THE ADJUSTEMENT OF THE HYDROGRAPHIC SURVEYS IN THE MOLUCCAS.

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An article bearing this title appeared in the March number of the *Marineblad*. As it may also be of interest for the *International Hydrographic Review*, it is reproduced here with slight alterations in view of the somewhat different circle of readers of this periodical.

The surveys of the Moluccas (*) were started in 1914 on the East coast of Halmahera after the completion of those of the Coasts of Western New Guinea. The outbreak of the war caused this work to be interrupted and, although the surveys in the East Indian Archipelago were gradually resumed in 1915 and 1916, those in the areas under consideration were not continued before 1919. They were finished last year only although, since 1922, three vessels were working there the whole year round. Many persons in the Netherlands who have followed the energy with which these surveys were being pressed forward will undoubtedly have wondered why it takes such a long time before the resulting charts are published.

This is partly explained by the fact that the drawing of a new chart cannot be finished before the whole area it covers has been surveyed. Now, the weather conditions in the Archipelago — although favourable — do not allow the continuation of the survey of any one coast during the whole year and therefore the work has to alternate according to the monsoons. There are also exposed islands which can be surveyed during the change of the monsoons only. The principal reason, however, is another and its explanation requires that a short digression be made.

When, at the close of last century, it was understood that accelerated progress in the hydrographic survey of the Archipelago was absolutely required, simplification of surveying methods was considered in the first place. Arguing that an error in base is eliminated when the triangulation is corrected by astronomical observations, it was considered waste of time to trouble much about

(*) In this article the Moluccas are understood to be the islands between Celebes, New Guinea, Wetar and Timor, the Tanimbar — and the Kei groups although, strictly speaking, the Banda islands are the most southerly group of the Moluccas.

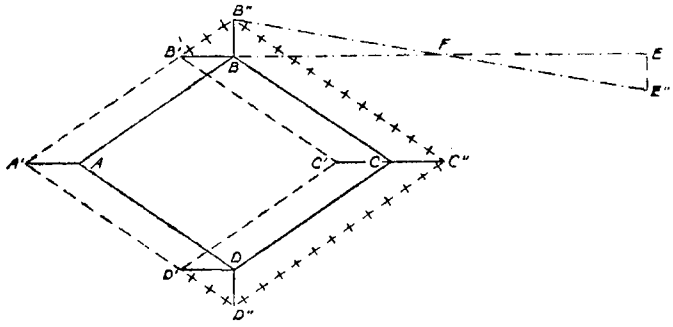
accurate measurement of a base. A preliminary base obtained by the somewhat crude method of mast-head angle observations was deemed to serve the purpose just as well, since the adjusted surveys were charted on the basis of the astronomical positions. To a certain extent this reasoning is acceptable, although the errors resulting from the observations, especially in longitudes by chronometer, required adequate distances between the astronomical positions. These positions are determined by observations made with a six inch universal instrument and it was understood that the results were accurate within 2" of arc in latitude, and 10" in longitude, provided that the observations were serial; in the case of detached observations greater departures were admitted. However, the more accurate observations obtained in later years by means of wireless time signals have proved that, as regards longitude, the amount mentioned above is too small, as was shown by an observation for the longitude of Ambon by wireless in 1923. The result differed by 23" of arc from that obtained by a very skilled observer using seven chronometers on two voyages expressly made for the purpose in 1866 and 1867.

In those days the influence of local deflection of the plumbline was not taken into account. So far as it was considered, it was deemed that this influence could be neglected with regard to the requirements of charts sufficiently accurate for navigational purposes. As until then the surveys were made chiefly in the more alluvial Western part of the Archipelago these deflections presumably will not have led to too great distortions. It was recognised however in later years that this reasoning could not be maintained for the Eastern part of the Archipelago, with its fragmental geological structure, and its steep coasts, falling abruptly into deep seas having depths up to 4000 m. (2200 fathoms) and more.

On the island of Tindjil, off the South coast of Java near Soenda Strait, a deviation of 37" due to deflection has been found by the topographical triangulation of Java and it was expected that in the Moluccas the deviations would not be less, but perhaps even larger!

Supposing for the moment the distribution of mass for a given steep coast to be normal, *viz.* an excess to landward and a deficit to seaward, the consequence will be that the vertical inclines, above sea level, towards the sea, and beneath sea level, towards the land. As a further consequence, astronomical observations will give a position to seaward of that which should have been obtained if no deflection of the plumbine were existent.

Supposing too that an island *A B C D*, possessing such normal distribution of mass, be surveyed, and that the survey be started with a preliminary base from the astronomical position *A'*, with a divergence *A A'* due to deflection of the plumbline. Let astronomical positions be also determined at *B*, *C* and *D* and their divergences to seaward be *B B"*, *C C"* and *D D"*. If the method under consideration were applied to this theoretical example, the island would be charted as *A' B" C" D"*, *i. e.* too big, and if *E* represents a point of another island, with a divergence of the astronomical position *E E"*, the error in bearing *B E* would be represented by the angle *E F E"*.



