RECENT PROGRESS IN HYDROGRAPHIC SURVEYING.

by

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The narrow continental shelf on the Pacific coast and the absence in general of off-lying shoals, which tend to absorb or to reflect the sound waves from the explosion of the depth-bombs, have been favourable factors in the progress under modern methods of the hydrographic surveys along that coast. The comparatively low water-temperatures in addition furnish a medium quite conducive to successful underwater sound transmission. Experiments have demonstrated that the sound wave travels faster in warm water than in cold, but does not go so far; the water of high temperature apparently absorbs the wave energy.

The favorable features presented by the physical conditions on the coast have permitted the installation of hydrophone stations along the actual coast-line, and the obtaining of accurate positions of the surveying vessel at considerable distances off shore. A bomb explosion in one instance carried through a distance of 206 miles.

The Atlantic coast, on the other hand, presents difficulties which have not yet been entirely overcome. The wide continental shelf and off-lying shoal water on the north Atlantic coast constitute adverse conditions for the sound waves, generated by distant off-shore explosions, to reach hydrophones located on shore, and along the south Atlantic coast the comparatively high water-temparatures are unfavorable to successful sound transmission.

Radio Acoustic Triangulation.

The unfavorable conditions on the North Atlantic coast, however, have been partly overcome by a variation in technique; a system of marine triangulation is extended from a buoy anchored off shore on the continental shelf and located by a long series of star observations made from the surveying vessel anchored nearby. This method was used for the first time, and successfully, on the recent survey of Georges Bank.

Georges Bank extends to the eastward about 200 miles off the New England coast and contains an area of about 15,000 square miles within the 100-fathom contour. The depth over a large part of this area is less than 50 fathoms, and generally from 20 to 30 fathoms along the backbone or ridge of the bank.

The origin buoy is anchored in about 30 fathoms near the outer end of the bank and is located by the series of astronomical observations within a probable error of about 400 metres. This position has ample accuracy for the scale of an off-shore chart and is held fixed for the purposes of the survey. A second buoy, forming a base line approximately at right angles to the axis of the proposed triangulation system, is anchored about ten miles distant.

A station ship, with a hydrophone suspended under the keel and connected with the radio transmitter, is anchored near the origin buoy and the mobile survey ship is steamed past the second buoy close aboard, a depth charge being dropped in passing. The sound wave from this explosion travels via the sea water to the hydrophone of the station ship; thence electrically to the radio set, and its receipt is automatically and instantly flashed back by radio to the survey ship's chronograph in a manner similar to that used on regular surveying operations on the Pacific coast. A determination of the length of the base line is thus furnished; at least three determinations of this length are made.

The mobile survey vessel is now anchored near the second buoy for the determination of the azimuth of this base line. If during the day time, a sextant angle is observed between the sun and the station ship anchored at the origin buoy; if at night, the angle is observed between a suitably located star and the searchlight of the station ship. The azimuth of the line is readily computed by means of this inclined angle.

An azimuth and a base line with a survey buoy at each end having been determined, a system of quadrilaterals is now extended shoreward along the ridge of the bank; this system is composed of triangles with sides 10 to 12 miles long, with a

survey buoy at the vertex of each triangle. The lengths of the triangle sides are determined in a manner similar to that for the base line, and an occasional azimuth is observed over some line of the system as a check on the data.

Two station ships, with suspended hydrophones, are now anchored at any two of the buoys and the mobile survey vessel steamed along on a system of sounding lines; positions are obtained as on the Pacific coast except that the station ships replace the shore hydrophone stations.

Obviously the physical conditions obtaining on the Atlantic coast, necessitating the use of two station ships in place of two comparatively inexpensive shore hydrophone stations, render this variation in procedure considerably more costly than the method employed on the Pacific coast and, in addition, slow up the work somewhat by withholding the two station ships from active, productive surveying operations. Later experiments may point the way to a more economical solution of the problem, but in the meantime, quite accurate and interesting surveys are being accomplished in the manner briefly described above, and much more rapidly than was formerly possible by the older methods.

Pacific Coast Surveys.

