Coast and Geodetic Survey Sesquicentennial Papers

A Sesquicentennial of Public Service

REAR ADMIRAL H. ARNOLD KARO Director

Ninth Congress of the United States (Act of February 10, 1807)

The Coast and Geodetic Survey in the Philippine Islands

REAR ADMIRAL EARLE A. DEILY (Retired)

A Century and a Half of Scientific Nautical Charting

A. L. SHALOWITZ

Hydrographic Work of the Coast and Geodetic Survey

COMMANDER KARL B. JEFFERS

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A Sesquicentennial of Public Service

REAR ADMIRAL H. ARNOLD KARO, Director
U. S. Coast and Geodetic Survey

FEBRUARY 10, 1957, marked the 150th anniversary of the founding of the Coast Survey. It is proper that note be taken of such occasion, and that the record, as it stands, be hailed as an achievement. The Survey is proud of what has been accomplished, and in the electronic-atomic age ahead plans an even greater contribution. Within the Department of Commerce the Bureau will continue to serve the best interests of commerce, industry, business, and the defense of the Nation.

The early settlers of this country approached its shores with no knowledge of the waters beyond stout hearts, keen eyes, and an intuitive sailing skill. When independence was won the new democracy had many problems to solve but none so vital as the need for charts to keep maritime commerce moving. President Thomas Jefferson recognized that the prosperity of the infant republic depended upon safety of navigation and the growth of commerce. In keeping with this concept, the Bureau had its beginning along with the very first agencies to be created by our forefathers. Thus was initiated the great undertaking of surveying and charting the coastal waters which has progressively expanded in scope and breadth.

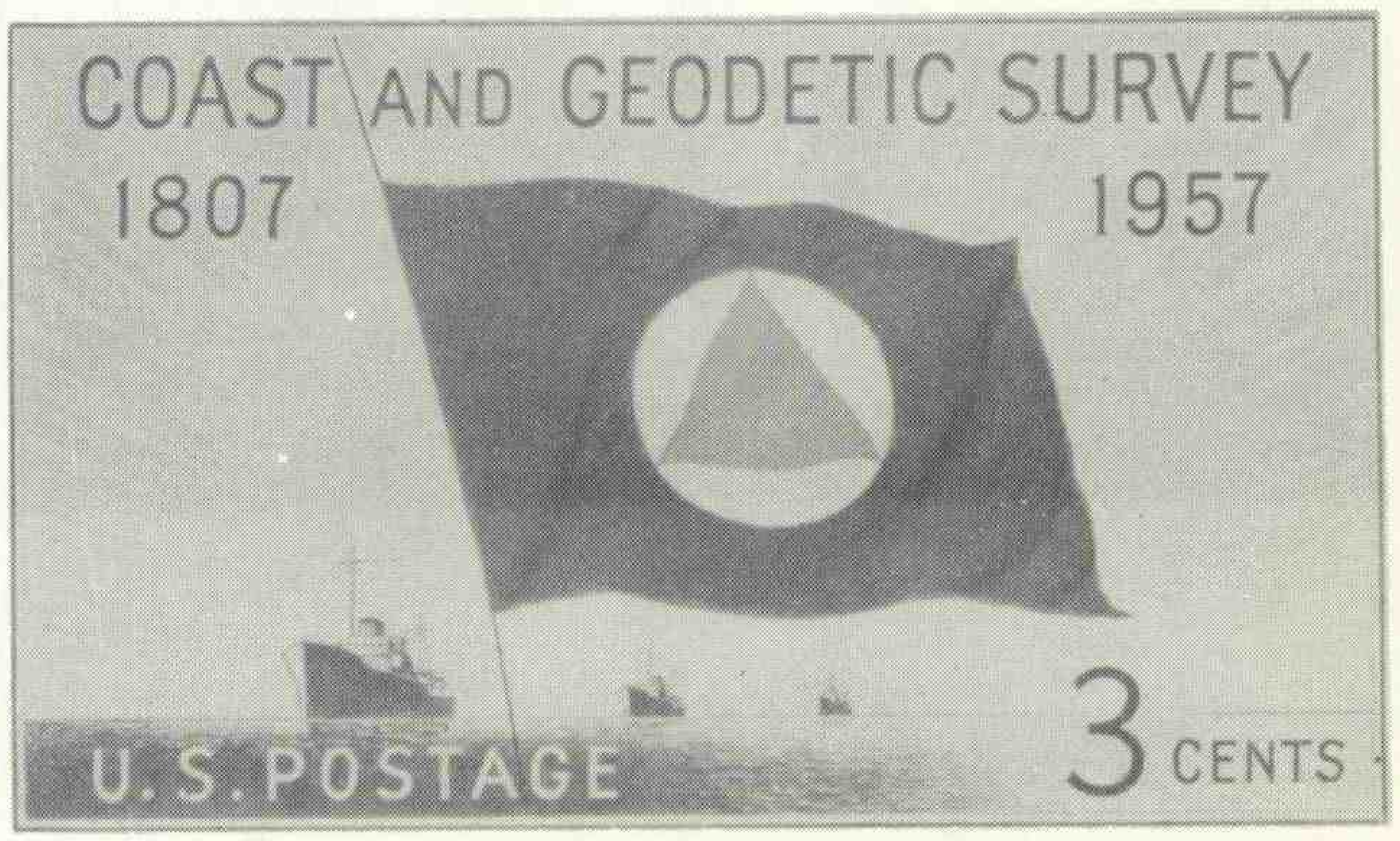
The example set by the Bureau over the years is a constant and ever-present challenge. It reflects the untiring efforts of devoted men and women making diligent application of their intellect, energy, and time. It has steadfastly demonstrated the best in technical proficiency, in devotion to duty, and in an unwavering fidelity to sound scientific principles.

In performing a vital function of Government, the long succession of dedicated public servants who have contributed unselfishly, decade by decade, to our national heritage exemplifies the finest traditions of the Federal service. Their achievements are an inspiration to the present generation and those who will follow. I commend the host of unsung patriots who have demonstrated in a practical way inspired and unselfish labor in the national interest.

In every generation pioneer personalities of the Survey have been widely known for their practical contributions to science. Bureau scientists have been closely identified with the work in related agencies of Government, both national and international. The great benefits from these efforts which all enjoy today reflect the highest attainments in scientific applications. I am glad that these accomplishments deserve and are accorded the approbation of the leading learned bodies of the world.

The Survey's illustrious history is enriched with dramatic heroism on land and sea, and is resplendent with honored names. Many great men and women share in the honors accorded the Bureau during our Sesquicentennial year. Each period of its existence has produced men who consistently displayed courage, integrity, and sound judgment in carrying out their assigned tasks. They seldom faltered in their missions even when the work took them to almost inaccessible mountaintops, under the very guns of enemy warships; to remote areas of the Philippines, with exposure to tropical diseases; and, in later decades, to the frozen wastes of arctic Alaska.

Always in step with national progress, new applications are found for the unique services of the Bureau. Progressive charting of coastal waters has made safe our maritime commerce, and intensive mapping of air routes has contributed to the safety and advancement of air navigation. The pioneering effort that has expanded in scope and importance, in keeping with national progress, will continue in the decades to come. Plans for the future envision an ever-broadening capacity of the Bureau to serve the American people.



COMMEMORATIVE STAMP

NINTH CONGRESS OF THE UNITED STATES,

At the Second Session.

Begun and held at the city of Washington, in the territory of Columbia, on Monday the first of December, one thousand eight hundred and six.

AN ACT *to provide for surveying the coasts of the United States.*

Be it enacted by the Senate and House of Representatives of the United States of America, in Congress assembled, *that the president of the United States shall be, and he is hereby authorized and requested, to cause a survey to be taken of the coasts of the United States, in which shall be designated the islands and shoals, with the roads or places of anchorage, within twenty leagues of any part of the shores of the United States; and also the respective courses and distances between the principal capes, or head lands, together with such other matters as he may deem proper for completing an accurate chart of every part of the coasts within the extent aforesaid.*

Sec: 2. And be it further enacted, that it shall be lawful for the president of the United States, to cause such examinations and observations to be made, with respect to St. George's bank, and any other bank or shoal, and the soundings and currents beyond the distance aforesaid to the gulph stream, as in his opinion may be especially subservient to the commercial interests of the United States.

Sec: 3. And be it further enacted, that the president of the United States shall be, and he is hereby authorized and requested, for any of the purposes aforesaid, to cause proper and intelligent persons to be employed, and also such of the public vessels in actual service, as he may judge expedient, and to give such instructions for regulating their conduct as to him may appear proper, according to the tenor of this act.

Sec: 4. And be it further enacted, that for carrying this act into effect there shall be, and hereby is appropriated, a sum not exceeding fifty thousand dollars, to be paid out of any monies in the treasury, not otherwise appropriated.

Nath^l Macon Speaker of the House of Representatives

Geo Clinton Vice President of the United States, and President of the Senate.

February 10. 1807

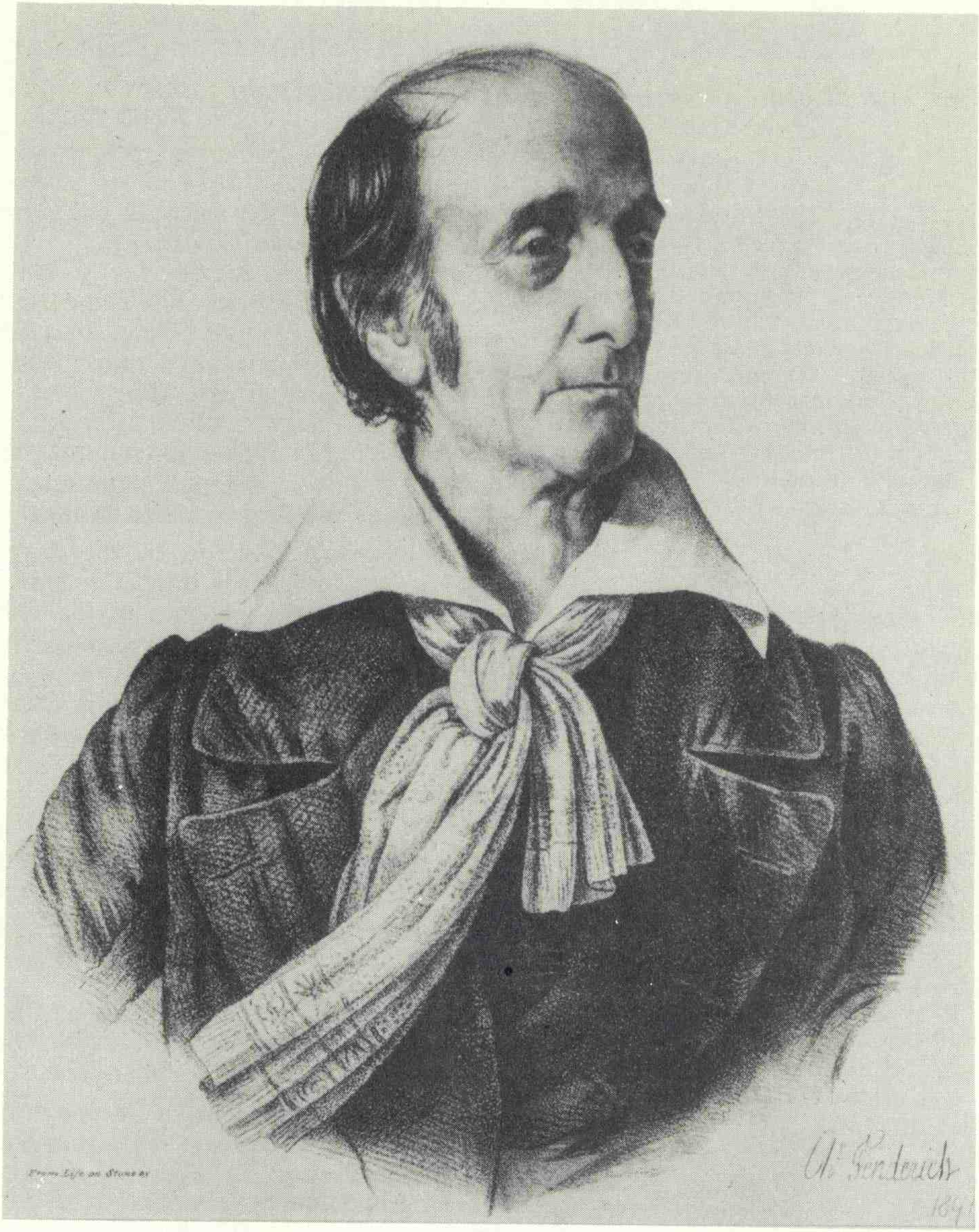
Approved

Th: Jefferson

I certify that this act did originate in the House of Representatives.

John Beckley Clerk.

THE ACT OF FEBRUARY 10, 1807, WAS THE BEGINNING OF THE COAST AND GEODETIC SURVEY



FERDINAND R. HASSLER, THE FIRST SUPERINTENDENT
OF THE COAST SURVEY

The Coast and Geodetic Survey in the Philippine Islands

REAR ADMIRAL EARLE A. DEILY (Retired)
U. S. Coast and Geodetic Survey

(Awarded First Prize in the Sesquicentennial Essay Contest)

This and the following article were adjudged the first and second prize-winning papers, respectively, in the Sesquicentennial Essay Contest held during 1956 under authority of the Incentive Awards Program of the Bureau. The first prize carried with it an award of $100 and the second an award of $50. The panel of judges consisted of Comdr. Franklin R. Gossett, Assistant to the Director, Coast and Geodetic Survey, Chairman; Mr. Henry Scharer, Deputy Director, Office of Public Information, Department of Commerce; and Dr. Henry Birnbaum, Assistant to the Director, National Bureau of Standards. The articles have been condensed for publication.—Editor.

THE SCOPE of the survey operations of Government mapping bureaus always expands with the acquisition of new territories. When Spain ceded the Philippine Islands to the United States the production of nautical charts became the official concern of the United States Coast and Geodetic Survey. Defined by law, its charting jurisdiction covers not only the continental limits of the United States but its territories as well.

Manila was still under martial law and military operations were in progress throughout the islands the September morning in 1900 when the first official of the Survey arrived there to make the preliminary studies needed for inaugurating a systematic survey of the coasts of the Philippines. In fact the times were so unsettled that no one without authority was allowed on the streets of the city after 10 o'clock at night.

Although many maps had been produced in the years since Magellan first visited the islands in 1521, it was found that the American inheritance of nautical information was far from complete. It was contained entirely in a collection of 136 Spanish charts of various dates and in the *Derotero del Archipielago Filipino* or Spanish Coast Pilot. This had last been published in 1879 and was much outdated.

The Spanish colonial surveys and the production of charts were entrusted to a bureau separate from that which exercised the same function in the Spanish continental areas. This "Bureau for the Colonies" was abolished subsequent to the Spanish-American war. Surveys and records were always sent to Madrid and the charts published there. Unfortunately few late records concerning the Philippines were available in Madrid as a great number were lost in the sinking of the survey ship *Argo* at Cavite.

Each particular survey was a unit unto itself and connected to other surveys by only a reconnaissance. Extensive areas had not been explored at all. Above all, there was no general system of triangulation tying the work together as a whole. Such coordination as was effected resulted from observed astronomic latitudes and longitudes for which the designated base point was the Dome of the Cathedral at Manila.

The existing surveys of the large island of Palawan and much of the Sulu Archipelago and Sulu Sea were the product of the British. Some were as recent as 1882. Actually the extensive work along the island of Palawan was only in the nature of an exploration and had been done by a sailing vessel. The British charts which resulted were published on the very large scale of 1 inch to 10 miles.

When one gives due consideration to the methods and equipment used in surveying during the nineteenth century and realizes the large area covered, the Spanish charts were really not too bad. The existence of many errors in the maps was early suspected but it was only in later years when a comparison with the surveys of the Coast and Geodetic Survey would be made that any real evaluation of these discrepancies was possible.

The Spanish positions of the large islands were found to agree relatively in latitude but there were great differences in shapes. There was considerable displacement from true position of the smaller islands, points and bays.

The east coast of Luzon as well as the islands to the northward toward Formosa fell as much as 5 miles to the eastward. At some places the northeast coast of Samar--a large island on the east side of the archipelago--was found to be quite crudely drawn and fell about 5 miles farther inland. Parts of Mindanao also fell 7 miles eastward and the head of Davao Gulf, at the southeast corner of the island, was actually 6 miles to the northward. A group of islets in the Sulu Sea which appeared on the Spanish charts derived from the surveys of 1792-93 actually were nonexistent. The island of Palawan to the west of the Sulu Sea lay 2 miles more to the eastward.

But worst of all, there were innumerable shoals and navigational dangers throughout the island group that were not even indicated.

There are over 7,000 islands and rocks above water in the Philippine group, with a tidal shoreline of 21,000 statute miles. In view of the great area to be charted, it was immediately seen that the work of adequately surveying the islands would be a large undertaking. Remote areas had to be explored for the first time. Four full decades, a considerable force of men, and a number of surveying vessels were required to bring the task to completion.

FIRST COAST SURVEY WORK

The work of the Coast and Geodetic Survey in the Philippines was conducted under a joint agreement between the Bureau and the Insular Government. Each supplied certain personnel and equipment and defrayed particular classes of expenditures. The local administration was conducted through a suboffice in Manila which in turn was under the general supervision of the Bureau in Washington.

