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The backbone of colonial mapping in Eastern Africa

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Abstract

The backbone to any mapping is a good skeleton of triangulation stations over the area concerned. In a number of instances this has been a meridian arc measurement. This paper concentrates on the description of the 30th Arc in East Africa. The only other comparable Colonial Arc was that through the centre of India by Lambton and Everest between 1800 and 1843. The usefulness of such arcs was highlighted in 2005 with the inscription by UNESCO of the Struve Geodetic Arc on the World Heritage Monument list. The 30th Arc is a possible extension to the Struve Arc Monument. Braun, at the ICA gathering in Cape Town in 2003, detailed the political machinations of the 75 year history of the 30th Arc; here it is hoped to fill in other aspects including some facts and figures.

The Indian Arc took 43 years to complete but the African Arc took 75 years. The 125th anniversary of the inception of the 30th Arc was celebrated in 2005 as was the 50th anniversary of its completion. Such long-term projects illustrate the dedication of the participants in striving towards goals, the fruits of which, they may not live to see.

Background

The measurement of the Arc of the 30th Meridian of east longitude was initiated by Sir David Gill (1843-1914), while Her Majesty's Astronomer at the Royal Observatory at the Cape of Good Hope between 1879 and 1907. He visualised this project as very important for practical as well as for scientific purposes. Gill's idea was to extend a chain of triangles from the Cape to Egypt and even further north to the Arctic Ocean. The geodetic survey of South Africa, which formed the southern end of this arc, commenced in 1883. The last remaining gap of about 1000 km in the chain of triangulation, between Sudan and Uganda, was surveyed in 1954. By this time the tie across the Mediterranean Sea connected the European Datum with the primary Arc of the 30th Meridian, thus realising some of Gill's vision. This paper gives an historical review of the great project. Comment is also made on the contribution of this Arc towards all countries concerned and the advancement of geodesy. [**14**]

The paper brings together from a variety of sources the sequence of events that led from the original idea of a chain of triangulation in Cape Colony to the Arc along the 30th Meridian across British Imperial Africa, through the lengthy period of its observation, frustrated by many setbacks in funding, to its final completion in impressive style by the United States military forces. It notes with some sadness that, though this major geodetic enterprise was computed as a whole by the US Army Map

Service, no analysis appears to have been published that would cast any light on the precision of the results that were achieved [**8**] Braun, [**3**] at the ICA gathering in Cape Town in 2003, detailed the political machinations of the 75 year history of the 30th Arc; here it is hoped to fill in other aspects of this work including some facts and figures. After all, surveying is a profession of number gathering and crunching.

LaCaille, Everest and Maclear

It was in 1752 that l'Abbé de LaCaille (1713-1762) a French astronomer, measured a short arc of a meridian near Cape Town. This was not part of the future Arc of 30th meridian as it was more nearly at 18½º than 30ºE. Although his primary aim while at the Cape was to catalogue 10 000 stars of the Southern Hemisphere he was also interested to investigate how the shape of the area south of the Equator compared to that to the north. Were the hemispheres identical, i.e. both flattened by the same ratio, or was one nearer spherical than the other ?.

No words such as "surveying", "geodesy" or "triangulation" appeared in his intentions when he left Paris but maybe it was felt that such ideas might inflame the authorities who were wary as to the intentions of foreigners on their territory, or perhaps LaCaille originally thought that he would have no time for such activity.

Whatever the reasons he did manage to observe an arc of 1º 13 ? 17.3 ? of length 69 669.1 toises to give the length of a single degree of arc as 1º = 57 037 t. Unfortunately when this was compared with the arcs of the northern hemisphere it did not fit with expectations. Was the southern polar radius really longer than its equatorial radius? i.e. contrary to that found in the northern hemisphere and more in line with the original thinking of the Cassinis in Paris?

This particular question was not answered until 1820-1 when George Everest (of mountain fame) was in the Cape for a year of convalescence. Not one to sit around even when recovering from the ravages of the jungles of India, Everest gathered all that he could find of the material relating to LaCaille's work. This was nowhere near 100 per cent since much had gone back to Paris.

