The Belgian Contribution to the 30th Meridian Arc in Africa

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Key words : Africa, 30th Meridian Arc Measurement, Anglo-Belgian or Congo-Uganda

SUMMARY

The Academie des Sciences in Paris promoted the scientific expeditions to go and to measure the arc of a meridian near the Pole – Lapland (1736-7), the Equator – Peru (1735-45) and in the southern part of Africa, in the Cape Colony

This latter arc was measured by Nicolas de la Caille when he was there on an expedition to chart 10000 stars as seen in the southern hemisphere. It was remeasured and extended by Maclear (1837-47). Towards the end of the 19th century David Gill instigated the measurement the southern part of what was to become the Arc of the 30th Meridian.

The aim of F.G.W. Struve and D. Gill to liaison the northern part of Europe with the southern part of Africa, was realised over a century later.

The Belgian contribution in the eastern part of Central Africa (in former Belgian Congo), 1908-09 was between 1°11′ N and 1°11′ S. The Belgians Wangermee and Dehalu were mainly involved with astronomical and some geodetic observations. Between 1930-35 Maury and Verlinden carried out the reconnaissance between 1° S and 4°30′ S.

RESUME

Avant toute chose, il y a lieu de remettre la mesure des Arcs de Méridien dans leur contexte historique de la recherche de la figure de la terre. Depuis les philosophes grecs et après l'application de l'intersection par Gemma Frisius de Louvain, dès 1533 la cartographie scientifique fut appliquée. Après la méridienne de Picard les grandes expéditions en Equateur et en Laponie, l'Académie des Sciences voulait une mesure du méridien dans la partie australe, ce qui fut réalisé par l'Abbé de la Caille, ce fut le départ de ce qui devait devenir bien plus tard la mesure du 30e degré du méridien à travers l'Afrique.

La collaboration Anglo-Belge en début du 20e siècle est développée en fin d'article.

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1. INTRODUCTION

The 30th Arc of Meridian was only finalised in the 20th century and the link with the European network just after World War II, but its history started a couple of centuries earlier near Cape Town in Southern Africa.
In 1666 the Academie des Sciences was introduced in France by Colbert and the King Louis XIV to promote science. The Observatory of Paris was one of the early achievements.
The Academicians discussed the figure of the earth and its implications for cartography, but mainly for security, travel and commerce, infrastructure and navigation.
The first meridian measurement was conducted by Abbé Picard (1668-70) from Paris to Amiens, and concluded that 1° of meridian = 57007 toises (de Paris) converted to 57060 t.

This exercise was enlarged by Abbé de la Caille to Dunkirk (1718), and by Cassini I & II to Collioure, to embrace a larger meridian. Results :

Paris – Dunkirk : 1° = 56960 t.
Paris – Collioure : 1° = 57096 t.

to form a meridian of ± 8° 30′ and was later extended to Barcelona 8° 45′ and to the Balearic Islands by Mechain (1803) and Arago and Biot in 1808 – 1809.
The well known controversy about the earth – is it prolate or oblate – was introduced by the calculation of Eisenschmidt in 1691 and did not cease until 1736. With others it forced the Academie des Sciences to prepare the expeditions to the Equator and to the Pole, well known as the « Peru » (1735-45) and « Lapland » (1736) expeditions. These themes have been developed by the International Institution for the History of Surveying and Measurement in previous seminars over recent years in the FIG conferences and by Jim Smith' book *From Plane to Spheroid.*
By comparing the results the question arose : but what happens in the southern part of the earth ?
Clairaut in 1743 raised the question of the hydrostatic equilibrium in his *Théorie de la figure de la terre, tirée des principles de l'hydrostatique*. So the Academie des Sciences sent Abbé Nicolas de la Caille to South-Africa to measure 1° of a meridian near the Cape in 1751. (Fig.1)

