REPORT ON THE SCIENTIFIC RESEARCHES CARRIED OUT BY H. I. M. S. "CITTÀ DI MILANO" AT SPITZBERGEN DURING THE ARCTIC EXPEDITION OF 1928.

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During her stay in the Arctic Seas (April to September 1928), the *Città di Milano* was instructed to carry out a series of scientific researches and particularly hydrographic research work in the Spitzbergen area. A brief report of the results of this work is given below. The complete reports, relative to each separate subject, will be published in a special volume of the "*Annali Idrografici*" issued by the Hydrographic Institute of the Royal Italian Navy at Genoa, as was done recently for the *Amiraglio Magnaghi* expedition to the Red Sea and for earlier hydrographic expeditions.

Although the vicissitudes of the expedition did not allow the ship to pursue her programme of thalassographic researches in peace and quiet, it is nevertheless a fact that an abundant harvest of soundings has been reaped, and that the time available to a small party landed at Kings Bay, in the London district (Bloomstrand Peninsula), was sufficient to enable an hydrographic survey, as well as astronomical, gravimetric, magnetic and tidal observations, to be made; a short account thereof is given below.

SOUNDINGS.

The *Città di Milano* carried a Langevin-Florisson Ultra-Sonic Depth-Finder, which worked perfectly throughout the expedition ; whenever the correction attained any degree of importance, the soundings were corrected by the British Admiralty tables, taking as a basis the temperatures actually taken at various depths.

For these temperature observations, a Richter reversing thermometer was used. These thermometers were lowered by means of a wire sounding machine of the "Lucas" type fitted with an electric winch.

The sounding apparatus was fitted with water bottles at the same time.

Already during the outward voyage, on 1st April 1928, the Ultra-Sonic Depth-Finder had enabled a new contribution to be made towards the knowledge of the very uneven sea-bottom that exists in the vicinity of Capes Ortegal and Finisterre. Similar soundings were taken during the return voyage, on 10th October, and these soundings have been added to those already taken in this interesting locality (*See* Hydrographic Bulletin of the International Hydrographic Bureau, 1929).

In the vicinity of the coasts of Spitzbergen, echo-sounding enabled the trace of the 500 metre contour line to be filled in at numerous points and the surv·y of Kings Bay to be completed. As is well known, the Spitzbergen coast is closely bordered by deep depressions, so that, for these regions, the 500 metre contour line is of prime navigational importance, comparable to that of the 10 metre contour line at numerous places.

The sounding taken may be grouped as follows :

a) A line from Tromsö to about latitude 74°, 30', run during the outward voyage from 29th April to 2nd May, 1928.

b) A second line from Tromsö to about the same latitude, run from 5th to 8th August, 1928.

The positions of these soundings (which, as is known, are taken at short intervals) have been interpolated between points, the positions of which were determined astronomically.

c) A line between Bear Island and Kings Bay, from 29th April to 2nd May, 1928.

d) A second line between Bear Island and Kings Bay, from 5th to 8th August, 1928.

e) A line of soundings nearly at right angles to the Spitzbergen coast in the latitude of Kings Bay (on 26th and 27th August).

The positions of these soundings have been, as far as practicable, referred to points on Prince Charles Promontory. These soundings fill in the Norwegian and British charts N° 303 and N° 2751 respectively.

f) A line from South Gat to Kings Bay, run on 29th May.

h) A line from Kings Bay to Virgo Bay (24th June).

i) A second line from Virgo Bay to Kings Bay (7th July).

l) A line northwards of Spitzbergen, run on 28th and 29th May.

Whenever possible, the soundings were fixed by points on shore. Generally speaking, the state of the sea was good.