> … instead of seeking his own ease and amusement he employed himself in objects connected with his professional pursuits… [**12**] p.27.

From visits to the sites of LaCaille's stations, studying what written evidence there was considering the terrain he concluded that the effects of the mountains near each terminal of the Arc upon the plumb line could amount to almost 9 seconds of arc. [**12**] Whilst this was not the complete story he was correct in his deductions except that the value he used for LaCaille's arc length in feet was taken from Hutton's *Philosophical Dictionary* of 1795 where unbeknown to Everest it contained a typographical error – given as 410 814 instead of 418 014 French feet which Everest turned to toises as 68 469 instead of the 69 669 toises. The erroneous figure was perpetuated in various notable publications until it was uncovered in 1990. [**11**] Luckily it did not greatly affect his deductions.

Verification of Everest's findings came in 1841-48 when Sir Thomas Maclear, Her Majesty's Astronomer at the Cape, extended LaCaille's triangulation south to Cape point and north to Koeberg. This gave an Arc length of 4º 37 ?. For the measurement of the angles of his triangulation Maclear often made 100 repetitions of the angle and in one case 800. [**1**] p. 31. From his results he declared that LaCaille's baseline was 2 t too long in a length of 6 467 t, which seems hardly credible considering the care taken by LaCaille. [**13**]. This would suggest one possibility that the measuring bars – each of 18 ft- were in error by an amount of about 2+ mm equivalent. This would be by no means the only possibility so there is no point in stretching this idea.

Other than some triangulation by Bailey in 1859 of the south east coast of the Colony nothing further happened until Gill came on the scene in 1879. As Lacaille and Maclear before him, so Gill went to the Cape Colony as an astronomer albeit Her Majesty's Astronomer at the Cape, rather than as a surveyor. However, so often in the history of surveying the notable activities in geodesy were achieved by astronomers and Gill was no exception. He had some practical experience of geodesy before arriving in S Africa and had made contact with many of the leading astronomers of Europe – particularly Otto Struve, son of the Struve who observed the arc from North Cape to the Black Sea. They both had dreams. Otto Struve to extend his father's arc south and Gill to observe an arc not only from the Cape to Cairo but for it to be extended further to join the Struve arc and result in a continuous triangulation from near Port Elizabeth in S Africa to near Hammerfest in N Norway.

Gill's dream

Within four months of his arrival at the Cape Gill put a memorandum to the Governor giving in great detail his grand scheme of principal triangulation and putting various recommendations for the future. These included:

> A plan of value in a geodetic sense as contributing to our knowledge of the form and dimensions of the earth. The general principle of which is that upon which the Great Trigonometrical Survey of India is founded, viz the construction of chains of triangles in meridian and longitude series, and along coast and boundary lines. [**1**] p.4

> I look upon this as the first step in a chain of triangles which ultimately will connect Natal with the Mediterranean and Alexandria. [**1**] p.8

Later Gill went even further:

> ... But this is not all. By an additional chain of triangles from Egypt along the coast of the Levant and through the islands of Greece, the African Arc might be connected by direct triangulation with the existing triangulation of Greece and the latter is already connected with Struve's great arc of meridian which terminates at the North Cape in latitude 70° North - the whole arc would then have an amplitude of 105° [**6**] [**7**] p viii

Gill knew that even if the chain only went as far as the Mediterranean it would be of considerable value to science. It would contribute to a better knowledge of the form and dimensions of the earth and also form a basis upon which all subsequent mapping of East African territories could be in one unified system rather than all piecemeal.