The discovery of gold in California precipitated a need, more pressing than ordinarily results in the case of a new, undeveloped country, for charts and hydrographic information along the Pacific coast of the United States. The mad rush in 1849, by every available vessel, of gold seekers and adventurers to this new Eldorado created a demand which has continued to the present day, a demand not fully met until the period following the Great War. The introduction of these late developments and methods for hydrographic work has made possible a vigorous and expeditious prosecution of these surveys and the construction of charts suitable to meet the exacting demands of modern commerce.

The survey of the Pacific coast (1) was started by the United States government in 1850; it consisted of a reconnaissance of the coast from Monterey to the Columbia River and a preliminary hydrographic survey of the entrance to the Columbia as far up as Tongue Point; also a survey of Mare Island Straits.

Prior to this first reconnaissance the coast was represented on no chart worth the name; many mariners drew their own charts from information and data obtained on voyages. The coast-line had been crudely charted by various exploratory expeditions of the Spaniards; of the Russians, of DRAKE, the English adventurer; and of VANCOUVER. The first chart, by the Spaniards, was made as early as 1542. The coast had been charted in some places as much as 20 miles out of position geographically. The first work, therefore, by the Coast Survey consisted of the determination by means of moon culminations and occultations of the various headlands along the coast. This work was accomplished under the usual hardships and dangers incident to pioneering work: navigation in small sailing craft during heavy weather along an exposed coast; attempted mutiny brought on by the avaricious dreams of untold wealth to be had in the rich gold fields; and encounters with hostile Indians. Observations at Neah Bay were made behind breastworks with an armed guard as a protection against the Indians.

The hydrographic work was continued along this coast under various adverse conditions until 1895, but from that year little hydrography was done on the exposed portions of the California, Oregon, and Washington coasts until the period following the Great War. The paucity of the soundings on a section of United States Coast and Geodetic Survey chart No. 5802 (1918 edition) speaks eloquently of the incomplete condition of Pacific coast surveys at the close of the War.

Philippine Islands Surveys.

The first map (2) on record of the Philippine Islands consists of several crude sketches made by PIGAFETTA, an Italian nobleman who was a member of MAGELLAN'S

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(1) *This brief history is based on Jones, E. Lester,* The neglected waters of the Pacific coast, *Coast and Geodetic Survey, Special Publication No.* 48, 1918.

(2) *This brief history is based on Bach, John,* Philippine maps from the time of Magellan, *Military Engineer, July-Aug.* 1930.

expedition (1521). This archipelago was called by MAGELLAN the San Lazaro Islands; VILLALOBOS, however, in his expedition of 1543, renamed them in honour of Prince PHILIP of Spain.

This first map of PIGAFETTA's was followed by LEGASPI's (1565-72) and by the maps of LANGREN in 1595; LANGREN's showed all the major islands except Palawan. Then followed Sanson D'ABBEVILLE's in 1654 and COLIN's in 1659. An important map of the islands by Admiral Don Francisco Diaz ROMERO appeared in 1727; the valuable work of Father Pedro Murillo VELARDE, 1733, comprised a comprehensive representation of the entire archipelago and served as a model for half a century.

Following their occupation of Manila in 1762, the British government published several good maps of the Philippines, and early in the 18th century the Spanish Hydrographic Commission began a systematic charting of the islands under the direction of Alejandro MALASPINA; the first charts were issued in 1808. Spanish naval officers had carried on for about 50 years hydrographic surveys in the archipelago and at the time of the American occupation, the Spanish Hydrographic Commission in Madrid had issued, based on these surveys, 110 charts, which for the most part were in the nature of reconnaissance and unfit for the purposes of navigation.

The United States Coast and Geodetic Survey began a systematic, modern survey of the Philippine Islands on January 1, 1901. This gigantic undertaking, except for several unimportant areas, is now practically completed. The completion of this vast project in 30 years, considering its comprehensive nature and the large area involved, may be considered an achievement in hydrographic surveying.

The Philippine Islands surveys progressed more rapidly in their early years of United States sovereignty than those of any other of our outlying possessions; in fact, more than those of the coasts of continental United States. This progress has been due in part to the fact that the surveying seasons extend throughout the entire year and that the weather is well adapted to surveying operations; but in a large measure, to the funds and to the four vessels supplied by the Philippine government in the early years of occupation. The Philippine surveying fleet during this early period comprised these four insular vessels and one furnished by the federal government; all these vessels were manned by United States Coast and Geodetic Survey officers.

