Travelling OBSERVATORY

Seeking correction from the stars
The Observatory travels with the Survey, a major player in the drama of accuracy. At every key station, the telescope is turned skywards, to track the precise latitude, and sometimes longitude, of the location. But in addition to this routine task, astronomical experiments are conducted, which are later cited as landmarks in surveying history.

The Arc is well on the way to its northern goal when Everest is struck by doubt about the correctness of a large section of the survey. Even if slightly inaccurate, this could damage the work being done to derive the amplitude of the earth. Everest orchestrates an accuracy check that takes nine years to plan, two months to execute, and involves a huge outlay of human resources.

1,500 observations are taken in clear skies
The latitude locations of Kaliana and Kalianpur, two stations on the Arc 398 miles (640 km) apart from each other, will be recalibrated with reference to the stars.

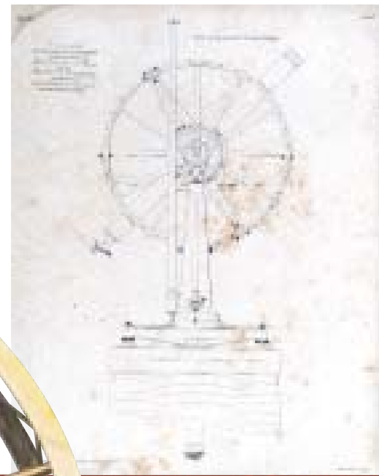
Observations commence on 4th December 1839. Col George Everest and Lieut Waugh, positioned at either station, simultaneously observe 36 stars for 48 continuous nights. Everest and Waugh can take a break of only four minutes between successive stars.

Fortunately, they are blessed with “unusually clear and favourable skies”: the experiment is a success and ends on 4th February 1840, almost completely according to plan.

At the end of the year another set of simultaneous observations take place, at Kalianpur and Bidar. This time the stars selected are only 32.

Curious innovations
The experiment stimulates Everest’s fertile mind. To arrive at an accurate adjustment of the line of sight he incorporates a mother of pearl disc and spider web lines into the viewing aperture of the telescope. To illuminate the reading microscope and the bubble of the level, he fits the astronomical circles with oil reading lamps and nozzles that throw light directly into the telescope.

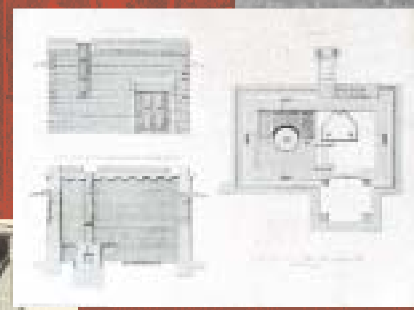
Zenith Sector
24 inch astronomical instrument by Troughton & Simms, London, 1830. Redivided at Park Estate, Hathipaon, Mussoorie by Saiyad Mir Mohsin, instrument maker, on the design given by Sir George Everest.



Survey of India eclipse party at Dumraon.

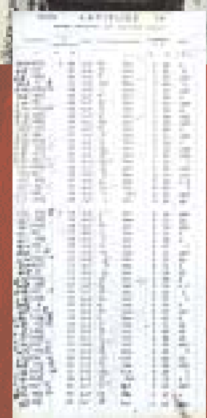
Observation tower at Barrackpore Road.

Observatory at Madras



Detail plan of the Observatory at Kalianpur.

Captain Lennox and party at Pulgaon 1898



Star List

Astrolabe was used as an aid to surveying and navigation.
Indian astrolabe from the Jaipur Museum

In the WILDERNESS

Hostile, wild, uncharted…
"the chances are much against man ever returning alive"

The surveyors lead their men into unknown dangers. They cross swollen rivers, take risks in infested forests, battle with fever far away from medical help. They travel with armed guards to keep at bay hostile, sword-yielding inhabitants. And wandering bands of thugs. Deadly encounters take place with tigers and cheetahs. And with bears, hyenas, snakes and scorpions. In choking dust and broiling heat, they are often short of sustaining food and water. Life runs out for many. And yet, the Survey marches on!