These errors in scale and azimuth can be avoided if the survey is started with an accurate base and is not corrected for each part of the coasts between two successive astronomical positions, but adjusted as a whole for the mean of the divergences between these positions and the triangulation after the survey has been completed.

The survey being that of an island, the triangulation must close *i. e.*: on returning to the starting point the same coordinates as those with which the triangulation were begun should be obtained. In reality there will be a discrepancy, which allows the accuracy of the triangulation to be determined and which should be applied to each position in proportion to the distance from the starting point. After having squared up the triangulation in this way, the corrected coordinates of *B*, *C* and *D* are obtained and the differences from the corresponding astronomical positions can be established. Let it be assumed, in order to reduce the problem to its simplest form, that the triangulation is absolutely correct and is represented by the figure *A' B' C' D'*; let *B' B* be the difference in longitude between the (corrected) triangulation and the astronomical position of *B*, and *B B''* the difference in latitude, while for *C* be found *C' C''* and nought respectively, and *D' D* and *D D''* respectively for *D*. By shifting the whole survey $\frac{1}{4}$ $(B\,B'' + D\,D'')$ in latitude and $\frac{1}{4}$ $(B'\,B + C'\,C'' + D'\,D)$ in longitude, the adjusted survey will be represented by *A B C D* and will exactly cover the ground.

It is clear that this example is purely hypothetical and will not be met with in practice, an island is never symmetrical nor is the distribution of mass ever normal. Even if this should appear to be the case, hidden cavities or masses of ore may cause irregularities. Neither will it always be possible to make astronomical observations in those places which are the most suitable, and, further, errors in triangulation and in the astronomical positions will occur. Deflection of the plumbline cannot, as a rule, be absolutely ascertained from purely hydrographic triangulations, because they are not accurate enough for this purpose. Should they be, these triangulations would surpass the exigencies of navigational charts. The differences between the results of hydrographic triangulation and astronomical observation may give more or less trustworthy *indications* for deflection of the plumbline; an accurate topographical triangulation with a large number of astronomical observations is absolutely necessary for establishing this deflection undeniably and for determining its amount at each place.

The prospect that, in the Moluccas, considerable deflections of the plumb-line would be met with and the fact that the various groups of islands, although too distant from each other for all to be included in a regular network of triangles, yet were not so far apart that a connection of the triangulations by astronomical bearings was excluded, gave some general indications as to the mode of working. According to the conclusions deduced from the hypothetical case developed above, it was indicated to work as far as possible with an accurate base checked at appropriate places; to determine, in addition to the astronomical positions obtained in former years, a sufficient number of new positions, deducing the longitude by Wireless; to connect the triangulations of the different groups of islands by astronomical bearings as far as possible and, last but not least, not to correct each part of the surveys between two astronomical positions, even if the longitude were obtained by wireless, but to adjust the various surveys of the Moluccas as a whole, using all available data and after having squared the survey of each island or group of islands as indicated in the theoretical example mentioned above.

It was not expected that it would be possible to find a mathematical solution. In the first place, because it was a condition that former surveys, which were already definitely charted, should be left unaltered. On this account the positions of Ternate and Boeli (East coast of Halmahera), Manokwari (North New Guinea), Djoeha (Little Soenda Islands, near Roma), the Sermata group and the Northern part of the Banggai group (East coast of Celebes) had to be accepted as they stood. In the second place, the restricted number of astronomical bearings and positions, the errors to which they are liable and the comparative lack of accuracy of hydrographic triangulations, during which the drifting ship had very often been used as a temporary station, were opposed to a mathematical adjustment. Of course, more than one solution was possible and a suitable solution had to be sought, scrutinizing each of them with a critical eye as to the acceptability of the divergences between the adjusted and the observed original data. It will be seen at the end of this article that the accepted solution contains no errors of an amount which will either be inconvenient for navigation or will create difficulties when subsequent partial resurveys have to be inserted. This has been furthered by applying the corrections in scale and orientation of the surveys, required for the adjustment over very large areas which, as a rule, do not directly join other parts of coasts which have been corrected in quite a different way. If they join, special care has been taken that these difficulties will not arise.

The adjustment of the surveys of the Moluccas started from the squared triangulation of Ceram. The survey of the North coast was begun at Kawa where, some years before, the astronomical position had been observed (longitude by chronometer) and a base measured; that of the South coast set out from the astronomical position observed at Ambon (longitude by wireless) and a base obtained from an accurate topographical triangulation of the island of Ambon. A check base was measured near the Southeast point of Ceram. Excepting the Western part of the island from Kawa to Amahai, which was triangulated by fixed triangles, the triangulation of Ceram was made by the

ship method, wherein the drifting ship formed temporary stations, as the depths did not allow the ship to anchor during the observations.

