

SUBMARINE VALLEYS

by

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The past several years have seen a revival of interest in the general subject of submarine valleys which occupied some space in geological literature over a generation ago. This has been due in some measure to the tireless efforts of Professor Francis P. SHEPARD, of the University of Illinois, who for a number of years has devoted a large part of his time and energy to the subject and has published many papers (1). It has also been due to the improved methods of hydrographic surveying by the U.S. Coast and Geodetic Survey and others which have made it possible to map these features accurately for the first time.

It is now about seventy-five years since *Dana* (2) first called attention to the Hudson submarine valley, and suggested that it may have been formed by subaerial erosion. A lively interest was shown in the subject for some years, and it was actively discussed before the Geological Society of America and elsewhere up until about 1912 (3). During this period the U.S. Coast and Geodetic Survey contributed to the discussion through George DAVIDSON (4) and A. LINDENKOHL (5), and the soundings taken along the coasts of the United States and its possessions, then as now, gave geologists and oceanographers much new material with which to work. Unfortunately, however, the majority of these features on the Atlantic coast of the United States are at such great distances from the shore and in such deep water, that the hydrographic methods in use until the last few years were inadequate to supply even approximately accurate details, and the exact physiography could not be determined. This was true even of the great Hudson submarine valley, to which the work prior to that of the present year seemed to give an S-shape owing to the fact that the inaccuracies in locations of the earlier soundings forced an interpretation which connected the part of the valley immediately below the 50 fathom curve with the lower part of what has been proved, by the accurate work of the present season, to be an entirely different submarine valley.

Thus, with the passing of time, hydrographic methods have been developed so that it is now possible to make surveys which are both accurate and thorough at great distances from land; and the resulting surveys with their wealth of detail in offshore areas are disclosing numerous heretofore unknown submarine valleys as well as giving accurate details of those which were only partially known or suspected. For example, the present 1936 season's work has shown that the Hudson submarine valley is but one of a number of entirely analogous submarine valleys on this part of the ocean floor; that it is except for a slight deflection between the 50 and 100 fathom contours an almost straight line normal to the 100 fathom curve, and that the slightly incised valley which can be followed seaward from the entrance to New York Bay to about the 40 fathom line is, at the present time, without any topographic connection with the great canyon that starts at and slightly indents the 50 fathom contour.

The first importance of these submarine features as related to the nautical chart is their value to merchant vessels equipped with echo sounding devices. These instruments enable them to use submarine physiography in navigation provided it has been charted accurately. An instance where the lack of knowledge of the existence of a valley was disastrous was given by George DAVIDSON (6) in 1897:

(1) F. P. SHEPARD: "Changes in Sea Level as the Cause of Submarine Canyons", *Abs. Geol. Soc. Am.* 48th An. Meeting (1935) p. 30 (also many other papers).

(2) "Dana's Manual of Geology", 1863, p. 441.

(3) J. W. SPENCER: "Submarine Valleys off the American Coast and the North Atlantic", *Geol. Soc. Am. Bul.* Vol. 14, 1903, pp. 207-226 (and many other papers).

A. C. VEATCH: "Development of Major Drainage of the North Atlantic Coastal Plain", *U. S. Geol. Sur., Prof. Paper* No 44, Pl. VI.

Edward HULL: "Monograph on the Sub-Oceanic Physiography of the North Atlantic Ocean", 1912.

(4) George DAVIDSON: "Submarine Valleys on the Pacific Coast of the United States", *Bul. Cal. Acad. Sc.*, Jan. 1887; "Submerged Valleys of the Coast of Lower California, U. S. A., and of Lower California, Mexico", *Proc. Cal. Acad. Sc.* Vol 1, 1897, pp. 73-103.

(5) A. LINDENKOHL: "Geology of the Sea Bottom in the Approaches to New York Bay". *U. S. Coast and Geod. Sur. Report* 1884, App. 13; *Am. Jour. Science* 3rd Ser. Vol. 29, 1885, pp. 465-480.