As may be seen from paragraph (*e*), in spite of the vicissitudes of the expedition for which the ship was acting as base, it was possible to run a line of soundings, and while doing so, collect water samples and take water temperatures on a course perpendicular to the coast, similar to that which was run by the Swedish gun-boat *Svenskund* at the entrance of Ice Fiord but in the higher latitudes corresponding to the open part of Kings Bay. These soundings have shown the existence of a long submarine ridge towards the North of the mountainous Prince Charles Island. Although the definite analysis of the water samples brought back is not completed, from the examination of the temperatures it is possible to deduce that the ship encountered the eastern limit of the arm of the Gulf Stream which runs up the western coast of Spitzbergen and to which, in spite of the latitude, the exceedingly mild climatic conditions, which exist in the North of the Island, are due. Farther to the southward of Prince Charles Island, the Gulf Stream is known to be separated from the coast by a cold current which passes round the southern point of Spitzbergen and thereafter sinks to a lower level ; on the contrary, northwards of Prince Charles Island, the warmer current almost skims the coast and is separated from it only by the cold water due to thawing of the glaciers or by that which flows into the bays.

Other soundings were taken which are of importance because they are in little known regions; at the same time, water samples were collected and temperatures taken. They were carried out by Officers of the Royal Italian Navy on board the chartered whaler *Braganza* during her fourth cruise, i. e. during her voyage of circumnavigation of North East Land and her stay at Great Island and Phipps Islands.

All the soundings and necessary tracings will be published in full in the final report.

HYDROGRAPHIC WORK AT KINGS BAY.

Ice conditions and the duties arising out of the ship's mission did not allow this work to be begun before 1st June. The necessity to avoid interference with the vessel's obligations limited the means which might have been available under other circumstances for this kind of study. The programme laid down before starting, had to be reduced to the most essential and important surveys only i. e. that of the coaling anchorage (Plan of Ny Aaalesund) on the South coast and that of the southern coast of the Bloomstrand Peninsula (Plan of London), a favoured spot, for it is sheltered from nearly all winds and offers good anchorage at all points ; such conditions are rather infrequent at Kings Bay where depths of over 100 meters are generally found, except at very short distances from the shore. Besides, these two anchorages have the advantage of being near the entrance of the Bay, i. e. within a privileged zone and free from ice.

The *plan of Ny Aalesund* was made on the scale of 1:5,000 between Ankerpynten and Miethe Island. Traces of the marks of a Norwegian precise triangulation of this region were found and the triangulation was developed in order to refer the primary and secondary points necessary for the hydrographic survey thereto.

The *plan of London* was drawn on the scale of 1:10,000 between Eskieret Island and a point located 1200 metres to the westward of Marble Inlet. For this region the 1:100,000 survey of the Norwegian chart of Kings Bay only was available and it was necessary therefore to extend the Ny Aalesund triangulation to this area before beginning the topographic survey of the coast and the hydrography of the sea. It thus became necessary to base this survey on an extension of the triangulation carried out across the Bay. The taking of soundings was made difficult owing to the rugged nature of the bottom; particular difficulties were experienced by the small boats owing to drifting ice. Taking into consideration the movement of the ice, two anchorages were chosen and charted, one of which is more recommendable for anchorage and shelter, but which is ice free somewhat later on in the season only, and the other which (in 1928) was available already in the early days of June.

As a basis, the records of a self-recording tide gauge were taken ; this apparatus, which will be dealt with hereafter, was in operation continuously during the sounding. The level of low water springs adopted as the datum for soundings, and which enabled the height of the principal topographical points with reference to mean sea level to be determined, was deduced from these records. Mean sea level was ascertained by means of a 3 bench mark geometrical levelling; two (I and II) at London (the first near the tide gauge and the second on the observation spot pillar), the third (III) on the southern beach at Ny Aalesund. The differences of level between the two first bench marks and the pillar of the tide gauge were determined by precise levelling, carried out with a Zeiss level. The heights of the bench marks at London resulted therefrom as being 5.57 m. and 27.40 m. respectively above sea level. The height of the Ny Aalesund bench mark above sea level was ascertained by numerous simultaneous observations of the difference of level between the bench mark and the water surface.

