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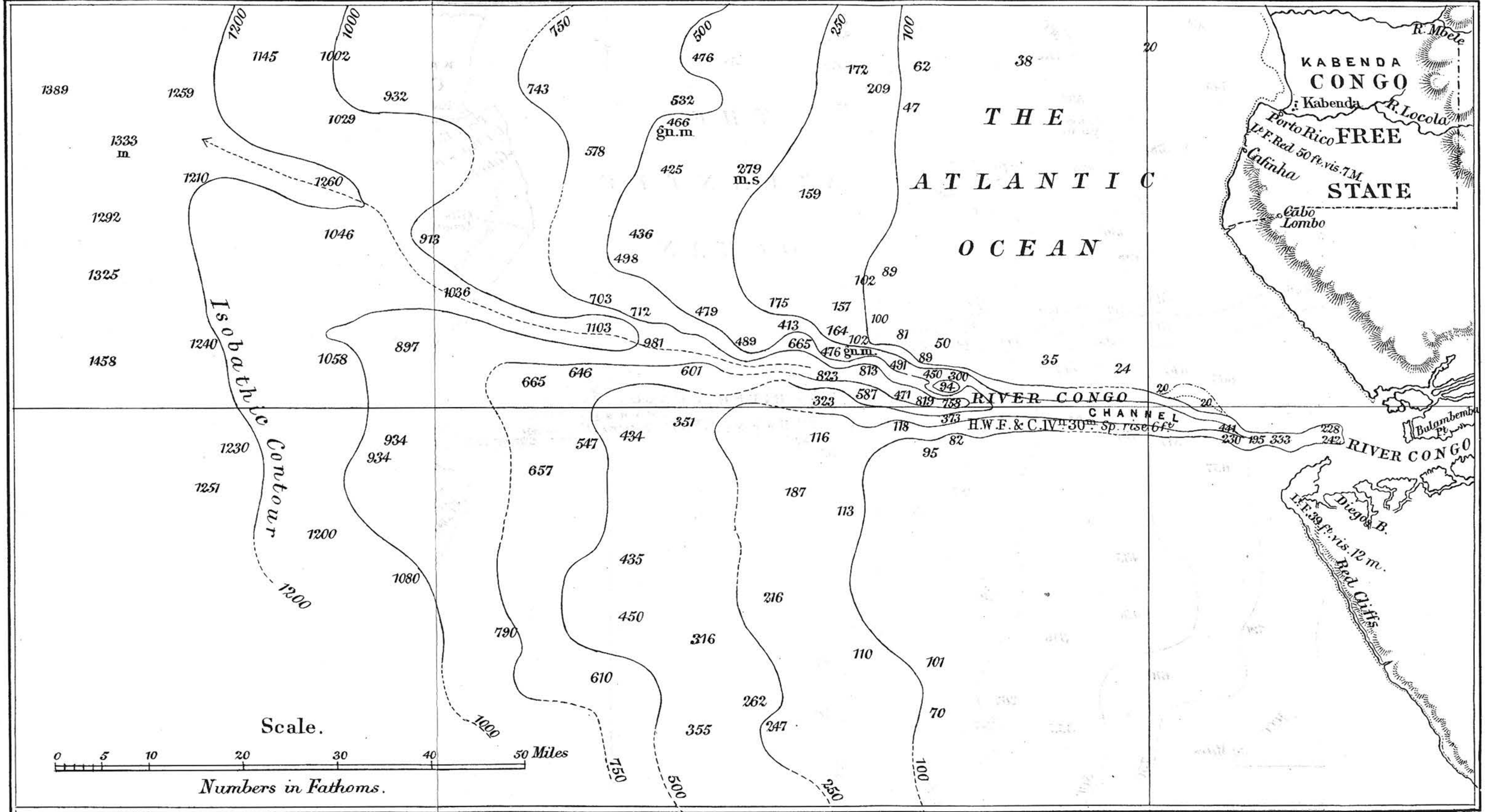
SUB-OCEANIC VALLEY OF THE RIVER CONGO.

PLATE I.



Harrison & Sons, Lith.
S. Martins Lane, W.C.

Isobathic Contours from soundings on the Admiralty Chart No. 604.

ORDINARY MEETING.*

THE REV. CANON GIRDLESTONE, M.A., IN THE CHAIR.

The Minutes of the last Meeting were read and confirmed, and the following elections took place :—

MEMBER :—S. P. Klein, Esq., M.A., F.R.A.S., F.L.S.

ASSOCIATES :—E. J. Gardiner, Esq., Kent ; J. Walter Brown, Esq., Wilts.

The following paper was read by the Author :—

THE SUB-OCEANIC RIVER VALLEYS OF THE WEST AFRICAN CONTINENT AND OF THE MEDITERRANEAN BASIN. By Professor EDWARD HULL, LL.D., F.R.S., F.G.S. (With Map.)

