CHAPTER II.

Departure from Portsmouth—Sounding and Dredging—Arrival at Lisbon—Soundings and Dredgings off the Tagus—Gibraltar—Soundings and Dredgings between Gibraltar and Madeira—The Pennatulida—Teneriffe—Soundings and Dredgings in the vicinity of the Canary Islands—Departure from Teneriffe for the West Indies—Description of Method of Sounding, Dredging, and of making other Observations at Sea.

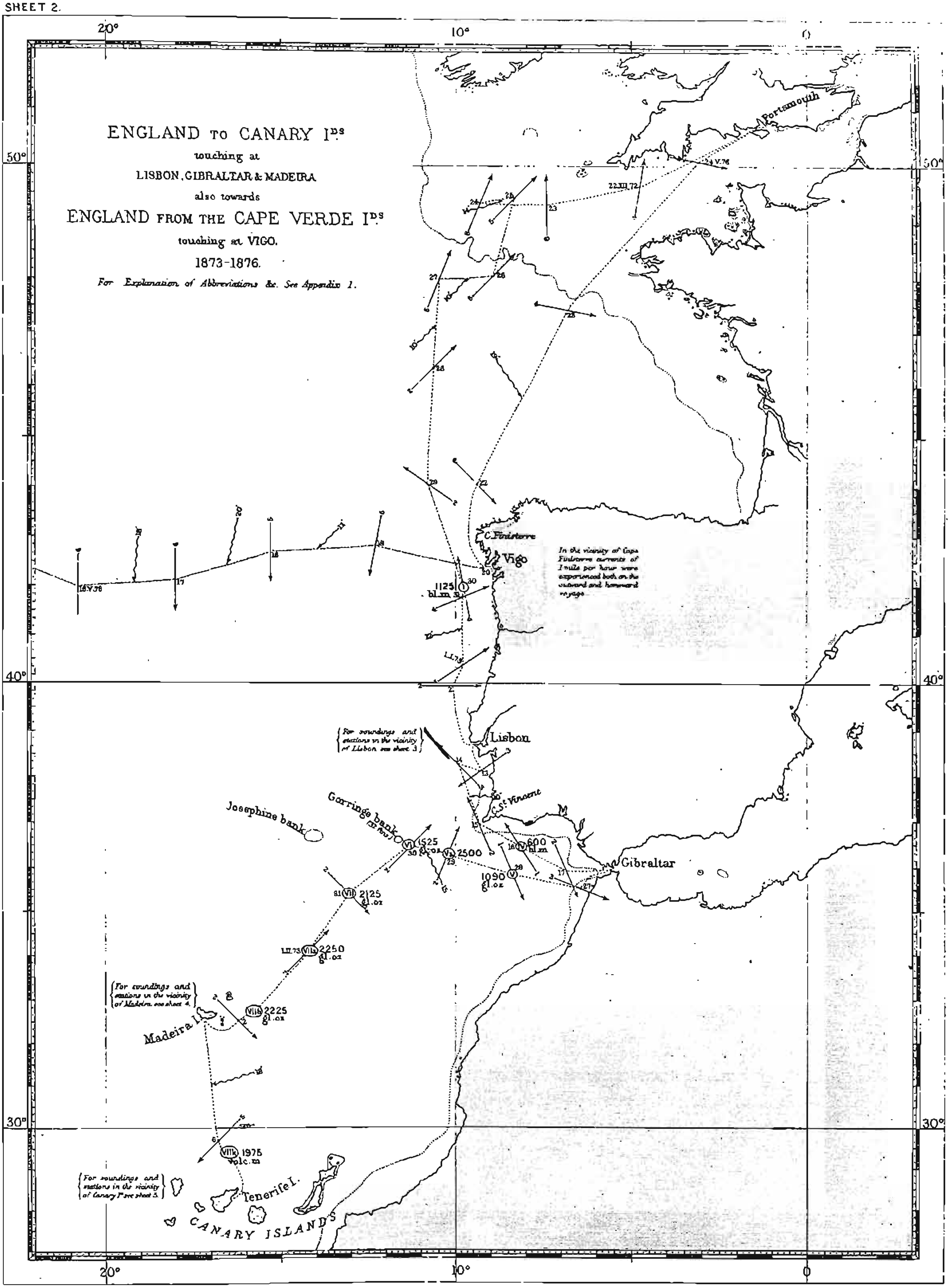
PORTSMOUTH TO GIBRALTAR.

THE Challenger left England on the 21st December 1872, and experienced heavy southwesterly gales until the 30th, when the parallel of Cape Finisterre was reached. From this position to Lisbon, which port was reached on the 3rd January 1873, the weather was variable, but on the whole fine, so that it was possible to test the sounding and dredging gear, and instruct the ship's company in duties new to nearly all of them. Five soundings and three hauls of the dredge were obtained in depths varying from 325 to 1975 fathoms (see Sheets 2 and 3). These first operations were not very successful, as the sounding line parted on three occasions, the dredge rope once, and the dredge on one occasion came up foul. These accidents were due partly to inexperience, and partly—as was found out afterwards—to the defective condition of the medium-sized sounding line which was at first used instead of the No. 1 line, its breaking strain being 7 cwt. instead of 10 cwt. The dredge rope was lost owing to the dredge fouling something at the bottom, from which it could not be cleared, and at the time it parted the tension was certainly equal to, if not greater than, the warranted breaking strain, viz., 2½ tons. It has been suggested that the dredge may have fouled the telegraph cable which passes along this coast.

The ship was detained at Lisbon till the afternoon of the 12th January by a heavy gale from the southwest and by cloudy weather, which prevented the observations necessary for rating the chronometers being obtained.

On leaving Lisbon light easterly and northerly winds were experienced, and several soundings and some successful hauls with both the dredge and trawl were taken, in depths varying from 84 to 1800 fathoms (see Sheet 3). The incline off the river Tagus was found to slope gently down to 1475 fathoms, 31 miles from the shore.

The deposit at 560 fathoms, off the mouth of the Tagus, was a green mud, consisting of Foraminifera, Coccoliths, fragments of Echinoderms, Molluscs, and Polyzoa; angular fragments of quartz, felspar, mica, magnetite, and many glauconitic particles. The calcareous organisms made up 32 per cent. of the deposit, and, after treatment with weak hydrochloric acid, many dark and pale green, perfectly formed, glauconitic casts were observed. The percentage of carbonate of lime in the deeper deposits remained about the same, but the glauconitic particles were not nearly so abundant. The mineral constituents of this



ENGLAND TO CANARY I$^{\text{ds}}$
touching at
LISBON, GIBRALTAR & MADEIRA
also towards
ENGLAND FROM THE CAPE VERDE I$^{\text{ds}}$
touching at VIGO.
1873-1876.

For Explanation of Abbreviations &c. See Appendix 1.

deposit are chiefly derived from the disintegration of continental land, and are similar in all respects to those found later on to prevail along the borders of the great continents.

Between Cape St. Vincent and the Straits of Gibraltar, it occurred to Captain Nares to use an ordinary beam trawl in place of the dredge. This was a very happy idea, for the trawl was found to answer admirably, and, as is well known, has since been almost exclusively used for deep-sea work.

GIBRALTAR.

Gibraltar was reached on the 18th January at 8 A.M. The ship remained seven days, and during that time a plan of the anchorage inside the new mole was made on a large scale, by means of lines, marked at every 25 feet, stretched across from side to side of the space enclosed by the mole, at distances of 50 feet apart. The soundings were reduced to 5 feet below the level of the mole in Rosia Bay, or to 6 feet below the level of a line cut in the masonry of the camber at the head of the dockyard mole, thus—

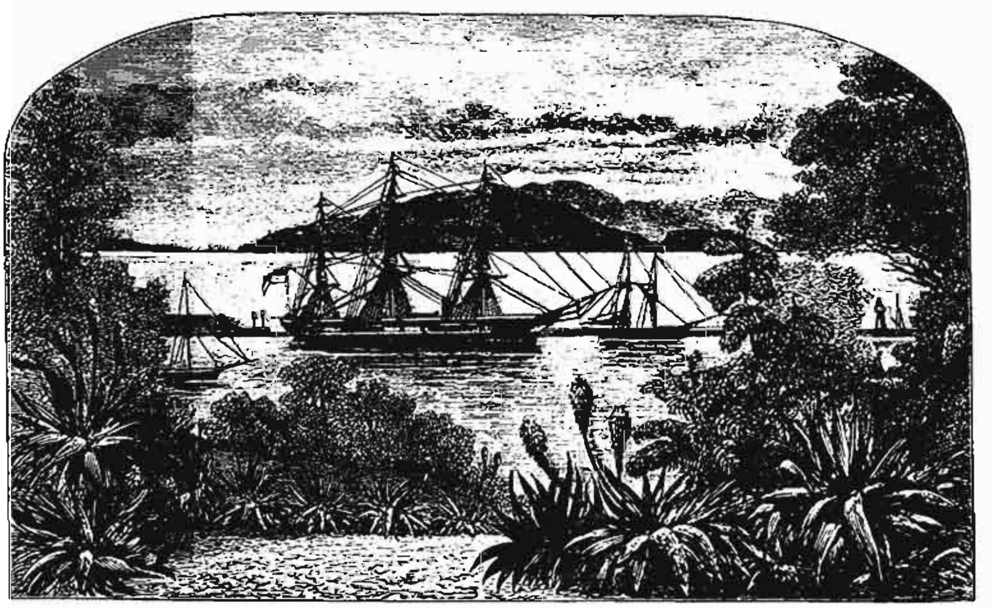


Fig. 9.—H.M.S. Challenger at the New Mole, Gibraltar.

"CHALLENGER."

↑

H. W. 2 feet.

The mean level of high-water spring tides was found to be 2 feet below that line.

H.M. surveying sloop "Shearwater" being at Malta during the stay at Gibraltar, the surveying officers took the opportunity of determining the meridian distance between Gibraltar and Malta, by means of the telegraph cable kindly placed at their disposal for this purpose by the superintending electricians at those places. The observing station at Malta was Spencer's Monument, and at Gibraltar the head of the mole in Rosia Bay, and the following were the results :—

	h.	m.	s.
Meridian distance, by signals transmitted from Gibraltar to Malta,	1	19	29·75
Do. do. Malta to Gibraltar,	1	19	28·54
Mean meridian distance, ...	1	19	29·15

From which it appears that it took 0·60 s. to transmit the signal between the two places, a distance of 1000 miles.

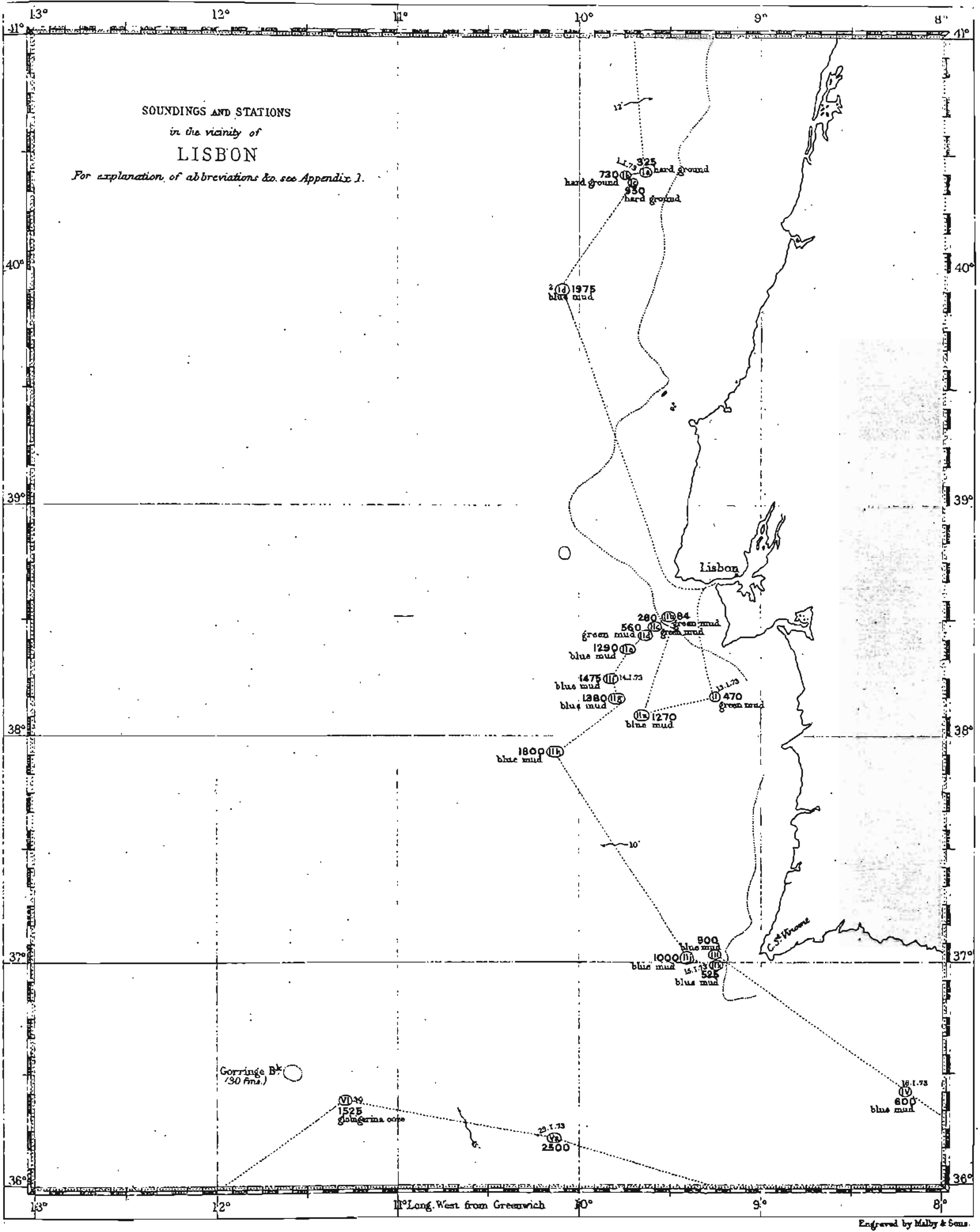
The magnetic observing station at Gibraltar was in the middle of the garden of the Main Guard, on the Neutral Ground. The observing station for rating chronometers was the head of the mole in Rosia Bay, which is a much more convenient place for this purpose than almost any other in Gibraltar, as, besides its seclusion, the sun is seen there earlier in the morning than at the Ragged Staff, or the dockyard mole, a matter of some moment when the easterly winds, so frequent in summer, keep the summit of the rock constantly capped with cloud, for when this occurs, the town, the Ragged Staff, and the dockyard are in the shade during the greater part of the forenoon, whilst the sun is shining brilliantly on Europa Point, and nearly always as far north as Rosia Bay.

On the 26th January, at 9 A.M., the vessel proceeded to the eastward of the Rock to be swung for the errors of the compass and dipping needle. For the deviation of the compass the ship was swung on the line of transit of Frayle Tower with Europa Lighthouse, the true bearing of which had been previously ascertained. The error of the dipping needle was ascertained by keeping the ship steaming slowly and steadily on a given point of the compass, while observations were made for inclination, and these observations were repeated on a sufficient number of points, to allow a curve to be drawn from which the error could be ascertained for any part of the circle. The force of the ship was ascertained by vibrating a needle on the four cardinal points, and comparing its results with those obtained by the same needle on shore. These operations having been satisfactorily completed, the ship returned to port to land letters, &c., and finally left at 6 P.M. for Madeira.

Gibraltar to Madeira.

