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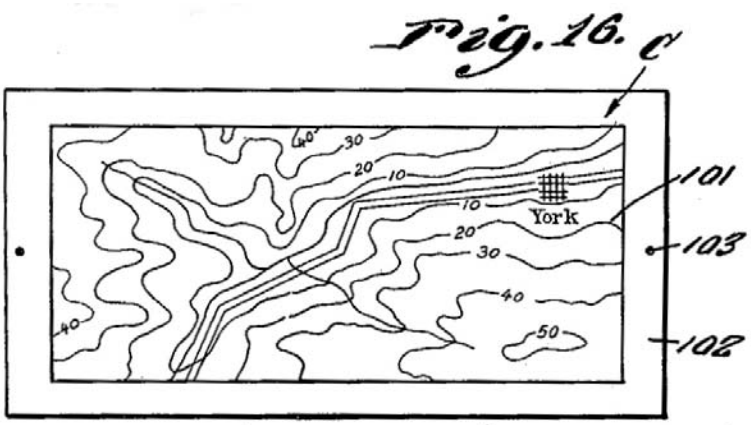
Extending Relief to the Nation:
Director Raymond Stanton Patton (1929-1937)



Schematic from the Braund Reliefograph Patent , 1935

E. Lester Jones had been the very last Superintendent of the Survey, and also its first Director. The name change was a small part of the great reorganization and revitalization effected under Jones, but was significant, none the less. Superintendents served until they died, were incapacitated, or removed for scandal. Directors were to be appointed by the President for terms of four years, with renewals possible but not guaranteed. Jones served until his death, on April 9, 1929. Twenty days later, President Herbert Hoover commissioned Captain Raymond Stanton Patton, a member of the Survey Commissioned Corps and at the time the Chief of the Charts Division, to be the twelfth leader of the Coast and Geodetic Survey. Like Jones before him, he would serve until he died in 1937.

Like many men who served at sea during a major part of their lives, Patton was born and raised far from the ocean in Ohio. He lived in Ohio from his birth in 1882 until after graduating from Western Reserve University (now Case Western University) in 1904. He then joined the Field Corps of the Survey, and, like Superintendent Tittmann before him, would spend the rest of his life working with the Survey. As a member of the Corps of the Survey, he was trained for shipboard service and eventual ship command; and he was also trained in the myriad of activities on ship, on shore, and in the office that

constituted Survey work. An examination of his early work assignments, and their locations, conveys the scope of the Survey in his era. Patton began as a Junior Officer on the ship *Hydrographer* working on revisions to the Atlantic Coast Pilots and also on topographic surveys in Virginia. In 1906 he was posted to duty on the *Gedney* in Alaska. In 1907, he began a three- year tour of duty in the Philippines as a part of the Survey's efforts in the Philippine Survey. Patton arrived when the Philippine independence forces were still battling with the US military forces. Living and working conditions were very difficult, far beyond the difficulties Survey personnel encountered in stateside work. Patton was noted for his friendly efficiency and good humor under stress, qualities that would later serve him well as he guided the Survey through the depths of the Great Depression and tremendous challenges in American life.

Upon his return to the United States in 1910, he worked in various capacities on the Atlantic and Gulf coasts, on approaches to the Panama Canal, and Alaska again. He found time in 1912 to marry Virginia Mitchell of Seattle, Washington, presumably in-between ships. After an additional command of the ship *Explorer* in Alaska, in 1915 he was posted to Washington to oversee revisions to the Coast Pilot series. At that point, E. Lester Jones entered as the 11th Superintendent. And then the war came, and Patton was transferred to the Navy as a lieutenant and later was promoted to lieutenant commander. Patton returned to the Survey after the war as Captain Patton. Jones and Patton returned to the Survey at a critical moment. Jones reorganized much of the Survey, especially map production and its relation to other branches of the Survey. He elevated cartographic production to the status of an independent division reporting directly to him. Jones appointed Raymond Patton the first Chief of the Printing Division. Patton coordinated not just new kinds of charts and maps, but entirely new cartographic production systems which would become the foundation for the extraordinary cartographic explosion of the Survey and its staff during the Second World War.

By the time of Director Jones' last and fatal illness, Captain Patton had worked in every area under jurisdiction of the Survey, in every Survey division, and with every major type of publication and map series the Survey produced. As Alexander Dallas Bache built the Survey on Ferdinand Hassler's foundation in the 19th century, so also did Raymond S. Patton build on the foundation that Jones had made in the 20th century.

By the time of Patton's directorship, the scientific divisions of the Survey were a third of a century old. Survey personnel moved between divisions, but for the most part, before Patton's era, "what happened in hydrography stayed in hydrography"; the nature of the work and research results within a division had little impact on other work. This was to change markedly in Patton's era. In keeping with the ordering of these chapters, the Survey history will be described division by division, but the inter-connections between these will become increasingly important and complex. As a key example, new research on earthquake distribution patterns in the Division of Terrestrial Magnetism and Seismology would intersect with an explosion of technologies developed in Hydrography and Topography, with vastly expanded ranges and detailing of hydrographic mapping off American coastlines in the Pacific and Atlantic Oceans. The convergence of these two arenas of earth research would return to undermine, literally, the concept of continental

stability based on isostatic equilibrium espoused by William Bowie in the Division of Geodesy, and would provide critical data for an idea about the structure and history of our planet's continents and oceans that would eventually move the earth literally and conceptually.

Division of Terrestrial Magnetism and Seismology

The Survey's work in terrestrial magnetism can be traced back to A.D Bache himself. Nearly a century later, the Survey's emphasis had shifted away from primary research in the subject largely because there were other institutions that had assumed that role, particularly the Department of Terrestrial Magnetism of the Carnegie Institution of Washington which was founded by personnel from the Survey. However, the Survey maintained the network of national standard observatories which began with the Cheltenham, Maryland station that celebrated its third of a century anniversary during Patton's era[1].

The Survey concentrated on increasing the density of observations for the locally observed magnetic elements for two very different applications. First, in keeping with the drive to standardization of datums and reference systems of both federal and state agencies pioneered by Jones after World War I, the 48 states developed or improved and extended state-level reference systems, the state plane coordinate systems[2]. Surveyors in the local state planes needed local values for magnetic declination to better correct their surveys and also to better re-construct or estimate historic magnetic declinations experienced by surveyors in the past. To provide this information, magnetic observing parties were dispatched across the 48 states to acquire the data sets needed within the individual states. The state systems also required sophisticated cartographic transformations between the state plane systems and the Survey's North American Datum of 1927 (NAD 27), so the Survey issued and re-issued many special publications to assist state agencies and civil surveyors in this.[3]

Second, the Survey needed local magnetic declination data broadly across the US and its territories for its expanding series of aeronautical charts. Under Jones the Survey began its own civilian versions of military strip maps, which charted the routes between specific airports. Early in Patton's era, the profusion of strip maps necessary to fly to, Chicago, for example, from increasing numbers of other airports led to the decision to abandon strip maps for maps that covered all American airspace. These were and are the sectional charts, which will be described further under the Division of Charting. Aeronautical charts note true and magnetic north azimuths on each chart, and as the plan

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[1] Heck, 1934.

[2] Essentially, the area of a state or discrete sections of it were treated as a plane instead of a portion of the curved earth, and an x-y coordinate grid was established for that plane. This was then correlated with appropriate coordinates in latitude/longitude of the Survey's North American Datum of 1927 (NAD 27). If the size and/or shape of the state made this unworkable for civil surveying accuracies, then the state was divided into a set of smaller and differently oriented planes, and then the x-y coordinates within each plane were coordinated with NAD 27. As well, counties and even cities developed their own coordinate systems, all correlated with NAD 27.

[3] See especially Deetz and Adams, 1934. [URL to Special Publications by function]

of the sectional charts was to cover the area of the 48 states, then the Survey required magnetic declination values for the entire country.

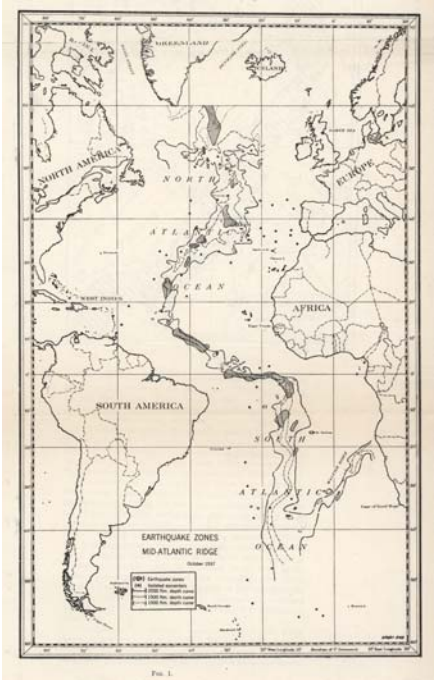
Finally, the Survey re-extended work far north of the "lower 48". In 1882-83, Survey personnel had participated in the first International Polar Year, occupying stations at Point Barrow, Alaska. There they had built a geomagnetic observatory. Fifty years later, for the second International Polar Year the Survey returned to Point Barrow to re-occupy the non-ferrous observatory for new observations of terrestrial magnetism and to construct an integrated geophysical observatory at Fairbanks in collaboration with the University of Alaska and the Division of Terrestrial Magnetism of the Carnegie Institution of Washington, all under a grant from the Rockefeller Foundation. That laboratory became the nucleus of a great set of laboratories and projects in Fairbanks to the present day[4].