Everest follows the monsoon and succumbs to "jungul fever"

Everest is in his first year as Lambton's assistant. Crossing the swollen Mosee River, west of Hyderabad, he enters "great forests of teak and ebony…infested with tigers and boa constrictors". The forest is magnificent, but the soil is "teeming with vapour and malaria. Jungul fever fells each and every person. Elephants and camels sent out by the local Resident rescue a party that resembles a crowd of corpses recently torn from the grave".

Everest survives, but the typhus fever is to pursue him for more than 20 years "like a nest of irritated bees".

From raised swords to friendly encounters

The local population is hostile and suspicious of the Survey party which places flags at the highest points in the land much in the manner of a victor. Winning the confidence of the locals is a difficult job that the avuncular Lambton attempts with great sensitivity and success.

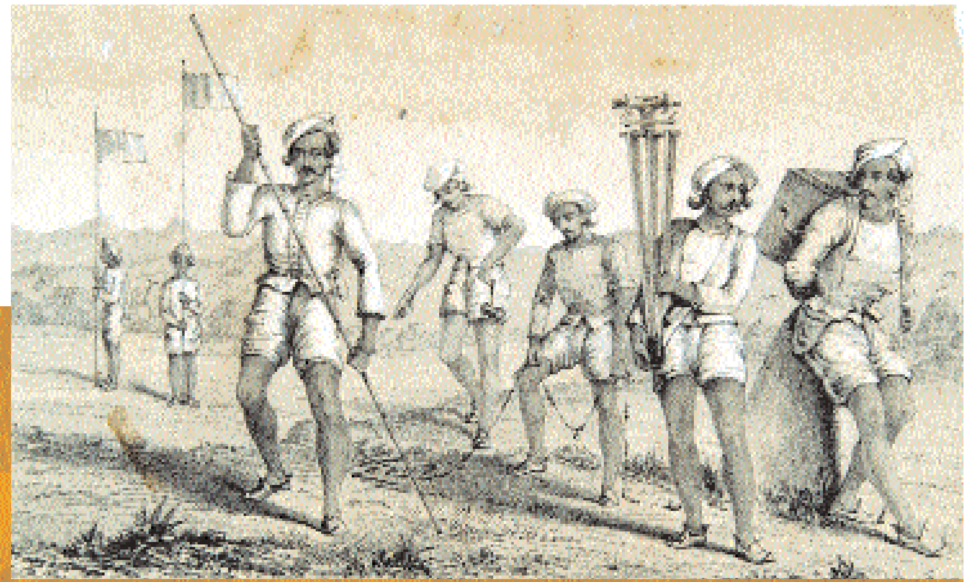
Everest is more impatient and demanding. Approaching Gwalior, inadequate arrangements incite a fine display of tantrums. He is mollified by the Maharajah of Gwalior with invitation to a 4-day stay so that he may receive due honour, with "fireworks and nautches and elephant fights and everything to delight and amuse you".

Everest's reply is typical: "Remember I have lost 13 fine days already, so that now I have not a day to spare…I must march tomorrow."

