South African Journal of Science, *Vol. XXXIV, pp. 18-28, November, 1937.*

THE HISTORY OF LAND SURVEY IN SOUTH WEST AFRICA

BY

A. C. Parry,

Surveyor-General, Windhoek.

Presidential Address to Section A delivered 5 July, 1937.

With 1 Text Figure.

In introducing this subject, I propose to outline the events which led up to the time when the foundations of the geodetic survey of South West Africa were laid, and then to indicate the development which has been made with the trigonometrical and cadastral surveys.

Copies of a small scale map of the Territory, indicating the positions of the principal places which are referred to in this paper, are placed at the disposal of members for guidance. A further map of the Territory to the scale of 1/800000, showing the farming area and the main triangulations is also on view.

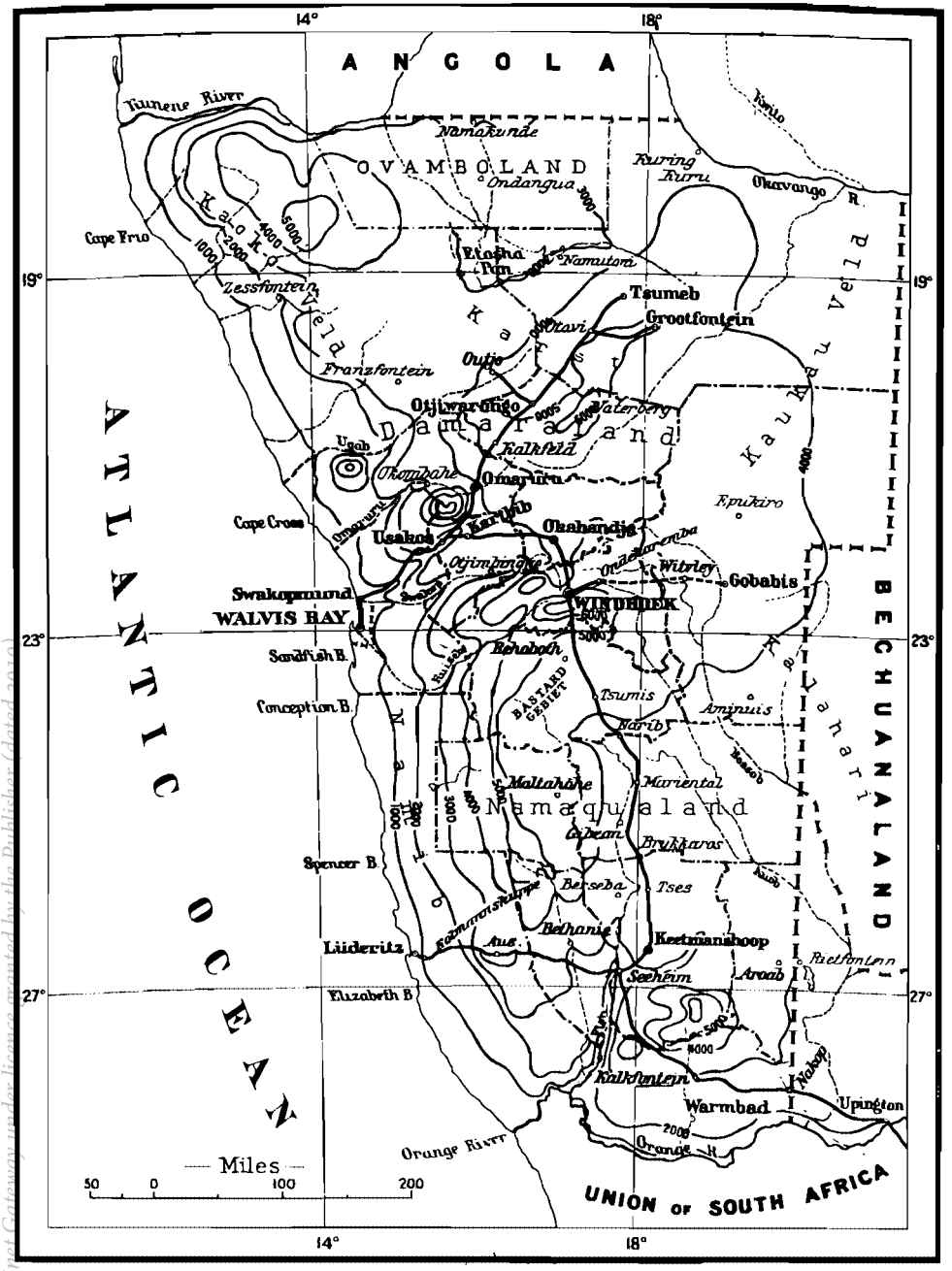
The Territory embraces an area of 317,725 square miles, and while the triangulations do not cover the whole Territory, the area covered is fairly extensive.

