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HYDROGRAPHY.

HYDROGRAPHY (from the two Greek words, *ὕδωρ, water,* and *γράφω, description,* is the important branch of physical science and descriptive geography which has for its object the graphical representation of the waters of our globe and their shores, with all their properties bearing upon navigation

Their exploration to this end, their description by means of charts and directions for the use of the navigator, as also the generalization of the local data in order to ascertain the laws governing the physical phenomena upon which navigation depends, the winds, currents, weather, tides, terrestrial magnetism, etc., is the responsible and arduous task of the nautical surveyor and hydrographer.

The most essential requirement for navigation is charts, general charts of entire oceans, or parts of them and their shores, compiled by the hydrographer from existing data, and special charts of smaller areas, of harbors, roadsteads, etc., prepared from special surveys. The earliest sea-charts date from the middle of the fourteenth century. They were necessarily rude and imperfect, the earth's shape and dimensions being then unknown, the log for measuring nautical miles not in use, and the means for ascertaining astronomical positions very imperfect.

The discovery of America and the Cape of Good Hope, together with the reformation in astronomy by Copernicus and Galileo, instituted a new era in geographical knowledge; the earlier charts of this period, however, were still grossly inaccurate, especially as regards geographical positions, and many of the isolated islands of the Pacific Ocean,

seen and described by the early Spanish voyagers, have been searched for at later periods in vain, until islands in positions differing hundreds of miles from those given to them, but answering their description completely, have been adopted for them; many of the islands shown on the present charts with queries, in regions not yet sufficiently explored, will prove to have been similarly misplaced at that early date.

The science of hydrography, by which the correct establishment of positions and exact delineations of the shores are attained, remained meagre until the middle of the eighteenth century, when it may be said to have fairly commenced with the expeditions of Captain James Cook under the auspices of Great Britain, which were soon followed by similar undertakings by other nations, especially by France and Russia, and at a later period by the United States. Almost all these voyages of discovery and explorations were of circumnavigation, and, though many localities were examined more or less in detail, in general they could only result in skeleton charts to be filled in by systematic surveys, at a future period, conducted under the direction of organized institutions. In the first quarter of the present century hydrographic offices were established by the principal maritime nations for the survey of their waters at home and in their colonies. To the hydrographic office of Great Britain, which has been liberally provided with means by the Government, belongs the credit of having taken the lead in extending systematic surveys into almost every water traversed by vessels, and to its zeal and energy all navigators and commercial communities will ever be deeply indebted. At present almost every nation having a seaboard has it hydrographic office for the survey of its own coast, and to participate in the survey of such waters as are considered the common possession of nations, and of the coasts of countries which do not provide for surveys. Almost every European nation has provided for the trigonometrical survey of its entire domain.

The British Ordnance Survey, commenced in 1783, will probably take ten years yet to complete; the trigonometrical surveys of France, Germany, the Netherlands, Belgium, and the European portion of Russia, are in course of completion; in other countries they are in progress. The several governments have also agreed on measures for the careful connection of the triangulations across the borders of their states. Where such rigid geodetic operations were instituted previous to the hydrographic survey of the coasts and waters, they furnish the hydrographic surveyor, not only with the correct outlines of the coast, but also with the precise position of the landmarks upon which he may base his work, or, in other words, a skeleton for the same. But, when such surveys are not existing, he is compelled to lay down the coast-line also, with its detail as far inland as there are landmarks auxiliary to navigation, thus performing the labors of the topographer as well as those of the hydrographer. Both require the greatest care, for on the precise establishment of the landmarks depend in a great measure the delineation of the shoreline, the establishment of outlying dangers, and the exact location of the soundings, by which the profile of the bottom is represented on the chart.

Sudden elevations, shoals, and especially submerged rocks, the great dangers to navigation, sometimes escape the lead as well as the eye, even in the most careful survey, and are only discovered by accident, often from disaster. Such dangers are found from time to time in the most frequented harbors, which have been surveyed with the greatest care. While the land, with the present means, can be laid down absolutely correct, the hydrographic surveyor can never be certain that he has thus represented the most essential portion of his chart.

The hydrographic features of coasts, not rock-bound, are subject to changes, gradual by the action of the sea, and sudden by natural phenomena, as great gales, etc.; volcanic activity also affects at times the rock-bound coasts. The mouths of rivers and the embouchures of inland waters are especially subject to changes by the wash of the discharging waters, and the sediment and *débris* carried along by them, which mostly accumulate on the bars, and are shifted to and fro by the force of the sea before they settle firmly; the depth of water in the channels, and even the course of the latter, does not remain the same for any great length of time, and some bars change with every shift of the wind. The surveys of such localities will only hold good in their general features; in the shore-lines and in the landmarks by which a vessel may approach and feel her way in; the more frequented harbors of this nature require reëxamination from time to time.