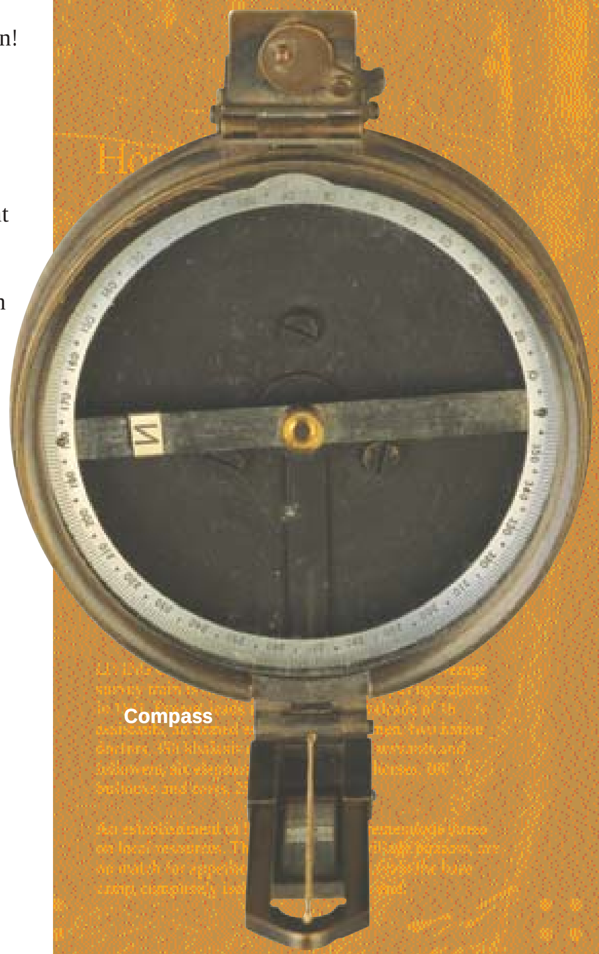
Living on the edge, magnificently

The average Survey train is impressive. For the Kalianpur operations in 1841, Everest leads a magnificent cavalcade of 16 assistants, an armed escort of about 60 men, two native doctors, 350 *khalasis* or handymen, 100 servants and followers, six elephants, 115 camels, 50 horses, 100 bullocks and cows, 25 donkeys.

An establishment of this nature puts tremendous stress on local resources. The impoverished village bazaars, are no match for appetites. Approaching the Siwalik range by April 1834, Everest notes that there are "no villages whatever from which supplies can be obtained." Water, food, medical aid are scarce. The privations are extreme. Adversities increase manifold when surveying parties move away from the base camp, completely isolated for weeks on end.

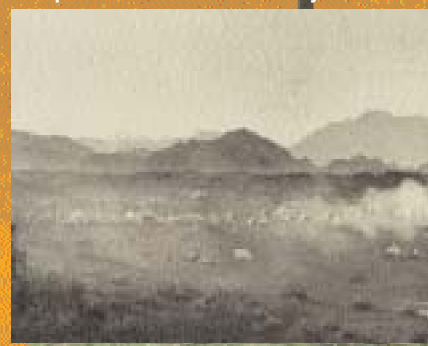


Revenue survey *khalasis*

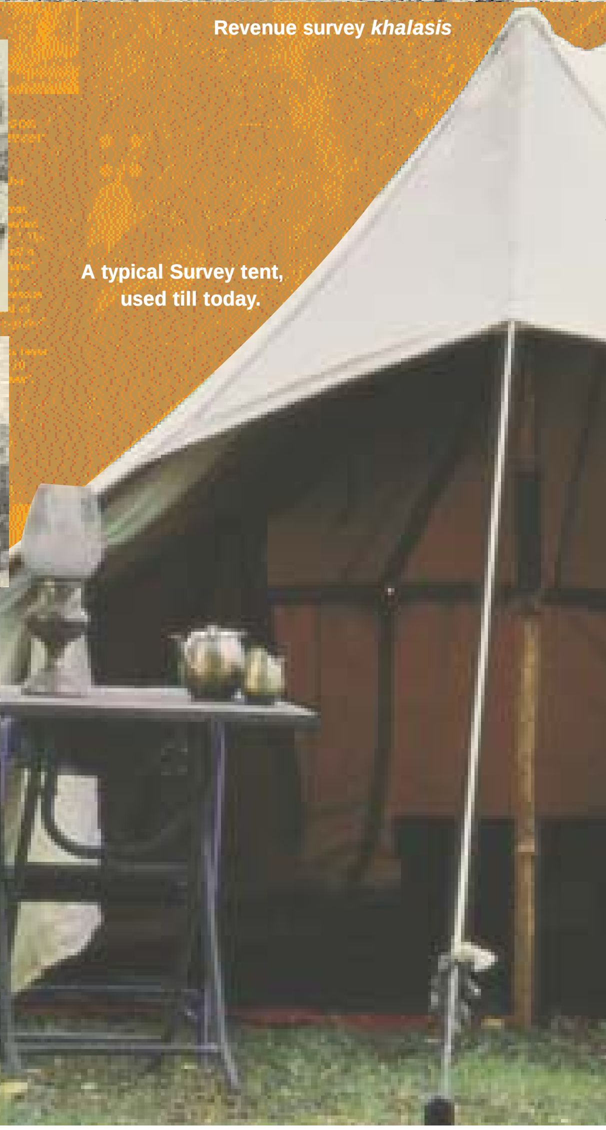


Compass

Etchings from 19th century India .



Camp in the Hindukush Himalaya.



A typical Survey tent, used till today.