Between Gibraltar and Madeira six soundings and three hauls of the trawl were obtained, in depths varying from 1090 to 2600 fathoms (see Sheets 3 and 4). The deposit at each of these Stations was a Globigerina ooze. The percentage of carbonate of lime ranged from 53 to 75, and consisted almost entirely of pelagic Foraminifera, Coccoliths, and Rhabdoliths. The residue, insoluble in weak acid, consisted of a few Radiolarians, minute particles of quartz, felspar, augite, glassy volcanic fragments, and clayey matter.

SHEET 3



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The trawl again worked admirably, and brought up many specimens of fish, Echinids, Asterids, Molluscs, Pennatulids, and other animals. The trawl after this was used throughout the voyage for deep-sea work almost to the exclusion of the dredge. It produces on the whole better results, and naturalists are much indebted to Captain Nares for having had the courage to attempt the use in deep water of an instrument which must fall on its proper side in order to work successfully.[1] On the other hand, it must be remembered that the results appear to show that the trawl is not so favourable as the dredge[2] for catching certain forms, such as Corals and Molluscs.

The Pennatulida.—On the 31st January, at a depth of 2125 fathoms, a fine representative specimen of the remarkable Alcyonarian genus *Umbellula* was taken. *Umbellula* belongs to the suborder of the Alcyonarians, called by Professor v. Kölliker the Pennatulida. It is a colonial organism, consisting of a bunch of polyps borne on the one extremity of a long stem, provided with a flexible horny axis, the opposite end being implanted firmly in the deep-sea mud. In the present specimen, which proved to be a new species, named by Professor v. Kölliker *Umbellula thomsoni*, the stem measured 36 inches in length. It is shown in fig. 10 (cut short). Many of the Pennatulida are known to be phosphorescent, and in this specimen of *Umbellula*, when taken from the trawl, the polyps and the membrane covering the axis of the stem exhibited a most brilliant phosphorescence. A like phenomenon was observed in the case of many other Alcyonarians obtained from the deep sea,—a matter of peculiar interest in connection with the presence of eyes in certain deep-sea animals, which inhabit a region totally devoid of any other source of light.

Umbellula was long one of the rarest of zoological curiosities. The first specimens ever described were obtained on the coast of Greenland, early in the last century, by Captain Adriaanz, commander of the "Britannia," while on a whale-fishing expedition; on this occasion two specimens were found adhering to the sounding line at a depth of 236 fathoms. These were described by M. Christlob Mylius, and one of them was again described in the Philosophical Transactions for 1754, in a letter from Mr. John Ellis to Mr. Peter Collinson, "Concerning a cluster-polyp found in the sea near the coast of Greenland." Mr. Ellis compared it to the "*Encrinos* or *Lilium lapideum* of the curious in fossils," and indeed the resemblance to a Crinoid is not a little striking. For more than a century the animal was not seen again, and it is only a few years since two specimens were dredged in deep water during the cruise of the Swedish ships "Ingegerd" and "Gladan," in the Arctic Ocean. These were described in 1874 by J. Lindahl as two new species,—*Umbellula miniacea* and *Umbellula pallida*.[3]

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[1] Since this page was in type, Mr. Rathbun (*Science*, vol. iv. p. 56, 1884) states that the trawl was systematically used in scientific research by the U. S. Fish Commission in 1872, but he does not say whether they employed it for deep-sea work prior to Captain Nares' suggestion.

[2] A comparison of the results obtained by means of the trawl and dredge will be given in the concluding Report of the Challenger series.

[3] Lindahl, J., Om Pennatulid-slägtet Umbellula, *K. Svensk. Vetensk.-Akad. Handl.*, Bd. xiii., No. 3, 1874.

The Report on the Challenger collection of Pennatulida,[1] by Professor Albert v. Kölliker, adds much to our knowledge of this suborder—especially with regard to the geographical distribution of the species. All the previously known species, with a few exceptions, are from shallow water, but the number of deep-sea forms dredged during the voyage of the Challenger is so considerable as to nearly equal the total number of known shallow-water forms. A species of *Umbellula—Umbellula leptocaulis*—dredged S.E. of New Guinea in 2440 fathoms, lives at a greater depth than any of the other known species of Pennatulida, and of the eight new species of *Umbellula* described in the Report, no less than six are, so far as is known at present, confined to depths greater than 1000 fathoms, while the remaining two were dredged in 565 fathoms, off the coast of Japan.

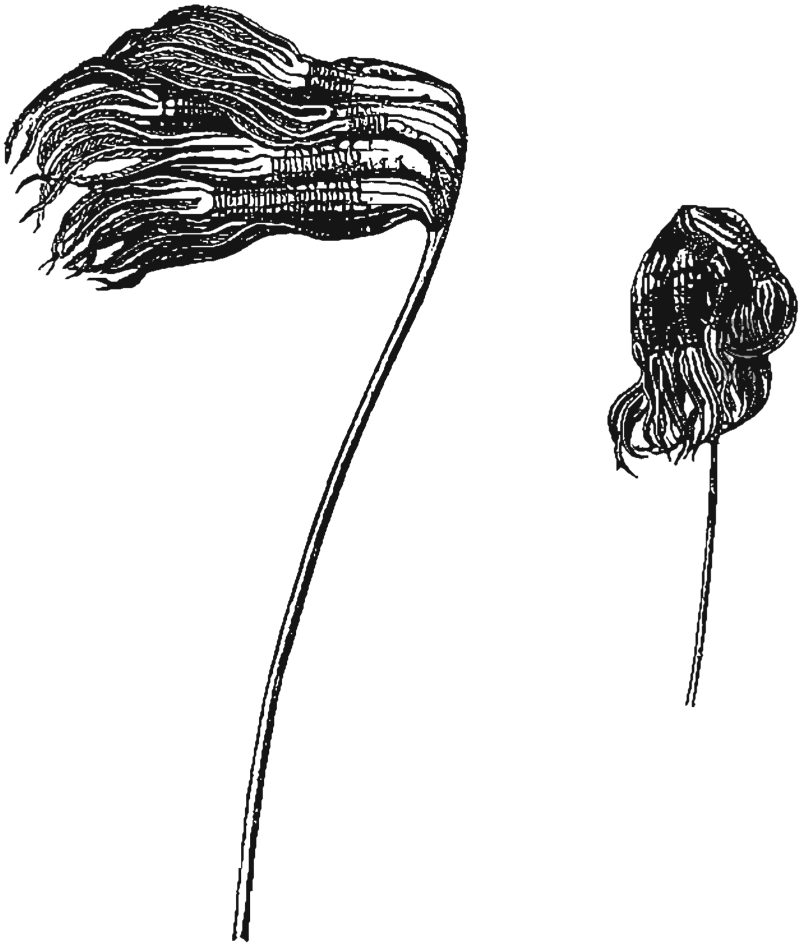

FIG. 10.—Two views of *Umbellula thomsoni* with the stem cut short to show the bunch of large polyps by which it is surmounted.

The Umbellulidæ belong to the simpler and more archaic of the Pennatulida,

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[1] Zool. Chall. Exp., part ii., 1880.

in which the polyps are directly sessile upon the stem, instead of being borne on lateral pinnules, as they are in the more complex forms. One of the most important conclusions to which Professor v. Kölliker has been led by the study of the Challenger collection, is that the simpler forms of Pennatulida more especially abound in great depths. There are altogether eight families in this lower group, of which seven are—with the exception of one or two species—invariably found in deep water. Of these the Umbellulidæ and Protoptilidæ are the most important, and have furnished the greatest number of new species, many of which have also a wide horizontal distribution. The eighth family, that of the Veretillidæ, seems, however, to be confined to shallow water. On the other hand, the members of the higher group, comprising the families Pteroeididæ, Pennatulidæ, Virgularidæ, and Renillidæ are nearly always found in depths less than 100 fathoms.

With regard to horizontal distribution, the general conclusion arrived at is :—Of the various families the Umbellulidæ are the most widely distributed; they occur in the North Polar Sea, in the Atlantic Ocean, in the South Polar Sea, in the Southern Ocean west of Kerguelen Island, and in the North and South Pacific. The Stachyptilidæ, Protocaulidæ, and Protoptilidæ have two centres, one in the Pacific Ocean on the coasts of New Zealand, New Guinea, and Japan, and the other in the North Atlantic and North Sea. In the Pacific, Atlantic, and Southern Oceans, far removed from land, the representatives of this order are exceedingly rare, but are more abundant as land and shallower water are approached. The Anthoptilidæ are only found on the east coast of America, but range from Halifax as far southward as Buenos Ayres and Tristan da Cunha. The Kophobelemnonidæ and Veretillidæ, on the other hand, appear to have a limited distribution, but very little has been added by the investigations of the Challenger to our knowledge of the distribution of these two families.

Among the more complex forms, the Virgularidæ and Pennatulidæ are the most widely distributed; the latter are found on the coasts of Europe, China, Japan, Australia, New Guinea, on the west coast of North America, and on the east coast of Africa. The Pteroeididæ have a well-defined centre in the southeast coasts of Asia, extending as far northward as Japan, and as far westward as the Red Sea and the west coast of Africa; one species indeed, *Pteroeides griseum*, inhabits the Mediterranean. There are altogether seven new genera and twenty-seven new species in the Challenger collection, and Professor v. Kölliker has, in consequence, found it necessary to form a new systematic arrangement of the suborder.

MADEIRA.

On the 2nd February the Madeira group was sighted, and the ship proceeded towards the south end of the Dezertas to obtain soundings for the Lisbon-Madeira submarine cable (see Sheet 4). At 8 P.M., when between the Dezertas and Madeira, the trawl was put over, it being too dark to continue sounding during the night; but at 2.30 A.M. on the 3rd, the trawl fouled something at the bottom, and the rope parted at 6 A.M., after four hours tedious labour in endeavouring to recover it. The ground being evidently unfit for trawling at this place, sounding operations were resumed towards Madeira, and were completed by 11 A.M., at which hour the anchor was let go in Funchal Bay. The deposits about the Dezertas and Madeira were volcanic sand and mud, with usually 30 to 40 per cent. of carbonate of lime. The mineral particles in the deposits were fragments of felspar, magnetite, lapilli, basaltic scoriæ, and glassy fragments.

At Madeira magnetic observations were taken at three places: (1) on the highest part of the rocky cliff forming the first point west of Pontinha Fort, after crossing the bridge over the valley, on some waste ground close on the seaward side of, and rising a little above, the main road, immediately opposite a garden gateway, in a wall on the opposite side of the road; (2) in Fort Pontinha; and (3) on the small almeida on the eastern side of the above mentioned bridge.

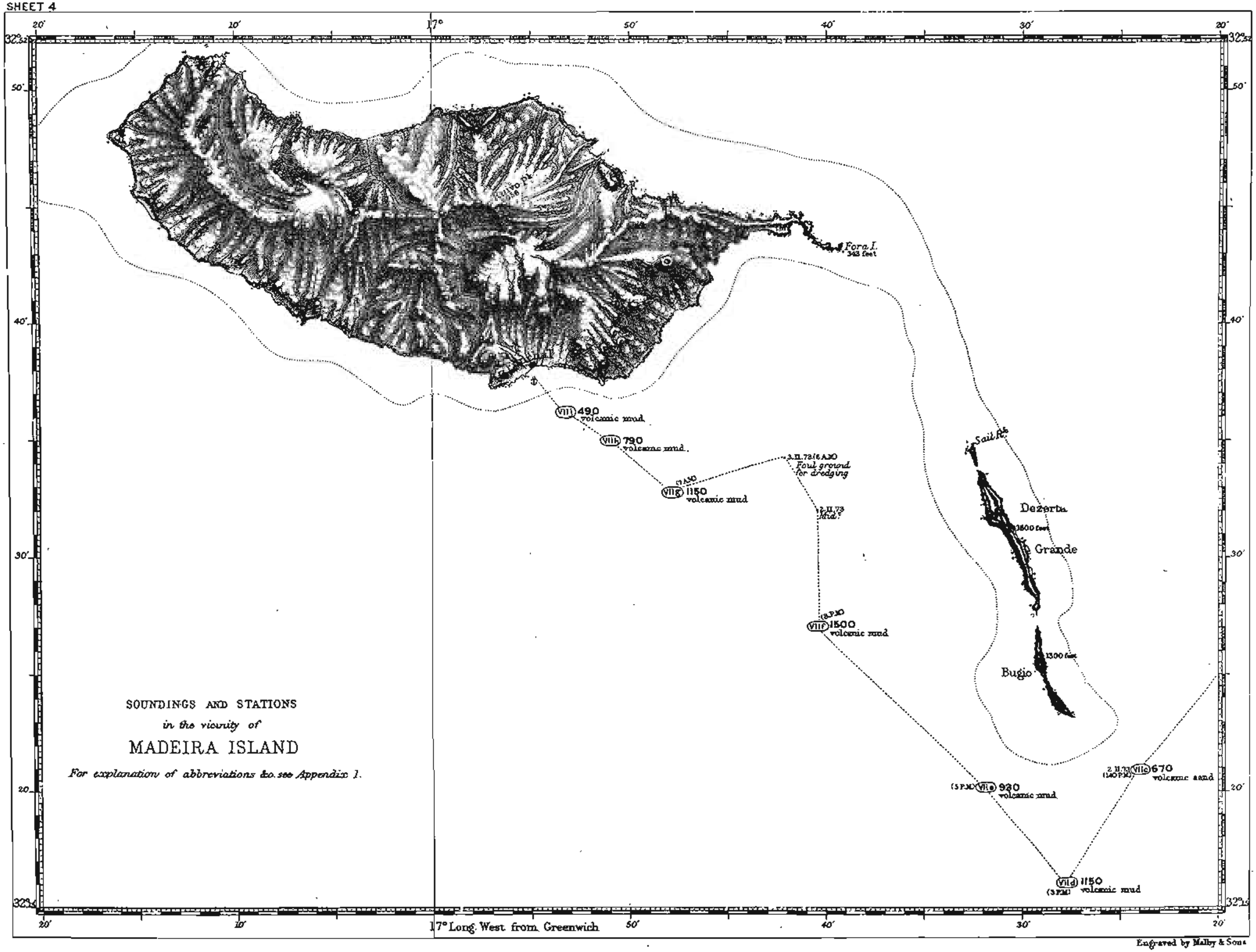
TENERIFE.

On the 5th the ship left Madeira for Tenerife, arriving at that island on the 7th, one sounding having been obtained on the passage (see Sheet 2). On the way from Madeira to Tenerife a very strong N.E. trade wind was experienced, which prevented dredging or any other deep-sea work at or near the Salvage Islands. Immediately after the ship anchored at Santa Cruz, a salute of 20 guns was fired from the shore, and on inquiry it was found to be in honour of a son born to King Amadeo, who by that date had abdicated the throne and left Spain.

The anchorage off the town of Santa Cruz being imperfectly known, the permission of the Governor of Tenerife was obtained to resurvey it, and that work was commenced at once. The usual magnetic observations were taken on a circular enlargement of the main road to Laguna outside the town south of the first bridge. The observations for rating chronometers were taken in Fort San Pedro, and during the operations it was noticed that the mercury in the artificial horizon occasionally vibrated considerably for a few seconds, without there being any apparent reason for its doing so. Whether this arose from seismic action or not is uncertain; it clearly did not arise from the movements of carts, or men in the vicinity, especially as it occurred in the afternoon, when every one on shore was enjoying the usual siesta.

On the 10th the ship left the anchorage at Santa Cruz for a sounding and dredging excursion round the island, obtaining twelve soundings and two dredgings (see Sheet 5). The weather was remarkably fine, and the Peak of Tenerife, capped with snow, distinctly visible.

SHEET 4



SOUNDINGS AND STATIONS

in the vicinity of

MADEIRA ISLAND

For explanation of abbreviations &c. see Appendix 1.