Several nations have provided for a trigonometrical survey of their coasts only, in advance of geodetical operations embracing their entire domain.

The United States Coast Survey was first organized by act of Congress in 1807, which provided for surveying the coasts of the United States, but the first labors in this field did not commence until 1817, and were shortly after interrupted; in 1832 they were resumed, and have since been carried on, with energy and but little interruption, to the present date.

The United States Hydrographic Office, for the purpose of constructing and publishing charts, sailing directions, and all hydrographic information relating to the coasts and waters outside of the boundaries of the United States, for the use of its marine, both naval and commercial, and for directing the examination and survey of the channels of commerce in foreign waters, was established under the Navy Department in 1866.

Connected trigonometrical surveys have also been instituted for the waters of the more important of the European colonies, especially in the West and East India waters and in Australia, but for far the greater part of the navigated portions of the globe the navigator will for a long time have nothing but reconnoissancesand running surveys, of which the earlier are more or less rough ad unconnected, and even some of later dates cannot be entirely relied upon.

Running surveys, more or less in detail, are generally the precursors of the more strict geodetic survey, but, in order to answer the wants of navigation, these should always be based upon a triangulation between natural landmarks, checked at reasonable distances by Very careful shore observations for latitude and longitude, and the latter carried directly from a central position to the most prominent points of the thus surveyed area and back again, and the central position connected in the same manner with the nearest satisfactorily determined position, to which the longitudes of that locality are generally referred.

The telegraph-cables which already connect many of the most important places will soon gird the globe in several belts, and will afford the means for ascertaining great meridional distances with almost absolute correctness. There will thus be furnished a great number of primary positions from which the longitude may be carried in coördinate lines to secondary places. In this manner a network of points spread over the globe will be attained, corresponding to the primary and second triangle points of great geodetical operations.

The completeness and correctness of a running survey depend upon the time devoted to it and the difficulties encountered; frequently the coast-line is only traced in from point to point, or from the shore-ends of the lines of soundings by the eye; the points of

land, however, especially the salient ones, should always be fixed by angles to or from the established landmarks, as should also all outlying dangers and all features bearing directly upon or assisting navigation.

The surveys of harbors and anchorages should be as complete as possible; if time permits, beacons should be erected for triangulation, and the plane-table employed for obtaining the shore-line. The parts of the latter which are merely traced in approximately should be distinguished on the chart by a broken line.

The soundings should always be numerous enough to show the configuration of the bottom of harbors, and off a seacoast the gradual rise from great depths to the shore, islands, and banks, so that the characteristic curves of the depths may be shown with precision on the charts; for harbors generally the one, two, three, and five fathom curves are marked; on coast-charts, those of three, five, ten, twenty, fifty, and one hundred fathoms.

When sounding from a vessel in motion or from a boat, the lead should be tried at intervals, even when it is anticipated that the bottom will not be readied, not only on account of the possibility of the discovery of a sudden elevation, but for the purpose of placing the negative soundings on the chart, which show conclusively the absence of danger and that the ground has been examined.

For such negative soundings, as much line should be used as the speed of the vessel will permit, and at reasonable distances the deep-sea lead should be employed to obtain actual depths. Positive soundings exceeding 100 fathoms should be obtained as far to seaward as circumstances will permit the survey to be extended.

A difficult task of the hydrographic surveyor is, to search for the islands and dangers shown on the charts, or enumerated in nautical guides as uncertain in position or of doubtful existence.

Many facts show that the origin of a great number of these may be traced to deceptive appearances, to misplacement from faulty observations or reckoning, or to typographical errors in the reports published.

Reports of new dangers grow more frequent, as the sea-routes extend into regions heretofore but little traversed, and as the commercial navigator manifests a greater interest in hydrography. All these obstructions to navigation are placed on the charts, usually with queries, until they are verified and correctly located, or their nonexistence proved by professional authority through local search. Such dangers have frequently been found to exist at considerable distance from the positions given, from indifferent astronomical observations, or from reckoning referred to observations taken several days before or after their discovery; the search must, therefore, be extended over a considerable area. The search for islands is naturally less difficult than that for submerged dangers, which on the broad ocean can in some instances hardly be detected but by chance.

In causing reported dangers of this nature to be erased from the charts, on the strength of a search which has not been thorough in every particular, the hydrographer incurs a grave responsibility; there are a number of instances on record where dangers which had been searched for most carefully and by very competent authority, have been replaced exactly in the position from which they were erased, after they have been assured by the loss of a vessel on them, and the reëxamination of the position in consequence of it.