Complex COMPUTATION

Hardworking young graduates form a bank of human computors

Numbers are generated like soap bubbles in the field and carried to the office for computation. Everything has to be computed - triangles, base measurements, astronomical observations, error compensation, spherical excess, geodetic parameters . And everything has to be rechecked. Computation completely consumes Lambton towards the end of his life. He leaves the backlog of four years of work for Everest.

The bright young computing office

To set the house in order, Everest organises an efficient computing office at Calcutta on return from England. Bright young graduates are recruited, including Radhanath Sickdhar "the ablest pupil that the Hindoo College has yet produced." By the time the Arc reaches Dehradun, bringing in its wake more and more computations, the computing machinery is well oiled. There is frenetic activity in Calcutta; the office is crowded with more than a dozen "wild" apprentices, all young, all Bengali.

And most of them want more pay. A sympathetic Everest pleads their case with the Directors but protests in "perfect fairness and impartiality" that they cannot all become chief computers! In a stunning revolt, seven of them leave together, to join the Revenue Department as Deputy Collectors, with a nine-fold increase in salary.

Radhanath Sickdhar

Everest is perturbed, but he has Radhanath with him, "high in favour with everybody, and universally beloved in the G.T survey. …a hardy energetic young man, ready to undergo any fatigue, and acquire a practical knowledge of all parts of his profession. …. There are few of my instruments he cannot manage; and none of my computations of which he is not thoroughly master….He can not only apply formulae but investigate them…" Radhanath Sickdhar is to become a key figure, discovering the height of the tallest mountain on earth.

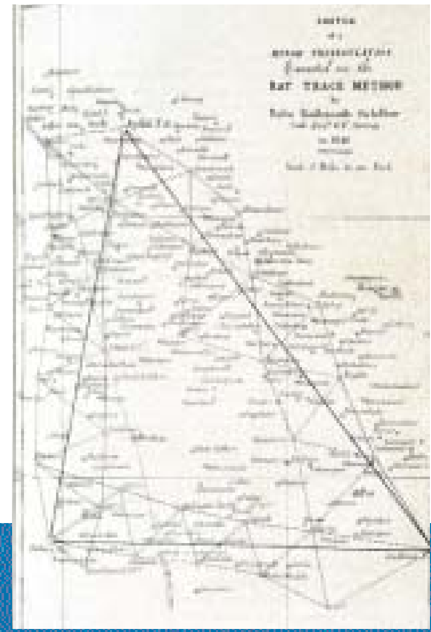
Another of the bright lads is Nil Comul Ghose, whose number crunching genius upholds the "correct mathematical principles" of the survey.

Talented draftsmen feverishly convert data for the Atlas of India

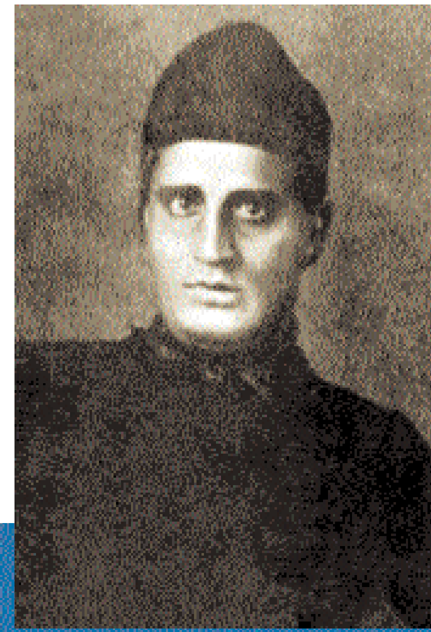
The Atlas of India is the dream project of the East India Company - a single repository of knowledge on the Indian subcontinent, in the scale of one mile to a quarter inch. The Surveyor General of India, George Everest, is firm about rejecting any survey not based on the strictest trigonometrical principles. With this decision, he discards masses of work already done in other surveys, and questions the standard of several trigonometrical operations.

The Atlas emerges, sheet by sheet, with painstaking detail.

