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# The Struve Geodetic Arc

Since 1994 the International Institution for the History of Surveying and Measurement – a Permanent Institution within FIG –, has been working on a project to get recognition of the Struve Geodetic Arc as a UNESCO World Heritage Site. This arose from a resolution put to the FIG at its 1994 Congress in Melbourne. But what is the Struve Geodetic Arc and what, in this context, is a World Heritage Site? Before answering these questions it is necessary to fill in some of the background to the project and discuss the determination of the parameters of the earth in terms of its size and shape.

*Seit 1994 arbeitet die FIG-Arbeitsgruppe Vermessungsgeschichte (heute: International Institution for the History of Surveying and Measurement – a Permanent Institution within FIG) an einem Projekt zur Anerkennung der Meridianmessung vom Schwarzen Meer bis Hammerfest durch Friedrich Georg Wilhelm Struve (Struve Arc) als Unesco-Welterbe. Das Projekt entstand aus einer Resolution am FIG-Kongress 1994 in Melbourne. Der Artikel beschreibt, was der «Struve Arc» ist und wie er ein Unesco-Welterbe werden kann.*

Depuis 1994, le groupe de travail FIG «Histoire de la mensuration» (aujourd'hui: International Institution for the History of Surveying and Measurement – a Permanent Institution within FIG) s'occupe à élaborer un projet visant à la reconnaissance de la mesure du méridien entre la Mer Noire et Hammerfest par Friedrich Georg Wilhelm Struve, comme héritage mondial de l'Unesco. Le projet est né d'une résolution du congrès de la FIG de 1994 à Melbourne. L'auteur décrit ce qu'est «Struve Arc» et comment il peut devenir un héritage mondial de l'Unesco.

*Dal 1994, la Institution for the History of Surveying and Measurement – un'istituzione permanente in seno alla FIG – sta lavorando ad un progetto per il riconoscimento dell'Arco geodesico di Struve (la misurazione del meridiano dal Mar Nero fino a Hammerfest effettuata da Friedrich Georg Wilhelm Struve) quale patrimonio dell'umanità, sotto l'egida dell'UNESCO. Questo mandato è scaturito da una risoluzione del Congresso FIG del 1994 a Melbourne. Ma in cosa consiste l'Arco geodesico di Struve e cosa si intende – in questo contesto – con patrimonio dell'umanità? Prima di rispondere a questi quesiti è necessario spiegare i retroscena del progetto e discutere la fissazione dei parametri della Terra, cioè la sua dimensione e forma.*

*J. R. Smith*

## Background

Since the time of Eratosthenes (c276 BC-c195 BC) the dimensions of the earth have been determined from arc measurements. In fact the theory developed by Eratosthenes remained in use until the era of satellite geodesy. Many famous names in the fields of astronomy, mathematics and surveying have been involved in the gradual improvement in both techniques, equipment and results. Among these one might mention Fernel, Picard, the Cassinis, Newton, Bouguer, La Condamine, La Caille, Maupertuis, Delambre, Mechain, Airy, Everest and many others. Notice how many of these were Frenchmen.

The focus of this paper is another name, that of F G W Struve, who made an important contribution during the 19th century. Such was the importance of the work by Struve that it is the hope that some of his survey points that still remain can be designated as world heritage monuments. But more of him later. To put his work in context some background detail is necessary.

Fig. 1: Friedrich Georg Wilhelm Struve (1793–1864).

### The problem

Prior to Eratosthenes, back to the time of Pythagoras around 500 BC, it had been known that the earth was not flat but of some spherical shape. Why spherical was the next step after flat and not some other shape is open to conjecture. At the time however the sphere was considered to be the perfect shape, perhaps because of its regularity in all directions, and could well have been selected in this case just on that assumption. The fact that it turned out to be a correct choice would then, have been pure luck.

The problem over the intervening centuries has been to determine its exact shape and size. While it was considered to be a true sphere the problem resolved itself to one of just determining its size, but by the time of Isaac Newton in the second half of the 17th century even the idea of a true sphere was being questioned. (By «true sphere» and other terms mentioned later, is meant the sea level surface assumed continuous around the earth. In relation to the overall size of the earth the topography is insignificant).

Why was knowledge of these parameters of importance? This can be illustrated simply by saying that if Christopher Columbus had known the true size of the earth, he would not have gone where he did. By working with a figure that was much too small he had a distorted idea of the earth he was navigating upon. It was almost as if he thought he was going round a tennis ball when in fact he was on a football. Not only would he be using incorrect distances but incorrect directions as well [1].

### The measurement difficulty

The problem of measuring accurately an object the size of the earth is not an easy one yet the principle, first deduced by Eratosthenes around 230 BC, has remained the basis of all attempts until the advent of satellites. Although the method devised by Eratosthenes was based on the mathematics of a sphere it was later possible to modify it to apply also to shapes that were not quite true spheres.

