboniferous surface presents a corresponding light slope from south to north; and the strata are traversed by a series of faults and congenetic monoclinal flexures, running in north and south courses, but showing a convexity toward the west. These define the several minor plateaus which diversify the surface; but the region, as a whole, is characterized by the proximate horizontality and undisturbed condition of its rocks, and is in marked contrast to the turmoil of flexed beds found in the adjacent sierra country. Across the carboniferous platform, in a general south-westward course, the great cañon has been cut, — a vast chasm, with a total length of about two hundred miles, a depth of from five thousand to six thousand feet, and a width of from five to twelve miles.

The history of the cañon district, from the later paleozoic to the present day, is naturally divided into two widely contrasted periods; the first extending from early carboniferous time into the eocene, having been one of steady, conformable deposition, bed succeeding bed, till a thickness of about fourteen thousand feet was accumulated. To this succeeded a period of continuous erosion, during which an average thickness of ten thousand feet of the strata was removed from a large part of the surface.

Though rather heterogeneous in character as compared among themselves, the beds of the Grand Cañon region in general closely resemble those representing the same horizons in other parts of the west. The archaean and other basal rocks, not throwing any light in the physical problem proposed in the monograph, are merely mentioned. The carboniferous, broadly viewed, may be characterized as chiefly limestone; and the conditions of a somewhat deep sea at the time of its formation are implied. The Permian and triassic are mainly represented by sandstones, which frequently display cross-bedding, and denote that the water at the time of their deposition was continuously shallow. In the cretaceous, argillaceous and marly rocks become more abundant; and the occurrence of coals and carbonaceous layers throughout, shows that portions of the region became land-surfaces from time to time.



DIKES IN THE CAÑON WALL OF THE INNER GORGE, GRAND CAÑON OF THE COLORADO.

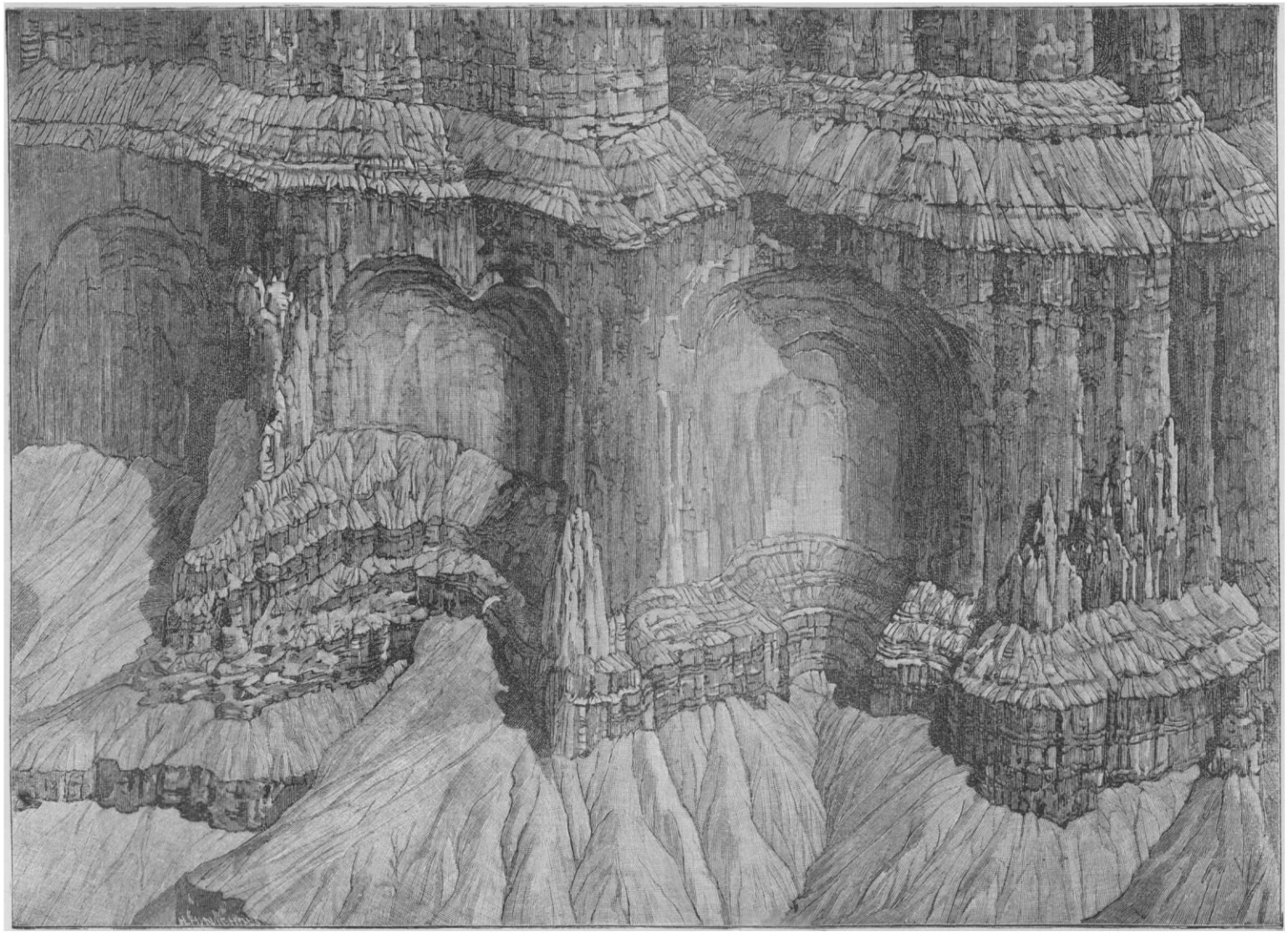
This period closed amid important disturbances; as, in neighboring districts, the succeeding beds are occasionally found to rest directly on the Jura-trias, or basset edges of the cretaceous. As a result of these movements, a great eocene lake was formed, which appears to have been not far above the sea-level, and to have outflowed southward. The change from salt to fresh water conditions is quite sudden. During the eocene period this lake gradually shrank back, and finally disappeared to the north, near the base of the Uinta Mountains, where alone the later eocene deposits are found.