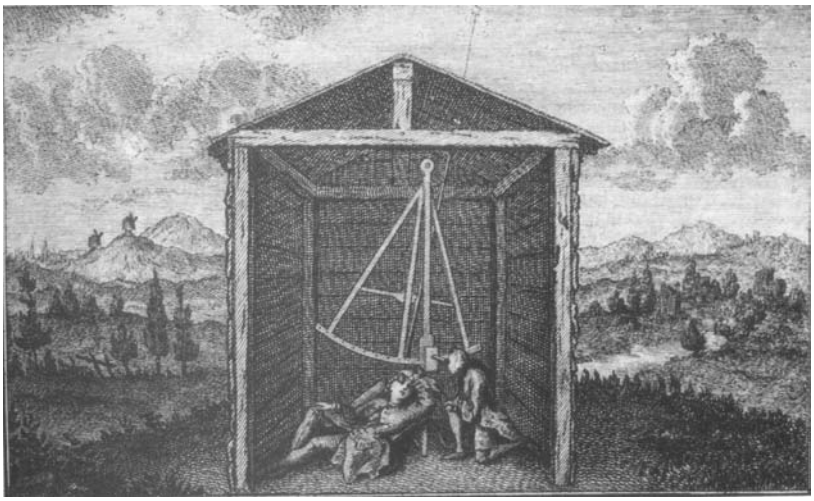

Fig. 1 La Caille observing

His measurement at a latitude of 33° 18′ south, over an amplitude of 1º13′17″.3 gave a result of 1° = 57037 toises corrected to 56906 toises, and he also measured with the second pendulum to determine gravity by correcting the length of the pendulum : G = 9,7978 by de la Caille, actually 9,7963.

The Abbé Nicolas de la Caille came to South Africa mainly to observe the southern skies, he had already the experience of measuring the extension of the meridian of Picard to Dunkirk and without prior discussion one of his first projects on arriving at the Cape was to consider the measurement of a meridian arc.

Prior to travelling to South Africa de la Caille had published other works :

a. 1744 : The Ephemerides from 1744 to 1754
b. 1746 : *Leçon Elémentaire d'Astronomie, Géométrique & Physique*
c. 1748 : he contributed to the Mémoires of the Academie
d. 1749 : Bouguer published *La Figure de la Terre* confirming his Peru arc results
e. 1750 : *Leçon Elémentaire d'Optique, and Avis aux Astronomes*, where he said he travels to the southern hemisphere par ordre du Roy
f. 1751 : La Condamine : *Journal du voyage par ordre du Roy à l'Equateur : 3 premiers degrés du Méridien*.
g. 1753 : *Observations faites au Cap de Bonne-Espérance, pour en déterminer le parallaxe de la lune, de mars et de vénus*
h. 1754 : the second Ephemerides tables from 1755 to 1764
i. 1757 : *Astronomiae fondamenta novissimis solis et Stellarum Observationibus stabilita …*

Résumé des valeurs des arcs de méridien mesurés au XVIIe et XVIIIe siècle

Arc	Observateurs	Epoque	Latitude moyenne	Amplitude	Longueur (toises)	1º observé (toises)	1degré théorique
Paris-Amiens	Picard	1670	49º 23′	1º 11′ 57″	68 348	57 007*	57 063
Paris-Amiens	Cassini I & II	1700	49 23	-		56 973*	57 063
Paris-Amiens	Le Monnier	1740	49 23	1 01 12	58 327	57 087*	57 063
Paris-Amiens	La Caille & Cassini III	1740	49 23	-		57 074	57 063
Paris – Collioure	Cassini I & II	1700	45 40	6 18 57		57 040*	57 025
Laponie	Maupertuis et al	1737	66 20	57 28.7	55 023.47	57 438	57 215
Le Cap	La Caille	1751	-33 18	1 13 17.3	69 669.5	57 037	56 906
Pérou	Bouguer La Condamine	1743	-1 30	3 07 03.1	176 945	56 737	56 733
Pérou	Godin	1743	-1 30	2 40 55	152 262	56 751.6	56 733
Pérou	Juan-Ulloa	1743	-1 30	3 26 52.7	195 734.5	56 768	56 733
Rimini	Boscovitch	1755	43 00	2 09 47	123221.3	56 966	56 999
Laponie	Svanberg	1802	66 20	1 37 19.6	92 777.98	57 196	57 214

