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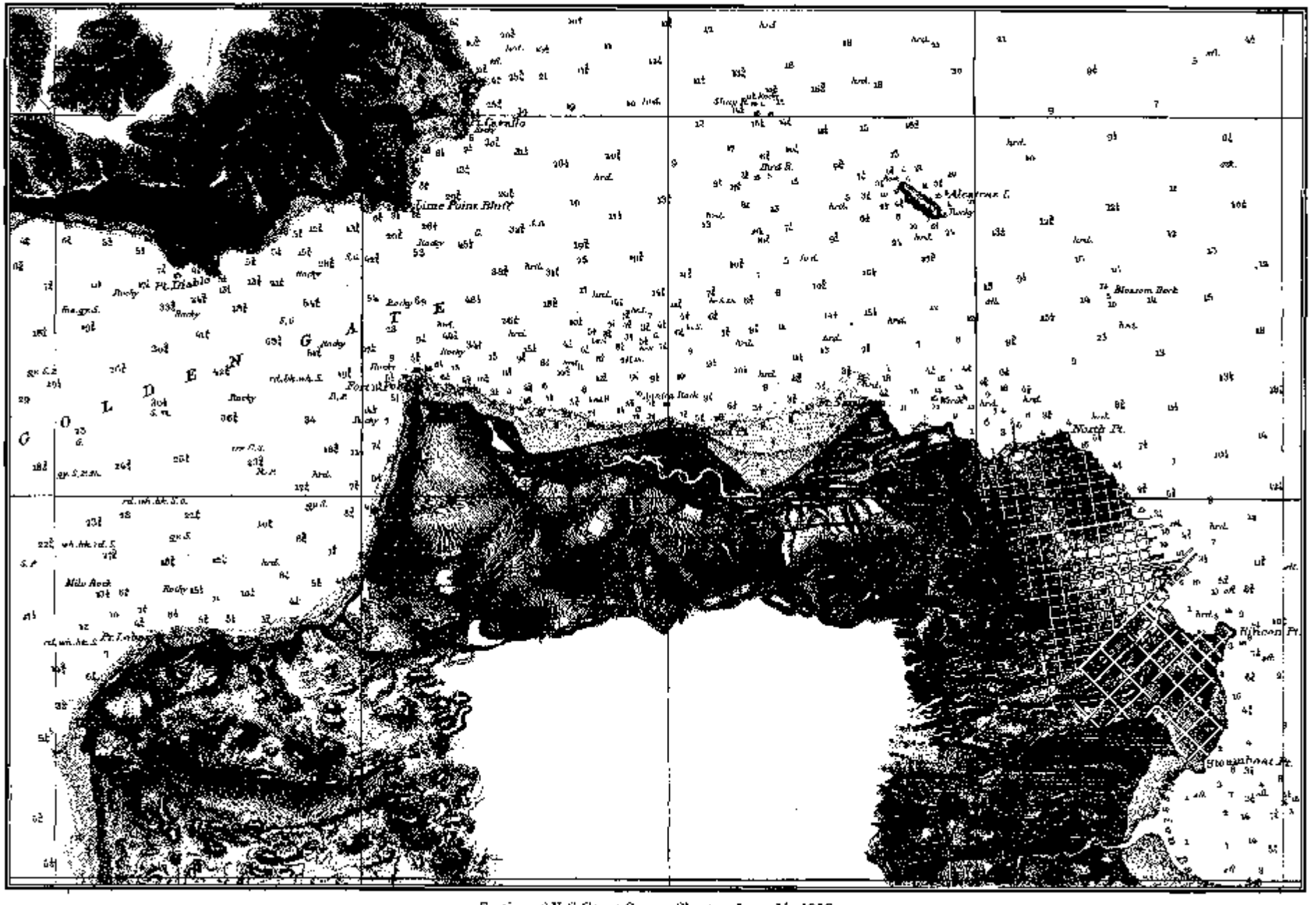
U. S. COAST & GEODETIC SURVEY

DECEMBER 1936



Section of U. S. Coast Survey Chart engraved in 1859

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VELOCITY AND RAY PATHS OF SOUND WAVES IN SEA WATER

O. W. Swainson, H. & G. Engineer
U. S. Coast and Geodetic Survey

Radio Acoustic Ranging is the best method available for obtaining positions at considerable distances off shore, or when the land objects are obscured by weather conditions. The desire to improve this method and increase the limits of accuracy led to the following experiments and study of the propagation of sound waves in sea water. With the existing methods and knowledge of the ray paths the position of the vessel is obtained with an error usually less than fifty meters for distances up to fifty miles and a maximum error of four hundred meters up to two hundred miles. The main cause of errors is intervening irregularities of the sea bottom.

In all our present hydrographic surveying using R A R the apparent horizontal velocity that is, the horizontal distance divided by the travel time of the sound wave — to each of the hydrophones is determined experimentally in various portions of the area, and as far off shore as possible, by firing bombs simultaneously with obtaining the true position by visual fixes on land objects. This method provides a close approximation to the apparent horizontal velocity at greater distances. The fundamental purpose of these experiments was to provide a practical method for obtaining the apparent velocity in deep water, and to determine the actual path over which the energy usually is transmitted. With such knowledge a satisfactory adjustment of apparent discrepancies can be made.

The first experiments for the study of the propagation of sound waves in sea water were made in November, 1933 by the surveying vessels Pioneer and Guide. (See report, "Velocity and Ray Path of Sound Waves in Sea Water" of April, 1934). These experiments definitely indicated the refraction and reflection theory. Consequently, the same two vessels conducted additional experiments in January, 1935. The general program was the same as before with numerous refinements introduced as a result of the knowledge gained at that time. One of the most important differences was that during the latter experiments accurate distances between the bomb and hydrophone were determined.

The site of the experiments was the same as for the previous work. (Fig. 1). In the deep water tests (1000 fathoms over the entire distance between bombs and hydrophones) electric bombs were fired near the surface and at depths for distances from the hydrophone varying from 4 to 75 km. with the bombing vessel stationary, and the fuse bombs from 4 to 86 km. with the bombing vessel underway. In the deep to shoal water tests the program was similar but tests were made over a maximum distance of about 46 km. Shoal to deep water tests, that is bombing in shoal water (20 fathoms) with hydrophone at 30 fathoms where the water was 1000 fathoms deep, were carried out with distances varying from 3 to 36 km.

During the deep water tests one hydrophone was lowered to 30 fathoms and one to 390 fathoms. A supplementary test was made where bombs were fired at various depths to 800 fathoms with the deep hydrophone at the same depth as the bomb. Positions of the bombs and hydrophones were obtained by four observers with theodolites and radio transmitters and receivers stationed on Santa Barbara, San Nicolas, and Santa Cruz Islands.

For those who do not care to go into the detailed discussion of the experiments and the results, the Summary, Interpretation, and Recommendations as applied to R A R are given in the first part of the report as follows:

SUMMARY

The velocities as given in the British Admiralty tables are correct (or less than 0.2% in error). Fig. 6.

The sound wave traveling through sea water is refracted and reflected and for short distances may suffer diffraction. See Fig. $1.

The sound traveled direct from the bomb to the hydrophone for only a very short distance. Its amplitude faded out rapidly with distance. Figs. 7, 16, 26, 27, 32.

Sound arriving at the surface hydrophone at distances greater than 20 km. (through a constant depth of water of 1000 fathoms) had been reflected one or more times from the sea floor. Sound reflected once from the bottom was observed to a maximum distance of 73 km. in the all deep water tests, but the last 35 or 40 km. of travel depended on diffraction. Improvements in the reliability and accuracy of R A R in deep water rests on a full knowledge of this effect. Figs. 7, 8, 26.

Some energy from a bomb fired at 30 fathoms traveled along a narrow constant velocity layer at 100 fathoms and reached a near the surface hydrophone at distances up to 17½ km. Fig. 12. A similar wave from the near the surface bomb along the 400 fathom layer was not observed at the surface hydrophone. With bomb and hydrophone at 100 fathoms a wave that apparently traveled along the 100 fathom layer was recorded at 26½ km. The first arrivals at a hydrophone 400 fathoms deep, from bombs exploded at that depth may have traveled along the 400 fathom layer as far as 56 km., but other interpretations also satisfy these data.

The apparent horizontal velocity (See definition above) of sound in the open sea is a discontinuous function of the distance, the magnitude of the discontinuities depending on the bottom profile, depth and size of the bombs, and sensitivity of the hydrophone. With decreasing depth of bottom, or, increasing bomb size the magnitude of the discontinuities decreases and may become negligible under certain conditions. With a uniform depth of about 1000 fathoms between the bombs and hydrophone, a drop of 14 meters per second in the apparent velocity occurred at a distance of 45 km. with 4 ounce bombs (Figure 27); when the bomb charge was doubled, (½ pint bombs), a change of 11 meters per second was observed at 57 km. The two types of bombs were not fired at exactly the same depth, which may have had a small effect. A more spectacular discontinuity occurred at short distances where direct waves died out. See Figures 24, 26, 27.

The mean velocity between 30 and 1020 fathoms obtained in the experiments agrees within a few meters per second with the theoretical. A wave was observed with an instantaneous velocity practically equal to the theoretical velocity at about 100 fathoms. The instantaneous velocity of the direct waves is practically equal to the average theoretical velocity from the surface to 25 or 30 fathoms.

A high initial velocity is indicated. (By the travel time curve of the direct wave not going through the origin. Fig. 11, 13, 22.)

The underwater explosions acted as a multiple source, that is there seemed to be several impulses sent out. The reason was not established by the experimental data. The first impulse generated was as strong as the later ones.

Frequencies from 100 to 2000 hertz were observed with the 100, 200, 450, and 550 predominating. These frequencies may have been inherent in the apparatus although there is a suggestion that 200 was actually present in the bomb noises. (Blasts set off in rock are said to set up a

very narrow range of rather low frequencies.) The ability of the bomb noises to induce or set up the higher frequencies in the recordings showed a marked decrease with distance, the tendency being greater for the smaller bombs. Fig. 33 and 33A.

There is good evidence for dispersion of frequencies since the direction of the first motion of several waves showed a gradual change in sign. This would necessitate the presence of more than one frequency in the wave trains. Fig. 15. (See also Trace Amplitudes - Deep Water Tests)

The trace amplitude curves of the reflected impulses show a maximum at the distance at which the tangent ray is received due to the focusing action of the vertical velocity distribution. Fig. 17, 18.

The maximum distance diffraction was detected for direct waves was much less than that for the reflections (about 12 and 40 km. respectively). The only reasonable explanation is that the energy was carried mainly by high frequencies near the source and by lower frequencies at a distance. It has already been remarked that the tendency of the higher frequencies to record decreased with increasing distance. Diffraction effects are theoretically more pronounced at low frequencies than at high frequencies.

With the hydrophone at the head of a steep slope, zones of silence were observed. Fig. 32, 21, 22, 23, 24, 29. The area at the foot of the slope was flat and the horizontal distance along the slope was about the same as for one leg of the tangent ray, (i. e., the distance between grazing the surface and reflecting from the bottom). Fig. 3. This profile gave rise to a travel time curve that was not affected appreciably by the presence of the slope.

A variable increase in the travel time as much as 0.2 second was observed several times at one distance in the deep to shoal water tests, apparently due to irregularity of the bottom.

Plotting of log readings against chronograph times is of value in determining sharp changes in apparent velocity when the vessel is holding a straight course cutting sharply across the distance arcs.

The R A R chronograph had a negligible small daily rate but showed a variation as high as .04 second in 10 seconds. It was not determined whether this was periodic.

The velocity of sound in the water soaked mud floor of the Santa Barbara Islands Basin may be about 1580 meters per second.

The travel time curves of the impulses that operated the chronograph can be represented by the equation.

$$t = \frac{s}{v} + c; \quad \text{or} \quad s = v\,(t - c)$$

when t = travel time

s = distance

v = the surface velocity

c = parameter (time interval between the arrival of PD, PR_1, PR_2, etc.)

The theoretical velocity computed from bottom temperature and salinity can be used for the apparent horizontal velocity down to depths of 250 fathoms. See page 6

INTERPRETATION

Any method of utilizing R A R travel times for the plotting of fixes must be simple and rapid to be of practical value. A variable increasing and decreasing velocity must be taken into account, the amount and rate of variation depending on the temperature and salinity curves, and the depth and uniformity of the bottom. It must also be borne in mind that occasional discrepancies which cannot be evaluated will occur (as for example at 35 km. in the deep to shoal water tests where a delay of 0.2 second was observed in the arrival of PR-1.).

From the standpoint of R A R the first arrival that has sufficient amplitude to operate the shore station transmitter is the most important. The change in path of the first arrival with distance is shown in Fig. 31. The bottom is assumed to be level, and the numerical values that follow were obtained from the deep water tests which were carried to a much greater distance than were the deep to shoal water experiments. A wave that traveled a more or less direct path from bomb to hydrophone was observed to a maximum distance of 20 km. Its amplitude dropped sharply at about 8 km. showing that it reached greater distances by diffraction. After it faded out, PR-1, the next first sound to arrive, had been reflected once from the bottom. To a distance of 35 to 40 km. this was a true reflection, but its transmission to greater distances depended on diffraction, and the diffracted PR-1 was observed to a distance of approximately 73 km. but recorded on the chronograph to only 56 km. PR-2 was a true reflection to 6l km. after which it was also diffracted. The attenuation of the reflections is due to the curvature of the ray paths which was discussed in some detail in the report of the November, 1933 experiments in Santa Barbara basin.

In the deep to shoal water tests where bombs were fired in deep water and the hydrophone was in shallow water (as in actual R A R) the general results were the same, but a zone of silence was introduced by the presence of the slope. (See Fig. 19). It is thought that the zone of silence could have been crossed successfully by diffraction through the use of more powerful bombs. It is important to note that outside of the zone of silence the travel times were unaffected by the presence of the slope. If the horizontal travel of the tangent ray between grazing the surface and reflection from the level part of the bottom approximates the distance from the foot of the slope to the hydrophone, as was the case in Santa Barbara Basin, the travel time curves along the profiles should have the same general characteristics as those of the experiments.

The chronograph travel time curves are approximately parallel lines, excepting the interval between the fading out of the direct (PD-1) and the beginning of diffraction effects in PR-1. (Figs. 7, 8, and 19). The reciprocal slope of the straight lines is the velocity of the direct wave. The reason for this is evident in that the diffracted portion of the path is the same regardless of number of reflections that have occurred. (Fig. 31). It is proposed to utilize this parallelism in the plotting of R A R positions.

The equation of the straight portion of the travel time curve may be written: (See Figs. 7, 8, 19)

$$t = \frac{s}{v} + c, \text{ or } s = v(t-c).$$

Where t is the travel time;

s is the horizontal distance;

v is the velocity of the direct wave;

c is a parameter.

v usually can be obtained experimentally by measuring the velocity to short distances from the hydrophone; however, the accuracy in timing ordinarily available renders such determinations somewhat uncertain. An empirical rule for v suggested by the experiments is to use the average theoretical velocity of the upper 25 or 30 fathoms. The times arcs on the hydrographic sheets would of course be drawn with this v velocity, and then c subtracted from t in plotting the positions. (Using each hydrophone as a center, arcs are drawn on the sheet at regular intervals equal to the distance the sound wave will travel in five seconds assuming a certain velocity).

Under favorable conditions, c for the change from first reflection to second reflection can be determined experimentally if a visual fix can be obtained in the PR-1 diffraction interval. c is then the measured travel time less the quotient $\frac{s}{v}$.

If the bottom is reasonably level, c for PR-2 will be twice c for PR-1. Therefore if both PR-1 diffracted, and PR-2 are recorded on the chronograph tape in the region in which PR-1 fades out, the time interval between is c for PR-1 and ½c for PR-2. It is strongly recommended that the apparatus be arranged so that second arrivals can be recorded and this is one of the reasons why a hydrophone with high damping is desirable. The amount to be added to c as the various reflections fade out then can be measured.

c can be computed to a good degree of accuracy if the vertical velocity distribution is known. It is (for PR-1) the travel time along the tangent ray between two successive intersections of the surface less the travel time along a horizontal path at the near surface velocity v. A method of computing the travel time along a refraction path was given in the report of the November 1933 experiments. This method assumes a spherical earth but the computations are not simplified nor lessened by assuming a flat earth. The value of c is not materially affected by small errors in the near surface velocity distribution.

Computing c in this way using Table III of the 1933 report and 1500 m/sec for the velocity of the direct wave as observed in the deep to shoal water experiments of January 1935 (Fig- 24) gives a value for c (PR-1) of 0.35 second for a depth of 1020 fathoms, within .01 or .02 second of the observed average value. The same computation for the deep water tests of January 1935 (using the observed velocity of the direct of 1495 m/sec), gives 0.28 second against an observed 0.24 second. (Fig. 26)

The foregoing discussion applies when the velocity-depth curve has a minimum below the surface. It is only in this event that the rays are bent downward at depths above the velocity minimum. With the velocity minimum at the surface the rays would be bent upward by refraction but the distance to which a given reflection could be observed would still be limited by refraction curvature. It is very likely that if the velocity increased steadily with depth from the surface down, the travel time curve of the first arrivals would be quite smooth and continuous and that no sudden large changes in apparent velocity would occur. In high latitudes the velocity depth curves might have a minimum at the surface during the winter months and this should be considered when sound ranging in deep water in such areas is contemplated. It has already been observed* that the range of under water signals is greater during the winter months than during the summer which is another reason for preferring the colder seasons for R A R when other factors are favorable.

The reason why a constant velocity is successful in sound ranging in shallow water may be seen from the following rough calculations.

* See Unterwasserschalltechnik, F. Aigner (Berlin, 1922).

A horizontal bottom is assumed and a decrease of velocity with depth. The equation of the travel time of the first arrivals is taken as

$$t = \frac{s}{v} + nc$$

c, being the constant for PR-1 and n the number of reflections that the first arrival has undergone from the bottom. The numerical values are taken from Table III of the November 1933 report and a depth of 150 fathoms is assumed. c, then is 0.04 second. The tangent ray travels 5.6 km. between grazings at the surface so n may be written $n = \frac{s}{5.6}$ with a maximum error of .04 second.

Then $t = \frac{s}{v} + \frac{.04s}{5.6} = s\left(\frac{1}{v} + \frac{.04}{5.6}\right)$

$\frac{ds}{dt} = \frac{5.6v}{5.6+0.04v}$ = l.484 Km/sec since v is approximately 1.500 Km/sec

Using a velocity of 1484 m/sec introduces a maximum error of .04 second or a displacement of the distance arc of 60 meters in this particular case.

It appears that R A R will always have slight errors which it may be impracticable to determine in areas of rough sea bottom, and if the velocity of sound decreases with depth near the surface. In special cases, when there is a constant velocity layer, good results may be obtained to comparatively short distances by utilizing the propagation along such a layer. Bomb and hydrophone would need to be lowered to this depth to obtain the best results. The possibility of constructing bombs that would explode at a predetermined depth opens the way for bombing of this type if the need arises. It is not known how general the distribution of such constant velocity channels is, but it could be easily determined from the temperature and salinity data available.

It also can be shown why the theoretical velocity for bottom temperature and salinity for depths less than 250 fathoms approximates the observed apparent velocity. For a depth of 150 fathoms the horizontal distance between two successive surface tangents of the ray as given in Table III of the November 1933 report, is 5.60 km. The theoretical travel time, same table, was 3.78 seconds. 5,600 m/3.78 sec = 1,482 m/sec. The theoretical velocity for bottom temperature and salinity (Figure 11 of same report) was 1483 meters per second.

For 225 fathoms the theoretical bottom velocity was 1482 and the theoretical apparent velocity 1478. For 400 fathoms the theoretical bottom velocity was 1480 and the theoretical apparent velocity was 1471. This shows why the bottom velocity does not apply for the greater depths, which is consistent with actual field experience.

Distance and Travel Time to Point of Reflection of Ray Horizontal at the Surface (From Table III and Fig. 11 of 1933 Report)

Depth (Fms)	Travel Time (Sec)	Horizontal Distance (Km)	Velocity at Depth Indicated
0	0	0	1502
15	.7690	1.1553	1501
30	.9611	1.4413	1489
50	1.1250	1.682	1485
90	1.433	2.134	1483
150	1.888	2.799	1483
225	2.445	3.613	1482
400	3.699	5.442	1480
500	4.403	6.469	1480
930	8.067	11.846	1494
1000	8.873	13.057	1496
1233	14.576	21.606	----

RECOMMENDATIONS FOR R A R

When there is a choice, the hydrophone should be situated at the head of the steepest slope available. It is also desirable to have the hydrophone as far out as possible, preferably on the shoulder of the slope, if steep, (unless, of course, this introduces an undesirable bottom profile between the hydrophone and the area to be surveyed, such as ridges or submarine valleys, which can be avoided by a different location of the hydrophone).

The data suggest that there may be a decided advantage in having a hydrophone and amplifier particularly sensitive to the lower frequencies. Hydrophones with low frequency diaphragms are undesirable because of the persistence of the diaphragm vibrations, especially when loaded with a unit. A hydrophone with rigid walls and lighter than the water it displaces may be a satisfactory solution. Such a hydrophone would move with the water and there would be no dependence on diaphragm vibrations. In fact it would not be necessary to mount the unit on a diaphragm face. It is very difficult to damp low frequency hydrophones successfully, but comparatively easy to damp the units. A light body hydrophone, say an ebonite sphere, with rigid walls and large enough to be buoyant is suggested. The body of the hydrophone would move with the water and diaphragm vibration could be eliminated by the design. The unit should not have pronounced directional qualities because of the difficulty of keeping a submerged buoyant hydrophone oriented. Further investigations of the frequency characteristics of bomb noises is necessary and may indicate the desirability of a narrow band pass filter in the amplifier circuit.

It is very desirable to arrange that radio returns of the second and later arrivals be recorded instead of having the radio dash, started by the initial impulse, continue until stopped manually. This would furnish a direct measurement of corrections to be applied at the fading out of the previous first arrival.

Chronometers should be tested for uniformity of rate over short intervals of time by comparison with radio time signals on the chronograph.

The shore station equipment should be so designed that the lag is reduced to a negligible quantity.

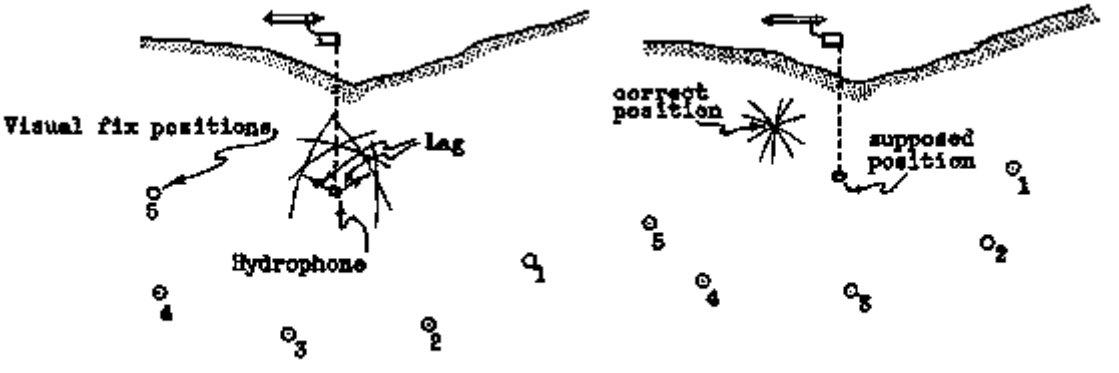
No less than three shore stations should be used in order that good intersections may be obtained as well as a check or a triangle of error. If only two stations are established, the intersection of their arcs may be in error as much as one mile.

A long area of shoal water between the hydrophone and bomb will materially decrease the effective distance R A R can be carried from that station.

The operators should report after each bomb whether the first of the sound train actuated his transmitter; that is, if he heard the sound before it operated his transmitter; or, in other words, if there was a build-up in the amplitude before his transmitter operated. This will give the hydrographer valuable information on the velocity to be used. When the operator can hear the sound coming, so to speak, it means that there is a change taking place in the path of the first arrival at the hydrophone. The diffracted wave is fading out before the arrival of the reflected wave. This lag should be from two to four tenths of a second depending upon the distance and the depth of the intervening water. When the operator reports a short interval during which amplitude increases, a larger bomb may often overcome the difficulty.

The surveying vessel should obtain good velocity tests three or

four miles distant from the hydrophone to measure the velocity of the direct ray. The hydrophone should be encircled with a series of velocity tests at a distance of about one mile. If R A R distance arcs drawn from the visual fixes as centers, pass behind the position of the hydrophone, using the theoretical velocity for the 10 or 15 fathom layer, the distance from the hydrophone to the arc will be a measure of the total instrumental lags. (See Sketch A). If the arcs intersect at a point other than the plotted position of the hydrophone, the point of intersection will be the true position of the hydrophone. (Sketch B).



Sketch "A" Sketch "B"

During R A R hydrography the run between bomb positions should be plotted as accurately as possible by course and log or engine revolutions. When the R A R arcs do not check the dead reckonning between bomb positions, a change in the apparent horizontal velocity should be suspected for one of the distances.

GENERAL DESCRIPTION OF THE EXPERIMENTS

APPARATUS USED

The underwater sounds were received by non-directional hydrophones having Utah loud speaker units attached to the inside center of one diaphragm. After vacuum tube amplification, the sounds were photographically recorded by a two string oscillograph, one string connected to the shoal hydrophone and the other to a deep type hydrophone as described in the report covering the November, 1933 experiments.

Two amplifiers were used, one connected to each string of the oscillograph. The amplifiers were calibrated in decibels and full amplification. was seldom necessary. Unfortunately it is not known whether the connections in the electrical circuit between the hydrophones and oscillograph were always made in the same way, so it is not possible to correlate the diaphragm motion with the direction of trace motion throughout the experiments. It is almost certain that the "direction" of the electrical connection was different at various times. The amplitudes on the oscillograph records can, however, be reduced to a common standard for direct comparison due to the calibration of the amplifiers. It was found that the A amplifier had about 2.5 decibels more gain than the B amplifier. The A amplifier recordings are the lower traces on the oscillograms; the B amplifier recordings are the upper traces.

Travel times were measured by an R A R chronograph and surface hydrophone, with time marks every second on the chronograph and with time marks every .01 second on the oscillograph.

The.oscillograph time units were marked by a synchronous motor

operated from a tuning fork. The apparatus is the same as that used last year with the exception of the amplifiers. During part of the deep water tests the spool of sensitive paper in the oscillograph was turned by a small motor. Usually, only fractional seconds were measured on the oscillograph, i. e. it was turned off between the arrival of the initial and the onset of the bomb noises to save photographic paper.

HYDROPHONES

During the experiments in the Santa Barbara Islands Basin three hydrophones were used, all equipped with small Utah units.

The near surface hydrophone was a cast aluminum pot. It has a 7-3/4" (diameter) diaphragm, l/4" in thickness. The fundamental frequency as measured in air with the Utah unit in place is about 1250 hertz. The theoretical frequency* in air without the unit is 17OO hertz. Considering the entire weight of the unit as effective in reducing the fundamental frequency, it is theoretically 840 hertz with the unit in place. It is concluded that the entire weight of the unit is not effective. This is not surprising because of the flexible connection between the diaphragm and the main mass of the unit.

If the frequency of the diaphragm is very high in comparison with that of the Utah unit when the latter is clamped by the pin, the effective mass of that part of the unit not connected rigidly to the diaphragm would be expected to be very small. The entire weight of the unit should be effective when the diaphragm frequency is low in comparison with that of the unit. The frequency of the aluminum pot in water was not measured. As the frequency is lowered by immersion, the effective mass of the unit is increased by an unknown amount. Since the effective mass of the unit will have a value between that in air and the total mass of the unit, an upper and lower value of the frequency in water can be set. Therefore, the fundamental underwater frequency of the aluminum pot hydrophone with unit should be between 640 and 675 hertz.

The characteristics of the deep sea hydrophone used for bombs Nos. 437 to 465 inclusive were not determined. The deep sea hydrophone used the rest of the time was identical with the one described in the report of the November, 1933, work. Its fundamental frequency in air with the unit is 300. Low frequency diaphragms are probably seriously distorted by the turning moment of the suspended unit so that the theory would not apply. The fundamental frequency is lowered by immersion in water. The underwater fundamental is estimated to be, very approximately, 230 hertz. (See also "observed frequencies" this report).

PROCEDURE

The following procedure is typical for electric bombs:

The changes for fuse bombs are sufficiently obvious to need no comment.

Wireless signals were sent by the Guide 60, 30 and 15 seconds before the explosion. About ten seconds before the firing switch was thrown, the chronographs on the Guide and Pioneer and the oscillograph on the Pioneer were started. At the firing dash the observers at the triangulation stations cut in the Guide. The oscillograph was stopped after a firing dash recorded and started again about 5 to 10 seconds before the arrival of the sound at the hydrophones, the approximate travel time being known. The arrival of the sound operated the Pioneer's radio transmitter which was recorded on the Guide and also served as a signal for the triangulation observers to cut in the Pioneer. As previously stated the instant of the explosion was thus recorded on the Guide's chronograph and on the

* Wood, A. B., A Textbook of Sound, p. 158 (Macmillan Co., 1930)

chronograph and oscillograph on the Pioneer, and the arrival at the surface hydrophone was recorded on all three instruments, and the arrival at the deep hydrophone on the oscillograph. No maneuvering of the Pioneer occurred from 30 seconds before the explosion until after the oscillograph was finally stopped.

TESTS OF EQUIPMENT

The following results of the tests of the equipment are reported by Dr. C. G. McIlwraith:

1. There is no lag larger than .001 second between recording of sound on oscillograph and start of plate current in ship's transmitter.

2. There is a time of about .003 to .004. second during which the current through the coil of the Pioneer's chronograph builds up. The pen marks some time towards the end of that period, usually about .002 to .003 second after start of current in coil.

3. The A amplifier has about 2.5 decibels more gain than the B amplifier.

4. The two contacts of the Guide's Leach relay close within .002 second of each other, the left one being the later. The left contact opens about .006 second before the right contact. Right contact of Leach firing relay to Guide's transmitter; left to bomb.

5. The marking pen of the Guide's chronograph is operated by application of 67 volts across the magnets, takes .04 to .06 second to make its mark, the mean being .05 second. It returns in about .002 second after the current is off.

6. Two measurements on electric detonators give lags of .004 and .006 second between the application of 110 DC to the detonator and the rupture of a wire wrapped around the detonator.

7. The aluminum hydrophone in air has a resonant frequency of about 1300 hertz.

8. The diaphragm and small unit for the deep hydrophone have a frequency in air of about 240 hertz With the hydrophone head clamped on the frequency is 300 hertz.

9. The Pioneer's transmitter shows a lag of .024 to .028 second between start of plate current and start of radio frequency current when tuned for maximum output. When slightly detuned the lag is .017 to .020 second. With another crystal the lag was .003 to .005 second.

10. The shore station transmitter used at Laguna and Santa Cruz has a lag not more than .003 second in radio frequency output.

11. When clamped by the pin and tapped on the body the small unit has a frequency of about 160 hertz, and the large unit 150 hertz. The small unit also has another frequency of about 85O hertz.

CALIBRATION OF TUNING FORK

The tuning fork was compared with the R A R chronometers and the chronometer with the radio time signals from Mare Island. In both cases comparisons were made on the chronograph, over a period of 4 to 9 minutes. The daily chronometer rate was also determined and found to be very nearly zero. However, the rate over small intervals was found to be quite variable

* Dr. Dyk made the following measurements of this test of the small unit - The dominant frequencies were 150 to 500 hertz. 1100 was generally superposed, particularly on the 150. 600 occurred in one place.

as the following table shows.

Comparison of Timing Chronometer With Mare Island Time Signals

2/7/35		1/18/35		3/8/35	
Chronometer (seconds)	M.I. Signal (seconds)	Chronometer (seconds)	M.I. Signal (seconds)	Chronometer (seconds)	M.I. Signal (seconds)
0	0.52	30	30.42	0	0.77
15	15.515	35	35.41	60	60.77
31	31.515	40	40.40	70	70.765
45	45.515	41	41.40	80	80.765
54	54.51	42	42.39	90	90.76
60	60.51	43	43.39	100	100.76
61	61.497	44	44.385	109	109.745
62	62.495	45	45.385	110	110.75
63	63.49	46	46.38	113	113.74
64	64.49	47	47.38	114	114.74
65	65.485	48	48.38	120	120.735
66	66.485	75	75.375	121	121.735
67	67.485	90	90.38	122	122.735
68	68.48	150	150.39	123	123.735
69	69.475	210	210.41	180	180.73
70	70.47			240	240.73
80	80.47			250	250.73
91	91.47			260	260.725
100	100.47			280	280.73
120	120.47			285	285.73
140	140.465			286	286.725
160	160.465			287	287.725
180	180.46			288	288.73
200	200.46			289	289.73
220	220.46				
240	240.46				
260	260.46				
289	289.46				

The above readings were made on the chronograph tapes starting from an arbitrary zero.

The maximum rate over a time interval comparable with the time intervals used during the tuning fork calibration is 22 seconds per day or .00025 second per second. A rate of .004 second per second does occur in one ten second interval but this is not sustained nor frequent and the sign apparently changes with time.

The tuning fork calibration curve is probably correct to .0002 second per second but errors in the chronograph tape time of around ±.004 may be expected.

THEORETICAL VELOCITIES

Since one purpose of the experiments was to check the theoretical velocities, complete serial temperatures and salinities were obtained. One hundred forty eight temperatures and forty one salinity observations were made by the two vessels during the course of the work, affording excellent material for the calculation of the theoretical vertical velocity distribution. The temperature and salinity curves are shown in Figures 4 and 5 and the theoretical velocities taken from the British Admiralty Table* in Figure 6. The full line curve was used for the computation of theoretical ray paths. The distribution has the same characteristics as that obtained in 1933, with constant velocity layers at 100 and 450 fathoms and, in the present case, at the surface. Although the near surface temperatures are subject to variations, it is probable that the theoretical velocity was very nearly a constant in the upper 15 fathoms throughout the experiments.

* Table of the Velocity of Sound, etc., HD 282 Hydrographic Department (British) Admiralty 1927.

DEPTH OF WATER

Two lines of soundings were run to supplement the depths obtained by previous hydrographic surveys. The profiles of these lines are shown in Figures 2 and 3. Slightly greater depths were found than are indicated by the chart of the area.

TRAVEL TIMES - DEEP WATER TESTS NEAR SURFACE BOMBS AND HYDROPHONES

The travel time curves obtained on the deep water tests are shown in Figures 7 and 8. On all the diagrams the points plotted vertically over each other are arrivals from the same bomb, and the curves are observational. The nomenclature is the same as previously used with the exception of PD which was not observed in 1933. The P indicates a compressional wave, D a direct path, and R reflection. When the bomb and hydrophone are near the surface, only one numeral follows "PR" and it indicates the number of times reflection from the bottom has occurred. When either or both bomb and hydrophone are at an appreciable distance below the surface, two numerals follow the "PR"; the first indicates the number of reflections from the bottom, and the second the number from the surface.

The identification of reflection paths rests on the travel times. The travel time of PR-1 at any distance should be about half that of PR-2 at twice the distance, about one-third that of PR-3 at three times the distance, etc. The same holds for the reduced travel times. By reduced travel time is meant the travel time in seconds minus the quotient, distance in km. divided by 1.5. This is a device to secure a more open time scale for the diagrams. It has the advantage that impulses separated by only a few thousandths of a second can be shown. It should be noted that straight lines on the travel time curve are also straight lines on the reduced travel time curve. In Figure 9 the reduced travel times of PR-1 are compared with one half the reduced travel time of PR-2 at twice the distance and the comparable times of the other observed reflections. The comparison is not carried beyond 30 km. for PR-1 or much beyond 60 km. for the other reflections to avoid serious complications due to curved ray paths or changing depth of the bottom. The check is excellent considering the variations in the depth of the bottom and the fact that the bombs and hydrophones were not directly at the surface, and the probable high velocity near the bombs. (To be discussed later).

A striking feature of the travel time curves is the absence of the multiple reflections at the shorter distances. Very often the oscillograph was stopped too early to record the later reflections even if they were strong enough to record. Records 431 to 434 inclusive, at distances of 20.9 and 23.3 km. show no trace of PR-4 at the expected time. At 26.9 km. one record shows no evidence of a PR-4 while it was feebly recorded on another. All were electric four ounce bombs. At greater distances PR-4 was always recorded when the oscillograph was run for the necessary length of time. PR-5 was not very well recorded at any distance. The shortest distance at which it was observed is 37.5 km. but it does not appear on many of the records even at greater distances.

The absence of PR-4 and PR-5 at the shorter distances must be due to the transmission of a large percentage of energy into the material at the ocean bottom. Since they were recorded at some distances, they should have been recorded at all distances at which total reflection occurred. The minimum distance at which they were recorded should give an emergence angle to or greater than that for total reflection, in other words a maximum value of the velocity of compressional waves in the material on the ocean floor. Since PR-4 was observed first at 26.9 km.

$$\tan e_{max} = 1/3$$

$$\text{or} \quad e_{max} = 18°$$

which by Snell's law gives a maximum velocity of 1580 m/sec. in the material underlying the water. This is the value at the boundary. Velocities of this order have been reported for water soaked sand.

More important from the standpoint of R A R is the failure of PR-1 to record beyond certain distances due to the curvature of the ray paths. It was observed on the oscillograph to 51.6 km. with four ounce bombs and to 73 km. with l/2 pint bombs. (Four ounce bomb contained about one half the amount of TNT of the 1/2 pint bomb.) In both cases PR-1 becomes very weak and the duration on the record is reduced from the order of tenths of seconds to about a hundredth of a second. The greatest distance at which it recorded on the chronograph is 45 km. and 55 km., respectively.

The maximum distance to which PR-1 should travel without diffraction effects is difficult to predict even though the theoretical velocity distribution is known for any particular condition since this distance depends very greatly on the near surface velocities which are constantly changing during the day. For example, if the velocity in the upper fifteen fathoms were constant, due to the earth's curvature a ray starting horizontally at a depth of 15 fathoms would travel approximately 18 km. before reaching the surface; if the velocity decreased 2 m/sec. from the surface to 15 fathoms, the maximum horizontal travel between the surface and the fifteen fathom level would be only 1 km.

The data of Figs. 7 and 8 are plotted on a more open time scale in Figure 10 where the ordinates are travel time less distance in km. ÷ 1.500. The early arrivals at distances less than 21 km. are not shown in Fig. 10 but are shown separately in Fig. 11.

There is a clearly marked tendency for the waves from the l/2 pint bombs to occur in groups of three, the intervals between being very nearly .10 second. (See Fig. 10). For example they were observed in the first reflection at 9.3 km. and in the second and fifth reflections at 59.5 km.

In addition a beginning was often observed at .03 second after the first one in the groups of three. The intervals are independent of the distances and the number of reflections that have occurred and of the depth of the hydrophone. The latter fact can be seen in Fig. 13 and is the final proof that the source of the multiplicity is in the explosion and not due to difference in paths. The repetition of the intervals from bomb to bomb indicates a very striking uniformity in the mechanics of the explosion. The deep-to-shoal-water tests check the observations.

The small electric bombs show the multiplicity to a much lesser extent. The presence of two waves in the "directs" separated by a time interval of .03 second is shown in Fig. 11. The same interval appears sufficiently often in the reflections to prove its origin at the explosion. (Discussed more fully later).

The PR-1 points beyond 25 km. lie on a straight line practically parallel to the PR-2 curve at distances greater than 50 km., the instantaneous velocity (reciprocal slope of travel time curve) being 1498 m/sec. and the time separation .27 second. The travel time for both curves is given by an equation of the form:

$$t = s/1498 + c$$

when t is time, s is distance, and c is a parameter. In R A R this type of relation between the distance and time would be convenient if the distance arcs are laid off according to the instantaneous velocity. (See discussion of application to R A R).

In order to study the multiplicity of the impulses in the directs, the reduced travel times are drawn on a rather large time scale (Fig. 11). The points show considerable scattering due to small errors in time and distance measurements, as is to be expected. Before attempting to draw curves it is necessary to be reasonably certain that the impulses can be defi-

nitely correlated from record to record. This was done by plotting the travel time of PR-1 less the travel time of the earlier arrivals as a function of the distance (Fig. 12). It suppresses the errors of observation and it should be possible to draw smooth curves through the earlier arrivals as presumably PR-1 should lie on a smooth curve. This is simply a method of correlating beginnings.

Fig. 12 establishes the validity of the lower two curves of Fig. 11 and offers an excellent justification for drawing the third, P100. The existence of the third curve is better established than some of the curves in seismic travel times. The shape of the curves at once suggests that they can be represented as straight lines on a reduced travel time graph. The points on the lower curve of Fig. 12 are shown as X's in Fig. 11, those on the middle curve as circles and those on the upper curve as Greek crosses. The unexplained points appear as squares in Fig. 11. The fact that the two upper curves intersect the time axis at about the same place was established by drawing a third curve with travel time later arrivals less travel time PD-1 as ordinate. The lower curve of Fig. 11 is designated PD-1, the middle PD-2, and the upper F-100 for reasons that will appear directly.

The data are insufficient to justify a least square analysis. Rectilinear curves are indicated. Fig. 12 shows that the lower curves should be approximately parallel and .03 second apart. As has been stated, the upper curves should intersect the time axis at approximately the same height. With this information as a guide, the curves were drawn in by eye.

Parallelism in the travel time curves of the P waves in earthquakes has been observed and Byerly* suggests it is due to change of type upon incidence at a discontinuity. This explanation is, of course, of no help in the present instance. It seems necessary to look to the mechanics of the explosion for an explanation. The first impulse no doubt is due to the displacement of the water by the expanding gases and the second could be due to inrush of the displaced medium. The two impulses have about the same maximum amplitude which is consistent. A difference in sign of the first motion between the two impulses was observed in the three instances (Bombs Nos. 422, 423, and 536) when the direction of first motion of both impulses could be determined from the oscillograms. This is weakened as a supporting evidence by the probability of the existence of dispersion as discussed elsewhere. (Direction and trace amplitude of first motion.) The fact that two phases, one about .03 second later than the other, are also observed in the reflections, is also evidence of a multiple source. Since the path associated with the two lower curves (Fig. 11) is undoubtedly more or less direct from bomb to hydrophone these arrivals are called PD-1 and PD-2. It is not intended to imply that the paths are right lines since there must be refraction curvature, and beyond 8 km. diffraction probably plays a part in the transmission. The lower curve does not pass through the origin. This might be due to errors in observation but is very likely due, in part, to an abnormally high velocity near the source. The high velocity of waves of finite amplitude is well known and very recently has been observed in air by Partlo and Service**.

It is worthy of note that two bombs at 17.5 km. show arrival on the upper curve and the direct waves are absent.

Jeffreys*** found it necessary to explain the amplitudes of indirect compressional waves in near earthquakes by diffraction. He considered diffraction at a first order discontinuity. It is extremely interesting and possibly significant that here we have evidence of this type of diffraction at a second order discontinuity under the special condition that there is a constant velocity layer with second order discontinuity above

* Byerly, Bull. S.S.A. Vol. 28, No. 1, Jan., 1935.
** Partlo & Service, Physics, 6. pp. 1-5, Jan., 1935.
*** Jeffreys, H., Camb. Phil. Soc., 23 pp. 472-481, 1926.

and below. Possibly the fact that we have waves of finite amplitude near the source facilitates getting energy into the constant velocity layer.

The intercept at zero distance is .03 second above that of PD-1. Hence the ray path from bomb to the 100 fathom layer could not have been straight down. An emergence angle of about 30 degrees would give an intercept of about .03 second.

REDUCED TRAVEL TIMES
DEEP BOMBS AND DEEP HYDROPHONES

The results from the firing of the few deep bombs were insufficient to allow definite conclusions to be made. Four bombs were exploded at a depth of four hundred fathoms with a hydrophone at the same depth, and another hydrophone at the surface, for which distances and travel times were obtained. The observations at the deep hydrophone are shown in Fig. l4. The lines PR-1.1, PR-2.2, PR-3.3 and PR-4.4 are the observed PR-1, PR-2, PR-3 and PR-4 curves of Fig. 10 (surface hydrophone and bomb); it can be seen at once that the travel time of PR-n.n with bombs and hydrophone at the same depth are independent of this depth and equal to the travel time of PR-n with bombs and hydrophone at the surface, assuming a level bottom. In the present case it is true to a first approximation only. It should be noted that there are two paths n.n - one being first reflected from the bottom and the other from the surface. Between the curves n.n and (n+l). (n+l) there are the possible curves for PR-(n+l).n and PR-n.(n+l), which are not shown in Fig. 14. In addition PR-1.0 and PR-0.1 should be observed ahead of PR-1.1 at short distances.

Observations at depth are subject to a rather large uncertainty due to the errors possible in the location of the bomb and hydrophone. If a maximum error of 5° lead in the supporting cable is assumed, a maximum error of 65 meters in each position at a depth of 400 fathoms can occur or a .08 second error in the travel time due to this cause. This is the main source of error. It seems extremely unlikely that the error was this large in most cases since a great deal of care was taken to keep the visible part of the cable vertical.

Returning to Fig. l4, the first arrival can be interpreted as having traveled in practically a straight line from bomb to hydrophone, allowing for errors of .05 second, as evidenced by the straight line indicating a velocity of l483 m/sec. at a depth of about 400 fathoms. However, the points can be explained otherwise. The first arrival at 56 km. may be PR-1.2, at 43 km. and 36 km., PR-1.1, and at 6 and 8 km. PR-0.1; the one at 26 km. may be PR-1.0 diffracted. There is very good a priori reason to expect the transmission of energy along the constant velocity layer at 400 fathoms. To verify this beyond doubt the observations would need to be spaced much more closely and the amplification should be low enough to avoid the loss of impulses in recording due to large amplitudes and faintness in the records*.

Simultaneous observations were made with a near surface hydrophone. The first arrivals could have traveled along the four hundred fathom layer and reached the surface by a least times path from that depth but here again alternative explanations can be found without good reasons apparent for preference.

The later arrivals in each case are the expected reflections and nothing unusual appears that warrants discussion.

* It might be said in this connection that in this type of work it would be desirable to have an oscillograph with enough strings so that each hydrophone can produce two records at different amplifications side by side. In view of the large range of amplitudes in the various impulses it was usually desirable to have the amplification high enough to record the weaker impulses, which lessened the value of other portions of the record.

There is insufficient data with bombs at other depths to yield definite information. A more detailed study of the properties of constant velocity layers may be of value for special problems in R A R and coast defense. As an example of the first, it may help to fix the position of dangers to navigation in areas where the irregularities of the bottom render reflection R A R inaccurate and the importance of a good fix justifies the expense of firing bombs at depth.

CHECK OF THEORETICAL VELOCITIES

With the possible exception of the velocity at about 100 fathoms, the data yield only the average vertical velocity between certain depths. (The instantaneous velocity of PD-1 and PD-2 cannot be attributed to any one depth because of the uncertainty regarding the path.)

During the Guide's fuse-bomb run, a sounding line was run taking soundings every minute (Fig. 2). All the deep water tests were carried out near this line or its extension. The slope of the bottom is quite steep until a depth of 1020 fathoms is attained after which it is extremely gentle for some distance. The steep slope ends at about 5 km. from the average position of the Pioneer. There is little error in taking the depth of bottom from the profile at distances greater than 6 or 7 km.

The average velocities from a depth of 30 fathoms to the bottom were computed from the travel time of PR-1 taking the depths from the profile for the bombs when it was certain that the point of reflection was on the level part of the profile. Bombs Nos. 424, 425 and 426 at 10.4 km. were included since the position of the Pioneer for these bombs was about a mile south of the average position assuring the reflection from the level part. Bombs Nos. 535, 536 and 538 were also included since it appears extremely likely that the reflection occurred on the level part of the profile at a depth of about $80 fathoms. Only electric bombs at distances less than 21 km. were used so that it can be assumed reflection from the bottom actually occurred, and the ray paths approximate straight lines. The bombs and hydrophones were all at a depth of 30 fathoms.

The average experimental velocities from 30 fathoms to 1020 fathoms were obtained as follows:

Bomb Number	Average Velocity	Residuals
424	1491 m/sec.	-2.8
425	1491	-2.8
426	(1500) Rejected	
427	1487	+1.2
428	1486	+2.2
429	1488	+0.2
430	1487	+1.2
431	1485	+3.2
432	(1482) Rejected	
542	1491	-2.8
543	1489	-0.8
544	1490	-1.8
546	1491	-2.8
547	1487	+1.2
548	1487	+1.2
549	1488	+0.2
550	1486	+2.2
	Mean 1488.2	

Mean Experimental Average Velocity betweeen 30 and 1020 fathoms 1488 m/sec.
Mean Theoretical Average Velocity between 30 and 1020 fathoms 1486 m/sec. (computed from British Admiralty Tables).

TRACE AMPLITUDE - DEEP WATER TESTS

In the majority of instances, the direction and amplitude of first motion at hydrophone cannot be ascertained because either the oscillograph string motion was too rapid to record or strays or motion of earlier arrivals obscure the beginning. The relation between the direction of first trace motion and the water motion is not known since it is not certain that the electrical connections between the hydrophones and the oscillograph were always made in the same way. Hence, the graphs for different bomb series cannot be compared for actual direction of motion. In Fig. 15 only those measurements are grouped together for which it is quite certain no change in the connections was made.

It is seen that for a given path the direction of first motion depends on the distance. This is contrary to views that have been expressed in this connection*. The front of the advancing wave train is a changing thing, the wave train itself being then, of necessity, oscillatory in character. The changing front could come about either through dispersion or loss of complete half waves at the front.

Consider a simple oscillatory wave train advancing into an undisturbed medium. The first crest AB will lose energy more rapidly than the succeeding one since the later ones encounter a medium already disturbed, and BC eventually will become the front of the train.

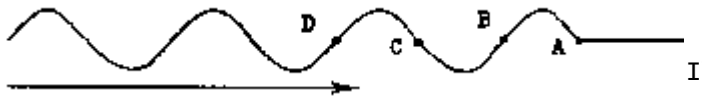


Illustration "A"

On this argument, BC will have its maximum amplitude (as first arrival) when it first appears at the front of the train and the distance - amplitude curve of first motion should have the general characteristics of illustration B.

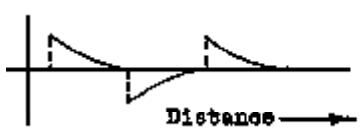


Illustration "B"

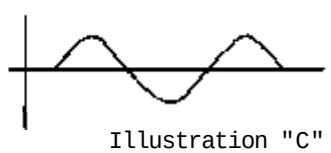


Illustration "C"

In contrast, the curve, if due to dispersion should tend to be of the character of illustration C. The latter type of curve is observed and this is considered very strong evidence of dispersion. It is felt that change of direction of motion with distances along a given path is by itself, not conclusive evidence of dispersion.

Boyle and Taylor** found no change in wave velocity of sound in water from 29,000 to 570,000 hertz and this has been verified by other workers***. No experimental work of this nature has been done, however, for the range of frequencies observed in the present work.

On theoretical grounds, velocities between the Newtonian $\sqrt{\frac{p}{\rho}}$ and the Laplacian $\sqrt{\frac{p}{\gamma\rho}}$ could be expected, depending on the completeness of the adiabatic state, the lower frequencies having the higher velocity, according to Herzfield and Rice#. Since $\sqrt{\gamma}$ is approximately 1.005 for sea water, the expected dispersion due to this cause would be very small and it is not surprising that it has not been observed in measurements of wave velocity, if indeed it exists.

* See for example Jeffreys, H., The Earth, p. 94. Cambridge University Press, 1929, and Dorsey's comments on p. 73 of the U.S.C.&G.S. Field Engrs. Bulletin, December, 1934.

** R. W. Boyle and G. B. Taylor. Trans. Royal Society of Canada., Vol. 211 Sec. 3, p. 79, 1927.

*** Wood, Loomis and Hubbard. Nature, Aug. 6, 1927.

\# Herzfield and Rice. Phys. Rev. 31, p. 691, 1928.

The maximum trace amplitude of any impulse was taken as the maximum occurring within the first .1 second or less of that impulse. The trace amplitudes were all reduced to a uniform amplification. The amplification was varied by known amounts during the experiments by the introduction of a potentiometer bridge on the plate circuit of the output.

Due to fast motion or lack of contrast in the oscillograms it was often impossible to measure the maximum amplitude. This is shown by up and down arrows on the graphs. Usually, but not always, this indicates a large amplitude.

Other than surprisingly large amplitudes in P-100, the directs show nothing unexpected. If the suggested path of F-100 is correct, one would expect an amplitude small in comparison with that of PD, particularly at short distances. However, in near earthquakes, where ray paths are better established than that of P-100, similar difficulties are encountered in the explanation of observed amplitudes so this cannot be regarded as a serious objection.

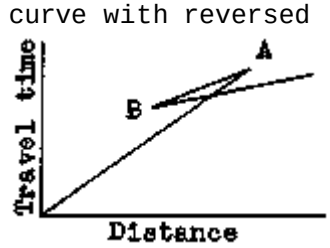
The amplitudes of bombs 532-55O inclusive appear to be considerably larger than those found on other days for the same size bombs at the same distances. In Fig. 17 the observations for these bombs (532-550) are set apart by surrounding them by a dotted line. Apart from these, the trace amplitudes of PR-1 show the same characteristics with distance for both the fuse and the electric bombs. The PR-1 curve shows a maximum at 35 km., PR-2 at 60 km., and PR-3 at 80+ km. The observations of November, 1933, indicated the same sort of thing but were rendered uncertain by unknown variations in the amplification.

The theoretical relation between trace amplitudes and amplitude of the passing waves is very difficult to determine because of the complex nature of the instrumental system and the fact that both diaphragm motion and motion of the hydrophone as a whole excite the Utah unit.

One possible explanation of the maximum was advanced in the report of the 1933 work. If the hydrophones have directional properties, the maximum could be caused by the decrease of the emergence angle of the incident rays with distance. The hydrophones supposedly respond to pressure variations and should thus be non-directional, but a study of the frequencies recorded suggests that the* motion of the hydrophones as a whole is recorded, in which case directional properties may exist.

The hydrophone was suspended from its cable and hence free to turn. Consequently if there was any directional effect there would be a variation in the sound amplitude due to the direction of the hydrophone diaphragm when the sound arrived.

A more likely cause lies in the theoretical existence of reversed segments in the travel time curves, with the consequent focusing effect. Slichter* has shown that with the type of velocity depth curves normally found off the coast of Southern California (i. e. velocity first decreasing and then increasing with depth) the travel time curve must have a reversed segment if the depth is great enough. A travel time curve with reversed segment is shown thus:



Slichter shows that if the quantity

$$\frac{(dz/dv)_0}{(V_m^2 - V_0^2)^{\frac{1}{2}}} + \int_{V_0}^{V_m} \frac{\frac{d^2z}{dv^2}}{(V_m^2 - V_0^2)^{\frac{1}{2}}} < 0$$

the travel time curve will have a reversed segment, where

* Slichter, L., Physics, Vol. 3, No. 6, pp. 273-295. Dec, 1932.

z = depth
Vo = velocity at z = o
Vm = velocity at the maximum depth attained.

It is assumed that the ray returns to the surface by refraction, i. e. the emergence angle is zero at the lowest point reached. For his case (1) he gives:

"When the slope at the surface $\left(\frac{dz}{dv}\right)$ is negative, the ray paths will be concave downwards initially, and the shallowest ray will penetrate to such a depth that the velocity at its apex is equal to the surface velocity, $v_m = v_o$. With this value for v_m, the first term . . . . is negatively infinite. Furthermore, if the velocity function has a curvature of constant negative sign the integral

$$\int_{V_o}^{V_m} \frac{d^2z/dv^2}{(V_m^2 - V_o^2)^{\frac{1}{2}}}\, dv$$

will also be negative and the existence of a reversed segment is assured,"

Considering the velocity curve as represented by a series of straight lines as in Fig. 6, the integral is zero for any depth range. For a source below 10 fathoms depth, the first term is negative and a reversed segment occurs if the bottom is deep enough so that the rays are refracted back to the surface which was certainly the case for the electric bombs and probably for the fused ones.

The reason for increased amplitude in the vicinity of the ends of the reversed segments lies in the large value of $\frac{de}{d\Delta}$ in these regions? e being emergence angle and Δ distance along the earth's surface measured as an angle (with the vertex at the earth's center). Jeffreys* has shown that the measure of the energy in the wave front is given by $E = \frac{\cot e}{\sin \Delta} \frac{de}{d\Delta}$

The emergence angles were plotted as a function of the travel distance for a depth of source of 15 fathoms and a depth of bottom of 1072 fathoms. When e = 0° 30' the rays were reflected from the bottom. A large increase in intensity occurs at 2°. The same result will hold even if the theoretical velocities are somewhat in error since the shape of the velocity curve is undoubtedly correct.

Amplitude peaks due to this cause obviously should broaden with each reflection but the observations do not show this. Unfortunately fuse bomb records between 36 and 44 km. were not obtained to better delineate the PR-1 maximum.

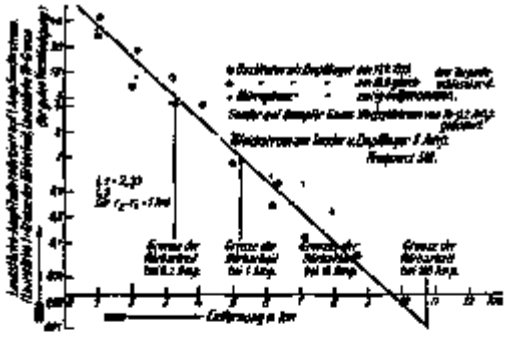
The distance to which PR-1 diffracted is observed is rather surprising. Presumably all the PR-1's beyond the diminishing amplitude drop at 40 km. were diffracted. The extension of the diffraction interval with increasing size of bombs is particularly apparent in PR-1 and explains why large bombs often give good R A R intersections from three or more stations when smaller ones give large triangles. In such cases a later reflection with a low apparent velocity records from the smaller bomb. The importance of diffraction in deep water sound ranging must be fully recognized since it is the prime reason that R A R is so successful.

The diffraction interval of PR-1 extends over 30 km. and yet the direct wave is observed to only 20 km. It is not clear why diffraction effects should be the more pronounced after reflection.

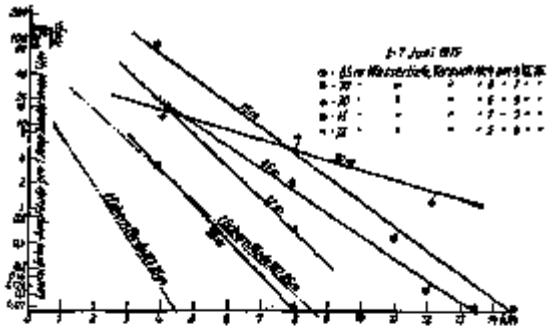
The only previous measurements of variation of intensity of under water signals with distance that have been published to our knowledge are those of Aigner**and Barkhauser and Lichte***in shallow water. The measure-

* Jeffries, H., M.N.R.A.S., Geoph. Sup., June 1926.
** Aigner, F. Unterwasserschalltechnik.
*** Barkhauser and Lichte. Ann. d. Physik.

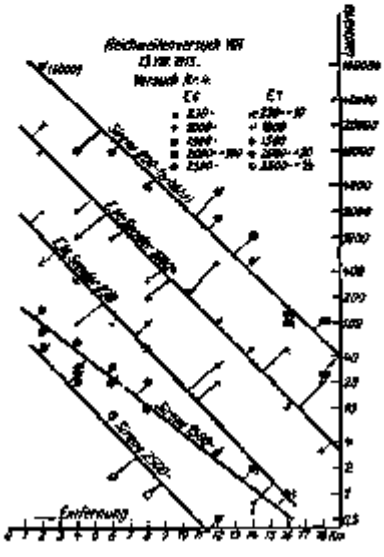
ments were made by having a variable resistance in series or parallel with the underwater detector and adjusting the resistance so that the signal was just audible through earphones. The source of the signals was a Fessenden oscillator or underwater sirens. Barkhauser and Lichte found the decrease in amplitude with distance to be exponential and independent of the frequency and the depth of water (under 100 fathoms). It is not known whether the source was sustained or intermittent but presumably it was sustained. Certainly the results are quite different in deep water with a source of short duration. Their curves are reproduced below, illustrations D, E and F.



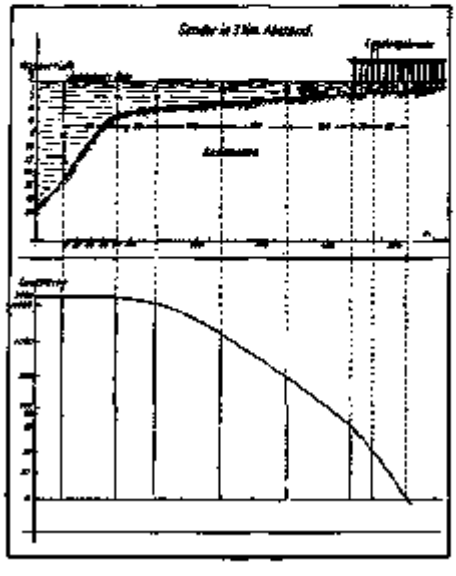
D



E



F



G

Aigner shows a very interesting result, the illustration G being self-explanatory.

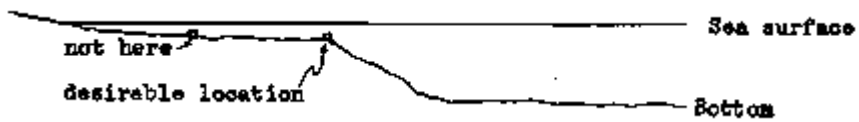
The amplitude drops very sharply just inshore of the steeper portion of the slope which he thinks is due to the depth of bottom becoming equal to the wave length of the sound which was generated by a Fessenden oscillator. It is quite likely that the slope was an important factor, as indicated in Fig. 3.

DEEP TO SHOAL WATER EXPERIMENTS

The simplified conditions of the deep water tests were necessary to determine experimentally the acoustic properties of sea water. The purpose of the deep to shoal water experiments was to develop practical rules of general use in R A R under conditions found on the Pacific Coast where the sea bottom slopes rather steeply from the beach.

The bottom profile of the experimental area is shown in Fig. 3. The vertical scale is exaggerated, but the average slope of the bottom is about 10° at the steep part. Since the emergence angle is increased by an amount equal to twice the angle of slope upon reflection, it can be seen that the conditions are not favorable for sound propagation. At large emergence angles over 90% of the incident energy is transmitted into the underlying material, and the small amount of energy reflected may start seaward after a few reflections from the bottom.

The travel time curves are shown in Figs. 19, 20, 21 and 22. Reference to the profile, (Fig. 3) shows that the horizontal distance along the slope is practically the same as that along one leg of the tangent ray. In other words, the average slope of the bottom is about the same as the average slope of the tangent ray. The bottom, at the foot of the slope, is quite level. With this combination of conditions, the travel time curve of the first arrivals outside of the zones of silence was not affected by the presence of the slope. This is an important observation for sound ranging; when there is a choice, the hydrophones should be situated at the head of the steepest slope available*. It is also desirable to have the hydrophone as far out as possible, preferably directly at the peak of the slope.



The direct impulse was not observed beyond 8½ km. It had an instantaneous velocity of 1500 m/sec. and a negative time intercept. The instantaneous velocity is 5 m/sec. higher than observed in the deep water tests, the near surface temperatures having been slightly higher inshore than offshore. The intercept below the origin was also observed in the deep water tests and could be due to a higher velocity near the source.

There is some doubt as to the accuracy of the timing of the electric bombs in this series. The crystal in the ship's transmitter was set into oscillation when the firing switch was thrown. It was found on testing the equipment after finishing the experiments that a lag of .026 second occurred between the start of the plate current and the oscillation of the crystal when the transmitter was tuned for maximum output. The lag was small when the transmitter was slightly detuned. The travel times of the fuse and electric bombs agree when no lag is assumed, showing that if there was a lag in actual operation, it was small. Many of the oscillograph initials (i. e. time of the explosion) of electric bombs show a double beginning separated by from .01 to .02 second, the first being a single complete wave, the second the usual continuous oscillation. The indications are that the first should be used as the initial and the

* Unless, of course, this introduces an undesirable bottom profile between the hydrophones and the area to be surveyed, such as ridges of submarine valleys, which can be avoided by a different location of the hydrophones.

magnitude of the interval between the two leads to the belief that it is a measure of the time between the start of the plate current and the oscillation of the transmitter crystal. Presumably the preliminary initial was absent when no lag occurred.

From 13 to 20 km. the arriving sounds were too weak to operate the radio return but they did record weakly on the oscillograph. (Fig. 23) This was the region in which only multiple reflections from the slope were recorded. As the distance is approached at which a tangent ray is reflected at the foot of the steep slope, the slope no longer acts as a barrier (See Fig. 3) and the intensity at the hydrophone increases. As the distance is further increased PR-1 diffracted dies out before a PR-2 reflected the second time at the foot of the slope comes through, and hence another zone of quiet is observed at about 42 km. Of course, the transition from multiple reflections involving the slope to the tangent rays reflected from the level bottom is gradual; the points on the PR-2 curve (Fig. 19) are not true PR-2's and the bombing was not carried to the distance at which the tangent PR-2 should have been observed.

At 35 km. both the fuse and electric bombs (which were fired under different conditions) came in from .05 to .22 second late (Figs. 21 and 22), no doubt because of an irregularity in the bottom. It is very fortunate that this observation is so clearly substantiated since it illustrates admirably the limitations of the accuracy of R A R over irregular bottom.

OBSERVED FREQUENCIES

The major frequencies present in each impulse were recorded. However, no effort was made to evaluate their relative durations. Frequencies ranging from 100 to 1600 hertz were observed, but for a given experimental set-up two or three frequencies predominated heavily. The frequency statistics are shown in tables. It is stressed that the numbers are not intended to indicate relative duration of the frequencies as they occur, simply the number of times they are observed to occur, ordinarily only one occurrence per frequency being recorded per impulse.

The frequencies observed during preliminary experiments at Laguna Beach are included in the table. The hydrophone had a steel diaphragm 21 inches in diameter and 3/16 inch thick. The fundamental frequency measured in air is 88 with an overtone of 204, the latter presumably being vibration with one nodal diameter. The corresponding under water frequencies are probably around 50 and 100. A large Utah unit (weight 2 pounds) was used in this hydrophone.

Neither the hydrophones (See "Hydrophones") nor oscillograph were satisfactory means of determining actual frequencies present in the bomb noises. The hydrophones with the units comprised a complex vibrating system with a number of inherent vibration frequencies of somewhat doubtful magnitudes, and the oscillograph string itself is a vibrating system with an infinite number of modes of vibration. None of the vibrating elements were particularly well damped, making it practically certain that the inherent frequencies would predominate in the records.

A few supplemental records were obtained with a Rochelle salt crystal hydrophone which should respond to all frequencies the oscillograph will record. It showed frequencies of from 205 to 260 with 220 hertz ca. being the most prominent. Since strays of frequency 1900 hertz were present throughout the records, it seems extremely likely that no considerable portion of the energy resided in frequencies between 260 and 1900 hertz. These records were obtained at ten miles in comparatively shoal water.

For a given hydrophone combination the frequency distribution was not affected by a change in bomb size from 4-ounce bottles to l/2 pints, having a charge ratio of roughly 1 to 2. The depth of the explosion also does not affect the frequency distribution.

Segregating the frequency statistics into groups according to travel time shows that the ability of the bomb noise to induce the higher frequencies decreases with the distance. (See tables at end of report.) This, of course, would be expected.

There is a tendency for the higher frequencies to persist to greater distances with the larger size bomb than with the smaller. Pint size bombs still excited a rather high percentage of high frequencies even at a travel time of sixty seconds, particularly in the first arrivals. The high frequencies are present in the first arrivals in practically all cases in the deep water tests. This is not true in the deep to shoal water tests which is important from the standpoint of R A R. The Laguna Beach statistics are particularly significant in this regard since at distances greater than 40 km. (25 seconds), the highest frequencies (about 900 hertz) do not appear on the records. The low frequency of this particular hydrophone no doubt has some bearing on this, but the higher frequency hydrophone showed similar tendencies in the deep to shoal water tests off Santa Cruz Island.

The data suggest that there may be an advantage in having a hydrophone and amplifier particularly sensitive to the lower frequencies. Hydrophones with low frequency diaphragms are undesirable because of the persistence of the diaphragm vibrations, especially when loaded with a unit. A hydrophone with rigid walls and lighter than the water it displaces may be a satisfactory solution. Such a hydrophone would move with the water and there would be no dependence on diaphragm vibrations. In fact it would not be necessary to mount the unit on a diaphragm face.

RELATIVE DISTRIBUTION OF MAJOR FREQUENCIES

(Note: The first column is the unit of measure.)

Deep water Tests	Frequencies--		200	450	900
Santa Barbara Ids. Basin	Travel time	0-15 sec	1	0.2	7.4
Electrically fired bombs at		15-30 "	1	1.2	3.3
30 fms.; Aluminum Pot hydro-	over	30 "	1	0.2	1.3
phone at 30 fms.					
Deep water Tests	Travel time	0-20 sec	1	0.5	3.4
Santa Barbara Ids. Basin	over	20 "	1	0.1	2.0
½ Pt. Fuse Bombs; Aluminum					
Pot hydrophone at 30 fms.					

Deep to Shoal Water Tests	Frequencies--		200 to 600 inc.	over 600
Santa Barbara Ids. Basin				
Electrically fired bombs at	Travel time	0-15 sec	1	0.4
30 fms., Aluminum Pot hydro-	over	15 "	1	0.1
phone at about 10 fathoms.				
Deep to Shoal Water Tests	Frequencies--		300 to 600 inc.	over 600
Santa Barbara Ids. Basin				
½ pint fuse bombs; Alumi-	Travel time	0-15 sec	1	0.3
num Pot hydrophone at about	over	15 "	1	0.4
10 fathoms.				

Deep to Shoal Water Tests	Frequencies--		100	500	950
Laguna Beach					
½ pint fuse bombs; Kettle	Travel time	0-12 sec	1	1.3	1.6
Drum hydrophone at about		12-25 "	1	1.3	0.1
10 fathoms.	over	25 "	1	0.6	0

Deep to Shoal Water Tests		Frequencies--	100	450	950
Laguna Beach	Travel	time 0-10 sec	1	1.6	2.0
Electrically fired bombs at		10-20 "	1	0.7	0.2
30 fms.; Kettle Drum hydro-		over 20 "	1	0.7	0.0
phone at about 10 fms.					

See also the Table of Frequencies

COMPARISON OF TIME INTERVALS MEASURED BY THE CHRONOGRAPH AND THE OSCILLOGRAPH

During the deep to shoal water tests the oscillograph was ashore and only one hydrophone was used, it being in 15 fathoms of water l/2 mile offshore (depth of bottom 20 fathoms). The B string of the oscillograph was used to record the start of the plate current in the shore radio transmitter upon the arrival of the sound at the hydrophone. The radio signal was received at the Pioneer and operated the ship's chronograph. During the all deep water tests an auxiliary electromagnetic shutter was employed to cut out a small band of light at the top edge of the oscillograms when the chronograph marked the receipt of the bomb noise. This time mark is called a return in this discussion. A check of the chronograph times is thus possible regardless of what portion of the bomb noise operated the chronograph. Instrumental lags should introduce a difference of less than .01 second in the time intervals measured by the two separate devices as can be seen by reference to the lag determinations. There is excellent reason to believe that the lag in the ship's transmitter was negligible in actual operation as shown elsewhere. (Paragraph of Deep to Shoal Water Tests.)

In the tables, the columns headed Chrono. Time and Osc. Return are, apart from minor lags, measurements of the same interval of time. In the columns of Tables A and B headed Osc. Time, the time of the first arrival is also entered in the event that a later arrival operated the chronograph.

In table A a number of the differences "Chrono minus Return" are rejected since the character of the return made it uncertain which portion recorded on the chronograph tape. Ordinarily, this occurs when the beginning is weak, i. e., the amplitude of the first arrival is small and its duration short. The algebraic sum of the differences between the Osc. Return and the Chrono. Times is so small that it can be assumed that the differences are due to accidental errors. However, an inspection of the differences is disconcerting since it shows absolute values of the differences greater than .03 second in a number of instances, involving a displacement of an R A R intersection line of more than 50 m. If a large percentage of errors of this magnitude are to be expected due to a faulty chronograph, the application of intelligent analysis of radio acoustic data is rendered exceedingly difficult. It seems that some estimation of velocities is necessary in deep water areas with an uneven bottom, but it would seem that satisfactory results can be obtained if the equipment is reliable.

The most obvious source of part of this error is in the apparent variable rate of the chronometer which has been discussed. It is probable that this is built into the mechanical arrangement of time marking in the chronometer and is unavoidable. If break second (or make second) chronometers are commonly subject to apparent irregularities in rate of this order, it may be desirable to replace them with tuning forks or vibrating reeds.

During the deep water experiments with fused bombs, very few oscillograph returns were recorded so the chronograph times are compared directly with the oscillograph times in Table B. This is legitimate since Table A shows that the return was usually sent a very few thousands of a second after the onset of an impulse which is the magnitude of the measured lag

in the relay recording the return. The same comments that were made about Table A apply to these results. A correlation between the measured time and the difference (Chrono minus Osc.) is not noticeable in either case.

The differences, Table C, for the deep to shoal water tests show an indisputable relation to the length of the time interval measured indicative of a difference in rate between the chronometer and tuning fork of 3½ minutes per day, the tuning fork being the faster. There was no such discrepancy in the deep water tests. Evidence that the assumed tuning fork rate may have been four minutes per day too high during the deep water tests has already been given in the discussion of the theoretical velocities. However, Table A and B do not substantiate it unless it be assumed that the chronometer rate was also high at that time and lower during the experiments conducted during the work of the previous week. It is contrary to experience with chronometers that the rate should change by the required amount in such a short time under proper treatment. The same is true of tuning forks. No explanation of the apparent change in rate (or frequency) seems reasonable unless the tuning fork was mounted in a different manner on the ship than ashore on Santa Cruz Island. The tuning fork was calibrated on the ship after the deep water tests.

DEEP WATER TESTS — Table A.
Electric Bombs

Bomb No.	Chronograph Time	Oscillograph Time	Oscillograph Return	Chronograph Return
404	35.03	35.026		
405	35.00	35.017		
406	28.64	28.654		
409	24.25	24.253		
410	24.32	24.319		
411	24.33	24.329		
412	20.06	20.066		
413	20.08	20.095		
415	4.22†	4.235		
416	4.15	4.149		
417	3.95	3.960	3.962	-0.01
418	3.91	3.913	3.915	-0.01
423	4.28	3.552 & 4.269	3.553 & 4.270	+0.01
426	7.33	7.294	7.297	+0.03
427	9.78	9.520 & 9.790	9.790	-0.01
428	9.80	9.547 & 9.803	9.804	0
429	11.99	11.79 & 11.981	11.982	+0.01
430	12.01	11.813 & 12.008	12.010	0
431	14.29	14.285	14.286	0
432	14.29	14.276	14.278	+0.01
434	15.88	15.867	15.868	+0.01
435	18.27	18.272	18.267	0
436	18.26	18.253	18.255	0
437	18.05	18.062	- - -	
438	17.86	17.859	17.860	0
439	17.62	17.537 & 17.624	17.624	0
441	21.25	21.230	21.231	+0.02
442	21.22	21.207	21.209	+0.01
443	25.32	25.319	25.321	0
444	25.30	25.314	25.315	-0.02
445	25.29	25.301	25.303	-0.01
446	30.30	30.252	30.254	+0.05

(Continued)

Bomb No.	Chronograph Time	Oscillograph Time	Oscillograph Return	Chronograph Return
447	30.22	30.220	30.220	0
448	30.18	30.203	30.202	-0.02
450	33.06	32.84 & 33.081	33.082	-0.02
451	33.04	32.81 & 33.038	33.039	0
452	37.79	37.795	37.772	+0.02
453	37.78	37.782	37.712?	+0.07-R
454	37.77	37.786	37.776	0
455	37.60	37.477 & 37.618	37.617	-0.02
456	37.49	37.522	- - -	
457	37.46	37.459	37.460	0
458	37.24	37.217	37.219	+0.02
459	37.14	37.134	37.136	0
460	53.44	53.407	- - -	
461	53.35	53.344	53.358	-0.01
463	59.12	59.14	- - -	
464	59.35	59.32		
470	67.55	67.56±	67.559	-0.01
471	67.78	67.762	67.776	0
532	2.73	2.728	2.730	0
	3.59	3.577		
533	2.71	2.712	2.714	0
	3.56	3.562		
534	2.70	2.709	2.711	-0.01
	3.56	3.559		
535	4.80	4.810	4.811	-0.01
	5.37	5.369		
536	4.81	4.813	4.814	0
	5.34	5.371		
538	5.16	5.156	5.158	0
	5.69	5.685		
539	5.24	5.227	5.228	+0.01
	5.55			
542	8.10	7.997	7.997 Sputtery	+0.10-R
	8.39	8.383		
543	8.09	8.014	8.016 do	+0.07-R
	8.40	8.40		
544	8.11	8.023	- - -	
	8.40	8.41		
545	9.61, 9.78	9.518 and others	- -	
546	9.64, 9.90	9.520, 9.604 and others.		
547	9.91	9.559	9.560	0
		9.905	9.906	
548	14.10	14.045	14.047	+0.05
549	14.05	14.031	14.032	+0.02
550	14.08	14.073	14.074	+0.01
551	14.05	13.879	13.880	+0.17-R
552	24.28	24.292	24.293	+0.01
554	29.14	29.089	29.090 Sputtery	+0.05-R

Sum of negative difference -0.16
Sum of positive difference +0.29
Average difference ± .01 sec.

COMPARISON OF TIME INTERVALS
MEASURED BY THE OSCILLOGRAPH AND THE CHRONOGRAPH

Table B.

DEEP WATER TESTS
Fuse Bombs

Bomb No.	Chronograph Time	Oscillograph Time	Oscillograph Return	Chronograph - Return	Chronograph - Oscillograph
481	57.85	57.902	57.903	-0.05	-0.05
486	52.58	52.580	52.573	+0.01	0
488	50.37	50.38	- - -		-0.01
489	49.23	49.25			-0.02
491	46.96	46.963			
495	42.55	42.219 42.493	42.461	-0.09	+0.06
496	41.82?	41.101 41.394	41.340		- - -
497	40.28	40.289	- - -		-0.01
500	36.58	36.586			-0.01
502	34.35	34.347	- - -		0
503	32.86	32.838	- - -		+0.02
506	29.87	29.867	29.869	0	0
510	24.35	24.327			+0.02
511	23.22	23.208	- - -		+0.01
512	22.11	22.095	- - -		+0.01
517	17.20	17.177	- - -		+0.02
525	7.81	7.470 7.807	- - -		0
526	6.73	6.286 6.742	- - -		0
				Algebraic sum	+0.03

Note: Oscillograph and Chronograph aboard Pioneer.
Bombs fired at Guide.

DEEP TO SHOAL WATER TESTS

Table C.

Bomb No.	Chronograph Time: Sec.	Oscillograph Time: Sec.	Oscillograph Return	Chronograph - Return
202	3.85	3.769		
203	3.16	3.124		
204	3.14	3.106		
206	5.33	5.260		
207	5.27	5.212		
222	14.73	14.685	14.817	-0.09
223	17.05	17.043		
224	17.08	17.087		
225	19.38	19.382		
229	20.12	20.112	20.138	-0.02
230	24.58	24.603	24.622	-0.04
231	24.61	24.631	24.652	-0.04
236	27.56	27.620		
238	30.79	30.745	30.783	+0.01
242	9.60	9.589	9.608	-0.01
243	9.675	9.627	9.680	0
245	9.00	8.908	8.961	-0.04
246	9.01	8.915	8.963	-0.05

(Continued)

Bomb No.	Chronograph Time: Sec.	Oscillograph Time: Sec.	Oscillograph Return	Chronograph Return
247	7.41	7.363	7.411	0
248	7.41	7.385	7.409	0
249	5.76	5.726	5.747	+0.01
250	5.76	5.711	5.746	+0.01
251	4.14	4.112	4.140	0
252	4.16	4.128	4.141	+0.02
253	2.48	2.438	2.459	+0.02
254	2.46	2.438	2.455	0
255	1.49	1.469	1.481	+0.01
256	- -	1.464	1.481	
257	0.80	0.760		
258	1.73	1.729		
259	2.82	2.799	2.817	0
261	4.07	3.985	4.067	0
262	5.04	4.915	5.033	+0.01
263	6.01	5.944	6.022	-0.01
272	13.78	13.461	13.813	-0.03
274	15.65	15.637	15.685	-0.03
275	16.57	16.563	16.578	-0.01
278	19.58		19.625	-0.04
279	20.64	20.659	20.675	-0.04
280	21.74	21.756	21.782	-0.04
283	24.71	24.757	25.773	-0.06
286	28.05	28.104	28.117	-0.07
291	26.41	26.444	26.47	-0.06
292	26.62	26.660	- - -	
293	23.75	23.758	- - -	
294	23.71	23.755	- - -	
298	34.05	33.096	34.101	-0.05
301	36.88	36.69±		
302	38.94	38.908	39.094	-0.15
304	39.28	39.16	39.361	-0.08
306	27.79	27.831	27.845	-0.06
307	27.72	27.732	27.777	-0.06
309	22.57	22.583	22.627	-0.06
310	22.79	22.798	22.830	-0.04
311	17.50	17.478	17.495	0
313	17.49	17.54	- - -	

Oscillograph ashore; Chronograph on Pioneer. Bombs fired at Pioneer.

