H.M.S. CHALLENGER'S WORLD VOYAGE 1950-52

Part I. Atlantic & Pacific Oceans

By Dr. T. F. Gaskell and Commander G. S. Ritchie, D. S. C., R. N.

« For purposes of oceanographic research, a very sturdy, seaworthy vessel capable of working under practically all weather conditions and of withstanding any storm is required ». The Oceans, Sverdrup, Johnson & Fleming.

H. M. S. *Challenger* left Plymouth on the morning of 1st May, 1950, bound for Bermuda, the first port of call on a round the world voyage which was completed on the 27th September, 1952, at Portsmouth. During the two years and five months that she was away from England, *Challenger* visited many parts of the globe and made oceanographic measurements in the great oceans of the world. In this communication a narrative of the voyage is given, together with a description of the types of scientific and survey work carried out and a summary of the results achieved. Part I describes the journey to the Pacific and the year spent in the Pacific ; Part II tells of the voyage home through the Mediterranean, and gives details of the various experimental techniques which, from the early stages became standard routine. Fuller reports of many of the subjects studied are to be found in various papers which have been published and are listed at the end of Part I. It is hoped that this general account will serve to coordinate these reports and to provide suitable references to them.

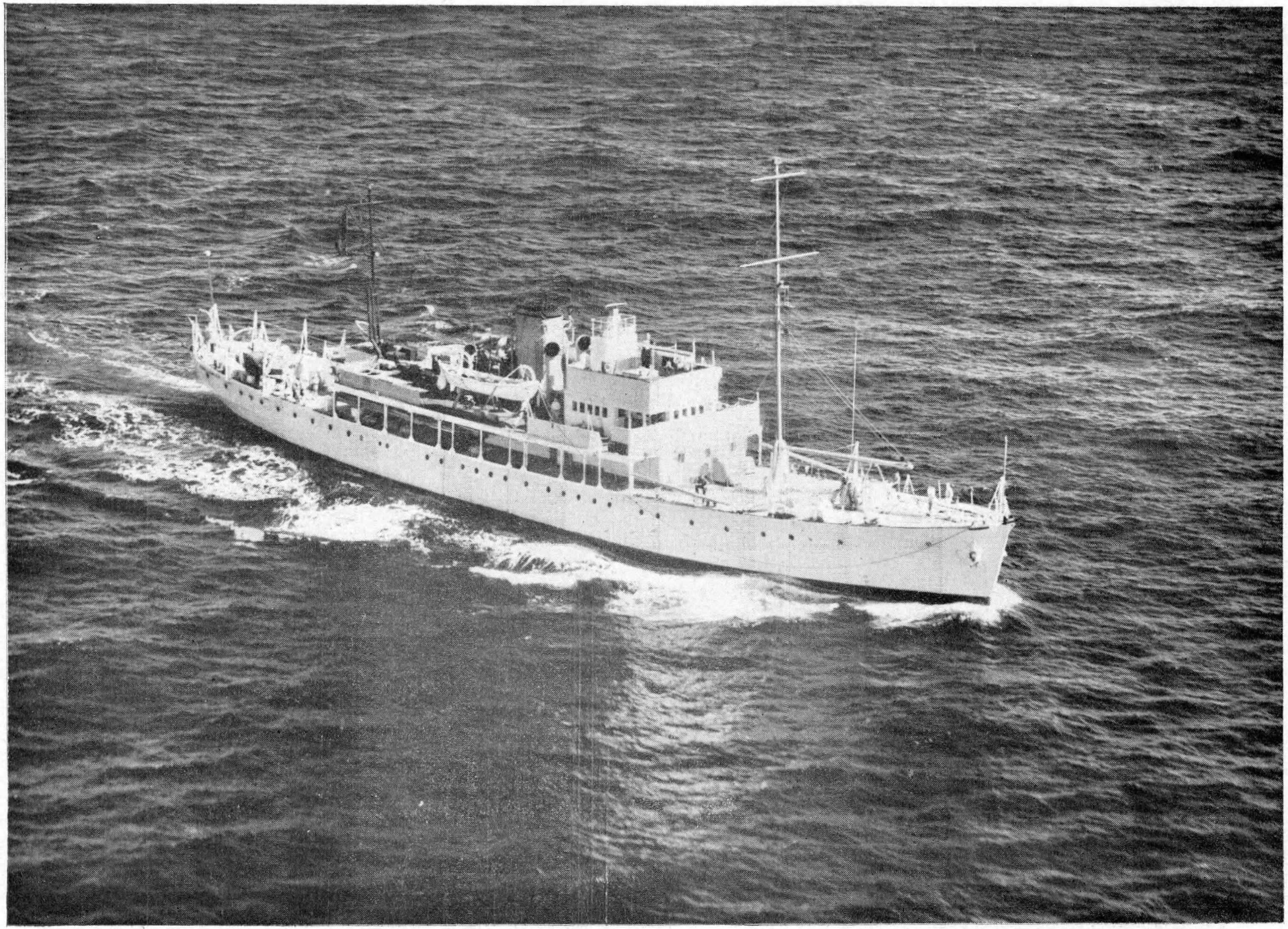
Increasing interest in oceanic soundings, together with the existence of a number of small outstanding survey commitments left undone in isolated parts of the world during the war years were the chief factors deciding the Hydrographer of the Navy to send a surveying ship on this voyage. It was also decided that scientists should be accommodated in the ship, in addition to specialist survey officers. This opportunity to carry out deep-sea measurements was welcomed by the Department of Geodesy and Geophysics, Cambridge, and the survey cruise assumed the role of an expedition. In sponsoring a scientific voyage in this way, the Hydrographer of the Navy was following the great pioneering traditions of the past centuries, when the Royal Navy played a leading part in geographical discovery and research in natural history. Because of the small likelihood of there being any new unvisited land, the Naval Hydrographic Service of the 20th Century concentrated on detailed investigation of shallow-water in order to provide charts to make navigation ever more accurate and safe. However, interest in the geology of the rocks beneath the sea had been aroused a few years before the war by the extension of land seismic techniques in the experiments of Bullard and Gaskell (1) in the English Channel working from H. M. S. *Jason*, and during the war the problems set by the enemy in mining and submarine warfare showed that a knowledge of all aspects of ocean behaviour and structure were of great importance. The deep oceans occupy about two thirds of the earth's surface, and so provide a vast new field of research and discovery, adequate to satisfy the enquiring nature of the scientist and the exploring instinct of the sailor. This recent *Challenger* expedition had as its chief aim an increase in the knowledge of the configuration and structure of the ocean bed in many parts of the world ; it is not wise to attempt too many different lines of research in one ship, and the *Challenger* was more suited to the physical than to the biological type of oceanographic studies.