Seismology

Seismology was linked to terrestrial magnetism since Bache's era because a part of the "variation of the needle" could be attributed to earth tremors. The Survey had received primary responsibility for seismology in the federal government in 1925. Jones initiated the new program by making Nicholas Heck the head of the division. Hence, the man most responsible for initiating Radio Acoustic Ranging was now charged with developing the key technologies for seismology. There were two basic types of instrumentations and applications that Heck and the division concentrated on. First, the Survey needed to coordinate data networks from a myriad of seismographs, including state, federal, university and religious networks (primarily Jesuit) in order to locate the epicenters and intensities of earthquakes. The distribution of contemporary earthquakes tended to be closely correlated with past earthquakes which led Heck to direct that significant historical research on the earthquake history of the United States[5] be undertaken. The combination of the patterning of historic earthquakes, which were mainly located on the land because these were the ones perceived by humans, and the contemporary earthquakes located through world seismic network data located primarily under the oceans, revealed patterns of earthquakes that did not support the nested assumptions of the model of continental isostatic adjustment and un-moving continents of which William Bowie was one of the strongest proponents. Under that model, earthquakes should be concentrated on continental margins where the processes of erosion and sedimentation would concentrate changes to the isostatic equilibrium of the continents. Earthquakes, under this model, were the results of shifting masses re-establishing equilibrium. But Heck's data showed clearly that earthquakes were concentrated not only in the vicinity of the great oceanic trenches which only paralleled some continental margins, but also on "the great ridges or rises in the Pacific, Indian, and Atlantic Oceans," the areas farthest removed from the zones of sedimentation and erosion.[6] Eventually, Bowie's horizontally stationary continents were to be undermined

[4] Eickelberg, 1932.
[5] See especially Bowie, 1924 and 1928; Heck, 1928; and Wood, et al, 1934.
[6] Heck, 1938, p. 97.

by Heck's seismology. The next synthesis that would converge, beyond the lifetimes of both Bowie and Heck, was the theory of plate tectonics as the driver of continental drift.[7]



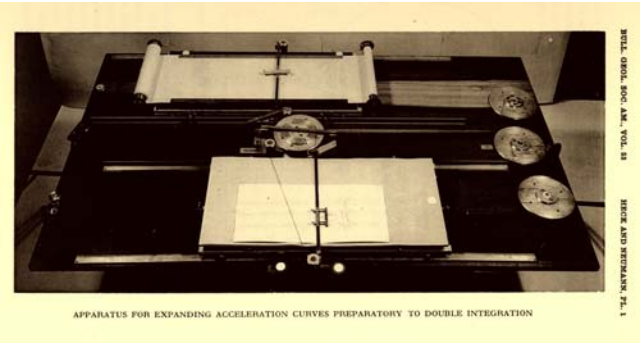
Earthquake Zone of the Mid-Atlantic Ridge
From Heck, 1938

Heck could theorize, but he also had superb skills in marshalling scientists and technicians to develop new technologies for new needs. Seismographs are best suited for measuring the intensity and timing of earthquakes whose epicenters are located at some distance away from the instrument. A local earthquake causes them to swing wildly. The Survey needed instruments that could measure the patterns of locally experienced earthquakes with minimal distortion and error in the data. Eventually, Heck and his staff developed a cluster of instruments to do this. The key device was the accelerograph, which used three separate instruments to detect horizontal motions of the earthquake in horizontal (x,y) and vertical (z) directions. The data from all three instruments would then be recorded simultaneously on a revolving paper drum, similar to a regular seismograph. From this data the pattern of acceleration of the movements in each direction was derived.

[7] The standard history of all this is now Oreskes, 1999.

Accelerograph, U. S. Coast and Geodetic Survey type.

The Survey then developed a mechanical device, similar to the pantographs the Survey had used since the era of Ferdinand Hassler. In this case, the expander device allowed a mechanical transformation from the acceleration curves to a double integration, leading to a graphic that was an integrated curve that showed the resultant horizontal motion of the earthquake in time as perceived at the site[8]. Very busy and hard to interpret data was thereby condensed to elegant curves.



APPARATUS FOR EXPANDING ACCELERATION CURVES PREPARATORY TO DOUBLE INTEGRATION

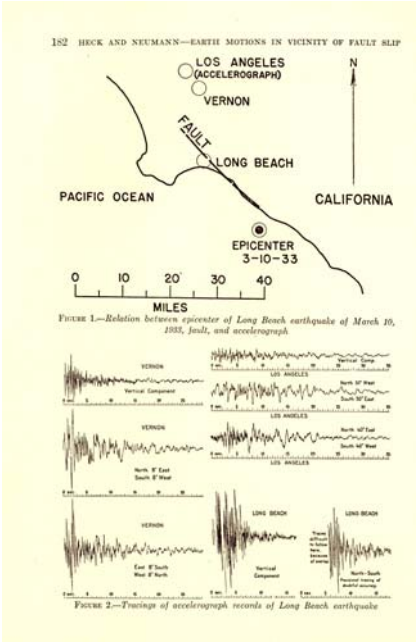
The Survey Apparatus to Expand the Acceleration Curves
From Heck and Neumann, 1942

The Survey's new instruments were deployed around the country, concentrating on areas with a significant history of earthquakes and/or a terrain that made earthquakes especially destructive. In particular, a set of three instrument clusters were established in southern California and placed in buildings in downtown Los Angeles, the nearby industrial city of Vernon, and the seaport town of Long Beach.

On March 10, 1933, at 5:54 pm, the earth and the Coast and Geodetic Survey converged. A powerful earthquake, estimated at magnitude 6.4 and intensity VIII, shook a major area of southern California. The movement occurred on what is now called the Newport-Inglewood fault zone, and the epicenter was situated about a mile offshore from

[8] See Heck and Neumann, 1942 for a detailed explanation of the instrument and these graphics.

Newport Beach. Next to Newport Beach is Long Beach. The instrument was located only 8 miles from the epicenter.



Positions of the Fault, the Epicenter of the Earthquake, and the Positions of the three C & GS Accelerographs, and their Data, 1933

The Survey's accelerograph worked well and survived the destruction of the earthquake. The data from the instrument was the most accurate earthquake motion data ever recorded from very near the epicenter of a major earthquake.

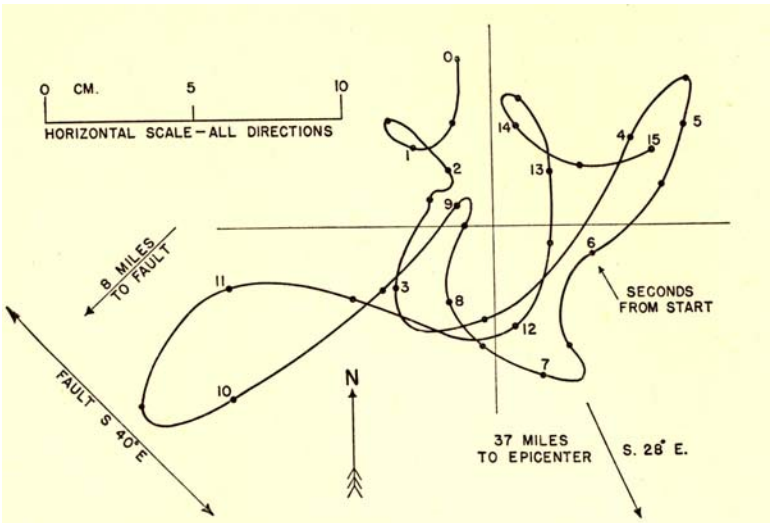


FIGURE 8.—*Resultant horizontal motion at Los Angeles during first 15 seconds of Long Beach earthquake*

The integrated horizontal motion of the earthquake in the first 15 seconds as recorded in Long Beach

The Long Beach earthquake, like all very powerful earthquakes, was a great tragedy for those who experienced and suffered it. But it was also a major source of validation for the Survey and its Division of Seismology, only eight years old at that moment. And, the Long Beach earthquake demonstrated that it was possible to design and deploy seismic instruments that could function where data was most critical - the places where the earthquakes occur. As a direct result of this, the Survey started a collaboration with the California Institute of Technology (Caltech), the state of California, and other partners by helping develop a series of laboratories and experimental stations for designing and applying a new generation of instruments for studying how buildings moved and failed in earthquakes and how building structures could be changed to better survive earthquakes. As the Inspector of the San Francisco Field Office noted, "The property loss from the Long Beach earthquake was conservatively estimated at $41,000,000, and the most valuable data obtained for engineers came from $1200 worth of instruments installed by the Coast Survey in that area".[9] These investigations, implemented through seismic design elements of building codes, have saved an untold number of lives in the decades since[10].

The Division of Geodesy

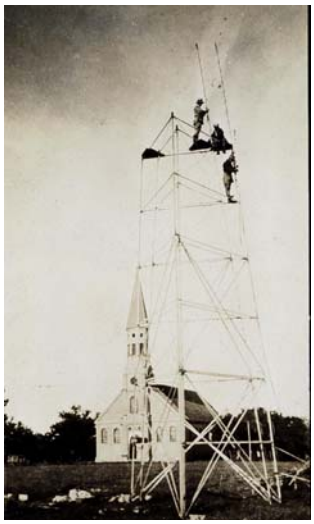
The Division of Geodesy was the foundation of the Survey, and it was an agency directed to highly organized and meticulous fieldwork; but it was also the mathematical and computation heart of all the other enterprises of the Survey. In 1927 the Division had completed the North American Datum of 1927 (NAD 27) which was an effort that began over half a century earlier with the planning and execution of the transcontinental arc of the 39th parallel.

The major work of the Division during Patton's era was, essentially, tying more and more of the land masses of the US and its territories under Survey responsibility via NAD 27 through extension of first, second, and third order horizontal networks as well as greatly extending the vertical network. In 1927, the Sea Level Datum of 1927 was established which clarified and corrected the disparities between sea levels as determined by tide stations on both coasts. This new datum was then transferred across the country by leveling crews working inland from the coasts and by systematic corrections to earlier heights based on the previous sea levels. Leveling parties continued to use railroad corridors whenever possible; serendipitously this era was the high point of railroad development in the United States. As will be described later, during the Roosevelt Administration's response to the Depression, the field crews and office personnel necessary to support this vast undertaking were expanded to the point that the Survey had the highest number of personnel working for it in its history.