Even within South Africa Gill had his problems because of the various administrative areas. Each had to make its own agreement to have the survey pass their way. By January 1883 Gill had everything in place for a start to be made on the principal triangulation and by June 1883 a team of Royal Engineers arrived in Durban. The first task was the measurement of a baseline near Pietermaritzburg. This was measured in three sections using five 10ft long, wood encased, steel bars and gave a result of 10 800.4571 ft (3.3 km) and was at an altitude of 2087 ft above sea level. This was then extended through a complicated set of triangles to the main triangulation stations of Mt Gilboa and Zwartkop 1 and a length of 111 814.3217 ft. Although the terminals were marked by concrete blocks which were then overlain with concrete slabs, and covered by an earth mound and fenced in [**6**] p.24 they have long since been consumed by the construction of a large reservoir. NB. The "ft" mentioned above are not Imperial feet but South African Geodetic feet See below.

Baselines such as this are essential components of a triangulation scheme and by the time the Arc was completed it had 24 baselines. Not all were measured using bars because by the turn of the century the use of invar wires had been introduced. This was a technique designed to reduce as much as possible the effects of temperature on the length of the material used for the measurement. Invar had a temperature coefficient some 10 times less than that of other possible materials such as steel. The wires, used in sets of five, were generally of 24 m or 100 ft in length, and used suspended between tripods that carried special reading heads and straining devices. The longest baseline, at Houts River, was almost 34 km long.

It is opportune here to mention in relation to baseline measurement the problem of standard unit of measurement. Each country has various standard units of length and even within a country these have been known to vary considerably from place to place. When computing the triangulation for any location it is essential to be sure of the unit of measurement that is appropriate and its relationship to some higher level reference. For example, it might be required to have results in terms of the metre as defined in Paris in 1799 but the local unit used in the work might be the toise du Nord. Has a comparison been carried out between these and if so what was the result? Similarly in Africa where all survey may have started in S Africa but there were various units around at the time. This is complicated and too involved to be detailed here but was dealt with at length by Zakiewicz [**15**], [**16**] particularly in relation to the South African Geodetic (SAG) ft. The early work on the Arc was carried out in terms of the Cape 1-foot standard bar A as used by Maclear. But various other forms of the foot and later the metre were to complicate the issue. Where accuracies are quoted for the baselines they are of the order of 1:1M

Moving northwards

By 1892 the work in South Africa was complete in the areas where agreement had been reached. A break ensued until Alexander Simms started in 1897 on a chain in Southern Rhodesia between Bulawayo and Gwelo in the south and Salisbury to the north. He appreciated that there would need to be extensions both to the north and south to make the 30th Arc continuous but initially he was restricted by Cecil Rhodes who stipulated that work must first progress towards Lake Tanganyika thus leaving an initial gap to the south. Simms was a member of the Simms family of C.T. & S. the instrument company but one about whom little information has survived. He was to suffer an early death in the sinking of the Galway Castle in 1918 when he was on his return to South Africa from France.

For his baselines at Inseza in 1898 and Gwibi in 1900 he used the early Jäderin technique of suspended wires but with separate wires of brass and iron. It was not until a little later that invar wires became associated with the Jäderin method.

They actually had 10 wires, 6 of which were 80ft long, 2 were 160 feet and the final two were 320 ft. Generally it was the shorter ones that were used with the longer reserved for special circumstances such as crossing rivers. The Inseza base was measured in 3 sections and had a total length of 18 903.427 m. After a very wet 1899 with extensive illness in both humans and oxen the line at Gwibi was finally measured as 21 690.980 m In addition to the previous wires here they also used two extra pairs each with one wire of invar nickel steel and one of another alloy with a coefficient of expansion of 1/17th that of steel. Extensive inter-comparisons were made between these as it represented cutting edge technology at that time. For his angles Simms was using a 10 inch Repsold theodolite with a micrometer eyepiece. With this he had a probable error on an angle using 8 zeros of 0.34 ?. Over 34 triangles the maximum triangle closure was 1.4 ?. By early 1901 lack of funds curtailed Simms' work when almost within sight of the Limpopo to the south and the Zambezi to the north.