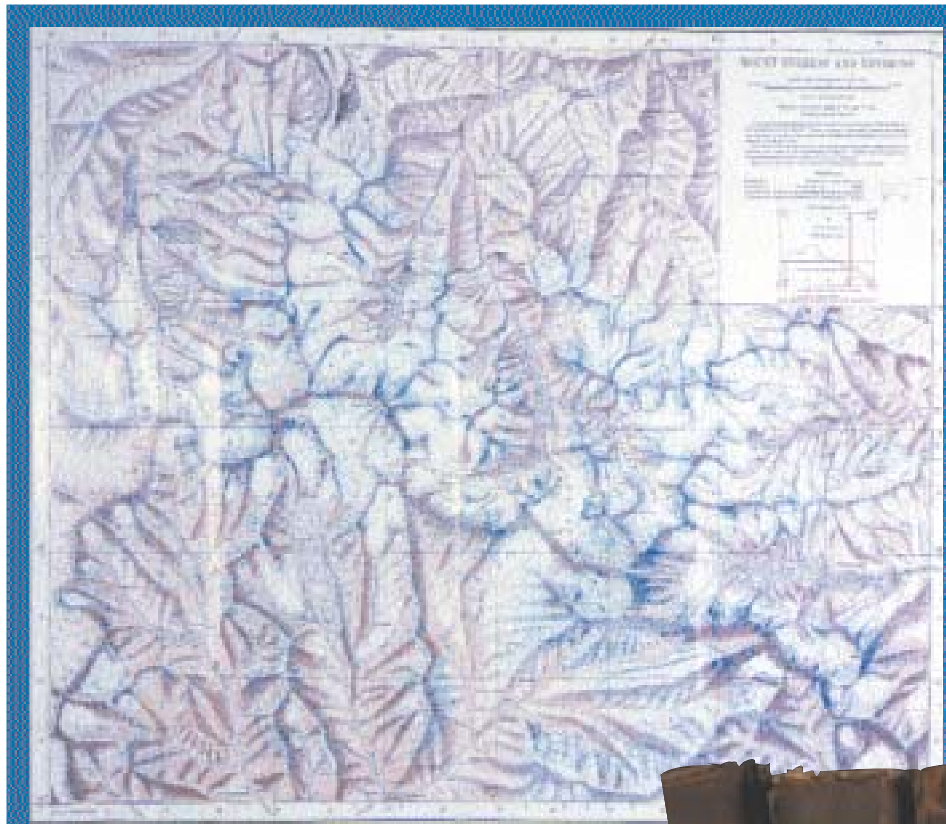
Compilation of data and rough drafting are executed at the Calcutta Drawing Office. The rough drafts are sent to the India Office in London where detailing and engraving are carried out. Everest estimates that a draftsmen, however proficient, can accomplish only one square degree



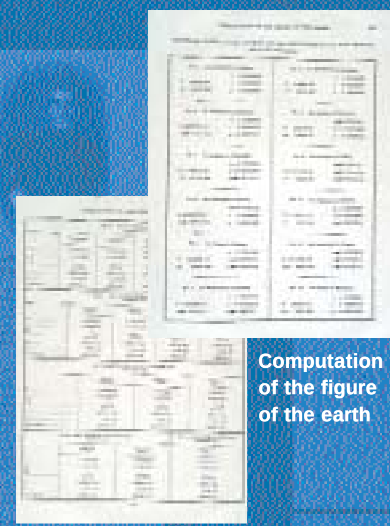
Ray Trace Method of triangulation
This method was developed by Everest. The legend on the map reads: Sketch of a minor triangulation executed on the Ray Trace Method by Radhanath Sickdhar, Sub-assistant in the Great Trigonometrical Survey in 1840.



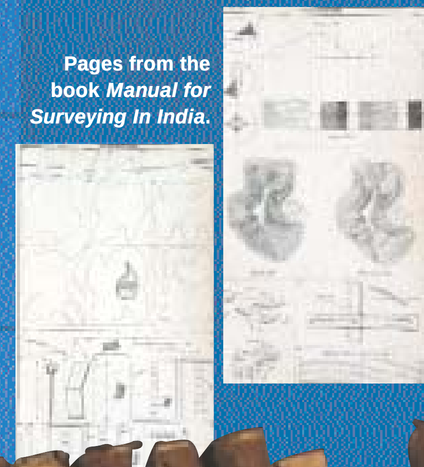
Radhanath Sickdhar
Joined the Survey of India in Calcutta at the age of 21. Later he became Everest's 'right hand' and Chief Computor. He is said to have calculated the height of Mt Everest and thereby discovered the highest mountain in the world.



Map of the Himalayas



Computation of the figure of the earth



Pages from the book *Manual for Surveying In India*.