The immediate line of action for improving the nautical charts was planned to meet the pressing needs of commerce and of the military whose deep-draft transports were reaching remote and previously unused anchorages. Extension to cover the entire archipelago would come in general course at a later date. Obviouslv the first surveys would have to be made of detached areas and in such sequence as to take advantage of the periods of good weather alongshore. Hydrographic operations were only possible where sheltered from prevailing winds. The northeast monsoon predominates from November to March and the southwest winds are felt from May to October. Field parties therefore had to be shifted frequently from one side of the islands to the other. Typhoons also could be expected in August and September. The instructions issued to the survey parties made sure that the field work would be done in a permanent and detailed manner despite the urgency for immediate results and would be so rigidly controlled that it could later be incorporated in the over-all survey of the island group.

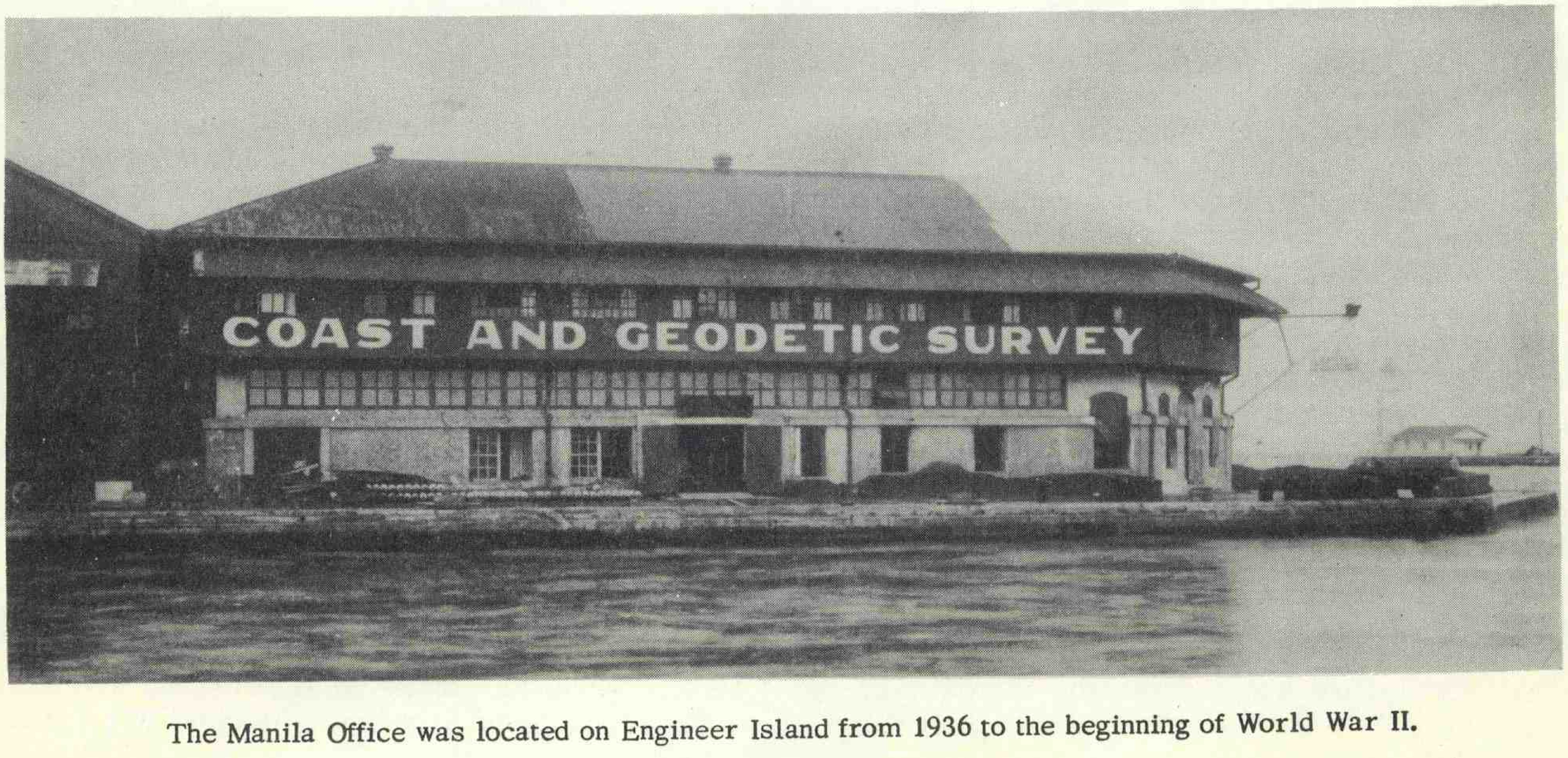
The Manila office was designed to be a center for directing operations and as a collecting and distributing point for information. Charts and sailing directions were compiled and published there.

Astronomic observations were proposed for the geographic positioning of a number of marked points throughout the islands. These astronomic stations became the base points for the surveys.

Local hydrographic and topographic surveys were to be made of harbors and landing places and of the important approach channels and main routes of travel, in such order as required. Ultimately, the work would be extended until the whole water area of the archipelago would be covered. Tidal and magnetic determinations were of course a necessary phase of these operations.

As soon as conditions permitted during the extension of the hydrography and topography, a coordinating scheme of triangulation was to be observed throughout the islands.

The first field party to reach the Philippines consisted of four officers, one draftsman, and four recorders, with a somewhat limited outfit of instruments. It began field work early in



The Manila Office was located on Engineer Island from 1936 to the beginning of World War II.

Survey party starting for Badoc Island on the west coast of Luzon.

January 1901. For awhile this work was confined to the vicinity of garrisoned posts, but after a few months the general conditions improved so greatly everywhere that survey operations were carried out where desired.

No serious difficulties were encountered because of hostilities of the native population during the insurrection years, although in some instances parties were in towns that were "shot up" during the fighting. The survey parties were armed and this practice was continued for many years during operations in the more remote and primitive areas.

As late as 1922, when the ship *Pathfinder* was in Zamboanga, the commanding officer reported that he made inquiry of the department commander of the Philippine Constabulary concerning conditions in the Sulu Archipelago. He was advised that an armed guard be sent with all shore parties and that the officers be cautioned to use care at all times and keep any Moros at a distance. Arrangements were therefore made to take aboard a party of one sergeant and eight men.

Throughout the long years of operations in the islands there was only one recorded attack on Coast Survey personnel--the brutal butchering of Commander Shaw in Jolo in 1941. By a miracle he survived to be flown to the hospital in Manila, endured the Japanese internment in Bilabid prison while recovering from his ghastly wounds, and was finally brought back to the States where he died in 1947.

TRANSPORTATION PROBLEMS

Transportation was ever a great problem in the Philippines. Many years passed before the island roads supported traffic in the rainy season. Operations of interisland steamers in the early days were irregular and infrequent and even in the late 1930's made scheduled runs only between Manila and the main island ports. Local water travel was by banca, by sailing "prao," or sometimes by small power launch.

Few piers were available except at the major ports and lightering was the usual procedure. Unfortunately there were few lighters. Freight was simply dumped on the beach or on the bank of a river and wagons immediately began to haul it to the town, usually some distance away. Where there were wharves at the little outlying ports of call one reads time and time again in the survey reports: "There is a stone jetty but nothing can go to it but small boats." "Small steamers can go to the wharf." "It is impossible for boats of any size to come near the shore; even rowboats have to lie some 50 feet offshore because of sandy shoals."

There was a railroad between Manila and Dagupan near Lingayen Gulf but the trip of some 125 miles took about 4 hours; a remarkable and terrifying speed for the days of carabao carts and one-horse vehicles. "Sigue Dagupan" (proceed to Dagupan) was the cry of the conductor to the engineer when the train was ready to start for Dagupan. "Sigue" began colloquially to mean "hurry" but with particular derision when used in the phrase "Sigue Dagupan spera Caloocan" (proceed to Dagupan stop at Caloocan). The train dashed off toward Dagupan and then stopped for an interminable wait in the heat at Caloocan just a few kilometers up the line.

For many years "Sigue Dagupan" was the cry everyone gave the Manila carromatta drives when speed was desired. What speed! The "cochero" yelled wildly and flailed his whip; the little pony jumped ahead; the passengers banged back against the seat; and away the whole thing went careening in and out of traffic and just missing people and bull carts. Autobuses and taxis were far in the future.

Outside of Manila, in the villages and countryside, traffic moved at the slow methodical pace of the carabao, or water buffalo, pulling a lurching cart with wheels of solid planks. Travelers rode horses.

In the wilder sections one walked, and hired "cargadores" to carry the instruments and outfit and to hack a passage through the jungle. In the years of the Survey, such a band on the trail was a somewhat ludicrous string of Filipino sailors from the ship, local residents of the beach, and primitives from the hills. All spoke different dialects.

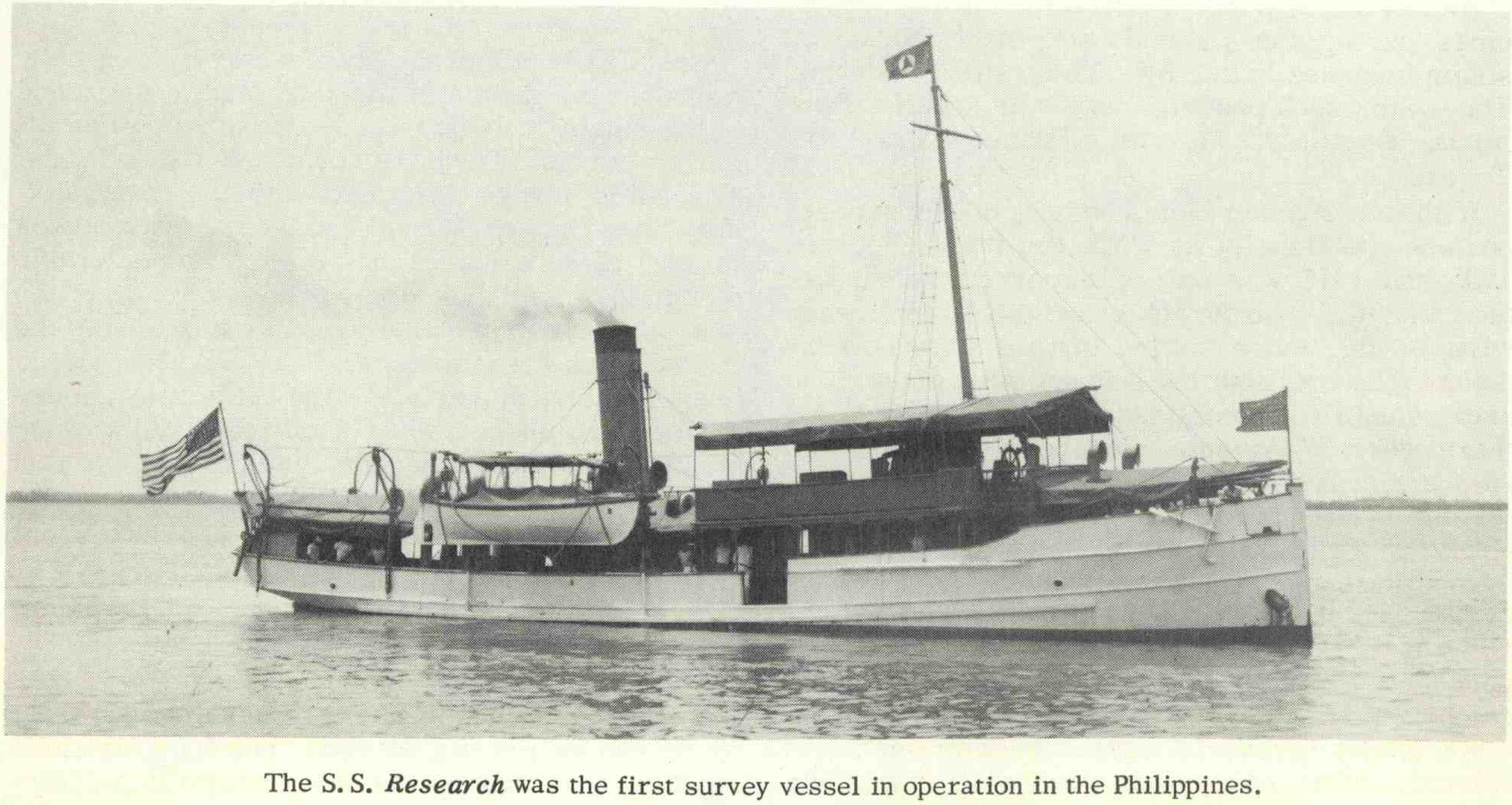
So! The first survey party "sigued" or rather "rushed off" to Dagupan. Then, after arriving there at about 3 o'clock in the afternoon of the same day, it waited 2 more days for transportation to Sual, a then important port of call on Lingayen Gulf.

The observations for latitude and longitude at Sual showed a difference in position from that given by the Spanish and indicated that such disagreement might be expected elsewhere. The latitude differed by 2' 42" from the Spanish chart and 1' 53" from the British Admiralty and United States Hydrographic Office charts. The longitude differed 0' 46" and 0' 25", respectively.

As field work was attempted it was found that launches and boats in any way suitable for hydrographic surveying were only obtainable at the few major ports and then only rarely. Ships were indispensable for carrying on offshore work and to furnish dependable transportation for the field parties. An over-all scheme of triangulation connecting the various islands could not be attempted without ships.

SURVEY VESSELS

The first survey vessel in operation was a small wooden steamer *(S.S. Vitaliana,* renamed *Research)* purchased early in 1901 by the Insular Government. The original agreement for operations specified that the Insular Government supply two vessels and the Federal Bureau one. All ships' officers and other technical force were to be supplied by the Coast Survey. The ***Research*** was 101 feet long, 15 feet extreme breadth, and 95 tons displacement. She had a draft of 8 feet 6 inches and made about 10 knots in smooth water. There were quarters of a kind of 7 officers and 12 men, and an additional 9 men slept



The S. S. *Research* was the first survey vessel in operation in the Philippines.

on deck. Boat equipment was a 22-1/2-foot whaleboat, a 19-1/2-foot cutter, and two 16-1/2 foot dinghies. Small-boat hydrography was done under sail or under oars. This small vessel, commissioned in October 1901, gave faithful service throughout the islands until sold in 1917.

The Coast and Geodetic Survey steamer *Pathfinder*, at that time the newest and largest survey unit in the States, arrived in Manila in November 1901 direct from a season in Alaska. She continued at work in the islands until scuttled in the waters of Manila Bay, off the Cavite Naval Station, at the beginning of World War II. This vessel began its work on a survey of San Bernardino Strait and its eastern approaches. Afterwards, as it was a large and thoroughly seagoing vessel, its efforts were usually confined to the more exposed sections of the coast.

Plans for an additional vessel for the Insular Government were drawn up in 1903 and the ship was constructed to Bureau design at the Whampoa Dock Company plant in Hong Kong in 1904. The *Fathomer*, too, reached its end in World War II when it was beached near Corregidor.

The Insular Government made two additional vessels available for survey duty in 1905. These ships, the *Romblon* and *Marinduque*, were twin-screw, composite steamers built in Japan for the Philippine Coast Guard only a short time before. Shortage of officers available for duty in the Philippines made necessary a considerable curtailment of field work after World War I, and the *Romblon* was sold in 1920. The *Mariduque* in later years operated almost entirely among the southern islands and in the Sulu Sea; it was decommissioned and sold in 1932.

Annual reports of the Directors in the Philippines during the first decade mentioned hired steam launches in use by various survey parties. They bore such peaceful names as *Amelia, Filipinas, Comillas, Morven, Evening Star,* and *Teresa*.

With five steamers and a number of shore-based parties continually at work the decade between 1905 and 1915 was one of major effort. It was then that the hydrographic and topographic surveys of the more settled central islands were made. The coordinating triangulation of the same area was also completed. In the year 1911, there were 27 American officers, 12 mates and ship engineers, and 11 recorders on duty in the islands. The ships' crews were composed entirely of Filipinos. By the end of 1915 it was even felt in some quarters that the greater part of the archipelago frequented by shipping had been charted with sufficient accuracy for navigational purposes. Actually much work remained to be done.

As all the vessels consumed coal and had limited bunker space, the matter of obtaining a resupply of fuel was always a problem. Imported coal was available in Manila. In later years, a mine was opened at Liguan near Legaspi and coal of fair quality could be loaded there. Another mine operated for some time at Malangai in southern Mindanao but this coal was of somewhat indifferent quality. At times some coal could be secured from government storage at Puerto Princesa in Palawan.

Long runs to obtain fuel were usual. To eliminate this the Survey at one time built a wharf at Coron in the Calamianes island group and coal was stored there while work was in progress in that area. Coal was also delivered by freighter from Japan.

Vessels operating in the Sulu Sea and along the southern Palawan coasts ran to Sandakan in British North Borneo where local coal was obtainable.

Fueling everywhere was always a long, slow process, as coal usually came aboard in baskets slung on a pole between the shoulders of a couple of men. In Sandakan, many Chinese women were employed in carrying coal. There was always much clatter and much shouting, and much dirt.

Fresh water in quantity at dockside was never available at any but the major ports, and ship storage was so limited that boating water from streams was always common practice. If a convenient waterfall could be found a pipe was sometimes laid and the slow process began of filling a whaleboat and towing it out to the ship. More often a hand pump and a hose was the only way of filling the boat.

