Mapmakers

3. Techniques of Cartography

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Harini Nagendra has worked extensively with satellite images, and their conversion into maps, for ecological analysis. During this process she became interested in the history of mapmaking, and how things were done in the pre-satellite days. Hence, this article! Her other research interests include the study of landscape organization and dynamics at various scales, and the design of computer-based visual aids to help in teaching ecology.

Previous parts of the series:
1. The Province of Philosophers, *Resonance*, Vol.4, No.4, 6–11, 1999.
2. Going places, *Resonance*, Vol.4, No.6, 8–14, 1999.

In this, the last part of the series, we shall see how the science of cartography developed in the recent past, largely due to the need for accurate maps for further exploration and colonization.

Although a system of mapping the earth using latitude and longitude had been devised, an important issue remained to be resolved – the question of how to measure these quantities. The direct distance between two points was rarely if ever known, and the difference in latitude or longitude could never be correctly translated into a difference in distance or vice versa. Despair over this lack of accuracy was beginning to be felt, as ships found accurate positioning essential for their navigation.

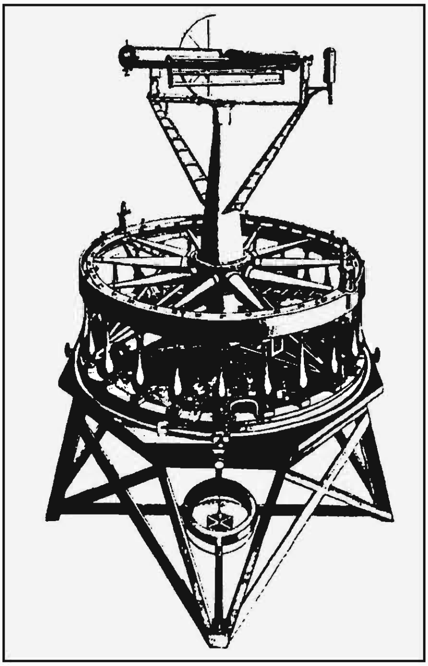
In a hallmark beginning in 1616, Galileo Galilei fabricated an involved methodology to keep track of time, based on tracking the position of the four then known moons of Jupiter. He suggested that people wishing to calculate local time could do so based on these clocks. This was also useful for mappers, as the difference between local time and that in Galileo's observatory would provide the difference in longitude between them. Unfortunately, Galileo had to spend sixteen fruitless years trying to convince King Philip III of Spain of the value of his methodology – after which he gave up in frustration and went to the Dutch, who thankfully welcomed his ideas. Galileo's methodology was laborious, no doubt, but even the best clocks in Galileo's day gained as much as fifteen minutes a day. It therefore became the standard way of measuring time for the next two centuries.

Following this, surveying became a more integral part of cartography in the seventeenth and eighteenth centuries. Earlier surveyors were constrained by primitive instruments, and limited to measurements of small property lines, building sites and roadways. Mapmakers were dependent on the travellers who came their way, for tall tales and crude sketches. The development of more accurate instruments and more mathematical surveying techniques elevated surveying to the status of a science, with methodology and techniques of its own.

Figures 1 and 2 in this article are reproduced from *The Mapmakers: The Story of the Great Pioneers in Cartography from Antiquity to the Space Age*, by John Noble Wilford – originally published by Knopf, New York, 1981 and reprinted by Vitange Books (a division of Random House), New York, 1982.

The first of these, the plane table is believed to have been used in some form by the Romans while laying out their famous roads. In Europe during the 16th and 17th centuries, it came into general use as the first mapping device for recording and establishing angles. It was employed based on the simple principles of triangulation – if you know one side and two angles of a triangle, you can determine the properties of the rest of the triangle. This made it possible to determine the distance to remote objects without having to go there, measuring ceaselessly along the way! Triangulation provided the means for even more ambitious surveys – for if you figured out the details of one triangle, you could use any side as the known line for another triangle, and in this manner extend an entire network of triangles across large areas.

Figure 1. An eighteenth century theodolite. ***(Courtesy The Royal Society, London)***



For non-astronomical angle measurements, the theodolite then became the surveyor's basic instrument (*Figure* 1). This instrument is used for measuring both horizontal angles, used to derive distances by triangulation, and vertical angles, used to derive elevation also by triangulation. Elevation was alternatively measured by using spirit levelers or barometric measurements. For very crucial baseline measurements, the surveyor's chain measuring 66 feet long, with 80 chains equaling one mile, was in use for several years, until it was replaced by steel tape – which in turn has now been largely replaced by electronic, distance-measuring equipment.

In the 1670s, Abbe Picard made the first accurate measure of the length of a meridian arc by combining measurements on the ground and in the sky.