When South West Africa was occupied by the Imperial German Government in 1884, no survey work had been done in the country, but in the development of the country a need for surveys to compile correct maps and to obtain registered title to land was soon felt.

The first surveys of farms were undertaken in the year 1894, and owing to there being no primary triangulation, the farms were beaconed off by means of the compass and measuring band. Later in the year 1900 when larger blocks of farms were required, the triangulations were carried out from a local measured base and an arbitrary origin. In this way the district of Karibib and the western part of the district of Okahandja were surveyed into farms of about 5,000 hectares each on a special system called the Uitdraai System. The townships of Karibib and Okahandja were also surveyed on this system.

Further north, in the district of Grootfontein, the South West Africa Company had their land around Grootfontein and Otavi surveyed into farms in 1907 in a similar way.

During the years 1896 to 1898 a triangulation chain of a II Order, called the Wettstein Chain, was undertaken on a special system with one of its stations, Kaiser Wilhelm Berg, as origin. This chain extended from Windhoek south-westwards over a



SOUTH WEST AFRICA Altitudes - - 1000 Feet

distance of 80 miles to Nauchas, in the north-western parts of the district of Rehoboth.

Little further survey work was done on special systems before the geodetic survey was begun, and in carrying that out, the earlier surveys were connected with the primary triangulation.

The Geodetic Survey.

The first geodetic chain undertaken in the Territory was on the eastern border extending from the Orange River northwards to the 22nd parallel of south latitude, during the years 1898 to 1903. The purpose of this triangulation was designed in the first place to define the international boundary between South West Africa and British Bechuanaland. The Border is represented by the 20th meridian of east longitude between the Orange River and the 22nd parallel of south latitude, and by the 21st meridian to the north of the 22nd parallel.

For the purposes of the survey, Commissioners were appointed by the respective Governments under the direction of Sir David Gill, Her Majesty's Astronomer at the Cape at the time. The Commissioners assembled at the place Rietfontein, near the border, in the Gordonia District of the Cape Province. The geodetic survey of the Cape Province had been extended to this point, and the triangulation for the Border chain was extended from these stations at Rietfontein.

North of Rietfontein the 20th meridian crosses the Kalahari Desert, a tract of country intersected with sand dunes and flat and waterless for a distance of 300 miles or more.

The Commissioners, therefore, found it impossible to carry a triangulation along the 20th meridian. Further west the country was more suitable, and the Commissioners had practically no alternative but to arrange the triangulation north-westwards from Rietfontein, and follow the valleys of the Fish and Nosob rivers to Gobabis, and from there eastwards to the Border again, where it is intersected by the 22nd parallel. An offset chain was set out from the Nosob river over Aminuis to the Border.

During the survey the Border line was demarcated with beacons southwards from Rietfontein, at a point opposite Aminuis and in the neighbourhood of the 22nd parallel. The intervening portions of the line were not beaconed owing to the country being heavy and waterless, which made it impossible for the Commissioners to cross with the animal transport at their disposal. The line to the north of the 22nd parallel was also not beaconed for similar reasons. My Administration, however, has found it necessary, recently, to have the line located where it intersects the latitude 19°30′, and I shall be proceeding to this point during this month to determine its position from astronomical observation.