Whatever one is measuring it is advantageous to determine by direct measurement as large a part of it as possible before resorting to extending a value by calculation. One has however to keep within the bounds of practicality. For example, if you wanted to measure the circumference of a football that would be done by putting a tape measure around it. If on the other hand it was required to measure the circumference of a large circular roundabout it might be more practical to measure the length of an estimated quarter of it and multiply the result by four, or alternatively determine the diameter and multiple up by p. When the structure or figure involved becomes the size of the earth then a small fraction, say 1°, might be the more practical amount to measure and then multiply up by 360. This is in effect the basis of the method used.

### Why a great circle?

As is well known, a line of longitude circles the earth and goes through both poles. Such a line is called a great circle of the earth. All lines of longitude are of that form but in latitude the only line that is a great circle and of comparable size is the equator. Thus to get the full circumference in as simple a way as possible it was necessary to measure (or calculate) the length of a circle or arc of longitude or of the equator. (This is rather an over simplification but can be accepted as the basis of what is required). As theory later developed so it became possible to use

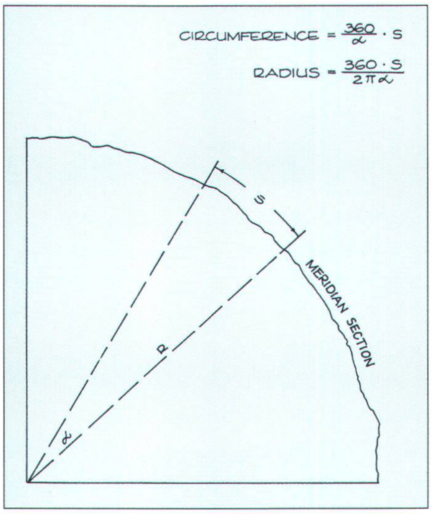


**Fig. 2: Principle of determining size of earth as a sphere.**

arcs that were not sections of great circles.

Assuming a spherical earth, Eratosthenes said that if you measured the linear distance between two points on a particular line of longitude (also called a meridian line as, for example, that of zero longitude through Greenwich), and were then able also to determine the angular distance subtended at the centre of the earth (see figure 2) between the same two points then the radius and other parameters of the earth could be easily determined. Such an angle is not as inaccessible as it might at first appear as it can be found from star observations at each of the two points. The angle determined represented some fraction of the 360° circumference and its length was also known. A simple calculation would then give the circumference or radius.

For example, if the angle was 6° then that would represent 6/360 or 1/60th of the circumference. If in turn the distance between the same two points was 600 km then the circumference would be 600 x 60 = 36 000 km. (Of course they did not use kilometres at that time but the idea is the same.)

Unfortunately there are many sources of error inherent in such observations, particularly in the angle and distance measurements. These in turn were functions of the inaccuracies of the equipment and methods of the time. Despite gradual improvements even by the late 15th century calculated values of the earth's size varied considerably and unfortunately the value selected by Columbus was incorrect by about 25%.

### Measure long lines

One of the difficulties in all the early measurements was that the linear distance required had to be physically measured from end to end by whatever method was felt appropriate. Each distance had to be of the order of 60 miles (100 km). If much shorter distances only were used the accumulation of errors in the results would have been unacceptable. There were no tape measures then as we know them and the methods were pacing, knotted ropes, camel days journeys, the distance travelled by horsemen in a given time and variations on these.

As far as the angular value was concerned this could be found by observing the stars or the shadows of obelisks but in either case the results were crude.

### The advent of triangulation

It was not until the early 17th century that a more convenient method, triangulation, was developed in Holland and better measuring equipment became available. While it still kept to the basic principle of Eratosthenes for measuring a very long distance now an element of computation entered the method. It required a much shorter line to be measured as accurately as possible (a baseline) and the longer distance calculated by simple geometry.