The expansion of the horizontal network of NAD 27 was facilitated in this era through the evolved versions of the Bilby tower, designed by Jasper Bilby, who had risen to the position of chief signalman of the Survey. These towers, some of which were over

[9] Inspector, 1934, p. 127.
[10] See especially Wood, et al, 1934, and Anonymous, 1936, and McComb, 1936.

150 feet high, provided inter-visibility between distant survey points. Bilby towers are a system of two steel towers, one built inside the other but completely independent and not touching each other. Crews climbed up and down and worked on the outer tower, while the survey instruments were located on the inner tower, unaffected by vibration and movement on the outside tower. The towers were built out of prefabricated and standardized lengths of angle iron, which were adapted from materials designed for oil derricks and windmills. The system was based on complete standardization of parts, and experienced crews could put up and take down the towers in a few hours.



The oldest known photograph of a Bilby Tower being erected, 1928

Finally, there was, in Patton's era, one particular horizontal network observation site that was unique in the experience of the Survey. As part of the expanded federal workforce under FDR, there was a renovation of the Washington Monument. This required sheathing the Monument in scaffolding. The Survey requested permission to occupy the summit with theodolites in order to clarify and correct observations extending back to the earliest Survey work in the District of Columbia. In 1999, during the second renovation of the Monument, the National Geodetic Survey occupied the Monument's apex once more, this time the NGS used Global Positioning System equipment.

Survey geodesists at the apex of the Washington Monument, 1934

As mentioned under the section on Terrestrial Magnetism, much of the work of extending and infilling the geodetic networks was related to establishment of state plane coordinate zones in the 48 states, which correlated state-level Cartesian coordinate systems (x,y) to the geographic coordinate systems of longitude and latitude of NAD 27. The state-level zones could be divided further into local control systems, as for example covering a single city or county within the state. The work to establish the local control surveys was a particular focus of the FDR years because local control projects could hire people locally, who worked in their own cities or counties, in contrast to the triangulation and leveling crews which traveled across the country like Gypsy caravans[11].

The final major scientific project of the Division of Geodesy during the Patton era was acquiring local gravity data. The Division chief, William Bowie, was the great American patriarch of the concept of isostasy, and continental isostatic equilibrium. A discussion of this very complex debate is beyond the scope of this history—Oreskes (1999) is to be consulted there—but suffice to say that the most critical areas of scientific interest to Bowie and people in his camp—but not Heck—were the broad zones at the edges of continents and oceans. The major activities of the Survey regarding this in Patton's era was cooperative participation with national and international scientific projects to acquire gravity data using a unique and revolutionary instrument, a pendulum-based gravimeter designed by Felix Andries Vening Meinesz (1887-1966) a Dutch scientist. Vening Meinesz' gravimeter was used at sea mounted inside a submarine on numerous expeditions. In the 1930's, Survey personnel worked with various submarine expeditions in the waters between Florida, the Bahamas, and the Caribbean. The accumulated data, ironically, eventually "undermined" Bowie's concepts of local isostatic equilibrium[12].

Division of Tides and Currents

[11] See Hemple 1934 for the origins of the local control survey projects.
[12] See Hoskinson, 1938 for the Survey's work in the Vening Meinesz gravity surveys.

Tides and Currents was a small but critical office within the Survey, pursuing observations and research that tied in to every other division. They operated about 20 permanent tide stations distributed at carefully selected points along the coastlines under Survey jurisdiction. Data from the tide stations were used to check and correlate with tide prediction data produced by the Survey tide prediction machine No. 2, at headquarters in Washington. The tide station data were also used to control hydrographic surveys, determine initial points for precise leveling work, determine datum planes for charting and defining title to lands bordering tidal waters, and hence of great economic and political significance, and finally to extend the historical record of tidal observations given what seemed to be the inexorable rise in sea level underway. Further, in keeping with Director Patton's own focus on shore preservation, there was a major emphasis on the application of tidal data to issues in coastal stability. Patton's foresight was reflected in the following, "The coast is not a stable feature of our earth. There is indubitable evidence that the land and sea have changed in relative elevation at various times in the past. Whether such changes are going on now is not only an interesting scientific question, but one of more than academic importance to our seaboard cities. The primary means of answering this question is through the continuous tide observations being made at the Survey's primary tide stations".[13]

Finally, it should be mentioned that Tides and Currents played a role in environmental science education. The Survey scientist Henry Marmer wrote the Survey treatise on tidal datum planes which were local sea levels established by long-term datasets from specific local tide stations. But he also wrote several popular books, including *The Tides*, originally published in 1926, and *The Sea*, published in 1930, each of which went through many editions as they became standard and frequently used references on the subject.[14]

Division of Hydrography and Topography

The seashore is the most dynamic environment on earth occupied and used by humans, and so members of the Coast Survey were preoccupied from the very beginning of the Survey with noting and mapping shoreline and coastal changes which then evolved into devising models and explanations of coastal dynamics. Coast Survey repeat mappings of coastal changes have been the basic data source for much or most coastal change research in the United States.

Patton recognized this when he wrote, "Members of the United States [Coast and Geodetic] Surveys, Bache, Mitchell, ... Whiting, Marindin, Davidson, and others, have worked out many of the details of coastal forms and their changes, and a large number of observations recorded upon maps and charts have been the basis of much of the work of this paper".[15]

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[13] Patton, 1932, p.5.
[14] See Marmer 1926, 1927, 1930.
[15] Gulliver, 1899, p. 153

The annual reports of the Superintendent of the Coast Survey, later the Coast and Geodetic Survey, contain dozens of detailed reports and analyses of coastal, harbor, and inlet processes and changes, a constant preoccupation of Survey scientists since the beginning of the Survey[16].

A convergence of natural events, coastal development, new research initiatives organized by the US government for World War I, and Raymond Patton's intelligence and insight led to him, and the Survey, playing a starring role in the initiation, if not the execution, of major federal involvement in coastal management in the US. The place in question was the long shore of New Jersey. Changes in transportation and the rise of a broad middle class in the late 19th century brought many thousands of people from New York City and other crowded urban areas to "summer" on the New Jersey shore. Temporary camps and summer hotels were developed into year-round settlements located as close to the shore as possible. But the New Jersey shore is almost constantly retreating, as the shore has little source of deposition from inland, and storms and waves erode the coastal margins. This mattered less when the major settlements along the shore were fishing villages situated in bays and harbors for maximum protection of the inhabitants and their boats. But summer people wanted to stay as close to the beach as possible, exposing them and their settlements to the dynamic processes of the waves. In addition, a direct hurricane strike and a number of near misses as well as "northeaster" storms swept over the New Jersey shore in the early 20th century, every time creating more destruction because there was continually more to destroy.

Then the US entered the Great War. In 1917, the National Research Council was formed to coordinate scientific research and technology development for the war effort. A little more than a year later, the war was over, but the National Research Council (NRC) continued as a source of coordinated federal research. Meanwhile, the processes of development and erosion and storm loss first noted in New Jersey led the leadership of that state to create the State Board of Commerce and Navigation, charged with studying the problems and developing solutions. The State Board appealed to the NRC to bring in federal involvement. Into that mix came Raymond Patton and his coastal surveying experience, ranging from Alaska to the Philippines and all coasts of the contiguous 48 states. Patton became the founding chairman of the NRC Committee on Shoreline Investigations of the Atlantic and Gulf Coasts.[17] The initial collaboration was between the New Jersey Board and the NRC Committee, but much of the rest of the Atlantic and Gulf coasts was also "New Jerseyifying"[18]. The problems were national, so the enterprise to address it must also be national. Patton became a founding member and officer of the American Shore and Beach Preservation Association, established in 1926[19].

The basic problems, as the Association found them, were that beach areas were increasingly important and valuable, that beach erosion and other problems were increasing and increasingly difficult and costly, and that the major responses to these

[16] Notable examples are: Whiting, 1850 and 1886; Mitchell, 1869 and 1871,and many more.
[17] American Shore and Beach Preservation Association, 1928.
[18] Pilkey and Dixon, 1996, p. 7.
[19] The Association's history described in Patton, 1930.

matters were individualized by homeowners, towns, and states. In addition, the Association noted that, particularly on the Atlantic and Gulf coasts, riparian laws and their jurisdictional zones were very complex, ancient and not well understood by hardly anyone, not uniform and at times in conflict from state to state, and also in conflict in various ways with federal responsibilities for navigation. The Association proposed to address these problems by serving as a source of experts for various committees to research a variety of geophysical and social aspects of the problems, and to induce all coastal states to develop effective state level agencies to address matters based on the model of the collaboration between the NRC and the New Jersey Board[20]. "Heretofore little has been accomplished because these matters were everybody's business and therefore nobody's. We propose to make them somebody's business; somebody whose bread and butter depends on getting results".[21]

As matters evolved, however, another player entered the arena, along with an enormous amount of bread and butter. The Army Corps of Engineers had been given primary responsibility for coastal and inland navigation at the beginning of the 19th century. Now the Corps entered as a player along the entire length of the coasts, outside the context of navigation. In 1930, Congress authorized the Corps to establish the Beach Erosion Board which in 1936 became the Beach Erosion and Shore Protection Board.[22] The Board would then coordinate matters with state level authorities in each coastal state.