It was probably coincidence that the name *Challenger* should appear again in a scientific expedition, for the *Challenger* cruise of 1872-76 had made history by bringing back the most comprehensive early collection of samples from the sea-bed and of deep sea soundings. The work chosen for the 20th century *Challenger* was a direct extension of the early results, both in filling in the gaps between isolated single soundings, and in learning more about the sediment and rock layers that lie below the ocean floor.

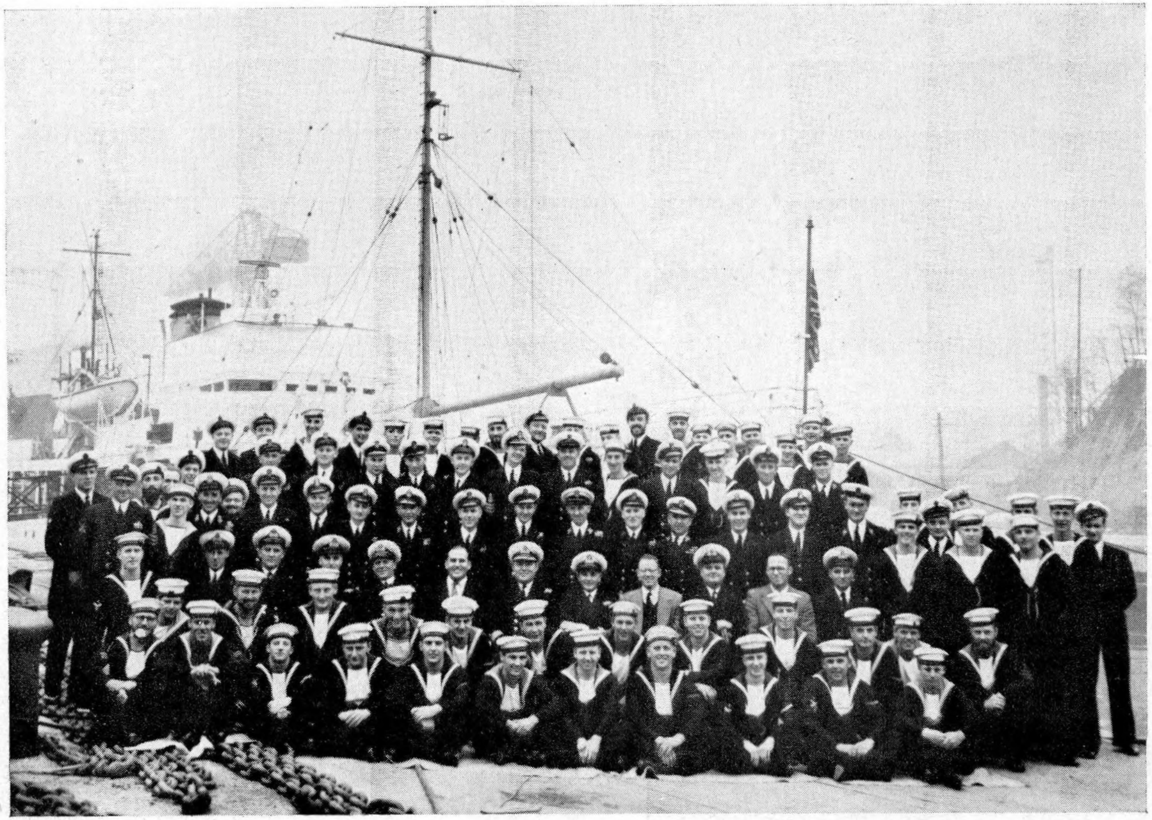
In the earlier *Challenger* the soundings were obtained laboriously by lowering a sinker on a rope, but although a comparatively limited number of soundings were possible by this means during the whole voyage, they were sufficient to show that the sea bed was not a flat plain as had been previously supposed (by those who thought about it at all) but was full of character, and contained deeps and shallows and rapid changes of depth. With the continuous sounding that is possible now, the configuration of the deep ocean bed is being plotted with such detail that comparisons and contrasts with land-surfaces can be made, and « islands » and « mountain ranges » are being charted in the large expanses of deep sea where previously only isolated soundings were marked.

In a similar way to that in which the sound waves of the echo-sounder replace the old rope and sinker, so sound waves from underwater explosions are used to probe thousands of feet into the sediment and rock that form the seabed. Where the earlier *Challenger* took a surface scraping of the top few inches to show whether the sediment was for example red clay or volcanic ash, the modern method of seismic refraction prospecting gives an insight into the geological structure of the earth's crust, and provides some facts on which to base geological theories which in the past have produced conflicting arguments as to whether the oceans are permanent, or whether they are merely sunken continents. The « seismic probings » made thus far provide only a minute fraction of the knowledge that is available of rocks on land, but a consistent picture is emerging from the results of *Challenger's* comparative work in the Atlantic, Pacific and Indian Oceans and of more localised studies made from the United States in the Pacific and Atlantic, and from Great Britain in the Atlantic.

Fig. 1 shows the track followed in the two *Challenger* cruises. The 1872 expedition went round the world in an easterly direction, after spending more time in the Atlantic than did the recent *Challenger*. There was no Panama Canal in the 1870's and the old *Challenger* passed through the Straits of Magellan. This took her much farther south than the southernmost limit reached (New Zealand) by the recent *Challenger* and in fact the old *Challenger* was the first steam ship to cross the Antarctic circle. Except for the North-South traverse in the Pacific, the cruise now being described was confined almost entirely to the Northern hemisphere. However, the two tracks cross in many places, and the accounts of the earlier *Challenger* voyages made interesting reading when re-visiting some of their ports of call; even in the deep ocean the shades of the old *Challenger* appeared, for the world's deepest sounding found in the Pacific in 1951 was in the area marked by Sir John Murray as Challenger Deep (2) and where her deepest sounding of her voyage, 4475 fathoms was obtained.