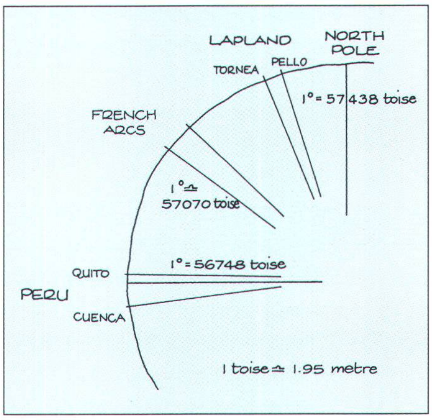


**Fig. 3: Spread of 18th century arcs.**

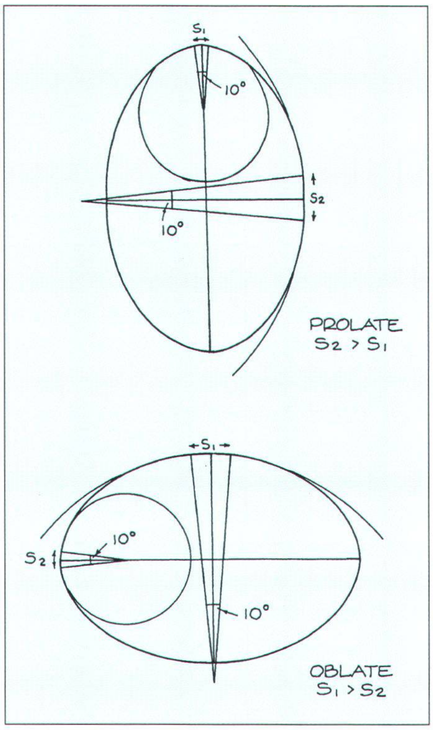


Fig. 4: Oblate or prolate?

The angles were measured by instruments such as quadrants and later, theodolites. Essentially the solution revolved around the fact that from a chain of triangulation it was possible to determine the distance between a point at each end of the chain [1].

### The «true» shape

Both theory and practical results suggested that the earth was probably not a true sphere after all but some slightly distorted shape. Ignoring the land elevations and sea bottom depressions around the world, sea level forms a sensible datum surface to which everything can be referred and can be treated mathematically .

Various long triangulation schemes were observed, particularly in different parts of France but by the first half of the 18th century also in Peru, Lapland, Italy, S Africa and Austria. During the second half of that century and the early 19th century other arcs were observed in USA, Hungary, India, Sweden, England, Spain, Denmark and Germany.

The arcs in Peru and Lapland during the 1730s and 40s settled the problem of the shape of the earth in that it was finally proved to be oblate (slightly flattened at the poles) rather than prolate (or elongated at the poles), as shown in figures 3 and 4. The full name of this figure is an oblate spheroid. The difference from a true sphere is small, being only some 20 km between the maximum and minimum radii in a total of almost 6400 km. (i.e. only 0.3%), but nevertheless highly significant when navigating.

But that only solved half the problem. There was still the matter of an accurate value for the size of the earth and this was complicated by the fact that it was not now sufficient to do the calculations as if it were a perfect sphere.

### The size of a non-spherical earth

To determine the dimensions of an oblate spheroid (or a prolate one if it had turned out to be that shape), requires the accurate determination of at least two long arcs as widely separated in latitude as possible. The various pre 19th century arcs in the list above were all useful but they did throw up difficulties not least the effects of large mountain masses on the true position of a plumb bob, universally used to level observational instruments. It was proved during the 18th century survey work in Peru that if a plumb bob is hung in the vicinity of a large mountain mass then it is pulled (or attracted) slightly out of the vertical by that mass. If the plumb bob is not vertical then any instrument that is itself made level (horizontal) by use of a plumb bob, will also be out of level by the same amount as the plumb bob is attracted.

Increasingly as further arcs were measured and the accuracy improved so the uses to which the results could be put required yet greater accuracy. The vicious circle thus required further arcs to be measured. More uses were also found for the networks of triangles that resulted, not least the basis of accurate mapping of the countries concerned.

### First moves in Russia

At about the same time that the Peru and Lapland arcs were being measured Joseph Delisle published in 1737 [2], a proposal for an arc to be measured through the Russian empire and embracing some 22° of meridian. He stated that «...this set of degrees when determined would display in an incontestable manner, if their variations were uniform, ...would show whether different meridians have different curvatures...» Surprisingly the Empress of Russia was not frightened by such a vast proposal and gave it her backing to contribute to the progress of science.

Unfortunately in 1739, after Delisle got as far as measuring a base on the ice from Peterhof Castle in Kronstad to Doubki Castle and connecting the base to several points by triangulation, a journey to Siberia in 1740–41 interrupted his work and it was never restarted.

At that time the kilometre had yet to be developed and the base had actually been measured as about 20 verstes, an old Russian unit of approximately 1.067 km per verste. The measurement itself was by wooden bars of known length placed end to end. Nothing was published on this work but in 1844 Otto Struve, son of F G W Struve, did come across Delisle's manuscript in the Paris Observatory archives. [3] For his angles Delisle talked of using a 30° sector of 12–15 ft radius and a quadrant of 2–3 ft radius.

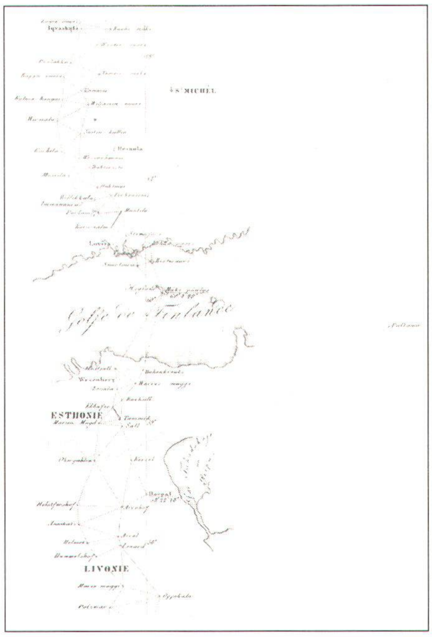


Fig. 5: Struve Arc (detail).