(6) *Op. cit.*

"Practical bearing of these northern submerged valleys.

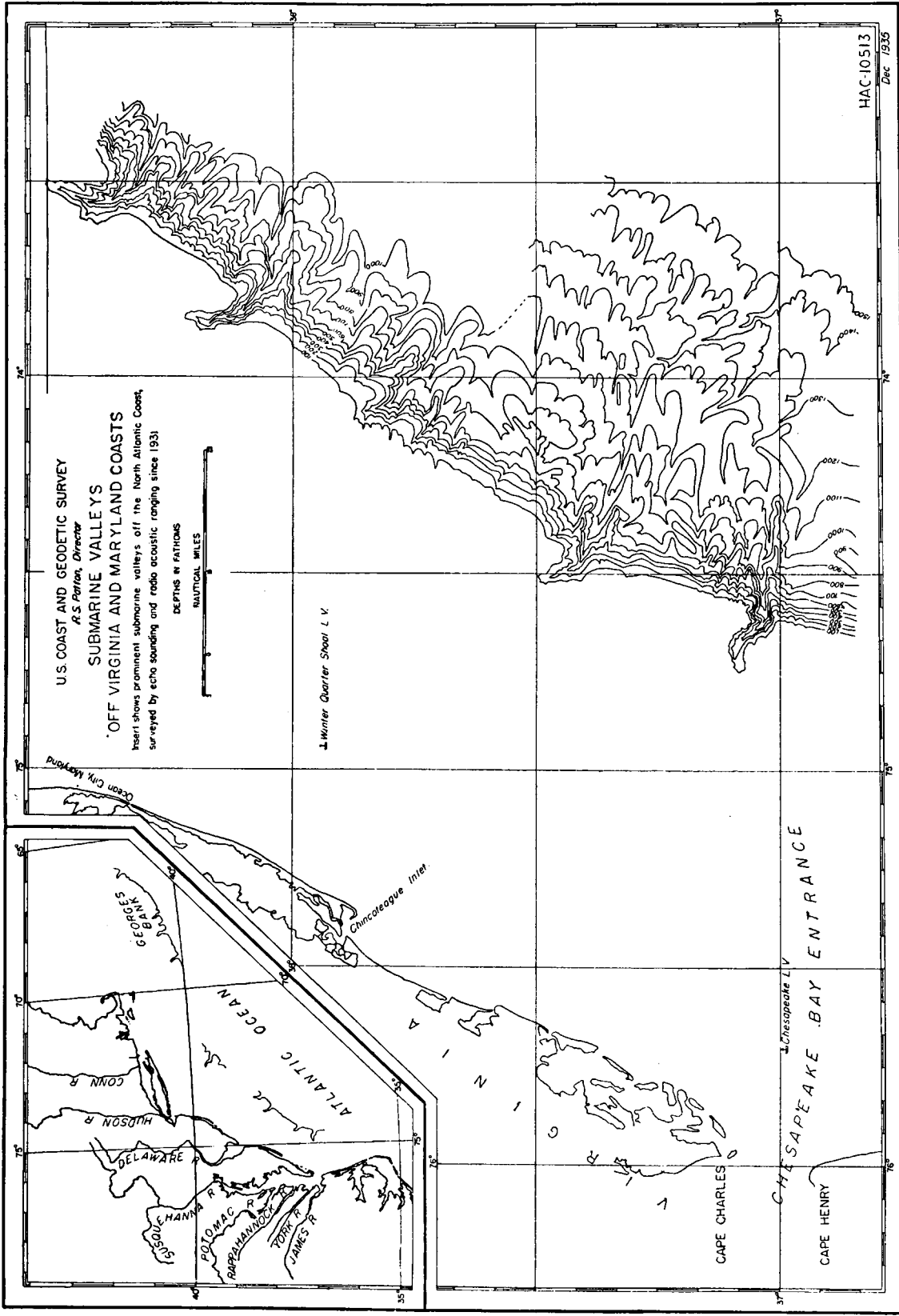
Two problems are at once suggested by these four submarine valleys; one is eminently practical: Steam coasting vessels bound for Humboldt Bay, when they get as far northward as Shelter Cove, haul into the shore to find soundings and then continue their course parallel to the shore. One vessel has been lost by failing to find bottom until close upon the rocky coast, and the blame was attached to the captain. This steamer doubtless sounded up the axis of the King Peak submerged valley and necessarily found no bottom with the ordinary lead line. She would run into danger between casts that were deluding. Had the existence of this valley been known at that time, the vessel would have proceeded in a different manner".