HAVING on former occasions laid before the Victoria Institute the evidence for recognising that the rivers which enter the Atlantic from the British Isles and Western Europe have their channels carried down to a depth of several thousand feet under the water of the ocean,† I have now the honour of extending these descriptions to the coast of West Africa, as far as the valley of the Congo. In the discussion which took place after the reading of my paper on "The Sub-oceanic terraces and River Valleys of Western Europe," Professor Etheridge, F.R.S., expressed a hope that I would continue my investigations beyond the Straits of Gibraltar to the south-western extremity of Africa‡; and, feeling certain in my own mind that these straits could not form a physical limit to the submarine features characterising the coast of Europe, I determined to follow my friend's advice, with the results I am now about to lay before the Institute. I may observe, however, that as the possibility of carrying out these investigations

* February 19th, 1900.
† *Trans. Vict. Inst.*, vol. xxx, p. 305, and vol. xxxi, p. 259.
‡ *Ibid.*, p. 290.

depends altogether on the number and extent of the soundings on the Admiralty Charts, we can only restore the submarine features where these soundings occur in sufficient number, and are extended to considerable depths.

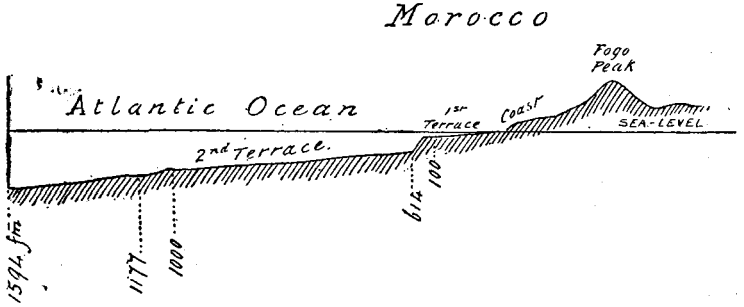
My subject naturally divides itself under two heads: first, the western coast of Africa; and, secondly, the Mediterranean basin.

PART I.

Submerged Physical Features off the Western Coast of Africa.

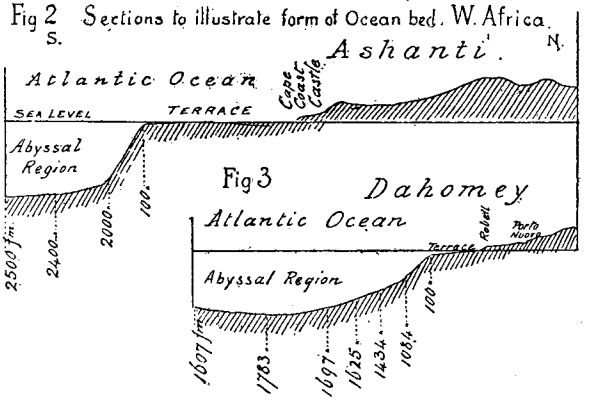
1. *The Continental Platform.*—The gently sloping terrace extending out from the coast of Western Europe known as "The Continental Platform" loses much of its importance, or sometimes altogether disappears, to the south of the Straits and passes into a more or less gradual slope, from the 100-fathom contour to that of 1,200 fathoms. This slope, in all probability, consists of a succession of minor terraces breaking off in cliffs; but it would be difficult to determine this with certainty unless with the aid of maps on a large scale containing very numerous soundings. We were somewhat prepared for this remarkable change in the character of the submarine litoral of the two continents by the contraction of the Continental Shelf on approaching the vicinity of Cape St. Vincent, where it has contracted to a breadth varying from 10 to 20 miles. Directly opposite the Straits of Gibraltar and again along the coast of Morocco, between 31° 10′ N. and the Canary Islands, there occurs a broad terrace extending for about 50–60 miles in breadth between

Fig. I. Section to illustrate form of Ocean bed W. Africa



the 500 and the 1000-fathom contours, which may be taken to represent the Continental Platform at a lower level (*see* Fig. 1), and indicates a prolonged pause in the process of elevation or depression of the crust at this stage.

Along some parts of the coast, however, the descent into deep water is very rapid, sometimes precipitous. Such is the case along the Ivory Coast and the Bight of Benin, where the descent from the 100 to the 1,200-fathom contour is precipitous. Off Cape Coast Castle the base of the escarpment descends to over 2,000 fathoms (Figs. 2 and 3).



From Cape Lopez southwards along the French Coast and as far as Cape Lombo in Loanda, the soundings on the charts are few, except in the vicinity of the Congo, but they indicate a wide expansion of the Continental Platform from the coast to the 100-fathom contour—in striking contrast with the precipitous coast described to the north of this tract.

