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THE SCOTTISH GEOGRAPHICAL MAGAZINE.

ON THE LAND SLOPES SEPARATING CONTINENTS AND
OCEAN BASINS, ESPECIALLY THOSE ON THE WEST
COAST OF AFRICA. OBSERVED AND SURVEYED IN THE S.S.
"BUCCANEER," BELONGING TO THE INDIA-RUBBER, GUTTA-PERCHA,
AND TELEGRAPH WORKS COMPANY (LIMITED) OF SILVERTOWN.

(With Diagrams.)

By J. Y. BUCHANAN.

IN the year 1883, owing to the kindness of the Silvertown Company, I had the advantage of accompanying the ships surveying the route of the cable connecting Spain with the Canary Islands. In the course of this survey several unsuspected shoals rising abruptly out of deep water were discovered and carefully investigated. Numerous and very close soundings made round the edges of these shoals showed that they were in all cases very steep, and in one or two instances direct evidence was obtained that they were precipitous.

The seaward slopes of the volcanic islands forming the Canary group were also carefully sounded, and they were found almost always to be very steep. They differed, however, in character from the slopes of the banks. These consist always of shell or coral—indeed, good evidence was obtained to show that they have in most cases been built up from great depths by deep-sea corals, and their sides are steep all round, but not much indented. In the case of volcanic islands, on the other hand, the lava streams or flows which form the substance of the visible island, and give it its rugged character, are continued with much the same features below the surface of the ocean, from the bottom of which they have been raised or built up by the solidification of successive overflows of melted lava. Both above and below water, these flows, when solidified,

form radiating ridges, separated by deep and rugged ravines which can usually be traced to a depth of 800 or 1000 fathoms.

In the beginning of the year 1886, I accompanied the expedition sent to survey the route for the continuation of the cable down the coast of Africa, from the French settlement Conakry, about 70 miles north of Sierra Leone, as far as St. Paul de Loanda, in lat. 9° S.

The s.s. *Buccaneer*, which was selected for this service, left Conakry on 31st December 1885, and began work immediately, sounding round the coast of the Gulf of Guinea. This gulf is the receptacle into which the great easterly counter-equatorial current of the Atlantic, often called the Guinea Current, empties itself, and the source from which proceeds the great equatorial current which runs in a westerly direction all the way across the Atlantic, and is probably the most powerful proximate factor in the production of the Gulf Stream. Hitherto these waters had been entirely unexplored, and even hurried investigations could not fail to give interesting results.

The chief object of the expedition was to delineate the seaward continental slopes, with the view of discovering a suitable bed for the cable about to be laid. This was done by carrying a continuous line of soundings parallel to the coast, in depths of about 1000 fathoms, and interrupting it at more or less regular intervals by short lines of soundings at right angles to the coast. The soundings on these lines were usually taken very close together, and they give a very accurate profile of the side of the ocean basin at the particular locality. Extended series of observations of the temperature and the density of the water at different depths were made. The tow-net was used constantly for making collections at different depths, and the mud was sampled with the sounding tube and the dredge; but the results of the soundings themselves are perhaps the most interesting of all.

In carrying out work of this kind, it is not uncommon in surveying practice to make soundings every 10 miles or every 5 miles, or at less intervals; in the *Buccaneer* it was endeavoured to place the soundings on the lines of profile, at such distances apart that no two consecutive ones should differ by more than 200 fathoms. On certain parts of the coast this necessitated taking soundings half a mile apart at the steepest part of the slope, and it was usual to take them at distances not more than 2 miles apart as long as the depth ranged between 100 and 1000 fathoms. Profiles based on soundings of this degree of closeness give a fairly accurate representation of the continental slope of the bottom of the ocean. Indeed, even in running lines of soundings across the middle of the ocean, it is better, and gives much more useful information, to place the soundings at alternate long and short distances apart. Thus it is better to take soundings along such a line at alternate intervals of 9 miles and 1 mile than at regular intervals of 5 miles. In most cases the 9-mile soundings will give as much information as the 5-mile ones, but the 1-mile soundings at an average distance of 10 miles apart give definite and precise

information about the actual nature of the bottom, and not merely its average character, which is all that can be learned from widely spaced soundings.

Between Sierra Leone and Porto Novo, a French settlement about 50 miles west of Lagos, fourteen profiles were sounded. In Fig. 4 some of the more characteristic ones are represented graphically. Most of them were off prominent points on the coast, or points of proposed landing for the cable. They showed that the bottom of the ocean at the edge of the continent has a roughly-terraced shape. First, we have the coast flat, running from the shore out to 100 fathoms; this along the Guinea Coast is generally about 12 or 15 miles broad, and is very flat until a depth of 30 fathoms is reached, when the depth rapidly increases to 100 fathoms. The slope gets rapidly steeper, attaining a maximum generally between 200 and 400 fathoms. Between 500 and 1000 fathoms it becomes less steep, and indeed along a considerable part of this coast there is a very well marked terrace at about 700 fathoms. Between 1000 and 1200 fathoms a further steepening occurs, after which the slope gradually flattens out towards the deep water, though a slight steepening is frequently noticed at about 1800 fathoms. The soundings along this coast revealed a rather remarkable law—namely, that the slope on the east side of the principal points or headlands is always much steeper than that on its west side. This is well shown at Cape Palmas, Cape Three Points, and Cape St. Paul. On the Krou coast, west of Cape Palmas, the 100-fathom line projects out in a tongue, and the slope down to 600 fathoms is gentle—not more than 70 fathoms per mile; and there is reason to conclude from the temperatures of the bottom water at great depths, observed east and west of this point, that a line could be traced from it to Ascension Island, with a depth nowhere exceeding 1800 fathoms. The distance of the 500-fathom line from the 100-fathom line is 11 miles off the Krou coast, and approaches within 25 miles of it, off and slightly to the eastward of Cape Palmas. The distance from the 100-fathom to the 1000-fathom line is 22 miles off the Krou coast, and 11 miles off Cape Palmas. The profile off Cape Palmas is remarkable, giving a very high average slope down to very deep water. From 100 to 1500 fathoms there is an average increase of depth at the rate of 150 fathoms per nautical mile. Judging from analogy, there can be no doubt that part of the slope must be very much steeper. After rounding Cape Palmas, and on entering the large bight to the eastward of it, the steepness of the continental escarpment seems to increase. In longitude 7° W. a depth of 1054 fathoms was found at a distance of 11 miles from the coast, and only 3 miles from the 100-fathom line, as indicated on the Admiralty chart. This steepness of escarpment at depths between 100 and 1000 fathoms is found to continue all round the bight which stretches from Cape Palmas to Cape Three Points. The ground flattens much at depths over 1000 fathoms, and the result of the soundings was to show that, while the contour lines of 500 and of 1000 fathoms follow closely the

direction of the coast-line, the 1500-fathom line keeps an east and west direction across the bight. Off Cape Three Points the 100-fathom line runs out to a distance of 40 miles from the coast. On the west side of this point the slope was found comparatively gentle—the contour lines of 100 and of 500 fathoms being about nine miles apart. A remarkable profile was obtained on the eastward slope of Cape Three Points. The position of the ship having been carefully verified by the land, a sounding was taken in 30 fathoms, which agreed well with those found on the chart. The next sounding gave a depth of 434 fathoms, and then three soundings, at distances little over two miles apart, gave depths of 1083, 1727, and 1973 fathoms, giving evidence of declivities of altogether exceptional steepness. Between 434 fathoms and 1083 fathoms the depth increases at the rate of 232 fathoms per mile, and between 1083 fathoms and 1727 fathoms it increases at the enormous average rate of 322 fathoms per mile. Between 1727 and 1973 fathoms it falls off to the still considerable rate of 91 fathoms per mile. On this, the steepest slope observed, the distance from the 100-fathom line to the contour line of 500 fathoms is 1·8 mile; to that of 1000 fathoms, 3·8 miles; to that of 1500 fathoms, 5·3 miles; and to that of 2000 fathoms only 8·9 miles.