The results of the accurate triangulation between Kawa and Ambon with fixed triangles and a base, which was absolutely correct from a hydrographic point of view, gave strong indications of deflection of the plumbline in one or both places. In view of the use of chronometers at Kawa there was some uncertainty about the difference of longitude from Ambon; the difference of latitude between both places, situated approximately on the same meridian, was 45'36.3" by astronomical observations and 45'15.5" according to triangulation. The former difference being the larger, it indicates that at one of the two places, or at both, there is a deflection of the plumbline in a meridional direction to the landward side of the nadir, *i. e.* in the direction in which it would be expected, assuming the distribution of mass to be normal (*).

The triangulation of the North coast and that of the South coast meet at Boela on the East coast. Shifting the North triangulation in accordance with the astronomical position of Ambon gave as a result a gap of 7.6" in latitude and 21.6" in longitude or a linear error of 680 m., corresponding to 0.07 % over 1020 km. in a triangulation of which 870 km. were made by means of the ship method.

In order to judge the accuracy of similar triangulations some other results also are given here. For that of Soemba, carried over 560 km. and nearly entirely by the ship method, 0,1 % was found; for the triangulation of Halmahera the gap over 1500 km. was 0.11 %. These three examples give a mean error of 0.09 % in distance for a triangulation of which approximately three fourths were made by the ship method, carried out by more than one ship on coasts where the depths do not allow the vessel to anchor. This result may be called fairly satisfactory as it amply surpasses the requirements of navigation.

Compared to the triangulations of the North coast and the South coast the astronomical position observed at Boela (longitude by wireless) gave respectively 0.7" and 8.3" to the North and 38.5" and 16.9" to the East. These differences to seaward corroborate the impression of the existence of deflection of the plumbline and this supposition is strengthened by the comparison of astronomical positions at intermediate stations of the triangulation.

A study of the connection of the survey of Ceram with those of Misool and other islands led to the conclusion that it would be preferable not to take the astronomical position of Boela into account and to square the two triangulations by leaving that of the South coast unaltered and by linking up that of the North coast to the position of Boela in accord with the triangulation of the South coast. The triangulation of the North coast had therefore to be stretched 7.6" in latitude and 21.6" in longitude.

The positions of some mountain peaks, determined in both triangulations, were recomputed in the modified North triangulation and the result agreed satisfactorily with the South triangulation. One of these peaks, "Bianaja", had

(*) In this connection Ambon is considered to be situated on the shore of the Banda Sea, not on that of the comparatively small Bay of Ambon.

been determined also by astronomical bearings off the South coast of Misool and use had been made of this peak for connecting the survey of Ceram to that of Misool and further on to that of Halmahera, etc.

Misool was connected by astronomical bearings to the Northward with Kofiau and to the N E^{d} with Batanta and Salawati. The position of Samatee, which is situated on the latter island, was determined astronomically (longitude by wireless) and the triangulation of the North coast of the peninsula of New Guinea connects this position with Manokwari. As had been stipulated, the latter position (longitude by wireless) could not be altered, for the survey of Geelvink Bay had already been adjusted definitely.

To the West, the islet Pisang, determined by astronomical bearings from Kofiau and Misool, and also from the Southeast point of Halmahera and Obi Major, enabled the surveys of those islands to be connected and to ascertain how far they tally with that of Ceram. For this purpose the position of Binaja Peak was computed :

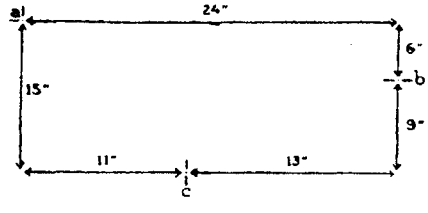
a) starting from the astronomical position of Ternate (longitude by wireless) and using the triangulations of Halmahera, Obi Major and Misool ;

b) starting from the astronomical position of Samatee and using the triangulations of Salawati, Batanta and Misool.

These two positions for Binaja can be compared to that found in the squared triangulation of Ceram (*c*). It should be remembered that this position is obtained by the triangulation of the South coast of the island, which was started from the astronomical position of Ambon (longitude by wireless).

The results are shown in the following figure.

Position of Binaja according to :



A second of arc in the Archipelago is roughly equivalent to 30 m.

Several solutions for eliminating these differences are possible and have been examined. As has been explained, the available data are neither complete nor sufficiently accurate to allow a mathematical solution. Consequently the solution which gives the smallest resulting discrepancies and requires the smallest deformations of the original surveys, both in scale and in orientation, had to be investigated empirically. Besides, this solution had to be tested as to its effect upon :

— the connection of the survey of Halmahera with those of Waigeo and Misool by the chain of astronomical bearings between Tandjong Ngollopoppo, Gebe, Gag, Jef Doif, Kofiau and Misool ;

— and the connection of the survey of Ceram with the astronomical position of Djoeha (which should remain unaltered ; longitude by wireless)

by the chain of astronomical bearings between Ceram, Banda, Manoek, Seroea, Nila, Damar and Djoeha.

