

The Struve Geodetic Arc and Its Possible Connections to the Arc of the 30th Meridian in Africa

James R SMITH, United Kingdom

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SUMMARY

This paper discusses the possible connections between the Struve Geodetic Arc and the Arc of the 39th Meridian in East Africa. Was the proposal by Otto Struve in 1868 carried out? If so, where are the results, if not, why not?

Brief mention is made of the various later connections from the Struve Arc in Belarus to North Africa and hence a join in Egypt to the Arc of the 30th Meridian.

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1. INTRODUCTION

The Struve Geodetic Arc was from near North Cape in Northern Norway to near Ismail on the Black Sea was observed under the supervision of F G W Struve and Carl F de Tenner between 1816 and 1852.

The Arc of the 30th Meridian from near Port Elizabeth in S Africa to near Cairo in Egypt was initiated by David Gill in South Africa in 1879 and was finally completed with the last section in the Sudan in 1954.

The Struve Geodetic Arc has recently been submitted to UNESCO for possible recognition as a World Heritage Monument. If this is successful then it would seem appropriate to try and extend the project to include the Arc of the 30th Meridian. Or, even better, to also incorporate the connection between the two. Herein lies the difficulty.

First, however, a few statistics to illustrate the magnitude of these arcs.

2. STATISTICS

	Struve Geodetic Arc	Arc of 30th Meridian
Northern terminal	Fuglenaes	F-1 North East of Cairo
Latitude	70° 40' 11"N	30° 01' 43"N
Longitude	23° 38' 48"E	31° 16' 34"E
Southern terminal	Staro-Nekrassowka	Buffelsfontein
Latitude	45° 20' 03"N	33° 59' 32"S
Longitude	28° 55' 40"E	25° 30' 43"E
Overall length	2 821.833 km	approx. 7 120 km (Using 1° = 111.2 km)
Overall angular length	25° 20' 08"	64° 01' 15"
Countries involved (modern-day boundaries)	10 = Norway, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Belarus, Moldova, Ukraine.	11 = Egypt, Sudan, Uganda, Tanzania, Congo, Burundi, Zambia, Mozambique, Zimbabwe, Botswana, South Africa.
Number of main stations	265	608
Number of baselines	10	23
Number of astronomical stations	13	42
Started	1 816	1 879

	Struve Geodetic Arc	Arc of 30th Meridian
Completed	1 852	1 954

Fuglenaes to Buffelsfontein 104° 39' 43" = approx. 11 635 km

3. OTTO STRUVE'S RECONNAISSANCE

F G W Struve always envisaged an extension of the arc from Izmail to the Mediterranean area and in 1868 Otto Struve (son of F G W Struve) published a detailed paper (Struve, 1868) on reconnaissance that had been done under his supervision. This extended from the first baseline north of Izmail - that at Tachbounar- through present-day Roumania and Bulgaria to Greece, Turkey and the Greek Islands near Crete.

This ran generally about 100 km west of the coast of the Black Sea before crossing into Turkey near Edirne and continuing south to near Gallipoli and then Izmir to Kos and the possibility of sighting to Crete.

Whilst Crete was the most obvious end point the political situation at that time made it uncertain whether or not observations could be made to, and on, the island.

At the same time possible sites for four baselines were selected.
Struve said that

At this time (1868?) one is occupied in our place (Pulkova) in examining and preparing the instruments destined for the work, and I calculate that all being well to be a state to leave with MM Kartazzi and Artamonov in the current month of May (1868?).

Unfortunately nowhere is there to be found any report of the work actually taking place. But one must ask why, if the start was so imminent, and the publication of the details of the reconnaissance must have taken some months before it was in print, was it not possible to either stop the publication or at least amend it IF the work was not to happen.

So far it has proved impossible to find out any more about this proposed scheme.

It will be seen from the above notes that:-

- Reconnaissance had been completed from the first baseline up the Struve arc down through the present day Roumania, Bulgaria and Turkey to the islands near Crete.
- That Otto Struve (son of the Struve after whom the arc is named) who was at that time at Pulkova Observatory, was essentially supervising the preparation of the equipment for a start on the field work in the next month or so.
- Despite much research to date no write-up has been found that even mentions the field work let alone give any details.

This raises the questions:

- Was the fieldwork ever carried out?
- If not, why not?
- If the field work had been so imminent and for some reason was stopped there would probably still have been time for Struve to stop his letter being published or at least to amend it.
- This brings us back to Gill's statement. We know that Gill corresponded with Otto Struve so surely Gill would have known the outcome for certain long before he made his definitive remarks in the 1890s.