In 1916, the steamer *Bay*, southbound in thick weather was proceeding on soundings north of Cape Mendocino. Misled by soundings obtained in a submarine depression, unknown at that time, the commanding officer altered the course, thinking he had passed Cape Mendocino, and the vessel stranded about 2 miles northward of the cape. This accident cost the lives of six persons and a vessel valued at \$1,000,000. (1).

The published charts usually are on such small scales, especially in the offshore areas that they are not of great value in showing details of the topography of the ocean floor; consequently the field surveys which always are made on larger scales have been in demand by students of this subject. This is an additional reason why coastal surveys in deeper water should provide as complete a development of submarine features as is practicable, where such development can be made without undue delay to the progress of hydrographic surveys for simple charting needs.

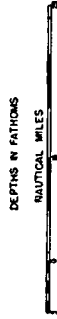
The development of deep water submarine configurations is a radically different problem from that encountered in shoal regions, and it has received comparatively little consideration in the past mainly due to the lack of facilities for accomplishing such development. Here, all parts of the feature may have equal significance, whereas in charting shoal areas for navigation, the dangerous rocks and shoal banks have outstanding importance for commercial reasons, and justly receive the major attention of the hydrographers. Furthermore, the depth curves or contours outlining the configuration of the deeper portions of the ocean floor should be drawn with due regard to the type of topography indicated by the general features. In the shoal water found off the Atlantic and Gulf coasts of the United States, where it is always possible to obtain many soundings, the contours usually indicate smooth, rounded shapes characteristic of the loose sediments continually undergoing wave planation, local deposition from rivers and bays and tidal current scour. The result of the work of these ever active forces of nature is to obliterate the original character of the topography on which they act. We have become so accustomed to this appearance of contours representing the ocean floor that it seems unnatural for the depth curves on charts to have other forms. Another reason for this prejudice is that until recently the deeper parts of the sea could not be surveyed in detail, and only a comparatively thin scattering of soundings was available. It naturally follows that the contours drawn from these insufficient soundings should betray the uncertainty of the person contouring the area. Fathometer hydrography, however, provides very close spacing of soundings along the profile of a ship's course, and from several neighboring lines of these soundings the fundamental form of the topography usually can be inferred, i.e., whether it is orogenic, erosional or otherwise. The geological nature of the general region of the survey also must be considered. In the vicinity of the Aleutian Islands, and some parts of the Pacific Coast of the United States, one would expect to find numerous indications of faulting and volcanic forms. In tropical seas, as for example the Philippine Islands, one would expect submerged coral formations, as well as orogenic features and volcanic indications. On all of these might be superimposed plainly the work of more recent streams. To those of an inquiring turn of mind it should be self-evident that hydrography and oceanography are not separate and distinct sciences, divorced from geology, but are closely related to all branches of earth science. It is, therefore, most essential that a thorough knowledge of geology be acquired in order to gain the maximum efficiency in hydrographic work, particularly in deep water regions. This knowledge will be invaluable in delineating the depth curves on boat sheets as the survey progresses, and may enable the hydrographer to change his plan of survey so as to take advantage of a revised plan of sounding line

(1) U. S. C. & G. S. Ser. Pub. No. 81, 1918. "The Neglected Waters of the Pacific Coast", pp. 13-15.