The following adjustment was chosen :

The scale of the survey of Ternate to Pisang (including that of Obi Major) was modified, without altering the orientation, so that :—

— position *a* of Binaja Peak agrees with the latitude of position *b* ;

— the survey of Ceram was shifted as a whole to the North till position *c* of Binaja tallied with the latitude of position *b* ;

— the surveys of Salawati, Waigeo, Kofiau, etc., and Misool were shifted as a whole to the West till position *b* concords with the longitude of position *c*.

In this adjustment the position of Ternate has been left unaltered, as was stipulated. The consequences of the adjustment are :

a) The definite position of Pisang deduced from Ternate is 7" in longitude to the West of that resulting from the adjusted triangulation of Misool, etc., and of Ceram. This gap is of no importance however, considering the sea room between Pisang and the surrounding islands to the East, which is 26 sea-miles at the narrowest.

b) The distance Ternate-Pisang being about 9600" was increased by this adjustment by 9", although a check base measured at Laboeha proved to be smaller than the length deduced from the Ternate base. However, the difference in latitude between Laboeha and Ternate by astronomical observation exceeded that by triangulation by 29", which is in contradiction with the results of the base check and points to too *small* a base between Ternate and Laboeha. But the discrepancy is so great that deflection of the plumbline must be considered to exist. This supposition is corroborated by the result of the astronomical observations at Obi Latoe, which give 12.5" *less* difference in latitude from Ternate than the triangulation, whereas observation at Gomoemo gave 9" *more* (*). It is certain therefore that, in these areas, deflection of the plumbline exists and that it is fairly large and irregular as may be deduced also from the astronomical observation (longitude by wireless) at Lifoematola, the East point of the Soela Islands. This observation gave 43" to the North and 27" to the East of the position computed by astronomical bearings of Obi Latoe and Boeroe.

c) The shifting of the entire survey of Ceram to the North causes a difference of 9" between the astronomical latitude of Ambon and the adjusted one. On the other hand the existing discrepancy for Kawa diminishes from 20.8" to 11.8" and that at Boela is eliminated. An observation made some years earlier at Wahai gives practically the same result ; for Pelauw, where the conditions for deviation are apparently the same as at Ambon, the resulting difference is 10".

The astronomical longitude at Boela has been disregarded. In the first place because it is contradicted by triangulations both of the North and of the South coast of Ceram which were made independently of each other ; secondly because the gap between *a* and *c* (see above) would have increased and thirdly

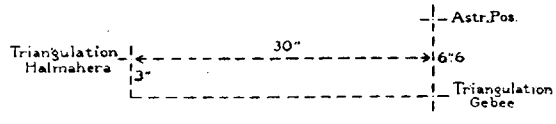
(*) At Laboeha, Obi Latoe and Gomoemoe observations for latitude only were made.

because it would not fit into the adjustment to the South of Ceram (Banda Islands etc. to Djoeha). On the other nand the astronomical longitude of Boela, which lies 17" to the East of the adjusted longitude, accords with the astronomical longitude of Samatee. The position of that place has been shifted deliberately 13" to the West for the sake of the adjustment.

It still remains to examine how this adjustment tallies with the triangulations between Waigeo and Halmahera. The triangulation of the former island is a continuation of that of Batanta, which was started from Samatee and has accordingly been shifted 13" to the West, as well as of the triangulations of Misool and Kofiau. The Jef Doif group has been connected by astronomical bearings with Kofiau, Batanta, Waigeo, Gag and Gebee; Gag is connected in the same way with Kawe, Batanta and Gebee.

At Gag astronomical observations were made (longitude by wireless). Finally Tandjong Ngollopoppo was connected to Gebee by triangulation made by the ship method. The same point at Ngollopoppo had been determined in the triangulation of Halmahera and thus connected with Boeli (the position of which could not be altered) and it has also been fixed astronomically (longitude by wireless).

The results were :



In order to make the latitudes of both triangulations agree, the Djailolo passage, with a width of 18 sea-miles, has been widened by 6.5", without altering the orientation, after which the latitudes of both triangulations agree, but the longitudes still have a difference of 23.5". This has been covered by stretching the triangulations of both sides of the East arm of Halmahera, approximately to the same degree as the widening of the Djailolo passage and changing the azimuth Boeli-Ngollopoppo by 5'42" and that of Ngollopoppo-Weda by —4'29". These distortions are the largest that the adjustment required and are mainly a consequence of the condition that Boeli should be accepted as it stands.

The survey of the Banggai group and of the Soela Islands originates from that of the East coast of Celebes near Peleng Strait, which should not be altered. The East point of the survey, the islet of Lifoematola, was connected by astronomical bearings with Obi Latoe and the Hoorn Peak on Boeroe. Using these bearings, the position was computed starting from the adjusted triangulations of Obi Major and Boeroe. Astronomical observation (longitude by wireless) placed Lifoematola 43" to the North and 27" to the East of the computed position, which large differences are, for the greater part, imputed to deflection of the plumbline. Various considerations have led to the application of a slight change of scale, to the triangulation of the Soela Islands, leaving differences of 34.5" in latitude and 8" in longitude between the astro-

nomical and the adjusted position of Lifoematola, the former lying to the North and East (to seaward) of the latter.