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Although Newton had predicted that this length would be different at the poles and the equator, it was not widely believed until proven by the Abbe. He led the first ever well-planned scientific mapping of an entire nation, in France. A basic framework of points was first chosen, and their latitudes and longitudes carefully determined through astronomical observations and baselines. Upon this, a detailed map was then added with roads, bridges, rivers, estates etc. Picard was the first to apply telescopes to measure angles in surveying. Using these to place 13 triangles, he calculated that a degree measured 110.46 kilometers, a remarkably accurate result! Historically, this must therefore be viewed as much more than a mere mapping exercise. It laid the framework on which all great national surveys, including those of India, were based.

However, at the same time that Picard was making his measurements, Newton was challenging the notion of a spherical earth, stating that the earth will tend to bulge at the equator and be flattened at the poles due to centrifugal effects created by rotation. If the earth were a sphere, the value of a degree would be the same everywhere, for latitude or longitude. But was this really the case?

Maupertuis, during 1736–1737, surveyed the Arctic regions of Lapland (*Figure* 2), and Bouguer during 1736–1744 did the same at the equator, proving beyond doubt that Newton had been right in the first place.

Late in the seventeenth century, as the Newton debate raged, the French academy decided on a test involving extending Picard's meridian line to the north and south of Paris – a task carried out by Jean and Jacques Cassini, a father and son team. Instead of settling the controversy, this fanned the flames, the Cassinis stating that the earth was not a sphere but it was flattened at the equator and bulged at the poles – the exact opposite of what Newton had claimed! If this had been an earlier age, the issue would have been settled based on dogmas, but being the age of the Scientific Revolution, it was put to the test. Maupertuis, during 1736–1737, surveyed the Arctic regions of Lapland (*Figure* 2), and Bouguer during 1736–1744 did the same at the equator, proving beyond doubt that Newton had been right in the first place. Indeed, as Voltaire remarked, the two French expeditions had been enough to "flatten both the poles and the Cassinis".

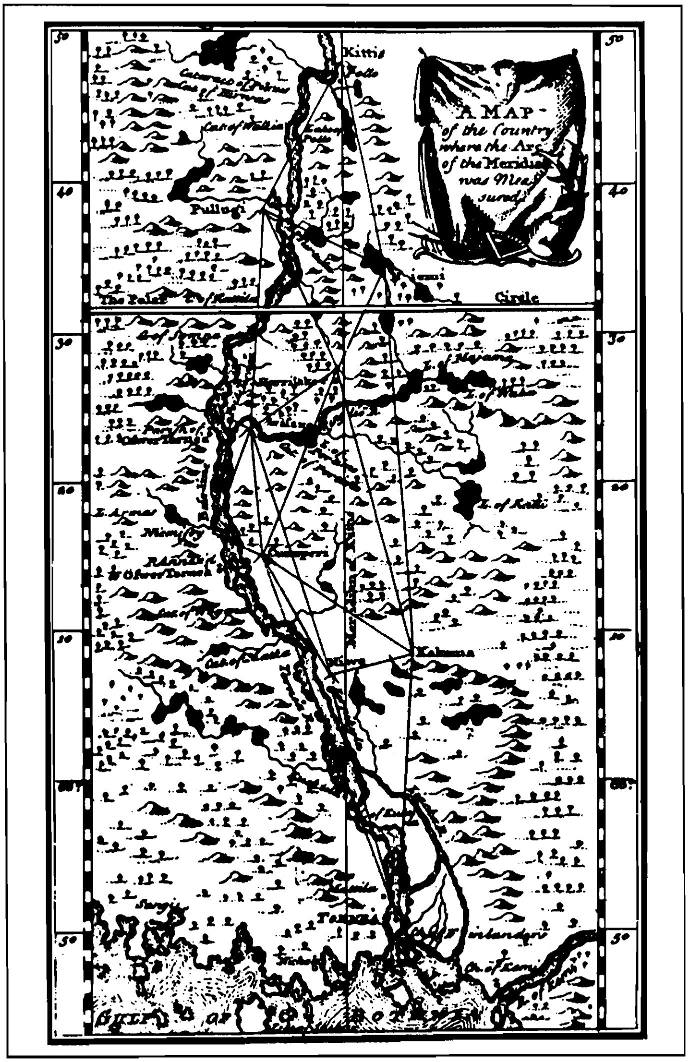

Figure 2. This eighteenth century French map of Lapland, developed by triangulation, helped prove that the earth was in fact not spherical, but bulged at the equator!