Scientists EXTRAORDINARY

Measuring the roof of the world with two feet and a prayer

In the 1850s, a deadly game is played - of mapping the remote, unseen and uncharted lands of Tibet and Afghanistan. Caught in the tussle for control between three powers - the British, Russians and Chinese - are the Indian surveyors, some of them simple schoolteachers trained on the job. With death dogging every footstep, they carry out their duties clandestinely. The heroic dedication of these individuals to their mission is a story without parallel.

The Great Game

Eventually, in 1913, British and Russian interests will finally reach an understanding. Surveying teams from both sides will meet in northern Kashmir and the triangulations of India and the Russian territories in Asia will be officially joined "in the interests of science".

The roof of the world

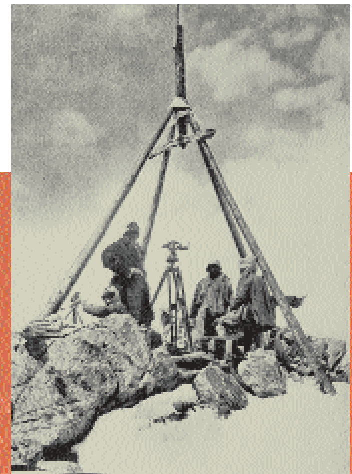
There is no elevation on the earth's surface that can compare with Tibet. The topography is unique, of different tablelands separated by inaccessible mountain chains. Its 2,400 km border is difficult to cross. In 1850, Tibet is completely sealed off by the edict of the Chinese emperor that "no Moghul, Hindustani, Pathan or Feringhi (Eurasian) shall be admitted into Tibet on pain of death".

The challenge of mapping Tibet, under cover

Nain Singh, a schoolteacher by profession, enters Tibet in the guise of a lama, armed with prayer wheel and rosary. He has been trained to take measured steps and count them on a 100 bead rosary (instead of the usual 108 beads). Two thousand of these steps measure a mile (1.6 km). Precious instruments - the compass, sextant, thermometer, chronometer and bottle of mercury - are concealed in a secret compartment in his trunk.

The secret observatory in the forbidden city of Lhasa

Whenever possible, Nain Singh records distances and compass bearings on small slips of paper which he stores in his prayer wheel. The roof of his inn at Lhasa becomes his secret observatory, where he takes latitude fixes. Using the boiling-point method, he determines the height of Lhasa as 3,420 m above sea level. (today's sophisticated instruments place it 3,540 m).



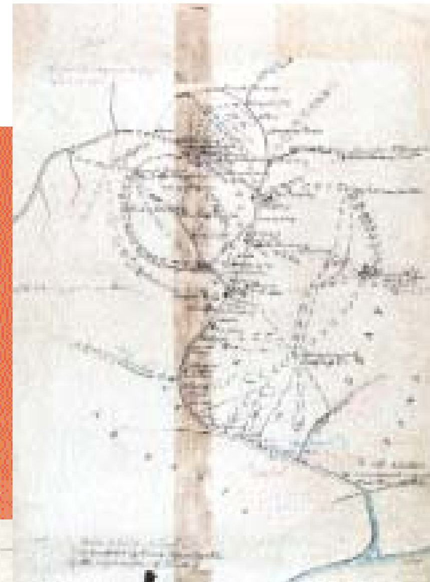
On the Russian Station of Saarblock in the Pamirs, 17,284 feet.

Is the Brahmaputra river another name of the Tsangpo?

Over 21 months, Nain Singh surveys 2000 km trade route, takes 31 latitude fixes, determines elevations at 33 places. Nain Singh follows the course of the great Tibetan river, the Tsangpo, for 800 km. Later Kinthup is assigned the task of floating logs down the Tsangpo. If this is indeed the mighty Brahmaputra, the logs will float through. Eventually it is proved that the rivers are the same, and another mystery is solved.

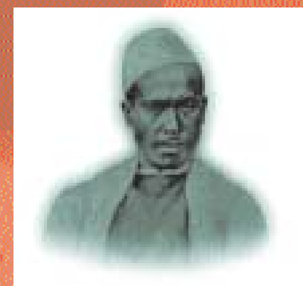
Those who dared

- Hari Ram gives descriptions and data on 48,000 km of Tibet
- Kishen Singh called 'A-K' - surveys Tibet's Nyenchitanglha mountains and China up to the headwaters of the Mekong, Salween and Irrawaddy rivers
- Kinthup - works as a slave while sorting out the riddle of the Tsangpo and Brahmaputra
- Mirza Shuja surveys the Oxus river and the Pamirs in the north of Afghanistan. Later, while on another expedition to the area he is murdered.
- Ata Muhammad, the "Mullah", traces the course of the Indus and one of its tributaries.