Progressive changes of the names of the organizations tell the story. There was an initial interest in "shore and beach preservation". Preservation has many nuances. When the Army entered, the emphasis was clear: "beach erosion". When the title changed to "beach erosion and shore protection", it signaled that the Army had displaced the original Association. The Army's subsequent history on the coasts, primarily devoted to erecting structures to prevent erosion (or at least displace it down the beach) led to the whole enterprise becoming known as ocean engineering or beach engineering. By contrast, consider the title and implicit model of one of Patton's most important research papers on these matters: "Moriches Inlet: A problem of beach evolution". [23] Patton was an evolutionist! But as matters developed, beach evolution turned into beach engineering, and the history of what followed is almost entirely that of the Corps of Engineers.[24]

[20] NRC, 1929.
[21] ASABPA, 1928, p.10.
[22] Beach Erosion Board, 1938.
[23] Patton, 193.
[24] See, for example, Wicker, C.F., 1951; Pilkey and Dixon, 1996; Wiegel and Saville, Jr., 1996

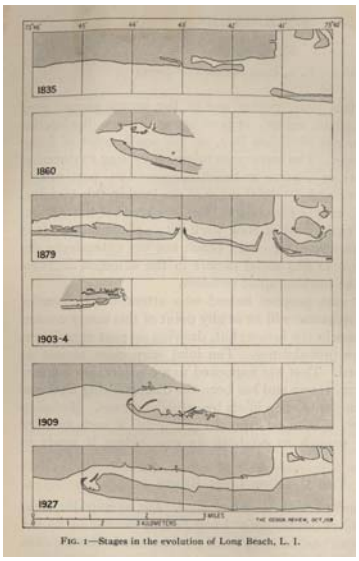


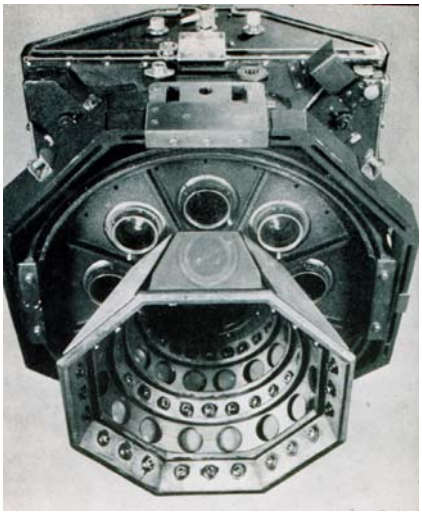
FIG. 1—Stages in the evolution of Long Beach, L. I.

Stages in the Evolution of Long Beach, Long Island 1834-1927

At the beginning of Patton's era, the Survey was producing t-sheets ("t" for topography) and h-sheets ("h" for hydrography) that were produced by equipment and techniques essentially identical to those of Hassler nearly a century earlier. The major differences between the older and newer sheets were the veritable explosion in new innovative technologies that were used to acquire the data mapped on the sheets.

Topography

By Patton's era, topographic surveying was based, almost always, on aerial photography as rectified and positioned by locating control points on the photographs that could be correlated with survey stations and monuments. The theodolites used in establishing the ground correlations were essentially the same as in Bache's era. The photography systems evolved to an apex in Patton's time: the Survey's nine lens camera.



The Nine Lens Camera

The camera, designed by Lt. Oliver Reading of the Survey Corps, was the most advanced photogrammetric camera in the United States at that time. The camera was part of a complex system: the camera matrix, with one large camera in the center, surrounded by eight smaller cameras which photographed terrain off to the side as reflected to these cameras by tilted mirrors; all nine separate images focused by prisms onto one single piece of film, 23 inches on a side. The system then used a special transforming printer, which rectified each of the eight distorted side images, and printed them with the image from the large central camera on one very large paper photograph.[25]

Washington, DC with original negative and transformed print, 1938

The Survey's camera system allowed much larger areas to be photographed quickly and efficiently, which meant more areas could be covered, and also that re-surveys of changes in areas previously surveyed could be made readily. The camera was used, especially, for surveys of enormous areas of Alaska, although that occurred after Patton's era.

Hydrography

There were two new major technologies that transformed hydrographic surveying in the Survey in Patton's era. The first was Herbert Dorsey's fathometer. As was described in the Jones chapter, Coast Survey in and out of the military in World War I worked with underwater acoustics for communications, positioning, hazard avoidance, and submarine detection. After the war, the Survey's first plan for direct application of acoustics was to obtain a Navy-designed acoustic depth finder. That quest led them to the Army Coast Artillery and the National Bureau of Standards, in a collaboration that led to Radio Acoustic Ranging (RAR). RAR used sound transmitted horizontally. That

[25] Reading, 1935.

still left the quest for a vertically sounding instrument. The Navy's instrument wasn't accurate enough for the standards of hydrographic surveying.

In 1925, through Director Jones' intervention, the Survey had acquired responsibility for federal research in seismology. Jones directed Nicholas Heck out of the Division of Topography and Hydrography to the Division of Terrestrial Magnetism and Seismology. This is possibly closely correlated with the decision of Dr. Herbert Dorsey, a senior physicist and accomplished inventor, to leave his position with the Submarine Signal Corporation working with Reginald Fessenden and come to work at the Survey. He quickly became the chief electrical engineer and chief of the Radiosonic Laboratory. There, he had access to the extensive investigations of the speed of sound in sea water made by Survey scientists in the development of early RAR[26].

Dorsey eventually developed a sounding acoustic instrument that was simple and brilliant. Pulses of sound were emitted directly from the ship. The sound echoed off the bottom would be received with a delay correlated with the double path to and from the bottom. Dorsey figured out how to translate the perceived ocean depth into distances between lit-up parts of the instrument dial, so that crewmen could easily note and record the depth. By changing the frequencies of sound emission using a simple dial, Dorsey's device could sound accurately in waters from quite shallow to quite deep. He had devised a universal sounding machine, which he named the Fathometer[27].

Herbert Dorsey and the Fathometer, circa 1930

[26] See Dorsey, 1932.
[27] See Dorsey, 1935.

The Fathometer was an extraordinary instrument, highly accurate and versatile, and also easy to use. It was so successful that Dorsey's former employer, the Submarine Signal Corp., adopted the name as a general term for echo sounding devices, and the term was in use for decades.

Major progress had been made on the vertical component of hydrographic sounding, but that still left the problem of the horizontal position of the ship. The early work with RAR had been tantalizing, as participants knew they were on the verge of perfecting a revolutionary technology. But, from the beginning, the RAR work on the Atlantic coast, and then on the Pacific, encountered results that were counter-intuitive and difficult to explain. RAR was initially developed and tested in the relatively shallow broad shoals of the Atlantic coast. When the Survey ship *Guide* tested RAR in the Pacific, it was initially thought that the dramatic waves and surf noises of the Pacific would overpower the RAR acoustic signal unless much larger bombs were used. In fact, in the deep Pacific waters, RAR acoustic signals were received at much greater distances than had been the case in the Atlantic. These results were encouraging, but also unsettling, as they indicated how little the Survey, or anyone for that matter, really knew about ocean acoustics.

In 1929, the Survey had been dispatched to survey the Georges Banks, off the coast of New England. The eastern flanks of the vast banks extended nearly two hundred miles offshore from the nearest point of land in New England. In order to position the Survey ships properly, a system of anchored RAR station ships was devised, which then allowed the ships conducting the hydrographic surveys to use the anchored boats as navigation stations and work much farther distances offshore. Unfortunately, this also meant that the anchored boats, often lying under persistent fog cover, were exposed to great danger from collisions with passing ships[28]. Completion of the Georges Bank Survey was accomplished during the field seasons of 1930-32.[29] The completed survey, and the special maps for the fishermen created from the data, to be described later, fulfilled a mandate extending back to the very enabling law that authorized President Jefferson to create a Survey of the Coast: "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 Gulf Stream, as in his opinion may be especially subservient to the commercial interests of the United States".[30]

The Georges Bank RAR surveys covered vast areas quickly and reasonably accurately, and they also disclosed complex submarine canyons on the outer sides of the banks. But the baffling problems of sound wave paths in the water remained. Given their knowledge of the variation in sound velocity dependent on the variables of temperature, pressure, and salinity, the most probable explanation for the velocities they had measured were that the sound waves traveled to the bottom and traveled across at the bottom, before somehow rising to the surface

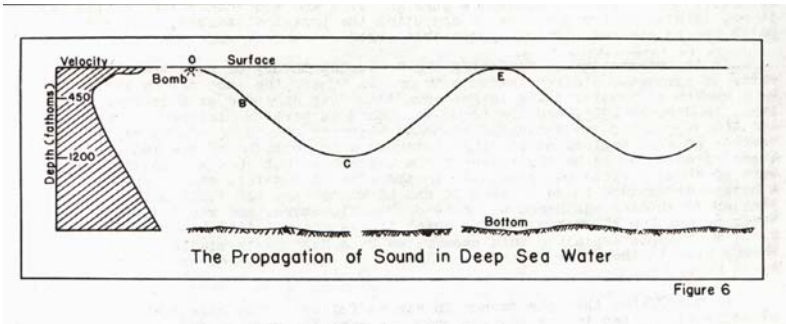
[28] Anonymous, 1932, p. 1.
[29] See Rude, 1932 for explanation of the Georges Bank survey strategy.
[30] Ninth Congress, Act of Feb. 10, 1807, Section 2.

Aaron Shalowitz, who had a long and varied career in the Survey, acted as a theoretician in the enterprise. As he noted, after the 1929 Georges Bank field season was over:

"...I believe it is too early to formulate a definite theory regarding the behavior of the sound wave. It will be time enough to consider these possibilities when we have supplemented our present data with experimental work carried out along certain lines which the investigation has shown is urgently needed.

"For the present, the important thing is that a practical working relation has been established between experimental and theoretical velocities that has enabled us to adopt a definite policy for the work on the Georges Bank. In addition, the study has shown that any assumption that the effective sound wave travels along the surface or close to the surface is wholly untenable. Other than that the investigation should be considered in the nature of a preliminary finding and as laying the foundation for a thorough and comprehensive study, both in the field and in the office, of the whole subject of sound transmission in all its ramifications"[31].