Pl. 1. — H.M.S. *Challenger* at sea.



Pl. 2. — The ship's Company of *H.M.S. Challenger*, 1951.

The recent *Challenger* track is shown on Fig. 1 in pecked and firm line, the firm line representing the parts of the voyage where oceanic soundings were taken. Lists of these soundings are available in the Hydrographic Department. Larger scale surveys were made in certain oceanic areas, the appropriate reference number of the originals of these surveys being shown on Fig. 1. Some exceptional deep and shallow soundings are also indicated.

A number of seismic stations were occupied during the voyage, and their positions are shown on Fig. 2.

The earlier *Challenger,* as is well known, brought back a vast quantity of chemical and physical data and a huge collection of plants and animals from the oceans. This was not possible in the present, smaller expedition, but seventeen stations for observing a standard series of temperatures and salinities were made, the position of these stations being shown on Fig. 2. The results obtained at these stations will shortly be published by the Hydrographic Department. About a thousand bathythermograph observations were taken and a great number of sea surface temperatures were observed. A number of swings to determine magnetic variation were made, and a collection of plankton was made for the British Museum (Natural History).

The present H. M. S. *Challenger* (Plate I) is 200 feet long and 1140 tons displacement. She was built at Chatham in 1931 as a fishery research vessel, but was taken over by the Admiralty while under construction, and since 1932 has been employed continuously on surveying duties in all parts of the world, from Labrador to the Far East. The complement during this voyage was 98 officers and men, including three scientists. There were some changes during the three years. The photograph (Plate II) shows the ship's company at the end of 1951 at Kure, Japan.

Plymouth to Bermuda.

The expedition had its first taste of bad weather as soon as the ship cleared Plymouth breakwater ; it was a pity that this bad weather dogged *Challenger* for most of the voyage, since most oceanographic work, and especially deep sounding and seismic refraction studies, require calm seas if accurate results are to be obtained. The timing of the route was somewhat out of phase with the weather because of a late start. However, although it is wise to plan experiments at sea for good weather periods, there are many exceptions to the average figures given in meteorological guides, and a leisurely itinerary is advisable so that calm days can be awaited in areas of scientific interest.

The fresh wind and sea in the English Channel precluded any seismic experiments near the line of the old 1938-9 experiments of Bullard and Gaskell (1), but a measure of the sea-bed structure was obtained in 2540 fathoms beyond the foot of the continental shelf. The results check very well with those found by Hill in 1952 during an Atlantic cruise with *Discovery II* and H. M. S. *Scott,* when a completely independent experiment was carried out within a few miles of the Challenger Station No. 1. This agreement between two sets of what are difficult observations gives confidence in the method of elucidating submarine geology. A second seismic station was attempted on the Western flank of the Atlantic Ridge, but the bad conditions made the results uncertain. The geological structure of this ridge might be the result of vast volcanic out-pourings ; the volcanic Canary Islands lie on the Ridge. On the other hand, the structure may be a long fold in the sea-bed rock, formed in a similar manner to long mountain ranges on the continents. Thirdly, the ridge may be an old vestige of granitic or continental type rock, left behind when a solidifying scum was floating on a sea of molten basement rock which ultimately formed the rock-layer beneath both the water of the deep ocean and the sedimentary and granitic type rocks of the continents. A combination of detailed surveying of the shape of the sea-bed over the Atlantic Ridge and of seismic refraction measurements to show the types of geological material present should decide which structure exists. There was no opportunity to return to this interesting problem later in the cruise, but the *Challenger* is engaged in a oceanographic cruise in this area of the Atlantic at this moment (September, 1953).

Cruises from Bermuda.

Bermuda was the base for operations in the Western Atlantic for the months of June and July. The entrance channel through the reefs was resurveyed and shallow water seismic experiments were made to determine the velocity of sound in the rock of the Bermuda island area. Two successful seismic stations Nos. 3 and 4 (Fig. 2) were occupied in 2750 and 2920 fathoms, and lines of soundings were run west of Bermuda, and to the North, being extended to the Newfoundland bank. During this cruise a small seamount was found and investigated having a least depth of 1371 fathoms in 43°45' N., 46°15' W. and two « shallow » soundings, obtained in poor sounding conditions, of 1347 fathoms in 36°27.5' N., 59°16.7' W. and 1423 fathoms in 36°45.3' N., 58°53.0' W. indicated the crossing of a probable ridge of seamounts in this vicinity.

In broad daylight with overcast sky in the vicinity of 47°56' N., 41°22' W. layers appeared on the echo sounder at a depth of 28 - 30 fathoms, being clearly delineated and having a vertical thickness of 7 to 8 fathoms. The depth of the water in this position was 2480 fathoms. Three or four runs over these layers indicated that they were only about 3 to 4 cables in extent, and their texture appearing on the trace as rather rough, it was presumed that they were caused by pelagic fish shoals and were not the deep scattering layer. Plankton hauls indicated an abundance of pteropoda, of a species resembling *Clio pyrimidata*, within the layer, and the bathythermograph showed some slight indication of a cold layer of water at 200 feet depth. It is possibly significant that a 40 foot fin whale remained in the close vicinity of the ship during the latter part of the observations, approaching within about 20 yards of the ship when the engines were stopped.

The erratic track followed by the ship on this cruise from Bermuda shows the attempts of a low speed vessel to steer clear of two hurricanes, finally resulting in the ship remaining hove to for three days south east of Bermuda waiting for a slowly moving hurricane to move north of the island, while the level of fuel in the tanks fell lower and lower. Such conditions allowed no seismic work. However there were lighter moments at Bermuda and *Challenger* acted as guard ship at the finishing line of Bermuda Race, the oldest of the regularly organised ocean races, and won on this occasion by Bolero taking 3 days and 3 hours to sail the 630 mile course.

Bermuda to the Pacific.