4. THE ARC OF THE 30th MERIDIAN

It was in 1879, soon after taking up his appointment, that David Gill conceived the idea of an arc stretching from the Cape to Cairo. That year he sent a memorandum to the Governor giving great detail of his grand scheme. It must however be remembered that Gill was not the first to embark on important survey work in the Cape since particularly LaCaille, Maclear and Bailey had made important contributions during the previous 127 years.

Gill's enthusiasm was probably sparked by the survey work he did in Egypt 1874-1876 when he measured a baseline and surveyed the Pyramids.

Over a period of 75 years the arc gradually proceeded from South Africa through the countries to the north until there was only a 1000 km gap to be completed. This was over the most difficult territory of the Sudd in Sudan. It was finally observed by the US Army Map Service and completed in 1954.

Similar in many ways to the Struve Arc, the 30th Arc passed through 11 countries but in all other respects it was the larger by far by about 2½ times.

5. GILL'S COMMENTS

But the idea of an extension of the Struve Arc was also thought of in South Africa. It is known that David Gill, Her Majesty's Astronomer at the Cape of Good Hope, had at some time met Otto Struve and that they corresponded over a period of years.

In 1896 Gill wrote :

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....

In pursuance of these aspirations (i.e. Arc extended to the North Cape) I had in 1895 endeavoured to interest Cecil Rhodes in this great enterprise (see (Gill, 1896))

The statement there that Greek triangulation *is already* (i.e. in 1896) connected to the Struve arc is of particular interest. Where was the join and what was the route from Greece?

But the first sentence of the above quotation is referred to elsewhere as

In his letter to the Governor of the Cape Colony and High Commissioner for South Africa, Sir Bartle Frere, dated 26th September 1879.....

Thus although it only appeared in print in 1896 it had been made 17 years earlier and in the interim Gill would have had ample opportunity to modify his statement if it were incorrect. The reference in the above quotation to "... his letter to the Governor...." should possibly read "... his Report to the Governor ..." as we find in (Gill, 1908) p.viii reference to pp 157 and 158 of the *Report on the Geodetic Survey of Cape Colony and Natal* and to "... my Report, addressed to Sir Bartle Frere ..." both of which appear to relate to (Anon, 1880) of 1880.

Further it is noted that in 1904 Gill wrote to the financial "advisor" to the Egyptian Government (E H Corbett)

The ultimate idea is to complete the arc from the Cape to the Mediterranean, thence round the eastern shore of the Mediterranean till it meets Struve's arc along the 30th meridian, which is already completed from Turkey to the North Cape (Gill, 1904)

By the time he made a presentation in 1905 to the British Association for the Advancement of Science (Gill, 1905) p 231, (see also (Anon. 1914b) p 231 and (Anon. 1914a) p 113) Gill slightly modified the above quotation to read

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 with the Roumanian and Russian arc, so as to form a continuous chain of 105 degrees in amplitude, extending from Cape Agulhas to the North Cape- the longest meridian measurable in the world.

Now as Gill corresponded with Struve he would surely have been told if the arc measurements had not taken place. So why was he repeating over more than 20 years later that the extension was complete? Similarly why was it that in the 1920s there was a call for connections to be made from Greece to Struve's Arc? Had the earlier work been forgotten or was it just a figment of Gill's imagination?

6. THE MEDITERRANEAN SEA

So there is an arc coming south to the Black Sea and another working its way northwards towards Cairo with the huge barrier between them of the Mediterranean Sea. In the first half of the 20th century the sheer width of this sea defeated all possibilities of joining across from North Africa to Crete by survey techniques. Not that there was a lack of ideas since at least three possibilities for contriving a direct crossing were contemplated in detail.

In 1923 Mr Wade of the Survey of Egypt made various experiments and decided that it would be feasible to photograph from North Africa and from Crete flares set off around half way

between these two areas. The flares to be from charges of magnesium placed in balloons at convenient heights or dropped from aircraft.

In 1927 during a Congress in Prague Professor Athanassiadis of the University of Athens questioned the feasibility of Mr Wade's ideas and at a subsequent gathering in 1931 proposed the possibility of using *phototriangulation aérienne* where the trigonometric measures were to be made with the aid of photographs.

By 1933 General Boskovic of Yugoslavia was getting a little impatient and restated his idea, first proposed in 1922, of luminous points raised by balloon from two ships anchored in the Mediterranean Sea.

Before any method could be used the Second World War arrived and nothing further was done until the 1950s.

