SHORT SKETCH OF THE PROGRESS OF OCEANOGRAPHY AND OF THE EXPEDITION OF THE ROYAL DUTCH VESSEL "WILLEBRORD SNELLIUS" (1)

by

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Leaving aside the closely-related branch known as "hydrography", the object of which is the determination of the configuration of coasts, the exploration of bordering seas, the search for dangers to navigation and the insertion of these data on charts and in Sailing Directions — it may be said that the study of the science of oceanography dates but from yesterday. In fact, it began to be seriously taken into consideration only about eighty years ago. It is true that ARISTOTELES and PLUTARCH expressed opinions, to the best of their judgment, on ocean depths; but these opinions rested on no solid foundation and the first known attempt to measure such depths is due to MAGELLAN and was made during his voyage round the world in 1521, between the islands of St Paul and Tiburon in the South Pacific Ocean. MAGELLAN did not touch bottom and one can only regard as somewhat naïve his conclusion that he had discovered the place where the ocean reached its greatest depth. He does not mention the length of line paid outh but the French Reverend Father Georges FOURNIER, in his treatise on "Hydrography" published in 1647, is led to conclude that this length probably was about 400 fathoms. FOURNIER states, moreover, that to his knowledge no navigator of his age had sounded in depths greater than 400 fathoms.

More than a century elapsed before the first authentic sounding on the high seas could be recorded. This honour belongs to the English north-pole explorer, Captain PHIPPS who, in 1773, to the west Norway, took a sounding of 1250 metres and brought up as bottom sample clay of blue colour. As early as 1749, however, Captain ELLIS had sunk bottles for water-samples and thermometers to a depth of 1630 metres in the vicinity of the Canary Islands. Immediately after comes the name of Sir John Ross who, in 1818, succeeeded in sounding in a depth of 1920 m. in Baffins Bay, with the aid of a bottom-sampler having the form of pincers; he brought up not only soft mud but also traces of animal life. Later, in the course of an expedition towards the South Pole, his nephew, Sir James CLARK ROSS, sounded in depths of 4435 and 4895 metres to the west of the Cape of Good Hope.

What, then, is the meaning of these four depths disseminated throughout the globe? As VON HUMBOLDT very aptly stated in 1845:— the depth of the oceans and the height of the atmospheric stratum are elements unknown to mankind.

The glory of erecting the first landmark in modern oceanographic science must be accorded to the American naval officer F. MAURY. He was not satisfied with merely consulting old navigational publications for statistical data concerning the prevailing winds and the currents: but he was also ceaselessly engaged in investigations pertaining to maritime meteorology, maritime biology and ocean depths. By studying old logbooks, he succeeded in shortening by 25 % the duration of certain sea voyages; for example, by following his instructions the duration of the voyage from New York to San Francisco round Cape Horn, which averaged 183 days, was reduced to 135 days.

However, we must not forget or underestimate the difficulties in taking soundings which had to be met in those days. The use of a line as thick as one's finger, carrying the weight of

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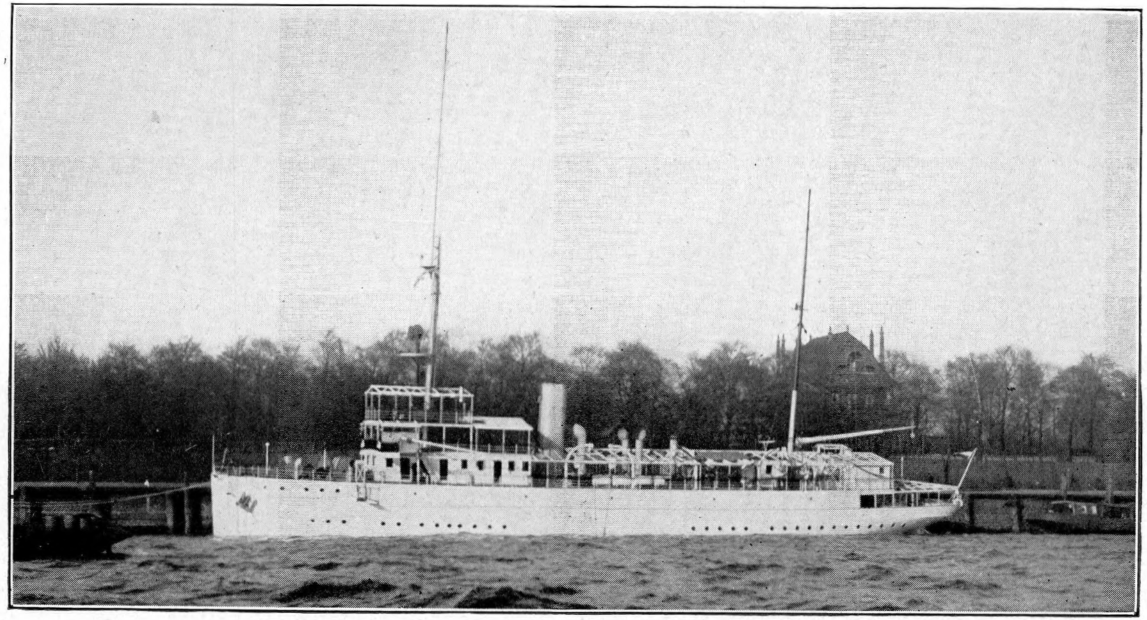
(1) *With regard to this expedition, the explanations and information given by* Mr. VAN RIEL, *Oceanographer and Chief of the Expedition, by* Mr. BOSCHMA, *Biologist, and* Mr. KUENEN, *Geologist on board the "Willebrord Snellius", have been utilised for the purposes of this article.*



H. N. M. S. "*Willebrord Snellius*"

a cannon ball of from 30 to 60 lbs, contributed to render the results in great depths, very much a matter of chance. Various reports dating from the first periods when soundings were taken by the American Navy record 10 to 15 kms. without having found bottom. The specific gravity of the kilometre of line and the influence of ocean currents probably accounted for the failure to perceive the instant when the lead touched bottom. To that was added the impossibility of taking soundings on board a sailing vessel. In spite of being stopped, the vessel drifted during the sounding operation, with the result that the more line paid out, the greater its inclination. For this reason soundings were taken from launches, which could be kept stationary by means of oars. As an example, there may be noted the 15 soundings taken in 1858 by Commander SIEDENBURG of the Dutch brig *Cachelot* in the Banda Sea according to MAURY's method, and in connection with which 11 samples of sea-bottom were brought up. Among other remarks, his report on this event contains the followings: — "The sounding was taken from the launch and required 12 hours, about 10 of which were needed to haul in the lead. Under the influence of strong submarine currents (the majority of which ran N. E.) 5000 fathoms of line were paid out, and it is to be presumed that, in view of the irregularity in paying out the last 1000 fathoms bottom had been reached after 4000 fathoms." Later, at the time of the *Siboga* expedition, it appeared that in this position, the depth of water was only 4400 metres.

It is not astonishing that, under these conditions, navigators manifested little inclination to make a practice of deep-sea sounding.

The first results of the experiments made by the American Navy led to trials with very fine lines. It was even thought that twine might be used. All the vessels were fitted up with smoothly-revolving reels containing 10,000 fathoms of line marked every 100 fathoms. A weight of 30 lbs was attached to the end of the line and it was allowed to run out; the moment the weight touched bottom the line was cut, and the quantity remaining on the reel indicated the depth. However, at depths greater than several kilometres, the line invariably broke as a result of the great strain produced by friction with the water. A better method was then sought which finally resulted in the discovery of a process of manufacture of very fine wire weighing only 2.5 kgs. per kilometre which, at the same time, was capable of supporting a weight of 30 kgs. Later, Midshipman BROOKES invented the sounding-lead which bears his name, in which the weight becomes detached on touching bottom; thus only the core is hauled up with the sample of ocean bottom. A suitable device had just been conceived which was destined to find a still happier application on board steamships which, meanwhile, had come into use.