The total water areas of the islands had been 64 per cent surveyed during the 18 years from 1900 to 1918; the entire water area is 86 per cent surveyed at the present time. The first survey of the more important areas of the islands was completed several years ago. The allotment of funds by the Philippine government has been, therefore, gradually decreased; at the present time only two vessels are furnished to the one furnished by the federal government.

The hydrography yet to be accomplished in the islands consists of the following areas only:

1. On Luzon, off the extreme north-west corner, along the north coast and along the north-east coast.

2. On Palawan Island, about 80 per cent of the west coast.

3. Vicinity of Sibutu Island, the last small island at the extreme west end of the Sulu Archipelago.

4. About 10,000 square miles of off-shore work off the north coast of Borneo between the international boundary and work already completed in the extreme southern part of the Sulu Sea.

Alaskan Surveys.

Alaska, the last frontier of America, has not, on the other hand, been allotted funds to carry on rapid and efficient surveys in keeping with the vast wealth it has produced, nor sufficient for making its channels safe for its water-borne commerce, so necessary for its full development. Only nine per cent of Alaska's water areas had been surveyed during the period from 1867 to 1918; about 18 per cent has been surveyed at the present time.

The comparatively short surveying season in these latitudes, coupled with the lack of funds and with the considerable amount of unsuitable weather during the season for surveying operations, has militated against the economical and expeditious progress of its survey.

The physical properties of the sea water in Alaska, as on the Pacific coast of the United States, are quite suited to the successful use of radio acoustic ranging; and this method, together with echo-sounding, is permitting of more than doubling the area surveyed as compared with the area ordinarily surveyed in former years.

Little was known of Russian America, now Alaska, until BERING's first expedition in 1725 (1), and this territory was conspicuous by its absence from world maps. Crude outlines of this vast territory began to appear in this blank space soon after BERING's exploratory expeditions.

Other explorers contributed at intervals to the knowledge of Alaska; the explorations of the English adventurers, COOK and VANCOUVER, made the largest additions to the maps of this early period. These expeditions were followed by those of the French, of the Spanish, and by American whaling vessels.

The early Spanish explorers left their imprint in the place names throughout south-eastern and south-western Alaska. They apparently had little interest in the north, however, beyond exploring; they limited their voyages to those of discovery only. The inhospitable climate as compared with that of their native land caused even these hardy voyagers to limit their operations in the north to those of the true explorer — the desire to see beyond the horizon. They generally favoured for colonization sub-tropical climates characterized by long summers and short pleasant winters, as evidenced by the settlement of southern California, Mexico and Florida.

When Alaska was purchased from Russia in 1867, the charts were crude generalizations consisting of compilations from these exploratory data. The Coast and Geodetic Survey began work in the territory the year of its cession to the United States, but until 1882 the work was limited in general to reconnaissance in one small schooner. The first comprehensive survey of Alaska was begun in 1882 when the steamer *Hassler* was made available. Other vessels were added from time to time to the surveying fleet and the work was carried on as the limited funds allowed.

As in California, the discovery of gold and the stampede to the Alaskan placer fields in 1898 resulted in increased commercial activity and in an imperative demand for surveys. Such a suddenly increased and vast field of operations overtaxed the resources at that time of the Coast and Geodetic Survey, and the inadequacy of funds and of vessels rendered impossible the carrying on of hydrographic surveys along the continental Pacific coast and at the same time the meeting of the urgent demands in Alaskan waters. Practically the entire facilities, therefore, of the Bureau on the Pacific coast of the United States were employed in Alaska from 1898 to the period immediately following the Great War. Despite this procedure, the greater part of Alaskan waters is yet inadequately surveyed owing to the enormous area involved and the character of the coast-line, although the whole area has been covered by surveys of a reconnaissance nature, and the more important areas by comprehensive modern surveys. The coast and inside waters of south-east Alaska have had more attention than any other similar large area in the territory; the greater part of these important waters has now been surveyed and, in addition, practically the whole of the inside passage from Dixon Entrance to Skagway and out to Cape Spencer has been wire dragged. The greater part of the coast and the inside waters from Cape St. Elias to and including Kodiak Island has also been quite well surveyed.