The author finds a little difficulty in explaining the great horizontal similarity in character of the materials laid down during the later periods in a wide expanse of water so persistently shallow. It is suggested, however, that the very shallowness of the sea or lake may, by insuring a constant sectional area, have resulted in maintaining the velocity, and consequent transporting-power, of any currents which existed. The continuance of shallow-water conditions also proves that the profound subsidence required by the volume of the sediments was not acquired suddenly, but that the two increased *pari passu*.

With the eocene the immensely prolonged period of subsidence came to an end, and elevation — shown to have been somewhat spasmodic — and consequent erosion began. It is found by reducing the faults and flexures of the region, and taking into consideration the thickness of the beds, that at this time the carboniferous must have lain over considerable areas, at a depth of from ten thousand to twelve thousand feet below the level of the sea; and it is interesting to remark in passing, that no great degree of alteration appears to have resulted from this deep burial in the earth's crust. The present altitudes of the plateaus mark the difference between the amount of the succeeding uplift and that of denudation; and it is shown that the total movement in elevation has been in different places from twelve thousand to eighteen thousand feet.

The 'great erosion,' as Capt. Dutton names the second period of the history, began at the time of the drainage of the eocene lake, of which there is good reason to believe the Colorado still marks the position of the deepest portion. The immutable permanence in position of the channels of the Colorado and its main tributaries, and the fact that they have been able thus to maintain their original courses in opposition to the superimposed northward dip of the beds, is one of the most striking facts brought out in the study of this district, being, in fact, that which has been most influential in impressing it with its peculiar features. In the latter part of the eocene, and in the miocene, great progress was doubtless made in the removal of the mesozoic strata. The process of elevation continued, and rapid corrasion by numerous streams made steady progress; the Colorado, at this time, probably flowing in a cañon walled by these mesozoic formations, the escarpments of which have now retreated to the terrace district, fifty miles or more to the northward. Through all this lapse of time we are, however, without any very precise data as to the progress of the erosion; and it is not till a date approximately referred to the close of the miocene that any measure of the waste accomplished can be arrived at. The elevation of the district was then for a time arrested; and the streams reached what the author, following Major Powell, calls a 'base level of erosion,' in which, with the production of a uniform light gradient, the wear of their channels clased, and denudation acted only in reducing the probably rough and irregular features of the neighboring country to an approximate level. The Permian strata apparently at this time constituted the actual surface.