Map drawn by Kinthup

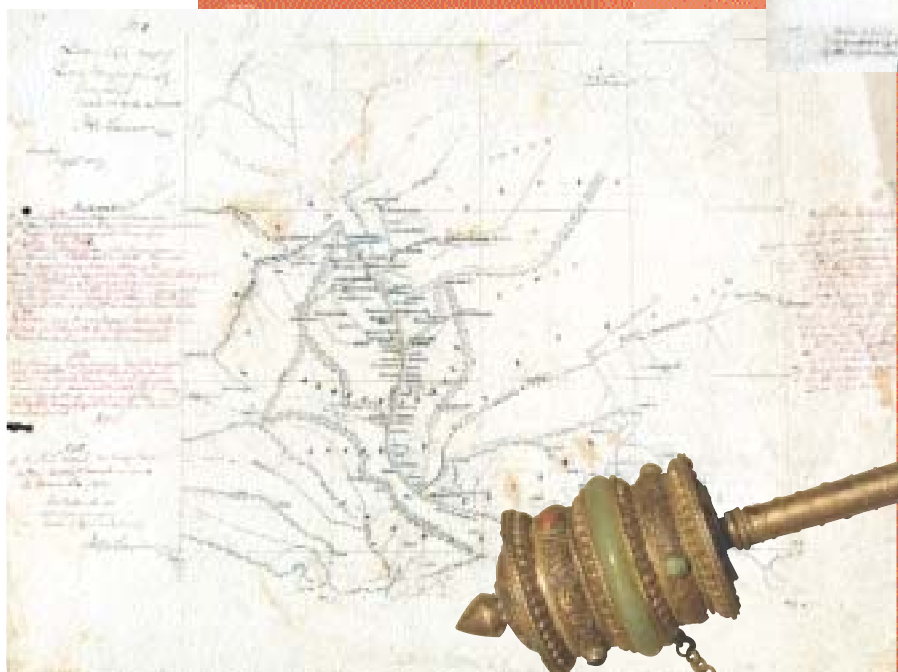
Map of Lhasa



Nain Singh

Kinthup

Kishen Singh



Lama's 11G, map

Unparalled PEAKS

Discovery of the tallest point on earth, so high, you can see it 200 miles away

"Sir, I have discovered the tallest mountain in the world!" cries Radhanath Sikhdar in 1852, unscrambling the results of four years of computation. But this news is announced to the world only after another four years. Surveyor General Andrew Waugh is uncertain about the height of Peak XV though it has been surveyed from six independent stations in the plains.

Mount Everest or Chomolungma 'Goddess Mother of the World'

Peak XV is known to be a shy and retiring mountain, which hides behind the other towering peaks of Makalu and Gauri Shankar. The mountain is known by many local names. Among them is Chomolungma 'Goddess Mother of the World', the Tibetan tribute to a towering presence and 'Sagar Mata' to the Nepalis. Waugh, however, finds 'Everest' a suitable name, in honour of a man who set his sights higher than most others.

Tallest mountain in the world?

The issue of the tallest mountain is fraught with controversy. During the 17th and 18th centuries, the tallest mountain is believed to be Chimborazo (20,702 ft) in Peru. Only in the 19th century is the supremacy of the Himalayas acknowledged. The spotlight keeps shifting - from Dhaulagiri (26,860 ft), to Nanda Devi (25,645 ft) to Kanchenjunga (28,168 ft).

Mountains of illusions

Mountains are extraordinarily difficult to define.

The outline of the peaks changes from different views. The altitude of the mountain increases and decreases with snowfall. Andrew Waugh instructs his surveyors to observe the height and position of every snow peak that is visible, but not to attempt to identify the peak. The identification is done when the results are unscrambled by the computers in the computing office.

The refraction of light, or bending of light rays, makes the mountain rise visually in height. Dhaulagiri has been found to have an illusory change in height of 500 ft between morning and afternoon. (Everest talks about similar problems of refraction in 1830 and Lambton in 1814.)