An appreciable improvement in deep-sea sounding took place in 1873 after the introduction of steel wire of 1 m/m diameter; which at present combines a specific weight of only 6 kgs. per kilometre, with a breaking-load of 180 kgs. The fine, smooth steel wire gives rise to very slight friction in the water and is only slightly influenced by submarine currents. These wires are used in conjunction with a rather complicated apparatus.

MAURY set forth the result of his studies on the constitution of the oceans in his classic work entitled: "The Physical Geography of the Sea", the second edition of which appeared in 1854. This book has been translated into Dutch by his colleague and collaborator, Lieutenant, afterwards State Councillor, M. H. JANSEN. In his work, MAURY deals also with ocean depths and the chapter in question commences as follows :—

"Until the commencement of the plan of deep-sea soundings, as now conducted in the American Navy (*i.e.* in 1854), the bottom of what the sailors call "blue water" was as unknown to us as is the interior of any of the planets of our system..."

It was commonly supposed at that time that the bed of the ocean, exactly like certain regions on land, was traversed by ranges of steep submarine mountains, separated by deep chasms. Even MAURY, though he had at his disposal a considerable number of observations, wrote as follows :—

"Could the waters of the Atlantic be drawn off, so as to expose to view this great sea-gash, which separates continents, and extends from the Arctic to the Antarctic, it would present a scene the most rugged, grand and imposing. The very ribs of the solid earth would be brought to light."

Little by little, in the light of a great number of soundings, the conviction grew that the elevations of the sea-bed, in the majority of cases, were gentle slopes; but in proportion as the number of observations increased and, thanks to echo-sounding, it became more and more possible to guess at the real configuration of the elevations, a further partial change of opinion became necessary and we must now admit that the abyssal depths are not so flat as we once supposed.

The experience acquired by the expeditions of the *Meteor* and of the *K.XIII* has revealed the truth of the assertion of the German oceanographer O. KRÜMMEL that "the monotony of the sea-bed is a function of our ignorance". What strikes one as rather curious is that in MAURY'S time attempts at echo-sounding had already been made. MAURY writes :—

"By exploding petards, or ringing bells in the deep sea, when the winds were hushed and all was still, the echo of reverberation from the bottom might, it was held, be heard, and the depth determined from the rate at which sound travels through water. But, though the concussion took place many feet below the surface, echo was silent and no answer was received from the bottom."

There was an inherent difficulty in the matter which MAURY and his contemporaries could not succeed in overcoming but which, in our century of microphones and bulb amplifiers, is no longer insurmontable, although it can by no means be asserted that a perfect solution of the problem has been attained.

Stimulated by the requirements for the laying of telegraph cables, efforts to ascertain the configuration of the ocean bed were redoubled. For this purpose, in 1851-52 MAURY participated in soundings taken on board the surveying vessel *Dolphin*; in 1857, the first attempt to lay a cable was risked between Ireland and Newfoundland. This attempt failed, as well as its repetitions in 1858 and 1864. It was only in 1866 that the cable did not break; and it is still in use to-day. Deep-sea soundings had borne their first fruits.

Submarine telegraphic connections have also indirectly aided progress in oceanographic research. At that time the theory of the British zoologist FORBES (enunciated in 1838) was universally accepted, namely, that no organic life could exist below 300 fathoms. Experience acquired in repairing cables gives formal lie to this theory. For example, let it be recalled that in 1860, on raising a cable between Sardinia and Algeria, it was perceived that at depths of 1200 metres, quantities of animals were clinging to it. These circumstances aroused the interest of biologists in the conditions of life in the oceans, from which it was admitted that all terrestrial life had developed! Research with regard to temperature, salinity, form of submarine relief, penetration of light, etc. was pushed forward. A strong impetus was given to profound researches in this domain which, among others, led to the celebrated expedition of the *Challenger* in the three oceans. It was with pride that Sir John MURRAY, the successor of Sir Wyville THOMSON, in publishing the results of this expedition, was able to declare that, since the voyages of discovery of MAGELLAN and COLUMBUS, no other work of such great importance to the knowledge of our globe had been accomplished. Various expeditions of more or less importance have since been carried out but these, insofar as concerns the duration and the extent of the area explored in particular, remain far behind that of the *Challenger*. A complete enumeration of these expeditions would be out of place in this article and it will be sufficient to mention the German expeditions of the *Gazelle* (1873 — in the three oceans) and of the *Valvidia* (1898-99 — in the South Atlantic and Indian Oceans), also the Dutch expedition of the *Siboga* (1899-1900 in the Indian Archipelago). In addition, the Scandinavians have explored the Arctic Ocean and its approaches; the Germans and the Belgians have undertaken the exploration of the Antarctic polar regions and meanwhile considerable data have been supplied by cable-ships.

In the course of these expeditions, depths have been determined, small samples of sea bottom have been collected, temperatures have been measured at various depths, water-samples have been collected; moreover, meteorological observations have been made, and fishing and dredging carried out. Because of the great, not to say absolute penury of knowledge, it was necessary first to get a general view of the whole, and to this task the large expedition of the *Challenger* and her successors devoted themselves, while small expeditions operated locally. Having collated general data extending more or less over the whole, a desire for still more profound research began to be manifested; to some extent this desire had taken definite shape as a result of improvements made in instruments during the war, above all in echo-sounding devices and accurate thermometers, although improvements in methods of physical and chemical research were also not lacking.

In this connection, the honour of having shown the first proof of perspicacity must be accorded to Germany which consolidated these researches by inaugurating the *Meteor* expedition of 1925-27. Thanks to the excellence of the preparations made, this expedition was able to explore intensively the South Atlantic Ocean between approximately Latitude 60° S and Latitude 30° N. The object of the expedition was accomplished by traversing the ocean from coast to coast with regularity on 13 courses with occasional stops for the purpose of more detailed exploration. During this expedition about 33,000 echo-soundings were taken ; 310 of these were duplicated by line-sounding: this was a great step in advance with regard to knowledge of the morphology of the bed of the South Atlantic Ocean, for which up till then only one-tenth of the data had been available. At the 310 stations where line-soundings were taken, samples of bottom were brought up and serial temperatures at various depths, with water-samples, were obtained. At seven positions at anchor in the open ocean, the force and direction of the currents were measured for a total duration of 330 hours. Plankton fishery was regularly carried out and observations made concerning the fauna. Meteorological and hydrographic observations were made and stereographic photographs of the movement of the waves taken. Thanks to this expedition, the South Atlantic is the best known of the oceans and not until the others have been explored in the same manner may it be said that the second chapter of oceanographic research is closed.

Leaving aside observations relative to meteorology, to hydrography and to movement of waves, the principal subjects studied by the expedition were the following :—

a) *Morphology and the nature of sea-bottom.* — For this purpose the *Meteor* was equipped with three echo-sounding instruments and two large line-sounding machines.

b) *Circulation of sea-water.* — Up till then the conception which had been formed of this phenomenon had been, briefly stated, that the warm surface water originating at the equator flowed slowly towards the poles, while the deep water flowed in the contrary direction along the ocean-bed. It was a simple closed circular movement. The observations of the *Meteor* have demonstrated that the general circulatory system is far from being such a simple matter; that it takes place in a horizontal and not in a vertical plane and that it is strongly influenced by the form of the submarine relief. It would be well to mention here, in few words, the manner in which the extremely slow movement of certain currents, is determined. The specific gravity of the water for a given spot may be determined from the depth, the temperature and the salinity. If this specific gravity is not in exact accord with that in its immediate proximity, currents are produced. From the calculated specific gravities, the relative strengths and the directions of the currents can be determined. It is essential, however, that the temperature and the salinity should be measured with great accuracy. From time to time the indirect results thus obtained are tested, by means of direct measurements of currents at various depths — which necessitates anchoring the vessel in deep water.