Nothing more materialised in that region until 1814 when B A von Lindenau, Director of the Seeburg Observatory, proposed an arc of meridian on the shores of the White Sea in North Russia. This did not progress because of a disagreement over which instruments – German or Russian should be used. Struve's opinion however was that in any case it was not a good site for well conditioned triangulation.
Enter the subject of this paper, F G W Struve.

## The Struve Geodetic Arc

### Struve and colleagues

The early 19th century saw the commencement of a very long arc through India by William Lambton. On the death of Lambton in 1823 it was continued to its completion in the 1840s by George Everest so that it extended from the southern tip of India to the foothills of the Himalayas.
At about the same time F G W Struve, Professor of Mathematics and Astronomy at Dorpat, was put in charge of a trigonometrical survey in Livonia. This terminated in a baseline on the ice of Lake Werz-Jerw. This work enabled Struve to interest officials in the idea of an arc of about 3½° between Högland, an island in the Gulf of Finland, and Jacobstadt to the south. This he was able to observe between 1822 and 1827. During more or less the same period (1816–1831) another surveyor, de Tenner, was doing similar work further south in Lithuania but at that stage he was not operating jointly with Struve.
Once he had completed his early surveys, Struve was keen to extend the measurements further north and south so that a very long line would result and could be the basis of a sound set of values for the earth parameters as well as having other uses. He would have been aware of the work at that time in India and that it would be an ideal partner to anything he did through Russia, to determine the earth's parameters. (As indicated above, one arc on its own is insufficient to determine the parameters of an oblate spheroid.)

### The selection of route

It is little surprise, since Struve worked at Dorpat University, that he decided any extensions of his surveys should follow, as nearly as possible, the line of longitude (meridian) through Dorpat Observatory. Looking at this line on a map it was clear that some work had already been done in its vicinity in the far north (by Maupertuis 1736–37; and by Svanberg 1802–03) from the top of the Gulf of Bothnia well into the Arctic Circle. Here was an opportunity to connect to that work and further extend the line. At the same time it became clear that Tenner was working more or less along the same meridian. While Struve could envisage the northward extension, Tenner similarly noticed how there could be a southern extension as far as the Black Sea. Thus the elements were present for an arc that stretched from Fuglenaes near Hammerfest in the far north over some 2822 km (1753.3 miles) to Staro-Nekrassowska near Ismail in the south over 25° of latitude. Today the line stretches through ten different countries.

### Units of length

Although at the time of the surveys, the metric system was well established, the measurements were recorded in the old French unit of the toise which is approximately 1.949 m. Both English and French feet appear in some of the results, where the two different feet varied by a noticeable amount with 1 French foot = approximately 1.067 English feet.

### The daunting task

To even contemplate such a huge scheme of extensions and collaborations was a daunting task in itself. Such an arc would however:

- build upon the previous schemes in Peru and Lapland which basically set out to prove the shape of the earth but the equipment for which was still relatively crude
- allow computation of accurate figures for the earth dimensions
- be the first arc to feature in Russian territory
- be the first multi-country arc
- be the longest arc at that time.

In the 1860s A R Clarke, made very extensive inter-comparisons of arcs around the world in an endeavour to get the best possible overall results for the earth's dimensions. The Struve arc featured prominently in his calculations and was the longest of the six he used.
Further extensions in the 20th century have resulted in the «Struve» arc now theoretically reaching from near North Cape to the Cape of Good Hope. It was 1954 when two quite separate arcs – that by Struve and that started by Gill around 1882 in South Africa which gradually worked its way northwards, made a link-up feasible.

### The field work

Bjorn Harsson, speaking at the FIG Congress in Melbourne in 1994 [4] summarised Struve's [5] reported division of work on the arc in four phases totalling seven sections.

*First phase*
*Central West Russia 1816 to 1830*

c 1816
The early work by Struve had baselines measured with wooden bars and angles by sextant yet even so he got good results.

1820
Struve obtained a grant from Dorpat University to fund further arc measurement including development of his own form of base line equipment He consulted with Gauss, and decided to adopt the observing method used by Schumacher on the arc between Denmark and Hannover. He took his reconnaissance northwards to Högland but whilst building substantial signals he did not leave bolts in the rock to mark the positions.

1822 to 1827
Struve fitted observing in between his lecturing duties. Professor Paucker from Latvia helped with the astronomical observations at Jacobstadt and Högland.

Fig. 6: Monument on Kittisvaara.

Fig. 7: Station at Nivavaara.