Fig. 2 Resume of values for the length of 1º

In the Cape Colony he made a choice for his baseline of = 6457,25 toises = 41355,44 (English feet). It was north of Darling and formed his triangles to Riebeck Castel and Capocberg and to his observatory in Strand Street in Cape Town ; north to Klipfontein near Picqueberg, north of Aurora. The results are seen on Fig. 2.
He made 4 triangles. He used a 6 ft sector which is still preserved in the Paris Observatory.
Fig. 3, is the map with de la Caille's triangulation. The results revealed that in the southern hemisphere the earth was shaped not as an orange, as in France, but had an elongated shape like a pear. In fact his most northern station was influenced by the proximity of the Picqueberg for the plumbline which was deviated by the mass of the mountain.
George Everest, while in the Cape on a year's sick leave from India, took an interest in trying to resolve the problem that La Caille's result had highlighted. He searched for the baseline of Abbé de la Caille but could not find it. : see Jim Smith : *Everest, the Man and the Mountain.*

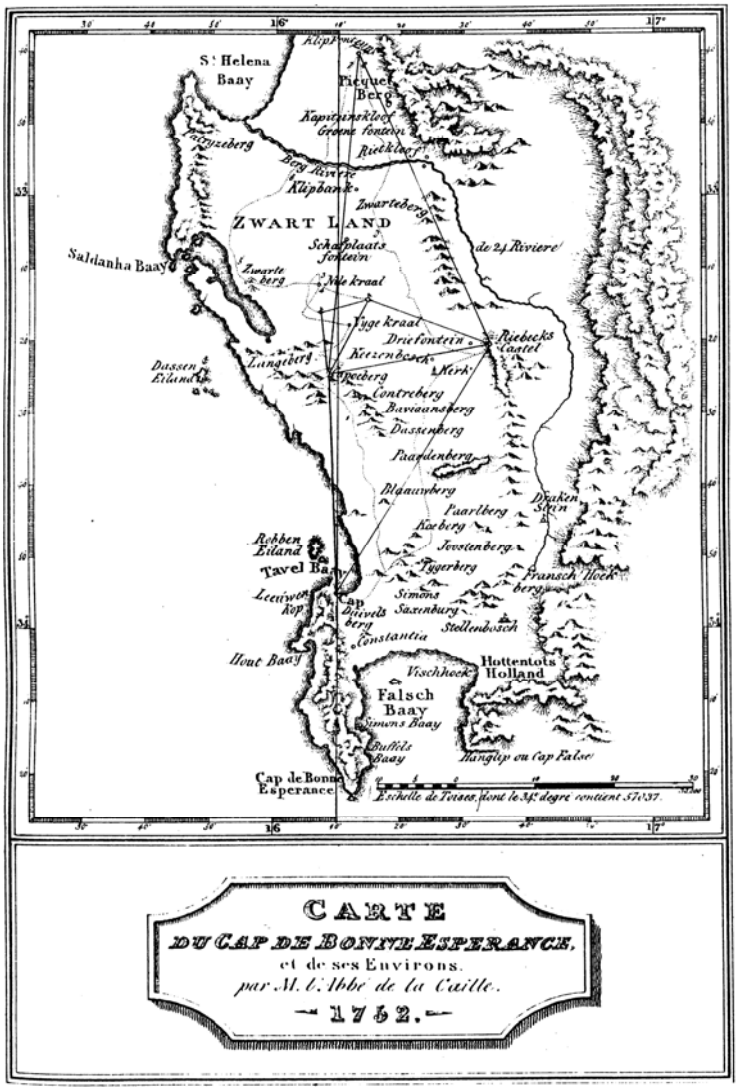

Fig. 3. La Caille's triangulation at the Cape

Maclear was the second scientist to play a major role in the early meridian measurement in South-Africa. (Fig.4)