U.S. COAST AND GEODETIC SURVEY
U.S. Patton, Director

**SUBMARINE VALLEYS
 OFF VIRGINIA AND MARYLAND COASTS**
 Insert shows prominent submarine valleys off the North Atlantic Coast,
 surveyed by echo sounding and radio acoustic ranging since 1931



↓ Winter Quarter Shoal L.V.

↓ Chesapeake L.V.
 CHESAPEAKE BAY ENTRANCE

CAPE CHARLES

CAPE HENRY

U.S. COAST & GEODETIC SURVEY
R.S. PATTON, DIRECTOR

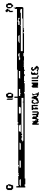
APPROACHES TO NEW YORK

Vessels: OCEANOGRAPHIC, LYDONIA, GILBERT, WELKEN

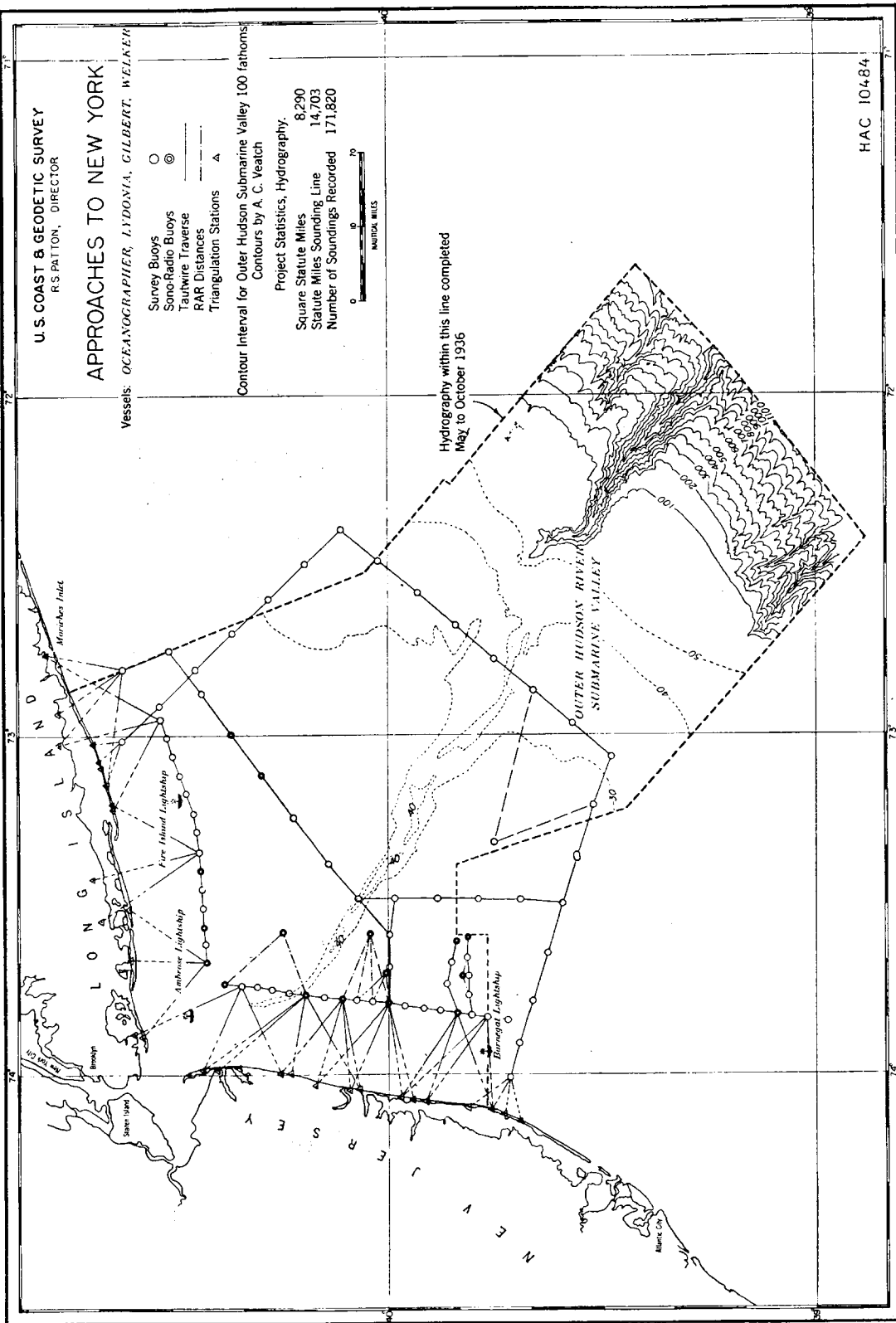
- Survey Buoys
- ⊙ Sono-Radio Buoys
- Tautwire Traverse
- RAR Distances
- △ Triangulation Stations