The Survey personnel in this enterprise decided to use, as a natural laboratory for the "thorough and comprehensive study," the deep, stratified basin of Pacific Ocean water between the northern and southern Channel Islands, offshore from Santa Barbara, California. The deep and largely still waters were highly stratified by temperature; meaning that sound would travel fairly uniformly in velocity within each "layer cake" layer of water in the basin. Observers posted with radios on the bounding islands could position the survey ships' horizontal positions easily and accurately, so they would have accurate data about the real distances between the ships, to correlate with the distances derived from RAR distances. They also developed electrically triggered RAR bombs, which could be lowered on cables and detonated at precise depths[32]. Given these, they would attempt to work out, experimentally and theoretically, the velocity paths of the sound in the water.



Recent Acoustic Work by the US C & GS, Paul Smith, 1934

[31] Shalowitz, 1930, p.455.
[32] Smoot, 1935.

What they discovered was that the velocity of sound was at a maximum in the warmer water at the surface, then decreased with decreasing temperature down to a depth of around 450 fathoms (2700 feet), after which, the temperature did not decrease much, but the pressure did, causing sound velocity to increase, eventually to a level equivalent to the velocities in shallow water. Based on this data, and the results of RAR determined ship positions and ranges compared to visual positions and ranges, they then theorized as to how the sound had traveled. This profile of changing velocities would then cause sound waves to refract downward from the surface towards the depths, but turn upwards from the depths back towards the surface, traveling great horizontal distances via refraction around the zone of lowest velocity at 450 fathoms. They had theorized and observed what is now called the deep sound channel of the oceans.[33]

The California research results, assimilated into hydrographic survey practice, led to a literal explosion in survey work in the Pacific and Atlantic Oceans. Following the work in 1934 to fully realize RAR, research shifted to finding a substitute for the dangerous anchored ship-borne RAR installations, as had been used in the Georges Bank survey. Almon Vincent, of the Survey, invented the concept for the radio-sono buoy, which was a buoy-mounted radio repeater that could be anchored off shore and positioned using shore stations. Essentially, the radio-sono buoy automated what had been an installation requiring human supervision. There were difficult technical problems to resolve lasting until about 1936, but eventually advanced RAR, equipped and extended by the radio-sono buoys, was ready[34].

With RAR and the radio-sono buoys, survey ships could position at full speed as much as hundreds of nautical miles offshore, while Dorsey's fathometer could determine depths with great accuracy as they steamed along. This allowed the Survey to map far out on continental slopes and beyond, and also allowed a densified network of soundings that allowed more fine-grained details of submarine geomorphology to be identified. Two experimental nautical charts, one from each ocean, reveal the Survey personnel at the apex of their work in Patton's era.

In 1938, C.K. Green of the Survey published a pair of new nautical charts under production by the Survey, both covering the waters offshore California from San Diego to Santa Rosa Island. Both charts were based on the greatly increased volumes of hydrographic data now available through advanced RAR and the Dorsey fathometer[35]. The first chart, 5101, presented the soundings in the traditional way, and used contouring of depth for the three traditional contours of very shallow water.

[33] The key papers on the Santa Barbara Basin RAR research results are Smith, 1934, and Swainson, 1936.
[34] Borden, MacIlwraith, and Cowie, 1936. pp. 142-149.
[35] Green, 1938.

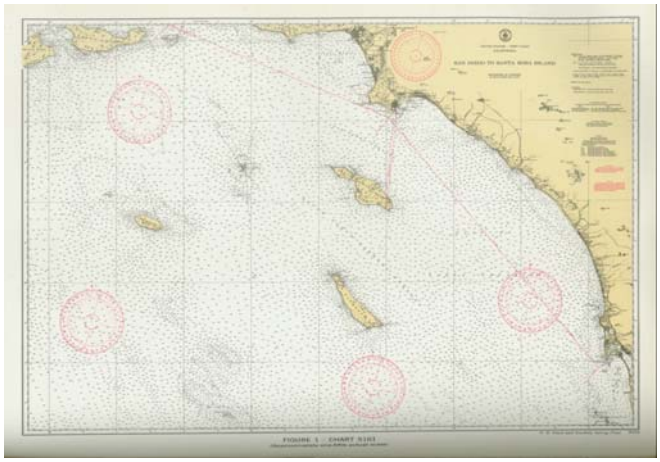


Chart 51010 using traditional hydrographic techniques

The newer chart design utilized exactly the same sounding data, but was contoured with 50- fathom contours through the full range of charted depths.

Chart 5101A contoured bathymetry to the ocean bottom

The submarine topography of the complex ridges and basins is clearly revealed. But what use was complex geomorphology to mariners? As Green, and the chart text makes clear, Chart 5101A was an experimental chart. RAR was a difficult and sophisticated horizontal positioning system based on uniquely specialized equipment mariners would not have access to. But fathometers were becoming common. The Survey proposed that, in far offshore waters, mariners could navigate by changes in bathymetry, roughly positioning themselves by watching the changes in bottom depth compared to the depths on the chart.

Ocean and submarine geomorphology conditions on the Atlantic, as well as new technologies for radio navigation, were very different than on the Pacific. In 1932 and 1934, the Survey published two new experimental charts “for the Fishing Industry” for

the vast, fish-filled Georges Banks offshore from Massachusetts. The charts were produced at the suggestion of The Massachusetts Fisheries Association, because "the nautical charts constructed therefrom are lacking in some details desired by the fishermen"[36]. The maps were based on the extensive new hydrographic data acquired in 1929-31 with RAR and radio-sono buoys. As well, there were now radio stations broadcasting signals that could be used by ship-board radio direction finders. The Survey again used depth contours, but in this case, they used color-coded depths, in a schema appropriate for the vast shallow submarine plateaus of Georges Bank. The project was a productive experiment for the Survey, as "for, in reality, what the fishermen actually want is something that combines all the advantages peculiar to both large and small scale charts, and it has been found that complying with their desires is not such a simple matter".[37]

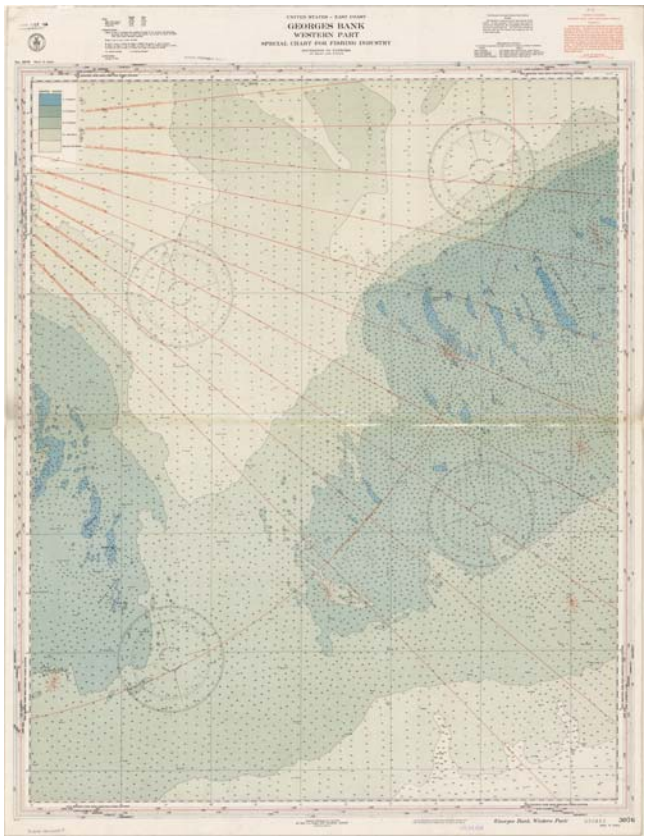
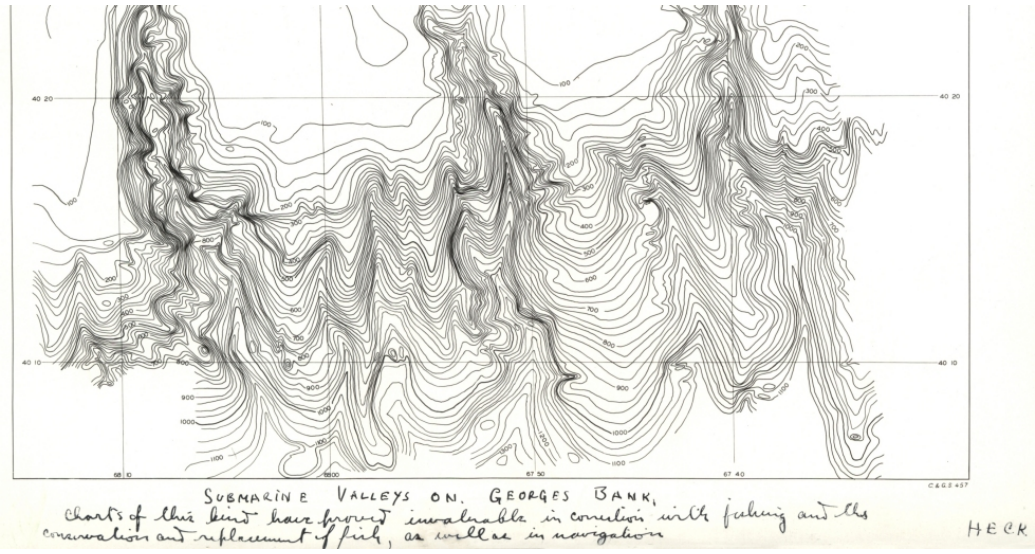


Chart 3076 Special Chart for Fishing Industry, Georges Bank, Western Half

Very prominent in the chart are the incisions of submarine canyons on the margins of the submerged plateau, here delineated in greater detail than ever possible before, because of the combination of RAR and the Dorsey fathomer. Nicholas Heck noted, in annotations to a copy of fine contouring of several of these canyons by Francis

[36] Kirsch, 1932, p. 75.
[37] Krisch, ibid, p. 75.