COMPARISON OF LOG READINGS AND REVOLUTION COUNTER WITH CHRONOGRAPH TIMES

In order to detect marked changes in the apparent velocity of bomb sounds in actual R A R through the use of log reading (L.R.) or revolution counter reading (R.C.R.), the ship's course must be quite constant and the instruments must be reliable. The taffrail log and the R.C. might be expected to measure distances with sufficient accuracy to indicate sudden changes in the apparent velocity, if the ship's course cuts the distance circles at an appreciable angle. If this is not appreciable then a bomb distance that plots off line would indicate the change in apparent velocity.

R A R conditions were simulated to a certain extent during the fuse bomb runs in both deep and deep to shoal water tests with the special condi-

tion that the lines were run directly toward or away from the hydrophones.

During the deep water tests a line was run toward the hydrophone and the course was not changed during the entire run. The log readings plotted against travel time should then be equivalent to a travel time curve. In Fig. 28 the travel times were measured by the chronograph. From 5 to 31 seconds the points fall on a smooth curve the upper end of which is a straight line, and those from 37 to 57 seconds fall on a straight line nearly parallel to the first and 0.30 seconds above. Comparison of the chronograph and oscillograph times indicates that the first reflection tripped the chronograph pen to a distance equivalent to 31 seconds travel time after which the second reflection tripped the pen. The sudden change in apparent velocity is very clearly indicated and is of the order of 12 m/sec. which is in good agreement with the facts. Another jump of about 150 m/sec. is indicated at 5 seconds where the direct waves ceased to record on the chronograph, again in agreement with the oscillograms. The jumps in the R.C. curves agree with the facts better than do the log readings.

In actual R A R the sounding lines do not radiate from the hydrophone stations and the relation between the log readings and bomb distances is not linear. In this case, a linear travel time curve would mean a log time curve of varying curvature. The log time curves should, however, be smooth and show sudden large changes in the apparent velocity if the ship's course cuts the distance arcs at a favorable angle. To properly evaluate the magnitude of the change, every effort should be made to record and measure on the chronograph tapes the second arrivals at the hydrophones.

The effect of changing course is readily seen in Fig. 30 where the log-times for the deep to shoal water tests are shown. The course was gradually changed to the left during the early part of the run and then gradually to the right during the latter part of the run, thus making a curved instead of a straight line on the graph. The effect is probably more striking in Fig. 29 where log readings are plotted against actual distance. Fig. 30 could not be successfully interpreted to assist materially in obtaining good distance arcs from the chronograph times as it stands.

Since this latter type of data is probably more typical of R A R it would be of interest to determine if the changes in course can be conveniently taken into account. If an average course is assumed, the difference in L.R. between successive bombs multiplied by the cosine of the angle between the actual course and the assumed average gives the difference in L.R. that would be observed along the projection of the actual course on the assumed average. If the data were plotted in this manner it might be more consistent with the travel time curves.

Another way of handling the data is to divide the difference of successive log readings by the difference in chronograph time when sudden changes in the ratio would indicate breaks in the travel time curve. However, this method is probably not as satisfactory as the other since in the graphical method the interpretation is more obvious.

As stated elsewhere, the best method of detecting when there is an abrupt change in velocity is when the distance arc does not go through the approximate dead reckoning point, and when the shore station operator first reports hearing a wave arrive before the one that trips the transmitter.

Perhaps it is fortunate that in the first R A R work the full complexity of underwater-sound-wave travel was not suspected, for if it had been known this valuable and accurate method might not have been developed. However, the empirical relations used in earlier work have been explained and justified by the recent experiments, and it is believed that this new knowledge will improve the accuracy of R A R even beyond the present limits, which now give the most accurate control known for offshore hydrography.

There are many problems and investigations (which are purely of academic interest) suggested by these recent experiments. Although it is not within the province of this investigation to analyze thoroughly all the suggested possibilities, numerous ones have been noted in this study, and it is hoped that sufficient data are given herein to enable those who pursue some particular branch of this work to study it further in the light of knowledge gained.

ACKNOWLEDGMENT

It is my pleasure to offer grateful acknowledgment for the valuable assistance rendered by the following:

To Captain F. H. Hardy, Hydrographic and Geodetic Engineer, Commanding Officer of the Survey Vessel Guide, who cooperated enthusiastically in the execution of the experiments and offered many important suggestions.

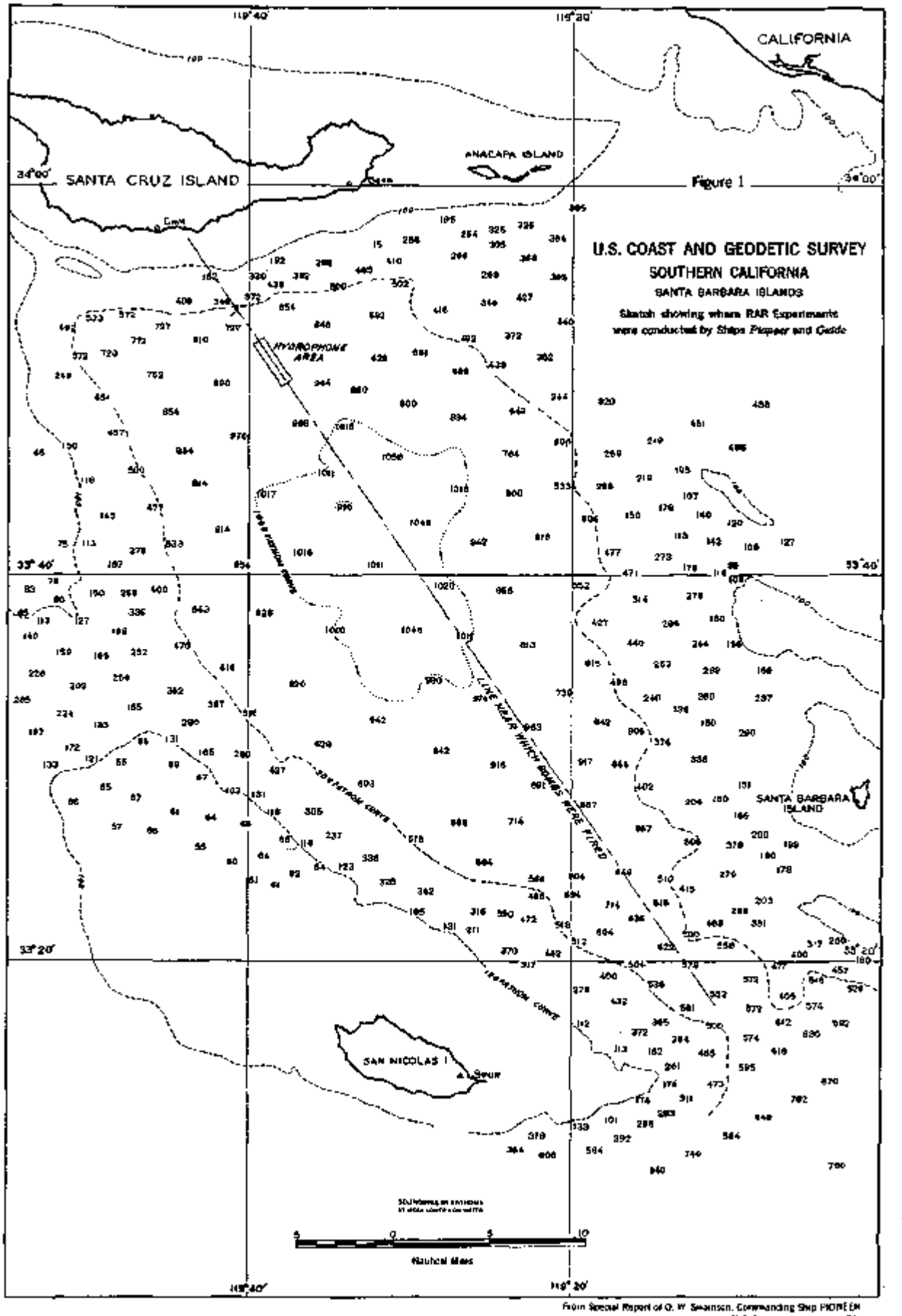
To Dr. Karl Dyk, Seismologist, who assisted in planning the program, sealed and studied the oscillograms, analyzed and interpreted the data obtained, and wrote much of the technical section of the report.

To Dr. Charles G. McIlwraith, Senior Electrical Engineer, who was in charge of the instrumental equipment.

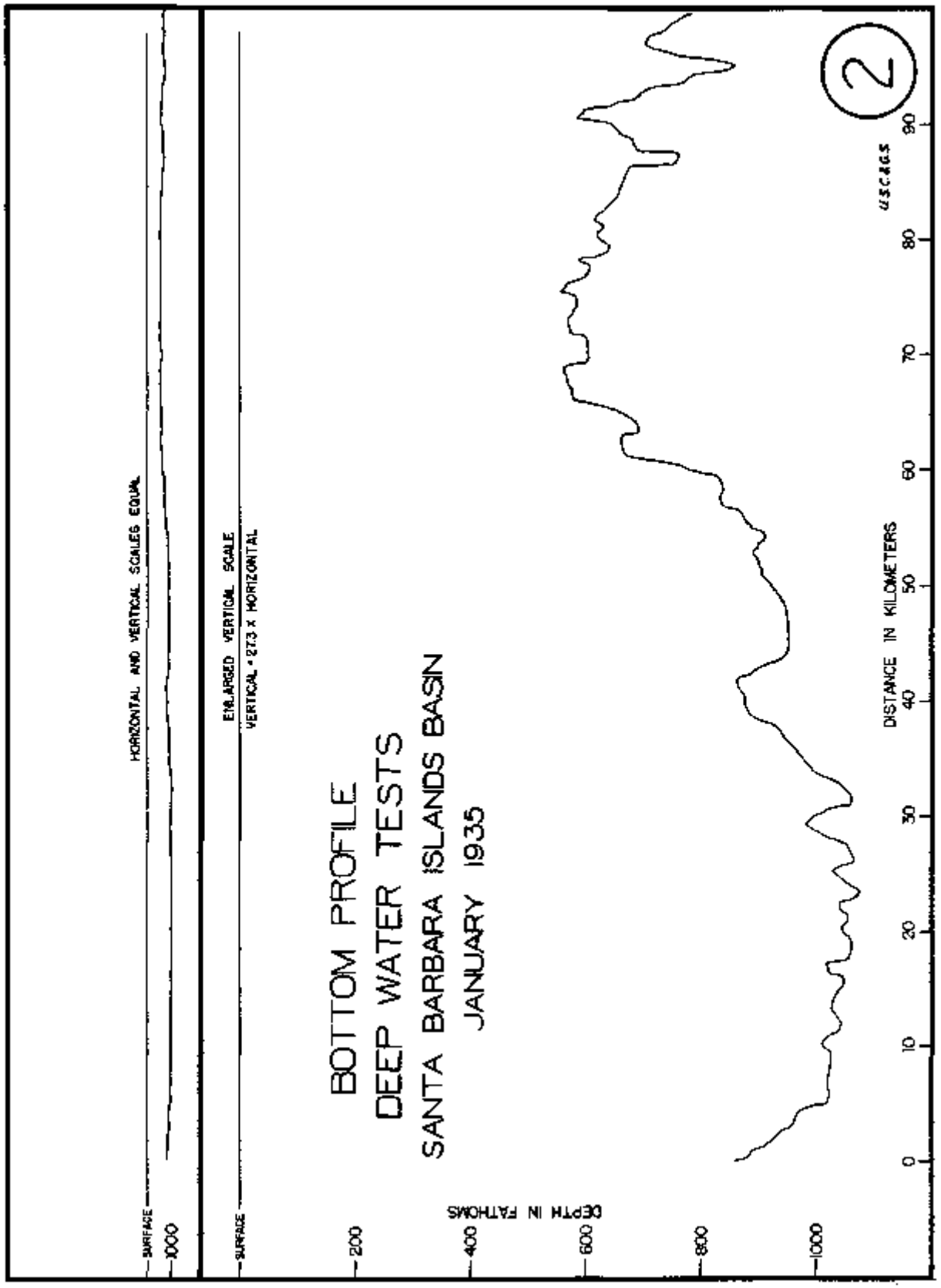
To all the officers of the Pioneer and Guide and the other officers who carried out their work so ably, and assisted in the drawing of the diagrams.

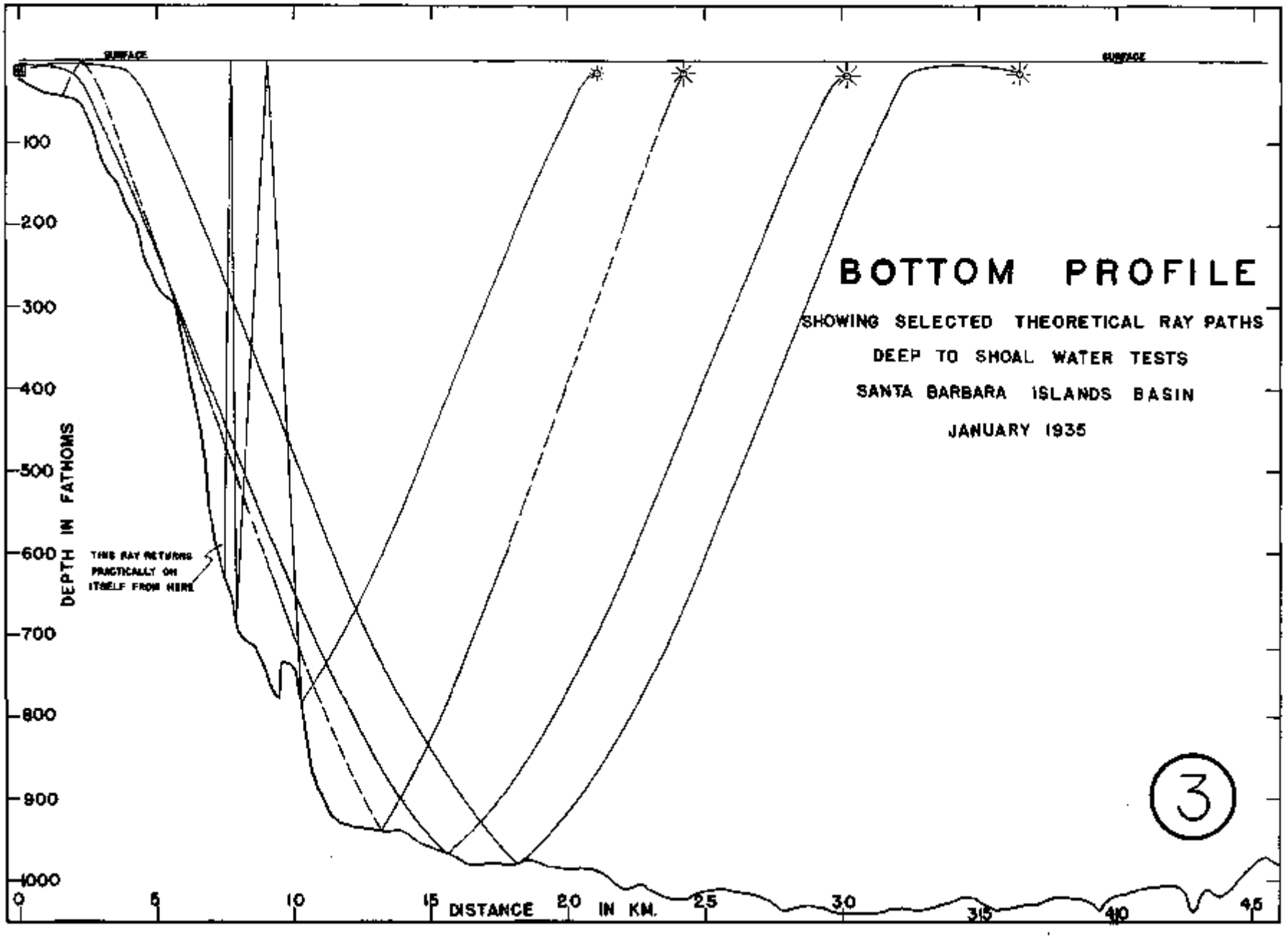
And to Dr. Herbert Grove Dorsey, Principal Electrical Engineer and Lieutenant Paul A. Smith who reviewed the manuscript.

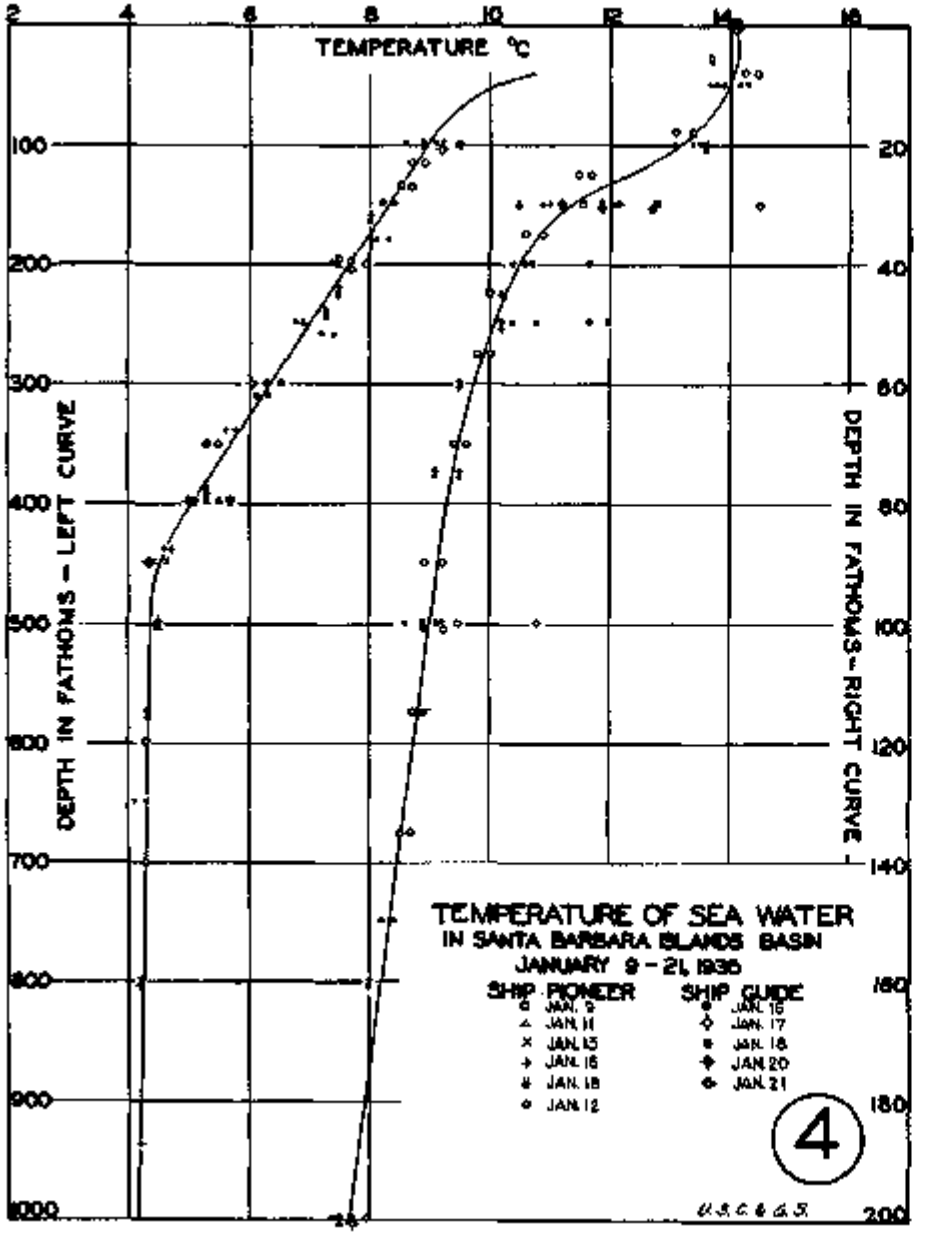
O. W. Swainson,
Lieutenant Commander,
United States Coast and Geodetic Survey,
Seattle, Washington. February 28, 1936.

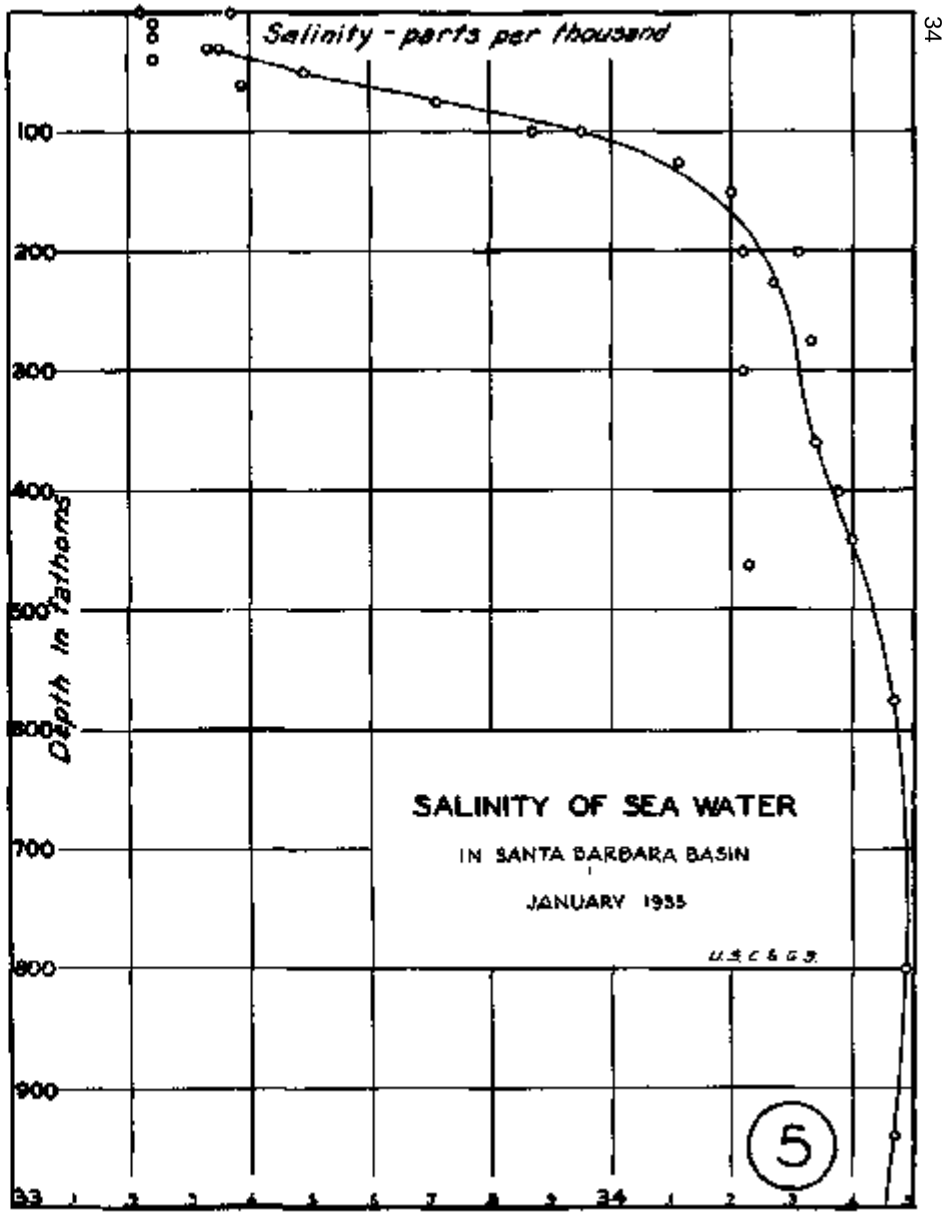


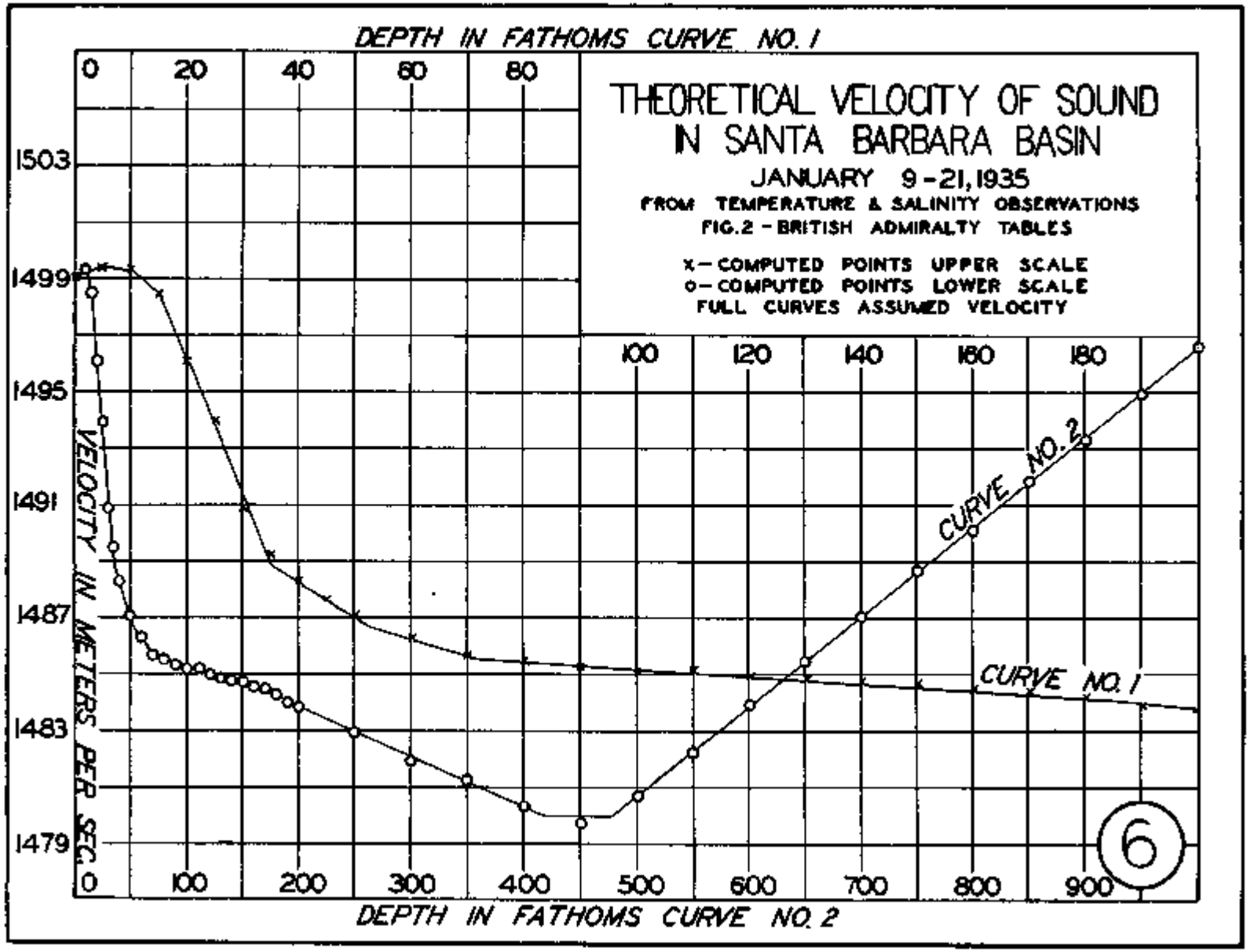
From Special Report of O. W. Swanson, Commanding Ship PIONEER
U. S. Coast and Geodetic Survey Ship

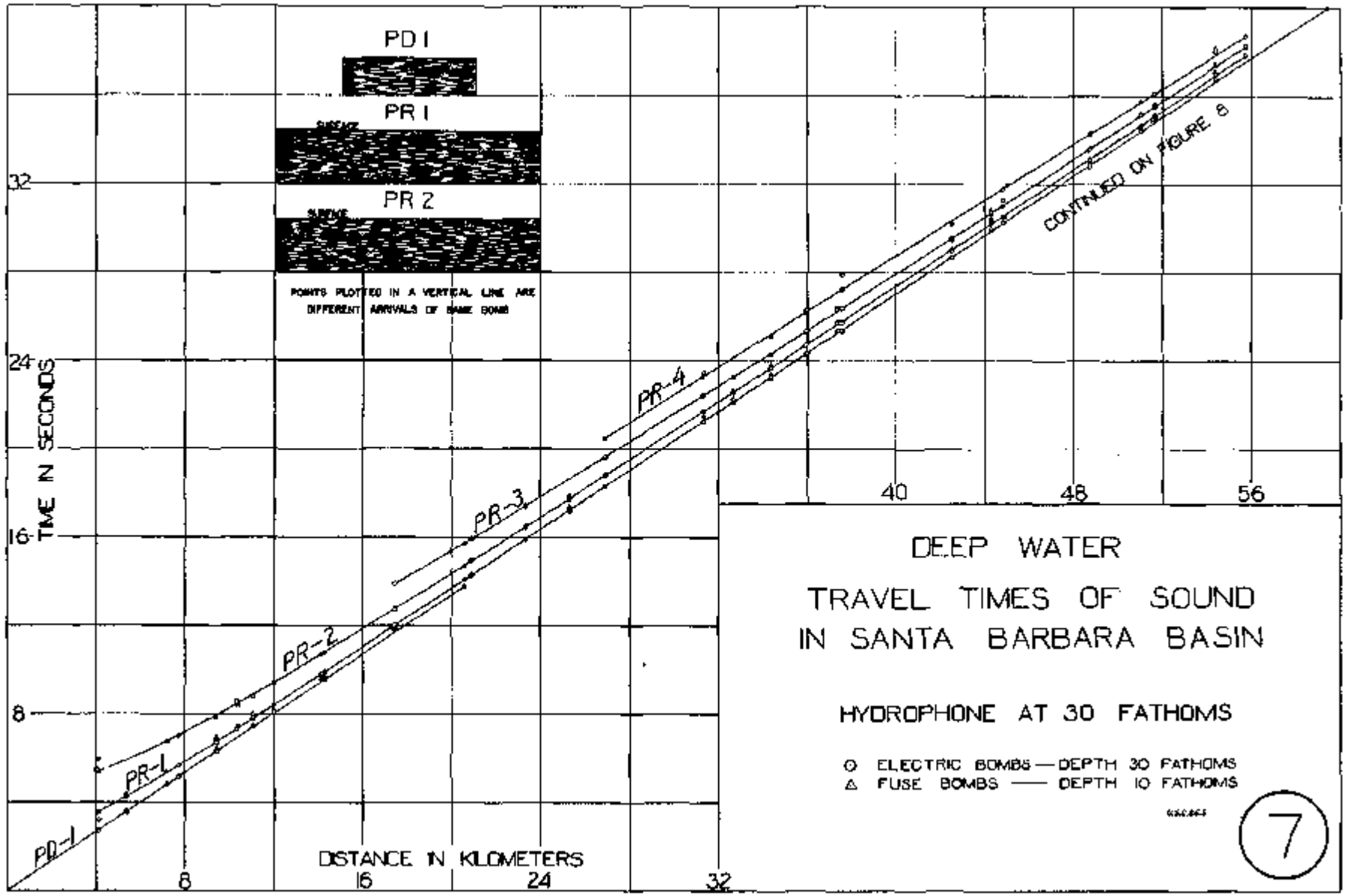

HORIZONTAL AND VERTICAL SCALES EQUAL
SURFACE
1000
ENLARGED VERTICAL SCALE
VERTICAL = 27.3 X HORIZONTAL
SURFACE
200
400
600
800
1000
DEPTH IN FATHOMS
BOTTOM PROFILE
DEEP WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
0
10
20
30
40
50
60
70
80
90
DISTANCE IN KILOMETERS
USCAGS
2

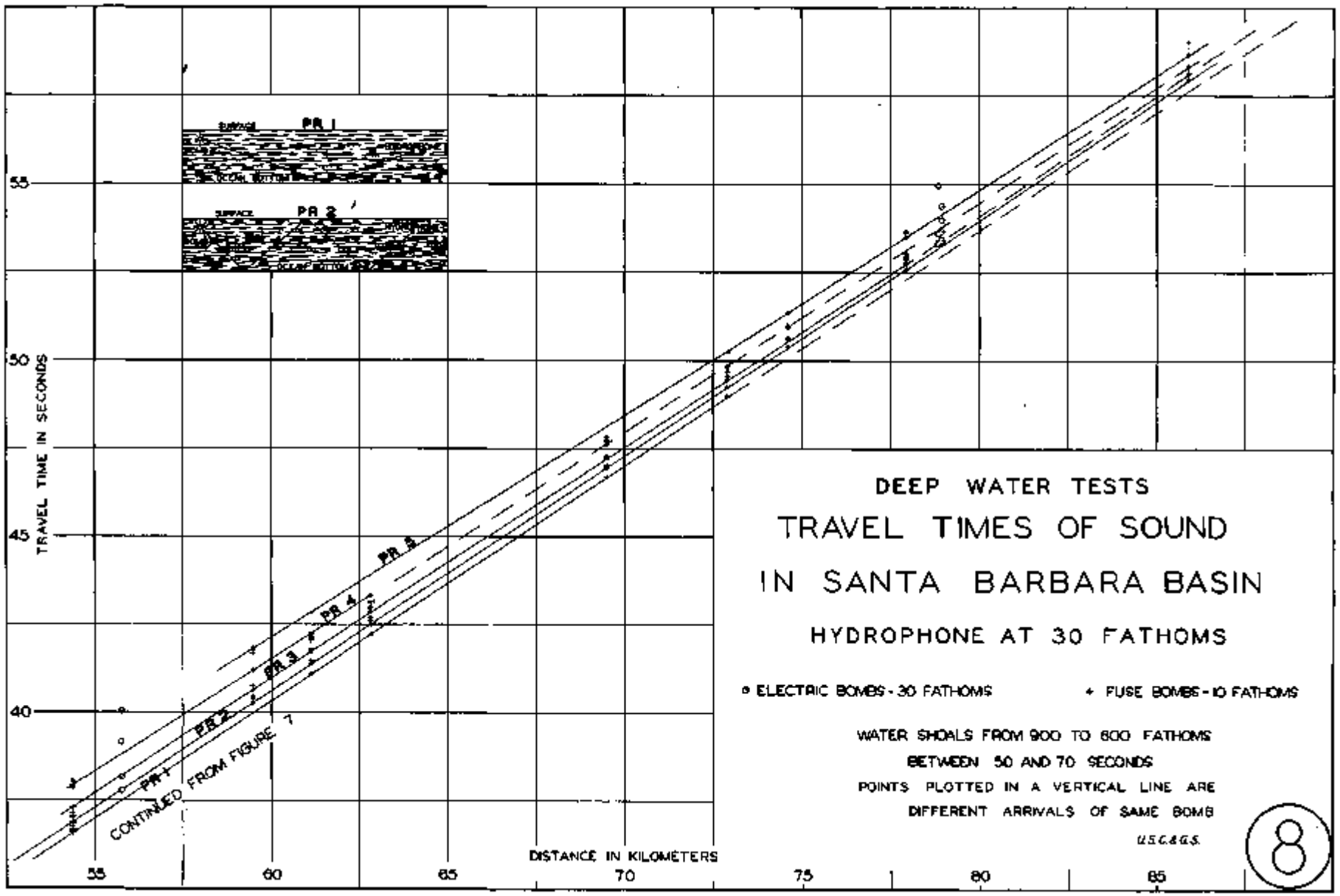

BOTTOM PROFILE
SHOWING SELECTED THEORETICAL RAY PATHS
DEEP TO SHOAL WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
3
SURFACE
SURFACE
THIS RAY RETURNS PRACTICALLY ON ITSELF FROM HERE
DEPTH IN FATHOMS
100
200
300
400
500
600
700
800
900
1000
0
5
10
15
20
25
30
35
40
45
DISTANCE IN KM.

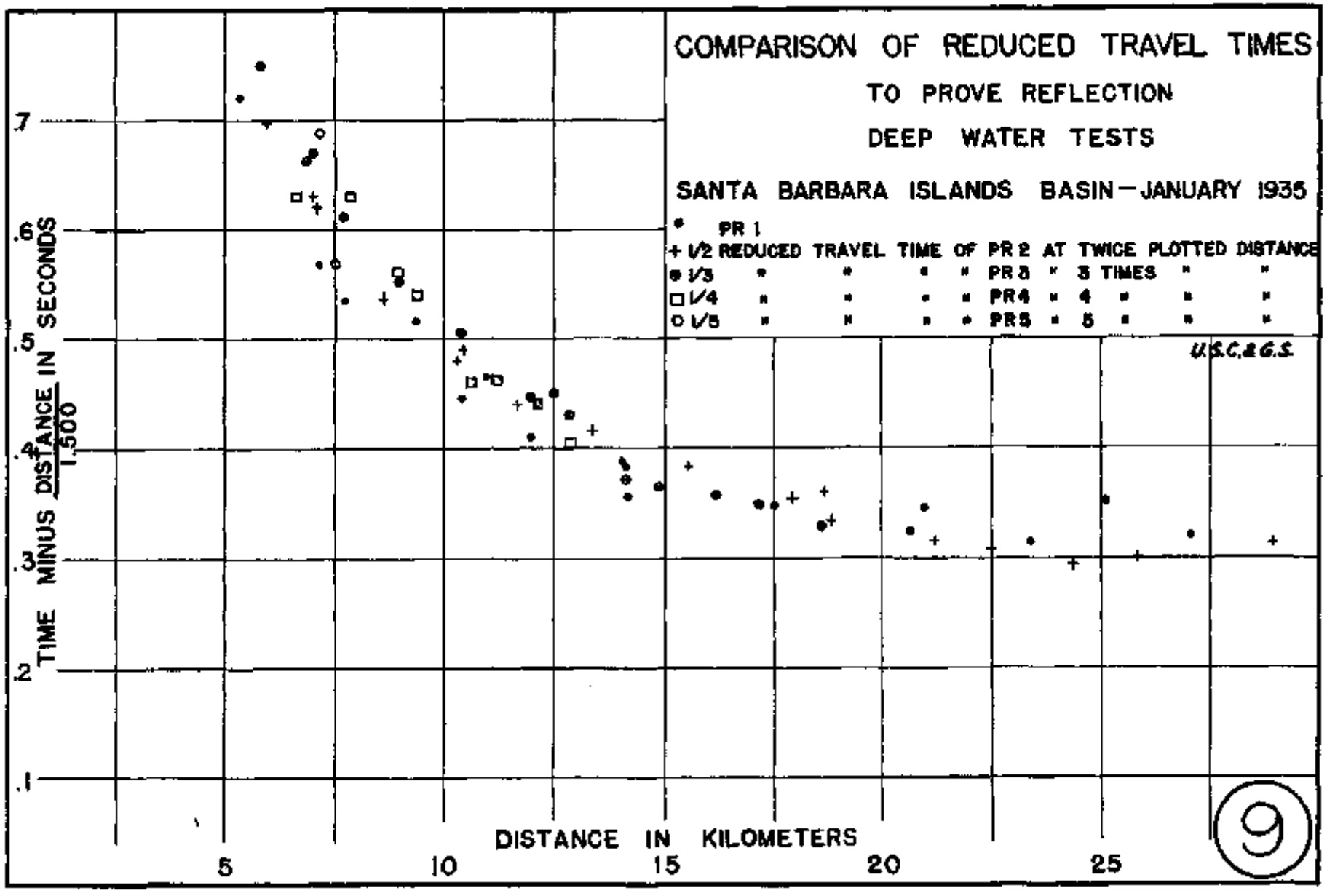

TEMPERATURE °C
DEPTH IN FATHOMS – LEFT CURVE
DEPTH IN FATHOMS – RIGHT CURVE
TEMPERATURE OF SEA WATER
IN SANTA BARBARA BASIN
JANUARY 9 – 21, 1935
SHIP PIONEER
JAN. 9
JAN. 11
JAN. 13
JAN. 15
JAN. 18
JAN. 12
SHIP GUIDE
JAN. 16
JAN. 17
JAN. 18
JAN. 20
JAN. 21
4
U.S.C.&G.S.

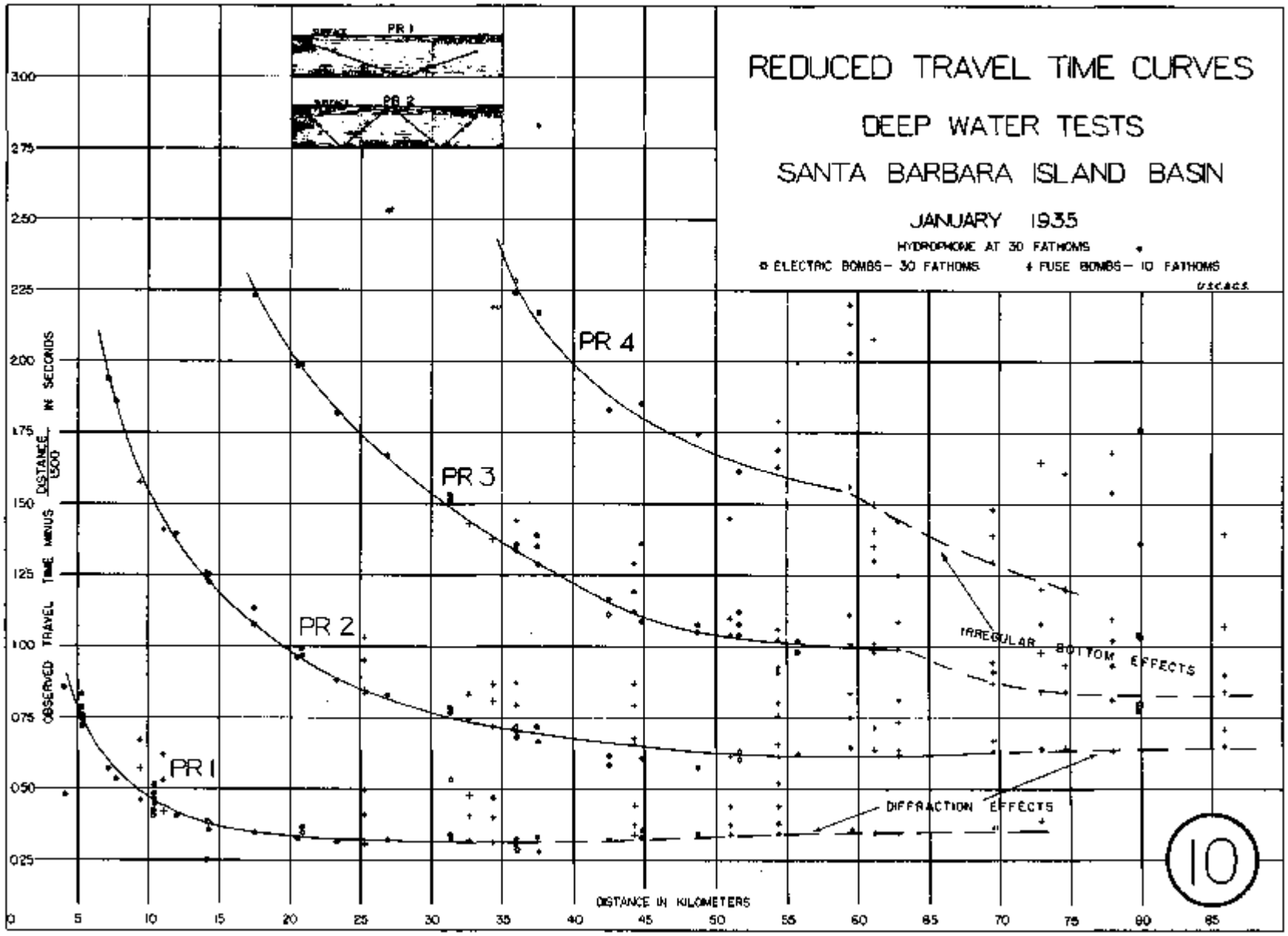

Salinity - parts per thousand
Depth in fathoms
SALINITY OF SEA WATER
IN SANTA BARBARA BASIN
JANUARY 1935
U.S.C.&G.S.
5

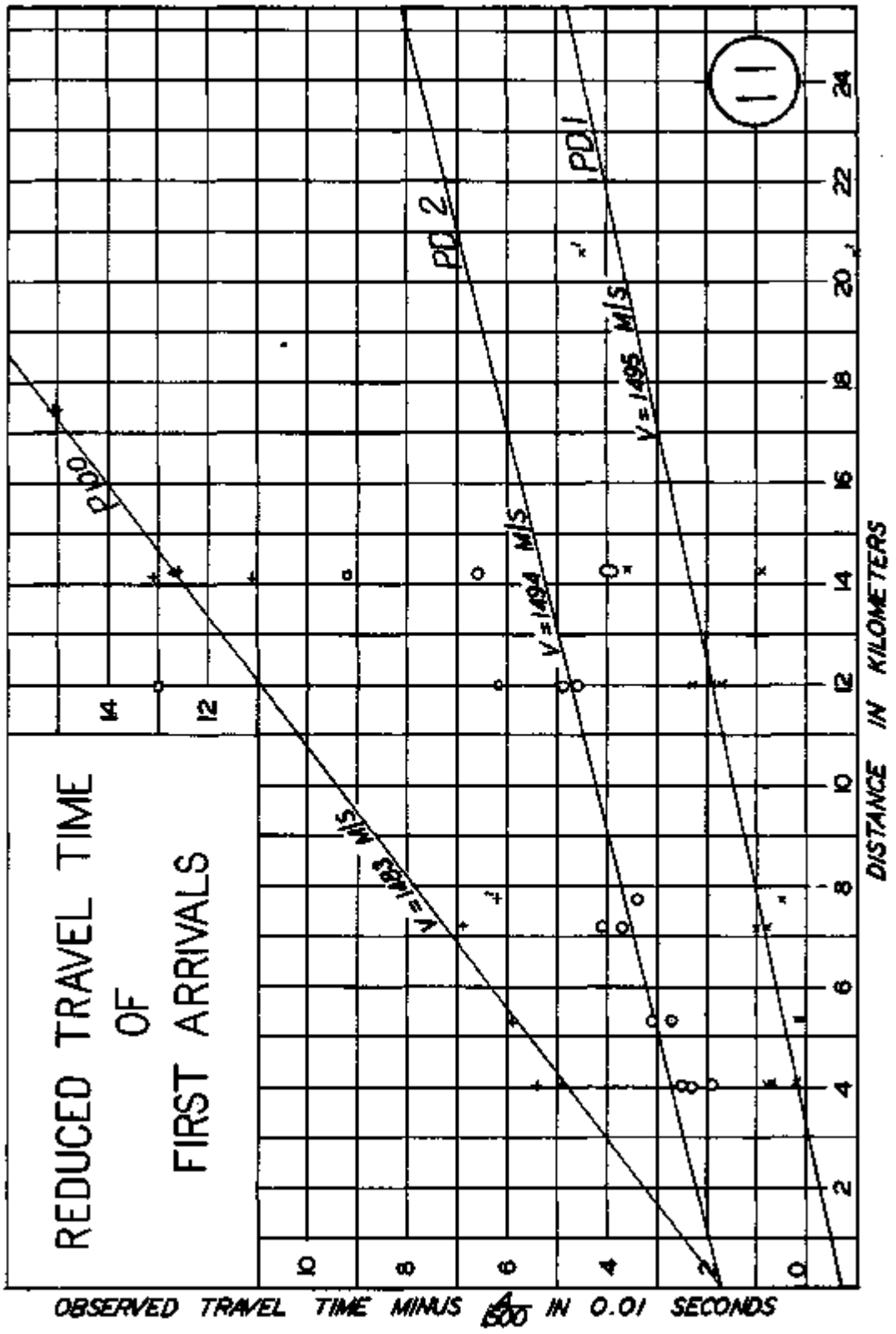

THEORETICAL VELOCITY OF SOUND
IN SANTA BARBARA BASIN
JANUARY 9-21, 1935
FROM TEMPERATURE & SALINITY OBSERVATIONS
FIG. 2 - BRITISH ADMIRALTY TABLES
x - COMPUTED POINTS UPPER SCALE
o - COMPUTED POINTS LOWER SCALE
FULL CURVES ASSUMED VELOCITY
DEPTH IN FATHOMS CURVE NO. 1
0
20
40
60
80
100
120
140
160
180
DEPTH IN FATHOMS CURVE NO. 2
0
100
200
300
400
500
600
700
800
900
VELOCITY IN METERS PER SEC
1503
1499
1495
1491
1487
1483
1479
CURVE NO. 2
CURVE NO. 1
6

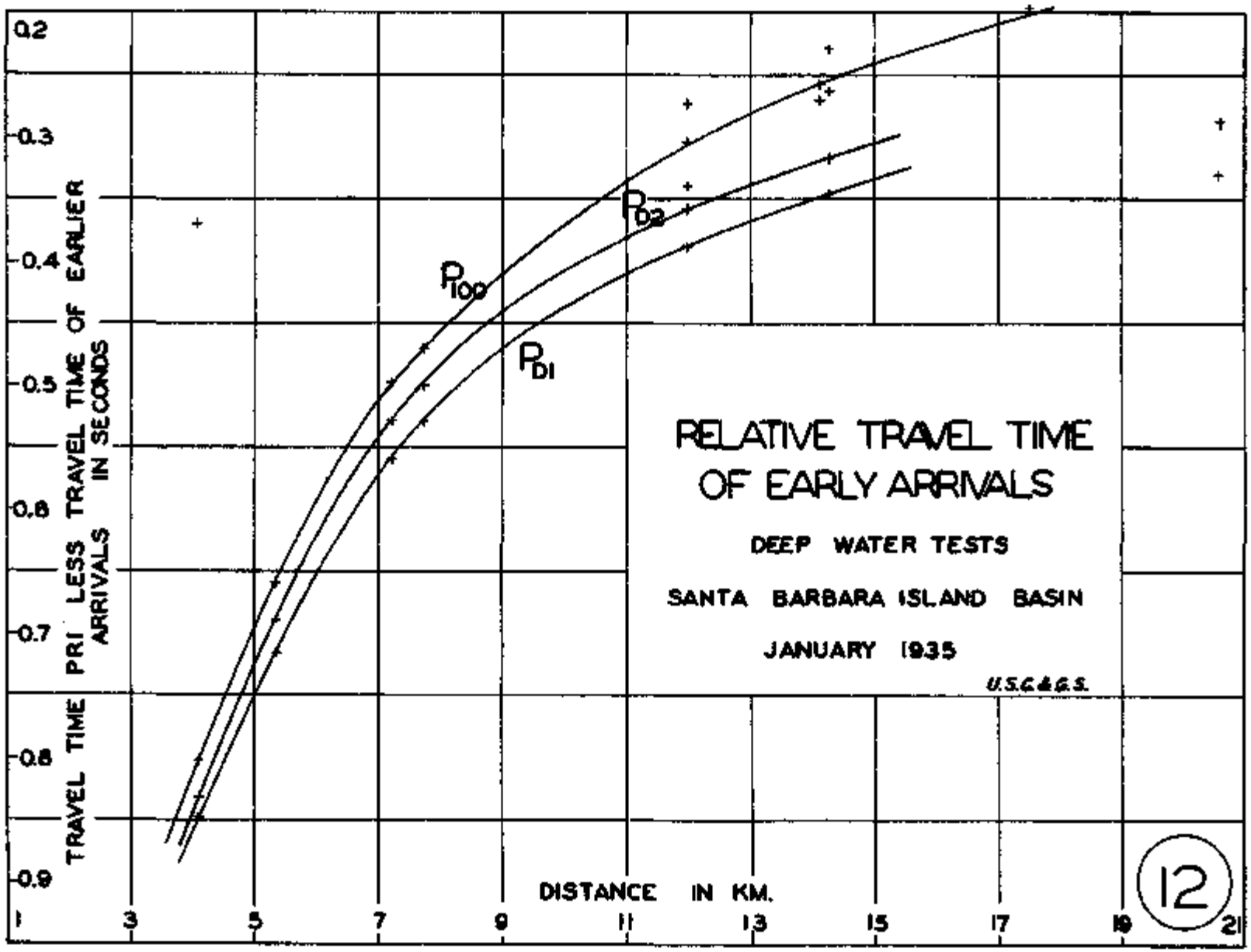

PD I
PR I
PR 2
POINTS PLOTTED IN A VERTICAL LINE ARE DIFFERENT ARRIVALS OF SAME BOMB
TIME IN SECONDS
32
24
16
8
DISTANCE IN KILOMETERS
8
16
24
32
40
48
56
PD-1
PR-1
PR-2
PR-3
PR-4
CONTINUED ON FIGURE 8
DEEP WATER
TRAVEL TIMES OF SOUND
IN SANTA BARBARA BASIN
HYDROPHONE AT 30 FATHOMS
O ELECTRIC BOMBS — DEPTH 30 FATHOMS
△ FUSE BOMBS — DEPTH 10 FATHOMS
7

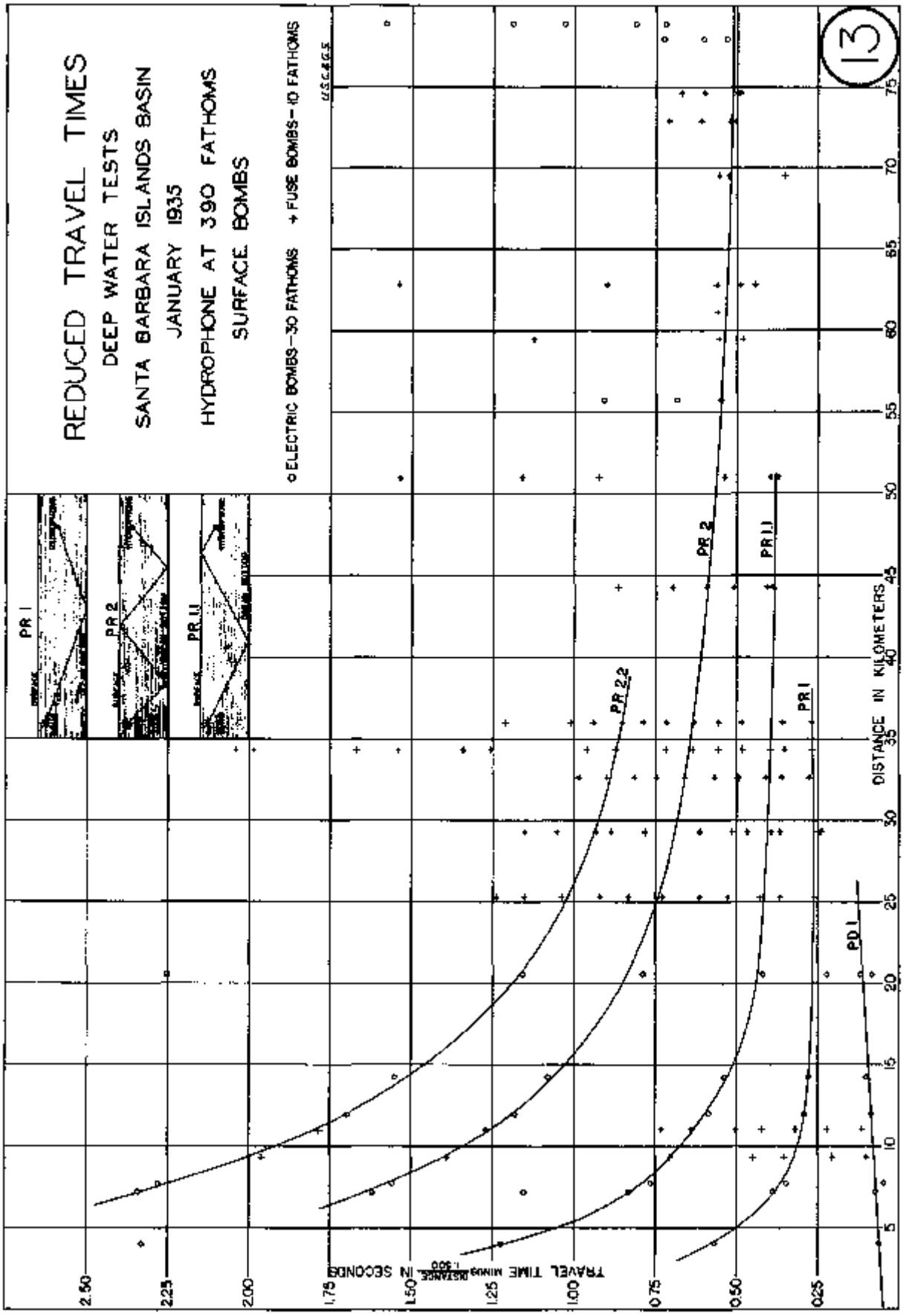

DEEP WATER TESTS
TRAVEL TIMES OF SOUND
IN SANTA BARBARA BASIN
HYDROPHONE AT 30 FATHOMS
ELECTRIC BOMBS - 30 FATHOMS
FUSE BOMBS - 10 FATHOMS
WATER SHOALS FROM 900 TO 600 FATHOMS
BETWEEN 50 AND 70 SECONDS
POINTS PLOTTED IN A VERTICAL LINE ARE
DIFFERENT ARRIVALS OF SAME BOMB
U.S.C.&G.S.
8
TRAVEL TIME IN SECONDS
DISTANCE IN KILOMETERS
55
50
45
40
55
60
65
70
75
80
85
PR 1
PR 2
PR 3
PR 4
PR 5
CONTINUED FROM FIGURE 7

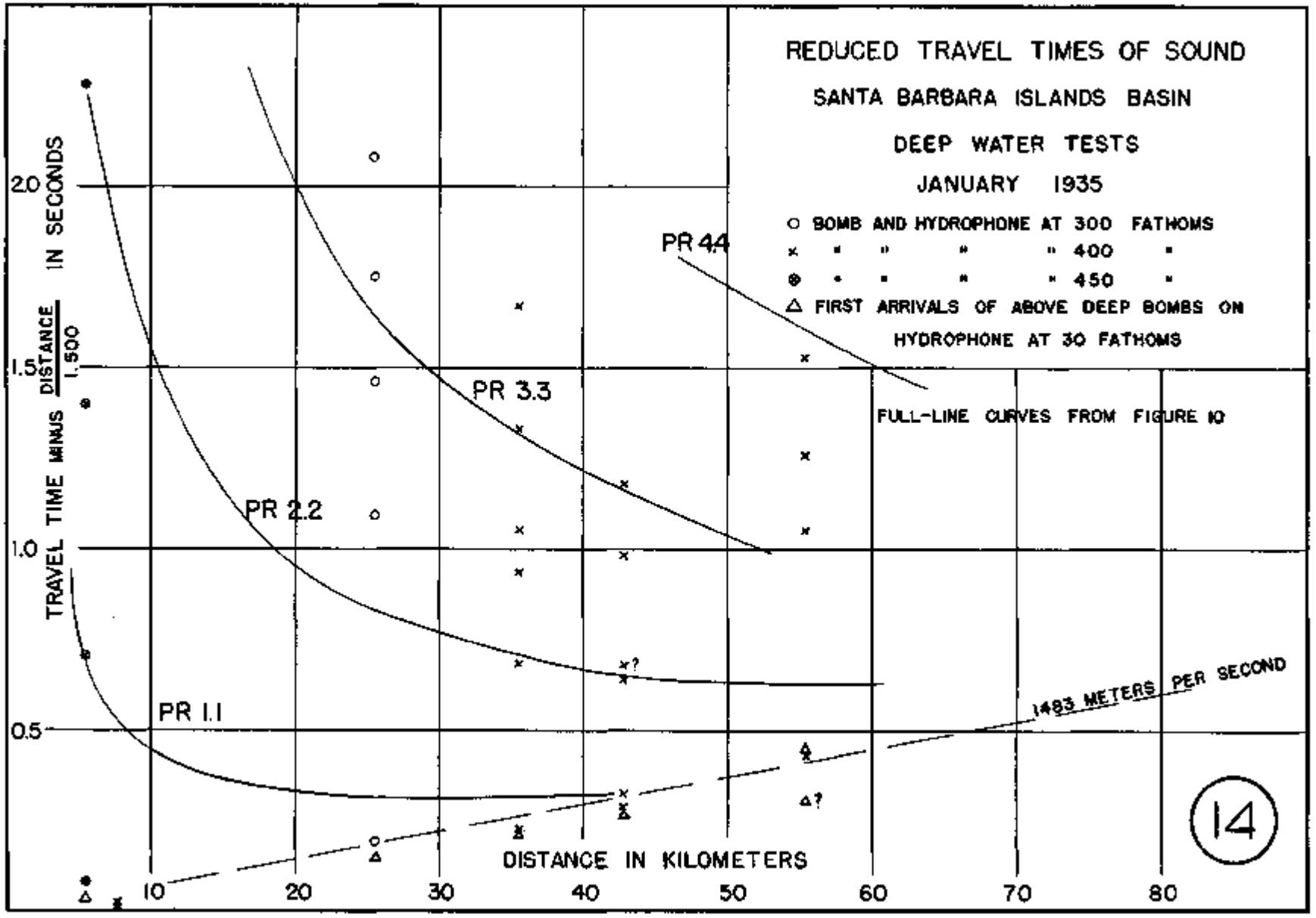

COMPARISON OF REDUCED TRAVEL TIMES
TO PROVE REFLECTION
DEEP WATER TESTS
SANTA BARBARA ISLANDS BASIN—JANUARY 1935
• PR 1
+ 1/2 REDUCED TRAVEL TIME OF PR 2 AT TWICE PLOTTED DISTANCE
● 1/3 " " " " PR 3 " 3 TIMES " "
□ 1/4 " " " " PR 4 " 4 " " "
○ 1/5 " " " " PR 5 " 5 " " "
U.S.C.&G.S.
TIME MINUS DISTANCE/1,500 IN SECONDS
.1
.2
.3
.4
.5
.6
.7
DISTANCE IN KILOMETERS
5
10
15
20
25
9

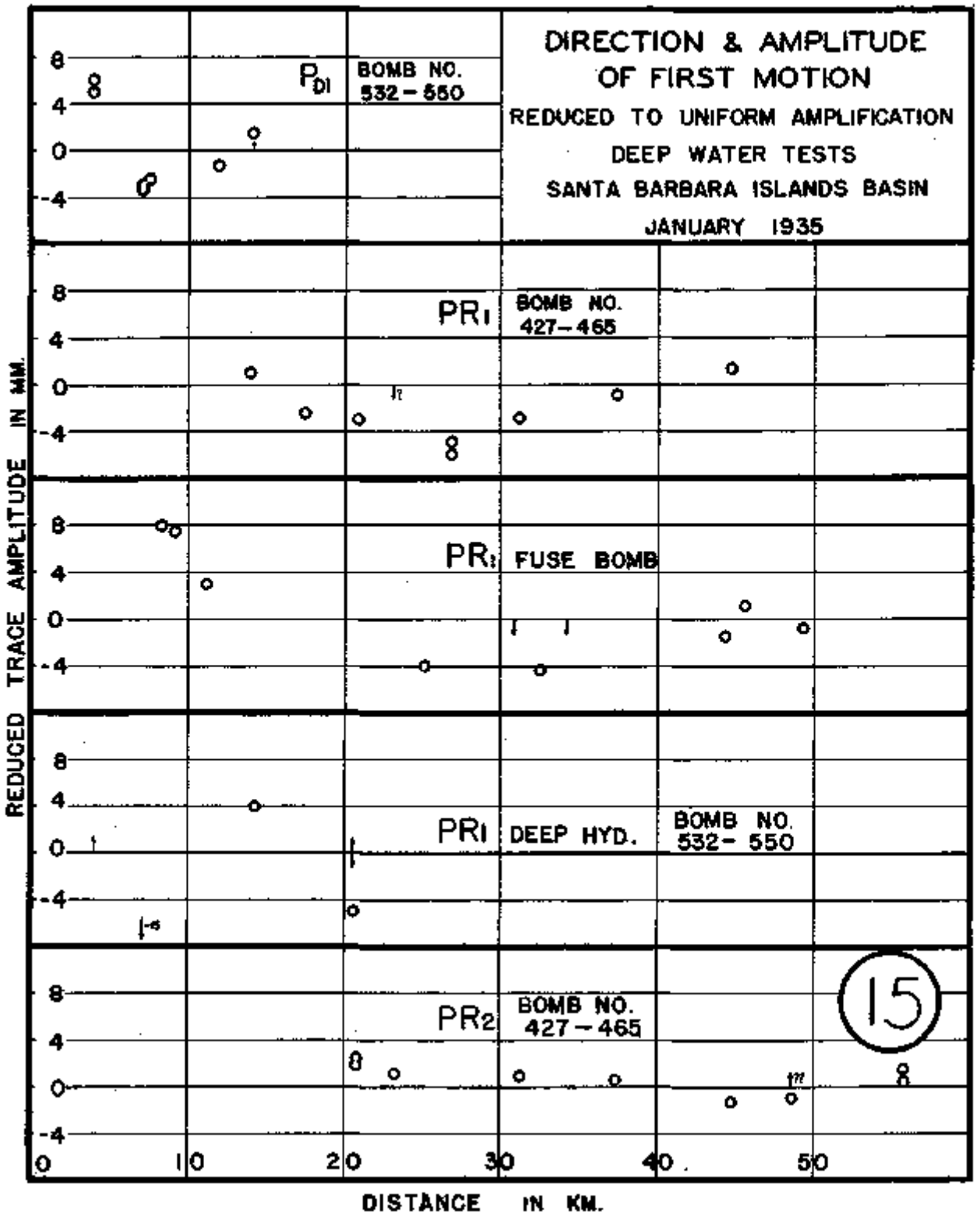

REDUCED TRAVEL TIME CURVES
DEEP WATER TESTS
SANTA BARBARA ISLAND BASIN
JANUARY 1935
HYDROPHONE AT 30 FATHOMS
ELECTRIC BOMBS - 30 FATHOMS
FUSE BOMBS - 10 FATHOMS
PR 1
PR 2
PR 3
PR 4
IRREGULAR BOTTOM EFFECTS
DIFFRACTION EFFECTS
OBSERVED TRAVEL TIME MINUS DISTANCE/1500 IN SECONDS
DISTANCE IN KILOMETERS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
025
050
075
100
125
150
175
200
225
250
275
300
10

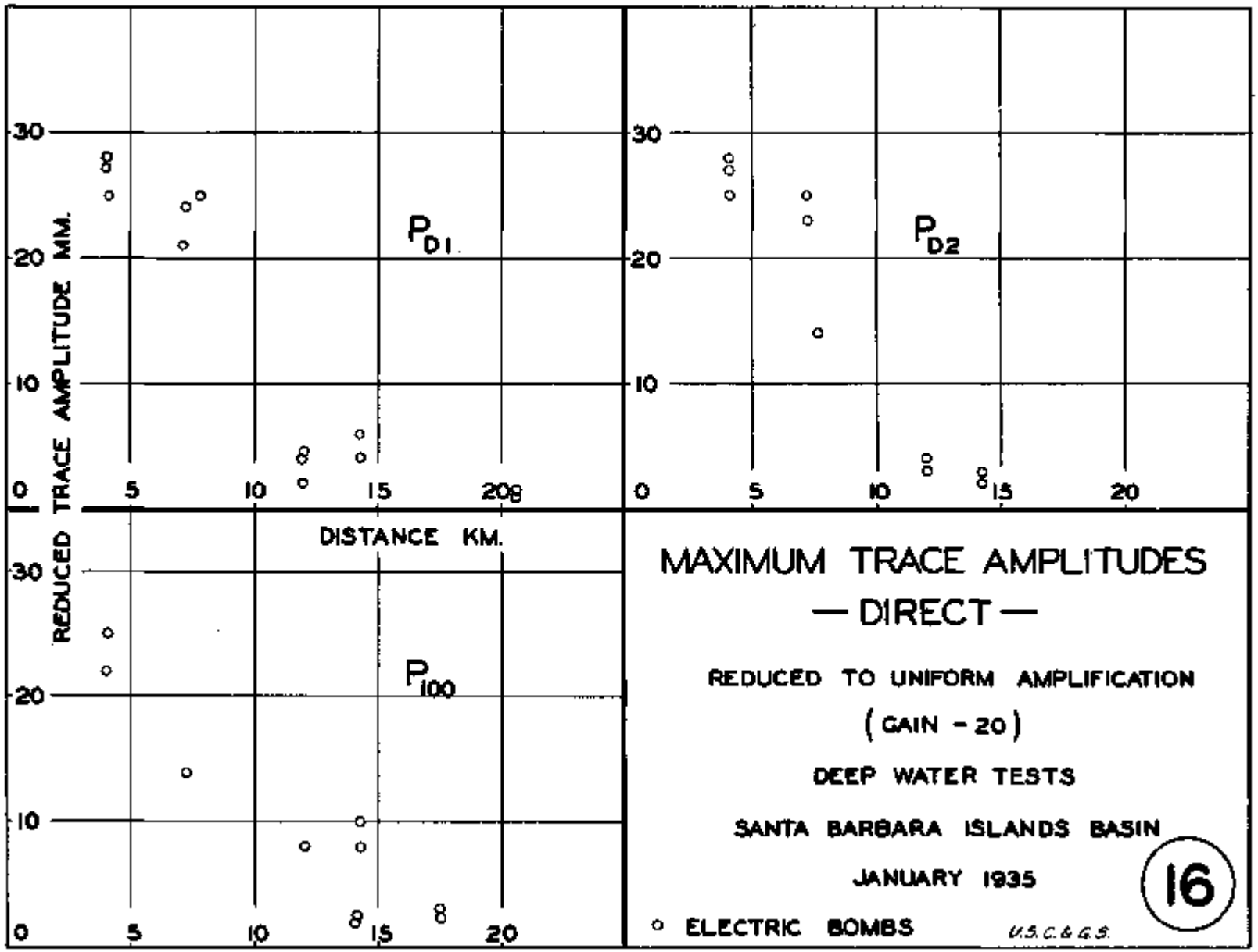

REDUCED TRAVEL TIME
OF
FIRST ARRIVALS
PD0
PD2
PD1
V=1493 M/S
V=1494 M/S
V=1495 M/S
DISTANCE IN KILOMETERS
OBSERVED TRAVEL TIME MINUS Δ/500 IN 0.01 SECONDS
11

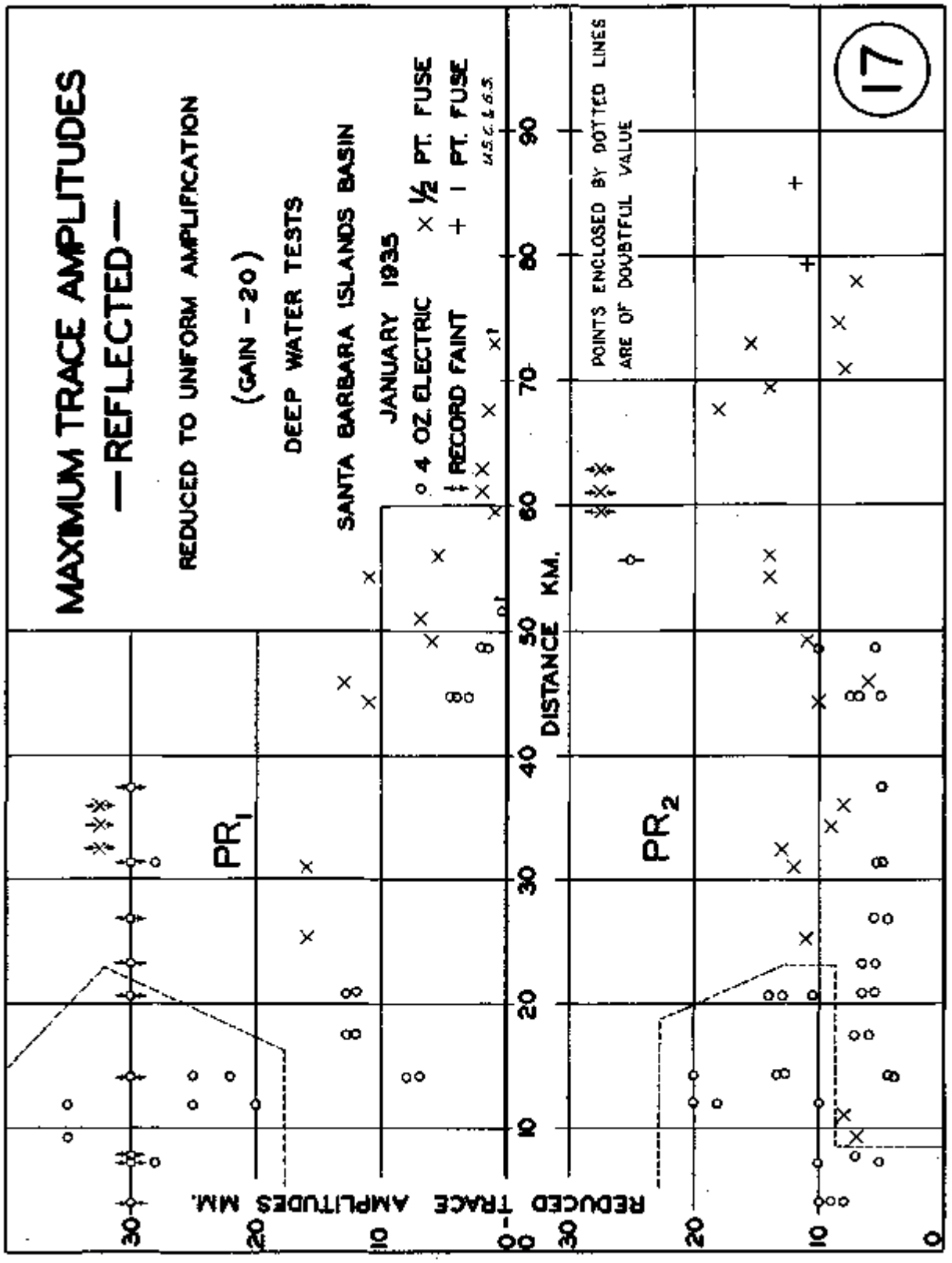

RELATIVE TRAVEL TIME
OF EARLY ARRIVALS
DEEP WATER TESTS
SANTA BARBARA ISLAND BASIN
JANUARY 1935
U.S.C.&G.S.
TRAVEL TIME PRI LESS TRAVEL TIME OF EARLIER ARRIVALS IN SECONDS
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
DISTANCE IN KM.
1
3
5
7
9
11
13
15
17
19
21
P_{100}
P_{02}
P_{01}
12

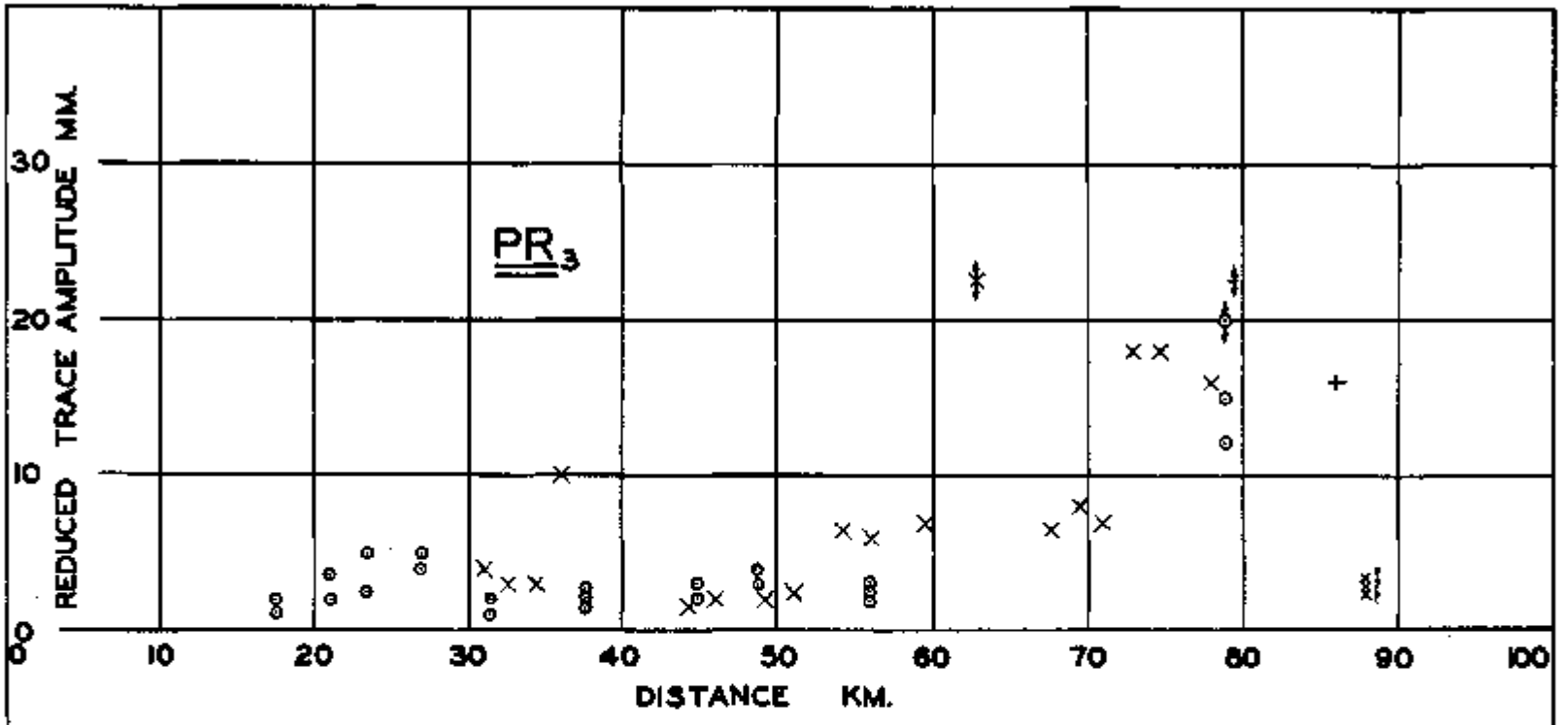

REDUCED TRAVEL TIMES
DEEP WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
HYDROPHONE AT 390 FATHOMS
SURFACE BOMBS
○ ELECTRIC BOMBS—30 FATHOMS + FUSE BOMBS—10 FATHOMS
PR 1
PR 2
PR 1.1
PR 2.2
PD 1
DISTANCE IN KILOMETERS
TRAVEL TIME MINUS DISTANCE/1.500 IN SECONDS
13


REDUCED TRAVEL TIMES OF SOUND
SANTA BARBARA ISLANDS BASIN
DEEP WATER TESTS
JANUARY 1935
○ BOMB AND HYDROPHONE AT 300 FATHOMS
× " " " " 400 "
⊗ " " " " 450 "
△ FIRST ARRIVALS OF ABOVE DEEP BOMBS ON HYDROPHONE AT 30 FATHOMS
FULL-LINE CURVES FROM FIGURE 10
PR 4.4
PR 3.3
PR 2.2
PR 1.1
1483 METERS PER SECOND
TRAVEL TIME MINUS DISTANCE / 1,500 IN SECONDS
2.0
1.5
1.0
0.5
DISTANCE IN KILOMETERS
10
20
30
40
50
60
70
80
14


DIRECTION & AMPLITUDE
OF FIRST MOTION
REDUCED TO UNIFORM AMPLIFICATION
DEEP WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
P_{D1}
BOMB NO. 532 – 550
PR1
BOMB NO. 427 – 465
PR1
FUSE BOMB
PR1
DEEP HYD.
BOMB NO. 532 – 550
PR2
BOMB NO. 427 – 465
15
REDUCED TRACE AMPLITUDE IN MM.
8
4
0
-4
0
10
20
30
40
50
DISTANCE IN KM.


REDUCED TRACE AMPLITUDE MM.
30
20
10
0
5
10
15
20
P_{D1}
P_{D2}
P_{100}
DISTANCE KM.
MAXIMUM TRACE AMPLITUDES
— DIRECT —
REDUCED TO UNIFORM AMPLIFICATION
(GAIN - 20)
DEEP WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
16
○ ELECTRIC BOMBS
U.S.C.&G.S.