The survey of Boeroe was made on a base measured at Bara and checked near Namrole. Returning to the starting point, a gap of 8" in latitude and 12" in longitude was found and squared up. The lighthouse on Manipa Island was connected with Boeroe by triangulation across the Strait of the same name. The position of this lighthouse being known by the Ceram triangulation, Boeroe could be connected with Ceram. Astronomical observations were made at Bara (longitude by wireless), at Namrole (longitude by chronometer) at Saroma (ditto) and at Wapotih (latitude only). Subsequent to the adjustment of the Boeroe triangulation to that of Ceram, the mean difference from the astronomical observations was 5" in latitude and 4" in longitude; which means that, according to the mean results of the astronomical observations, the island lies 5" to the South and 4" to the East of the adjusted position.

To the South, the Banda group has been laid down by astronomical bearings on mountain peaks of Ceram. At Manoek the latitude was observed and astronomical bearings on Banda, Nila and Seroea were taken; at Seroea the longitude was determined by wireless and an astronomical bearing of Nila was obtained; at Nila the astronomical bearings of Teoen and Dai were taken. From the top of the volcano of Damar astronomical bearings of Roma, Moa, Sermata, Babar, Dai and Nila were observed. By means of these bearings the position of Damar was deduced from the definitely adopted surveys to the West and to the South (Roma, Moa and Sermata) and subsequently Nila and Babar were connected with Damar.

An astronomical bearing of Babar was also obtained from the uncovering bank Bara Sadi, West of the Tanimbars, but as the mountain top in question is not very conspicuous and was insufficiently determined from the Babar triangulation, the position of the Tanimbar Islands has been laid down independently in accordance with the mean of some astronomical observations.

Manoek was located on the mean of the intersections of the astronomical bearings from Banda, as adjusted in the Ceram triangulation, and Nila as adjusted in the Southern triangulation, with the latitude by astronomical observations, which intersections were 5" distant on the parallel.

Seroea was fixed by astronomical bearings from Manoek and Nila. Appendix *B* shows the differences between the astronomical observations and the adjusted positions which were found for Damar, Wetan, Dai, Nila and Seroea. Some of these differences are great! They may be caused partly by the fact that these positions were obtained from the survey of the Roma - Sermata groups, which had to remain unaltered and in which undoubtedly there are errors. This may account for the differences found at Damar (latitude + 5", longitude by chronometer + 18.6"), but the fact that the differences at Wetan (latitude —0.2", longitude by chronometer + 7") and at Dai (latitude —0.1", longitude by chronometer + 7.2") disagree with that at Nila (latitude +18.3" longitude by chronometer + 29.4") and that the differences of none of the three islands agree with those at Damar, suggests a strong suspicion that

deflection of the plumbline exists. For, apart from an error in the base, derived from the survey of Roma-Sermata, no errors of any importance have been made in locating Damar, Wetan, Dai and Nila, which was done by means of triangles in which all the angles were observed by theodolite. Besides, an error in the base would have affected the positions in proportion to the distance! This suspicion becomes stronger when is remarked that the large discrepancies in an Easterly direction which exist at Nila and Seroea (at the latter island longitude by wireless + 38.1") corroborate this opinion, for to the Eastward and close to these islands of the so called Inner Banda Arc lies the Weber Deep, which has a maximum depth of at least 7300 m. (4000 fms). This explanation is supported by the small discrepancies at Dai and Wetan.

The longitude of Banda by chronometer, depending on Ambon, makes it inadvisable to stretch the triangulation of Ceram on account of the longitude observed at Boela.

In order that the information be complete, it should be mentioned that the triangulation of the North coast of New Guinea has been adopted as based on the astronomical position of Manokwari (longitude by wireless), which should not be altered, and the adjusted position of Samatee, and that the Ajoe and Asia Islands have been fixed by astronomical bearings between these islands and Waigeo, combined with observations of latitude.

This account of the way in which the various locally squared surveys were adjusted as a whole, shows that the condition of unalterable positions of surrounding surveys and the lack of more precise data prevented a mathematical solution from being obtained. The adjustment chosen has been found by cutting and adapting, but it is considered not to contain errors of any importance either for navigation or for insertion of subsequent partial resurveys. The differences between astronomical and charted positions resulting from deflection of the plumbline, are of little or no importance to navigation, it being quite probable that the deviation vanishes at a short distance to seaward of the observation spot. The deformations of the surveys caused by squaring and adjusting are comparatively small and cover large parts of the coasts, which do not join directly onto other parts deformed in a different way. This is proved by Appendix *A*, which gives a summary of the alterations in scale and orientation applied both for the tallying and the adjusting.

Appendix *B* shows the resulting differences between the observed astronomical positions and the corresponding positions on the chart.

