STRUVE ARC

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THE BACKGROUND OF THE MEASUREMENT

The seeds of the Struve Arc were sowed by the Great French Revolution. Many traditional habits were replaced by new systems. Especially old measures were toppled by a new metric system. It was quite simple to stipulate that one quarter of a meridian makes 10 million metres. But how long was the meridian? Some determinations were made, the longest between Barcelona and Dunkerque. First they yielded a prototype of the new unit, the Legal Metre. However, it was based on quite inadequate measurements and calculations.

The best possible result from the early arc measurements was derived by a Finnish astronomer Walbeck. He applied for the first time the method of least squares to compute the dimensions of the earth ellipsoid. However, a more reliable knowledge of the dimensions was still missing owing to the limited number and limited length of measured arcs.

As another result of the French Revolution wars were raging around Europe and yet wider. The Napolenic wars stretched from Nordkapp to Cairo and from Moscow to the Atlantic Ocean. After wars that lasted a quarter of a century Napoleon was defeated. This resulted in the Vienna Conference which set out to bring order back to Europe. Even while negotiations were taking place Napoleon escaped from Elba and started new wars. He was defeated a second time and only then was the Conference able to continue. By 1815 international boundaries were established in Europe and steps taken that were supposed to prevent any further revolutions or uprisings.

Then the general feeling among the rulers was quite restless in Europe. They did not trust on a lasting peace and tried to get prepared for new wars. The mapping for military purposes was appreciated and all steps to its promoting were advanced.

The proper framework for the topographic mapping was a problem at that time. As a lower order framework polygonic traversing was available. The higher order was more complicated. The astronomic observations were too difficult to the density needed in traversing, especially due to the determinations of the longitude. In addition, the coordinate system required still the final word of ellipsoid dimensions.

Especially in Russia both needs were felt deeply, the need of fundaments of geodetic surveys and the fundaments of map grids. Every attempt to foster new knowledge of them was

favoured. The proposal of the Estonian astronomer Wilhelm Struve to Czar of Russia combined both elements. In addition, the Czar Alexander the First was in favour of higher education and science and so Struve met deep wishes and so got all the resources he needed.

The way was open to an arc measurement along the west boundary of Russia to serve the scientific aims, to develop the basis of geodetic framework and to start the topographic mapping.

In the year 1814 Director Lindenau of the Seeberg observatory has proposed an arc measurement following the west provinces of Russia. He presented the proposal to Wilhelm Struve and to Carl von Tenner independently. This was the beginning.

THE RUSSIAN-SCANDINAVIAN MERIDIAN ARC MEASUREMENT

This is the proper name for the project although it is shorter to call it the Struve Arc. Geographically it runs across Russia and Scandinavian countries. The name Struve honours the central person of the project. The Estonian astronomer Wilhelm Struve was the initiator and responsible geodesist as well as the publisher of the results of the Russian-Scandinavian meridian arc measurement.

Besides Wilhelm Struve, Carl von Teller belongs to the remarkable names of the arc measurement history. He was an Estonian general in the Russian army and had the responsibility of trigonometric and topographic works in Kurland. To the same time they bouth carried out arc measurements separately and independently. Struve got his permit and resources from the Czar and von Tenner his permit from Prince Wolkonsky. Outwardly the Struve Arc gives an impression of carefully designed project. However, it has been built piece by piece

Struve measured a triangle chain along the meridian of Tartu from Hogland (Suursaari) to Jekabpils and von Tenner along the meridian of Vilnius from Belica to Birzai The ends of both chains were not far from each other. In 1828 Struve and von Tenner agreed to connect the chains. As a result they got in 1831 an arc of 8° 02,5´ equipped with three base-lines and five astronomical stations with latitude and azimuth observations. It was a fine result for that time, but still more was coming.

The problem of the longitude determining was the reason to assume the astronomic position of Tartu or Vilnius as a zero meridian. Then the latitudes and azimuths could give longitudes to the other points in relation to the zero meridian.