Fig. 4. Sir Thomas Maclear

In 2004 the Institution of Professional Land Surveyors & Geomaticians of the Western Cape organised its 2nd symposium on history of surveying : *History of Surveying and Land Tenure.*
At the first symposium in 1984 I was honoured to give a paper in Stellenbosch on the theoretical knowledge of land-surveying in the period of the first settlers and Professor Roger Fisher was already of that party presenting the 12 first land parcels measured in Cape in the period of Van Riebeck. Prof. Fisher's paper was *Land Surveyors and Land Tenure at the Cape 1657-1812.* Jim Smith as you know, participated in the follow-up 2nd symposium in 2004 with Thomas Zakiewicz, we will hear later after my paper.
Maclear was well aware of the deviation of the plumbline by the mass so he was instructed to check the work of de la Caille. Maclear as Everest had failed to find the baseline of de la Caille, so he measured a similar but longer baseline 42818,75 (English) feet and measured a similar pattern of triangles but could not terminate his triangle at de la Cailles'observatory as a new building prevented this link. Instead he linked the Observatory of de la Caille with the Royal Observatory, the Herschels' Observatory and Kings Battery.
We have already referred to the deviation of the plumbline, due to mass.
Maclear found the deviation error that affected de la Caille results to be +7 seconds of Arc in the northern point and –1 second in the southern point, due to the proximity of Table-mountain : -8″ in total. Very similar to the value of 9″ that Everest calculated it should be.
Already Bouguer in Peru had observed a differential deviation (although he did not know what is was) but attributed the difference to the missing mass of the volcano that was empty in comparison with other mountains of the Andes.
Maclear requested permission to extend the measurement of the arc to 4° 30′ W to Cape Aghulas in the south and beyond Springbok in the North. He was the second to contribute to the meridian measurement in Southern Africa. He was also known to have instructed David Livingstone to use the sextant and to fix the latitudes and so find his position, with the sextant.