About the time at which the Colorado began to cut into the carboniferous rocks, a climatic change occurred, which resulted in producing very arid conditions, and dried up the smaller streams to their sources. This, from what is elsewhere known of the western tertiary, is presumed, with great probability, to be synchronous with the close of the miocene and beginning of the pliocene. Nearly contemporaneous with these events was an uplift of two thousand to three thousand feet, and the outpouring of the earlier basalts, which, forming protective cappings, have preserved portions of the Permian surface above alluded to. The great faults, also, about this epoch first betray their existence; though it is by no means certain that all were then formed, and the evidence is clear that their throw subsequently continued to increase gradually. Corrasion, or the wear by the rivers of these beds, now again became active, but only in the case of the larger streams, which, by reason of their origin in high, well-watered uplands beyond the cañon district, had been enabled to survive. A base level was soon again reached: and the Colorado remained during the greater part of the pliocene at the level of what Capt. Dutton calls the esplanade, or wide upper valley of the present cañon; which valley continued to increase laterally, but not in depth, till the



NICHES OR PANELS (OVER 600 FEET HIGH) IN THE RED WALL LIMESTONE, GRAND CANON OF THE COLORADO.

final paroxysm of upheaval set in, producing a further rise of from three thousand to four thousand feet. The faults, which are strictly correlated with the varying uplifts of the several minor plateaus, again increased their displacement; and at the same time, or shortly afterward, the volcanic forces resumed their activity, producing cones of eruption which still display their characteristic form. These, and the lavas erupted from them, afford evidence, that, though the cañon had at the time a considerable depth, the greater part of its excavation still remained to be affected by that last great effort of corrasive action which has only lately come to an end.

It is believed that the elevation of the plateau region has now ceased, and that the rivers have again nearly reached a base level of erosion. Some, at least, of the faults cut the older basalts; but no evidence has been found, where the newer lavas cross them, of any renewed movement. The glacial period passed over this region without leaving any traces of ice-action, manifesting its occurrence merely as a pluvial episode, very brief in comparison with the stages of the great erosion, but of which some effects may nevertheless be traced.

Such is a very brief and necessarily imperfect outline of the train of reasoning in which the author follows out the exceptional processes which have acted in the Grand Cañon district, and eventuated in producing its present remarkable features. Very few of the conclusions arrived at are open to any question; and, though it has been for so short a time known to science, it may be considered as one of the most fully thought out of geological problems. Among the collateral facts illustrated in this region are several, which, from their apparently anomalous character, are of special interest to the student of dynamical geology. Such is the want of coincidence between the great faults and points of volcanic eruption, the bending-*down* of the strata along the dropped sides of the faults, the connection of the latter with the peculiar monoclinal flexures, the not uncommon reversal in direction of throw in the opposite ends of a single fault, and the remarkable observation that the general light dip of the strata is increased notably at the bases of the terraces. The last-named circumstance the author is disposed to connect, though doubtfully, with the theory of plastic equilibrium in the earth's crust, — a theory which we believe few geologists will be ready to follow so far.

A notice of this monograph would be incomplete without special reference to the accompanying atlas, containing geological maps and panoramic views of the district. The latter, together with a number of illustrations in the volume itself, are from the pencil of Mr. W. H. Holmes, and convey a better idea of the proportions and intricacy of the physical features than could be accomplished by any word-painting, however elaborate.