Shepard, that the increased geomorphological detail might benefit the fisherman in various ways, which was an aim of the project. These charts were also notable for being the first Survey charts ever published with electronic navigation aids—in this case, the configuration of azimuths to various radio direction-finding stations newly established on the New England coast.



Submarine Valleys on Georges Bank
from notes for a paper by Nicholas Heck, 1934

Knowledge of the submarine canyons could benefit fishermen, but they could also benefit earth scientists. As Heck noted: "In geology, not only does the physiographer have a better understanding of what happens to the sediments which constantly leave the land, but the working area of the geologist has been extended to the edge of the continental shelf with accuracy comparable to that obtained on land. The finding of great gorges or submarine valleys has stimulated thought in regard to their possible origin. Accordingly work that was done to aid the needs of the mariner is aiding in revealing the history of the portion of the continent that is at present submerged beneath the sea".[38]

Other scientists, as well, were quick to see the importance of this new data, and where investigations of it might go. ""… the invention of radio-acoustic position-finding and the invention of echo-sounding has made possible the recognition of minutiae of sea-bottom configuration that was entirely impossible only a few years ago."[39] Scientists making use of the new data, particularly the oceanographer Francis Shepard, then passed on the data and its significance to others. "Little by little, however, it was found that such canyons exist also where no connection with a river is possible, and that they are so numerous that most of the continental slopes are notched by several, even by innumerable gullies. A debt of gratitude is particularly owed to the American Shepard for having

[38] Heck, 1935, p. 404.
[39] Vaughn, 1937

directed attention to these most remarkable formations. This investigator arranged that the vast echo-sounding material collected in recent years by the U.S. Coast and Geodetic Survey be put at his disposal….”.[40]

In sum, Patton’s era was one of skilled personnel in a well-managed enterprise, wielding brilliant new technologies, developed both within and without the Survey, which greatly extended Survey data and data products, such as the new experimental charts on both the Atlantic and Pacific coasts, made with new cartographic methods and directed to new purposes. What else was the Survey publishing?

The Division of Charting.

E. Lester Jones had elevated the chart-making operations of the Survey to a separate division, reportable directly to him. Raymond Patton had ascended to be Director from his post as head of the Charting Division. This was an era of great changes and innovations and experiments in cartography and printing, perhaps even greater than the important decade 1850-1860 under Bache.

Perhaps the greatest change in the Division of Printing, and certainly one that enabled so many other changes to take place, was the move of the Division to the new facilities of the Commerce Building in Federal Triangle in 1932. Printing was the very first arm of the Survey to make the move from quarters all over Washington to which the elements of the Survey had been scattered after the ancient warren of buildings on New Jersey Avenue was razed in1928 for the new House Office Building. At Commerce, for the first time in the entire existence of the Survey, almost all the facilities and operations of chart compilation, production, printing, and distribution were together under one roof.

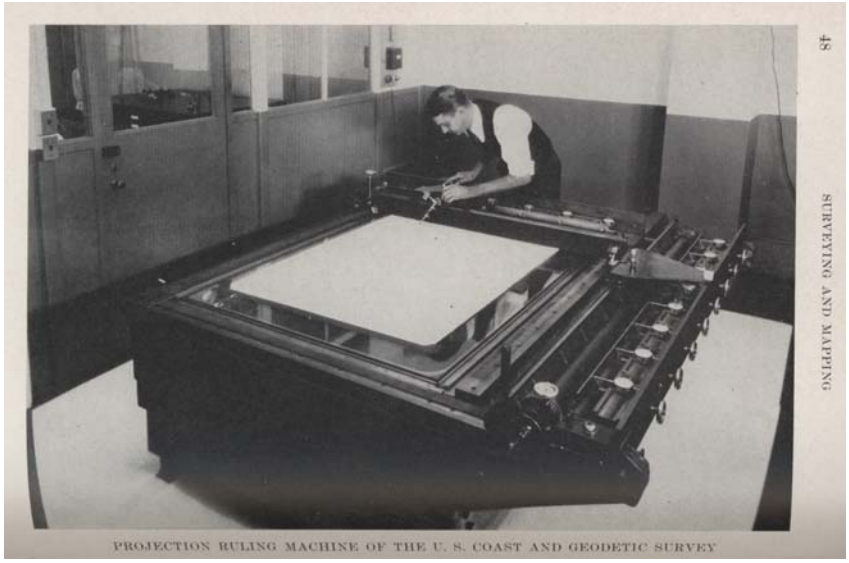
The printing equipment assembled in Commerce ranged from Bache’s original copperplate engraving press, purchased in 1851 and used until well into the Patton era, although sparingly, to lithographic transfer presses to move between engraver charts and lithographs, to new Harris Co. two-color and then five-color offset lithograph presses. The vast proportion of the charts and maps published by the Survey in this era were printed on the Harris offset lithograph presses, just as NOAA charts are to this day.

The printing plates for offset lithography are thin aluminum plates wound around rollers. The images on them are translated photo-mechanically from plate masters which are stable “originals” of the chart. In Bache’s day, the masters were the copper plates themselves which were never used to print directly since the Survey’s development of electrotype plates in the 1850s. In Patton’s era, there were still some copper plates in use as masters, but these would be used only once to pull an impression on a transfer press. That single impression would be used to develop printing plates photographically, which would then be wound on the Harris offset lithograph presses. The major new development in Patton’s time was the creation of stable glass plates which were painted with a dark emulsion which could be scribed mechanically or etched with chemicals to leave lines and dots showing as clear glass against the areas covered by the dark

[40] Kuenen, 1939.

emulsion. These glass plates were the new plate masters. When a printing plate was needed, light would be shined through the glass allowing only the clear glass areas to transmit light with the rest of the plate area blocked by the dark emulsion. That pattern of light would be transferred photo-mechanically to the aluminum printing plate; and then off to the presses it would go.

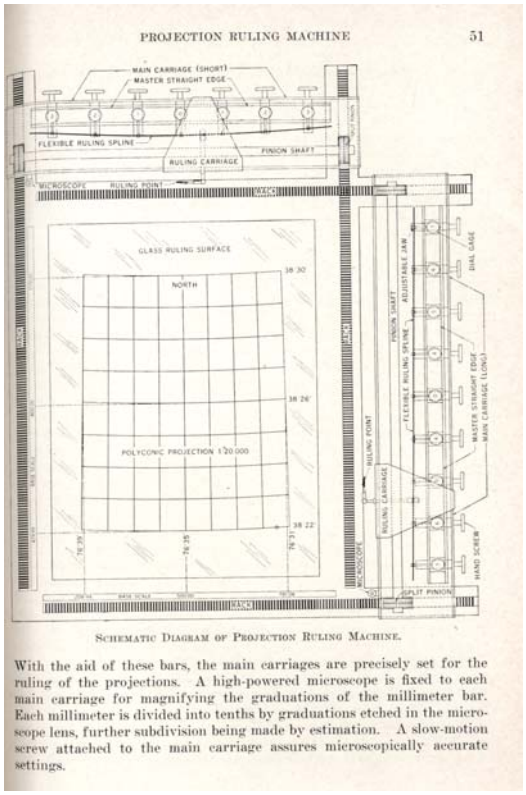
There was one unique machine devised by the Survey to which every map and chart was bound in common. Regardless of the type of chart, its projection, whether it was colored or not, that chart was printed from plates that were designed in a certain projection, with a certain size and map extent, all of which was first calculated and then drawn using the great projection ruling machine.



The Projection Ruling Machine, 1934

Any map, whatever its projection, can be described and bounded by a set of lines, the map's boundaries and graticule, the network of crisscrossing lines (like latitude and longitude), or simply tick marks, which help map users orient and determine their position relative to the map. These lines, except in the simplest cases, are in fact complex curves. Defining and drawing these lines correctly gets to the heart of cartographic production. Survey cartographers devised a system by which the lines and graticules and tick marks of any map in any projection could be scribed accurately and precisely on a stable medium, first a glass plate, and then, eventually, a vinylite plastic sheet. The key to the system was an orthogonal set of two thin steel blades, each of which could be bent into any arbitrary curve with a series of thumbscrews, based on a set of calculations derived from specialized mathematical formulas developed by Survey computers for each projection to be used. Using a scribing pen that followed a path parallel to the curve, any arbitrary line needed could be scribed in the right position on the glass or plastic sheet. Depending on the projection, the steel curves would then be bent to the next curve shape, and the next parallel curve line would be drawn. Gradually, the master frame for the map

would emerge. The curves could be fine-tuned to a precision that was, literally, microscopic.[41]



SCHEMATIC DIAGRAM OF PROJECTION RULING MACHINE.

With the aid of these bars, the main carriages are precisely set for the ruling of the projections. A high-powered microscope is fixed to each main carriage for magnifying the graduations of the millimeter bar. Each millimeter is divided into tenths by graduations etched in the microscope lens, further subdivision being made by estimation. A slow-motion screw attached to the main carriage assures microscopically accurate settings.

Schematic of the blades and the adjustment system

The projection ruling machine was essentially a universal cartographic resource for the Survey. Projections, geographic positions, and all manner of charting data could be scribed quickly and accurately for many applications, including many outside of chart printing. "Projections are prepared on celluloid for field airphoto reductions, on aluminum-backed drawing paper for cartographic compilations, and on copper plates for chart engravings".[42]

The Survey published many kinds of maps and charts, but there were four major classes of maps and charts published in this era.

The first class was maps and schematic diagrams for control surveys associated with the horizontal network of NAD27 and graphics associated with precise leveling and the vertical network. The emphasis was on meticulous accuracy, but beyond that, they were not graphically elaborate and were rarely printed in any more colors than black.