Subsequent mapping techniques owed a lot to the men of the Survey of India, from the late eighteenth century onwards, for their advancement. Prior to this, during the 16th/17th century the first known map of India was drawn from measured routes and astronomical calculations. This was the work of a Jesuit priest, Father Monserrat, a visitor to the Mughal emperor Akbar's court. This map was not as widely known as a possibly less accurate map drawn by another visitor to the Mughal court in 1619, Sir Thomas Roe. He prefaced his map with the Latin words "Vera quae visa; quae non, veriora" — the things that we have seen are true; those that we have not seen are truer still. This is a clear indication of the desires and beliefs of Europeans, about the fabulous wealth of India. Roe was in fact the spearhead of the British East India Company, and had come looking for trade opportunities.

Roe's visit paved the way for regular trade between Britain and India. For more than a hundred years afterwards though, the Europeans remained ignorant of India's interior. The best available map of India in 1752 by a Frenchman, d'Anville, still depicts only the coastline, a few major rivers and the coastal cities of Madras, Bombay and Calcutta. Things quickly changed, however. Within a decade, the East India Company under Robert Clive fought the Moguls and annexed the Bengal Presi-

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dency in the east, while in the south, the British defeated the French and took over the Madras Presidency. Very soon, the 'Company' demanded surveys of the new regions they owned. This was done with three purposes in mind – to estimate potential revenue, maintain communications between the coast and the inland areas, and protect the land against attack.

The renowned Survey of India was set up in response to these demands by James Renell, a young twenty-one year old when he came to India to seek his fame and fortune. His very first assignment, in 1764: Take a barge and find a quicker way of shipping goods down the Ganges to Calcutta, he was told. And oh, while you're at it, why don't you map the Ganges delta too! This amazing man spent the next year in the jungle and swamps surrounding the Ganges, coming out relatively unscathed, and with a new route to boot! In 1775, Renell received his next orders from Clive to map the rest of the Bengal Presidency. He travelled through India after this, badly wounded a few times, though escaping with his life and managing a final, comfortable retirement in England (the Indian soldiers who went with him were not so lucky, a few got carried off by tigers).

By 1777, his *Bengal Atlas* was complete, compiled from 500 surveys by him and his nine assistants. When he retired as the Surveyor General of India, he left behind a company of trained men, Indian and British, to carry on the work he had started. The East India Company was however not too enthusiastic about spending a lot of money on detailed and precise surveys – all they really wanted to know was how much different parts of India were 'worth'.

This severely practical view of mapping did not appeal to William Lambton of the Survey, who had a much more ambitious plan in 1802, of which he convinced the 'Company'. Majestic in scope and conception, his idea was to cover the whole of India, from the southern tip to the Himalayan foothills, with triangles. The latitude and longitude of the vertices of these triangles would be determined with great accuracy, and these would serve as a base map of India, the 'arc', onto which further details could be added. Twenty years later, his men had completed half of this Herculean task, the first time in the world that a task of this magnitude had been completed! This is especially noteworthy when one considers the battles he fought with his paymasters, to convince them of the need to fund his exercise. He contended with finance committees composed of members like the man who once commented – "If any traveller wishes to proceed to Seringapatnam, he need only say so to his head palanquin bearer, and he will find his way to that place without recourse to Captain Lambton's map".

Lambton handed over charge to George Everest in 1817, who took over the Survey, and headed it until 1843. In his first two attempts to continue Lambton's arc, he and his party succumbed to fever and several of them died. With what must have been almost superhuman determination, they restarted work each time, and managed to cover most of northern India with a grid of triangles. Everest's successor Andrew Waugh supervised the surveying of the Himalayas (*Box* 1).

Box 1. The Highest Mountain in the World...

Everest's successor Andrew Waugh supervised the surveying of the Himalayas. During his time in 1849, surveyors climbed lesser summits around a majestic peak known only as 'Peak XV' rising from the Nepal–Tibet border, which they were forbidden to cross, and took six different measurements from various directions – of which no two were in agreement! The story goes that a Bengali clerk averaged these measurements, determined the mountain to be 29,000 feet (8,700 metres) high, and rushed excitedly to Waugh exclaiming "Sir, I have discovered the highest mountain in the world". This figure was initially dismissed as preposterous by 'learned' Europeans who declared it impossible for mountains to be higher than, say, about 25,000 feet. Since a value as well rounded as 29,000 feet would certainly have made people even more skeptical, the surveyors arbitrarily added 2 feet to their calculations and released the height as 29,002 feet – and thus it remained for several years in geography textbooks throughout the world! Peak XV was known in Tibetan as Chomolungma, 'Goddess Mother of the World'. The surveyors had made it a policy to give newly mapped peaks numbers instead of names, on the belief that it would be presumptuous for them to rename what already had been named for centuries by the local Asians. This was a laudable policy, one rare to explorers and surveyors as a rule – Peak XV however proved too hard to resist renaming, and Waugh eventually ordered the mountain renamed Everest, in tribute to his predecessor, George Everest.