On 18th September *Challenger* left Bermuda for the last time and sailed south for the Panama Canal. A short stay was made at Jamaica to take on fuel and some survey work was done in the Approaches to Kingston. The northern limits of Pedro Bank were also delineated. It was remarkable when surveying this extensive sand and coral bank that the north eastern limit of the Bank is bounded by a « wall », with a depth of 14 fathoms over it and which rises about 36 feet higher than the mean depth of the Bank before falling steeply away into deep water.

A fifth seismic station 200 miles south of Bermuda completed geophysical work in the Atlantic (3) ; although a second chance for further studies was expected later in the cruise, circumstances made this impossible. The five stations, however, provide a useful link between the work of Hill in the North East Atlantic (4) and that of Ewing in the area round Bermuda. (5) The structure of the sea bed in the North East region consists of a hard layer, characterised by a sound velocity of about 6.6 km./sec. (22,000 ft./sec.), covered by a few thousand feet of light sediments ; around Bermuda a layer several thousand feet thick is interposed between the hard rock (6.6 km./sec.) and the sediment. The velocity of sound in this intermediate layer is about 4.5 km./sec., so that it could be a light volcanic rock, a limestone, or a consolidated sediment of hard shale quality. There is good reason for supposing the material to be volcanic, since a borehole in Bermuda shows only a thin cover of coral limestone before volcanic rock is reached. Furthermore, a layer of very hard rock, velocity 8 km./sec. lies below the 6.6 km./sec. layer at a much shallower depth than does a similar 8 km./sec. layer beneath the continents, indicating that the ocean structure is different from that of the land. Bermuda is a shallow area, isolated by a large expanse of this deep ocean from any continental sources of thick limestone or other sedimentary rocks. Therefore the volcano source of material appears to be more likely since volcanoes can erupt in deep oceans. However, seismic experiments do not identify rocks unambiguously, and can only give a set of figures for depths of discontinuities between materials labelled by sound velocities.

The Pacific at first lived up to its name, and a day was spent near the uninhabited island of Socorro to take water samples and temperatures. While steaming northward from Socorro to San Diego the true deep scattering layer was encountered, the ascent towards the surface at dusk and the descent at dawn being regularly observed on the echo sounding machine over a period of five days. Twice more during *Challenger's* voyage the layer was observed on the echo sounder long enough for investigations to be made. The results of plankton hauls and bathythermograph runs in these layers together with details of the diurnal migrations as recorded on the echo sounder have been set down. (6)

It is interesting to note that a new species of siphonophore, *Lensia challengeri,* has been found by Mr. Totton of the British Museum (Natural History) when examining plankton samples taken from the scattering layer between Socorro and San Diego. (7)

Two seismic refraction experiments were carried out within a hundred miles of the American coast, and at both these were two distinct layers ; the velocity of sound in the deeper layer was substantially less than observed for the basement layers in the Atlantic ocean, probably because there is a difference between true ocean and continental structure.

A short visit to fuel at San Diego provided an opportunity to visit the famous Scripps Institution of Oceanography. An American expedition under Dr. R. Revelle had just returned from a topographical and geophysical survey of part of the Pacific ocean, and a useful exchange of results and ideas on technique took place.

On the journey from San Diego to Esquimalt B. C. the Black-footed Albatrosses (*Diomedia nigripes*) joined the ship, and were almost ever-present companions for the whole of the North Pacific cruises.

Canada.

A cruise off the coast of British Columbia enabled the ship to visit some of the more remote harbours and anchorages along the West Coast of Vancouver Island and in the Queen Charlotte Islands,. Excellent charts produced by the Canadian Hydrographic Service are available for many of these anchorages which are used by the fleets of fishing vessels which operate along these coasts during the season. Some excellent deer and duck hunting was available, and the bag made a welcome change on the menu.

The denseness of the Canadian forests was impressed upon all when two crew members who had entered the woods from the beach « for only a few yards » were lost for two days and nights with temperatures below zero, while search parties from the ship were able to proceed through the labyrinth of fallen trees and pot holes at a speed of about 400 yards an hour only.

After a pleasant and most hospitable Christmas and New Year in Victoria it was time to move on westwards round the world. A seamount having a least depth of 22 fathoms had been reported in 1950 by the exploratory fishing vessel U.S.F.W.S. « John N. Cobb » off the coast of Washington; this mount was now further investigated and surveyed, a least depth of 18 fathoms being found in 46°46.4' N., 130°49.0' W., this peak being very small in extent, about 200 feet or so across in all directions.

Vancouver Island to Honolulu.

The run to Honolulu was not very productive because of the weather, but one seismic refraction station, No. 8 gave good results. The U. S. Navy at Pearl Harbour provided a breezy welcome with a Naval Band and hula-dancers. Later on, after visits to the south sea islands, grass skirts were to become commonplace, but the Hawaiian Islands were the first exciting introduction to what might be called popular Pacific local colour.

The visit to Kilauea crater and the recent lava flows of Mauna Loa in the island of Hawaii by some of the scientists and officers was following in the footsteps of the 1872 *Challenger*. The bubbling lake of lava described and sketched in the old *Challenger* records (8) had disappeared but the enormous mass of material thrown up by Mauna Loa in the 1950 eruption made a strong impression and a visit to Hawaii should convince even the most sceptical of the ability of volcanic action to produce large geographical features.

Honolulu to Japan via the Aleutian Islands.

In order to learn something about the little explored North Pacific, a course was chosen from Honolulu to Adak, the U. S. Naval Base in the Aleutian Islands, which was a convenient fuelling stop before moving on to Japan.

Two seismic refraction experiments near the chain of the Hawaiian Islands produced results which help to confirm the theory that the islands are volcanic cones that have built up from the flat ocean bed. Fifty miles to one side of the islands the sea bed is rock in which the velocity of sound is about 6.3 km./sec. (21,000 ft./sec.), while on the axis of the island chain, there is about 2.7 km. (9,000 ft.) of material in which sound travels much more slowly, at about 4.3 km./sec. (14,000 ft./sec.). This slow material is most probably volcanic rock, similar to that which constitutes the islands, for laboratory measurements on the island rock show it to have a velocity of about 4.1 km./sec. Beneath the 4.3 km./sec. material is the 6.3 km./sec. rock, which has been depressed below its normal sea-bed level, as shown by the section in Fig. 3 (c). It is reasonable to suppose that the material erupted from the ocean-bed volcano sinks, both because of an empty space left behind it and because of the extra weight of a column of rock instead of water. Fig. 3 (a) and (b) show various stages in the life of a Pacific volcano. There is geological evidence that the older, dead volcanoes of the northwestern end of the Hawaii chain of islands have sunk. There are also many steep-sided, often flat-topped, sea mounts in the Pacific, which would be the natural outcome of the volcanic cycle described above. The structure of coral atolls also finds a ready explanation on this basis.