MAXIMUM TRACE AMPLITUDES
—REFLECTED—
REDUCED TO UNIFORM AMPLIFICATION
(GAIN - 20)
DEEP WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
4 OZ. ELECTRIC
RECORD FAINT
½ PT. FUSE
1 PT. FUSE
U.S.C. & G.S.
POINTS ENCLOSED BY DOTTED LINES ARE OF DOUBTFUL VALUE
PR1
PR2
DISTANCE KM.
REDUCED TRACE AMPLITUDES MM.
17



MAXIMUM TRACE AMPLITUDE — REFLECTED

REDUCED TO UNIFORM AMPLIFICATION (GAIN-20)

DEEP WATER TESTS

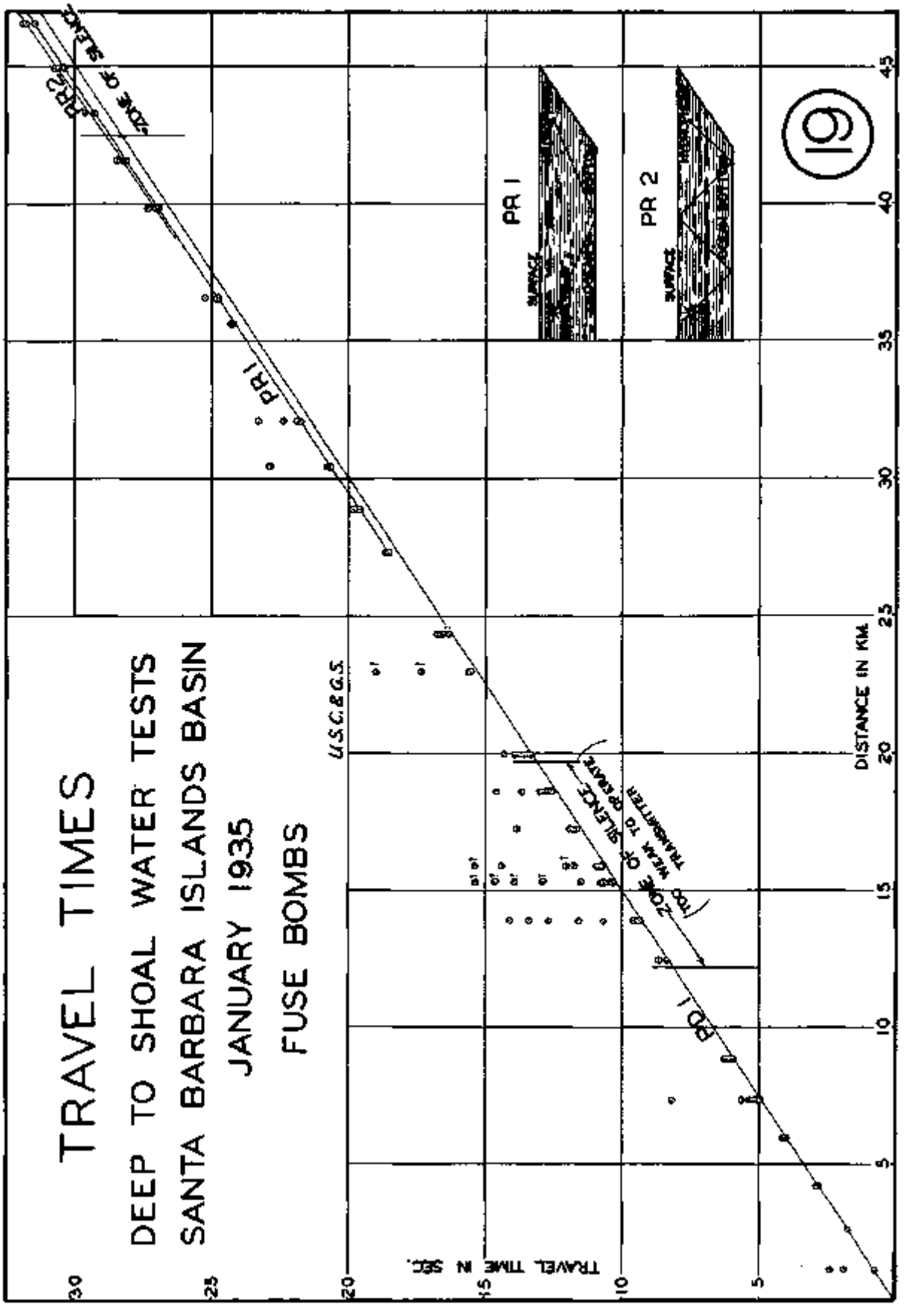
SANTA BARBARA ISLAND BASIN

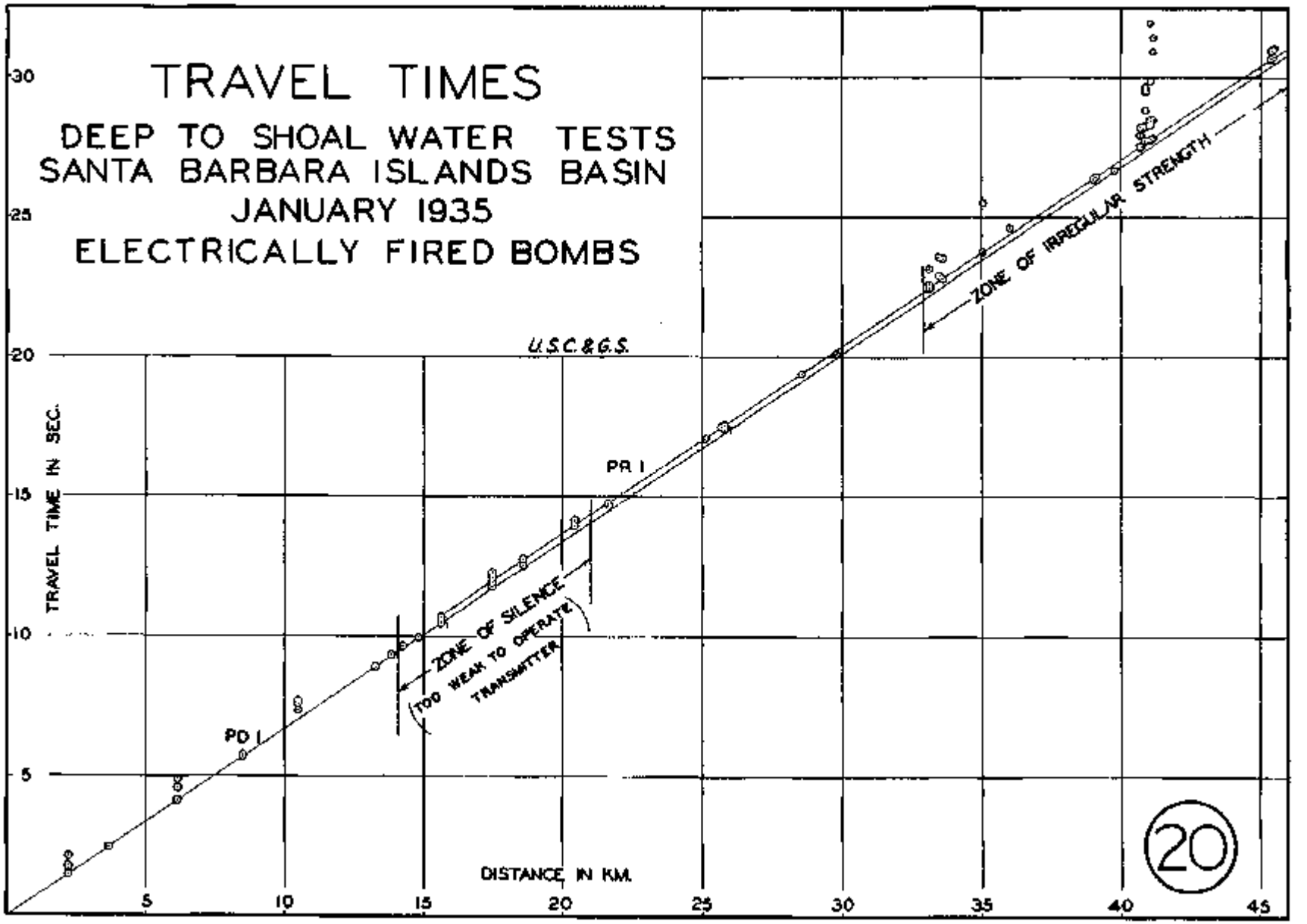
JANUARY 1935

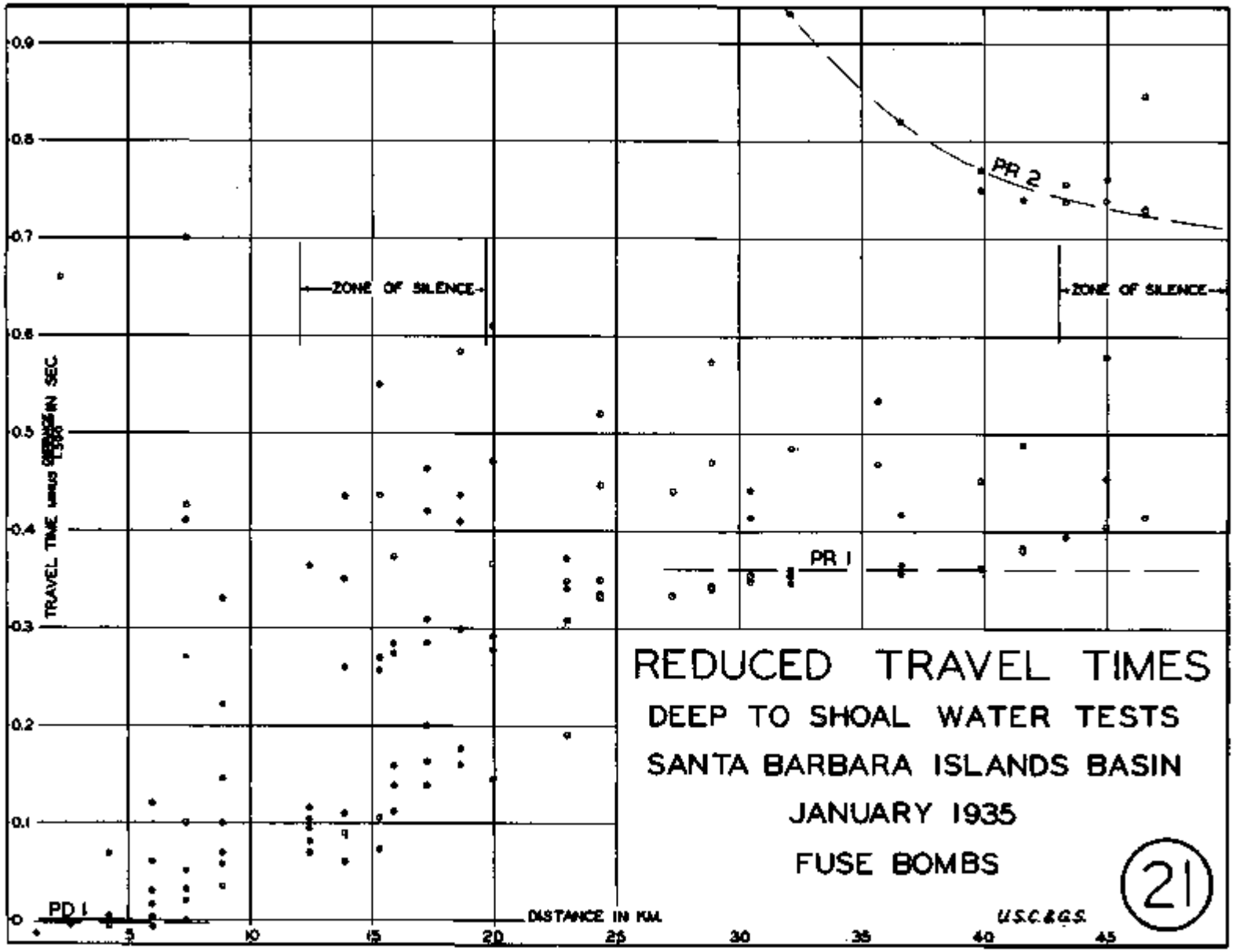
18

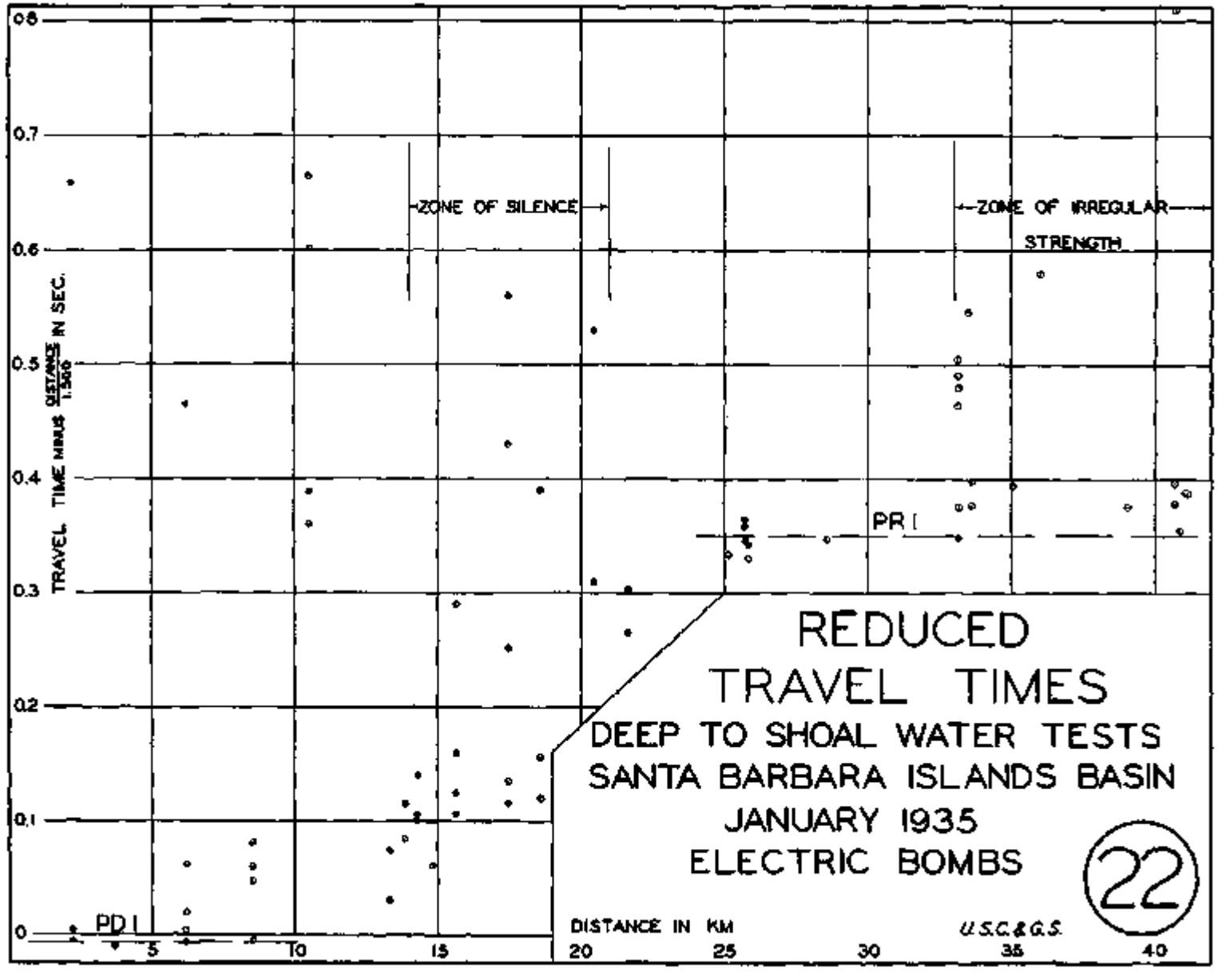
○ 4 OZ. ELECTRIC × ½ PT. FUSE + 1 PT. FUSE ↕ RECORD FAINT

U.S.C. & G.S.


TRAVEL TIMES
DEEP TO SHOAL WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
FUSE BOMBS
U.S.C.&G.S.
TRAVEL TIME IN SEC.
DISTANCE IN KM.
PR 1
PR 2
ZONE OF SILENCE
(100 MILES TO SEA TRANSMITTER)
PR 1
PR 2
SURFACE
SURFACE
19


TRAVEL TIMES
DEEP TO SHOAL WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
ELECTRICALLY FIRED BOMBS
U.S.C.&G.S.
TRAVEL TIME IN SEC.
DISTANCE IN KM.
PD I
PR I
ZONE OF SILENCE
(TOO WEAK TO OPERATE TRANSMITTER)
ZONE OF IRREGULAR STRENGTH
5
10
15
20
25
30
35
40
45
20


REDUCED TRAVEL TIMES
DEEP TO SHOAL WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
FUSE BOMBS
21
U.S.C.&G.S.
ZONE OF SILENCE
ZONE OF SILENCE
PR 2
PR 1
PD 1
TRAVEL TIME MINUS DISTANCE/1500 IN SEC.
DISTANCE IN KM.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
30
35
40
45

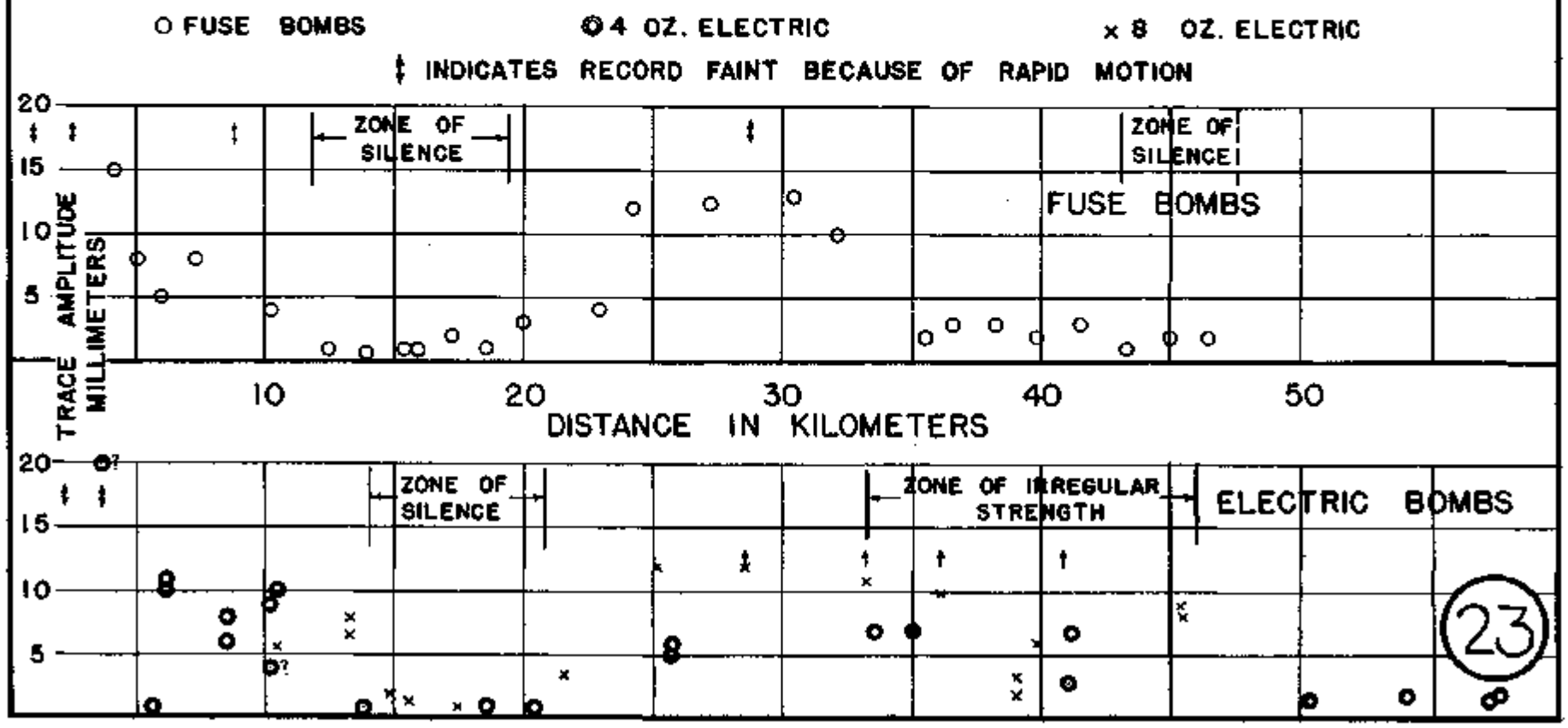

REDUCED
TRAVEL TIMES
DEEP TO SHOAL WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
ELECTRIC BOMBS
22
U.S.C.&G.S.
ZONE OF SILENCE
ZONE OF IRREGULAR STRENGTH
PR I
PD I
TRAVEL TIME MINUS DISTANCE/1.500 IN SEC.
DISTANCE IN KM
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
5
10
15
20
25
30
35
40

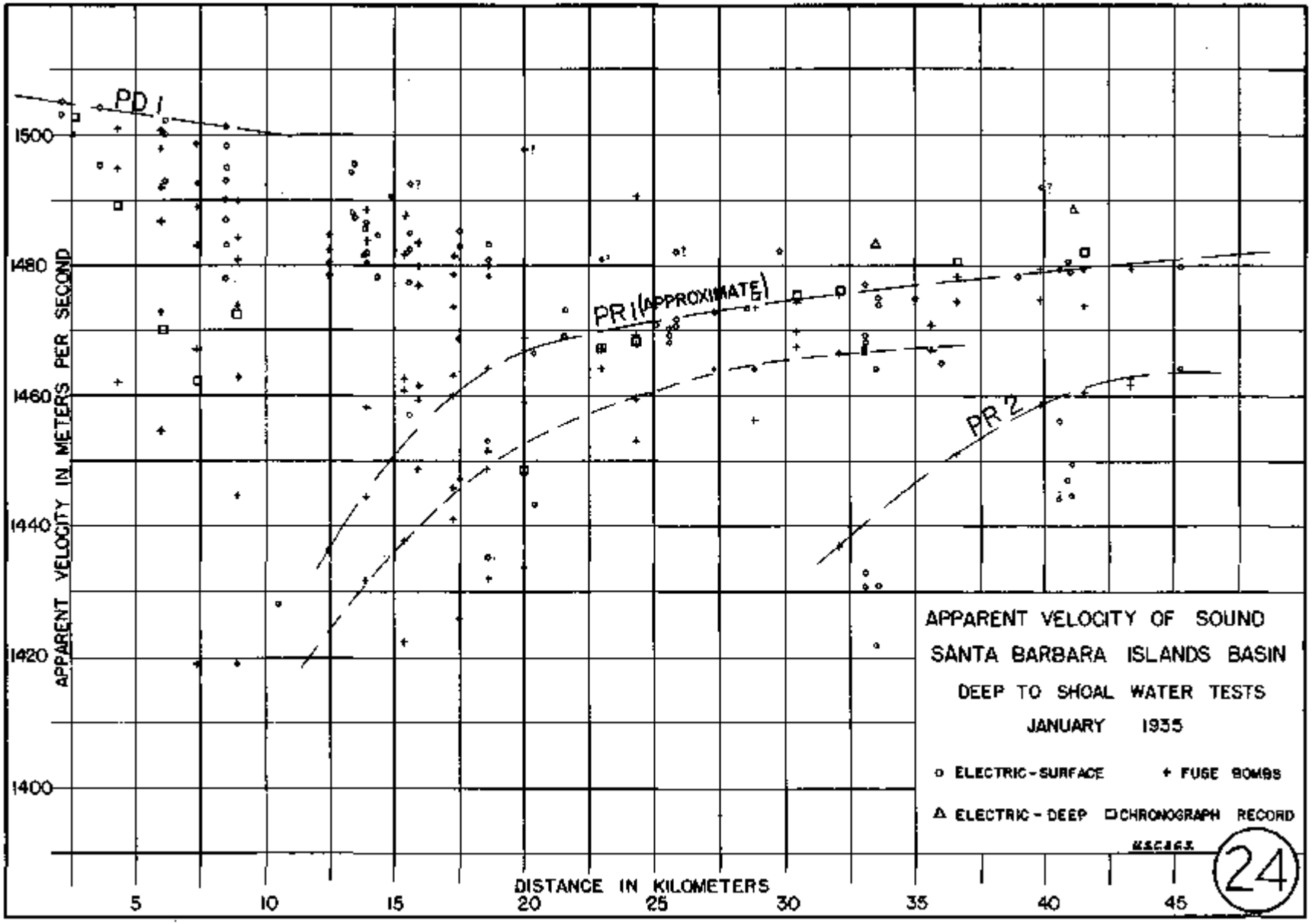
MAXIMUM TRACE AMPLITUDES

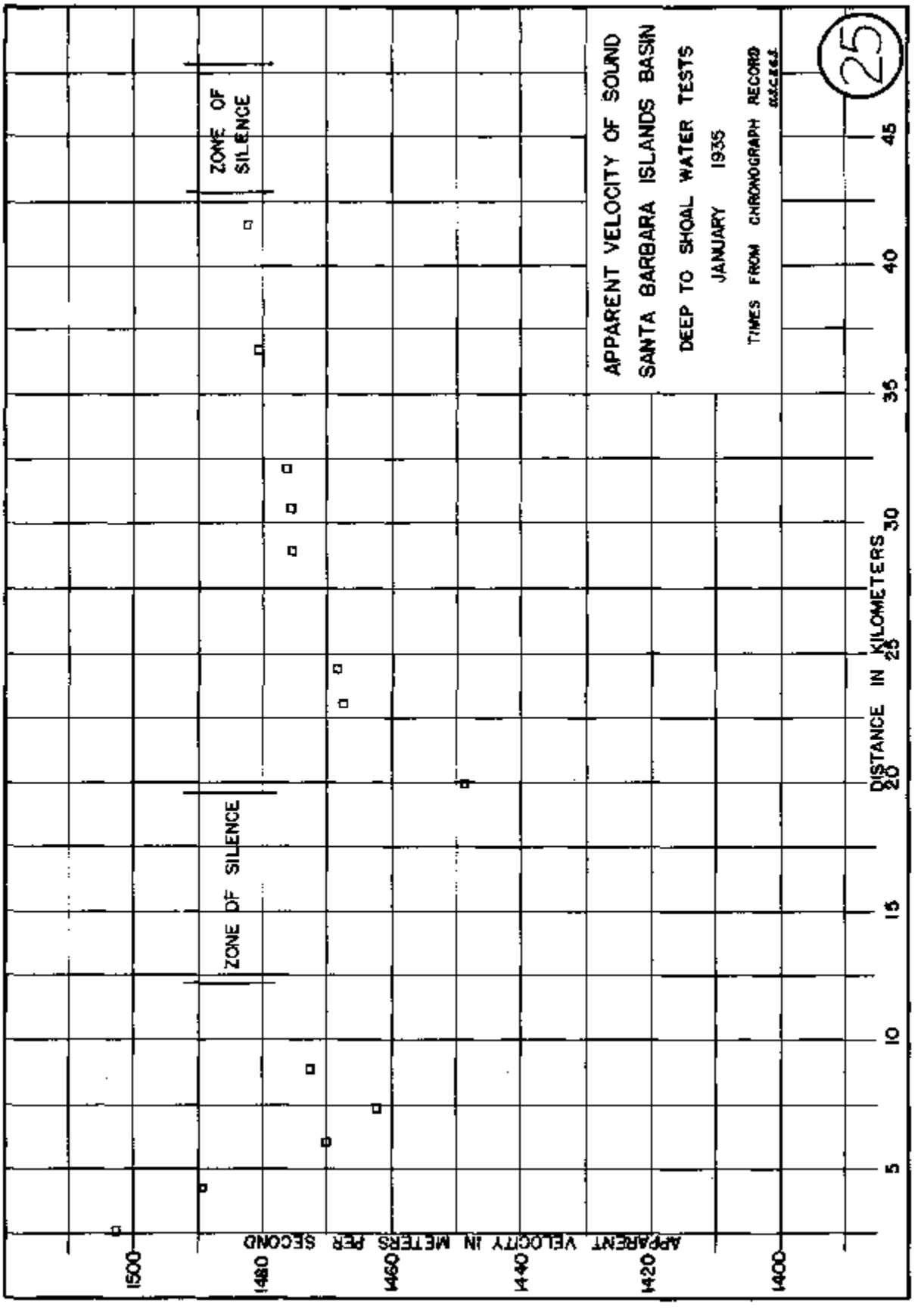
REDUCED TO UNIFORM AMPLIFICATION (GAIN −20)

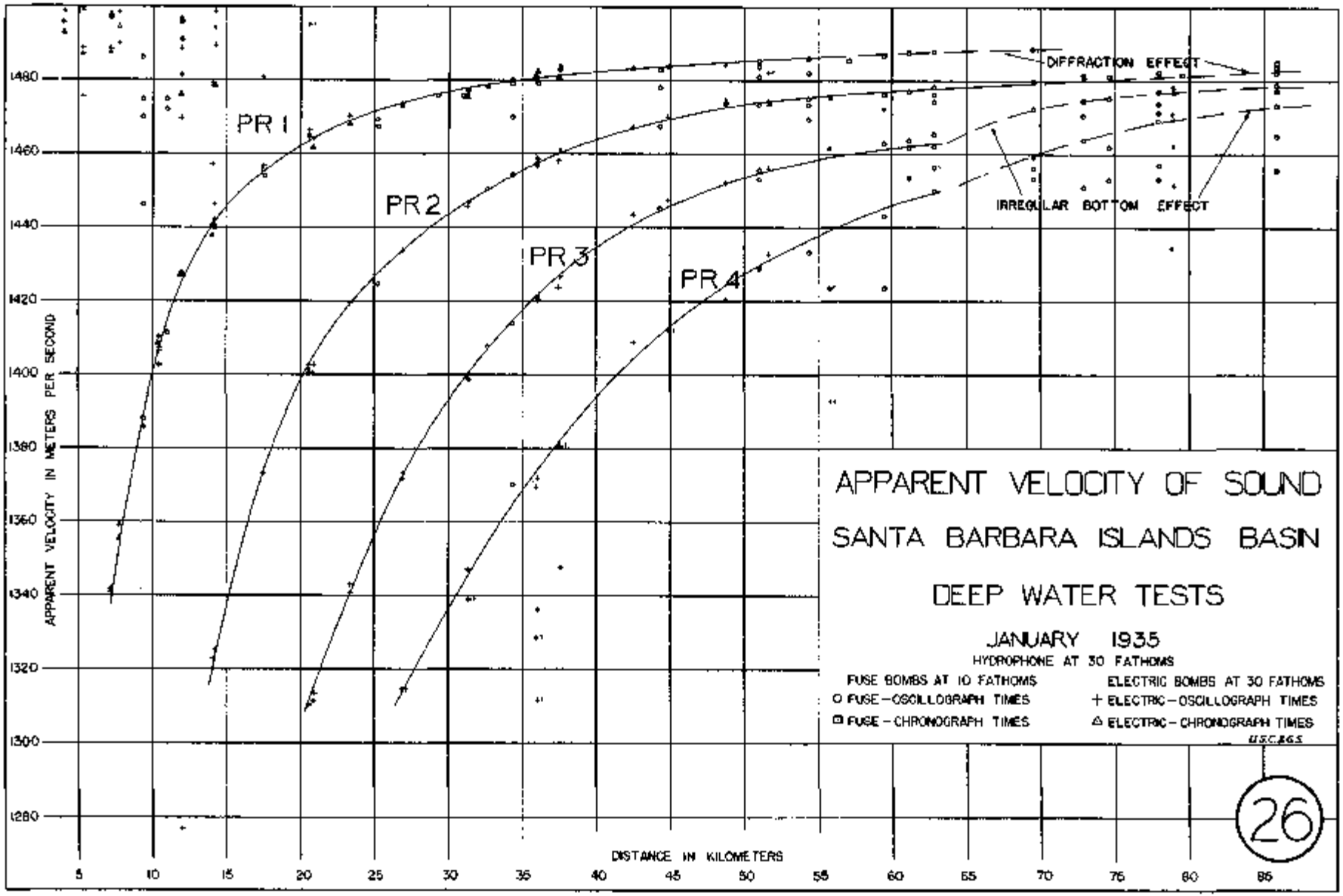
DEEP TO SHOAL WATER TESTS

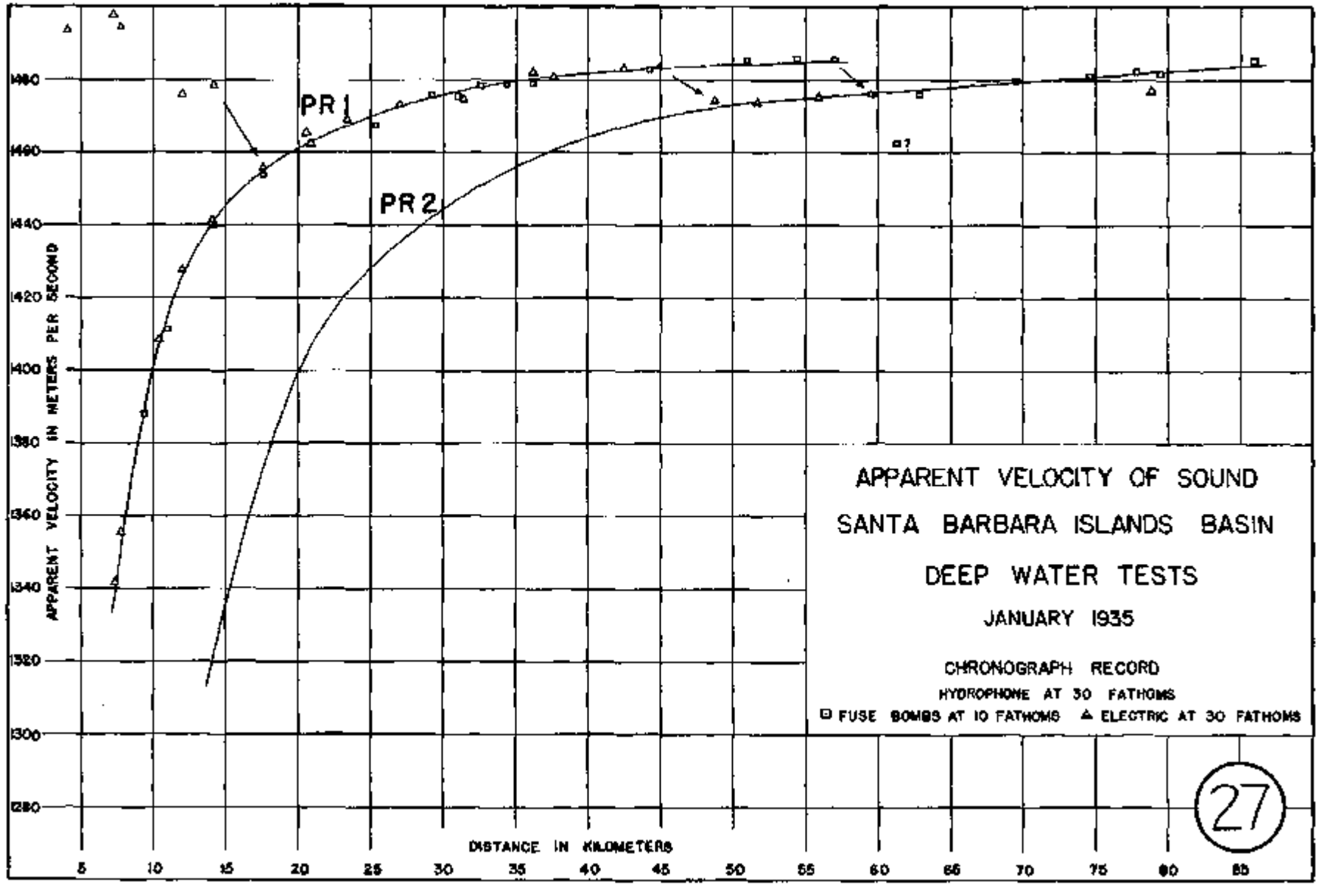
SANTA BARBARA ISLANDS BASIN — JANUARY 1935

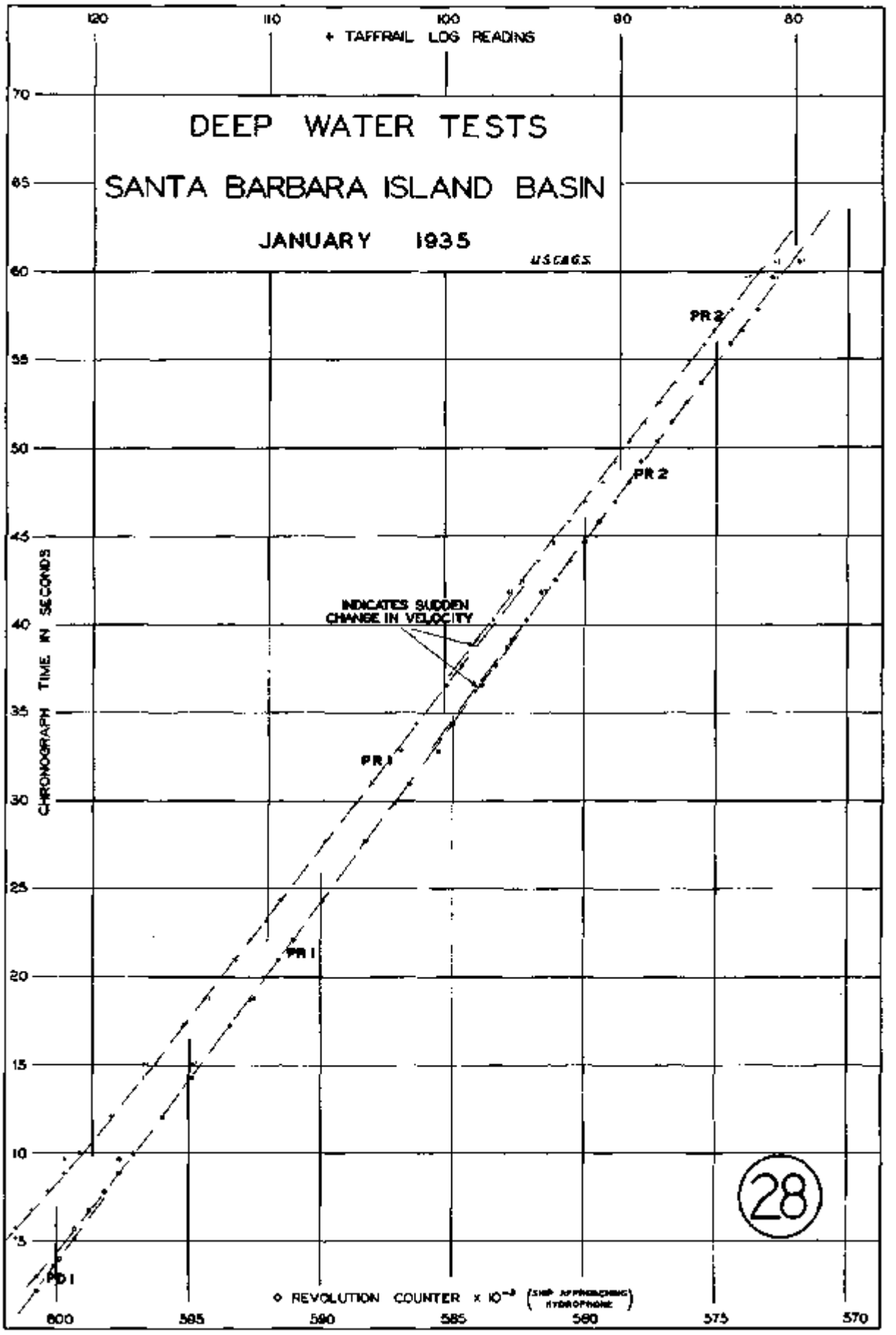


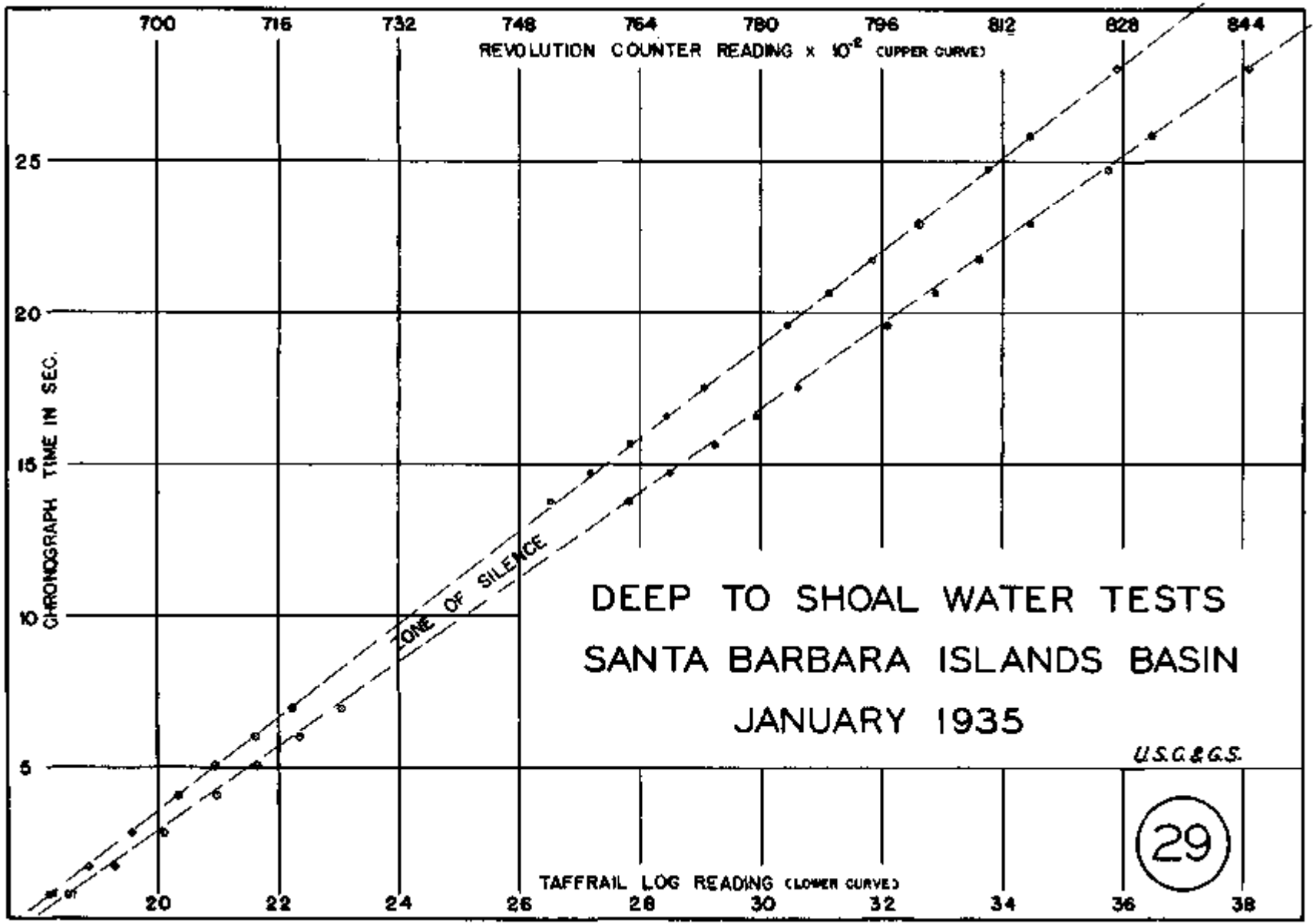

PD 1
PR 1 (APPROXIMATE)
PR 2
1500
1480
1460
1440
1420
1400
APPARENT VELOCITY IN METERS PER SECOND
5
10
15
20
25
30
35
40
45
DISTANCE IN KILOMETERS
APPARENT VELOCITY OF SOUND
SANTA BARBARA ISLANDS BASIN
DEEP TO SHOAL WATER TESTS
JANUARY 1935
o ELECTRIC-SURFACE
+ FUSE BOMBS
Δ ELECTRIC-DEEP
□ CHRONOGRAPH RECORD
24

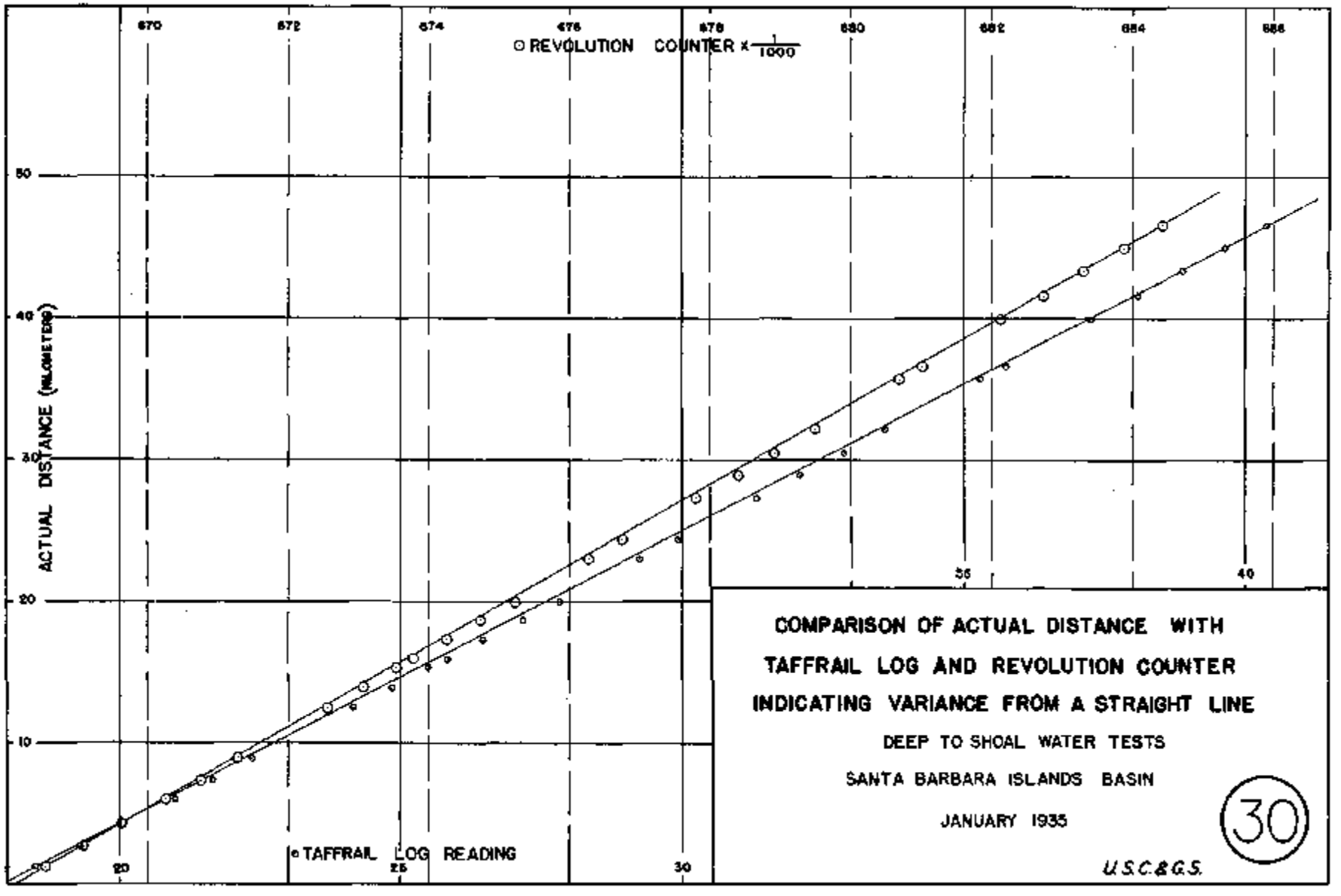

APPARENT VELOCITY OF SOUND
SANTA BARBARA ISLANDS BASIN
DEEP TO SHOAL WATER TESTS
JANUARY 1935
TIMES FROM CHRONOGRAPH RECORD
ZONE OF SILENCE
ZONE OF SILENCE
DISTANCE IN KILOMETERS
5
10
15
20
25
30
35
40
45
APPARENT VELOCITY IN METERS PER SECOND
1500
1480
1460
1440
1420
1400
25


APPARENT VELOCITY OF SOUND
SANTA BARBARA ISLANDS BASIN
DEEP WATER TESTS
JANUARY 1935
HYDROPHONE AT 30 FATHOMS
FUSE BOMBS AT 10 FATHOMS
O FUSE—OSCILLOGRAPH TIMES
⊡ FUSE—CHRONOGRAPH TIMES
ELECTRIC BOMBS AT 30 FATHOMS
+ ELECTRIC—OSCILLOGRAPH TIMES
△ ELECTRIC—CHRONOGRAPH TIMES
U.S.C.&G.S.
PR 1
PR 2
PR 3
PR 4
DIFFRACTION EFFECT
IRREGULAR BOTTOM EFFECT
APPARENT VELOCITY IN METERS PER SECOND
1480
1460
1440
1420
1400
1380
1360
1340
1320
1300
1280
DISTANCE IN KILOMETERS
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
26


APPARENT VELOCITY OF SOUND
SANTA BARBARA ISLANDS BASIN
DEEP WATER TESTS
JANUARY 1935
CHRONOGRAPH RECORD
HYDROPHONE AT 30 FATHOMS
FUSE BOMBS AT 10 FATHOMS
ELECTRIC AT 30 FATHOMS
PR 1
PR 2
APPARENT VELOCITY IN METERS PER SECOND
1480
1460
1440
1420
1400
1380
1360
1340
1320
1300
1280
DISTANCE IN KILOMETERS
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
27


DEEP WATER TESTS
SANTA BARBARA ISLAND BASIN
JANUARY 1935
U.S.C.&G.S.
+ TAFFRAIL LOG READING
120
110
100
90
80
70
65
60
55
50
45
40
35
30
25
20
15
10
5
CHRONOGRAPH TIME IN SECONDS
PR 2
PR 2
PR 1
PR 1
PD 1
INDICATES SUDDEN CHANGE IN VELOCITY
28
◇ REVOLUTION COUNTER × 10⁻³
600
595
590
585
580
575
570

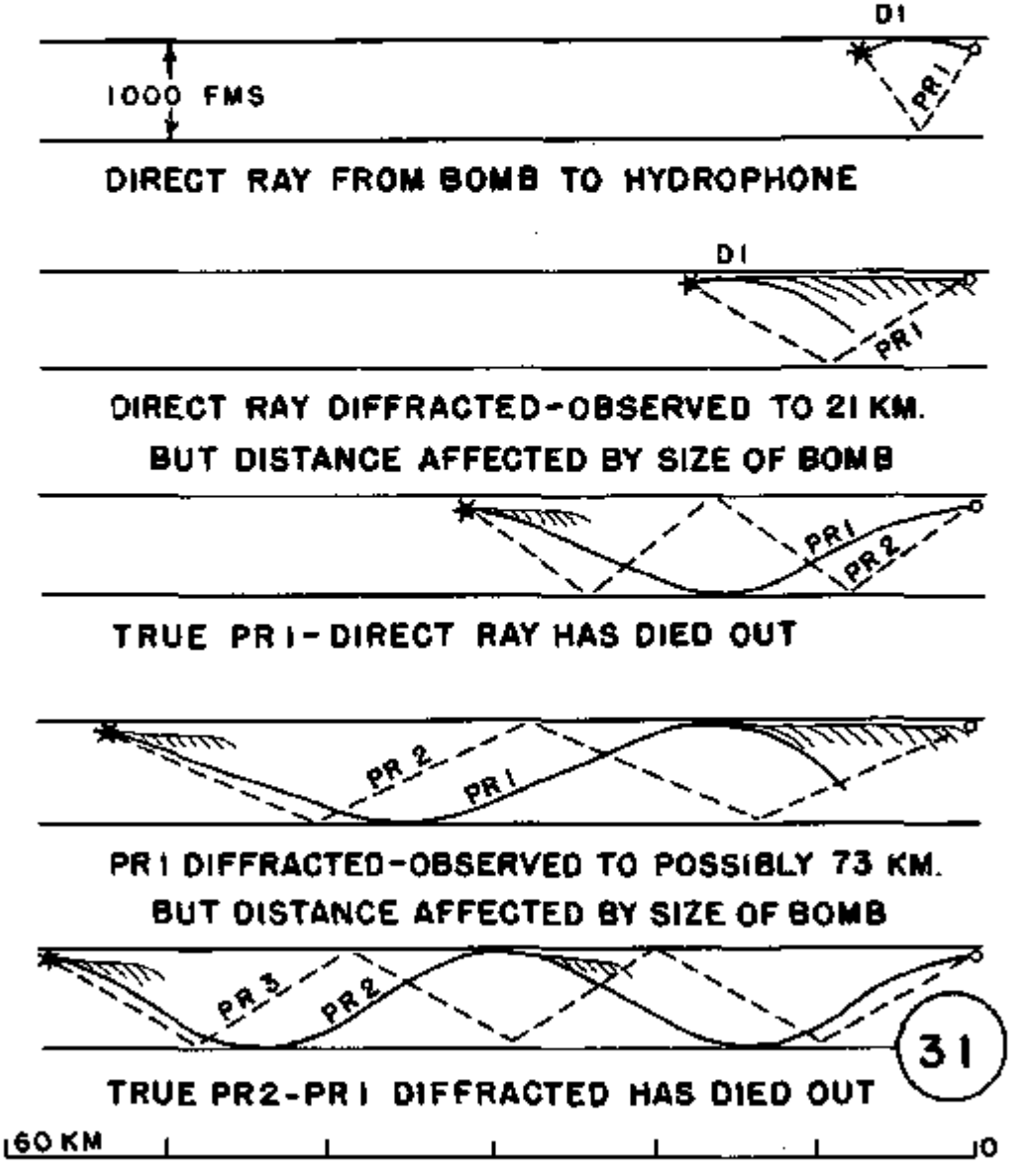

700
716
732
748
764
780
796
812
828
844
REVOLUTION COUNTER READING x 10² (UPPER CURVE)
25
20
15
10
5
CHRONOGRAPH TIME IN SEC.
ZONE OF SILENCE
DEEP TO SHOAL WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
U.S.C.&G.S.
29
TAFFRAIL LOG READING (LOWER CURVE)
20
22
24
26
28
30
32
34
36
38

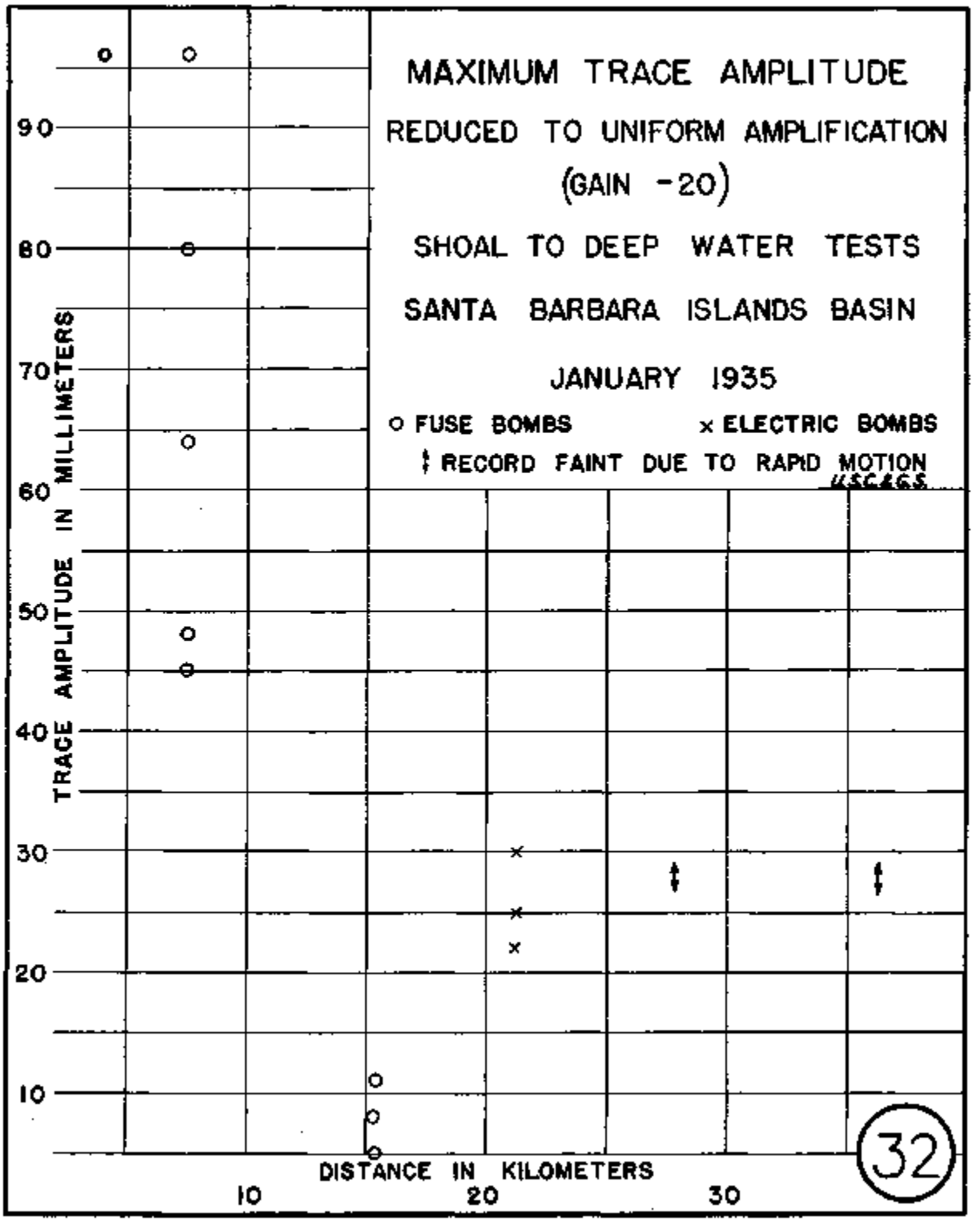

670
672
674
676
678
680
682
684
686
⊙ REVOLUTION COUNTER x 1/1000
50
40
30
20
10
ACTUAL DISTANCE (KILOMETERS)
20
25
30
35
40
• TAFFRAIL LOG READING
COMPARISON OF ACTUAL DISTANCE WITH
TAFFRAIL LOG AND REVOLUTION COUNTER
INDICATING VARIANCE FROM A STRAIGHT LINE
DEEP TO SHOAL WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
30
U.S.C.&G.S.

RAY PATH OF FIRST & SECOND ARRIVALS AT A HYDROPHONE NEAR THE SURFACE

DEEP WATER TESTS

SANTA BARBARA ISLANDS BASIN
JANUARY 1935




MAXIMUM TRACE AMPLITUDE
REDUCED TO UNIFORM AMPLIFICATION
(GAIN -20)
SHOAL TO DEEP WATER TESTS
SANTA BARBARA ISLANDS BASIN
JANUARY 1935
o FUSE BOMBS
x ELECTRIC BOMBS
RECORD FAINT DUE TO RAPID MOTION
USC&GS
TRACE AMPLITUDE IN MILLIMETERS
90
80
70
60
50
40
30
20
10
DISTANCE IN KILOMETERS
10
20
30
32

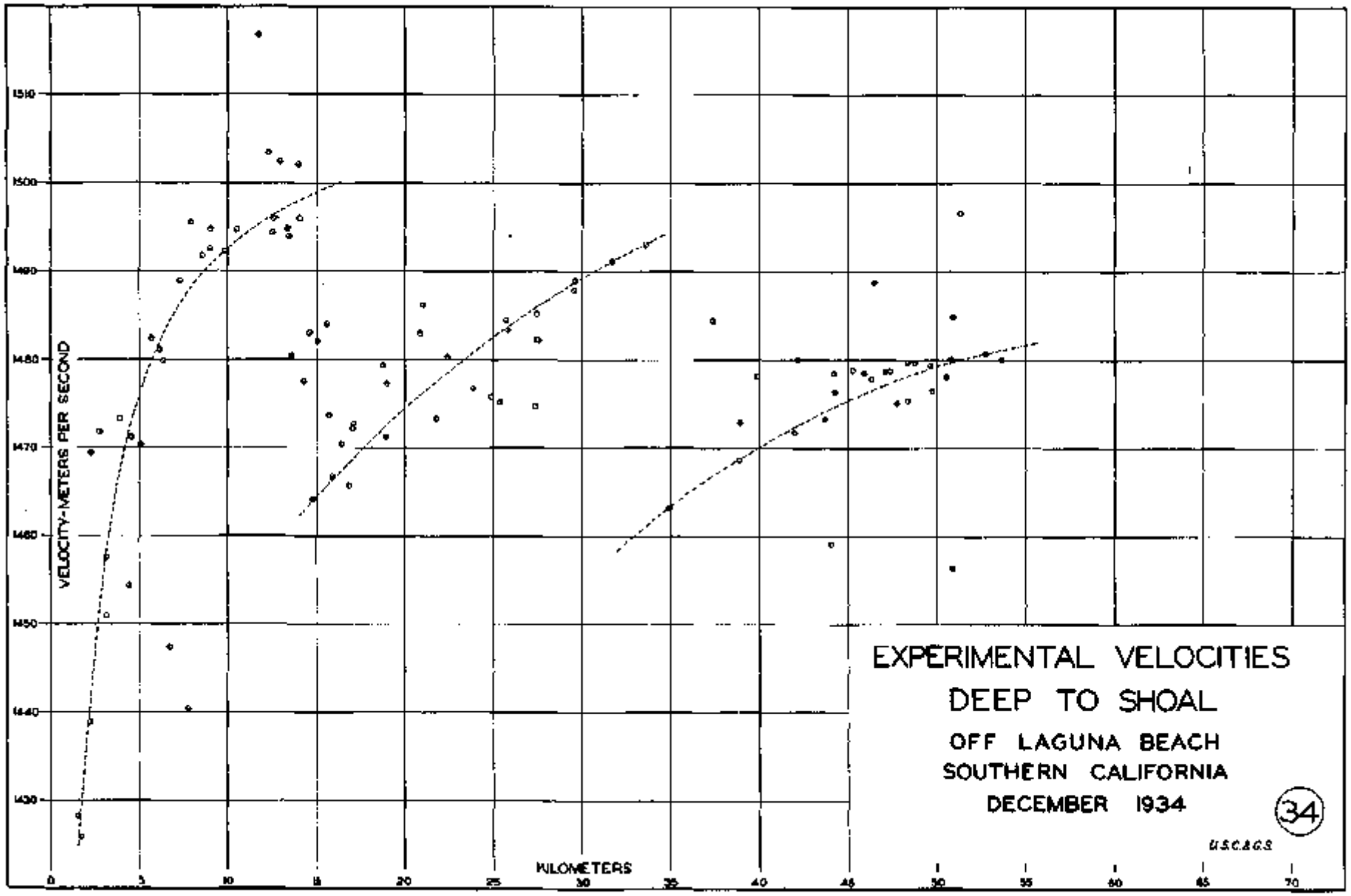
TYPE OF TEST LOCATION	TYPE OF BOMB AND HYDROPHONE DEPTH AND TRAVEL TIME	
DEEP WATER TESTS SANTA BARBARA ISLANDS BASIN	Fuse bombs - one half pint Aluminum pot hydrophone at 30 fathoms	
	Electric bombs at 30 fathoms Aluminum pot hydrophone at 30 fathoms	
	Electric bombs at 100 fathoms and over Aluminum pot hydrophone at 30 fathoms	
	Fuse bombs - one half pint Deep hydrophone 4 at 390 fathoms	
	Electric bombs at 30 fathoms Deep hydrophone 1 at 30 fathoms	
	Electric bombs at 30 fathoms Aluminum pot hydrophone at 30 fathoms	Travel time, 0-15 seconds
		Travel time, 15-30 seconds
		Travel time, over 30 seconds
	Fuse bombs - ½ pint Aluminum pot hydrophone at 30 fathoms	Travel time, 0-20 seconds
		Travel time, over 20 seconds
DEEP TO SHOAL WATER TESTS SANTA BARBARA ISLANDS BASIN	Fuse bombs - one half pint Aluminum pot hydrophone at 10 fathoms	
	Electric bombs at 30 fathoms Aluminum pot hydrophone at 10 fathoms	
	Electric bombs-30 fathoms Aluminum pot hydrophone at 10 fathoms	Travel time, 0-15 seconds
		Travel time, over 15 seconds
	Fuse bombs ½ pint Aluminum pot hydrophone at 10 fathoms	Travel time, 0-15 seconds
		Travel time, over 15 seconds
DEEP TO SHOAL WATER TESTS LAGUNA BEACH	Fuse bombs - one half pint Kettle-drum hydrophone at 10 fathoms	
	Electric bombs at 30 fathoms Kettle-drum hydrophone at 10 fathoms	
	Electric bombs at 30 fathoms Kettle-drum hydrophone at 10 fathoms	Travel time, 0-10 seconds
		Travel time, 10-20 seconds
		Travel time, over 20 seconds
	Fuse bombs one half pint Kettle-drum hydrophone at 10 fathoms	Travel time, 0-12 seconds
		Travel time, 12-25 seconds
		Travel time, over 25 seconds
SIGNAL CORPS HYDROPHONE		

U.S.C.&G.S. 33A

MEASURED FREQUENCIES

100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1200	1500
		76	11	2	1	5	6	1		1	1	1	1	7	20	154	7	1		
	2	41	18	14	3	4	13	10	4		1	2	1	4	25	124	18	16	1	
1		28	3	4			4	2		3	3			5	15	41	8			
	5	7	2	3	84	76	7	5	6			1								
4	4	7	27	6					5	7	3	5	2	1	1			1	1	
		8	3	3			1	1		1		1		3	11	62	6	7	1	
		12	2	3	2	1	9	6	4						10	29	5	6		
	2	21	19	6	2	2	3	3		3	1	2	1	1	4	33	3	1		
		7	1				4					1			5	16	2			
		68	11	2	1	5	2	1		1	1		1	7	16	135	3	1		
		1	1		1	16	40	54	11	4	1			2		1	1	21	15	3
				2	3	52	54	53	9	10				1	1	2		16	5	13
				1	1	11	28	20	4	9					1	2		6	4	13
				1	2	20	27	33	5	1				1				10	1	
		2			1	6	20	36	7	3	1					1	1	9	10	2
		1				7	18	20	3	1								12	5	1
93			1			3	42	63		1		1		1		11	47	6		
56						2	34	17								12	16	3	2	
14						2	17	4								11	15	1	2	
19							8	6								1	1	1		
23							9	7										1		
38			1			2	38	10		1						10	47	3		
32						1	2	41				1		1				3		
23							1	13												
	8	29	6	4	5	1	1	6	3	3	1		1			1		5	2	3

U.S.C.&G.S. 33B


VELOCITY-METERS PER SECOND
1510
1500
1490
1480
1470
1460
1450
1440
1430
KILOMETERS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
EXPERIMENTAL VELOCITIES
DEEP TO SHOAL
OFF LAGUNA BEACH
SOUTHERN CALIFORNIA
DECEMBER 1934
34
U.S.C.&G.S.

FREQUENCY OF WATER WAVES

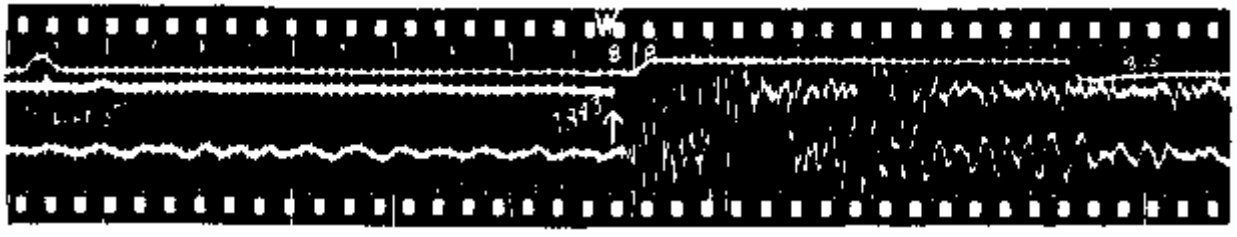
Maurice Ewing, Physics Department
Lehigh University.

Oscillograms of water waves generated by explosions in sea water were obtained in some submarine seismic tests which we conducted in 1935. A special dynamite was used which required no protection from the water. The explosive charges were placed on bottom and fired electrically. The sound waves were recorded by a vertical-component seismograph placed on bottom at distances up to eight miles from the explosion. The seismograph consisted of a rigid, oil-filled, cylindrical case inside of which an inertia mass was mounted on a suitable spring suspension. The natural frequency of the system was 35 cycles per second and it was critically damped in oil. The seismograph generated electrical impulses which were amplified in a 4 stage resistance capacity coupled amplifier, designed to respond to low frequencies, and recorded in an oscillograph whose vibrator had a natural frequency of 90 cycles per second with critical damping.

The charges used ranged from 1 to 25 lbs., the depth of water from 8 to 33 fathoms, the distance from 2,000 to 45;000 feet. The frequency of the recorded wave was 200 - 250 cycles per second, its duration .06 to .20 second, its beginning always gradual with some indication of dispersion, its time of arrival usually about .01 second later than at a surface point approximately directly above it. Since the seismograph is not suited to measurement of waves in the water, it seems probable that the recorded motion was introduced into the seismograph by local action of the water wave upon the bottom where the seismograph rested. Since the seismograph recorded perfectly waves through the sediments and rocks beneath the bottom having frequencies 10 to 80 cycles per second it is almost impossible that the frequency attributed to the water wave is introduced by the apparatus.

A Submarine Signal Company watch-case type hydrophone, suspended over the side of the ship at a depth of 5 to 8 feet beneath the surface, recorded the water wave also. The oscillogram of this wave shows several essential points of difference from the recording on the seismograph. It shows a violently abrupt initial arrival lasting several hundredths of a second followed by a less intense irregular train of approximately 300 cycle waves, lasting from several tenths of a second up to several seconds. A section of one of the oscillograms is reproduced below to illustrate the points mentioned.

The work was supported by the Geological Society of America and carried out on the ship "ATLANTIS" of the Woods Hole Oceanographic Institution. Preliminary tests were made on the "OCEANOGRAPHER". A description of the preliminary tests was given by Captain N. H. Heck (vol. 8, p. 62). Field Engrs. Bul. U. S. C. & G. S.



Oscillograph record showing the arrival of the water wave at 7.983 seconds. Middle line is the hydrophone trace; bottom line the geophone trace.

CADASTRAL SURVEYS

Report of the Chairman of the Committee on Cadastral Surveys
of the Board of Surveys and Maps of the Federal Government
Washington, D. C., February 11, 1936.

Historical data, early practices and instructions, relating
to the public land surveys.

On September 12, 1933, the Board approved a report of the committee on cadastral surveys submitted at the meeting held on May 9, 1933, regarding a compilation of data relating to the instructions and practices that were followed in the execution of the early public-land subdivisional-surveys; in this report the committee pointed out certain phases of the work that might well be carried out by the General Land Office in a revision of the rules for the restoration of lost comers published by that office.

Previous to the committee report, the Commissioner of the General Land Office, by letter to the Board, dated December 4, 1931, advised:

> "No attempt has ever been made, so far as is now known, to prepare such a report as is suggested by Prof. Dodds, nor does it appear that, without a collation of the records in the archives of the State custodians, could such a report be compiled as would answer the inquiry."

The chairman of the committee on cadastral surveys wishes to supplement the record in this matter by bringing to the attention of the Board the extremely interesting information that an exceptionally valuable compilation of historical data, early instructions, and statements of the methods relating to the early public land surveys, is now an accomplished fact, this compilation having been prepared and published recently by Lowell 0. Stewart, Associate Professor of Civil Engineering, Iowa State College.

The subject was first presented to the Board at the meeting on November 10, 1931, when Prof. J. S. Dodds, of Iowa State College, emphasized the need for the compilation of the information concerning the early public land surveys, and sought to enlist the support of the Board for this purpose. It was then proposed that the General Land Office prepare and publish the data, but it was explained in the letter from the Commissioner that the magnitude and cost of the proposed work made the suggestion impracticable.

A review of the new book follows:

Public Land Surveys, - History, Instructions, Methods, 1935, by Lowell 0. Stewart, M.S., C.E., Associate Professor of Civil Engineering, Iowa State College. A most complete and authentic historical review, tracing the development of the technical aspects of the rectangular subdivision of the public domain. The author has devoted much time for exhaustive research, and expense incident to the compilation and printing of this valuable data.

No Federal agency has been in a position to compile for publication the information indicated by the title on the broad scale of covering the whole history and instructions relating to the public land surveys. The General Land Office furnishes such information when requested for a specific area, but that office has been compelled to refuse treating the subject as a whole, particularly in view of the fact that many of the early instructions were not sent out in printed form, and that all of the several Manuals published by the General Land Office, excepting the latest (1930), are now out of print.

The author has exercised the greatest care in tracing both the legislative and administrative background, and then carries the reader into the field to give a true picture of the conditions that have surrounded the execution of the original subdivisions. The citations of the laws, and the extracts from the early instructions, are very full and helpful, all of which has been verified by a complete bibliography. The manifest thoroughness will earn for this publication a deserved recognition as an authentic reference book.

The book is one to be used primarily for reference purposes, as it supplies a great fund of material that is essential to an understanding of land boundary retracements, treating the subject in a manner that lies entirely outside of the scope of text books on surveying, and quite apart from the current rules governing the execution of original surveys.

Many of the questions that come to the practicing surveyor, that ordinarily may not be apparent until after considerable experience, are presented logically and made entirely clear. The citations of the controlling laws and complete copies of important instructions furnish a convincing showing of the development of the technique of the rectangular subdivisions, and the stage that had been reached at various dates. An accompanying table shows the periods of the beginning and closing of the surveys within the various public-land States, also the intermediate period of greatest activity, so that the reader may readily ascertain by reference to these dates what rules were in effect when the subdivisions were being made.

The author has displayed considerable care in showing that the State of Ohio was the experimental ground for the development of the rectangular system, where conflicting theories were tested in a practical way, superior methods were demonstrated in some areas, and unreliable or inferior practices were made apparent by trial in other localities, leading to a revision of the surveying laws made applicable for the States of Indiana, Illinois, Michigan and elsewhere; the improvements are shown step by step until finally perfected into the ideal system found in the States of North and South Dakota nearly a century later. The explanations are very enlightening, extremely interesting, and well worth careful study even by those already quite well acquainted with the subject.

Heretofore, in shorter articles that have appeared, various writers have directed attention to those individuals, Thomas Jefferson (1784), Thomas Hutchins (1785), Rufus Putnam (1796), Jared Mansfield (1803), Edward Tiffin (1812), Ethan A. Brown (1836), John M. Moore (1836), William A. Burt (1833-1855), and others of less prominence, who appear to have been largely responsible for the creation and improvement of the rectangular system. Different conclusions have sometimes been advanced as to where the greater credit should rest. This is most courteously disposed of by this author, without preference to any individual, by showing historically, supported by liberal citations, the part taken by each in this large-scale land surveying project as applied to the public domain.

The reader will be gratified, if there may be reason to trace the laws or instructions beyond the scope of the book, to find the citations that lead directly to the known sources of information, and will be impressed with the unusual care that has been shown in this respect.

The township plats furnish the basic identification of titles in all of the twenty-nine States within the region originally known as the public domain; today the major problems of the surveyor are those of reconstruction and maintenance of these official subdivisions, whereby all property rights and title records may be traced back and referenced to the original Government grant or patent, the development of which the author has made very clear and extremely interesting.

The author expresses a hope that others may expand upon the history within individual States, where indeed there may be room for further elaboration, but the broader historical statement has been so well prepared that little need will be found to trace beyond the original records to be found in each of the States; very little can be shown additionally other than to bring attention to exceptional local practices.

The scope of the subject is too extensive for individual investigation, and too much is involved for non-expert compilation, so that the author has supplied a most important contribution to the library of the engineer who wishes fully to grasp the background of the land survey practice.

The accomplishment of the author makes it possible to state, after careful review, that most of the essential information and copies of original instructions for the early public-land surveys has been made readily available for the use of engineers in retracing these surveys, all of which has been coupled directly to the basic Federal laws.

Text, illustrations, copies of instructions, bibliography, and index, 202 pages, Collegiate Press, Inc., Ames, Iowa. Price $2.25.

The contribution made by Professor Stewart, now available in printed form, coordinates perfectly with the explanations that are contained in the Manual of Surveying Instructions published by the General Land Office in 1930, also with the printed instructions on the restoration of lost comers, and with the advice furnished by the General Land Office to engineers by letter in reply to specific inquiries.

One remaining complement to this entire subject can be supplied only by the General Land Office. The latter question has been considered officially, the data has been assembled, and some progress made towards accomplishment. This additional material is designed to furnish the needed explanations covering the operations of Federal, State, county, private and other engineers and surveyors, when engaged upon retracing the public land surveys, not essentially historical, and not too highly specialized or technical, but to fill distinctly the intermediate gap that lies between the text books on surveying and the official Manual.

It is suggested that the Board take action to commend Professor Stewart for his valuable contribution, and to express to Professor Dodds due appreciation for first directing attention to, and sponsoring this work.

(Sgd) Arthur D. Kidder,
Chairman, Committee on Cadastral Surveys.
Associate Supervisor of Surveys,
General Land Office.

Professor Stewart was with the Coast and Geodetic Survey as Hydrographic and Geodetic Engineer from 1917 to 1923 and will be remembered by many of the present personnel of the Bureau.

On behalf of his former associates and friends in the Coast and Geodetic Survey, the Editor of the Field Engineers Bulletin is pleased to extend congratulations and thanks to him for his recent book.

RECTANGULAR COORDINATES

T. J. Mitchell, Assistant Geodetic Engineer
U. S. Coast and Geodetic Survey

By training I much prefer the direct methods of Geodesy to the artificial methods of rectangular coordinates. In fact, I find it difficult to enthuse very much over the latter, particularly for my own use. Many of the preliminary features necessary for the use of a rectangular coordinate system seem to be as complicated as the usual procedure in Geodetic work. I am referring specifically to such things as the scale corrections necessary in rectangular coordinates based upon the Mercator or the Lambert projections or the limited longitudinal extent of those based on the polyconic projection and the resulting double system of coordinates where two systems meet. The artificial azimuths employed with a rectangular system differ so materially in places from those obtained by astronomical observations that I am afraid that they will tend to discourage observations, which I believe to be a healthily growing practice.

There is another side to the situation that may be designated the practical or rather attainable one and on that I would base my arguments for the rectangular system. The C. W. A. and related activities have indicated to a large number of engineers the desirability and necessity of having some general method of control. Their labors have produced a keen interest in precision methods and have demonstrated the limitations of ordinary instruments in obtaining precision. This is notably true in methods of obtaining precise azimuths without an instrument equipped with a sensitive striding level. Everywhere I go, I find engineers eager to find out more about the field methods of the Coast and Geodetic Survey. They can understand them, but when it comes to Geodetic computations the interest lags, and when the position computation formula is reached the interest completely disappears. They seem to hold a firm conviction that those computations are unusually theoretical except to a professional geodesist. I have always considered that the Survey's publications were excellent and it was quite a shock to find that they were considered so hopelessly technical by others.

The engineers in responsible positions in the Local Control Surveys have been recruited quite largely from the ranks of Consulting Engineers. While many values will accrue to the country from their activities, an important one, to my mind, is the training these men are receiving in precise methods. If they can be furnished something definite and apparently simple to control their surveys, they will gladly adopt it and their standing in their own states will induce others to do likewise.

I believe that the first requirement for an accurate map is a projection, otherwise the map becomes merely a mechanical drawing and after it is reproduced by blueprinting or other commercial methods it is almost certain to be so distorted as to be harmful. A projection which to these engineers is as simple as a rectangular one and which covers their whole state would be used by them whenever control points were available. On the other hand, a projection which seemed complicated to them would not be used in spite of its superior merit. This practice of tying local surveys to a state system would tend to discourage the isolated loop traverse survey with all its premium on unstandardized equipment.

In this discussion, I am interested mainly in hydrographic and topographic surveys and maps, incident to and preliminary to construction, and to the field of Cadastral Surveying. The various mapping agencies of the Federal Government will handle their problems in the future, as in the past in an efficient manner. At present many construction surveys have a very limited salvage value even to the organization that made them, and certainly less to anybody else. As an example of this, it may be stated, that I have known organizations to check their earlier surveys by uncorrected airplane photographs and accept the latter rather than the

former.

In the field of cadastral or land surveying, conditions are worse. Due to severe competition in this field, only an extremely conscientious and, I might add, an affluent surveyor can afford to do anything approaching precise work. Without control and a coordinate system, there can be no adequate check on such surveys without duplicating the work and its costs. If these aids are available, the better practitioners will gladly use them to demonstrate the quality of their work and public sentiment will force others to do likewise. Geodetic control could and should be used, but in all probability would not be used for it is too far a cry from a practice that in at least some places does not compute traverses, but checks them only by plotting. In my judgement, the engineering schools are in the main responsible for this condition, but I do not see any particular evidence of a change for the better in the near future.