2. *Base-level of Erosion, or Old Coast Line.*—Assuming the base of escarpment, or declivity, which descends from the margin of the Continental Platform, to be the original land margin at the time that the sub-oceanic rivers were eroding their valleys and pouring their waters into the ocean of that period, we are always able to define its depth with great accuracy when we know the level at which the rivers open out on the sloping plane of the abyssal region, and we have seen this level to be at (approximately) 1,200 fathoms (7,200 feet) below the surface off the coast of Western Europe. But where rivers are absent, as along a large

extent of Western Africa, and where the descent into the abyssal region down to, say, 2,000 fathoms and upwards is rapid, or almost continuous, as off the coast of Ashanti (Fig. 2), it is difficult or impossible to define the level of the old coast during the period of maximum elevation, because we are confronted with the question;—Was the bed of the ocean actually raised to the extent here indicated by the base of the escarpment, which is so much deeper than that shown in other places, or did deep water extend to the very edge of the land? We cannot answer this question. It is fortunate for our purpose that the *embouchure* of the Congo valley at a depth of 1,200 fathoms is very clearly defined; but along many parts of the African coast there is apparently no very marked change of gradient from below the 100-fathom contour till we reach depths of 2,000 fathoms and upwards, as is the case off Cape Coast Castle. It is possible to assume that in such cases the vertical movements both of elevation and depression have been greater than those which characterise the submarine lands of Western Europe; and on reflection this appears probable, as it is not to be supposed that throughout a coast-line of 3,000 to 4,000 miles the amount of vertical oscillation would be exactly the same throughout. Variations to some extent are more than probable.*

3. *The Submerged Valley of the Congo.*—In dealing with this subject I feel that an apology is needed, because this is almost the only river on the west coast of Africa of which the continuation of the channel under the ocean has been described by previous authors. I might well have brought my own investigations regarding the sub-oceanic river valleys of the eastern side of the Atlantic to a close on reaching the Straits of Gibraltar, but when describing the submerged channel of the Tagus, and showing to what a great depth it could be traced, it became evident that the Straits could not be regarded in any sense as a physical limit to the region of elevation and depression, but that it must have extended far southwards along the coast of Africa itself. From the actual investigations I shall now lay before you, supported as they are to a great extent by those of other writers, I hope

* It is to be recollected that the submerged river valleys and the base of the great declivity off the coast of the British Isles corresponds rather to the 1,000-fathom contour, while off the coast of Western Europe they are represented by the 1,200-fathom contour.

to show beyond question that these great terrestrial oscillations of level which have characterised the coast of the British Isles and of Western Europe are continuous, and undiminished in extent, far beyond the equator itself—and that the lands bordering the eastern Atlantic, through its whole extent, have been subject to the same vertical movements which, as we have seen, characterise those of the region to the north of the Straits of Gibraltar.

Reference to Previous Authors.—In 1887, Mr. Edward Stallibrass, F.R.G.S., read a paper before the Society of Telegraphic Engineers on "Deep Sea Soundings in connection with Submarine Telegraphy," * in which he describes the sub-oceanic channel of the Congo, and traces it from its upper limit, where the river itself enters the Atlantic, down to the 1,000-fathom contour, giving the length of the channel at 100 miles. The map which accompanies his paper showing the course of the submerged Congo agrees very closely with my own, but is on a smaller scale than that of the Admiralty Chart, and fails to give the full length of the submerged channel, which actually extends some 20 miles farther out to sea than is shown by this author.

In the remarkable paper contributed by Mr. Warren Upham, of the United States Geological Survey, on the "Causes of the Ice Age," in which he indicates his opinion, founded largely on the existence of the submerged valley of the Congo, that the great "epeirogenic movements" which characterised the close of the Tertiary period embraced the western side both of Europe and Africa, he states that, from soundings carried out by Mr. J. Y. Buchanan for telegraphic purposes, he found the channel of the Congo to extend 80 miles under the ocean, and to a depth of more than 6,000 feet, and he proceeds to give further details regarding the breadth and depth of the channel.† Here, then, we have two independent authorities for the existence of this great sub-oceanic river valley. Both, however, fail to give the entire length of the valley, and, therefore, to give an adequate idea of the extent and depth of this magnificent submerged cañon; it will, therefore, not be considered a wholly gratuitous undertaking if I attempt a description of it drawn from my own examination of the soundings on the Admiralty Charts.

The Congo.—The Congo is one of the largest rivers of the

* *Journ. Soc. Teleg. Engineers*, vol. xvi, p. 479.

† Warren Upham, *Journ. Vict. Inst.*, vol. xxix, p. 218. Mr. Upham quotes the *Scot. Geog. Journ.* vol. iii, p. 217 (1887).