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Excursion up the Peak of Tenerife.—As a means of testing the appliances of the Scientific Staff, and affording its members an opportunity of making a preliminary trial of their capabilities as collectors and observers, and accustoming themselves to exploring work generally, an excursion up the Peak was organised, and a party, consisting of Sub-Lieut. Lord George Campbell, Mr. Buchanan, Mr. Moseley, Mr. Murray, with a marine and a blue jacket, ascended the Peak as far as was found practicable during the absence of the vessel from the harbour. The island was crossed to the town of Orotava, on the opposite shore to Santa Cruz, and from thence the ascent was made by the usual route. From an elevated point on the road between the two towns the first view of the Peak (Pico de Teyde), which is not visible from Santa Cruz, was obtained. The middle part of the mountain was concealed by a dense bank of white clouds, the condensed vapour of the trade wind. Beneath, a broad valley stretching down to the bright blue sea with its snow-white edging of surf, was thrown partly into deep shadow by the cloud-bank, partly lit up by the bright hot sun, which shone brilliantly upon the snowy peak of the mountain, high up in the sky above the clouds. The town of Orotava was seen lying on the shore below.

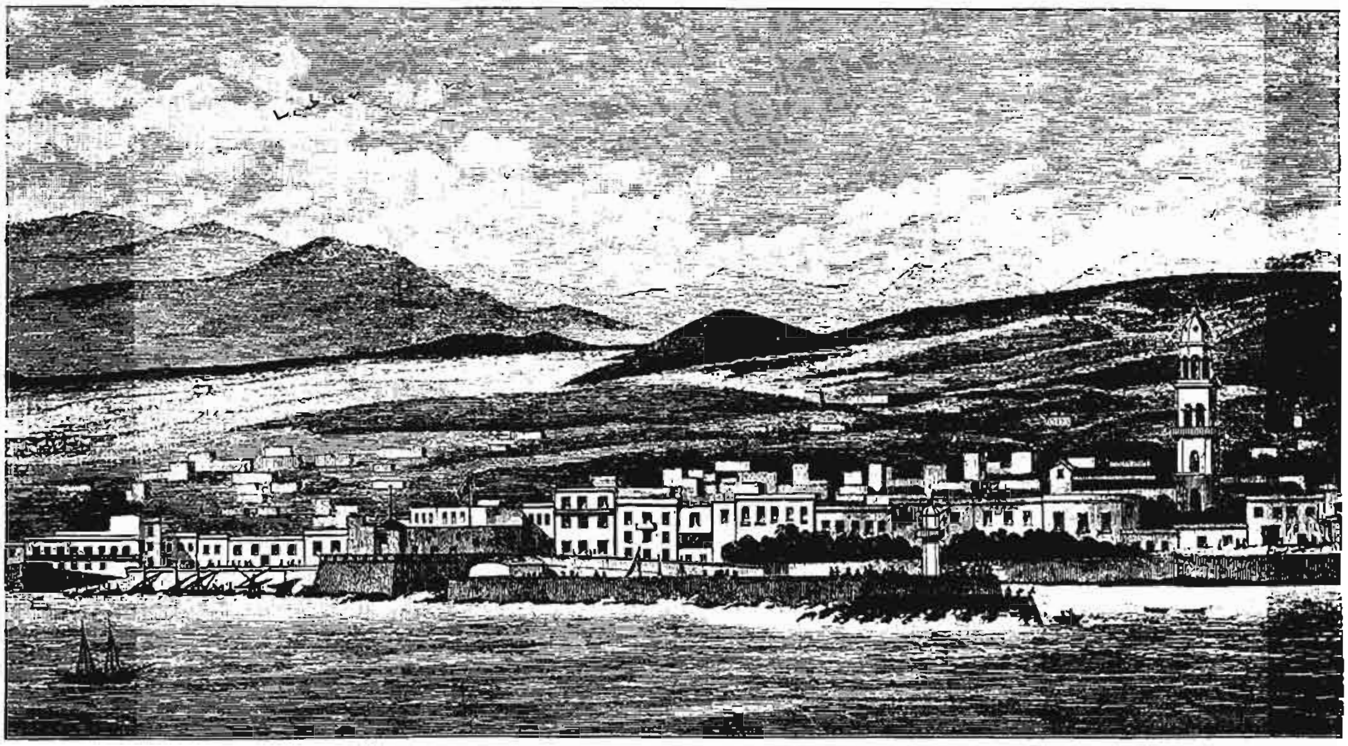


FIG. 11.—Santa Cruz, Tenerife.

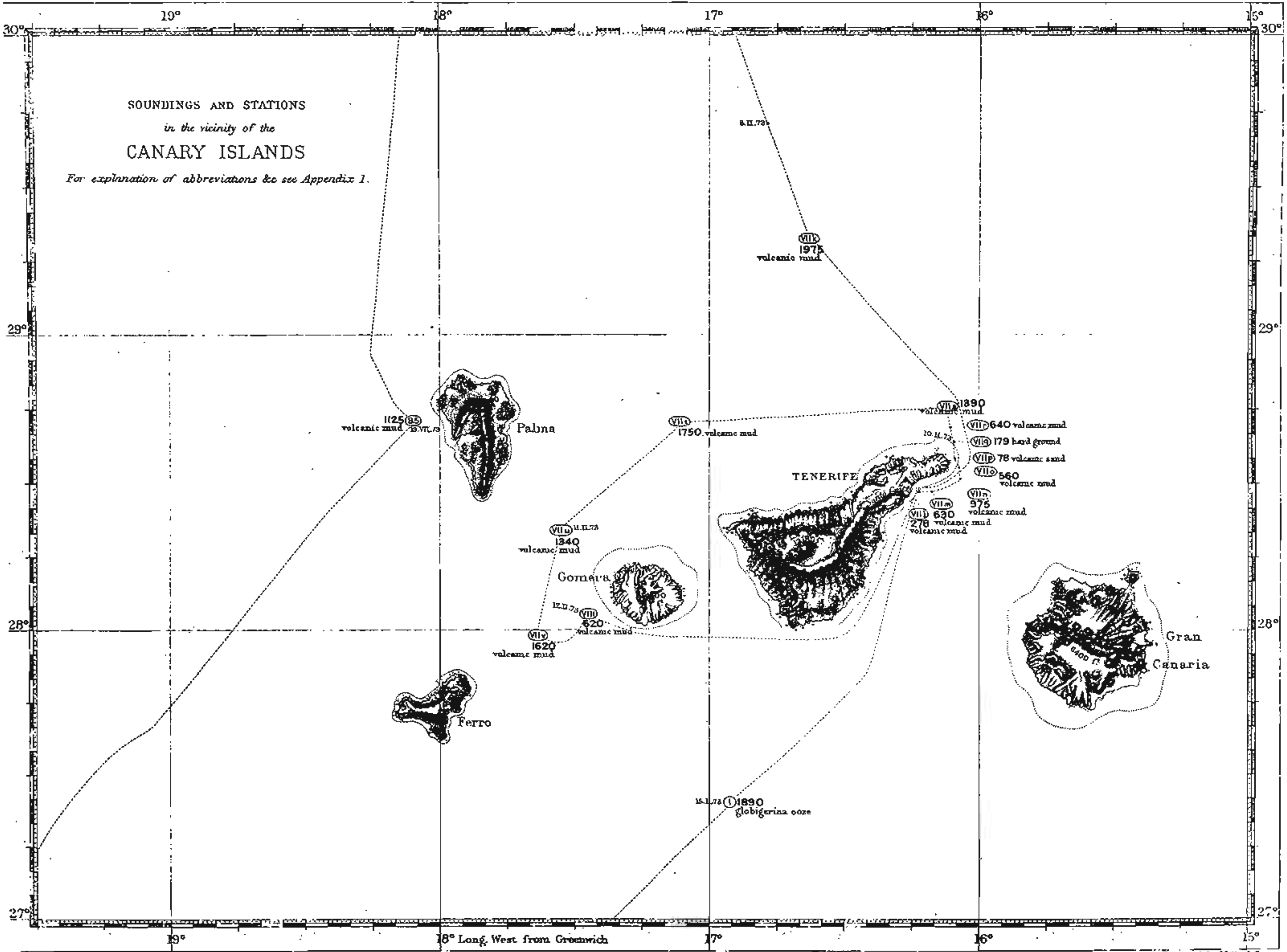
Mr. Murray started for Orotava by stage-coach early on the 10th, and was followed later on the same day by the rest of the party. With the kind assistance of the British

Vice-Consul, all the arrangements were made for an ascent of the Peak on the following morning. The route lay up a long sloping ridge, which leads to the base of the actual cone of the Peak. This ridge is bounded by a precipice on the side facing Orotava. When a height of about 2000 feet had been attained, the villagers tried to dissuade the party from going farther, saying that all would be frozen to death.

The well-known zones of vegetation of the Peak of Tenerife are not very well defined on the ordinary route which was the one adopted. The limit of cultivation was reached at about 3000 feet, at which height corn of some kind was just springing up, and above this a zone was entered covered with a tree-like Heath (*Erica arborea*), which continued for about 2000 feet, and then ceased abruptly. A little higher up, the mountain side was somewhat sparsely covered by large bluish-green bushes of the species of Broom (*Spartocytisus nubigenus*), called by the natives "Retama," and well known from the accounts of numerous travellers; amongst these shrubs a tent was pitched, at an elevation of 6500 feet. Above the retama, a small Violet (*Viola teydea*) is said to extend up to 10,000 feet, and beyond this all is barren. The Pine (*Pinus canariensis*) which grows on some parts of the mountain is not seen on the usual track of ascent. A halt was made amongst the heath for lunch, and plenty of water cresses were found growing in a spring. Water had to be carried up from this spring, since there is none to be obtained above, except by melting snow, as the porous volcanic ashes soak up all the water yielded by the natural melting of the snow, and there is no place where any can collect. At about 4000 feet elevation a dense bank of cloud, formed by the trade wind, was passed through, a similar one to that which had been seen from below on the day before, and had hidden the middle of the mountain from view, but not the same, for in the early morning there had not been a cloud in the sky; the bank formed about mid-day. At the camp, far above this cloud-bank, the sun shone brightly, until about six o'clock in the evening, when it began to disappear, and the air, which had been almost too hot, became suddenly cold, the temperature going down almost to freezing point.

A very extraordinary sunset effect was observed. The upper surface of the cloud-bank stretched below in every direction, like a snow-white billowy sea hiding the actual sea from sight entirely, but just allowing a glimpse to be caught of the far-off island of Palma, which appeared as a purple streak at the edge of the cloud horizon. As the sun went down, the clear sky beyond the white motionless cloud-bank became tinged of a brilliant orange colour, and over it there shot out from the descending sun a fan of pale crimson streamers deeply tinted at their base, and gradually fading off into the dark blue sky above but visible nearly to the zenith. Beyond the great cloud-bank more distant streaky clouds, lit up of a brilliant violet, formed a sort of background to the scene. Some of these little distant clouds from time to time assumed fantastic shapes, and once it seemed almost certain that it was the sea in the distance that was seen below with

SHEET 5



SOUNDINGS AND STATIONS

in the vicinity of the

CANARY ISLANDS

For explanation of abbreviations &c see Appendix 1.

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two very far-off ships upon it, but it was merely an illusion. The actual sea was entirely shut out from view, except once for a few seconds, when a small rift in the cloud-bank occurred and gave a momentary glimpse of the rippling surface far below, a sort of vista dimmed by the misty frame through which it was seen. All the while the snowy Peak itself was perfectly cloudless, and stood out clear and sharp against a deep blue arctic looking sky. Soon the sunlight faded, and the moon shone out brightly, and the Peak glistened in its light, which was strong enough to read by easily. The view of the tent and camp fire amongst the dark broom bushes, with the moonlit snowy Peak in the background, fronted by some dark ridges of lava, was most picturesque. Some of the large dry retama bushes were set fire to, and a glaring blaze was soon raised, the flames shooting high up into the air, so that they were seen at Orotava, and even as far as Santa Cruz. The ground was frozen on the surface around the tent during the night, the thermometer standing at 30° F. just before sunrise.

From the camp the party walked to the Cañadas—a remarkable plain covered with scoriæ, and shut in on nearly all sides by a perpendicular wall of basaltic cliff. From this plain of vast extent the present terminal cone of the mountain rises. The Cañadas represents an ancient and much larger crater, in the centre of the remnant of which the more modern smaller peak has been thrown up. The bottom of the Cañadas is dotted over with the retama bushes, but the ground is devoid of any other vegetation. Rabbits were found to be tolerably abundant, but were so wary that none were shot. They feed on the retama and make no holes, but live in any chance crack or hole in the rocks. The radiant heat of the sun was extremely powerful on the arid plain of the Cañadas. Both guides and mule drivers had deserted the party, refusing to accompany it at this season of the year to the top of the Peak. The ascent therefore was only accomplished to a height of about 9000 feet, the last 200 of which was climbed over snow. From this height were watched the often described struggles of the opposing winds, the trades and anti-trades, as shown by the eddying and twisting of the wreaths of cloud. In the neighbourhood of the camp, at 6500 feet, winter was evidently still in force as far as the animals were concerned. All the spiders and beetles found there were under stones, apparently hibernating.[1]

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[1] The Rev. O. P. Cambridge writes—"The collection of spiders from Tenerife contains twenty-one species, of which twelve have been previously described, these are :—

Dysdera wollastoni, Bl.
Zoropsis ochreata, C. L. Koch (immature).
Tegenaria derhamii, Scop.
Scytodes thoracica, Latr.
Pholcus phalangioides, Fuessl.
Stealoda versuta, Bl.
Argyrodes epeiræ, Sim.
Tetragnatha extensa, Linn.
Epeira perplicata, Cambr.
Cyrtophora opuntiæ, Duf.
Uloborus zosis, Walck.
Ocyale mirabilis, Clk.

"The remaining species await further consideration ; one or two seem to be new to science, the others may probably be referred to the following genera—*Segestria*, *Tegenaria*, *Theridion* (*Theridion pulchellum*, Bl. ?), *Linyphia*, *Xysticus*, *Lycosa*, The camp was moved, after remaining two nights at 6500 feet, to the spring at about 3500 feet altitude, called Fuente Pedro, amongst the arboreal heath, on the verge of the precipice bounding the ridge where lay the route of ascent. Here it was much warmer at night, and at daybreak the temperature was 45° F. But the descent had brought the party within the cloud-bank, and there was constant heavy rain. The steep side of the ridge overlooking Orotava is covered with a luxuriant vegetation of laurels, heaths, and ferns, and is very different in this respect from the comparatively barren surface of the slope above.

The rocks collected during this excursion were basaltic scoriæ, tephrite, trachyte, augite-andesite, phonolite, felspathic basalt, obsidian, and pumice.

The vessel returned to Santa Cruz on the 13th, and was rejoined by the party from the Peak, and, after the soundings off the town had been completed and rates for the chronometers obtained, left for St. Thomas Island, West Indies, at 7.30 P.M. on the 14th.

METHODS OF OBSERVATION AT SEA.

From the date of departure from Tenerife the full routine course of scientific investigation systematically pursued during the remainder of the voyage was commenced. Hitherto soundings, temperatures, and dredgings had been taken more with a view of exercising the ship's company, and testing the apparatus supplied, than for scientific purposes; however, the labour was by no means thrown away, the results having been in some cases extremely valuable. Before, however, commencing the account of the work accomplished during the trip, it will be necessary to give a detailed description of the methods employed to obtain accurate soundings, temperatures, &c., &c., and in doing so the whole subject will be treated as viewed from the experience gained throughout the voyage, instead of describing the modifications introduced with a view of increasing the accuracy of the results, or decreasing the labour expended in obtaining the observations.