The data of Appendix *B* have been plotted graphically in the chartlet. The direction and length of some of the arrows are not as might have been expected. This is partly the consequence of the differences being affected by the errors resulting from the adjustment, and is partly imputed to the fact that in some places the latitude only has been observed astronomically or that the longitude has been obtained by chronometer and, last but not least, may be caused by invisible irregularities in the distribution of mass.

However, a certain regularity cannot be denied; for in nearly all stations the arrow points to areas of less visible mass, especially in the vicinity

of Ceram, Boeroe, Lifoematola, Batjan, Obi Major, the Southern part of Halmahera and Misool.

When coasts which have not been surveyed systematically have to be charted by compilation, using all available data, such as partial running surveys, bearings taken by different ships at various times, sketch-maps, reports from travellers etc., (data which are generally more or less in contradiction with each other) astronomical positions are of great value and may form the basis of the compilation. Deflection of the plumbline, even if assumed to be large, may then be neglected and this must inevitably be done as nothing will be known about it. This neglect will not have any influence as the defects of the compiled chart due to other sources will most certainly be considerably greater.

The case is different as soon as the coasts which are to be charted have been systematically surveyed. Thus this article shows that astronomical positions may not be used implicitly as so many fundamental points of the chart; they are still data of high importance, but not of a higher order than the triangulation and they should not be used singly but combined. A third case arises when the triangulation and the astronomical observations are both highly accurate and are adjusted beforehand. The geodetic triangulation of the Netherlands, for instance, has been made with a probable error of 0.23" in the azimuths, and astronomical observations for latitude and azimuth (with a probable error of 0.05" in the former and of 0.22" in the latter) have been taken in 14 places, regularly spread over the Kingdom. As concerns azimuth, it may be remembered that deflection of the plumbline affects observations made for this purpose in the same way as an erroneous position of the vertical axis of the theodolite.

The latitude of Amersfoort, centrally situated in the Kingdom, and the azimuth from this place to another in the vicinity, have been deduced from each of these observed latitudes and azimuths by means of the triangulation. The means of these deduced data have been accepted as those for Amersfoort and working backward, the corresponding coordinates for the places of observation were deduced. The differences between these data and the astronomical positions are considered to be the result of deflection of the plumbline which is largest in the neighbourhood of Maastricht (S E corner of the Kingdom) where it amounts to 5".

Accurate topographical triangulations, combined with astronomical observations have also been made in Java and Sumatra and hydrographic surveys may be inserted there relying entirely on the topographical stations. Excepting the island of Ambon and the nearest neighbourhood, this has not been done in the Moluccas and the adjustment of hydrographic triangulations should be made with great caution. Adapting each part of the surveys between two consecutive astronomical positions would certainly introduce errors larger than these made by the triangulation and give rise to unacceptable deformations.

APPENDIX *A*.

SHOWING THE ALTERATIONS OF SCALE AND OF ORIENTATION WHICH THE VARIOUS SURVEYS HAD TO UNDERGO FOR THE SQUARING AND THE ADJUSTMENT.

SOUTH AND WEST COASTS OF CERAM...	Unaltered.
NORTH COAST OF CERAM	Alteration of scale from 1:100,000 to 1:100,220 ; graduation turned through 2'47", Northern part of meridians to the Westward.
WEST COAST OF HALMAHERA, SOUTH OF TERNATE.....	Alteration of scale from 1:100,000 to 1:100,078.
OBI MAJOR AND VICINITY	Alteration of scale from 1:100,000 to 1:100,230.
EAST COAST OF HALMAHERA, FROM BOELI TO TANDJONG NGOLLOPOPPO.....	Alteration of scale from 1:100,000 to 1:100,520 ; graduation turned through 5'42", Northern part of meridians to the Eastward.
TANDJONG NGOLLOPOPPO TO WEDA.....	Alteration of scale from 1:100,000 to 1:100,240 ; graduation turned through 4'29", Northern part of meridians to the Westward.
WEDA TO SOUTH POINT OF HALMAHERA	Alteration of scale from 1:100,000 to 1:100,130.
MISOOL AND VICINITY.....	Squaring of the survey of this island was effected by altering the scale of the Southwest coast from 1:75,000 to 1:75,585, combined with a turning of the graduation through 4'6", Northern part of meridians to the Westward. The other parts of the survey were left unaltered.
SALAWATI AND VICINITY.....	Unaltered.