As we got further north the stormy weather cut down most oceanographic measurements, but by this time great interest had been aroused in the ship's company in the different birds that were to be seen, even in the ocean hundreds of miles from land. A regular bird log was kept, notes being made of the number and species of bird, together with the characteristic points used in identification, and with photographs where possible. These reports have been analysed by Dr. J. D. McDonald of the British Museum (Natural History), and his paper on the subject will appear shortly in « Emu ».

To reach Adak the ship passed through Adak Strait in very heavy weather. U.S.C. & G. chart 9193 was used which shows a wide channel through the Strait as « swept to 10 fathoms » giving the navigator considerable confidence in these dangerous waters.

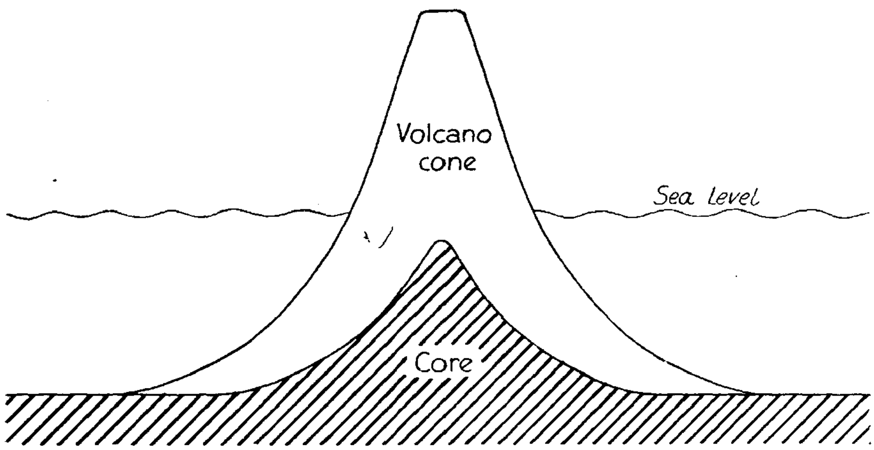
From Adak we sailed to Kure, reaching there on 26th, and after refuelling left again for a cruise in the North Pacific. Two Admiralty type 767 E/S sets were fitted in *Challenger* for normal sounding work and the deepest soundings obtained with these particular sets during the voyage were obtained in the Japan Trench on this cruise. These soundings were 3629 fathoms with the ship stopped. Aeration caused by the ship moving through the water was the presumed reason for the higher performance with the ship stopped. The sea surface temperatures when these soundings were taken were 20.40° C and 19.65° C respectively. A bathythermograph record showed the near surface temperature to be isothermal to a depth of 90 feet when a slight and steady gradient commenced. Particularly good reflection shots were obtained with the seismic apparatus in this area, the returns being of the same strength as those normally expected in 2000-2500 fathoms depth.

During this cruise a Short-tailed, or Steller's albatross (*Diomedia albatrus*) was sighted and photographed (9). This bird had been considered extinct for about fifteen years.

The North Pacific seismic work was ended with station No. 11 (Fig. 2) where the simple type of sea bed structure of hard rock (sound velocity 6.4 km./sec.) covered by about 0.5 km. of sediment, was found.

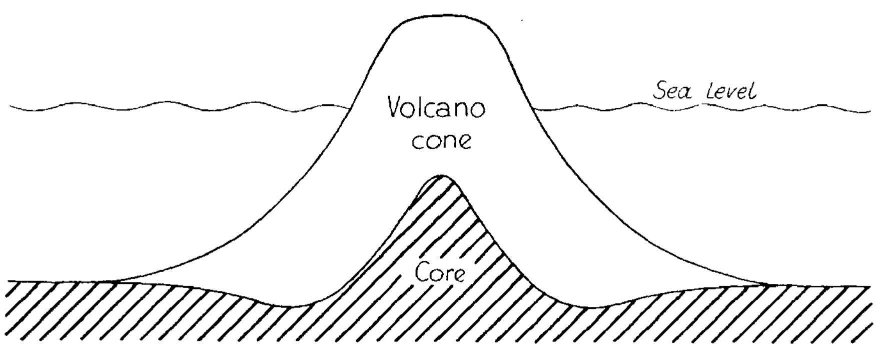
Japan to New Zealand.

On the second return to Kure the ship was dry-docked allowing a few



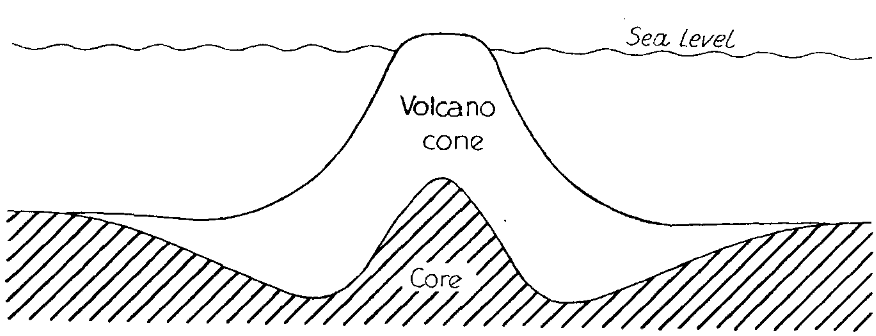
3(a)

Fig. 3 (a). — Growth Stage.



3(b)

Fig. 3 (b). — Mature island stage.
Slight sinking and some erosion has taken place.