7. ROUTE THROUGH ASIA MINOR

As will be seen above, an alternative route was proposed for circumventing the Mediterranean Sea. This was to be from Northern Egypt, going East through Palestine, Lebanon, Syria and Turkey to join with the Greek triangulation and hence that of Bulgaria and Roumania to connect with the Struve Arc. This would essentially join the Otto Struve suggested route at the Dardanelles.

A connection between the triangulations of Greece, Turkey and Bulgaria took place in 1938. In 1941 the Survey of Egypt was connected to that of Palestine and in 1944 this was extended to embrace Syria. So that left the Syria - Turkey boundary. Now over the years this boundary has moved several times so that triangulation that was once in Syria became part of that of Turkey so a connection between these two countries was achieved solely by this means. Thus a connection between the Arc of 30th Meridian and the Struve Arc would have been feasible via this route.

8. ROUTE FROM POLAND TO CRETE

In parallel with the problems of crossing the Mediterranean Sea the AIG at its Congress in 1922 in Rome proposed a new meridian arc from the Arctic Ocean to the Coast of Africa. At the time Boskovic quoted thus from F G W Struve (1860):-

the Arc between the mouths of the Danube and the Arctic Sea can be seen as a major part of an unfinished task. In effect nature must not be any obstacle to the continuation of our triangles by an arc of around 12 degrees, in a meridional direction towards the Isle of Candie (Crete), from there crossing through continental Turkey and the Archipelago. Between Fuglenaes and the Isle of Crete there are more than 37 degrees of latitude, which constitutes the longest possible European meridian, and this arc is at the same time- very near the central meridian of the continent of Europe ...

The Report of the Rome meeting in the Bulletin Géodésique (Perrier, 1922) said the proposition by Boscovic read (roughly translated).

Triangulations of the 1st Order of Norway, Russia, Germany, Austria- now Poland and Roumania - Serbia and Greece are now joined between themselves and furnish the necessary data for the calculation of a grand arc of meridian from the Glacial Ocean as far as the Mediterranean.

But I propose that the measure of degrees is continued further south, in a manner such that the triangulation of Greece reaches and crosses the Mediterranean Sea, through Crete, as far as the coast of Africa, where it would join the great arc measured by the English in Africa. In this way one could execute the measure of an arc from the Arctic Glacial Ocean as far as the Cape of Good Hope.

The distance from Crete to the coast of Africa is 300 to 400 kms. The division in two could be by means of signals established on two vessels placed between Crete and the Coast of Africa. Determining the position of these signals would allow with two stations at least on each coast to establish the join.

The principal difficulties they saw were:-

- International friendship between the countries concerned which is not always readily realised. However they considered it would be easier if all countries concerned joined IUGG.
- The problems of delimiting the frontiers between the measurements in different States.
- The tying of the Isle of Crete to the African triangulation which at that time was difficult to effect.
- The tying of the Russo-Scandinavian arc to the African arc (Cape to Cairo) could be made easier by prolonging the Russo-Scandinavian arc through Asia Minor, Syria and Palestine. (Perrier, 1922)

Despite the problems a join was achieved in the period between the two World Wars from Poland to Crete. From several Struve stations in what was then Poland the triangulation passed through Czechoslovakia, Roumania, Yugoslavia and Greece to Crete some 2300 km. with around 208 survey stations and 19 baselines.

With today's international boundaries the stations are distributed approximately as: Latvia 7, Lithuania 3, Belarus 57, Ukraine 31, Poland 5, Roumania 39, Yugoslavia 11, F.Y.R.O.M. 11, Greece 34 and Crete 10.

As the baselines in this area have not been found listed together elsewhere they are tabulated here for reference but the details should not be taken as definitive.

Country	Date	Location	Observers	Length (m)	Latitude	Ht (m)
Crete	1930 also 1907	Crete	Capt. Iacoumelos & Capt. Paparodou	7919.220693	35°05'	49.2

Greece	1889	Athens	Lt.Col. Hartl	4924.654934	38 05	
	1929	Athens	Spiliotopoulos	4924.644295	38 05	
	1927	Larissa	Spiliotopoulos	5055.030325	39 35	75.0
Yugoslavia	1922	Prilep	Boskovic	5982.5551	41 20	
	1922	Strumica/ Stroumitza	Boskovic	6623.8-59	41 30	
	1904	Vranjie/Vragna	Boskovic	4970.446437	42 20	
	1904	Paracin/Paratchine	Boskovic	5603.047928	43 59	
	1904	Negotin/Negotine	Boskovic	4656.346054	44 10	
Roumania	1936	Lugoj		7530.5821	45 45	
	1927	Oradea Mare**		3935.116	47 03	
	1928	Satu-Mare		6688.5089	47 50	
Czechoslovakia	1928	Mukacevo	Benes & Hrdlicka	9611.4917	48 20	
Poland	1933-5	Stryj	Dejmicz & Raniecki	12388.87184	49 05	328.9
	1933-5	Hrubieszow	Dejmicz & Raniecki	1582.21618	50 35	204.8
	1928	Kobryn		17162.418	52 20	
	1927	Grodno	Kowal & Miedziewski	10894.57401	53 30	
	1933-5	Braslaw	Dejmicz & Kobylinski	9188.80194	55 45	146.9
Latvia	?	Daugavpils	?	?	55 55	