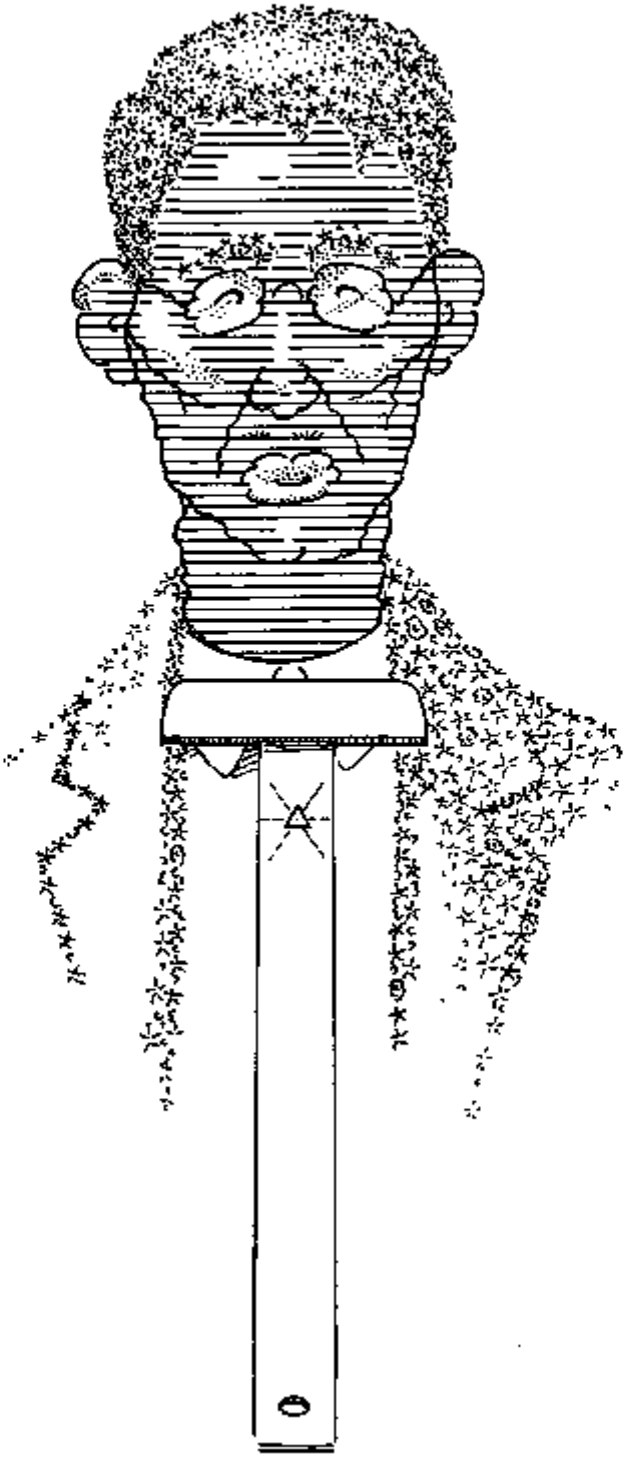
Land survey notes and maps are legal documents and subject to review by the courts at any time. While land descriptions have been written in terms of geodetic azimuths and coordinates and accepted by the courts in some instances, I am afraid that it will be a long time before this precedent is generally followed, for geodetic methods are far beyond the experience of the average judge whose education has been along very different lines. The practice of the western part of this country, in the early days, of describing county and state boundaries by latitudes and longitudes long before triangulation was available for laying out these lines on the ground, and the resulting difficulty in the collection of taxes has had an unfortunate effect which is not lost on the judiciary. Plane coordinates, on the other hand have an apparent simplicity which appeals to the judicial as well as the lay mind.

Land monuments by their very nature are apt to be short lived, especially in a thickly settled community where land values are high and where they are especially needed. For instance, most city monuments are placed in the centerline of streets. The pavement has to be renewed periodically and a steam shovel or construction gang has little regard for monuments. These markers could be tied to geodetic control and replaced when needed, but that would probably require an Inverse Position computation, which would not appeal to the local engineer. If they were tied in with rectangular coordinates, they would be much more likely to be replaced quickly and accurately. Then, too, most land monuments are located where it is extremely difficult to connect them with triangulation, but where they could easily be tied in by traversing, providing that it could be done according to the experience of the local engineers.

It might seem, from the foregoing that the place of the Geodetic Engineer is to be minimized in the future. 1 do not think so. Rectangular coordinates do not seem so simple to me as to many others and I believe that their use on an extended scale will require the help of a geodesist. Furthermore, to make them available and useful there must be a more closely laid out system of second and third-order control than we contemplate at present. Local engineers make an extremely hard and expensive thing out of triangulation and control in general and they will always look to the expert for reasons of economy and leadership.

It is then my conclusion that while rectangular coordinates are not ideal and are probably not the ultimate solution for control, they are the best solution we can expect for some time, and the necessity for available control is sufficient to justify the present compromise.

THE SAD EFFECT OF TOO MUCH
AIR PHOTO COMPILATION



J. A. Giles

THE NEPTUNE ORIENTAL

Earle A. Daily, H. and G. Engineer
U. S. Coast and Geodetic Survey

Gold is where one finds it and one certainly finds things in the moat unexpected places. While browsing around in an antique shop some months ago in search of copies of Blunts "Coast Pilot" of which I am making a collection, I casually asked the manager of the store if he had any old maps. To my surprise he replied that he had a book of old maps that had been lying around there for some time and that he would gladly dispose of cheaply. He finally unearthed a large, dusty, canvas covered book from the bottom of a pile of seeming junk.

Outwardly the volume appeared extremely ragged but the first chart I glanced at on opening the book bore a notation in the margin "Published according to Act of Parliament by Alexander Dalrymple, December 10, 1771" This was sufficient to whet my curiosity and on stripping the temporary canvas cover from the volume I saw a fine leather binding and the words "Neptune Oriental" which was enough information for me to quickly replace the canvas and attempt to conceal my excitement before calmly enquiring the small price of which he was continually speaking. It was so ridiculously small that I immediately paid it and, securing a receipt which said "Book of old maps", dashed from the store with the book under my arm. To my surprise and great pleasure on a later careful examination I found it to be complete and all the charts well preserved.

The Neptune Oriental, a bound collection of nautical charts whose dates range from 1730 to 1772, is probably less known to American hydrographers than the Atlantic Neptune. Compiled and first published by DeMannevillette in France in 1745, the Neptune Oriental should be of interest to Coast and Geodetic Survey officers because it included four charts of the Philippine Islands, more particularly of the Sulu archipelago, and undoubtedly suggested the name "Atlantic Neptune" to that publication of the English concerning the east coast of North America which followed the Neptune Oriental some thirty years later. An excellent copy of the Atlantic Neptune is in the possession of the Coast and Geodetic Survey.

The Neptune Oriental consists of 69 charts and views embracing the coast of Europe from the English Channel to the Straits of Gibraltar, the coasts of Africa, Arabia and India, the Malay Peninsula with the islands of Sumatra, Java and Bali, Indo-china and the China Sea, the Sulu Archipelago, the Bay of Manila and two other charts of portions of the west coast of the Island of Luzon in the Philippines. Detailed charts of Port Louis and L'Orient in France, Tringuemalay in the island of Ceylon, and a Plan of the Bay and Port of Rio Janeiro, dated 1730 and verified in 1751, are also included. All these are bound in one volume which lacks title page, frontispieces and maps numbered 10 and 46. Apparently these two were never included. In size the volume is approximately 16 by 22 inches and is similar in every detail with the three copies in the Library of Congress.

Little information is available concerning this chart atlas except that it was a product of the French due to the efforts of DeMannevillette who,in 1762, became the Director of the "Depot des Cartes et Plans de la Navigation des Indes". The results of thirty years effort, the first edition, probably published in Paris, appeared in 1745, & second edition about 1775, and a supplement in 1781.

That the work of gathering and compiling the necessary data for such a monumental work and the correcting of such charts as were existing at such an early date must have been tremendous is self-evident, especially when one realizes the possible sources of information concerning the East which, up to the l8th century, had been explored so little. It is amazing that so much was known at that time of many of the remote

and even now comparatively little known portions of the globe.

That the French early realized the value of a systematic gathering of nautical information for the use of their merchant marine as well as for the Navy is shown by the following portions of a "sensible ordinance", of the date August l68l, concerning hydrography.

"Of the Professor of Hydrography

Art.1 .- We will, that in the most considerable maritime towns of our kingdom, there be Professors of Hydrography to teach publicly navigation.

Art.2 .- The Professors of Hydrography must draw, and instruct their scholars to make them capable of figuring the ports, coasts, mountains, trees, towers and other things serving for marks to harbors and roads, and to make Charts of the lands they discover.

Art.5 .- The Professors of Hydrography shall carefully examine the Journals of Voyages lodged with the Register of the Admiralty, of the place of their establishment, and correct them in preference of the Pilots, who had erred in their track."

The fact that the journals and charts of individual navigators must have been examined and the information recorded is evidenced by the numerous sailing tracks laid down on many of the charts of the Neptune Oriental. These tracks were transferred in such detail that the days'run of the vessel can be detected easily.

Chart No. 22d of "The Islands and Dangers situated to the northeast of the Island of Madagascar" delineates a foul area and shows some 20 such tracks with the names of the vessels, commanders, and the dates of sailing. These dates range from 1712 to 1776.

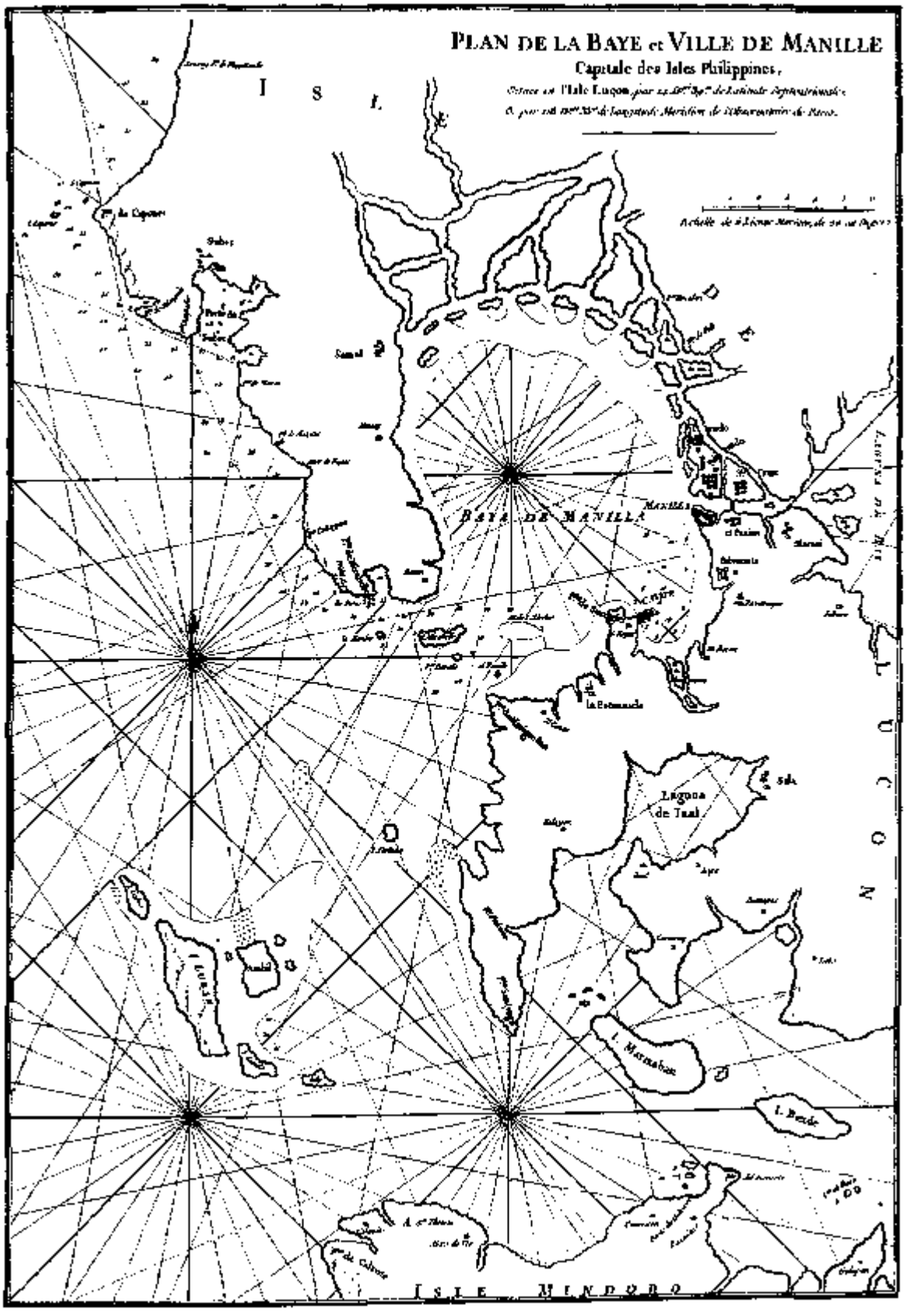
Chart No.52, "A Chart of the China Sea", also shows many such tracks, particularly in that great unfrequented area in the China Sea lying to the westward of the island of Palawan. This chart shows the position of "Scarboro Shoal" and contains the following note which may possibly be the first reference concerning that important danger lying to the west-northwestward of Manila Bay.

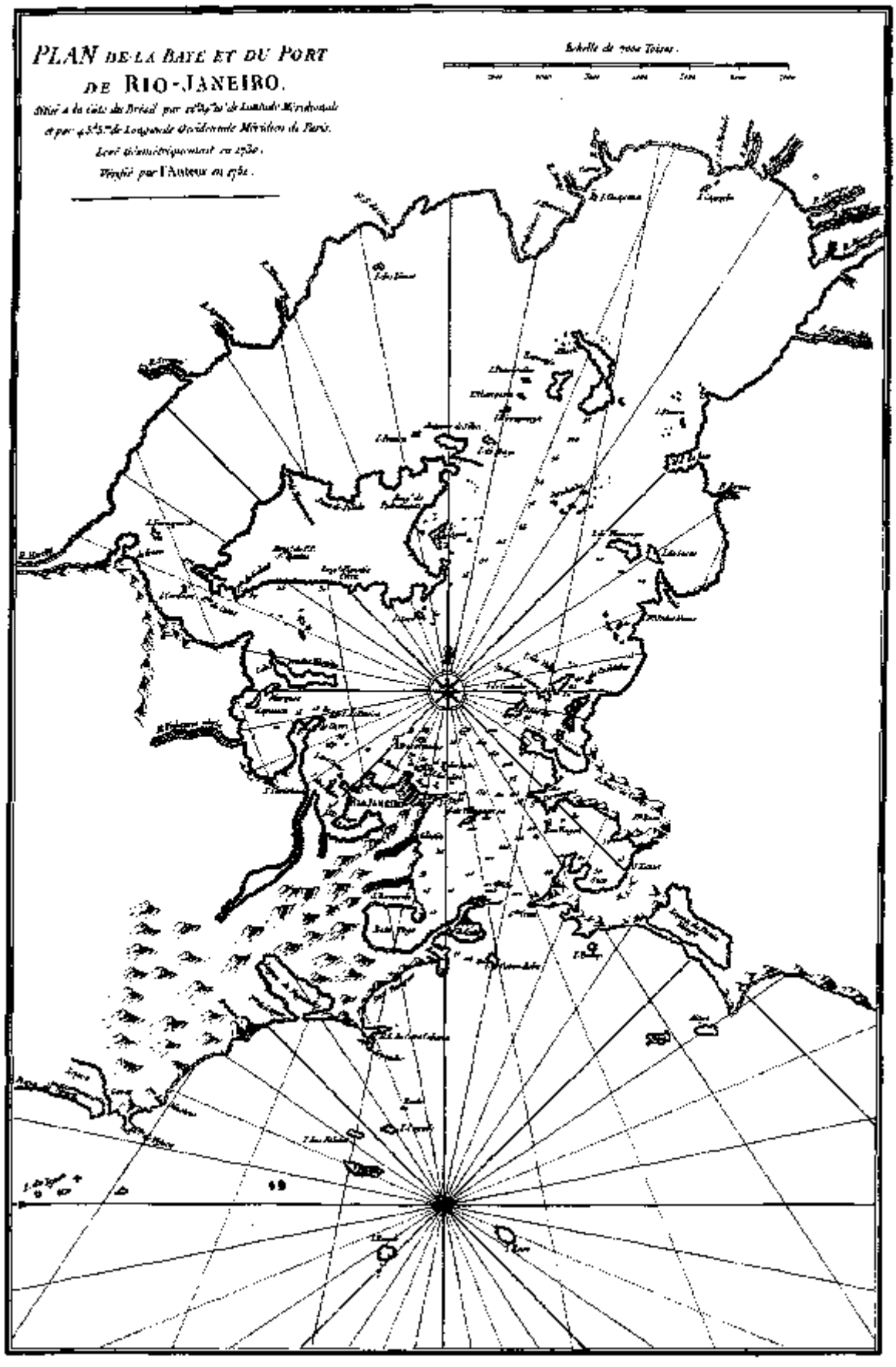
"This shoal is placed according to the Spanish Account, having been seen in 1755 by a ship bound to Manila from Macao."

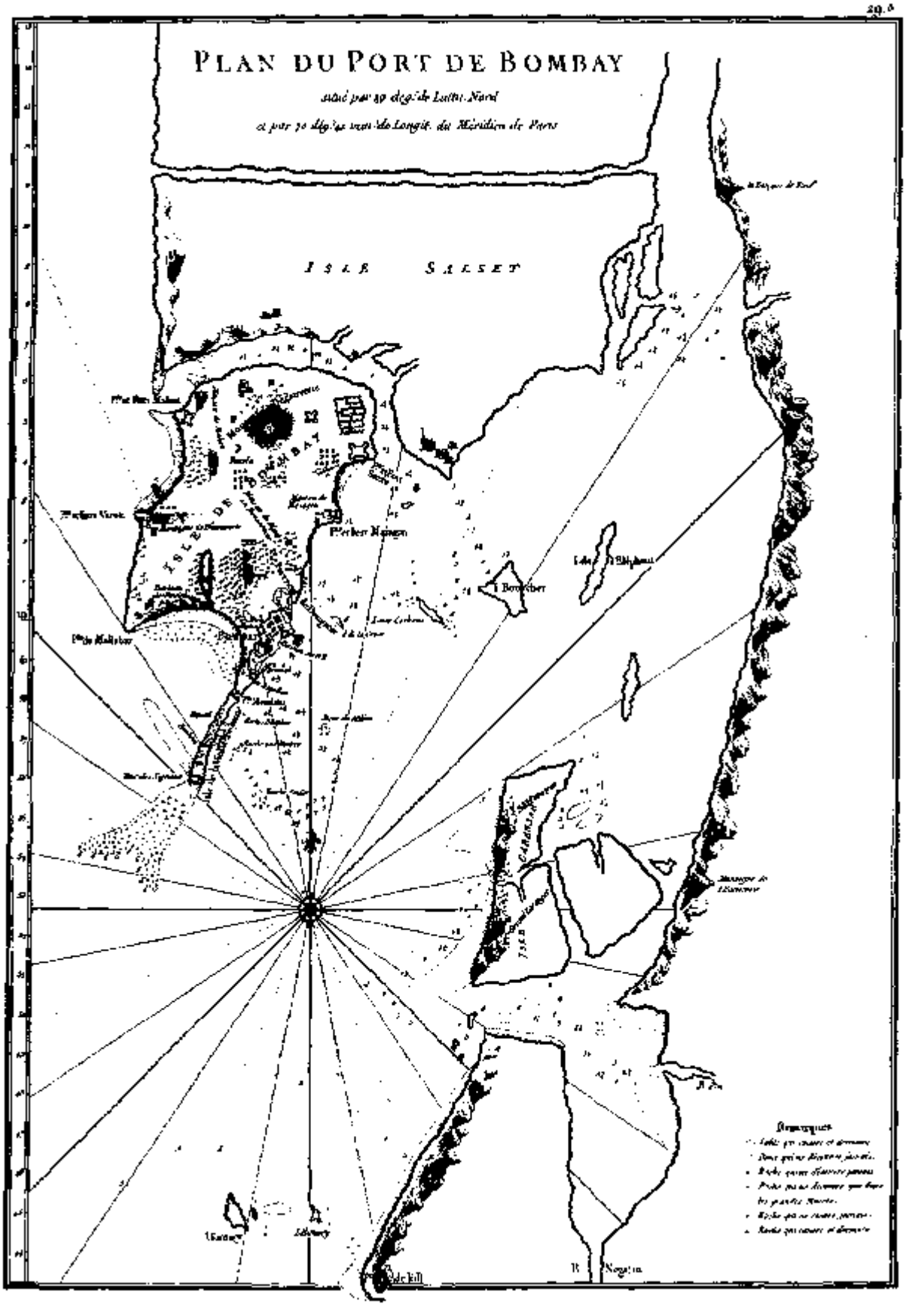
Five of the charts in this collection are copies of the work of Alexander Dalrymple, the eminent British Hydrographer; laid down chiefly from his personal observations made in 1761, 1762, 1763 and 1764, and printed according to an Act of Parliament. These five charts are titled as follows:

Chart No. 33 Chart of the Northern Part of the Bay of Bengal.
Chart No. 52 A Chart of the China Sea.
Chart No. 54 A Map of part of Borneo and the Sooloo Archipelago.
Chart No. 55 A Chart of Felicia and Plan of the Island of Balambangan.
Chart No. 56 The Sooloo Archipelago.

As the Neptune Oriental is a French publication the longitudes given were related to the Meridian of Paris and so noted on the plates. The charts are profusely illustrated with views of the various landmarks and ranges. Detailed sailing directions are included for entering harbors. Among the many views in this volume is a well executed one of the Harbor of Goa, the Portugese capital of the Indies.


PLAN DE LA BAYE et VILLE DE MANILLE
Capitale des Isles Philippines,
BAYE DE MANILLA
Laguna de Taal
I. Marabao
ISLE MINDORO


PLAN DE LA BAYE ET DU PORT
DE RIO-JANEIRO.
Levé géométriquement en 1730.
Vérifié par l'Auteur en 1761.


PLAN DU PORT DE BOMBAY
ISLE SALSET
ISLE DE BOMBAY
Pierre Nagen
Pile Malabar
Bombay
Isle d'Elephant
Nagoa

The accompanying reproductions are particularly illustrative of the more detailed charts in the Neptune Oriental. It is interesting to note that these plates show how the Portolano lines were already evolving into the compass rose.

The "Plan De La Baye et Ville De Manille" is of especial interest to Coast and Geodetic Survey officers who have been on the Philippine station. That the area to the southward of Manila Bay is greatly distorted of course is self-evident. The wide opening into Laguna de Tual seems to be an attempt to show the Pansipit River. The passage between Golo and Mindoro is certainly wider than as remembered by anyone who has passed Cape Calivite.

Jean Baptiste Nicolas Denis d'Apres de Mannevillette (1707-1780), to whom the Neptune Oriental has been ascribed, studied mathematics at Paris. In 1726 he sailed along the north coast of San Domingo aboard the "Marechal d'Estrees." With the aid of an octant and instruments invented by James Bradley, he corrected the latitudes of a number of points during a voyage to China. This happily suggested the task of correcting all the maps of India, the results of which appeared in the Neptune Oriental.

Alexander Dalrymple (1737-1808) was appointed a Writer in the service of the East India Company in 1752. On his first voyage to the East from India, Dalrymple visited Sulu and concluded a commercial treaty with the Sultan. This voyage was the means of giving the English a share in the spice trade which was previously controlled by the Dutch. On his second voyage, in 1763, he obtained a grant for the company on the island of Balambangan and of the north end of Borneo and the south end of Palawan, with the intermediate islands. Thus began the holdings of the present British North Borneo Company.

From the time of his return to England in 1765 he was almost constantly engaged in collecting and arranging materials for a full exposition of the importance of the Eastern Islands and the South Seas. In 1779 he was appointed by the East India Company to examine their ships' journals and publish charts and nautical instruments which eventually amounted to 58 charts, 740 plans, 57 views of land, and 50 nautical memoirs. These apparently were compiled from all known sources. That he must have collaborated with DeMannevillette and borrowed from his work, as well as DeMannevillette borrowing from him, is particularly evidenced by the fact that one of the charts incorporated in the Neptune Oriental bears the following title:

A
CHART of the CHINA SEA
Inscribed to
Monsr. D'APRES de MANNEVILLETTE
the ingenious Author of the
NEPTUNE ORIENTAL
TRIBUTE due to his LABOURS
for the benefit of
NAVIGATION
and
in acknowledgement of his many signal Favours
to
Dalrymple

ing documents, compiling charts, and engraving plates. He apparently preferred to risk blame for lack of immediate show rather than be held responsible for the issue of charts that were incomplete and inaccurate. This necessary period of compilation was later repeated in the United States where an impatient Congress demanded of Ferdinand Hassler that charts be forthcoming immediately after the establishment of the Coast Survey. The British Admiralty also resented the non-productiveness in the way of printed charts and after an investigation Dalrymple was invited to resign. He never recovered from the humiliation of his enforced retirement and died within a few months.

ONCE UPON A TIME —

There was an officer who turned in perfect field records. On triangulation he never -

designated an intersection as distant spire, far tank, brown house, yellow chimney, unpainted shed, beacon, house, lighthouse, etc.

failed to designate a station as No. 2 when it replaced a lost station.

used angles in the triangle computation, different from those taken from the list of directions.

turned in several sets of values for angles, without indicating which should be rejected and which retained.

turned in a list of directions with more than one initial.

failed to reduce directions to a zero initial where the initial direction had an eccentric reduction applied.

left two stations such as North Twin Spire and South Twin Spire reversed in the list of directions.

changed the name of the station without carrying this change throughout the records and computations and on the sketch.

turned in a computation of an intersection station that would require 2 or 3 minutes change on an angle to get a satisfactory side check.

tied in earlier surveys by no-check triangles.

tied in earlier surveys repeatedly by point connections when with a little more time line connections could have been made.

occupied a station eccentrically without making a sketch in the record.

spelled a proper name several different ways on the same description card.

designated the general direction of a reference object as north of the station when the list of directions shows it to be at least 90 degrees from that.

(A computer's dream)

THE PRODUCTION OF THE NAUTICAL CHART

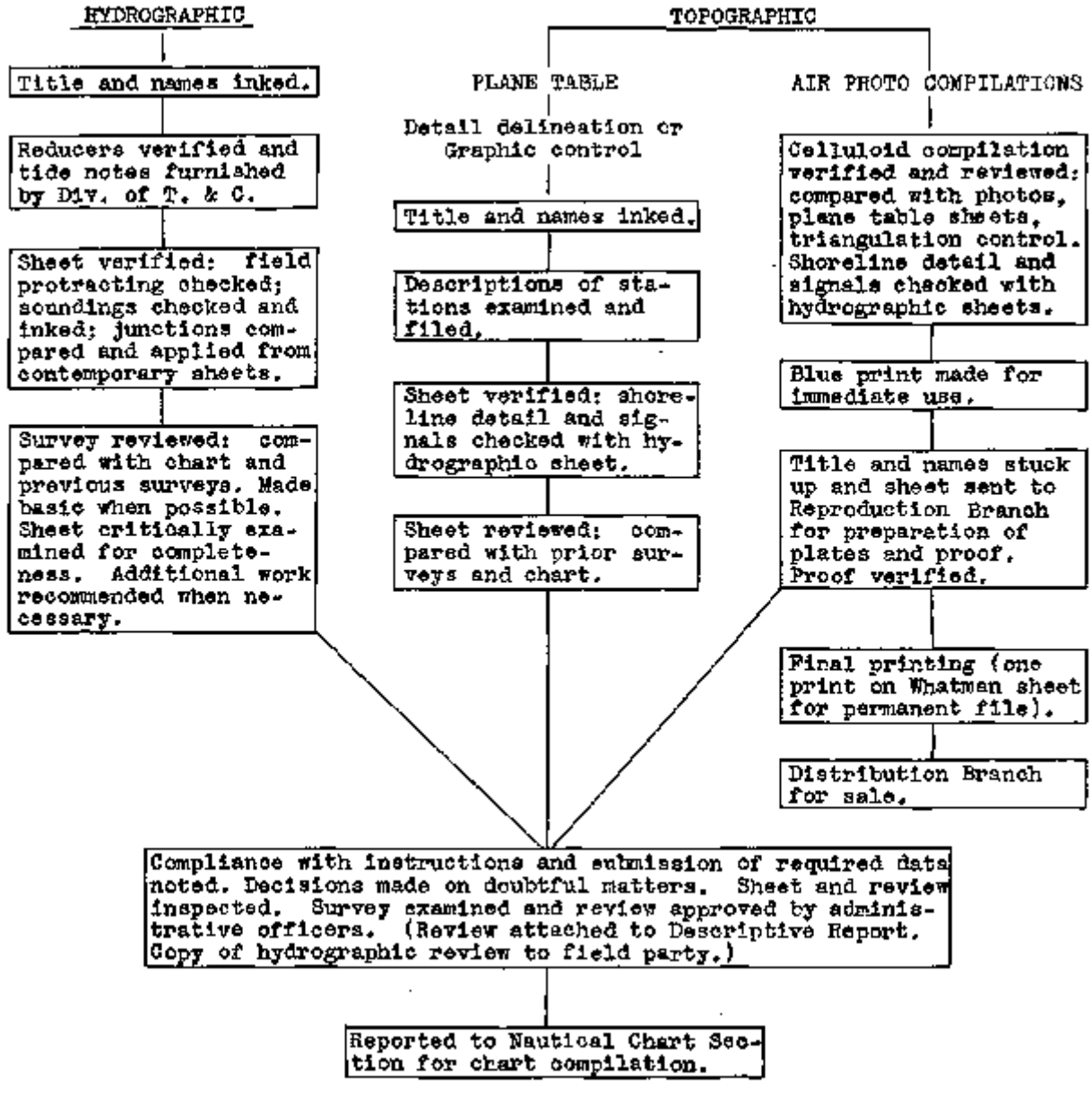
FIELD RECORDS

Surveys received, checked in transmitting letter and acknowledged.

Registered and diagrammed. Special forms attached to Descriptive Report.

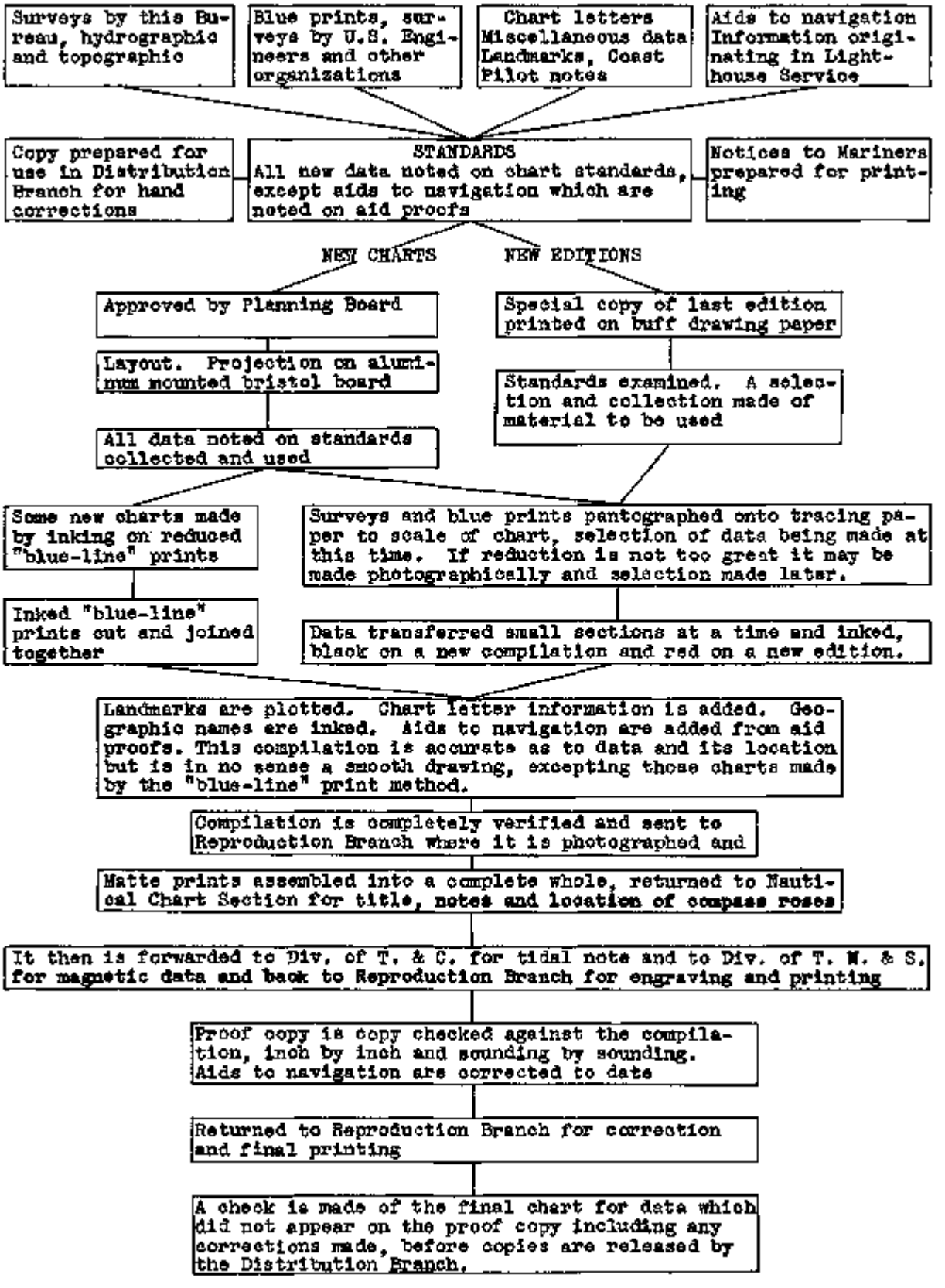
Preliminary inspection

Geographic names edited



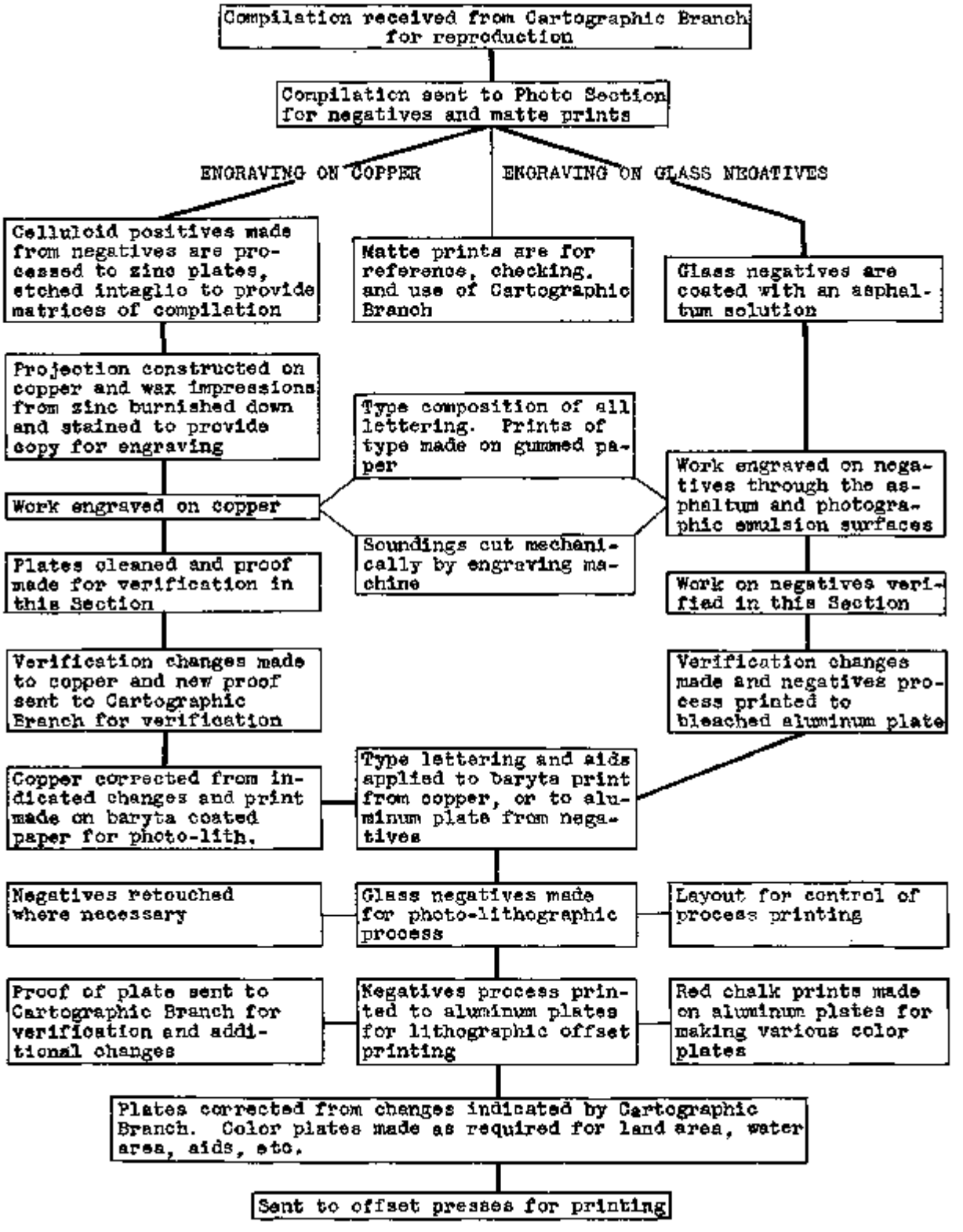
THE PRODUCTION OF THE NAUTICAL CHART

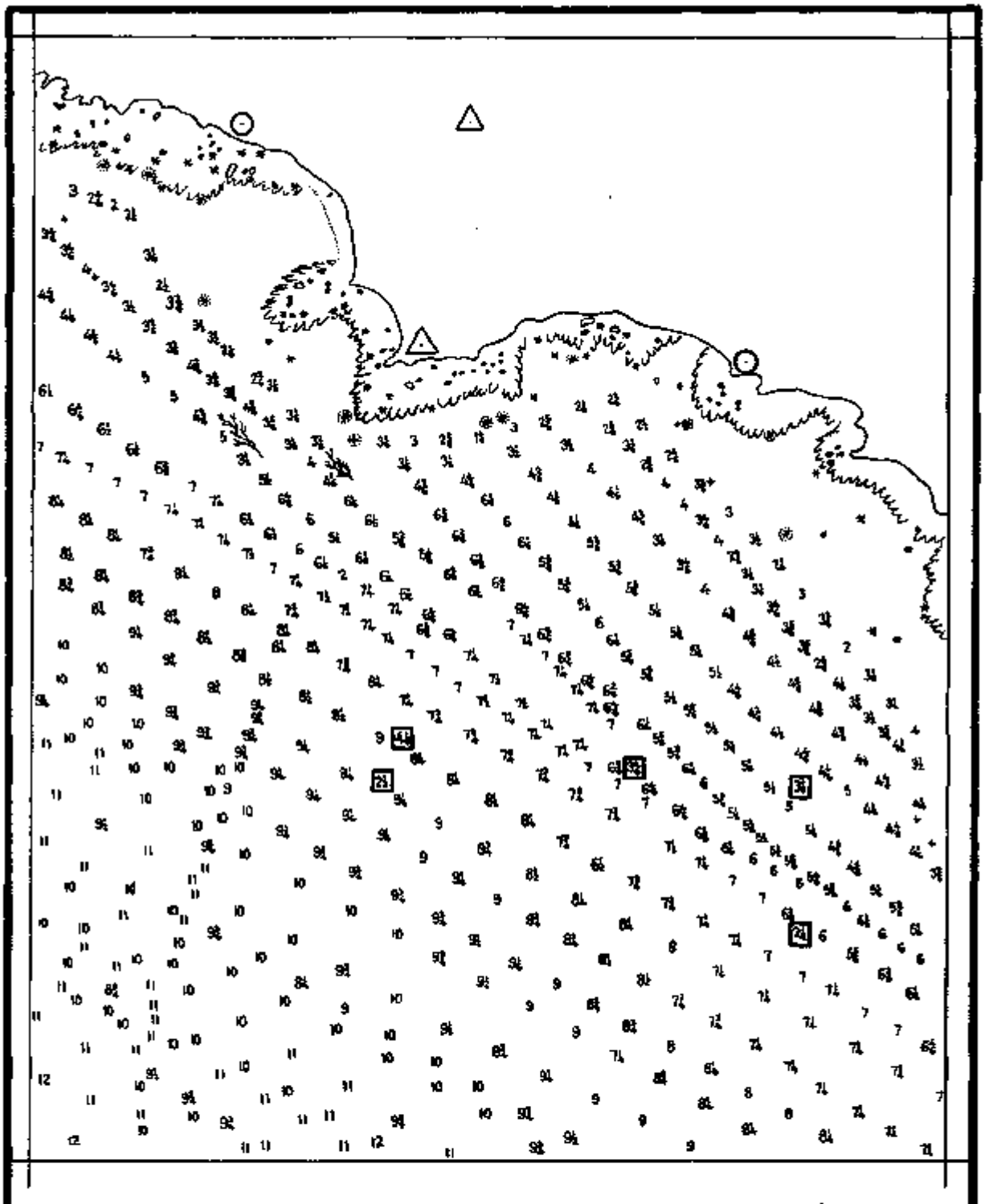
COMPILATION



THE PRODUCTION OF THE NAUTICAL CHART

REPRODUCTION





Section of Hydrographic Survey

Scale 1:10,000 Soundings in fathoms

WATCH THE KELP!

"A close watch should be kept on both sides of the sounding line for shoal indications, such as · · · kelp · · · etc." *(Par. 111 · Hydrographic Manual)*

Sounding lines spaced 70 meters apart failed to indicate dangers. Two years later, hand lead investigations of small kelp patches resulted in the soundings shown in "boxes".

THE WRECK OF THE COAST SURVEY BRIG WASHINGTON

R. R. Lukens, H. and G. Engineer
U. S. Coast and Geodetic Survey

Shortly after Professor Alexander Dallas Bache became the second Superintendent of the Coast Survey, that organization began an investigation of the Gulf Stream. It will be recalled that the first man to call the attention of the scientific world to the Gulf Stream was Benjamin Franklin and it is unique that Professor Bache, who was a direct descendant of Franklin, was the man to begin the orderly scientific examination of that marvelous river in the sea.

The first vessel to be assigned to this work was the brig Washington. She was apparently a fine sea boat and a smart sailer. Those of us who have done oceanographic work in the Gulf Stream with a well found steamer can easily visualize the difficulties in the path of those oceanographers on the WASHINGTON who had neither mechanical propulsion or suitable machines for sounding.

The WASHINGTON in command of Lieutenant George M. Bache, U.S.N., a brother of Superintendent Bache, had finished a very successful cruise in the Gulf Stream and at the end of the season was returning to Norfolk, Virginia. Captain Bache had purposely discontinued work early in September because of the destructive hurricanes that frequently sweep this coast during that month.

During the evening of September 7, 1846, as the WASHINGTON approached the entrance to Hampton Roads she encountered fresh breezes from the northward and eastward with a heavy swell from the southward. By midnight the breeze was fresh from the E.N.E. with thick and squally weather. At 12:20 a.m. on September 8, Smith's Island Lighthouse was sighted bearing N.W. 1/2 W. but was lost sight of almost immediately afterwards.

The brig was then headed around and a course was laid for Cape Henry in the hope that the light could be picked up. By 2:30 a.m. Cape Henry Lighthouse had not been seen and land was visible under the lee. This placed the WASHINGTON on a lee shore and of course in a dangerous situation. The commanding officer immediately wore ship and made all sail possible to the southward and eastward. By daylight the brig was laboring in heavy gales from the north and eastward. The jib-boom carried away and both starboard boats filled and were torn away from the davits. By 10:00 a.m. it was blowing a hurricane and the ship was on her beam ends. The main-mast was cut away and the lee guns hove overboard. The vessel then slowly righted herself but soon the fore-topmast and the fore yard were carried away and remained hanging up and down the mast.

The following is quoted from the ship's log, "Got her before the wind and hove overboard the larboard guns; sounded in eight fathoms of water, not able to see a cable length ahead; the tops of the seas blowing completely over and aboard us, the men clinging to keep from being washed overboard". Judging from the testimony of officers who survived the gale it was Captain Bache's plan to anchor the brig and then in case the chains parted, to drive the vessel ashore under the bare fore-mast. He considered that if the chains did not part the brig would drag slowly and probably the wind would shift before the vessel got into the breakers.

At 11:00 a.m., therefore, they let go the stream anchor with a 6½" Manila hawser 180 fathoms in length bent to it in order to bring her head to the wind preparatory to anchoring.

About 10 minutes after 11:00 while in the act of letting go the starboard anchor the brig shipped a tremendous sea which carried before it everything and everybody amidships and on the quarter-deck. At this time Captain Bache was on the quarter-deck with three men at the wheel and all were carried overboard by that overwhelming sea. The vessel

partly righted herself and some of the men succeeded in getting back aboard but the commanding officer and ten men were lost. It was thought that many of them were injured and for that reason were more or less helpless in the water. Upon the loss of Captain Bache the command of the brig fell to Lieutenant John Hall, U.S.N., whose subsequent actions won the praise of both the Coast Survey and the Navy Department.

As soon as possible after the sea was shipped the pumps were manned, the fore-mast cut away and the anchor dropped. The brig was then brought head to the wind and with the hurricane abating she rode to her anchors.

While everything both above decks and below was a complete wreck, the hull of the WASHINGTON remained tight and she stayed afloat.

During the next day heavy gales from the N.N.W. continued and all hands were employed in preparing a jury fore-mast. That night a lighthouse (supposed to be Cape Hatteras) was sighted bearing S.S.W. From this it may be inferred that the vessel was somewhere off Nags Head, North Carolina, when the disaster occurred.

On September 10, the third day of the gale, the crew was so completely exhausted that they were permitted to remain below the entire day.

On the following day they succeeded in getting some sail on the jury-rigged fore-mast and after heaving up the anchors, stood offshore. It was found that the anchor chain had parted about 10 fathoms from the starboard anchor. While at anchor after the hurricane several sailing vessels passed; some apparently did not see the distress signals and one which came fairly close refused to board the brig on account of the heavy sea running.

September 13 being Sunday, divine services were held aboard the WASHINGTON. At 1:00 p.m. they spoke the brig J. PETERSON bound from Wilmington, North Carolina, to New York. A contract was made with the Master of the PETERSON to stand by and convoy the WASHINGTON until arrival at some harbor between Cape Henry and Newport, Rhode Island. The PETERSON remained with the WASHINGTON for four days and furnished considerable equipment to enable the brig to rig more sail. On September 16, however, the PETERSON disappeared and was seen no more. Whether this disappearance was by accident or design is not indicated in the log book of the WASHINGTON.

On the afternoon of September 17 a large sail was made out to the southward standing in toward the WASHINGTON. This proved to be the U. S. Frigate CONSTITUTION, Captain Percival, from Rio de Janeiro, bound to Boston. Lieutenant Hall went aboard the CONSTITUTION and arrangements were made for a tow. At 6:00 p.m. the CONSTITUTION took the brig in tow and sent aboard various supplies including 75 gallons of water and 7½ gallons of whisky. As the crew of the WASHINGTON had been on short water rations for several days, it can be imagined how these supplies must have raised their spirits.

On the evening of September 21 the CONSTITUTION and her tow arrived off the Delaware Capes and at 6:10 p.m. the tow line was cast off. As the frigate filled away the crew of the WASHINGTON gave her a rousing cheer.

The WASHINGTON then took on board a Delaware pilot and stood for the river entrance in tow of the pilot boat ENOCH TURLEY. After a short time the hawser was cast off and the brig proceeded under her own sail. When inside the capes a boat was sent ashore with an officer bearing dispatches for Washington, D. C.

The WASHINGTON then continued up the river and arrived at the Philadelphia Navy Yard at 2:00 p.m. September 24, l846, or 16 days after the hurricane in which she came so nearly being lost.

In the Congressional Cemetery, Washington, D. C, there is a small monument erected to the memory of Lieutenant Bache and the ten men who lost their lives on the brig WASHINGTON. The monument is in the form of a stump of a. mast, symbolical of the dismasting of the WASHINGTON.

Adjoining this cenotaph is the grave of Captain Dallas Bache Wainwright, who on his mother's side, was a direct descendant of Benjamin Franklin and Professor Alexander Dallas Bache, the second Superintendent of the Coast Survey. Captain Wainwright, who died on January 13, 1934, served over 55 years in the Coast and Geodetic Survey and was the last of the lineal descendants of Franklin and Bache to be actively identified with the Surveys.

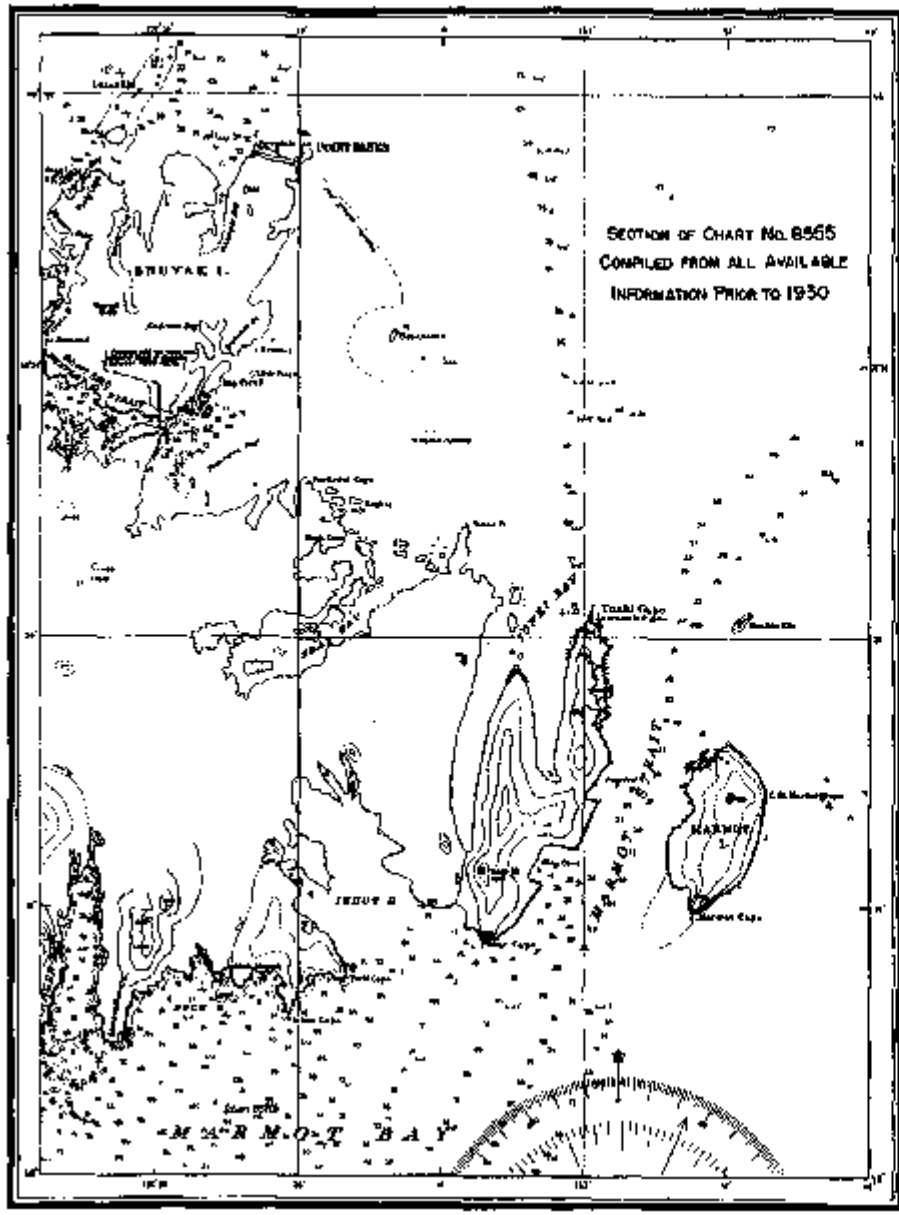
EARLY OBSERVATIONS IN THE RED SEA

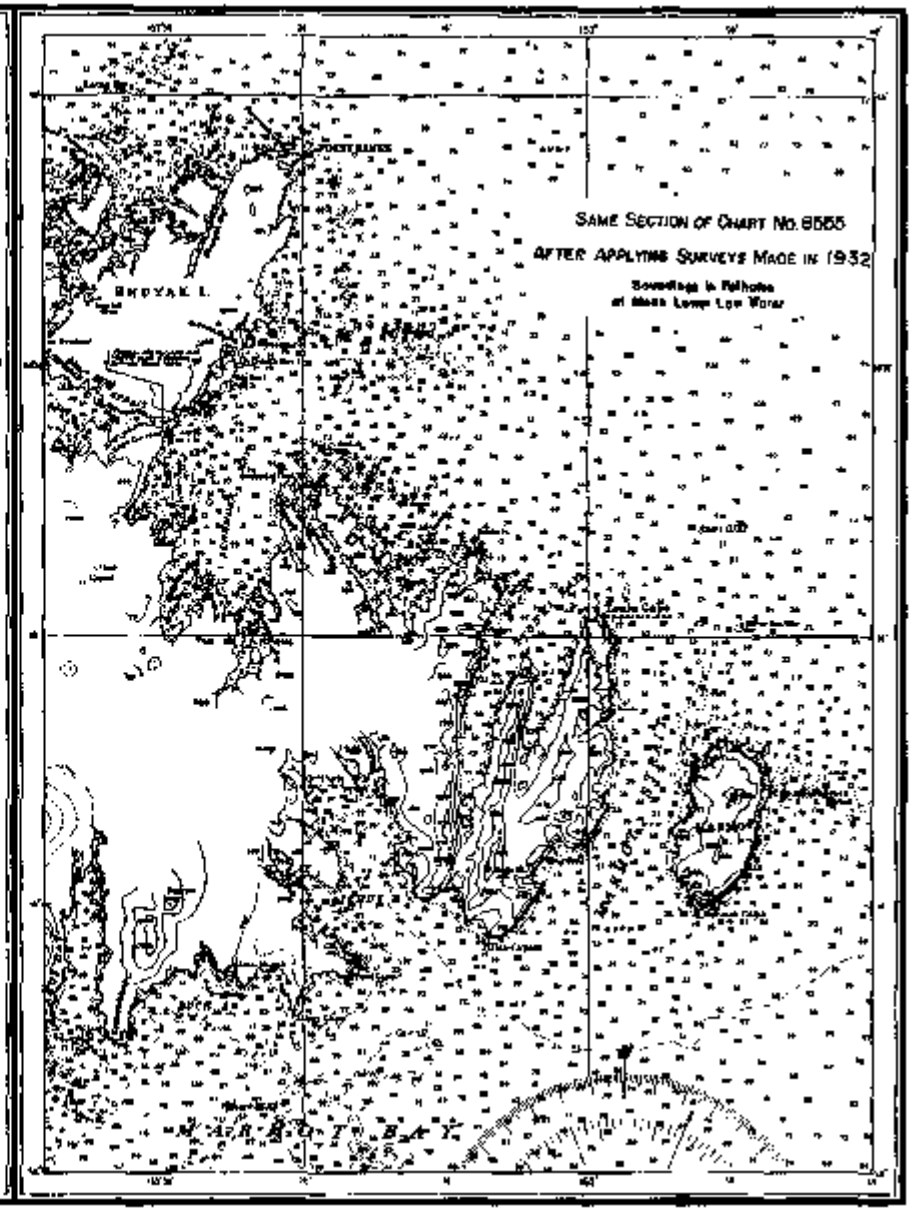
N. H. Heck, Chief
Division of Terrestrial Magnetism and Seismology

In the magazine "La Geographie" for February 1936 there is an article by E. Chabanier on "Knowledge of the Red Sea". One item is of considerable interest from the viewpoint of hydrographic, geodetic and magnetic surveys. About 1538 a situation developed in Ethiopia in which Portugal was concerned, relating to the placing of the Abyssinian Church under the jurisdiction of Rome. In the protection of Portuguese interests an expedition consisting of 64 vessels and many small craft and with about 4.50 armed men left Goa, the Portuguese settlement on the west coast of India on December 31, 1540, and on January 29, 1541, was off the Straits of Babel Mandeb. In command of one of these vessels, the Coulao Novo, was Joham de Castro and another member of the expedition was a son of Vasco de Gama.

Castro took advantage of his opportunities in a manner very similar to what would have been considered correct by a member of the Coast and Geodetic Survey as seen from the following translation.

"Castro possessed a latin translation of the Geography of Ptolemy and a Natural History of Pliny the Elder. At each important anchorage he went ashore with his instruments and measured the magnetic declination and the latitude. It appears that he used for his table of declination (astronomical) one of those disks of which the chart of Diego Ribero gives us the design. Knowing the date of spring he brought into coincidence the mark of this date on the disc of days with the zero origin mark of the sign of the Ram. He deduced the position of the sun on the ecliptic which permitted him to enter the astronomical declination tables. Without comparing the maximum declinations corresponding to different epochs, it can be noted that for seven latitudes the departures from those on modern charts are in minutes -28, -20, -10, -100, +12. Be did not limit himself to astronomy ------. On March 15 while the squadron was anchored in the channel south of Port Sudan (west side of Red Sea) about 19° 29' N, he went ashore and observed the tide."





CONTRAST BETWEEN ADEQUATE AND INADEQUATE SURVEYS

DIFFICULTIES IN FIRST ORDER LEVELING

Glenn W. Moore, Junior Engineer
U. S. Coast and Geodetic Survey
(Extract from Season's Report, 1936)

Mr. Moore's report describes the first order leveling done by his party in the vicinity of Galveston Bay for the purpose of establishing a common datum for the tide gages used in an investigation of the tides in Galveston Bay, Texas, in cooperation with the U. S. Engineers, War Department. The section of his report relating to the special features of the survey is reproduced below.

(Editor)

The special features of this work were: namely, the south jetty spur, the Houston Ship Channel line, the Cove swamp crossing, the Karankawa Reef crossing, the Red Fish Reef crossing, and the Fort Point to Bolivar crossing.

The Galveston South Jetty is about 3.3 miles long. It is a rubble mound capped with large granite boulders. At high tide and in rough windy weather most of the boulders are under water. The tops of the boulders are very slippery making walking extremely difficult and dangerous. Most of the line was run by using row boats to transport the rodmen and to move the instrument between stations. High corners of boulders were used for turning points. We were fortunate in having a calm day for the work.

The work on the line up the Houston Ship Channel from Morgan Point to Houston was slow, tedious, and difficult. It took us from two to three hours to get to the site of the work in the morning and the same length of time to return in the afternoon. Many instrument "set-ups" were unstable because of soft wet ground. It was slow and hard work, walking through brush and briars and across soft wet swamps. The lengths of our sights averaged less than 250 feet since it was necessary to tie each reference monument on the line into the direct line of levels. Intervals could not be obtained by pacing because of the bad walking, and so for the most part the interval was obtained by estimation and by set-ups for that purpose. Several crossings had to be made over the channel. Some of the crossings were between 500 and 800 feet-long.

The river crossing method is not adaptable for crossings under 1000 feet because of the length of time it takes to carry out. A modified method of reciprocal leveling was, therefore, used in making the short crossings over the Houston Ship Channel. This method was used only where it was not convenient to cross the channel in one sight, having both foresight and backsight over water. A brief description of the method we used in making the short crossings follows.

Geodetic levels were set up on both sides of the channel and rods were read on both sides at the same instant. The instruments were then exchanged and the operation repeated. This constituted one running of the section. For the forward running the 4 sets of readings on the backsight rod were recorded as backsights, and the 4 sets of readings on the foresight rod were recorded as foresights. The resulting difference in elevation was divided by 4 to obtain the difference in elevation between the support of the back rod and the support of the front rod. The backward running of the crossing was made in the same way except that the eights were reversed. On the crossings that we made we did not have any difficulty in getting the two runnings to check within the required limits of first-order accuracy. At a distance of 800 feet over water the graduations on the rod were definite enough for accurate readings.

By having readings across the water from both sides at the same instant refraction and curvature are theoretically eliminated. By transferring instruments and repeating the observations the instrument constants

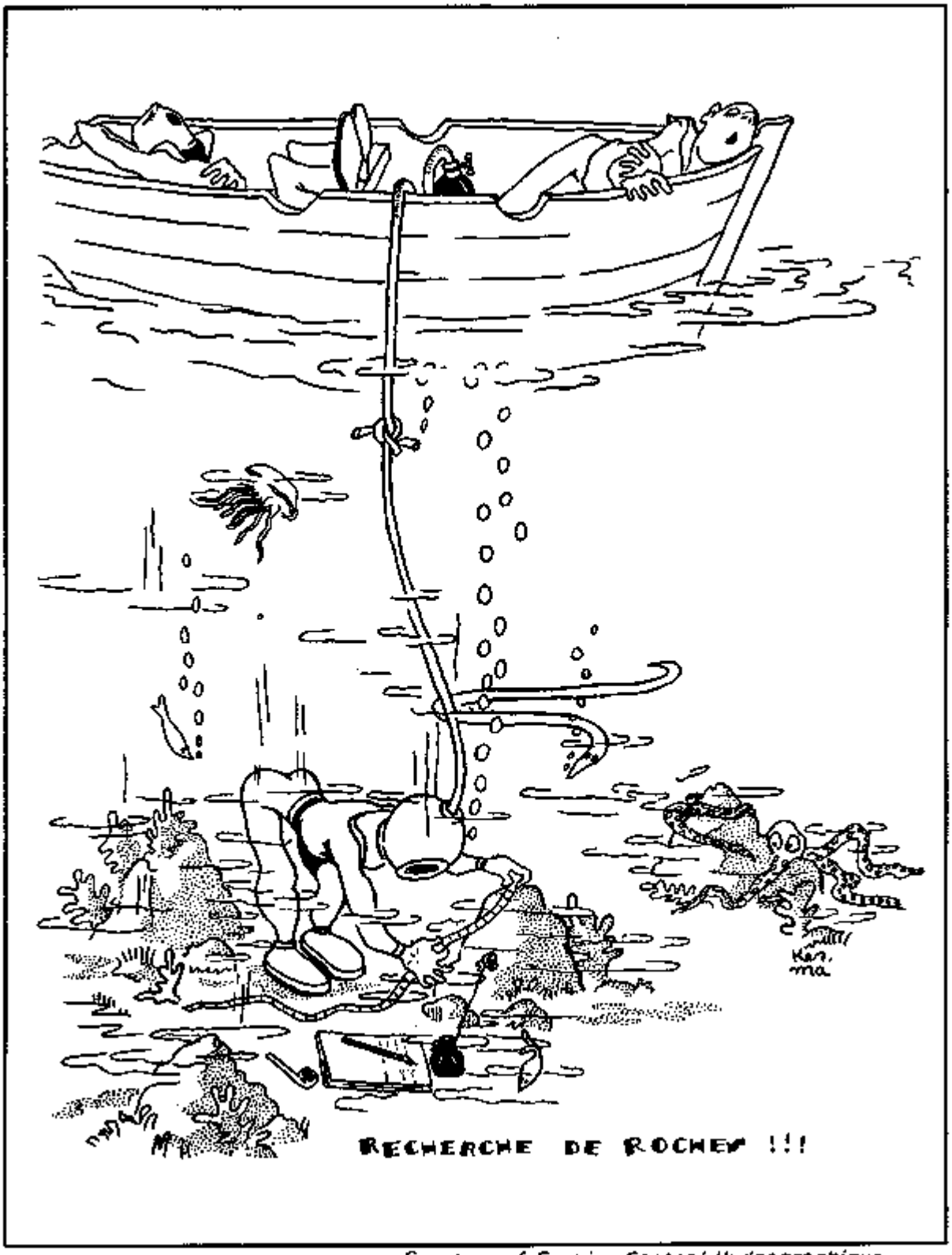
are theoretically eliminated. This method of short crossings is adaptable only for distances short enough for clear definition of the rod. It seems that this method of crossing streams or bodies of water might be generally advisable even where the distance across does not exceed the maximum length of sight, because there is a decided difference in refraction between sights over land and sights over water.

The crossing from Cove to Wallisville was made by leveling directly across a swamp. Turning points were set in water at times, and instrument set-ups were frequently made in water 2 to 3 feet deep. A stable instrument set-up could not be obtained on soft water covered mud. Set-ups in such places were made by setting the tripod down gently in place, then jiggling the tripod until it felt fairly firm, and then taking the observations as fast as possible. The results obtained were good and we did not have any rerunning of lines across the swamp.

The crossing over the swamp at Karankawa Reef was similar to the Cove swamp crossing except that it was not nearly so long. The Red Fish Reef Crossing was made as follows:

First, a river crossing about 1,500 meters long was made from the mainland to a 10-foot square shell island that barely showed above the water. The instrument was set up in about 4 inches of water on the small island. Another river crossing about 1,500 meters long was made from this small island to the large island lying to the west of Red Fish Reef Light House. The lines of sight on these two crossings were about 4 feet above the water.

Second, a river crossing about 3,000 meters long was made from the mainland to the large island lying just to the west from Red Fish Reef Light House. The lines of sight on this crossing were about 15 feet above the water. This crossing was made under unfavorable conditions. The targets on the mainland rod as viewed from the island were very indistinct. The white lines of the targets were not visible and the targets appeared as a dark blotch. The targets on the island rod as viewed from the mainland were quite distinct, even the white lines were visible. It was a clear, hot day on which the observations were made. Heat waves were very bad. There was a strong wind which made readings uncertain especially from the mainland side. Despite these unfavorable conditions, the value obtained for the difference in elevation between the mainland bench mark and the island bench mark by this method checked the value for the difference in elevation determined using the two crossings within the limits of first-order accuracy.



Courtesy of Service Central Hydrographique

CAPTAIN HECK'S BOOK SELECTED BY SCIENTIFIC BOOK CLUB REVIEW
(Copy of Scientific Book Club Review for August, 1936)

Earthquakes.—There could be no better example of the change in attitude which has generally resulted from the widening spread and deepening hold of scientific habits of mind than that afforded by popular ideas concerning earthquakes. Something really significant is involved in the contrast between modern concepts of this most terrifying of physical phenomena and those current a few decades ago when earthquakes were commonly viewed as "acts of God and tokens of His just displeasure." When modem man views earthquakes both as a menace which must be dealt with intelligently and as a tool which may be used to advance knowledge of the interior of the earth, he demonstrates his qualifications for citizenship in a world of science.

Curiously enough, although several technical books and innumerable papers have been contributed to the extensive literature of the subject in the last few years, no comprehensive study of seismology, intended for the general reader, has appeared in this country since the establishment of the Scientific Book Club. Captain Heck's thoroughly authoritative and up-to-date contribution is therefore peculiarly welcome. It is highly recommended to all who are sufficiently interested in earthquakes to want to know as much as they can concerning what seismologists are doing at the present time in the attempt to gain knowledge which will reduce the menace and increase understanding concerning the structures and the forces concealed within the earth.

The author is largely responsible for the fine program of seismic study which has long been under way as a part of the work of the U. S. Coast and Geodetic Survey, in which he is chief of the Division of Terrestrial Magnetism and Seismology. He has been one of the most conspicuous figures in the Seismological Society of America and especially in the Eastern Branch of that organization, which he was influential in founding. He has few if any peers in knowledge of the equipment, personnel, and accomplishments of the many stations established in this country by the U. S. Coast and Geodetic Survey, by numerous universities and colleges, and by a few private individuals for the study of earthquakes. There need be no lack of confidence in the scientific accuracy and comprehensive reliability of the statements he makes and the ideas he advances.

Although Captain Heck has designed the volume now in hand for the general reader and has omitted "mathematical treatment and highly technical matters" it must be said that in one respect it fails to meet the high standards of the Editorial Committee by which the books selected for "Principal Recommendation" each month are appraised. If the reader expects to find the smooth diction and mastery of the art of exposition which he has learned to expect in the popular writing of such scientists as Jeans and Eddington, Millikan and Jennings, he will be disappointed. Nevertheless, though the flair for fine literature is absent, this book unquestionably presents a broad and comprehensive picture of modern seismology in terms that adequately meet the need of the layman.

The book begins with a brief description of the vibrations which originate within the earth, with just enough of physics to give the necessary foundation for the understanding of the discussions which are to follow. A longer chapter is devoted to the effects of earth tremors on men and animals and on the earth's surface. The cause of earthquakes is adequately considered and in Chapter IV there is a thoroughly satisfactory discussion of earthquake prediction.

Two chapters are devoted to a description of modem methods of studying earthquakes, both with instruments and without them. The illustrations here are particularly good and help greatly toward an understanding of the symbols and vocabulary used by seismologists as well as the highly sensitive mechanisms installed in their specially designed laboratories. The analysis and interpretation of earthquake records are clearly described,

despite the technicalities encountered by the expert in this important and difficult phase of his work.

The process of locating earthquake epicenters and foci is explained and some consideration is given to the inferences which have been drawn concerning the layers within the earth. Of greater importance to the majority of readers is the description of the seismic belts indicated by the historic records of destructive tremors. The importance of earthquakes in the life of man, especially since the congestion of people in great metropolitan areas has become such a significant factor, is emphasized by the description of a score of great earthquakes which have occurred in the last half century.

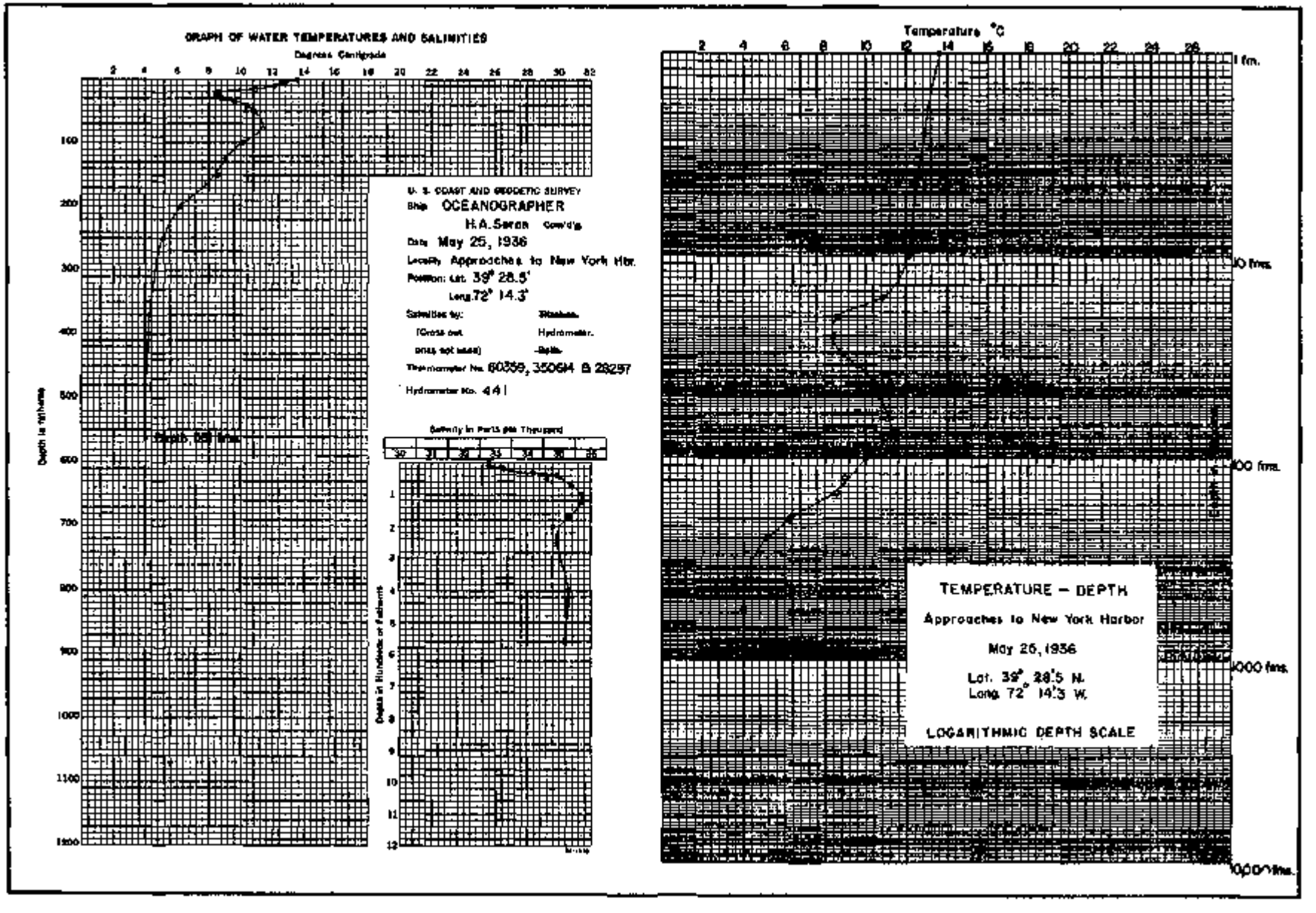
The way is thus paved for a general survey of the nature and probability of earthquakes in various parts of the United States. Finally, there are chapters devoted to the regional investigations now under way in the more critical localities in North America and in Japan, as well as an excellent summary of the progress which has been made with respect to safe construction in earthquake regions.

(Signed) Arthur H. Compton
Kirtley F. Mather
Harlan T. Stetson
Edward L. Thorndike

LOGARITHMIC PLOTTING FOR TEMPERATURE DEPTH GRAPHS

While seeking a method for standardization of procedure in plotting temperature-depth curves, a sheet of logarithmic paper, 4 cycle by 10 to the inch was tried. The curves plotted on this paper gave a very desirable balance between the shoal and the deep section when plotted with fathoms as the depth unit and degrees Centigrade for temperature. A comparison between the two methods is shown on the accompanying plate. The peculiarly happy relation between depth units in fathoms expressed in logarithmic ratio to the linear temperature scale seems to be just about right for the expansion of the shoal sections of the curves. Since the paper is from a, standard commercial plate it can be obtained easily, and adapted to the needs of the parties if no serious objections from technical or practical viewpoints arise. There is a movement underway to standardize the forms in use by various organizations making oceanographic observations, and this form of graph may make it possible to eliminate the usual shoal water graph. There is one objection, however. When meters are used for the depth units, the balance between the upper portion where temperature variations are greatest, and the deeper section of the curve, is not so advantageous. Logarithmic paper is used widely in plotting the results of physical and electrical investigations, and the suggestion for its use for temperature-depth graphs was made by Dr. Herbert Grove Dorsey, Principal Electrical Engineer, U.S.C. & G. Survey.

(Editor)


GRAPH OF WATER TEMPERATURES AND SALINITIES
Degrees Centigrade
Depth in Fathoms
U. S. COAST AND GEODETIC SURVEY
Ship OCEANOGRAPHER
H.A.Seron Com'd'g
Date May 25, 1936
Locality Approaches to New York Hbr.
Position: Lat. 39° 28.5'
Long. 72° 14.3'
Salinities by:
Hydrometer.
Thermometer No. 60359, 35064 & 28257
Hydrometer No. 441
Salinity in Parts per Thousand
Depth in Hundreds of Fathoms
Temperature °C
1 fm.
10 fms.
100 fms.
1000 fms.
10000 fms.
TEMPERATURE – DEPTH
Approaches to New York Harbor
May 25, 1936
Lat. 39° 28.5' N.
Long. 72° 14.3' W.
LOGARITHMIC DEPTH SCALE

ENGRAVED CHARTS*

K. T. Adams, H. & G. Engineer,
Assistant Chief, Division of Charts, U.S.C. & G. Survey.

Engraving is primarily the art of drawing on metal, or other substance, by means of an incised line. The term was first applied only to the work produced on the metal but later was also applied to the impression of the engraved plate upon a piece of paper. Copper is usually the metal upon which the engraving is made on account of its comparative softness.

Engraving as an art is a comparatively recent development, the earliest known illustrations having been made about the middle of the fifteenth century. Printing, however, had been invented only recently and paper certainly was not procurable in large quantities much before 1400.

The first charts of the Coast Survey were engraved and the impressions made for distribution were known as engraved charts. Some of the engraved charts of the Coast Survey display artistic work of the finest grade and none but a true artist could have engraved some of the excellent headland and harbor views found on the earlier editions of those charts. The engraver attempted to reproduce some thing of nature and not a spiritless copy of a drawing. The engraving tools and etching needles had a power of art which no drawing-pen possessed, and their work has life, quality and a color, found only in this type of reproduction.

The first published charts of the Coast Survey of which we have record were harbor charts on a scale of 1:10,000; that of Bridgeport Harbor, Connecticut, dated 1835; New Haven Harbor, Connecticut, 1838; and Newark Bay, New Jersey, 1839**. These three charts were probably engraved commercially on contract and it is very probable that Congress had the engraving done. At least they were not engraved by Coast Survey personnel since no engravers had been employed at this time.

The Newark Bay chart is of particular interest in that during the Congressional investigation of the Coast Survey in 1842 this chart was advanced as one of the reasons why Ferdinand R. Hassler, the first superintendent of the Coast Survey, was not competent as such and should be displaced. It seems that an error had been made in the scale of the chart and it had been so published.

Prior to the Coast Survey charts, no map or chart had been published in the United States which included detailed topography and there were therefore no engravers available here competent to do this type of work. Late in l841. Professor Hassler imported two engravers from Europe, and in May l842 an apprentice engraver from Philadelphia was employed. These engravers began work on a 1:80,000 scale chart of New York Bay and Harbor, and another chart in six sheets covering the same area on a scale of 1:30,000.

It was intended that the imported engravers should train apprentices in this most difficult form of the art but they evidently had little success, because in 1854 first class engravers still were being imported from Europe and at one time a Coast Survey officer actually went to Europe for no other purpose than to procure additional engravers.

In this early period every line, every figure, every letter and every dot was engraved by hand on the copper plates. The sailing directions and other notes at times covered a large portion of the chart area, and when all of this hand lettering together with the extensive sanding on some charts is considered the only wonder is that the charts ever were completed. The work was divided into subjects, and each engraver did that class of work in which he was most proficient; one engraved only soundings, one only shoreline, one only topography; one did sanding, one lettering and one

* See Frontispiece

**Neither the plates nor any copies of these charts are available at this date.

artist engraved the views.

Beginning with l845 same of the harbor charts were engraved commercially on contract, but this was evidently an unsatisfactory arrangement since in 1847 Superintendent Bache reported that outside engravers would not undertake further work.

Lithograph printing was in use commercially by 1850 and many of the sketches and preliminary charts were reproduced by this means for the early annual reports, but this form of reproduction was not considered satisfactory for a finished chart. Evidence that the employees of the Coast Survey were awake to its possibilities is given in the 1860 annual report where it is stated:

> "During the year the development of photography has been closely watched, with a view to the further application of the art to the purposes of the Survey. The processes of photolithography and carbon printing have received especial attention, ... Though I think the photolithograph too imperfect to be used for the publication of our charts, ... *

What really made photolithography a necessity was the physical impossibility of printing charts from the copper plates fast enough to satisfy maritime needs. When it is realized that it took about five minutes to print one copy from an engraved plate, the limitation of this form of printing is at once apparent. For each impression the plate had to be cleaned and re-inked, the ink being rubbed into the engraving by hand.

Another advantage of chart reproduction by the photolithographic process is the comparative ease with which corrections can be made. Making any correction, either small or large, to a copper plate is laborious and an expensive proceeding.

All charts of the Coast and Geodetic Survey are now printed by photolithography although a few charts were printed directly from the copper plates as recently as 1930. Because of this it is often assumed that engraving on copper is no longer practised in the bureau. This is far from the truth because a large percentage of the new or completely reconstructed charts are today originally engraved on copper.

After the original engraving, all following processes of reproduction are by photolithography. The chart, as engraved on copper, includes all of the hydrography and topography, but it does not include names, title, notes, compass roses nor aids to navigation. These are added during the photolithography. After the first edition, changes are not made on the copper plate but are made on the glass negative.

All charts, issued by this bureau, if they have been engraved on copper originally, contain a number in the center of the upper margin. This is the number of the engraved copper plate and is known as the plate number. When engraved charts were printed directly from the copper plates, the plates wore out rapidly and had to be replaced; consequently the plate number was changed more frequently than the edition date. When it is necessary to identify a very early edition of a chart, this plate number is often the best source of identification on the chart.

An interesting report on Engraving in the Coast Survey may be found on page 201 of the appendix to the 1854 annual report of the Superintendent of the Coast Survey. The author of this report is Lieutenant E. B. Hunt, Corps of Engineers U.S.A., who at that time was attached to the Coast Survey, and who had been in charge of the Engraving Division to February of that year.

For those who are unfamiliar with the engraved charts of the Coast Survey and in order to recall the excellence of the work to others, there is reproduced for the frontispiece of this issue of the Bulletin a section of engraved chart No. 621, San Francisco Bay Entrance, the 1859 edition. This chart, like others of the same period, contained views and extensive notes but in the section reproduced these, of course, do not appear.

THE OTHER SIDE

In Bulletin No. 8 was reproduced Captain Riesenberg's article from the Nautical Gazette entitled "Dial Navigators" in the hope that some of the heated arguments on this very subject, overheard during our wardroom assignments, might be brought to light in rebuttal. It is with some chagrin that the first defense of American Merchant officers was read in a British Magazine. It is reproduced here by courtesy of the Nautical Magazine.

"DIAL NAVIGATOR"

By U. E. G.

Captain Felix Riesenberg has written a slashing article in the NAUTICAL GAZETTE of America under the heading of "Dial Navigators." The inspiration for the title is given in the opening paragraph. This runs: "An old sailor admiral, now retired, once grumbled to me about the newer officers. 'When I ask one of them what the force of the wind is he runs into the chartroom and looks at the anemometer dial.' "

With all respect for Captain Riesenberg's known abilities as an experienced and accomplished seaman, we cannot help questioning the justice of same of his remarks. However skillful and competent an observer may be in his estimates of such matters as wind force, he can never attain to the precision of the indications of an instrument specially constructed for the purpose. Consequently, if a man is asked a direct question on the force of the wind it is his obvious duty to consult an anemometer if one is available. No sane man would expect anyone to tell the temperature of the air by taking three sniffs and hazarding a guess: why, therefore, should a man be held up to scorn because he consulted an anemometer for wind pressure in the same way that he would consult a thermometer for temperature? We quite agree that no observer should be totally dependent on the readings of instruments, and we heartily agree that he should strive to be able to do without them if necessary; but we emphatically contend that one who has access to an instrument is more likely to develop the sense of estimating than is one who can never "calibrate" his estimation to actual accuracy. The records of logged wind force in ships in the same place and at the same time will often show appreciable differences; and until a man has bad an opportunity for occasionally comparing his estimates with those that are correct he cannot reach perfection.