The final latitude, longitude and height above mean sea level of each of the stations of the Border chain were computed

from the geographical co-ordinates of the stations of the geodetic survey of the Cape at Rietfontein.

By this time the country was becoming more developed, and there was a need for better maps and more rigid surveys.

The Imperial German Government, therefore, in the year 1904, took steps for the carrying out of a systematic triangulation of the country which would form the basis and serve all requirements with regard to mapping and cadastral surveys.

The first work undertaken in this connection was the establishment of a double chain of triangles extending from Swakopmund over Windhoek and connecting with the Border chain at Gobabis. The chain covered a distance of 300 miles and involved 33 primary stations. The country over which the chain was carried was favourable for a large scale triangulation, and the triangles were arranged with the lengths of the sides averaging from 30 to 60 kilometres. Twelve arcs were observed of each angle of the triangles, and the average closing error of 41 triangles was 1·03 seconds. After adjustment the probable mean error of an observed angle was 1·29 seconds, and of an observed direction 0·91 seconds.

At Windhoek a base four kilometres long was measured, and the latitude, longitude and azimuth were determined. The correct time used for the calculation of the longitude was transmitted by cable and land line from the Capetown Observatory via Swakopmund.

The observed angles of the triangles were adjusted as a free chain with the length obtained from the measured base at Windhoek.

The Swakopmund-Gobabis chain connected with the Border chain at the stations Schwarzeck and Langer Forst, and a comparison was made with the latitude, longitude and azimuth of the Windhoek station determined from the astronomical observations and from the stations of the Border chain, with the following results:

Windhoek Station.	Astronomical.	Geodetic	Difference.
	° ′ ″	° ′ ″	″
Latitude ...	22 33 42·73	22 33 42·64	0·09
Longitude ...	17 05 03·05	17 05 00·95	2·10
Azimuth ...	291 32 39·0	291 32 36·7	2·3

These minor differences proved that there was no material displacement in the geographical position, and it was, therefore, decided to adopt the latitude and longitude of the station Schwarzeck, and the azimuth Schwarzeck-Langer Forst determined from the Border survey as the base for the geodetic surveys of the country.

The Border chain had been computed on Clarke's dimensions of the earth's figure, but as the Imperial authorities wished to use Bessel's dimensions to conform with the surveys in their

other possessions, the Border chain was recomputed on Bessel's dimensions with Schwarzeck as the starting point, for the purpose of the geodetic surveys in the country. The metre was adopted as the unit of measure, and is used still for all land surveys in the Territory.

The two geodetic chains now completed, namely, the Border chain and the Swakopmund-Gobabis chain, afforded a suitable base from which to extend others.

A chain of triangles was extended southwards from Windhoek to Bethanie, while another was brought across westwards from the Border chain in the vicinity of Keetmanshoop to connect with it at Bethanie and close the circuit. This chain was continued westwards from Bethanie to the coast at Luderitz, and a further chain was extended southwards from the Border chain at the Karasberg to link up with the geodetic survey of the Union along the Orange river. In the north a double chain of triangles extending from the Swakopmund-Gobabis chain at Omaruru and following the narrow gauge railway as far north as Grootfontein and Tsumeb has been established.

Heliotropes were used to furnish light from the stations observed, and 12 arcs were observed of each angle of the triangles. The beacons of the stations were constructed of cairns of loose stone built over the centre marks from two to three metres high, with a centre pipe carrying a sheet-iron signal. The centre marks were permanently marked in the ground with iron pegs in concrete or in holes drilled in solid rock. An eccentric mark was placed outside the beacon for control and similarly marked.

The geodetic surveys were carried out by the Imperial General Staff during the years 1904 to 1910, and all records of the field work were sent to Berlin, where the final computations were made.

