# OBLATE or PROLATE?

## An Account of the 1736 Geodetic Survey in Lapland which Investigated the Shape of the Earth

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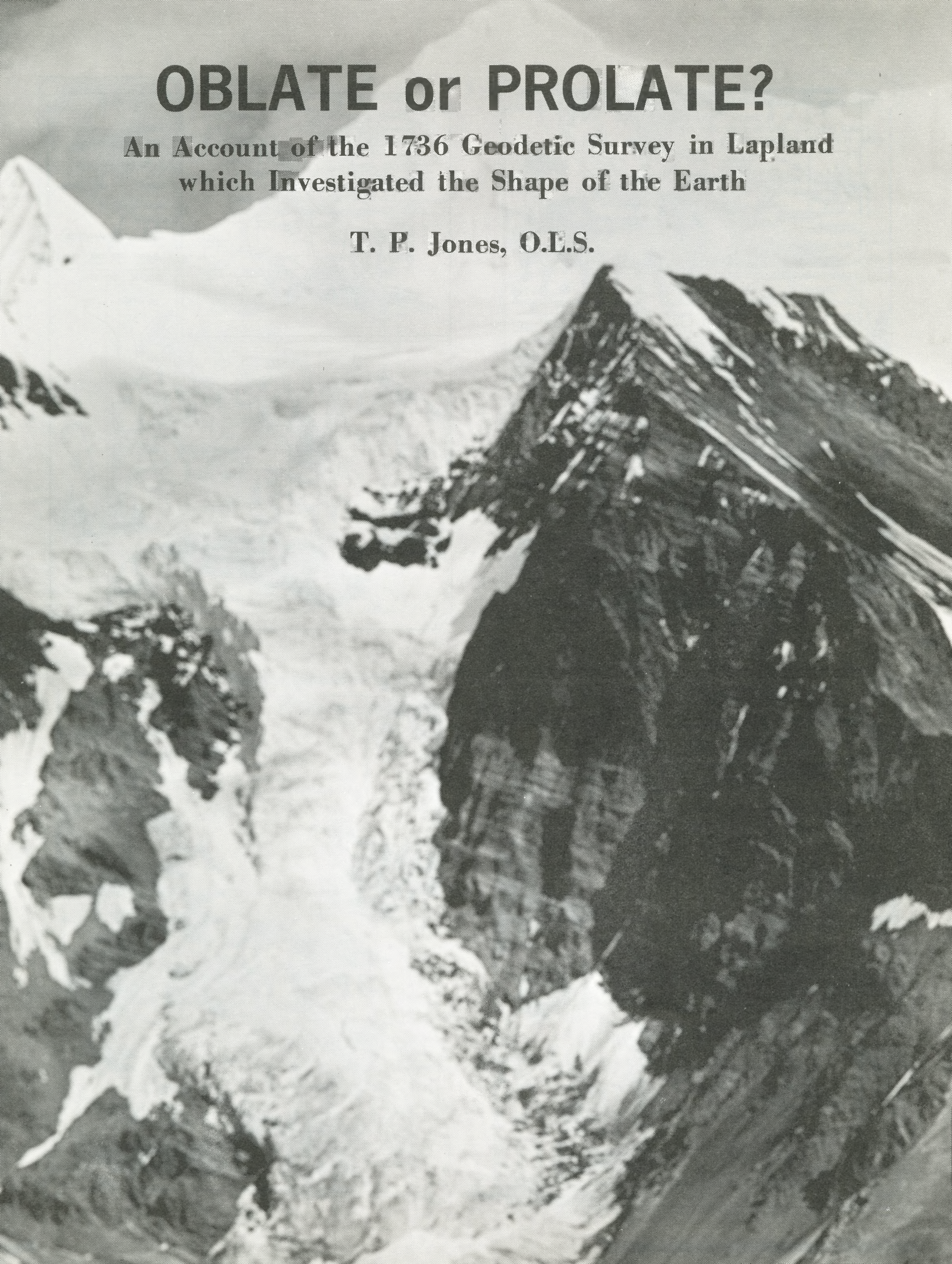


One of the first problems that must have suggested itself for solution in the intellectual infancy of mankind was:— "What is the earth, its size and shape?"