But Captain Riesenberg does not stop at anemometers. To quote his own words: "There is not enough use of the hand lead, which should be used whenever a steamer is entering or leaving port, be the weather what it will, just for practice. The use of the old 'dipsea' lead should be revived, as a further matter of seaman-like drill, requiring quickness and team work. On a cold night it is considered disagreeable work."

There are one or two items that seem to have escaped the captain's notice. While we are fetching back the old-time relics, why not bring back the old log "chip," the astrolabe and the backstaff? Why not work an occasional lunar distance instead of trusting to a time ball or a wireless signal? Why not put away great circle courses for a voyage or two and set the course on the old-time practice of making the latitude of the destination and then steering East or West? To be quite comprehensive, why not empty the Zoological Gardens into the ship now and again as a matter of practice in case there is another Flood? In short, why not spend so much time in revivifying the usages of strongly manned ships that the modern short-handed ship will not have time to perform the duties she is intended to do?

We do not know how much the American navigator deserves the implied charges levelled in the references to steam-heated, closed-in bridges. Our own opinion is that comfort on the bridge tends to better navigation

than does a bleak, windswept structure on which an officer has to be muffled up to the eyes. The use and abuse of comfort on the bridge depends on the man — not the bridge.

When our candid critic tells us that, during his trips as a passenger, he often chats with the officers, "admiring their quarters and damning the boats and deck gear," we wish some lines from his sharp and unequivocal pen had dealt with the subjects he damned. Our own acquaintance with American officers convinces us that they are smart and capable men who are up-to-date seamen. Perhaps, however, we have not met the "newer officers" who, according to Captain Riesenberg, "positively look pale" and "often look like the proprietors of small delicatessen stores, not like sailors."

There is a vague possibility that we have misread the article we have been discussing. Reading it over again we notice that its three complaints are that instruments have simplified seamanship and navigation, that quarters and bridges are too comfortable, and that there is far too much to eat. If that does not act as an incentive to the American boy to go to sea it will not be the fault of Captain Riesenberg!

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We are gratified to hear from one of our own retired seafaring men, who makes the following comments on the Field Engineers Bulletin, and who also has a word to say about "Dial Navigators".

. . . . In reading, it is easily seen, that the copy is largely devoted to the interest of your own personnel, and for whom, as your letter states it is really intended. However, I think many of the articles would be of interest to most officers and navigators in the merchant marine, and would likely be in demand by them if they knew such service was at hand.

The article which appeared of most interest to me, was the short discussion of the advantages of the "Lambert Conformal Conic Projection" as a network for navigational maps or charts, in preference to the better known and more used "Mercator's Projection".

Although superior in many respects for air navigation, where radio bearings of distant points are in constant demand, I think it will take considerable time before it will come into favor with marine navigators as I remember well, the disfavor of the few coast sheets on the similar and perhaps inferior "Polyconic Projection".

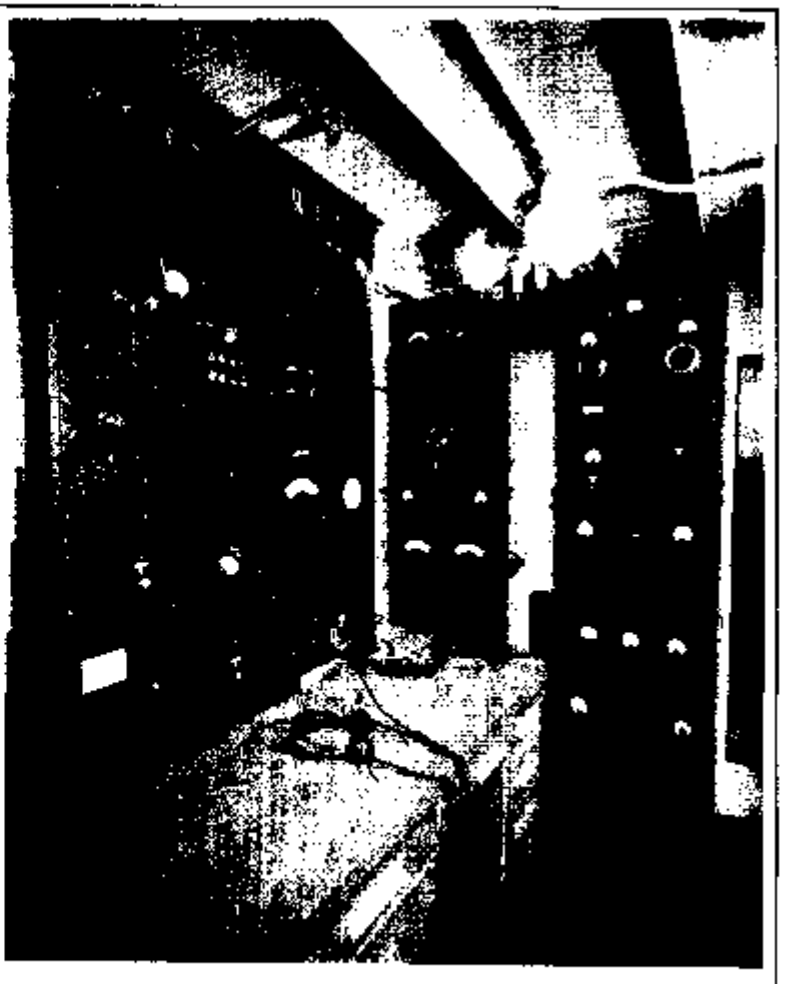
I want to mention the article from the Nautical Gazette, "The Dial Navigator" by Captain Felix Riesenberg. Although some of his arguments may be sound, it seems to me most of them are steps in a backward direction. I don't think any of your personnel would revert back to, or rely much on some of the methods used 40 or 50 years ago. The same holds true with the modern navigator.

There are many other articles which I think would be of interest if read by merchant officers, as it would give them a better insight and appreciation for a service which has done, and is doing, so much for the safety of the merchant marine.

A. Frederiksen

M.M.Ret.

Radio Equipment 1926, during the early stages of the development of Radio Acoustic Ranging.



Same Radio Room, 1934.

Some Changes in RAR Equipment
U. S. Coast and Geodetic Survey Ship *GUIDE*

SEARCH FOR LOST PLANE, GREAT SALT LAKE, UTAH.

I. E. Rittenburg, H. & G. Engineer, U.S.C. & G. Survey.

On the morning of October 6, 1935, the Douglas Airliner of the Standard Oil Company of California, en route from Oakland, California, to Salt Lake City, and carrying a crew of three men, failed to arrive at the Salt Lake Airport. About ten minutes before the scheduled arrival of the airliner at the Salt Lake Airport, the pilot had radioed in requesting ground wind velocities and data preparatory to landing there. From the time elapsed between the take-off at Oakland, his various reporting in stations and the time of his last request, his air speed was estimated at about 209 miles per hour. These data tended to locate the plane between Delle, Utah, and the Great Salt Lake.

On October 9, 1935, the body of George Anderson, mechanic of the lost plane, was found on the eastern shore of Stansbury Island. The next day, the body of R. S. Allen, the pilot, was found in the same vicinity about one to two miles northeast of the first body. Neither body was bruised or injured and death in both cases was due to strangulation. Two pillows, identified as pillows from the lost plane, were then found about 5 miles northeast of the northeast point of Stansbury Island.

These facts led to the theory that the plane had made a forced landing in the Great Salt Lake, that the landing had been a good one, the plane had remained afloat long enough for the men to divest themselves of clothing, that they had intended swimming to Stansbury Island, possibly using the pillows for rafts, and that they had dived into the water and had been strangled immediately as the waters of the Great Salt Lake are 28% salt solutions.

The Standard Oil Company was desirous of locating this plane and the third body which had not been found. A reward of one thousand dollars was offered for this information, i.e., the location of either the body or the plane, and numerous small boats with outboard motors attached began searching. Several ideas and methods, very fantastic to say the least, were proposed for a dragging of the Lake to attempt to locate the plane. Finally after about a week, the Standard Oil Company requested the Coast and Geodetic Survey for the loan of an officer and the necessary equipment to make a systematic wire drag survey of the Lake to locate the lost plane.

Therefore, on October 16 a telegram was received from the Director assigning me to this task. Contact was made with the officials of the Standard Oil Company and work was begun. This work was carried on every day including Sundays from October 17, 1935 to February 27, 1936, when the search finally ended in success.

Before any actual wire dragging could be attempted, numerous obstacles had to be overcome. Chief among these were a lack of available launches in the immediate vicinity; no landing for the launches could they be acquired, where supplies could be kept; no chart of the Great Salt Lake, only rudimentary topographic survey showing a few control stations; practically no hydrographic information of any sort; no actual knowledge of the area into which the plane had fallen; and the approach of winter with its adverse weather conditions.

It was found that at Colin, Utah, (the upper end of the Great Salt, at the Southern Pacific Trestle, Lucin Cut-off) two launches, suitable for the work and the only two launches that could be called suitable on the entire Lake, could be had. One of these proved to be practically a wreck and its engine of no value. The good launch was outfitted; the wrecked launch was rebuilt and the engine replaced by a new one. All this was accomplished in less than a week. Meanwhile a landing was built at Sunset Beach for the loading and storing of supplies, and as a base of operations.

As a reef extends about 1½ miles offshore from this landing, it was necessary to anchor the larger launches outside and ferry gasoline and

other supplies from the landing to the launches by smaller outboard motor-boats. The floor of the lake was found to be crystallized salt, about 18 inches thick and smooth and hard as glass. It afforded such poor holding ground for the launches that it was necessary to imbed the anchors in the salt. This was done by a diver who chopped a hole in the salt and placed the anchors in the soft sand beneath.

The only practicable method of finding this plane was to wire drag the Lake systematically. No hydrographic data of any kind were available. Accordingly it was necessary to run as many sounding lines as possible to secure information about the depths of water to be encountered, so that the drag could be set to the proper depth. This was done during the week while the launches were being repaired. The topographic maps were then taken into the field, checked, and found to be satisfactory in so far as the triangulation stations shown on the sheet were concerned. The hydrographic survey showed that the maximum depths to be encountered were about 25 feet.

On October 27, 1935, everything was in readiness and wire drag work was begun. Considerable difficulty was experienced on that day in trying to keep the launches on line. This was due to the inexperience of men hired, as naturally Salt Lake City being an inland city no sailors could be found. Consequently, it was requested that the office detail another officer to this project to be in charge of the end launch and to assist in the training of the men. Therefore, Lieutenant (j.g.) W. J. Chovan was immediately sent to Salt Lake City to take up this work. Too much credit cannot be given Lieutenant Chovan for his able assistance, as without his services the progress of the work would have been considerably retarded.

The next difficulty to overcome was procuring tenders suitable for this work. There were no inboard launches available on the lake that could throttle down low enough or that could continue to run all day. It was necessary then, to attempt to use outboard motor boats. These proved very unsatisfactory because of their unseaworthiness in general and the continual stopping and starting required of them with the incident delays to starting. The result was that considerable time was being lost by the wire going aground needlessly because of gradual shoaling of the water. This was inevitable as the ground wire was kept not over two feet from the bottom, and the launches could not make their rounds fast enough. Therefore, the Standard Oil Company purchased a launch in San Francisco and shipped it to Salt Lake City. This was a 28 foot fishing boat and proved to be suitable for the work although it did have too much freeboard and too large a turning radius. Better results were immediately apparent in the reduced number of times the ground wire hung up needlessly. However, it was felt that the wire should be tested for lift and depth more often than it was possible with only the one tender. Consequently another launch, previously used by the Coast and Geodetic Survey on the California coast wire drag, was purchased and shipped up. With the two tenders needless groundings were practically eliminated. Two way radio communication was established between all launches and the base at Sunset Beach. The drag launches would take frequent soundings and radio the depths obtained to the tenders. In that way the tenders knew at all times the depths of water being dragged.

Heretofore all the obstacles met with had been technical or physical things that could be overcame with the expenditure of effort and funds. Our greatest obstacle was still waiting for us in the person of Mother Nature. Winds will blow, cold and snow will come in the winter to Salt Lake, and daylight hours will be reduced. It was found that winds of 15 miles per hour would make it too rough for good dragging and winds of 25 miles or more would kick up a sea comparable to a heavy storm on the ocean. This was due to the shallowness of the lake with its maximum depth of 25 feet and the weight of the water. As this water is 28% salt, its specific gravity was about 1.2 or about 75 pounds per cubic foot, considerably heavier than sea water. This salt was very dangerous to the comfort of the men as the spray in the eyes, nose or mouth would burn and smart. It is said that a single mouthful of this water inhaled into the back of the

throat could very easily strangle a man. This happened evidently to the three aviators lost with the plane. In passing, I might add that these seas were very short and steep which naturally tossed the launches around considerably. With the approach of winter the weather of course became colder and colder. However, work was carried on in temperatures ranging as low as 4 degrees below zero Fahrenheit as the lake water never freezes because of its heavy salt content. Aside from the personal discomfort of the men in working in this extreme weather, our greatest difficulty on the entire project was the slowing down of the launches and the clogging up of the water systems of the launches because of this cold weather and the precipitation of Sodium Sulphate occasioned by the cold.

At the beginning of the search the lake water was fairly warm and salt, Sodium Chloride, was precipitated as the lake is a super saturated solution of salts of various kinds. This salt would form on the hulls of the launches and around the drag lines and buoys. It did not, however, clog up the water systems of the launches. The speed of the launches at this time was about 7 miles per hour. This continued until about the first week in December. At this time the temperature of the water of the lake approached the freezing point of fresh water with the result that the lake stopped its precipitation of Sodium Chloride and began to precipitate Sodium Sulphate. This proved to be much worse than the chloride salt as it formed faster on the hulls and drag and even clogged up the circulating water systems of the launches 3 or more times a day. This sulphate salt slowed the launches down to barely 5 and even less miles per hour. All the time the work was getting farther and farther away from the base at Sunset Beach; the days were getting shorter and shorter with the result that the output of the party was being gradually cut down to the vanishing point. Ice scrapers were bought and an attempt to scrape this sodium sulphate from the sides of the launches was made. While all the salt on the sides and a few feet below the water could be scraped off, there would still remain vast quantities of this salt on the propeller blades, rudder and along the keel. Fresh water seemed to be the solution, so we went in search of a fresh water anchorage for these launches. During the Christmas holidays time was available for sounding and a fresher water anchorage was found. This new anchorage would add about 1 mile per hour more speed to the launches for a few hours in the morning, but during the day the sulphate salt would gradually accumulate again and the speed would be reduced again. From a dragging speed of about 2 miles per hour, we were reduced to a speed of a little better than 1 mile per hour. Rather than cut down the width of the drag, 5000 feet, it was decided to add a third towing launch to act as a booster. Various positions were tried out for this third launch and finally it was found that maximum efficiency was had by having this third launch tow from the second buoy. This would allow the near towing launch full freedom in handling and would still be in the overlap areas to counteract any undue lift at this second buoy. By means of this booster launch our speed in dragging was increased to about 1.8 miles per hour. Finally about the middle of February 1936, the lake water began to warm up and the speed of the launches increased about 1/2 mile per hour daily until they were finally making their full speed of 8½ miles per hour. Needless to say this was quite a help. Our drag speed also increased to slightly better than 2 miles per hour without the booster launch. As this was fast enough because of lift, the third towing launch was dispensed with and she returned to her "tending". It seems as if there is a period from the middle of February to the first of June or July when the temperature of the water is too warm for the precipitation of Sodium Sulphate and too cold for sodium chloride. It is at this time when vessels can make their maximum speeds. Because of this slow speed, the increasing distance from the base to the working grounds and the desire to complete the job as soon as possible, it was decided to work long hours, from daylight to dark. Otherwise not much dragging could have been done as moat of the time would have been spent in running to and from work.

As has been said, dragging began on October 27, 1935, and was continued every day until discovery of the plane. It was decided to use a 5,000 foot drag with 400 foot sections as this seemed to give maximum efficiency con-

sidering the towing capabilities of the launches. As there was neither traffic nor tides on the lake it was decided to anchor the drag at the close of the day's work rather than take it up. This method worked well. The scale of the survey was l:60,000 because of the large extent of this body of water. Because of this small scale it was impracticable to locate the end buoys so the launch positions were plotted. To obviate any chance of splits in these overlap areas, it was decided to use an overlap of 1,000 feet between adjacent drag lines which more than compensated for the error introduced in using the launch positions rather than the end buoy positions. The airplane was finally found on February 27, 1936 in 25 feet of water with a 25 foot drag. This culminated the longest and most expensive airplane search on record. A diver was sent down and the plane was positively identified and an examination of the plane was made. It was found that the wire of the drag had caught under the propeller hubs and wrapped itself around the wings. The plane was found upright which bore out the theory of a good landing, practically intact and partially salt covered. There was about l½ to 2 feet of salt inside the cabin of the plane. The location of the plane was about 7½ miles from the bodies and in almost the exact middle of the lake northeast of the northeast end of Stansbury Island.

At the outset of the search, the prevailing opinion was that the plane would be found in the south end of the Lake near Sunset Beach. This opinion was arrived at from rumors furnished by people claiming to have seen the plane, the airline course the pilot was supposed to be following lying near the south end, wind drift calculations and logic which would lead one to believe that if in trouble any pilot would logically attempt to land on the salt flats at the south end of the lake. Therefore, the search was started in this south portion of the lake with the result that this opinion was proved to be wrong. However, wind drift calculations did show that regardless of the direction of the wind the plane must lie in an area described by an arc of 8 miles radius from the bodies. Consequently this arc was swung on the sheet and a systematic dragging of this area was begun. Unfortunately the dragging was started from the Stansbury Island shore eastward. The plane when found was in this area but in the extreme NE end of this circumscribed area.

Upon the finding of the plane, the phase of the work to which I had been attached was over. Consequently, the instruments were transferred to the Standard Oil Company and I returned to my station in Florida.

The following information was obtained by correspondence:

After locating the lost plane there still remained the raising and dismantling of the plane. It was decided to tow the plane under water to Colin on the Southern Pacific Trestle across the Great Salt Lake, for the following reasons rather than to bring it to Saltair. There would be less interference with the operations from the curious. A locomotive crane was available there and the Southern Pacific Railroad could furnish as many men as would be required for the actual lifting. The plane was freed from the bottom, raised about 7 feet off the bottom by means of hydraulic jacks and towed. Swings were put under the 2 larger drag launches, and attached to the nacelles of each engine. These 2 launches bore the greatest weight. They were lashed the proper distance apart by timbers across the bows and sterns. The larger of the two tenders, with a line rigged from the bow, carried the weight of the tail. With this 3 point suspension the tow left the scene of the discovery at about 9:30 A.M. and arrived at Colin about 7:30 that night.

Lifting the plane was far more difficult than anticipated due to the water absorption of the upholstery, carpets and sound proofing. For example, a chair cushion normally weighs eight or ten pounds, and when saturated with Lake water it weighed sixty-two pounds. Similarly all of the structure which had small openings contained about 18 inches of salt. This includes the wings, fuselage and stabilizers. The net result was that instead of weighing between eighteen and twenty thousand pounds, the plane weighed between forty and fifty thousand pounds. The plane was finally lifted and set in the cradles provided for it.

Examination so far of the plane both inside and out has revealed no apparent reason for the accident. A detailed analysis based on facts obtainable from taking the plane apart piece by piece will be necessary before the cause of the disaster can be determined. Fifty gallons of gasoline were pumped from the tanks. Except for those parts of the plane made of a magnesium alloy, the gyrocompass, parts of the wheels, etc., the plane was apparently in perfect condition. These parts were eaten away completely due, no doubt, to the lake water. The plane is to be dismantled, every piece, bolt, nut, etc. will be washed off with fresh water and packed in oil for shipping to San Francisco where the final detailed inspection and analysis to determine the cause of the accident will be made.

Launch towed is "Marsh" rebuilt and used as one of the drag launches. Note foam on water.

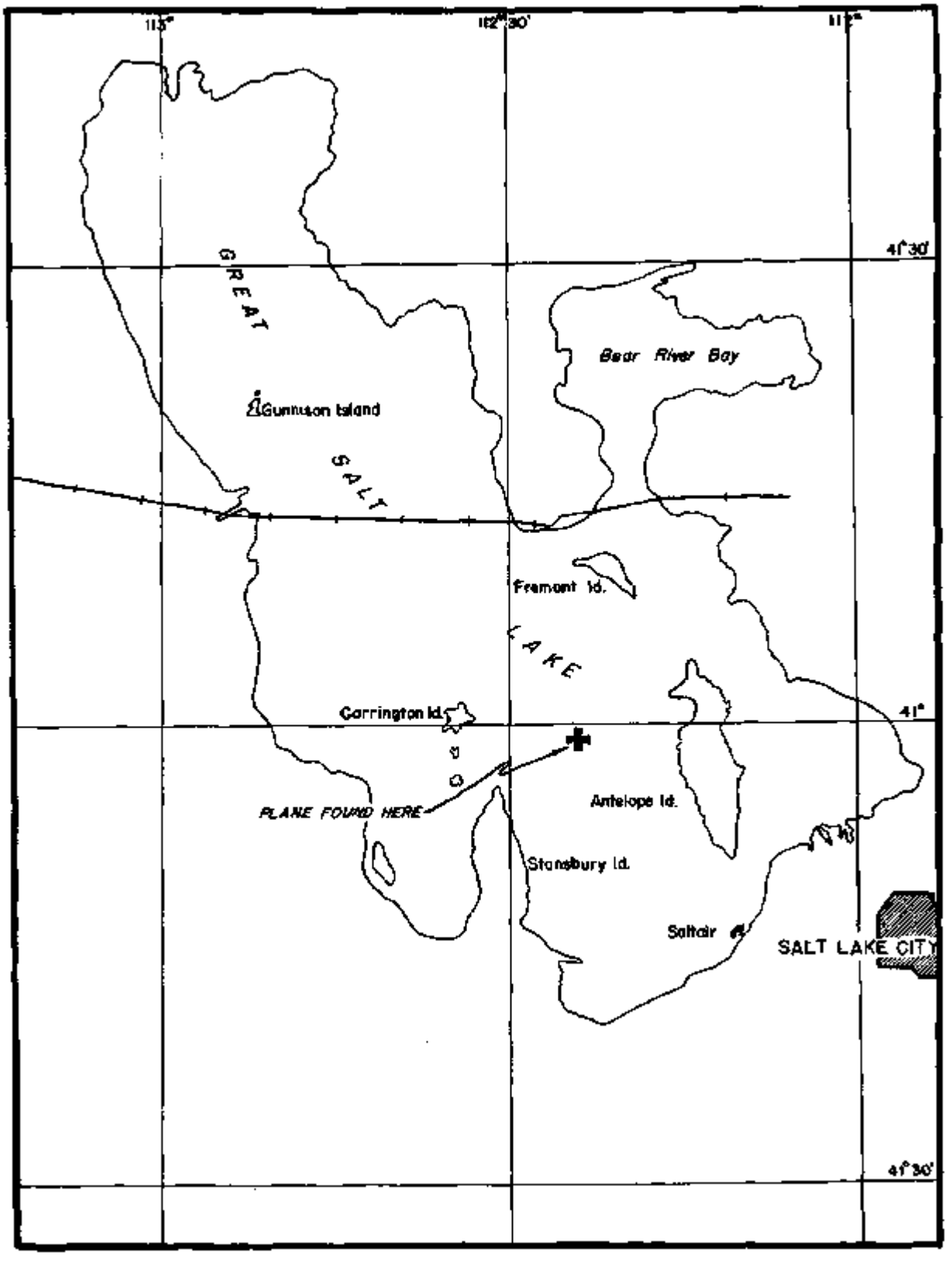
"Marsh" after rebuilding showing heavy salt accumulation on sides.

Salt Deposits around landing at Colin, Utah.

Salt (Sodium Sulphate) accumulated around aluminum toggle buoy.

Salt chipped away to show amount of deposit.

Model of plane showing the position of drag when found.



Sketch Showing Position of Plane Found by Wire Drag

USE OF COLOR FILTERS ON GEODETIC INSTRUMENTS

H. C. Warwick, E. & G. Engineer
U. S. Coast and Geodetic Survey

Paper read before the American Geophysical Union, Section of Geodesy
April 30, 1936.

For several years the Coast and Geodetic Survey has carried on intermittently a series of experiments with color filters on first and second order theodolites and first-order levels in an attempt to improve the appearance of the object pointed upon by eliminating as far as possible the disturbances caused by heat radiation and scattering light. It is consistent with Huyghen's theory that the red and yellow filters are found to be the best for absorbing the disturbing lights of the short-wave length, namely, those approaching the ultra-violet part of the spectrum.

Investigation along this line has given not only interesting and conclusive proofs, but also some more or less conflicting results. It is believed that the installation of the filter on the precise level is a benefit to the observer, and as this is the simpler of the two phases, it will be considered first.

Some time ago, we started experimenting by running a series of short loop closures with various types and colors of filters under different atmospheric conditions. In comparison with the length of sights on triangulation and generally on traverse, the length of a level sight is short. The maximum length of these sights under the most favorable conditions, according to the specifications of the Coast and Geodetic Survey for leveling, does not exceed 150 meters. On cloudy or overcast days and even in a light rain when the atmosphere is clear and still, filters are not found to be an advantage but rather a hindrance as they absorb too much of the needed light. In the bright sunlight, however, the "boiling" caused by heat radiation and the presence of scattering light of the short-wave length makes observing difficult, and we find that the filters are a decided help.

After trial of the various shades of glass filters, it was determined that a red, equivalent to the Eastman Kodak Company's Wratten No.26, Stereo Red, was the best for general use. Possibly other shades would be better under various conditions, but as it is not practicable to equip an instrument with many shades, it was found that the glass referred to seemed to fit all conditions more satisfactorily than any other. This filter is installed at the eye end of the level telescope; no error from this source is introduced when fitted in this position.

A remarkable change in the appearance of the rod when the filter was in place was noted immediately when observing in strong sunlight. The contrast between the black and white on the invar strip appeared more pronounced, and to some extent the "boiling" caused by heat waves diminished. The short loop closures were run with and without the filter under identical conditions by the same observer, with the same lengths of sight and within a short time of each other. It was found that the closures were uniformly better when the filter was used.

The consensus of the various observers using the filters on actual field work is that the filters will make it possible to increase the maximum length of sight about 20 per cent on days when heat radiation is prevalent. Obviously, this will add appreciably to the efficiency of a level party.

The use of filters on theodolites or telescopes for longer sights is a more difficult problem. From my own observations and from those made by others, there is conflicting opinion. Theodolite observations are

made under many conditions, each line of sight at the same station may differ greatly from the others, and while one shade of filter may improve vision under one or more conditions, we have not proved that any one color is generally better than another in all cases. It is believed that a light amber shade, corresponding to Eastman Kodak Company's Wratten Filter No. 8, K-2 orthochromatic, probably will best fit most observing conditions to be encountered, and for lack of knowledge of a better one this is being installed on a number of our theodolites.

Naturally it is not practicable for an observer on triangulation, traverse, or reconnaissance to equip himself with a dozen or more filters for trial at each station in order to determine which is most suitable for the particular conditions under which he is observing. These conditions are controlled by such factors as the character of the atmosphere, whether cloudy, bright sunlight, blue haze, smoke, or dust. The angle the line of sight bears to the sun, and the character of the terrain over which it passes; all affect the vision.

Another interesting feature relating to conditions encountered is brought out by the characteristics of the individual eye. This was discovered a short time ago while observing with various shades of filters from the roof of the Commerce Building in Washington. The morning had been spent observing at different angles from the sun using a number of filters from a book of Eastman Kodak Company's Wratten gelatin filters, consisting of 60 shades. Several field engineers interested in the procedure were asked to make some observations. There were present three light and three dark-eyed men. By chance it was learned that whereas the darker shade of filter assisted the men with light eyes to see the object pointed on more clearly, the light shade was of more assistance to the men with dark eyes. An impromptu discussion of this fact led me to consult with an eye specialist on this question. He substantiated what we had suspicioned, namely, that light eyes are generally more sensitive to light than dark eyes, varying from the albino who has no pigment and invariably suffers from a distress known to the medical profession as photophobia, to the native of the tropical countries whose eyes are constantly subjected to bright sunlight with no resulting ill effects.

Some time ago a light amber and a red filter were sent to the field to each of several triangulation parties for trial. Reports from these parties using the filters, both in daylight and at night on observations on signal lamps, indicate that the amber color is in some cases beneficial. None of these reports favored the darker red. One officer stated that when observing on natural and artificial objects during the day, that these objects were brought out and defined more clearly when using the amber filter. It is not expected that the filters will greatly improve visibility at night when there is no sunlight to be filtered out and the only source of light is the object pointed on, however, one officer stated that the amber filter apparently reduced the flare from a flaring light. Another remarked that when pointing on lights before dark, the light was reduced to a fine yellow pinpoint extremely pleasing to point on. One officer occupied four stations of a quadrilateral at night by alternating each four of the sixteen positions taken with and without the amber filter. He closed the triangles with observations made under both conditions, and found the closures when using the filter were consistently better, not to any great extent, but in some cases possibly enough to cause a triangle to close to within the required limit, when otherwise it would not have done so.

In addition to the application of filters to theodolites there is yet the possibility of using monochromatic light at the source for triangulation signals at night. This is, so far as is known, an unexplored field.

The use of filters on reconnaissance instruments should prove of benefit to the observer. Reconnaissance engineers should be given a

somewhat wider choice of colors than other observers. The nature of his work may be placed in the experimental class and it is essential that he be equipped with every possible means for improving visibility. It is a well known fact that a camera equipped with a fast lens and an infra red filter will record, on material having a high degree of sensitivity to infra red light, objects invisible to the unaided eye. It does not follow, however, that when the eye replaces the sensitized plate that the very long wave filter is of especial advantage. However, it has been observed that when the distant horizon is viewed through a filter (the shade of the filter depending somewhat upon existing atmospheric conditions) the various ridges will stand out more clearly than when no filter is used. Mr. J. H. Churchill of the Nigerian Survey Department in one of his several articles on this subject appearing in the Empire Survey Review speaks of using the tinted cover glass of his eight power Zeiss binoculars for this purpose. Mr. Churchill's statement is somewhat as follows: The day was fine and sunny, but there was a faint haze which limited visibility to fifty miles. He set up his theodolite and searched the horizon in vain for a hill known to exist 65 miles distant. He also failed to distinguish the hill with the unaided eye, but when he used the binoculars equipped with tinted cover glass he saw the hill faintly, but with each detail of its outline clear. After having located the hill he tried again to pick it up with the theodolite with the same poor result. This shows an increase in visibility of 30 per cent with the tinted cover glass and had the proper filter glass been used the result would probably have been still more favorable. Mr. Churchill does not state whether or not he used the binoculars without the tinted glass, and this fact makes the conclusion somewhat questionable in that the magnification of the binoculars is lower than that of the theodolite.

The use of color filters is a very interesting problem and one well deserving more study and experiment. The use of proper shades of filters will increase the output of a field party as well as improve the quality of results. Even the indication of this possibility should encourage those interested to proceed with further investigations.

THE ROYAL RESEARCH SHIP RESEARCH*

By Dr. H. Spencer Jones, F.R.S., Astronomer Royal

The destruction of the non-magnetic ship CARNEGIE by an explosion, at Apia, Western Samoa, on November 29, 1929, brought to a sudden end the magnetic survey of the oceanic areas, which had been carried on for twenty-five years by the Carnegie Institution of Washington. The CARNEGIE had been specially designed and constructed for obtaining magnetic observations at sea. She was a hermaphrodite brig, built of white oak and pine, with copper or bronze fastenings, and with a displacement of 568 tons. She was equipped with an auxiliary engine, capable of giving a speed of about 6 knots in calm weather; the engine was of internal combustion type and, at first, used gas generated from solid fuel, but, as this proved not altogether satisfactory, petrol was substituted. Sufficient fuel was carried to give a cruising range of 2,000 miles at 6 knots. With the exception of cast-iron pistons for the cylinders of the engine and the steel cams necessary for operating the valves, amounting in all to less than 600 lb., no magnetic material was used in the construction of the ship.

In six cruises between 1909 and 1921, the CARNEGIE traversed 252,702 miles in 3,267 days actually at sea. Her last cruise was planned to extend from May 1928 to September 1931 and to cover 110,000 miles. It was designed to determine the secular change of the earth's magnetism in all oceans, by making numerous intersections with the tracks of previous cruises. Nearly one half of this cruise had been completed at the time of her loss.

The results obtained by the CARNEGIE were placed freely and promptly by the Carnegie Institution at the disposal of the British and other Governments, for use in the construction of world magnetic charts. Successive issues of these charts were based to an increasing extent upon the data provided by the CARNEGIE.

The secular changes of the magnetic elements at any given place are not constant quantities. Extrapolation over long periods may therefore lead to considerable errors. The continual accumulation of observations is necessary in order to determine both secular change and the rate of change of the secular change of each element. At the present time, the magnetic data are most uncertain in the Indian Ocean. The last cruise of the CARNEGIE in the Indian Ocean was in the year 1919. The cruise on which she was engaged at the time of her destruction was to have taken her into the Indian Ocean in 1930 and 1931. In South Africa there has been a considerable decrease within recent years in the secular change of the magnetic declination, and in Western Australia there has been a considerable increase. There are no data available as to how the secular change is altering in the southern Indian Ocean between South Africa and Australia. The magnetic charts for this area are therefore based at present upon very uncertain extrapolations. In other areas, where the magnetic elements are known at present with reasonable accuracy, the extrapolated values would become less and less reliable in the course of time, in the absence of further observations, such as were provided by the CARNEGIE, to serve as a control on the changes in the secular variations.

In view of the fact that Great Britain is the principal maritime nation, the British Government has accepted the responsibility of providing accurate magnetic data at sea, and a non-magnetic ship is to be built, equipped and operated for this purpose by the Admiralty. The ship is to be known as the Royal Research Ship RESEARCH (R.R.S.RESEARCH), and she will fly the Blue Ensign and Jack with the yellow Admiralty anchor in the fly.

The plans for the new ship have been prepared at the Admiralty and it is hoped that the construction will be commenced shortly. The Department of Terrestrial Magnetism of the Carnegie Institution of Washington not only placed at the disposal of the Admiralty all information with regard to the

* By courtesy of "Nature", August 8, 1936.

construction and the instrumental and other equipment of the CARNEGIE, but also generously gave the services of Mr. W. J. Peters as consultant, without charge. The experience and advice of Mr. Peters, who commanded the CARNEGIE on her first two cruises, have been of the greatest value in the design of the ship and of her equipment.

The R.R.S. RESEARCH will be somewhat larger than the CARNEGIE. She will have a displacement of 650 tons and will be brigantine rigged. She will be provided with a single screw Diesel engine and will carry sufficient oil fuel to give a radius of action of about 2,000 miles at 6 knots. Her cables will be of bronze, instead of the hemp rope used in the CARNEGIE, and to some extent brass or bronze will take the place of wood. She will carry a total complement of 31, including the commanding officer, three deck officers, three scientific workers, a surgeon {who will also be a scientist) and an engineer.

The work of the R.R.S. RESEARCH will not be restricted solely to magnetic observations. She will undertake observations of atmospheric electricity. Such observations are particularly valuable at sea, where the air is less contaminated by suspended impurity than it is on land. It may be recalled that it was by means of observations on the CARNEGIE that it was established that the maximum potential gradients are related to Universal Time and not to the local time of the place of observation. The RESEARCH will be provided with an oceanographic winch and motor for oceanographic work, will carry an echo depth sounding gear, and will also make meteorological observations, including upper air observations by means of pilot balloons.

The principal magnetic instruments for observations at sea will be a marine collimating compass for observations of declination; a sea-deflector, for observations of the horizontal intensity; and a marine dip inductor for observation of the dip. The collimating compass is a modification of the standard marine liquid compass. The magnet system carries four concave speculum mirrors, adjusted so that their optical axes are in the direction of the four cardinal compass points. A scale is mounted in the focus of each mirror. The four scales are carried on arms attached to the magnet system. The angle between the sun, when at low altitude, and one or other of the four compass points, as defined by the scale images, is measured with a sextant, the scales being viewed through windows in the compass bowl. This observation provides the means of calculating the magnetic declination. The compass will be mounted in such a position that it will have as clear a view of the horizon as possible.

The sea deflector consists of a marine compass, provided with permanent attachments, whereby a deflecting magnet can be mounted in a horizontal position and vertically above or below the compass magnet system. The bowl is rotated until the deflecting magnet is perpendicular to the compass magnet, as shown by the reading of the card. The angle of deflection is read on a graduated scale on the edge of the bowl. The deflector is mounted in an observatory adjacent to, and forward from, the chart room, in which is the standard compass. As the observer at the deflector reads off the angle of deflection, a second observer at the standard compass reads off the direction of the ship's head. The horizontal intensity is proportional to the cosecant of the deflection. The constant of proportionality is determined periodically by simultaneous observations ashore, with the sea deflector and land magnetometer.

The marine earth-inductor follows the general design of earth-inductors, but is provided with a special gimbal stand that is not affected by the rotation of the coils. It is important, for observations at sea, that It should be driven at a constant speed, and a special tuning-fork controlled rotary converter, situated in the after part of the vessel and driving through an articulated phosphor-bronze shaft, will be provided to ensure this. Two galvanometers, one of the moving coil type, with short period, and the other of the string type will be provided and experience will be gained at sea of the relative suitabilities of the two types. The

earth-inductor will be mounted in an after observatory.

Portable instruments for land observations, at fixed magnetic observatories and elsewhere, will also be carried. The designs of the instruments have been based on the Carnegie Institution designs, with such modifications as were suggested by experience on the CARNEGIE or as seemed desirable for various reasons.

The magnetic observations on the R.R.S. RESEARCH will be made primarily in the interests of navigation. But they will provide at the same time valuable information about the earth's magnetism, which is needed for the investigation of such matters as the non-potential portion of the earth's field and the line integrals around closed contours on the earth's surface.

EMPIRE SURVEY REVIEW

We wish to thank the "Empire Survey Review" (No.20, Vol. III.) for the very frank and comprehensive review of our Field Engineers Bulletin Ho. 9.

The review of PLANE TABLING (Fourth Edition) Survey of India Handbook of Topography, Chapter V, published by order of Brigadier H. J. Couchman, D.S.O., M.C., Surveyor-General of India, Calcutta, 1935, contains several pertinent remarks which will be appreciated by all topographers.

> "Plane tabling methods may be summed up as a really straight straight-edge, clean fingers, a sharp pencil, and a puritanical conscience.
>
> "Traversing on the plane table is given a good deal of space just because it is so difficult to do. The fact is that the plane table is a thoroughly bad contrivance for this purpose."

It is noted from the review that some difference in opinion exists among British, Indian, and African surveyors concerning the type of "tops" or paper to be used in plane tabling. We wonder if our aluminum mounted, sealed bristol board sheets have been tried. Anyone who has used the new sheets will be impressed with the accuracy which can be obtained from them, as well as the pleasing quality of the paper surface, and the lack of any distortion due to changing humidity.

A most interesting section of the "Empire Survey Review" entitled "Jottings" always carries interesting, humorous, and human anecdotes from field experiences. The No. 20, Vol. III, has several papers under the heading "Some Survey Oddities from British North Borneo". The vicissitudes and experiences related therein make us homesick for another visit to Sandakan where, in days gone by, we were wont to exchange yarns with our British friends during our brief stops in that outpost for supplies. The dim shape of Kini Balu, rising faintly over the southern horizon beyond Banguey is familiar to our field engineers who have worked in the southern Sulu Sea, especially around Balabac Island.

BOGOSLOF ISLAND

George E. Morris, Jr., Jr. H. and G. Engineer
U. S. Coast and Geodetic Survey.

The first complete survey of the active volcano, Bogoslof Island, was accomplished from the Ship DISCOVERER, E. B. Campbell, Commanding, during the 1935 season. The following paragraphs are from the Descriptive Report of the topographic survey.

Bogoslof Island consists of two islands, the main island and Fire Island (first called Grewingk) connected by a rocky bar which bares in spots at mean lower low water. Fire Island resembles a medieval castle which rises nearly perpendicularly from the water. The "mainland" consists of Castle Rock, the Plateau, and the Volcano. Castle Rock (pinnacle rocks) has two summits, sharp in outline rising at the southwestern edge of the plateau. The plateau ends in a vertical cliff along the beach but breaks away in a series of steps to the north. The volcano, a rounded mass of lava, is northwestward of Castle Rock.

Both Fire Island and Castle Rock are beginning to disintegrate and the movements of the nesting fowl start minor rock slides from time to time. The volcano is of more recent formation (reported by the Coast Guard Cutter "Northland" in 1927). It is a mound of porous lava rock or cinders, l40 feet high, that has weathered but little and is still sharp and rough. Steam mixed with a trace of sulphur fumes issues gently from cracks near the top of the volcano. In a few places the rock feels warm to the touch.

The pond at the base of the volcano is salt water with some sulphur in it. The surface is four feet below high water, but a very high tide will cause the pond's surface to rise about a foot. This height is not reached until several hours after the time of high tide. A very low tide does not affect the elevation of the pond. Gas from the volcano bubbles through the water near the southern shore of the pond. This gas has no odor. The surface temperature of the water measured several times during June, July, and August was 68° F. This is several degrees warmer than the sea water and much warmer than the average air temperature. On the warmest days all members of the party went in swimming. The bottom drops away from the shore at an angle of about 60°. There is a large amount of drift wood scattered along the shore of the pond. This undoubtedly was washed there during an extremely high tide when the water covered the low sand barrier between the pond and the sea.

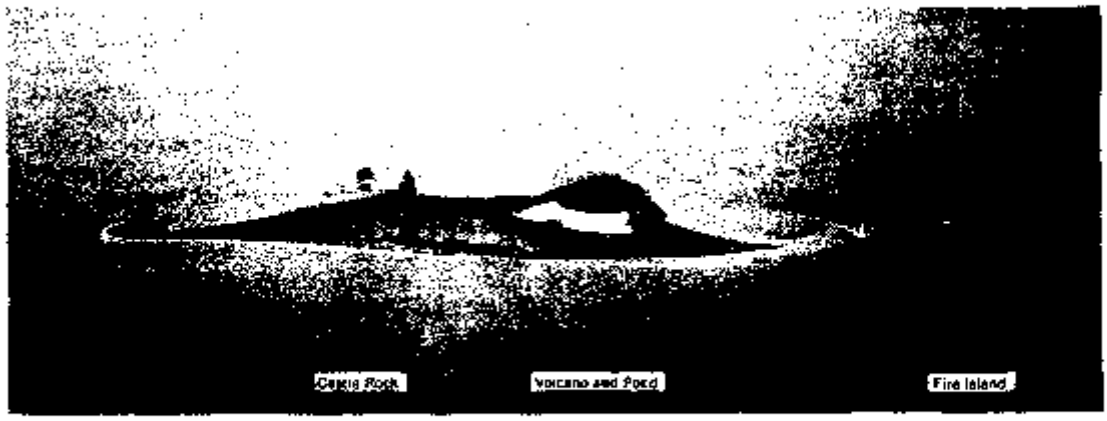
The plateau of the island is a mixture of black sand, lava dust and cinders, and rock.

The beach is black sand except along the northern spit, where it is pebbles and small boulders, and around the volcano, where it is rocky. The sand is unstable and shifts with the sea. The spit on the southeast end of the island hooks toward the west when the sea has been easterly for a continued period and toward the east when the sea is westerly. Both extremes which were observed between June 19th and August 28th are shown on the sheet. The rocky portions of the beach are more stable.

There is a small patch of wild rye (Elymus mollis trin) and a narrow fringe of a low creeping vine along the easterly shore of the pond. Another very small patch of wild rye is on the plateau. There are numerous small tufts of grass and a very short green moss on the plateau and the eastern slope of Castle Rock. The sea gulls spread the wild rye and other seed in making their nests and in a few seasons the plateau will be covered with grass and moss unless there is

BOGOSLOF ISLAND
1935

Courtesy United States Navy



Bogoslof from the air, bearing southwestward

Bogoslof from the air, bearing southeastward

another volcanic eruption. At present the vegetation is too sparse to change the grayish black hue of the island as seen from the sea.

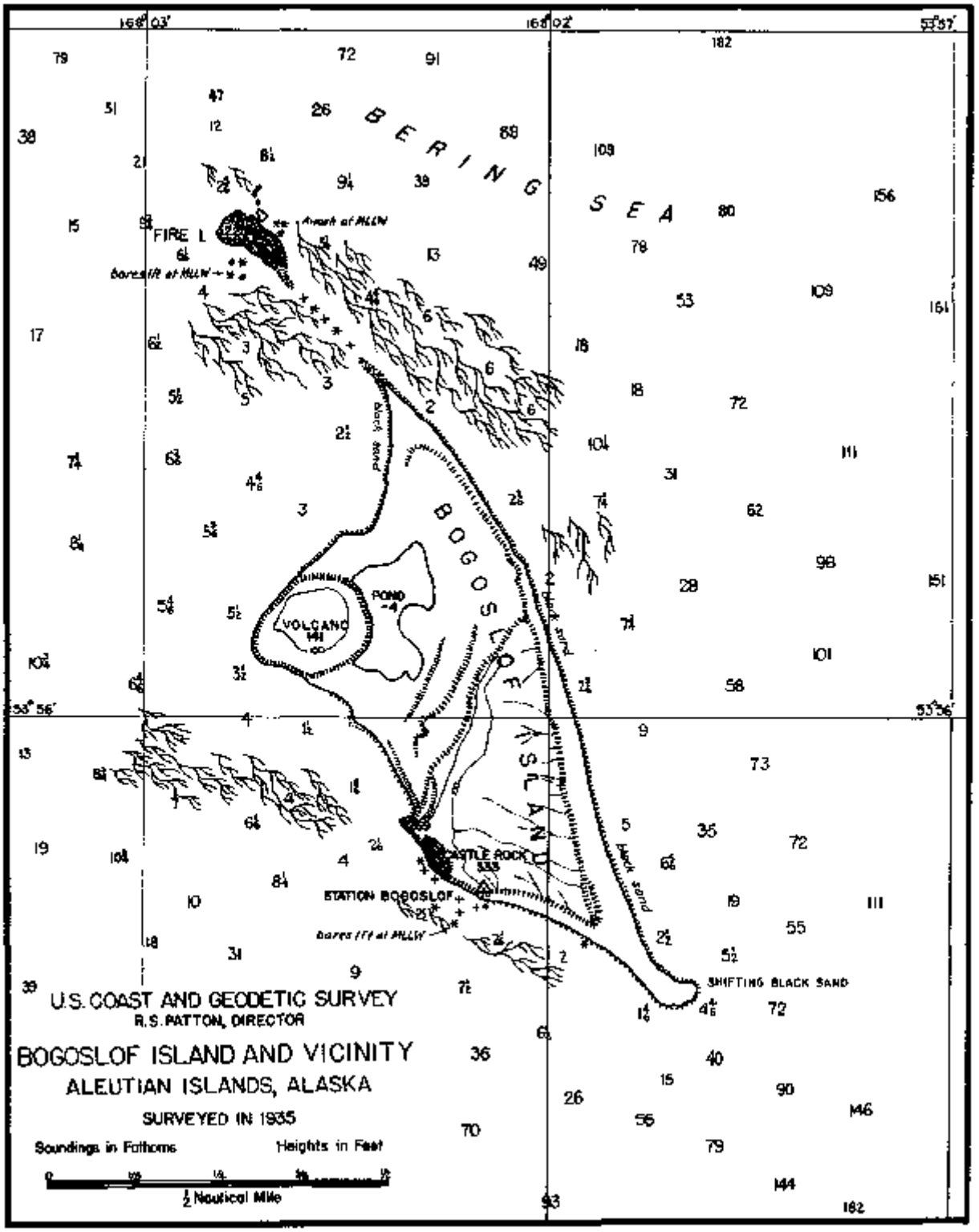
There was no fresh water on the island so all drinking water was brought ashore in kegs. The washing was done in sea water.

The island is used as a breeding ground by sea lions. There were hundreds of sea lions along the sand beaches of the island on the first of June. At that date most of the sea lion calves had been born although there were a few born as late as June l6th. A rough estimate would apportion the cows and bulls at about twenty cows to each bull. At this time of the season the bulls jealously guarded the cows, always staying between the cows and the intruders. Both bulls and cows would abandon the calves and get out of possible danger. The calves would make small effort to escape, but would bawl loudly when handled by anyone. When the calves were about two months old they became more wary although at three months they could be approached when asleep. About the second week in July the bulls and cows began leaving until near the first of August there was only one cow for every six or eight calves and about fifty bulls left on the island. Each cow would herd about six or eight calves, keeping them in the water a good deal of the time evidently teaching them the fine points of swimming and fishing. The roar and barking of the entire herd made a continual sound like an airplane a short distance overhead. The herd was quiet for only a few of the very early hours of the morning. When the camp was first established the sea lions were very timid and wouldn't allow one to get close to them, but as they became more accustomed to us they became more indifferent; in fact, the rodman had trouble getting them to move so he could rod in the high water line without walking among them. I found it difficult to approach close enough to get close-up snapshots with a camera.

About one thousand sea gulls (glaucous gull) were nesting on the plateau. The nests consist of slight hollows in the sand lined with a wisp of grass or a short piece of kelp. The gulls lay two or three eggs in a nest about the first of June. They did not replace any eggs taken after the third week in June. One of the party placed a dozen eggs in one nest and the gulls had distributed the eggs so there were no more than three in any nest by the following morning. The eggs hatched the latter part of July. After the young had hatched, the gulls would try to rout intruders by swooping at them in a "Power dive" and by setting up a great racket. Occasionally a gull would drop a murre egg near the intruder but this was more likely by accident than by intent.

The pallas murres arrived between the first and fifteenth of June. There were fifty thousand of them by a conservative estimate nesting on the pinnacle rocks and Fire Island. They laid a single egg pushed against the side of the cliff.

The sea gulls preyed on the murres, stealing the eggs when the murres left them. The gull would sometimes break open the egg and eat it, but usually would carry it away in its beak or throat. When the young gulls were hatched the old ones swarmed around the murres to steal eggs. I've often seen a gull tug at the tail feathers of a murre to get it to move while a second gull would take the egg. The gulls would carry eggs in their beaks for a quarter of a mile to their nests. Early in August when the murres began to hatch, the gulls would steal the young murres and swallow them head first at a gulp or carry them away to feed to the young gulls. The murres would try to fight off the gulls from the young, but the gulls would hover around until their opportunity came to steal either an egg or a murre. The murres stopped laying eggs near the middle of August. The gulls would try to take the murres from one another while in flight and several murres would change captors in mid-air. A few fell to the ground and escaped for the moment. When the young murres grew so large that the gulls could no longer swallow them, the gulls would carry them away and de-


BERING SEA
BOGOSLOF ISLAND
FIRE L
VOLCANO
POND
CASTLE ROCK
STATION BOGOSLOF
SHIFTING BLACK SAND
U.S. COAST AND GEODETIC SURVEY
R.S. PATTON, DIRECTOR
BOGOSLOF ISLAND AND VICINITY
ALEUTIAN ISLANDS, ALASKA
SURVEYED IN 1935
Soundings in Fathoms
Heights in Feet
½ Nautical Mile

capitate them and eat all but the feathers and the breastbone. A few gulls that were killed were eaten by other gulls.

A few cormorant nested in inaccessible places on Castle Rock and Fire Island. A few sea parrots (tufted puffins) nested in the crevices of the volcano, hiding their eggs from the thieving gulls.

Toward the end of August a large flock of sabine gulls came to the island and fished in the surrounding water. Nearly all of the birds had left the island by September 15th.

Swarms of furry covered flies infested the loose rocks around the pinnacle rocks. These were very sluggish even on warm days and did not bother our camp.

The murres were pestered by a tick about the size and appearance of a small wood tick. These became especially numerous the second week in August. As many as one hundred were picked off the inner walls of the tent each day for a week. Several got on the members of the party but only one tick drew blood.

Bogoslof Island has a local reputation for shifting position rather frequently. This can be accounted for by two reasons other than faulty navigation. Although the island is small it presents a marked difference in appearance when viewed from different directions. Anyone glimpsing the island from different directions on widely separated occasions might believe the island to have changed. The charted positions of the shorelines of Unalaska and Umnak Islands in the vicinity of Bogoslof are in error by a few miles. A navigator taking his departure from different points on Unalaska or Umnak Island would obtain different dead reckoning positions of Bogoslof Island which would create the impression that Bogoslof had shifted in position.

The position of Eogoslof may change the next time the volcano erupts, but that can be proved only after the next eruption. Until then it is doubtful if there will be any major change in the configuration of Bogoslof Island.

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A reference list of the physiographic history of Bogoslof Island, prepared in 1934 by Dr. Helen M. Strong, then of the Field Records Section, Coast and Geodetic Survey, is reprinted here for those interested. In addition to published material, the data include letters, photographs, and blueprints in the files of the Survey.
Editor.

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National Bird and Animal Reservations In Alaska in charge of United States Department of Agriculture, U. S. Department of Agriculture, Bureau of the Biological Survey, Circular 71, 1910, p. 15: an executive order signed by Theodore Roosevelt, dated March 2, 1909 establishes the Bogoslof Reservation for the protection of native birds. It includes all the volcanic islets in the group. Map.

*Jaggar, T. A., Jr.: Journal of the Technology Expedition to the Aleutian Islands, 1907. The Technology Review, Jan., 1908, map between pp. 6 and 7, picture between pp. 18 and 19, and text pp. 30 to 32; also diagrams and pictures. P. 32. Series of diagrams, showing changes in island 1826-1907.

VIEWS OF BOGOSLOF ISLAND

TAKEN IN 1935

Bogoslof Island bearing northeastward

Fire Island bearing northwestward

Fire Island bearing southward

The Volcano and Fire Island bearing northwestward

Castle Rock bearing northwestward

Castle Rock bearing eastward

The Plateau and Castle Rock bearing southward

Sea Lions

Merriam, C. Hart; Harriman Alaska Series, Vol. II, 1910, Smithsonian Institution, pp. 291 - 336 complete history of the area, and discussion of physiographic and volcanic activities. Best and most comprehensive of all the references. Bibliography.

Report of the Cruise of the Revenue Steamer Corwin, for 1884 and 1885 pp. 45 - 46 and illustrations; p. 6 and illus.

*Science Vol. III, no. 57, March 7, 1884, pp. 282 - 286, text and illust., by George Davidson, Asst., U. S. Coast and Geodetic Survey; not so complete as the article by Merriam, but so far as it goes, excellent.

Munger, Capt. P. M., Senior Captain U.S.R.C.S.: A Jack in the Box, an account of the strange performance of the most wonderful island in the world; Nat. Geog. Mag., 1909, vol. 20, No. 2, Feb. 1909, pp. 194. - 199, text, map, illus. (not as accurate a statement as those cited above).

Pictures in Coast and Geodetic Survey files. #1828-1, 1828-2, 9804-9822; and with letters listed below.

Alaska Pilot, Part II, 1931, PP. 288-289.

*Jaggar, T. A., Jr.: The Evolution of Bogoslof Volcano, Bull. of the American Geographical Society, 1908, Vol. 40, No. 7, pp. 385 - 400. Excellent, and detailed. Photographs, series of maps and corresponding sketches 1826 - 1907.

*Dall, W. H.: Agashagok or Saint John the Theologian, Annual Rept. C. & G.S., 1886, pp. 115 - 116; and Science, Jan. 25, 1884.

Coast and Geodetic Survey Piles.

Letters:		Blueprints:
1920 -- 319	1926 -- 409*	12227
1920 -- 381	1928 -- 12	18549
1922 -- 316*	1932 -- 822	25933
1923 -- 336	1934 -- 110	25934
1926 -- 313		

Coast Guard Sailing Directions, Survey files.
Bering Sea, 1933, par. 6l.

Surveys by Coast and Geodetic Survey - topographic No. 6433 and hydrographic No. 5965. Also descriptive reports accompanying these surveys.

Physiographic History
1796 - 1909

Bogoslof Island: The location as determined by the Coast and Geodetic Survey in 1935 is latitude 53° 56' N., longitude 168° 02' W.

1768 or 1769 - Ship or Sail Rock, Krenitzin and Levasheff. On their map of 1780. H. 321+. Dall does not believe that this is the rock known for years to the Aleuts.

1778 - Capt. Cook, Oct. 29, 1778, discovered an elevated rock-like tower near the same place. H. 322+.

1796 - May 7, 8, Bogoslof Island thrown up - H. 291+. Ship Rock a short distance to northward. Earthquake - falling rocks.

* Photographs or illustrations included.

l806 - Langsdorf - reports natives' account of upheaval of Bogoslof 1795. H. 293*.

1817 - Kotzebue - Bogoslof Island increased in height and size. H. 322+.

1820 - June 2. Imperial sloop "Good Intent". Attempted landing, but heavy breakers prevented. H. 295+.

1826 - Ship Rock and Bogoslof Island on Krusenstern's chart. H. 322+.

1832 - Lütke quotes Tebenkof as saying Bogoslof not more than two nautical miles in circumference and 1500 feet altitude. Sketch by Tebenkoff, H. 296+.

1872 - Dall, W. H.: Bogoslof shown on Sketch 17. Annual Rept., C. & G.S.

1873 - Dall, W. H.: Observations prove reef does not extend from Bogoslof to north end of Umnak Island. Believes position approximated by Lutke most nearly correct. Position on Sarycheff's Chart in gross error. Ship Rock and other rock nearby have same relative position and height assigned to them by Sarycheff. No crater, and Island merely a jagged mass of rock upheaved through some channel by volcanic ejection.

Ship Rock is a perpendicular square-topped pillar, half a mile north and west of the north end of the island.

A small rock, also given on Sarycheff's chart, half a mile north and east of the island, rises only a few feet above the water. Scattered breakers were observed on all sides of the island except the west, and especially east-southeast of the island, and extending less than three-quarters of a mile from shore, numerous observations indicate the height of the summit as 844. feet. The position is farther to the north and east than any of the charts place it. C. & G.S. Annual Rept. 1873, pp. 115-116.

1873 - Ball, W. H.: Sketches of island H. 296-7+. His sketches to scale, and proportions corrected by horizontal and vertical angles. (Note H, 297;) Science Jan. 25, l884.

1883 - Sept. 27, New Bogoslof or Grewingk or Fire Island. First seen by Capt. Anderson of Schooner Matthew Turner, Sept. 27, 1883. It is about one-half mile northwest of Old Bogoslof. H. 303-305+.

l884 - May 21. First landing on New Bogoslof, Revenue Steamer CORWIN (Capt. M. A. Healy). He visited it four times during 1884 and 1885. The two volcanoes were connected with a broad bar or isthmus. H. 307+.

1884. - May 28, Lieut. George M. Stoney of the Navy arrived at Bogoslof, and spent three days making soundings around island. H. 310+.

1884. - Sept. 10. Corwin. H. 311+.

1885 - June 9) Corwin. H. 311+.
Sept. 14)

1887 - Wm. G. Greenfield. Bar connects Old and New Bogoslof. E. 312+.

1890 - Aug. 2. Albatross, Capt. Z. L. Tanner. Ship Rock fallen. Old and New Bogoslof connected, and total length, including spit, 1¼ miles. H. 312+.

1891 - C. H. Merriam and T. C. Mendenhall. Albatross grounded on sunken pock. Albatross, Command Capt. Tanner. Bar had disappeared. Only spits remained. Open channel about quarter mile wide between Old and New Eogoslof. H. 3l3+.

1891 - August, Lieut. D. H. Mahan, U.S.N. Pecit. Tracing (filed as C. & G.S. Blueprint 12227). Sketch.

1892 - Photographs - C. & G.S. #1828-1, 1828-2.

1893 - Capt. Tanner reported volcano in eruption "as usual" - probably-meant it was steaming violently. H. 317+.

1895 - Eecker and Dall of U.S.G.S. visited Bogoslof. Apparently "clear passage, nearly three quarters of a mile in width, separated the two islands*. H. 317+.

1897 - Dr. Leonard Stejneger passed north of island and photographed it. New Bogoslof flattened on top. H. 3l9+.

1899 - Harriman expedition photograph showed flattened form of New Bogoslof. E. 320+.

1906 - May. Metcalf Cone (Perry Peak) reported between Old and New Bogoslof by "Albatross". Lieut. Stromberg on revenue cutter "Perry" sketched Metcalf Cone attached to New Bogoslof, but separated by seven fathoms of water from Old Eogoslof. J. 32+.

1907 - July 4. "McCulloch" revenue cutter, found Metcalf Cone broken in two, extending itself into McCulloch Peak on the south, and a bar connected islands again. J. 32+. C. & G.S. Photographs # 9804, 9805, 9806.

1907 - Sept. 1. McCulloch Peak exploded, sand and dust fell 100 miles to eastward. J. 32+.

1907 - Oct. 15. Revenue Cutter McCulloch visited spot, and found watery lagoon at south base of Metcalf remnant. McCulloch Peak was gone, and all the rocks covered with heavy mantle of volcanic debris. "No such extraordinary story of growth and alteration of an island in the sea in a history that has lasted one hundred and eleven years has ever been told in the records of science before, and the changes of the last sixteen months are unique in the records of volcanology." Sketches of island. Photographs in. C. & G.S. # 9807, 9808, and J. 32+.

1908 - June 20. U.S.R.C. RUSH (Photo in C. & G.S.) found a ridge connecting Fire Island (New Bogoslof) and Castle Rock (Old Bogoslof). Perry Peak (Metcalf Peak) had disappeared. Spits from both Fire Island and Castle Rock. Photographs C. & G.S. # 9809, 9810, 9811, 9812.

1909 - June 20. U.S.R.C. RUSH (Photo in C. & G.S.) Spit extends from Fire Island toward Castle Rock, separated by clear channel from ridge leading to Castle Rock. (Castle Peak). Photographs C. & G.S. § 9813, 9814, 9815.

1909 - Sept. 20. U.S.R.C. RUSH. (Photographs in C. & G.S. # 9816, 98l7, 9818, 9819, 9820, 9821, 9822). Clear channel, spits and low ridge in same position as June 20, 1909: Steam rising half way between Fire Island and Castle Rock, within the long ridge extending from Castle Rock (Old Bogoslof) toward Fire Island (New Bogoslof).

1920 - Aug. 10, 1920, Coast Guard, Bothwell's cruise to Bogoslof Island. (C. & G.S. Letter 319, for 1920). Landed on lee side of island.

Bogoslof consists of two small islands with passage between. Depth of passage could not be obtained, but from discolored water and breaks, believed not passable for seagoing vessels. No evidence of recent eruption. All water in vicinity of islands was same temperature as the sea water, - 44°. None of the land or crevices were above normal temperature.

Location based on good observations of the sun found to be 6½ miles west of its charted position, in lat. 53° 59' N., long. 168° W.

1920 - Dec. 27, (C. & G.S. Letter 381 for 1920). Blueprint of sketch made by Bothwell, Aug. 9, 1920.

1922 - Sept. 11, (C. & G.S. Letter 316 for 1922, including report, four photographs, blueprint by Wm. T. Stromberg, Commander Coast Guard Cutter ALGONQUIN. Castle Rock peaks 400 and 350 feet elevation surrounded by a plateau which is apparently uplifted sea bottom. From this on the north side a long sand spit extends, forming an island about one nautical mile long north and south. Channel between Castle Rock and Grewingk (Fire) Island passable by vessels of moderate draft. All rocks cold and no indication of volcanic activity. Castle Rock seemingly solid, though subject to erosion, but Grewingk of softer material which is disintegrating more rapidly. Stromberg estimates it to be only about one-eighth its 1906 size. Soundings a few hundred yards off shore seem not to have changed as compared with 1906.

1923 - July 30, (C. & G.S. Letter 336, J. F. Hottel, Coast Guard Cutter HAIDA, and C. & G.S. blueprint 18549). Bottom found with sounding machine at 110 fathoms about ½ mile off the beach on the northeastern side of the islands. Vessel anchored in 17 fathoms, 600 yards from shore, Castle Rock bearing 209°, Sea Lion Spit bearing 280° and Fire Island right tangent bearing 297°. Found bottom gradual incline to beach. No evidence of volcanic activity. Rocky portions of islands appeared unchanged as compared with conditions of Sept. 11, 1922, reported by the ALGONQUIN, but sandy portions had changed (compare two blueprints), evidently due to action of wind and sea. Fire Island appeared unchanged. Heights of Castle Rock and Fire Island as observed by the Haida's party are considerably lower than those reported by the ALGONQUIN.

Camp site used by Mr. Kleinsmith last summer was observed. Tent stakes and tackle legs still in place, and little drift of sand had occurred there.

No attempt made to land on Fire Island. Sides so steep that a climb to top would be difficult. Shore party, in charge of Lieut. Comdr. C. H. Jones, using compass, range finder, and sextant made as thorough a survey of the island as time allowed. Weather precluded taking of astronomical observations, but some good pictures were obtained.

1926 - May 31. (C. & G.S. Letter 313, signed by F. S. Van Boskerok Coast Guard cutter UNALGA) - "checking distance off Castle Rock by bow and beam bearings (2.2) miles with latitude of vessel from meridian altitudes by three officers (which agreed within one mile) place this group of islands five miles to the southward of the charted position. This agrees with results obtained last year under similar conditions, except that the vessel was to the northward of the group at apparent noon."

1926 - July 24 (C. & G.S. Letter 409, signed by W. H, Shea, Commanding Officer, Coast Guard cutter HAIDA, including blueprint and photographs). Approached from south and eastward to within 350 yards of shore in soundings of forty-two fathoms. In 1924 HAIDA anchored in 20 fathoms within two hundred yards of shore, but writer considers this dangerous. Passage between Castle Rock and Fire Island closed by new made land. In 1924 the passage was about 300 yards wide and from 2 to 2-3/4 fathoms deep. In 1924, there was no land west of line drawn from the west base of the Castles and the left tangent of Fire Island. Now there is a sand spit running north which forms a cove. Yacht WESTWARD reported it as a sheltered anchorage with 15 fathoms soundings. New land low, apparently formed by tidal currents and winds working on the soft lava deposits. A small spit with several large rocks, extending north from Fire Island appears to be new land.

The southeast point of Castle Island has been built up to the southeastward for a distance of approximately 200 yards.

Volume of steam observed rising from three points at base of cliff to the northeastward of the Castles. None observed in 1924. Elevation Castle Peaks, 368 and 315 feet; of Fire Island 270 feet. (Note: Both Fire Island and Castle Rock seem to be more weathered and worn down than in the 1909 C. & G. S. photographs. H. M. S.)

1927 - Sept. 27. (C. & G. S. Letter 12, for 1928, Daily Memorandum from H. O. dated Jan. 3, 1928). The island was 4 miles south of its charted position and possibly one mile to the eastward. Castle Rock and Fire Island connected by a long sand spit. Great activity has taken place and is now in progress. A new mound has arisen about 175 feet above the plane of the island in approximate former position of Metcalf Cone and McCulloch Peak. A great amount of steam was escaping from this new mound or cone. Approx. pos. lat. 53° 59' N., Long. 168° 00' W.

1932 - Nov. 30. (Rept. C. G. from Capt. John Boedeker, Commander, Bering Sea Patrol Force. - see C. & G.S. Letter 822, and blueprints 25933, and 25934. Memo from Field Records Section attached). "Position of Bogoslof Island replotted and placed on chart at lat. 53° 57' N., long. 168° 01' W., the average of four astronomical observations, because positions obtained thus are, more accurate than those by dead reckoning". Quoted from memo. Contains a summary of positions reported.

1933 - Coast Guard "Notes and Sailing Directions Bering Sea, 1933". Par. 6l. Generally accepted position is in lat. 53° 55' N., long. 167° 58' W. This position checked with a run made by the CHELAN in 1933, starting from Cape Cheerful. Last record of a landing was of the TALLAPOOSA in 1931. Island was approached from south, steering 0° true for the larger of the two peaks. Landing made on beach without difficulty. Pilot of the S.S. STAR has anchored several times 500 yards offshore. The only danger is a long sand bar which makes out from northwest point.

1934. - June 30, 1933. (C. & G.S. Letter 110, Coast Guard Cutter SHOSHONE, R. L. Jack commanding). "The position of Bogoslof has been checked repeatedly and it is unquestionably true that this island is located four or five miles south of the position in which it is plotted on the chart".

Position, Height, Size

Position of Ship Rock, H. 309+. Observations by Lieut. J. W. Howison, Lat. 53° 55' 18" N., Long. 168° 00' 22" W. Lieut. George M. Stoney, Navy, Lat. 53° 55' 56.3" N., Long. 167° 57' 17.l4" W.

Position of New Bogoslof - H. 309+. by Capt. Z. L. Tanner of the U. S. Pish Com. Steamer ALBATROSS, Lat. 53° 54'.

Heights and Distances. - Lieut. D. W. Hall, H. 309+.

	Feet
Height - East pinnacle Old Bogoslof	334
Center " " "	289++
West " " "	324
Breadth base " "	933
Ship Rock " "	87.5
Width of isthmus (narrowest)	326
Length of southern spit	1824
Extreme length of island	7904
Height - Southeast peak New Bogoslof	403
Southwest " " "	475-500

++ An error because middle peak is highest part of the island.

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+H and page refers to Harriman Alaska Expedition, Vol. II, published by Smithsonian Institute in 1910.
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(See also article in the Military Engineer, May-June 1936, by Commander R. R. Lukens, U.S.C. & G.S. Editor.)

DORSEY FATHOMETER, OPERATING NOTES

F. S. Borden, Hydrographic and Geodetic Engineer
Commanding Officer, U.S. Coast and Geodetic Survey Ship HYEROGRAPHER

The survey party on the Ship HYDROGRAPHER has just closed the 1936 field season after having run approximately 12,000 miles of sounding lines. Since seventy-five per cent of this mileage was sounded with the Dorsey Fathometer that instrument has been given a thorough test.

The principles involved in the construction of the instrument are described in an article on page 12 of the Field Engineers Bulletin of December 1934. Its accuracy is also discussed therein but in my opinion the writer of the article was far too modest. The performance of this instrument under actual field conditions is to me nothing short of marvelous.

When one talks about measuring depths from a survey vessel underway with errors not exceeding two tenths of one per cent we are inclined to raise our eyebrows and yet that is exactly what the Dorsey Fathometer on the HYDROGRAPHER is capable of doing and has done, day after day, for six months. Furthermore, there has been very little delay as a result of the instrument being out of order. Dr. McIlwraith and Chief Radio Operator Nedley have done an excellent job of keeping it in operation. One of its principal advantages is that it either gives exact results or it does not give anything. There is never any question about the constancy of the speed, the variation of the initial, or the distance between the hydrophone and oscillator, all of which questions are bothersome in the 312 type of Fathometer.

Because of its accuracy and dependability the Dorsey Fathometer furnishes an excellent means of appraising the results of the deep water Fathometer which, on the HYDROGRAPHER, is the 312 type. By running both instruments at the same time and comparing the results, in depths up to the limit of the Dorsey Fathometer, definite information can be obtained regarding the performance of the deep water Fathometer without the delay of stopping to take vertical casts. Although designed and graduated for sounding only to depths of 20 fathoms, during the past season the Dorsey Fathometer could be used at times, to depths as great as 140 fathoms. Ordinarily, however, it could be carried to approximately 100 fathoms.

The method of determining and applying corrections to Dorsey Fathometer soundings during the 1936 season is shown on the accompanying plate. Field Memorandum No. 3, for correcting soundings taken with the 312 type has been followed, insofar as these instructions are applicable.

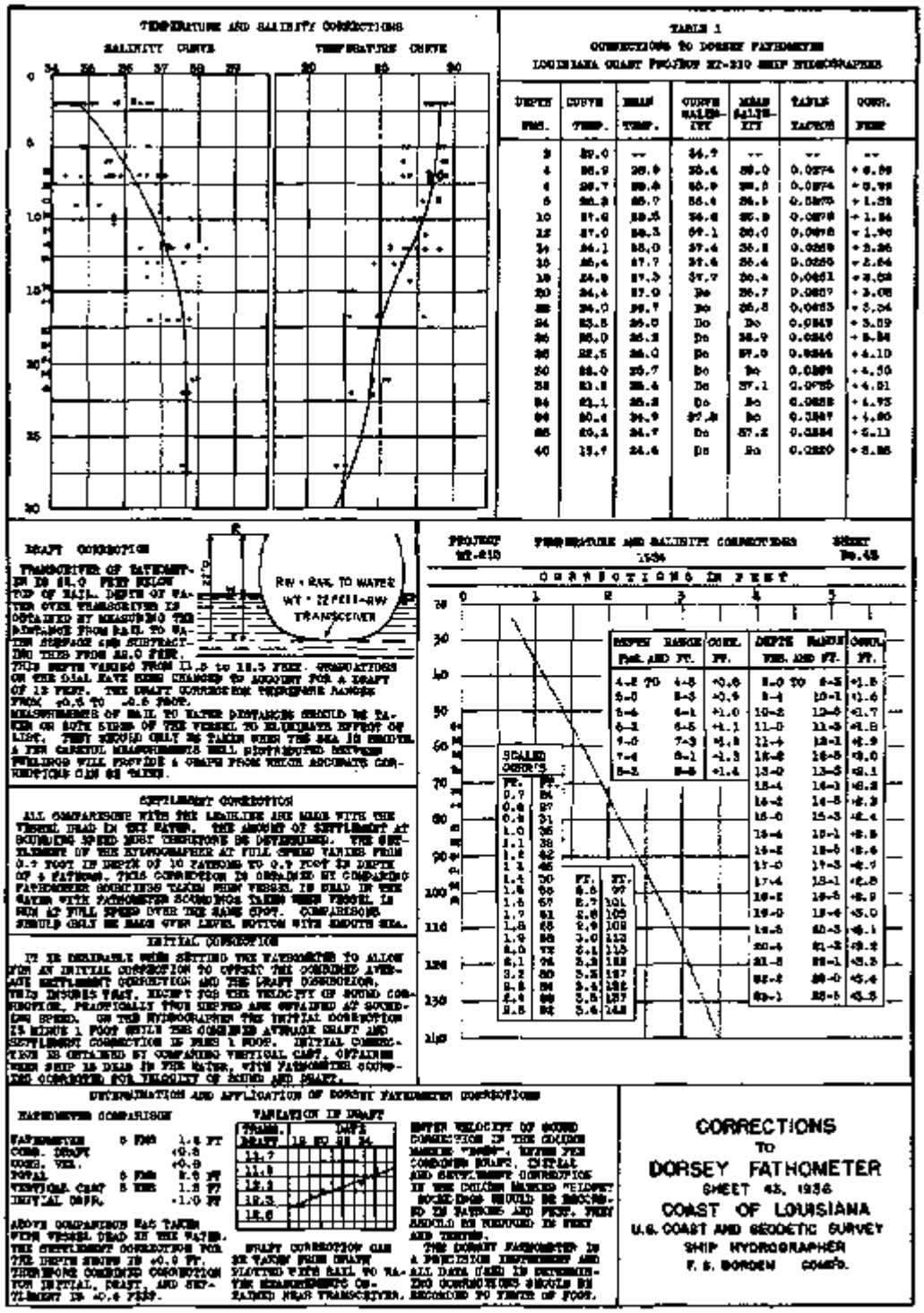
In the case of the Dorsey Fathometer comparisons of readings on it are made with vertical hand lead soundings when the vessel is stopped dead in the water. The Fathometer is then adjusted so that its soundings corrected for salinity and temperature read one foot more than the vertical casts. This one foot allowance is to compensate for the settlement of the vessel when underway at full speed, and the amount has been determined by actual tests.* This adjustment at the time made corrects for the combined errors of draft, settlement and index. Any variations of these factors will be very slight and no further correction for them need be applied to the deeper soundings.

*(So far as is known this is the first occasion on which the amount of settlement of a vessel under way has actually been measured at sea. The values determined by the Survey Vessels HYDROGRAPHER and LYDONIA confirm theoretical values shown by model basin tests.

See: Taylor, Speed and Power of Ships, pp. 21, 68, 73.Editor)

Comparisons with hand lead soundings should be made only over level bottom and with a smooth sea. Data should be read and entered to the nearest tenth of a foot. It has been the practice on the HYDROGRAPHER to use no comparisons made in depths over 15 fathoms to determine the initial setting.

The Dorsey Fathometer is a precision instrument in every respect. In my opinion each of our ships should have one regardless of where it is working or how well its deep water Fathometer is functioning. A Dorsey Fathometer used to supplement a 312 Fathometer will improve the results of the latter instrument.



THE STRANDING AND SALVAGING OF THE "FATHOMER" IN THE TYPHOON OF AUGUST 15, 1936, FORT SAN VICENTE, P. I.

Official Report of R. F. A. Studds, H. and G. Engineer, Commanding Officer, U. S. Coast & Geodetic Survey Ship FATHOMER

With only a few days left to conclude the season's work on northeast Luzon, the Ship FATHOMER was forced on Sunday, August 9, to suspend survey operations and seek shelter in Port San Vicente from an approaching typhoon. This typhoon passed about 50 miles from the ship's position on Tuesday, August 11. The barometric minimum on the ship was 29.29 inches.

An attempt was made on Wednesday, August 12, to return to the working grounds but confused seas and heavy swells compelled the ship to return to Port San Vicente. It was planned to sail again on the following day, but another approaching typhoon made it advisable to stay in the harbor.

On Friday, August 14, it was apparent, from plotting the track of the approaching typhoon, that its effect would be felt in the vicinity of the ship, and accordingly, preparations were made for the storm.

In the afternoon the ship entered the inner harbor and moored with one of the two large stock anchors. Awnings were furled and all gear securely lashed down. The following morning the track of the typhoon led to the belief that the strongest wind would be encountered from the north quadrant and the second large anchor was put down in such a position that the ship would be moored for a wind from that direction.

A scope of 7 to 1 was given the two anchor cables. The scope was governed by two conditions; first, the small amount of swinging room, and second, the condition of the port cable. This cable had been condemned the previous year and a new one ordered in the fall of 1935 by the Division of Purchase and Supply. The order was placed in the United States and the cable was not delivered in Manila until the first part of August 1936 which was too late for delivery to the ship at Legaspi. Shots of the condemned cable had been shifted so that the best shots led outboard.

Wire cable preventers were put on the two cables and additional anchors were suspended from each rail; a stockless bower anchor on the port side and a large stock kedge on the starboard side. These were secured to the largest rope on board, 6" mooring lines. These anchors were intended for precautionary measures so that if a sudden shifting of wind occurred they could be dropped and thus hold the ship's head until the strain was taken on the larger anchors.

The effect of the approaching typhoon on the weather began with moderate rain squalls about 6 a.m. on August 15. These squalls increased throughout the day in frequency and intensity. The sky was heavily overcast from early morning. Observations were sent every four hours to Manila Observatory until a message was received sending thanks and requesting more frequent reports. From then on weather conditions were reported hourly.

At noon indications were that the ship was in the path of the typhoon and that the storm would be a severe one. All ports were well dogged down, watertight doors closed and every other possible precaution taken. A shelter was erected in the bow of the ship where a watch could be kept on the anchor cables; drift leads Were put out on both port and starboard wings of the bridge and the main engine made ready.

By 5:30 p.m. the wind had increased to hurricane force, blowing about 90 miles per hour. The Executive Officer stationed himself in the

bow to watch the cables, two men tended each drift lead, a watch was on deck to see that nothing got adrift and a watch stood by in the engine room. The wind continued to blow at about this force for another hour, the barometer dropping steadily. At 6:30 the wind began to increase and the spare port bower anchor was dropped. At 7:00 p.m. the wind began to gain even more rapidly in velocity and the engine was put at half speed ahead; then full speed ahead at 7:05. The barometer began to drop as much as a tenth of an inch per minute. The wind was estimated to be blowing at 120 to 150 miles per hour. The men tending drift leads relieved each other every minute or two as it was impossible to watch the lines properly for a longer period. The Port San Vicente Lighthouse, a kerosene light, had been blown out much earlier but visibility was so low it could not have been seen had it been burning. Rain was practically solid sheets of water. The wind had a sweep of only a couple of hundred meters but even in this short distance seas were about six feet high. The Inner Harbor of Fort San Vicente is landlocked but the hills are low and did not affect the force of the wind. The estimate of 120 to 150 miles velocity was substantiated by the Director of the Manila Observatory who, upon seeing the barometric record, said it was very probable the wind blew that strongly. When this typhoon reached Hongkong several days later and probably had decreased slightly in intensity, a velocity was measured of 131 miles per hour.

At 7:15 the drift leads showed evidence of dragging. The port lead carried away. A second lead was bent on the line and this, too, carried away. A third lead was bent on and as it was heaved over, a sounding of 8 feet was obtained. At the same time, the ship's stern was felt bumping lightly. The engine was immediately stopped to avoid damaging the propellor and tail shaft. About the time the drift leads indicated dragging, the Executive Officer noticed the anchor cables pulling together. He made his way aft to report dragging but before he reached the bridge, the ship was aground. This was about 7:25 p.m.