The plan of the geodetic chain of the Union is shown on the map in a green colour, while the Border chain is shown in blue and the Swakopmund-Gobabis chain in yellow. The other chains referred to are printed in light red.*

With the establishment of these geodetic chains the greater part of the occupied area of the territory has been covered, and no further chains have been laid down since then.

In regard to the conditions in the country under which this work was carried out, I would emphasize the difficulties encountered. Conditions were primitive and parts of the country were entirely unoccupied. Until quite recently only animal transport could be used; there were very few roads, which were extremely bad and watering places were scarce. Great difficulty was, therefore, experienced by the field staff in moving about the country, and credit must be given to the officials and staff, who did the pioneer work under such adverse conditions.

---

* It was found impossible to publish the coloured map mentioned. The map on p. 19 has been substituted.—EDITOR.

Main Triangulations.

Having now a net of geodetic work in the country, the main triangulations have been confined to filling the open spaces and breaking down the large triangles with triangulations of the II and III Order.

These main triangulations are based entirely on the framework provided by the geodetic chains and constitute a basis for all cadastral and other surveys.

The trigonometrical surveys to date consist of a primary triangulation having an average length of a side of a triangle of 40 to 60 kilometres; a II Order triangulation with sides of 20 to 30 kilometres, and a III Order triangulation with sides of 10 to 18 kilometres.

A fair amount of the II and III Order work has been completed, but a great deal more requires to be done.

For economic reasons, the beacons of the primary and II and III Order stations consist of cairns of loose stone built over the centre mark with an iron pipe in the centre surmounted by a sheet-iron signal. The centre marks are permanently marked with an iron peg cemented into the ground or into a hole drilled in solid rock. Three reference marks are placed from one to three metres away from the centre mark for control and are similarly marked in the ground.

The observations are made with the 5½ inch Wild precision theodolite, which has proved itself to be very satisfactory. Twelve arcs of angles are observed for all primary work, while in the II Order triangulations eight arcs of angles of directions are observed and six arcs of angles of directions in the III Order triangulations.

Heliotropes are used to furnish light from the stations observed in all primary work, but it is found from experience that they are not necessary in the II and III Order triangulations, except where the background of the signal observed is not clear.

A triangulation net of the III Order was carried out last year at the Waterberg in the district of Otjiwarongo within the frame of five primary stations. The area was comparatively flat and covered with tall trees, and the only means of carrying out the work was by using an observation tower and elevated signals. Twenty-two stations were involved with an average length of the side of a triangle of 12 kilometres.

A signal fixed to the top of a two-inch pipe, 12 metres high, was erected over each station centre, while the surveyor used an observation tower seven metres high, which was transported from station to station. The theodolite was placed on an iron plate fixed to the signal pipe at a suitable height, after removing the upper section and signal, and six arcs of the angles of direction were observed at each station.

The mean closing error of the observed angles of 41 triangles was 1·2 seconds, and after adjustment of the net with the rectangular co-ordinate values of the primary stations, the probable mean error of a direction is 1·04 seconds.

A triangulation net of the II Order is at present being carried out in the Windhoek, Rehoboth and Gibeon districts to fill the open space between the geodetic chains. The reconnaissance and beacon building have been completed and the observing is in progress. The III Order triangulation within the II Order net is being carried out at the same time.

The Co-ordinate System.

Since the establishment of the main triangulations, the Gauss conform co-ordinate systems have been in use. In the first instance, two systems were introduced, namely, the intersections of the 15th and 18th meridians with the 22nd parallel of south latitude as origin. It was considered at the time that, with the large areas to be surveyed and the cheap value of the land, the inaccuracies caused by the greater distortion on the outer edges of the three-degree strip system would be immaterial.

In recent years, however, a change has been made to the two-degree strip system, which conforms with the systems adopted in the Union. The systems now in use, therefore, are the intersections of the 15th, 17th and 19th meridians with the 22nd parallel of south latitude as origin.