c) *The chemical composition of sea-water and sedimentary deposits.* — In addition to the salinity, it is important to know the concentration of hydrogen-ions, the oxygen content, the percentage of phosphates and nitrates in sea water, as well as its alkalinity. These data can give answers to numerous questions in the domains of physical oceanography and biology. Thus, for instance, the oxygen content plays a primary rôle in the determination of vital conditions; but it also gives an indication as to the length of time during which the layer examined has been deprived of contact with the atmosphère.

d) *Biological research — principally with regard to the nature and quantity of plankton.* — These tiny organism of vegetable and animal origin, not endowed with any appreciable power of movement, simply drift about, chiefly in the upper ocean layers and form the basis of the animal life of the seas. Enormous quantities of plankton drift thus in the oceans ! For example, a rough estimate for the English Channel gives an annual production of 1400 tons of wet plankton per square kilometre: the expedition of the *Discovery* to the Falkland Islands, the principal object of which was the search for the routes followed by and the conditions of existence of whales, discovered a close relation between the wealth of plankton and the routes and feeding-places of these cetaceans. Exact knowledge as to the different kinds of plankton, their habitat and mass, is of great importance for fisheries. The oceanographer equally will profit by such knowledge, for on account of the feeble powers of movement of these organisms, they may be considered as floating matter and, from their distribution, conclusions may be deduced with regard to currents.

The expedition of the *Meteor* has been dealt with at greater length because it is the first to be carried out by modern methods and the first to have as its object the *intensive* examination of a definitely-defined region, be it, half of an ocean. Moerover it has exercised a great influence on the conception, design and organization of the *Snellius* Expedition.

To encourage the exploration of the seas — which cover more than 70 % of the surface of the globe — is necessarily of primary importance from a scientific point of view. In this way only can we increase our knowledge in the domain of oceanography, and such knowledge indirectly provides us with the power of solving many climatologic, tectonic and biological problems — which, in turn, become of practical importance. Take, for instance, among other things, accurate knowledge of the influence of oceans on climate; this influence is exercised in the first place by the surface layers but the deeper layers are not without effect. Consider also the question of the formation of the earth's crust — its distribution into continents and seas, the modifications which it undergoes and the nature of these changes. Finally let us consider a knowledge of the animal life in the bosom of the oceans and its distribution, together with the diversity of conditions necessary for its existence in the different regions. It is not the purpose of this article to give a dissertation on the practical utility of progress in purely scientific research, but perhaps it may be permissible to note that certainly neither GALVANI, nor his contemporaries, ever dreamt of how the results of his experiment would one day resound throughout the world.

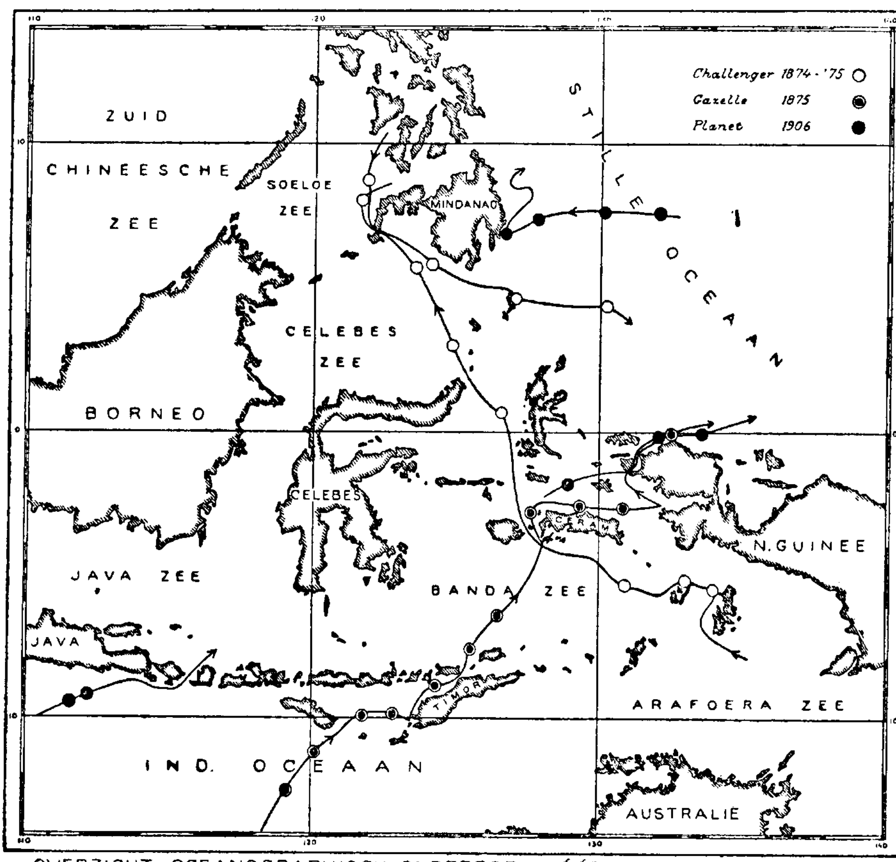
The youthful science of oceanography already begins to bear fruit: first it has allowed sea-voyages to be shortened; soon thereafter it demonstrated the feasibility of laying telegraph cables and finally it has thrown light on conditions indispensable to the developement of an ever more flourishing industry :— fishing. It is to be expected that the ever-widening knowledge of the morphology of the ocean bed, made possible by echo-sounding appliances, will find its recompense in increased safety at sea, since with these instruments it will be possible to fix the position of the ship by reference to the characteristic forms of the submarine relief.

The intensive method of conducting research, inaugurated by the *Meteor*, has aroused considerable interest among oceanographers. This expedition deserves to be imitated and it is the duty of each maritime nation to lend its support to the exploration of the *Mare Librum* of Hugo DE GROOT. The Netherlands' part in this work is indicated :— the Archipelago of the Dutch Indies and, primarily, the deep basins in the eastern part of the Archipelago, a total of about three millions of square kilometres or equal to the combined areas of the Mediterranean and the Black Sea.

There exists probably no other corner of the terrestrial globe which, from an oceanographic and geological point of view, comprises so many interesting problems — problems which, so far as geology is concerned, may to some extent be solved only by research conducted from on board ship. In this connection, attention is particularly directed to the bathymetric chart given at the end of this article — or better still, to that which is inserted in the Jubilee publication of the Royal Dutch Geographical Society, entitled :— *De Zeeen van Nederlandsch Indie* (The Seas of the Netherlands Indies) — 1922. Imagine the aspect of mountainous peaks rising nearly 3000 metres above the edge of basins with depths of 7000 metres and more! Does not the earth here offer us enigmas enclosed in these parallel folds, here emerging from the water, there engulfed under it and separated by abrupt deeps or edged by them? Enormous vertical differences are disclosed within relatively short distances; undoubtedly the greatest differences of level is found on the east coast of Mindanao (Philippines) where an altitude of 1875 metres is situated at a horizontal distance of 140 km. from the greatest abyssal depth known — 11,800 metres; here the total difference in the vertical direction is 13,675 metres. This formation is most apparent in the arcs of the outer-and inner Banda-arc, at the point of the sharpest bend, separated by the WEBER DEEP which has a depth of more than 6,500 metres. The curve of the outer Banda extends from Soemba, across Timor, the Sermata-Tanimbar-and Kei Islands towards Ceram and Boeroe. The inner curve is a prolongation of the Little Sœnda Islands, over some smaller islands towards the Banda group; from there it follows a southwesterly direction across the Schildpad Islands, Lucipara and Goenoeng Api. The latter arc is more broken than the first. Geologists consider the Moluccas as a mountainous alpine chain in which the horizontal forces have not yet reached a state of equilibrium while the vertical forces which apparently will subsequently elevate this chain have been effective for a short time only. By a conjugate study of the Alps, of the Moluccas and of other mountainous masses, deeper knowledge will be gained of the history of the origins of such disturbed portions of the earth's crust. No part of the globe offers a more attractive subject for a study of this kind than the eastern part of the Archipelago.