Everyone was ordered to don a life belt, the bilges were sounded and a check made on all ports and watertight doors. As the ship was in communication with R.C.A., sending weather observations, an informal message was sent advising them that the ship was aground but it was not known whether assistance was needed.

The wind, blowing with unabated force, caught the ship on the port bow and swung it around. As it struck further forward on the keel, the ship listed heavily to starboard, filling the starboard boats. The boats were ordered cut adrift, which was done with difficulty, and were made fast to stanchions along the starboard rail. The ship then righted to some extent but as the wind was still on the port side, everyone was ordered to seek safety on the weather side, using such shelter as they could find.

From 8:10 to 8:15 p.m. the wind decreased rapidly from maximum velocity to a force of 3 as the vortex of the typhoon approached. The vortical calm, which lasted until 8:35, was not absolute as a wind of force 3 continued to blow and shifted during this period from north-northeast to east. The barometer during this time was at its lowest reading and remained stationary. First and second magnitude stars were apparent overhead, with a thin veil of cirrus clouds obscuring the less bright stars. This opening in the clouds, at 8:25, extended in a circular manner for a radius of 20° from the zenith. At the edge of the clear sky overhead, the cloud formation was very heavy with sheet lightning flashing completely around the opening. This lightning was not particularly brilliant and must have been well above the lower level of the clouds.

During the twenty minute period of relative calm, a careful appraisal of the situation was made. A roster was called and no one found missing. The starboard boats were riding alongside in the lee of the

ship although filled with water. Bilges were sounded and found to be dry. A door in the chart room which had been blown open was nailed up. Although not much hope was placed on it, the starboard kedge was dropped so that if the wind shifted to the starboard side of the ship after the vortex passed, and the ship was blown off the reef the kedge might hold the ship's head until the anchors took the strain. Soundings were taken around the ship and the latter found to be afloat except at the after end where the depth was 8 feet.

The seriousness of the situation was fully realized. From the direction of the wind our approximate position was known, but little could be seen beyond the ship. No one entertained the least thought of abandoning the ship.

The window on the port side of the radio room had blown partly open and the rain drove through this window and the house, grounding the main transmitter. The emergency set was put in operation and the following distress message sent to R. C. A. in Manila.

"FATHOMER aground in Fort San Vicente center of typhoon now passing safe at present hot leaking but do not know what will happen when wind resumes."

Some of the crew had started to remove their life belts but they were quickly advised that the danger was by no means over and were ordered to keep their life belts on and seek shelter on deck.

At 8:35 the wind began to increase in force and in five minutes was blowing at least as strongly as before. The wind began blowing from the east and as the ship's head during the calm was southeast, it struck the ship again on the port side, swinging the bow around until the heading was southwest and the ship was broadside to the reef. As the wind continued to blow, the ship was driven broadside on the reef and gradually listed over until the starboard boatdeck rail was under water. The galley range and rice boiler broke adrift and tore off a ventilator to the forecastle, flooding the latter. The starboard side of the engine room house was under water and the engine and boiler rooms flooded. As the water mounted in the boiler room, fires were hauled and steam allowed to escape, the engine room force escaping on the port side. The generator stopped about 9:00 p.m., and the ship was in darkness. The radio operator, who had been trying to keep in communication with R. C. A. was forced to leave the set as the radio house was working and in danger of being carried away. He escaped through the port window.

The demeanor of the crew throughout this entire period was remarkable. At no time was there any sign of panic and although they must have been frightened they continued to perform all duties until no hope was left to do anything but save life.

The majority of the officers and crew were sheltered along the port alleyway between the bulwark and the engine room house, and although this was well above water, seas were washing completely over them. These seas which were much higher than had been experienced before dragging, were due either to the greater sweep of the wind when blowing from the east, or from breakers piling up on the reef south and southeast of the ship's position.

At about 10:00 p.m. the wind began to moderate and at 10:30 it was possible to move about deck, the wind then blowing with a force of 8. Flashlights were brought into use and a roll call was made of all hands. Everyone was found to be aboard with no serious injuries. About five men had minor cuts incurred by being hurled against metal projections. Everyone was bruised and suffering from exhaustion and exposure. Fortunately the sick bay was on the port side, enabling first aid to be administered. Two quarts of brandy, stored in the sick bay, were

By Courtesy 6th Photo Section, Air Corps, U. S. Army

rationed out to all hands, and undoubtedly resulted in no one developing a severe cold or pneumonia.

Soundings were taken amidships, revealing a depth of 5 feet on the starboard side and 6 feet on the port side. The starboard boats which, with the exception of the dinghy, had ridden the worst of the storm in the lee of the ship, were caught under the overhanging davits. They were cleared and bailed out, and although damaged were still serviceable. The dinghy, apparently, had swamped and crushed as the ship listed over.

The emergency radio transmitter was now grounded and the ship was without means of communication.

Nothing further was done until daylight, except to make the crew as comfortable as possible. At daylight mess supplies and ship and survey records were salvaged. The icebox door was under water so that only dry stores could be obtained. The port whaleboat, dinghy, and skiff were lowered by using skids and a force sent ashore to prepare breakfast and build a camp. Meanwhile the radio operator had obtained a spool of dry wire and began rewiring the emergency transmitter.

A site was selected on shore for a camp and sanitation established. As soon as food supplies and records were safe, instruments, tents, bedding and personal belongings were taken ashore. Great precautions were taken against disease. A latrine was built over salt water and a spring was found about a quarter of a mile from camp with no habitation above it. This spring was blocked off to be used for drinking and cooking water exclusively. Lower down from the spring a site for bathing and clothes washing was selected. Garbage disposal was achieved by digging a pit and burning the garbage in it each day. Injuries were dressed as soon as medical supplies were brought ashore from the ship. Each man was required to take 10 grains of quinine the first day in camp, and 5 grains thereafter until he had taken 35 grains. Despite all of these precautions a moderately severe enteritis developed which affected one fourth the personnel.

Daylight after the storm revealed a desolate sight. Trees that were not blown down were denuded of all foliage, the few nipa houses in the vicinity were in ruins and a 60 foot Launch ISLANDER which had sought shelter in the harbor, was on a reef, completely out of water. About 8:00 a.m. the lighthouse keeper at Cape Engaño arrived in camp and reported that his lighthouse and dwelling, both concrete structures that had withstood typhoons for 50 years, were destroyed. He also reported experiencing the vortical calm at the lighthouse which is 4 miles north of the ship's position. Natives from the surrounding country began drifting into camp for treatment of injuries sustained during the storm. One odd injury was caused by a grain of rice driven with such force in the ear of a native that it pierced the ear drum and could not be removed.

At 1:00 p.m. Sunday, August 16, rewiring of the emergency transmitter was completed. Although most of the electrolyte had spilled from the bank of storage batteries, sufficient charge remained to operate the transmitter. As the range and length of operation of the transmitter were limited, a message to the Director of Coast Surveys, Manila, was broadcast as an S.O.S. The call was almost immediately answered by the English S. S. CITY OF FLORENCE, en route from Iloilo to Japan. This vessel then not only relayed this message to Manila but kept in communication with the ship until it was beyond the range of the latter's transmitter, relaying messages to and from Manila.

Upon receipt of knowledge of the FATHOMER's distress and with the cooperation of the U. S. Army and the Bureau of Public Works, the Director of Coast Surveys made all arrangements for relief in an astonishingly brief time. By Tuesday noon, August 18, the Lighthouse Tender

CANLAON left Manila with complete salvage equipment and personnel and a three weeks' supply of provisions. Stopping at Aparri, en route, the CANL&ON took the derrick dredge APARRI in tow. The two vessels reached Fort San Vicente at 2:00 p.m. August 20.

Salvage operations were begun immediately. A foreman from the Government Marine Railway and Repair Shops, with salvage experience, was in charge of the skilled personnel. The Master of the CANLAON, also an experienced salvager, gave valuable assistance. Labor was furnished by the crew of the FATHOMER and in general the salvagers were permitted to proceed in their own way. It was insisted, though, that the ship be sealed and pumped out before an attempt was made to right it as it was feared it would capsize in the greater depth to port if the water inside was allowed to shift suddenly.

All work was supervised by the FATHOMER's officers and suggestions were readily accepted and complied with. The ship was first sealed by the use of lumber, cement, burlap sacks and cotton. A wrecking hose was led from the CANLAON, which had anchored nearby, mooring fore and aft, but the distance was too great for its pumps to be effective. A portable pump was placed alongside on the derrick dredge, and this was successful in removing the water.

A pile driver was rigged on the derrick barge and a cluster of piles driven on the reef south of the ship's position. This piling was backed by three anchors imbedded in the reef.

Wire rope bridles were placed completely around the forward and after parts of the FATHOMER and attached to tackles composed of triple iron blocks. These tackles were made fast to the cluster of piles and the hauling parts led to the CANLAON. A ten inch hawser, secured to a bridle around the launch davits on the port side, led directly to the CANLAON's stern.

After the ship was emptied and all purchases rigged an attempt was made at high tide to right the FATHOMER and haul it off the reef. The derrick dredge hove upwards on the starboard side and the CANLAON's engines were put full speed ahead. The ship was righted about 10 or 15 degrees but the water was too shoal on the port side to permit it to move off.

As this tide was especially high, it was realized that dredging would have to be done before the ship could be salvaged. Divers were sent down and the shoalest spots dynamited. The loose coral thus dislodged was removed by the dredge.

This dynamiting and dredging was completed on the afternoon of Friday, August 28. As the least water was at the stem of the FATHOMER, the dredgers secured their hoisting gear at this point, and at the next high tide, which occurred just after midnight, began working the stem by rapid pulls and releases. The CANLAON at the same time went ahead on the engines, putting a strain on all tackles. At 2:15 a.m., August 29, the ship righted and slid into deep water.

Steam was piped to the FATHOMER's anchor windlass and anchors hove home. The starboard kedge, which was dropped after the ship grounded was taken aboard. The mooring line which had been secured to the port stockless bower anchor was hove in, and found to have parted. This was expected as the line could not have withstood the strain of dragging. The port anchor cable was then hove in and the connecting link to the swivel on the anchor found to have opened at the weld.

This was a surprising discovery. The wind had blown with such terrific force, it had been assumed that steam and ground tackle were simply inadequate to prevent dragging. The open link and loss of the

large stock anchor now definitely established the cause of dragging and consequent stranding. As mentioned previously in this report, the ship withstood a wind of hurricane force from 5:30 to 7:15 p.m., the time the vessel began to drag anchors, and withstood a wind of maximum velocity from 7:00 to 7:15. Another surprise was the fact that the poorly conditioned port chain held, while the swivel link, recently installed, failed. With this knowledge the actual occurrence was assumed to be as follows. When the link opened and the port anchor was lost, the ship, which was putting an equal strain on both cables, swung to the starboard cable. This sudden increase and change of direction of strain caused the starboard anchor to start. Once started, it was bound to pull through the holding ground. The port stockless anchor was useless, as the strain of dragging was too great for the line attached to this anchor. The total time of dragging was recorded as ten minutes, but this could well have been less, as the activities incidental to the dragging made it difficult to record exact time.

After the starboard anchor was taken aboard, the FATHOMER was towed to deeper water and at daybreak camp was struck and all property taken aboard. The CANLAON, with the FATHOMER in tow, left at 12:50 a.m. August 30 for Manila, arriving 3:00 p.m. September 1.

Examination revealed that the principal damage resulting from the stranding was in the engine and boiler rooms, caused by the equipment being immersed in salt water. Some additional damage resulted from dynamiting.

Shortly after the vessel's arrival in Manila, a report of the meteorological data of the typhoon was forwarded to the Director of the Manila Observatory and the ship's barometers compered to the observatory's mercury barometer. The needles of both ship's barometers had been well off the scale at the time of the center of the typhoon but their positions were marked on the dials and upon comparison gave the barometric minimum on the ship as 685 mm. or 26.96 inches.

From an inspection of the Weather Bureau's Publication "Catalogue of Typhoons, 1348* to 1934" published in 1935, only two typhoons are listed with barometric minima below this. These minima are 683.17 mm. aboard the S. S. LOANG in 1913 and 683.5 at Fuga Island in 1922. The barometers recording these pressures were apparently never compared and as the FATHOMER's barometers read, by extending the scale, 680.0 mm. or 26.77 inches (uncorrected) at the time of the vortical calm, it is very probable that the FATHOMER's reading is the lowest pressure ever recorded at sea level in the Philippine Islands.

In concluding this report, I wish to commend highly the entire ship's personnel for their seamanship, courage and fortitude. The following are to be particularly commended:

Lieutenant K. G. Crosby, Executive Officer, for the thoroughness with which he supervised the securing of all gear and his general activity and assistance throughout the whole period of the storm and the subsequent salvage operations. Undoubtedly the fact that very little gear went adrift during the storm was responsible to a great extent for the few injuries sustained.

Lieutenant (j.g.) C. A. Schanck, for his presence of mind and efforts in saving the life of the ship's surgeon, Dr. James W. Wetzel. When the ship first listed heavily to starboard, Dr. Wetzel was emerging from the Wardroom. He lost his footing and fell to the starboard rail. This rail was under water and Dr. Wetzel managed to catch hold of an overhead beam. With the exception of his hands he was completely submerged. Lieutenant Schanck, following closely behind Dr. Wetzel, saw his plight, and made several efforts to reach him. Failing this, he called to Lieutenant Crosby who tore several curtains from staterooms

and, bending them together, the two officers were able to haul the surgeon to safety.

Chief Engineer G. W. Hutchison, for his attention to duty. Throughout the storm he was in the engine and boiler rooms directing his men until the mounting water made it imperative to leave. He then hauled fires and allowed the steam to escape, thus preventing any explosions. He saw all of his men to safety and was the last to leave from below.

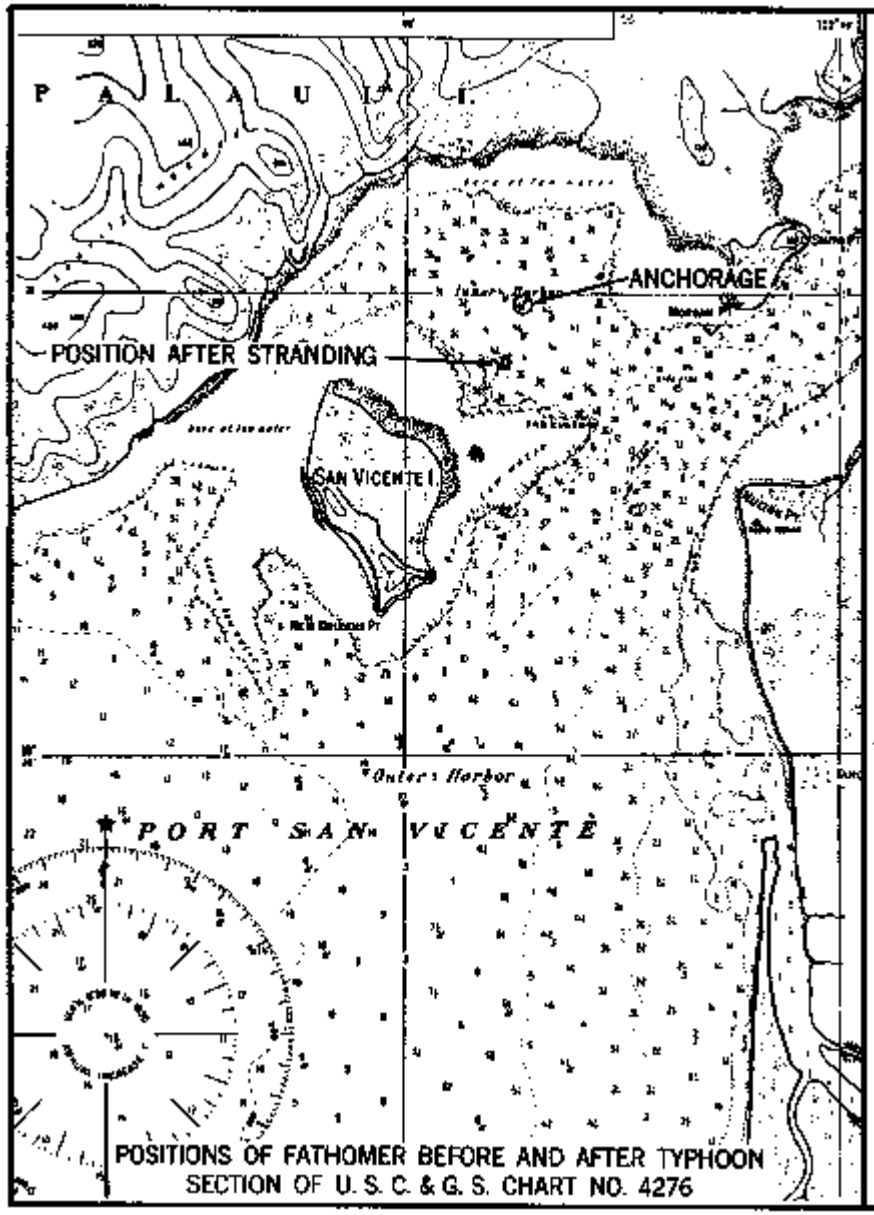
Boatswain Roman Rodriguez, for his assistance to Lieutenant Crosby. Throughout the storm and salvage operations, he did not spare himself. During the storm he was everywhere that anything could possibly be done and in the subsequent salvage work would take no relief, working at times twenty hours without stopping.

Wireless Operator Ricardo I. Ventura, for his competency and attention to duty. Despite the fact that the ship was listed badly, he kept in communication with Manila until both main and emergency transmitters were grounded. He continued to stand by until the house began working and then escaped through the port window. The day after the storm, he rapidly rewired the emergency transmitter, putting it in operation by 1:00 p.m. After the batteries lost their charge he built a 36 meter set in camp which enabled the party to maintain contact with the Director of Coast Surveys.

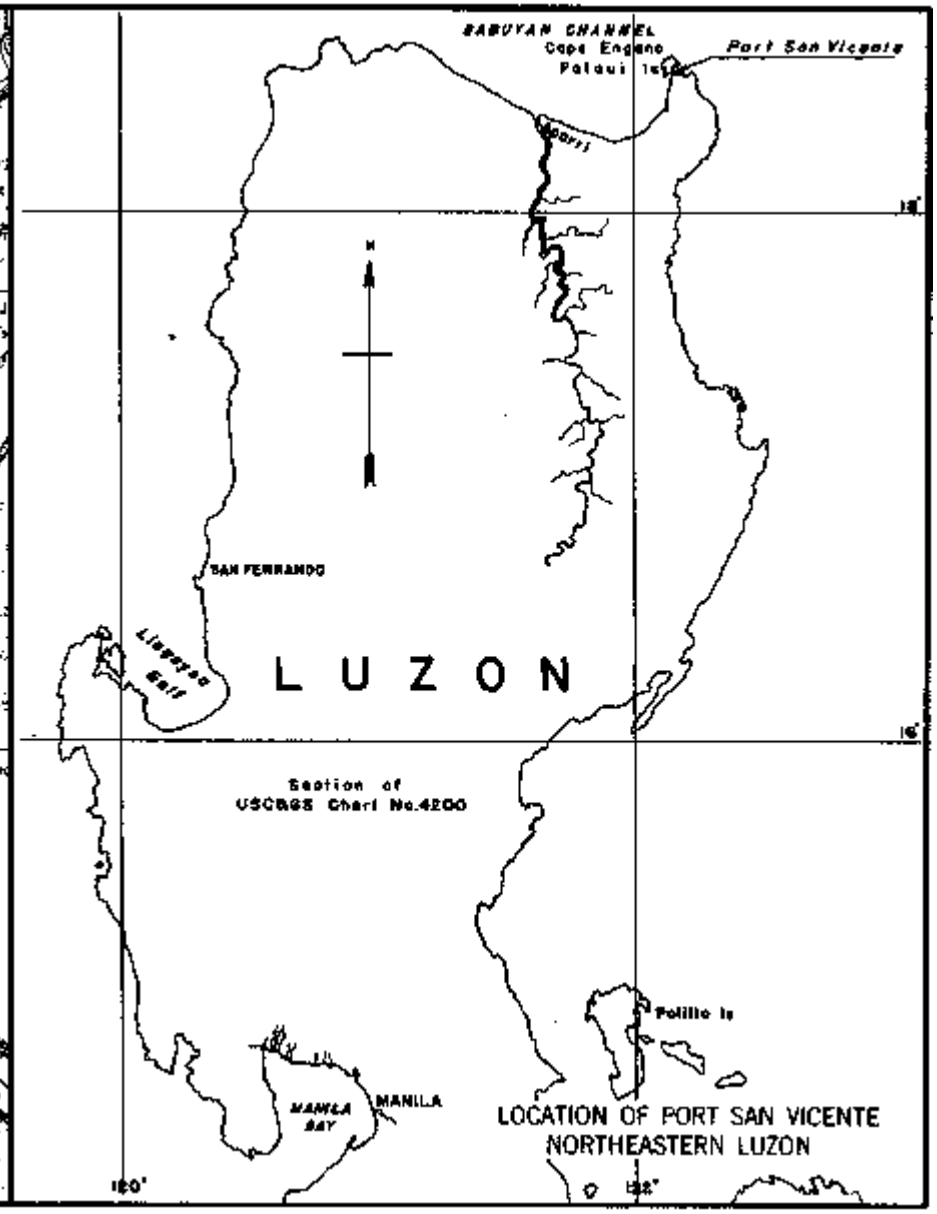
Appended to this report is a copy of a section of Chart 4276 showing the ship's position before and after the storm, and an aerial photograph taken by the United States Air Corps. This aerial photograph and others were taken on Tuesday, August 18, when an amphibian plane flew over the site in order to obtain a more definite impression of the situation than could be imparted by radio.

Charts of Remarkable Typhoons in the Philippines, 1902 - 1934 and Catalog of Typhoons, 1348 - 1934, by Rev. Miguel Selga, S. J., Manila Observatory 1935, P. 22, mentions the following interesting historical typhoon:

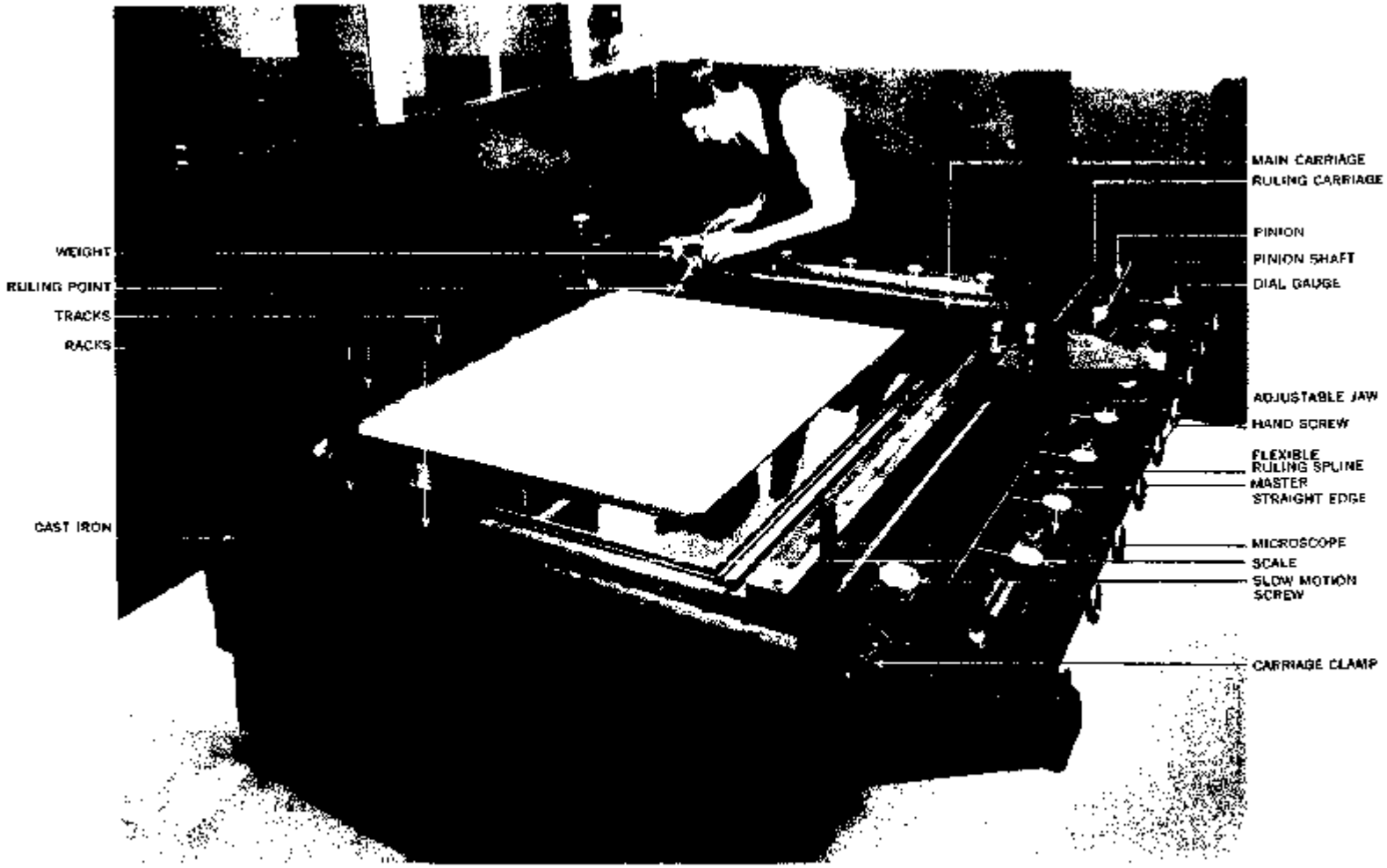
1348, July. - The Moorish traveller, Ibn Batuta, visited Sumatra, the Philippines and China, crossing the China Sea twice, during the middle of the l4th century. Ibn Batuta, on his return trip to Sumatra, sailed from a place near the modern Amoy, about July or August, 1348 (or 1347?), on board a swift ship belonging to the king of northern Sumatra. It was the custom of these ships, sailing from Amoy, not to follow the coast, but to direct their course straight towards southern Sumatra, passing some distance to the west of the Philippines and Borneo. Of the trip, Ibn Batuta says: "We had a fair wind for ten days, but as we got near the land of Tawalisi, namely Sulu, Palawan and northern Borneo, it changed and grew violent, the sky became black, and heavy rain fell. For ten days we never saw the sun, and then we entered on an unknown sea. The sailors were in great alarm, and wanted to return to China, but this was not possible. In this way we passed forty-two days, without knowing in what waters we were. On the forty-third morning after daybreak we descried a mountain in the sea, some twenty miles off, and the wind was carrying us straight for it. The sailors were surprised and said: 'We are far from the mainland and in this sea no mountain is known. If the wind drives us on this one we are done for ..... It was then some ten miles from the junk. But God Almighty was gracious unto us, and sent us fair wind, which turned us from the direction in which that mountain was. . . . . Two months from that day we arrived at Sumatra, and landed at the city of Sumudra."



POSITIONS OF FATHOMER BEFORE AND AFTER TYPHOON
SECTION OF U. S. C. & G. S. CHART NO. 4276



LOCATION OF PORT SAN VICENTE
NORTHEASTERN LUZON



U. S. COAST AND GEODETIC SURVEY
PROJECTION RULING MACHINE

THE PROJECTION RULING MACHINE OF THE COAST AND GEODETIC SURVEY

O. S. Reading, H. and G. Engineer
U. S. Coast and Geodetic Surrey

The first step in making all charts, maps or graphic surveys is the drawing of the projection, a series of fine lines representing latitude and longitude (or certain convenient intervals of distance from an origin if a plane coordinate system is used.) These fine lines serve to coordinate the surveys or maps with surveys of adjacent areas. They also make it possible to scale or to plot the coordinates of positions by short measurements from the nearest lines and to determine and allow for any changes in dimensions of the paper, or other material, which may occur after the lines are drawn thereon. Since the positions of the control are plotted relative to these lines and all careful measurements are referred to them when the data is transferred to other surveys or compilations, it is important that the lines be drawn in their correct positions as nearly as practicable.

The normal human eye without the aid of magnification appreciates differences in the coincidence of fine lines of about two thousandths of an inch or 0.05 millimeter. Yet occasional errors of five times this amount (one hundredth of an inch or 0.25 millimeter) are considered permissable in good drafting when points must be pricked or lines ruled by hand at specified distances from others. Higher accuracy than this requires much painstaking care which in turn greatly reduces the output of the draftsman. This is particularly true when ten to fifty lines from 30 to 50 inches (800 to 1250 millimeters) long must be so drawn, as in the case of projections used by the Coast and Geodetic Survey.

The chart compilations of the Coast and Geodetic Survey have been made on Bristol board mounted on aluminum for many years and more recently a similar distortion free sheet has been adopted for plane table surveys. A fifty by fifty inch precision copying camera capable of reproducing graphic surveys or chart compilations correctly to the nearest two thousandths of an inch (0.05 mm) has also been constructed. The camera and the aluminum-mounted sheets disclosed the need for a projection ruling machine, capable, with only ordinary care in operation, of ruling the projections or grids with line displacements not exceeding two thousandths of an inch. The machine was designed in the bureau, constructed on contract and installed in the autumn of 1934. It has successfully met the requirements and has retained its satisfactory adjustment for more than a year.

The machine is composed of a heavy, rigid, cast iron table with supporting ribs 10½ inches deep and 1¼ inches thick. This casting was machined and then very carefully annealed, with only a very light finishing cut after the annealing. On this table top are supported combination tracks and racks on which the two main carriages roll at right angles to each other. On the main carriages are the master straightedges, the flexible ruling splines and the ruling carriages. The racks were cut in pairs so that any small errors in cutting the teeth would be duplicated in each corresponding tooth of the pair. The parallelism of all positions of the main carriages is obtained by these racks and pinions. The pinions, also cut in pairs, are split with one half of each pinion floating on its shaft and pressed with strong springs against the opposite side of the tooth to which the half fixed to the shaft is engaged, thus preventing backlash or lost motion. Shafts 2 inches in diameter were used for connecting the pinions in order to avoid appreciable flexure.

The master straightedges are connected by two adjustable screws to the main carriages and rest on carefully scraped supporting pads without other restraint. On these master straightedges the supporting bases of

the dial gages are held by light springs, the stems of the dial gages resting against the flexible ruling splines. The straightedges also have scales attached to them with verniers on the dial gages, by means of which the gages may be set with their clamps and slow motion screws, at any desired interval along the straightedges. The flexible ruling splines are made of carefully tempered saw spring steel ground to 3/l6" x 1 1/2" in cross section. These splines are held to the desired straight line or curve by strong jaws which can be adjusted toward or away from the straightedges by convenient hand screws bearing on the backs of the main carriages. With these devices the ruling splines may be easily and quickly set parallel to the straightedges or at any curvature or inclination needed in drawing projections of 1/500,000 scale or larger. The dial gages read directly to 0.01 millimeter and have less than two hundredths of a millimeter error throughout their travel.

The lines are ruled on the projection parallel to the flexible spline by means of the ruling table assembly. These ruling tables roll along the tops of the main carriages and each carries a tracing point holder supported on "V" grooves by spring-loaded balls. This holder carries on preloaded ball bearings a rotating shaft to which the tracing point is rigidly attached. The holder and shaft are constrained to follow parallel to the ruling spline by spring-loaded opposed ball bearings attached to the holder and rolling along the spline. Provision is made for varying the pressure on the tracing points by weights adjustably attached to the side of the shaft. A ruling pen is used for ruling ink lines on paper of all types and low shrinkage celluloid; a steel blade for cutting lines through collodion emulsions on glass negatives; and a diamond point for ruling on copper plates and glass.

The intervals between the ruled lines are set by scales fastened parallel to the combination tracks and racks and read by microscopes on the main carriages. A clamp and slow motion worm and gear are provided at the ends of the shafts for setting and holding the carriages in position.

The central portion of the table top is of plate glass three-fourths of an inch thick. Lights with reflectors and diffusing glasses are provided to give an even illumination underneath the glass when desired for making layouts or tracings. Ventilation openings are provided for carrying away the heat generated by the lamps. Most of the work done on the machine, however, is lighted by indirect fixtures placed several feet above the table in order to avoid temperature changes. The machine is installed in a glass enclosed room which protects it from dust and extreme atmospheric changes. A humidifier in the enclosure controls air moisture.

The machine is capable of ruling projections up to 39 inches by 53 inches in size. Practically all projections on celluloid for the use of airphoto compilation parties in the field have been made on the ruling machine since early in 1935. These projections are constructed under the same degree of humidity as is maintained in field offices, which are humidified. Such field parties on the East Coast, as so desire, may have a reasonable number of projections on aluminium mounted topographic sheets or Whatman paper made for them on the machine. Any such requests should be sent to the office as far in advance as practicable and must be accompanied by a sketch outlining the area to be covered. Such requests should state the dates by which the projections are needed by the field party.

The machine was built by the American Instrument Company from preliminary designs and specifications made by the Coast and Geodetic Survey. It is estimated that the cost of the machine will be saved in three or four years time from the cost of the extra time which would have been required by draftsmen if the projections were made by hand. A much

greater saving is resulting from the elimination of allowances for occasional small errors in the positions of hand-drawn projection lines. An interesting result of the machine-drawn projections was the discovery of errors in several meter scales which were used by draftsmen to check the machine-drawn projections to see if they were really as good as reported. The discrepancies found were immediately traced to errors in the scales used in checking the machine projection.

The first chart projection was constructed on the machine in October, 1934. This was chart No. 5143. Practically all chart projections are being made by machine now and the cartographers are without exception enthusiastic about the results.

The machine is now used for all projections made on copper plates, and with a considerable saving in time.

For a projection the usual data must be taken from the projection tables and a layout made similar to that when a hand-made projection is constructed. Additional time of fifteen minutes to one hour is required to compute the settings for the machine.

Recently the machine has been used to rule various state plane coordinate systems on photo compilations. Some of these have been added to compilations for which the original projection was made by hand and the difficulty encountered has exposed numerous small errors in the hand-drawn projections, previously undetected.

CARTOGRAPHY

"Cartography" by Charles H. Deetz, has recently been published by the Government Printing Office and all who are interested in this subject will welcome the appearance of this authoritative work. Mr. Deetz, who has just retired, is a cartographer of life long experience, who is best known for his many publications and studies on projections.

In this publication of 80 pages with many illustrations, Mr. Deetz has described the general considerations underlying the art of cartography. Those who expect to find a manual of procedure for details of the work will be disappointed; but those who seek to know the fundamentals of constructing well balanced charts and maps as required for various purposes will find in this book a wealth of material relating to the finer considerations of map structure. A section of the publication is a guide for the identification of projections, with a brief outline of their properties. This will be welcomed by all who have attempted to identify projections.

The book contains a brief historical review of the art and science of cartography, and a discussion of the various uses of charts and maps together with many of the problems of surveying and navigation which are intimately related to cartography. Occasional references to classical literature are interspersed throughout the text, and add to the general interest of the work.

Cartography, U. S. Coast and Geodetic Survey Publication No. 205, may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., price 60 cents.

LITUYA BAY, GULF OF ALASKA

E. W. Eickelberg, Hydrographic and Geodetic Engineer
U. S. Coast and Geodetic Survey

There is an area of uncompleted hydrography and topography lying about 40 miles north of Cape Spencer in the Gulf of Alaska, between Lituya Bay and Yakutat Bay. It is a region of great natural beauty. Mount Fairweather and Mount Crillon, part of the Fairweather Range and so useful to the navigator and hydrographer dominate the picture. This range is one of the highest groups of coastal mountain peaks on the face of the earth and has been the scene of a number of unsuccessful as well as successful attacks by climbing parties. Lituya Bay usually has been the base for such operations. It is a "T" shaped bay, eleven square miles in area, the bottom of the "T" affording a narrow and treacherous connection to the Pacific Ocean. The entrance channel is only 80 yards in width and about 18 feet deep through which the large volume of water created by a tidal range of from 5 to 10 feet must pass four times daily. The ebb and flood currents reach maximum velocities estimated at 12 knots The ebb current causes the most dangerous condition at the entrance by breaking up the ocean swell into a bedlam of smaller cross seas in which no small craft would long remain afloat. The general depth of the bay is about 100 fathoms, although there is a good anchorage in a bight just inside the entrance and well out of the strong current. Glaciers come down to the water's edge in both arms of the bay, discharging icebergs into the bay.

The first record of Lituya Bay (although Captain Cook[2] reported the existence of the Fairweather Range in 1778) is by the French explorer La Perouse[1] who navigated its treacherous entrance with two frigates in 1786, a very nice piece of seamanship. He made a survey and map of the bay on a scale of 1:50,000, which map, when compared with more recent surveys, discloses the fact that the glaciers at the head of the bay have advanced so that the distance between them has changed from 8 nautical miles to about three. That this is without doubt a real movement is evidenced by the unusual accuracy of the other features on the map when compared with the modern surveys. La Perouse also made astronomical observations and recorded the plant and animal life, Indian life and culture. While his fleet was anchored in the bay six officers and fifteen men in two small boats approached too close to the entrance while they were surveying the bay and were swept out to sea in the strong ebb current. The boats were swamped in the broken sea and all hands were lost.

In l874, seven years after the purchase of Alaska, the Coast and Geodetic Survey Schooner YUKON, in charge of Acting Assistant W. H. Dall, with Marcus Baker as astronomical observer, entered Lituya Bay for the determination of elevations of the Fairweather Peaks and for astronomical observations. A brief account of this project is quoted here from the Superintendent's report, Coast Survey 1875.[3][4]

"On the 3rd of May, 1874, Mr. Dall took up the coast reconnaissance at Sitka, and from thence in passing up the coast recorded current and temperature observations and plotted soundings. Vertical angles were measured to determine the heights of mountains in that region that serve as landmarks at sea. Observations for time, azimuth, and latitude were made at Lituya Entrance, and the position given on most charts found to be erroneous. The chart of the inner bay, by La Perouse, was tested, and proved to be generally accurate. Here the party on the YUKON had much difficulty in preventing the persistent attempts of the natives to board the vessel, but fortunately they were kept off without bloodshed. It is added in the report that these natives distil their own rum, and are well supplied with the best kinds of firearms. Before leaving the place, observations were made for correcting the positions heretofore assigned to Mount Fairweather and Mount Crillon. It is recorded that except at slack water the sea breaks quite across the entrance to

Lituya Bay, even in calm weather.

"A few days following the 20th of May were occupied in hydrographic work at Dry Bay, in reaching which the YUKON passed the seaward face of the Grand Plateau Glacier of La Perouse. Mr. Ball procured data for a corrected sketch of the Bay, and for a general chart of the coast southward as far as Lituya Entrance. Of the region inland, he says: 'The scenery is grand; the mountains, reaching 16,000 feet above the sea, are bedded in forest lowlands, and are scored by enormous glaciers."

As a matter of passing interest it is noted that "on the 29th of September, the YUKON sailed from Unalaska (in the Aleutian Archipelago) for San Francisco and arrived there 13 days later after a stormy passage." The YUKON was a two masted schooner of 100.7 tons, 83.1 feet by 23.5 feet by 8-2/3 feet draft. She was built in Kennebunk, Maine in 1873.

Although nothing is reported of the earlier Russian visits to this region, it is known that they discovered gold deposits in the sands along the beach north and south of Lituya Bay and placer-mined them for some time. In 1894 Americans began to work these placers and continued to do so for a number of years. In 1926 there was still some evidence of the gold mining of previous years along the beach. Some of the old machinery and workings were identified and one of the gold-rush pioneers, Mr. Jim Huscroft, then engaged in fox farming, was living on Cenotaph Island. Also in 1894 a topographic map of Lituya Bay was made by the International Boundary Commission, published by the Alaskan Boundary Tribunal, and included in The Atlas of Award. This collection contains 25 sectional maps of the Alaskan boundary and was printed in 1904. In 1906 a U. S. Geological Survey party, headed by F. E. and C. W. Wright, spent three days in Lituya Bay. In 1917 J. B. Mertie, Jr., U. S. Geological Survey, spent three days in Lituya Bay making geological observations and collecting fossils. This work is described in Bulletin 836-B[5] entitled "Notes on the Geography and Geology of Lituya Bay, Alaska . It is prefaced by a very interesting history of the region and lists many references.

In 1926 the Coast and Geodetic Survey Ship SURVEYOR, after several seasons of work in the Gulf of Alaska, reached the region of Icy Point about 30 miles below Lituya Bay. Triangulation was extended 7 miles north of this point to a position just south of La Perouse Glacier. On account of the difficult terrain, high peaks, and glaciers, and the fact that much of the beach north of this point was suitable for traverse, it was decided to carry the control by this method rather than by triangulation. This work is well described in a season's report by the Commanding Officer, A. M. Sobieralski,[6] and a special traverse report by the writer included therein giving recommendations for future work.

Many interesting features were connected with this work. Due to uncertain landing conditions the topography and traverse were done mostly from camp. Most of the walking in sand and gravel, particularly at high tide, was very tedious inasmuch as rubber boots had to be worn for crossing glacier streams. One of the men, without rubber boots, attempting to cross the stream coming out of La Perouse Glacier, failed in three attempts; and returning to shore after the third attempt, dropped to the ground because his limbs collapsed under him probably due to lack of circulation. A tape thermometer immersed in the stream gave a temperature of +0.5°centigrade.

Some of these streams were deep enough so that they could not be waded. In such cases the party went upstream a short distance and felled trees to serve as bridges. The streams were usually narrow enough so that they could be spanned by a fifty meter tape. In only one case was triangulation necessary to carry control across a stream.

This difficult traverse had its compensation however. For a distance of 12 miles the sandy beach was bordered by one continuous bed of strawberries indulged in both by members of the party and by native brown bears (not simultaneously).

Several hunting parties started from camp but none of them ever was successful in getting a bear. On one occasion one of the seamen returned out of breath, and upon asking him where the other man in the party was, he explained that their service rifle had jammed in shooting at a large bear and that he had made for camp in obvious and prudent haste while his companion had climbed a tree.

The salmon and trout fishing were, of course, excellent in this isolated area. In Lituya Bay salmon fishing was particularly interesting and was indulged in frequently by members of the SURVEYOR'S complement who were cautioned to keep away from the entrance during ebb tide. In the excitement of landing a salmon, two of the men in a skiff were swept out to sea and their boat was swamped. They had left the ship after supper and were not missed until after dark when search parties were organized which proceeded along the beach in both directions from the bay. These parties returned to the ship without having found any trace of the missing men. At daybreak search parties were again sent out and soon located the men asleep under some brush for a cover. The noise of the approaching party had not awakened them because of their sound sleep resulting from sheer exhaustion in their efforts to reach shore. After they were swamped they clung to the skiff long enough to remove their clothing and managed to swim ashore.

In this same year Allen Carpe and Dr. William S. Ladd of New York City and Andrew S. Taylor of McCarthy, Alaska made an unsuccessful attempt to scale Mount Fairweather from Sea Otter Bight 25 miles north of Lituya Bay.

In 1930 H. Bradford Washburn, Jr. made a similar unsuccessful attempt. In June of 1331 Carpe, Ladd and Taylor and Terris Moore of Haddonfield, New Jersey, operating from Lituya Bay, were successful in reaching the summit of Mount Fairweather.[7]

The Harvard-Dartmouth Alaska Expeditions of 1933 and 1934 have been described by H. Bradford Washburn, Jr. and Richard P. Goldthwait in various journals. The purpose of these expeditions was to make scientific observations in connection with glacier movement, thickness of the ice, and other phenomena, and also for the purpose of scaling Mount Crillon. All of the aims of the expedition were achived, Mr. Washburn's party succeeding in reaching the top in July, 1934.[8][9]

An interesting feature of this work was the use of a seaplane in transferring equipment from Lituya Bay to Crillon Lake where a base camp was established. The seaplane was again used in transferring 900 pounds of canned food and tents separated into 31 wire-bound packages and dropped from the air into the snow at an elevation of 5600 feet for the establishment of another camp. No parachutes were placed on the packages and although they fell nearly 1000 feet there was very little breakage; only a few tins of vegetables were broken. In this way they accomplished in a single day the work of six men for two weeks which would have been required had the material been packed to this location.

The work on the glaciers involved the application of seismic methods in the measurement of their thicknesses.[10] Artificial earthquakes caused by blasts of from 1 to 5 pounds of dynamite generated the necessary waves. The apparatus consisted of 2 geophones, (vertical seismometers) recording through galvanometers on moving photographic tape. A tuning fork furnished time control, and phase interpretations were made with an accuracy of .001 of a second. The thickness of the ice was determined by reflections from the underlying rock. The shape

of the bottom profile was very similar to the shape of the bottom of Crillon Lake which was determined by measuring the depth of water. This lake has a bowl-shaped bottom. It is 640 feet deep and its surface is 315 feet above sea level. The bottom is therefore considerably below sea level. Observations were made for determining the speed of movement of the glaciers. It was found that this varies throughout the day. In the early morning, at noon and again at sunset the ice moves nearly twice as fast as at other times during the day. The ice movement also depends largely upon the weather, and an average is 40 cm. in 12 hours during clear weather. This drops to as low as 19 cm. for 12 hours during the night in rainy weather. The observing was done with theodolites on targets and lights. An excellent reconnaissance map was compiled from existing data and the U. S. Forest Service air photographs, using as control the Coast and Geodetic Survey traverse and triangulation stations supplemented by the expedition's own triangulation. This map is on a scale of l:40,000 and was compiled at the Institute of Geographical Exploration, Harvard University. A copy of this map reproduced on a scale of 1:100,000 may be found with the articles in references 9 and 10.

The difficulties of mountain climbing in this region are well described by Washburn. He says: "One must wade to climb"; in other words land through surf and start to climb in wet clothing. He says rightly: "There are no huts, no porters and no guides but the beauty of the country casts a spell which it is well-nigh impossible to shake off."

List of References:

(1) 1786 La Perouse, "A Voyage around the World", Vol. 1, London, 1799, pp. 364 - 416.

1894 Notes on the glaciers of southeastern Alaska and adjoining territory: Geog. Jour. Vol. 14, pp. 524 - 526, 1899.

(2) 1778 "Cook's Last Voyage", Vol. 2, 1784, pp. 345 - 6.

(3) Report of the Superintendent, U. S. Coast Survey, 1875, Appendix No. 10 and also Section 12, page 64.

(4) Alaska Tertiary Deposits; American Journal of Science, Vol. 24, pp. 67, 68, 1882, W. H. Dall.

(5) Notes on the Geography and Geology of Lituya Bay, Alaska; Bulletin 836 B, Dept. of the Interior, Geological Survey.

(6) Seasons Report for 1927, No. 102, Coast and Geodetic Survey Ship SURVEYOR, season March 22 to November 7, 1926.

(7) The Conquest of Mt. Fairweather by Allen Carpé; Alpine Journal, Vol. 43, 1931; pp. 221 - 230.

(8) The Conquest of Mt. Crillon, by H. Bradford Washburn, The National Geographic Magazine, March 1935, Vol. LXVII.

(9) The Harvard - Dartmouth Alaska Expeditions 1933-34 by H. Bradford Washburn, Jr., & Richard P. Goldthwait, Geographical Journal, London, Vol. LXXXVII, June 1936, pp. 48l - 495.

(10) Seismic Sounding on South Crillon & Klooch Glaciers by Richard P. Goldthwait; Geog. Jour., London, Vol. LXXXVII, June 1936, pp. 496 - 517.

RUSSIAN BOOK ON AMERICAN GEODETIC METHODS

The field engineers who had the pleasure of knowing Mr. S. V. Shirokov, Central Geodetic Department, Moscow, USSR., during a visit to field parties in 1930, will be pleased to know of the recent publication of his book entitled "The American Method of Geodetic Work". This book, 519 pages, is well illustrated by photographs and drawings and thoroughly describes the work of the Coast and Geodetic Survey, the Geodetic Survey of Canada, and the U. S. Geological Survey. It is noted from Mr. Shirokov's correspondence that at present he has the title of Chief Engineer of the Trust of Geodetic and Air Surveys, USSR. Moscow High Post Office. A translation of the introduction by Mr. E. C. Ropes of the Bureau of Foreign and Domestic Commerce is as follows:

"In 1930 I was sent by the Chief Geodetic Administration to the United States to familiarize myself with the organization and technique of the geodetic work there. During my stay in America, from September 30, 1930, to December 27, 1930, I succeeded in visiting in Canada the Geodetic Service and the Topographic Service, and in the United States the Coast and Geodetic Service and the Topographic Section of the Geological Survey. In the United States, in addition, I was able to attend a number of field parties and to become acquainted on the spot with their work.

Thus, I was an eye-witness of the American technique and speed of work. This gave me an opportunity to convince myself that the geodetic work is carried on according to exactly the same instructions that have become known to geodesists in the U.S.S.R. in recent years, and that in the United States there is no other 'great geodesy', except that which has been in practice by the Coast and Geodetic Survey for more than a hundred years.

Having taken the opportunity personally to know and study the instructions, records and literature, I decided to write a book, in which I could describe the present technique of the fundamental geodetic work in America. My object was to give the Soviet reader a presentation both of the organization of geodetic work in America, and of the technique of carrying out individual projects, without criticising the methods involved.

With this object in view, I endeavored to utilize as much as possible official sources.

The book is illustrated with pictures, taken partly from American publications, partly from photographs obtained from the Coast and Geodetic Survey, especially from the head of the (field) party, P. Smith, through the director of the Geodetic Division, Dr. W. Bowie. The latter, and also his assistant, engineer Garner, and the party leader P. Smith, gave me great assistance both in collecting materials, and in acquainting myself with the work of the Coast and Geodetic Survey.

I cannot help mentioning in this connection also the head of the Triangulation Division, O. Adams, the head of the Leveling Division, H. S. Rappleye, the head of the Library and Archives, Hartley, the leader of the leveling party Porter and the head of the topographic party of the Geological Survey, R. R. Monbeck. In Canada the Assistant Director of the Geodetic Survey of Canada, engineer W. M. Tobey, was of great help to me.. To all these men I express my deep gratitude.

In the work itself here engineer B. P. Lisogorovski was of great help to me, recalculating the geodetic tables contained in the appendix, according to the Tobey method and working out some of the examples included in the text, and also engineer S. I. Yurov, who worked out an example of differential equilibrium according to the Tobey method.

In my book there are included a number of tables, drawings, examples. In this way it suggests American direction.

All the tables referring to dimensions of the earth are recalculated according to the Bessel ellipsoid and given in metric measurements.

Part of the tables have been borrowed in their entirety from the books of Beregova, the Geodetic Survey, and others; part of them have been recalculated and amplified. Some tables are entirely new."

ASSOCIATION OF FIELD ENGINEERS
U. S. COAST AMD GEODETIC SURVEY
WASHINGTON

September 29, 1936.

Lieutenant Commander Frank S. Borden,
U. S. Coast and Geodetic Survey
Ship HYDROGRAPHER,
New Orleans, Louisiana.

Dear Commander Borden:

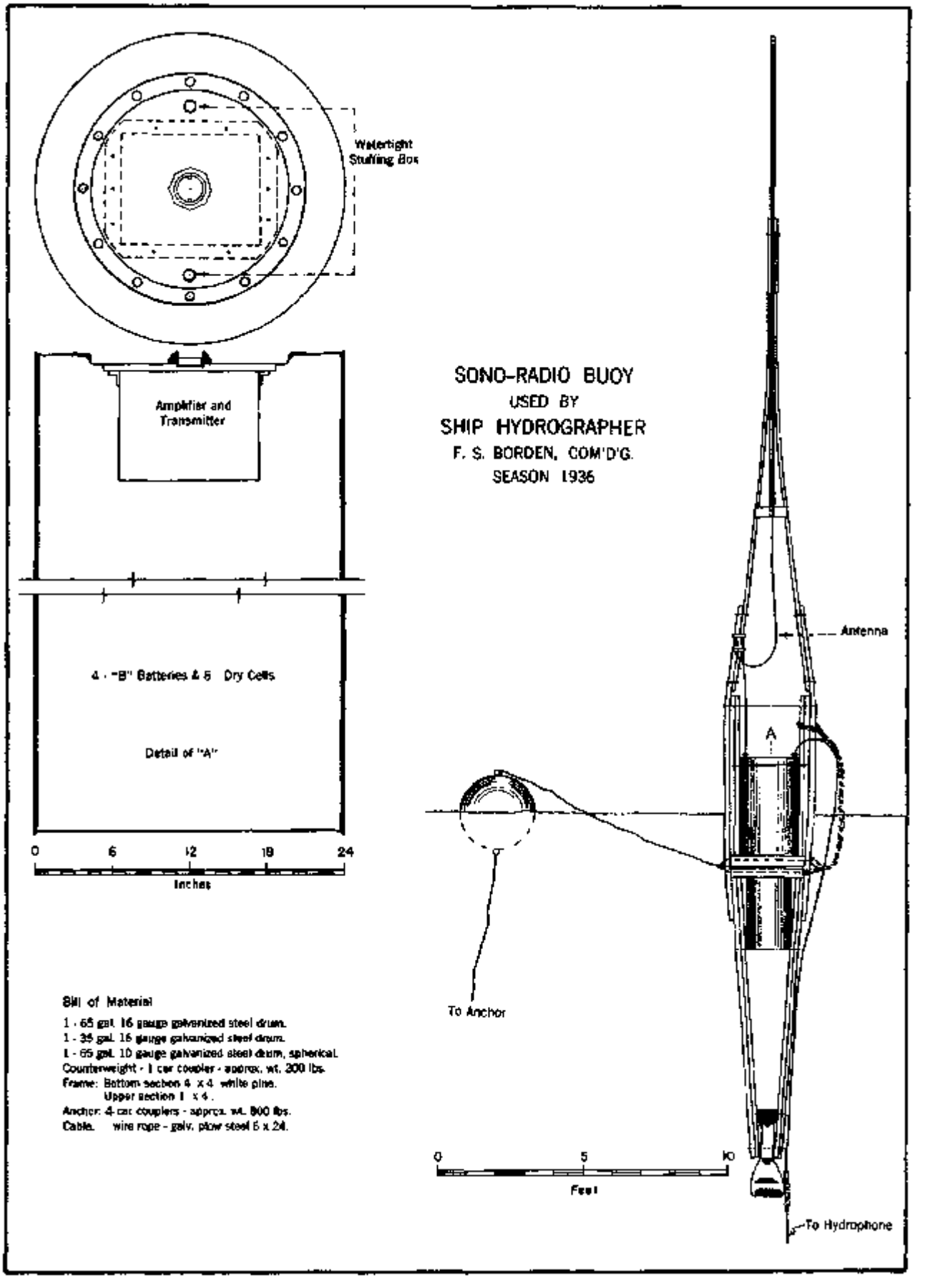
Upon your detachment from this office for sea duty I want to express my appreciation and that of the Executive Committee of the Association of Field Engineers of the Coast and Geodetic Survey for your excellent work in the development of the FIELD ENGINEERS BULLETIN during the period that you served in this office as Chief, Section of Field Work.

This unofficial publication, sponsored by our Association, has been well received throughout the technical world and we all feel that its evolution from a few mimeographed pages to its present format has been due almost wholly to your vision and efficient editorship.

Sincerely,

G. Rude

President,
Association of Field Engineers,
U. S. Coast and Geodetic Survey


Watertight Stuffing Box
Amplifier and Transmitter
4 - "B" Batteries & 5 Dry Cells
Detail of "A"
0 6 12 18 24
Inches
SONO-RADIO BUOY
USED BY
SHIP HYDROGRAPHER
F. S. BORDEN, COM'D'G.
SEASON 1936
Antenna
A
To Anchor
0 5 10
Feet
To Hydrophone
Bill of Material
1 - 65 gal. 16 gauge galvanized steel drum.
1 - 35 gal. 16 gauge galvanized steel drum.
1 - 65 gal. 10 gauge galvanized steel drum, spherical.
Counterweight - 1 car coupler - approx. wt. 300 lbs.
Frame: Bottom section 4 x 4 white pine.
Upper section 1 x 4.
Anchor: 4 car couplers - approx. wt. 800 lbs.
Cable. wire rope - galv. plow steel 5 x 24.

THE SONO-RADIO BUOY

Charles G. McIlwraith
Senior Electrical Engineer
U. S. Coast and Geodetic Survey

Foreword by Commanding Officer of Ship HYDROGRAPHER:

Radio Acoustic Ranging as a method of determining the position of a surveying vessel was first used successfully by the U. S. Coast and Geodetic Survey on the Pacific Coast of the United States in 1924. R. A. R. stations on the west coast have always been shore stations. When its use was attempted on the east coast difficulties were encountered in obtaining results with shore stations and in order to overcome these difficulties mobile offshore stations were used by having the R. A. R. equipment on surveying vessels or large launches anchored well offshore. This method brought satisfactory results but, of course, at an increased cost.

The advantage of automatic radio buoys to replace the station ships became apparent in 1931 during the first season's survey on Georges Bank when Radio Acoustic Ranging with floating hydrophone stations was successfully accomplished, as had been predicted from results of experiments made by the LYDONIA and Launch ECHO in September, 1929. Actual work on the circuits for the buoy was started in the winter of 1932 and 33 during which it was demonstrated that dry batteries could be used to furnish the power. An experimental unit operated for 57 days without change of batteries. This, work was stopped for the development of the Dorsey Fathometer but resumed again in July, 1935 and continued intensively during the fall and winter, culminating in the first official report of operation at sea from the LYDONIA on June 13, 1936.

Several automatic buoys were made available to the party on the HYDROGRAPHER during the 1936 field season. These were tested thoroughly and used successfully on the Louisiana Coast Project. The development proceeded so satisfactorily that by the latter part of the season it was possible to dispense with one of the station launches. Only one launch will be needed during the 1937 season. While there are a few minor difficulties to be overcome I believe that after next season station launches can be replaced entirely by Sono-Radio Buoys for the off-shore surveys on the Gulf Coast. The advantages, in decreasing the risk to personnel on the launches and in reducing the cost of off-shore surveys are apparent.

The development of the Sono-Radio Buoy was in charge of Dr. Herbert Grove Dorsey assisted by Mr. Thomas J. Hickley, Assistant Electrical Engineer, and Dr. C. G. McIlwraith, Senior Electrical Engineer. The results of one of the tests made on the accuracy of Sono-Radio Buoys are given at the end of the article by Dr. Mcllwraith.

F. S. Borden, Commanding Ship HYDROGRAPHER.

A Sono-Radio Buoy (abbreviated "SRB") consists of a floating structure which supports the RAR equipment. The buoy itself is similar to the ordinary hydrographic buoy except that it is somewhat larger and of heavier construction. The electrical gear, designed and built in the Washington Office, is contained in a 65 gallon steel drum with a removable head. This drum is a standard type used for shipping semi-fluid substances, and costs only $5.00 complete. The head, pressed from the same material as the drum, is secured with 12

l/4 inch cap screws and is made water-tight by a tubular rubber gasket. A 35 gallon drum is secured in the frame below the larger drum to provide additional buoyancy. The frame is made of 2" x 4" lumber, doubled, and extends 14 feet below the water line. A superstructure of 1" x 4" lumber is carried to a height of 23 feet above the water line. A large car coupler is bolted to the bottom of the frame as a counter weight.

The R. A. R. equipment of the buoy consists of a hydrophone, amplifier, radio transmitter, antenna, and the necessary batteries.

The hydrophone is one designed and built in the office. It uses a small Baldwin unit and the outer diaphragm is sufficiently heavy to obviate the use of internal air pressure. It is suspended at a depth of 10 fathoms and is connected to the amplifier by Tyrex cable.

The amplifier uses two type 32 and one type 30 tubes. Its voltage gain is between 95 and 100 decibels and it is tuned so that the gain is a maximum at a frequency of 100 cycles per second and falls off rapidly with increasing frequency, being only 47 decibels at 500 cycles per second. This is quite different from the R. A. R. amplifier ordinarily used, which has rather uniform gain from 200 to 1500 cycles per second.

The transmitter consists of a type 33 tube in a crystal controlled circuit. A type 30 tube, used as a keying tube, controls the operation of the transmitter by varying the voltage applied to the screen grid of the 33 tube. The type 30 keying tube takes the place of the thyratron or relay generally used. It permits the type 33 tube to oscillate only so long as the output of the voltage amplifier is above a definite level, determined by the bias on the keying tube. Hence, the SRB gives a return as long as the sound of the bomb at the hydrophone. This is rather a nuisance when two SRB's are at about the same distance. A change in the keying circuit can be made which will make the return uniformly short for any duration of sound, and such a change may be desirable in the future.

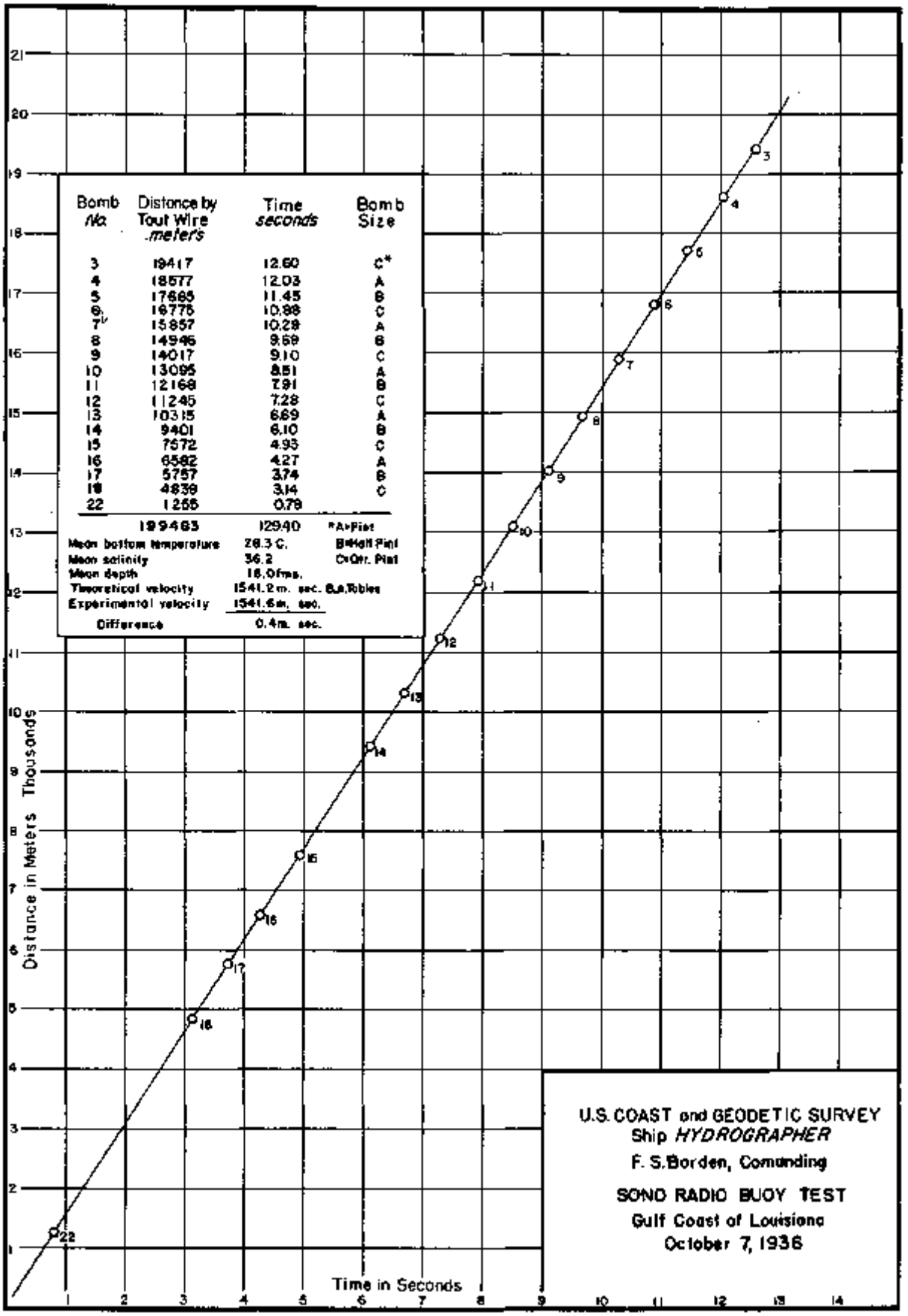
The antenna is a 19 foot piece of 3/8" copper tube, supported on the superstructure by small stand-off insulators. Its lower end is 3 feet above the water line, and connects to a tuning unit enclosed in a shield of pipe fittings. The antenna is fed by a low impedance transmission line (Tyrex cable) from the transmitter. This arrangement is necessary because waves, washing over the top of the drum, would detune an antenna fed directly from the transmitter.

The amplifier and transmitter are enclosed in a bakelite box 11" x 9" x 8" which is bolted to the under side of the head of the drum. An opening, about 2" in diameter, closed by a screw plug, gives access to the controls, which permits the apparatus to be turned on or off, or tuned, without removing the head of the drum.

The batteries used include a special 3 volt dry battery for filaments, four 45 volt heavy duty B batteries, four dry cells, and two 22-1/2 volt C batteries. The C batteries are contained in the bakelite box, the others are packed in the bottom of the drum. A can of calcium chloride is used to absorb excess moisture.

The complete buoy weighs about 500 pounds, and while its great length makes it rather clumsy, it has been handled with the ship's gear without difficulty.

The hydrophone is suspended by Manila line directly under the SRB. No difficulty, while setting out the SRB, has been encountered keeping the hydrophone from fouling the moorings, and in no case has a hydrophone ever fouled after the SRB was planted.



Bomb No.	Distance by Taut Wire meters	Time seconds	Bomb Size
3	19417	12.60	C*
4	18577	12.03	A
5	17665	11.45	B
6	16775	10.88	C
7	15857	10.29	A
8	14946	9.69	B
9	14017	9.10	C
10	13095	8.51	A
11	12168	7.91	B
12	11245	7.28	C
13	10315	6.69	A
14	9401	6.10	B
15	7572	4.93	C
16	6582	4.27	A
17	5757	3.74	B
18	4839	3.14	C
22	1255	0.79	
	199463	129.40	

*A=Flat
B=Half Flat
C=Qtr. Flat

Mean bottom temperature	28.3 C.
Mean salinity	36.2
Mean depth	18.0 fms.
Theoretical velocity	1541.2 m. sec. B.A. Tables
Experimental velocity	1541.6 m. sec.
Difference	0.4 m. sec.

The anchor used was made of four car couplers secured together. (Note: Scrap car couplers are used for anchor and counterweight, the average weight of a coupler being about 200 pounds). The anchor line was made from both chain and wire rope. The weight of the moorings was carried by a relieving buoy and the SRB floated at the end of a four fathom bridle. Some ingenuity was required to make the connection to the relieving buoy quiet since in the rattling of the moorings was discovered a fertile source of stray returns. No attempt was made to use more than one anchor.

Twp SRB's were anchored in depths of 60 fathoms, one with 120 and the other with 140 fathoms of chain and wire rope. In these cases two relieving buoys were used with each. The second buoy was not necessary, however, for the support of any of the weight of the moorings, but was only added as a safety precaution. The two SRB's in 60 fathoms were picked up without difficulty during moderately rough weather.

Four Sono-Radio Buoys, numbers 7 to 10 inclusive, were used during the 1936 season. One of these, number 8, was lost in a storm after but four days use. The others have survived and have given very satisfactory service. The three were used for a total of 108 buoy-days, number 7 leading with 53 days. One set of batteries was in use a total of 45 days, the others about 30 days each. In no case did the B.batteries show serious loss of voltage, but in the buoys that were in use 45 days it was evident that the filament batteries were approaching the end of their useful life.

In general, it appears that at the same time and place, an SRB will give satisfactory returns from a distance about 75% of that which may be expected from a manned RAR station. This difference is not surprising, since the SRB is on all the time, and must have its sensitivity low enough that it will not be actuated by the average water noises; while the operator of an RAR station can adjust the sensitivity to the noise conditions of the moment. The longest distance from which returns were received from an SRB was 4l.l8 seconds (equal to about 34.2 nautical miles) with a quart bomb.

As for reliability, during this season at leasts the launch RAR stations had more technical troubles than did the SRB's. Most of the difficulties with the SRB's were due to noisy tubes or imperfectly soldered connections. It must be admitted, however, that a launch RAR station which is having trouble is silent, while the commonest ailment of an SRB is the emission of a steady series of chirps, which can interfere very seriously with returns from other stations. If that occurs, the offending SRB can only be silenced by personal attention from the survey ship.

Measurements made in the office show that with the keying circuit used on these SRB's there is a constant lag of 0.01 second in the return. With other keying circuits the lag may be appreciable.

It is occasionally necessary to moor an SRB in a position where there is danger of its being struck by passing ships. It is suspected that such an accident may have happened to the one which was lost. To diminish that risk, experiments were made with a light on the superstructure. A small 6 volt light in a Fresnel lens was mounted on the top of the antenna frame and lighted from dry cells within the drum. A relay was arranged so as to turn on the light whenever the transmitter was actuated. Since the noise of the propellor of any ship within about a mile will actuate the SRB, an almost steady light will be shown from the buoy which should prevent the ship's collision with it. Two SRB's were equipped with such lights. It was necessary to install choke coils in the wires to the light to avoid detuning the antenna. Type B1 telephone relays were used and they worked reasonably well.

It is difficult to estimate the money saving resulting from the use of SRB's. With no real data on the cost of the units, it is estimated that the value of material and labor in each buoy would not exceed $150. A set of batteries costs about $15.00 and will probably last all season.

Against these low costs must be set the fact that an SHE can not be ordered from station to station as can a launch but must be carried to its station by an otherwise unproductive trip made by the survey ship.

Before the present season and the development of the automatic SRB, station launches have been used as R. A. R. stations and since these launches must be large enough to be anchored on exposed offshore stations, it seems reasonably certain that statistics will show that the use of SRB's substantially reduce the cost of R. A. R. operations with no sacrifice in accuracy of control.

SONO-RADIO BUOY

George D. Cowie, H. and G. Engineer
U. S. Coast and Geodetic Survey

This new type of buoy was first tested in actual field work in 1936 on the Atlantic and Gulf Coasts. It was hoped that their performance would be so successful that sono-radio buoys could replace station ships for R. A. R. work at a considerable saving in cost of operation, and would eliminate the necessity of such dangerous assignments for the smaller vessels of the service.

The buoy as now constructed on the Ship LYDONIA is similar to a two drum survey buoy, minus the target. The purpose of the lower drum is to furnish buoyancy only, the upper one containing the radio parts. An antenna coupler in a capped water-tight pipe is located on the buoy frame just above the drum and this is connected to an eighteen foot copper tube antenna mounted on insulators on the buoy upright. The same type of hydrophone used on the Atlantic Coast station ships was used with the buoy. It was mounted, however, on a triangular frame with rubber suspension and secured to the buoy anchor cable about 30 feet down from the buoy itself.

A counter weight of two car-couplers was necessary to keep the buoy upright. This increased the weight of the sono-radio buoy to approximately 750 pounds, about all that the LYDONIA's boom could safely handle. The buoy was anchored with the usual survey-buoy ground tackle.

The operation of the buoy is similar to the operation of a station ship. The bomb signal is picked up by the hydrophone, causing an electrical wave to be conducted to the audio amplifier, passing through a keying-tube and put on the air through a crystal-controlled transmitter tube. The power (about 5 watts) is supplied by dry batteries whose life is about 2½ months.

As the OCEANOGRAPHER and the LYDONIA were working in adjoining areas it was necessary that each ship use crystals of different frequencies in their sono-radio buoys to avoid interference. The frequency used by the LYDONIA was ip.60 kilocycles.

Before the buoy is placed on station the sensitivity of the bomb amplifier is adjusted so that it will not be actuated by ordinary water noises. This degree of sensitivity is determined by experimentation with a buoy in the water and subsequently by electrical measurements.

The radio signal strength of the buoy is such that it can be recorded regularly by chronograph at distances of seventy-five miles.

During the 1936 field season in the approaches to New York Harbor the LYDONIA, using four sono-radio buoys, anchored them in 19 different locations. At no time however were more than three buoys in simultaneous operation. These buoys were anchored in depths of from 10 to 20 fathoms and were used to control R. A. R. work in the areas outside that which could be surveyed by visual fix control on a single line of survey buoys located approximately ten miles off shore.

The operation of the Sono-Radio buoys was fairly successful. A few buoys remained in operating condition for over a month without attention. A few others failed immediately after they were placed on station, due to leakage or tubes burning out. At no time did the LYDONIA attempt to get bomb returns for distances over fourteen miles, it being unnecessary for the work assigned. Results indicated however that quarter pint bombs could not be relied upon for results at distances greater than ten miles, but that at this distance quart bombs would generally give results. It is presumed that ridges and valleys in this reasonably shoal water cut down the range of bombs considerably. The OCEANOGRAPHER bombed successfully at distances of 22½ miles in greater depths of water, and received returns on ¼ pint bombs at distances up to 20 miles.

The accuracy of the distances obtained when using the Sono-Radio buoy was not all that could be desired. With the present type of buoy errors as great as 0.3 miles may be obtained when ¼ pint bombs are used at distances of ten miles. While sufficient tests have not been made to warrant positive statements regarding the probable errors which may be encountered our experience in 1936 indicated roughly the following results: ¼ pint bombs are generally satisfactory up to distances of 4 or 5 miles, ½ pint bombs up to distances of 7 to 8 miles, and quart bombs for distances up to at least 10 miles, with the probability that all these distances can be increased in water deeper than 20 fathoms, where there are no intervening shoals nor deep valleys. On a very few occasions when bombing close to the son-radio buoys there have been indications that velocities of sound as great as 1575 meters per second would have to exist to make the bomb distance check the dead reckoning position. (This may be due to the sound passing through the mud bottom for part of the distance, as was found by Commander Swainson.)

Where ¼ pint bombs have been used at distances of ten miles they have frequently given too long a distance. The explanation may be that there is a lag in the radio buoy apparatus when the received sound is weak. Even at shorter distances returns are frequently received which are found subsequently to be in error. This condition may be due to incorrect tape recording, interference by static, unaccountable lags, wrong velocity of sound, possibly an indirect sound wave path, bottom conditions, i.e. shoals, valleys, mud bottom, etc., hence it is necessary to plot the returns from several bombs in order to be reasonably certain which results can be relied upon and which must be rejected. The courses steered and speed of the ship must be considered in connection with the R. A. R. distances. This makes it difficult to decide promptly what course the ship is making good, and just when to change course to cover the working area economically.

The cost of the material used in the buoys is quite small. Omitting labor costs it is approximately $200. per buoy, with small operating costs. With such a small investment there is no great need to skimp on the number of sono-radio buoys to be used during a season. As they are almost as easily established on station as survey buoys, using them at distances of ten miles or more apart calls for only a small expenditure in time in placing and locating them. On the LYDONIA's project they

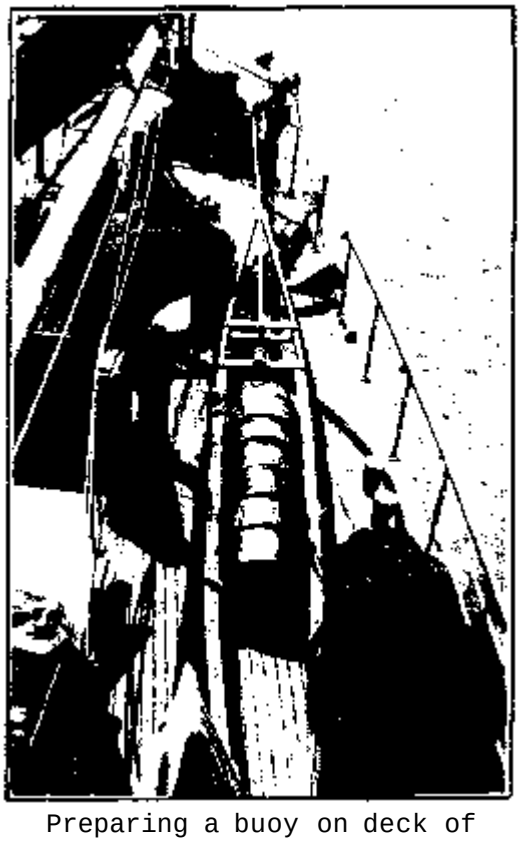
were generally anchored within 500 yards of a located survey buoy and tied into the control by a range-finder distance, or depression angle, and compass bearing.

Those planted ten miles further seaward were generally located by bombed distances from two other located sono-radio buoys. Experience showed that this method was not the best, or that only quart bombs should have been used. In one case an extra line of survey buoys was extended to join up with an off shore radio buoy which was then located by taut wire distance and sun azimuth. As suspected from the errors indicated by the bomb arcs from the three radio buoys it was found that the bombed location of this buoy was about 0.3 mile in error.

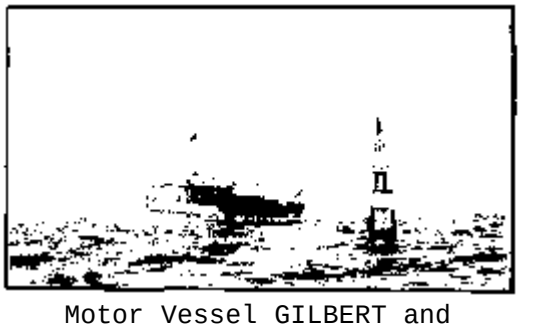
As a preliminary plan for control of an area such as surveyed by the LYDONIA this season it is suggested that a row of survey buoys be established parallel to the shore about ten miles off, sono-radio buoys at ten mile intervals along the line of buoys, and spur lines of survey buoys running to off-shore radio buoys (10 miles seaward) at intervals of 20 miles. As improvements in these buoys are made, or additional proof is given that quart or other sizes of bombs are accurate over longer distances the intervals between radio buoys may be gradually increased.

One of the principal advantages in the use of radio buoys is the fact that work in foggy or hazy weather, or at night if personnel is available, can be accomplished when no other field work can be done, and without the use of station ships and their personnel.

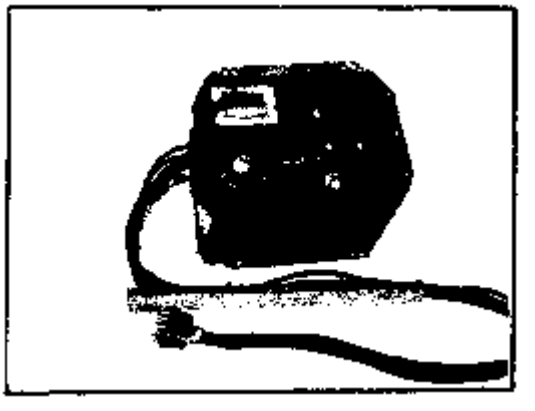
When sufficient proof of the reliability of these buoys has been obtained it may be possible to avoid the use of the usual survey buoys and survey that area immediately beyond shore control by R. A. R. buoy control.



Preparing a buoy on deck of LYDONIA



Motor Vessel GILBERT and Sono Radio Buoy



Radio and Audio Parts

SONO RADIO BUOY

SUBMARINE VALLEYS

Paul A. Smith, Jr. H. & G. Engineer
U. S. Coast and Geodetic Survey

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 unkown 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

(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. 207-326 (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. 475-480.

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.

> "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 1316, the steamer BEAR, 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.[7]

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

(6) op. cit.

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

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 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[8] 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[9] 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[10] 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,[11] 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 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 [12] 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.

(8) C. S. Piggott: Apparatus to Secure Samples from the Ocean Bottom. Bul. Geo. Soc. Am. vol. 47, pp. 675-684 (1936).

(9) C. S. Piggott: Geol. Soc. Am. Bul. (In press).

(10) B.C. Stetson: Geology and Paleontology of the Georges Bank Canyons. Bul. Geo. Soc. Am. vol. 47, pp. 339-366 (1936).

(11) Ewing, Crary, Rutherford, and Miller: Geophysical Investigations in the Emerged and Submerged Atlantic Coastal Plain. Geo. Soc. Am. Bul. (in press) 1936. N. K. Heck: Sounding to Granite. Field Engineers Bul. No.9, U.S.C.& G.S. (1935)

(12) J. W. Spencer: op. cit.

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.[13]

Differential density, currents arising out of the conditions prevailing during the glacial period have been proposed[14] 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[15] 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.[16]

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.[17]

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 in depths as great as 150 fathoms. The deeper

(13) A. C Veatch: Personal Correspondence. (1935).

(14) R. A. Daly: Origin of Submarine Canyons. Am. Jour. Sc. vol. XXXI, No. 186.