Contour Interval for Outer Hudson Submarine Valley 100 fathoms
Contours by A. C. Yeatch

Project Statistics, Hydrography:
Square Statute Miles 8,290
Statute Miles Sounding Line 14,703
Number of Soundings Recorded 171,820



Hydrography within this line completed
May to October 1936



HAC 10484

spacing and direction, and with the same expenditure of time and money he may be able to accomplish far more than without this knowledge.

It now appears that different plans for the directions of the preliminary as well as the developing sounding lines would yield a more economic survey of areas beyond the 100 fathom curve. When the program of surveying the waters of the Atlantic coast out to the edges of the coastal shelf was inaugurated, the existence of only a few of the submarine valleys since found was then suspected. Consequently the sounding lines were run approximately normal to the general trend of the 100 fathom curve, in order to provide a strong and thorough location of this curve. These valleys indenting the edges of the shelf are far more numerous than was anticipated, and in practically all cases they exhibit the characteristics of the dendritic systems found on land.

It is not difficult to see that with the wide spacing of sounding lines usually specified for deep water, some important valleys may lie between the sounding lines of the proposed system normal to the trend of the edge of the shelf and might be missed completely. A system of sounding lines running at approximately 45° to the general trend of the depth curves seems to be the most desirable because the majority of these valleys on the Atlantic coast lie normal to the shelf. Such a procedure not only will give the maximum information for the minimum amount of work, but the lines will cross the steepest slopes of the features at an angle rather than normal to the surfaces of the slopes, thereby aiding the fathometer observers to follow sudden changes in depths. With the proposed direction of lines, the depths would change more slowly in any sounding time interval than if the features are crossed at right angles to their axes. This suggestion was made in personal correspondence by Dr. A. C. VEATCH (July, 1935) after he had contoured a number of the valleys found during the past two years in a survey off the Virginia-Maryland coast, in one part of which all the survey lines beyond the 100 fathom curve had been run at 45° in contrast with the lines normal to the 100 fathom curve found in the remainder of the area. I might mention that all field officers who have considered this suggestion do not agree that it is an improvement, and hope that the mention of its possible advantages may invite some discussion in this Bulletin on the subject. There are, of course, considerations of control which may affect the direction of lines to be run, and the above plan may not always be practicable due to conditions beyond the control of the hydrographer.