A comparison may be made between the slopes indicated by these soundings and those of well-known mountainous countries. The highest and the best known mountain in the British Islands is Ben Nevis. It is 4406 feet above the sea-level, and the horizontal distance between its summit and Fort-William at its base is about 4 nautical miles. The average slope between these points is 1100 feet per mile, and it is along this line that the path for the ascent is carried, and it is good mountain walking. The shortest horizontal distance between the summit and the valley of Glen Nevis is 2 miles, and the descent over 4000 feet, giving an average slope of 2000 feet per mile; and no one would describe the country lying on the line connecting these two points otherwise than as a succession of precipices. The average slope between our soundings of 434 and of 1083 fathoms is 232 fathoms, or, in round numbers, 1400 feet per mile, and between those of 1083 fathoms and 1727 fathoms it is 2000 feet per mile. Moreover, both at 434 and at 1083 fathoms the bottom was hard rock. There seems, therefore, no reason to suppose that the continental slopes forming the sides of the ocean basins do not rival in steepness and in ruggedness those of the most mountainous regions of the land surface. Fig. 5 represents a comparison between the slopes observed on the deep profile at Cape Three Points (No. 1), and two profiles of Ben Nevis (Nos. 2 and 3), as taken from the Ordnance map. No. 2 represents the profile on a northerly line from the top to the sea at Banavie, and No. 3 represents the profile in a westerly direction from the top to the bed of the river Nevis. It will be seen that the average slope between the soundings at 1083 fathoms and 1727 fathoms on line No. 1 is very little less than that of the line (No. 3) from the top of Ben Nevis to the bed of the river, and this is nothing but a series of precipices.

At Cape St. Paul the same law was found to hold —namely, that its eastward slope is steeper than its westward one; but the slopes generally become gentler on entering the Bight of Benin. From Porto Novo, in long. $2^{\circ} 30' E.$, a line of soundings was carried across the Bights of Benin and Biafra to the island of St. Thomas. The continental slope of Porto Novo was found to be much gentler than in previous profiles, and this was to be expected on approaching the head of the bay into which the Niger and other great rivers pour their waters and the abundant land *débris* brought down by them. Between the coast and the island of St. Thomas the soundings were carried in a direct line S. $34^{\circ} W.$, with occasional soundings to the right and left of the line in order to show the slope of the bottom. For nearly one half of the way the line runs parallel to the coast, forming the western margin of the delta of the Niger, and at a distance of about 100 miles from it. For the remainder of the route it crosses the mouth of the Bight of Biafra. The bottom is very uniform, both as regards elevation and nature. Although there seem to be no steep ridges or valleys, there are some well-marked depressions and elevations which deserve to be noticed. A first maximum depth of 1783 fathoms was met with in lat. $5^{\circ} 15' N.$ and long. $3^{\circ} 10' E.$, which no doubt indicates the line of the deepest water of the Bight of Benin, terminating in the remarkable gully called Avon's Deep, a little to the eastward of Lagos. Proceeding southwards, the water shoals gradually to a minimum observed of 1391 fathoms, in lat. $3^{\circ} 55' N.$, long. $4^{\circ} 7' E.$ It then deepens rather rapidly in the next 25 miles to 1916 fathoms, and the bottom remains very level until it begins to rise rapidly towards the volcanic island of St. Thomas, where the slopes had precisely the same character as those observed in the Canary Islands. Prince's Island, to the north-east of St. Thomas, has also the steep and irregular escarpments of volcanic islands, and between the two islands the water attains a depth of 1600 fathoms.

After leaving Porto Novo, and all the way as far south as St. Paul de Loanda, the soundings showed an altogether different character of water and bottom from that observed westward of Cape St. Paul. There the gradients were steep, here they are gentle; there the bottom consisted of the usual stiff blue or green muds characteristic of continental coasts, here it consists of very soft black oozy mud, characteristic of river estuaries. Between the island of St. Thomas and the French settlement on the Gaboon a very good profile was sounded (see Fig. 3). Here the 500-fathom line was 10 miles, the 1000-fathom line 34 miles, and the 1500-fathom line 67 miles from the 100-fathom line. All the way down the coast as far as Loanda the same gentle gradients and the same very soft river mud were found. It appears that the land *débris* brought down by the Niger and Congo, and by other less important rivers, is collected and concentrated in this district. The prevailing current past the mouth of the Congo is a northerly one, while all along the coast from Cape Palmas to the Niger an easterly current sets. These help to confine the drainage matter of both rivers to a comparatively small extent of littoral. If from the

soundings west of Cape St. Paul we compute the mean continental slope, we find that the 500-fathom line is at a mean distance of 4.1 miles, the 1000-fathom at 11.7 miles, and the 1500-fathom line at a distance of 17 miles from the 100-fathom line (line AD, in Fig. 3). If it is assumed that in the absence of the Niger and the Congo the continental slope would be much the same as the average found in the profiles west of Cape St. Paul, it may be concluded that the excess of mud forming the flatter talus along the coasts affected by these rivers, is due to the mud brought down by them. Taking the figures given above, the sectional area of this excess-talus ABC is 60 square nautical miles, and it extends for a distance of at least 1100 miles along the coast. This represents a deposit of 66,000 cubic miles of detritus due principally to the Niger and Congo. The drainage areas of these two rivers are roughly :—of the Niger, 750,000, and of the Congo 1,150,000 square nautical miles, making together 1,900,000 square nautical miles. The 66,000 cubic miles of detritus spread over this area would cover it to a thickness of 200 feet.

Along the Guinea Coast as far as Cape St. Paul the 100-fathom line is at an average distance of 15 miles from the shore ; and on the south-west coast between the Niger and the Congo it is from 30 to 40 miles from the shore. At three localities there are remarkable exceptions. Off Grand Bassan the 100-fathom line approaches within a quarter of a mile of the shore, and the curving-in shorewards of the contour lines produces the very remarkable submarine gully known by the name of the "Bottomless Pit." From the *Buccaneer* five lines of soundings were run across it at distances of two miles between the lines. At one mile from the shore the width of the gully is under a mile, with a depth of 150 fathoms ; at eight miles from the shore its width is $1\frac{1}{2}$ miles, with a maximum observed depth of 327 fathoms ; while two miles further seawards its width has increased to 4 miles, with a maximum observed depth of 452 fathoms. The accompanying sketch-plan (Fig. 1) of the contour lines gives a better idea of this extraordinary feature than can be conveyed by description. The bottom consisted everywhere of a soft dark-coloured mud, and the slopes of the sides averaged in many places 2000 feet per mile.

Another similar gully occurs to the eastward of Lagos, called Avon's Deep, but it does not reach so close to the shore as the one just described.

The most remarkable feature of this kind occurs at the mouth of the river Congo (Fig. 2). Here the gully penetrates inland up the river, a depth of 150 fathoms being found 20 miles within its mouth, while it was traced by the *Buccaneer* to a distance of nearly 100 miles seaward. It forms an immense submarine cañon, with steep mud sides, penetrating deeply into the land. The 100-fathom line runs at a distance of about 35 miles from the coast both north and south of the cañon ; the 500-fathom line runs at about 60 miles, and the 1000-fathom line at about 80 miles from the coast. Of these contour lines, that of 100 fathoms penetrates 20

miles within the coast line, that of 500 reaches to within 10 miles, and that of 1000 fathoms to within 50 miles of it. At the mouth of the river, off Shark Point, the width of the gully is three miles, and the deepest sounding was 333 fathoms. The deepest sounding obtained in the river, off Banana Creek, was 242 fathoms. Thirty-five miles off the mouth of the river the width of the gully is six miles, and the maximum depth observed was 573 fathoms. The bottom of the cañon is here 3000 feet below the surface of the plateau in which it is cut.

It is difficult to furnish a satisfactory explanation of these gullies, but the Congo cañon is certainly connected with the river which flows over it, and the "Bottomless Pit" may be connected with the river Akba, which flows into the sea a few miles to the eastward of it. The Congo cañon is not due to erosion by the river, for the current, strong though it is, does not extend more than 20 fathoms from the surface, and is felt to a considerable distance out to sea, where it thins out considerably. For many miles off the mouth of the river the water has a dark reddish-yellow colour, but this forms only a thin layer, as the ship's propeller turns up the colourless salt water beneath. The existence and the persistence of the cañon are due to an agency which prevents the mud brought down by the river being deposited along its axis. This agency is probably the sea water running up the gully at the bottom and returning in the upper layers, mixed with the river water. A circulation in a vertical plane is thus produced, and in the axis of it, settlement of sediment is more difficult than on either side of it. The bottom of the cañon, or gully, would thus resemble more nearly the original form of the bottom of the sea before the Congo discharged its waves into it, than the flatter and shallower bottom on each side of it. In fact the cañon has been built up, not hollowed out. In how far a crack in the crust of the earth may have had to do with the depth or the position of this cañon, it is impossible to speak certainly, but the preservation and accentuation of it are certainly due to the prevention of the deposition of sediment.