The thirty odd basins encircled by sills at various depths arouse particular interest because conditions here are quite other than in the oceans. Thus, for example, the Soeloe Sea, with a depth of over 4,000 metres, is not co-extensive with the neighbouring seas except above the level of sills which are situated 400 metres below the surface more or less. In the Sea of Celebes, a temperature of 10° is found at this depth and for this reason no lower temperature has been found in the Soeloe Sea; whereas in the Ocean, even in tropical regions, the temperature at a depth of 4,000 metres falls below 2°. For the same reason the salinity, also, remains constant below the depth-level of the sills, contrary to conditions in the oceans where the different superimposed layers show sometimes more and at times less salinity.

The chemical compositions of the water and of the bottom deposits in the basins likewise differ in certain respects from those of the oceans. According to the theory generally accepted up to the present, the content in carbonate of lime of these deposits, for instance, should be greater than in oceanic sediments, and yet the *Siboga* expedition has proved that the contrary is the case.



OVERZICHT OCEANOGRAPHISCH ONDERZOEK VÓÓR DE SIBOGA EXPEDITIE

Ensemble of oceanic researches prior to the expedition of the "Siboga".

A peculiar interest attaches to living coral reefs and to petrified coral reefs, both because of the possibility of making comparisons between the present and the past and to study their formation and the movements of the soil on which they rest, or variations in the level of the surface of the sea, in order to determine which of these movements have favoured their growth and which have retarded or arrested it. The study of these reefs and of the calcareous corals which have risen to appreciable altitudes above the level of the sea, make it possible to determine the movements to which the earth's crust has been subjected.

The nature, kind and quantity of the plankton in the Archipelago are only incompletely known and it would be useful to make a study of them in relation to the greater or less wealth of fish in these regions. Various parts of the eastern half of the Archipelago — among others the waters of the Kei Islands — have abundant riches in both quality and quantity.

All of these form a group of problems which cannot be treated separately, but which are closely interlinked with each other; so intimately are they associated that this part of the globe with its seas is justly considered (and not only in Holland but abroad also) as one of the most fertile fields for scientific development. In fact Professor G. H. SCHOTT of the *Deutsche Seewarte* has written as follows :—

"In the seas of the Netherlands East Indies it is possible as in no other part of the ocean to make oceanography greatly progress — in the widest application of the term — at the same time favoring the advance of allied sciences, such as the biology and the geology of the seas."

What has been accomplished so far with regard to the exploration of these seas? For convenience, we refer to the small chart inserted above, pertaining to the period prior to the expedition of the *Siboga*. From it we may see that it was principally the *Challenger* and the *Gazelle* which in the course of their scientific cruises passed through the Archipelago and made observations at a few stations. These observations, however, are insufficient for modern requirements. For further details the reader is referred to the work already mentioned: "The Seas of the Netherlands Indies". Certain high seas oceanographic work has also been carried out by Surveying and other Government vessels. In the field of biology the researches made on a large scale by the Health Officer, Dr. P. BLEEKER (1819-1879) must also be mentioned, as well as the last, but first in importance — the memorable and fruitful expedition of the *Siboga* (1899-1900) — an undertaking directed by Prof. Dr. M. WEBER. The small chart given below shows the course followed by this vessel.

A more detailed description of the inauguration and the work accomplished by this expedition will be found in the same volume: "The Seas of the Netherlands Indies", which also gives a list of the publications on this subject which have appeared. The results obtained form the subject matter of an almost complete series of works comprising 66 volumes and entitled :— "The Expedition of the *Siboga*"; it was published on behalf of the "Society for the Advancement of Research in Natural Science in the Dutch Colonies."

It will be sufficient, for the purposes of this article, to recall once more that the object of the expedition was to carry out thorough researches on the fauna and flora in the waters of the Netherlands Indies and particularly in the deep basins. Examination of the formation of reefs took second place, though the Government of the Indies, in giving full support to the expedition, laid down as an additional condition, insofar as this could be done without interfering with its principal object, that the expedition should endeavour during its cruise to correct the charts and the Sailing Directions which at that time left much to be desired.

The expedition lasted nearly a year; it collated much material and made many observations of interest to biology. In the field of hydrography it operated with success and procured various data with reference to physical oceanography.

The general interest in oceanography widely manifested after the war, gave rise in 1925, in the above-mentioned Society, to a desire to send a new expedition to these very promising regions. From that time on it was realized that researches relating to geology and physical oceanography should now take first place; that biological work should be undertaken as a secondary study only and then only when opportunities occurred. This was natural because the *Siboga* expedition had already made such a great stride forward in the study of the fauna and flora of the waters of the Netherlands Indies and the data collected by it had not yet been completely examined and classified. Research in the domain of Maritime Meteorology should be limited, also, to such observations as could be made without loss of time.

The "Society for the Advancement of Research in Natural Science" in agreement with the "Royal Netherlands Geographical Society" appointed an Investigation Committee which, after having reported favourably, set to work to prepare the expedition. Men well-known in each of

REISROUTE DER SIBOGA EXPEDITIE

Course followed by the "Siboga" expedition.

the branches of science with which the expedition should deal, were members of the Committee while the effective support of influential Dutchmen facilitated the initiation of the plan and contributed towards the collection of the necessary funds. Their Majesties the Queen and the Queen-Mother gave large contributions; scientific institutions, oil, shipping and land cultivation companies, as well as private individuals, also contributed to such an extent that, in a short time, the necessary sum was exceeded. In spite of this, it was only due to the liberality and breadth of outlook of the Government of the Indies that the expedition could really be organised; this Governement placed a surveying vessel at the disposal of the expedition and undertook to pay all expenses in connection with the vessel in addition to contributing a very considerable sum to the funds. Thanks to a happy combination of circumstances which occurred during the work of preparation, a Netherlands-Indies surveying vessel was put on the stocks in Holland and the Government of the Indies kindly placed this vessel at the disposal of the expedition, thus making it possible to complete the fitting-out in Europe. This was particularly desirable with regard to the echo-sounding appliances from the point of view of their installation and test, which could thus be left entirely in the hands of the experts from the firms which supplied them. It is true that the use of this new vessel delayed the departure of the expedition, but this delay was fully compensated by the better preparation and the more satisfactory equipment due to it; besides, it allowed the practical handling of the instruments to be learnt during the voyage to the Indies.

The vessel was designed by the Ministry of Marine and was constructed by the "Fijenoord" Company of Rotterdam. The keel was laid in November 1927 and the ship was named by the Queen, after the Professor at Leyden, WILLEBRORD SNELLIUS (1580-1626) who had so greatly distinguished himself by his work in astronomy and geodesy and in that of determining the position at sea.

One of the points which particularly occupied the attention of the organising Committee was the selection of a chief of the expedition. This choice was rather embarrassing, for those who devote themselves to the study of high seas physical oceanography are somewhat few in the Netherlands. Without doubt the Royal Netherlands Meteorological Institute enjoys a universal reputation for its studies in maritime meteorology and oceanography — which have been published in various works; these studies aim at being of service to navigation and deal chiefly with the Atlantic and Indian Oceans, confining themselves to the atmosphere and the surface of the seas; and not dealing with lower levels. The Committee believes that a happy choice has been made in the person of Mr. P. M. van Riel, a retired Naval Officer, Chief of the *Section of Maritime Meteorology and Oceanography* of the above-named Institute, as Chief of the Expedition; in addition, this selection will serve to give the Institute in question the necessary impetus for advancing the study of the physical oceanography of the depths of the high seas.

The command of the vessel has been entrusted by the Queen to Senior Lieutenant F. Pinke, an experienced hydrographic surveyor who has superintended the entire construction of the vessel and has taken part in fitting her out. Should circumstances require, Commander Pinke will be able to replace the Chief of the expedition. As Geologist, the scientific expedition will include Dr. Ph. E. Kuenen; the Biologist will be Dr. G. Boschma who has already earned a reputation in the Tortugas (Florida), the Kei Islands, etc. There will also be Dr. A. B. Boelman as Chemist, Mr. G. H. Hamaker as 2nd Oceanographer, Dr. H. J. Harden as 3rd Chemist and Assistant-Oceanographer and Madame M. M. H. van Riel-Verloop as Assistant Chemist.