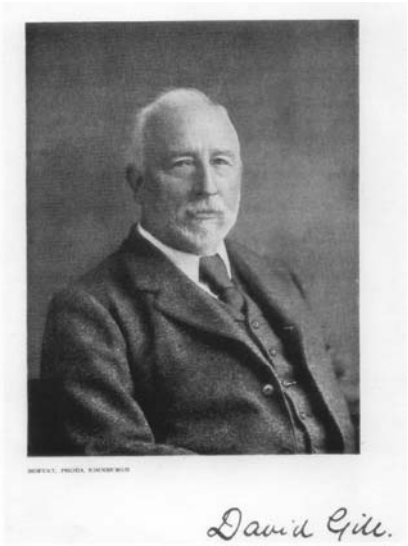

Fig. 5. Sir David Gill

The third was Sir David Gill. (Fig.5)
Son of a Scotch watchmaker he graduated in electricity under James Maxwell and improved the Aberdeen time service. He build Lord Lindsay's Observatory near Aberdeen. On his return from Mauritius in 1874, Gill stopped in Cairo and joined the Egyptian officials to assist the measurement of a geodetic baseline near Cairo of about 1km long .
This was his first task in geodesy.
In 1878 he applied to become the Her Majesty's Astronomer at the Cape of Good Hope where he arrived in 1879, at 37 years of age.
He had been inspired by Friederich George Wilhelm STRUVE – who measured the Struve meridian Arc from Fuglenaes (near Hammerfest) to Staro-Nekrassowka (near Ismail on the Black Sea) :2820 km, through 10 countries in the first half of the 19th century.
As you know, our International Institution for the History of Surveying & Measurement has prepared the work for F.I.G. and the 10 countries involved to preserve the Struve Meridian Arc and to inscribe it on the World Heritage Monument List. The decision on this will be known this July.
It was the successful aim of F.G.W. Struve to measure from the North Cape to the Black Sea and later his son Otto had prepared the link between the southern part of the Struve Arc to Crete. Our research conducted by Jim Smith, is looking for the link(s).
For the moment we know by the I.A.G. and other reports that Otto Struve carried out the reconnaissance of the terrestial link through Roumania, Bulgaria, Greece and Turkey to Crete in 1868 but there appears to be no record that it was effectively measured.
Between the two World Wars a further meridian arc was measured somewhat parallel to the Struve Arc and coincident with it at several points in what was then Poland, but is now mostly Belarus. This joined to Crete via the then Czechoslovakia, Roumania, Yugoslavia and Greece.
We would like the assistance of the concerned countries to look in their archives for evidence and we would be glad to offer them the floor here or next year in Munich 2006 Congress.
Gill's first years were essential.
He had studied the Struve Arc measurement : *Arc de Meridien de 25° 20′ entre le Danube et la Mer Glaciale, mesuré depuis 1816 jusqu'en 1855, sous la direction du Général C. de Tenner, Chr. Hansteen, N.H. Selander et F.G.W. Struve – St Petersburg 1857 / 60.* It is further thought that he corresponded extensively with Otto Struve so he would have been aware of the plans to extend southwards.
The other great meridian, measured in India and known as the Great Arc was finished by Sir George Everest : *An account of the measurement of an Arc of the Meridian between parallels of 18° 3′ and 24° 7′ being a continuation of the great meridian, Arc of India as detailed by the late Lieute(nant) Col(onel) Lambton in the volumes of the Asiatic Society of Calcutta* – London 1830.
By that time also the methodology of Delambre : *Méthode analytique pour la détermination d'un arc de méridien – 1799*, had laid the foundations for the meridian measurement for the next century.
Gill considered it part of his duty as a Royal Astronomer to advance the geodetic survey of South Africa, both as an extension of Maclear's work and to create a geodetic order of triangulation to connect the 4 provinces in an accurate and integrated way : « the framework of principles on geodetic quality triangulation applicable to the whole of South-Africa ».

In his memorandum to the governor he concluded : « the geodetic plan as a first step in a chain of triangulation, that could connect Natal to Alexandria » his dream of a 30th Arc of Meridian up the great Rift Valley that would cover 65° of latitude.
His proceedings are preserved in 5 volumes (1883 to 1907) and a 6th volume concerning the Southern Rhodesian part, published in 1933.
Gill replaced the 18 inch Troughton & Simms theodolite of 1882 by a 10 inch Repsold theodolite, now preserved in Cape Town. In Repsold we read (p. 46) : « in the meantime a series of new geodetic instruments were introduced, including an universal instrument « mit sicherheitsrohr von 1886 » that was used by the South Africa survey under Gill. (also in Russia this instrument is improved with a micrometer on the vertical supports) » not applicable in the RSA theodolite. (See Fig.6)

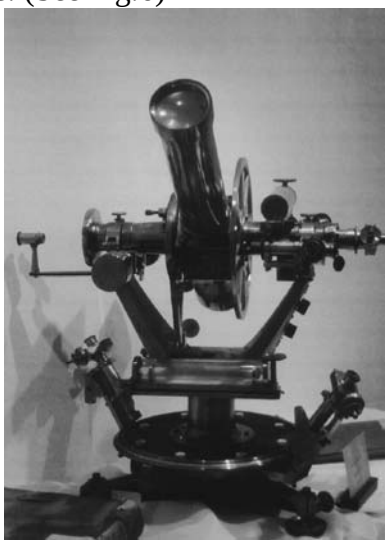

Fig.6. The Repsold 10 inch theodolite of 1864

You may have read, ladies and gentlemen, a book : *The adventures of Three Englishmen and Three Russians in South Africa, by Jules Verne,* published by Hertzel, where the names have been correlated to the Struve Arc measurement.
The 3 Russians : Mr Mathieu Strux, Nicolas Palander, Michel Zorn, to compare with Struve, Selander and …
The adventures to measure 8° meridian arc from the Orange River to the Zambesi is a novel inspired by the trigonometric arc measurements by Gill and his colleagues « à la sauce française ».