The "Bottomless Pit" is situated only fourteen miles from the mouth of the large river Akba. As is usual on this coast, behind the beach of pebbles, heaped up and arranged by the combined action of the surf and the prevailing easterly current, there is an extensive lagoon formation connected with the river; and at the point where the "Bottomless Pit" approaches nearest to the beach, the width of the beach separating the lagoon from the sea is smallest, being little over a quarter of a mile. The mouths of these rivers frequently change their positions, and it is not improbable that the Akba may have entered the sea where the "Bottomless Pit" now is, and produced similar conditions to those existing at the mouth of the Congo. Since the date of the *Buccaneer's* visit, the lagoon at Porto Novo has opened a new communication with the sea.

In Europe, at the head of the Bay of Biscay, and on a coast resembling in some of its physical features the coast of the Gulf of Guinea, a gully or cañon quite like the Bottomless Pit penetrates close up to the shore

at Cape Breton, where, in former times, the river Adour entered the sea. This remarkable gully forms a deep indentation in the littoral flat, and runs parallel with the range of the Pyrenees and the mountains of the north coast of Spain. It is not impossible that, in their origin, these two features may have had some connection with each other. Much trouble was experienced with the first cable laid from Bilbao over the deeper part of this gully, indicating some instability in the features of the bottom in this region, even at depths of over 1000 fathoms. Earthquakes are a frequent cause of rupture of cables in the neighbourhood of the steep slopes connecting the continents with the ocean beds.

The nature of the circulation of the water at the mouth of a deep river like the Congo will be better understood if we imagine for a moment a barrier across its mouth at Shark Point, and the whole of the bed of the river above it filled with fresh river-water. The depth of the channel both above and below the barrier is between 200 and 300 fathoms. On the seaward side the water is salt, with a density of, say, 1.023, as compared with that of the water inside, which is unity: that is, a column of the outside water 1000 feet high would balance one of the inside water 1023 feet high. If the barrier be now removed there will be an immediate rush of the denser water inwards to occupy the lower part of the bed of the river, and a rush outwards of the fresh water to occupy the surface layers of the sea outside. If the barrier be now re-established, although it might take some considerable time to clean out the last vestige of salt water from the deepest parts of the inner bed, it would not take long to eliminate enough of the salt water to establish a very decided difference of density on the two sides of the barrier. On its removal again a similar redistribution of the waters would take place, the denser sea-water going to the deeper parts of the river-bed, and the fresher water going to the surface of the ocean. Now these operations, which we have here imagined to take place *per saltum*, go on continuously in nature. The constant supply of fresh water from the river produces a constant difference between the weight of a column of water at the upper part of its estuary, and that of an equal column at the lower part of its estuary. This difference may, and probably will, fluctuate in amount, but it will be always in favour of the seaward column, and against the landward one. It finds its natural balance in an under-current from the heavier column to the lighter one. A very good example of this kind of circulation is afforded by the well-known currents of the Bosphorus. These are due to the surplus water, supplied to the Black Sea by rain and rivers, over that removed by evaporation from its surface, which finds its outlet at the Bosphorus into the waters of the Mediterranean. Here the conditions are reversed, the evaporation from the Mediterranean much exceeding the supply by rain and rivers, including that derived from the Black Sea. If a barrier were erected at the Bosphorus so as to admit of the waters on each side attaining their natural density, exactly the

same phenomena would be observed on its removal as have been described above when considering the case of the Congo.

At the Straits of Gibraltar we have a curious instance of a similar phenomenon; here, however, the Atlantic Ocean performs the part of the river, while the Mediterranean is the receiving ocean-bed, kept at a constantly lower level by the evaporation from its surface.

COAST FLATS.—Hitherto we have considered only the slopes at greater depths than 100 fathoms. A few words may be said about the slopes between the beach and the 100-fathom line.

TABLE I.—Profiles of Coast Flats.

Number, of Profile.	1	2	3	4	5	6	7	8	9	10	11
Longitude,	9° W.	8°	7°	8°	3° 30'	1°	0°	0° 55' E.	1°	3° E.	
Depth, Fathoms.	Distance of Depth from shore in nautical miles.										
10	1.5	1.2	0.7	2.0	1.0	2.5	2.2	7.0	1.0	3.5	1
20	3.0	5.5	2.0	5.5	3.0	16.0	4.0		4.0	7.5	4
30	5.5	6.5	5.0	9.5	6.5	31.0	10.0		5.5	10.0	6.5
40	13.0	8.0	8.0	10.0	9.5	35.0	12.8			12.5	9
50	20.5	12.5	12.0	16.5	13.0	37.0	13.8			13.5	13.5
60	22.0	14.0	13.0		13.5	38.0					14
70	23.0										
80	24.0										
90	24.5										
100	25.5	15.0	14.0	17.0	14.0	39.0	15.0	8.0	6.5	14.5	15

In Table I. are given the distances in nautical miles from the shore at which certain depths are found, on lines of profiles between long. 9° W. and long. 3° E. It will be observed that only at the first locality, in long. 9° W., a little to the west of Cape Palmas, was it possible to find the locality of the depths between 60 and 100 fathoms. At this station there is a remarkable projection of the 100-fathom line seaward, which is found repeated in the contour lines of greater depths. Judging from the observations of bottom temperature, it is probable that the contour lines of 1800 fathoms run across to the Ascension plateau. At all the other localities, when a depth of 60, or even 40 or 50, fathoms has been found, the edge of the slope from continent to ocean has been reached. No. 6 represents soundings on the great flat stretching from Cape Three Points, where the 100-fathom line is nearly 40 miles from the coast. At Cape St. Paul there is a curious configuration of the shore flat. On the west

side of it (No. 8), a depth of under 10 fathoms is found to a distance of 7 miles from the shore, and then in another mile the depth is over 100 fathoms. On the east side of it (No. 9) the slope is only very little less abrupt, and 100 fathoms is found within 7 miles of the coast. These are exceptional cases, and Nos. 2, 3, 4, 5, 7, and 10 represent the normal configurations of the coast flat as it is met with in this part of the world. In Column No. 11 we have the means of the distances found in Nos. 2, 3, 4, and 5, which all lie on the coast between Cape Palmas and Cape Three Points. On this coast the beach, consisting, as it does, almost invariably of shingle, is always "steep to," so that, at a distance of a few yards from it, there is usually a depth of four or five fathoms; the gentle slope then commences. With a depth of 10 fathoms at 1 mile from the shore, we have to go 4 miles before the water deepens by another 10 fathoms to 20 fathoms, 2·5 miles further to get 30, 2·5 miles further to get 40 fathoms, and 4·5 miles to get 50 fathoms. A mile further we have 60 fathoms, when the rapid descent begins, and in another mile we have over 100 fathoms. We may say, then, that on the Guinea Coast the littoral flat extends to a distance of about 14 miles from the shore, and to a depth of 50 fathoms.

This coast flat represents the gain of the sea on the land. We may suppose that originally the average slope between the coast-line and a depth of 100 fathoms was not very different from that between 100 and 200 fathoms. The retreat of the coast-line is due to the wearing action of the waves, charged with the *débris* of the already disintegrated land. To a certain extent, therefore, the depths to which the coast has been cut back from the 100-fathom line indicates the work done by the waves since the continent and ocean attained their present relative positions.

Fig. 6 represents some sections in profile of coast flats on the Guinea Coast, Nos. 1, 10, and 11, and for comparison some from the North Atlantic, Nos. 12, 13, and 14. These profiles meet at 100 fathoms, which is the common depth from which they are all drawn.