When the first arcs were completed Struve and von Tenner started to extend the combined chain, Struve northwards and von Tenner southwards. Von Tenner continued in 1830 - 1844 the triangulation chain as far as to Ismail, located near the mouth of the river Danube. Three more base-lines were measured and three astronomical stations.

Struve had a more complicated task. The first leg across autonomous Finland was not politically difficult. Moreover, he could leave the practical implementation to a Finnish astronomer Woldstedt. Later political steps were needed and the necessary agreements made.

The chain was joined in the north to that part carried out by Sweden as their share. In Sweden the responsibility for the work was given to the astronomer N. H. Selander. There the chain followed first the old Maupertuis Arc, western points at the Swedish side and the eastern ones at the Finnish side of the boundary.

Continuing further to north there was a new political problem. Norway belonged to the Swedish realm but had her own administration. Consequently, the rest of the chain up to the Barents Sea was measured under the responsibility of Christopher Hansteen as far as the northernmost point at Fuglenes. This finished the field work. The northern part included four additional astronomical stations and four base lines.

Considering especially the difficulties of transportation in the first part of the 19th century the work has been immense. The total length between the ends of the long chain covered 25° 20' 08,29" of latitude or 2821,854 metres when converted from the toise-unit. The unit of length applied in the measurements was the French fathom, the toise. To modern people the metres are more illustrative.

However, the amount of work is not the only merit. Taking the instrument and observation techniques of that time into account the achieved accuracy was amazing. Co-ordinate transformations between some Struve points and coinciding new points measured applying the best methods about one century later, have revealed an unexpected quality. The discrepancies were of the order of some centimetres, maybe one or two decimetres. One lost Struve point was found when measured from a nearby new triangulation point. It was about one decimetre from the computed site. Perhaps the accuracy of the modern methods deserve the admiration.

Another remarkable item of the Struve Arc is the monumentation of the stations. They were marked on the solid rock by drilling a hole. The hole was filled with lead and on the top of the lead was a plate of brass. In the course of time the plates have disappeared first. Most of them were found missing in 1890s already. Later the lead has been digged out, maybe to be made shots for the hunters. However, nobody has been able to take along the holes in his pockets. The monumentation belongs probably to the merits of von Tenner.

A still more amazing feature of the Struve Arc is the documentation. Struve gathered all the material of the measurements and made a final report. After some busy years everything was published in three volumes. This tome belongs to the most valuable literary historical products of the time. It gives a very carefully drawn history of the accomplishment of Struve Arc in details.

THE VALUE OF THE STRUVE CHAIN

The Struve chain brought several benefits. The long and accurate chain gave a fine addition to the determination of the ellipsoid. Further it had plenty of indirect influence. The principles of the work were published in all details. Then the Arc could be used as a good example. Even the personal contacts were important. For instance, Struve had an influence to the measurement of the parallel arc along the latitude of 52° and Tenner tied its end to the Struve Arc. Many chains were measured in different continents in the following years. Some results of these works can be seen in the development of the computed dimensions of the earth.

	Year	a	f	Meridian quarter
Walbeck	1819	6376 896	1 : 302,8	10 000 271 metres
Bessel	1841	6377 397	1 : 299,15	10 000 857
Clarke	1880	6378 249	1 : 293,5	10 001 869
International	1924	6378 388	1 : 297,00	10 002 288
Krassowskij	1935	6378 180	1 : 298,9	10 002 071
International	1967	6378 160	1 : 298,2471	10 001 955

Here are some examples of generally used values. Very clearly the mutual agreement has become better since the publishing of Struve Arc and succeding measurements. This has given a good start to the uniformed mapping, its framework and the map projection systems.

Indirectly it has also helped assuming the metric system. It became quite generally accepted on principle in the international agreement in the year 1875. It is true, the length of the base unit does not depend any more of the deterimination of the earth dimensions. However, their good determinations have given some good will to the system.