* * *

In 1900 in Paris, Sir David Gill presented the results of his triangulation measurement, at the International Conference for Geodesy along the 30th meridian from Southern Rhodesia to the Lake Tanganyika. At this conference David Gill proposed **to extend the 30th meridian triangulation over all of Africa and to extend it by the Struve Arc to Norway and so form a triangulation of 104°.** The project F.G.W. Struve had already proposed in the eighteen-sixties, but then it was only wishful thinking. At the 1903 conference, in

Copenhagen, the German delegation was willing to cooperate but was lacking funds and finally they did not take part.
This Anglo-Belgian cooperation came in a period where that central part of Africa was artificially divided by England, Germany and Belgium and some meridians form the Angola land border with South-Africa and the border between Egypt and Libya, the northern boundary of Sudan with Tchad, Namibia and Botswana, Angola and former Zambia, etc. are formed by meridians or great circles.
In 1906 – 07, the joint boundary commission under Lt. Col. Bright was operating near the 30th meridian, between Lake Albert and 1° south. It seemed a good opportunity to Sir Herbert Read to use the operations of this joint commission to perform a part of the 30th meridian arc measurement, to which both governments agreed. The measurements of 1907-08 concern the triangulation for south of Lake Albert at 1°10′ south of the Equator along the Ruwenzori-mountains (at 5000 m high) through the Kagera to end in the north part of the former German East-Africa territories.
The English party, was conducted by Capt. Jack, assisted by McCaw and Mr. Dehalu from Liège University, assisted by Mr Wangermee for the Belgian part.

Both parties measured jointly the baseline Makog – Kibuku for ± 16,50 km near Semliki. The geodetic measures were performed by the English party most sides of the triangles were ± 50 km, and were published by the Colonial Survey Committee as : *Report of the measurement of an arc of meridian in Uganda, vol 1* in 1912 : base measurement, horizontal and vertical angles and the geodetic calculations and the use of invar wires in the Colonies.
The results of the Belgian party were published in volume 2 : The Astronomical data in the Academie Royale de Belgique : *Observations astronomiques faites à l'occasion de la mesure d'un arc Equatorial de Méridien en Afrique, Brussels – 1926*. (See Fig.7)

Latitudes

Point	Dates	Instrument	Total pairs of stars each evening	Nos. of distinct pairs	Latitude	p.e.
Muruha	17.05.1908 02.06.1908	Repsold II	32	17	+00º 57′ 00.65″	± 0.10″
Isura	27.06.1908 03.07.1908	Repsold II	15	11	+01 10 23.39	± 0.165
Omunturok	24.07.1908 09.08.1908	Repsold I	30	13	+00 59 18.165	± 0.07
Oruha	11-16.10.1908	Zenith telescope	28	20	+00 39 10.025	± 0.115
Karangora	29.10.1908	Zenith telescope	14	14	+00 38 27.585	± 0.205
N'Kenda	11.11.1908 18.12.1908	Zenith telescope	54	48	+00 14 37.55	± 0.065
Kabuga	27-28.12.1908	Zenith telescope	49	34	+00 13 21.765	± 0.085
Singiro	05-07.01.1909	Zenith telescope	49	40	-00 15 38.325	± 0.10
Kasunju	14-17.01.1909	Zenith telescope	59	49	-00 19 18.125	± 0.095
Kiara	26.01.1909	Zenith telescope	38	38	-00 43 10.665	± 0.075
Nyarawari	31.01.1909 01.02.1909	Zenith telescope	47	30	-01 03 30.875	± 0.085
Igurua	04.02.1909	Zenith telescope	10	10	-00 57 18.495	± 0.115
Kikerere	10.02.1909 18.02.1909	Zenith telescope	56	48	-01 10 42.79	± 0.08
Karamrani	26-27.02.1909	Zenith telescope	33	31	-00 43 11.445	± 0.095

Fig. 7. Results of Anglo-Belgian cooperation

By this time the Bureau International des Poids & Mesures had printed : *La Mesure rapide des bases géodésiques, by J. René Benoit et Ch.Ed. Guillaume, Paris –1908 : Gauthier Villars*, écrit après le percement du Tunnel du Simplon.