Adjustment of the Triangulation.

The adjustment of the triangulations of the I, II and III Order are made by the method of least squares. The II Order triangulation is adjusted within the framework of the I Order, while the III Order triangulation is adjusted within the framework of the I and II Orders.

Trigonometrical Levelling.

The vertical angles between stations of the main triangulation are observed during the same operations as the horizontal angles. Owing, however, to the great length of the sides of the primary triangles, the vertical angles are observed over the sides of the II and III Order triangles. The results of the trigonometrical levelling are satisfactory.

All heights are based on mean sea-level datum obtained from a series of observations taken at a tide guage at Swakopmund, and are expressed in metres.

The highest station in South West Africa is on the mountain Moltkeblick, south-east of Windhoek, the elevation of which is 2,483 metres, or 8,146 feet. The highest mountain in the Territory is the Brandburg, situate about 60 miles from the coast, north-east from Swakopmund. Its elevation is 2,606 metres or 8,550 feet.

Precise Levelling.

The precise levelling was begun in 1906, and the first line levelled was that from the tide gauge at Swakopmund along the railway line to Windhoek, a total distance of 378 kilometres. Bench marks are established at these two centres and at different points along the line. The mean error per kilometre is 1·23 mm.

The elevation of Windhoek railway station is 1,657 metres or 5,437 feet.

At present levelling is in progress from the rail head at Outjo, northwards to the border of Portuguese Angola, a total distance of 420 kilometres. The route being followed touches the western edge of the Etosha Pan and then proceeds north-westwards along the Oshana Etaka, which is one of the principal watercourses in that area. The instrument in use is a Zeiss precision level together with the Zeiss precision staves, which have graduations marked on an invar bar. The equipment is capable of very high precision.

The primary object of running this line of levels is to establish the levels of the Etosha Pan and of the flat country in Ovamboland on a sea-level datum. It is further desired to determine the direction of the flow of storm waters and the differences in altitude between different points in that area.

A site for a large dam on the Kunene river at Olushanja in Angola was surveyed in 1926, and by the extension of the levelling to the border, it will be possible to reduce the levels of the dam site to the same datum.

It is with much regret, however, I am not in a position to give any results at this stage.

Instruments.

Attention should be drawn to the great improvement in survey instruments, which has resulted in increasing accuracy and greater sped in carrying out the field work.

In the earlier surveys the theodolites used for the main triangulations were the 21 cm Hildebrand pattern, owing to the excessive weight of the larger instruments for the mountainous country. In recent years we have been able to procure theodolites by Wild of the 5½ inch pattern, which weigh only 50 lbs. They are capable of high accuracy, and are popular owing to their light weight and their rapidity of manipulation.

The time factor in observing is important in this country owing to the climate, where the haze makes conditions very difficult. The best time of the year for the long distance observations begins about February after the summer rains have fallen, and continues to the end of July.

Topographical Survey.

In 1905 a beginning was made with the topographical survey of the country, when certain areas around Usakos and Omaruru

in the north, the Windhoek district, and the western part of the Rehoboth district and the Gross Karas Mountains in the Keetmanshoop district in the south were surveyed.

The work was carried out by plane-table on 20 minute sheets to the scale of 1/100000.

The Diamond Area No. 1, bordering on the coast line at Luderitz, has also been topographically surveyed to the scale of 1/100000 by the Consolidated Diamond Mines, Ltd. A further topographical survey has been made by the Deutsche Kolonial Gesellschaft to the scale of 1/200000 of the districts of Swakopmund and a part of Omaruru.

The surveys were completed prior to 1920, and no further topographical work was undertaken till last year, when an area of 1,000 sq. miles covering the Klein Karas Mountains in the south was photographed from the air. A topographical map of the area is being prepared from the aerial photographs on the scale of 1/50000.