The part of the Struve Arc has been remarkable to the framework for mapping. Strong chains with permanent marking and good documentation have ever since belonged to the basic work in many countries. Base lines and astronomical stations distributed along the triangulation chains have become a part of good triangulation. These principles have then been followed for nearly two hundred years until the GPS has completely changed the methods. Thus Struve Arc can be considered as the Mother of Triangulations.

Struve Arc has not served tringulations as an example only. Its points have been starting points to many new triangulations and travesrses in the course of a century. Still up to sixties in the 20th century Struve Arc was the only connection of coordinates between South and North Finland. An additional advantage has been the careful trigonometric levelling along the chain

All in all, the Struve Arc makes an early and exceptional incident in the history of geodesy. It has served scientific and practical aims and stays as a memorial to get preserved.

MEASURES

About the time in sixties when the Struve arc was sent to the well-earned retirement a new interest in the chain was arisen in Finland. In connection of the new co-ordinate system comparisons were made to the modern triangulation. Because it revealed unexpected

accuracies, it started investigations of the material more thoroughly. The more was learned the more respect and admiration was felt.

Professor Petrelius had checked the stations in three excursions in the years 1886, 1888 and 1889 and had made a catalogue of his findings. At that time only few points were missing. Now a new search was started. The task to make an inventory of the points was entrusted to Mr. Aarne Veriö. He has taken the issue carefully and has collected plenty of information. Doing this he has realized that the preservation of the remaining sites is very important to the honour, the Struve Arc deserves. In this sense he had prepared a paper to present it at the Tartu scientific conference. Due to his sickness he could not arrive to the conference. However the paper was presented and his idea on the UNESCO declaration to preserve the relics as a World-Heritage sites.

The Scientific Conference in Tartu assumed the idea and gave August 28, 1993 the resolution No 1:
"Considering the scientific, historical and practical importance of the measurement of the arc of meridian through Tartu, made by F.G..W. Struve,
Urge the governments of those countries that still possess relics of that enterprise to take all possible steps to preserve those relics, including an approach to UNESCO to declare them to be World-Heritage sites."

Corresponding resolutions have since been made later in FIG Congresses. Consequently International Institution for the History of Surveying & Measurement (a permanent body within FIG) has worked hard to achieve the preservation of the Struve points and to get the aforementioned declaration of UNESCO

It is quite natural that in Finland the interest was high. There are more Struve stations situated in Finland than in any other country, probably more still identified, too. In addition their practical significance has been very important. Aarne Veriö has worked hard to advance the matter. Director General of the National Survey Organization, Mr. Jarmo Ratia has contacted the directors of relevant organizations along the Struve Arc and urged them to join the project.

The desired World-Heritage declaration provides, that the included Struve stations are already protected in those countries where they are situated. The task is not easy because the legislation deviates from one country to another. For instance in Finland it is still unclear whether to apply the rules of planning or nature conservation. Similar problems may arise anywhere. However, a close co-operation of all ten countries involved and Mr. Jim Smith, General Secretary of the International Institution for the History of Surveying & Measurements is really worth while before the case can be put to UNESCO.

If a submission can be achieved by the end of this year then it is hoped that some definite progress will be able to be reported to the FIG Congress of 2002 in Washington.

There is still one more aspect to be discussed. As mentioned before, the tome by Struve where the Arc was documented, belongs to the history of surveying. It is valuable and it is

interesting. Unfortunately the book is now a rarity, seldom found in the libraries. It is uncertain whether it is found in every involved ten countries. It is true, it has been reprinted already once in Russian in the year 1957 in Moscow. No doubt, it must also be out of print.

It would be a cultural achievement to reprint the tome. Still better if it would be in English to get more readers. In French it could be a facsimile product. Perhaps International Association of Geodesy could support the idea. It is worth thinking of this idea.

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