WAIGEO AND VICINITY.....	Squaring of the survey of this island was effected by altering the scale of the North coast between the bay of Fofak and Tandjong Lamarche from 1:100,000 to 1:101,300 (*). The other parts of the survey were left unaltered.
NORTH COAST OF NEW GUINEA, FROM SAMATEE TO MANOKWARI	Alteration of scale from 1:100,000 to 1:100,282.
BANGGAI ARCHIPELAGO, SOUTH OF 1°25'S	Alteration of scale from 1:100,000 to 1:99,138 (**).
NORTH COAST OF SOELA ISLANDS	Alteration of scale from 1:100,000 to 1:99,845.
SOUTH COAST OF SOELA ISLANDS	Alteration of scale from 1:100,000 to 1:99,154; graduation turned through 3'18", Northern part or meridians to the Westward (***).
BOEROE, WEST COAST	Alteration of scale from 1:100,000 to 1:100,410; graduation turned through 9'27", Northern part of meridians to the Eastward.
BOEROE, EAST COAST.....	Unaltered.
BANDA ISLANDS AND THOSE BETWEEN THIS GROUP AND THE BABAR ISLANDS, INCLUDING THE LATTER.....	Unaltered.

(*) The survey off the island of Waigeo was made in parts by more than two ships between the years 1914 and 1920, and these parts were not surveyed with equal accuracy. The base for the part Fofak-Lamarche was a preliminary one, deduced from the construction sheet of a former survey by taking off the distance between two points of which one was graphically fixed.

(**) This survey was a continuation of a survey made in 1909, which was started with a preliminary base, deduced as mentioned for Waigeo.

(***) Owing to circumstances this survey had to be made with a preliminary base.

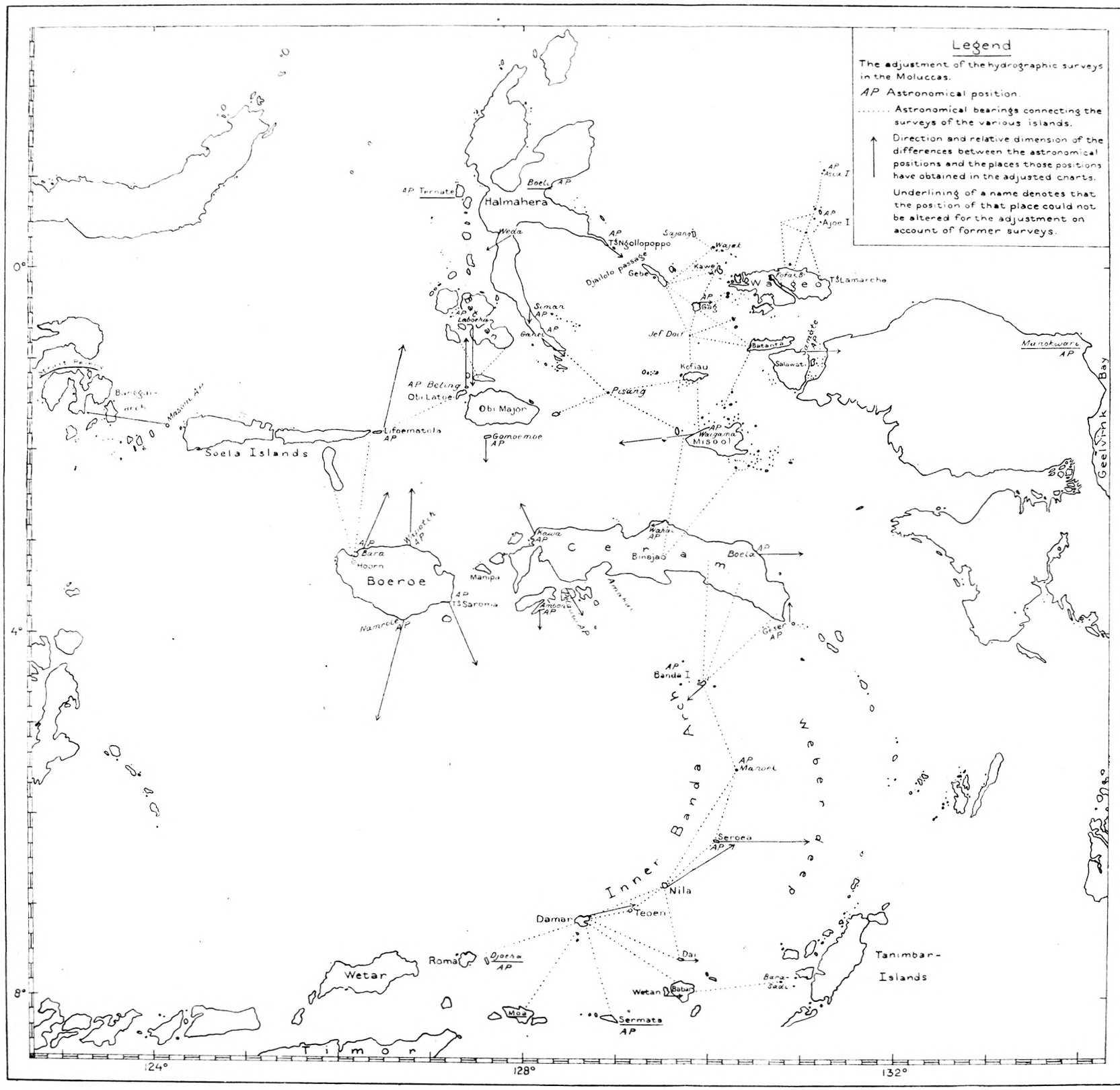
APPENDIX *B*.