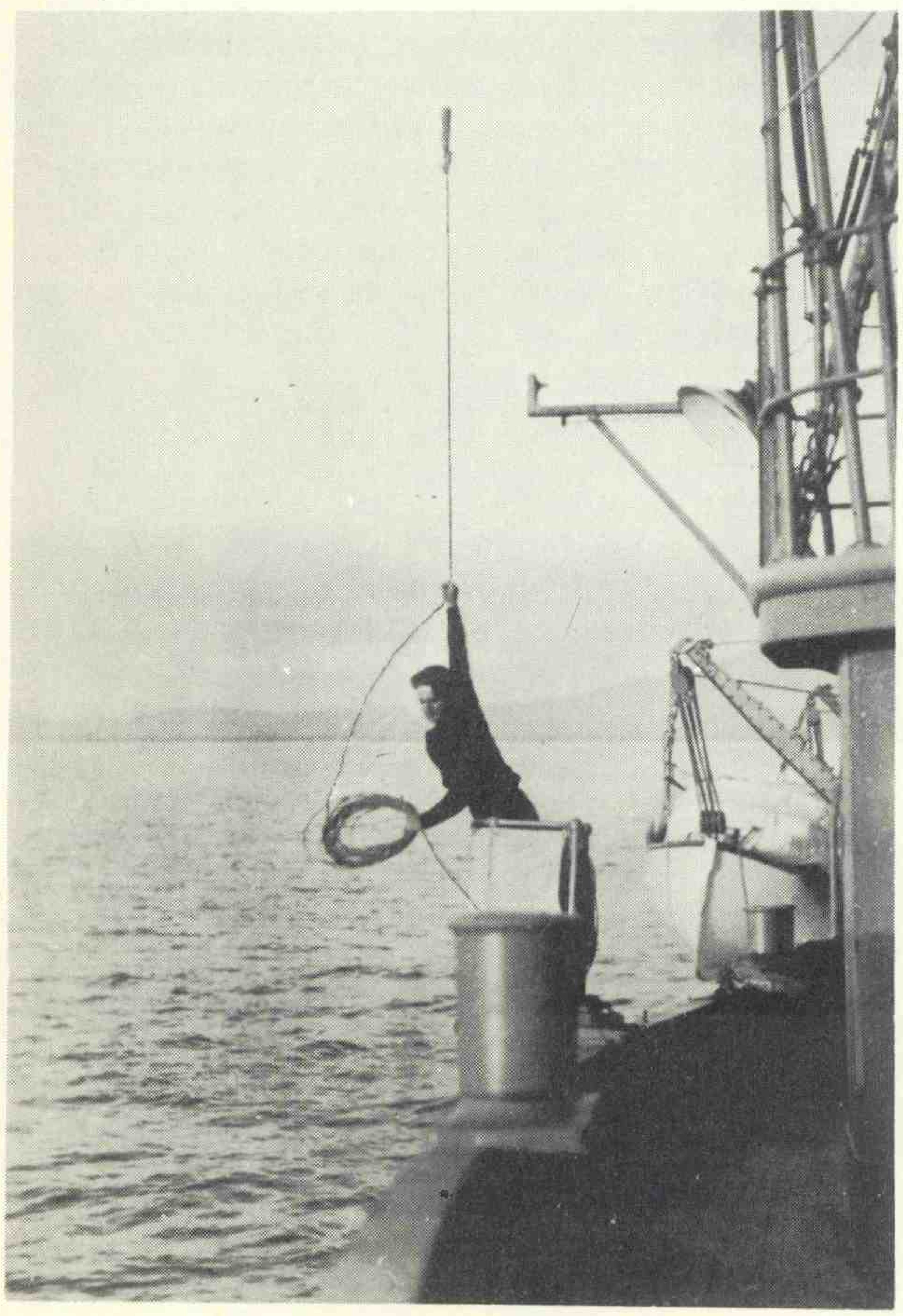
HYDROGRAPHY

Practically all of the shoal water hydrography was done by means of the hand lead to the sound of the singing cadence of the leadsman calling off the soundings. They are counted in the millions. The ships always navigated with a lookout aloft searching the sea. Coral shoals are often steep-to and of small area but even at considerable depth show well as discolored water when the sun is right. Ship soundings, like those from the boats, were also made with the hand lead or, in deeper water, by vertical wire casts or by the use of pressure tubes. It was not until the 1930's, when the Fathometer came into use, that it became possible to record a continuous profile of the bottom. The ships were not even equipped with a radio before 1920.

TOPOGRAPHIC MAPPING

Topographic mapping of the shoreline was done by means of the planetable. The fringing coral reefs and mangrove-covered shore presented dif-

Planetable surveying in the Philippines



Sounding with the hand lead was the common method of doing hydrography in the Islands.

ficulties as did the rocky headlands overgrown with dense timber. Much of the work was done with the table set up in nearly waist-deep water. Crocodiles sometimes encountered in the swamp-lined streams of the southern islands were ever a source of anxiety. In places, a portable enclosure was set up about the table and the observer, and a rifleman stood by to guard against the danger of attack.

ASTRONOMIC DETERMINATIONS

The determination of the geographic positions of points throughout the islands by means of telegraphic longitudes and zenith telescope latitudes was of first importance. This work was greatly facilitated by the wide extension of the Insular telegraph system for military purposes. It was fortunate that this Coast Survey work was carried out promptly, as many lines were abandoned with the passing of military necessity. In fact, operation of the telegraph system was always somewhat uncertain. An observer reported in 1901 by letter to Manila that it was impossible to work longitudes at that time between Manila and Aparri at the north end of Luzon as "all messages are now repeated six times by hand and the telegraph line cannot be worked for even half the distance."

Despite such hindrance, 39 latitudes and telegraphic differences in longitude were determined by the end of 1906. The points were fairly well distributed over the archipelago from the north coast of Luzon to Zamboanga. They were marked and described for future reference and a meridian laid out or an azimuth measured at each station. The extension of the cable from San Francisco to Manila, by way of Hawaii and Midway, made possible a telegraphic longitude tie with stations at each of those places and completed a circuit around the world.

Additional work and some repeat stations were observed in later years when radio time signals became available. These were in conjunction with the world longitude determinations made in 1926. Gravity observations were also made in Manila at that time.

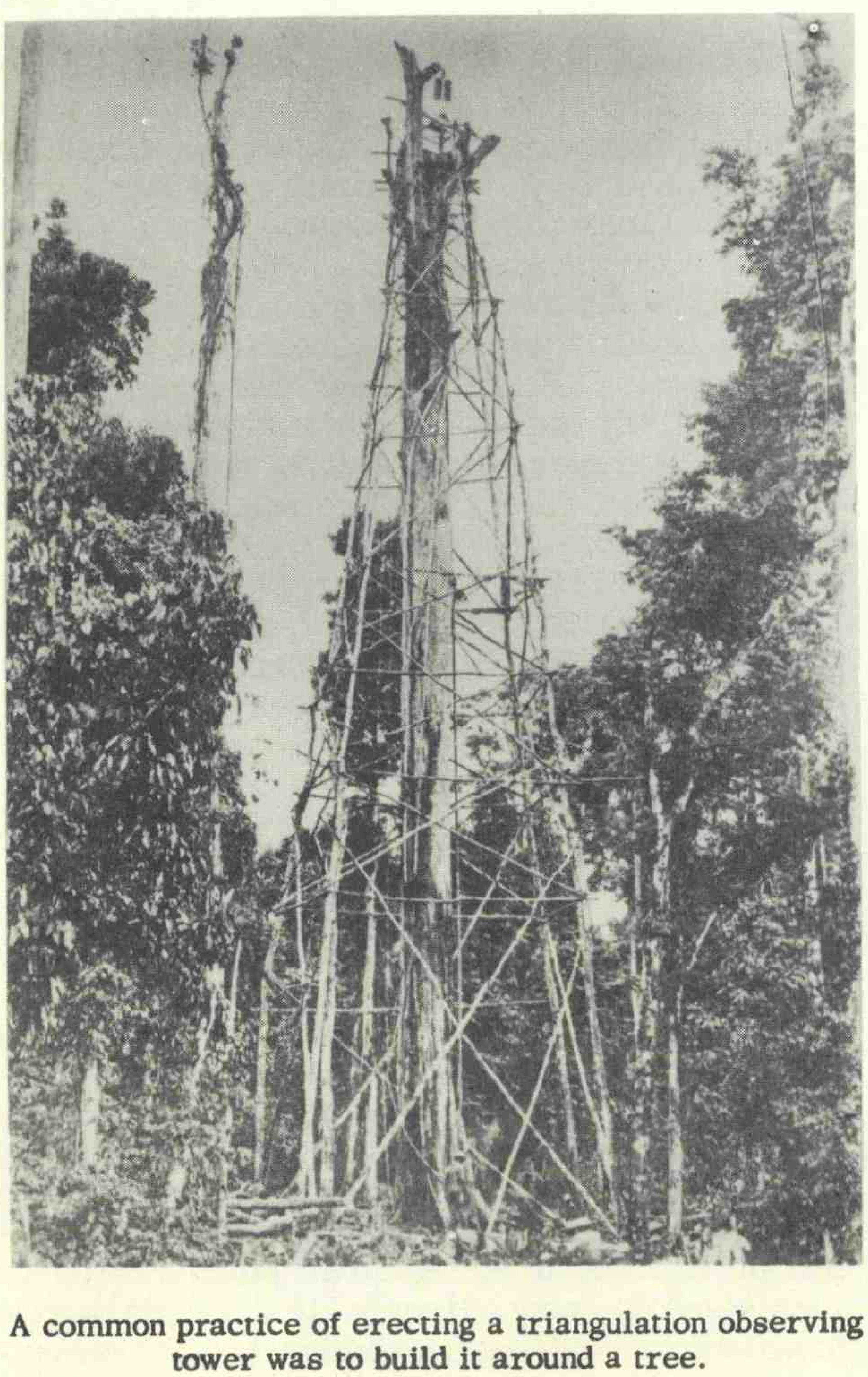
A MEMORABLE ASSIGNMENT

In the absence of more modern surveys, any pertinent information concerning the coasts, sailing routes, and dangers to navigation that might be encountered was invaluable to shipping interests. The Manila office of the Coast Survey always made special effort to gather and supply such data. The nautical expert who was detailed to that office collected much information in a number of cruises to the various ports visited by interisland shipping. He quickly developed a wide acquaintance with ship captains and these seafaring men in turn supplied him with a continuous stream of material which ultimately found its way into the published *Notices to Mariners* and *Sailing Directions*.

Survey operations, as they progressed, also supplied a great wealth of information that could not well be incorporated in the charts, and the *Coast Pilot* grew until there was complete coverage of the archipelago.

After 3 decades there came a very pressing need for a thorough field examination to bring the publication up to date through an actual determination of which parts of the *Pilot* were still correct. New and additional material was also required. This revision was made in 1937, 1938, and 1939--a very opportune time, as the war years found a new two-volume *Pilot* available for use. A running check had also been made of the charts and numerous corrections effected.

This field examination was probably one of the most interesting assignments any one Coast Survey officer ever had. An 80-foot launch was supplied by the Commonwealth Government and a cruise of over 9,000 miles was made throughout the islands. Some 1,600 miles were also covered by automobile. By the time the examination was completed there were only a few portions of the entire shoreline that had not been visited and investigated in detail because of their inaccessibility.



A common practice of erecting a triangulation observing tower was to build it around a tree.

The automobile trip up the Cagayan Valley to Aparri, then westward along the north coast of Luzon and down the west coast of Lingayen Gulf was a venture in itself.

West of Aparri every stream had to be crossed on rafts of bamboo. At one place a carabao hauled the car through a particularly muddy stretch of the road.

Beyond Pamplona it began to rain, and near Pasaleng where the road skirts the mountain side, the officer was informed by a Filipino official that "the bridge is falling down, but if you hurry they will hold it until you get there and you can pass." The little matter of passing meant driving the length of some heavy planks laid to span the partly caved-in mid-section of the bridge. The whole thing collapsed a few minutes later despite all efforts to prop it up.

With darkness, further travel became impossible on the muddy road and in the driving, tropical rain. The night was spent in the car pulled off the highway. Busses, however, driven in the usual carefree native manner, careened wildly by with much shouting several times during the darkness. The government rest house was a really welcome sight when it was reached some hours after daylight.

TRIANGULATING THE ISLANDS

The triangulation operations of the Coast and Geodetic Survey in the Philippine Islands were designed primarily for control of the hydrographic and topographic surveys. In general, triangulation was confined to a relatively narrow strip of land along the coasts, as movement into the interior was quite difficult due to the rough and heavily timbered terrain and the lack of roads and trails. The matter of carrying a general scheme of relatively large figures the full length of the archipelago and from shore to shore across the channels was early decided upon. This coordinating scheme of triangulation was needed to tie all the Philippine mapping together.

A start was made by executing small local networks to control the early detached surveys. In January 1903, the continuous coastal triangulation of northwestern Luzon was started. By the end of 1905, there was a connected scheme all the way to Manila. The overland connection from Lingayen Gulf to Manila, which followed the valley traversed by the railroad, made a good start for the general control of the islands.

By 1913, a connected scheme of triangulation had been extended southward over the intervening water areas to the island of Mindanao, and southwestward to Palawan. This permitted an adjustment upon a uniform datum.

Connection to the south side of Mindanao from Iligan to Illana Bay was held up for some time by the unsubdued Moro tribes in the Lake Lanao region. This work was finally accomplished with the assistance of one company of the 21st Infantry. Difficulty was also experienced by the ship *Pathfinder* in attempting to get triangulation to Baganga on the east coast of Mindanao.

Along the coasts of Mindoro and Tablas, the peaks which had to be used were between 2,000 and 3,000 feet high. Many of them were thickly overgrown with trees and from a half to a day's travel from the shore. It was a real problem to supply the observing parties who often camped from 1 to 2 weeks near the summit.

The extensive triangulation scheme which paralleled the east coast of Palawan in 1917 was a particularly difficult piece of work. The mountain peaks along the backbone of the island are as high as 6,800 feet and each station occupied became an individual journey of exploration. The Palawan country is very wild and covered with heavy undergrowth with no trails or communications whatever. Even the wild hillmen were familiar only with the immediate vicinity in which they lived.

As much as 8 days were required to reach the most difficult stations, and parties were away from the ship as long as 3-1/2 weeks. A party reported that at one place they had "built the longest tunnel in the world." They had cut an actual tube through the jungle from the coast to the station.

It required 9 days of travel from the beach to reach the top of Mount Mantalingajan, westward of Brooks Point. The survey party consisted of an officer and two sailors from the ship *Romblon* and 11 Tagbanua natives of the area. Water was scarce, so that after reaching an elevation of 3,000 feet the party had to depend almost entirely on rainwater or on the little water found in pitcher plants. Nights at the top were intensely cold. There was one place where the route, on approaching the final ridge to be ascended, passed through an area covered with scrub hardwood trees so dense that it was practically impossible to cut a trail. When this station was reoccupied in 1930, during the extension of triangulation northward along the west coast of the island, the party cut poles and laid a half-mile long runway 20 feet above ground in the treetops.

Bulanjao Peak to the southward of Mantalingajan and some 3,500 feet in elevation also presented considerable difficulty.

After ascending the Iwahig River to the head of boat travel and using up 3 more days on the trail, the Moros refused to go any further and the party returned to the beach. A new party was formed with one officer and four men from the ship, and four Tagbanuas were induced to accompany the party. The peak was reached in 3-1/2 days.

As the southern end of the Palawan triangulation scheme was approached, taller and taller towers had to be built to get above the trees. The record tower, on Bugsuk Island, was 235 feet high and constructed entirely of poles cut in the forest.

By 1918, the war conditions had so increased the cost of operations that only three vessels continued survey work. A further though temporary curtailment of effort was caused by the influenza epidemic which was so severely felt that at one period the whole company of the *Pathfinder* was incapacitated and eight persons died. On the *Fathomer* there was one time when only two men could be mustered on deck. By the end of 1920 and for several years thereafter there was such a serious shortage of officers in the States that resumption of survey work on the islands was impossible on the previous scale.

After the close of World War I, the major effort of the Coast Survey in the Philippines was shifted to the southern islands, but some work was continued along the north and east coasts of Luzon as the seasons permitted.

The triangulation which then began its extension southward through the Sulu Archipelago made final connection with the British work in north Borneo in 1938. This completed a continuous line from the most northern island of Y'Ami as an overland scheme had recently been measured through the Cagayan Valley from the north coast of Luzon to Lingayen Gulf. An extension also ran eastward from this last scheme to a connection with the Luzon coastal triangulation in the vicinity of Palawan Bay.

There was only one place in the Philippines where triangulation was not used for control. This was along the wild south Mindanao coast between Lebak and Sarangani Bay, where a traverse connection was measured along the beach.

Survey work in general was completed everywhere by 1940. The final work off the Borneo coast was ended at the beginning of World War II.

TRAINING PROBLEMS

One of the great problems facing the Survey at its establishment in the islands was that of securing an adequately trained field and office force. Career employees were sent from the States to officer the ships and head the shore parties on definite tour of duty. The difficulty was in enticing persons from the States to duty in subordinate positions in a hot climate so far from home and at the small salaries then prevalent in the Government service.