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and *Menemerus*. *Argyrodes epeiræ* was doubtless found in the mazy snares of *Cyrtophora opuntiæ*, of which several examples are in the collection. The thoroughly European character of the above list is very strongly marked."

Mr. Edgar A. Smith gives the following list of Helicidæ collected at Tenerife :—

1. *Vitrina lamarckii*, Fér.
2. *Zonites cellaria*, Müll.
3. *Helix malleata*, Fér.
4. „ *adansoni*, Webb and Berth.
5. „ *lactea*, Müll.
6 „ *apicina*, Lamk.
7. „ *circumessa*, Shuttl.
8. *Helix lenticula*, Fér.
9. „ *fortunata*, Shuttl.
10. „ *pavida*, Mouss.
11. „ *phalerata*, Webb and Berth.
12. „ *lancerottensis*, Webb and Berth.
13. „ *lineata*, Olivi.
14. *Bulimus tarnerianus* (juv. ?), Grasset.

Of these Nos. 2, 5, 6, 8, 12, 13 are not restricted to the Canaries, but range either to North Africa or Europe (see Wollaston's Testacea Atlantica). Two small specimens of *Limax canariensis*, d'Orb., were also collected at this locality, apparently only half grown (*Proc. Zool. Soc. Lond.*, p. 276, 1884).

Three species of Lizards were brought from Tenerife, *Tarentola delalandii*, *Lacerta galloti*, and *Lacerta muralis*.

Sounding.—The apparatus used to obtain soundings consisted of—(1) a deep-sea sounding line; (2) a reel on which this line was kept; (3) a number of sinkers; (4) an apparatus for detaching the sinkers when they reached the bottom, technically termed a sounding rod; (5) some iron wire and discs to attach the sinkers to the disengaging apparatus during their descent; (6) a number of india-rubber bands, technically termed accumulators; and (7) some iron gin-blocks with patent sheaves for the line to reeve through.

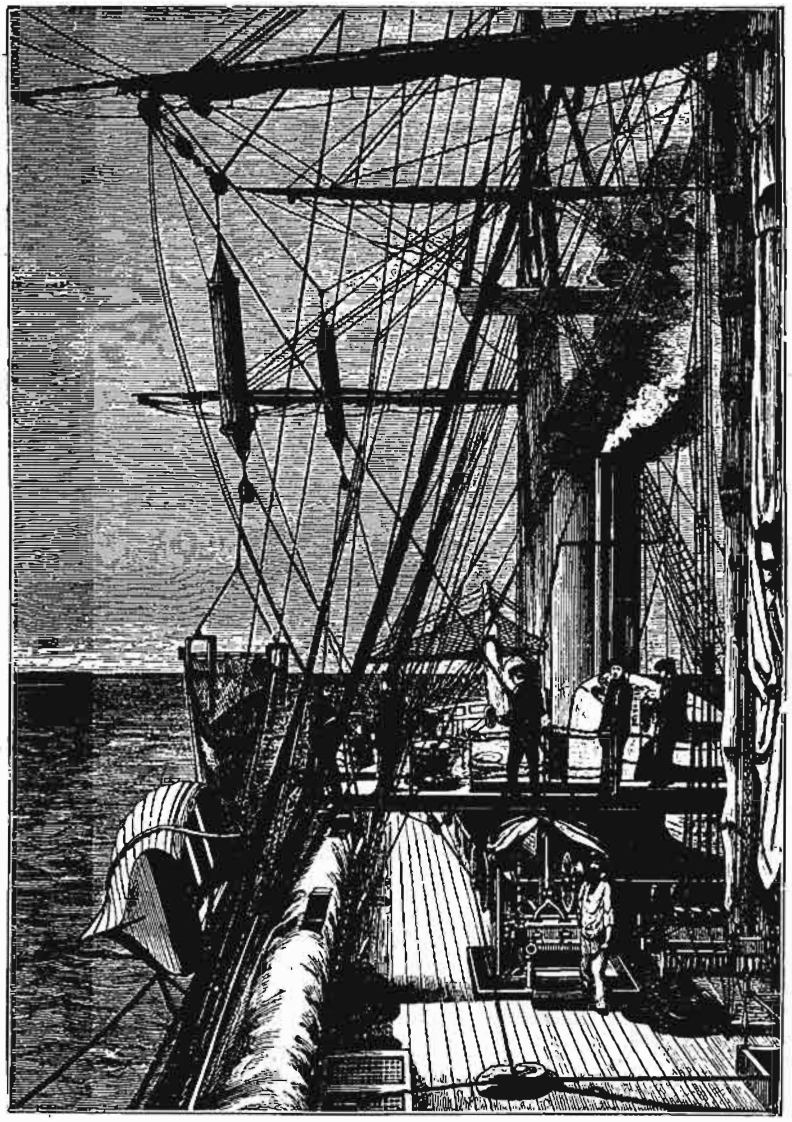

FIG. 12.—Dredging and Sounding arrangements on board the Challenger.

Sounding Lines.—Two kinds of sounding line were supplied, the first being 1 inch in circumference, with a breaking strain of 14 cwt. (called No. 1 line), and the second being ¾ inch in circumference, with a breaking strain of 10 cwt. (called No. 2 line). These lines were made of the best Italian hemp, well hackled and rubbed down, to prevent any ragged parts projecting outside and increasing the friction of the cordage during its descent through the water; they were made in lengths of about 120 fathoms each, a number of which were spliced together so as to form a connected line of 3000 fathoms, which was marked at every 25 fathoms, the 25 and 75 fathom marks being white, the 50 fathom marks red, and the 100 fathom marks blue. The material used for marking was worsted, and the number of 100 fathoms was indicated by tucking this worsted under and over the strands of the rope, one tuck for every 100 fathoms up to 1000 fathoms, and then again commencing at 1100 fathoms with one tuck. The whole length of 3000 fathoms was kept on one reel, so that it might run out uninterruptedly, the first 25 fathoms being doubled, as they had to bear the strain of lifting the sinkers over the side. The object of marking the line with worsted "tucked in" was to prevent any projections rendering it liable to foul, either in the blocks or on the drum when heaving in.

Great care was necessary in splicing the lengths of the sounding line together, as if too short a "long splice" were made it was very apt to draw, in consequence of the line being laid up slackly to increase its strength and pliability.

Owing to some defect in its construction, the No. 2 line was found unequal to the strain it was intended to bear, so that it parted in "heaving in," and therefore, after a few trials, it was entirely discarded for deep-sea soundings, the No. 1 line, which was of excellent quality, being exclusively used. The cost of this line was £10, 5s. 6d. per 1000 fathoms, and its weight per 100 fathoms was 18 lbs. 9 oz. in air and 8 lbs. in water.

Sounding Reels.—The reel on which the 3000 fathoms of sounding line was kept, was 5 feet in length, and, with the line on it, 2½ feet in diameter. The heart of the reel was 5 inches in diameter, and through its centre was driven an iron rod, which projected at each end so as to form an axle. Extending out from, and firmly fixed to, the ship's side, on the forecastle, were iron cranks on which these axles rested and revolved, so that the reel could be turned easily and smoothly. To prevent the sounding line becoming entangled in the axle or cranks, a wooden disc, 2½ feet in diameter, was fitted at each end of the reel, and one of these discs was grooved, so that by passing a gasket over it, one end of which was attached to the ship's side, and the other end held in a man's hand, the revolutions of the reel could be retarded when the impetus given by the pitching or rolling of the ship would otherwise have caused it to revolve too quickly.

The Sinkers.—Each sinker was of cast-iron, 56 lbs. in weight, cylindrical in form, with a hole through its centre, and a groove on each side; on its upper surface were fitted two studs, and on its lower were two holes, so that when one sinker was placed upon another the studs on the upper surface of the one fitted into the holes on the under surface of the other, and the holes through their centres, as well as the grooves at their sides, coincided. (See Baillie sounding machine, fig. 14 B.)

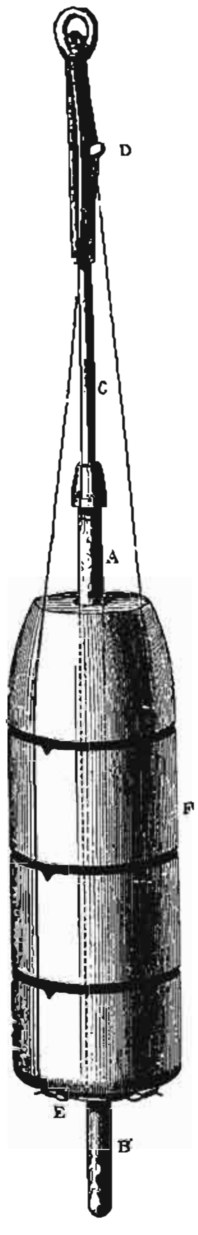

Fig. 13.—Hydra Sounding Machine.

Sounding Machines.—Two kinds of apparatus for detaching the sinkers were supplied; one the Hydra rod, before leaving England, and the other, the Baillie rod, at the Cape Verde Islands.

The Hydra rod (so called from its having been made by the blacksmith of H.M.S. "Hydra," as an improvement on Brooke's rod, the American invention) is a cylinder of brass tubing 1⅛ inches in diameter and 3½ feet in length (see fig. 13), having at its bottom B a butterfly valve, and at its top a sliding iron rod C 2½ feet in length. On the upper part of this iron rod is a small stud D, with a spring that reaches out to the head of the stud when there is no pressure on it. The sinkers were attached to the rod, and on reaching the bottom they were disengaged. To attach the sinkers, an iron disc or washer E with a hole through it (of a slightly larger diameter than the cylinder of the sounding-rod) was placed over one of the holes in a grating; a piece of wire (No. 9 gauge), two fathoms in length, was fastened at each end to this disc, and the bight of the wire was left standing up; on the top of the iron disc a sinker was placed so that the hole through its centre corresponded precisely with that in the disc and grating; other sinkers F were now added until the weight was sufficient for the supposed depth of water, two sinkers, or 1 cwt., being generally allowed for each thousand fathoms. When the requisite number had been placed in position, one on another, the rod was passed through the hole in their centres, and through the iron disc at the bottom, and the bight of the wire attached to the disc was placed over the stud D on the upper part of the rod (the spring being fastened back with a piece of twine to facilitate this operation), and the rod A on being lifted raised with it, by means of the wire on the stud, the sinkers which were kept in their places by the rod passing through their centres, and by the wire fitting into the grooves at their sides. When the full weight of the sinkers was on the stud, the twine which confined the spring was cut so that it was then only kept back by the weight of the sinkers on the wire. On reaching the bottom the weight of the sinkers no longer rested on the wire, so that the spring pushed it off the stud, and the sounding rod was thus relieved from the weights; the disc, wire, and sinkers being left at the bottom

It will be evident from this description that the whole secret of the successful disengaging of the weights at the bottom rests on the spring of the rod being nicely adjusted as to strength—that is, it must not be so strong as to push the wire off the stud directly a portion of the weight of the sinkers is removed by letting go the line, and it must be strong enough to spring sharply back into its place directly the whole weight is removed. The system adopted was to ease the sinkers down without jerks for about 400 or 500 fathoms, so that when the line was eventually let go the friction of the 500 fathoms of cordage passing through the water above the rod was sufficient to keep the requisite strain on the spring. By letting go the line suddenly when the sinkers were near the surface, they were found frequently to disengage at once.

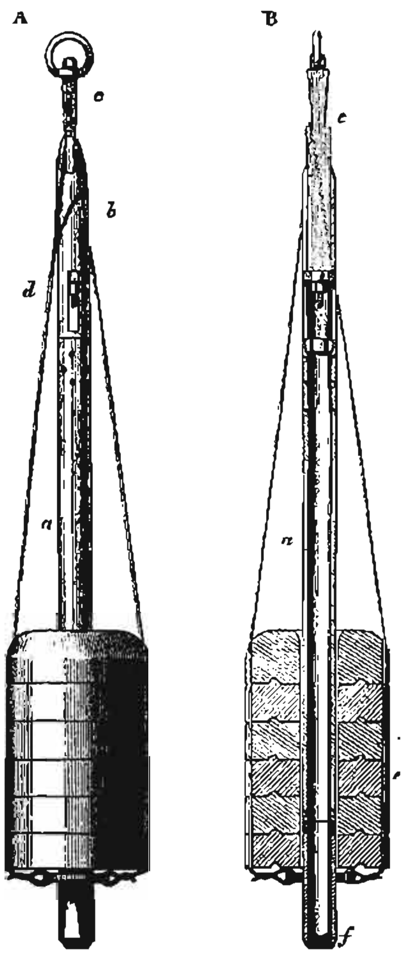

Fig. 14.—Baillie Sounding Machine.

The Baillie rod (which is an invention of Navigating Lieutenant Baillie, R.N.) is a much better apparatus than the Hydra rod, as the arrangement for disengaging the sinkers is entirely independent of springs. It consists of an iron cylinder with a butterfly valve at the bottom *f* and a brass tube *b* on the top, which screws on to the cylinder (see fig. 14). The brass tube is bevelled at its upper end, and in it is a cylindrical iron weight *c* which slides backwards and forwards, the length of movement being regulated by a slit *d* cut in the side of the brass tube *b*, through which a stud, fastened on to the weight, projects. Attached to the upper part of the weight is a flat bar of iron, which protrudes through another slit, cut in the pointed top of the brass tube, and this bar moves in or out as the weight is moved backwards or forwards. The upper part of the flat bar is narrowed abruptly so as to form two shoulders, and the distance of these shoulders from the weight is so regulated that when the stud fastened to it is at the upper end of the slit these shoulders are above the brass tubing, but when the weight falls down, and the stud rests on the lower end of the slit, they are concealed by the tubing, which thus forms a sort of sheath for the shoulders. The upper part of the bar is furnished with a ring to facilitate the attachment of the lead line. When the sounding rod is lifted by this ring the weight inside the brass tubing is pulled up until the stud fastened to it is at the upper end of the slit at the side of the tubing, and consequently the shoulders on the iron bar are above the head of their conical sheath, and so long as the rod is suspended by the ring they remain in that position; directly, however, the rod is placed upright on the ground, and the power which suspended it is relaxed, the weight inside the tube falls down until the stud fastened to it is at the bottom of the slit, and the shoulders on the flat bar are concealed in their sheath.

The method of using this apparatus was to pass the iron cylinder through the hole in the centre of the sinkers, in a similar way to that in which the Hydra rod was rove, to suspend the rod by the ring, and then place the bight of the wire attached to the disc under the sinkers, over one of the shoulders of the flat iron bar. The apparatus was then ready for lifting over the side, the sinkers being suspended from the shoulders of the iron bar, which remained outside its sheath as long as the whole apparatus was hung by the ring. When the rod reached the bottom, the lower end of the cylinder touching the ground, and the sounding line above being relaxed, the weight in the brass tube fell down and the shoulder disappeared in its sheath, so that the wire which suspended the sinkers was pushed off and the rod thus became freed from the weights. The shoulder over which the suspending wire was placed was slightly hollowed to prevent the wire being knocked off as the apparatus was hoisted over the side. Care was requisite in making this hollow, for, if too deep, the wire was apt to jam between the outer part of the shoulder and the brass tubing. The Baillie rod, which weighed 35 lbs., only failed once in the Challenger, and then not from any fault of construction, but from the wire being caught by the spout of the slip water bottle which descended on the rod. To facilitate collecting the mud brought up by the tubes their lower ends were made to unscrew. The tube of the Baillie rod was 2½ inches in diameter, and was usually made to project 15 inches beneath the weights. A substantial valve of some sort is necessary to prevent the bottom samples falling out when the tube is being brought on board. When, however, the bottom is a tenacious clay, no valve is required, as the rod, without a valve, frequently brought up a section of the bottom 2 feet in depth. A valve is always a great impediment to the entrance of the mud into the tube.