3(c)

Fig. 3 (c). — Slow sinking.
Profile as observed in measurements near Hawaiian Island.

days in which to see the beauties of Japan in spring. *Challenger* then sailed southward for Manus in the Admiralty Islands, encountering a very irregular area of seabed between 28° N. and 24° N. with numerous « peak » soundings. (Fig. 1). A seamount with a least depth of 494 fathoms was located and surveyed in position 12° 46.3' N., 142°25.0' E. The course then crossed the Marianas Deep, which is part of the long narrow submarine valley, often greater than 5,000 fathoms in depth, that extends in an arc from the Eastern side of the Japanese Islands to westward of the Carolines. These deep trenches occur near the boundary between continental areas and the flat ocean of about 2800-3000 fathoms depth. Their origin is not certain, so that any light thrown on their structure by seismic measurements is important. Some good results were obtained at station 12 about 200 miles north of the deep (see Fig. 2), and it appeared that the 8 km./sec. layer was shallower (less than 10 km.) than usual below the sea surface and was overlain by 3.0 km. of 6.0 km./sec. material and 1.5 km. of sediment in addition to 4.9 km. of water. These results differed from those found in the Pacific far removed from land, because, with similar experiments, no 8 km./sec. layer was observed with the apparatus and the size of charge used in *Challenger* (although Raitt has found in the Pacific that the junction of the 6.3 km./sec. and the 8 km./sec. layer occurs at about 12 km. below sea surface) (10). The 8 km./sec. layer was detected at station 12 because the water was shallower than in the deep Pacific, the overlying material had a lower sound velocity than the 6.3 km./sec. material found near the surface in open ocean, and because the 6.0/8.0 km./sec. interface is shallower than normal. The result was unexpected because beneath the continents the 8 km./sec. layer is generally about 30-40 km. deep ; a complete repeat of station 12 on the return journey from New-Zealand some months later gave results agreeing with the first observations (11).

An attempt was made to find the rock structure at the bottom of the deep trench, but the trench was so steep and narrow that drifting of the sound receivers gave large changes in depth of water and this made interpretation ambiguous. Furthermore, the great depth gave a sea-water path of over 10 miles for the sound waves, and the signal strengths for the explosive charges available were seldom above background level. However, while locating the line of the bottom of the deep trench prior to carrying out a seismic experiment, an abnormally deep sounding was noted, indicating that the trench was deeper than the Philippine trench which up till that time was the greatest ocean depth recorded. The first soundings were taken by timing the sound from 1 1/4 lb. T.N.T. charge to travel to the sea bed and back, using a seismic hydrophone and photographic recording camera. These soundings were checked by lowering to the sea bed an iron weight on steel wire in the manner of old-fashioned lead sounding. A careful survey was made on the return journey north from New Zealand ; this time the echo-sounder, which had been cleaned and re-fitted, gave audible results, and allowed continuous profiles to be obtained across the deep. More soundings by steel wire were recorded, and a sample was obtained from the side of the trench in 5744 fathoms. The greatest depth, after consideration and application of corrections, is now taken as 5940 fathoms. The details of this work are given in *Nature* by Carruthers and Lawford (12) and in a paper by Gaskell, Swallow & Ritchie in « Deep Sea Research » (13).

Several seismic stations, marked on the map Fig. 3, were occupied during the run down to New Zealand and on the return journey north. The results and others in the Pacific fell into two distinct groups ; the first, Type A, was simply 0.3 to 0.6 km. of sediment covering rock in which the velocity of sound was

6.3-6.5 km./sec. (American work in the Pacific indicates that the 6.3-6.5 km./sec. layer is about 6 km. thick and rests on an 8 km./sec. material); the second, Type D, all showed two distinct layers, but the velocity and thickness for the top layer were varied, and the velocity of sound in the deeper layer was always substantially less than the 6.3 km./sec. of the Type A stations. The map (Fig. 2) shows the position of the andesite line, drawn on geological and geographical evidence to mark the boundary between different types of island rock, and believed by some to define the perimeter of the true permanent ocean. It will be seen that the Type A structures are always observed to seaward of this andesite line, while the Type D, which is the variable type of geological formation that is found on continents, is always to the landward side of the andesite line. Stations 9 and 16 are Type A modified by interposition of several thousand feet of volcanic rock ; they are classed as Type B, and have been discussed above. This classification into typical structures was suggested by the Pacific results, but it may well apply to other oceans. Type C structure refers to stations 20 and 21 in Fig. 2, and is similar to Type A except that the sound velocity in the rock below the sediment is 5.6-5.8 km./sec. instead of 6.3 km./sec. ; more extensive seismic refraction lines are necessary, in order to determine the depths of the 8 km./sec. layer, before Type C can be classed as oceanic or continental, or whether it is really an intermediate type.

The stop at Auckland was a long one, in order to give the ship an extensive refit and to allow all the ship's company a shore leave. The hospitality in New Zealand was wonderful, and the stay was all too short ; visits were made to scientific establishments and to museums in Auckland and Wellington, and when the ship sailed north on 27th August, 1951, commitments had been undertaken to run lines of soundings and to collect samples of mud, shells, seaweed, palm-toddy and even rats, for scientists who all had in common a shortage of sea-going transport for their experiments. A ship engaged in work such as *Challenger's* is able to do a great deal of useful research, outside the normal specialist work, since there are many long periods where the main work cannot be done, and there are often spare hands when visiting interesting out of the way places whence biological collections are desired.

Fiji and the South Sea Islands.

Coral atolls are a common and peculiar form of island in the Pacific Ocean and their origin has for a long time been a source of speculation and argument. Darwin proposed that they were formed by subsidence of volcanic islands accompanied by upgrowth of a fringing reef ; in support of this hypothesis there are found a complete range from volcanic island with fringing reef to true atolls, as well as intermediate states in which a small volcanic peak sticks up in the centre of a lagoon. Murray had noticed during the *Challenger* 1872-1876 expedition that in certain of the Solomon Islands coral rested on clay, and he suggested that all atolls were formed by growth of shallow-water corals on clay-like sediments covering submerged volcanic sea-mounts. Since reef building corals do not live in depths greater than about 200 ft., this thickness would be the maximum possible by Murray's mechanism, whereas if subsidence occurs a very great thickness could be formed. Funafuti was chosen by *Challenger* as a typical Pacific atoll suitable for testing by measuring the thickness of the coral rock by seismic methods. This atoll was in 1901 the scene of test bore-holes, one of which was still in coral rock at a depth of 1,114 ft. on the edge of the atoll. Since the edge of the atoll may have been thickened by coral debris, the bore-hole test was not conclusive. Seismic experiments in the lagoon of Funafuti showed several thousand feet of coral rock ; similar results were found at the neighbouring island of Nukufetau, so that there must have been considerable subsidence. This is in agreement with the picture of volcanic island growth in the Pacific that was indicated by the seismic results near Hawaii. Further evidence for the growth and subsequent sinking of volcanoes was provided by the structure found 20 miles from Funafuti, at Station 16 (Fig. 2). Here, in 2670 fathoms of water, about 1.5 km. of 4 km./sec. velocity rock was interposed between the sediment and the 6.3 km./sec. velocity sea-bed, as at the Hawaiian Island seismic station (No. 9). This interposed layer could well be part of the outpouring of the Funafuti volcano during the growth period (14).