It was originally hoped that Filipinos could be more completely utilized in the surveying operations than was actually found possible. At the time of the American occupation there were few if any Filipinos with an engineering education. In fact, there was no school in the islands comparable to an American high school. This lack of an engineering education combined with little if any knowledge of English was the great drawback in employing native help. The only recourse was to slowly train a staff of native employees to ultimately replace the civilians brought from the States.

Chart compilation, as an example, requires a high degree of individual technical judgment as well as artistic skill and common sense. Despite early difficulties in securing men with such particular qualifications, there were ten or more Filipino draftsmen working under supervision in the Manila office as early as 1903. The training program for the employees was continued to the point where in later years the office was completely staffed by Filipinos, with the exception of the director--a commissioned officer of the Coast Survey--and his two civilian assistants. A number of men had even been sent to the United States for periods of advanced instruction in the Washington office of the Survey.

Further impetus came to this instruction program with the establishment of the Philippine Commonwealth. Complete severance from any direction in field or office activity was of course contemplated for the day of complete independence. In 1936, a number of Filipino cadets were taken aboard ship to receive specialized training as a nucleus for a future field force. These young officers were the product of the now more mature Philippine educational system and some of them had additional schooling in the United States.

The beginning of World War II found the Coast Survey personnel still engaged in survey work but in an almost entirely advisory capacity. Vessels were captained by Coast and Geodetic Survey officers and there was still a director in Manila. The bombs on Manila which ended all operations also unfortunately ended the life of the director. One officer and the civilian assistant to the director (also an Army reserve officer) were taken at the fall of Bataan and endured Japanese captivity in Korea. Another officer was killed in 1945 in the torpedoing of a Japanese vessel transporting prisoners of war. The officers' wives and the officer succeeding the director in Manila were interned in Santo Tomas until finally freed on recapture of the city.

At the cessation of hostilities there was by good fortune a Coast and Geodetic Survey officer on duty with the Army in Manila. He saw the need for reestablishing the Survey office and was granted permission and assistance in bringing some order out of the chaos. The former employees of the service were readily located but the damage, which included the buildings, vessels and small boats, instruments and equipment, and the reproduction plant, was hard to repair. The records were completely destroyed and much of the information in them was thought lost forever. A thorough search of all possible sources, however, throughout the islands and in the States during these intervening years unearthed as much as 85 percent of the control data. Most of the hydrographic and topographic information was recoverable, as the plotted survey sheets had been reproduced and sent to the States before the war. Only the very recent surveys were lost.

The successor to this reorganizing officer administered the Coast Survey's participation in the Philippine Rehabilitation Program during the years 1947 to 1950. Under the Philippine Rehabilitation Act of 1946, an agreement between the United States and the Republic of the Philippines, the Coast Survey was authorized to continue until June 30, 1950, such survey work as it had conducted prior to December 7, 1941. The particular job of the Bureau was to furnish a commissioned officer as director, to aid in the establishment of a counterpart Philippine organization under their Department of National Defense, and also to train personnel in both the Philippines and in the United States.

Some 50 Filipino trainees were carefully selected from engineering graduates of Philippine Island colleges and sent to the Coast Survey office in Washington for 10 months of intensive instruction in all phases of survey work, including final chart reproduction. These trainees are now the officers of the Philippine survey ships and fill the key administrative and operational positions in the Manila office.

CONCLUSION

What were the positive accomplishments of the United States Coast and Geodetic Survey during the 40 years that it was actively engaged in the Philippines? Surveys were completed of approximately 98 percent of the water and coastal areas. Only a small portion of the west side of Palawan and of the southern Sulu Sea remained unsurveyed. The 136 Spanish charts were replaced by a modern series of 12 general sailing charts and 152 coast and harbor charts. All this was done at an expenditure of approximately $11 million paid jointly by the United States and by the Insular Government. (This, however, does not include the salaries for officers which were paid entirely by the United States Government.) The Republic of the Philippines was left with a trained and organized Bureau of Coast Survey capable of maintaining the legacy left them.

A Century and a Half of Scientific Nautical Charting

A. L. SHALOWITZ

U. S. Coast and Geodetic Survey

(Awarded Second Prize in the Sesquicentennial Essay Contest)

TO A MARITIME NATION such as the United States, the safety of its waterborne commerce is dependent on a full and complete knowledge of the coast, its nature and form, the depths of the water and character of the sea bottom near it, the locations of reefs, shoals, and other dangers to navigation, the rise and fall of the tides, the direction and strength of currents, and the behavior of the earth's magnetism in areas which must be navigated. Such information is furnished by the nautical chart. Without the chart our great ports and harbors would be as effectively closed to maritime commerce as if blockaded by an enemy fleet.

The need for such undertaking was recognized almost from the beginning of our national independence. The young nation was concentrated along the Atlantic coastal plain, fisheries and shipbuilding were important industries, and waterborne commerce between the harbor cities was the medium for the movement and exchange of these and other products. To promote that commerce and to develop trade with foreign nations, President Jefferson, on February 10, 1807, signed into law the Act which set in motion the machinery for surveying and charting the coast and harbors of the United States together with the outlying islands and fishing banks. This was the inception of the Coast Survey, and it is this historic event that we are observing in this year 1957--150 years later.

EARLY PIONEERS

In commemorating this century and a half of charting progress, we cannot fail to take note at the outset of the many men of science and engineering who were associated with the Coast Survey and who, in their respective fields, broadened its horizons--men such as George Davidson, who authored the ***Pacific Coast Pilot*** of 1889, the most complete record of the coast ever to be published for the use of the mariner; Rollin Harris, who pioneered in the field of tidal research and published a voluminous ***Manual of Tides***, in which a new and comprehensive theory of the tides was formulated; Charles Schott, who for 50 years directed all the intricate computations and adjustments of field observations required in the geodetic, magnetic, cartographic, and tidal operations; and John Hayford, whose investigations of the size and shape of the earth resulted in the derivation of a new figure, the International Ellipsoid of Reference. These are only a few in a long roll--a roll of honor in the annals of the Survey. But tribute, in particular, should be paid to two early leaders--Ferdinand Hassler and Alexander Bache--under whose direction the Survey evolved from a mere concept into an organizational entity with a fully developed plan of execution that became easily adaptable to a developing and expanding America. Both bequeathed to the Bureau a heritage of zeal and singleness of purpose that has been an inspiration to those who have followed them.

FERDINAND R. HASSLER

Ferdinand Hassler, may rightly be called the "father of the Coast Survey." It was his plan that President Jefferson accepted for the survey of the coast, and it was he who was later entrusted with its direction. It was fortunate for the country in general, and for the Bureau in particular, that so far-seeing a person as Professor Hassler, with the indomitable will and courage of the pioneer, was chosen to organize and direct the operations of the Survey. Hassler immigrated to the United States in 1805, at the age of 35, after filling a number of the most important official positions in his own land, Switzerland--among them those of head of the Geodetic Survey, Attorney General, and member of the Supreme Court.

Hassler's fundamental plan provided for a division of operations into three great branches--the geodetic, the topographic, and the hydrographic. Of these, he considered the geodetic operation to be the most important, for it affected the accuracy and final value of the other two. Hassler's plan had the approval of the most eminent scientists of Europe and of this country. It is a tribute to his farsightedness and his genius that his original plan of organization, broadened and thoroughly worked out in succeeding years, is still the fundamental directing plan of the Bureau a century and a half after its adoption.

The difficulties that faced Hassler would have

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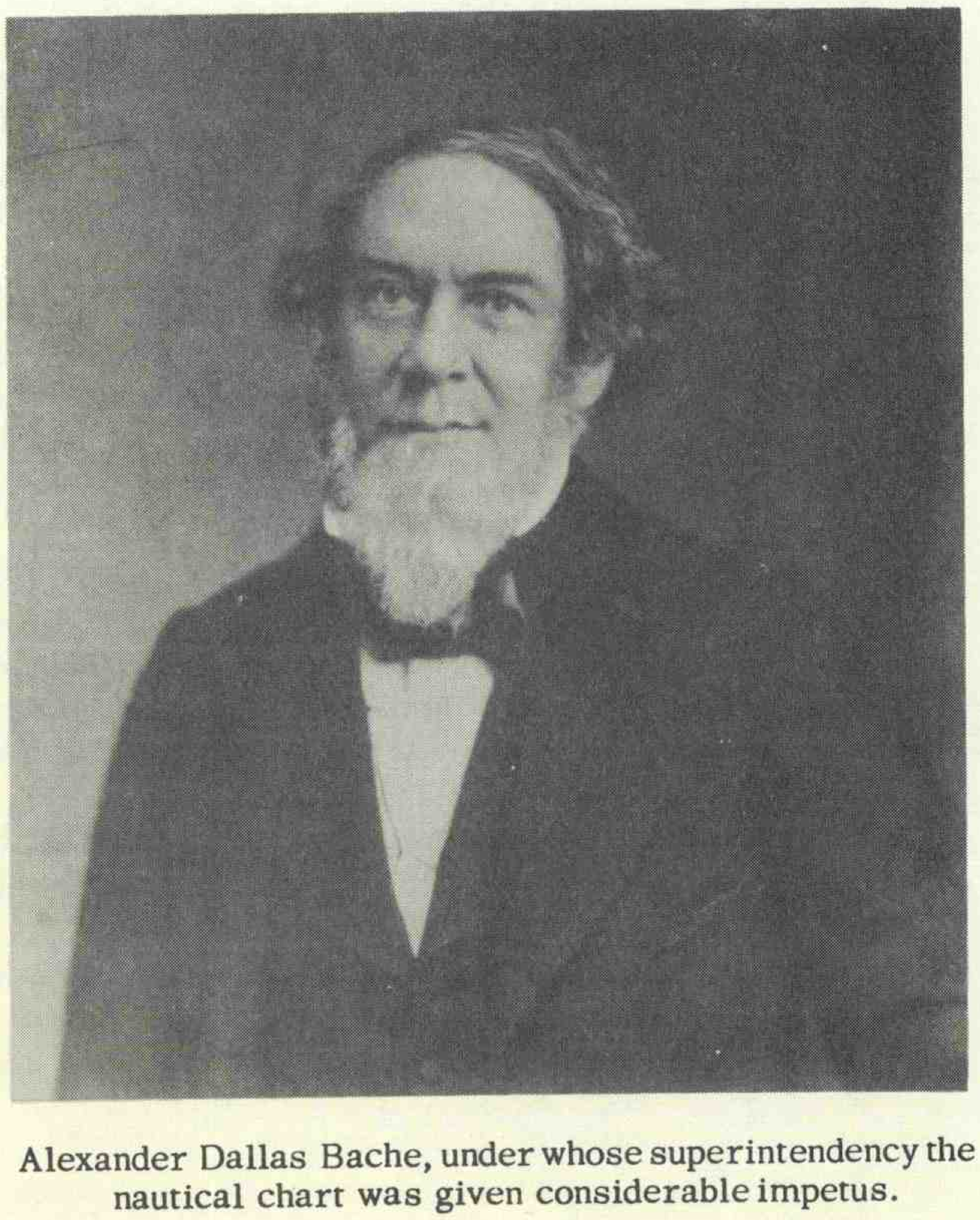
completely discouraged one of less strength and fortitude. Instruments such as those necessary for a geodetic survey were not available in this country at the beginning of the 19th century. Hassler had to prepare his own drawings and designs, and some of the more important ones, such as theodolites and chronometers, that were eventually constructed for him bear the impress of his inventive genius in the shape of modifications and improvements that he devised. It is an interesting fact that not a single working observatory for the training of astronomers existed in this country at that time, and there was not a single college that included a course in geodetic surveying in its curriculum.

Although the need for results was urgent, the level-headed Hassler fortunately did not allow himself to be stampeded into haphazard decisions. Instead, he approached the great task scientifically and never deviated from the high standards he set for the work. He knew that the survey of the coast, if it were to have a lasting value, could not be attacked as a problem of ordinary surveying. The operations were to be bound together by a trigonometric survey with long lines, and executed by the most accurate instruments and the most refined methods. The best of foundations was thus laid for the geodetic operations of the Bureau. This was Hassler's great contribution. Had he planned to meet only the needs of his time, he would have effected but a negligible saving, and his work would have had to be done over at greater expense in later years. Instead, the first Hassler surveys meet modern requirements and, today, form part of the permanent primary network of the country.



Alexander Dallas Bache, under whose superintendency the nautical chart was given considerable impetus.

ALEXANDER DALLAS BACHE

When Hassler died in 1843, the foundation for the survey of the coast had been laid, and the detailed surveys of the ports and harbors were begun with a survey of the approaches to New York Harbor. The building of the superstructure fell to his successor in office, Alexander Dallas Bache. Bache was the great-grandson of Benjamin Franklin and a grandson of Alexander Dallas, Secretary of the Treasury under President Madison.

During his lifetime, Bache held many responsible posts, any one of which might have been considered the successful culmination of a life's work and ambition. His rise to positions of prominence in the fields of education and science was meteoric. As a West Point cadet he distinguished himself by his scholastic excellence, graduating at the head of his class at the age of 19. At 22 he was named to the faculty of the University of Pennsylvania as professor of natural philosophy and chemistry. In addition to his 8 years at the university, his service to American education included the presidency of two of our foremost schools--Girard College and the Central High School of Philadelphia; the general superintendency of a city school system; and the publication of a monumental work on European education, the result of 2 years of intensive study abroad.

Bache attained preeminence while serving as head of the Coast Survey. His selection to this important scientific and technical post had the concurrence of all the principal scientific and literary institutions of the country. It was said that no such weight of recommendation was ever brought at any time, in support of a candidate for office on purely intellectual grounds.

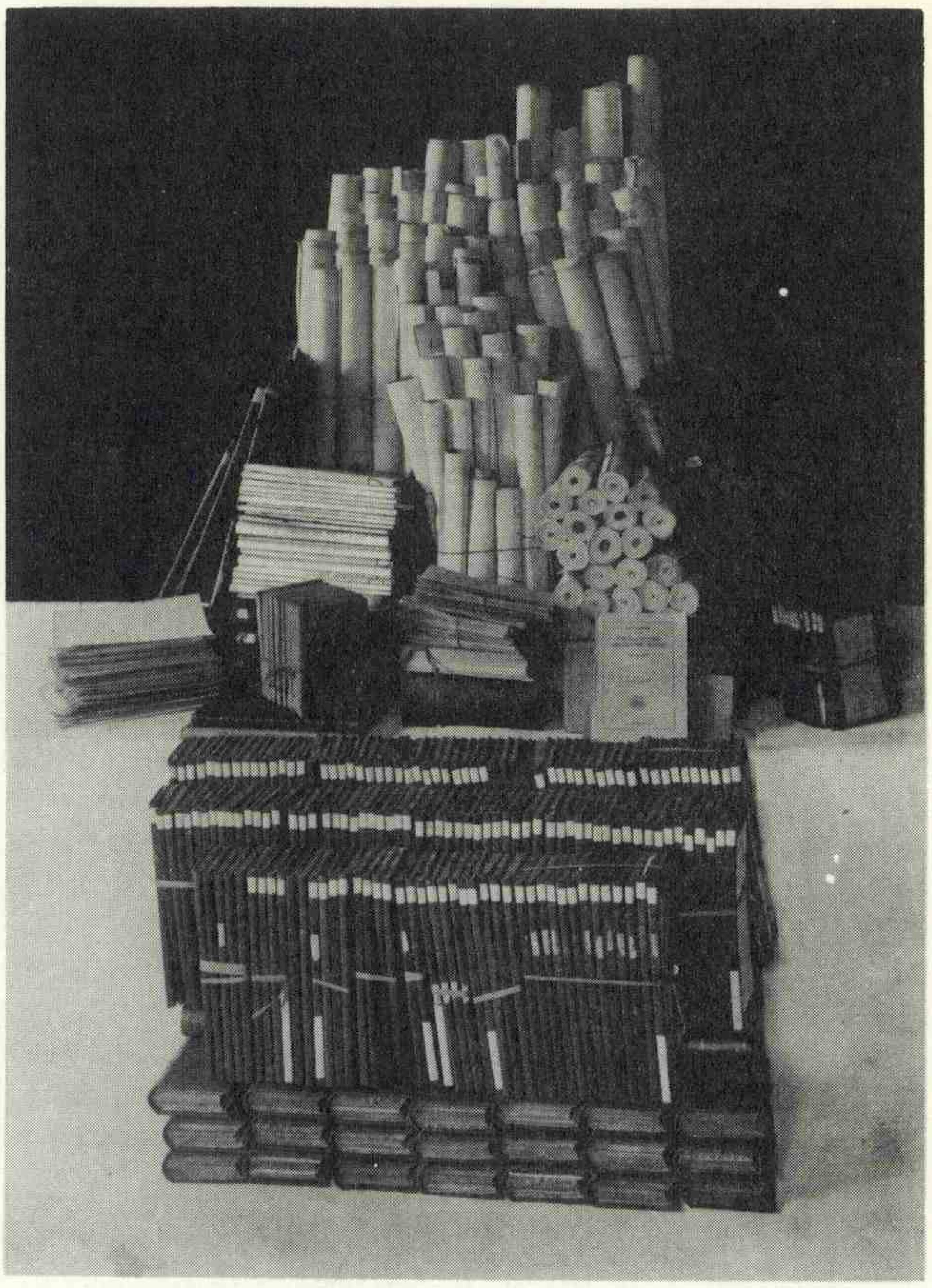
In original concept, the plan for the Survey of the Coast was Hassler's, but Bache gave it form and direction. Hassler built on a rigid scientific foundation; Bache adapted that plan to an expanding America. (Texas, California, Oregon, and Washington were added during his tenure.) His determination that the maps and charts of the Coast Survey should be carried to every man's door having an interest in commerce, navigation, geography, or science, was an indication of his broad vision of the scope and purpose of the Survey. Under Bache's careful guidance and sympathetic understanding, the Coast Survey not only kept pace with the progress in art and science but many notable and original contributions were made in the fields of practical astronomy, physical hydrography, and cartography.