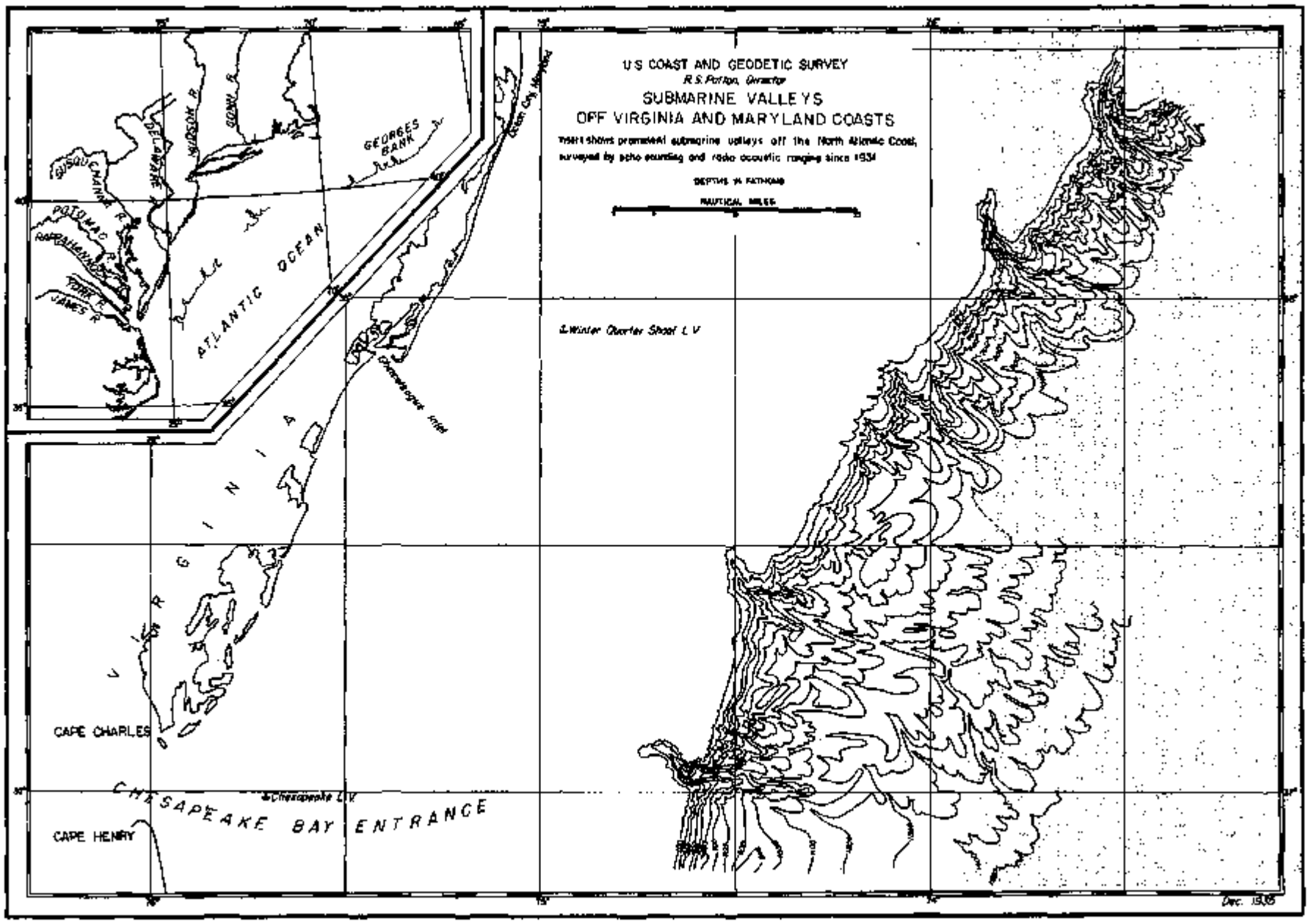
(15) Hess and MacClintock: Submerged Valleys in Continental Slopes and Changes of Sea Level. So. News Ser. vol. 83 (1936) pp. 332-334.

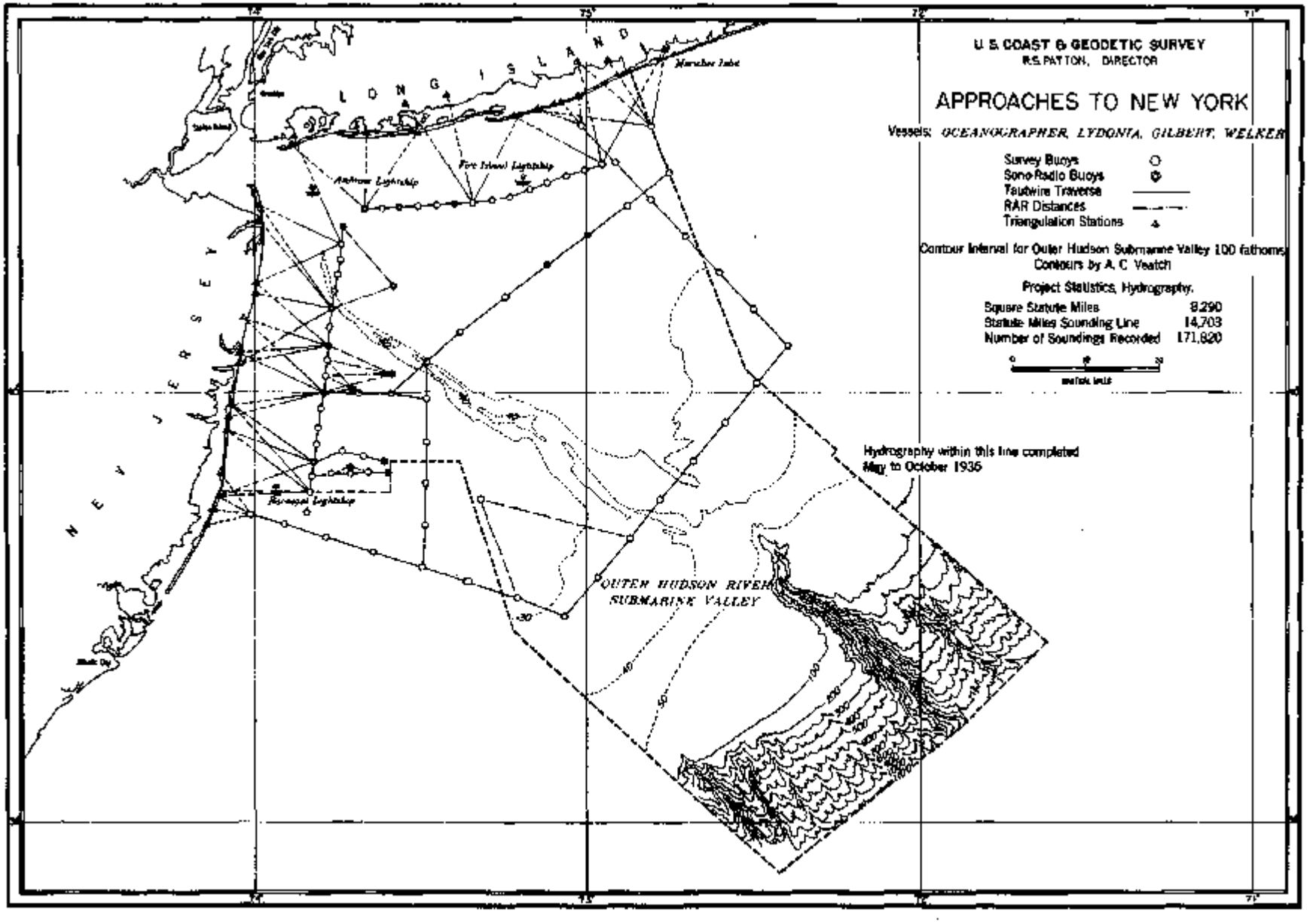
(16) A. C. Veatch: Personal Correspondence. (1936).

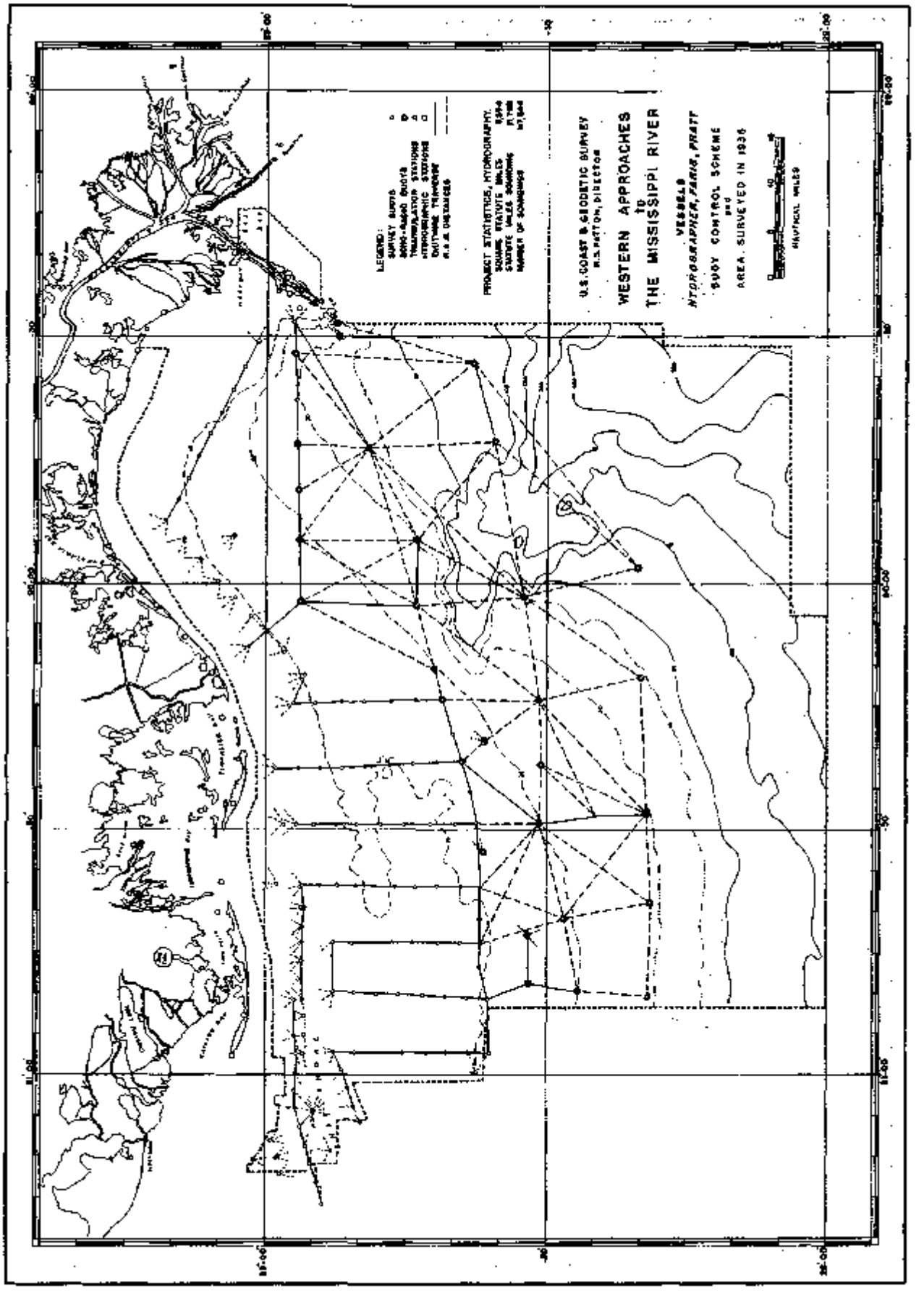
(17) F. P. Shepard: op. cit., and Am. Geo. Union Trans., April, 1936.

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.


U S COAST AND GEODETIC SURVEY
R 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 1934
DEPTHS IN FATHOMS
NAUTICAL MILES
GEORGES BANK
HUDSON R
POTOMAC R
RAPPAHANNOCK R
YORK R
JAMES R
ATLANTIC OCEAN
Winter Quarter Shoal L V
VIRGINIA
CAPE CHARLES
CAPE HENRY
CHESAPEAKE BAY ENTRANCE
Chesapeake L V
Dec. 1935


U. S. COAST & GEODETIC SURVEY
R.S. PATTON, DIRECTOR
APPROACHES TO NEW YORK
Vessels: OCEANOGRAPHER, LYDONIA, GILBERT, WELKER
Survey Buoys
Sono-Radio Buoys
Taubwire Traverse
RAR Distances
Triangulation Stations
Contour Interval for Outer Hudson Submarine Valley 100 fathoms
Contours by A. C. Veatch
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
LONG ISLAND
NEW JERSEY
Montauk Point
Ambrose Lightship
Fire Island Lightship
Navesink Lightship
OUTER HUDSON RIVER SUBMARINE VALLEY
30
40
50
100
200
300
400
500
600
700
74°
73°
72°
71°

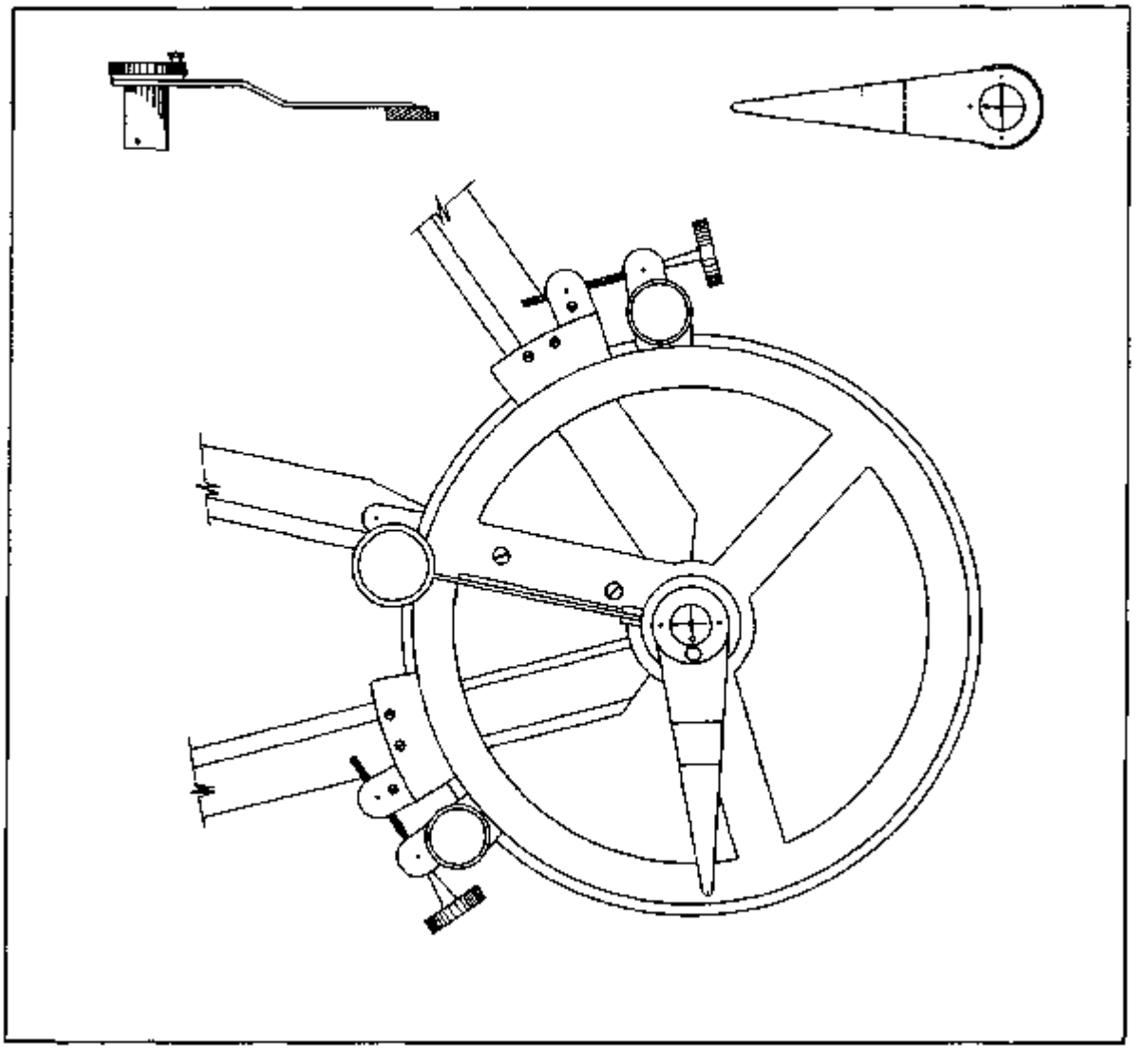

LEGEND:
SURVEY BUOYS
SONIC-RADIO BUOYS
TRIANGULATION STATIONS
HYDROGRAPHIC SOUNDINGS
OUTLINE TRIANGLES
R.A.M. DISTANCES
PROJECT STATISTICS, HYDROGRAPHY:
SQUARE STATUTE MILES
STATUTE MILES SOUNDING
NUMBER OF SOUNDINGS
U.S. COAST & GEODETIC SURVEY
H.S. HUTTON, DIRECTOR
WESTERN APPROACHES
to
THE MISSISSIPPI RIVER
VESSELS
HYDROGRAPHER, FARIN, PRATT
BUOY CONTROL SCHEME
and
AREA SURVEYED IN 1935
NAUTICAL MILES

PROTRACTOR FITTING FOR WIRE DRAG

Raymond P. Eyman, Hydrographic and Geodetic Engineer
U. S. Coast and Geodetic Survey

In plotting drag work for the past summer one of the members of the party, Mr. Gregg Elliott, Jr., improvised a simple device to be used with the regular three arm steel protractor for plotting the boat position, near buoy position, and direction to far buoy with one setting of the protractor. The device is merely the center piece with celluloid bottom containing the cross lines and center hole; a second hole was drilled at a distance from the center corresponding to the length of towline (in this particular case it was 50 meters); on the upper part of the center piece a pointer was mounted in line with the two holes and reaching to the graduated limb of the protractor. In plotting, the fix gives the position of the boat (center hole), then the buoy angles are set with the pointer and spotted through the offset hole, the near buoy being plotted direct and a short direction obtained to far buoy. (This latter direction used as a check only as dual control was used.)

Different lengths of towline or sheets of different scale would, of course, require different center pieces which could be made up easily.

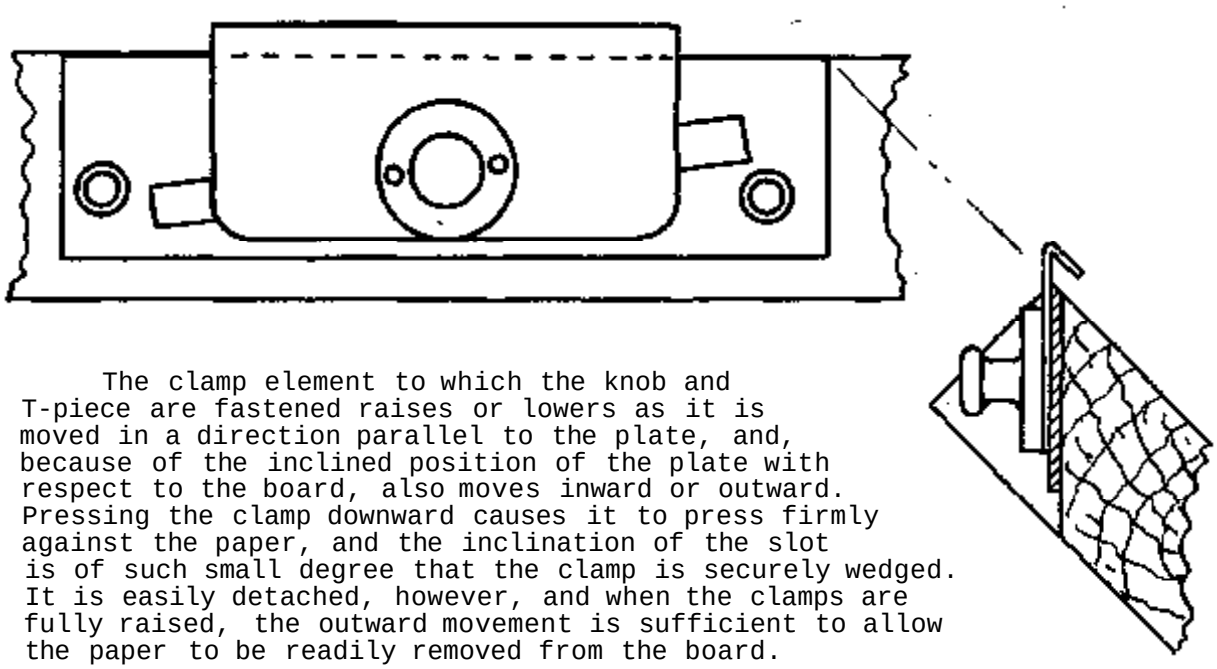


PLANETABLE CLAMP FOR METAL-MOUNTED PLANETABLE SHEETS

D. L. Parkhurst, Chief, Instrument Division
U. S. Coast and Geodetic Survey

This clamp, made of brass, consists of a plate screwed to the plane-table board, one near each corner, the part of the board to which it is attached being cut away at forty-five degrees.

This plate carries an inclined slot through which a T-shaped piece of brass is fastened to the knob shown in the sketch.



The clamp element to which the knob and T-piece are fastened raises or lowers as it is moved in a direction parallel to the plate, and, because of the inclined position of the plate with respect to the board, also moves inward or outward. Pressing the clamp downward causes it to press firmly against the paper, and the inclination of the slot is of such small degree that the clamp is securely wedged. It is easily detached, however, and when the clamps are fully raised, the outward movement is sufficient to allow the paper to be readily removed from the board.

The recessing of the clamping unit is of sufficient amount so that there is little or no projection to strike against anything in the ordinary handling and storing of these planetable boards.

DEMOUNTABLE PIPE TOPOGRAPHIC STAND

Raymond P. Eyman, E. and G. Engineer
U. S. Coast and Geodetic Survey

In running in shore line or cutting in signals the topographer frequently encounters a stretch of coast line that is exceedingly difficult to traverse by ordinary means. The following described stand was constructed to overcome such difficulties along the Alligator River, North Carolina. The stand could be quickly and easily assembled in five feet of water in about ten minutes and dismantled and stowed in the boat in five minutes.

By use of the stand the topographer was able to make a set-up in the water, clear of the shore obstructions and in water too deep for a straight set-up, and thus obtain many more shots along the shore and to carry much longer azimuths between set-ups when necessary.

The stand was constructed of pipe and pipe fittings, the members of which were slid into place and held rigid by the weight of the topographer, no tools or wrenches being necessary once the various members had been made up. All diagonal and horizontal members are screwed into the fittings. The vertical members slide freely into the oversize (2") tees when assembling.

The cost of such a stand was very moderate and proved a good investment in enabling the topographer to cover the difficult area in but very little longer time than would be required for "easy going" beach.

List of Material and Cost

4 uprights - 8 ft. each = 32 ft.)		
8 horizontals - 6½ " " = 52 ft.)	84 ft. of 1½" pipe @ 15¢ ft.	=$12.60
8 diagonals 8 3/4 ft. " = 70 ft.	of l" pipe @ lO¢ ft.	= 7.00
16 Tees, 2" xl½" @ 37½¢ each		= 6.00
l6 Y's, 45° - 2 " xl½" @ 52½¢ each		= 8.40
16 Nipples, 1½" x 1" @ 15¢ each		= 2.40
4 Flanges, 1½" @ 25¢ each		= 1.00
	Total Cost	$37.40

Notes on Assembling

1. Equipment
   Small launch to carry pipe stand,
   Flat bottom skiff,
   Extra anchors for both skiff and launch,
   Boat hook,
   Pipe wrench (see note 9).
2. Assemble the stand between the launch and skiff, using two men in the skiff and three men in the launch. The third man in the launch passes the material.
3. Attach two 10 foot pieces of line (with float) on each of the bottom horizontals. In soft bottom the horizontals may sink slightly in the mud, the lines will assist in dismantling the stand.

Type of coast line along which stand was used.

4. The vertical pipes go in the water first, then the bottom horizontals, next the diagonals and last the top horizontals. It will be necessary to hold the verticals until the bottom horizontals are down. It is important that the opposite sides be built symetrical, i.e., if the diagonals on the north and south sides are placed on first at the bottom then they must go on first at the top.

5. In case the three corners of the stand are on an "even keel" but the fourth corner is slightly raised because of a snag or rock, the stand may be shifted from the boats without dismantling.

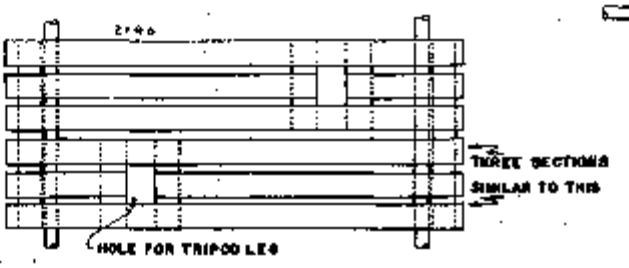
6. The tripod legs of the plane table rest on 2x4s across the lower of the top horizontals. The observing platform is supported on the higher of the top horizontals, with clearance between.

7. The 8 foot stand can be assembled in 5 feet of water to the best advantage.

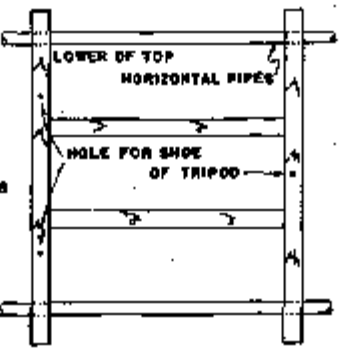
8. Five men can assemble the stand easily in ten minutes. It can be dismantled and stowed in the launch in 5 minutes.

9. Occasionally a fitting receives a ¼ turn and it is necessary to use the pipe wrench on it.

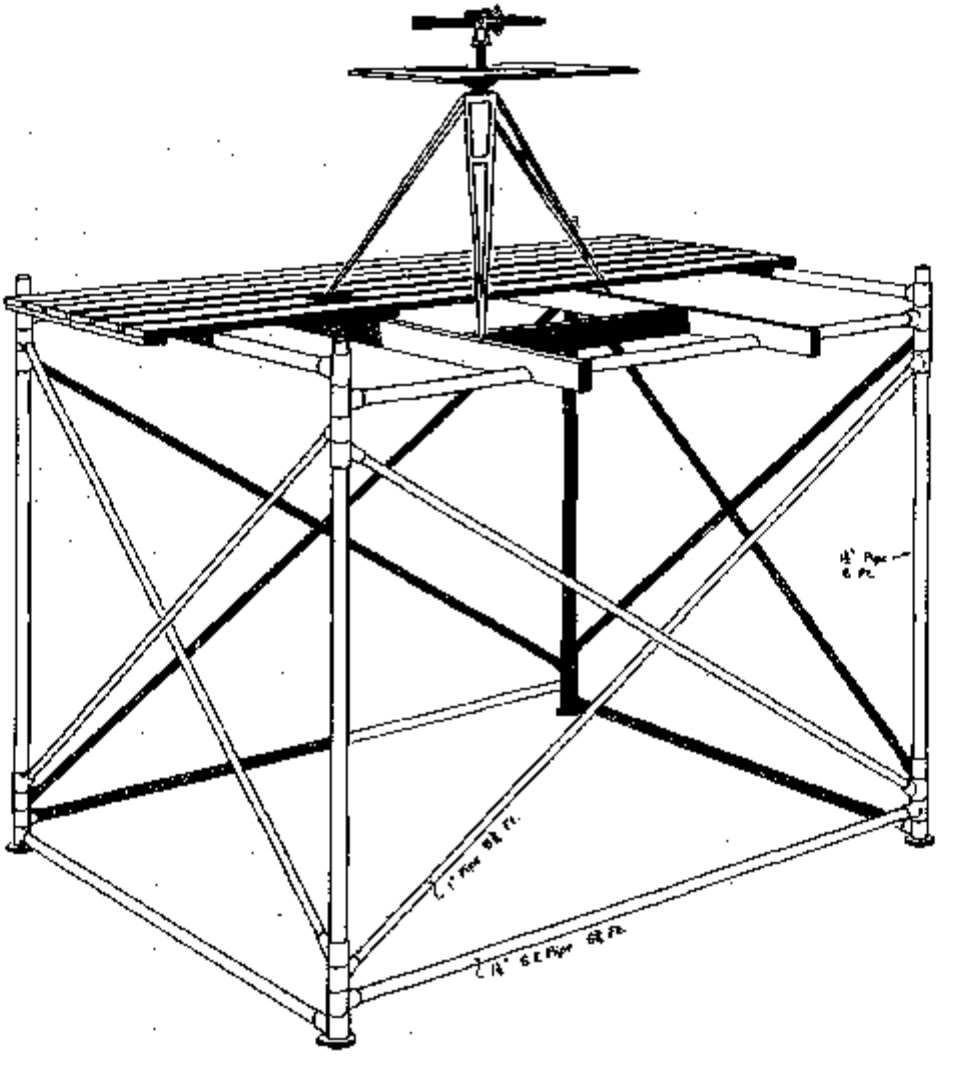
PIPE TOPOGRAPHIC STAND



OBSERVERS PLATFORM



INSTRUMENT SUPPORT



Meaning of Marginal Notes on Charts and Terms Applying To Various Editions

U. S. COAST AND GEODETIC SURVEY

NEW CHART. A new chart is always designated by a number not previously assigned to a chart published by this Bureau. It may cover an area heretofore unchartered or it may be of a scale larger or smaller than existing charts of the same area.

The date on which this chart is printed appears in the publication note in the center of the lower margin of the chart, thus:

> Published at Washington, D.C., March, 1935
> By the U.S. Coast and Geodetic Survey
> H. S. Patton, Director.

A similar date also appears in the lower left hand margin, thus: 35-3/10.

At the time of the printing of a new edition of a chart the date of the first publication is erased and the date of the new edition will appear in both places. The original date does not again appear on the chart.

NEW EDITION. A new edition of a chart is one which contains extensive corrections essential to navigation, additional to those published in Notices to Mariners; these in all being of such extent and importance as to make all previous prints obsolete, thus including new surveys in critical areas, changes in datum, etc. The date in the publication note in the center of the lower margin of the chart is changed at this time, as to "September 1935" and a similar date shown in the lower left hand margin thus: "35-9/15" (1935 - Sept. 15) which is the date on which the new edition was printed; all previous dates in both places having been expunged.

NEW PRINT. A new print of a chart is one which contains corrections of minor importance to navigation or which are of such small extent that the necessary change can be made by hand on the printed copies of the chart. These include such changes as are published in the Notices to Mariners. The date of the new print is added in the lower left-hand margin of the chart in a manner similar to and following that of the new edition. The dates of all subsequent new prints are added in the same manner until it becomes necessary to issue a new edition, at which time all the dates are expunged and the date of this new edition is inserted as above mentioned.

REPRINT. A reprint of a chart is an exact duplication of the current issue and is only for replenishment of stock. The date of a reprint is not shown on the chart. (A reprint is also known as a "Like Over" printing.)

SMALL CORRECTIONS. All changes to aids to navigation, newly discovered dangers, important changes of charted depths, etc, as are published in the Notice to Mariners, information of which has been received in the U. S. Coast and Geodetic Survey office at Washington, D. C. subsequent to the printing of the current editions of charts are added by hand to the charts affected before being issued from this office. The date of issue is changed bodily the note printed in the lower right margin of the chart as follows:

> Lights, beacons, buoys and dangers corrected for information received to date of issue. (DATE)

U. S. NAVY HYDROGRAPHIC OFFICE

(From "Hydrographic Bulletin" No. 2398, Aug. 21, 1935, published by the Hydrographic Office, Navy Department, Washington, D.C.)

On all Hydrographic Office charts the system hereinafter described is followed in entering notations on the margins of charts, and the signification of these notes is stated for the information of all concerned.

(a) **PUBLICATION NOTE.** This note is placed at the center of the bottom margin of the chart and shows the place and date of original publication, thus:

> Washington, D. C., published Dec. 1929 at the Hydrographic Office, under the authority of the Secretary of the Navy.

This note is not changed while the chart remains on issue.

(b) **EDITION NOTE.** This note is placed at the right-hand edge of the bottom margin, just to the left of the chart number. It shows the current edition number only, with the date of edition, thus:

> 5th Edition, Feb. '30.

A subsequent edition of a chart is given a consecutively higher edition number, thus, 7th or 8th, etc., but a new edition number will be assigned only when corrections to a chart are so extensive or important as to necessitate a replacement of all previous issues.

(c) **NEW PUBLICATION NOTE.** This note is placed on the bottom margin, about halfway between the Publication Note (see par.(a) above) and the Edition Note (see par.(b) above), thus:

> New Publication: 10th Edition, June 1934.

This note is added when the chart is made over or is extensively changed as to require a new plate. (In reality this note is an office record and need not concern the navigator using the chart.)

The foregoing marginal notes are included in the printing of the charts.

(e) **SMALL CORRECTIONS NOTE.** This note appears at the left-hand edge of the bottom margin and shows the number of the Notice to Mariners from which the information contained has been used on the charts and dates of other source corrections that have been made. In addition, the note has separating lines to indicate in groups the corrections made at each printing and the dates of printing, thus:

Small corrections	Printed Aug. 1931	Feb. 1933
From Notices to Mariners:	51-9,11,22	h1 (32-7,13 h1)95-1,6
From other sources:	VIII '31	II '33

This note indicates that since the current edition of the chart was published, as given in paragraph (b) above, the chart has been reprinted twice, namely, in August 1931, and again in February 1933. When when reprinted in August 1931, small corrections published in Notice to Mariners Nos.5, 11 and 22 of 1931, were made to the chart plate, and that one or more small corrections from a source other than the Notice to Mariners was made to the chart plate in August 1931. That when again reprinted in February 1933, additional small corrections were made from Notice to Mariners No. h1 of 1932; Nos. 7, 13 and h1 of 1932; and No. 1 and 6 of 1933, and that other small corrections from a source other than the Notice to Mariners were made in February 1933.

When a new edition is published the small corrections note itself remains, but all notations of previous printings and corrections are expunged.

The latest editions of charts are invariably corrected for all information published in the Notice to Mariners between the date on which the chart was printed and the date of issue from the Hydrographic Office. The date of issue is indicated by a stamp placed on the face of the chart, thus:

> Corrected Through
> Notice to Mariners
> No. 27, July 5, '34,
> Hydrographic Office
> Navy Department.

THE BRITISH ADMIRALTY

British Admiralty charts after (a) first publication, are kept corrected by means of (b) new editions, (c) large corrections and (d) small corrections.

(From the British Admiralty, Pacific Islands Pilot, Vol. II.)

(a) **NEW CHARTS.** The date of the first publication of a chart is shown in the center of the lower margin, e.g.: Published at the Admiralty 27th January, 1887. This date appears on all subsequent issues of the chart.

(b) **NEW EDITIONS.** A new edition of a chart embodies the latest information received in the Hydrographic Department. The chart is entirely revised throughout and modernized in style, all copies of the chart in circulation being cancelled.

When a New Edition is published the large and small Corrections dates are removed (these corrections being embodied in the New Edition).

Editions are not numbered consecutively, but are dated, e.g., a chart would be described as "Chart No. 2045. Owen to Christchurch. Published 27th January 1888. New Editions: April 1893, June 1906, October 1910, etc."

(c) **LARGE CORRECTIONS.** When important corrections are so large that they cannot be made conveniently by hand or promulgated by Notices to Mariners, the dates on which these corrections are made will be entered on the chart plates under the heading "Large Corrections" and will appear below those of "New Editions".

A "Large Correction" will automatically cancel all existing "Small Corrections" dates on the plates.

All copies of the charts in circulation will be cancelled when a Large Correction is made in a similar manner to a New Edition, but attention is drawn to the fact that in this case the chart has not been revised generally throughout.

(d) **SMALL CORRECTIONS.** When a chart is corrected from information promulgated in an Admiralty Notice to Mariners (except temporary and preliminary notices), the year, if not already shown, and the number of the notice are entered in the lower left-hand margin, e.g.:-Small Corrections 1908-905.

When a chart is corrected from information which is considered of no importance from the standpoint of safe navigation and which is therefore not promulgated in an Admiralty Notice to Mariners, the year, if not already shown and the date of the correction are entered on the chart, in one of two ways in the lower left-hand margin and in sequence with the notations referred to in the preceding paragraph, e.g.:-

> Small Corrections, 1926 - 5.20 or
> Small Corrections, 1928 - (Pl.25)

These indicate the chart received small corrections on May 20th or June 25th, 1928, respectively.

Notices to Mariners are occasionally accompanied by reproductions of portions of charts known as "blocks" which show the corrections printed in red. These "blocks" may be pasted in their proper positions on the charts which they affect.

See Paragraph (c) above.

REPRODUCTIONS OF ORIGINAL SURVEYS

K. T. Adams, Hydrographic and Geodetic Engineer
Assistant Chief, Division of Charts, U. S. Coast and Geodetic Survey

A total of approximately 11,900 hydrographic and topographic surveys, made by the personnel of the Coast and Geodetic Survey during the last century, is on file at the bureau in Washington, D. C. at the present time (October 1936). These original surveys are preserved in a fireproof vault in the Washington office. Practically all such surveys are made for the purpose of obtaining the data necessary for the compilation of nautical charts and in such charts are published the results of the surveys, combining the topographic and hydrographic surveys into one compilation.

The original surveys are, however, almost always on a larger scale than the published chart and in many cases, especially in hydrographic surveys, they contain more complete detail. In any event, they are the originals, and in many instances copies of them are desired for special purposes by field parties, other government agencies or the public. Since printed copies of only a comparatively few of these are available they must be duplicated especially for that purpose. The various methods of accomplishing this are explained herein, with the limiting sizes and usual practice in this Bureau stated, as well as the principal uses of the various reproductions.

The total number of surveys is divided approximately into 6,050 hydrographic and 5,850 topographic surveys, of which latter 53O are air photo compilations. Photolithographic prints, on chart paper, are available for almost all of the air photo compilations which have been completed. Practically all of the original surveys, excepting the air photo compilations, are inked on an opaque drawing paper and transparent tracings are not available.

The air photo compilation differs in many respects from all other surveys. In the first place, the aerial photographs themselves may be considered the originals. From these photographs the first and original drawing is made on transparent celluloid, but this drawing is almost always on an odd scale. A photolithographic copy, reduced or enlarged to a standard scale, printed on drawing paper is filed in the vault as the original survey.

PHOTOSTAT

A photostat is a photographic copy made by a patented machine, in which the original is copied directly on photographic paper without the use of the usual glass or film negative. Such a copy is a negative, i.e., the black and white of the original are reversed, but the copy is in correct position and not reversed as in a glass or film negative.

The photostat machines in the bureau use paper of two sizes, 18 x 22 inches and 11 x l4 inches and photostats on paper of other sizes can not be made. In practice the larger size is in constant use but until there is an accumulation of material of a small size to be copied it is not economical to put the smaller machine into operation. This is why small subjects sometimes are photostated on the 18 x 22 size.

A photostat is made usually on the same scale as the original. Photostats can be made on an enlarged or reduced scale provided that the enlargement is not more than double or that the reduction is not more than one-half the size of the original. The only way that a greater enlargement or reduction can be made is by making a photostat of a photostat of the original.

A photostat is normally a negative in so far as the reversal of the black and white is concerned, and when the word "photostat" alone is used a negative photostat is always intended. Positive photostats, i.e., with the black and white the same as the original, can be made by making a photostat of a photostat. The cost and labor of making the positive is just twice as great as that of making a negative and this is done only in special cases, or in cases where more than several copies of the same original are desired.

A photostat copy of an original of practically any type can be made, except, of course, that colors can not be reproduced in color and that the resultant copy is in black and white. A blueprint may be photostated, the blue reproducing on the photostat as white, and the white lines as black.

A photostat is for most purposes a satisfactory copy but it can not be relied upon to be to correct scale. When such copies are used for the transfer of shoreline or the geographic positions of signals, they must be used with extreme care. If the size of the rectangle formed by the meridians and parallels, enclosing the area in question, is measured and checks with the values in the polyconic projection tables, it is a safe assumption that the detail within that rectangle is true to scale; but if the measurements do not check, even a careful adjustment to any scaled values may give doubtful results.

BROMIDE

This is the name used in this bureau to describe an enlarged photographic copy, other than a photostat, and the name is taken from the kind of paper on which the copy is made, i. e., bromide paper.

All bromides are enlargements, even though the photographic copy is reproduced on the same scale as the original. A bromide is obtained by first making a small glass negative, on a reduced scale, of the original, and then from the negative making an enlargement on bromide paper. The bromide paper does not come in contact with the negative.

A bromide copy theoretically is unlimited in size, but practically it is limited by the size of the copyboard, and the size of the bromide paper. At present, the largest size which can be made is 38" x 60".

A bromide can be made to any desired scale. Most bromides made in this bureau are copies of entire survey sheets reproduced on the same scale as the original.

A bromide is one of the most unsatisfactory of all copies. The copy sometimes has a tendency toward a fuzzy appearance, because first a reduction and then an enlargement of the original is made and it is subject to unequal distortion. The extreme comers of the copy are quite likely to be distorted and there is difficulty in making the copy to an exact scale.

Bromides should never be used for the accurate transfer of signal locations and rarely for the transfer of shoreline if any other type of copy can be obtained. Bromides are unsatisfactory for file copies, unless mounted; the paper has a tendency to tear easily and in time to become brittle, although the use, in recent years, of an improved paper has remedied this to some extent.

Bromides since they are made from glass negatives, are always positive copies, i. e., similar to the original.

BLUEPRINT

A blueprint is a contact print on a special paper of a subject drawn on a transparent material. A blueprint is a negative, in that the original appears as white on a blue background, but it is not necessarily a reversed copy of the original.

In making a blueprint the paper is in contact with the original, but since the subject is on a transparent material, either side of the original can be placed next to the blueprint paper.

The width of a blueprint is limited to the size of the machine and paper, the maximum width available in this bureau being 54 inches. The length is unlimited.

Since the original is in contact with the blueprint paper when a copy is made, no change in scale can be made and since there is always some shrinkage in the paper during drying after development, no blueprint can be made to the scale of the original. This shrinkage due to development and drying is also a factor in making a photostat or a bromide but the amount is known approximately and an allowance can be made for it. The amount of shrinkage which takes place during drying depends on whether the print is dried naturally in air or dried by artificial heat, the shrinkage being far more in the latter case.

A blueprint can be made only of a tracing or drawing on transparent or translucent material such as tracing paper, vellum, or celluloid. Tracings of the original surveys are rarely made; hence, it generally is impossible to furnish blueprints of surveys except in the case of air photo compilations, in which case a blueprint can be made of the celluloid drawing. This, of course, will be at the odd scale of the compilation, and generally will not contain geographic names, names of signals, nor legends, since these are pasted on the celluloid and are not transparent.

BLACK AND WHITE PRINT

This type of print is made on a special paper in the same manner that a blueprint is made except that the paper must be developed in a special machine. The resulting copy will be black on a white background. The process is somewhat critical and perfect copies are more difficult to obtain than in the case of blueprints. The advantage is that notes or additions can be made to the copy in black or colored ink whereas such additions must be made to a blueprint in white ink.

Since this type of copy is similar to a blue print, all the remarks made regarding "blueprints" also apply, except that the maximum width which can be made is 47 inches.

CONTACT PRINT

A contact print is a photographic print made from a negative, with the paper or other sensitized material in contact with the negative. The scale of the print will be the same as the scale of the negative, except for shrinkage, but it must be understood that the negative itself can be made to any desired scale. In the Coast and Geodetic Survey the term "contact print" usually means one which has been made from a glass negative of the original, and to the scale of the original. When making the glass negative an allowance can be made for the expected shrinkage of the paper print during drying after development. Such prints are usually "matte" prints, so-called from the fact that they are made on paper with a mat or dull finish. Contact prints may be made on any kind of sensitized paper or other sensitized material; in fact "glossy" prints usually are preferable if they are to be used for

further reproduction.

A contact print is the most accurate copy which can be made on paper. The original is kept perfectly flat during the photographing and since the print is made with the paper in contact with the glass negative the paper is kept flat during the process.

Contact prints can be made on celluloid and these have the advantage of a very low shrinkage factor, which is uniform in all directions. Such copies are the most accurate obtainable for use in the transfer of shoreline and signal location but they are somewhat more expensive than paper prints. Celluloid contact prints are especially useful when it is necessary or desirable to make an accurate and detailed comparison of one survey with another on the same scale, or even on a different scale if a projector is available.

It is now possible with the large precision camera in the bureau to make contact prints 48 x 48 inches in size. In practice this is rarely done and in general the largest that will be made is 34 x 40 inches.

FILM NEGATIVES

Negatives on celluloid film are made by placing a low shrinkage film in the copying camera instead of a sensitized glass plate. The celluloid film negative has the same advantage as the celluloid contact print of being nearly true to scale and is less expensive, but on account of its opaque background it can not be used for direct comparison with another survey as can the celluloid contact print.

Although it is possible to make celluloid film negatives, size 40 x 48 inches, in general practice the size that is made is 20 x 24 inches.

LITHOGRAPHIC PRINTS

The previous paragraphs have dealt with photographic copies. Lithographic prints in general are not and will not be made of original surveys, excepting air photo compilations. They are made when, for any reason, many copies of one survey are necessary, and for special transfer purposes.

Lithographic prints on chart paper are now available for 500 air photo compilations and will be made for all air photo compilations as they are completed and reviewed. In the case of these compilations there is, or will be, a printing plate available from which the lithographic prints are made.

Lithographic prints can be made, not only on chart paper, but on practically any flat material which will take ink. For special purposes, such prints can be made on cloth-mounted drawing paper, on grained aluminum, on tracing paper, or on drawing paper mounted on aluminum.

One print of each air photo compilation is made on Whatman paper for the file copy, which is registered in the archives and considered to be the original.

Prints on grained aluminum of air photo compilations have been used as basic sheets on which additional surveying can be done. Such sheets were used for the hydrographic surveys of the San Joaquin-Sacramento Delta. The result is an accurate basic sheet, free from distortion, but the size of the sheet, which can not be rolled, makes its use and storage very inconvenient. The use of such prints in large sizes for field work, except in special cases, is not encouraged.

A print can be made on tracing paper with the subject reversed so that the print can be placed with the inked surface in contact with another surface and the shoreline or other detail transferred from the tracing paper by "burnishing down" or rubbing the upper side of the tracing paper. A special slow drying ink is used in printing these reversed tracings and transfers can be made several months after printing.

BLUE-LINE PRINTS

A blue-line print is a print made in non-photographic blue, either from a glass negative or from a lithographic plate. Such prints from a rough original are the background upon which finished ink drawings for reproduction are made. They are used when a revision survey or an addition in the field is to be made in an area covered by an air photo compilation. Such prints are used also in cartography when it is necessary to make drawings of overlay colors requiring close registration with the original.

For use in the field a lithographic blue-line print of an air photo compilation can be made on an aluminum mounted topographic sheet. This will show in blue all details of the original compilation. Additions or corrections can be made on the blue-line print in black ink and when the sheet is again photographed, only the revision survey in black will be reproduced.

WHEN COLORS ARE INVOLVED

Black ink is used for most of the data on an original survey sheet but various colored inks are used for special purposes. When a photographic copy of a survey sheet is made the various colored inks do not reproduce equally well. It is not practicable to arrange a table of colors in the order in which they will be best reproduced photographically. There are too many variable factors, such as the type of emulsion, the type of lens, whether or not a filter is used, and the "depth" of color.

"Line-Photography" is used in chart reproduction, and in this type of work the sharp and perfect reproduction of "lines" has been emphasized to the subordination of other factors. Filters are not used in this bureau in wet-plate photography. The amount of pigment in the colored ink, with which the original was drawn, is perhaps, as much of a factor in whether it will reproduce, as the choice of color itself. A "thick" line, in which there is much pigment, will photograph much better than a "watercolor" line, in which there is comparatively little pigment.

By the use of special "panchromatic" plates or paper the entire spectrum may be photographed relatively well and color filters are an assistance in reproducing certain colors. Color filters may be used in making photostats but plates and paper with the special emulsions are usually not available for the photographic reproductions made in this bureau.

The colors in the blue end of the spectrum are photographed with difficulty on ordinary emulsions and this is especially so when artificial light is used, while those in the red end of the spectrum are reproduced relatively well. For practical purposes, then, it is sufficient that one remembers that the blue colors, especially blue and violet, are photographed with poor results and may not be reproduced at all; and that the red and yellow colors, especially yellow, orange, and red, are reproduced relatively well, sometimes as well as black; and that green and brown are intermediate colors, generally but not always reproducing well.

How well the intermediate colors will photograph seems to depend on the percentage of yellow in the color. This is also somewhat true of the colors in the red end of the spectrum. It has been noted in the work of the bureau that yellow photographs almost as well as black, and that in the mixed colors the yellower the color is the better it will reproduce.

With respect to photographic reproductions it would be advantageous if the use of the colors in the blue end of the spectrum were not required on original surveys, or better still, were prohibited. But since they are now required for certain features, the field officer can avoid the use of them only in those cases where a choice of colors is permitted, e. g. day letters and position numbers, used on hydrographic surveys; and when an original drawing, other than a survey, is being made.

REQUESTS

When copies of surveys are requested from the Washington office, the terms described in this article should be used, or the purpose for which the copy is required should be stated and copies will then be furnished, photographed by the most suitable method.

The majority of surveys are at least 31 x 52 inches in size and it is manifestly impossible to furnish a photostat of a survey on the same scale, since the largest photostat which can be made is only 18 x 22 inches in size. At times a survey may be copied in two sections and included in two photostats. However, it is the practice of the office never to make photostats of more than two sections of a survey. When the entire survey must be copied and it can not be included on two photostats, a bromide is always made.

The cost and labor of making bromides is considerably more than that of making photostats, blueprints or black and white prints, as can be appreciated from the previous descriptions of the processes. The field officers are requested to cooperate with the office in ordering photostats of a section of a survey or photostats on a reduced scale when these will answer the purpose, rather than bromides on the same scale of the entire survey.

When photographic copies are requested it is always assumed, unless otherwise stated, that these are desired on the same scale as the original. It is believed, however, that in many cases a reduced copy will serve the purpose just as well and sometimes better. Oftentimes copies of hydrographic surveys are requested when they are for use in comparing a junction between new work on a smaller scale and the previous work. In such cases a reduced copy is generally an advantage and can be used as well as one on the original scale, provided the reduction is not so great as to make soundings or notes illegible. Of course the reduced copy can be furnished at a lower cost. In general, copies reduced one-half are perfectly legible although greater reduction may make some figures illegible.

Requests are occasionally made for copies of surveys enlarged several times. The bureau considers with disfavor any enlargements to more than double the scale of the original because the original surveys were made by methods particularly adapted to the scale of the survey and had a larger scale been advisable other methods would have been used. Enlargements will be made for field officers in special cases.

Copies of original surveys are sometimes requested for use in court. In such cases, a request should be made that the copies be "certified", otherwise they may not be accepted by the court as evidence.

A request for photographic copies of surveys should state the registered number of the survey, if that is known. If the registered number is not known, the request should state the approximate latitude

and longitude of the area, in addition to any field number or description by reference to named geographic features. Such requests always should state whether a reduced scale copy can be used; whether the survey to be copied is a topographic or hydrographic survey, and the approximate date of the survey.

The following samples of requests for copies of surveys contain the desirable information:

"A full-scale photostat copy of a section of the most recent hydrographic survey off Point Judith, R. I.; photostat to be centered at latitude 41° 20', longitude 71° 25'."

"A half-scale photographic copy of hydrographic survey by John Doe, field number 4234 (or field number 2 surveyed in 1934) located in approximate latitude 41° 20', longitude 71° 25'."

SUPERINTENDENTS
United States Coast and Geodetic Survey*

F. R. Hassler	Ferdinand Rudolph Hassler, June 18, 1816, to April 29, 1818, and August 9, 1832, to November 20, 1843
A. D. Bache	Alexander Dallas Bache, December 12, 1843, to February 17, 1867
Benjamin Peirce	Benjamin Peirce, February 26, 1867, to February 16. 1874
C. Patterson	Carlile Pollock Patterson, February 17, 1874, to August 15, 1881
J. E. Hilgard	Julius Erasmus Hilgard, December 22, 1881, to July 23, 1885
F. M. Thorn	Frank Manly Thorn, September 1, 1885, to June 30, 1889
T. C. Mendenhall	Thomas Corwin Mendenhall, July 9, 1889, to September 20, 1894
W. W. Duffield	William Ward Duffield, December 11, 1894, to November 30. 1897
Henry S. Pritchett	Henry Smith Pritchett, December 1, 1897, to November 30, 1900
O. H. Tittmann	Otto Hilgard Tittmann. December 1, 1900, to April 14, 1915
E. Lester Jones	Ernest Lester Jones, April 15, 1915, to April 9, 1929 (designation changed to Director July 1, 1920)
R. S. Patton	Raymond Stanton Patton, April 29, 1929 - Present Director

*Titular designation of Survey changed from Coast Survey to Coast and Geodetic Survey, June 20, 1878

THE DIVISION OF TERRESTRIAL MAGNETISM AND SEISMOLOGY

A description of its work

E. W. Eickelberg, Hydrographic and Geodetic Engineer
Assistant Chief, Division of Terrestrial Magnetism
and Seismology

Due to the increasing value of magnetic observations in many commercial activites, and the importance of seismological data in connection with the design of earthquake resistant structures, some of the important aspects of the work of the division of T. M. & S. should be of general interest to readers of the Field Engineers Bulletin.

TERRESTRIAL MAGNETISM

The magnetic activities of the Coast and Geodetic Survey have been carried on as an essential part of its charting activites since 1833. Declination observations on land were made with a portable declinometer or some type of magnetic theodolite and were taken in conjunction with the triangulation observations. At sea they were made with the ordinary navigating instruments of the time. Numerous problems were encountered from time to time which made it necessary to establish permanent observatories at important and widely spaced localities to obtain additional, precise data to be used as standards for the comparison of field instruments and for the diurnal variation corrections to the detached field observations.

The first magnetic observatory in the United States was established by Professor A. D. Bache at Girard College in Philadelphia in l840 and was continued in operation under the direction of Professor Bache after his appointment as Superintendent of the Coast Survey in 1810 and until discontinued in 1845. The first Survey observatory was established under Superintendent Bache at Key West, Florida in 1860 and continued in operation until 1866. Other Survey observatories were located at Madison, Wisconsin from 1876-1880; Point Barrow, Alaska, 1882-1883; Los Angeles, California, 1882-1887; San Antonio, Texas, 1890-1895. In 1901 the first of the Survey's permanent observatories was established at Cheltenham, Maryland. The others were gradually added in the following years.

The early field observations were confined almost entirely to the Coast States and were, in most cases, executed in conjunction with the triangulation and hydrographic surveys. It was not until 1899 that funds were provided for a systematic magnetic survey of the country. Observations for declination, dip, and horizontal intensity were made in the following years until a magnetic station was available in nearly every county seat in the United States, so that a surveyor would have the necessary information to enable him to determine the error of his compass and also to serve as data for providing information on secular change for the relocation of boundaries.

For providing compass variation for the coastal charts and the general charts, the declination observations were taken on the adjacent shores and special observations were made on board the Survey's vessels. Dr. L. A. Bauer, formerly Inspector of Magnetic Work in this Survey, while Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington makes the following statement in Volume III on "Ocean Magnetic Observations", Carnegie Institution of Washington (1917).

"The work of the various vessels of the Coast and Geodetic Survey also deserves notice, for it was the successful inauguration of the magnetic work on these vessels in 1903, which gave me the requisite experience for undertaking the ocean magnetic survey of the Carnegie Institution of Washington. Since 1903 these vessels have utilized every opportunity in passing from port to port while engaged in their regular surveying duties to determine the 3 magnetic elements. Thus valuable series of observations have been obtained along the Atlantic and Pacific Coasts and in the Gulf of Mexico."

With the loss of the non-magnetic Vessel CARNEGIE in 1929 the obtaining of secular change data for the ocean areas came to an abrupt end. Survey vessels are no longer suitable for magnetic observations and the magnetic charts of the oceans are fast becoming obsolete. Navigators while crossing the various oceans are finding changes in compass deviation which are explainable only by errors in the published ocean magnetic declination charts. Experience shows that the data obtained on shore can not be extended very far out to sea, and it is in making landfall that the compass variation is most important.

The British Government has appropriated funds for the construction of a non-magnetic vessel to be somewhat larger than the "CARNEGIE" but a voyage long enough to bring the oceanic secular change data up to date will require at least three years, so that we can not expect new data in American waters in the very near future. It has been reported also that the Japanese have designed a 200-ton non-magnetic tender to work in conjunction with one of their survey ships.

To provide offshore declination observations the survey ships of this service are testing out a method for the determination of magnetic declination in non-magnetic whaleboats using standard compasses and azimuth circles.

In addition to the need for magnetic data over the water areas we now add aerial navigational needs over land and sea. Contrary to popular belief the magnetic compass is the controlling directional instrument in aerial navigation. A grue gyro compass can not be used on an airplane and instead of it the directional gyro is used which has to be set by comparison with the magnetic compass at intervals of about 20 minutes. Radio ranges and radio compasses fail in heavy static and the pilot then must rely entirely on his magnetic compass. In other words, when conditions are most adverse he is forced to navigate by magnetic compass.

The changes in the earth's magnetism are so irregular that they can not be predicted in advance for more than a few years and periodic magnetic observations in the field controlled by continuous observatory data are necessary to determine these changes accurately.

Comparing the isogonic maps of the United States for 1930 and 1935, we note that in 1930, the line of no change extended from a point slightly south of the California-Mexican boundary to the northern boundary of Texas, thence to central Florida. In 1935, this line extended from Los Angeles in a curve up to the central part of Lake Huron curving sharply and passing out to sea between Cape Lookout and Cape Fear, thence down to central Cuba. In other words, for Chesapeake Bay in 1930, an annual change of 3 minutes had been predicted for the ensuing 5 years, whereas this had actually changed to zero by 1934.

In order to predict such changes with accuracy it is necessary to make determinations of declination, horizontal intensity and dip periodically, usually once in every five years, at about 150 selected stations called "repeat stations" distributed throughout the country. The observations are made by a one-man party traveling by auto truck and the usual progress is about ten stations per month, observations being continued over a two day period at each station.

In the establishment of old boundaries, originally surveyed with a magnetic compass, lawsuits result occasionally and this bureau is required to furnish certified values of the changes in magnetic declination between the date of the original survey and the date of the survey in question. The publication "Magnetic Declination in the United States", issued at intervals of five years, is a compilation of all the magnetic observations available in this country. The observations are tabulated in such manner to permit the computation of changes in declination for

any point in the United States from about 1750 to date. The data which are obtained from field parties assist in keeping this publication up to date. The observatory records consist primarily of continuous recording of the variation in declination, horizontal intensity, and vertical intensity with suitable absolute observations for controlling the base lines. These records are analyzed and abstracted in the Washington office and published in limited quantity for the use of investigators in terrestrial magnetism all over the world who, in turn, send their observatory data and the results of their investigations to us.

Such data are not only useful as an accurate record of secular changes but in solving the fundamental problem of the causes of the variations in the earth's magnetism. They are also used by investigators in the phenomena of radio transmission for the correlation of magnetic conditions with exceptionally good or poor radio reception and the forecasting of times favorable to special overseas broadcasts.

The daily "Ursigram", furnished by the Cheltenham Magnetic Observatory and broadcast by radio from Arlington (NAA), is a compilation of daily observations of various geophysical phenomena including terrestrial magnetic activity, solar radiation, sunspots, Kennelly-Heaviside layer and auroral data.

The Cheltenham and Tucson Observatories furnish telegraphic information (on request) to geophysical prospectors using horizontal and vertical intensity magnetometers. Such data include the time of beginning of a magnetic storm, its intensity, and a later telegram stating the time of ending of the storm. This information enables the operators to discontinue field surveys until the return of normal magnetic conditions, when the intensity of a storm is such that it would overshadow the magnetic anomalies they are seeking.

SEISMOLOGY

The government's part in seismology was assigned by the Congress in 1925 to the Coast and Geodetic Survey, principally because seismographs were operated at its five strategically located magnetic observatories. (Cheltenham, Tucson, Sitka, Honolulu, San Juan, P. R.) The original purpose of these seismographs was to distinguish in the photographic magnetic variometer records the disturbances due to earthquakes.

At present our observatory seismographs form a part of a great net of cooperating seismograph stations all over the world. In the United States many stations cooperate with "Science Service" and the Coast and Geodetic Survey by sending promptly by telegraph interpretations of all important records of earthquakes so that a preliminary determination of the epicenter may be made by the Coast and Geodetic Survey and the Jesuit Seismological Association as soon as possible and published by "Science Service", charges for all messages sent being paid by the latter. The stations cooperating in this work are listed below:

STATIONS REPORTING TO SCIENCE SERVICE FOR IMMEDIATE DETERMINATION OF EPICENTERS BY COAST AND GEODETIC SURVEY

Ann Arbor, Michigan	University of Michigan
Apia, Samoa	Voernment of N. Z.
+Balboa, C. Z.	Panama Canal
Berkeley, California	University of California
*Bozeman, Mont.	University of Montana and Coast and Geodetic Survey
Buffalo, New York	Canisius College
*Burlington, Vt.	University of Vermont
*Butte, Montana	Montana School of Mines and Coast and Geodetic Survey

*Chicago, Illinois	U.S.C. & G.S., University of Chicago, and U. S. Weather Bureau
*Callege, Alaska	University of Alaska, and Coast and Geodetic Survey
*Columbia, S. C.	University of South Carolina and Coast and Geodetic Survey
*Des Moines, Iowa	M. M. Seeburger (Private Station)
*E. Machias, Me.	Massachusetts Institute of Technology
Ebro, Spain	(Reports occasionally by cable through St. Louis University)
Florissant, Mo.	St. Louis University
Fordham, New York	Fordham University
Georgetown, D. C.	Georgetown University
Harvard, Mass.	Harvard University
*Honolulu, T. H.	University of Hawaii and Coast and Geodetic Survey
*Huancayo, Peru	Carnegie Institution of Washington
Ithaca, New York	Cornell University
Madison, Wisconsin	University of Wisconsin
Manila, P. I.	Weather Bureau of the Philippine Islands
Ottawa, Canada	Dominion Observatory
Pasadena, California	Carnegie Institution of Washington and California Institute of Technology.
*Philadelphia, Pa.	The Franklin Institute
Phulien, China	Reports through Weather Bureau of the P.I.
St. Louis, Mo.	St. Louis University
*San Juan, P. R.	Coast and Geodetic Survey
*Sitka, Alaska	Coast and Geodetic Survey
State College, Pa.	Pennsylvania State College
*Tucson, Arizona	Coast and Geodetic Survey
*Ukiah, California	Coast and Geodetic Survey
Victoria, B. C.	Dominion Meteorological Service
West Bromwich, England	J. J. Shaw (Private; Reports on request)
Weston, Mass.	Weston College
Zi-ka-wei (Shanghai) China	Jesuit Mission of Nanking

+ Interpretations published by Coast and Geodetic Survey
* Records interpreted and interpretations published by Coast and Geodetic Survey.

The operation of seismographs and the study of the records is of necessity a cooperative international project. The various stations interpret and publish their own records for the location of earthquake epicenters and these data finally are compiled and published in the "International Seismological Summary", a publication sponsored by the British Association for the Advancement of Science and the International Union of Geodesy and Geophysics.

Certain earthquakes are studied intensively by individual investigators, to whom upon request, are loaned all records of that particular earthquake, either the original records or photostatic copies. The cooperation is so wholehearted that only a form request to any station in the world is necessary in order to obtain its record. Such research in seismology has been so successful that a large portion of our present knowledge of the structure of the interior of the earth has resulted therefrom. Furthermore, the methods, instruments, and computations used in seismology have been adapted to the determination of local geologic structure in the search for underground resources, principally oil. The seismograph, in this case, measures the velocity of waves produced by explosions from which can be deduced the structure of underlying formations to depths of several miles. Heiland (la) has shown that 55% of geophysical discoveries result in successful oil wells compared with only

12% for purely geological discoveries. Such geophysical explorations[1b] are conducted principally by large commercial companies who expend millions of dollars annually in financing them, and is only mentioned here on account of its similarity to the work of the division.

The seismographs in general use prior to 1930 were, with few exceptions, very sensitive instruments capable of recording strong shocks at a great distance or weak nearby shocks but much too delicate to record the important ground movements caused by strong nearby earthquakes. Seismologists were severely criticized for their failure to seek practical knowledge which would aid in the protection of human life and property from the damage caused by earthquakes.

This criticism from prominent engineers reaching the ears of Congress resulted in an additional appropriation for the fiscal year 1932 for the design and construction of instruments which would measure ground and building motions in the immediate vicinity of an earthquake. With the cooperation of the National Bureau of Standards and others these instruments [2]were built and installations were completed just before the Long Beach earthquake of March, 1933. Records of that earthquake were obtained from three different installations. [3] They were excellent considering that this was the first practical trial of the instruments in the field. One might expect to have waited perhaps ten to twenty-five years for such an occasion although the Santa Barbara earthquake occurred in 1925, eight years prior to the one at Long Beach.

Since the occasion of the Long Beach earthquake many additional strong-motion instruments have been installed until there are now fifty-five installations in California, Montana and Nevada, and one in the Canal Zone. The development and improvement of these instruments is still in progress. Immediately after the first heavy shock at Helena, Montana, on October 18, 1935, an accelerograph and vibration meter were rushed there by the seismological field party from San Francisco. Numerous aftershocks were recorded and also the important shock of October 31st which was almost as strong as its predecessor of the l8th and which completed the destruction of many buildings partially wrecked or weakened by the first shock. As a result of this activity three accelerographs have been permanently installed in Montana.

One of the duties of the seismological field party is to rush instruments to the central region of a major shock in order to obtain important records of the disturbances which invariably follow.

The records obtained from the Long Beach and Helena earthquakes have been studied by the Coast and Geodetic Survey by means of a process of double integration [4]) going from acceleration to velocity to displacement, the latter furnishing the element of motion which is often used in research in structural design. It is interesting to note that the double integration of accelerograms has resulted in the elimination of equipment in the field previously necessary for the satisfactory study of ground motions by former methods. A more complicated method of analysis, involving the computation of the response of a set of simple oscillators to the earthquake motion, has been carried out. [5] This method provides a fairly satisfactory dynamic characterization of the earthquake motion, but involves a considerable amount of computation unless the work is done by machine. Several mechanical devices exist or have been proposed for this purpose, and one of them, the Neumann torsion-pendulum analyzer[6], is in process of development at the present time. Such a machine will accomplish the work of a corps of computers.

A city water supply, forming as it does the principal means of combating fire hazards during an earthquake, should be properly protected from destruction. During the Long Beach earthquake a number of elevated water tanks collapsed and in an attempt to improve the design of these important structures the Massachusetts Institute of Technology in its

seismological research laboratory [7] has been testing model tanks by utilizing the displacement curves obtained from the Long Beach earthquake. These model tanks were placed on a shaking platform upon which was duplicated, by a photo electric method, the actual ground motion as represented by the computed displacement curves obtained from the accelerogram. The results of these tests revealed that an entirely new attack was necessary in the problem of earthquake resistant design of water tanks because of the ability of these structures to reach excessive amplitudes quite suddenly, i. e., without the succession of waves of the same period as that of the structure. The theoretical conclusions that damping might be expected to help considerably in suppressing large amplitudes of motion of the tank were confirmed and a new design in which special damping devices are incorporated in the diagonal members was devised.

If it is desired to make existing structures more earthquake resistant it is necessary to determine their natural periods of vibration and then by the addition of stiffening members or other changes, to bring their periods outside the dominant ground vibrations resulting from earthquakes. A seismological field party is equipped with vibration meters and instruments for determining such vibration periods.(9) A machine, consisting of an unbalanced rotating mass, sets up the vibrations, or sometimes the vibrations resulting from wind or traffic are of sufficient magnitude to be recorded. In the case of ground vibrations a similar machine or a dynamite explosion is used to set the ground into motion.

This newer seismology is a broad scientific work similar to and yet apart from that of the geophysical explorers. The information obtained is furnished to the engineers and architects and others who apply it in formulating building codes and in the design of earthquake resistant structures. In the field of construction the federal government itself is one of the largest owners of buildings and other structures in the country and is, therefore, directly interested. Special observations and other investigations have already been made for the War and Navy Departments, the Treasury Department in the determination of ground periods at the site of the San Francisco Mint, the Bureau of Reclamation in connection with the earthquake resistant design of the intake towers at Boulder Dam and in the installation and operation of accelerographs.

That earthquake activity is not restricted to California alone is evidenced by the Earthquake History of the United States.(8) The earthquakes which occurred in Charleston, South Carolina in 1886 and New Madrid, Missouri in 1811 were the most severe ever experienced in this country. In 1935 minor damage from earthquakes was experienced in New York, Georgia, North Carolina, Tennessee, Nebraska, New Mexico, Arizona, and California; and in Montana the property damage was placed at $5,500,000, and six lives were lost.

At the present time a special seismological party financed by the Veterans Administration is determining the periods of vibration of hospital buildings and the ground periods at several proposed sites of construction in earthquake areas. It is particularly important that hospitals be earthquake resistant because many of the patients may be in a condition that they should not be moved.

One of the important activities in seismology is the non-instrumental work. It is only recently that reports of the perceptible effects of earthquakes has been systematically collected. Our knowledge of the earthquake history of most parts of the earth even today, and of all regions until recently, is only fragmentary and haphazard. There is now organized in the United States and its possessions, especially in the regions that are subject to frequent earthquakes, a system of obtaining information by means of questionnaires which are distributed to a large number of cooperators. The compiling of these data is expected in time to make possible the estimation of the seismicity of the various regions in which earthquakes occur. This information should ultimately be of

great value in the selection of suitable locations for buildings, in the determination of the proper amount of earthquake resistance to be used in structures built in various localities, and in the establishment of equitable insurance rates. It will also yield information of academic interest in connection with problems of crustal structure.

1. (a) Elements of Geophysical Prospecting, Vol. XXVIII, October 1933.
(b) "Science or Magic," by Aubrey D. McFadyen, Scientific American, October 1936.

2. "Selection, Installation and Operation of Seismographs" by H. E. McComb. Special Publication No. 206, U.S. Coast and Geodetic Survey.

3. "Destructive Earthquake Motions Measured for First Time", N. H. Heck and Frank Neumann, Engineering News Records, June 22, 1933. Also "U. S. Earthquakes 1933", Coast and Geodetic Survey Serial No. 579, by Frank Neumann.

4. "A Method of Analyzing Seismograms by Precise Integration", by Frank Neumann, contained in U. S. Coast and Geodetic Survey Strong Motion Report No. 4.

5. "The Results of Strong-Motion Measurements - Preliminary Report", by A. Blake. Earthquake Notes and Abstracts of the Proceedings of the 1935 Meetings, Eastern Section of the Seismological Society of America, page 10.

6. "A Mechanical Method of Analyzing Accelerograms" by Frank Neumann; Transactions, American Geophysical Union, 1936.

7. "Earthquake Effects on Elevated Water Tanks", A. C. Ruge, Civil Engineering, Vol. 5, No. 8, August, 1935.

8. "Earthquake History of the United States", N. H. Heck; Special Publication No. 149, U. S. Coast and Geodetic Survey.

9. "Man Made Earthquakes", Franklin P. Ulrich; Engineering News Record, Vol. 115, No. 20, Nov. 14, 1935.

Other References

"Earthquakes", N. H. Heck, Princeton University Press.

Earthquake Investigations in California, 1933-1934, Coast and Geodetic Survey, Special Publication No. 201.

Destructive and Near Destructive Earthquakes in California and Western Nevada, Coast and Geodetic Survey, Special Publication No. 191.

Principles underlying the Interpretation of Seismograms, by Frank Neumann. Coast and Geodetic Survey memeographed publication.

"The Earth's Magnetism", D. L. Hazard, U. S. Coast and Geodetic Survey, Serial Publication 313.

THE "AVERAGE" HYDROGRAPHIC SURVEY

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U. S. Coast and Geodetic Survey

A hydrographic survey has not served its most important purpose until the results have been charted and published. The survey is not available for charting until it has been verified, inked, reviewed and examined by the administrative officers concerned. Therefore the elapsed time between the completion of field work and the completion of the review is of prime importance.

In order to visualize the volume of field work and the time required to accomplish the various phases of office work for the average survey a large number of surveys were averaged and statistics were compiled for what might be termed the average survey. The statistics reproduced here are averages for all of the 231 hydrographic surveys received in the fiscal year 1936. Wire drag surveys and special work are hot included in the averages. The tabulation serves a very useful purpose in the Field Records Section for planning office work on a large number of surveys, but it can not be used as a gage against which to measure the data for any particular survey, or for that matter any small group of surveys.

Sounding volumes, number of	7.5
Positions, number of	2,026
Soundings, number of	10,563
Statute miles of sounding lines	500
Number of days on which field work was done	18.4
Period between last sounding date and receipt in Washington office	4.9 months
Number of days verifying and inking	8.8
Number of days reviewing	2.8
Period between receipt in Washington office and completion of review	4.2 months

The statistics for field work for the surveys received in 1936 averaged about one fourth larger than for those received in 1935. This increase is due to a larger proportion of ship surveys in 1936, as compared with the 1935 receipts which included a high percentage of surveys by shore parties, established under the P.W.A. program.

The table of averages for 1936 shows that the period between the last sounding date and receipt of the survey in Washington was 4.9 months. This period generally includes an interval of inaction before the office work can be started by the field party, and also includes the time necessary to compute tidal planes and reduce soundings; construct the projection, protract positions, and pencil soundings; complete the descriptive report, and transmit sheets and records to Washington.

The period of 4.2 months between the receipt in Washington and the completion of the review includes the time necessary to register and index the survey; check the reducers in the Division of Tides and Currents; verify, ink, and review the survey. The length of this period is dependent on the accumulation of unreviewed surveys. There were 179 on hand at the beginning of the fiscal year 1936 and receipts for that year were 231. Since the number on hand at the beginning of the present fiscal year was reduced to 95, it follows that the period will be reduced in the 1937 averages.

GEOGRAPHIC NAMES OF INTEREST

Geographic names which perpetuate the names of men who served in the Coast and Geodetic Survey are of especial interest to the personnel of this Bureau. A few such names, and the circumstances relative to their adoption are given. Neither the prominence of the geographic feature named nor the importance of the individual after whom named were considered in the selections presented herewith.

ADAMS KEY
Florida

The most northerly of a group of small mangrove keys, at Ceasar Creek, near the southern end of Biscayne Bay, Florida.

No doubt named after Isaac Hull Adams, at that time Sub-Assistant, who served in the Coast Survey from 1849 to 1877.

I. H. Adams was in charge of the party which made the first topographic survey of this area in the spring of 1853. In a report to Superintendent Bache describing the keys of the vicinity, he states, "To these keys I was obliged to give names - - - ". Adams Key is one of these, and it seems probable the he named it after himself.

AMMEN ROCK
Offshore - New England

A 4½ fathom shoal spot on the extensive bank, called Cashes Ledge, about 75 miles ENE from Cape Ann, Massachusetts.

Named in 1849 after Daniel Ammen (1820-), Passed Midshipman, U.S.N., serving in the Coast Survey at the time.

This ledge and rock had been previously charted but were reported to be 9 miles in error in latitude. In 1848 Superintendent Bache instructed Lieutenant Charles H. Davis, U.S.N., Assistant in the Coast Survey, who was in charge of a survey party in New England, to locate the rock. Daniel Ammen volunteered for this duty and "under circumstances of no little hardship" went there on a fishing smack and after reaching the ledge spent 2½ days searching for the shoal spot, without success. The least depth he found was 27 fathoms. The next season Davis, commanding the Coast Survey Steamer BIBB, located the shoal on June 6,1849, and he proposed to the Superintendent to call it "Ammen's Rock, in compliment to the difficult enterprise of Mr. Ammen last year". Midshipman Ammen (later Rear Admiral) served with the Coast Survey for a period ending in 1851.

BLAKE CHANNEL
New Jersey

A channel in Delaware Bay about 20 miles above the entrance and just west of Joe Flogger Shoal, New Jersey.

Named after the discoverer, Lieutenant George S. Blake, U.S.N., Assistant in the Coast Survey from April 15, 1835 to early 1846. Lieutenant Blake made many of the first hydrographic surveys on the Atlantic Coast.

BOWEN ANCHORAGE *
Alaska

A small harbor on the east side of Day Harbor, 11 miles north northeast of Cape Resurrection, south side of Kenai Peninsula, Alaska.

Named in 1928 in honor of William H. Bowen, (1897-1927), a member of the crew of the Coast and Geodetic Survey Ship SURVEYOR.

W. H. Bowen first enlisted on the SURVEYOR in 1922 and served as an oiler until October 3, 1927 when he was drowned in Seward Harbor, Alaska, in a heroic effort to rescue two of his shipmates, whose skiff had swamped.

* Decision of the U. S. Geographic Board.

GEDNEY CHANNEL

New York

One of the ship channels leading into New York Harbor, 2 miles northeast of Sandy Hook.

Named after Thomas R. Gedney, (-1862), Lieutenant, U.S.N., Assistant in the Coast Survey from l834 to 1847.

Lieutenant Gedney made the first hydrographic survey by the Coast Survey, in the Schooner JERSEY in 1834. This survey was located in Great South Bay, Long Island, and after its completion he extended his work westward and in 1835 discovered and surveyed the channel which from that time on was known as "Gedney's Channel". It had a depth of 2 feet greater than the old channel. Superintendent Bache in 1851 says, "had the true depth of this channel been known in 1778, the French fleet under Count D'Estaing would have passed into the bay and taken the assembled British vessels. It is probable, from comparing the old and new charts, that this channel then existed".

HEALD BANK

Texas

An offshore bank, with a least depth of 25 feet, located about 34 miles east-southeast of Galveston, Texas.

No doubt named after Lieutenant E. D. F. Heald, U.S.N., Assistant in the Coast Survey from November 23, 1882, to November 18, 1885.

The first survey in this area by the Coast Survey was in 1883 by Lieutenant Edward M. Hughes, but in l884, while surveying an adjacent area, a more thorough survey of the bank was made by Lieutenants E. D. F. Heald and G. C. Hanus, who commanded the Steamer GEDNEY.

In 1903 the Lighthouse Board requested the charting of the name, and apparently the bank was so known at an earlier date. The name first appears on the charts in the February 1905 edition of Chart 1007, at the time the light vessel was first established on this bank.

HERBERT GRAVES ISLAND*

Alaska

An island, about 3 or 4 miles across, the center of which is in approximate latitude 57° 41', longitude 136° 11', on the southwestern coast of Chichagof Island, and approximately 47 miles north-northeast of Sitka, Southeastern Alaska.

Named in 1920 after Herbert C. Graves (1869-1919), Assistant in the Coast and Geodetic Survey.

Mr. Graves was born August 17, 1869 and appointed to the Coast and Geodetic Survey August 16, 1898, where he served until his death on July 26, 1919. He acted as Nautical Expert until 1916, being Chief of the Coast Pilot Section from 1910. In 1916 he was made Chief of the Division of Hydrography and Topography. He died in England while on an important official mission.

HODGKINS PEAK *

Alaska

A 5526-foot peak located about 8 miles north of the foot of Taku Glacier and 21 miles northeast by north of Juneau, Southeastern Alaska.

Named after William Candler Hodgkins (1854-1922), Lieutenant Commander in the U. S. Coast and Geodetic Survey.

W. C. Hodgkins was given a temporary appointment in the Survey on July 5, 1871 and a permanent appointment on November 7. He was assigned to many miscellaneous surveys and commanded the Steamer BLAKE on the Atlantic Coast and Puerto Rico; the Steamers PATTERSON in Alaska and the BACHE on the Atlantic Coast.

Decision of the U. S. Geographic Board.

In 1893 he surveyed the Pennsylvania - Delaware boundary. Between l894 and 1898 he assisted in the Alaska - British Columbia survey; an examination of the South Carolina boundary; a survey to mark the boundary between Missouri and Iowa, and was a member of the commission in the Maryland - Virginia boundary survey.

In 1901-5 he was engaged on a resurvey of the Macon and Dixon Line; marked the boundary between Virginia and Tennessee, and served on the Alaska Boundary Tribunal.

He served as Director of Coast Surveys, Manila, P. I. in 19l4-15; was retired on May 18, 1920 and recalled to active duty on the same date.

JUNKEN LEDGE

Maine

An 18 foot ledge in Penobscot Bay, 8 miles south-southeast of Rockland, Maine.

Named after the discoverer, Charles Junken, at that time Sub-Assistant in the Coast Survey.

Charles Junken was a civilian employee, who served in the Coast Survey from before 1862 to his death January 23, 1893. After the Civil War he was in charge of many hydrographic surveys. During a survey of this area in the small Steamer ENDEAVOR in 1866-7 he discovered this ledge.

TEMPLE LEDGE

Maine

A 30 foot shoal in Casco Bay, about 2 miles southwest of Cape Small.

Named after the discoverer, William Grenville Temple, Lieutenant, U.S.N., Assistant in the Coast Survey.

Lieutenant Temple, commanding the Steamer CORWIN, discovered and located this shoal, previously unknown, in August 1857 while making a hydrographic survey of the area. Superintendent Bache in his 1857 annual report states, "I propose to call it Temple's Ledge after the discoverer".

Lieutenant Temple, later Rear Admiral in the Navy, served with the Coast Survey from May l849 to October 1850; and again from June 1855 to April 1859. He was b o m March 23, 1824.

WESTDAHL ROCK

California

A submerged rock pinnacle, with a least depth of 18 feet of water covering it, located 1.3 miles southwest of Point San Luis Lighthouse, near San Luis Obispo Bay.

No doubt named after Ferdinand Westdahl (1810-1919) for many years an officer of the Coast and Geodetic Survey.

This rock was discovered and surveyed in 1875 during a hydrographic survey by Louis A. Sengteller, Assistant in the Coast Survey. Ferdinand Westdahl was at that time an Aid in the party. He joined the Coast Survey on November 1, 1867 and served until his death on October 25, 1919.