Struve had already thought of crossing the Gulf of Finland although the connection would be difficult.

By 1825
Tenner's responsibilities extended into Moldova. He was also authorised by Prince Wolkonsky to carry out an arc measurement tied to baselines at Ossownitza and Ponedeli. As a result Tenner's most northerly point was then only 32 km west of Struve's most southerly station.

1828
The possibility of joining the two arcs brought the two astronomers together, possibly for the first time, and with it notice of the serious problem of scale differences.

*Second phase*
*Extension to the south and north*
*1830–1845*
This began with Struve requesting resources from the Tsar Nicholas I to extend northwards to Torneå. The idea was to connect with the earlier work of Maupertuis and the extension of that by Svanberg.
Meanwhile Tenner was continuing his geodetic work south of the River Dnestre passing through parts of the Ukraine. His baselines at Ossownitza and Staro-Konstantinow were among the longest in the whole arc. Astronomical observations were made at Kremenetz (lat. 50° 06') and Ssuprunkowzi (lat. 48° 44'). It was at this time that Tenner began to establish permanent station marks.

1831
Struve obtained permission to extend northwards and connect with the Lapland arc and even to extend that to the Arctic. He worked with 3 Finnish officers who had similarly been educated at Dorpat.

1832
Angle measures began with measurement in Finland mostly led by Woldstedt.

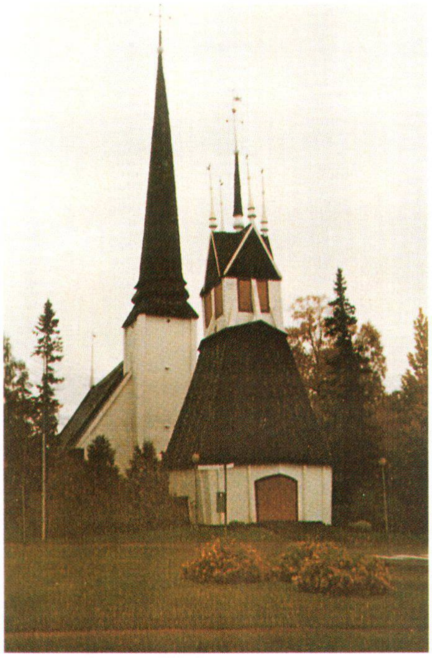

Fig. 8: Torneå Church. Incorporated in the triangulation of Maupertuis.

1844
A baseline was measured near Elimä (lat. 60°> 50'). Further agreement to extend the scheme south to the mouth of the River Danube and its observation by Tenner. When Tenner passed his results to Struve he also included values for the arc that connected to the Prussian geodetic network, thence to France and the British Isles. This was the first major transcontinental European East-West geodetic framework.

1845
Astronomical observations were made near Torneå (lat. 65° 51') and at Kilpi-Maki (lat. 62° 57'). A further base was measured at Uleåborg (lat. 65° 00').
This then allowed a readjustment of the chain from Torneå to Ssuprunkowzi, an arc of 17° 05' 33" which was later used by Bessel in his final determination of the figure of the earth.

*Third Phase*
*Sweden and Norway 1844 to 1851*

1844
Struve conferred with scientists from Norway, Sweden and Russia as well as with Tenner, on the possible extension southwards to the Black Sea and for a northern extension to the Arctic. Commissioners were appointed by Sweden and Norway to assess the feasibility – Sweden from Torneå to Kautokeino and Norway from there to North Cape. Later the same

year Struve met with King Oscar I and proposed the extension to the Barents Sea. This was quickly agreed and N H Selander was made responsible.

1845
Norwegian participation was put in the hands of Christopher Hansteen (1784–1873) Director of the Christiana Observatory.

1845
13 June saw agreement between Sweden and Norway for the arc to begin. Hansteen despatched two young officers to reconnoitre the area, build signals and determine suitable sites for the baseline and astronomy.

1846 to 1850
The field observations.

1848–1849
After Tsar Nicholas I gave his assent Tenner completed the arc southward to Ismail = Staro-Nekrassowska (lat. 45° 20') on the Black Sea.

1850 May
The Alta base was measured by Klouman (1813–1885) and a Swede from Struve's staff at Pulkovo. The area was flat but the base was only 1154.7 t = 2251.7 m. Each terminal was monumented with a stone block, and small iron bolt at the centre. Bad weather severely delayed the astronomical observations at Fuglenaes and Lindhagen just managed to get the last boat south before the permanent winter dark set in. Unfortunately his assistant Lysander died on the long journey back to Pulkovo. There were 15 stations between Hammerfest and the Swedish border near Kautokeino. The astronomy was at Fuglenaes near Hammerfest because North Cape itself was unsuitable for the final station because of the weather conditions and persistent fog.

1851
A baseline was measured near Torneå and the astronomy completed at Stuor-oivi. There were 24 stations in the Swedish section which was mostly observed by Selander, Lindhagen, Skogman and Wagner.