The height of the Ny Aalesund bench mark had already been determined by the Norwegians as being 13.629 m.; but from the measurements carried out, the height, with reference to the mean sea level deduced from the tide gauge records, is 13.511 m.

The bench marks are marked by sealed bronze plates, on which however the heights could not be engraved at the time of the survey, but they will be described in detail in the final report.

DETERMINATION OF ASTRONOMICAL POSITION.

No astronomical observation station had ever been made in this region and the position of the points had simply been determined by means of a long triangulation, starting from the observation spots in Red Bay, in the South of Spitzbergen; therefore, the party landed from the ship at Kings Bay was ordered to make observations at a station at London on the solid rocky promontory which forms the East Shore of the small bay called Marble Bay. A well illuminated SALMOIRAGHI universal transit instrument, of the most recent type, mounted on a solid masonry pillar, was used. The chronometers employed were checked by the Paris, Bordeaux and Nauen rythmical W/T signals, picked up by means of a field receiving set. The longitudes were determined by the Döllen method, and the mean of 80 values gave the result:

$$\lambda = 12^{\circ}\ 03'\ 36''\ \text{E. Gr.} \pm 1.35''$$

The latitude was determined by circummeridian star observations and the result of the mean of 60 values was :—

$$\varphi = 78^{\circ}\ 57'\ 39.10''\ \text{N.} \pm 0.19''$$

The position thus found was then connected by a series of triangles both to the general triangulation of Spitzbergen and to the special triangulation of Ny Aalesund. The connection to the pillars of Bloomstrand and Schetelig, and to the triangulation station at Ny Aalesund, required 7 theodolite stations at the points mentioned, all angles being repeated 6 times. A Zeiss theodolite was used for all topographic work, and, besides, beacons were erected at Schetelig, at Bloomstrand, at the northern station of the triangulation of Ny Aalesund and on the Riaer summits which are included in the outer triangulation of the Bay.

The charts and plans resulting from this work, and the detailed report of the operations, have abready been published by the Hydrographic Institute.

[Nº 643 - Ancorragio di London, Scale (1/10.000) ; Nº 644. Ancorraggio di Ny Aalesund. (Scale 1/7.500) ; Nº 645. Ancoraggi nella Baia del Re (Scale 1/15.000)]

TIDAL RESEARCH.

The curve of the tide gauge set up at London is very clear on account of the calmness of the sea in the bay. A tide gauge of the lacustrine type, a description of which is given in *Publication N° 30 of the Hydrographic Office* of the *R° Magistrato delle Acque*, (Venice 1911), was used; the movement of the sea level is recorded in the ratio of 1 to 5 on a roll of paper, 40 c/m wide which advances as the rate of 2 c/m per hour.

The tide gauge worked regularly from 5th June to 24th August. 1928. It was visited every day in order to note the correct time on the paper as well as the height above the reference mark reached by the water.

The case containing the tide gauge was rigidly fixed to the vertical side of a steep-to rock situated below an old crane belonging to a British Company which had tried to exploit the lime-beds of London, in 1911.

Fifty-eight consecutive days from the record were selected from which to collate hourly records for an accurate abstract. During these 58 days the following meteorological conditions obtained: the atmospheric pressure oscillated around 757 m/m (29.804 ins) of mercury; it was below this mean during 29 days and above it during 29 days, reaching respectively, after nearly equal durations, a minimum of 732 m/m (29.213 ins) and a maximum of 769 m/m (30.278 ins). In the bay, the wind force never exceeded force 2 of the Beaufort scale, except on 31st July, when an E.S.E. wind reached force 5. According to observations made on board the ship, the winds blowing from the eastern quadrant reached a force of over 3 and under 6, during 6 days, outside of the bay and those from the western quadrant, forces over 3 and under 5, during 5 days, from which it may be gathered that the mean level was not serious perturbed owing to meteorological causes.