The natural conclusion to be deduced from daily experience and observation would be:— if the earth were deprived of its valleys and mountains, its surface would be a plane. The exact date of the abandonment of this theory is unknown.

Pythagoras made the first authenticated announcement that the earth is spherical, although this honour is sometimes assigned to Thales and Anaximander.

Over the years many attempts were made to calculate the earths size, from measuring the lengths of shadows to counting the revolutions of measuring wheels.

Early in the 17th Century, the first attempt was made to determine the radius of the earth by adopting the principle of measurement by triangulation.

The work comprised the measurement of two arcs, between Alkmaar and Leyden, and Alkmaar and Bergen-op-Zoom in Holland, and was carried out by one Willebrod Snell, Professor of Mathematics at Leyden University. He published an account of this degree measure in Leyden in 1617.

About fifty years later, another survey was made by the Abbé Picard, an astronomer, in France. He had conceived the brilliant idea of combining a telescope equipped with cross-wires with his angle measuring instruments. His subsequent work was a great deal more accurate than anything that had gone before.

He measured a base-line nearly seven miles long, and with a sector of ten feet radius, to which was attached the telescope, the angles were carefully read, until Malvoisine, near Paris, and Amiens were connected by a chain of triangles. This subtented an arc of 1° 22' 58", from which he computed 57,060 toises as the length of a degree.

One toise, or fathom, an old French measure, equalled about 1.95 metres.

The very high accuracy of Picard's work, while reflecting great credit on his abilities, was subsequently proved to be due to a fortunate compensation of errors.

One of the results of Picard's work was that it enabled Sir Isaac Newton to complete his doctrine of gravitation as published in the Principea in 1687. Amongst other things, Newton was able to prove that the earth was flattened at the poles, and was thus an oblate spheroid.

Between 1684 and 1718, the father and son team of Giovanni and Jacques Cassini extended Picard's work across France, northerly to Dunkirk and southerly to Perpignan, measuring a base at each end.

From the northern portion of the arc they obtained 56,960 toises as the length of a degree, while the southern portion gave 57,097 toises. This showed the figure of the earth diminishing as it approached the poles, and they therefore surmised the polar diameter to be greater than the equatorial, and that the earth was in fact lemon shoped, or a prolate spheroid. This pleased the French, as it gave them the opportunity to say that the country across the Channel was a "Nazareth from which no good thing could come."

Nevertheless, this statement, on so great an authority as Cassini, that the earth is a prolate, not an oblate, spheroid, as maintained by Newton, Huygens and others, found at the time many adherents, and on this question the scientific world was divided into hostile camps.

Under the excitement caused by this controversy, as well as from a desire to know the truth, the French Academy of Sciences, with the support of Louis XV, decided to submit the problem to a crucial test by measuring one arc of the meridian crossing the equator, and another arc crossing the polar circle. Knowing the fierce criticism that would be brought to bear upon every feature of the work, the participants determined to use the most refined instruments and most approved methods of the time.

Accordingly, in May, 1735, a survey party under the direction of De la Condamine proceeded to Peru, and after several years of laborious effort, succeeded in measuring an arc intersected by the equator. Some indication of the work involved can be gathered from the fact that seven of the triangulation stations they occupied were at elevations exceeding 14,000 feet above sea level.

The second party, headed by Capt. Maupertuis, were to measure an arc in Lapland.

What follows is a brief description of the geodetic survey carried out in the North.

**THE SURVEY PARTY**

Pierre Louis Maupertuis was a musketeer in the French Dragoons; he taught mathematics at the Academy of Sciences. Four years after returning from Finland, he was taken prisoner by the Austrians at the Battle of Mollwitz. Members of his party were as follows:—

A. C. Clairaut; mathematician, calculated path of Uranus before its discovery, calculated perihelion of Halley's comet, designed circular slide rule.