Progress started again in 1903 when Dr Tryggve Rubin, who had been on an Arc measurement in Spitzbergen during 1901-2, was recruited. Joined by G T McCaw they progressed the triangulation through 35 principal and 25 secondary stations to extend the chain a further 800 km northwards. Much of the countryside here was almost impenetrable and the work exceedingly tough. In addition latitude observations were made at 18 stations. A baseline in the Luangwa valley, straddled both the border between Northern Rhodesia and Portuguese East Africa (Mozambique) and the river Luangwa- a tributary of the Zambezi. This line was 17 km long and was measured in 1904-5 using invar wires. Interestingly the standard 2½m steel bar against which the tapes were standardised was loaned from the Russian Government.

Although more financial constraints halted progress in 1906 Rubin was not to be deterred and continued for a further six months of his leave to complete the section. Gill at this time was very anxious to obtain sufficient funds to close the gap with the Transvaal. Rhodes was sticking by his stipulation that he would only provide funds when the survey was complete to the Limpopo. Gill eventually raised the £1600 necessary through donations from various sources. This allowed him to detail Col. Morris to continue the section in the Transvaal and Orange River Colony as far as the Limpopo (N border of South Africa), and this was completed by 1906. During three years the party observed 3200 km of triangulation (only some on the 30th Arc) with 178 triangles and six baselines of which two (Belfast and Houts River) were on the arc. These were all measured using the same techniques as before.

The last part of the gap was between this new triangulation and that in Southern Rhodesia by Simms. In 1906 Capt Gordon was transferred from Morris's party to complete the last of the gap. This took a further 22 triangles again through very difficult terrain. The final connecting line to the work of Simms was at Standaus and Wedza indicated considerable differences including a swing of some 9 seconds of arc.

Thus by the time that Gill retired in 1906 the geodetic survey of South Africa was complete and the Arc extended from the Cape to the southern shores of Lake Tanganyika, a distance of some 26º of latitude. A truly magnificent achievement by Gill in the light of all the financial and political difficulties he had overcome to say nothing of the hostile terrain.

To East African territories

The scene then moved north where a 2º section was observed in Uganda during 1908-1909. At that period there were three colonising powers in East Africa – Belgium, Germany and Great Britain and this gave rise to a series of boundary demarcation problems. In particular the Anglo-Belgian Boundary Commission was operating near the 30th meridian and it was persuaded to use some of its personnel to measure part of the Arc. So it was that 2º were covered in Uganda during 1908-1909. The Belgians appointed M Dehalu to assist and the British party was initially under Col Bright but later under Capt Jack with McCaw as an assistant observer. They covered the arc from 1º 11 ? N to 1º 11 ? S. The Belgians made the necessary astronomical observations for 14 latitudes and three azimuths. The single baseline at Semliki was jointly measured in 1908 by the two countries as 54 240.175 British feet (16 532.376 m) using six invar wires each of 24 m. Interestingly in 1908 when it was measured both ends of the base were in British Territory.

Egypt

For 20 years nothing further happened except in Egypt which will be covered later as an entity. There was much debate as to who should continue the Arc in light of the prevailing economic difficulties. Then in 1928 the British Association passed a Resolution calling for completion of the Arc. In 1931 Major Hotine was tasked to continue observations from Rubin's points at 10ºS northwards to 4º 30 ?S when funding again ran out. The 400 km or so from there to the Ugandan border at 1ºS was observed by the Tanganyika Survey Department. A baseline at Kate, 8º S was measured with three 100 ft invar tapes in the Macca method of catenary measurement. Each tape was 99.6 ft between the zeros and graduated outwards to give a total length of 100.4 ft. This was a modified form of that of Jäderin designed by McCaw in conjunction with the firm of Cooke, Troughton and Simms. The length of this base was 19 161 m. The angles were measured with three different types of geodetic theodolite, a large Geodetic Tavistock; a geodetic Wild and a special eight inch reflecting theodolite which replaced the Wild when it had axis problems. This last instrument was unique in that it was a one-off production to the design of Hotine, McCaw and others at the War Office at the time. It was "re-discovered" in 1999 see [**9**].