The analysis of the tidal observations was carried out by two independent methods. The first method was applied to each of the 58 days in conformity with the well known Darwin calculation process as set out in the U. S. Coast and Geodetic Survey Special Publication N° 98, entitled "*A Manual of Harmonic Analysis of Tides*", by SCHUREMAN; the other method was applied to the observations of 29 days, in accordance with the method recently put forward by Dr. A. T. DOODSON in the Trans. of the Roy. Soc., London, 1928.

A comparison of the results obtained shows the great practical advantage of this new method of calculation and its complete efficiency, even for the computation of the N_2 component, in spite of the shortness of the period utilised.

The results of the harmonic analysis of the Kings Bay tides are given in the accompanying table; they have been compared to the results obtained from the records taken at Virgo Bay in 1892, at Mossel Bay in 1872-1973, at Treuremberg Bay in 1900 and at Toeplitz Bay (Franz - Joseph Land) in 1904.

This comparison makes it evident that, for the Mossel Bay constants 4°, which were taken from a Swedish publication, there must be an error of 180° in the calculation of the situations (K) of the diurnal tides.

The details of the observations and of the calculations will be given in full in the final report, together with various conclusions as to the tides of the Arctic Ocean. These conclusions may be summarized as follows : the semi-diurnal tide of the Arctic Ocean is largely *induced* by the tide of the Atlantic Ocean ; the diurnal tide is a tide pertaining to this body of water when assumed to be deep and consequently deprived of the shoals and islands which Harris thought that he could postulate.

Semi-diurnal tides		M_2	S_2	N_2	K_2	*Duration*	*Long. from Gr.*
KINGS BAY	H =	44,9	14,9	7,2	3,6	58 d. 1928	12°3'
	K =	26	74	5	74		
VIRGO BAY	H =	41,4	7,9	7,6	8,1	29 d. 1897	10°52'
	K =	38	70	13	91		
MOSSEL BAY......	H =	35,1	10,1	6,5	3,8	104 d. 1872-73	16°04'
	K =	74	121	42	118		
TREUREMBERG....	H =	27,9	10,6	7,1	2,9	104 d. 1900	16°52'
	K =	98	150	71	150		
TOEPLITZ BAY...	H =	15,0	6,0	3,0		58 d. 1904	57°59'
(Franç.-Joseph)	K =	178	229	155			

Diurnal tides		K_1	O_1	P_1
KINGS BAY	H =	5,4	2,0	1,9
	K =	253	92	253
VIRGO BAY	H =	2,7	1,2	1,0
	K =	215	12	215
MOSSEL BAY	H =	7,0	2,7	2,2
	K =	(65) = 245	(239) = 59	(63) = 243
TREUREMBERG....	H =	7,2	2,2	2,4
	K =	270	70	270
TOEPLITZ BAY....	H =	3,0	1,2	
	K =	26	49	

Hence there is obviously, and even at first glance, a left-handed semi-diurnal clock tide as suggested by Sterneck in the "*Annalen der Hydrographie*", 1928.

Such a phenomenon fully agrees with the above mentioned conclusions regarding the depth and unity of the Arctic Ocean, because it is due to the transversal oscillations caused by the displacement of water required by the tide induced by the Atlantic Ocean, and engendered by the deflecting force which the Earth's rotation exerts on these currents.

TERRESTRIAL MAGNETISM.

The fact that the expedition worked during a year of maximum sun spots led to a comprehensive study of the magnetic perturbations, together with the measurement of the absolute value of the terrestrial magnetic field, being planned. For this purpose, the small party of surveyors left by the *Città di Milano* at London had been equipped with a complete set of instruments enabling a photographic record of magnetic changes to be taken, and also with a new Kew magnetometer and a Wild induction inclinometer.

In order to enable full use of the instruments for measuring the absolute values to be made, a suitable entirely non-magnetic hut had been brought, and this was erected about 300 metres from another similar hut containing the astronomical instruments. The usual Kew and Wild tripods had been replaced by a solid tripod of brass trellis-work, in which the total absence of proper magnetism had been carefully verified.