It would be a great improvement so to arrange the Baillie tube that the weight should be more effectually utilised in pushing it into the ground, as it is of importance to procure samples of the deposits below the superficial layer (see page 118).

The Accumulators.—The accumulators are india-rubber bands ¾ of an inch in diameter and 3 feet in length, having at each end a thimble "seized in" (fig. 15 A). They are used to prevent any sudden jerks arising from the pitching or rolling of the ship, bringing an undue strain on the sounding line. They are capable of stretching 17 feet, when they each exert a force of 70 lbs.; beyond this they should not be stretched, as they are then liable to "carry away." When stretched 13 feet they each exert a force of 56 lbs.

Forty of these accumulators were found sufficient for sounding purposes in the Challenger, as they were strong enough to withstand the strain of the sinkers on the lead line without being too strong to give readily with the motion of the ship. In order to combine these forty accumulators so that they should exert a force proportionate to

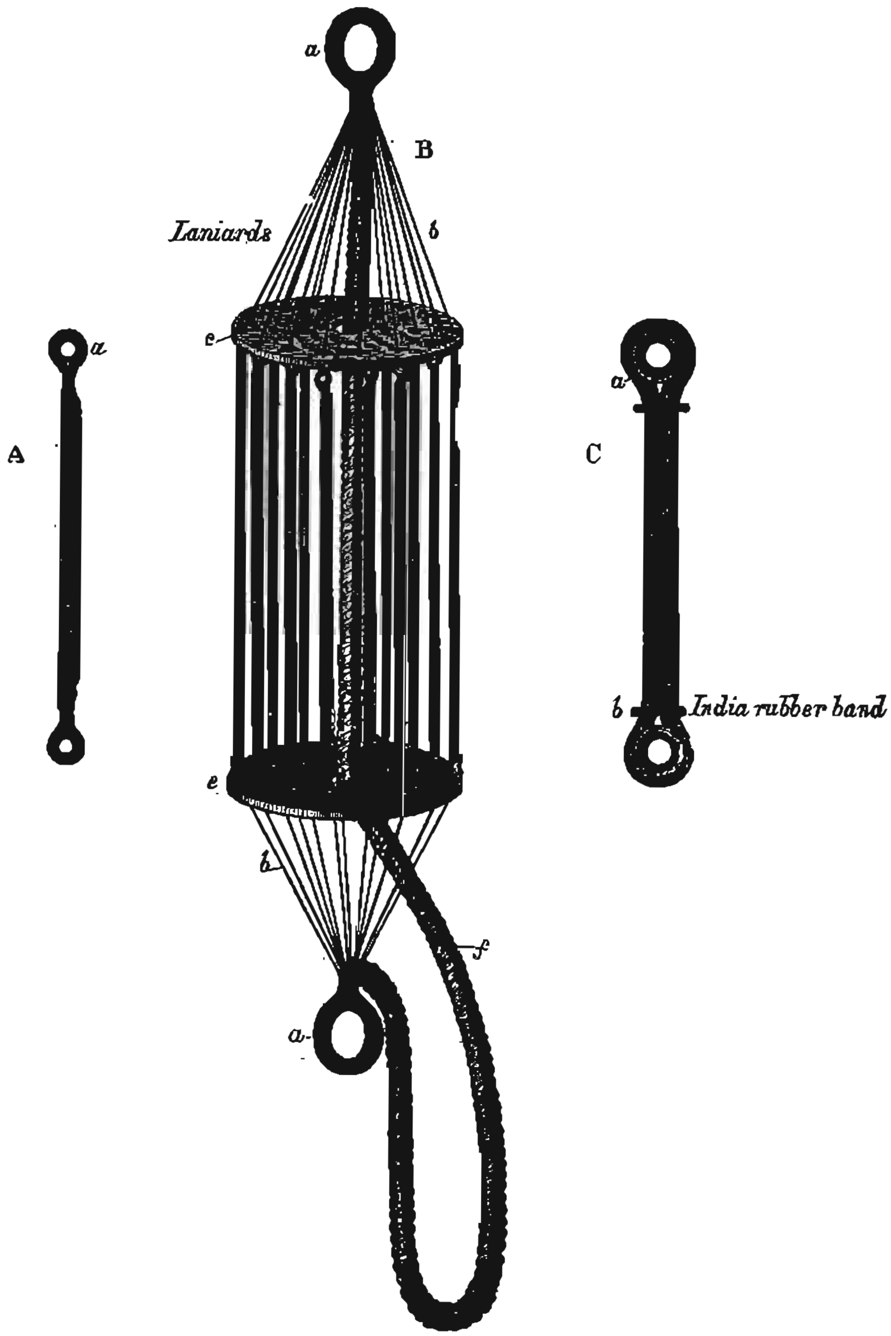

Fig. 15.—The Accumulator.

their number, they were attached to two discs of wood by laniards spliced into the thimbles at each end. These laniards were passed through corresponding holes in the upper and lower wooden disc, and were then collected together and formed into an eye at top and bottom, so that a rope could be "bent on," or a block "hooked on," to these eyes. To keep the discs at right angles to the line of accumulators the eyes of the splices which fastened the laniards to the thimbles were made sufficiently long to come through the disc, so that a small toggle driven in through these eyes, on the upper part of the disc, wedged it in its place (see fig. 15 B). To prevent the accumulators being by any accident stretched to such a length as would render them liable to break, a short piece of 4-inch rope was rove through a large hole in the centre of the wooden discs and spliced into the eyes formed at each end by the accumulated laniards, and the length of this rope was regulated so as to allow the accumulators to stretch 15 feet, after which any additional strain, which would otherwise have been borne by them, was borne by this preventor rope.

It was found by experience that, owing to the compression of the india-rubber by the seizings used to secure the copper thimbles at each end, the accumulators occasionally broke just below the compressed part. In order to remedy this defect Captain Nares suggested to the maker that he should construct the accumulators in the form of a ring, and put a wooden thimble in each bight, securing it there with a small india-rubber band, as shown in fig. 15 C. Some accumulators made in this manner were forwarded for trial, and were found to answer exceedingly well; being doubled only half the number were required, and this reduced the number of laniards securing them together, which was a great advantage. It was also found that nothing damaged the accumulators so much as smoke from the funnel; during the first eighteen months of the commission, when Welsh coal was in use, they suffered little or no damage, but when Australian coal was burnt the smoke dried up and ruined them very quickly.

The Gin-Blocks.—The blocks used for sounding purposes were 9-inch gin-blocks with patent sheaves. The sheaves were made to fit close to the shell of the block, so as to prevent the sounding line getting between the sheave and block.

Method of Sounding.—When a sounding was required steam was got up and all sail shortened and furled except the spanker. This proceeding was indispensable, as no trustworthy soundings could be obtained from the ship under sail, even in the calmest weather, the heave of the sea, or the surface current, being sufficient to drift her in a very short time a considerable distance from the place where the lead was originally let go, and thus prevent the line from running out perpendicularly. Sail being shortened and steam up, the ship was brought head to wind and the sounding gear got ready, as shown in fig. 16. A block A was secured to the foreyard a little outside the boomiron, and a whip rove through it to trice up the set of accumulators B. At the bottom of the accumulators a 9-inch gin-block C was hooked with the sounding line rove through it and secured to the sounding rod and sinkers D. To the line immediately above the sounding apparatus was attached a water bottle E, and above the water bottle two, or sometimes three, thermometers (these instruments will be described subsequently), and a pressure gauge F. The whole apparatus ready for sounding is shown in the figure, but it must be explained that, owing to the constant motion of the ship, the sounding rod and sinkers were lowered into the water directly they were lifted over the side to prevent their swaying backwards and forwards with the risk of doing considerable damage, and the water bottle and other instruments were attached after the sinkers were in the water. Before the sounding line was bent on to the rod it was rove through a thimble at the end of a lizard, so that the bight of the line could at any time be hauled in close to the dredging platform.

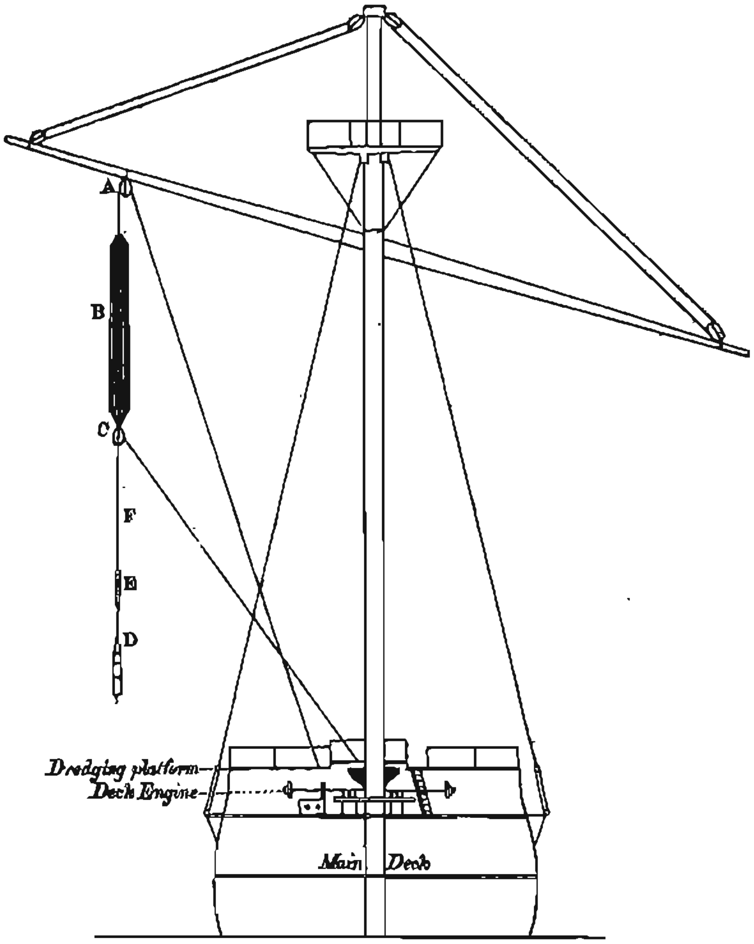

FIG. 16.—Diagram to illustrate the method of Sounding.

When all the instruments had been attached to the line it was eased down 400 or 500 fathoms by being passed round the drum of the donkey-engine, which was fitted with a break for this purpose. When that amount of line had been eased out it was allowed to descend freely, the ship being kept exactly over the spot where the sinkers entered the water. As the line ran out the exact time each 100 fathom mark entered the water was registered and entered in its appropriate column in a book provided for that purpose, and the interval between these times was calculated and entered in another column. These intervals gradually increase in length as the depth increases, the sinkers being retarded in their descent by the friction of the line as it passes through the water, which increases with the amount of line paid out; they will, however, be found to increase in regular proportion as long as the sinkers are descending, but directly they reach the bottom there will be a sudden lengthening of these intervals, as then only

TABLE *showing the Mean Rate of Descent of Sounding Lines with Weights of* 3 *and* 4 *cwt. attached.*

No. 1 line with 3 cwt. attached.			No. 1 line with 4 cwt. attached.	
Interval.	Time each 100 fathom mark entered water.	Depth in fathoms.	Time each 100 fathom mark entered water.	Interval.
m. s.	h. m. s.		h. m. s.	m. s.
...	9 0 0	500	9 0 0	...
1 8	1 8	600	0 59	0 59
1 13	2 21	700	2 1	1 2
1 18	3 39	800	3 7	1 6
1 23	5 2	900	4 17	1 10
1 28	6 30	1000	5 31	1 14
1 33	8 3	1100	6 49	1 18
1 37	9 40	1200	8 11	1 22
1 41	11 21	1300	9 37	1 26
1 44	13 5	1400	11 7	1 30
1 47	14 52	1500	12 40	1 33
1 50	16 42	1600	14 16	1 36
1 52	18 34	1700	15 55	1 39
1 54	20 28	1800	17 37	1 42
1 56	22 24	1900	19 22	1 45
1 58	24 22	2000	21 10	1 48
2 1	26 23	2100	23 1	1 51
2 3	28 26	2200	24 54	1 53
2 5	30 31	2300	26 49	1 55
2 7	32 38	2400	28 46	1 57
2 10	34 48	2500	30 45	1 59
2 12	37 0	2600	32 46	2 1
2 14	39 14	2700	34 49	2 3
2 16	41 30	2800	36 54	2 5
2 18	43 48	2900	39 1	2 7
2 20	46 8	3000	41 10	2 9

the weight of the sounding line plus the impetus given it by the descending sinkers will be dragging the line off the reels. Directly, therefore, a sudden lengthening of the intervals was observed it was known that the sinkers were at the bottom, and the heaving in of the line was commenced by bringing it to the drum of the donkey-engine. Care was taken not to heave up too quickly at first, and also to keep the ship carefully in position over the line, for if allowed to fall off, the wind drifting her to leeward, brought an unnecessary strain on the sounding line. When hove up, the water bottle and thermometers were taken off, and the lower part of the cylinder of the sounding rod unscrewed and its contents carefully preserved.

The preceding table shows the rate of descent of the sounding lead from 500 to 3000 fathoms, and being the mean of a great number of observations, will probably be useful to surveyors taking deep-sea soundings with apparatus similar to that used on board the Challenger, as any great difference from the numbers therein given would show either that the weights were at the bottom, that the line was incorrectly marked, or that a current was affecting it.

The time-intervals observed in seven of the exceptionally deep casts obtained by the Challenger are given in the following tables, from 1000 fathoms to the depth obtained; five of them with 4 cwt., and two with 3 cwt., of sinkers attached.

It may be as well to remark here that although only the time each 100 fathom mark entered the water, and the intervals between these times are given in these tables, in actual practice the time each 50 fathom mark entered the water was registered when 2000 fathoms of line had been paid out, and the time each 25 fathom mark entered the water when 3000 fathoms had run out, so that it was possible to detect at once when the sinkers reached the bottom.

[TABLE of Challenger Soundings.