A correct representation of the character of the bottom of the waters is very important, not only for the selection of anchorages, but also as a guide to the navigator when he cannot otherwise obtain the position. of his vessel, especially when approaching a coast in fogs and thick weather, or when passing through channels not bordered by good landmarks; for this purpose specimens of the bottom should be brought up for examination, and every change of it noted.

The tidal relations, tidal hour, and the rise and fall at the various stages of the moon, and in the various seasons, the influence of the winds upon the tides, etc., can be deduced accurately only by observations continued through a longer period than the limited time of a running survey will generally permit. Observers should, if possible, be left for this purpose at the important points. A lunation is the shortest period in which approximate data can be arrived at, but observations for a shorter time, and by rough means, may prove of some value, and such should be made daily.

Meteorological observations, the direction and force of the winds, the appearance of the sky and clouds, temperature, the pressure and humidity of the atmosphere, etc., should be made at the stations occupied for tidal observations; they can then be made with more precision than those usually made on board ship.

Every opportunity should be availed of for gathering information from intelligent residents in regard to the local, tidal, and meteorological relations, in order to complete deficient observations. Permanent currents are correctly ascertained in places where a vessel can anchor, by various methods of observation, on the deep sea generally by the difference between the position by observation and that by the dead-reckoning.

The active hydrographic surveyor will not, while on the ocean, neglect to aid in the labor of the physicist, by examining into the condition of the water, its temperature at the surface and at various depths, its specific gravity and salinity, its fauna and flora, and by contributing to the natural sciences, general geography, geology, and ethnology, while in regions which may be not at all, or but little, explored.

The hydrographic part of the information thus obtained is laid down for the use of the navigator in charts and text-books in such a manner as to be rendered complete without interfering with clearness and ready comprehension.

Charts must contain with distinctness every feature upon which the navigator relies, coast-line, outlying dangers, peaks of mountains, with their height, conspicuous objects, etc. Sea-charts are constructed for publication on Mercator's projection, although this projection distorts the relative size of the several areas and the bearings of points; the more so the farther the chart is extended toward the poles. Navigators, however, prefer it to the more correct conic projections, as it represents the meridians and parallels of latitude in straight lines, thereby facilitating the laying down positions and bearings. The careful hydrographer will plot his work on a conic projection, and thence transfer it to that of the Mercator. The gnomonic projection—projecting areas on a plane tangent to the earth from the earth's centre—represents the great circles, the shortest distances between two points by straight lines, and in this has advantages for charts of entire oceans. As yet, this projection has not been used to any extent. All conspicuous objects on which the navigator depends should be given preference in distinctness of delineation over that of mere detail.

Upon the intricacy of the configuration, especially that of dangerous passages, will depend the scale to be adopted, which should not be so large as to render the chart unhandy, and not so small as to interfere with clearness. Usually the work is first laid down on a scale large enough to show at a glance any fault in the projection, and then

reduced to the scale decided on for publication. On the latter, objects of importance, especially dangers to navigation, should be exaggerated in preference to their not being sufficiently conspicuous. The soundings obtained, especially in harbors, will be far too numerous to represent them all, even upon the working-sheet; care must be taken in selecting the characteristic soundings, which must be reduced to a certain state of the tide, usually to low water, and they must be placed on the exact spot representing that in which they were obtained. Heretofore these were expressed in the standard measure of the country in which the chart was published, but recently the French metre has been adopted by all maritime nations, excepting Great Britain and the United States, who use the English fathom and foot. It is preferable to use on the same chart but one unit, either fathoms or feet, as the use of both, even with the shading, frequently leads to error. In order to show better the structure of the bottom, and to make irregularities more conspicuous, curves of equal depths—fathom-curves—are laid down. The denomination of the curves depends upon the depth of water that can be carried into the harbor or along the coast. Harbor charts generally show the five, three, two, and one fathom curves, the latter three often distinguished by shades of sanding (dots to represent sand); the five-fathom curve is expressed by rows of five dots on the line of the curve. Coast-charts generally show in addition a ten, fifty, and one-hundred fathom curve.

The character of the bottom is represented by the first letter, or an abbreviation of the word, expressing it; currents by arrows, with the force in knots per hour or per day placed along them; buoys and beacons are shown by conventional signs.

Lines of bearing point out the courses to be steered, and guide also in avoiding dangers. Views, placed so as not to interfere with the sailing-ground, show the appearance of the land on the bearings on which they are taken.

