MAGNETIC SURVEY ON THE PACIFIC OCEAN.

BY HERBERT T. WADE.

One of the most important of modern scientific undertakings is the general magnetic survey of the globe now being executed by the Department of Research in Terrestrial Magnetism of the Carnegie Institution of Washington, under the direction of Dr. L. A. Bauer, formerly in charge of the magnetic survey of the United States under the United States Coast and Geodetic Survey. One phase of this work in which considerable interest is being manifested is the magnetic survey of the Pacific Ocean which has been conducted by observers in the sailing ship "Galilee" during the past three years. The practical value of magnetic work is appreciated instantly when one realizes that the underlying basis of surveying and navigation is the compass. As is well known, the magnetic needle does not point to the true or geographical North Pole except at a comparatively small number of points located on what are termed agonic lines. Nor are the indications of the needle for a given place constant with time, and as an example can be cited a survey originally made at Baltimore, Md., in 1800, where the compass directions for the same bearings, if measured to-day, would vary about five degrees from those of a century ago. In the eastern part of the United States there is a tendency at present for the magnetic needle to move westerly at an average yearly rate of from 3 to $3\frac{1}{2}$ minutes. It is, of course, important not only to study these changes of declination or variation of the magnetic from the geographical meridian, in their various aspects at as many points as possible, but also the inclination from the horizontal of a freely swinging magnet, known as its dip, and the magnetic intensity or strength of the earth's magnetism. To that end there are maintained many government and other magnetic observatories and surveys, so that in the United States there are about 3,500 well distributed points where the above elements have been accurately determined.

As the surface of the earth includes nearly three times as much water as land, it is most essential to know the magnetic conditions of various points on the oceans in order to supply to the navigator as precise and comprehensive information as possible, as well as to afford the magnetician an adequate idea of the distribution of magnetism over the earth. This knowledge of the magnetic elements is most necessary in deep-sea sailing, since the navigator is forced to correct his compass bearings as indicated by the magnetic needle by adding or subtracting the proper magnetic variation or declination given on his chart. Now suppose the voyage is made in stormy or cloudy weather, where for days it is impossible to determine the position of the vessel by the usual sextant observations of the sun or other celestial bodies, then the navigation must be by dead-reckoning, ascertaining the position from the distances as given by the log and the direction from the compass. But before the compass courses are laid off on the chart they must be corrected by adding or subtracting the variation scaled from the chart.

For the Pacific Ocean, despite its increasing commercial importance, comparatively little had been done prior to the Carnegie Institution work to improve and extend the magnetic information given on the charts. Indeed, the past magnetic charts were based largely on observations made on such exploring expeditions as those of the British ships "Erebus," "Terror," and "Pagoda" (1840-45), the Austrian frigate "Novara" (1857-60), the famous deep-sea exploring vessel "Challenger" (1872-76), the German vessel "Gazelle" (1874-76), and other more or less extended surveys made by warships or other vessels engaged in hydrographic work. Mention might be made of the valuable magnetic work done by recent Antarctic expeditions in addition to those mentioned, but in the main the more recent magnetic data for Pacific charts have been obtained from observations made either on islands or the coasts of the continents, and the continued use of the earlier material. As a result there were important errors in the magnetic values taken from the various government charts, even on such

well-traversed routes as between San Francisco and Honolulu, where both the British and the German Admiralty charts were in error by from 1 deg. to 2 deg., giving too small a value for the easterly declination. Now, this distance is about 2,000 miles, and if a systematic error of 1 deg. persisted on a voyage where clouds or fog prevented observation of the sun or stars, a ship navigated by compass and log at the end of its journey would be too far north by about 35 miles or one-sixtieth of the distance traveled, an error whose possible serious consequences it is not difficult to imagine. In other regions of the Pacific Ocean the errors in some of the previous magnetic

small amount of iron have to be considered and applied to the observations.

The only striking feature of the ship is the fore-and-aft bridge 15 feet above the deck extending from the foremast to the mainmast, on which are mounted the compasses and other instruments. Three of the fixed instruments are essentially marine compasses of well-known types, but the dip circle is provided with a special mounting, as is shown in more detail in a separate illustration. The declination can be measured with any of the compasses provided with an azimuth circle, which is a device fitted on top of the compass and provided with sights for observing the bearing of the sun or other celestial body. Knowing thus the angle which the direction of the sun makes with the magnetic meridian as indicated by the compass, the exact time of observation from the ship's chronometer, the sun's declination from the Nautical Almanac, and the latitude and longitude of the place of observation, the true north and south meridian can be found and the variation of the compass for that time and place determined. In making observations of the celestial bodies, clear weather is all-essential, and this has been the greatest difficulty so far experienced in the magnetic work on the Pacific.

For declination, as well as for dip and intensity, two simultaneous observations are usually made at different parts of the bridge, and the motion of the ship does not interfere with the observations as much as the meteorological conditions. The method of making the most accurate observations is to "swing ship," that is, cause it to point in different directions as respects the magnetic meridian, and then to attempt readings at eight equidistant points. In a harbor where there is a tug available this is comparatively simple, and also in calm weather at sea, as the "Galilee" now carries a naphtha launch to assist in this maneuver, but in heavy weather or when a

sea is running it is often quite difficult, if not impossible, and the observers must be satisfied with fewer observations. From the "swings," the necessary corrections are likewise determined, due to the effect of the remaining iron on board, consisting chiefly of the iron bolts in the sides of the vessel. The endeavor is to make a "swing" about every third or fourth day; it then suffices to make the observations on the intervening days on the ship's course. In port it is customary to make still more elaborate observations and also measurements on shore, and where possible to compare results and standardize the instruments with those of some magnetic observatory.