THE MODERN NAUTICAL CHART--END PRODUCT OF SYSTEMATIC SURVEYS

In assessing the contributions of the Coast Survey to the development of nautical charting, cognizance must be taken of the fact that what had previously been called a chart was largely the result of exploration or of limited surveys, and was generally the work of individual effort and private undertaking. The Portolanos of the 14th century, the Cosa chart of 1500, and the Atlantic Neptune charts of the late 18th century are all examples of this exploratory period. These, like all the early charts, suffered from two great defects--the want of detailed surveys and the lack of a rigid system of connection between the various ports.

Not until the early part of the 19th century did governments begin to recognize the wisdom of systematically charting their coastal waters as a necessary prelude to their commercial intercourse with other nations. This marked a new era in chart making and was the beginning of the accurate chart of today.

The modern nautical chart is the end product of all the field operations. Into its construction enter the results of the geodetic, topographic, hydrographic, tidal, and magnetic work of the Bureau. Progressive improvement in the nautical chart is, in the main, coextensive with the development of systematic surveying and of surveying techniques, including instrumentation and equipment. A consideration of these components is therefore essential in any evaluation of the nautical chart proper.



The nautical chart is the end-product of all the field operations of the Survey. This shows the many records that go into the making of a single chart.

A GEODETIC BASE FOR CHARTING

That good and reliable charts can be made only from correct surveys is a truism that need not be belabored to the engineer and the scientist. No one appreciated this more than Hassler. From the very beginning he insisted on a strong triangulation as the backbone for all the harbor and coastal surveys, but the need for this was not so obvious to others, and, as a result, Hassler was subjected to much humiliating criticism. His scientific approach, nevertheless, prevailed, and the tradition of accuracy which he inaugurated has been steadfastly maintained through a century and a half of progressively increased activity.

Triangulation is to the nautical chart what the steel framework is to a building--it gives it rigidity and knits together all portions into a harmonious whole. Without this framework of control, our charts would be subject to the same deficiency that characterized the charts of the Colonial period and exemplified by the Atlantic Neptune of Des Barres.

If a survey, or group of surveys, on which a chart is based, were to be positioned with respect to the astronomic latitude and longitude of an initial point, it would soon be found that discrepancies exist in the overlapping portions of adjacent charts, and scaled distances between points spanning two charts would not be true, nor would the geographic relationships be correct. Because of the varying density of the earth's crust and its effect on the plumb line, such results are inevitable if surveys are based solely on astronomic determinations.

In any engineering or scientific undertaking involving a large area, it is important that full coordination and correlation exist in the surveys, maps, and charts of the country. A hydrographic or topographic feature on the earth can have but one latitude and longitude, and it must be the same on every map or chart on which such feature appears. This can be accomplished only through the adoption of a single geodetic datum for the entire area; that is, by taking the position of a single point in the country as the initial or datum to which all other stations are referred. In the United States, this initial is station *Meades Ranch* in central Kansas. Its latitude and longitude on the spheroid of reference were fixed by mathematical adjustment based on a study of numerous astronomic stations throughout the country that had been connected by a continuous system of triangulation. Today, the whole of the United States, through Canada and Alaska to the Bering Strait, is coordinated on this single geodetic datum--the North American datum of 1927. The establishment of this datum has resulted in the complete coordination between nautical charts of the Atlantic and Gulf coasts and those of the Pacific coast and Alaska--a most enviable position for any country to be in.

Recently, the distant, offshore islands in the Bering Sea were connected for the first time with the triangulation network on the mainland of Alaska by a system of trilateration, in which the sides of the triangles were measured by electronic methods, the longest line being 501 statute miles. The successful completion of this project furnishes a control net for hydrographic surveys from which accurate charting of this vast, strategic area can proceed with minimum danger to men and ships.

THE ADVENT OF PHOTOGRAMMETRY

An important feature of the nautical chart is the land area, with its characteristic shore forms, landmarks, elevations, and depressions. In close, inshore navigation, a mariner relies a great deal on prominent shore objects to fix his position and sometimes even uses the configuration of the shoreline for identification.

From the beginning, the principal instrument used in the Coast Survey for topographic surveying was the planetable. The introduction of the telemeter rod, about 1865, for measuring distances with the alidade, greatly facilitated the surveying of complex shorelines and gave the chart increased fidelity. With proper precautions, a remarkable degree of accuracy is obtainable by this method of surveying.

The years preceding and following World War II saw the emergence and flowering of the new science of aerial photogrammetry--the greatest advance in topographic mapping since the prototype of the modern planetable was developed by Johann Praetorius, in 1590. Ground topographic methods are rapidly giving way to this more economical and more expeditious method of mapping from the air. The wealth of information and fullness of detail embraced in an aerial photographic survey cannot be matched by any other practicable method of surveying.

The design of a nine-lens camera by the Coast Survey--together with transforming, rectifying, and stereoplotting equipment--gave considerable impetus to our topographic survey work in Alaska, where difficult and inaccessible terrain could be bridged by this camera with a minimum of ground control.

Recently, a low-distortion, wide-angle, single-lens precision aerial mapping camera, which uses an infrared lens cone, was acquired. The use of infrared photography for mapping the high- and low-water lines will result in greater charting accuracy of these tide lines, particularly in areas that are difficult of access for identification of shoreline. Techniques are being studied for use of this type of photography, in conjunction with tide observations, for charting riparian boundary lines based on tidal definition.

The advent of photogrammetry in the Coast Survey has had two salutary effects on the nautical chart: (1) It has further increased the accuracy of the chart, particularly in inaccessible areas; and (2) it has brought within practicable scope the immediate revision of areas where natural or man-made changes have occurred--an important factor in safeguarding our sealanes.

HYDROGRAPHIC ADVANCES

From the standpoint of the nautical chart, the greatest advances made, since the early days of charting, have been in the field of hydrographic surveying. The chart can be likened to a map of the water area on which elevations above the bottom (depth soundings) are shown. Hydrography is thus the principal visible characteristic of the chart. By it the navigator is guided into the safe lanes and can avoid the known dangers.

Hydrographic surveying for charting purposes consists essentially of two simultaneous but independent operations: the measurement of depth and the determination of the survey vessel's position at the time the depth is obtained. The revolutionary advances made in this field during the past three decades have had a profound effect on the accuracy and usefulness of the nautical chart. Depth measurement by sound--better known as echo sounding--has superseded the hand lead and the wire machine, and electronics has replaced all previous, less accurate methods of position determination.

Echo sounding is based on the principle that a sound impulse sent out by the survey vessel will be reflected from the ocean bottom and will return to the vessel as an echo, just as echoes are received in air from distant objects. From the elapsed time interval and a knowledge of the velocity of sound in sea water, the depth can be determined. Echo-sounding equipment is designed to produce the sound, receive the echoes, measure the elapsed time intervals and convert them into depths, and register the depths on a dial or in the form of a graphic profile. The Coast Survey developed a precision, dial-type echo instrument (the Dorsey No. 3), which had a probable reading accuracy of 1/10 foot for soundings up to 100 fathoms.

Methods of positioning the sounding vessel in latitude and longitude, and, in turn, the soundings, have undergone more radical changes during the life span of the Coast Survey than perhaps any other activity. The early hydrographers, who operated close inshore, located their positions by sextant angles on shore objects. When out of sight of land, observations were made on the heavenly bodies, or "dead reckoning" was used. Although refinements were made in the latter methods, their application to hydrographic surveying still left much to be desired, and an accurately coordinated offshore survey was the exception rather than the rule. The first major change occurred in the late 1920's with the development, in the Coast Survey, of Radio Acoustic Ranging (RAR) for measuring horizontal distances over the water by means of underwater sound transmission. This was, in reality, an adaptation of echo sounding in which the horizontal path of the sound wave was used to measure the distances from the survey vessel to two or more known stations on shore or in the water.

While RAR is no longer in use, having been superseded by later developments in position determination, it is noted here because of its influence on the nautical chart. Together with echo sounding, it gave us a new conception of accuracy, as applied to offshore hydrographic surveys, and laid the foundation for the development of a new type of nautical chart.

World War II ushered in the electronic era. It is well known that electronics played an important role in the prosecution of the war. Shoran, a form of radar, was developed for strategic aerial bombing. The Coast Survey was first to adapt this technique to the accurate location of a survey ship's position.

Shoran is based on the principle that electromagnetic waves travel through the atmosphere at a nearly constant rate of speed—186,000 miles per second. In the familiar radar, dependence is placed on the reflection of such waves from natural objects. In shoran, this reflection is strengthened and specialized by use of responding stations set up at known points which return intensified signals.

Shoran constitutes no new principle in hydrographic surveying, but it does apply a new and more effective technique for determining distances from control points. Shoran does the job quickly, accurately, and independent of adverse weather conditions. Being a line-of-sight system, it is limited, under practical operating conditions, to distances of 50 to 75 miles with a probable error of 8 meters in a single measurement.

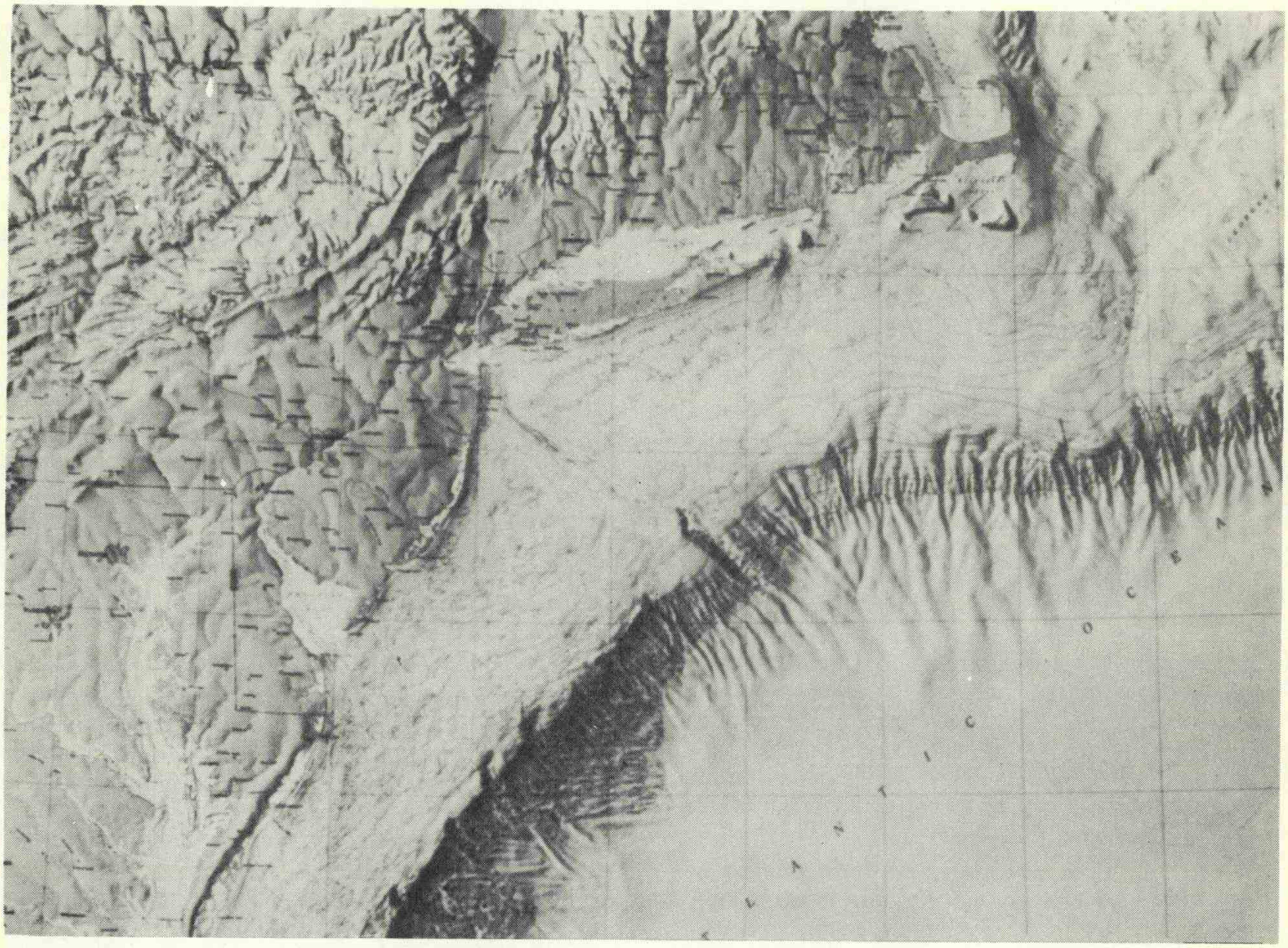
To extend the operating limits of shoran, a new electronic device, called the Electronic Position Indicator (EPI), was developed by the Coast and Geodetic Survey. This system combines the long-range characteristics of loran with the distance-measuring features of shoran and thus makes possible the measurement of distances in excess of 300 miles. EPI operates in the low-frequency range of about 2 megacycles per second and utilizes the ground wave, so that its distance range does not depend upon the elevation of the control stations. The principles of position fixing with EPI are essentially the same as with shoran; both involve the measurement of small time intervals of the order of one ten-millionth of a second. The overall accuracy of the system is about 75 meters and is independent of distance from the control stations. The maximum distance offshore to which EPI has thus far been carried is 550 statute miles.

The acoustic and electronic methods have steadily pushed seaward the frontiers of accurate hydrographic surveys. They have made feasible the exploration of the intricate patterns of our continental shelves and slopes with an accuracy and completeness undreamed of by the early methods, and thus have added to the safety of life and property at sea. The rapidity with which great depths can be measured by echo sounding (a matter of seconds compared to the hour or more required by the older method) has made it possible to take thousands of soundings in areas where formerly only a few scattered ones were economically feasible. This has increased immensely our sum total of geographic knowledge. And it is a gratifying circumstance that nearly all the Bureau personnel who have had a part in this revolutionary change-over are still alive today.

SCIENTIFIC CHART MAKING

What has been the impact of these developments in surveying techniques on the navigational chart? Mention has already been made of the lack of coordination that characterized the charts of the Colonial period. The first chart published under the auspices of the Coast Survey was in striking contrast to anything that had previously been called a chart of our coast. The outstanding improvements were high accuracy of geographic position, more thorough hydrography, and complete topography.

With each accession of new data, resulting from surveying developments, the nautical chart improved in accuracy standards and in coverage. But the chart also developed in its own right, cartographically. Since publication of the early



Submarine topography of continental shelf and slope along northeast coast of the United States.

charts, there has been a progression of improvements both in the character of the chart and in the methods of reproduction--all designed to enhance its value to the navigator.

CHART COMPILATION

Chart making is a combination of the work of the cartographer, who prepares the engineering drawing, and the engraver or lithographic artist, who translates the drawing into a finished product for reproduction. The nautical chart, unlike many other cartographic efforts, is intended for serious use in the solution of navigational problems; hence, all the rules of engineering must be meticulously observed in its preparation.

Chart compilation is a process of selection. The usefulness and accuracy of the chart depend not only on the material entering into its construction but also on the critical appraisal of such material and the intelligence with which the essentials are portrayed. "Easy reading is hard writing" may well apply to nautical charts. The skilled cartographer must sift, from the mass of data before him, the important from the unimportant, the strong from the weak, the stable from the changeable. Some data he rejects entirely, some in part, and he coordinates and selects from the rest the information that is to appear on the finished chart.

In addition to these engineering elements, the chart compiler must be ever conscious of the importance of artistry in the chart. There must be no crowding of matter to confuse the navigator, and there must be no haphazard arrangement to throw the chart off balance. It is just as important to make proper and effective use of various forms of graphic presentation in the chart as it is to study the values of different methods of verbal or written presentation.