African continent, and enters the Atlantic Ocean in lat. 6° S. Its depth opposite Banana Creek only reaches to 9 fathoms (54 feet), but at a distance of 5 miles to the westward under the ocean, the soundings suddenly plunge down to depths of 228 and 242 fathoms (1,368 and 1,452 feet) representing the head of the sub-oceanic river valley; at this point its breadth is about 2 miles, with well-defined, steep or precipitous sides. At a distance of 50 miles from its head, the breadth of the cañon has increased to 10 miles, and its depth to 813 fathoms (4,878 feet) from the surface, or 713 fathoms (4,278) from the edge of the Continental Platform—here represented by the 100-fathom contour. From this point the descent of the floor is gradual for the next 57 miles, when it reaches its maximum depth of 1,200 fathoms (7,200 feet) below the surface, and opens out on the general floor of the abyssal ocean, bounded by banks of moderate depth and steepness. The total length of the cañon from its head below Banana Creek to its *embouchure* is about 122 miles. Throughout this distance, owing to the remarkably uniform slope of the floor of the ocean from the 100-fathom contour downwards, there do not appear to have been any great falls or cascades such as occur in the submerged channels of some of the European streams. (See Plate.)

In order to realise the length of this sub-oceanic valley we have to compare it mentally with distances with which we are familiar, and I have taken a few of these at random; speaking in all cases approximately. For example, the sub-oceanic valley is twice the distance from Kingstown to Holyhead in crossing the Irish Channel; it is more than twice the distance from London to Brighton; it is longer than the distance from London to Bristol or Birmingham, and it would take a train three hours to traverse, travelling at the rate of 40 miles an hour—which is the average speed of "through" trains for long distances. These comparisons may, perhaps, enable the reader to realise the magnitude of this great submerged river valley. Then we have to recognise that the breadth of this gorge, near its centre, is seven miles, and it is bounded in some parts by nearly vertical cliffs more than 4,000 feet in height. As far as I am aware there is no physical feature in Europe to compare with it.

One would like to further dwell on the characteristics of this magnificent submerged valley; but I am restrained by the consideration that I might be charged with unduly giving way to fancy for my facts.

4. *The Grand Bassam.*—Another West African submarine channel is that of the Grand Bassam (lat. 5° N.) described by Mr. Stallibrass. The Continental Platform is here from 40 to 50 miles broad, with a gentle slope to the margin of the 100-fathom contour; and across this shelf the old river channel is traceable, with a well-defined margin to the 400-fathom contour and beyond. This channel is called on the Admiralty Chart "The Bottomless Pit," and was sounded by the officers on board the S.S. "Buccaneer" in 1886. The submerged channel is probably that of the River Akha, which now enters the sea about 15 miles to the east of the point where the channel begins. I am unable, owing to the paucity of soundings, to add any further information regarding this sub-oceanic channel to that given by Mr. Stallibrass in the paper already quoted.

5. *The Niger or Quarra.*—It might have been expected that concurrently with the well-developed sub-oceanic channel of the Congo there would be one continuous with that of the great African river, the Niger. This may be so; but unfortunately we are unable to ascertain the fact, because the soundings on the Admiralty Chart fail us just where we might expect the channel to be found. Along the Bight of Benin on both sides of the mouth of the Niger, the soundings are sufficiently numerous to enable us to trace approximately the isobathic contours, showing that the land descends from the 100-fathom to below the 1,000-fathom contour with a very steep, almost precipitous, gradient; but between long. 6° 30′ and 7° 5′ the soundings are shown only twice, viz., those of 228 and 270 fathoms, neither of which had touched bottom, and, therefore, give no certainty regarding the actual depth. Until this gap in the soundings is filled up the form and extent of the submerged channel of the Niger, supposing such to exist, must remain unknown.

6. *The Orange River.*—This is the third of the great rivers opening out on the ocean from West Africa, and it would have been interesting to know whether or not it has a sub-oceanic channel indicating vertical oscillations of the floor extending to the very south of the continent; but I have only the same statement to make regarding the soundings off the mouth of the Orange River that I have made above regarding those of the Niger. They absolutely fail us just where they are most wanted for the purpose of determining the existence of a submarine channel continuous with that of the Orange River itself.

PART II.

The Mediterranean Basin—Submerged River Valleys.

That the Mediterranean Basin, at least in its western portion, must have partaken in the great vertical oscillations which have affected the regions bordering Western Europe and the continent of Africa requires no proof. The general elevation of the ocean-bed and adjoining lands to the extent of 7,000 or 8,000 feet through a distance of over three thousand miles must have influenced the regions embracing the Mediterranean and bordering countries. But while this is the case, it is not to be expected that the physical features of the submerged lands should be as clearly developed within the confined area of the Mediterranean Sea as along the shore of a great ocean extending for thousands of miles in two directions, and exposed to the action of prevalent westerly winds originating powerful wave action on the opposing coast. To such action we owe the cliffs bordering the British and Continental coast along the Atlantic, the formation of the Continental Shelf, and the stupendous line of cliffs by which it is bounded.* These features, however, are not so clearly defined within the Mediterranean area, if at all in some parts; but the submarine coast is found to descend into deep water by a broken slope, continuous with the bordering lands down to a depth of 1,000–1,200 fathoms, when it gives place to the abyssal region, which descends to depths of over 1,500 fathoms. As a consequence of this, and as we might *a priori* expect, the submerged river valleys are also less clearly defined than those off the coast of France, Spain, Portugal, and, we may add, of West Africa.