TABLE *of Challenger Soundings at Depths exceeding* 3000 *Fathoms with* 3 *cwt. of Sinkers.*

Depth in Fathoms.	Wednesday, 26th March 1873. Wind, E^{b}N. Force, 4. Weather, bc. Sea, moderate. Line, No. 1. Machine, Hydra. Lat. 19° 41′ N., long. 65° 7′ W.			Tuesday, 23rd March 1875. Wind, E^{b}N. Force, 4. Weather, bcp. Sea, swell from ENE. Line, No. 1. Machine, Baillie. Lat. 11° 24′ N., long. 143° 16 E.			REMARKS.
	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	
	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	
1000	6 42 48	1 36	1 28	6 1 30	...	1 28	
1100	44 25	1 37	1 33	3 0	1 30	1 33	
1200	46 3	1 38	1 37	5 0	*2 0	1 37	* Line checked slightly.
1300	47 45	1 42	1 41	7 12	*2 12	1 41	
1400	49 32	1 47	1 44	8 43	1 31	1 44	
1500	51 20	1 48	1 47	10 22	1 39	1 47	
1600	53 12	1 52	1 50	12 4	1 42	1 50	
1700	55 7	1 55	1 52	13 52	1 48	1 52	
1800	57 5	1 58	1 54	15 43	1 51	1 54	
1900	59 2	1 57	1 56	17 41	1 58	1 56	For explanation of the letters used to denote the state of the weather, see Narr. Chall. Exp., vol. ii. p 301, 1882.
2000	7 1 6	2 4	1 58	19 47	2 6	1 58	
2100	3 8	2 2	2 1	21 54	2 7	2 1	
2200	5 13	2 5	2 3	24 15	2 21	2 3	
2300	7 24	2 11	2 5	26 28	2 13	2 5	
2400	9 38	2 14	2 7	28 32	2 4	2 7	
2500	11 53	2 15	2 10	30 40	2 8	2 10	
2600	14 11	2 18	2 12	33 4	2 24	2 12	
2700	16 26	2 15	2 14	35 25	2 21	2 14	
2800	18 37	2 11	2 16	37 56	2 31	2 16	
2900	20 59	2 22	2 18	40 13	2 17	2 18	
3000	23 26	2 27	2 20	checked	...	2 20	
3100	25 45	2 19	...	52 53	...	...	
3200	28 11	2 26	...	55 1	2 8	...	
3300	30 38	2 27	...	57 10	2 9	...	
3400	33 5	2 27	...	59 30	2 20	...	
3500	41 40	checked	...	7 1 48	2 18	...	
3600	44 20	2 40	...	4 3	2 15	...	
3700	47 12	2 52	...	6 26	2 23	...	
3800	57 22	checked	...	8 52	2 26	...	
3900	8 0 19	2 57	...	11 25	2 33	...	
4000	4 39	4 20	...	13 57	2 32	...	
4100	...	...	...	16 36	2 39	...	
4200	...	...	...	19 1	2 25	...	
4300	...	...	...	21 25	2 24	...	
4400	...	...	...	23 51	2 26	...	
4500	...	...	...	26 20	2 29	...	
4600	...	...	...	...	...	...	
4700	...	...	...	...	...	...	
4800	...	...	...	...	...	...	
4900	...	...	...	...	...	...	
5000	...	...	...	...	...	...	

TABLE *of Challenger Soundings at Depths exceeding* 3000 *Fathoms with* 4 *cwt. of Sinkers.*

Depth in Fathoms.	Wednesday, 26th February 1873. Wind, E. Force, 6. Weather, bc. Sea, moderate. Line No. 1. Machine, Hydra. Lat. 23° 23′ N., long. 35° 11′ W.			Tuesday, 11th March 1873. Wind, E. Force, 4-5. Weather, bc. Sea, smooth. Line No. 1. Machine, Hydra. Lat. 19° 15′ N., long. 57° 47′ W.			Thursday, 13th March 1873. Wind, E by S. Force, 4-5. Weather, bc. Sea, smooth Line No. 1. Machine, Hydra. Lat. 18° 54′ N., long. 61° 28′ W.			Tuesday, 23rd March 1875. Wind, E by N. Force, 4. Weather, bcp. Sea, swell from ENE. Line No. 1. Machine, Baillie. Lat. 11° 24′ N., long. 143° 16′ E.			Friday, 18th June 1875. Wind, SSW. Force, 5-6. Weather, ocdf. Sea, swell from SW. Line No. 1. Machine, Baillie. Lat. 35° 18′ N., long. 144° 8′ E.			Remarks.
	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	
	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	
1000	11 45 0	1 24	1 14	1 45 55	1 22	1 14	2 33 19	1 20	1 14	10 54 21	...	1 14	...	...	1 14	For explanation of the letters used to denote the state of the weather, see Narr. Chall. Exp., vol. ii. p. 301.
1100	46 25	1 25	1 18	47 17	1 22	1 18	34 42	1 23	1 18	55 36	1 16	1 18	...	...	1 18	
1200	47 50	1 25	1 22	48 40	1 23	1 22	36 5	1 23	1 22	56 57	1 21	1 22	11 39 17	...	1 22	
1300	49 12	1 22	1 26	50 8	1 28	1 26	37 31	1 26	1 26	58 24	1 27	1 26	41 2	1 45	1 26	
1400	50 37	1 25	1 30	51 36	1 28	1 30	38 59	1 28	1 30	11 0 1	1 37	1 30	42 43	1 41	1 30	
1500	52 5	1 28	1 33	53 11	1 35	1 33	40 33	1 34	1 33	1 41	1 40	1 33	44 26	1 43	1 33	
1600	53 45	1 40	1 36	54 48	1 37	1 36	42 11	1 38	1 36	3 23	1 42	1 36	46 6	1 40	1 36	
1700	55 21	1 36	1 39	56 30	1 42	1 39	43 50	1 39	1 39	5 5	1 42	1 39	49 46	checked	1 39	
1800	57 2	1 41	1 42	58 12	1 42	1 42	45 33	1 43	1 42	6 44	1 39	1 42	51 27	1 41	1 42	
1900	58 41	1 39	1 45	59 59	1 47	1 45	47 18	1 45	1 45	8 24	1 40	1 45	53 23	1 56	1 45	
2000	12 0 25	1 44	1 48	2 1 45	1 46	1 48	49 1	1 43	1 48	10 11	1 47	1 48	55 24	2 1	1 48	
2100	2 12	1 47	1 51	3 33	1 48	1 51	50 46	1 45	1 51	12 2	1 51	1 51	57 23	1 59	1 51	
2200	3 53	1 41	1 53	5 26	1 53	1 53	52 42	1 56	1 53	14 0	1 58	1 53	59 22	1 59	1 53	
2300	5 55	2 2	1 55	7 20	1 54	1 55	54 36	1 54	1 55	15 55	1 55	1 55	12 1 22	2 0	1 55	
2400	7 50	1 55	1 57	9 12	1 52	1 57	56 39	2 3	1 57	17 55	2 0	1 57	3 24	2 2	1 57	
2500	9 50	2 0	1 59	11 9	1 57	1 59	58 38	1 59	1 59	20 0	2 5	1 59	5 20	1 56	1 59	
2600	11 40	1 50	2 1	13 11	2 2	2 1	3 0 38	2 0	2 1	22 14	2 14	2 1	7 16	1 56	2 1	
2700	13 40	2 0	2 3	15 12	2 1	2 3	2 41	2 3	2 3	24 21	2 7	2 3	checked	...	2 3	
2800	15 43	2 3	2 5	17 22	2 10	2 5	4 48	2 7	2 5	26 15	1 54	2 5	12 3	...	2 5	
2900	17 45	2 2	2 7	19 32	2 10	2 7	6 56	2 8	2 7	28 14	1 59	2 7	13 54	1 51	2 7	
3000	19 50	2 5	2 9	21 45	2 13	2 9	9 7	2 11	2 9	30 37	2 23	2 9	17 53	checked	2 9	
3100	21 53	2 3	...	24 59	3 14	...	12 6	2 59	...	36 15	checked	...	19 36	2 3	....	
3200	24 45	2 52	...	...	...	...	...	...	..	38 14	1 59	...	21 35	1 59	...	
3300	...	...	...	...	...	...	...	..	...	40 23	2 9	...	23 24	1 49	...	
3400	...	...	...	...	...	...	...	...	...	42 36	2 13	...	26 40	3 26	checked	
3500	...	...	...	...	...	...	...	...	...	48 38	checked	..	28 24	1 44	...	
3600	...	...	..	...	...	...	...	...	...	50 43	2 5	...	30 12	1 48	...	
3700	...	...	...	...	...	...	...	...	...	52 57	2 14	...	31 58	1 46	...	
3800	...	...	...	...	...	...	...	...	...	55 15	2 18	...	33 48	1 50	...	
3900	...	...	...	...	...	...	...	...	...	12 0 10	checked	...	35 50	2 2	...	
4000	...	...	...	...	...	...	...	...	...	2 20	2 10	...	38 32	2 42	...	
4100	...	...	...	...	...	...	...	...	...	12 4	checked	...	...	...	...	
4200	...	...	...	...	...	...	...	...	...	14 34	2 30	...	...	...	...	
4300	...	...	...	...	...	...	...	...	...	16 58	2 24	...	...	...	...	
4400	...	...	...	...	...	...	...	...	...	19 20	2 22	...	...	...	...	
4500	...	...	...	...	...	...	...	...	...	22 3	2 43	...	...	...	...	
4600	...	...	...	...	...	...	...	...	..	25 51	3 48	...	...	...	...	
4700	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
4800	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	
4900	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
5000	...	...	...	...	...	...	...	...	...	....	...	...	...	...	...	

The sounding machine and disengaging sinkers were only used when there was reason to expect a depth of over 1000 fathoms; for lesser depths either a valve or cup lead of 56 lbs., 112 lbs., or 168 lbs. was used, and the apparatus was recovered.

The Cup Lead (see fig. 17) is an ordinary deep-sea lead A, having at its lower end an iron spike C driven in; at the bottom of this spike is an inverted hollow iron cone B, and above the cone is a sliding iron disc D movable up and down the spike between the lead and the top of the cone, and just large enough to cover the opening of the cone when resting on it. During the descent of the lead the disc is raised off the cone by the friction of the water, so that when the bottom is reached the cone penetrates and is filled with the mud or other material it encounters, and as the lead is raised to the

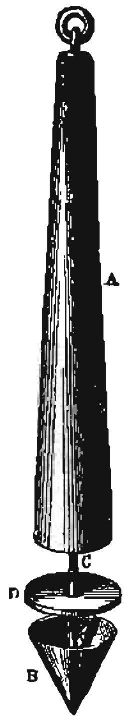

FIG. 17.—The Cup Lead.

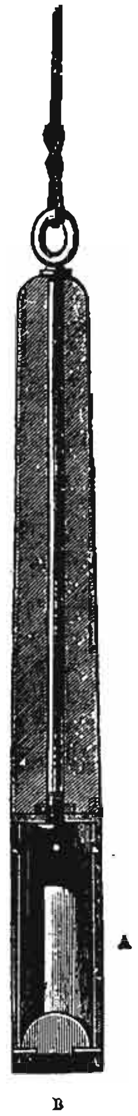

FIG. 18.—The Valve Sounding Lead.

surface the friction of the water forces down the sliding disc D on to the top of the cone B and prevents any of its contents being washed out.

The Valve Lead (see fig. 18) is an ordinary deep-sea lead, fitted at its base so that an iron cylinder A with a butterfly valve B at the bottom can be screwed on to it. It was found to be by far the best form of lead for ordinary sounding work, and the cylinder unscrewing enabled the contents to be collected expeditiously and without loss.

Wire Rope.—At the time when the Challenger was fitted out, Sir William Thomson had revived the subject of sounding in deep water with wire in place of hemp, and before the ship left England an apparatus of his was put on board. During the absence of the Challenger on her voyage, this method was energetically and successfully developed by Sir William Thomson, and being adopted by the American surveyors in the "Tuscarora" under Captain Belknap, and later by Captain Sigsbee, it is now universally used for rapid sounding in deep water. The great extension of oceanic telegraphy rendering detailed surveys of the various routes necessary, materially assisted in this development, and for this purpose the method is admirably adapted. The advantage which the wire possesses over the hemp is the rapidity with which the operation can be conducted, owing to the very slight friction of the wire against the water. In telegraph ships this is taken advantage of to its utmost limits, and as nothing is risked but a sinker and a length of wire, but little heed is paid to the parting of a wire. The work of the Challenger, however, was very different. It is true that at every station the depth had to be ascertained, but this was only a small part of the work, and a saving of half an hour in the operation, even if it could have been effected without risk, would have been unimportant. On the same line with which the depth was ascertained were attached deep-sea thermometers and piezometers, also one, and sometimes two, water bottles, together making up a heavy and valuable load, the loss of which, though only occasionally, would not have been compensated by any saving of time. In view, therefore, of the special character of the work assigned to the Challenger, and of the great value of the instruments used, and also of the fact that the captain and officers of the ship were thoroughly acquainted with the use of hemp for sounding and other investigations at great depths, while the programme of the voyage did not admit of time being spent in the development of a method adapted for a different style of work, hemp line was invariably used throughout the cruise, and with unvarying success. After the rejection of the No. 2 sounding line, there were few accidents, and during the last two years of the voyage neither a fathom of line nor an instrument was lost in deep sounding. The great disadvantage of wire arises from its liability to break, owing to circumstances independent of the strain to which it is exposed. A hemp line may be bent and twisted in any way without its strength being at all affected. With wire it is otherwise; it must never suffer a sharp bend, twist, or kink; if it do its strength is gone, and if the damaged part be not cut out an accident is sure to occur. Where steam power is not available for heaving up, the wire possesses a very great advantage, for it can be easily worked, even at very great depths, by hand.

Captain Belknap of the U.S.S. "Tuscarora," who in 1874 sounded out the route from San Francisco to Japan, and in so doing surveyed the deepest water in the world, did all his sounding by hand. His successor Captain Sigsbee, the author of the admirable volume on deep-sea sounding and dredging,[1] devised and constructed an elaborate wire-sounding apparatus with steam power, especially adapted for scientific work. More recently, Captain Magnaghi, Hydrographer to the Italian Navy, has fitted his ship the "Washington" throughout with wire, not only for deep-sea work, but for ordinary harbour surveying, all the boats used in this work being fitted with small stages for the wire sounding reel.

It is evident, then, that in the twelve years which have elapsed since the Challenger cruise began, the use of wire for sounding purposes has received enormous development. For purposes of deep-sea investigation, however, which includes actual sounding only as one of its items, good hemp sounding line is still indispensable. It is of course necessary to have steam power for working the line. With it in depths up to 500 or 600 fathoms hemp is better for all purposes than wire, and is equally expeditious, for a sinker can be used to make it descend nearly as quickly as wire, and with instruments attached it can be hove in with safety more rapidly from such depths than wire. Deep-sea thermometers which have been carefully compared with a standard, and which have been used in many soundings, are instruments of very great value, and if lost, are not replaced by the purchase of new ones. Further, it is important at every station to observe the temperature at as many different depths as possible. Where wire, with its liability to break, is used, it is very imprudent to use more than one or two valuable thermometers at a time, while with hemp, which is almost absolutely free from risk of rupture, eight or ten thermometers may be sent down at once. Therefore to obtain, with safety, the same number of observations with the wire, would require the operations of sinking and heaving in to be repeated a greater number of times than with the hemp; and as a thermometer must be allowed a certain time to take the temperature of the water, it is evident that for such work the wire is in the end not more expeditious than the hemp.

With regard to *dredging*, which formed so important a part of the Challenger's work, there can be no doubt of the great superiority of wire over hemp rope. The advantage in point of rapidity of work and of saving in stowage is much greater than in the case of sounding. Here we are indebted for a scientific instrument to the enterprise of those engaged in the manufacture of telegraph cables, for it is owing to the development of this industry that there is now a regular manufacture of the beautifully flexible steel-wire hawsers which are now to be found on board almost every well-appointed ship.

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[1] Sigsbee, Deep-Sea Sounding and Dredging, Washington, 1880.

Steel-wire rope was first used for deep-sea dredging by Alexander Agassiz, in the winter of 1877–78, and since then he has continued to use it with great success. His rope[1] "was one and one-eighth inches in circumference, and was composed of six strands laid around a tarred hemp heart. Each of the six strands was composed of seven galvanized steel wires of No. 19 American gauge (No. 20 Birmingham gauge). The ultimate strength of the rope was 8750 pounds, weight per fathom 1·14 pounds in air, and approximately one pound in sea water; price, eight cents per foot." Captain Sigsbee sets down the following as safe work when dredging with wire rope—"Time per one hundred fathoms paying out and hauling back, three to five minutes, according to circumstances; time for dragging, ten to thirty minutes, according to depth and the character of the bottom. The rate of dragging may be from one and a half to three miles per hour, according to the character of the bottom and the state of the sea."[2] In the summer of 1878,[3] Mr Buchanan fitted the steam yacht "Mallard" with a steel-wire rope for work in depths up to 200 fathoms. It consisted of five strands arranged round a centre of cotton, and each strand consisted of seven steel wires (No. 24 B.W.G.) 0·023 inch in diameter. The diameter of the rope was only 0·19 inch, its weight per fathom 0·33 lb., and its breaking strain 30 cwt. This rope was unfortunately not galvanized, and in the course of four seasons gradually perished with rust. It was replaced by a slightly stouter rope made of *phosphor-bronze*, which seems to have many advantages; especially it does not rust, nor does it fly into kinks whenever it gets loose on the deck, while its tensile strength is very little inferior to that of steel, and when worn out it has a value as old metal. In the "Mallard" the dredge rope was laid through a block suspended by a stout iron davit in the bow, and in-board it passed through a dynamometer. This arrangement was also adopted by Captain Magnaghi in the "Washington."