Among the officers of *H. M. S. Snellius* who have been appointed are :— Junior Lieutenants J. P. H. Perks, L. J. Veldman and F. H. M. van Straelen who, in addition to their ordinary duties on board, will have charge of the operation of the echo-sounding instruments, of fixing the position of the ship the accurate determination of which is of the highest importance for the expedition — and of meteorological observations; and Surgeon P. C. Broekhoff who, apart from questions of health, will collaborate in biological research.

The general object of the expedition, already indicated in broad outline in the course of this article, had been generally developed by the Committee and when the members of the scientific staff had been appointed, they co-operated with the Committee in drawing up the programme, the itinerary and the estimate of costs. There then remained only the general plans to be settled from which, however, deviation was permitted should circumstances require. With regard to the programme itself, it might be varied according to the results of observations, or abnormal conditions of wind, weather and sea.

The area to be explored comprises the deep basins and depressions of the eastern part of the East Indian Archipelago, including the Soeloe Sea; the Sahoel Bank, which is extensive, flat and shallow, will not be excluded however. As these are the seas which connect the Pacific with the Indian Ocean, research should embrace also a few observations in the adjacent portions of these oceans. To extend the explorations to the Indian Ocean south of Java, and to the south-west of Sumatra, would overload the programme.

Physical research will include :—

Observations of temperature, of salinity and of surface currents;

Determinations of depths by means of echo-sounding appliances and line-sounding; when taking the latter, observations of temperature near the sea-bottom will be made and bottom-samples will be obtained.

Simultaneous observations at some 300 stations relative to the temperature and to the chemical properties of sea-water at various depths; some measurements of currents on the sills and in the basins;

Observations with regard to the transparency and colour of sea-water.

It is expected that the data thus obtained will furnish indications on :—

The mutual exchange of waters between the basins and between these and adjacent oceans;

The form of the basins and of the depressions as well as of the sills and the ridges which separate them;

The nature and composition of the sea bottom;

The variation (if any) of the temperature of sea-water with increasing depth starting from a predetermined level;

The existence of vertical oscillations in the mass of water as a result of the influence of the tides.

Geological research will first be directed towards procuring new data relative to the tectonic constitution of the eastern part of the Archipelago, as well as towards geological problems in general such as, for example, the first period of growth of a chain of mountains in formation and the continental drift hypothesis. By taking a large number of soundings it should be possible to obtain the necessary material for this purpose, while measurements of acceleration of gravity will help to complete it — and that to a degree which has not yet been reached elsewhere in the world. These measurements will be made by Professor Dr. Vening MEINESZ, at whose disposal the Government of the Indies has kindly placed a submarine. They will continue the series of measurements made in 1926 on board the *K. XIII.*

On the other hand, the examination of a large number of bottom-samples will certainly give indications as to the distribution and nature of the sediments which collect at these spots ; at the same time a solution of the question of the decalcification of the sediment in abyssal depths, will be sought. The latter problem has a better chance of being solved at this place, because in the basins explored the process of decalcification is more intense than in the open seas, although the cold water from the polar regions, which is favourable to this phenomenon, flowing over the ocean bottom towards the equator, is lacking here. It is hoped that new bottom samples and a more intimate knowledge of the circulation of the water and its composition, will throw light upon this question.

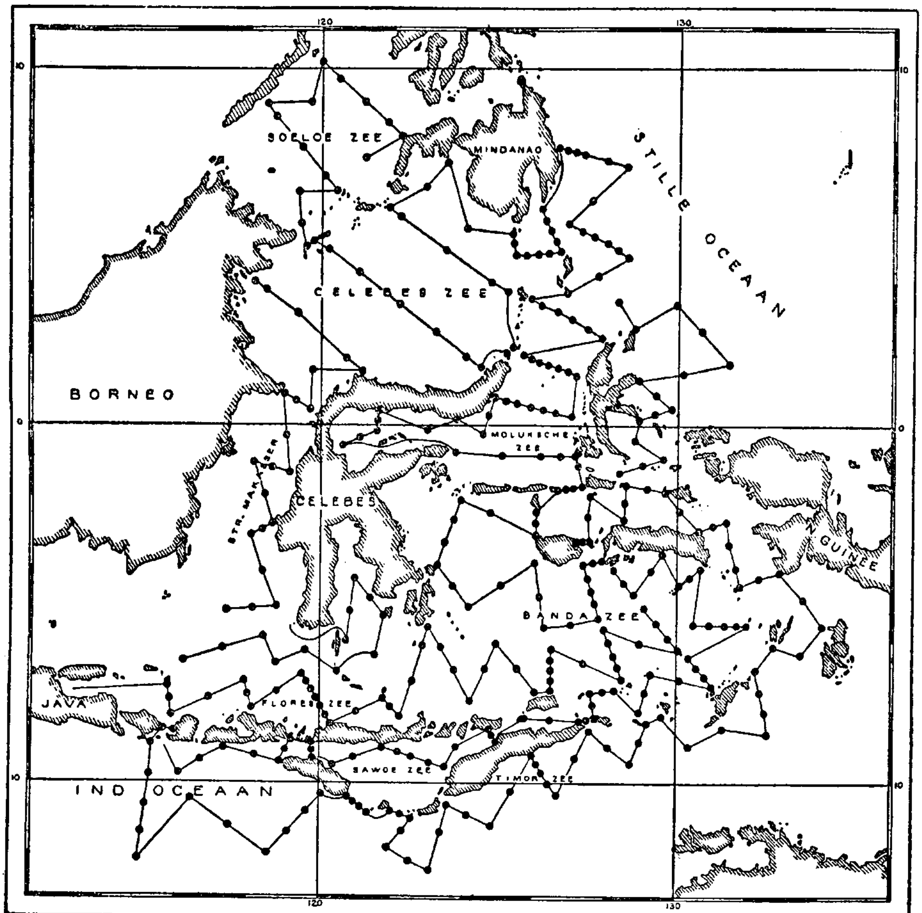
An endeavour will be made, by the examination of a certain number of coral reefs and of interesting atolls which have risen up and now form solid land, to find out how they have developed and what are the movements of their subsoil which generate mountains; the programme includes a simultaneous exploration of the little-known volcanoes of the Banda Sea.

In the field of biology, the presence and the distribution of animal life at the ocean bottom are sufficiently well-known as a result of the explorations of the *Siboga* and of some other less important expeditions, such as those to the seas to the north of Celebes, to Amboina Island and to the Aroe and Kei Islands groups. With regard to the process of formation of coral reefs and the distribution of coralline animal life, the data are still far from adequate. For this reason, very special attention will be devoted to these last questions. It is still unknown whether the vertical distribution of plankton in more or less enclosed basins differs from that of the oceans. So far as horizontal distribution is concerned, it is still unknown whether the plankton of the central part of the Banda Sea and of the Celebes Sea is of an oceanic character or whether there is an admixture of the nerite and, if so, in what proportion. Moreover, we are still ignorant as to the way in which areas where sedimentary alterations take place are characterised by a plankton differing from the ordinary species. To reply to these questions —and to others also — bottom samples will be examined, plankton will be regularly trawled and numerous coralline reefs and atolls will be explored. The most important group for this study of corals reefs is that of the Toekang Besi Islands, situated to the S. E. of Celebes — a group which is very interesting from a geological point of view also. The coral reefs generally and the fauna of the coastal zone around the islands at various points of the region to be explored, will be studied.

As the meteorological observations made on board of a ship continually on the move have usually a relative value only, attention will chiefly be directed towards observation of the phenomena which are related to the oceanographic data which it is desired to collate. Further, observations will be made at fixed intervals relative to temperature, humidity and atmospheric pressure, direction and force of winds and to nebulosity.