Of the Guinea Coast profiles, No. 10 represents the coast flat east of Cape St. Paul in long. 3° E., No. 11 is constructed from the mean of four profiles between Cape Palmas and Cape Three Points, and No. 1 is the profile at the point, west of Cape Palmas, where not only the 100-fathom lines extend further from the coast, but where, even at greater depths, the slopes are comparatively slight. In the cases of Nos. 10 and 11 it is evident that the wear-and-tear at depths greater than 50 fathoms is insignificant. The same holds with regard to No. 1; the part of the profile below 50 fathoms properly belongs to the continental slope, which is here exceptionally gentle. Turning now to the North Atlantic profiles, No. 12 is drawn from Cape Ferret, in lat. 44° 40' N.; No. 13, from the Saint Islands, a little south of Ushant; and No. 14 from Mizen Head, on the south-west coast of Ireland. They afford, therefore, examples of the formation of the coast flat on the stormiest coast of the world. The

effect is evident in the great distance, both horizontally and vertically, to which the waves have hollowed out the land.

In the Gulf of Guinea there may be said to be practically no wind. The surf which breaks on the beaches is due to waves produced by the storms of much higher latitudes, which travel as long low swells, which show no signs of breaking until close to the shore, in a depth of not more than three or four fathoms. Here their power is very apparent, and the surf which they produce is the greatest hindrance to communication with the coast. In deeper water their power is very slight.

On the other hand, the conditions at the entrance to the English Channel and in the Bay of Biscay are very different. In no part of the world are the storms more frequent, more violent, and of greater duration than in this part of the North Atlantic. They blow with their greatest violence while veering from SW. through W. to NW. The waves are produced in very deep water, where there is nothing to prevent their attaining any size proportioned to the power of the wind. They are then driven on the lee shores of Ireland, England, and France, not as swells, but as storm waves, still driven by the tempest which produced them. The result is apparent in the great distance inland and depth vertically to which they have carried their hollowing action. Off Mizen Head the wearing action is strong at 100 fathoms; off Saint Islands it is very apparent at 100, and strong at 90 fathoms, while off Cape Ferret it is hardly sensible at 100 fathoms, and only becomes strong in depths under 80 fathoms. Cape Ferret lies on the French coast in the southern part of the Bay of Biscay, and does not experience the full strength of the waves until the wind has passed from S.W. to W. This means that, for the first part of the duration of the storm, this coast is sheltered; the resulting wearing action is therefore by so much less evident. If we assume, as, in absence of evidence to the contrary, we have a right to assume, that there is no differential motion of the African and European continent with respect to the sea-level, the sectional area enclosed by these profiles and the sea surface represents approximately the work done by the sea on the land in calm and in stormy latitudes.

In Tables II., III., and IV. are given some figures deduced from the profiles. The total sectional area considered in any one case is that enclosed by the concavity of the profile, the surface line, and the vertical line from the surface line to the bottom in a depth of 100 fathoms. This area is subdivided into ten successive areas corresponding to the ten intervals of ten fathoms between the surface and 100 fathoms. In Table II. the mean horizontal distance, in nautical miles, to which each 10-fathom band has been cut into the land is given for each profile. In Table III. the proportion (per cent.) of the area of each 10-fathom band to the whole sectional area removed is given for each profile. In Table IV. the summations of these percentages are given for each profile. These give the areas of the bands from 100 fathoms to each tenth fathom in percentage of the whole area removed.

TABLE II., giving the mean horizontal distance, in nautical miles, to which each 10-fathom band has been cut into the land for each profile.

Pro- file No.	MEAN DISTANCES FOR THE DEPTH-INTERVALS.									
	100-90	90-80	80-70	70-60	60-50	50-40	40-30	30-20	20-10	10-0
1	0.4	1.2	2.0	3.0	4.0	8.0	16.6	21.6	23.0	25.0
11	0.4	1.0	1.6	2.2	2.7	6.4	14.2	18.1	24.2	29.2
10	0.1	0.3	0.5	0.7	0.9	1.4	3.1	5.7	9.0	13.1
12	0.5	1.5	4.0	11.5	15.8	20.2	24.3	27.5	31.0	34.4
13	8.0	19.8	27.8	32.5	36.0	39.3	43.5	47.0	48.6	48.9
14	2.0	7.8	22.4	39.3	50.0	55.0	58.5	60.7	61.5	61.9

These distances are given in nautical miles of 1000 fathoms each, and, when multiplied by 0.01' (= 10 fathoms) they give the area of each section in terms of a square nautical mile of 1000 fathoms. In other words, the figures under the depth-intervals in A. give the areas of the sections if the decimal point be shifted two places to the left. In the last column, where the depth interval is 100 fathoms, the point must be shifted only one point to the left.

TABLE III., giving the proportion (per cent.) of the area of each 10-fathom band to the whole sectional area removed.

Pro- file No.	PERCENTAGE OF AREA REMOVED FOR DEPTH-INTERVALS.									
	100-90	90-80	80-70	70-60	60-50	50-40	40-30	30-20	20-10	10-0
1	0.4	1.2	2.0	2.9	3.9	7.8	15.6	20.6	21.8	23.8
11	0.4	1.0	1.6	2.2	2.7	6.4	14.2	18.1	24.2	29.2
10	0.3	0.9	1.5	2.1	2.8	4.0	9.0	16.3	25.5	37.6
12	0.2	1.0	2.2	6.8	9.3	12.0	14.2	16.2	18.0	20.1
13	2.3	5.8	8.0	9.3	10.2	11.0	12.3	13.4	13.8	13.9
14	0.4	1.9	5.4	9.6	12.0	13.0	13.8	14.5	14.7	14.8

TABLE IV., giving the areas of the bands from 100 fathoms to each tenth fathom in percentage of the whole area removed.

Pro- file No.	AREA REMOVED BETWEEN 100 FATHOMS AND FOLLOWING DEPTHS :—									
	90	80	70	60	50	40	30	20	10	0
1	0.4	1.6	3.6	6.5	10.4	18.2	33.8	54.4	76.2	100.0
11	0.4	1.4	3.0	5.2	7.9	14.3	28.5	46.6	70.8	100.0
10	0.3	1.2	2.7	4.8	7.6	11.6	20.6	36.9	62.4	100.0
12	0.2	1.2	3.4	10.2	19.5	31.5	45.7	61.9	79.9	100.0
13	2.3	8.1	16.1	25.4	35.6	46.6	58.9	72.3	86.1	100.0
14	0.4	2.3	7.7	17.2	29.2	42.2	56.0	70.5	85.2	100.0

From this table it will be seen that between 50 and 100 fathoms there is less than 10 per cent. removed on the Guinea Coast, while as much as 35 per cent. has been removed on the Irish coast. On the Guinea Coast between 70 and 80 per cent. has been removed between the shore and a depth of 30 fathoms; in fact, the seas of these latitudes have hardly any action at depths greater than 30 fathoms. On the North Atlantic coast, the slope to 90 fathoms is much like the slope to 10 fathoms on the Guinea Coast, and from 50 to 60 per cent. of the whole wear-and-tear has taken place at depths greater than 30 fathoms.

The absolute amounts of the land removed at the different depths are interesting. In the following table the sectional areas removed at different depth-intervals are given in square nautical miles:—

TABLE V.

Depth-Interval.	Sectional Area Removed. (Square Nautical Miles.)					
	No. 1.	No. 11.	No. 10.	No. 12.	No. 13.	No. 14.
0 and 10 fathoms, . . .	0.250	0.150	0.131	0.344	0.489	0.619
0 „ 30 „ . . .	0.696	0.367	0.278	0.949	1.445	1.841
30 „ 50 „ . . .	0.246	0.106	0.045	0.445	0.828	1.135
50 „ 100 „ . . .	0.106	0.040	0.025	0.333	1.241	1.215
0 „ 100 „ . . .	1.048	0.513	0.348	1.707	3.514	4.191

If we take the mean of Nos. 1, 11, and 10, we have 0.636 square nautical mile for the mean sectional area removed on the Guinea Coast, and similarly, from Nos. 12, 13, and 14, we have 3.137 square miles as the mean sectional area removed from the North Atlantic coast, between the shore and a depth of 100 fathoms.