For dredging in very deep water it might be of importance to have a *tapered* wire rope. For, taking Agassiz's rope, with a breaking strain of 8750 lbs., and weighing in water 1 lb. per fathom, it would be working at half its breaking strain in 4000 fathoms of water, even without any dredge or dragging. This points to a definite limit of depth, beyond which dredging with wire rope becomes practically impossible. A similar limit to the use of hemp line exists also, but owing to its great buoyancy this is unlikely to be approached in any existing sea. It is conceivable that a sea might be so deep that it would be impossible to reach its bottom with a line of any known material.

Dredging and Trawling.—For dredging and trawling purposes the Challenger was supplied with three different sizes of rope—2, 2½, and 3 inches in circumference. This cordage was made of the best Italian hemp, tarred, well hackled and rubbed down, and laid up softly. The 2-inch rope weighed 95 lbs. per 100 fathoms, and

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[1] Sigsbee, Deep-sea Sounding and Dredging, Washington, 1880, p. 155.

[2] *Loc. cit.*, p. 146.

[3] *Journ. Soc. Arts*, vol. xxix. p. 326, 1881, London.

its breaking-strain was 1 ton 12 cwt.; the 2½-inch rope weighed 158 lbs. per 100 fathoms, and its breaking-strain was 2 tons 6 cwt.; and the 3-inch rope weighed 220 lbs. per 100 fathoms, and its breaking-strain was 2 tons 11 cwt. In proportion to its weight, therefore, the 2-inch was the strongest rope, and this or the 2½-inch was used for deep trawlings or dredgings, the 3-inch rope being reserved for comparatively shallow water. The rope was spliced together so as to form one uninterrupted length of 4000 fathoms, and was kept coiled away in racks on the forecastle, each size of rope by itself. Sheep pens were used as racks for coiling the rope away, and were found very convenient for that purpose. When rope was first used in such great lengths, swivels were spliced in at each 500 fathoms to take the turns out, but it was found by experience that these swivels were of little use for this purpose, and that they frequently got jammed in the blocks, so they were discarded. The rope was marked at each 100 fathoms, in the same manner as the sounding lines.

The Dredge consisted of two parts, the iron framework which skimmed the surface of the bottom, and the bag or sack which caught and retained the skimmings. A third part was added by Captain Calver in H.M.S. "Porcupine," viz., the swabs at the bottom, but the dredge itself was complete without this appendage. The iron framework was oblong in shape (see fig. 19), having attached to each of its short sides an arm A, A. These arms were connected together with iron screw bolts B, B, B, and between them was an iron tongue C, with a swivel-ring D at its upper end, to which the dredge-chain was fastened. When not in use the arms were disconnected and fell down on the framework, so that the dredge could be stowed away in a small space, a great advantage on board ship. On each of the long sides of the iron framework was a broad knife-edged piece of iron E, E, E, at an angle of about 10° from the perpendicular, intended to skim the surface off the bottom and throw it into the sack. The sack F was made of network of soft line (something like marline) in very small meshes, the size of the sack depending, of course, on the size of the framework. It was lined inside with cotton cloth or "bread-bag stuff" so as to prevent minute animals being washed out whilst heaving in, and it was secured to the framework by a lacing, eyelet holes being made at regular intervals in the framework for this purpose.

Under the sack an iron bar G, G was secured to the bights of two pieces of rope H, H the ends of which were spliced on to the framework on either side. On the bar G, G flat headed swabs K, K, K, K were hung, so that, trailing along the ground, they might entangle any animals missed by the dredge after it had become choked with mud. To prevent the rope chafing, five or six fathoms of chain were, in the first place, attached to the dredge and the rope secured to this, the ends of this chain were hitched to one of the short sides of the frame and the bight seized to the ring D, so that if the dredge caught a rock, the seizing carrying away would give a better chance of its recovery.

The iron framework of the largest dredge was 5 feet in length, 1 foot 3 inches in breadth, its weight being 137 lbs.; the next size, which was made much stronger, was 4 feet in length, 9 inches in breadth, and weighed 259 lbs.; and the smallest was 3 feet in length, 1 foot in breadth, and weighed 85 lbs. The smallest was generally used in great depths; and with it a successful haul was obtained in 3875 fathoms.

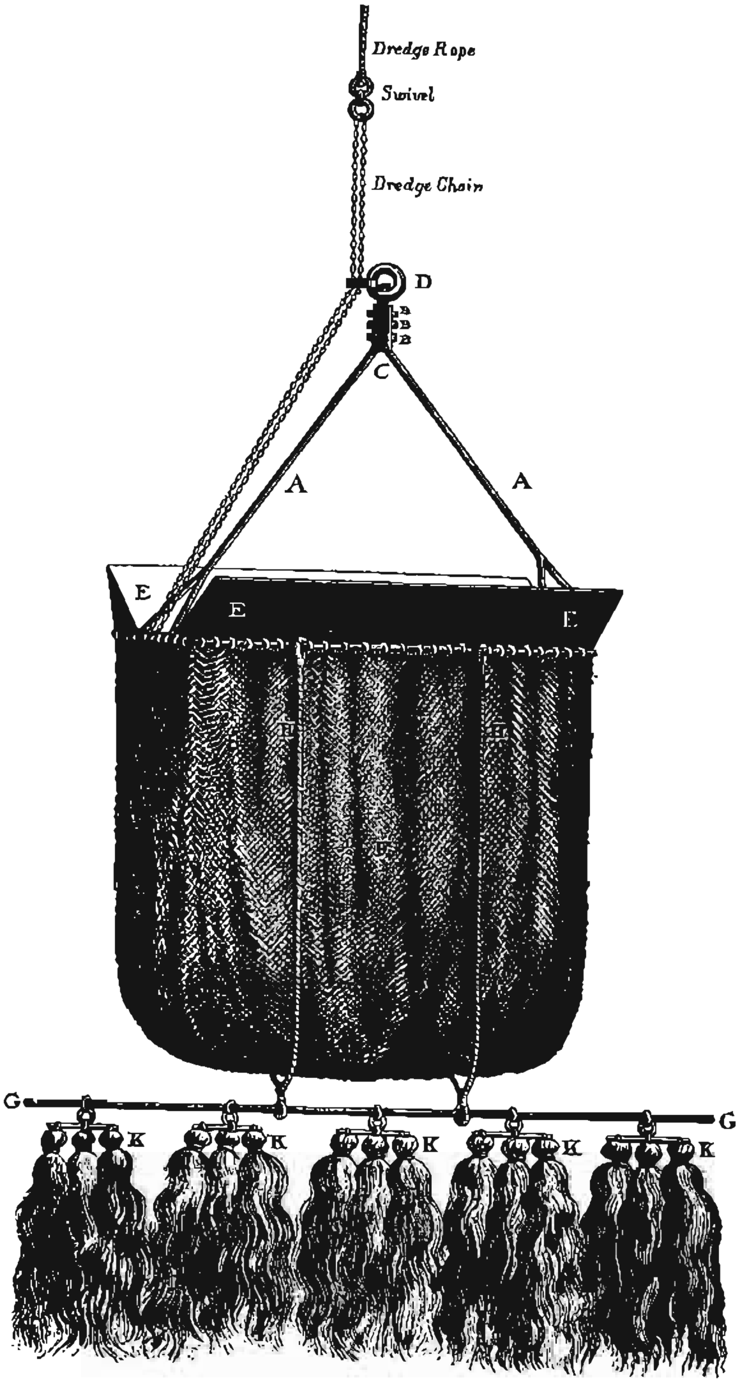

FIG. 19.—The Dredge.

The Trawl (see fig. 20) was of the ordinary pattern, consisting of a beam of wood with an iron at each end, to which a large V-shaped net was attached, so that its mouth was kept spread open by the trawl irons and beam. The size of the net depended on the length of the trawl-beams, which were 17, 13, and 10 feet in length; the smallest being used for very deep water and the others for lesser depths. On the trawl-irons and bag of the net were hung 28 lb. leads, so as to keep the net down to the bottom when trailing along. At first, beams made of fir were used for trawling in deep water, but were replaced by oak or teak beams, as the fir spars came up broken, and so much compressed from the pressure of the water that the knots in the wood stood out three quarters of an inch above the surface of the spar. The bottom of the netting was, as in the case of the dredge, usually lined with bread-bag stuff, to prevent the smaller animals being washed out whilst being hove up through the water. It is, however, preferable in place of this bread-bag stuff, to use a small strip of fine linen or cotton for the netting of both the trawl and dredge, and to change it at each haul. Improvements, both in the form and the method of using the dredge and trawl, have recently been suggested by Captain Sigsbee,[1] by the naturalists of the Norwegian North Atlantic Expedition,[2] and others.

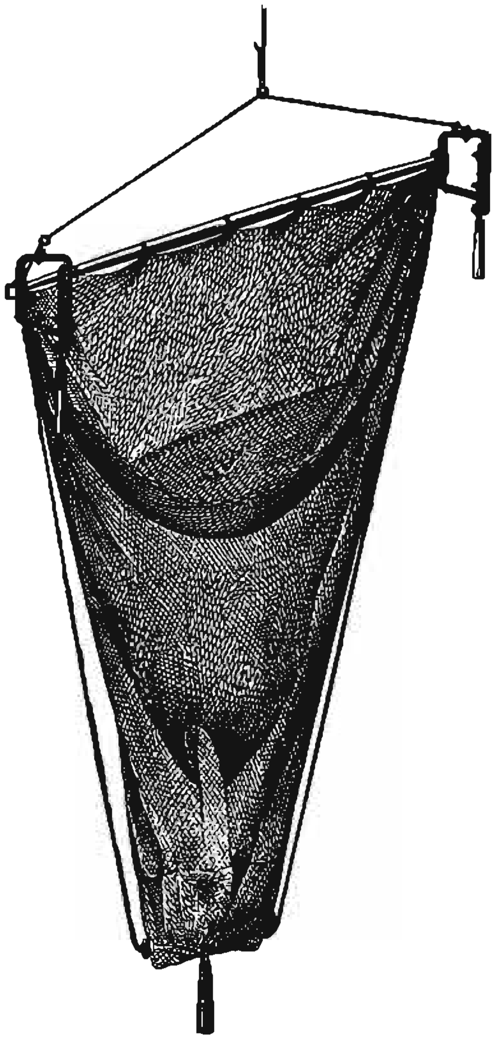

FIG. 20.—The Beam Trawl used in deep-sea work.

The Sieves.—Close to the place where the dredge was emptied there were always one or two tubs, about two or three feet in diameter and twenty inches deep, each of which was provided with a set of sieves, so arranged that the lowest sieve fitted loosely within the bottom of the tub, and the three succeeding sieves within one another (see fig. 21). Each sieve was provided with a pair of iron handles, through which the hand could pass easily, and those of the largest sieve were made long, so that the whole nest could be lifted without stooping and putting the arms into the water. The upper smallest sieve was usually deeper than the others; it was made of a strong open net of

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[1] Sigsbee, Deep-Sea Sounding and Dredging, Washington, 1880.

[2] C. Wille, Norwegian North Atlantic Expedition, 1876-1878, part iv., The Apparatus and How Used.

brass wire, the meshes half an inch to a side. The second sieve was much finer, the meshes a quarter of an inch to a side. The third was finer still, and the fourth so close as only to allow the passage of mud or fine sand. The sieves were put into the tub, which was then filled up to the middle of the top sieve with sea water. The top sieve was then half filled with the contents of the dredge, and the set of sieves gently moved up and down in the water. It is of great importance not to give any rotary motion to the sieves in this part of the process, for this is very ruinous to fragile organisms; the sieves should be gently churned up and down, whether singly or together. The result of the process was that the rougher stones and gravel, and the larger organisms, were washed and retained in the upper sieve, the fine mud or sand passing through the whole of the sieves and subsiding into the bottom of the tub, while the three remaining sieves contained, in graduated series, the objects of intermediate size. The sieves were examined carefully in succession, and the organisms which they contained gently removed with a pair of brass or bone forceps into jars of sea water, or placed at once in bottles with spirits of wine. The manner in which the sieves are used will, of course, vary according to circumstances and the nature of the deposit.

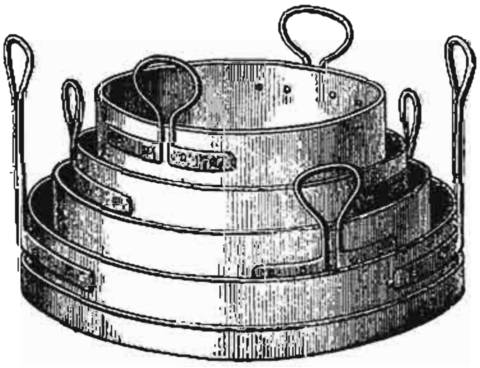
FIG. 21.—The Sieves.

The operations of trawling or dredging were carried on from the mainyard, the dredge rope being rove through an iron gin-block with a patent sheave, which was attached to the accumulators in the manner previously described. For dredging purposes, however, no less than eighty accumulators were used, and in order to stretch them 17 feet, a force of 2½ tons had to be exerted—that is a force equal to the breaking strain of the rope. The accumulators, instead of being triced up to a block on the yard, as they were for sounding purposes, were secured to a pendant hooked on to the cap, the pendant being hauled out, or eased in, by a burton on the end of the yard, as the dredge was required to plumb the sea or the dredging platform (see fig. 12). Before being fastened to the chain of the dredge, the dredge rope was passed through two thimbles. One was used for a special purpose, described hereafter; to the other a small tackle was hooked, to haul the rope close to the ship's side when required. The dredge or trawl being ready to go over, the ship was put before the wind, and the jib hoisted, the wind being kept a little on the quarter of that side of the ship it was intended to work from, in order to drift the dredge clear of the propeller. The dredge was now triced up to the block below the accumulators, and the burton on the mainyard hauled out until the dredge plumbed the sea; it was then lowered down a fathom or two below the surface, and the rope checked, so that from the platform the swabs might be seen to trail clear of the sack.

This having been satisfactorily ascertained, the rope was let go and allowed to run out freely, the ship forging slowly through the water, leaving the dredge to sink astern, and thus prevent all chance of fouling. The rope was checked occasionally to ensure its being taut from the dredge.