Workers in other branches of science have been stimulated to investigate the vast unknown areas beneath the ocean surface, mainly due to the widespread interest in the intricate submarine topography revealed by the recent surveys by the Coast and Geodetic Survey off the coasts of the United States. It is not beyond the realm of possibility that elements desirable in our present civilization, but rare on the land above the sea may be found in the ocean depths, and means devised by which they can be recovered. Oceanographers in the past have had to be satisfied with the small samples of the ocean bottom brought up by the bottom samplers used in hydrographic work. Recently, however, Dr. PIGGOTT (1) of the Geophysical Laboratory, Carnegie Institution of Washington, while engaged on the determination of the radium content of samples of the ocean bottom taken by the ordinary snapper cups, designed an apparatus which will obtain cores about two inches in diameter. On a voyage in the North Atlantic on the cable ship *Lord Kelvin* (2) he obtained one core over 10 feet in length in a depth of over 2000 fathoms. Numerous other cores over 8 feet in length were obtained at great depths. This remarkable achievement undoubtedly marks the beginning of more complete investigations of the sea bottom. H. C. STETSON (3) of the Woods Hole Oceanographic Institution, working with a form of deep sea dredge, has taken numerous samples from the walls of the submarine canyons of Georges Bank and those of the Virginia-Maryland coast.

Dr. Maurice EWING (4), of Lehigh University, aided by the Geological Society of America, has made seismic measurements by the refraction and reflection methods of the depths of the submerged coastal plain sediments overlying the crystalline structure

(1) C. S. PIGGOTT: "Apparatus to Secure Samples from the Ocean Bottom". *Bul. Geo. Soc. Am.* Vol. 47, pp. 675-684 (1936).

(2) C. S. PIGGOTT: *Geol. Soc. Am. Bul.* (In press), 1936.

(3) H. C. STETSON: "Geology and Paleontology of the Georges Bank Canyons". *Bul. Geo. Soc. Am.* Vol. 47, pp. 339-366 (1936).

(4) EWING, CRARY, RUTHERFORD, and MILLER: "Geophysical Investigations in the Emerged and Submerged Atlantic Coastal Plain". *Geo. Soc. Am. Bul.* (in press), 1936. N. H. HECK: "Sounding to Granite". *Field Engineers Bul. No. 9*, U. S. C. & G. S. (1935).

off the Atlantic coast. The first experiments to demonstrate the feasibility of the method in deep water were made by EWING on the Coast and Geodetic Survey Ship *Oceanographer* (1935).

The data and material obtained by these different methods of science are adding to the gradually accumulating evidence which is changing many of the cherished geological theories relating to the epeirogeny of the continental margins.

Natural human curiosity always has urged man to speculate on the origin of physiographic features and it follows that there have been many hypotheses advanced to account for the submerged valleys. SPENCER (1) was probably the first to suggest that there may have been a change in elevation of the order of 10,000 to 15,000 feet between the land and sea level as it now stands, and that the submarine valleys are the results of subaerial erosion during the period when the sea had retreated to lower levels. He thought that the change in shore line was due to a combination of movement both of land and sea. A. LINDENKOHL concurred in this view. Another supposition that seems to be gaining support by the accumulating evidence of facts, is that there were two periods in Post-Pliocene times during which the sea retreated to a position approximately 10,000 feet below its present level and in these periods the streams cut their valleys through the relatively soft coastal plain sediments (2).

Differential density currents arising out of the conditions prevailing during the glacial period have been proposed (3) for the cause of the valleys, but this theory has many serious objections from an engineering as well as a physical viewpoint, and the author himself is frank to admit that it was advanced only as a working hypothesis.

Some of the valleys of the Pacific Coast of the United States and other similar regions of the world have been attributed to faulting, but the recent hydrographic surveys have made it possible in most cases to differentiate between orogenic features and those of apparent erosional origin. The term "Submarine valley" can be applied properly only to those features of obvious erosional form.

If eustatic changes in sea level actually occurred as indicated by most of the hypotheses, a rational explanation of what happened to the water is desirable. HESS and MACCLINTOCK (4) proposed a sudden change in the rate of rotation of the earth resulting in distortion of the hydrosphere, with consequent diastrophic changes in the lithosphere, and eventual return of sea level to its original position.

Another theory offers as a working hypothesis the close approach of an astronomic object to the earth twice in Post-Pliocene times and so by inference at other times in the history of the earth. The proximity was such that there was slight, if any, distortion over the elastic limit of the lithosphere, but resultant liquefaction and subsequent consolidation of rocks below the "crust" produced uplift and subsidence and thus changes in the relative level of land and sea, in places exceeding 10,000 feet (5).