It is probable that some atolls formed as Murray supposed do exist where large vertical movements of land surface occur near the edges of continents, but seaward of the andesite line the coral atolls appear to be formed by Darwin's mechanism, and their volcanic cores are similar to the Pacific volcanic islands and to the ever-increasing number of sea mounts that come to light, as more and more deep ocean is surveyed in detail.

The journey from New Zealand to Funafuti was via Fiji, where great interest was shown in the scientific work by the Fiji society. Soundings were taken across the Kermadec trench, and gave a greatest depth of 5182 fathoms. The Kermadec group of islands was visited in order to deliver stores and to bring relief for a meteorologist, who was sick. The meteorological station is run by 8 people on a lonely island, which is visited normally only once a year. The bird life around the islands was prolific, and many Thin-Billed prions (*Pachyptila belcheri*) were seen, making it appear probable that this is one of their hitherto unknown breeding-grounds.

Further stores were taken to Rotuma, and while the ship anchored offshore in the evening, a magnificent dancing display was put on by the local inhabitants. To the music of simple drums and a home-made double bass, Polynesian folk dances of many styles were demonstrated by girls and men in colourful attire. This was much more the real thing than the hulas of Waikiki beach, and was the introduction to a few weeks of the carefree life in the pleasant sunshine, with the back cloth of palm trees, which is the South Sea Islands. Both at Funafuti and at Nukufetau, dancing was demonstrated, and the ship's company were persuaded to don grass skirts and become participants. At Fiji a large open air show, a vokomalolo, was staged in honour of the retirement of His Excellency the Governor, and this included massed dancing by the tall and elegant girls from Lau.

Extensive collections of shells, bottom samples and seaweed were made in the lagoon at Funafuti while the seismic work was in progress. Rats were collected on shore in order to see whether the small brown rat on the last century was being ousted by the grey one introduced from ships in recent years. Whilst operating between Fiji and the Ellice Islands a number of reported shoals and banks were searched for, those located being surveyed, and an extensive bank, with a least depth of 11 fathoms was located north of the Ellice Island of Niulakita (15).

A party was landed to fix, by theodolite star sights, the island of Nukufetau, which had been reported to be some miles out of position. In fact the charted position proved to be 6.4 miles eastwards of its actual position. During these observations seismic experiments were carried out in the lagoon which showed the atoll structure, as stated above, to be similar to that found at Funafuti.

Return to Japan.

Manus, the Australian naval base in the Admiralty Islands was again the fuelling port on the long run north to Japan, and on this second visit we were delighted to fall in with the Royal Australian Naval Surveying Ship « Warrego », meeting friends of earlier commissions during the war years.

The journey from Manus to Kure was along much of the track followed on the southward run. This was by choice, in order to check the seismic work, and to survey more fully the deep area of the Marianas Trench.

(To be continued).

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* Denotes papers referring directly to the work of *H.M.S. Challenger* 1950-51.


SOUNDING TRACK OF H.M.S. "CHALLENGER"
1950-1952
Solid lines along the track of H.M.S. "Challenger," 1950-52 show where soundings were obtained.
Some exceptional deep and shallow soundings obtained are shown thus : 1423 fms.
Larger Scale Surveys were made in certain oceanic areas, the appropriate office number
being shown — e.g. E.9029 refers to the survey of "Wolverine Shoal."
The track of H.M.S. " Challenger," 1872-76 is also shown in pecked line thus :
GREENLAND
NORTH AMERICA
SOUTH AMERICA
AFRICA
EUROPE
ASIA
AUSTRALIA
Seamount – 1371 fms. E.9360
1423 fms.
1347 fms.
Sept. 1950
May 1950
27th Sept. 1952
Dec. 1872
May 1876
Jan. 1873
Seamount – 794 fms. E.9283
Linosa Deep – 832 fms. E.9255
Bank – 66 fms. E.9240
Pedro Bank E.8833
June 1952
May 1952
Seamount – 1414 fms. E.9161
Java Trench
3455 fms.
Search for "Breakers repd (1937)" 1336 fms. – E.9138
Search for "Discoloured water (1945)" 164 fms. – E.9137
Seamount – 638 fms. E.9160
Jan. 1875
April 1952
Seamount – 1235 fms. E.9136
3629 fms.
Japan Trench
4100 fms.
Search for 24 fms. – E.8921
384 fms.
1077 fms.
185 fms.
212 fms.
289 fms.
Search for 14 fms. – E.8977
Seamount – 494 fms. – E.9045
Marianas Trench
5940 fms. – E.9044
Search for sand bank – E.9043
3955 fms.
Aleutian Trench
April 1951
Feb. 1951
Learmonth Bank – 38 fms.
36 fms.
Search for "11 fms. (P.D.)"
Seamount – 18 fms. E.8893
Oct. 1950
Oct. 1951
Morton Bank 9 fms.
Kosciusko Bank – 11 fms. – E.9032
667 fms.
307 fms. – Search for "5 fm. repd"
1250 fms.
380 fms.
E.9031
707 fms.
July 1951
Wolverine Shoal – 202 fms. E.9029
Two traverses of Kermadec Trench 5182 fms. – E.9030
Star of Bengal Bank – 167 fms.
Jan. 1874
Jan. 1876
West from Greenwich
East from Greenwich