The submerged channels which I have succeeded in tracing on the Admiralty Charts are those of the Ebro and Rhône, as also that of Admiral Spratt between "Adventure Bank" and Cape Bon; but I will take this opportunity of bringing before the members of the Institute the remarkable discoveries of similar channels made by Professor Arturo Issel off the northern coast of the gulf of Genoa, which

* It may seem strange that the same causes, namely, vertical movement of the crust and wave action along the border of the ocean, should have produced two such dissimilar features as the Continental Platform and the Great Declivity, but it can be shown that this is so; the difference in the features being due mainly to the relative duration, or length of time between the two components above referred to.

are of special interest as tending to confirm the conclusions arrived at by myself in this and preceding communications.

1. *The Submerged Channel of the Ebro.*—The number of soundings off Cape Tortosa is not as numerous as might be wished for the purpose of determining the course of the submarine channel of this river; still, the inward bend of the contours from that of 40 fathoms down to that of 1,000 fathoms, immediately opposite the mouth of the river, cannot be mistaken as indications of the course of the channel.* Along the Gulf of Valencia the representative of the Continental Shelf is unusually broad and well defined, breaking off at the 100-fathom contour at a distance (opposite Valencia) of 60 miles from the coast, and with a very steep descent for a depth of 500 fathoms.

2. *Channel of the Rhône.*—The submarine channel of the Rhône is perhaps even more definitely indicated than that of the Ebro by the inward bend of the isobaths, extending from 100 to 1,200 fathoms. The channel commences directly south of the city of Marseilles at a distance of about 30 miles to the east of the point where the river itself now enters the sea; but it is in a direct line with the course of the main stream below Arles; and between the two points the submerged channel may be supposed to pass along the Continental Shelf; though not apparent owing to silting up, as is usual at the *embouchures* of large rivers. The shelf itself is here of considerable breadth—varying from 50 to 25 miles in the Gulf of Lyons, and limited by the 100-fathom contour.

3. *Submerged River Valleys of the Gulf of Genoa.*—The remarkable series of submerged river valleys continuous with the rivers which descend from the Apennines into the Gulf of Genoa (the Ligurian Sea) have been determined by Professor Arturo Issel, of the University of Genoa, and are of peculiar interest both from their number and also from the light they throw upon the geological age of these submarine channels. These river-channels were described as far back as 1887 by Professor Issel, and subsequently in two other publications; but have not received, at least in this country, the attention they have deserved. I,

* The sounding "928" without touching bottom, and in close proximity to one of 137, which has done so, indicates a very steep slope for the western margin of the channel (see Chart No. 2158A).

therefore, feel great satisfaction in being the channel for bringing them before an English-speaking audience.*

The soundings upon which the determination of the submerged valleys depend were carried out by Capt. I. B. Magnaghi in the ship "Washington," of the Royal Italian Navy, and were laid down on a chart which enabled Professor Issel to trace the isobathic contours by which the submarine features of the ground have been portrayed. It was found that the sinuosities became especially well defined along the contour of 200 mètres (about 110 fathoms) which marks the edge of the Continental Platform at a distance of about 7 miles from the coast; they are called "*Sinuosites profondes*" and are always directed towards the coast.

The contour line of 500 mètres passes 25 miles to the south-west of Spezia; that of 1,000 mètres is irregular and runs at variable distances of 8 to 14 miles from the coast; all, however, are "notched" by sinuosities of the submarine valleys.† But the point of special interest is the fact that all these submarine channels are actually, or inferentially, continuous with those descending into the sea along the coast of Liguria and having their sources in the Maritime Alps. The following are named by Professor Issel, viz.:—the Basagno, Polcevera, Giuliano, Aquila, Merula, Arma, and the Roida; these streams keep their channels under the sea in the same directions as upon the land, and can be distinctly followed to a depth of 900 mètres, or nearly 500 fathoms. These observations lead the author to the conclusion that there has been an elevation of the whole region of Liguria to the extent of 900 mètres (about 3,000 feet), at a recent period (*à une époque récente*)—in other words Post-Tertiary—a conclusion in harmony with that arrived at by myself and other observers on other grounds. But I must here state the grounds of this conclusion as given by Professor Issel himself.

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* Professor Issel's observations on the submerged valleys of Liguria were first published in the *Comptes Rendus des Sciences*, Nos. 24th and 31st January, 1887; then in his work, *Il Terremoto del* 1887 *in Liguria* (Genova), and again in his work, *Liguria Geologica e Preistorica* (2 vols., Genova, 1892).

† I have myself endeavoured to trace these contours on the Admiralty Chart (No. 2158A), but the scale is too small to admit of a detailed representation of the small river valleys described by Professor Issel, and leads me to conclude that, with maps of sufficiently large scale and numerous soundings, many streams entering the Mediterranean might show their underground channels.