A NEW TYPE OF NAUTICAL CHART

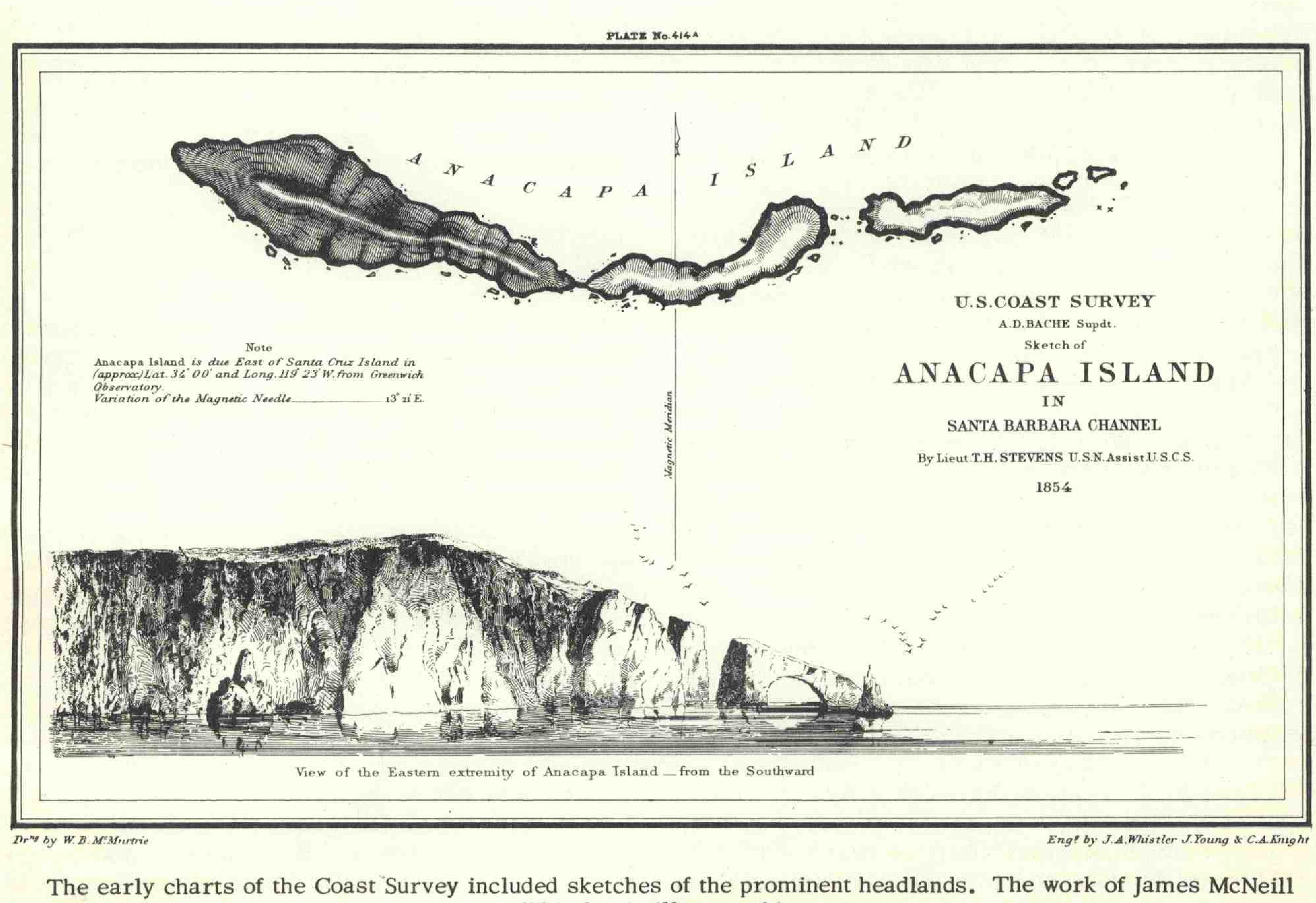
The most significant advance in nautical chart design--since the introduction of colors--was made in March 1939, when the Coast Survey published the first chart in which special emphasis was given to depth contours. The installation of echo-sounding apparatus on our naval and merchant vessels signaled the need for a new type of chart—one that would enable the navigator to utilize fully this new sounding technique for fixing his position at sea. It is axiomatic that the more faithfully the chart portrays the submarine relief, the greater will be its usefulness to the navigator. The answer was not found in an increase in the number of soundings charted; this was already a characteristic of the conventional chart. What was called for was a method that would utilize the wealth of submarine detail provided by modern hydrographic surveys, and that would portray this detail in a simple and useable manner. The new chart was the result.

In this chart, depth contours, which are equivalent to land contours on a topographic map, are given special emphasis. In the drawing of the contours, full use is made of all the soundings obtained on the hydrographic survey. Characteristic features of the ocean bottom are brought into prominence. These features are comparable to permanent landmarks and provide the navigator with a simple method for identifying his position by comparing a line of echo soundings with the charted depth contours.

Another significant innovation in nautical charting took place after World War II, when the United States Coast Guard established loran stations along our coasts as an aid to navigation. Lines of position in this electronic system are families of hyperbolic curves that do not lend themselves to ready plotting by the navigator, as is the case with a circular system such as shoran. To facilitate the navigator's use of this new aid, the Coast Survey, after experimenting with several methods of applying loran information to the charts, has evolved a form that combines the hydrographic information with the loran information without confusion and in a manner that makes the chart of maximum use to the navigator. Loran charts now include coverage of the Atlantic, Gulf, and Pacific coasts.

THE REPRODUCTION PROCESS

On the reproduction side, we have indeed traveled far from the early days of copper engraving and plate printing. Charts of this period were entirely engraved by hand--every line, every figure, and every letter. Many were artistic masterpieces. The fineness of detail that was made possible by this method of reproduction af-



The early charts of the Coast Survey included sketches of the prominent headlands. The work of James McNeill Whistler is illustrated here.

forded the engraver an opportunity for artistic expression seldom equaled by any other method. These early charts were all black and white reproductions. Many were embellished with elaborate views of harbor entrances and headlands for the guidance of the mariner. One of the finest of these was the view of Anacapa Island, off the southern California coast. This was engraved by James McNeill Whistler, who later achieved world renown as an artist. Whistler's stay in the Coast Survey was brief but hectic. The rules of the office he soon found too exacting for his artistic temperament, and he became an habitual late-comer. When chided about it in later years, his biographer tells us, he invariably replied: "It was not that I arrived too late in the morning, but the office opened up too early."

Photolithography paved the way for the introduction of colors and offset printing. Each rotary lithographic press in the Coast Survey today is capable of printing 3 to 5 thousand impressions an hour, as compared with the 100-a-day maximum that was possible with the older method of printing directly from engraved copper plates.

NEGATIVE ENGRAVING (SCRIBING)

The greatest single contribution the Survey has made in the reproduction process has been the development of negative engraving (now commonly referred to as "scribing"), around the turn of the century. This technique was first used as a more economical means of revising nautical charts. Revisions were applied directly to the wet-plate glass negatives using the conventional engraving needles then in use. Later, entire nautical charts were reproduced by this method. The compilation manuscript was photographed on glass negatives. These were then coated with an emulsion that was pervious to light and so afforded the engraver a facsimile of the manuscript. In 1935, the first engraving tool for specific use on glass negatives was designed. A special assignment for reproducing maps for the Tennessee Valley Authority gave impetus to the design of additional tools, and by 1940 all the basic instruments and techniques in universal use today had been perfected in the Bureau. Both glass and plastic are now used for negative engraving.

In the Coast Survey, the direction is toward complete conversion from drafting to scribing of final copy, in both the chart production and reproduction stages, so as to realize all of the inherent quality and economy of the technique.

AIDS FOR SAFE NAVIGATION

The modern nautical chart is thus a synthesis of the utilitarian and the artistic, suitable for meeting present-day demands for quantity and quality reproduction. It is a scientific achievement, the evolution of which has kept pace with the economic development of the Nation and with the progress in science and engineering.

It is of interest to examine the latest Coast Survey chart of the approaches to New York Harbor (Fig. 1) and note the variety of data which the navigator has available to fix his position as he enters or leaves the metropolis. (Tints and colors--not shown in the illustration--to accentuate the land topography, shoal-water areas, depth contours, etc., provide him with additional cartographic aids.)

At *A*, he has a range for a line of position through Ambrose Channel.

At *B*, he has a danger warning and channel marker--buoy with radar reflector by day, and light of fixed characteristics by night.

At *C*, he has radio beacons on the lightships and on shore for obtaining bearings by radio compass from the vessel.

At *D*, he has the height and visibility of lights for determining position.

At *E*, he has landmarks for taking angles and bearings--structures and natural objects by day and lights by night.

At *F*, he has depth contours for use with an echo sounder.

At *G*, he has Loran lines of position for use with his Loran receiver by day or night.

At *H*, he has isogonic lines (lines of equal magnetic declination) to be applied to his magnetic compass.

One rightly wonders how the ancient mariner, without any of the modern navigational aids and contrivances, ever managed to reach his destination. Perhaps the answer is that very often he didn't!

THE FUTURE

Thus, the work which Thomas Jefferson launched a century and a half ago, when our coastline was confined to the Atlantic seaboard and to a small stretch along the Gulf of Mexico, has been patterned through the years to a developing and expanding America. The cession of Florida and the Pacific coast states, the annexation of Texas and the Hawaiian Islands, the purchase of Alaska, and the stewardship over the Philippines, all added to the charting responsibilities of the Bureau.

The Coast Survey views with gratification and pride the contributions it has made to the overall program of surveying and charting our coastal regions. But its mission is not yet ended, nor will it ever be, as long as changes wrought by man and nature leave their impact on our shores. Change and not stability is the order of nature. This finds significant expression along the seacoast and the littoral. Breakwaters and jetties are built, channels and harbors are dredged, and new paths of commerce are opened. Rivers

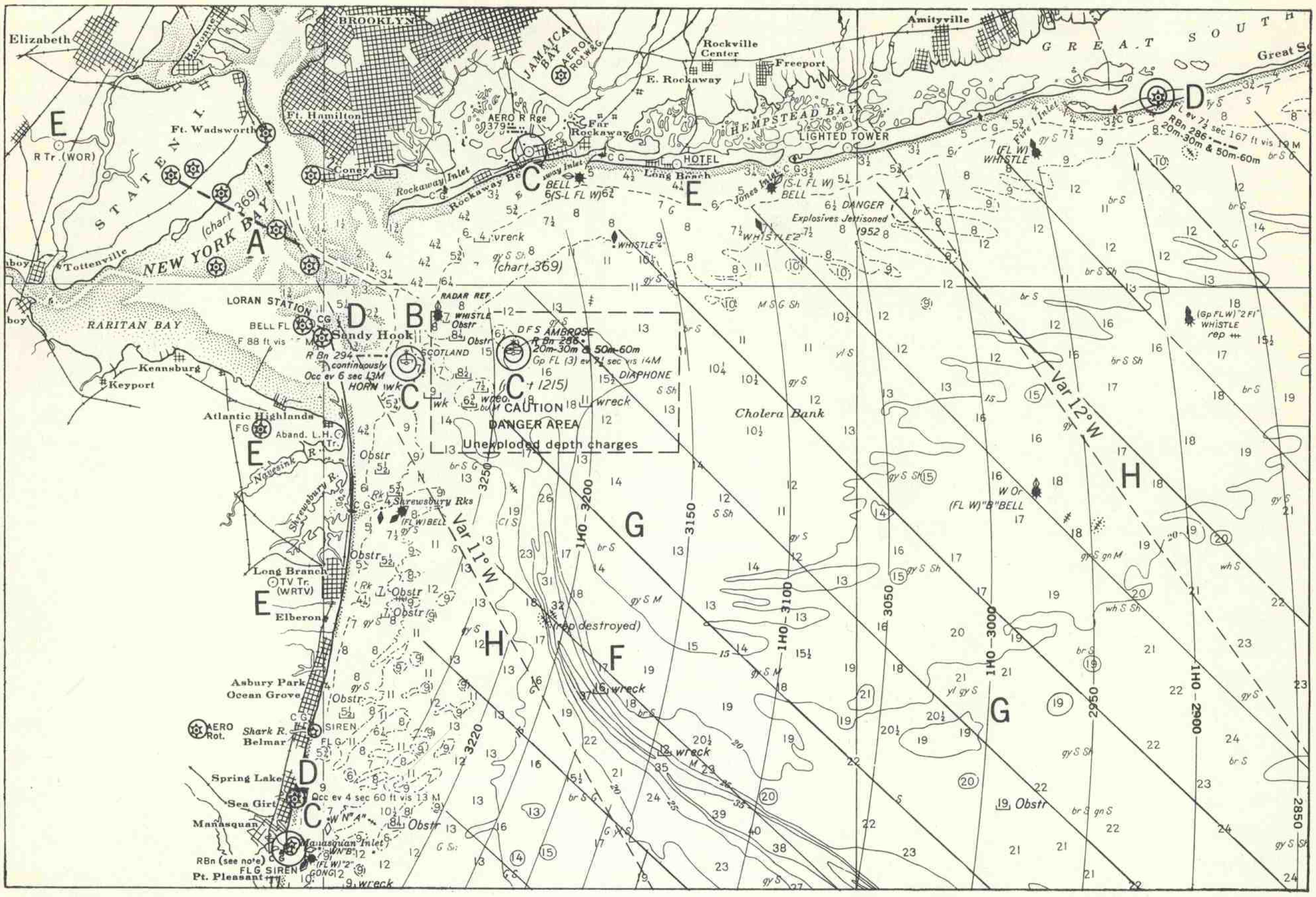


FIG. 1. —Section of Chart 1108 (reduced) showing aids to navigation available to the navigator in leaving or approaching New York Harbor. Tints are used to accentuate the land area and the shoal-water areas.

empty vast quantities of sediment near their mouths to build out the coastline and change the underwater configurations. The safety of navigation depends on an accurate representation of all these changes on the published nautical chart

Offshore, there are large areas, sparsely or inadequately surveyed, that require resurveys to insure the safety of submarine operations and to meet the exacting requirements of modern surface craft. As a byproduct, these surveys of the continental shelves will increase in importance as technology advances and makes practicable the recovery of resources the shelves are known to contain.

In Alaska, much surveying and charting remain to be done in support of the strategic defense of the Territory and in anticipation of increased commercial activity there.

As for the chart proper, it is fair to assume that its design has been stabilized, although not necessarily permanently fixed. Changes that do occur will be more in the techniques of compilation and reproduction, rather than in the character of the finished chart. "Navigation with safety and assurance" has been the guiding principle of the Coast Survey in its program of nautical charting. This will continue to be its motto in the days ahead, and it will fashion its charts to the needs of maritime interests.

We who are privileged to look back upon the first century and a half of the Bureau's existence are justly proud of the record that has been written in its promotion of commerce, industry, and the national defense. Those who will have the task of carrying forward this work will derive inspiration from the great heritage of public service that has been bequeathed to them.

Hydrographic Work of the Coast and Geodetic Survey

COMMANDER KARL B. JEFFERS
U. S. Coast and Geodetic Survey

LONG before the beginning of recorded history, seamen began to assemble information about the sea routes then in use. Most of the data collected were disseminated by word of mouth and illustrated by crude sketches. Today all the maritime nations of the world produce nautical charts which present in graphic form a vast amount of precise information. Even the so-called "backward" nations are establishing surveying and mapping bureaus which are comparable to those of more affluent nations. International cartographic symbols and practices have been adopted so that mariners of any nationality can understand and interpret the charts of foreign nations.

The conduct of surveys necessary for the production of nautical charts is recognized as one of the essential functions of government. In 1807, Congress authorized a survev of the coasts of the United States. The plan of operation submitted by Ferdinand R. Hassler was adopted, and this eminent Swiss scientist was engaged to carry out his plan.

The plan of operations proposed by Hassler was based upon the establishment of geodetic control of a very high degree of precision. The charts and maps were rigidly tied together under this system. Topographic surveys were made by planetable and alidade. Hydrographic surveys were controlled by sextant angles on signals located by triangulation or planetable. Aids to navigation were located precisely, and soundings accurately positioned in order that the mariner could be provided with a complete chart. The basic concepts of responsibility set forth by Hassler are valid today. Although instrumentation and procedure have changed in the ensuing 150 years, it is surprising to note that many of his methods are still in use.

FIRST HYDROGRAPHIC SURVEY

Hydrography is that branch of surveying which defines the depth and configuration of the bottom of the ocean and of lakes, bays, rivers, and other bodies of water. To be of value, depth measurements, or soundings, must be fixed in geographic position and precisely related to geodetic or topographic positions on the adjacent shores. It is quite easy, in many places, for a mariner to determine his position at sea by comparison of echo soundings with charted soundings. There are many landmarks under the surface of the water which are as recognizable as those apparent to the eye.

There are more than 8,300 hydrographic surveys in the vault, the oldest being numbered H-44. This is a survey of Great South Bay, Long Island, done at a scale of 1:10,000 in 1834 by Lt. T. R. Gedney. A channel in New York Harbor is named for this early hydrographer.

When the Coast Survey was first organized, it was responsible for charting the harbors and coastal waters from Maine to the western limit of the Louisiana Purchase in the Gulf of Mexico. Today, the area of responsibility has been extended farther seaward to the continental shelf and includes waters bordering our Territories and possessions in addition to our own coastal zones. The total area of responsibility is estimated at 2,500,000 square statute miles.

Waterborne commerce in the early days was vital to the young nation and the ports were jammed with shipping. The sealanes were particularly important before the construction of the railways. This commerce has grown steadily and will undoubtedly continue to increase for years to come.

COASTAL SURVEYS DIVISION

In the organizational plan of the Bureau, the hydrographic work is under the supervision of the Coastal Surveys Division, which is subdivided into three branches. The Coast Pilot Branch compiles and publishes ten volumes of *Coast Pilots* which supplement information printed on nautical charts. The Vessels and Equipment Branch is responsible for construction, maintenance, and repair of all survey ships and floating equipment. The Hydrography Branch is responsible for project planning and writing orders and instructions for hydrographic and planetable topographic surveys. This paper deals primarily with the work of the Hydrography Branch.

At present, the survey fleet comprises four major ships and ten auxiliary vessels. One ship is engaged in special offshore surveys for the Navy; two major units and three auxiliaries work in Alaskan waters; and one small unit is engaged in resurveys in the San Juan Island area of Washington. Only one major unit remains of the

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Commander Jeffers is Chief, Hydrography Branch, Coastal Surveys Division.