If we assume that in the absence of wave-action the true continental slope in this interval would have been at the rate of 100 fathoms per mile, we should have to deduct from the above figures 0.1 square mile as the sectional area of the continental slope, and the mean sectional areas would stand as 0.536 and 3.037. Roughly, therefore, we may say that during the time the European and African continents have maintained their present level relatively to the ocean, the strong waves of the North Atlantic have disintegrated and removed over five times more land from the western shores of Britain and France than the calm equatorial waters have been able to remove from the Guinea Coast.

Further, the study of the conformation of the sea-bottom between the shore and a depth of 100 fathoms affords the most convincing evidence,

that, for the time required to remove those masses of land the relative positions of the continent and the ocean *have* remained practically constant. It is not impossible that the terraced formation, observed at depths over 100 fathoms along most continental edges where soundings have been taken sufficiently closely to one another, may be the remains of former coast flats which have sunk in the course of the cooling of the earth. A very remarkable terrace of this kind is found running for a considerable distance along the western part of the Guinea Coast, at a depth of from 600 to 700 fathoms from the surface. This, however, is a subject of too difficult a character to be discussed at the end of a paper like the present.

APPENDIX.

DETAILS OF PROFILES ON WEST COAST OF AFRICA, WITH REMARKS.

No. of Sounding.	Profile.	Direction of Profile (true).	Latitude.	Longitude.	Depth, Fathoms.	Distance, Nautical Miles.	Gradient, Fathoms per mile.	Remarks.
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	
4	A	...	7 33 N.	15 18W	2406	...	...	Fig. 4.
5	"	N. 73° E.	7 38	14 59	2246	19·5	8·2	
6	"	"	7 41	14 51	2181	8·4	7·7	Flat
7	"	"	7 44	14 41	1991	10·0	19	
8	"	"	7 45	14 35	1911	6·0	13	F at
9	"	"	7 46	14 31	1764	4·0	41	Steep
10	"	"	7 47·1	14 26·8	1590	4·5	35	
11	"	"	7 47·9	14 23·6	1369	3·0	73	
12	"	"	7 48·5	14 21·5	1226	2·0	72	
13	"	N. 106° E.	7 48·2	14 19	922	2·5	122	Steep
14	"	"	7 48	14 16·4	706	2·5	86	
15	"	"	7 47·9	14 13·6	656	2·7	18	Flat
16	"	"	7 47·6	14 11	376	2·5	112	
17	"	"	7 47·4	14 8·4	197	2·5	72	Steep
18	"	"	7 47·3	14 5·7	52	2·5	58	
21	B	...	7 20	13 26	45	...	...	
22	"	N.	7 18	13 26	192	2·0	...	
23	"	"	7 17	13 26	357	1·0	165	Steep
24	"	"	7 14	13 26	609	3·2	79	
25	"	"	7 12	13 27	698	0·8	52	Flat
26	"	"	7 10	13 27	890	2·0	87	
27	"	"	7 8	13 27	1091	2·0	105	Steep
28	"	"	7 1	13 25	1817	7·0	104	"
33	C	...	6 34	12 39	1824	...	...	
34	"	N. 24° E.	6 36	12 38	1796	2·3	11	
35	"	"	6 38	12 37	1773	2·3	11	Flat
36	"	"	6 47	12 33	1604	9·9	16	
37	"	"	6 48·5	12 32	1510	1·8	52	Steep
38	"	N. 36° E.	6 51	12 30	1417	3·1	30	Flat
39	"	"	6 53·5	12 28·5	1317	3·0	33	"
40	"	"	6 56	12 27	1026	2·9	100	Steep
41	"	"	6 58·5	12 25	833	3·2	60	Flat
42	"	"	7 1	12 23·5	658	2·9	60	"
43	"	"	7 3	12 22	160	2·6	192	Steep

No. of Sounding.	Profile.	Direction of Profile (true).	Latitude.	Longitude.	Depth, Fathoms.	Distance, Nautical Miles.	Gradient, Fathoms per mile.	Remarks.
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	
51	D	...	6 8 N	10 55 W.	68	...	...	Fig. 4.
52	"	N.	6 7	10 55	199	1.0	131	Steep
53	"	N. 42° E.	6 6	10 55.5	256	1.0	57	
54	"	"	6 4.5	10 57.5	392	2.5	54	
55	"	"	6 3	10 58	442	1.5	34	Flat
56	"	"	6 1	11 0	560	2.9	41	Steep
57	"	"	5 58.5	11 2.5	661	3.6	28	Flat
58	"	"	5 56.5	11 4.5	782	2.7	45	
59	"	"	5 52.5	11 8	1103	5.2	62	Steep
67	E	...	4 21.5	9 8.3	556	...	...	
68	"	N. 41° E.	4 23.4	9 6.3	366	2.6	73	Steep
69	"	"	4 26	9 4.4	264	3.3	31	
70	"	"	4 28	9 2.4	188	2.7	28	
71	"	"	4 30.1	9 0.4	102	3.1	28	Flat
...	F	...	...	...	100	...	...	From Chart
79	"	N.	4 7.7	7 42.5	357	1.6	161	Steep
80	"	"	3 57.2	7 42.8	1567	9.5	127	
81	"	"	3 46.8	7 42.9	2010	9.6	46	Fig. 4
82	"	"	3 0.8	7 43	2546	46.0	12	
88	G	...	4 39.7	6 7.1	61	...	...	
89	"	N. 27° W.	4 37.7	6 6.5	234	2.2	79	
90	"	"	4 36.1	6 6.7	457	1.2	186	Steep
91	"	"	4 35.6	6 6	611	0.9	171	
92	"	"	4 33.2	6 5.5	944	2.2	151	
93	"	"	4 31.6	6 4.4	1123	2.0	90	
94	"	"	4 27.3	6 1.9	1327	4.8	43	
95	"	"	4 22.9	5 59.5	1513	5.0	37	
96	"	"	4 14.2	5 54.8	1643	10.0	13	
97	"	"	4 5.6	5 49.9	1817	9.9	18	Steep
128	K	...	3 58	3 42	1886	...	...	
129	"	N. 9° E.	4 7.6	3 40.7	1794	9.8	9	
130	"	"	4 27.4	3 37.5	1234	16.0	35	
131	"	"	4 32.1	3 36.5	1093	9.3	15	
132	"	"	4 37	3 35.5	916	4.8	37	Flat
...	L	...	...	...	100	...	...	From Chart
141	"	N. 40° W.	4 19.1	1 4.9	434	1.7	197	Fig. 4
142	"	"	4 17.3	1 3.4	1083	2.8	232	
143	"	"	4 15.7	1 2	1727	2.0	322	Steep
144	"	"	4 14.3	0 59.6	1973	2.7	91	
145	M	...	5 15.5	0 13 E.	1431	...	...	
146	"	N. 17° W.	5 17.6	0 13.2	1282	2.0	75	
147	"	"	5 22.3	0 11.6	868	5.3	78	
148	"	"	5 26.5	0 9.9	362	4.2	120	
149	"	"	5 28.4	0 9.6	107	2.0	128	Steep
150	N	...	5 22.4	0 1.5 W	35	...	...	
151	"	N. 56° W.	5 20.3	0 0.7 E.	166	3.2	41	
152	"	"	5 18.8	0 2.5	565	2.2	181	Steep
154	"	"	5 16.1	0 7.4	1041	5.7	84	Flat
155	"	"	5 14.7	0 9.8	1311	2.8	96	Steep
156	"	"	5 13.3	0 12.2	1488	2.9	61	