*Fourth phase*
*Completion 1852 to 1855*
Some supplementary reobservation of suspect values were made during this period. To honour the completion of the arc monuments were erected at Hammerfest and Ismail.

Fig. 9: Monument at Fuglenoes in Hammerfest. The northern terminal of the Struve geodetic arc.

### Subsequent use
Data from this arc was used even as recently as 1942 by Izotov and Krassovsky in their ellipsoid calculation. Norwegian geodesists repeated the astronomical observations at Fuglenaes in 1928 with Hans Jelstrup and in 1950 with Yngvar Schiøtt. There was good agreement with a variation in latitude of less than 6m.
In the 1970s the remains of the training base at Pulkovo was recovered and new pillars established at the terminals.

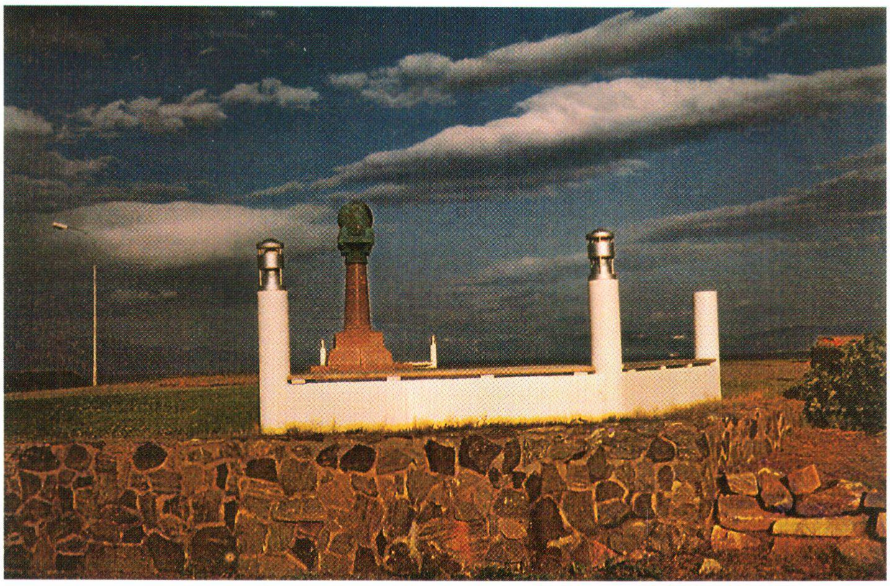

Fig. 10: The old «Fuglenoes Skane» in Hammerfest, with the Struve monument.

### Instrumentation
Struve used a universal instrument by Reichenbach of Munich which had a 13 inch diameter horizontal circle and 11 inch vertical circle. These were graduated to 5' and read directly by verniers to 4".
Tenner used a variety of seven instruments by a range of different makers. There were two repeating circles, one of 13 inches diameter by Baumann which read to 4" by vernier, and the other 14.3 inches by Troughton reading by vernier to 10" A 12 inch diameter terrestrial repetition theodolite by Reichenbach read by vernier to 4", an 8 inch astronomical repetition theodolite by Ertel reading to 10"; a repeating theodolite of 10 inches made in the Etat-major and reading to 5"; and two instruments by Ertel. The first two of these

instruments gave inclined angles whilst the other five used by Tenner and that by Struve gave horizontal angles direct [3].

### Standards of length

The standard unit used was the toise of Paris which was the same as the toise of Peru. It was designed by Struve and constructed by Fortin. From this standard two field standards were made each of about 2 toise or 1728 lignes long (1 ligne = 1/12 inch). Tenner on the other hand used a standard of 945 lignes which equates to the Russian sajène or 1.0946 toise. During 1850 to 1853 19 different standards were intercompared at Pulkovo. Thus the relationships become complicated.

That used on the baselines of Simonis, Elimä and Uleåborg was of 1728.01249 lignes of the Fortin toise at 13°R. For the bases at Alten, Over Torneå and Taschbunar the standard was of 1727.99440 lignes. For the Romankautzi base the standard was of 1728.01991 lignes. The value of Tenner's standard, used for the bases at Ponedeli, Ossownitza and Staro-Konstantinow was of 945.75779 lignes. [5]

### Baselines

Sprinkled among the 258 principal triangles were 10 baselines, five of which were measured by De Tenner, three by Struve and one each by Selander and Hansteen. Struve used four wrought iron bars each of 2 toise in length. One end of each bar had a small cylinder with slightly rounded end, the other end of each had a contact lever which was pivoted to the bar. Two thermometers were set into holes in the bars and the bars were each set in boxes from which their ends protruded. Seven of the baselines were measured using this equipment and Struve estimated the probable errors of each to be around 1 ppm.