DIFFERENCES BETWEEN ASTRONOMICAL POSITIONS AND THE PLACES THESE POSITIONS HAVE BEEN ALLOTTED ON THE ADJUSTED CHARTS.

+ denotes that the astronomical $\frac{\text{latitude}}{\text{longitude}}$ lies to the $\frac{\text{North}}{\text{East}}$ of the charted $\frac{\text{latitude}}{\text{longitude}}$; — denotes the contrary. Points which should remain unaltered are shown in italics.

NAME OF POINT.	Diff. in lat.	Diff. in long.	REMARKS.
CERAM AND ADJACENT ISLANDS.			
AMBON (*)	— 8.7"	0"	
PELAUW (*)	— 9.7	+ 6.7	
GÈSER	+ 7.9	—	Longitude not determined.
BOELA (*)	— 0.4	+ 16.9	
WAHAI (**)	— 1.1	— 4.1	
KAWA	+ 11.8	— 5.5	According to the mean of six positions (longitude by chronometer) in near vicinity of each other and connected by triangulation.
BANDA (**)	— 7.3	— 7.4	
Mean for CERAM and close surroundings	— 1.2	+ 1.1	
BOEROE.			
BARA (*)	+ 22.8	+ 10.0	
NAMROLE (**)	— 40.9	— 10.4	
SAROMA (**)	— 24.7	+ 11.1	
WAPOTIH	+ 21.9	—	Longitude not determined.
Mean for BOEROE	— 5.2	+ 3.6	
SOELA ISLANDS.			
MASONI (**)	+ 6.8	— 33.8	
LIFOEMATOLA (*)	+ 34.6	+ 7.8	
HALMAHERA AND ADJACENT ISLANDS.			
Ternate (*)	0	0	
LABOEHA	— 25.0	—	Longitude not determined

(*) Longitude by wireless. (**) Longitude by chronometer.


Legend
The adjustment of the hydrographic surveys in the Moluccas.
AP Astronomical position.
..... Astronomical bearings connecting the surveys of the various islands.
Direction and relative dimension of the differences between the astronomical positions and the places those positions have obtained in the adjusted charts.
Underlining of a name denotes that the position of that place could not be altered for the adjustment on account of former surveys.
Halmahera
AP Ternate
Boeli AP
Weda
AP Tg Gollopoppo
Sajang
Wajek
Djailolo passage
Gebe
Kawe
Waigeo
AP Asia I
AP Ajoe I
Tg Lamarche
AP Gag
Simar AP
Gahe AP
Laboeha
Jef Dour
Batanta
Salawati
Kofiau
Misool
Obi Major
AP Beling
Obi Latoe
Pisang
Lifoematola AP
Gomoemoe AP
Soela Islands
Manokwari AP
Geelvink Bay
Boeroe
Bara
Hoorn
Kaiea AP
Kaeli AP
Ceram
Binajao
Boela AP
Manipa
AP Tg Saroma
Amboina
Amahai
Namrole AP
Gisser AP
AP Banda I
Banda Sea
Weber Deep
AP Manoel
Seroea AP
Inner Banda Arc
Nila
Teoen
Damar
Roma
Djocha AP
Wetar
Dai
Tanimbar-Islands
Wetan
Babar
Banda-Saal
Moa
Sermata AP
Timor
124°
128°
132°
0°
4°
8°

NAME OF POINT.	Diff. in lat.	Diff. in long.	REMARKS.
GANEI (*)	— 8.0"	+ 9.5"	
BELING	+ 18.5	—	Longitude not determined.
GOMOEMOE	— 9.1	—	Longitude not determined.
SIMAN	— 4.5	—	Longitude not determined.
WEDA (**)	— 5.8	— 11.4	
Boeli	0	—	Longitude not determined.
NGOLLOPOPPO (*)	— 4.0	+ 5.8	
Mean for HALMAHERA	— 4.2	+ 1.0	
WAIGEO AND ADJACENT ISLANDS.			
GAG (*)	— 0.4	+ 4.3	
AJOE ISLANDS	0	—	Longitude not determined.
ASIA ISLANDS	0	—	Longitude not determined.
MISOOL.			
WAIGAMA (**)	— 3.5	— 30.8	
NEW GUINEA AND ADJACENT ISLANDS.			
SAMATEE (*)	0	+ 13.5	
Manokwari (*)	0	0	
DAMAR AND ADJACENT ISLANDS.			
MANOEK	0	—	Longitude not determined.
SEROEA (*)	—	+ 38.1	Latitude not determined.
NILA (**)	+ 18.3	+ 29.4	
DAMAR (**)	+ 5.0	+ 18.6	
DAI (**)	— 0.1	+ 7.2	
WETAN (**)	— 0.2	+ 7.0	
Sermata (**)	0	0	
Djoeha (*)	0	0	

(*) Longitude by wireless.
(**) Longitude by chronometer.