Geological Conditions.—The valleys which descend from the Alps are eroded through strata of successive geological ages in an ascending series as we approach the coast; thus the valleys of the Basagno, Polcevera, the Merula, and Arma are eroded through Eocene strata, but the Roida valley is eroded through both Eocene, Miocene, and Pliocene formations. And as this valley (as well as the others) is prolonged under the waters of the Mediterranean, it follows that the valley is of a newer geological epoch than the Pliocene, through which it is eroded; in other words, it is of Post-Pliocene age. This exactly brings us to the epoch to which I had ventured to refer the elevation of Western Europe and the formation of the sub-oceanic river valleys, and it is eminently satisfactory to have such confirmatory evidence. Such an elevation of the Alpine region as that determined by Professor Issel, namely, some 3,000 feet as a minimum, during the Post-Pliocene or Glacial period, would go a long way to account for the great accumulation of snow, and the extension of the glaciers beyond their present limits, which we know to have taken place at that epoch. But the elevation has been doubtless even greater, as inferred from the depth to which the sub-oceanic valleys have been traced, along the western European coast, as well as in those of the Ebro and Rhône above described. The soundings made by the officers of the "Washington" may not have extended far enough out to sea to permit Professor Issel to trace the river valleys further than the 900-mètre contour, but the valleys themselves probably descend to greater depths, involving conditions of greater elevation, and subsequent depression.

General Conclusions—Long duration of the Post-Pliocene Period.—From the above statements it will be apparent that the phenomena of terrestrial elevation, resulting in the formation of submarine valleys, and of subsequent depression, resulting in their submergence, which have been demonstrated in the case of Western Europe and the British Isles, are fully borne out by the soundings off the coast of Africa and within the Mediterranean. They are all in harmony, and point to an elevation of the lands bordering the Atlantic to the extent of about 7,000 to 8,000 feet, and subsequent depression during a period geologically "Recent" or "Post-Tertiary." Professor Issel's determination of the age of these great movements, based on geological grounds, coincides with my own, drawn from other sources. And in

order to give time for the natural (or physical) operations involved, namely, the erosion of wide and deep valleys, the sculpturing of extensive lines of coast rising several thousands of feet above their base, and the levelling down of a continental platform sometimes one hundred miles broad, from which the existing continents and islands spring—all these operations necessarily involve a lapse of time of long extended duration;—much longer than that which many of us were disposed to grant to the period succeeding the Pliocene.* Such a prolonged period, however, gives time for the great extension of glacial conditions which necessarily accompanied the elevation of the land, together with the subsequent submergence which characterised the Inter-Glacial epoch—during which portions of the British Isles were submerged to the extent of 1,200 feet, and the ultimate emergence which resulted in bringing about (approximately) the existing distribution of land and sea. Movement is still going on, but apparently on a less stupendous scale than in Post-Tertiary times. But to this subject I may probably return on a future occasion.

The CHAIRMAN (Rev. Canon GIRDLESTONE, M.A.).—I am sure all will be glad to pass a vote of thanks to the able author of this paper. (Cheers.) I will now ask the Honorary Secretary to read some correspondence which has been received.

Captain F. PETRIE, F.G.S.—The first letter is from Professor T. Rupert Jones, F.R.S. He says:—

This is a well considered and highly cymmendable continuation of Professor E. Hull's former conclusions as to the extent and character of the submarine extensions of the rivers, from the western coast of Europe, across the continental plateau and ancient coast line into the abyssal region. The work is now carefully continued along the west coast of Africa and within the Mediterranean area, partly by the application of the soundings given in the Admiralty charts; partly by the hydrographic map,

* Professor J. W. Spencer, in a recent letter to the author, has suggested this view of a prolonged period in Post-Tertiary times.

constructed by Mr. Stallibrass, Telegraphic Engineer, especially for the mouths of the Grand Bassam, the Niger, and the Congo rivers; and further with the special help of Professor A. Issel's researches on the submerged valleys of Liguria in the Bay of Genoa. These Alpine valleys having eroded Tertiary strata of the late Pliocene stage, the elevation of their water-shed must have been of Post-Pliocene date, and intimately associated with the great Ice age; and this is in accordance with already accepted theories. The subsequent erosions making terraces, cliffs, and cañons, must represent enormous lapses of time; and these protracted periods were followed, by the great submergence, probably quite slowly accomplished, accompanied with the gradual formation of ancient cliffs, and terraces, and the present existing coasts. These last also exhibit evidences of subsequent vertical oscillation, sometimes on a grand scale.

Cavaliere JERVIS, F.G.S., Turin, writes:—

We are led to infer from Professor Hull's investigations that the duration of the Post-Pliocene period, required in order to produce upheaval on the grandest scale over such a considerable area, must have ushered in the Glacial period in quite as gentle a manner as that in which contemporaneous geological movements take place. Both the number and relative state of preservation of submarine river valleys, and the oceanic platforms would likewise confirm the similar character of the subsequent depression, by which the glacial zone was gradually reduced to its present limit. Further, such marked features of the submarine valleys of existing rivers, conclusively show that their still emerged courses must have been already sculptured much as at present. Thus, the physical features of mountains and valleys at the present day (where not passing through still newer strata), are but the continuation—the finishing touch, as it were—of what already existed in later geological times, no intermediate break having occurred. Roman structures, built eighteen centuries ago, are common in towns situated in Alpine valleys, surrounded on either side by mountains many thousand feet high, in striking contrast to which the rivers now flow at a level of from 30 to 40 feet lower down, nor did the ancients build at the level of the river.