The other three baselines were measured by equipment devised by Tenner. Here the bars were of forged iron 2 sajènes long One end of each bar was fixed and the other free to move. At this latter end was a sliding scale that could be used to determine the distance between consecutive bars.

### Results

Observations for latitude and azimuth

## Dramatis personnae

A few words about the characters involved are appropriate here.

### Hansteen

Christopher Hansteen was born 26 September 1784 in Christiana (now Oslo) and died in the same city 15th April 1873. He studied law at Copenhagen and later became Professor at Christiana. By 1817 as a President of the Geodetic Institute he played a leading role in the survey of Norway. He was particularly interested in geomagnetism and magnetic charting.

### Lindhagen

Daniel Georg Lindhagen (1819–1906). Was a Swedish astronomer who worked in Pulkovo. He spent two years on survey work in Lapland. Later he became permanent secretary to the Royal Academy of Sciences in Stockholm. He married Wilhelm Struve's daughter Olga.

### Maupertuis

Pierre-Louis Moreau de Maupertuis was born 28th September 1698 in St Malo and died on 27th July 1759 in Basel. On 8th October 1745 he married Eléonore Catherine von Borck. He was said to have been a spoilt child and this resulted in a certain intransigence and unwillingness to be criticised that later led him into difficulties. His early education was private. His father was ennobled by Louis XIV as René Moreau Sier de Maupertuys. After studying in Paris he was in the French army until 1723 when he became involved in the French Academy of Sciences. By 1728 he strongly believed in Newton's idea on the shape of the earth and began to work on his own theories and even published a treatise on the figure of the earth which signalled the beginning of the establishment of the Newtonian hypothesis in France. In 1736 he led an expedition to Lapland to make a measure of a meridian arc and he was later involved in further arc measurements in France. In 1745 he accepted an invitation from Frederick the Great to go to the Academy of Sciences in Berlin where he became its President.

### Selander

Nils Haqvin Selander (1804–1870) Director of the Stockholm Observatory.

### Struve

Friedrich Georg Wilhelm Struve was born in Altona, Germany 15th April 1793 and died 23rd November 1864 in Pulkovo, Russia. He married twice with a total of 18 children. He graduated in philology from Dorpat in 1810 and started work at the University observatory. By the age of 20 he became Professor of Mathematics and Astronomy at Dorpat. His involvement in the survey of Livonia was the start of almost 40 years of work on the meridian arc. As a result of which, in 1857 he proposed the measurement of an arc of latitude covering 69° from the West coast of Ireland to Orsk on the Ural river. He was a founder of the Russian Geographical Society and belonged to some 40 scientific academies, learned societies and the like.

### Svanberg

Jons Svanberg was born 6th July 1771 in Neder-Kalix, Norrbotten, Sweden, and died 15th January in Uppsala. By 1787 he was studying at Uppsala University where he was to later become Professor of Mathematics. During the period 1799-1801 he led a team that reobserved the work of Maupertuis 60 years earlier at the north end of the Gulf of Bothnia. In doing so he extended the original. He had a love of decimals (which is evident in the exaggerated accuracy he quoted in his observations) and complicated calculations.

### Tenner

Karl Ivanovitsch de Tenner was born 22 June 1783 in Narva and died 28 December 1859 in Warschau. He spent much of his working life on the arc measurement. In 1848 with Zylinski he found earth parameters of a = 6380 880 m, f = 263.597. Tenner devised a base measurement system using only one bar with temperature obtained from two thermometers whose bulbs were inserted into the body of the bar.

were made at 13 selected stations 4 of these were in Scandinavia and the other 9 in the Russian states. This gave 12 arcs that could be computed separately. These varied from 1° 22' to 2° 54' in length.
From these the length of 1° was determined for each of the 12 arcs and these varied from 57 252 t in the far north to 57 068 t in the far south but there were some inconsistencies in between. Using seven different divisions there was a more regular decreasing pattern between similar extreme values.
Struve concluded that the overall length of the meridian arc was 1 447 787 toise (= 2 821 854 m) for 25° 20' 08.29" or 1° = 57 144 t.
Combining his results with those of Bessel gave the ratio of the earth axes as about 293.7 : : 294.7. He did however make other calculations with varied results.

### Summary

1830
End of phase one. There was a complete meridian arc from Högland in the Gulf of Finland (latitude 60° 05') to Belin (latitude 52° 02') = 8° 03' extent.

1844
End of phase two. There was a complete arc from Högland to the Dnestre river (latitude 48° 45').

1851
End of phase three. There was a complete arc from Fuglenaes to Staro-Nekrassowsa except for the need to add some supplementary data and reobserve various suspect stations – which took place during the last phase.
The full arc extended over 25° 20' 08.29" of latitude with the linear separation of the terminals as 2822 km. When combined with the observations of Bessel and with those in India it gave an oblate spheroid where the ratio of the major and minor axes were approaching 1 in 300, a value which is comparable with that acknowledged today.