A further area of 1,000 sq. miles lying between Grootfontein and Tsumeb in the north, and covering the Otavi Mountains, is at present being photographed from the air for geological and topographical purposes.

Steps are being taken to extend the topographical survey with field parties operating with the plane table. Instead, however, of mapping the topography on the scale of 1/100000, the surveys will be done on ten-minute sheets to the scale of 1/50000, and the contour lines drawn at 25 metres vertical interval.

Cadastral Surveys.

As I have mentioned previously, the main triangulations are based entirely on the frame work provided by the geodetic chains. The cadastral surveys also are based on the main triangulations, and the co-ordinate values of all beacons in a system have a common origin.

The triangulation points for the farm surveys are classified as IV Order stations.

The surveys of the Government land into farms was carried out almost entirely by land surveyors attached to the Government staff prior to 1914. The land companies employed private surveyors for their work.

The surveys carried out in the early days on special systems have since been connected with the triangulations.

The greater part of the country extending northwards from the Orange river to north of Outjo and Tsumeb, with the exception of the Namib desert along the coast line and the Kaokoveld, has been cut up into farms. In the south, owing to the arid nature of the country the farms average from 10,000 to 20,000 hectares in extent, while in the central parts they average from

5,000 to 10,000 hectares, and in the north from 3,000 to 5,000 hectares. The total number of farms surveyed in the Territory is 3,906.

Mapping.

Amongst the maps on view is one signed by Theophilus Hahn in October, 1879. which I feel sure will be of particular interest. Mr. Hahn was a missionary, who travelled a great deal throughout the country before its occupation by Europeans. The map was compiled in the Surveyor-General's Office, Capetown, from data supplied by Mr. Hahn, and is remarkably accurate in detail.

Other interesting information is to be found in a " History of South West Africa," by Dr. Vedder, who has lived in the country for many years. This book contains maps which give information of the country as far as it was known in 1820 and during the period from 1820 to 1860. It also contains an up-to-date map of the Territory.

A useful map of South West Africa to the scale of 1/2000000 was prepared by Messrs. Sprigade & Moisel, of Germany, in 1912.

In 1911 a farm area map on the scale of 1/800000 was published, which shows all surveyed farms, railways, towns, magisterial districts and the principal rivers.

No further mapping of the Territory was undertaken till the year 1921, when the Administration brought out a new farm area map. Several revisions have been made since that date, and the latest is at present with the printers. The map on view shows the privately owned land in green colour and land leased by the Government in yellow.

Another map of the Territory prepared and issued by the Administration in the years 1925 to 1927 is the topo-cadastral map. It is prepared in separate sheets to the scale of 1/500000, each sheet covering two degrees. A great deal of useful information has been, and still is, being collected by reconnaissance work outside the surveyed areas for the purpose of this map.

The Administration has, further, prepared and issued the sheet S.F.33 (Windhoek) of the 1 in 1 million international series.

Survey Records.

In conclusion I should like to give a brief account of our system of keeping the records of surveys made.

In the first place the records of all surveys must be submitted to the Surveyor-General for filing of record. When a survey has been completed, the records are indexed and bound in volumes. Every survey station and beacon is given a distinctive name or number. It is the practice to give names to the stations of the I, II and III Order, and numbers to the points of the IV and lesser Orders. The numbering of the points was first arranged for each magisterial district, but this has been found

unsatisfactory, and the practice at present is to number the IV and lesser Order points consecutively in each two-degree square. A beacon index is opened for each such square, in which every station and beacon falling within the area is entered, and the particulars with regard to the co-ordinate values and where the relative angle books and calculations are filled, are noted opposite each point.

For the purpose of recording the farm surveys and triangulations on plan, the two-degree square is divided into farm areas. A general plan of each area is framed to the scale of 1/100000 with the record of the farm boundaries and all survey points. The record of the triangulation is arranged on separate sheets, covering the same areas, and all the survey points and the observed directions are indicated on it.