Based on recent U.S.S.R. investigations in arctic regions, it has been suggested that during the last glacial age, enough water was taken from the sea to form stupendous ice caps, and this may have lowered the sea level about 500 fathoms from its present elevation (6).

The authors of some of these theories should at least be credited with offering them only as working hypotheses; even so, one cannot help but marvel at the fertility of human imagination in the efforts to explain the origin of these submarine features. What is most needed now is more comprehensive data, particularly seaward from the coastal shelves of the ocean. After all, most of the existing geological theories are based on facts that have been observed on the one quarter of the earth's surface above sea level. The ocean covers so much of the planet that the advancement of human knowledge needs the facts that can be found in the ocean, and the greater the amount of data obtained the more nearly will the hypotheses offered to explain them approximate the truth.

The commercial importance of the shoaler sections of the submarine valleys is apparent because we have echo sounders which are used with confidence by merchant vessels

(1) J. W. SPENCER: *Op. cit.*

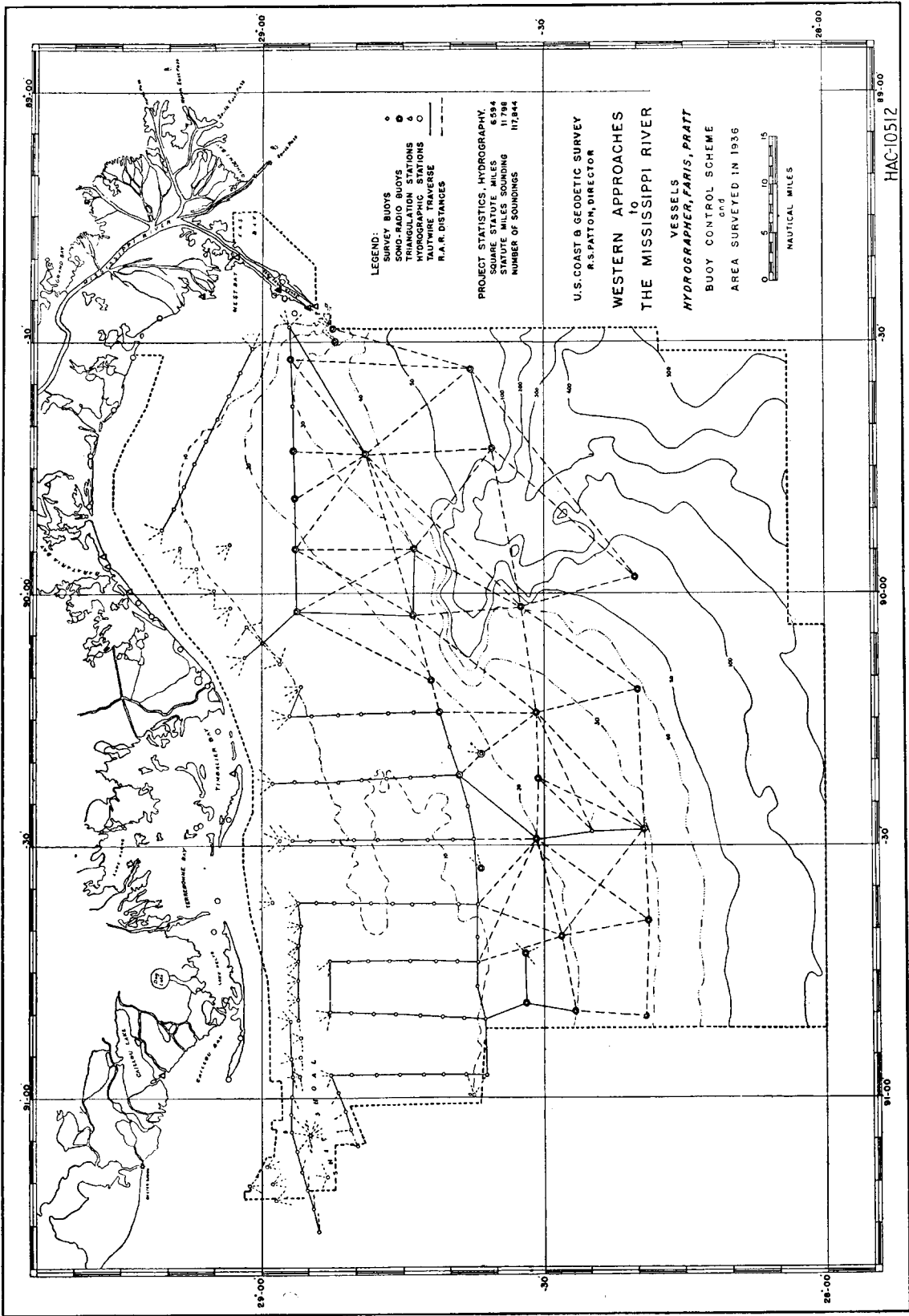
(2) A. C. VEATCH: "Personal Correspondence". (1935).