[41] Rose, 1945
[42] Patton, 1935, p. 136

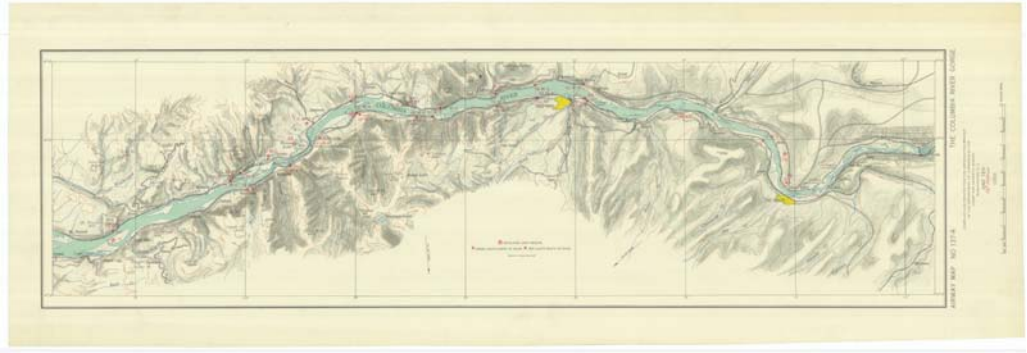
Nautical charts, the traditional cartography of the Survey, could be divided into two large classes. Harbor charts, coastal navigation charts, and charts for inland waterways on the Atlantic coast were developed in the polyconic projection introduced by Hassler in the 19th century. Sailing direction charts, ocean route charts, and specialized charts like the Georges Bank charts for the fishing industry, all of which were much smaller scale charts, were generally developed in the Mercator or Transverse Mercator projections. In some cases, harbor charts and other nautical charts, particularly pertaining to smaller harbors that didn't change very much, were still produced as engraved charts. However, the vast majority of the nautical charts of both kinds were produced by offset lithography. Some were monocolor, but by this time most were chromo-lithographs, with water or areas of specific depth of water in color(s), bright dots to show lighthouse locations, and directed tints to show lighthouse sector of visibility. (Many lights were shielded, so they could be seen only from certain directions around the lighthouse). As well, as was seen with chart 5101A on the Pacific and chart 3076 on the Atlantic, experimental charts allowed more color applied in new ways to be used to provide new or unusual information. In general, there was a close correlation with the arrival of new multi-color Harris offset presses and the use of significantly more color on the charts.

The aeronautical charts developed and changed rapidly in the Patton era. In the beginnings of aeronautical charts under Jones, the Survey inherited a system of airways strip maps developed by the US military. Strip maps extended from one airport to another. As airports developed as hubs, and more maps were needed to describe more routes to and from the hubs, the overlap of strips became inefficient. So, in the late 1920s, the Survey developed a completely different mapping system - the sectionals. These maps looked rectangular, and they tiled to fill the air space of the United States completely. The sectionals were developed on the Lambert conformal conic projection which Survey personnel had first encountered in Europe as the projection used in the map system of the Nord de Guerre, the French military map zone system that all modern military mapping systems are descended from. Similar to a military grid system, the plan for the sectionals was to create a spatial framework and map naming system that would cover all US airspace that was under responsibility of the Survey, and then "populate" the grid by completing maps. The first sectionals were published in 1930, and they were quickly adopted by all pilots.[43]

In Patton's era, the strip maps were phased out and the sectionals came in. To differentiate them clearly from the strip maps, a new name was necessary. By this era, the Survey had been producing nautical charts for almost a century. The Survey dubbed these new maps "aeronautical charts", which soon became their standard name world-wide[44]. The relative novelty of aviation, and the inherent dangers of flying, made a context for aeronautical charts in which there was rapid evaluation and feedback of charts between cartographers and flyers. The maps evolved rapidly, and the many changes in the flying environment, particularly with the introduction of radio direction finding and radio communications, meant that editions of aeronautical charts were updated and

[43] See Ross, 1932.
[44] Ristow, 1960, p. 146.

printed in revised editions in ways unimaginable with nautical charts. As well, given the exigencies of flying in low light or at night, it meant that aeronautical charts carried constraints on colors and visual perception very different from nautical charts. Aeronautical charts started out in multiple colors with many experiments made to optimize chart perception under actual flying conditions. In general, the Survey's aviation cartography was characterized by a tight coupling between map designers and pilots, as innovations were tested, adopted and changed to benefit the pilots better[45]. Many Survey personnel were integral to the aviation charting, but Lt. Paul Smith was particularly prominent in the evolution of the aeronautical charts. The result of all this was that the entire system of aeronautical charts became substantially different from nautical charts, like proverbial apples and oranges.



1932 Airway Map 137A Columbia River Gorge

The final class of maps and charts developed by the Survey in Patton's era were 3-D maps of coastal topography and hydrography produced through the use of John Braund's Reliefograph.

An interest in depicting topographical and hydrographical relief extends through the history of the Survey. Ferdinand Hassler brought with him from Europe a 3-D model of the Swiss Alps around Mont Blanc, and over two hundred years later the model resides in the collections of the American Philosophical Society in Philadelphia. As early as the 1880s, George Davidson had commissioned a 3-D model of topography and bathymetry of western North America and adjacent waters. At about the same time in the Atlantic and Caribbean, Adolf Lindenkohl and others experimented with various methods to display bathymetric depths and profiles. In 1923, the C&GS's Philippine adjunct, the Philippine Coast and Geodetic Survey, had experimented with different plaster and wood 3-D models of the Philippine archipelago showing both topography and hydrography. One of these models had been sent to Washington[46].

John Braund was a Washington-based inventor whose work came to the attention of the Survey. In 1931 Director Patton and Braund signed a contract giving the Coast

[45] Ehrenberg, 2006.
[46] Bureau of Coast and Geodetic Survey, 1923

and Geodetic Survey the rights to make and test one single set of machines that could make 3-D maps by his design while he was in the process of getting his inventions patented[47]. There were two basic assemblies to the process. First, a contoured map was printed on the back side of a thin metal plate. Then, using the Reliefograph, a machinist embossed down the area within the contour area representing the highest relief on the map. The depth embossed was controlled by a device called the altimeter. Then, the second highest contour area would be embossed down. Then the machinist embossed the third, and so on. After all contours were embossed down, the plate was turned over, and what had been valleys were now peaks, corresponding faithfully to the actual heights of the highest relief.

r model—a thin guage aluminum sheet—is formed on the Reliefograph. The "altimeter" is seen on the left.

John Braund"s Reliefograph in Action

The embossed metal plate was then put into the second major assembly of the process. The metal plate was installed, and a very thin metal plate printed with the map on it was placed over the bottom plate. A chamber of hot hydraulic oil was suspended over the top plate, and pressure was exerted on the oil, which warmed and deformed the top metal plate, forming it to fit the 3-D form of the first metal plate below it. Then the hydraulic oil assembly was lifted off, and the top metal plate, now a 3-D printed metal map, was pulled off the press[48]. The Braund 3-D maps were used mainly internally in the Survey in this era but that would soon change, when the war came. As will be described subsequently, after the war a new version of Braund's system was created and patented, using sheets of newly invented thermoplastic instead of metal plates. The second

[47] Braund and Patton, 1931.
[48] Braund, 1936.

generation of Braund's Reliefograph would yield important 3-D maps that played a critical role in visualizing both land topography and submarine geomorphology.[49]

Director Patton Extends and Receives Relief

The activities of the Coast and Geodetic Survey to map the coasts of the United States in Patton's era go back to the original charter of the Survey of the Coast in 1807. But that charter also contained another charge, with a profoundly social orientation, beyond the scope of preparing aids to navigation itself:

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 Gulf Stream, as in his opinion may be especially subservient to the commercial interests of the United States".[50]

A recurrent theme of Patton's administration is the activities of the Survey in new areas, with new projects, in order to further environmental, social and economic goals of the Nation. These did not begin with Patton, of course—in fact, special projects to analyze harbor sedimentation or establish local control for municipal projects goes back to the days of Hassler and Bache. But these greatly expanded in scope and nature in the 20th century. In Jones' era, there was the special map of the Mississippi Floods of 1927. Under Patton, the subject of beach and shoreline preservation became a major emphasis of the Survey, leading Survey personnel into new kinds of research. The Georges Bank chart "for the fishing industry" is another example of the shift in orientation of the Survey and its activities in direct application to projects with social and economic objectives. It was also the first Survey chart to include radio aids to navigation. And the providential fact that the Survey's Division of Seismology had accelerographs in place and functioning in southern California at the time of the 1933 Long Beach earthquake led directly to a major role in subsequent research in all aspects of earthquakes and seismic engineering in the US.

By far the greatest of these projects undertaken by the Survey in Patton's era was the Survey's response to the Great Depression and the many initiatives of the Roosevelt Administration to re-employ unemployed workers and direct them to socially productive tasks. There were many elements to this, as the crisis developed and, over time, the federal government created and evolved responses to it. But by far the greatest project the Survey was involved in was the Local Control Surveys Project. The project began in 1933, when the Survey was approached by the Federal Emergency Relief Administration, and asked to develop a program for productive work for unemployed persons with enough education and engineering background to be able to perform skilled surveying work quickly after appropriate training.