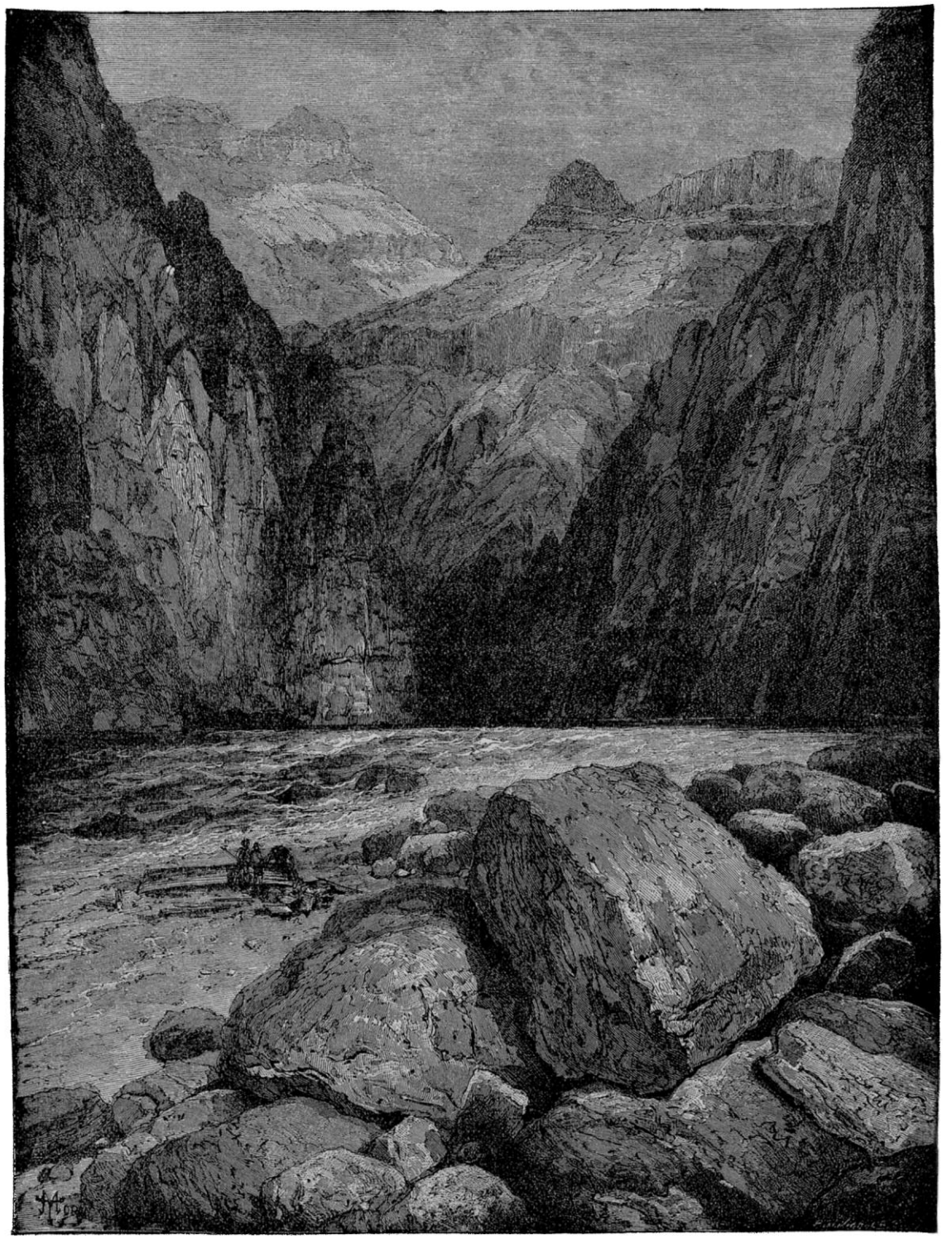
If the character of the critic must be maintained in reviewing this work, which in its main features demands our praise alone, it may be suggested that the 'effusive' style adopted in some of the chapters is scarcely in keeping with the incomparable dignity of the subject, and is not likely to appeal to the specialists for whom this class of publication is intended.

THE BACILLUS OF BERIBERI.

Etiologia e genesis do beriberi. Pelo Dr. J. B. DE LACERDA. Rio de Janeiro, *Faro & Lino*, 1884. 68 p., illustr. 8°.

THIS pamphlet gives the results of a medico-biological study, carried on in the physiological laboratory of the National museum of Rio de Janeiro, on a very obscure disease, which, introduced many years ago in Brazil from India, carries off annually a large number of victims, particularly in the northern provinces of the empire.

Employing the method of Pasteur, and introducing blood of beriberi patients in meat-solution, Dr. Lacerda obtained in numerous experiments a microphyte similar in form to the bacillus of carbuncle. This organism, which reproduces itself by segmentation and by spores, was also found in the fresh urine and blood of beriberi patients, the spores being at times extremely abundant in the blood. On making subcutaneous injections of the liquid in which the organisms were cultivated, in rabbits and guinea-pigs, these animals were found to succumb in periods of from five to twenty days, some of them presenting a true paralysis of the posterior members; others, a notable weakening of these members, with difficulty of locomotion, and loss of cutaneous sensibility. Death in many cases was caused by asphyxia, the paralysis having extended to the anterior members. The cultivated blood of these animals reproduced the same microphytes that had been obtained from the blood of beriberi patients. The microscopic examination of the spinal medulla and of the muscles revealed the presence of the microphyte and of its spores, their abundance in the medulla being especially remarkable.



GRANITE FALLS, A SCENE IN THE INNER GORGE OF KAIBAB DISTRICT, GRAND CAÑON OF THE COLORADO.