The instruments used for this geodetic and astronomical observations :

- Repsold theodolites I & II, to which was added a Zenithal Telescope.

The geodetic measurements were executed by MacCaw and Cpt. Jack, who in Omunturok did 8 azimuth determinations. All the others and in the other points : the azimuth, the zenith and gravimetry readings were performed by Dehalu and Wangermee. Observation of latitudes and all the astronomical observations, were performed by Repsold I, in Omunturok and by Repsold II in Muruha on Isura only, all the others by the Zenithal telescope.

The determination for azimuth :
- in Omunturok by Repsold I theodolite,
- in N'Kenda by zenithal sector,
- in Kikerere by Repsold II theodolite.

The latitude determination in 14 points, was based on the method of Horrebow – Talcott, applied to a pair of stars culminating near the meridian near the zenith and was performed in each of the station-points to correct the deviation of the vertical line. Magnetic observation were performed as well. This method depends upon precise levelling during all the procedure. A special construction was build with a double floor, one of which was independant for the observers so the weight of the observer had no influence on the stability and position of the instrument.

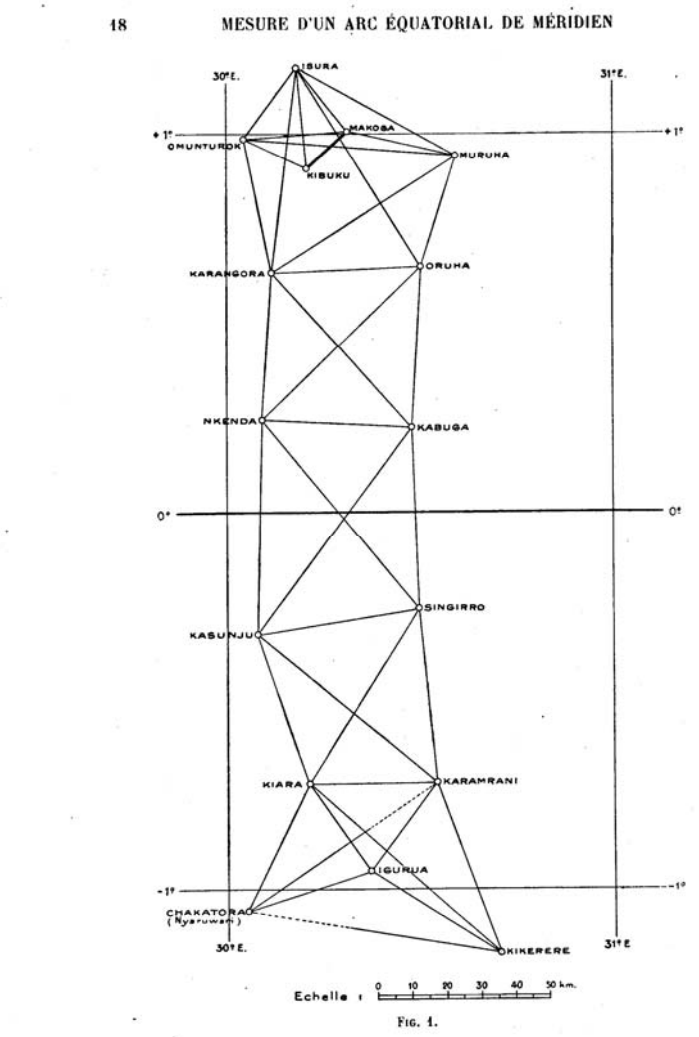

FIG. 1.