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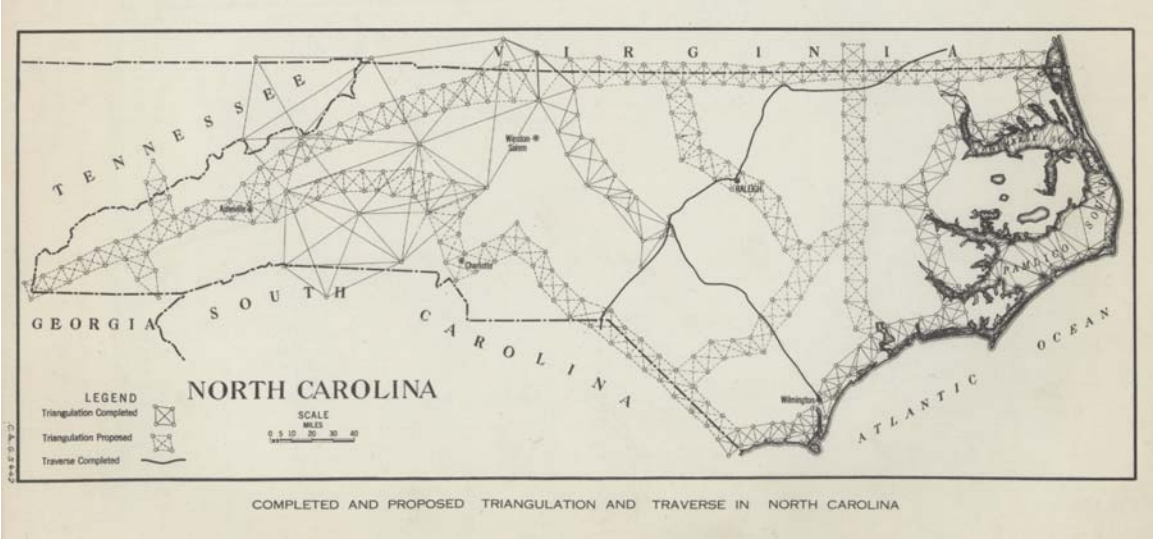
[49] Wilson, 1949: Rosen, 2005.
[50] Act of Feb. 10, 1807, Session II, Ch. 8, 2 Stat. 413-14 (1807)

C & GS Crew and Camp, Mojave Desert

In some ways, the task was a perfect match for work related to projects the Survey had been working on for a long time for completely different purposes. NAD 27 was completed in1927, but was begun over a half century earlier. Shortly after NAD 27 was completed, George Syme, the Senior Highway Engineer of the state of North Carolina, approached the Survey with a proposal for intensified triangulation and leveling by Survey parties in the state, which would then be the "skeleton" upon which a state-organized triangulation network would be developed, with particular reference to developing the system of highways in the state. Syme had, in 1932, been elected to the Executive Committee of the Surveying and Mapping Division of the American Society of Civil Engineers, and the new North Carolina project received national notice. As Syme noted, the funding for the project, which involved substantial funding from the state legislature for both Coast and Geodetic Survey work and work by a new state-level survey, was justified by the legislature from "a strictly highway point, although it was, of course, cognizant of the tremendous profit that would accrue to other state departments, counties, municipalities, corporations, and property owners".[51] Further, Syme noted that the new state triangulation network could serve as a foundation for a much larger enterprise. "Possibly some sort of general mapping agency, armed with the necessary authority but not connected with the Highway Commission will be set up at Raleigh to serve as a clearing house... since the geographic position of each control station will be known, plane coordinates will be used in our future surveying and mapping operations...".[52]

[51] Syme, 1932, p. 26
[52] Ibid., p. 27.



The Actual and Proposed Survey Network for North Carolina, 1932

Here Syme developed the idea, originally presented in 1921 by the Survey's chief geodetic computer Walter Reynolds, for a system that could correlate a plane coordinate system for "the survey of a city, town or county" with geographic positions from the Survey's networks.[53] Syme proposed developing a set of plane coordinate systems at the state level, which could then be used by smaller entities within the state. Thus developed the "modern" system of state plane coordinate systems in which latitudes and longitudes of points throughout a given state could be transformed into plane rectangular coordinates on a grid[54]. In many cases, the size and/or shape of the state would require a set of different zones, each with its own grid system. Further, the plane coordinate systems involved cartographic projections for the specific zones of the state. There were two principal projection systems, the Lambert conformal conic for areas trending east-west, and the transverse Mercator projection system, for zones trending north-south. Appropriately, the state of Florida used both. Survey geodesists and computers worked out how to coordinate geodetic coordinates with state plane coordinates, and then began to apply the system to specific states. North Carolina's pioneer system was completed in 1933. Soon every state had a developing plane coordinate grid system.[55]

The new infusion of unemployed persons with some technical background could then be immediately deployed to projects involving all states that were already underway, but at a lower level of activity. A full description of the activities of the project is beyond the scope of this history—there were stops and starts, and a bewildering number of program name changes (the classic "alphabet soup" of the Roosevelt Administration). But, in sum, despite many challenges, a great extension of local control projects and

[53] Reynolds, 1921, p. 5.
[54] In the 1890s, the state of Massachusetts developed a very different model for plane coordinate systems, which eventually was abandoned, and subsequently Massachusetts adopted the new "North Carolina-type" system.
[55] Smith, 1997, p. 197.

precise leveling surveys and other projects which involved survey crews in the field, and also offices full of computers, stenographers, clerks, and accountants. At its height, the Project employed over 10,000 previously unemployed people, people "among a class not reached by other work relief measures," of whom about 75% had had some college training. For those employed, and for those affected by the quality of the local control surveys, the project was a success. It was also a success for the Survey, "acquainting the engineer with the fact that accurate surveys can be obtained when using ordinary surveying equipment ... if certain precautions are taken".[56]

As the Depression deepened, and as the Roosevelt era took hold, many other divisions of the Survey took part in extending Survey work to skilled and semi-skilled unemployed people. Lt. O.S. Reading, the developer of the nine-lens camera, was dispatched to New York City in 1934 to organize a map compilation project based on rectified aerial photography to be worked by unemployed engineers. Reading saw at once that none of them had any background in cartography or surveying.

> "But I still have a hollow feeling around the diaphragm when I think of those men. Clean-cut, intelligent engineers who had been earning three hundred to a thousand dollars a month before the depression. There were also some youngsters, a couple of years out of college, with Phi Beta Kappa keys, all facing a world that had no use for their services. They did not say so at the time, but I learned from later questions that all had long since given up their telephones, and most had seen their life insurance reserves dwindle away. Some had no other means of support for their families except twenty-five dollars every other week for relief "made work" furnished by the City of New York. Since none of the men were specially qualified, I finally selected those men who needed the work most and could show by designs of bridges, yards, and building plans they had drawn up in previous years, that they were passable draftsmen".[57]

And so the maps were compiled, and the triangulation and leveling networks advanced overland, and the computers calculated endless tables, and the people progressed. Reading spoke for much more than his specific project when he noted: "But the most important lesson of all is that, given the procedure just described, there are thousands of engineers walking the streets looking for work today who could make during the next few years a beautifully complete and accurate large-scale map of this country; a map we are not likely to have for decades to come if this opportunity is wasted"[58].

Midway through his term, Director Patton became ill. He persevered, but eventually was overcome and died in office in 1937. Six years before he died, he had published a paper on his great focus, coastal preservation. It was an analysis of Moriches Inlet and the evolution of Long Beach, on the southern shore of Long Island. In a certain

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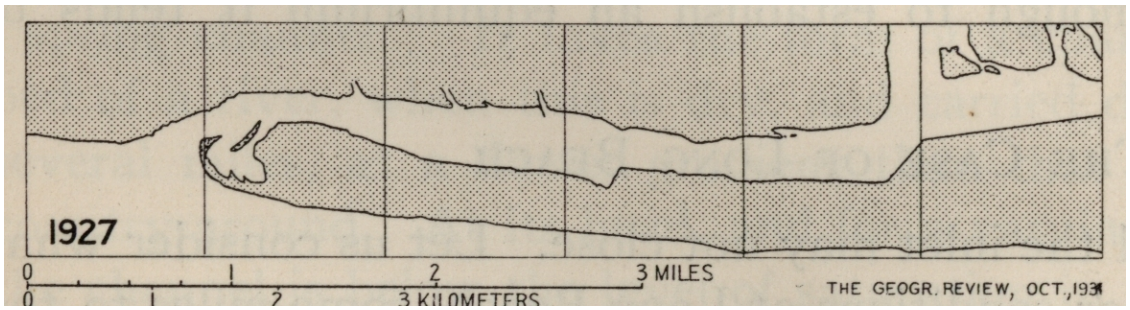
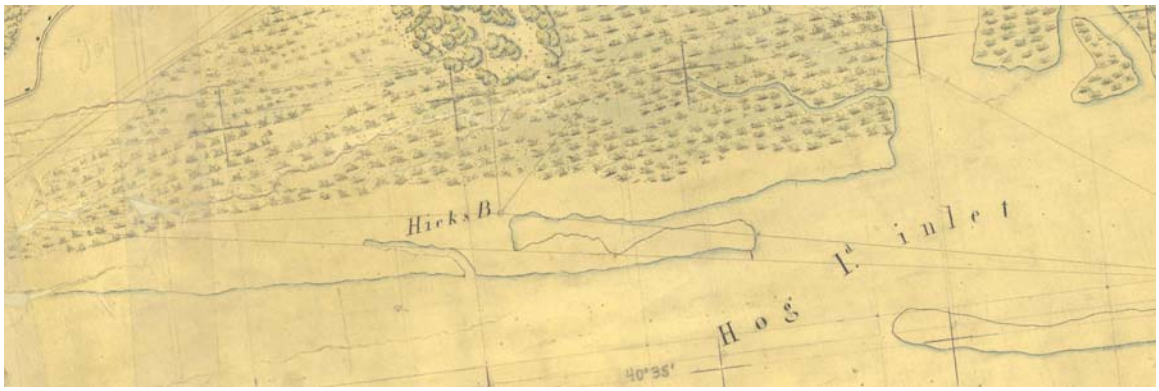
[56] Hemple, 1934, pp. 17-19.
[57] Reading, 1934. p. 118.
[56] Ibid., p. 119.

manner, Patton's paper condensed the entire history of the Survey. Much of the analysis was based on repeat surveys of the shore prepared by the Survey. The most recent survey was in 1927, using aerial photography and lead-line soundings and wire-drag. The oldest data in his analysis came from the very beginnings of Hassler's topographic and hydrographic field work for the Survey of the Coast.



Moriches Inlet and Long Beach, 1927, in Patton, 1931



Survey of the Coast, topographic sheet T-3, 1835

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