The almost uninterrupted magnetic disturbances which occurred during the month of June and July, 1928, made it necessary to substitute for the isolated measurements which are usual with such instruments, a system of observations similar to that adopted by Fleming during the Ziegler expedition to Franz-Joseph Land, viz. :

For magnetic variation, continuous observation, every minute, of a needle of unifilar suspension during eight hours daily (the observer was changed at the end of each period of four hours). These periods of observation were so distributed as to cover every hour of the day many times during the 45 days the observations lasted. The observations for variation thus consisted in taking readings on the scale of the collimator magnet and in deducing the variation from these readings, the azimuth of the optical axis of the telescope as well as the collimation error of the magnet's scale being known. The azimuth of the telescope was easily determined by laying it on a mark placed at about 6 kilometres distance, the true azimuth of which had been determined repeatedly by observation of the sun.

The large number of observations thus taken enabled it to be determined that the magnetic variation in Kings Bay, during the months of June and July, 1928, had a mean value of 1°21.1' *W.* ; that the mean diurnal change is 1.1° on each side of this mean, reaching its westerly maximum between 1900 and 2000 G.M.T. and its minimum between 0500 and 0600 G.M.T. More complete details may evidently be deduced from the photographic records, the collation of which is well advanced (April 1929). Considerable unexpected deviations of the needle, which reached 2 or 3 degrees within a few minutes, have not infrequently been noted.

For the measurement of the absolute horizontal intensity, the calmest moments were chosen, but other measurements relating thereto were also made by observing the duration of oscillations. For this purpose, a field chronograph was used with success ; this enabled the number of oscillations to be reduced considerably. The moment of inertia of the magnet measured at the times of departure and return to Genoa, remained perfectly constant ; during the measurements the magnetic moment underwent a slow and progressive but small diminution.

The mean value thus deduced from a considerable number of observations led to the provisional selection of the following value for the horizontal intensity, pending the collation of the diagrams recorded by the variometer :

0.0805 Gauss.

Further, this element was subject to fairly considerable perturbations occasionally of over 0.0150 Gauss (on 7th July).

By means of another portable Bamberg magnetometer, the following points in Kings Bay were examined : a reef South-East of London in the vicinity of the North coast of the Bay, the island lying off Cape Guissez at the entrance of Cross Bay, Port Zeppelin beach, Port Bloomstrand, Eskieret Island and Ankerpynten. The general result obtained therefrom is that the points examined have approximately the same horizontal component and the same magnetic variation as London, without any trace of local perturbation.

With reference to dip, there was no particular difficulty in handling the WILD induction in clinometer as the precaution was taken to set it up solidly. Repeated observations were made during every hour of the day, and the mean value of the dip deduced was 81° 20.2', which is in fair agreement with the result obtained with a Barrow inclinometer which was used both at London and at the other points in the Bay.

The toilsome collation of the curves of the *photographic record of the changes* in the variation, in the horizontal component and in the vertical intensity, appears to be of the greatest interest.

The collation is not yet completed, but already an important and entirely new discovery has been made. As is well known the vicissitudes of the expedition forced the ship's *W/T* station to work permanently on short waves at night and on medium and long waves during day time. In consequence of an agreement made between the party landed at London and the *W/T* staff on board, accurate record was kept of all the receptional disturbances which occurred and particulary of the fading and disturbances in signals from transmitting stations. No appropriate measuring instruments were available and, had they been, the continual sending and receiving would not have permitted their convenient and profitable use, but it should be stated that the observations were made methodically.

Now, if the moments which correspond to a disturbed short-wave (about 30 metres) reception of the type indicated above be plotted on the photographically recorded curves, it will be found that, without exception, these moments correspond to a typical diminution of the terrestrial field (both of horizontal and vertical intensity) and to a simultaneous disturbance in the magnetic variation which is now the object of careful analysis. This was found to be a fact in some fifteen cases at least. No fading or other trouble in transmission occurred without being accompanied by typical magnetic disturbances as described above.