Thus, coming down to our own times, I am of opinion that more ample data are required in order to establish generalizations

regarding the participation of the Apennines in the latest submergence which took place, unless they were subjected to a subsequent emersion, basing my argument upon the great geological differences between them and the Alps with the two N.W.–S.E. chains of mountains to their south. Professor Sacco alludes to Pliocene clay rising to the height of 500 metres (1,640 feet), at Pianfei (Cuneo). Strata of the same age, abounding with marine mollusca, largely of species still living in the Mediterranean, are among the commonest along the lower skirts of the Apennines, from one extremity to the other, often overlaid to considerable elevations by Pleistocene clays, sands, etc. Balducci found Pliocene strata in Sicily at the height of nearly 1,000 metres (3,200 feet). On the southern slope of the Western Alps, Pliocene strata are by no means common, and these towards their base, an apparent indication that subsidence occurred differently in the Apennines to what it did in the Alps.*

If this view be correct it may be inquired whether certain fractures may not have resulted from the greater subsidence of the Alps in which the Apennines participated to a far lesser extent. At their base, approximately parallel to their axis we find intrusive rocks of various periods, such as granite at Cavour and Traversella (*Turin*); syenite at Quittengo, and granite at Biella, Pella, and Baveno (*Novara*), basalt (*Vicenza*); trachyte in the Euganean hills (Padua). It is a question which remains to be investigated.

[The Rev. Professor BLAKE, F.G.S., took part in the discussion, and expressed the view that the sides of the submarine channels consisted of mud brought down by the rivers and deposited on either hand of the current.]

Mr. HENRY BENEST.—It has afforded me much pleasure to be present this afternoon, as the subject of Professor Hull's paper is one in which I take more than a passing interest. Last year I was favoured by the Secretary of the Geographical Society with an invitation to an afternoon lecture by Professor Hull, and found that his views coincided in some respects with those that I entertain myself, and, in fact, I had a paper before the Geographical Society at that time, which subsequently appeared in the Journal; from observations of the sea bottom, which have come within my

* There are none. It was the period of "the great elevation."—E. H.

own experience while fishing up and repairing broken telegraph cables. Cable repairing, requiring as it does close and careful survey, necessitates sounding at distances of perhaps half a mile apart, whereas in ordinary deep sea surveys for cable laying purposes sounding at distances of 10 to 12 miles apart have been considered sufficient. This close examination of the bottom by sounding enables us afterwards to draw contour lines that map out the configuration of the ground upon which the cable lies, and this has been our practice for the past 20 years. Sometimes we find it to be variable and uneven. This survey forms a very interesting study in itself, apart from the exigencies of cable operations, and one is loth to confine it to the area of the work in hand. I have wondered that the owners of steam pleasure yachts have not emulated the example of the Prince of Monaco, Mr. Coats, and a few others, and have taken up this subject as a pleasant and interesting field of research, the outfit required being light, simple, and comparatively inexpensive. The soundings taken over the Bottomless Pit by the Silvertown Company's telegraphic steamer *Bree* in 1886, and to which Professor Hull refers, were under the supervision of Mr. J. Y. Buchanan. The latest corrections show the width of this gully at a mile and a half from the shore to be less than one mile, with a depth of 170 fathoms. At about 7 miles from shore, the width is 2 miles, with a depth of 327 fathoms. At about 9 miles off, it widens to nearly 5 miles with a depth of 452 fathoms. The slopes of the sides averaged in some parts 2,000 feet per mile. During cable repairs in other localities more or less similar features to these have been met with, notably in vicinity of Cape St. Vincent and of the supposed sub river outlet of River Parvinas, North Peru; but I think the most remarkable instance that I know of, and one outside cable work, is the depression called on the Admiralty charts, "the Swatch of no ground" off the mouth of the Ganges. This gully formation is from 6 to 12 miles wide, with a maximum depth of close on 600 fathoms, with 75 and 80 fathoms to each side. From the fact of these submarine gullies existing, I am inclined to the belief that in some instances they are evidence, not only of possible ancient river courses, but of probable present outlets for freshwater escapes beneath sea level.

Commander HEATH, R.N.—The formation of the deltas of rivers is pretty well known to us, and they are formed at all rivers by the

silt there running down; but one effect of the constant running down is that the silt is deposited almost immediately, and in no case, that I am aware of, can you find outside the bar of the river, outside the deepest of the rivers, any trace of the river channel beyond the sea. You get at once into the normal depths of the sea bottom. As to the question of no deposit being found at the mouths of ancient rivers in abyssal depths, may not it be accounted for by the want of the alluvial soil which is in existence now and which is now brought down in large quantities? But was there at this time, any quantity of alluvial soil which if brought down would form those deposits and terraces at the mouth of a river?