East Coast fleet and is assigned to duty in the Gulf of Mexico, except when needed for more urgent work in the Atlantic. Four auxiliaries operate in the Atlantic and one on the west coast of Florida. The tenth is a small vessel assigned to Coast Pilot work in the Atlantic and Gulf coast areas. Field work is generally in progress from early spring to late fall when the fleet returns to assigned bases for processing of records, overhaul and repair, and preparation for new projects.

Since the principal function of the division is field work, only 4 officers and 12 civil service employees are assigned to the office staff. The field force is variable, but generally has in excess of 100 officers and 400 men during the field season.

SURVEY PROGRAM

The program for hydrographic survey operations is based upon the following:

(1) Requests for surveys in support of civilian pursuits.
(2) Military survey requirements.
(3) Requirements for new charts and reconstruction of old charts.
(4) Completion of surveys in all the area of responsibility.

A 4-year plan of operations has been laid out after consultation with representatives of the Chart Division. This plan is extended and adjusted each year to reflect changing circumstances. An example of this is found in the 1957 program: The ship *Hydrographer* had been scheduled to continue surveys in the Gulf of Mexico and Florida Straits. The New England Fishermen's Association requested a new survey of Georges Bank, in view of many reports that shoals and banks have shifted to such an extent that the present fishing chart is obsolete. A new chart is needed to help reduce the loss of fishing gear. The establishment of Texas Tower 2 on Georges Shoal has introduced a requirement for a detailed survey of the approaches to the tower, and construction of a large-scale approach chart. Similar changes have taken place on Nantucket Shoals, creating a danger to coastwise shipping. The urgency for resurveys in these areas is such that the *Hydrographer* is being assigned to this project to be completed in 1958.

After it has been decided to make a hydrographic survey of an area, a project plan is drawn up. Each operating division is notified of the plan and requested to furnish information as to its requirements in the area to be surveyed. All existing information is reviewed, and copies of pertinent data are assembled for transmission to the field. The Chart Division prepares a "presurvey review," in which all questionable soundings, or points requiring further investigation, are indicated. Basic instructions for the project are written and circulated for amendment, or approval. Although methods and requirements for hydrographic surveys are completely described in the *Hydrographic Manual*, it is customary to include in the instructions specific reference to the scale of the surveys, line spacing, crosslines, location of tide stations, current stations, magnetic stations, triangulation, and photogrammetric surveys.

THE HYDROGRAPHIC SURVEY

On receipt of instructions for a survey project, the chief of party is responsible for laying out the work program. Boat sheets are constructed on which all critical soundings and obstructions are plotted, and a few other charted soundings are plotted for comparison purposes. Control stations, if any, are plotted, and shoreline details are transferred to the sheet.

Each hydrographic survey unit has as its primary function the determination of subsurface contours by means of soundings. Much preliminary work must be done before sounding operations can begin. Triangulation control must be established first. Shoreline surveys must be made and topographic signals located. In recent years, much of this work has been done by photogrammetric methods. Each project presents its own problems for organization of the party and execution of the field work. Solution of these problems rests with the chief of party.

Soundings

For centuries, all soundings were obtained by the use of a marked line attached to a weight and suspended in a vertical line. The hand lead is still used extensively to examine shoals and submerged rocks, and to verify least depths obtained by echo sounders. Great depths have been measured by use of a fine steel wire running over a calibrated registering sheave. The wire-sounding machine is now used to obtain bottom samples, water samples at various depths, and for comparative soundings. Pressure tubes were used for a time in an effort to speed up sounding operations in water too deep for hand-lead sounding.

Since World War I, the echo sounding instruments have come into common use. This is a device which measures the time required for an emitted signal to travel from the hull of the sounding vessel to the bottom of the sea and be reflected as an echo. The elapsed time is converted to depth in feet or fathoms, and recorded graphically as a continuous profile of the bottom under the vessel as it proceeds on its course.

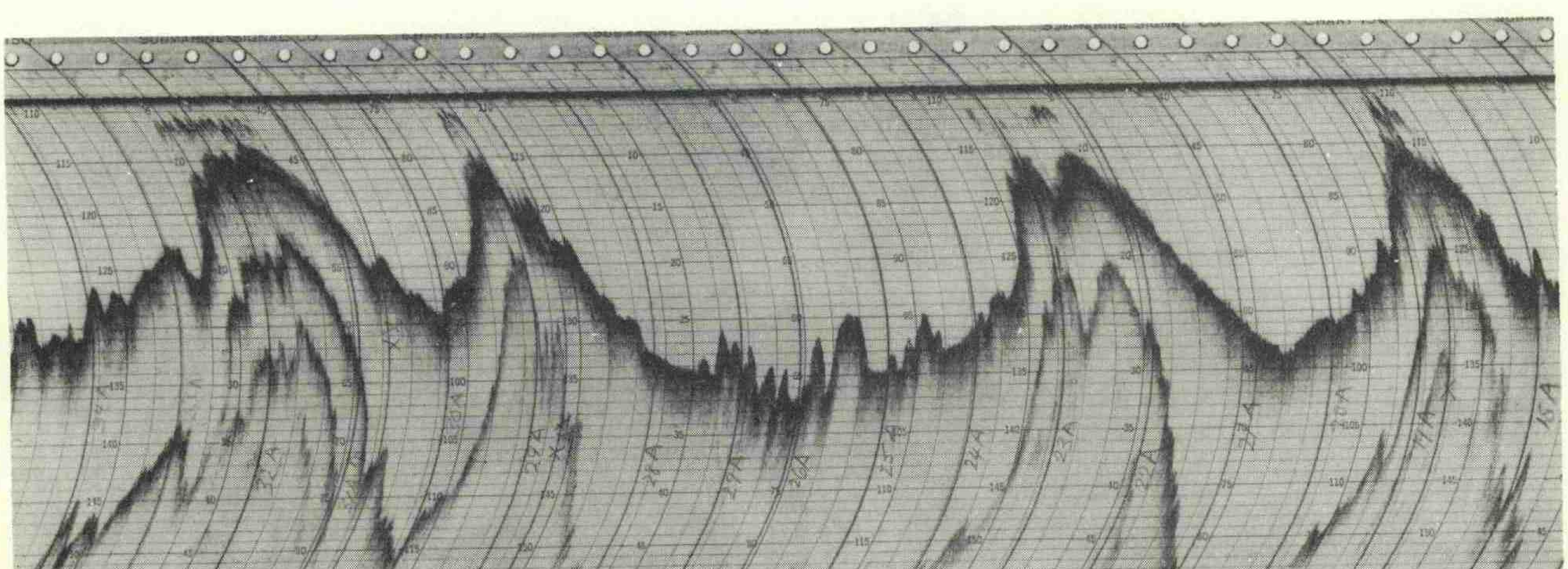
With the previous system of wire sounding, the individual soundings were widely spaced and it frequently happened that dangerous pinnacle rocks were not discovered. All indications of shoals are investigated. Least depths on rocks and shoals are verified by hand-lead soundings. Questionable echo soundings in kelp are also investigated by the hand lead.

Control of Hydrography

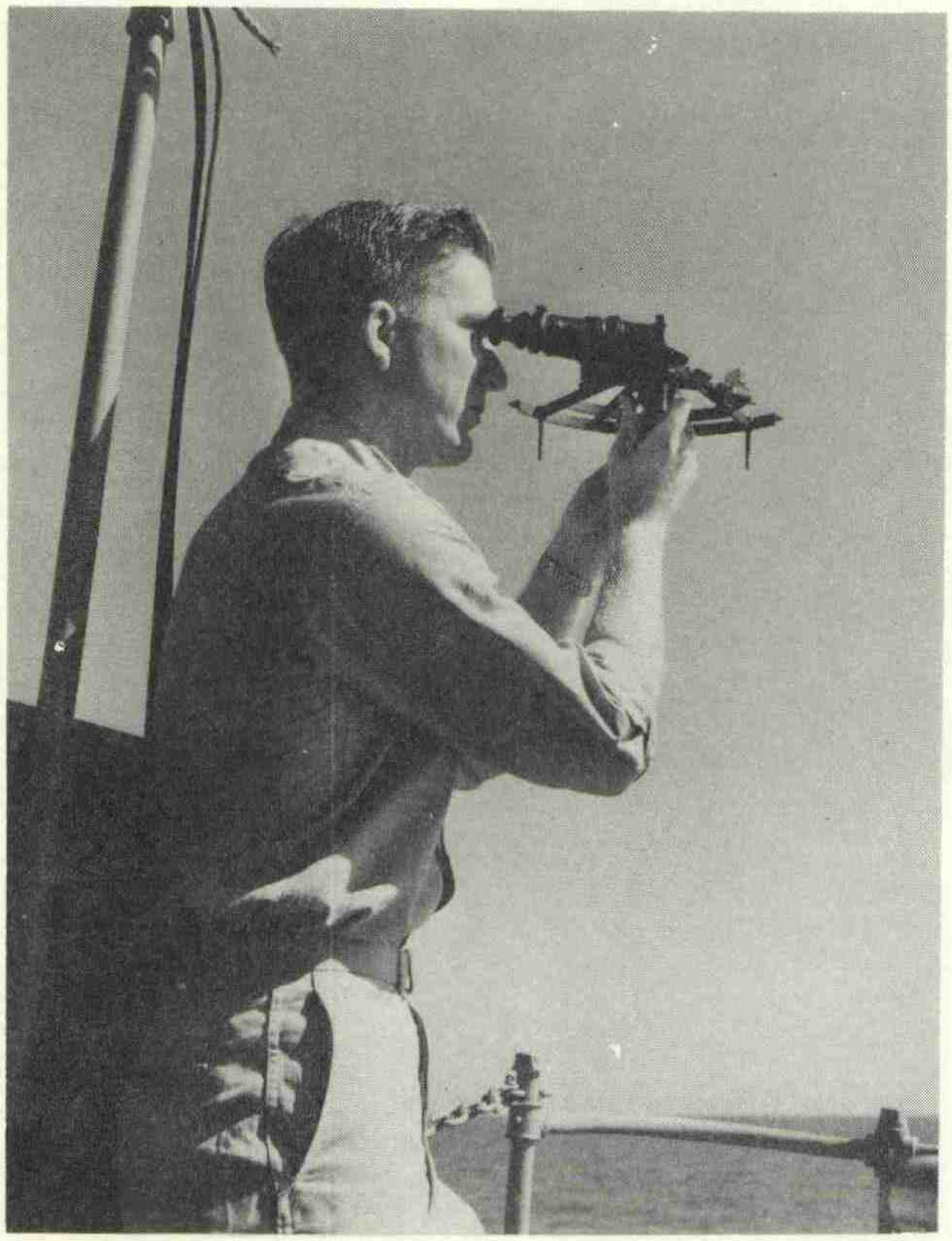
From the beginning of hydrographic surveys in this country, the position of the sounding vessel has been determined by sextant angles on signals ashore or afloat. The system is still used for inshore surveys. In offshore areas some sounding lines were fixed by astronomic sights. Prior to development of modern electronic systems, the Bureau developed and made extensive use of radio acoustic ranging. This system also depends on the speed of sound through water. The time elapsed between the instant of explosion of a small TNT bomb and the return of a radio signal keyed through a hydrophone is converted to distance from the hydrophone station, and plotted as an arc. The intersection of two or more distance arcs determines the position of the vessel.

World War II brought tremendous advances in the electronic field, among which were the development of Shoran and Loran. Shoran measures a line-of-sight distance which limits its area of use; however, it permits continuous surveys within its range regardless of visibility, and is particularly valuable in areas where fog is prevalent. It is sufficiently compact to permit

Type 808 portable graphic-recorder revolutionized sounding methods.



The echo-sounding instrument records a detailed and accurate profile of the bottom.



The sextant is still essential after more than 150 years of use.

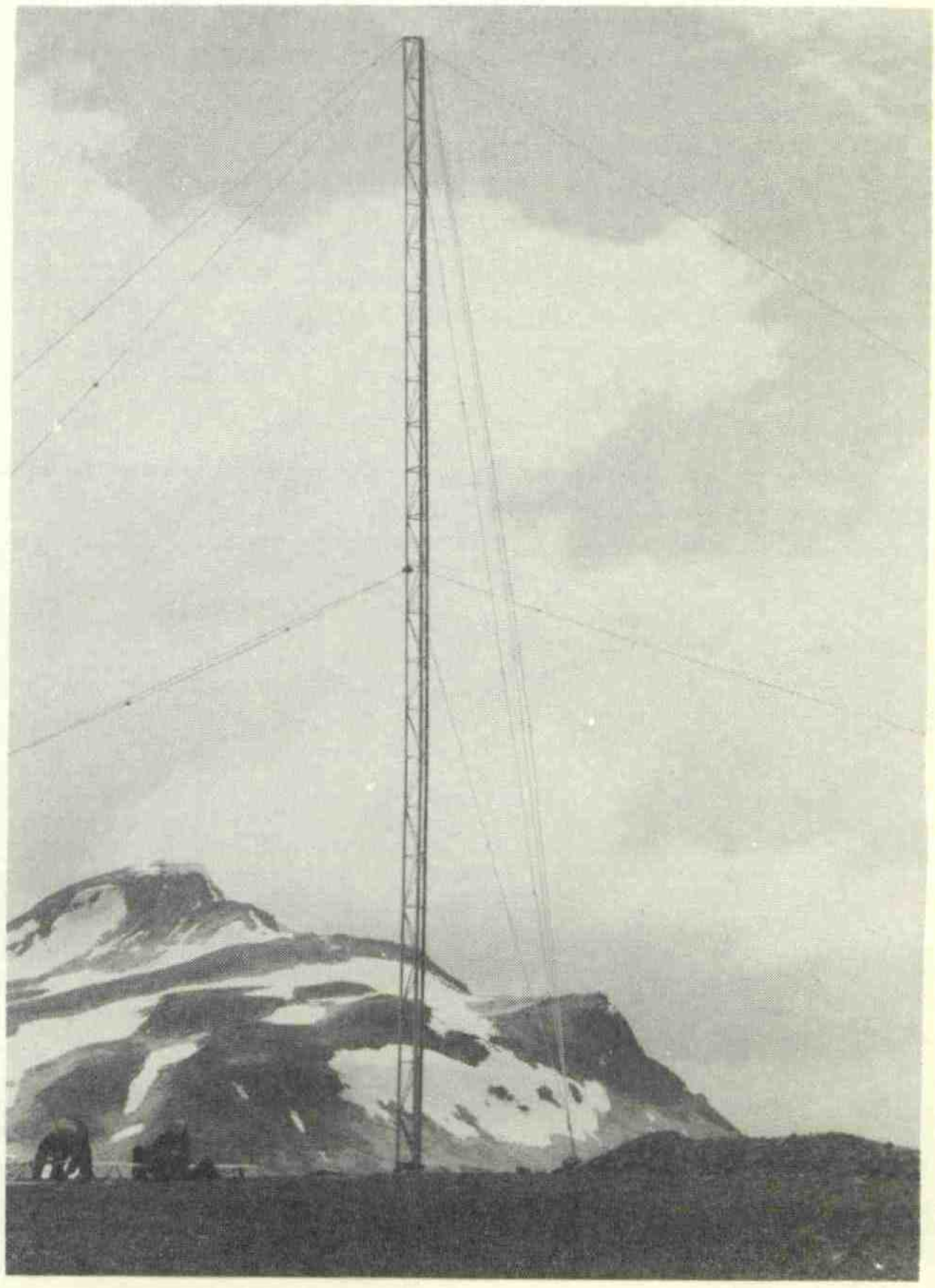
its use in small boats. The Electronic Position Indicator (EPI) was developed for control of hydrography beyond the limits of Shoran, and its use is restricted to ships. This equipment is not limited to line of sight and yields excellent results in measuring distances up to 300 miles. It has been satisfactorily used for distances in excess of 500 miles. EPI does not lend itself to large-scale surveys and is used exclusively for small-scale offshore operations. Corrections to observations are based on calibration tests over known distances. The EPI correction is generally constant regardless of distance, whereas, the Shoran correction varies with distance and is sometimes erratic. Both equipments yield results within the limits of precision required for hydrographic surveys. It is probable that one, or both, will be replaced by even better equipment as advances are continued in electronic development.

FIELD WORK

As previously stated, a hydrographic survey is generally a combined-operations project. Several operations are carried on simultaneously by a major survey ship. Before actual sounding operations can begin it is necessary to establish control for the hydrography. Signals are built and located by planetable, or photogrammetric methods, and fitted into a framework of triangulation which has been established in advance. If part of the survey is to be controlled electronically, it is necessary to build Shoran or EPI stations ashore and locate them precisely. At least one tide gage must be established and the staff referred to three or more tidal benchmarks.

Inshore hydrographic surveys are made in launches operating from the ship, or from a base camp ashore. The ship will accomplish the offshore surveys as time permits and is able to keep abreast of the launch work. Since the inshore work progresses rather slowly every effort is directed to its accomplishment, full advantage being taken of favorable weather conditions.