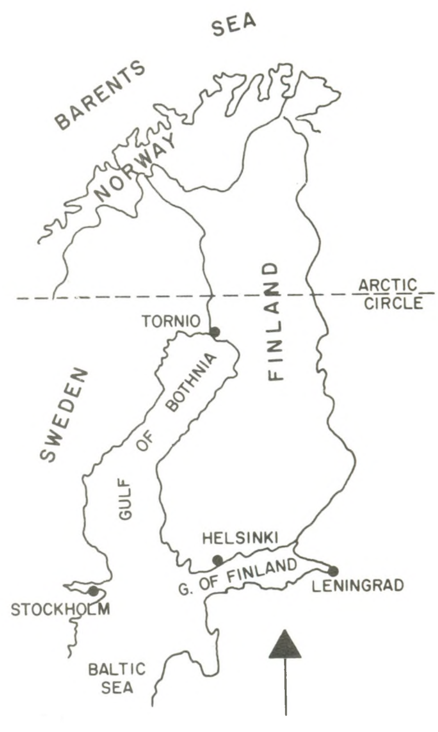
P. C. LeMonnier; astronomer, made a lunar map, which allowed him membership in the Academy of Sciences at age 20. At 21, he was the youngest member of the party in Lapland.

Abbé R. Outhier, astronomer.

C. E. L. Camus, Royal Architect, carried out research on forms of cogs with cogged wheels and pinions.

And, believe it or not, A. Celsius, Swedish, Professor of Astronomy at Uppsala University, inventor of the centigrade thermometer!

They took with them a clock to assist in their astronomical observations. This had been built by George Graham, the well known British inventor and watchmaker. M. Camus, with his unique qualifications, must have been responsible for this instrument.




**THE GEODETIC SURVEY**

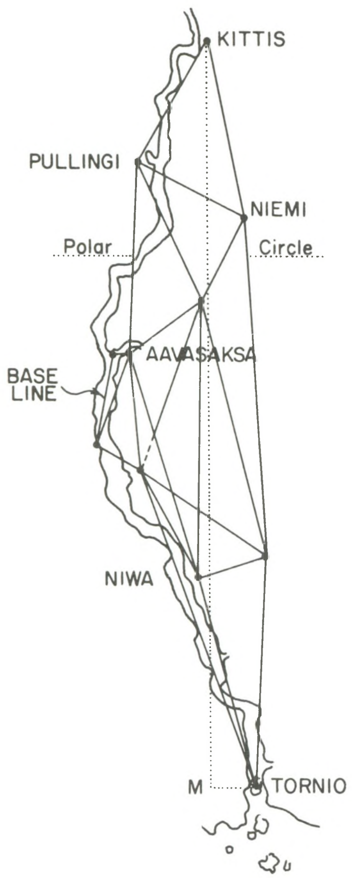
The survey party landed at the town of Tornio, which is at the mouth of the river of the same name, at the northern extremity of the Gulf of Bothnia, in the beginning of July, 1736.

From the 12th-century Crusades until 1809, Finland was a part of Sweden. Today, the Tornio River forms the boundary between these two countries.

They explored the river, found that its course was nearly north and south, and that there were many high mountains on either side. They determined to establish their stations on these mountain tops.

The signals they constructed were built of trees stripped of their bark, in the shape of hollow cones.

The network they eventually reconnoitred is shown in the accompanying diagram. You will agree that the arrangement, with the base line in the centre, is very good, and they regarded it upon its completion with pardonable satisfaction, remarking that "it looked as if the placing of the mountains had been at our disposal".




The angles were measured with a quadrant of two feet radius, fitted with a micrometer. This instrument had been checked a great number of times by closing angles around the horizon.

Each observer kept his own set of notes; the mean of these individual observations was accepted. The three angles of every triangle were always observed.