## A World Heritage Monument

How then does all this fit into the concept of a World Heritage monument? Such monuments to date have all been very large structures or features for which the area is often measured in many hectares. With the arc, the area covered by the chain of triangulation is large but the actual survey stations are essentially point positions only and even with any cairn that covers some of them the area taken up is but a few square metres per point. That does not appear to present a problem to the authorities who rather see the unusual concept as a challenge.
Today the Struve arc passes through ten countries: Norway, Sweden, Finland, and the SSR countries of Russia, Estonia, Latvia, Lithuania, Byelorus, Ukraine and Moldova. Each of these countries contain a good number of the Struve stations except Russia which has only – on the island of Högland in the Gulf of Finland.
The arc in total consists of some 265 points plus some ancillary ones in base extension networks. Of these a few are already permanently monumented such as those at Fuglenaes in North Norway, Kittis in Finland and Staro-Nekrassowka in the Ukraine. The first and last of these three have inscribed obelisks whilst that at Kittis has a form of pyramidal cairn with inset commemorative plate.
The aim is to select two or three points in each of the nine countries, other than Russia, that are recoverable as definite Struve positions and to have them marked in some commemorative manner. Those selected would be in positions of reasonable access to the public (some in North Norway for example require a helicopter to achieve access or alternatively several days trek).
The structure (if any) at the selected points would possibly vary from country to country but each would bear a similar plaque giving the briefest of information about the arc and the particular point.
Each of the countries involved is required to first of all identify two or three selected points and then to indicate how they would see them being permanently marked and maintained in good order and access. The authority for this would need to come from the national government department concerned. Considering the age of the points, the difficult access to the vicinity of many of them and the difficulty of recovering the ground mark, the task of compiling a summary for submission to UNESCO will obviously take hard work to complete.
Those working on the project hope to submit documentation by June 2000. This is being coordinated by the Survey Department of Finland. The arc passes through that country, and much of the material necessary is available there. Should UNESCO look favourably upon the idea and grant the arc World Heritage status, it would then be hoped to mount a remeasuring exercise by GPS at the selected points and to use that to investigate the accuracy of the original work. That could then lead to further investigative work relating to the original observations. However because of the very limited resources available at present, progress is one step at a time rather than opening up on several fronts at once.

### The Future

If the project should come to a successful conclusion then it would not be impossible to extend the idea south into Africa and down the 30th meridian to South Africa. As is indicated by Chovitz & Fischer in 1956 [6], for purposes of determining the figure of the earth the arc of the 30th meridian was linked across the Mediterranean to European arcs. Thus it could be an extension of the Struve meridian arc project to continue through the African arc of the 30th meridian and so preserve a series of points from the North Cape to Port Elizabeth or even along to Cape Point.

### Names

In the interval since Struve completed his work many place names have changed. Some have simply a change of one or two letters, others have completely altered their names. For example: Dorpat = Tartu, Donau = Danube, Leningrad = St Petersburg. The regional names also have changed so that, for example, Bessarabia is now Moldova and Livonia has been divided between Estonia and Latvia.

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# Basel und Umgebung 1836–1839

Im Verlag Cartographica Helvetica ist anfangs 2000 die Faksimile-Ausgabe der topographischen Aufnahme 1:25 000 für die Dufourkarte erschienen.

*L'édition facsimilé du relevé topographique 1:25 000 de la carte Dufour est parue au début de 2000 dans la maison Cartographica Helvetica.*

All'inizio del 2000 la casa editrice Cartographica Helvetica ha lanciato il rilevamento topografico – scala 1:25 000 – della Carta Dufour nel formato facsimile.

*H.-U. Feldmann*

Auf der Suche nach zuverlässigen topographischen Grundlagen für den Basler Teil der Topographischen Karte der Schweiz im Massstab 1:100 000 wandte sich Guillaume-Henri Dufour 1836 an den Basler Unter-Bauinspektor Friedrich Baader (1802–1867). Baader wurde von Dufour beauftragt, zunächst die vorhandenen Übersichtspläne der Stadt sowie von Riehen und Bettingen nach genauen Instruktionen zu einer Kartenvorlage in den Massstab 1:25 000 zu reduzieren. Im Zeitalter eines vereinigten Europas mag es erstaunen, dass bereits damals auch Pläne der benachbarten badischen Grenzgemeinden beigezogen wurden.

In der hier wiedergegebenen Karte ist ein Teil des Originales von 1836 (Stadt) in dasjenige von 1839 (Landschaft) eingesetzt worden. Praktisch das ganze dargestellte Gebiet war damals bereits vermessen, so dass Baader die vorhandenen Katasterpläne übernehmen konnte. Dufours Instruktionen entsprechend ist das Terrain mit Schraffen dargestellt. Der aufmerksame Betrachter wird feststellen, dass die