The course to be followed by the expedition is shown on the small chart shown below. The direction in which this course will be followed will depend on the season at which the expedition commences; in principle, during the European summer season, operations will be conducted in the North and during the European winter season, in the South; during the intervening periods (middle of March to middle of May and mid-October to mid-December) those parts of the area which are the most exposed to winds and to sea will be explored.

During the expedition and while under way, echo-soundings will be taken every quarter of an hour, night and day; so that the depth and the changes which it undergoes may always be known. This alone will result in a notable addition to our knowledge of ocean-bed morphology. It may be roughly estimated that more than 12,000 depths situated beyond the shelves, *i.e.* in more than 200 metres, will be known after the expedition, against about 1500 known at present.



VOORGENOMEN REISROUTE EN STATIONS DER SNELLIUS EXPEDITIE

Course and stations planned for the "Snellius" Expedition.

The black dots on the chart show approximately the stations at which it is proposed to make complete observations and thus give an idea of their distribution. Following the example of the *Challenger*, the name of "stations" has been given to these positions. At each station of this kind an echo-sounding will first be taken, followed by a line-sounding which will include the taking of bottom samples and of a water sample from near the bottom as well as an observation of temperature. Samples of water from the layers situated at various depths will then be taken, with simultaneous determination of their temperature. As has been previously explained, from the salinity of these samples, the depth of the layers and their temperature, the density of the water samples in question may be obtained and from this density the relative movements of the liquid masses involved can be deduced. For the purpose of verifying the conclusions deduced from calculations, the vessel will be anchored at certain stations and is therefore provided with an anchor cable 7,600 metres in length; by means of a recording current-meter, the currents at different depths will be determined. The total duration of one of these stops above a deep of from 5 000 to 6 000 metres, accompanied by the capture of plankton to a depth of 4,000 metres, will perhaps be about ten hours.

The samples of water will be handed to the Chemist for analysis from the point of view of the concentration of hydrogen-ions (necessary for verification of the depth from which the water has been drawn), of the salinity, of the oxygen content and of the alkalinity. Because of the great number of examinations of water and bottom samples, the chemist, in addition to his Assistants, will be aided by members of the crew who will have been trained to make simple analyses. Also, a few of the seamen will be trained in echo-sounding operations and this task will devolve upon them during the whole duration of the expedition.

While under way and during the stops at stations, the Biologist will have an opportunity to collate such material concerning animal life as he deems of interest. He and the Geologist will be landed on particularly interesting islands where they will camp temporarily; and they will be re-embarked later. This will permit them to explore these parts of the dry land, the coral reefs and the fauna in detail. For similar submarine explorations a diving bell will be carried, as also will a photographic camera specially adapted for sub-aqueous photography to make fixed records of the observations carried out. The Surgeon being on board, the biological work will not come to a standstill during these absences of the Biologist.

Accurate determination of the positions of stations and of the submarine profile obtained by sounding, will call for unremitting attention on the part of the naval personnel, particularly when the position is fixed by means of astronomical observations. Ordinarily, astronomical positions at sea are frequently in error by 1 to 2 sea-miles (*i.e.* 2 to 4 kilometres); the greatest attention will ge given to the determination of these positions in an endeavour to reduce these errors to within 1/2 and 2/3 of a sea-mile. For this purpose the vessel is equipped with an instrument to measure the dip of the horizon and a chronograph to record radio-telegraphic time signals.

The original article here gives a popular description of the *Willebrord Snellius*, of her echo-sounding machines and other oceanographic instruments. As, however, the ship has already been described in *Hydrographic Review*, Vol. V, N° 2, page 29, and as popular descriptions of instruments are of no interest to readers of this Review, this part is not included except for certain particulars which are considered worthy of insertion.

At the present moment geologists attach great importance to procuring *long* bottom-samples (some of those of the *Meteor* were more than 90 %m in length). The *Snellius* carries percussion tubes 2 and even 4 metres long. The future will show to what degree the optimism which suggested the creation of these tubes is justified. In certain places, long bottom-samples may be of certain interest as, for example, on the Sahoel shelf. According to Daly's glaciation theory this shelf was dry ground during the glacial period ; sea-level was lower then than it is now by 70 to 150 m. as a result of the great mass of ice held up at the polar caps. Would not this theory receive startling confirmation if, for instance, a sample of ocean bottom 2 metres in length showed in the open sea a coastal formation of former times covered with remains of dead plankton ?

Glass cylinders will be placed in the percussion tubes by means of which the samples may be examined after being hauled up; the cylinders may be sealed and the samples thus preserved can be studied in detail afterwards. A messenger, liberated the instant bottom is reached, causes the closing of the percussion tube and prevents the bottom samples from being lost while being hauled up.

Two metal cases for thermometers are fixed to the bottles for taking water samples. In one is placed a "shielded" thermometer, *i.e.* a thermometer in which the instrument itself is enclosed in a glass casing capable of supporting a pressure of 800 atmospheres and even more. Down to a certain depth, an unprotected thermometer will be placed in the other case; consequently this thermometer is subjected to the direct pressure of the water. Thus for a given pressure the temperature recorded by the two thermometers will show a difference of reading proportional to this pressure. The latter type of thermometer is capable of withstanding pressures up to 200 atmospheres. The advantages of knowing the *quantum* of the difference in readings lies in the fact that the depth can be deduced from it. Down to 2,000 m., depths can be determined in this way to within 10 m. Thus a fourth method of sounding is added to the method by line and the two methods by echo.

The accuracy, which is within 0,01°, with which temperature may be ascertained by means of modern reversing thermometers, the delicacy of modern chemical analysis which permits salinity to be determined to thousandths of one per cent, and the ability to take thousands of soundings where formerly only hundreds were possible, have marked the commencement of a new era in the realm of oceanographic research.

H. N. M. S. *Willebrord Snellius*, a photograph of which, taken while the ship was secured alongside at Rotterdam, accompanies this article, was commissioned on 28th January 1929. On 4th February she left for a trial trip towards the western approaches to the Channel and beyond into the Atlantic Ocean; the trip was made with a view also to testing the various instruments and in particular the echo-sounding installations. Returning on 13th February, some necessary final touches were given, the crew were given leave to permit good-byes to be said before undertaking such a long voyage and on 9th March the vessel sailed for the Indies. The members of the scientific staff also took part in this voyage and this fact is not without importance seeing that it is only on board ship that a nautical education can be acquired. It is true that the majority of them were already largely prepared by voyages of research both on land and at sea, for the task which they were undertaking. In the course of these voyages they had visited centres well qualified in the field of oceanography and had sailed in the exploring vessels of other coutries.

"Without luck, there is no good voyage at sea", says a mariners' proverb of our ancestors! We hope, in view of the sincere devotion shown by all who have embarked in the *Willebrord Snellius* with full consciousness of the responsibility which they assume towards the task to be accomplished, that luck will not be wanting.

The Netherlands Indies may take more and more pride in the fact of being considered not only a well-governed tropical country, but also a very progressive country from a scientific point of view. A thalassographic expedition, well directed and fruitful in important results, should shed over the Netherlands Indies a correspondingly brilliant light in this realm, which up till now has remained somewhat sterile.

POST-SCRIPT. (*)

The above article was written in April 1929 and it appears of advantage to add a short summary of the work done by the expedition since it sailed.

During the voyage to the Indies observations have been assiduously taken both for the sake of practice and to advance the science of Oceanography. Whenever circumstances allowed echo-soundings were taken, water samples were examined and other observations were made at 24 stations. Amongst the special work carried out the following may be cited :- an extensive examination of the shoaler soundings reported off the NW coast of Spain, similar examination in the Red Sea to the northward of Jebel Teir Island and observations at a special station in the Strait of Bab-el-Mandeb, in a depth of 165 m. At depths within 50 metres above the bottom the salinity reaches 40 °/°°, whereas in the layers above 36 °/°° were found, which clearly proves that there is an exchange of the more salt oceanic water, which enters near the bottom, and the less salt water of the Red Sea flowing out near the surface. On 20th May the *Willebrord Snellius* arrived at Batavia where

(*) *Note by I. H. B.* The article above had already been set up when Captain Luymes kindly offered to add this Postscript which brings the account of the *Willebrord Snellius* Expedition up to the end of 1929.