The measurement of the angles took sixty-three days. On September 9th, they arrived in Kittis, and began to prepare that station for the astronomical work.

Two observatories were built; in one was the clock and a small transit set up over triangulation station. These were to determine absolute azimuth, which was effected by observing the times of transit of the sun over the vertical of Niemi in the south-east in the morning, and over the vertical of Pullingi in the south-west in the afternoon. These observations were made between September 30th and October 8th.

The second observatory, close by, contained a large, brass telescope, nine feet in length, with attachments, and which had also been made by Graham. This instrument was not used to determine absolute zenith distances, but differences of zenith distance only.

The observations of S. Draconis, which passed close to the zenith, were commenced on October 4th and concluded on the 10th.

Ties were made from this second observatory to the triangulation station, so that the observations made there could be reduced to the station itself.

Leaving Kittis on October 23rd, they arrived at Tornio on the 28th. The observations of S. Draconis were made there between November 1st and 5th. The observations of the star at both stations were made by daylight without artificially illuminating the wires of the telescope.

They eventually found the amplitude of the arc between Kittis and Tornio to be 0° 57' 30.42".

**THE BASE LINE**

It now remained to measure the base line, and this had been purposely left until the winter time. The ends of this line had been selected so that it lay upon the river. When frozen, this made a very good surface upon which to measure.

They had brought with them from France a standard toise (known afterwards as the "Toise of the North") which had been graduated, along with a second one, to the true length at the temperature of 14° Reamur.*

The second standard, that is the one taken to Peru, on its return to France became known as the "Toise of Peru", and by a royal decree on May 16, 1766, King Louis XV made it the national standard. In fact, it could be said that this was the world standard right up until the distribution of the Metre Standards that took place in 1888/89.

Meanwhile, back at Aavarsaksa, five wooden toises were being constructed in a room heated to the temperature just mentioned. The ends of each wooden rod had an iron stud attached. These were filed down until their lengths agreed with the standard toise. Having driven two heavy nails into opposite walls of the room at a distance slightly less than five toises apart, the five newly constructed toises were placed in mutual contact upon trestles in a horizontal line between these nails. These nails were now filed down until the five toises just fitted the space between them.

*water freezes at 0° and boils at 80°.

Thus the distance between the prepared surfaces of the nails became a five toise standard.

By means of this standard they constructed for the actual measurement eight rods of spruce, each five toises (about 32 feet) long, and terminated in metal studs for contact. Many experiments were made to determine the expansions of the rods due to temperature variation, but the result arrived at was that the amount was "inappreciable".

They started to measure the base on December 21st, a very remarkable day, as Maupertuis observes, "for commencing such an enterprise. At that season the sun but showed himself above the horizon toward noon; but the long twilight, the whiteness of the snow, and the meteors that continually blazed in the sky furnished light enough for four or five hours work every day".

They split up into two groups, each taking four rods, and made independent measurements of the line. There is no record as to how the rods were supported or levelled — probably they were merely laid on the surface of the snow.

The measurement of the 8.9 mile long line took only seven days. The total difference in the two measurements was four inches. The average temperature at the time was minus six degrees Farenheit.

It was now a relatively easy calculation to get the length of the terrestial arc. They obtained the distance between the astronomical observatories at Kittis and Tornio, and also the distance from Tornio to the meridian of Kittis. This then gave them the direct distance between the parallels of their terminal stations.

From this they concluded that the length of the degree of the meridian which cuts the polar circle was 57,437.9 toises.

This value, being much in excess of that at Paris, showed decisively that the earth was an oblate and not a prolate spheroid.

As a postscript, it is interesting to note that Cesar Cassini, later to be known as 'Cassini de Thury', the son of Jacques, grandson of Giovanni, was commissioned in 1740 to check the earlier work between Dunkirk and Perpignan. His subsequent re-measurements of the same arcs proved the former results to have been erroneous, and confirmed the earths figure to be oblate.