(UGG, 1936) for much of Poland

(Benes, 1930) for much of Yugoslavia, Czechoslovakia and Roumania

In Poland the base extensions were to the following sides:-

Braslaw base - Dziedzinka- Dworne Siolo Measured in 6 sections

Grodno base - Kopciowka - Nowosiolki

Kobryn base - Skopowka - Dziazkowicze

Hrubieszow base - Zubowice - Poromow Measured in 12 sections

Stryl base - Jaroszyce - Paraszka Measured in 9 sections

In (Benes, 1930) the Yugoslavian baselines each measured by invar wires to better than 1:1M. Also (Perrier 1939b.)

In (Benes, 1930) the baseline was extended to the side Nagy hegy - Berezske vrchy with a mean error of $\pm 1:490\ 000$

Yugoslavian baseline values from (Perrier, 1939b)

** = also an astro. station

In (Perrier, 1939a) the Crete base measured with 4 invar wires by Carpentier of Paris to relative accuracy of 1:2 512 000. 9 sections, measured twice.

9. CROSSING THE MEDITERRANEAN SEA

By the 1950s technology developed during the recent warfare also had peace-time uses and the technique known as Hiran was used by the US Air Force 1953 to observe a crossing of the Mediterranean Sea. This joined three stations of a westerly coastal extension of the Egyptian triangulation to two stations on Crete and one on Rhodes.

Shoran (Hiran = high accuracy Shoran) was an airborne navigation system capable of determining long distances (several hundred km) to accuracies of interest to the geodesist. It was essentially a trilateration technique.

10. MATERIAL FOUND OR REQUIRED

The material on which the above notes are based was found in various scattered sources particularly those of the AIG. There must almost certainly be more hidden away in various Archives and it would be much appreciated if any readers who know of such sources could bring them to my attention.

The areas of particular interest are:-

- Did Otto Struve ever observe the extension that was reconnoitred?
- Are there detailed records and maps of the connection between Egypt & Palestine ?
- Are there accessible records of the triangulation in the vicinity of where Syria meets Turkey?
- If there had been a scheme to circumvent the Mediterranean what would have been the preferred route from Syria via Turkey to the Greek & Bulgarian connection?
- Are there any records and detailed maps of the survey from Poland down to Crete via Czechoslovakia and Roumania of the 1920s and 1930s.?
- Are there any records of the 30th Arc lurking in unexpected Archives?

11. THE FUTURE

What of the future? Much hinges on whether or not the case for the Struve Arc is accepted by UNESCO. The result will not be known until mid-2005. If that is positive then it would be logical to try and extend such a monument to cover both the connection to the 30th Arc and the extent of that down to Port Elizabeth. The results of the 30th Arc are far better known and have until recently been far easier to access than anything connected with the Struve Arc. In addition far more of the countries concerned speak English and that should also be an advantage. Thus expectations should be high for an early submission.

REFERENCES

Over 130 references have been found for the Struve Arc, 120 for the connection between the Arcs and in excess of 180 for the 30th Arc. All that are given here are those actually quoted from in this paper.

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BIOGRAPHICAL NOTES

J R Smith has been involved in various aspects of FIG since 1968 including Secretary to Commission 6 from 1979 to 1987 and Secretary since 1984 to the International Institution for the History of Surveying & Measurement, a body within FIG. In this last position he has been a lead figure in the submission to UNESCO of a case for the Struve Arc to be designated as a World Heritage Monument. He was on the Land Survey Council of RICS from 1967 to 1996 and Hon. Secretary to the Division from 1968 to 1980.

He retired from the University of Portsmouth in 1989 and acts as Editor of the *Survey Review*. He is author of 7 books, mostly on topics related to the history of surveying, and numerous technical papers since 1967.

CONTACT

J R Smith
 Honorary Secretary to the International Institution for the
 History of Surveying & Measurement
 24 Woodbury Ave
 Petersfield
 Hants GU32 2EE
 UNITED KINGDOM
 Tel. / fax. + 44 1730 262 619
 Email: jim@smith1780.freemove.co.uk