Surveys of a reconnaissance nature only have been made of the off-shore waters along the coast from Cape Spencer to Cape St. Elias and from the south-west end of Kodiak Island to Dutch Harbour. A large part, however, of the along-shore waters and of the important bays and harbours over this latter area has been adequately surveyed.

The whole of the area comprised within the Aleutian group from Dutch Harbour to Attu Island has had a reconnaissance survey only, and also the whole of Bering Sea, including its coast-line, with the exception of three coastal areas of which adequate surveys have been made: Bristol Bay, Kuskokwim, and Norton Sound. The survey of Norton Sound covers a considerable area, but because of its changeable character, this area will require resurveys in the future.

The entire Alaskan coast bordering on the Arctic Ocean from Bering Straits around Point Barrow to the International Boundary at the 141st meridian has had a reconnaissance survey only.

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(1) *This brief history is based on Jones, E. Lester,* Safeguard the gateways of Alaska, *Coast & Geodetic Survey Spec. Pub. No.* 50, 1918.

Hawaiian Islands Survey.

The Hawaiian Islands were discovered by Captain James COOK in 1778 and visited by PORTLAND, DIXON, and LA PÉROUSE in 1786, afterwards by Russian explorers who came down from Russian America (Alaska). The first actual survey in the Hawaiian group was made in 1796 in Honolulu harbour by Captain BROUGHTON of the British exploring ship *Providence*. Captain WILKES of the United States Navy in 1840 made preliminary surveys of the craters of Hawaii and reconnaissance surveys of many important harbours of the group.

At the time of the annexation in 1898 to the United States, the only surveys, begun in 1871 by the Hawaiian government, consisted entirely of control surveys for the determination of the extent of the crown lands and for the demarcation of land boundaries in the transfer of titles from a land system somewhat similar to the feudal system of the Middle Ages to a system of fee-simple titles. This general land division took place in 1846-9 under King KAMEHAMEHA III, but eventually, to bring order out of chaos, the execution of these control surveys, which were begun in 1871, was found to be necessary. The instruments for the base measurements for this triangulation were loaned by the United States Coast and Geodetic Survey, and the work was done under the direction of Professor W. D. ALEXANDER, then president of Oahu College.

The first systematic hydrographic surveys of the Hawaiian Islands were begun, after their annexation, by the United States government and, as executed, may be divided into two sections : one comprises the area in the immediate vicinity of the larger eastern group of islands, and within the 1000-fathom curve; the other extends to the westward, and includes the area of small islands and shoals scattered over the 1,200 miles between the Island of Niihau and Midway Islands.

The Islands of Oahu, Maui, and Kahoolawe only had received much attention prior to 1918 and practically no hydrographic work had been done around the coasts of the islands of Hawaii, Kauai, and Niihau; very little had been done along the coasts of Lanai and Molokai. The completed hydrographic work inside the 1000-fathom curve in the vicinity of the larger islands of the group comprised in 1926 some 3,700 square miles and 10,280 miles of reconnaissance or unsurveyed area (1).

All the channels among the whole group of larger islands had been surveyed by 1931 with the exception of a part of Kaiwi Channel between Oahu and Molokai, and surveys extending well off shore had also been made around all the islands of the group except the north-east coast of Molokai; an area just west of Lanai Island, and the east and south coasts of the Island of Hawaii. These unsurveyed areas, however, constitute a small percentage of the whole.

The section to the westward is now being surveyed; it extends from the main Hawaiian group to Midway Island, or approximately from 160° to 180° west longitude, about 1,200 miles. The average depth over this area is about 2,000 fathoms, with scattered shoals, reefs, and small islands. This work had reached at the end of the summer of 1931 to Lisianski Island, about 900 miles to the westward.

It may be of interest that the vessel now engaged on this survey, the *Pioneer*, takes aboard a month's fuel and supplies, and a run at full speed of from four to five days is required from the base at Honolulu to the present field of operations in the vicinity of Lisianski Island. A deep-sea sounding line is run each month to and from port, so that an area about 150 miles wide of deep sea work is being extended along this chain of islets and shoals from the main Hawaiian group to the Midway Islands. This additional work, obtained at practically no extra cost, has been made possible by the advent of echo-sounding.

(1) *Jones, E. Lester.* The survey of the Pacific Ocean an economic necessity, *Mid-Pacific Monthly, April* 1925.