No. of Sounding.	Profile.	Direction of Profile (true).	Latitude.	Longitude.	Depth, Fathoms.	Distance, Nautical Miles.	Gradient, Fathoms per Mile.	Remarks.
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	
162	P	...	5 35.5 N.	1 11.1 E.	1132	...	...	Steep
163	"	N. 45° W.	5 37.5	1 9.3	999	2.8	47	
164	"	"	5 39.6	1 7.4	847	2.7	56	
165	"	"	5 41.8	1 5.3	635	3.0	69	
166	"	"	5 42.9	1 3.2	366	2.2	122	
176	R	...	5 54.8	2 8.9	1105	...	...	Steep
177	"	N. 13° E.	5 59	2 9.8	651	4.2	108	
178	"	"	6 0.6	2 10.2	543	1.9	57	Flat
179	"	"	6 2.2	2 10.5	449	1.5	63	
180	"	"	6 4.3	2 11	168	2.2	128	Steep
181	S	...	6 5	2 45	418	...	...	Steep
182	"	N. 26° W.	6 3.3	2 46	591	2.0	86	
183	"	"	6 1.4	2 46.8	761	2.2	77	
184	"	"	5 58.2	2 47.7	1084	3.2	101	
185	"	"	5 49.8	2 52.2	1434	9.5	37	
186	"	"	5 41.1	2 56.3	1625	9.5	20	
249	T	...	0 22.3	8 52.2	65	...	...	Steep
250	"	W	0 22.3	8 50.4	165	2.2	45	
251	"	"	0 22.3	8 49.8	214	0.6	82	
252	"	"	0 22.5	8 48.5	237	1.3	17	
253	"	"	0 22.8	8 47.5	298	1.0	61	
254	"	"	0 22.8	8 41.5	465	6.0	28	
255	"	"	0 22.8	8 33.2	660	8.3	23	
256	"	"	0 22.8	8 25	825	8.2	20	
257	"	"	0 22.8	8 16.7	1096	8.3	33	
258	"	"	0 22.4	7 59.8	1367	16.9	16	
259	"	"	0 22.1	7 42.9	1532	16.9	10	
289	V	...	1 22.2 S.	7 45	1396	...	...	Steep
288	"	N. 60° E.	1 12.4	7 55.8	1138	14.0	18	
290	"	"	1 6.2	8 10.4	757	15.6	24	
291	"	"	1 1.2	8 19.7	342	9.8	42	
376	W	...	5 10.5	11 38.7	168	...	...	Steep
377	"	W.	5 10.3	11 29.2	206	9.5	4	
378	"	"	5 10.1	11 19.8	474	9.4	29	
379	"	"	5 9.8	11 10.4	737	9.4	28	
380	"	"	5 9.6	11 1	903	9.4	18	
381	"	"	5 9	10 43	1093	18.0	11	
219	X	...	0 25.3 N.	6 38.7	26	...	...	S. Thomas
221	"	N.	0 25.7	6 38.7	110	0.4	210	
220	"	"	0 26.1	6 38.7	201	0.4	228	
222	"	"	0 26.5	6 38.7	458	0.4	642	
223	"	"	0 27.4	6 38.8	780	0.9	358	
266	Y	...	0 20.1	6 45.6	150	...	...	S. Thomas Projected on line
265	"	N. 87° E.	0 21.1	6 46.5	391	0.9	268	
267	"	"	0 20.2	6 47.7	737	1.2	288	
268	"	"	0 20.3	6 48.8	933	1.1	178	
269	"	"	0 20.4	6 52.2	1256	3.4	95	

No. of Sounding.	Profile.	Direction of Profile (true).	Latitude.	Longitude.	Depth, Fathoms.	Distance, Nautical Miles.	Gradient, Fathoms per Mile.	Remarks.
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	
275	Z	...	0 22·3 N.	6 44·7 E.	18	...	...	S. Thomas
274	„	N. 42° E.	0 23·3	6 45·6	519	1·3	385	
273	„	„	0 24·2	6 46·2	957	1·1	398	
272	„	„	0 25·6	6 47·4	1384	2·0	214	
276	Φ	...	0 17·9	6 46·8	201	...	...	S. Thomas
277	„	N. 99° E.	0 17·7	6 47·4	557	0·5	712	
278	„	„	0 17·5	6 48·6	889	1·2	277	
279	„	„	0 17·4	6 49·8	1017	1·2	107	
280	„	„	0 17·0	6 52·7	1282	3·0	88	
238	Ψ	...	1 37·3	7 30·2	117	...	...	Prince's Island Steep
240	„	N. 90° E.	1 37·4	7 30·5	309	0·3	640	
239	„	„	1 37·3	7 31·0	561	0·5	504	Flat Steep
241	„	„	1 37·3	7 31·3	599	0·3	127	
242	„	N. 117° E.	1 36·9	7 32·4	887	1·2	240	
243	„	„	1 36·2	7 33·7	1092	1·4	146	

Profile A., off Sierra Leone, starts from a depth of 2406 fathoms in lat. 7° 33' N., long. 15° 18' W., and runs N. 73° E. for 60 miles to a position in lat. 7° 48' 5 N., long. 14° 21' 5 W., where the depth was 1226 fathoms. From here it runs N. 106° E. for 16 miles, to a position in lat. 7° 47' 3 N., long. 14° 5' 7 W., where the depth was 52 fathoms. From here to the 10-fathom line off St. Anne's Shoals is 26 miles. At this point the coast-line alters its trend considerably to the eastward, but the 100-fathom line runs from Bijuga Islands to Cape Palmas pretty constantly in a S.E. by E. direction. The profile is therefore not normal to the 100-fathom line, but is nearly so to the coast-line at Sierra Leone. This profile starts from the greatest depth, and runs for a distance of 28 miles inshore, shoaling only at the rate of 8 fathoms per mile. Between depths of 2200 and 2000 fathoms the rate of shoaling is doubled, rising to 19 fathoms per mile, and it falls off again slightly to 13 fathoms per mile between 2000 fathoms and 1900 fathoms. From this depth until 900 fathoms the rate of shoaling increases from 35 fathoms per mile to 122 fathoms per mile. Between 900 and 650 fathoms it falls off to as low as 18 fathoms per mile, increasing again to 112 fathoms per mile between 400 and 300 fathoms, and falling off again to 58 fathoms per mile between 150 and 50 fathoms. The average slope on the 26 miles of coast flat between the depth of 50 and 10 fathoms is only 1·6 fathoms per mile.

In this profile we have three maxima of steepness, occurring between 350 and 650 fathoms, between 900 and 1200 fathoms, and between 2000 and 2200 fathoms. A very marked terrace-flat occurs between 650 and 700 fathoms, and a deeper one between 1900 and 2000 fathoms. We find from the above data that our line of profile is cut by the contour line of 500 fathoms at 5·3 miles from the 100-fathom line, by that of 1000 fathoms at 13 miles, by that of 1500 fathoms at 19 miles, and by that of 2000 fathoms at 36 miles from the same line. Assuming that these contours are approximately parallel to that of 100

fathoms, their perpendicular distance from that line would be—500 fathoms, 4 miles ; 1000 fathoms, 10 miles ; 1500 fathoms, 14 miles ; and 2000 fathoms, 25 miles.

Profile B., on the southern flank of St. Anne's Shoals, was intended to be on a meridian, and it is sufficiently nearly so to justify the soundings being projected on a meridian. The slight deviations in the position of the actual soundings were caused by the strong easterly current which prevailed. The line extends from a position in lat. $7^{\circ} 1' N.$, long. $13^{\circ} 25' W.$, where the depth was 1817 fathoms, to a position in lat. $7^{\circ} 20' N.$, long. $13^{\circ} 26' W.$, with a depth of 45 fathoms. The length of the line is thus only 19 miles, and the depth increases after leaving the coast flat at an average rate of over 100 fathoms per mile. The maximum slope is between 200 and 350 fathoms, where it is as much as 165 fathoms per mile. This, no doubt, corresponds to the maximum slope between 350 and 650 fathoms in Profile A. ; also the comparative flat found here between 600 and 700 fathoms corresponds to the similar one found at A. between 650 and 700 fathoms, though it is less pronounced. The great steepness between 900 and 1800 fathoms is remarkable—105 fathoms per mile—as compared with 68 fathoms per mile in the same interval at A. The distance of the principal contour lines from that of 100 fathoms is—500 fathoms, 3·6 miles ; 1000 fathoms, 9·7 miles ; and 1500 fathoms, 14·7 miles. If we include the sounding in 2107 fathoms at lat. $6^{\circ} 49' N.$, long. $13^{\circ} 33' W.$, we see that the ground flattens out greatly, and the 2000-fathom line will be at a distance of about 22 miles from the 100-fathom line. It will be seen that these distances are less than those found at A., though they approximate to the projected distances estimated.