These facts naturally require careful consideration and the correlation thereof will be set out in the final report, together with reproductions of the interesting characters of the curves.

RESEARCHES CONCERNING NAUTICAL MAGNETISM.

In order to take advantage of the considerable alteration in the horizontal magnetic field which occurred during the great change in latitude of the ship, attempts were made to verify directly the behaviour of the stable quadrantal compensators, invented by Captains TONTA and MODENA, which are in general use on the compasses of the Royal Italian Navy.

It is a known fact that an increase in the magnetic moment of the compass needles makes it necessary to render the quadrantal compensators insensitive to undiction from the needles, and therefore (*See "Rivista Marittima"*, 1911) to replace the ordinary soft iron spherical compensators by elongated ones of suitable dimensions, and such that this induction will produce a force directed constantly in line with the axis of the needle and thus devoid of deflecting effect. Consequently, during various stays of the ship at Kings Bay ($H = 0.0801$), at Tromsö ($H = 0.120$), at Bergen ($H = 0.150$) and at Malaga ($H = 0.25$), compass swinging was carried out on shore for adjustment with compasses of most varied types (THOMSON — magnetic moment close to 200 C.G.S. units; MAGNAGHI — magnetic moment of 3000 units; 1928 pattern — magnetic moment 1700 units), using spheres and cylinders for observing the quadrantal effect.

The results were entirely in favour of the employment of cylinders. For example, with the compass of greatest magnetic moment, whereas the quadrantal effect varies from 5.3° at Kings Bay to 3.4° at Malaga, with spheres of 15 c/m diameter, that of cylinders 300 × 70 m/m varies from 4.7° at Kings Bay to 4.5° at Malaga. Besides the above and the computations relative thereto, it was proved that the sextantal, octantal, etc.... effects are practically negligible, both with spheres and cylinders; a more detailed report on the subject will be given in the final report.

DETERMINATION OF THE RELATIVE INTENSITY OF GRAVITY.

The only gravity measurements carried out at Spitzbergen dated from the time of the Russo-Swedish measurement of the arc of the meridian, but the results of this measurement have not yet been published. It is certain that, in the Kings Bay region, no measurements had yet been made, notwithstanding the desire expressed by scientists to be provided with accurate gravity values in high latitudes. This subject had been brought up and discussed at the International Geodetic Conference, Madrid, 1925.

The Italian detachment at London had a two-pendulum apparatus in vacuo, constructed in accordance with the suggestions of Prof. LORENZONI by Mr. MIONI, of Padua and a STERNECK two-pendulum apparatus for observations in the air. With two such instruments starting and finishing checks were carried out at the gravimetric pillar of the Hydrographic Institute, which at that time, had been connected up to Padua and Potsdam. At Kings Bay, the instruments were installed in a suitable hut on two masonry pillars similar to those of the Hydrographic Institute. In the report already published, a detailed description is given of the care of chronometers, to the flexure of the support and to the reduction of the observations; here, it will be sufficient to point out the definitive results deduced from 32 observations with the Sterneck two-pendulum apparatus, and from 16 observations with the Mioni apparatus; the value obtained therefrom for gravity acceleration at London, expressed on the Potsdam system, is the following :

$$g = \text{cm. sec}^{-2} \quad 983.031 \pm 0.004$$

and the anomaly :

$$g - \gamma_o = + 0.006.$$

The above value is the mean of the two following values :

g = cm. sec^{-2} 983.029 $\pm$ 0.0040 with the STERNECK apparatus,

g = cm. sec^{-2} 983.033 $\pm$ 0.0038 with the MIONI apparatus.

As may be seen, the agreement of the measurements could not be more complete. The very low value of the anomaly constitutes most certainly a result worthy of attention.

Such are, in the main, the researches carried out by the *Città di Milano* in June, July and August, 1928.

The party landed at London included Prof. M. TENANI, of the Hydrographic Institute of the Royal Italian Navy, and Lieutenants JANNUCCI, PELLEGRINI, PICELLA and ALBANI.