During the period 1907-1930 the whole of that section of the Arc in Egypt was completed. It very much follows the River Nile for the whole of its length to the Sudan border and Lake Nasser. The most southern baseline in Egypt is on the banks of Lake Nasser. Aimed at achieving the highest possible accuracy, it consists mostly of braced quadrilaterals straddling the river. In addition there is a coastal chain bearing West from Cairo as far as the border with Libya. Many years later this chain was to prove invaluable when it came to crossing the Mediterranean Sea.

The 30th Arc in Egypt has six baselines, two measured in 1908 and the others in the 1920s. They were all measured with 24 m long invar wires using the Jäderin technique and equipment designed and made in Paris. The longest, of 9 686 m was at Asyut. The astronomical and angular observations were with Repsold and Breithaupt theodolites of 10 inches circle diameter and read direct to 2 seconds by two microscopes. Both instruments had broken telescopes for assisting astronomical observations. Eight rounds of horizontal angles were observed to 5 inch helios or electric lamps at each station. Survey in Egypt at that time came under the Helwan Observatory near Cairo. The longitude of Moqattam Hill, a transit of Venus station, was determined in 1874 by connection to the Observatory. Gill was in Egypt at that time and was involved in using the exchange of telegraphic signals with Greenwich Observatory. The value for Moqattam Hill was subsequently thought to be in error by some 4 seconds due to deflection of the plumb line. The base measuring wires were standardised near the Observatory and the primary standard bar, similarly from France, was later also kept at the Observatory.

By the end of 1909 the survey had reached south from Cairo to Asyut but there was then a lull until it was continued on to the next base at Luxor in 1922 and then on to the Sudan border and on to Adindan on the Egyptian side across the border from Wadi Halfa in the Sudan. Transport needs made as much use as possible of the river to avoid the otherwise difficult desert terrain. Most of the stations built in the desert were on rock. The beacons were iron cylinders 60 cm diameter and 110 cms. high filled with concrete and with a tribrach cemented into the top to take an instrument. The baseline at Adindan, measured in 1930 was of 7866 m. This completed the main Egyptian part of the 30th Arc although the coastal chain towards the Libyan border came later in the 1930s. A further subsidiary chain ran Eastwards to Suez and would have been utilised for a circuitous route to Greece if the Hiran net across to Crete had not become possible.

By late 1937 the chain was complete from the Cape to the Equator plus Egypt.

The Sudan

Soon after the completion of the Egyptian section of the Arc so the Sudan started on its much longer stretch. Beginning in 1935 by the outbreak of the Second World War they had completed the 900 km stretch from 22º N to the Quleit baseline just south of 14º N and rigorously computed it. This base was measured with a modified version of the Macca equipment. From experience on the Amentego base in 1936 several areas for potential improvement in the equipment were noted and it proved possible to get these attended to before the 1939 measure. Reconnaissance for the next stage to 10º N was carried out just prior to the War but it was to be 1947 before measurements could resume. First D T F Munsey and later D P Mason were in charge of this section which went as far as Abu Qarn near 10º N. The base line here, of 1951-2, was again measured using 100 ft long invar tapes in the Jäderin style. This was the first of four base lines to be measured by D P Mason between 1951 and 1953.

All this activity left but one gap in the 30th Arc – some 1000 km from the Semliki base in Uganda to the Abu Qarn base in Southern Sudan. This was some of the most difficult surveying terrain of the whole arc and had been looked at several times to decide whether to go around it to the West or to the East or to simply traverse straight through rather than use triangulation. Even Hiran, as later used for crossing the Mediterranean, had been discussed as a possibility.

Closing the gap

Following informal discussions at the Conference of Commonwealth Survey Officers in 1951 a resolution was submitted and passed relating to the urgency for the gap in the Arc to be closed. Floyd Hough of the U.S. indicated that he would be making a proposal to his superiors in the Army Map Service. After inter-governmental discussions the idea of the AMS carrying out the necessary survey was quickly accepted and work started in December 1952. Bearing in mind that this was a major survey scheme over 1000 km long it is amazing that there appears to have been no official, nor unofficial, report written on the work. Despite extensive investigations all that appears to exist are brief scattered paragraphs and an un-published thesis.