Courses followed and Stations observed up to mid-December 1929

Bathymetric Chart of the East Indies Archipelago — Carte Bathymétrique de l'Archipel des Indes Orientales

DIEPTEKAART VAN DEN O.I. ARCHIPEL

the staff took part in the Pan-Pacific Science Congress. Mr. VAN RIEL spoke before the Congress setting out the object, extent and the methods of the expedition; several foreign Members visited the ship. The ship then spent nearly two months at Soerabaya where she and her equipment were adapted for service in the tropics, several improvements were introduced in the instruments as a result of the experience gained during the voyage and the thermometer corrections were determined. This work lasted until 27th July but the time was by no means lost as the Geologist and the Biologist seized the opportunity to make numerous local excursions.

The scheme for covering the area to be explored had been drawn up in advance in outline (*see* chart, page 152) but the order in which the courses should be run depended on the date of departure. At the end of July the SE Monsoon blows strongly in this vicinity, consequently it was obviously best to work to the northward of the Archipelago passing through the Strait of Makasser. The following chart shows the principal courses followed and the stations made during the month of August and until the middle of December. Several lines of soundings have been omitted in order to avoid crowding on the chart. The depth contours shown are based on data obtained earlier. The lines which connect stations 29 (**) to 32 inclusive, 34 to 36 and 37 to 40 inclusive, indicate three profiles across the southern portion of the Makasser Strait, between the 200 m. isobaths. These profiles give a general insight into the composition and the movement of the water in this Strait.

Near station 39 the ship remained at anchor in 2200 metres for three days in order to make current observations at various depths. Further, every two hours for 24 hours, observations of temperature and water samples were taken at depths of 50, 100, 150, 250 and 500 m. The salinity of thirteen samples from each depth was determined and the density was deduced therefrom by combining it with the temperature. These thirteen densities were plotted graphically for each depth and show very similar curves as to phase while indicating a preponderant semidiurnal character. It is probable that these changes are produced by internal waves. In order to determine the amplitudes of these waves, the different densities at various depths must be estimated. Previously this had been done only for the maximum differences, both positive, and negative, of the mean density. The highest value of the amplitude was 40 metres at a depth of 250 metres. This is twice as much as that found by the *Meteor* in the Atlantic in 12°37'.6 N and 47°36'.1 W. (***)

After making these observations the currents at the surface and at 50, 125, 400 and 1900 metres were determined from observations lasting 36 hours. The strongest currents were found at 50 and 125 m. depth, namely 83 and 60 c/m sec. on a SSE direction. Simultaneously a current of 30 c/m sec. running in a SE direction was observed at the surface. The speed was even less

(**) The stations were numbered serially from the departure from the Netherlands.

(***) A. DEFANT. — Kurzperiodische Schwankungen von Temperatur und Salzgehalt in den obersten Wassenschiften des Ozeans-Sonderabdruch aus der Zeitschrift der Gesellschaft fur Erdkunde zu Berlin. Jahrg. 1927, N2 5:6.

at 400 m. depth while, near the bottom, the mean speed of water movement was only 5 c/m sec. in a N'ly direction. Near Tandjong Mangkalihat, the most E'ly point of Borneo in the Strait, a sharp bend was found, by sounding, in the 1000 metre isobath which extends to the centre of the strait. On this ridge a minimum depth of 600 m. was found, at Station N° 42.

On the 14th of August the Biologist, the Geologist, one officer and several seamen were landed and were provided with a motor launch and 2 punts, at Maratoea (****) While this island, which is situated on an atoll of great extent, was being examined as was also the atoll of Moearas and Kakaban Islet, the ship was taking soundings in the open as far as Tarakan where she took in oil-fuel and returned on the 18th August to take the party left at Maratoea on board. This examination confirmed the supposition which is made in the Sailing Directions that all three are elevated atolls. The elevation must have been regular and at Maratoea reaches some 100 m. and in Kakaban about 50 m.

After leaving Maratoea, Stations N° 46 and the ones following were made, including N° 51. These were situated in the SW. part of the Celebes Sea on a curve across the Northern entry of the Makasser Straits. At the majority of these stations the depth was very great. Thereafter the ship remained at anchor for several days off the coast of Celebes near Palehleh, in order to carry out geological research, to examine the reefs and to finish off the analysis of a large number of water samples which had been taken during the previous days. Stations N° 52, etc. as far as N° 55 inclusive, were then made; after which the ship anchored on Manado Roads to enjoy a few days of well-earned rest.

During this first passage the weather on the whole was very favourable to the expedition. The monsoon had been very light except in the Southern part of Makasser Strait where it reached a force of 5-6 (Beaufort). In the Celebes Sea fairly frequent thunder-storms accompanied by westerly squalls which reached, on one occasion only, the force 10 (Beaufort), were experienced.

At Manado the birthday of H. M. the Queen was celebrated, and the cruise was continued on the 2nd September. A series of echo-soundings was taken on the submarine very steep slope of Manado Toea Islet, which is an extinct volcano lying eleven miles to the NW. of Manado. The aim was not only to determine this slope for the purpose of obtaining data as to the maximum inclination of submarine slopes in general but also to ascertain whether sonic sounding instruments, and particularly that of the ATLAS WERKE which had been specially fitted in this connection, could send out their oscillations almost exclusively in a vertical or nearly vertical direction. The result of these tests was negative. The oscillations of these instruments are not mainly emitted within a fairly sharp-pointed cone nor are they collected more or less in a flat plane in the German instrument. In addition to the research as to the directive capacity, the constant accidental errors of sonic soundings and the personal errors of the observers are being closely examined, and

(****) Maratoea lies to the West of Station 43; Moearas Reef about 27 miles S. E. of the island; kakaban Island 5 miles to the West of Maratoea.

besides, much data is being collected for the purpose of comparing the accuracy of sonic soundings at different depths with those made by wire.

Having completed this work, the ship proceeded towards the Basilam Strait making Stations 56, 57 and 58 on the way. The first of these stations is in the middle of the Celebes Sea; and thereafter Stations 59, 60 and 61 were made in the Strait but these are not shown on the chart for fear of overcrowding it. As the ship proceeded further North in the Celebes Sea the wind and sea became stronger but on entering the Soeloe Sea, conditions improved; though the sky was grey and overcast, the barometer was variable and below normal, probably under the influence of typhoons which were passing over the Philippines. However, a few squalls coming from the Westward were experienced. The work advanced regularly and Stations 62 to 69 inclusive were completed although these took a fairly long time; for instance at Station 66 where the lowest water-bottle hung at a depth of 4400 m. and required 11 hours.

The work in the Soeloe Sea was completed by taking a section across the Siboetoe Strait by means of three stations of which the last only, N° 72, is shown on the chart. At Siboetoe the party which had examined Maratoea was landed again and the ship went to Tarakan to take in oil-fuel.

On returning, observations at Stations 74, 75 and 76 were begun; the last of these is in the same position as Station 48. Thus the observations at this station, where the depth is very great (5700 m.), were repeated in order to ascertain whether any changes had occured in the interval. Special attention was given to the water samples taken at heights of 30, 60 and 90 metres above the bottom, on account of a possible change in oxygen content.

The following is an interesting example which proves how the oxygen content and the longitudinal section can show how the water moves between two basins. The water in the Soeloe Sea contains much less oxygen than that of the Celebes Sea. At a depth of 150 m. the former contains 1.9 cc/1; in the latter, the quantity is double this amount. The observations made at Station 71, which lies immediately North of Siboetoe Strait, still showed the usual quantity for the Soeloe Sea; under the influence of the water of the Celebes Sea the quantity had already risen to 2.8 cc/1 at Station 73, which is situated immediately South of the Strait; and at Station 74 the normal amount for the Celebes Sea was found. This was observed to be the case also at other depths. From this it may be concluded that the direction of the movement of the water is not from the Soeloe Sea to the Celebes Sea but that, on the contrary, it flows in the opposite direction. Direct observation of the currents as well as information given by the inhabitants confirm this conclusion.