The name appears first on the 1886 edition of Chart 673 but not on the 1876 edition of Chart 669, although the latter does show the rock.

WYCKOFF SHOAL

Washington

A rocky shoal, bare at low water, off the northwest point of McNeil Island, in Carr Inlet, Puget Sound.

Named after Ambrose B. Wyckoff, Lieutenant, U.S.N., Assistant in the Coast and Geodetic Survey.

Lieutenant Wyckoff, commanding the Schooner EARNEST, was in charge of the first hydrographic survey of this area in 1879. He served with the Coast and Geodetic Survey from early 1876 to late 1880.

STATISTICS AND DISTRIBUTION OF FIEID PARTIES
U. S. COAST AND GEODETIC SURVEY - DIVISION OF HYDROGRAPHY AND TOPOGRAPHY
July 1, 1935 - June 30, 1956

Locality	Project H.T. No.	Ship or Party No.	Personnel	Hydrography Miles	Hydrography Sq. Mi.	Hydrography Soundings	Topography Miles	Topography Area	Triangulation Miles	Triangulation Area	Triangulation Pos.	T.&C. Tide Sta.	T.&C. Current Sta.	T.&C. Eng. Est.
Mass., Buzzards Bay	179	5	W. D. Patterson G. W. Lovejoy	438.0	7.0	15,193	13.5	14.0	25.0	170.0	19	2		1
Mass. & Conn. Coasts	150	16	G. C. Mathison H. H. Reese T. B. Reed				150.0	70.0		60.0	80			
N.Y. & N.J. Approaches to N.Y. Harbor	207	OC.	H. A. Doran[10]	3130.0	5475.0	16,133							3	
N.Y. & N.J. Approaches to N.Y. Harbor	207	LX.	G. D. Cowie[7]	2725.1	798.5	32,483						1		3
N.Y. & N.J. Approaches to N.Y. Harbor	207	GI.**	H. Odessey[4]										7	
N.Y. & N.J., Hudson River, N.Y. Harbor	121	12	R. C. Bolstad				941.7	189.4						
N.J. Matedeconk Neck to Cape May	205	MI.	J. A. Bond[8]	866.4		25,659			30.0	150.0	47	6		12
N.J. Matedeconk Neck to Cape May	205	19	E. H. Rigg K. S. Jeffers	211.2	8.2	12,062	52.0	20.0	1.0	1.0	8	2		6
N.J. Matedeconk Neck to Cape May	205	21	E. H. Kirsch J. C. Sammons C. B. Reed				330.0	140.0						
Penn. & N.J. Delaware R.	202	8	E. B. Roberts				24.0		5.5	6.0	40			
Md., Chesapeake Bay	175	25	J.C. Partington				217.5	125.4	4.0	12.5	7			
Va., Chesapeake Bay	189	18	S. B. Grenell				164.3	84.7						
N. C., Albemarle Sound	189	MI.	H. P. Hyman[9]	478.1	52.9	15,330	42.0		4.0	4.0	21	2		
N.C., Pamlico & Neuse Rivers	197	MI.	J. A. Bond[8]	2211.4	80.0	80,212	288.7	50.0			23	3		8
N.C., Pamlico & Neuse Rivers	197	18	S. B. Grenell J. O. Tilson				353.8	492.1						
N.C., Pamlico Sound		27	G. L. Anderson						64.0 28.0*	500.0 140.0*	36			
Fla., St. Johns River	203	1	E. G. Crosby						35.0	100.0	34			
Fla., St. Johns River	168 168A	20 26	T. M. Price H. A. Paton	482.0	23.0	34,383	369.0	48.0						
Fla., Florida Keys	158	14	E. R. McCarthy J. C. Mathiason J. P. Jayman P. A. Weber	991.0	207.5	53,823	199.6	152.4				7	1	13
Fla., Florida Keys	191	22	W.H. Bainbridge	397.3	35.2	13,900					1	5		14
Fla., Gulf Coast	194	23	C. A. Zener C. A. Burnister	354.3	23.0	13,114	25.0		3.0	25.0	6	3		
La., Coast	210	MY.	R. P. Lace[6] F. G. Borden	9471.4	3276.0	93,807						2	2	2
La., Coast	156	4	T. B. Reed	926.0	118.0	22,103	41.0	10.0			1	1		3
Cal., Southern Coast	187	PI.	H.E.Campbell[11]	7410.0	11381.0	43,894	11.0	5.0	2.0	6.0	2	1	2	
Cal., Coast	206	GU.	F. H. Hardy[5]	3056.2 283.4**	535.9 185.6**	47,692 2,601**	51.5	23.5	2.0		10	4		1
Ore. & Wash., Columbia R.	201	9	R. W. Knox R. J. Sipe O. B. Reed	643.0	30.0	23,869	91.0	2.0	30.0 30.0*	84.0 84.0*	35	9		12 10+
Wash., Puget Sound	171	EX.	J. Senior[2] G. C. Jones	2483.1	114.8	71,660	270.1	60.8	86.0	95.0	223	9		5 24+
S.E. Alaska, Cardinena Channel, Chilkat R.	209	MB.	H. A. Kapp[13]	136.0	4.0	7,049	17.0	2.0	24.0	137.0	18			

Locality	Project E.P.No.	Ship or Party No.	Personnel	Hydrography Miles	Hydrography Sq. Mi.	Hydrography Sdgs.	Topography Miles	Topography Area	Triangulation Miles	Triangulation Area	Triangulation Pos.	T. & C. Tide Sta.	T. & C. Current Sta.	T. & C. Mks. Est.
Alaska, Alaska Peninsula & Unimak Id.	208 177	DI.	H.B.Campbell[1] Jack Senior	1605.3	1724.3	42,153	142.8	210.4	72.0 135.0*	1171.0 2350.0*	32	4		9 11+
Alaska, Aleutian Islands	176	SU.	A.W.Sobierajski[12]	5178.2 841.0	2098.1 378.0	60,276 6,805	127.3	212.3	88.0 12.0	281.0 20.0 40.0	102 20	3	2	6 3+
P.I., N.E. Luzon		PA.	R.F.A.Studds[3]	1542.2	175.7	31,833	92.6	244.0	32.5	72.1	32			
P.I., Bohol		PA.	R.F.A.Studds	7.9	0.3	212								
P.I., Biri Id.		PA.	R.F.A.Studds	87.2	3.5	1,774								
P.I., Albay		PA.	R.F.A.Studds	193.8	18.0	4,217								
P.I., San Bernardino		PA.	R.F.A.Studds	151.0	10.6	2,319								
P.I., Cagayan River		PA.	R.F.A.Studds	205.1	8.3	10,325								
			Totals	9105.4	4246.3	762,729	3878.4	2134.0	525.0 193.0*	2892.6 2614.0*	797	64	17	94 50+

* Reconnaissance
\+ Mag. Stations

** R. A. R. Station Ship
*** Wire Drag

Field Stations: Manila, E. H. Pagenhart, T. J. Maher, Director of Coast Surveys; Boston, F. L. Peacock, E. B. Roberts; New York, G. D. Gorie, O. A. Egner; New Orleans, O. C. Mattison; San Francisco, T. J. Maher, E. R. Lukens; Seattle, H. B. Derickson, O. W. Swainson; Honolulu, J. H. Pelord; San Juan, Porto Rico, E. H. Bernstein.

1. DISCOVERER: R. H. Campbell, J. Senior, Com'd'g, J. N. Smock, H. A. Karo, E. A. Daily, F. L. Bernstein, E. G. Fortin, E. B. Lewis, G. E. Morris, R. A. Gilmore, L. W. Ruhoston, J. C. Tribble, O. E. Hartzog, J. E. Waugh, D. H. Konichek, H. J. Seeberg, E. R. Gile, F. J. Soule.

2. EXPLORER: J. Senior, G. C. Jones, Com'd'g, L. C. Wilder, R. J. Sipe, H. C. Baum, H. F. Orther, C. H. Jones, E. E. Smith, S. W. Davis, W. Waldlich.

3. PATHFINDER: R. F. A. Studds, Com'd'g, H. E. Finnegan, E. G. Crosby, C. A. Schenck, G. R. Shelton, H. C. West, G. S. Hutchison, J. W. Wetzel, A. H. Bourgoutt.

4. GILBERT: H. Odessey, Com'd'g, F. Satella, W. H. Martin.

5. GUIDE: F. E. Hardy, Com'd'g, R. L. Schoppe, G. C. Jones, L. F. Seymor, I. E. Rittenburg, W. H. Bainbridge, F. H. Quinn, G. LeFever, H. J. Chovan, L. W. Swanson, M. G. Ricketts, E. S. Ilm, C. J. Seyum, H. G. Conerly, W. Seymour.

6. HYDROGRAPHER: H. P. Lane, F. S. Borden, Com'd'g, A. T. Ratti, H. W. Woodworth, T. B. Reed, O. L. Anderson, F. C. Doran, T. H. Bainbridge, O. A. Burmister, V. M. Gibbons, F. H. Cossett, J. N. Jones, K. B. Jeffers, R. A. Gilmore, J. T. Jerman, F. Taylor, W. E. Green, H. W. Sawyer, C. G. McIlwraith.

7. LYDONIA: R. L. Schoppe, G. D. Gorie, Com'd'g, E. G. Heaton, H. C. Fortin, C. A. George, W. C. Russell, J. E. Waugh, C. H. Jones, E. N. Davis, F. E. Gleason, R. C. Overton, T. J. Hickley.

8. KIRAWI: J. A. Bond, Com'd'g, F. H. Cossett, G. W. Lorenzo, E. L. Jones, J. C. Bull, C. F. Chenoweth

9. RATONA: R. F. Ryman, Com'd'g, M. C. Witherbee, J. C. Bull, E. L. Jones

10. OCEANOGRAPHER: E. A. Saxon, Com'd'g, L. D. Graham, M. C. Witherbee, W. D. Patterson, E. G. Crosby, F. C. Edes, E. A. Daily, R. A. Earle, J. S. Norton, R. A. Marshall, E. S. Brown, H. H. Carstens, T. W. Price, A. L. Marshall, C. F. Chenoweth, H. E. Green, E. W. Sawyer.

11. PIONEER: G. W. Swinson, H. B. Campbell, Com'd'g, R. R. Moore, D. M. Scaife, J. C. Sammons, H. C. Rowe, H. J. Healy, G. A. Nelson, G. M. Morehead, F. A. Riddell, M. E. Weaverwerk, E. G. Zimmerman, E. H. Larivierre, W. R. Scraggs, C. G. McIlwraith.

12. SURVEYOR: A. W. Sobierajski, Com'd'g, G. L. Bean, R. C. Rowe, W. F. Malnate, I. T. Sanders, C. A. Burmister, V. M. Gibbons, C. J. Wagner, A. M. Stewart, H. H. Reese, C. Kilcrhe, K. B. Uhr, H. C. Applequist, W. P. Deane, E. H. Sheridan, D. E. Sturner, J. C. Tisen, G. Johanson, E. G. Zimmerman, R. W. Kelly, W. J. Leary.

13. WESTWARD: H. A. Karo, Com'd'g, A. W. Stewart, D. H. Konichek.

Washington Office: Chief, Division of H. & T., G. W. Rude; Asst. Chief, H. M. Lukens and H. F. Lane; Chief, Section of Vessels and Equipment, F. G. Engle; Chief, Coast Pilot, F. S. T. Siems; Chief, Section of Field Work, F. S. Borden and F. L. Peacock.

Other Officers attached to Division of H. & T. on duty in Washington Office during all or part of fiscal year: E. E. Hand, R. P. Ryman, H. A. Cotton, C. Shaw, C. A. Egner, W. D. Patterson, O. S. Reading, E. A. Daily, F. A. Smith, F. A. Riddell

Section of Coast Pilot: F. S. T. Siems, Chief of Section; H. A. Cotton, C. Shaw, E. A. Daily. C. Shaw engaged in a field examination and revising the Coast Pilot of the Atlantic Coast from Sandy Hook to Cape Henry including Chesapeake and Delaware Bays. E. A. Daily engaged in a field examination of the New Jersey Inland Waterway.

DISTRIBUTION OF PARTIES AND STATISTICS

GEODESY - FISCAL YEAR 1936

Chief of Party	Locality	New stations established	Length of Scheme	Area
			Miles	Sq. Mi.
	TRIANGULATION FIRST ORDER			
C. I. Ashleman	Watertown, S.D. to Cedar Lake, Minn.	43	155	1550
	Bethany to Prairie, Minn.	9	35	420
J. Bowie	Lancaster, Pa. to Elkton, Md.	13	45	720
	Belfast to Hornell, N.Y.	10	30	300
	Harrisburg to Boalsburg, Pa.	29	70	700
	Hackettstown, N.J. to Staten Island, N.Y.	27	95	900
J. H. Brittain	Tigerville to Douglass, S.C.	9	70	840
E. S. Latham	Pastherville to King Hill, Idaho	26	20	300
	Missoula to Charlo, Mont., Missoula, Mont. to Headquarters, Idaho, Grove Peak to Lookout Mt., Idaho	26	175	3500
J. P. Lanham	Elizabeth Base Net, N. J.	2	5	25
E. R. Porter	Buena Vista to Antonito, Colo.	51	140	1400
	Parks, Neb., to Long Mont., Colo.	87	160	2400
C. Pierce	Sulphur, Nev., to Andrews, Ore.	38	100	1400
C. A. Schenck	Zion City, Ill. to Sinsinawa, Wis.	70	150	1300
	Guttenberg to Waverly, Iowa	16	65	650
	Watertown to Gettysburg, S.D.	32	145	1450
	TRIANGULATION, SECOND ORDER			
C. I. Ashleman	Jasper to Wheaton, Minn.	36	125	1250
	Wanali to Trey, Minn.	23	80	800
	Sherburn to Easton, Minn.	17	65	650
J. Bowie	Papago Indian Reservation, Ariz.	175	565	5665
	Sealapai Indian Reservation, Ariz.	50	115	1725
	Hassalero Indian Reservation, N.M.	29	100	1500
J. H. Brittain	Potomac River (D.C. - Va. Boundary)	22	10	15
M. A. Beckt	Stepstone to Louisville, Ky.	42	105	1050
C. Pierce	Vicinity of Portland, Ore.	30	70	980
W. H. Tryon	Pawcatuck River, Conn. and R.I.	6	10	50
Florida Mapping Project, Under Supervision of U.S. C. & G.S.	Clarcona to Tavaville, Fla.	7	35	245
	TRAVERSE, SECOND ORDER			
G. E. Fish	Huntington Beach, California		3.8	

Chief of Party	Locality	Length of Scheme	Area
	BASE LINES, FIRST ORDER		
R. B. Green	Missoula, Mont.	5.3	
	Battle Mt., Nev.	7.1	
	Elko, Nev.	4.3	
	Reno, Nev.	5.5	
	Romeo, Colo.	6.2	
J. P. Lanham	Elizabeth, N. J.	4.9	
	RECONNAISSANCE FOR FIRST-ORDER TRIANGULATION		
J. S. Silby	Circleville to Fair Haven, Ohio	95	1,330
	Georgetown, Ohio to Adrian, Mich.	210	2,100
	Elkhart to Alexandria, Ind.	105	945
	Monroe to Bolton, Ind.	90	720
	Bloomington to Michigan City, Ind.	170	1,700
	Pulaski to North Manchester, Ind.	45	450
	Shiloville to Rushville, Ind.	60	480
M. Z. Breaden	Tallahassee, Ala. to Ebro, Fla.	175	1,750
G. H. Brittain	Tigerville, to Douglass, S.C.	70	840
F. W. Bough	Laramie River Valley, Wyo.	55	825
	Gunnison, Colo. to Walcott, Wyo.	240	3,360
	Longmont to Youghal, Colo.	185	2,275
	Vernal to Fruitland, Utah	100	1,200
L. O. Johnson	Missoula to Twelf Creek, Mont.	130	1,820
	Tuscarora, Nev. to King Hill, Idaho	110	1,100
	Durkee, Ore. to Cloverland, Mich.	140	1,680
T. J. Mitchell	Lowell, Mass. to Albany, N.Y.	135	1,350
	Lancaster, Pa. to Elkton, Md.	45	720
William Wimsatter	Grand Rapids to Basswood Lake, Minn. and Galton to Pelican Lake, Minn.	150	2,700
B. B. Parker	Spokane to Seattle, Wash.	230	3,220
	Leavenworth to Liberty, Wash.	40	600
O. S. Rizvald	La Grand to Dayton, Ore.	60	720
	Lewis, Idaho, to Nathrum, Idaho	190	2,850
C. A. Schoene	Henderson, Ky. to Matthews, Ill.	100	1,000
L. G. Simmons	Underwood to Merl, N.D.	150	1,560
P. A. Wehap	Norbeis to Columbus, Mont.	205	3,075
	Vicinity of Livingston, Mont.	20	400
	RECONNAISSANCE FOR SECOND-ORDER TRIANGULATION		
J. S. Silby	Lee to York, Fla.	110	990
	Shady to Lily, Fla.	120	1,080
	Clarcona, Fla. to Colquitt, Ga.	130	1,300
	Carrabella, Fla. to Colquitt, Ga.	100	1,000
	Early, Fla. to Opelika, Ala.	190	1,900
	Winslow to Winkelman, Ariz.	140	1,680

Chief of Party	Locality	Length of Scheme	Area
		Miles	Sq. Mi.
RECONNAISSANCE FOR SECOND-ORDER TRIANGULATION (CONT'D.)			
J. Towle	Papago Indian Reservation, Ariz.	565	5,645
H. Z. Bradon	Pleasant Gap to Cusseta, Ala.	105	1,050
	Hiseville, Fla. to Calhoun, Ala.	115	1,150
J. S. Brittain	Potomac River (D.C. - Va. Boundary)	10	15
F. S. Bryant	Fredericksburg to Danville, Va.	150	1,500
H. A. Hecht	Kanta to Pauli, Ark.	20	360
F. H. Hough	Ennimal to Goodlet; Ennimal to Indio, Menard to Abilene; and Benjamine to Goodlet, Tex.	200	2,000
	Gualapai Indian Reservation, Ariz.	113	1,729
F. H. Hough and T. J. Mitchell	Mescalero Indian Reservation, N. M.	100	1,500
T. J. Mitchell	Pittsburg, Pa. to Wellsville, N. Y.	140	1,400
	Hamburg to Cortland, N. Y.	140	1,400
	Cortland, to Ravena, N.Y.	105	1,050
	Marlboro, N.Y. to Nicholson, Pa.	95	950
William Wasmotter	Clark to Mt. Vernon, S.D.	75	750
	Blue Earth, Minn. to Lakota, Iowa.	15	150
E. S. Palmer	Skull Springs to Lost Valley, Ore.	170	5,000
	Logdell to Sumpter, Ore.	60	700
	Contreras to Maxino; and Cedarvale to Antho, N. M.	120	1,140
C. A. Schoene	Stepstone to Louisville, Ky.	105	1,050
	Mt. Vernon to Harrisburg, Ill.	90	350
W. G. Simmons	St. John to Dunsig, N.D.	190	2,280
	Venturia, N.D. to Ralliance, S.D.	150	1,500
F. A. Weber	Sherburn to Hector, Minn.	65	650

LEVELING

Locality	No. of miles of 1st order	No. of miles of 2nd order	Total no. of miles of 1st and 2nd order
California	148	697	845
Colorado	9	555	564
Georgia	80	5	85
Idaho	50	809	859
Kansas	---	390	390
Maine	99	824	923
Maryland	---	46	46
Minnesota	147	840	987
Montana	147	488	635
Nevada	---	308	308
New Hampshire	1	9	10
New Mexico	26	154	180
New York	27	41	68
North Carolina	569	231	800
Oklahoma	---	42	42
Oregon	48	180	228
Pennsylvania	29	691	929

LEVELING (CONT'D.)

Locality	No. of miles of 1st order	No. of miles of 2nd order	Total no. of miles of 1st and 2nd order
Tennessee	238	691	929
Texas	227	38	265
Utah	2	87	89
Vermont	3	85	88
Virginia	12	1,064	1,076
Washington	59	70	129
West Virginia	16	79	95

The following Chiefs of Party were engaged in leveling operations intermittently during the fiscal year 1934:

G. R. Fish, W. M. Gibson, J. Lewkowski, C. De Ferar, G. F. Moore, H. F. Oliver, H. E. Stephens, W. W. Studdert, A. C. Thorsen, J. D. Underwood, W. M. Tucker.

ASTRONOMICAL OBSERVATIONS

Chief of Party	State	Number of Determinations		
		Latitude	Longitude	Azimuth
J. H. Brittain	South Carolina			2
E. E. Latham	Illinois		1	1
	Iowa	1	1	1
	Kansas	2	2	2
	Missouri	2	2	2
	Nebraska	2	3	3
J. F. Lenhart	Arkansas	1	1	1
	Georgia	1	1	1
	Kentucky	1	1	1
	Louisiana	1	1	1
	New Mexico	3	4	4
	Oklahoma	1	1	1
	Pennsylvania	2	2	2
	South Carolina	1	1	
	Texas	14	16	16
E. H. Smith	Minnesota		2	2
	North Dakota		8	8
	South Dakota		3	3
O. A. Whitten	Arizona	3	3	3
	California	3	3	3
	Colorado	2	2	2
	Idaho	1	1	1
	Kansas	3	3	3
	Montana	6	6	6
	Nebraska	2	2	2
	Nevada	3	3	3
	Oklahoma	1	1	1
	Texas	1	1	1
	Washington	3	4	3
	Wyoming	1	1	1

GRAVITY OBSERVATIONS

Chief of Party	State	Determinations
S. H. Wahl	Connecticut	21
	Florida	20
	Massachusetts	6
	New York	6
	Pennsylvania	31
	Rhode Island	6

SUMMARY OF STATISTICS

Geodesy - Fiscal Year 1936

TRIANGULATION

	New stations established	Length of Scheme	Area
		Miles	Sq. Mi.
First-order	488	1440	17,855
Second-order	431	980	13,210

TRAVERSE, SECOND ORDER		BASE LINES, FIRST ORDER	
Number of Miles	3.8	Number of Miles	33.3

RECONNAISSANCE

	Length of Scheme	Area
	Miles	Sq. Mi.
For first-order triangulation	3275	40,790
For second-order triangulation	3610	39,245

LEVELING

First-order, no. of miles	Second-order no. of miles	Total no. of miles
1,937	8,187	10,124

ASTRONOMICAL AND GRAVITY OBSERVATIONS

Number of Determinations

Latitude	Longitude	Azimuth	Gravity
60	80	81	90

THE CHART DIVISION

The commissioned personnel during the 1936 fiscal year consisted of:

L. O. Colbert	Chief of Division
K. T. Adams	Asst. Chief of Division
C. K. Green	Chief of Field Records Section
C. M. Durgin	Chief of Aeronautical Chart Section

During the year some of the outstanding accomplishments of the division were:

The completion and printing of 17 new nautical charts, of which 6 were of the new 1:40,000 scale Intracoastal Waterway Series.

The printing of new editions for 138 nautical charts.

The completion and printing of 41 new aeronautical charts and the printing of 66 new editions of previous published aeronautical charts.

The issue of aeronautical charts in 1936 was greater than the total in the five preceding years.

The total number of impressions made on the printing presses was 5,594,204 as compared to 2,868,070 in 1935.

A total of 555 new surveys were received from the field in 1936. This is the second largest ever received, being exceeded only in 1935.

DIVISION OF TIDES AND CURRENTS

Summary of Statistics - 1936

P. C. Whitney, Chief of Division

L. S. Hubbard

Tide Survey - State of Washington

Tide stations occupied	28
Number of Bench Marks established	519

E. F. Hicks

Washington Office and Various Stations

Other Field Activities of Division

Primary Tide Stations occupied	51
Long Period Current Stations occupied	7
Tide Stations occupied for hydrographic purposes	483
Short period current stations occupied	60

Tide and Current Survey of Los Angeles and Long Beach Harbors:

Tide stations occupied	22
Current stations occupied	26

DIVISION OF TERRESTRIAL MAGNETISM AND SEISMOLOGY

Summary of Statistics - 1936

N. H. Heck, Chief of Division
E. W. Eickelberg, Asst. Chief of Division
J. H. Peters, In charge Honolulu Magnetic Observatory
E. H. Bernstein, In charge San Juan Magnetic Observatory

Magnetics

Field Determinations - G. A. Weber, Chief of Party

No. of Declination Determinations	75
No. of Horizontal Intensity and Dip Determinations	40

No. of Magnetic Observatories in operation 5

Seismology

Earthquakes reported	110
Seismological instruments in use:	
Accelerographs	34
Displacement meters	6
Weed Seismographs	11
Tiltmeters	4
Shocks recorded, strong motion instruments	7
Vibration observations made	203
Shaking machines tests made	25
No. of Teleseismic Stations in operation	19
No. of stations reporting to Science Service for immediate determination of epicenters by Coast and Geodetic Survey	37

U. S. COAST AND GEODETIC SURVEY
FIELD MEMORANDUM No. 1 (1936)

March 16, 1936.

CONSTRUCTION AND GRADUATION OF STADIA RODS.

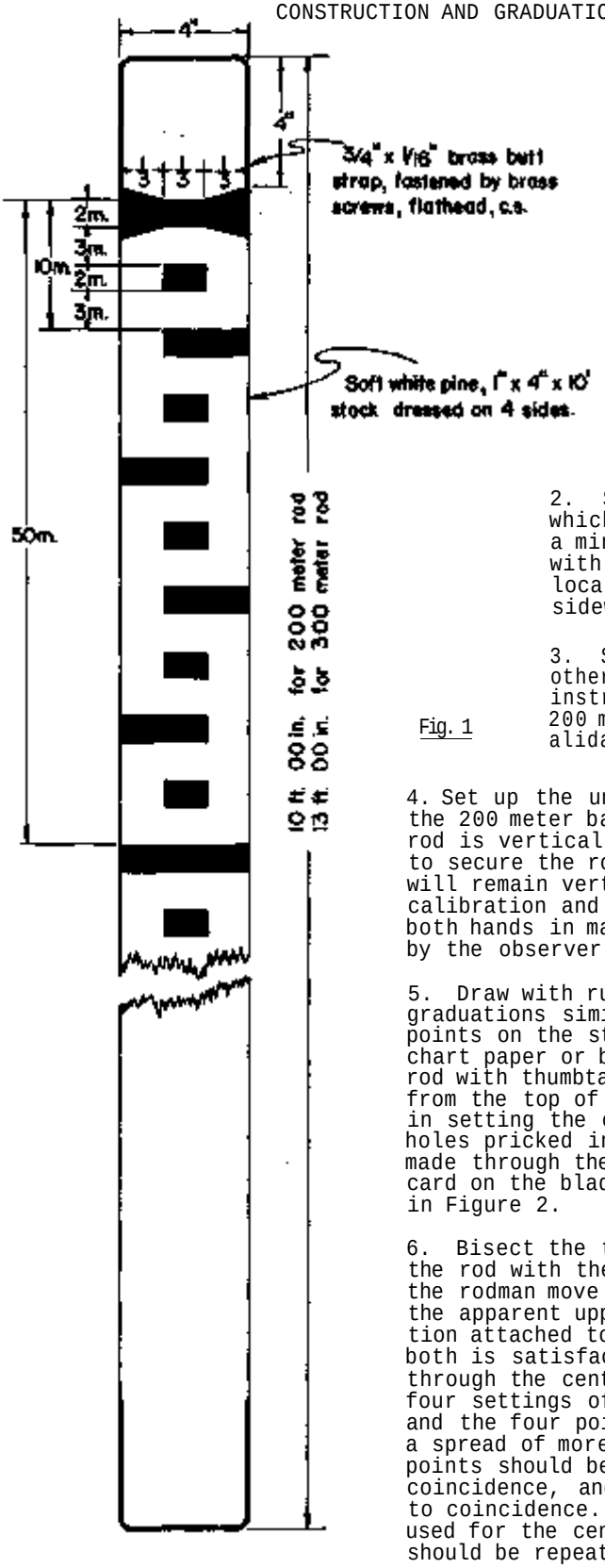


Fig. 1

The following notes have been prepared for field parties who desire to construct and graduate their own stadia rods in the field.

1. Prepare a board of soft, straight grain, clear white pine, 4" x 1" x 10' stock material, dressed on four sides. Apply three coats of flat white outside paint, and protect each end by a strap of 1/16 inch brass fastened with countersunk head brass screws. See Fig. 1.

2. Select a locality and time of day which will render radiation effects a minimum. Measure a 200 meter base with a steel tape on some horizontal location, such as a beach, sea wall, sidewalk, or pavement.

3. Set up the alidade on a planetable or other firm support with the center of the instrument plumbed over the end of the 200 meter base, and the telescope of the alidade horizontal.

4. Set up the ungraduated rod at the other end of the 200 meter base, taking particular care that the rod is vertical. An instrument tripod may be used to secure the rod temporarily in place, so the rod will remain vertical and in one position during the calibration and so the rodman may be free to use both hands in marking the points to be established by the observer.

5. Draw with ruling pen and India ink two index graduations similar to those used for the 100 meter points on the standard stadia rod, on a card of chart paper or boat sheet paper. Mount one on the rod with thumbtacks so the top edge is 4 inches down from the top of the rod. The two cards to be used in setting the calibration marks should have fine holes pricked in the center so that a mark may be made through them on the board. Mount the second card on the blade of a try-square far use as shown in Figure 2.

6. Bisect the temporary graduation near the top of the rod with the apparent lower stadia wire and have the rodman move the try square along the rod until the apparent upper wire bisects the movable graduation attached to the square. When the bisection of both is satisfactory, the rodman makes a prick mark through the center of the card on the rod. At least four settings of the movable mark should be made, and the four points thus established should not have a spread of more than 2 millimeters. Two of the points should be made by moving the target upward to coincidence, and two by moving the target downward to coincidence. The mean position of the points is used for the center of the mark. This same procedure should be repeated for the middle and the quarter

wires of the alidade for verification of the accuracy of the stadia interval on the diaphragm.

7. Subdivide the rod between the extreme marks made into four equal parts. Each of the three lines thus made to divide the rod should fall on the points established by observation through the alidade. If they do not check the observed points, the observations should be repeated, rotating the telescope through 180° to ascertain if the discrepancy is due to the unequal spacing of the lines on the diaphragm. If this be the case, the mean position of the marks as taken for both positions of the telescope will agree with the marks obtained from subdividing the rod. It is rare that such discrepancies are found, but a check should be made for this error. If it is found, a new diaphragm should be inserted in the alidade and the rods regraduated.

8. Outline the graduations on the rod with a sharp knife before painting the black portions to insure that the edges of the graduations will be clean, and to avoid any possibility of running of the paint. Paint on the black marks as shown in Figure 1.

Since this rod is accurately graduated only for 200 meters, corrections should be obtained for 50 meter intervals within the limits the rod is to be used. These corrections should be tabulated and posted in the alidade box for use, should the scale of the survey warrant.

The corrections obtained should satisfy this equation:

$$C = (c + f)\left(1 - \frac{d}{B}\right)$$

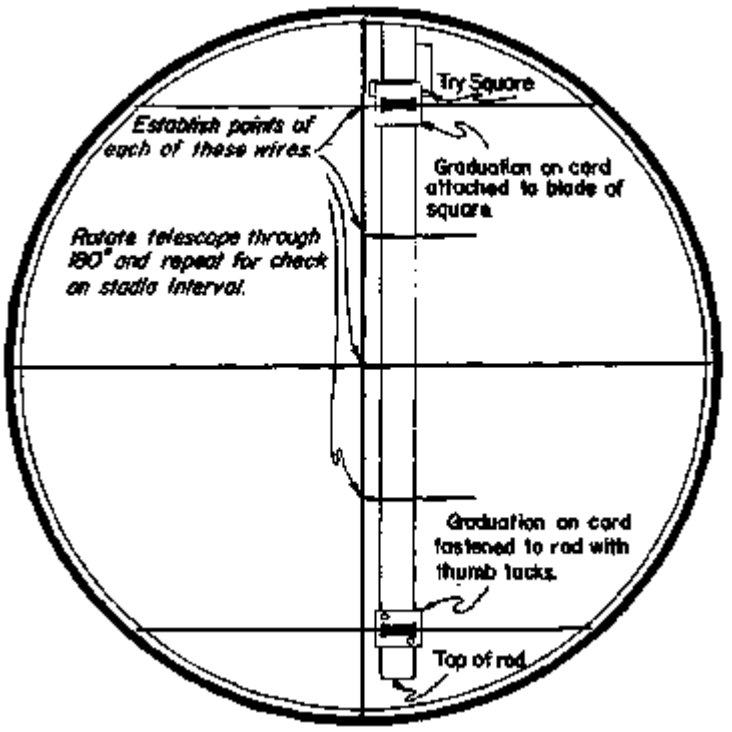
Where C = correction in meters:

(c + f) = approximately 1½ times the focal length of the telescope in meters.

d = distance read from the rod in meters.

B = length of base in meters used to graduate the rod.

The focal length for an external focussing telescope is about 0.35 meter, and the quantity (c + f) is approximately 0.525 meter for the average alidade telescope. (See pages 19 and 20 Topographic Manual, U.S.C.& G.S. Special Publication No. 144.)



METHOD OF MARKING STADIA RODS
Fig.1

If the alidade has an internal focussing telescope, this correction should be so small that it can be ignored as the focal point should lie close to the center of the instrument.

In some cases, it may be desirable to make up rods which may be used for 300 meters, using the full stadia interval (600 meters for the half interval). In this case, a slightly longer rod will be necessary, approximately 13 feet as it is desirable to keep the lower graduation several feet above the ground to avoid errors due to differential refraction between the lines of sight to the top and bottom graduations on the rod. When using stadia rods along a sand beach, or over flat terrain where the line of sight is always close to the ground, any chance for errors due to differential refraction should be reduced by attaching a foot piece to the bottom of the rods so that the lowest graduation is about three feet above the ground. If preferred, the rod may be made long enough so this is a permanent feature.

The use of a card with temporary graduation attached to a square as described in paragraph 5 has several important arguments in support. If this is done, neither the rodman nor the observer sees the previous marks made on the rod, and both are unprejudiced in the settings of the consecutive points.

Acting Director

U. S. COAST AND GEODETIC SURVEY
FIELD MEMORANDUM NO. 2 (1936) April 24, 1936.

NAMES OF AIDS TO NAVIGATION

A special file covering the history and position of lighthouses and lighted ranges is now being prepared in this office. There has been considerable confusion as a result of incorrect naming of aids to navigation located by field parties. An error in name necessitates a search through the records and oftentimes the plotting of positions to determine what objects were located. Incorrect names and inadequate descriptions may result in serious errors in the charting of aids to navigation. To avoid errors and save labor, the following practice shall be followed:

(1) In all cases use the names exactly as given in the latest edition of the Light and Buoy Lists (Lighthouse Service, Department of Commerce). If given a different name by a previous party, use the Light List name, and in the List of Geographic Positions give the previous name with date of location in parentheses after the Light List name. Example: BAY SHAFT LIGHTHOUSE (Sand Island Light, 1887).

(2) If located by topography, the correct name of the aid shall be lettered on the topographic sheet in parentheses, in black ink, under or adjacent to the topographic name. Many topographic sheets have been received in the office with only the topographic names of aids to navigation given, such as "Cat", "Hot", etc. In some cases it has been possible to find descriptions of these either in descriptive reports or on Form 524 or Form 567. In many cases, however, no indication can be found anywhere as to the nature of the objects.

(3) All permanent non-floating lighted aids to navigation shall be called "lights* in the record books. If unlighted, they are to be called "beacons". Much confusion has been caused by erroneously naming lighted aids "beacons". If a light previously located has been rebuilt since the date of location, it should not be balled a recovered station. The date of latest rebuilding of each light is given in the Light List.

(4) If a lighthouse is no longer used, this fact shall be stated, so as to distinguish it from used lights in that locality. Example: BIRD ISLAND LIGHTHOUSE (unused).

(5) When two lights form a range (indicated by brackets in the Light List) at least one of them shall be occupied if practicable to determine the azimuth of the range. (Azimuth of navigational ranges suitable for determining compass deviation and definitely known are published in degrees and minutes in the Light List. Others are published in even degrees) The azimuth obtained shall be compared with that given in the Light List and if a discrepancy of more than one-quarter of a degree is found, the local Superintendent of Lighthouses shall be notified and a copy of the report forwarded to this office. If ranges are located by topography, one of the aids shall be occupied or a set-up obtained exactly on the range if practicable and the azimuth line drawn on the sheet of sufficient length to permit accurate scaling by protractor. Hydrographic parties shall take every occasion to check ranges by obtaining strong sextant fixes on the range at a sufficient distance from the front range light to produce a long azimuth line for accurate scaling. Fixes taken to check entering ranges used in crossing a bar shall be obtained on or outside the bar. Such fixes must be listed in the index of the sounding volume.

(6) Field parties shall make a special effort to insure that all aids to navigation within the limits of their field of work are located accurately and that the azimuths of all ranges have been determined accurately. Where the new position of any aid differs by an amount sufficient to change the charted position on the largest scale chart on which the aid is shown, this Information shall be submitted in a"Chart Letter" separate from, and in advance of, the field records. This procedure is adopted in order to obtain corrections for the charts earlier than if the data are held until field records are submitted. The Light Lists should be consulted and referred to frequently in connection with all projects. All lights which have been rebuilt since the date of last determination of position shall be relocated. The location of any object having a doubtful position shall be cheeked. Geographic positions of all permanent aids to navigation

located by the party shall be submitted on Form 567, "Landmarks for Charts", in accordance with the Supplemental Instructions for the preparation and submission of that form. Copies of Light Lists may be obtained from this office on requisition.

(7) A "Description of Triangulation Station", Form 525, shall be submitted for each new light or beacon whose position is determined by triangulation by the field party. A "Recovery Note, Triangulation Station," Form 526, shall be submitted for each light or beacon in the survey area whose position has been determined previously by triangulation. If the light or beacon has been rebuilt since the date of the previous position, it should be considered a lost station and a reference made on the Recovery Note to the new position. This will obviate any attempt by the office to adjust such an old position to a new position when the light or beacon has been rebuilt in the meantime.

Acting Director.

FIELD MEMORANDUM NO. 3
1936

June 11, 1936

FATHOMETER SOUNDINGS - SERIAL TEMPERATURES AND SALINITIES

Where any of the instructions contained in this memorandum are contradictory to the paragraphs of the Hydrographic Manual relating to Fathometer soundings, the Field Memorandum shall supersede those paragraphs in the Hydrographic Manual.

It should be definitely understood that the main purpose of this memorandum is to standardize the procedure of making fathometer corrections and in preparing and submitting the results to facilitate office verification. This procedure has been specified primarily for the 312 Type fathometer. Where any departure is necessary due to mechanical design of the instrument (e.g. the 515 indicator), it should be done toward accomplishing the fundamental purpose of these directions. No other departure from these instructions shall be made without specific authority from this office.

Present experience with the Dorsey Fathometer is insufficient to specify a standard procedure. Chiefs of Party using this instrument should endeavor to obtain information and make suggestions toward standardization of methods in handling the corrections, which will tend to efficient verification of the field records.

1. The type and serial number of fathometer used shall be noted in the descriptive report and sounding records of each survey.

a. If there are more than one fathometer on the vessel and a change is made from one to the other at various times, complete notes for each fathometer identification shall be entered in each Volume I of the sounding records so that thereafter at the beginning of the day's work and when a change is made a short notation will suffice to identify the fathometer being used.

b. When there are more than one oscillator and more than one hydrophone, the identification notes and location of these shall be entered in each Volume I of the sounding records and thereafter the ones in use shall be noted in the record by some short code.

2. The speed indicator (or tachometer) shall be removed from the fathometer and forwarded to the office for calibration once each year.

a. During the field season the speed of the dial, when the middle reed is vibrating at a maximum, shall be measured once a month and the result recorded in the sounding records. This may be done as follows: Operate a chronograph as for R A R, connecting the bomb amplifier to a pair of wires running to the fathometer indicator where they should be connected to the low side of a filament transformer, the high winding terminals of which should be connected in series with the fathometer oscillator and contactors. Run the fathometer at slow speed and regulate the speed so that the middle reed is kept vibrating. At each closing of the contacts there will be a small e.m.f. generated in the secondary of the transformer, giving an impulse to the R A R amplifier, which will actuate the chronograph the same as would a bomb or returning radio signal. The chronograph can be run at standard speed and the tape measured to .01 second, the same as for position finding. Fathometers calibrated for 820 fathoms per second will make 41 contacts per minute and those calibrated for the velocity of 800 fathoms per second will make 40 contacts per minute. A record of at least four minutes' duration

shall be taken. The rate of the chronometer should be known and used if necessary. If the tachometer is found to be in error, determine which reed vibrates at full amplitude for the correct disc speed, and use that reed until the tachometer can be replaced with a correct one. If the correct speed is between two reeds keep one of these vibrating at maximum amplitude while its frequency is determined. Calculate the velocity for this reed and apply a correction for its deviation from the standard calibrated velocity of 800 or 820 fathoms per second when determining the factors from the correction factor tables for depths of 200 fathoms or less. For depths greater than 200 fathoms the velocity calculated for the reed vibrating at maximum amplitude should be used in computing the factors.

3. Each morning before the day's work is begun the following shall be accomplished: (a) Verify the draft setting and correct same if there has been a change in draft (mean draft between hydrophone and oscillator). (b) After the draft corrector has been set, obtain the readings on the dial at the point of closing and opening of the oscillator contacts for fast-disc speed. (c) Record the readings together with the ship's draft in the sounding record. Fathometer readings at all times shall be made on the shoal edge of the flash. To make these readings, the gear is placed in neutral so that the disc can be turned by hand, the disc turned forward until the oscillator is sounded and the red light flashes. Note the position of this flash, which, for example, may be 97.1 fathoms. Then approach the contacts in the opposite direction with the same portion of the dog (that part used for fast-disc speed) and note where the red flash comes, say at 99.2 fathoms. The difference of 2.1 fathoms is the measure of the total time of contact. The contact adjusting screw should be set for approximately 2.0 fathoms closing time and maintained at this value. If there were no lag in any part of the circuit, either in the sending or receiving, this circuit would be closed at 100 fathoms - the zero of time measurement. The lag is taken care of by closing the circuit in advance and this correction accounted for by the method of setting the dog as described in the next paragraph. Where amplifiers have adjustable grid bias, this grid voltage shall be set at optimum value and not changed during the season. The hydrophone sensitivity control should be adequate for all purposes.

4. To set the position of the dog on the cam wheel which operates the oscillator contacts: Select a calm day and a location where the depths are between 20 and 30 fathoms over a flat level bottom. With the ship at anchor, take a temperature and salinity serial, using as the surface temperature that obtained at about two fathoms under the surface, not directly at the surface since the sound does not pass through the water above the ship's draft. Take an accurate vertical cast on each side of the vessel, midway between the oscillator and hydrophone in use, and cheek the draft setting. With the temperature and salinity corrections, calculate what the fathometer should indicate and set the dog so that this depth is indicated by the shoal edge of the flash. Other hydrophones which are at different distances from the oscillator than the one for which the setting is made will need special corrections in shoal water. (See par. No. 7)

5. Apply corrections to the fast-disc-speed fathometer soundings for temperature, salinity and pressure only, except for special corrections mentioned in paragraph 7.

a. Temperature-salinity serials. Where station ships are used for R A R, these ships shall obtain not less than one complete temperature curve at each station occupied and each time a station is occupied. Additional temperature-salinity serials shall be taken by station ships as may be necessary to verify appreciable seasonal changes. The sounding vessel shall obtain not less than two complete serial temperature curves in deep

water near the outer limit of the survey. One of these serials should be obtained near the beginning of the season's deep water work and the other when work of that character has been practically completed for the season. This vessel also shall obtain one complete serial temperature in the intermediate area each month and such additional serials as are specified in the season's instructions. Such serials shall be distributed with respect to both the depth and extent of the area. In addition to this, each sounding vessel shall obtain surface and bottom temperatures and salinities when a vertical cast is made for fathometer verification or for bottom characteristics. These scattered surface and bottom temperatures should be used primarily as a means of ascertaining when another temperature serial is necessary.

b. Each serial temperature shall be plotted on a separate graph and at the time the observations are taken. For plotting the deep water serials, Form M-146 shall be used. For the observations taken by station ships or sounding vessels on the coastal shelf, the vertical scale of Form M-146 may be modified so that it reads from zero to 120 fathoms. No other scales shall be used. Previous surveys in the area or published studies by other organizations (See Woods Hole Oceanographic Inst. Vol. II, No. 4, Studies of the Waters of the Continental Shelf, Cape Cod to Chesapeake Bay, I. The Cycle of Temperature), may assist in determining the frequency necessary for temperature observations.

c. Temperature and salinity factors and fathometer corrections shall be calculated by the method given in the sample computation in this memorandum, using the British Admiralty Tables for the velocity of sound in water.

6. a. Comparative soundings for fathometer verification shall be taken not less than twice daily in depths not exceeding 50 fathoms. This has no reference to vertical soundings taken for obtaining bottom characteristics which should show a good distribution over the area surveyed. Such wire soundings shall be recorded with simultaneous fathometer soundings, taking all care to insure that the wire is vertical. The differences between these fathometer and wire soundings in deep water shall not be used to determine an index correction for the fathometer.

b. The procedure specified in paragraphs 2, 3 and 4 will eliminate the necessity of obtaining an index correction for the fathometer (fast-disc-speed) from vertical cast comparisons. Comparative vertical casts shall be taken solely for the purpose of recording evidence of the satisfactory operation of the fathometer. When the weekly average of the differences between fathometer soundings and vertical casts is less than 1½ per cent of the fathometer depths averaged for these comparisons, the fathometer shall be regarded as correct. If the weekly average of the differences exceeds this amount, the discrepancy shall be investigated by checking the setting of the dog, the fathometer tachometer, and the sounding sheave. An abstract of these comparisons shall accompany the special report. (See par. No. 9).

c. A comparison shall be made between the fast-disc-speed sounding and the slow-disc-speed sounding in about 200 fathoms' depth on a location where the bottom is flat. It is not necessary that the flat bottom be level. This comparison shall be made with the ship stopped, and shall be done not less than once weekly during the period slow-disc speed is being used. Enough comparisons shall be obtained distributed throughout the period slow-disc speed is used to insure a good

average correction, and in no case shall there he less than six such comparisons. The average difference between these comparative soundings throughout the season shall be applied to the slow-disc-speed soundings as an index correction. An abstract of all such comparisons, giving the dates of the observations and the volume and page numbers of the sounding records in which such comparisons may be found shall be included in the report on fathometer corrections to be submitted with each project. (See par. No. 9) In addition, slow-disc-speed soundings shall be corrected for temperature and salinity as shown in the example in this memorandum.

d. At least three readings should be made at each vertical comparison. The fathometer must be read without the operator having knowledge of the depth obtained on the vertical cast. When taking vertical casts for fathometer comparisons, the sensitivity of the amplifier should not be increased over that which normally is used during hydrography. This is done sometimes by the fathometer observer in an attempt to bring in echoes through the aerated water resulting from propeller cavitation after going astern and before the disturbed water has returned to its normal state. Such soundings are invariably in error.

e. Bottom characteristics should be obtained at each comparison and a fix recorded when possible in order that the characteristics, as well as the verification sounding, may be shown on the smooth sheet. (In this connection it may be of interest to mention that one field party obtained bottom samples, at full speed, in depths up to 47 fathoms.)

f. It is not necessary that every vertical cast be used for comparative purposes, but if any vertical cast is rejected for fathometer verification, the reasons for the rejection shall be given in the record.

7. Special corrections shall be applied to compensate for abnormal conditions, such as base line between hydrophone and oscillator differing from the amount for which the dial is calibrated.

8. In general, no other corrections should be made but if additional corrections are considered necessary by the hydrographer such necessity should be explained fully and the manner in which these corrections are computed and applied must be given in detail.

9. The computation of fathometer corrections shall be made the subject of a separate report and reference to this report shall be made in each descriptive report for the surveys to which these corrections are to apply. An abstract of the final fathometer corrections shall be attached to each descriptive report, but copies of the computations are not necessary.

SAMPLE COMPUTATION OF FATHOMETER CORRECTIONS

For Depths of 200 Fathoms or less

10. A temperature-depth curve is prepared for each sheet on Form M-146. This should be based on all the serial temperatures taken within that area, using a distinctive color or symbol for different months. Where there is a large seasonal variation in temperature it may be necessary to prepare more than one curve for this purpose. Where only a small seasonal change is found a mean curve may be plotted from all the serials taken.

a. The maximum variation between the temperature curves selected for computing correction factors will, of necessity, be a matter for the hydrographer's judgment, bearing in mind that no appreciable errors in fathometer corrections should result from using too wide an interval between temperature curves. (In general this difference in corrections should not exceed l/2 of one per cent of the depth).

b. Before any correction factors are computed a study should be made of the adopted temperature curves for the various sheets in order to determine whether one curve for the entire season's work can be used. The same considerations that govern the selection of a mean curve for a particular sheet should govern the selection of a mean curve for the entire area.

11. A salinity-depth curve is prepared from all the data obtained during the season unless in particular regions where there may be a wide variation in salinity it is necessary to use regional or seasonal salinity curves.

12. From the temperature-depth curve tabulate the temperatures from 2 fathoms (the usual depth of the oscillator and hydrophones) to 200 fathoms, using 5 fathom intervals between 2 and 102 fathoms, and a wider interval for greater depths. The interval to be used for depths below 102 fathoms will depend on the slope of the temperature curve. Generally 20 fathoms will be adequate. Table I shows the above tabulation and the necessary computations. The mean temperature shall be calculated for the various depths using the weighted mean where necessary, and the mean temperatures entered in column 3. The same procedure shall be followed with the salinity-depth curve and the results entered in columns 4 and 5. Using tabulated mean temperatures and mean salinities from columns 3 and 5, the fathometer correction factors shall be computed from the tables attached to this memorandum and the results entered in column 6 to four decimal places. These tables which have been prepared to facilitate this computation depend on the relation

$$\frac{\text{British Admiralty Table velocity - fathometer velocity}}{\text{fathometer velocity}} = \pm \text{ factor}$$

They have been computed by using the theoretical velocities of the British Admiralty Tables without any correction for pressure since for depths of 200 fathoms or less this correction is relatively small. Using the factors thus computed, the actual fathometer correction to two decimal places shall be tabulated in column 7.

a. From columns 1 and 7 of Table I a depth-correction curve shall be plotted and from this curve the depths for every .1 fathom correction shall be determined and tabulated on the depth-correction graph, the change points being taken as .06 fathom.

b. From the tabulation on the depth-correction graph a table of "Final Fathometer Corrections" (Table II) shall be prepared, giving the corrections to tenths of fathoms up to 20 fathoms and to the nearest half fathom beyond, the change points for the nearest half fathom being taken as 0.3 and 0.8. A copy of this table shall be attached to the descriptive report for each sheet to which the corrections apply, reference being made to the special report which carries the complete computation of fathometer corrections.

c. Should additional corrections, such as base line, dial speed, etc., be necessary, such corrections should be clearly indicated in Table II.

d. Appropriate corrections from Table II shall be entered in the sounding volumes omitting corrections of less than 1% of the depth for depths over 100 fathoms.

For Depths of over 200 Fathoms

13. A temperature-depth curve shall be prepared on Form M-146 from the deep water serials taken each month, using a distinctive symbol for each month combining into 1 mean curve all curves that do not differ by more than 2 degrees Centigrade in depths of 200 fathoms and over. Separate corrections will have to be worked out for the curves that fall outside of this limit.

14. A salinity-depth curve is also prepared from all data obtained during the season and a mean season curve determined.

15. Using these temperature and salinity curves, a Table of Fathometer Corrections (Table III) shall be prepared as follows:

a. In column 1 shall be entered the depths in fathoms, 200 fathom intervals, from the surface to the greatest depth sounded.

b. In columns 2 and 3 respectively shall be tabulated the temperatures and salinities for the depths listed in column 1.

c. In columns 4 and 5 the mean temperatures and salinities for each 200 fathom layer shall be tabulated from columns 2 and 3. The mean temperature and salinity for the first 200 fathom layer shall be taken from the computed tables for depths of 200 fathoms or less.

d. Using British Admiralty Tables 2, 3 and 4, the mean velocity shall be determined for each 200 fathom layer corresponding to the temperatures and salinities from columns 4 and 5, Table III, and the pressure for the mean depth of the layer, e.g., 100, 300, 500 fathoms, etc. These mean velocities for each layer shall be entered in column 6.

e. In column 7 the mean velocities from the surface to the various depths, indicated in column 1, shall be tabulated. - These mean velocities in column 7 are the actual sounding velocities to be used for the various depths.

f. In column 8 shall be tabulated the factors to four decimal places which are calculated from the relation

$$\frac{\text{British Admiralty Table velocity - fathometer velocity}}{\text{fathometer velocity}} = \pm \text{ factor}$$

the actual velocities being obtained from column 7.

g. In column 9 the corrections using the factors from column 8 shall be tabulated. These values represent the velocity corrections (temperature, salinity and pressure) to be applied to soundings at the depths listed in column 1.

h. From columns 1 and 9 of Table III a depth-correction curve shall be plotted and from this curve the depth range corresponding to the nearest whole fathom for every fathom correction shall be determined and entered in columns 1 and 2 of Table IV - Final Fathometer Corrections, the change points being taken as 0.6 fathom. This interval may be widened where necessary. These corrections will apply to all cases where the fast-disc speed is used.

i. In column 3 of Table IV shall be entered the index correction for slow disc speed as determined from the season's comparisons as specified in paragraph 6a, page 3, this memorandum. In column 4 shall be tabulated the corrections to be applied to all soundings obtained by the slow-disc method. A copy of this table shall be attached to the descriptive report for each sheet to which the corrections apply, reference being made to the special report which carries the complete computations of fathometer corrections.

j. Should additional corrections be necessary, such corrections should be clearly indicated in Table IV and tabulated in the abstracts accompanying the descriptive reports.

k. Appropriate corrections from Table IV shall be entered in the sounding volumes, corrections of less than 1% of the depth being omitted.

16. For plotting the depth correction curves in the above computations the style of paper accompanying this memorandum and the scales indicated thereon shall be used. The paper may be obtained on requisition from the Washington office. It is a standard paper known as cross-section drawing paper, 10 x 10 to the half inch, 7½ x 10" engraving.

Acting Director.

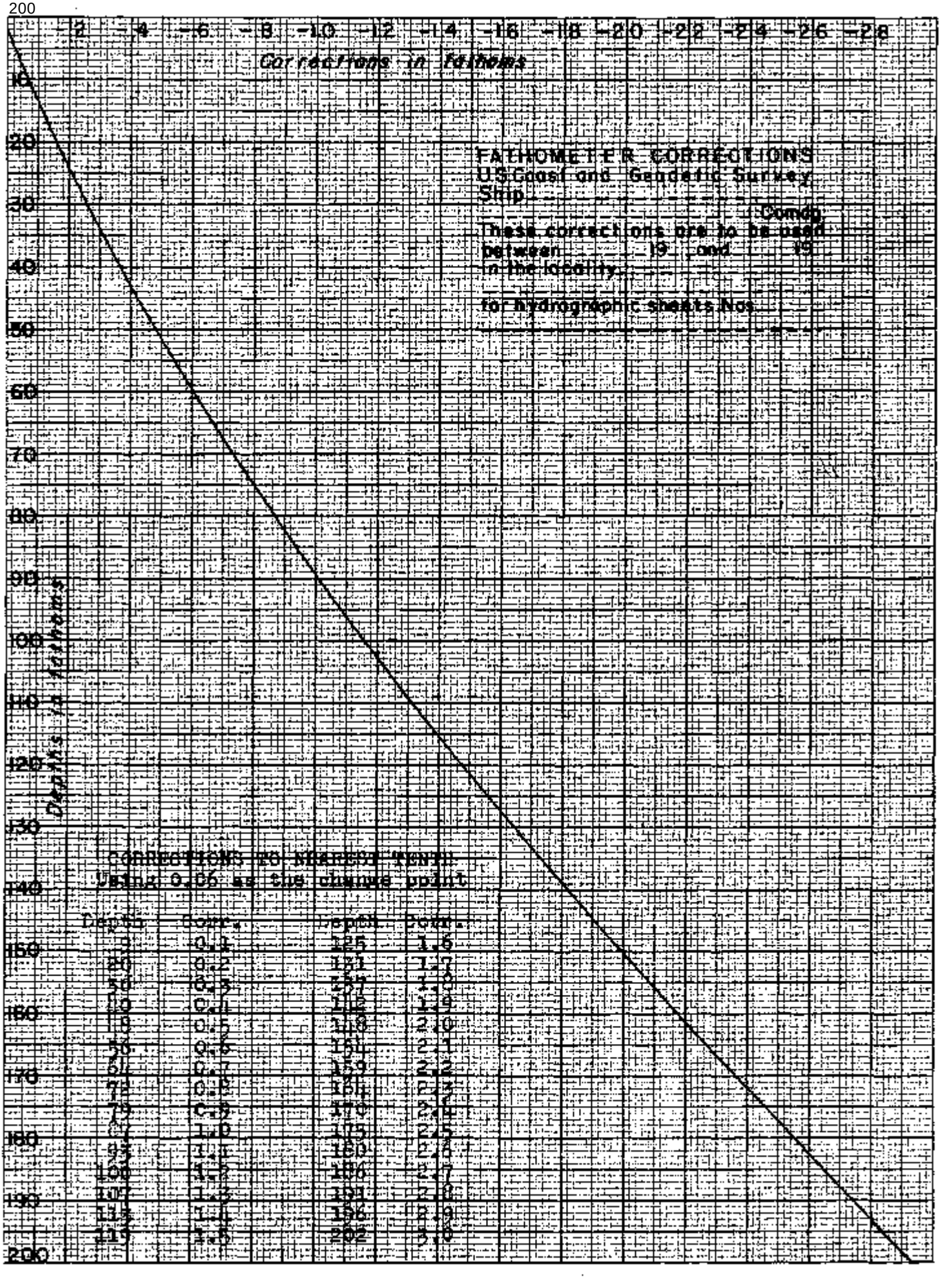
TABLE I

FATHOMETER CORRECTIONS

0 - 200 Fathoms

Fathometer Type 312 calibrated for 820 fathoms (1499.6 meters)per second

1	2	3	4	5	6	7
Depth in Fms.	Temperature °C	Mean Temperature	Salinity pp/1000	Mean Salinity	Factor	Correction in Fms.
2	11.5		34.0			
7	11.1	11.3	34.0		-0.0062	- .04
12	10.7	11.1	34.0		-0.0067	- .08
17	10.4	10.9	34.0		-0.0072	- .12
22	9.9	10.7			-0.0076	- .17
27	9.6	10.5			-0.0081	- .22
32	9.2	10.3			-0.0086	- .28
37	9.0	10.2			-0.0088	- .33
42	8.9	10.0			-0.0093	- .39
47	8.8	9.9			-0.0095	- .45
52	8.8	9.8			-0.0098	- .51
57	8.8	9.7			-0.0101	- .58
62	8.8	9.6			-0.0103	- .64
67	8.8	9.6			-0.0103	- .69
72	8.8	9.5	34.0	34.0	-0.0105	- .76
77	8.8	9.5			-0.0104	- .81
82	8.0	9.4			-0.0108	- .89
87	7.8	9.3			-0.0111	- .97
92	7.6	9.2			-0.0113	-1.04
97	7.5	9.1			-0.0116	-1.12
102	7.5	9.1			-0.0116	-1.18
120	7.2	8.8			-0.0123	-1.48
140	6.9	8.5			-0.0131	-1.83
160	6.6	8.3			-0.0136	-2.18
180	6.3	8.1			-0.0141	-2.54
200	6.0	7.9			-0.0147	-2.94



Depth	Corr.	Depth	Corr.
3	0.1	125	1.6
20	0.2	131	1.7
30	0.3	137	1.8
40	0.4	143	1.9
48	0.5	148	2.0
56	0.6	154	2.1
64	0.7	159	2.2
72	0.8	164	2.3
79	0.9	170	2.4
87	1.0	175	2.5
93	1.1	180	2.6
100	1.2	186	2.7
107	1.3	191	2.8
113	1.4	196	2.9
119	1.5	202	3.0

TABLE II

FATHOMETER CORRECTIONS
0 - 200 fathoms

Depth Range (Fathoms)	Corrections (in fathoms) (Temperature & Salinity)
0 - 8.9	0
9 - 19.9	0.1
20 - 29.5	0.2
30 - 71.5	0.5
72 - 106.5	1.0
107 - 136.5	1.5
137 - 163.5	2.0
164 - 190.5	2.5
191 - 200	3.0

TABLE III

FATHOMETER CORRECTIONS

For depths over 200 fathoms
Fathometer Type 312 calibrated for 820 fathoms (1499.6 meters.) per second.

1	2	3	4	5	6	7	8	9
Depth	Temperature	Salinity	Mean Temp. in 200 Fm. Layers	Mean Salinity in 200 Fm. Layers	Mean Vel. in 200 Fm. Layers from 4 & 5	Mean Vel. from Surface to Depth Col. 1	Factor+	Correction
Fathoms	°C	parts per 1000	°C	parts per 1000	Meters/seconds	Meters/seconds		Fathoms
0	11.7	34.0						
200	6.0	34.0	7.9*	34.0	1480.9	1480.9	-0.0125	- 2.5
400	4.0	34.4	5.0	34.2	1476.3	1478.6	-0.0140	- 5.6
600	3.2	34.5	3.6	34.4	1477.5	1478.2	-0.0143	- 8.6
800	2.6	34.5	2.9	34.5	1481.1	1479.0	-0.0137	-11.0
1000	2.2	34.5	2.4	34.5	1485.6	1480.3	-0.0129	-12.9
1200	2.0	34.5	2.1	34.5	1490.9	1482.0	-0.0117	-14.0
1400	1.8	34.5	1.9	34.5	1496.6	1484.1	-0.0103	-14.4
1600	1.8	34.5	1.8	34.5	1502.8	1486.5	-0.0087	-13.9
1800	1.8	34.5	1.8	34.5	1509.4	1489.0	-0.0071	-12.8

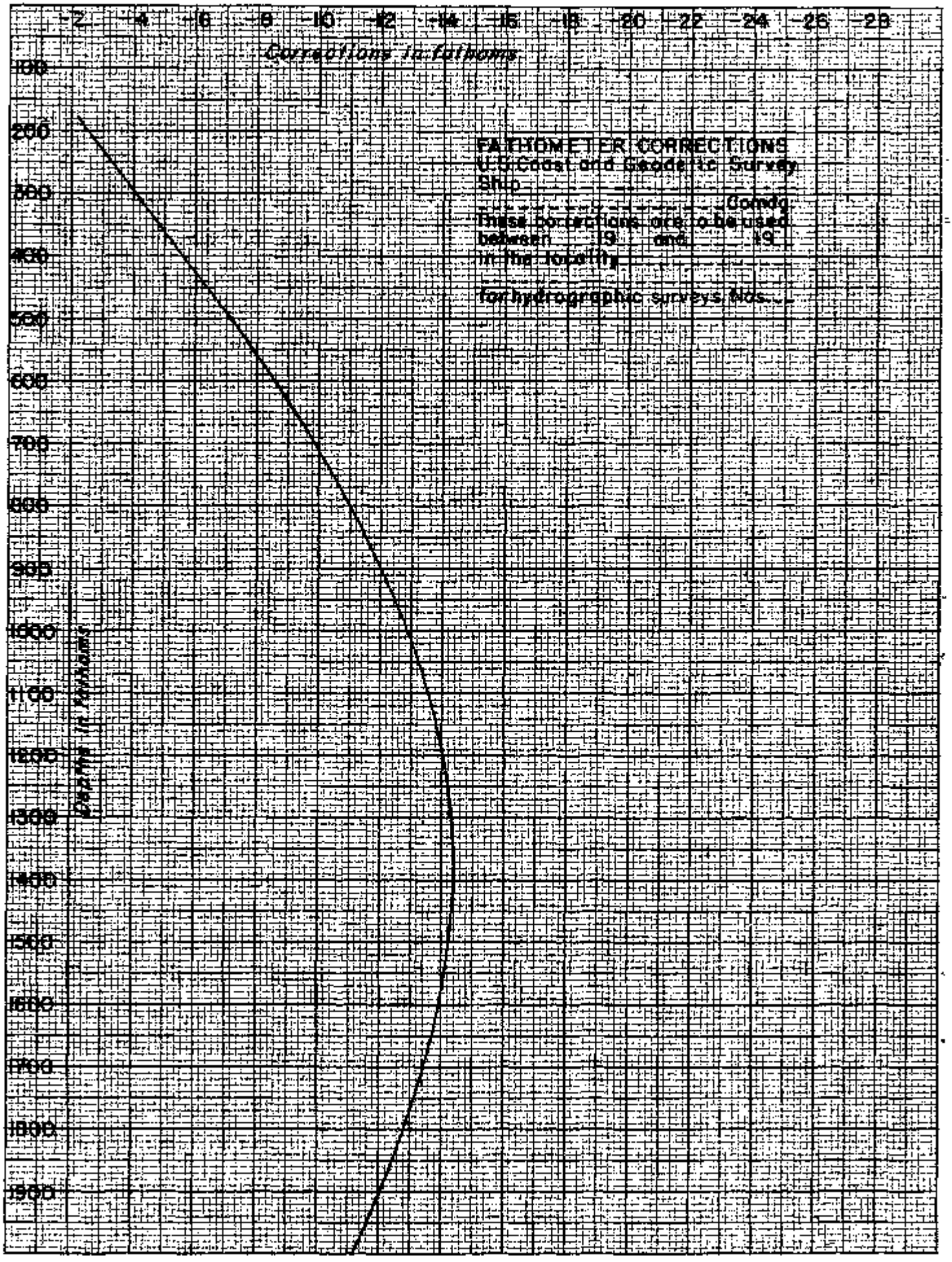
* Take from tables for depths of 200 fathoms or less.

\+ When other than the middle reed of the tachometer is used, these factors are to be computed using a fathometer velocity equivalent to the dial speed for the reed in use. See par. 2a.

TABLE IV

FINAL FATHOMETER CORRECTIONS
For Depths over 200 Fathoms

1	2	3	4
Depth Range fathoms	Velocity Correction fathoms	Index Correction slow-disc speed fathoms	Corrections slow-disc speed fathoms
200 - 269	- 3.0	- 3.0	- 6.0
270 - 334	- 4.0	- 3.0	- 7.0
335 - 399	- 5.0	- 3.0	- 8.0
400 - 464	- 6.0	- 3.0	- 9.0
465 - 529	- 7.0	- 3.0	-10.0
530 - 604	- 8.0	- 3.0	-11.0
605 - 679	- 9.0	- 3.0	-12.0
680 - 764	- 10.0	- 3.0	-13.0
765 - 859	- 11.0	- 3.0	-14.0
860 - 964	- 12.0	- 3.0	-15.0
965 - 1109	- 13.0	- 3.0	-16.0
1110 - 1665	- 14.0	- 3.0	-17.0
1666 - 1825	- 13.0	- 3.0	-16.0
1826 - 1950	- 12.0	- 3.0	-15.0
1951			


-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
Corrections in fathoms
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
Depths in fathoms
FATHOMETER CORRECTIONS
U.S. Coast and Geodetic Survey
Ship
Cond'g
These corrections are to be used
between 19 and 19
in the locality
for hydrographic surveys, Nos.

FATHOMETER CORRECTION FACTORS

For depths less than 200 fathoms
Computed from British Admiralty Velocity Tables
(Atmospheric Pressure)
To be applied to fathometer readings in accordance with sign

Temp. °C	Fathometer Velocity = 800 Fathoms (1463 meters) per second — Salinity (Parts per 1,000)							Fathometer Velocity = 820 Fathoms (1499.6 meters) per second — Salinity (Parts per 1,000)							Temp. °C
	31	32	33	34	35	36	37	31	32	33	34	35	36	37	
0°	-0.0155	-0.0146	-0.0137	-0.0130	-0.0121	-0.0111	-0.0103	-0.0396	-0.0387	-0.0378	-0.0370	-0.0362	-0.0353	-0.0344	0°
1°	-0.0124	-0.0115	-0.0106	-0.0098	-0.0090	-0.0080	-0.0071	-0.0365	-0.0356	-0.0348	-0.0339	-0.0331	-0.0322	-0.0314	1°
2°	-0.0094	-0.0085	-0.0076	-0.0068	-0.0059	-0.0050	-0.0041	-0.0336	-0.0327	-0.0318	-0.0310	-0.0302	-0.0293	-0.0284	2°
3°	-0.0063	-0.0054	-0.0045	-0.0038	-0.0029	-0.0020	-0.0012	-0.0306	-0.0297	-0.0288	-0.0281	-0.0273	-0.0264	-0.0255	3°
4°	-0.0033	-0.0025	-0.0016	-0.0008	0.0000	+0.0010	+0.0018	-0.0277	-0.0268	-0.0259	-0.0252	-0.0244	-0.0234	-0.0227	4°
5°	+0.0005	+0.0003	+0.0012	+0.0020	+0.0028	+0.0038	+0.0046	-0.0249	-0.0241	-0.0232	-0.0225	-0.0217	-0.0207	-0.0199	5°
6°	+0.0023	+0.0031	+0.0040	+0.0048	+0.0056	+0.0066	+0.0074	-0.0222	-0.0213	-0.0205	-0.0197	-0.0188	-0.0180	-0.0172	6°
7°	+0.0051	+0.0059	+0.0068	+0.0076	+0.0083	+0.0093	+0.0101	-0.0195	-0.0187	-0.0178	-0.0170	-0.0163	-0.0153	-0.0145	7°
8°	+0.0077	+0.0086	+0.0095	+0.0103	+0.0110	+0.0119	+0.0127	-0.0169	-0.0160	-0.0151	-0.0144	-0.0137	-0.0128	-0.0120	8°
9°	+0.0104	+0.0112	+0.0121	+0.0129	+0.0136	+0.0145	+0.0152	-0.0143	-0.0135	-0.0126	-0.0118	-0.0111	-0.0103	-0.0095	9°
10°	+0.0129	+0.0137	+0.0146	+0.0154	+0.0161	+0.0170	+0.0180	-0.0118	-0.0110	-0.0101	-0.0093	-0.0087	-0.0078	-0.0068	10°
11°	+0.0154	+0.0162	+0.0171	+0.0179	+0.0186	+0.0195	+0.0203	-0.0093	-0.0086	-0.0077	-0.0069	-0.0063	-0.0054	-0.0046	11°
12°	+0.0178	+0.0187	+0.0195	+0.0203	+0.0210	+0.0219	+0.0226	-0.0070	-0.0062	-0.0054	-0.0046	-0.0039	-0.0031	-0.0023	12°
13°	+0.0203	+0.0211	+0.0219	+0.0227	+0.0234	+0.0242	+0.0250	-0.0046	-0.0039	-0.0030	-0.0022	-0.0016	-0.0008	0.0000	13°
14°	+0.0226	+0.0234	+0.0242	+0.0250	+0.0256	+0.0265	+0.0272	-0.0024	-0.0016	-0.0008	0.0000	+0.0006	+0.0014	+0.0021	14°
15°	+0.0248	+0.0256	+0.0264	+0.0272	+0.0278	+0.0286	+0.0294	-0.0002	+0.0005	+0.0013	+0.0021	+0.0027	+0.0035	+0.0043	15°
16°	+0.0270	+0.0278	+0.0286	+0.0294	+0.0300	+0.0308	+0.0316	+0.0019	+0.0027	+0.0035	+0.0043	+0.0049	+0.0057	+0.0064	16°
17°	+0.0291	+0.0298	+0.0306	+0.0315	+0.0321	+0.0329	+0.0336	+0.0039	+0.0047	+0.0055	+0.0063	+0.0069	+0.0077	+0.0084	17°
18°	+0.0312	+0.0319	+0.0327	+0.0335	+0.0341	+0.0349	+0.0357	+0.0060	+0.0067	+0.0075	+0.0083	+0.0089	+0.0097	+0.0104	18°
19°	+0.0331	+0.0339	+0.0347	+0.0355	+0.0361	+0.0369	+0.0377	+0.0079	+0.0087	+0.0095	+0.0102	+0.0108	+0.0116	+0.0123	19°
20°	+0.0351	+0.0358	+0.0366	+0.0374	+0.0380	+0.0388	+0.0396	+0.0098	+0.0105	+0.0113	+0.0121	+0.0127	+0.0135	+0.0142	20°
21°	+0.0369	+0.0377	+0.0385	+0.0392	+0.0398	+0.0407	+0.0414	+0.0116	+0.0123	+0.0131	+0.0139	+0.0145	+0.0153	+0.0160	21°
22°	+0.0387	+0.0396	+0.0403	+0.0411	+0.0417	+0.0425	+0.0433	+0.0135	+0.0142	+0.0149	+0.0157	+0.0163	+0.0171	+0.0178	22°
23°	+0.0406	+0.0413	+0.0422	+0.0429	+0.0435	+0.0442	+0.0450	+0.0152	+0.0159	+0.0167	+0.0174	+0.0180	+0.0187	+0.0195	23°
24°	+0.0424	+0.0431	+0.0439	+0.0446	+0.0452	+0.0459	+0.0467	+0.0169	+0.0177	+0.0184	+0.0191	+0.0197	+0.0204	+0.0211	24°
25°	+0.0441	+0.0449	+0.0456	+0.0463	+0.0469	+0.0476	+0.0484	+0.0186	+0.0193	+0.0201	+0.0207	+0.0213	+0.0221	+0.0228	25°
26°	+0.0457	+0.0465	+0.0472	+0.0479	+0.0485	+0.0493	+0.0500	+0.0202	+0.0209	+0.0217	+0.0223	+0.0229	+0.0237	+0.0244	26°
27°	+0.0473	+0.0481	+0.0488	+0.0495	+0.0501	+0.0509	+0.0516	+0.0217	+0.0225	+0.0232	+0.0239	+0.0245	+0.0252	+0.0259	27°
28°	+0.0490	+0.0497	+0.0504	+0.0511	+0.0517	+0.0524	+0.0531	+0.0233	+0.0241	+0.0247	+0.0254	+0.0260	+0.0267	+0.0274	28°
29°	+0.0505	+0.0512	+0.0519	+0.0526	+0.0533	+0.0540	+0.0547	+0.0249	+0.0256	+0.0263	+0.0269	+0.0275	+0.0283	+0.0290	29°
30°	+0.0520	+0.0527	+0.0534	+0.0541	+0.0547	+0.0555	+0.0561	+0.0263	+0.0270	+0.0277	+0.0283	+0.0289	+0.0297	+0.0303	30°

TABLE OF PRESSURE CORRECTIONS*

(In Meters per Second)
Corrections to be added to British Admiralty
Velocities on account of Pressure or Depth

Depths in Fathoms	Temperature °C				
	-2	5	10	15	20
0	0	0	0	0	0
50	1.6	1.6	1.6	1.6	1.6
100	3.3	3.3	3.3	3.3	3.3
150	5.0	5.0	4.9	4.9	4.9
200	6.7	6.7	6.6	6.6	6.6
250	8.3	8.3	8.2	8.2	8.2
300	10.0	10.0	9.9	9.9	9.9
350	11.6	11.6	11.5	11.5	11.5
400	13.3	13.3	13.2	13.2	13.2
450	15.0	14.9	14.9	14.8	14.8
500	16.7	16.7	16.6	16.5	16.5
550	18.3	18.3	18.2	18.1	18.1
600	20.0	20.0	19.9	19.8	19.8
650	21.6	21.6	21.5	21.4	21.5
700	23.2	23.2	23.1	23.0	23.1
750	24.9	24.9	24.8	24.7	24.7
800	26.5	26.5	26.4	26.3	26.3
850	28.2	28.2	28.1	28.0	27.9
900	29.9	29.8	29.7	29.6	29.5
950	31.6	31.5	31.4	31.2	31.2
1000	33.2	33.1	33.0	32.8	32.8

Depths in Fathoms	Temperature °C						
	-2	0	1	2	3	4	5
1000	33.2						33.1
1050	34.9	34.9	34.9	34.9	34.9	34.9	34.8
1100	36.5	36.5	36.5	36.5	36.5	36.5	36.4
1150	38.2	38.2	38.2	38.2	38.2	38.2	38.2
1200	39.8	39.8	39.8	39.8	39.8	39.8	39.8
1250	41.4	41.5	41.5	41.5	41.5	41.5	41.5
1300	43.2	43.2	43.2	43.1	43.1	43.1	43.1
1350	44.8	44.8	44.8	44.8	44.7	44.7	44.7
1400	46.5	46.5	46.5	46.5	46.4	46.4	46.3
1450	48.1	48.1	48.1	48.1	48.0	48.0	47.9
1500	49.8	49.8	49.8	49.8	49.7	49.7	49.6
1550	51.4	51.4	51.4	51.4	51.3	51.3	51.2
1600	53.1	53.1	53.1	53.1	53.0	53.0	52.9
1650	54.7	54.7	54.7	54.7	54.6	54.6	54.5
1700	56.4	56.4	56.4	56.4	56.3	56.3	56.2
1750	58.0	58.0	58.0	57.9	57.9	57.8	57.8
1800	59.7	59.7	59.7	59.6	59.6	59.5	59.5
1850	61.3	61.3	61.3	61.2	61.2	61.1	61.0
1900	62.9	62.9	62.9	62.8	62.8	62.7	62.6
1950	64.6	64.6	64.6	64.5	64.4	64.4	64.3
2000	66.2	66.2	66.2	66.1	66.0	66.0	65.9

*This table replaces Table 4 of the British Admiralty Velocity Tables.

THE PRODUCTION OF THE AERONAUTICAL CHART

COMPILATION

Standard compiled showing all available material.
Material studied, features selected and pantographed.
Data transferred to projection on Whatman's paper. History written.
Aeronautical data added and reviewed by the Bureau of Air Commerce.
Compilation completely verified and bromides made.

FIELD DATA

Bromides mounted on cloth and sent to field for flight check.

Bromides sent to power companies for transmission line locations.

Compilation corrected for flight check, and transmission lines added.
Changes verified; compilation photographed, glossy and dull prints.

FINAL DRAWINGS

Glossy print cut into small squares and pasted to projection on aluminum mounted paper. Photographed to blue-line prints (4).

Type listed and impressions made on gum-backed paper.

Smooth drawings made on blue-line prints for black and purple; dark blue; contour brown; red and pink. Type stuck-up.

Dull print of compilation colored for use in making color plates,

Drawings verified, compared for color interference, and sent for proof.

NEW EDITIONS

Standards

Material from new quadrangles and other maps, blue prints, flight check, letters, engineering and railroad magazines, noted on standards.

Air Navigation Aids

Material from Weekly Notices to Airmen, Notices to Aviators, Airway Bulletin No. 2, Notices to Mariners noted on A. N. A. copies.

Changes applied to copy of latest printing, copy verified and sent to Reproduction Branch for changes and proof. In some cases original final drawings are revised or new drawings made and new negatives and plates prepared. Where stock of charts with all colors except red and pink is on hand, aeronautical changes only are made and the red and pink printed to the stock.

PROOFS

Proof is copy checked against compilation or correction copy and aeronautical data corrected to date.
Returned to Reproduction Branch for correction and final printing.
Final chart checked for corrections before copies are released.

THE BALLAD OF CHARLIE McGOFFUS

By Seven Yergensen - (The Hindu Mystic)

A field engineer named Charlie McGoffus,
Worked all day in the field and all nite in the office,
Checking contracts and vouchers and estimates, too,
To be picked all to bits by the Washington crew.

For the boys in D. C. in their double-lensed specs
Their sallow complexions and fried collar necks,
Care not for the time nor the money they waste.
If a carbon is missing, a comma misplaced,
And they bounce back the paper with ill concealed jeers
To harass the hard-working field engineers.

To get back to Charlie, he struggled along
'Till an ache in his head told him something was wrong,
He went to the doctor and "Doctor" said he,
"There's a buzz in my brain, what's the matter with me?"

Well, the medico thumped as medicos do,
And he tested his pulse and his reflexes, too,
And his head and his heart and his throat and each lung,
And Charlie said "ah" and he stuck out his tongue,
Then the doctor said "G--, what a narrow escape,
But a quick operation will put you in shape."

"Your brain's overworked like a motor run down,
And you're flirting with death every time you turn round,
I must take out your brain for complete overhauling;
In the interim, take a respite from your calling."
So Charlie McGoffus went under the knife,
He struggled home brainless and kissed his own wife,
While old Doctor Loomis and two other men,
Were putting his brain in order again.
Well, the weeks rolled along and Charlie McGoffus
Never called for his brain at the medico's office.
The doctor got worried, gave Charlie a ring,
Said, "You'd better come over and get the d----d thing."
"Thanks, Doc, I don't need it", said Charlie McGoffus,
"I'm being transferred to the Washington Office."

So Charlie now wears a fried collar to work,
And he hides in the lairs where the auditors lurk,
And his letters bring tremors of anger and fear
To the heart of each hard-working field engineer,
And the pride and the joy of the Washington Office,
Is brainless, predacious, young Charlie McGoffus.

Reproduced here with apologies to the author, the identity of whom investigation failed to disclose, although he is almost certainly not with the Coast and Geodetic Survey.
Editor.