Besides The Sudan and Uganda the Belgian Congo was also involved as several of the stations fell within its boundary.

The team consisted of 17 American men supplemented by around 100 other staff from local Survey Departments for which there were 24 four-wheel drive vehicles, two bulldozers and access to an aircraft. 16 different Bilby towers up to 103 feet high were employed and at onstage were being erected at a rate on one per day. The complete task took just 2 years and one month to complete when the closure from the Semliki base reached the Abu Qarn base on 27 January 1954.

In the first four months of the work three new baselines were measured. These were at Luluba, Ayod and Kwidok and all were under the control of D P Mason. All three were with the same equipment including 100 ft long invar tapes and reached similar accuracies of circa 1:1 M. The longest was of 33 874 English Ft. For the section within Uganda the average triangle misclosure was around 0.60 ? with a maximum of 2.14 ?. Such was the terrain that even with Bilby towers site lines through the Sudd were a maximum of 18 miles on diagonals of braced quadrilaterals. South from the Abu Qarn baseline to that at Luluba there was a series of 30 successive braced quadrilaterals almost identical in shape and size – a classic of its sort for strong-figure triangulation. Although for about the southern half of this stretch the Arc runs parallel to the White Nile it does not straddle it and in the northern half it is a long distance from the river because of the appalling surface that would have had to be crossed and the uncertainty its composition.

For the work the Americans were organised along Coast & Geodetic lines and followed the geodetic regulations as in the USC&GS Special Publication No. 247 throughout. The Semliki base of 1908 at the south end of the work in Uganda was considered accurate enough at a figure of better than 1:1M to be sufficient to carry the Arc 300 miles to the new Luluba base near Juba, well inside southern Sudan. Its extension figure was however strengthened. The base had last been visited in the

1930s but its two main points were readily found as steel pipes with round petrol drums as signals still standing. On removal the station marks of iron plugs leaded into bedrock were found intact and undisturbed. New witness marks were surveyed in for future use. Lack of river bridges on the river Semliki meant that a direct route of 20 miles required a circuitous journey of 300 miles south round the Ruwenzori and back up the west side to reach a particular station. A system of aerial reconnaissance was used where in four hours a stretch of 110 miles and possible station sites were identified, checked for inter-visibility and best approach routes. Using traditional ground methods this would have taken maybe 2 – 3 months.

The consequences

All the countries concerned use the 30th Arc as a springboard for other chains of triangulation crossing their territory in what is called in the ideal layout a “grid iron” pattern. India is a prime example of this but the African territories have adapted the idea to fit their requirements, which is often ruled by topography. For example, by 1933 Tanganyika had three main east-west chains attached to the 30th Arc and four north – south chains between the others. [**10**]. Even in 1879 when he designed his proposals for South Africa Gill envisaged five north – south and three east – west chains. The lower order work and details were then in-filled such as to be connected to the triangulation for control.

Crossing the Mediterranean Sea

On the completion by 1953 of the last piece of the Arc by the AMS and the Hiran connection across the Mediterranean Sea it became feasible to combine the whole arc, with others around the world, in a new computation for the figure of the earth. This was done by two U.S. geodesists who are still living today – Bernard Chovitz and Irene Fischer. The AMS published its Report in 1956 [**2**], and the authors had a paper on this published the same year [**4**]. They used two meridian and two parallel arcs, one of each in the Americas and the others from Scandinavia to South Africa, totalling almost 56 000 km in length. They used both gravimetric and astro-geodetic data and from 36 solutions determined, on the assumption of a flattening of 1/297 ? 1, a composite result for the Earth’s semi-major axis of 6 378 260 m ? 100 m. The outcome suggested the requirement for a shift of the European datum southwards by about 5 ?. The results further hinted that the Western Hemisphere was flatter and had a longer semi-major axis than the Eastern Hemisphere but for such a conclusion to carry any weight more investigations would be required.