Fig.8. Map of Anglo-Belgian cooperation

For the azimuth determination in Omunturok, the method recommended by Sir David Gill, was in use : « You observe the passing through the first vertical of 2 stars, one east and one west, continued with measures on 2 basis-points east and west ».
This method has some disadvantages and was no longer followed in Kikerere and N'Kenda. Due to the eccentricity of the telescopes, two series of measures left and right were taken, the instrumental errors were carefully examined. (Fig.8.)
We have seen that one of the major errors in astronomical determination was the deviation of the plumbline. This was avoided by the methodology of the modern equipment which was based on the perpendicularity to the horizontal line and was therefore independent of gravity.
Due to the proximity of the Ruwenzori at ± 5000 m the deviation of the vertical was + and – 20″ in a distance of 50 km ! this corresponds to an error in the field of 1200 m in length.
In 1930 « in Africa a first geodetic network of first order existed in Algeria, Morocco and Tunisia by the French. A second starts from Egypt along the Nile till Asouan and a third from Cape Colony, Orange, Basutoland and Transvaal and further along the 30th meridian to 10° south in Northern Rhodesia, and further along this meridian the Uganda – Congo meridian from –1°,1 to +1°,1 of the equator (the Anglo-Belgian meridian)
In 1909 the Egyptian Government starting from Cairo, measured a 2° triangulation along the 30th meridian. So in 1910, Sir David Gill announced that only two links, from Egypt to the Anglo-Belgian triangulation and south to Rhodesia had to been finished.
The political events changed and Germany was dispossessed of its East African territories. In a speech before the Academie of Science in Brussels, Mr Dehalu proposed in 1930 to continue the triangulation from Rhodesia to the lakes not by the west but through the east territories of Ruanda and Urundi; east of the great lakes and so to join over 10° to the Egyptian border. A substantial budget was prepared but the financial crash has changed the goodwill of the scientist.
In 1914, the oriental border of Ruanda – Urundi was linked to the Uganda – Congo meridian in Igura – Kikerere and on the Tanganyika side near Nyanza along the eastern border of the lake to the northern part of Rhodesia, Mapage – Kanyawakadi till Lukuga. The calculations have been executed jointly by the Geographical Service of the War Office (in England) and the Cartographic Service of the Minister of Colonies (in Belgium).
In 1930, the Anglo-Belgian cooperation wanted to proceed to the extension of the Uganda – Congo meridian as it was then called :

1) south through Ruanda – Urundi till the valley of Malegrozi where a control base would be measured by the Belgians,
2) north along the Lake Albert till Mahagi by the English. The Geographical Service would extend to the Rhodesian Arc south and north to Egypt.

For Belgian Congo the 30th meridian will give a rigid framework on its oriental border. It would be linked with the 6° parallel south to give a cross continental framework from Banana to Dar-es-Salaam and a rigid system of first degree triangulations.
The calibration of the instruments was in the 19th early 20th century, a very important component of the measuring techniques, also the multiplication of circle reading operations to avoid instrumental errors and to compare them by measuring one way and returning the instrument. The calculations also made great progress and the least squares adjustments (calcul des moindres carrés) were every day practise.

Although the 2 degrees are just a small part of the 30th meridian arc through Africa they have been an essential link between the northern and southern parts surveyed by the English surveyors and confirms the transborder cooperation of governments for scientific purposes.
The 30th Arc has been completed and the link with the Struve Arc in Europe in the nineteen fifties, but that is another story.

* * *

We have been working hard to preserve the Struve Geodetic Arc points in Europe over the last 10 years since the F.I.G. meeting in Melbourne, proposed and agreed to inscribe the Struve Geodetic Arc on the World Heritage List of Humanity.
In Durban this summer, the UNESCO delegates will vote on this project.
Can we ask each of you to contact your respective national delegate to the UNESCO to encourage him or her to vote in favour of the Struve Geodetic Arc preservation and inscription.
This will be the first scientific instrument to be inscribed on the World Heritage list.

With your help and the delegates of the African countries from Egypt to South-Africa all along the 30th arc we have work to do to find the original points measured in the 19th and 20th centuries, to protect and preserve them within your national inventories. We are willing to help each and all of you to work together to prepare the presentation of the 30th meridian arc to the World Heritage Monuments Commission with the link between Europe and Africa to preserve this unique meridian over 104° degrees « the largest great arc of meridian to be measured on the earth » as said Sir David Gill and Friedrich George Wilhelm Struve.

Note : All names have been written as read in different books, atlases and references but due to political changes many of these might have been called different over history and to-day.

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