Next to the compass with its azimuth circle, the most important instrument is the dip circle for determining the dip or inclination and also the total intensity. The Lloyd-Creak pattern, which is employed, consists essentially of a magnetic needle free to revolve about a horizontal axis and mounted on jeweled bearings. When freely swinging in the vertical plane of the magnetic meridian the needle will indicate the inclination for that particular point. The angle is read with microscopes on a divided circle and the magnetic needles can be reversed or different needles can be used. The total magnetic intensity can be deduced from observations made with the dip circle, while for horizontal intensity, or that part of the magnetic force that is exerted on a properly balanced compass needle, there is used a special apparatus differing from that usually employed on land where the magnet is placed in the same horizontal plane as the compass needle. On the "Galilee" the deflecting magnet is placed above the compass on a small brass bridge or frame as shown in the illustration of the Ritchie-Negus compass with the binnacle case removed. Now, the magnet used to deflect the compass needle has been studied carefully and its magnetic moment and other constants have been determined, so that noting the deflections it is possible to compute the horizontal intensity at any given place. The value of the horizontal intensity determined directly with this apparatus furnishes a check upon that deduced from the dip and total intensity measurements with the Lloyd-Creak dip circle.

As soon as the observations are

Kelvin Horizontal force Ritchie Dip circle and total
compass. instrument. compass. force instrument.
Scientific Personnel.
J. P. Ault, H. E. Martyn, J. C. Peters,
Magnetic Observer Surgeon and Recorder. Commander.

Observing Bridge of the "Galilee" and Instruments.

Taken by J. C. Pearson, Magnetic Observer.

charts amounted at times to from 3 deg. to 5 deg.

So when the Carnegie Institution determined early in its magnetic work to make a thorough survey of the Pacific Ocean, the proposition was well received not only by students of terrestrial magnetism, but by hydrographers and navigators. Accordingly, in 1905 the wooden sailing vessel "Galilee" was chartered at San Francisco and the first cruise was begun in August of that year. The "Galilee" is a wooden brig, built in 1891, and is 132.4 feet in length, 33.4 feet in beam, 12.6 feet in depth, and of about 600 tons displacement. The steel rigging was replaced by hemp, and as much as possible of the iron and steel in the blocks, tackle, and other fittings was changed to non-magnetic metal, so that while the entire elimination of iron and steel was impossible it was reduced to a minimum, and the vessel in this respect was far superior to any ship previously employed in magnetic work. Nevertheless deviation corrections incident to the presence of a

Cruises of the Magnetic Survey Yacht "Galilee" From August 1, 1905, to September 1, 1907.

The dotted lines show the track of the "Challenger" expedition, 1872-76.

Leaving Honolulu on September 26, 1907, the "Galilee" set her course via the Midway and Marshall Islands for Christchurch, New Zealand, where she arrived on December 24. At Christchurch the necessary observations were made for connecting the work of the "Galilee" with that of the English Antarctic ship the "Discovery." The "Galilee" then left Christchurch on January 17 bound for Callao, Peru, from which port she will return to San Francisco, some time in May, when the total course covered since August 1, 1905, will be about 65,000 nautical miles.

made they are reduced and tabulated to be mailed to Washington from the next port, and the office staff there proceeds immediately with their computation and discussion. The preliminary results as fast as they are available are placed at the disposal of institutions and individuals interested, and the first practical outcome of the Pacific work was the publication in May of last year by the United States Hydrographic Office of a new chart of the lines of equal variation for 1910 in which use was made of the data from the "Galilee's" survey. The Hydrographic Office also has in preparation charts showing lines of equal magnetic dip and lines of equal magnetic intensity which, because of this new material, will be far more accurate than those now in use.

The three cruises of the "Galilee" will amount in length to about 65,000 nautical miles by next May, when the vessel returns to San Francisco from South America. The courses traversed are shown on the accompanying map, and on these observations were made on an average about every 200 or 250 miles. For future work the Carnegie Institution has under consideration the design and construction of a vessel

especially adapted for magnetic work, with auxiliary motive power in the form of a gasoline engine. This would enable the survey to be carried on much more efficiently, as with a non-magnetic vessel the necessity for swinging ship is not so apparent. The special con-

struction of the hull for magnetic work would diminish the labor of observation and office reduction by bringing the deviation down to an inappreciable quantity.

The great value of the magnetic work in the Pacific Ocean by the Carnegie Institution has been demonstrated, and it must be remembered that this is only one branch of the work of the Department of Terrestrial Magnetism, which is devoting itself quite as actively to theoretical studies and investigations in inaccessible and unexplored places. The results so far attained from the annual appropriations (\$57,000 in 1907) show the wisdom of the Carnegie Institution in supporting adequately some particular branch of science instead of awarding small grants to a number of unorganized workers engaged in different fields of activity.

An improved "pedestrian catcher," to prevent accident to persons run down by tramcars, is attracting attention in Dresden. It is easily attached to cars, does not get out of order, and picks up and carries along life-size leathern manikins, living dogs, and even bottles filled with liquid.

Ritchie United States Navy Standard Compass and Azimuth Circle for Determining the Magnetic Declination (Variation of the Compass).

Horizontal Force Instrument Devised by the Department of Terrestrial Magnetism.

L. A. Bauer, director, making trial observations on the cruise from San Francisco to San Diego.

Dip Circle and Total Force Instrument Mounted on Gimbals Stand for Use on Board Ship, Showing Manner of Mounting and Details of the Instrument.

The "Galilee" at Anchor in Sitka Harbor, July, 1907.

Ship Horizontal Force Instrument Mounted on Tripod for Shore Observations at the Honolulu Magnetic Observatory, September, 1907.