Profile C., off the Liberian coast, extends from a position in lat. $6^{\circ} 34' N.$, long. $12^{\circ} 39' W.$, with a depth of 1824 fathoms for 14·5 miles in a N. $24^{\circ} E.$ direction, to a position in lat. $6^{\circ} 47' N.$, long. $12^{\circ} 33' W.$, with a depth of 1604 fathoms ; then for a distance of 19·5 miles in a N. $36^{\circ} E.$ direction to a position in lat. $7^{\circ} 3' N.$, long. $12^{\circ} 22' W.$, with a depth of 160 fathoms. A remarkable feature of this profile is the excessive steepness of the ground at a depth of 100 to 650 fathoms. Between 160 fathoms and 658 fathoms the average rate of increase of depth is 192 fathoms per mile. From 650 to 1000 fathoms the rate is only one-third of this, and apparently fairly uniform, corresponding to the ledge or flat, which was very pronounced at A., less so at B., and here seems merging into a more modified slope. Just as at A. and B. we find a steep slope between 1000 and 1300 fathoms, between 1500 and 1600 fathoms there is again an increase of steepness, and at 1800 fathoms it inclines to get a little steeper.

The distance from the coast to the 100-fathom line is 15 miles, and from this line the 500-fathom line is 2 miles, the 1000-fathom line 8·9 miles, and the 1500-fathom line 18 miles distant. The average slope is therefore steeper at depths from 100 to 1000 fathoms at C. than at B. ; at greater depths the reverse is the case.

Profile D., off Cape Mesurado, extends from a position in lat. $5^{\circ} 52'·5 N.$, long. $11^{\circ} 8' W.$, with a depth of 1103 fathoms for 20 miles in a N. $41^{\circ} E.$ direction to a position in lat. $6^{\circ} 7' N.$, long. $10^{\circ} 55' W.$, with a depth of 199 fathoms. Some shallower soundings, not exactly on the line, enabled the position of the 100-fathom line to be fixed with tolerable accuracy. This profile is very much less steep than any of the preceding ones. The steepest part is between 100 and 200 fathoms, and there are steep parts between 450 and 550 fathoms, and between 800 and 1100 fathoms. In fact, the features of the previous profiles are still discernible here, though they are much flattened.

The 100-fathom line is 12 miles distant from the coast, and from the 100-

fathom line the contour of 500 fathoms is 7·3 miles, and that of 1000 fathoms 19 miles distant.

Profile E., off the Krou coast, runs in a N. 41° E. direction from a position in lat. 4° 21'·5 N., long. 9° 8'·3 W., with a depth of 556 fathoms for a distance of 12 miles to a position in lat. 4° 30'·1 N., long. 9° 0'·4 W., with a depth of 102 fathoms. The position chosen for this profile was determined by the existence on the charts of a remarkable widening of the coast flat, producing a cape-like prominence of the 100-fathom line. The soundings on this profile do not agree with those on the Admiralty sheet, but the character of ground revealed by both is the same, and it is probable that the discrepancy is due to the great difficulty of accurately determining the position of soundings in cloudy weather, and out of sight of land and with a powerful current setting along the coast. The *Buccaneer's* soundings would tend to show that the 100-fathom prominence is less marked than is shown in the chart, but the gradients shown by both sets of soundings agree, and they are particularly remarkable for the gentle slope which they indicate between 100 fathoms and 400 fathoms—only about 29 fathoms per mile. There is a steep slope between 350 and 550 fathoms, with a comparative flat between 550 and 650 fathoms, followed by a steeper declivity between 700 and 1200 fathoms. The contour lines of 1000 fathoms and 500 fathoms are distant respectively 21·5 miles and 11 miles from that of 100 fathoms, which is distant 25 miles from the coast. Although our soundings tend to reduce the prominence of the 100-fathom line at this point on the coast, they show, when taken along with those between this and the next profile at Cape Palmas, that there is a decided and remarkable shoaling of the water off this part of the coast, as evidenced by the increased distance of the 500-fathom and the 1000-fathom contour line from the coast. Here the 1000-fathom line is 46·5 miles from the coast; 30 miles further east it approaches within 24 miles of it. It then again retires somewhat, only to approach again in the neighbourhood of Cape Palmas, as will be seen from the soundings on Profile F. There are reasons suggested by the higher temperature of the deep bottom water to the eastward of Profile E. as compared with that found to the westward of it, which render it not improbable that further investigations might prove the shoaling here to be not merely local, but part of an important oceanic feature, and might indicate the existence of a ridge with a maximum depth of 1800 or 1900 fathoms connecting the African continent with the great central ridge or plateau on which Ascension is situated.

Profile F., off Cape Palmas, runs in a north and south direction from a position in lat. 3° 0'·8 N., long. 7° 43'·0 W., with a depth of 2546 fathoms for a distant of 67 miles to a position in lat. 4° 7'·7 N., long. 7° 42'·5 W., with a depth of 357 fathoms. The line of soundings was made, starting with a good departure, from Cape Palmas; the profile between the shore and 357 fathoms is taken from the Admiralty sheet. The most remarkable feature in this profile is the very rapid descent from 100 fathoms to 1500 fathoms, and even 2000 fathoms. From 100 to 1500 fathoms there is an average increase of depth at the rate of 150 fathoms per mile, and, judging from analogy, there can be no doubt that part of the slope must be very much steeper.

The 100-fathom line is at a distance of 13 miles from the coast, and from the 100-fathom line we have the following distances to the principal contour lines—to that of 500 fathoms, 2·5 miles; of 1000 fathoms, 6·8 miles; of 1500 fathoms, 10·6 miles; of 2000 fathoms, 20·8 miles; and of 2500 fathoms, 61·0 miles.

From the position of the 2546-fathom sounding, the ship ran in again towards Cape Palmas, and took up the line of soundings along the coast. The easterly

current was here found to be much less strong than to the westward of Cape Palmas; in fact, there were occasional indications of an eddy current setting to the westward. The steepness of the continental escarpment seems to increase after rounding Cape Palmas; in longitude 7° W., a depth of 1054 fathoms was found at a distance of 11 miles from the coast, and only 3 miles from the 100-fathom line as indicated in the chart.

Profile G. runs from a position in lat. $4^{\circ} 5' 6''$ N., long. $5^{\circ} 49' 9''$ W., with a depth of 1817 for a distance of 38 miles in a N. 27° W. direction to a position in lat. $4^{\circ} 39' 7''$ N., long. $6^{\circ} 7' 1''$ W., with a depth of 61 fathoms. In this profile we again meet with the steep escarpment between 100 and 1000 fathoms, but, whereas at Cape Palmas the steepness continues to a depth of 1500 and even 2000 fathoms, here in the bight the ground flattens out at depths over 1100 fathoms, the slope here between 1100 and 1300 fathoms being less than that between 1500 and 2000 fathoms at Cape Palmas. There is a slight steepening between 1600 and 1800 fathoms, a feature which has been observed at other parts of the coast. The distance of the principal contour lines from the 100-fathom line are as follows:—1500 fathoms, 17.5 miles; 1000 fathoms, 6.5 miles; and 500 fathoms, 3.2 miles. The coast is 15 miles distant from the 100-fathom line. Proceeding eastwards the bottom seemed to continue remarkably even, soundings of 800 to 1000 fathoms being got along a line parallel to that of the coast and at a distance of 20 miles from it.

On 13th January some soundings were taken in profile, to show the slope of the ground in the deeper water in the middle of the bight.

Profile K. was from a position in lat. $3^{\circ} 58'$ N., long. $3^{\circ} 42'$ W., with a depth of 1886 fathoms for a distance of 40 miles in a direction N. 9° E. to a position in lat. $4^{\circ} 37'$ N., long. $3^{\circ} 35' 5''$ W., with a depth of 916 fathoms.

In this profile we have no information about the water of less depth than 900 fathoms, but the configuration between this depth and 1900 fathoms is remarkable. Between 900 and 1100 fathoms the depth increases at the rate of 37 fathoms per mile, after which the ground flattens out so that in 9.3 miles the depth only increases from 1093 to 1234 fathoms, or at the rate of 15.2 fathoms per mile. In the next 15 miles the depth increases at the rate of 35 fathoms per mile, and falls off again to a rate of 9.4 fathoms per mile at depths between 1800 and 1900 fathoms.