Having repeated the observations at Station 48, the ship steered to the Eastward towards the strait lying NE. of Celebes which forms one of the communications of the Celebes Sea with the Molucca Pass, between Celebes and Halmahera. The desired data were obtained at three stations (N^os 77, 78 and 79) in this strait.

In order to complete the work systematically, the ship then had to proceed South, for the SE. monsoon was weakening and the month of September and the period of change which precedes the NW. monsoon were approaching. It is intended to return about the middle of 1930 to the Celebes Sea to complete the work and, if time permits, to explore the very interesting Soeloe Sea once more.

On the 23rd September the ship anchored in Ternate Roads, which was left on the 30th of the same month to continue the cruise. The ship proceeded South and observation was taken at Station N° 80 which lies in the middle of the Batjan depression. Thereafter the Straits of Ombi and the communications between these straits, the Ceram Sea and the Halmahera depression were examined by making Stations 81 to 86.

As Misool is renowned for its richness in fossils and as its tectonic construction is interesting, the usual landing-party was put ashore on an islet called Kafal, quite close to and lying to the Southward of the main island, in order to make some explorations; meanwhile the ship went to Boela to take in oil-fuel and took soundings, both going and returning, in the Eastern part of the Ceram Sea. The bottom in this part is very irregular so that further sounding which is necessary will be carried out later.

Having reimbarked the explorers at Hafal, the *Snellius* sailed again for the NE. coast of Ceram to make observations over a section running from this island as far as New Guinea between the depth contours of 200 m. which surround these two islands (Stations 87 to 91). Another section was taken between Watoebela Island and Cape van den Bosch (92 to 96). The first section showed a depth of 1900 m. while, in the second section, a narrow trough was found quite close to the Cape: this trough was not more than five miles wide between the 1600 m. contours and had a maximum depth of 2000 m.

Then the ship went to Dobo, making Station 97 on the way, this station being situated in the trough of the Ceram depression. The landing-party was landed on the Aroe Islands in order to examine the strange channels which cut up the main island and which give rise to numerous theories to explain their origin. The Geologist of the Expedition considers that too complicated a view has been taken and that the matter is fairly simple. According to him these narrow arms of the sea are but the remains of a local system of rivers which have been submerged in consequence of a subsidence of the land of about 20 m.

Meanwhile the ship took observations over a section across the strait which separates the Kei Islands from the Aroe Islands (Stations 98 to 102) and, besides, examined the sill which is shown on the bathymetric chart between the Ceram depression and the depression Eastward of the Kei Islands and Tanimbar. From this it appears that this sill does not exist and that these two depressions are really one, called the Aroe depression, which extends between the 3000 m. lines from latitude 4°30' S. to 6°15' S. and has a maximum depth of 3700 m. and a width of about 30 miles (Stations N^{os} 103 and 104).

Having picked up the landing-party, the journey was continued to the S.; three sections to the Eastward of Tanimbar (Stations 105 to 112) were taken in order to explore the elongated depression mentioned above. These observations show that this depression is separated from the Timor depression by a ridge over which the greatest depth is 1600 m. Then the ship headed towards Wotap Island, where she remained at anchor for a few days both for the purpose of examining the extensive beaches which promised rich booty for the Biologist and to complete the analysis of the large number of water samples which had been taken. Once more getting underway, the sounding of the straits between Tanimbar, Babar and Sermata, which form — with the pass between Timor and Leti — direct communication between the Banda Sea and the Timor depression, was continued. The pass has yet to be examined; according to earlier data, it has a maximum depth of 1200 m.: the connecting passes so far examined havep deths of 1300 and 800 m. respectively.

Thereafter three sections were made across the depression which extends between the Sahoel and Timor Bank and the adjacent islands (Stations 113 to 129). The central section cuts through the trough of this depression.

On the slope of the Sahoel Bank the 4 metre collecting tube was tested. This tube is constructed to obtain very long bottom samples. As, however, the bottom is fairly hard just here, a sample of only 102 c/m long was obtained and this unfortunately did not show any stratified layers. Nevertheless this is a record which was not obtained without difficulty. The depth was 1550 m. and the tube had been weighted with 140 kgs: it required an effort of half-a-ton to pull it out from the bottom.

Having completed the above sections, the ship went to Koepang, where the Biologist and Geologist were landed for several weeks in order to make some explorations of Termor Island, which is rich in fossils. The ship then proceeded to explore the communications between the Sawoe Sea and the Indian Ocean, and this Ocean also in the vicinity of Timor, Sawoe and Soemba.

A beginning was made by sounding the sill which separates the Timor depression from the Ocean and there two stations were made (Stations 130 and 131); later Station N° 156 was made. Here the maximum depth of 1940 m. was found on the sill and thence the depression falls away to 3300 m. Thus the exchange of water from this depression is carried out in the layers of the ocean above 2000 m.

The examination of the straits on either side of Sawoe was made very closely by means of close sounding combined with four stations in each strait (Stations 133 to 136 and 137 to 139) as well as a station at anchor during three days (N° 135*a*) in a depth of 1140 m. Anchoring took two hours and weighing the anchor took two and a half hours; 1850 m. of cable were used. Observations of temperature and salinity at various depths, similar to those taken at Station 39*a* in the Strait of Makasser, gave similar results, though the amplitudes were less. Here also the periods had a semi-diurnal preponderance.

According to the current observations which were taken during 25 hours at 10 different depths from the surface down to 40 m. above bottom, it was possible to deduce that the flow and the ebb alternate regularly every six hours, although the ebb has only a very low velocity. The maximum ebb current flowing towards the NE. was 74 c/m sec. at a depth of 20 m. In the lower layers the period is shorter and the difference between the velocities in the two principal directions was less accentuated and the directions were not so definite. However, tidal currents were still noticed near the bottom in 1000 m. Eleven observations were taken at this depth in half-an-hour and a velocity of 1/3 of a knot recorded, which explains why the tube brought up nothing but sand, seeing that mud could not remain on the sill.

The general movement of the water is towards the Sawoe Sea.

The examination of these Straits was followed by an excursion into the Indian Ocean during which Stations 143 to 147 were made. Near Station 145 a sounding of 6300 m. was obtained in the great depression which extends Southward of Java and the adjacent islands to the Eastward. This great depth gives the impression that the Timor depression may be a continuation of the Java depression, which would be very remarkable and would give an unexpected explanation as to the significance of these depressions from a geological point of view.

Having made Station N° 148 at the entrance to the Soemba Strait, the *Snellius* went to Makasser, passing through the Sape Strait. She remained here several days and returned through the same strait where two stations were made — N^os^ 149 and 150. During the voyage to Makasser and back, two lines of soundings were run in the Flores Sea.

The exploration of the Soemba Strait, which has a sill lying at about 1000 m. and the Sawoe Sea, were then carried out (Sections 151 to 155) : then the two experts were reimbarked at Koepang and the Straits of Ombai were examined (Stations 157 to 160), as were also the communications of this strait and consequently those of the Sawoe Sea with the Banda Sea (Stations 161 to 163). These communications lie on the two sides of Kombing Island — to the left, *i. e.* to the East of Alor with a maximum depth of 1300 m., and to the right, *i. e.* between Kombing and Timor with a depth of 2300 m. This last is therefore the deepest sill of the Sawoe Sea, which is now entirely explored, the depth being known as are also the various sills, the composition and movement of the waters, etc.

After having finished the stations in the neighbourhood of Alor, the ship passed through the picturesque Strait of Pantar and on the 17th of December entered the Banda Sea.