The CHAIRMAN.—As time is advancing, I will ask Professor Hull to reply to the points that have been brought forward.

Professor HULL, F.R.S.—I am very pleased that Mr. Benest, who is familiar with this subject, is present this evening. What he said about the Ganges is very interesting, and it strikes me, if we had the necessary soundings made, some very important results would arise as regards the former extension of the great Indian Peninsula—that we should find it was vastly greater than now if those river valleys could be restored to their original positions. I am also glad to have heard Captain Heath's observations. As regards the spreading of the sediment at the mouth of the river we have exactly what Professor Blake referred to; the old river channel of the Congo no doubt extended far up into the land and is now filled with silt, and that sediment runs out to this point in the ocean,* and has filled up the original valley.

Professor ORCHARD.—Might I ask whether you refer all these submerged tracts to one source? Do you suppose that they all occurred in or about the same epoch in geological history?

Professor HULL, F.R.S.—Yes. I would remind you that these sub-oceanic channels are not peculiar to the eastern side of the Atlantic, but that they have been recognised on the western side as well. Professor Spencer and others,—have recognised them along the coast of America. So that the whole region of the Atlantic underwent some great physical change.

The Meeting was then adjourned.

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* Indicated by the 228 and 242 fathom soundings.—See Map.

COMMUNICATION RECEIVED.

Professor J. Logan Lobley, F.G.S., writes:—

All geologists ought to be grateful to Professor Hull for continuing his investigations of the ocean floor along the eastern side of the Atlantic. The results of these investigations are geographically highly interesting, but geologically they are more than interesting, they are exceedingly valuable.

Apart from the submarine ravines revealed, the continuation of the continental platform from Iceland in the north, to the south of the equator, is a most important fact, from which only one conclusion can be drawn—that there has been a general subsidence of the western parts of Europe and Africa from a former higher level. The suggestion that this great terrace, at the summit of a steep ascent of thousands of feet, and, with the exception of far separated indentations, continuous for thousands of miles, has been formed by the deposition of material at each side of the mouths of existing rivers that have brought it from the interior lands, is altogether untenable, for it will not for a moment bear examination.

If this be so, the formation of the depressions crossing the terrace has obviously been by subaerial water erosion, and the position of these depressions with respect to present river valleys undoubtedly points to the former continuation seawards of these valleys and their excavating rivers.

The great depth of the submarine ravines, however, if the whole has been due to subaerial erosion, requires such a great elevation of enormous areas of land in late geological times, that some hesitate to accept this conclusion. But other evidences of great changes of level in Post Tertiary times, the consideration that 5,000 feet is but the $\frac{1}{8000}$ part of the diameter of the globe, and that such an elevation affords the most simple explanation of the cause of the Glacial epoch, ought to lessen the disinclination to accept conclusions which have been drawn by Professor Spencer, Mr. Warren Upham, and Professor Hull, from the phenomena of the Atlantic floor both in its western and its eastern margins.

One apparent inconsistency is the greatness of the submarine ravine attributed to the lesser River Adour and the smallness of that attributed to the greater River Gironde. This, it seems to me, admits of a complete explanation, as I endeavoured to show to

the Institute in a recent paper; for, with elevated and consequent glacial conditions as well as during the subsequent subsidence, there would be converging on the ocean shore opposite to where is now the bight of the Bay of Biscay, vastly greater erosive power than at any place further north.

Evidences of the upheaval of the whole of the Iberian peninsula, and not merely of its western side, are not wanting. Professor Hull gives some facts as to the sea bottom of the Mediterranean opposite the mouth of the River Ebro. It seems to me, however, that the Ebro Channel, before the subsidence and the formation of the present delta, took a southerly direction. There is a very decided indentation of the continental platform, having a northerly direction from nearly opposite Valencia, and extending northwards between the Columbrates Isles and the coast at Castellon. It points directly to the Ebro at Tortosa before the delta is reached by that river. The present mouth of the Ebro at the Cabo de Tortosa I regard as having a quite different direction and being consequent on the formation of the delta of which the Cabo de Tortosa is the most eastern point. Opposite to the delta of the Ebro the sea bottom descends from 200 metres depth to 1,000 metres in a distance of 10 kilometres, but this is at a distance of from 90 to 100 kilometres from the old coast line on the landward side of the delta.

An explanation of the glacial conditions that undoubtedly prevailed over vast areas of the northern hemisphere during Pleistocene times, must be regarded as a most important geological result, and believing that continental elevation will afford this explanation, and that the investigations of Professor Spencer and Professor Hull furnish cogent evidence of such elevation, I think they deserve the hearty thanks of all geologists.