In the 75 years it took from inception to completion base measurement graduated from using bars, through various forms of wire to just about the day that EDM appeared on the scene. This last development would have reduced each baseline to just a few hours instead of several weeks work. Transport developed from ox wagon and foot slog through four-wheel drive vehicles to the use of helicopters. Today it would all have been done so much differently with satellite technology. But the loss would have been the taste of adventure, of exploration, going possibly where no-one had been before, self-sufficiency in the back of beyond and the slog of computing results by log tables.

For the future the hope is that this arc can be made an extension of the Struve Arc World Heritage Monument so that in the end there will be a World Heritage Monument stretching from near Hammerfest in Northern Norway over 105º of latitude to near Port Elizabeth in South Africa. Considering the time and effort required to achieve the original WHM status it will be a difficult exercise to achieve the extension which will involve the cooperation of a further 16 countries. If any readers of this paper have survey contacts in the countries from Romania south to Greece and from Egypt to South Africa the author would be pleased to hear from them.

Readers who are unfamiliar with the Struve Geodetic Arc as a World Heritage Monument are directed to the paper *The Road to a World Heritage Monument for Surveyors* in the March 2006 issue of *The Cartographic Journal*.

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References

1. Anon. 1880. *Despatches, Correspondence and Papers etc., relative to the proposed continuation of the Trigonometrical Survey of the Cape Colony in connection with the Adjacent Territories.* Cape Town.
2. Army Map Service. 1956. Technical Report. *A new determination of the figure of the earth from arcs.* Project MO-011. Corps of Engineers, U.S. Army. Washington.
3. Braun, L.F., 2003. *The Arc of the Thirtieth Meridian and Geography in British Africa*. Proceedings of Symposium of ICA Commission on the History of Cartography. The History of Cartography of Africa. pp. 83-101. Cape Town. August 4-5.
4. Chovitz, B. and Fischer, I., 1956: A New Determination of the Figure of the Earth from Arcs. *Transactions, American Geophysical Union*, 37, 5, October 1956, pp 534 - 545.
5. Everest, G., 1847. *Account of the Measurement of Two Sections of the Meridional Arc of India. …* 2 vols. London
6. Gill, D., 1896: *Report on the Geodetic Survey of South Africa executed by Lt.Col.Morris in the years 1883-1892. Under the direction of David Gill.* Cape Town.
7. Gill, D., 1908: *Geodetic Survey of South Africa.* Vol. V, Reports on the Geodetic Survey of the Transvaal and Orange River Colony executed by Col. Sir W G Morris and of its connection by Capt.H W Gordon R.E., with the Geodetic Survey of Southern Rhodesia. London.
8. Macdonald, A., 1997. From Cape to Cairo: *A chronology of the 30th Arc of Meridian triangulation*. iKusasa. Durban. 24-28 August.
9. Porter, R. T. and Smith, J. R., 2003. *A Special Eight-Inch Reflecting Telescope*. A draft dossier on the story of this instrument. Ordnance Survey International Library.

10. Rowe, H.P., 1933: Reports. Triangulation in Tanganyika Territory. *Empire Survey Review*, II. **9**, pp 171-177.
11. Smith, J.R., 1990. You can't be too careful. *S African Survey Journal*. December
12. Smith, J.R., 1999. *Everest. The Man and the Mountain.* Whittles Publishing. Scotland
13. Smith, J. R., 2001. *LaCaille- French astronomer and Geodesist*. CONSAS. 12-14 March. Cape Town
14. Zakiewicz, T., 1997. *The African Arc of the 30th Meridian.* iKusasa. Durban. 24-28 August.
15. Zakiewicz, T., 2004. *Units of Length Measure & Geodetic Standards at the Cape, 1813-1913*. Symposium on The Arc of the 30^{th} Meridian. Institute of Professional Land Surveyors of the Eastern Cape. 8 June 2004 in Port Elizabeth.
16. Zakiewicz, T., 2005. *The Cape Geodetic Standards and their impact on Africa*. FIG Working Week. Cairo. April.