When from 300 to 500 fathoms had been paid out a toggle was lashed to the rope, which was then let run until a sufficient quantity had been paid out to allow the toggle to reach the bottom were the line perpendicular. The dredge and rope then occupied the position A B, shown in fig. 22, and the ship was brought to the wind and kept stationary, or, if there were much wind, steamed slowly towards the dredge, taking care not to overrun it. A weight of 1½ cwt. was now attached to the thimble through which the rope had been rove previously to its being secured to the dredge chain, and the weight and

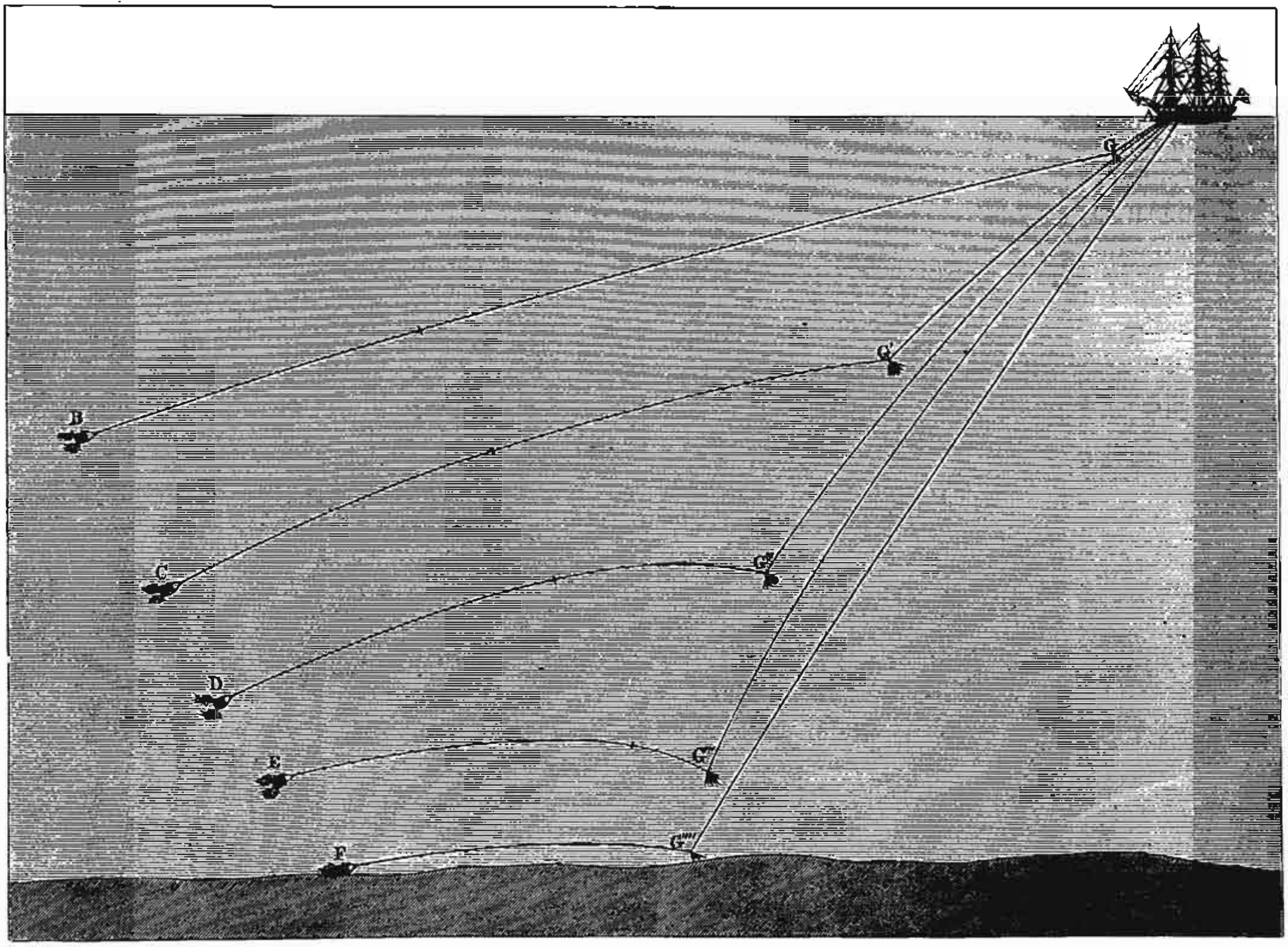

FIG. 22.—Diagram illustrating the supposed action of the Deep-Sea Dredge.

thimble being let go they travelled down the curve of the rope until they were brought up at the toggle G. The dredge and rope by means of this additional weight now successively assumed the positions A C, A D, and A E, until finally the dredge reached the bottom at F, the weights being in the positions G′, G″, G‴, G⁗.

It must be evident that, provided there were no surface or under current, the dredge would reach the bottom with the swabs trailing fairly behind it, if sufficient time were allowed for it to sink. The surface current could always be ascertained and allowed for; when the dredge, therefore, came up foul, as it occasionally did, this could only be ascribed to the influence of some under-current, which need not necessarily have been at the bottom, or to the rope when new twisting the dredge round and round with the weights on the toggle. It was found by experience that about three hours were required to sink the dredge in this manner when the depth was about 2500 fathoms. When it was once down the ship was allowed to drift broadside to the wind for a certain time, and the accumulators pointed out, by their expansion and contraction, that the dredge was being dragged slowly over the ground. When it fouled anything the strain of the ship immediately stretched the accumulators to their utmost, and the line was at once let go to prevent its carrying away, the ship being brought head to wind and kept stationary, while the rope was hove in easily. Did the dredge still continue foul, the ship was steamed ahead of and all round the supposed position of the dredge to endeavour to clear it (in the same manner as a boat's anchor is cleared when jammed on a coral reef or amongst rocks), until the dredge was freed by the stop (see fig. 19 D) breaking, or the line carrying away. Supposing no accident occurred, when the dredge had been on the bottom a sufficient time—from half an hour to an hour—the rope was brought to the donkey-engine, and the dredge hove up. It was found that the strain on the line was so great that the men could not hold on to it while it was being hove in, when turns were passed round only one drum of the engine. Fortunately, the engine was fitted with drums of the same diameter on each side of the deck, so that by taking a number of turns with the rope round the drum on one side, and then leading it abaft through two blocks across the deck, it was possible to take a number of additional turns round the drum of the engine at the other side, so that the men were enabled to hold on to it easily, and a great support was given to the bearings of the engine.

On one or two occasions, when, owing to the depth (over 3000 fathoms), sufficient time could not be spared to allow the dredge or trawl to sink in this manner, a sounding rod was fastened to the bottom of the dredge or trawl and 4 cwt. put on the rod. The dredge was then let go perpendicularly, the ship being kept stationary, until sufficient line had been paid out to allow the rod to reach the bottom and disengage the weights, when the ship was allowed to drift a little way, and then the weights were attached to the thimble and allowed to slide down the rope to the toggle. This is a very successful way of dredging or trawling quickly in deep water.

Tow-Nets.—These nets were continually in use during the cruise, and a stock of over a dozen was always kept ready to hand. The hoops were 10, 12, 14, and 16 inches in diameter, and the bags were made of fine muslin and buntin or strong cotton.

During the daytime they were usually towed from the ship about 50 fathoms beneath the surface with a 6 lb. lead, and sometimes to 200, 400 and 800 fathoms with a 14 lb. lead. The weights were placed about 10 fathoms in front of them, as represented in the woodcut (see fig. 23). The finest muslin ones were generally used when a boat was lowered from the ship for the purpose of tow-netting, and could be pulled very slowly through the water. During the last years of the voyage these nets were attached to the dredge line just below the weights, and also to the sides of the dredge and beams of the trawl.

On a good many occasions they were tied alongside a rope, as represented in the woodcut (see fig. 24), and sent down two miles with a lead and then hauled up again. In this operation, they, of course, only worked while being hauled up. The object of using them in this manner was to ascertain whether or not organisms lived in the deeper layers of water.

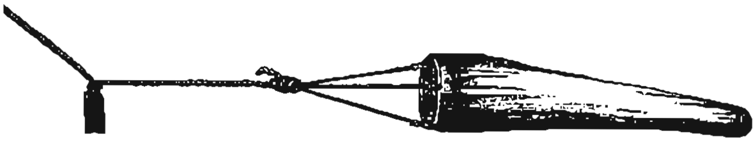

FIG. 23.—Ordinary method of using the Tow-Net.

FIG. 24.—A method of using the Tow-Net in deep water.

CURRENT OBSERVATIONS.

Current Drags.—Current observations were occasionally attempted on board the Challenger. The surface current could, of course, be roughly ascertained by the difference between the ship's position, as found by observation and by dead reckoning; but the accuracy of this estimate, depending as it does entirely on the correct steerage of the ship, and the proper allowance being made for speed through the water, cannot be implicitly relied on.

When circumstances were favourable, therefore, a boat was anchored by the dredge rope, and the speed and direction of the surface current ascertained by heaving a log from the anchored boat; and in order to ascertain by actual observation whether currents existed below the surface, an apparatus was lowered to such a depth as was thought advisable. As the movements of the apparatus could only be ascertained by attaching to it a float on the surface, it is evident that *exact* observation of the motions of the apparatus could not be ascertained, as these motions were liable to be retarded or accelerated by the friction of the surface water on the float, as well as by the friction of the water on the line connecting the float and apparatus. A fair approximation, however, of the movement of the sunken apparatus may be made if that apparatus be constructed in such a manner as to expose as large an area as possible to the influence of such forces as may be at work where it happens to be, while the float be constructed to present as small an area as possible to the surface current. The lower apparatus must be of sufficient weight to sink readily, and to keep the line between it and the float as nearly perpendicular as possible, otherwise there would be no certainty as to the depth at which it was; and the float must be of sufficient size to support the weight of the sunken apparatus and the connecting line together with the strain caused by the difference between the lower and surface currents.

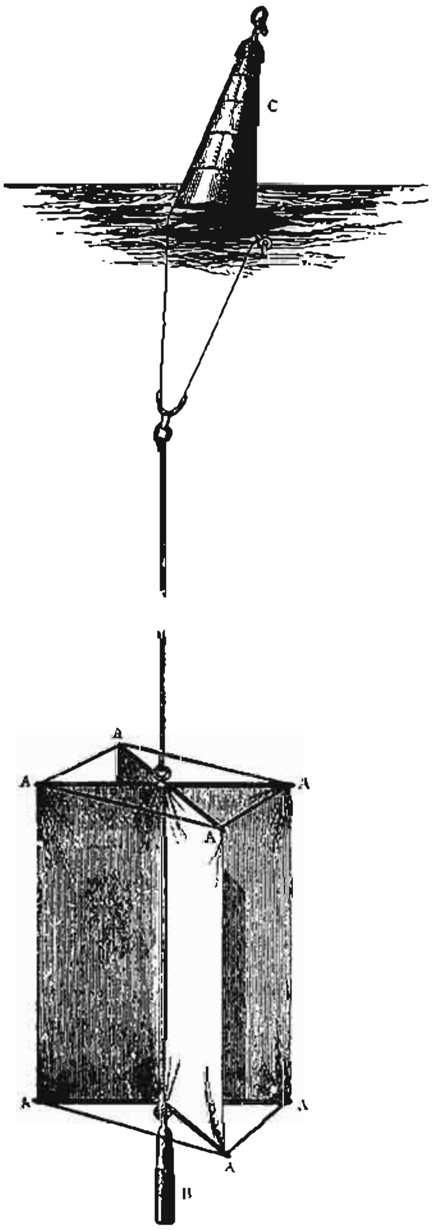

Fig. 25.—The Current Drag.

It will thus be seen that the current apparatus consisted of three parts, one called the "current drag," which was lowered down to such depths as were deemed requisite, another the "watch buoy," which pointed out on the surface the movements of the current drag, and a third the "current line," which connected the drag with the buoy. The current drag (see fig. 25) was made of two cross-pieces of iron at the top and bottom A A, A A, with canvas spread between them; the iron cross-pieces were each 4 feet in length, and were joined together by a bolt in the centre, so that they might be folded up when not required; they were kept at right angles when in use by a laniard fastened to their extremities. The canvas between the cross-pieces was 4 feet in depth. On the lower part of the drag was a ½ cwt. lead B to sink it readily, and the current line was fastened to the upper part; this was the ordinary service cod line. The current drag was lowered to the required depth, and the line was then fastened to the watch buoy C, which was like a large anchor buoy, being 5 feet in length and

1 foot in diameter at the centre, tapering towards the ends, and was capable of supporting in the water a weight of 70 lbs. If necessary, two or more buoys were used.

A boat was generally used to obtain the current observations. The first operation was to find out the direction and rate of the surface current by attaching the boat to the dredge rope and letting it go from the ship; the boat thus became anchored by the dredge. The surface current log was now hove and allowed to run out for from six to twelve minutes. The current log ship was made of a triangular piece of wood, with a weight at its apex, and it was kept close to the surface by an oar lashed across its base; the current log-line was marked to fathoms. When the log-line had been running a certain time it was checked, and the bearing of the log ship taken, which gave the direction of the current; the number of fathoms run out, divided by the time it was running (expressed as a fraction of an hour), gave the velocity per hour.

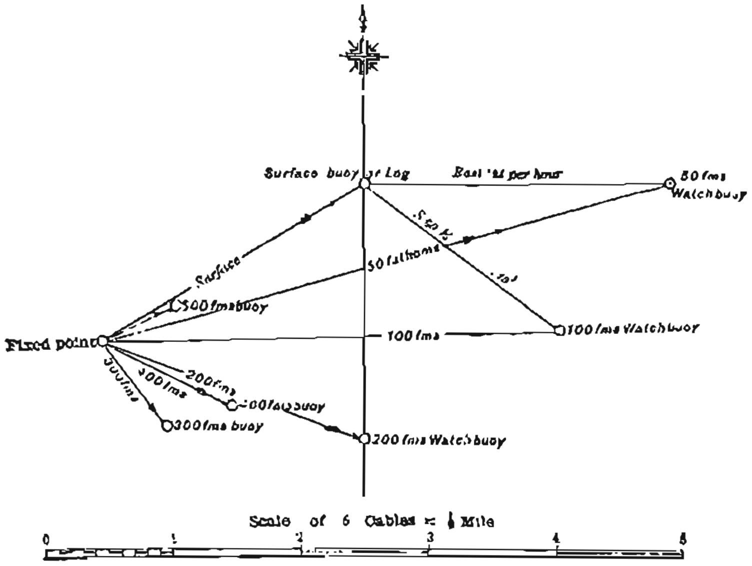

FIG. 26.—Diagram to illustrate the action of the Current Drag.

The current drag was next lowered to a depth of 50 fathoms, and the watch buoy attached. The boat now followed the buoy, keeping close to it, but taking care not to touch it in any way. The surface current log was next put over the boat's side, with a line attached, and the time when it was put over noted. This log was now perfectly stationary with reference to the surface water, moving exactly as the surface water moved, whilst the watch buoy of the drag was affected by the movement of the water at 50 fathoms. The boat continued to follow the watch buoy for from six to twelve minutes after the surface log had been put over, paying out line to the surface log. After a given interval the line to the surface log was checked, its bearings taken, and the number of fathoms run out, with the time it took to run out registered; this gave both the direction and rate of the movement of the watch buoy of the drag through the *surface water;* but during this time the surface water itself may have been moving, the actual movement of the watch buoy, with reference to a fixed point, was therefore represented by the resultant of the movement of the surface water and the movement of the watch buoy through the surface water.

Figure 26 shows the result of the observations made on the currents on the 24th April 1873. The surface current was found to be nearly N. 60° E. 0·24 mile per hour; the watch buoy of the drag at 50 fathoms was found to move E. 0·24 mile per hour from the surface current log; the movement of the watch buoy from a fixed point was therefore N. 75° E. 0·46 mile per hour. In the same manner the current was ascertained at 100 fathoms, 200 fathoms, &c.

These results were assumed as giving the rate and direction of the current at different depths with sufficient accuracy to ascertain any marked movements, but it is evident that they are not strictly accurate, as no allowance was made for the retarding or accelerating influence of the surface water on the watch buoy, or of the intermediate water on the line.

To facilitate lowering and hauling in the current drag, a small derrick was made to ship in the boat where the foremast stepped.