(3) R. A. DALY: "Origin of Submarine Canyons". *Am. Jour. Sc.* Vol. XXXI, No. 186.

(4) HESS and MACCLINTOCK: "Submerged Valleys in Continental Slopes and Changes of Sea Level". *Sc. News Ser.* Vol. 83 (1936), pp. 332-334.

(5) A. C. VEATCH: "Personal Correspondence". (1936).

(6) F. P. SHEPARD: *Op. cit.*, and *Am. Geo. Union Trans.*, April, 1936.



LEGEND:

- SURVEY BUOYS
- ◐ SOUND-RADIO BUOYS
- △ TRIANGULATION STATIONS
- ◊ HYDROGRAPHIC STATIONS
- AUTOWIRE TRAVERSE
- N.A.R. DISTANCES

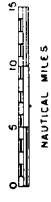
PROJECT STATISTICS, HYDROGRAPHY:

STATION COUNT	11,788
STATUTE MILES SOUNDING	117,884
NUMBER OF SOUNDINGS	117,844

U.S. COAST & GEODETIC SURVEY
 R. S. PATTON, DIRECTOR

WESTERN APPROACHES
 TO
 THE MISSISSIPPI RIVER

VESSELS
 HYDROGRAPHER, PARIS, PRATT
 & D
 BUOY CONTROL SCHEME
 AREA SURVEYED IN 1936



HAC-10512

in depths as great as 150 fathoms. The deeper reaches of these valleys may seem now to be quite unimportant for navigation but the echo sounding equipment is developing at a rapid rate, and it certainly will not be many years until it is as easy to obtain a sounding in 1,000 fathoms as it is now in 20 fathoms. A widespread use of echo sounders by merchant ships and naval vessels may bring about a radical change in the form of the nautical chart as it exists today. Any navigator who has used a fathometer for making a landfall, sketches on the chart being used additional contours from the printed selected soundings. These soundings, no matter how carefully selected never can portray the picture of the submarine topography with the fidelity shown by contours reproduced from the original survey sheets. Furthermore, the contours sketched by the navigator are not the ones which might have been obtained had all the soundings of the original survey been available. It is only from the very recent surveys that such a chart could be made with the requisite accuracy, and a sudden transition from the present form of nautical chart certainly is not to be advocated. The trend, however, is apparent and it appears that the nautical chart of the not far distant future will show the configuration of the ocean bottom by appropriate contour intervals commensurate with the scale of the chart.

Sincere thanks are offered to Dr. A.C. VEATCH, who has contributed in personal discussions and in extensive correspondence so generously from his broad experience, and who has predicted in advance numerous submarine valleys subsequently confirmed by the offshore surveys of the Atlantic coastal shelf.