SEISMIC INVESTIGATIONS and
TEMPERATURE/SALINITY OBSERVATIONS
H.M.S. "CHALLENGER"
1950-1952
Seismic refraction shoots for investigation of the ocean bed structure were carried out in 31 positions and are shown thus : ★31
Nine seismic investigations, also marked ★, were made near islands.
Standard series of Temperature and Salinity observations were obtained in 17 positions shown thus : ● 17
GREENLAND
NORTH AMERICA
SOUTH AMERICA
EUROPE
AFRICA
AUSTRALIA
JAPAN ISLANDS
PHILIPPINES
NEW GUINEA
Aleutian Is
Andesite line
Hudson Bay
Baffin I.
Iceland
Svalbard
Novaya Zemlya
Wrangell I
Victoria I.
Hawaii
Bermuda
Azores
Madeira
Canary Is
C Verde Is
Ascension
St Helena
Tristan da Cunha
Falkland Is
S Georgia
South Sandwich Islands
S Orkneys
S Shetlands
Graham Land
Kerguelen
Crozet
Pr Edward
Seychelles
Chagos Arch
Mauritius
Madagascar
Maldive
Marianas or Ladrones
Palau
Carolines
Samoa
New Hebrides
Marquesas
Tuamotu
Phoenix
Easter I.
Galápagos
Cocos
Chatham
New Zealand
Balleny Is
West from Greenwich
East from Greenwich
Vancouver
San Francisco
Valparaiso
Callao
Guayaquil
Buenos Aires
Rio de Janeiro
Washington
New York
Boston
Quebec
Ottawa
Charleston
New Orleans
Bermuda
Trinidad
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Recife
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Odessa
Batum
Baku
Basra
Bahrein
Suez
Cairo
Alexandria
Jidda
Suakin
Aden
Bombay
Madras
Colombo
Calcutta
Rangoon
Singapore
Borneo
Formosa
Hong Kong
Nanking
Shanghai
Peiping
Seoul
Vladivostok
Ominato
Hokkaido
Sakhalin I
Okhotsk
Kodiak
Perth
Adelaide
Melbourne
Sydney
Brisbane
Darwin
Auckland
Wellington
Christchurch
Zanzibar
Mozambique
Benguela
Walvis B.
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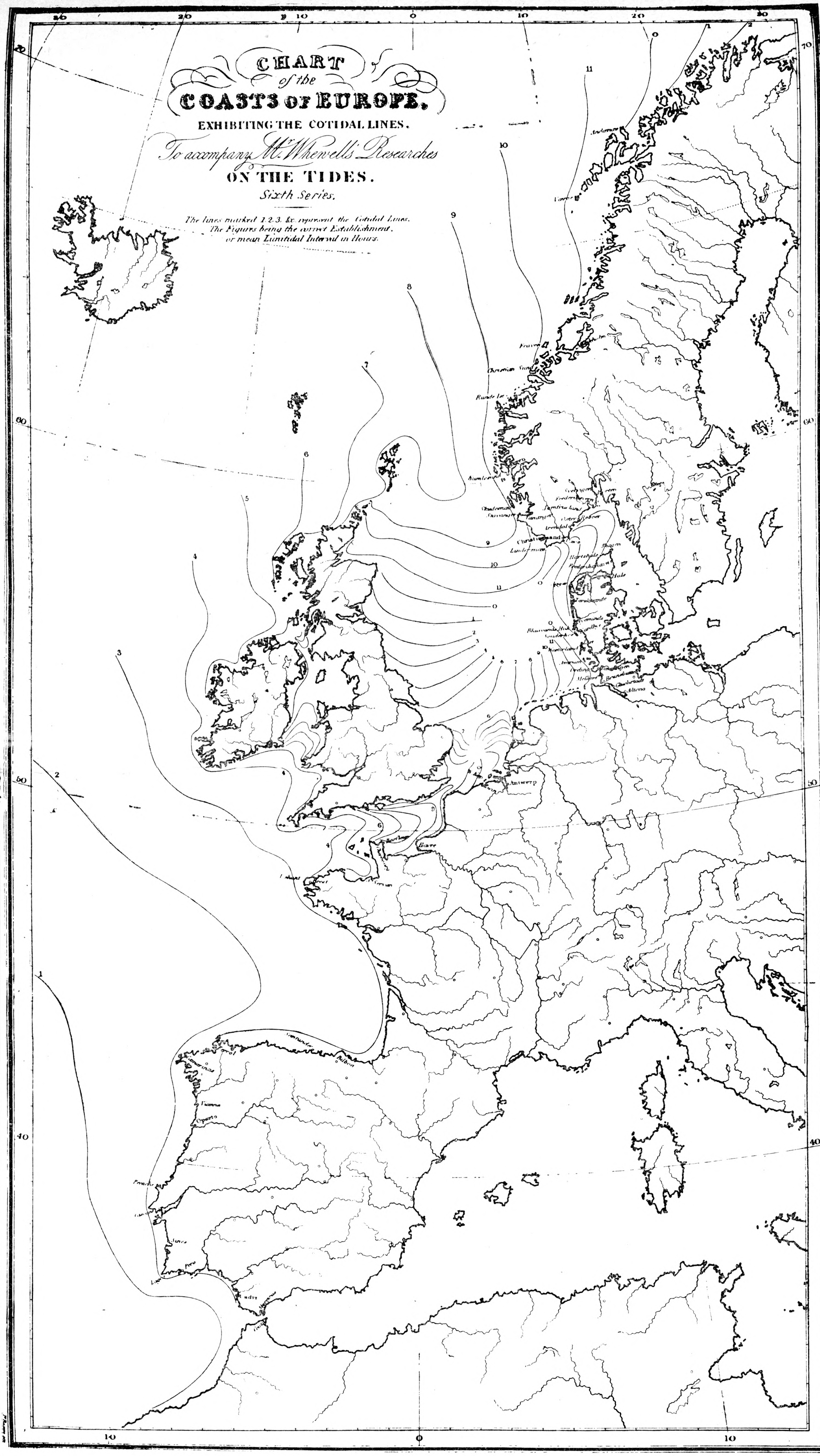
Cape Town
Bathurst
Freetown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