An important feature of the chart is the compass, placed in such positions as are most convenient for taking off the courses. On harbors and special coast-charts the compass-points are generally laid off from the magnetic north line; on general ocean-charts, on which the variation changes rapidly with the lateral distances from the direction of the magnetic curves, they are laid off from the true north.

General charts, and frequently harbor-charts, have the projection drawn over them, from which the latitude and longitude of any point represented on it can be ascertained minutely; where the projection is not thus drawn, the astronomical position of a well-defined point is given, usually under the title, with the mention of the primary position to which it has been referred. The title also embraces the tidal hour, with rise and fall of tide, at the full and change; the unit of measure in which soundings and elevations are expressed; the scale on which the chart has been constructed, and an explanation of the conventional signs used on it; these latter, however, are generally supposed to be known.

General notes regarding the winds, currents, tides, harbor facilities, etc., are frequently added, as also sometimes sailing-directions; but generally these are left for text-books, which, under the titles of "Directions," "Memoirs," "Manuals," or "Pilots," give to the navigator the information obtained by the hydrographer, with the general results arrived at, which cannot be engrossed on charts.

By a judicious arrangement and a complete index, these should be made as intelligible and as ready for reference as possible, and should contain all the points within the area treated on that are of interest to navigation.

The first treatise on marine surveying, published in a practical form, was by Alexander Dalrymple, in 1771. This was followed by the work of M. Beautemps Beaupré, in 1808; since which time there have been published many valuable works on marine surveying, adapted both to running surveys and to greater geodetical operations.

In hydrographic surveys and exploration, England has always been foremost. Her Hydrographic Office, dating from 1795, under Alexander Dalrymple, was not firmly established until 1828, when Captain Francis Beaufort became the hydrographer to the British Admiralty; since which time, under the administration of the line of distinguished navy officers his successors, it has steadily advanced, to the inestimable benefit of commerce, both British and foreign. At the present date the charts of this office number two thousand nine hundred and eighteen, and yet about one-half of the coasts and navigable waters of the world remain unsurveyed, a great part not even examined.

An interesting skeleton chart of the world, compiled at the British Hydrographic Office and attached to a paper delivered by Commander Hull, R. N., superintendent of the Admiralty charts, before the Royal United Service Institution, showed the portions of the coasts of the world surveyed, partially surveyed, and only explored. Taking this continent alone, between the parallels of 60° north and 60° south, beyond which whaling-vessels only generally go, it will be found by rough measurement that about 12,000 miles of the seacoast have been surveyed, 20,000 miles partially surveyed, and that 8,000 have been only explored. Coasts partially surveyed or only explored require the utmost caution for safe navigation; and, even with this, vessels are constantly in peril. For the remainder of the globe, with exception of Europe, the proportion of the inadequately-surveyed and almost unknown coasts and waters is much greater. This should demonstrate clearly the vast field of labor awaiting the maritime surveyor.

England perseveres in this work, and her hydrographic parties are found in every quarter of the globe, opening new channels to commerce, and defining the dangers of navigation. France, in her publications issuing from her Department des Cartes et Plans, is hardly behind Great Britain; from the time of the father of French hydrography, M. Beautemps Beaupré, to that of its present distinguished director. Vice-Admiral Jurien de la Gravière, this office has not ceased to assert its prominence and usefulness, France, however, though constantly and systematically prosecuting foreign hydrographic surveys, has not carried this work to the same extent as England. Spain, of late years, has rested on her laurels of the past, and with other maritime nations, with exception of casual foreign surveys, has restricted herself to the shores of her own possessions, and to issuing from time to time valuable publications and information for the benefit of navigation. The United States Hydrographic Office, though yet in its infancy, has made rapid progress, and now issues a respectable number of publications; no permanent system, however, of hydrographic surveys has ever been successfully instituted under the Navy Department. On its own coast, in its waters and harbors, the work of the United States Coast Survey is extensive, scientific, and thorough, and many years will yet be required for its completion.

All attempts to inaugurate a system of foreign surveys have failed, though, with intervals of many years, spasmodic efforts have been made and expeditions sent from her shores, which have done good service to hydrography and geographical science, though many and powerful attempts have been made by those interested in commerce and navigation to induce legislators to appropriate the small amounts requisite for this service; yet, even when such have been organized, and the hydrographic work was beginning to yield its fruit, the want of interest and legislation has crushed it out, and necessitated the withdrawal of the work, leaving only the hope that in time to come the United States may assist the other great maritime nations in making more smooth the

course of the mariner through the paths of the great deep. Millions of property have been lost, with thousands of valuable lives, from the lamentable neglect of continued hydrographic surveys.