A system of parallel sounding lines is run, usually normal to the depth curves. The line spacing is a function of depth-of-water and character of the area. Channels, anchorages, and shoals are developed much more intensively than areas of similar depths along an open

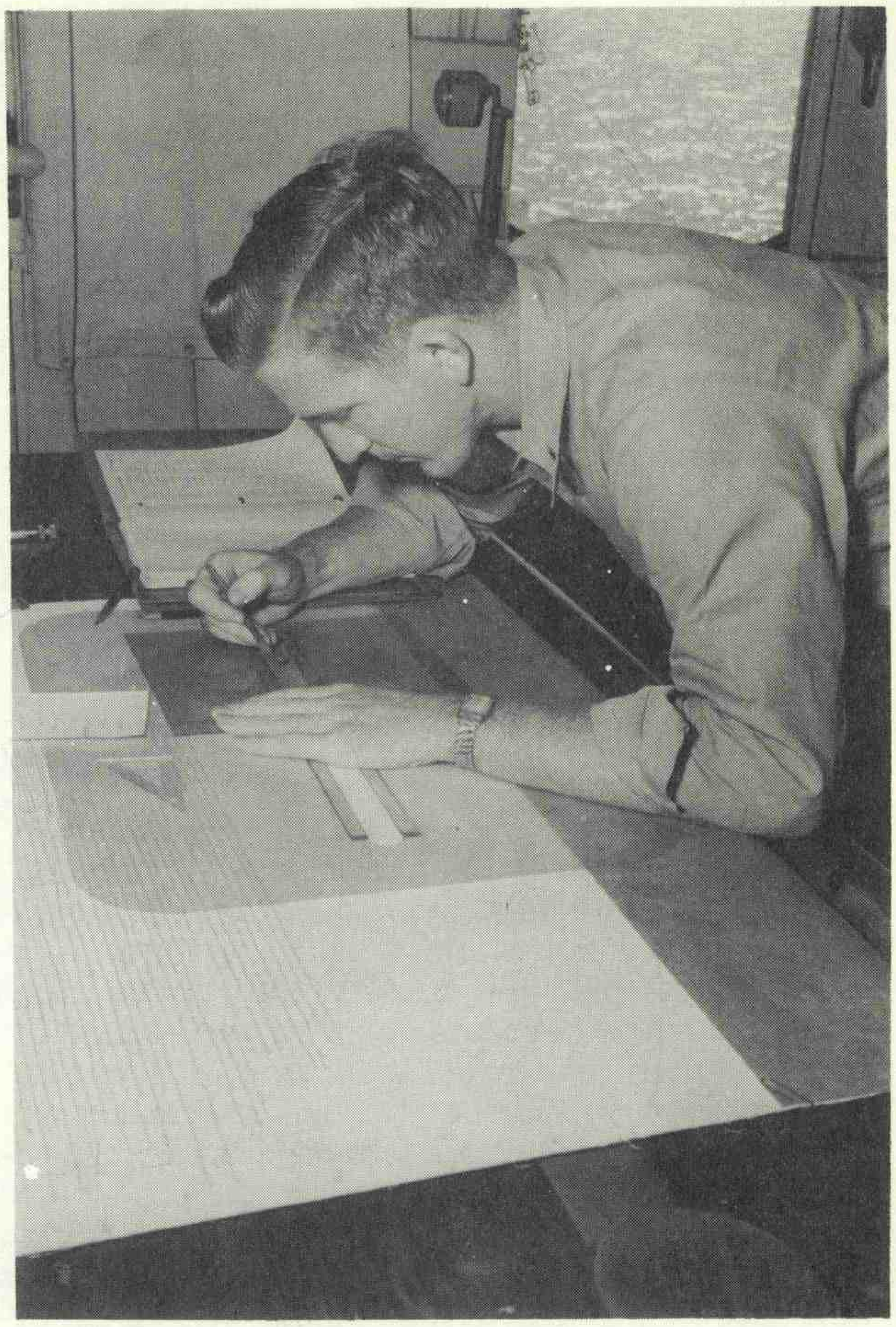


EPI Mast in Alaska.

coast. For example, a harbor being surveyed on a scale of 1:10,000 will have a general line spacing of 100 meters, with closer spaced lines in critical areas such as channels and anchorages. Sounding lines are several miles apart in open ocean areas where depths exceed 1,000 fathoms.

Random crosslines are run in addition to the regular system of sounding lines. These serve to detect errors in the operation of the echo sounder, or positioning of the soundings. A position fix is observed and plotted at regular intervals. The distances between fixes should not exceed 1-1/2 inches on the scale of the projection. Soundings are recorded at regular intervals ranging from 10 seconds to 5 or more minutes, depending on the scale of the survey. Soundings are also scaled from the fathogram at irregular intervals where necessary to provide data for plotting shoals and deeps in order that a true profile can be drawn. The hydrography is plotted on a boat sheet as the work progresses. Soundings are usually corrected for tide as they are plotted on the work sheet. Each day's work is carefully examined to make certain that any indication of a shoal, or obstruction, which could be a danger to navigation is detected and examined.

As a further safeguard, many areas are swept with a wire drag to eliminate all risk of missing a pinnacle rock. A wire drag is a small cable towed by two vessels and maintained at a predetermined depth by a system of weights, floats, and buoys. Many such rocks have been found which exceed 200 feet in height. Typical of such a danger is a shoal with a least depth of 2 fathoms found in the Bay of Waterfalls in the Aleutian Islands. This pinnacle lies in the approximate axis of the bay and projects from general depths of 35 to 40 fathoms.



Smooth plotting of positions and soundings is frequently carried on as field work progresses.

THE SMOOTH SHEET

When the field work for a hydrographic survey has been completed, the sounding records are processed for final plotting. The boat sheets are forwarded to the Washington office for preliminary review, and pertinent information to correct existing charts is recorded and frequently published in ***Notices to Mariners*** as advance chart information. The fathograms are scaled to verify recorded soundings; the soundings are corrected for instrumental errors, such as echo sounder phase, draft of the transducer, and drift of the initial setting. The soundings are finally reduced to the tidal datum plane used for charts of the area—mean low water in the Atlantic and mean lower low water in the Pacific.

The fixed positions are carefully replotted on a "smooth sheet," using final positions of control stations. The soundings are plotted and depth curves drawn in pencil. The completed smooth sheet is transferred to the Washington office, where the smooth plotting is verified and inked. The final result, as shown on the finished smooth sheet, is reviewed to determine the adequacy of the survey. If there are any doubts on this score, appropriate note is made and further investigation is ordered at the first opportunity.

THE CHART

The ultimate objective of the survey is the publication of a nautical chart of the area. The smooth sheet provides the necessary information as to depth of water, location of dangers and obstructions in navigable waters, and location of floating aids to navigation. Other field work performed by the survey party provides details of shoreline, position of fixed aids to navigation, information as to time and range of tide, direction and velocity of tidal currents, variation of the compass, names of important features, and information to be published in the *Coast Pilot*, which supplements the chart.

Occasionally, a survey is made to determine the amount of dredging required in a channel, or to determine the quantity of material removed by the dredge. Hydrographic surveys along shores characterized by accretion or erosion are valuable records frequently used in the courts to resolve cases involving land ownerships and riparian rights. These surveys are essential tools used by engineers in laying cables, and in constructing piers, jetties, bridges, dams, and tunnels. Combined with tide and current data, they are used in studies of water pollution, waste disposal, and beach erosion problems. Special surveys have been made in southeast Alaska to facilitate location surveys for paper mills and logging operations. Photostat copies of all hydrographic surveys are available to the public at a nominal fee.

The collection of oceanographic data is rapidly assuming greater importance in the field operations. Information is needed on a worldwide basis regarding temperature, salinity, mineral content, plankton density and type, surface and subsurface currents, and bottom core samples. The Bureau processes very little of this information, and the observations are turned over to interested oceanographic laboratories, such as the Hydrographic Office.

Tide and current observations are analyzed and used to supplement the data published in *Tide* and *Current Tables*. Magnetic observations are processed and add to the store of information on the earth's magnetic field.

SOME MAJOR ACHIEVEMENTS

The annals of the Coast Survey contain many stories of triumph, such as is to be found in the history of the ship *Surveyor*. As a convoy ship in World War I, she was credited with damaging a German submarine so severely that it was forced to put into a Spanish port where it was interned. Or the ship *Patterson*, which rescued some of the crew of the Revenue Service cutter *Tahoma* in the Aleutians. There are also stories of tragedy and disaster, such as the loss of Lieutenant Bache and ten men from the brig *Washington*. These are isolated instances of a dramatic nature. The real import of the service performed during the past century and a half can only be visualized after careful study of accomplishments.

The most urgent reason for undertaking the original surveys was the need to reduce the number of shipwrecks, which were so costly in lost lives, cargo, and ships. Marine insurance and freight rates were prohibitive until adequate charts were compiled and published. Only a few years ago, an oil company refused to send a tanker into a small bay in southeast Alaska until a complete hydrographic survey had been made. History is replete with such cases.

Incomplete records show that from 1867 to 1917 approximately 425 vessels were wrecked in Alaska with the loss of more than 500 lives (Special Publication No. 50, *Safeguard the Gateways of Alaska*). More than half of these wrecks were losses to which the lack of surveys and accurate charts were a contributing cause. Far too many hidden dangers are named for ships which lie buried beside them.

Nautical charts are essential prerequisites to the opening up of new areas for trade and development. Outstanding examples of this fact are the Philippines and Alaska. When the United States assumed stewardship over the Philippines in 1898, there were very few charts of the islands. The Coast Survey began work at once, and when the islands were granted complete independence in 1946 a series of 165 charts were available. The growth to economic, as well as political, independence was fostered by the commerce made possible by nautical charts.

The labyrinths of southeast Alaska were similarly opened up by nautical charts. These deep-water channels are infested with pinnacle rocks. In order that mariners could be assured that no danger had been missed by leadsmen, a complete wire-drag survey was made of all the principal channels.

When Fathometers and radio acoustic ranging were developed after World War I, the survey ships were able to extend their operations farther seaward. The general belief that the great ocean floors were flat was quickly disproved. One of the major accomplishments was a detailed survey of Georges Bank--a vast shoal area east of Cape Cod. A fleet of four survey vessels was engaged in this work from 1930 to 1932. The surveys were extended to the continental shelf, where a number of canyons were discovered. In later years, as the work was extended southward to Chesapeake Bay, other great canyons were discovered, the most spectacular being the Hudson River gorge.

Detailed hydrographic surveys along the coasts of Louisiana and Texas disclosed underwater domes which lead to the search for and development of the offshore oil deposits. Since World War II, the northern portion of Alaska has become of great strategic importance. A search for oil reserves in the northern plains contributed to the need for charts. Shore-based units carried on combined operations on the Arctic coast from 1946 to 1952 to provide charts for resupply expeditions. Some of the methods used have been previously described in this Journal.

FOUR-YEAR PROGRAM, 1957-1960

One major and six minor vessels are now in operation on the Atlantic and Gulf coasts. Surveys are planned for the coast of Maine, Georges Bank, vicinity of Nantucket Island, Narragansett Bay, Chesapeake Bay, Florida Straits, west coast of Florida, and Gulf of Mexico. Three vessels, the *Parker*, *Bowen*, and *Stirni*, are being retired from service. Wire-drag work to locate wrecks between Cape Hatteras and Cape Canaveral will be deferred until these vessels can be replaced.

One small vessel will continue surveys in the San Juan Island and Puget Sound areas. A shore-based party operating on the west coast will finish projected work plans in 1957. One ship will continue surveys in the Aleutian Islands and should complete this project in the next 3 to 4 years. Surveys on the north side of the Alaska Peninsula will be continued. Three minor vessels will be engaged in survey operations in Prince William Sound and southeast Alaska. The *Pioneer* is at the disposal of the Navy and will continue operating under plans originating in the Navy.

FUTURE PROGRAM

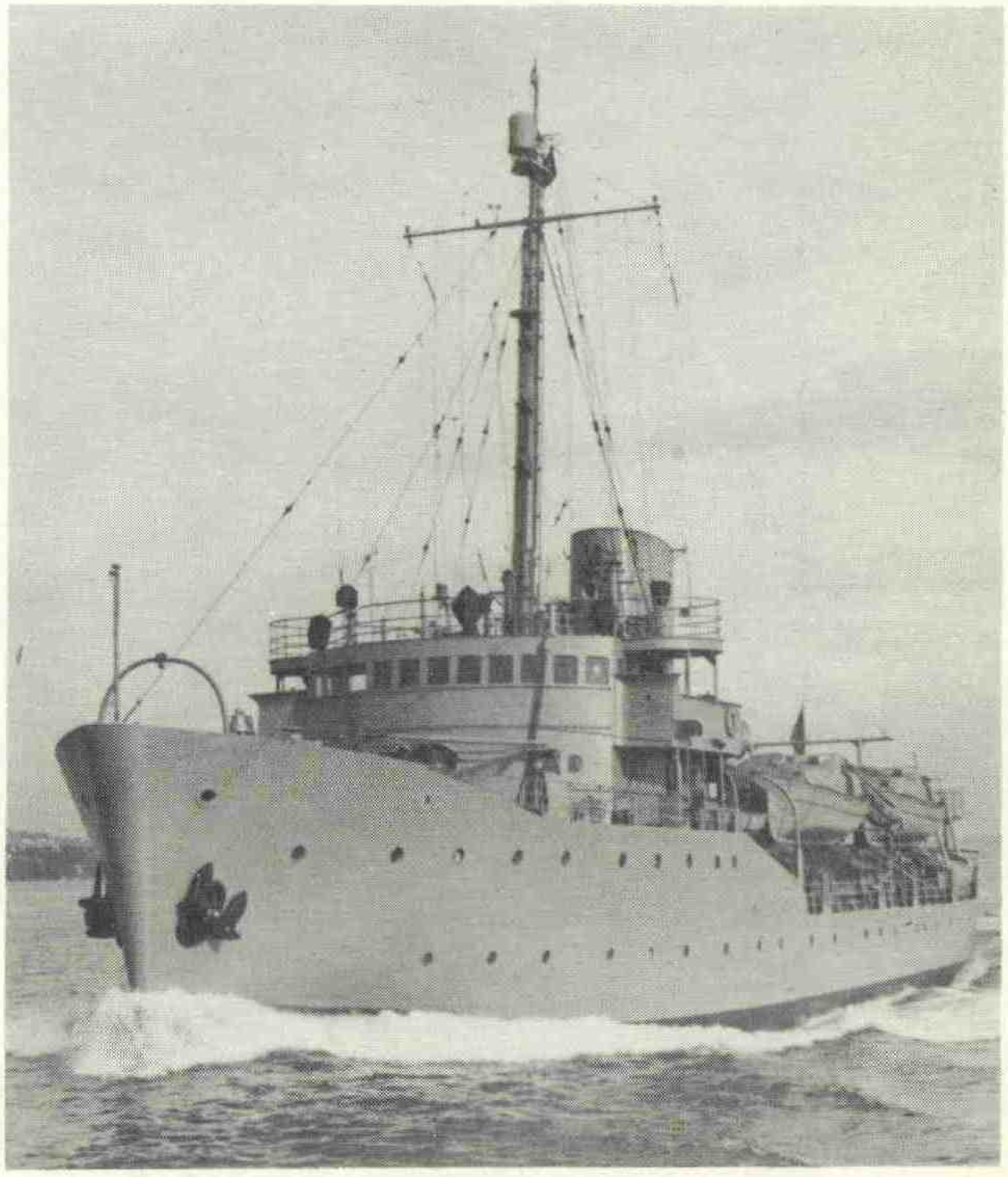
There has been a periodic repetition of the question first posed in 1818--"When will the survey of the coast be completed?" After nearly 150 years of hydrographic surveying, there are still thousands of square miles of unsurveyed areas, particularly in Alaska. The adoption of the echo sounder as an aid to navigation made it necessary to resurvey vast areas previously considered adequately surveyed. Many areas on the Atlantic and Gulf coasts must be resurveyed periodically to chart the changes in shoreline, channels, and shoals which occur naturally, or are caused by human interference with natural conditions.

The survey fleet has been gradually reduced from 8 to 4 major units. A number of smaller vessels placed in service after World War II are rapidly becoming obsolete; in fact, 4 such vessels have been retired. The fleet now consists of 4 major and 10 minor vessels. A 10-year replacement program has been proposed to provide a fleet of 7 major and 10 auxiliary vessels. If this program is carried out, it is believed that the present survey program can be completed in approximately 25 years.

The introduction of echo sounders and electronic-positioning devices has greatly increased the rate of production of completed hydrographic surveys. Survey sheet No. 5000 was registered in 1930, almost 100 years after the first survey was made. As of January 1957, there are over 8,300 surveys. Further increase in productivity can be expected as modern survey vessels join the fleet. Advances in survey techniques have created major problems in processing field data and publication of new material. New methods and procedures must be devised to keep pace with survey production.

No one can tell what future chart requirements will be. Ships are being built which will draw 60 feet; oil wells are being drilled in deep water; nuclear-powered submarines have requirements differing from previous models; the fishing fleet is becoming more exacting in its demands; electronic aids to navigation permit more accurate positioning of vessels in offshore areas; and military requirements continue to grow. As the science of oceanography grows and the world's population increases, there is no doubt that man will turn more and more to the sea as a source of raw materials.

The hydrographic work of the Coast Survey is thus a never-ending job. It is probable that future years may see a diminution of the work, but chart-maintenance surveys will be required as long as currents flow, storms beat on the coast, and man continues the development of the ocean shores.



Ship *Pathfinder*, a modern survey vessel.

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