The contour line of 1500 fathoms is 41 miles, and that of 1000-fathoms 22 miles from the 100-fathom line, which is 14 miles from the shore. An important result of these profiles is to show that while the 500-fathom and 1000-fathom lines follow closely the direction of the coast-line, the 1500-fathom line keeps an east and west direction across the bight.

Profile L.—From the position of the 916-fathom sounding a course was steered parallel with the coast, soundings being got in from 800 to 500 fathoms, showing that on the western side of Cape Three Points the 500-fathom line lies from 8 to 10 miles from the 100-fathom line. The ship was now steered in so as to make the land at Cape Three Points, and then a profile was run out from it in a south-westerly direction. A sounding was taken in 30 fathoms, which agreed well with those found on the chart. The next sounding gave a depth of 434 fathoms, and then three soundings, at distances little over 2 miles apart, gave depths of 1083, 1727, and 1973 fathoms, giving evidence of declivities steeper even than those found at Cape Palmas.

The position of the 100-fathom line at this point is uncertain, as our 434-fathom sounding falls within it as placed on the chart, and there cannot be any doubt about its position, as it was obtained immediately after getting

a good position by the land. If we assume the same slope to exist between 100 and 400 fathoms as between 400 and 1000 fathoms, the 100-fathom line will pass 1·5 miles inside of our sounding in 434 fathoms. Between 434 fathoms and 1083 fathoms the depth increases at the rate of 232 fathoms per mile, and between 1083 fathoms and 1727 fathoms it increases at the enormous average rate of 322 fathoms per mile. Between 1727 and 1973 fathoms it falls off to the still very considerable rate of 91 fathoms per mile. Assuming the 100-fathom line to have the position above assigned to it, the distance from it to the other contour lines is as follows :—to the 500-fathom line, 1·8 miles ; to the 1000-fathom line, 3·8 miles ; to the 1500-fathom line, 5·3 miles ; and to the 2000-fathom line, 8·9 miles. The 100-fathom line is here 50 miles from the coast. This is the steepest declivity observed on the coast.

A course was now set for a position off Accra, and Profile M. was sounded. Owing to the strong easterly current this profile fell considerably to the eastward of the desired position. It runs from a position in lat. $5^{\circ} 15' 5''$ N., long. $0^{\circ} 13'$ E., with a depth of 1431 fathoms, to a position in lat. $5^{\circ} 28' 4''$ N., long. $0^{\circ} 9' 6''$ E., with a depth of 107 fathoms, the direction being N. 17° W., and the distance between the two positions 13·5 miles. The gradients in this profile, though moderately steep up to 800 fathoms, are a great contrast to those of profile L. The distances from the principal contour lines to the 100-fathom line are—from that of 1500 fathoms, 14·5 miles ; from that of 1000 fathoms, 8·0 miles ; and from that of 500 fathoms, 3·3 miles. The 100-fathom line is 12·5 miles from the coast.

On leaving Accra, profile N. was sounded directly out into deep water. It runs from a position in lat. $5^{\circ} 20' 3''$ N., long. $0^{\circ} 0' 7''$ E., with a depth of 166 fathoms in a S. 54° E. direction for 13·5 miles, to a position in lat. $5^{\circ} 13' 3''$ N., long. $0^{\circ} 12' 2''$ E., with a depth of 1488 fathoms.

This profile is only a few miles west of profile M., which it much resembles, though it is steeper, especially between 100 and 500 fathoms. The distance from the 100-fathom line to the 500-fathom line is 2·4 miles ; to the 1000-fathom line, 7·9 miles ; and to the 1500-fathom line, 14·5 miles.

The next profile, P., off Cape St. Paul, runs from a position in lat. $5^{\circ} 35' 5''$ N., long. $1^{\circ} 11' 1''$ W., with a depth of 1132 fathoms in a N. 45° W. direction for a distance of 11·2 miles, to a position in lat. $5^{\circ} 42' 9''$ N., long. $1^{\circ} 3' 2''$ E., with a depth of 366 fathoms.

This profile again is less steep than M. in the deeper water. From the 100-fathom line to that of 500 fathoms there are 2·6 miles, and to the 1000-fathom one, 9·6 miles. A few miles east of Cape St. Paul the slope seems to be much steeper, following the general law which seems to hold all along this coast, that the eastern slopes of the salient points of land are steeper than the western ones.

The next profile, R., runs from a position in lat. $5^{\circ} 54' 8''$ N., long. $2^{\circ} 8' 9''$ E., with a depth of 1105 fathoms, in a N. 13° E. direction, to a position in lat. $6^{\circ} 4' 3''$ N., long. $2^{\circ} 11'$ E., with a depth of 168 fathoms. From the 100-fathom line that of 500 fathoms is 3·4 miles, and that of 1000 fathoms 10·4 miles distant. The ship steamed in and made the land, taking a fresh departure from Porto Novo towards the island of St. Thomas.

Profile S. gives the slope off Porto Novo, and it will be seen that the gradients are much gentler than in the previous profiles ; and this was to be expected, as we are approaching the head of the bight, into which the Niger and other great rivers pour their waters and the abundant land *débris* borne down by them. The maximum rate of increase of depth, 101 fathoms per mile, is observed between 800 and 1100 fathoms.

Between the coast and the island of St. Thomas the soundings were carried in a direct line S. 34° W., with occasional soundings to the right and left of the line, in order to show the slope of the bottom. For nearly one-half of the way the line runs parallel to the coast, forming the western margin of the delta of the Niger, and at a distance of about 100 miles from it. For the remainder of the route it crosses the mouth of the Bight of Biafra. The bottom is very uniform, both as regards elevation and mineral character. Although there seem to be no steep ridges or valleys, there are some well-marked depressions and elevations which deserve to be noted. A first maximum depth of 1783 was met with in lat. 5° 15'4" N., long. 3° 10' E., which no doubt indicates the position of the deepest water of the Bight of Benin, terminating in the Avon's Deep, a gully much resembling the "Bottomless Pit" further west, and cutting deeply into the coast flat off Lagos. Proceeding southwards, the water shoals gradually, to a minimum observed of 1391 fathoms, in lat. 3° 55'3" N., long. 4° 7'3" E. It then deepens rather rapidly in the next 25 miles to 1916 fathoms, in lat. 3° 36'6" N., long. 4° 28'1" E. This second maximum depth occurs immediately off the principal mouth of the river Niger. The depth now remains remarkably constant between 1800 and 1900 fathoms, a third maximum of about 1970 fathoms occurring 100 miles from St. Thomas. From the soundings obtained the course of the 1500-fathom contour line can be traced very clearly until it bends away into the Bight of Biafra, where it is uncertain whether it embraces or avoids Prince's Island. The soundings between St. Thomas and Prince's Island show that they are separated by water over 1500 fathoms in depth. The 1500-fathom line follows the line of the coast into the Bight of Benin; it then runs out into a point to the north-west of the mouth of the Niger, and to another point to the south-west of it, with a depression between them running up towards the mouth of the river, the so-called Nun entrance.

Profiles T, V, and W, between the Niger and the Congo, show the alteration in the continental slope caused by the *débris* of the great rivers entering the ocean in this neighbourhood.

Profiles X, Y, Z, Φ , and Ψ , are examples of profiles of volcanic islands, and resemble those of the Canary Islands.

CYCLONE IN THE MOZAMBIQUE CHANNEL.

(*With Diagrams.*)

FAMILIAR though the words "cyclone," "tornado," and "typhoon" are with the general public, every meteorologist knows that authorities differ much upon many points concerning them, and that their courses, dimensions, and even forms, are still a matter of dispute.

The thousands of observations collected by navigators in every sea, and carefully tabulated in such Observatories as those of Washington and London, have not yet sufficed to settle some very conflicting theories upon atmospheric currents. The work of observing goes on actively, and every record carefully made of storms on sea and land is a valuable contribution both to men of science and to practical seamen. From numberless independent and apparently discordant observations, general laws have been observed and rules laid down that now enable seamen "to manœuvre

DIAGRAMS ILLUSTRATING MR. J. Y. BUCHANAN'S PAPER
ON THE SLOPES OF THE OCEAN-BED ON THE COASTS OF ISLANDS AND CONTINENTS