In the entire nineteenth century, the Survey attracted brilliant and highly committed men, British as well as Indian. These men fought against tremendous odds, including the Company's lack of total support, to map India. It is difficult to understand what drove them. Scores died due to disease, and many animals in the jungle killed more. Less than one in seventy Britishers returned to England to enjoy their fortune. The rate of Indian death must have been, if anything, much worse and their rewards poorer. Their dedication and achievements in the face of such odds is truly astonishing. Even more admirable are the feats they accomplished in the later half of the nineteenth century.

The major remaining challenge at this time was to map the hills to the north. This was a formidable task, with political as well as physical barriers, as the Chinese emperor had banned all travel from the Indian side to Tibet. Thomas G Montgomerie of the Survey hit upon the idea of training Indians in the science of mapping, and sending them across the border disguised as monks. This idea, along with many Indians, was used several times until the travels (travails?) of the last such 'spy' to be sent out, an illiterate Indian called Kinthup from Sikkim, put an end to this fairly inhuman practice.

Kinthup was asked to determine whether the Tsangpo and the Brahmaputra were the same river (they are). For this, he was to travel as a servant of a Mongolian lama, and on a pre-specified date, throw 500 logs of wood into the Tsangpo. A watch would be kept in the Brahmaputra for the logs to see if they came out, which would prove that the two were the same. Kinthup's stars must have been severely crossed, for the lama sold him as a slave in Tibet. After eleven months of bondage, he managed to escape, and sought refuge in a monastery, where in his spare time he cut 500 logs! He then walked to Lhasa and asked a professional writer to write a letter to the Survey saying that he would be throwing the logs in, but the letter was delayed. Although he threw the logs on the specified days, no watch was kept on the Brahmaputra, and his efforts were in vain. He did not receive any official recognition for his work, and ended his life as a poor tailor. However, his

Suggested Reading

[1] Wilford John Noble, *The mapmakers*, Knopf, New York, 414, 1st ed, 1981.

[2] RV Tooley, *Maps and mapmakers*, 6th edn, Crown, New York, 140, 1978.

[3] G R Crone, *Maps and their makers: An introduction to the history of cartography*, 5th edn, Folkestone, England, 152.

[4] John Goss, *The mapmaker's art: An illustrated history of cartography*, Rand McNally, Skokie, IL, 376, 1947, 1993.

Box 2. The Incredible Journeys of Nain Singh

Thomas G Montgomerie was the first Britisher to devise a plan to send disguised Indians to map inaccessible parts of the subcontinent. He trained two cousins, Nain Singh and Mani Singh, for this purpose. They learnt the use of cartographic instruments, and practised walking with absolutely uniform strides, so that they could use the number of steps they took to calculate the distance they had traveled. Disguised as monks, they carried Buddhist rosaries, which were used to count their strides. Mani Singh went to western Nepal and collected some data, while Nain Singh headed for the border into Lhasa. He was robbed of most of his possessions and all his money, and did not give up. He walked through this strange, desolate country all alone, begging for food from occasional caravans, and entered the forbidden city of Lhasa in 1866. He stayed there in hiding, watching an illegal Chinese visitor beheaded. At night he climbed onto his roof to measure latitude with reference to the stars. At day, he boiled water on a stove and checked the temperature, to determine the altitude. From these simple measurements, his calculations were astonishingly accurate – he put the height of Lhasa at 3,420 m above sea level while it was actually 3,540 m. Over the next few weeks he was questioned several times by a few merchants, and fearing for his life, left with a Ladakh caravan. Here he traveled along the Tibetan river Tsangpo, tracing its course secretly for over 800 km. After two months with the caravan, he slipped away one night and made for the Nepal border. In his 21 month journey, he had surveyed a 2000 km route from Nepal to Lhasa, taken 31 latitude and 33 elevation measurements, and described the Tibetan capital in great detail. The Royal Geographic Society, awarding him a gold medal, described him as the "man who has added a greater amount of positive knowledge to the map of Asia than any individual of our time".

devotion to duty became such a legend that the British stopped the practice of sending disguised Indians to map areas for the Survey after this.

The achievements of the Survey continued steadily, leading eventually to detailed and precise maps of the whole of India. The groundwork for this was however laid in the late eighteenth, and nineteenth centuries. A hundred years later, it is still difficult to understand what drove these surveyors, especially the Indians, to such heroic efforts. It was surely not money or fame, since but for Nain Singh (*Box* 2) none got much of either. One can only marvel at the dedication of these untrained scientists, and aim to emulate them at least in part.

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