Mapping seventy nine prominent peaks

The exploration of the great Himalayan ranges becomes a passion towards the middle of the century. By 1852, 79 Himalayan peaks have been mapped at the ranges of Kangra, Chamba, Zanskar and Karakoram. Triangulation of the upper Ganges and Sutlej valleys is completed. Exploration leads to the discovery of the sources of the Ganga and the Brahmaputra. The Kashmir triangulation is undertaken by climbing a record-breaking height of 22,300 ft.

The Great Himalayan ranges

- Punjab Himalaya • Kumaun Himalaya
- Nepal Himalaya • Assam Himalaya
- Trans-Himalaya region of Central Tibet
- Ladakh range • Kailas range
- Muztagh Ata range

Peaks are important because they are the only features that can be observed with accuracy from a great distance. Peaks are the first step in a geographic survey of a mountainous region - the anchor points for plotting the paths of rivers and the positions of lakes.

Measuring the mountain

Observations of Peak XV are done repeatedly from six stations on the plains, as closer proximity by entering Nepal is forbidden.

Long angles increase the possibility of errors by 40 - 100 ft. The largest triangle taken is of 1706 square miles.

The computing is further complicated by the distance of the mountain to the sea - 450 miles from sea level.

Map showing the Kashmir Triangulation

Drawing Instrument Box used by Montgomerie
Captain Montgomerie was in charge of the Kashmir Survey and therefore numbered its peaks with the prefix 'K'. Most peaks were later named but 'K2' still remains for the second highest peak in the world.

The Hindukush
Photo Theodolite view from Kok-Tumshuk hill above the western shore of little Kara-Kul.

The saga of

THE GREAT ARC

The Foundation 1800 - 1815

The proposal for a "Mathematical and Geographical Survey" is put forward in November 1799 by William Lambton, of His Majesty's 33rd Foot Regiment, a survey that should extend right across the peninsula from sea to sea and serve as a foundation for all other surveys. The Government approves. The first baseline is measured at Madras in 1802.

The Great Theodolite arrives from London after being seized by the French but released in the interests of science. Triangulation begins with a meridional arc drawn from Madras to Cuddalore and observations of latitude, leading to the first geodetic measurement of the country.

Lambton himself makes the primary network of triangles and takes astronomical observations, leaving his assistants to make secondary triangles or 'fillers'. Observations are made from 'droogs' or hills, and then from the pinnacles of temples. Travelling westwards to Mysore, the triangles are carried up to the Malabar coast, linking the Bay of Bengal with the Arabian sea.

The first section of the Arc is extended along the 78th meridian: the southern peninsula is filled with secondary triangles and, in 1808, continued southwards to Cape Comorin.

After a brief preoccupation with military operations against Travancore, Lambton settles down at Pondicherry for a year to do his computations. Extensive triangulation of the peninsula has been carried out. Almost the entire peninsula is covered with the exception of a few areas. The triangulation has been punctuated evenly and perfectly with baselines which, as Lambton is fond of saying are "the foundation to the whole".

The northwards march is begun into the Nizam of Hyderabad's territory - with the Nizam's welcome.

Baselines:
Madras
Bangalore
Coimbatore
Tanjore
Palamcottah
Gooty
Guntur
Kumta
Bidar

Northwards with Everest - 1815 - 1830

Lambton is in his 60th year, passionately involved with the Great Arc's computations and reports. He has already measured 10 degrees of the 78th meridian. He now calculates values for the earth's figure. On the basis of new French and British measures, he recomputes his work not once but twice. All this keeps him at Hyderabad for six years.

Meanwhile, the Great Arc has begun to triangulate northwards. A new addition to the Survey team is George Everest who, after a few months training, is put to the test.

Lambton's procedure is to survey in the height of the rainy season when the air is clear, devoid of dust and haze. Everest's first operation is therefore very wet, in a malarial, densely forested country between the Kistna and Godavary rivers. Everest - and the entire party - fall severely ill. Everest tries to carry on, but is forced to depart for the Cape of Good Hope to recuperate.

The Nizam of Hyderabad's territories have been surveyed. In 1821 Lambton marches northward to extend the Great Arc to Berar. With the help of doctor and geologist Henry Voysey, an ailing Lambton is able to complete base measurements and astronomical observations.

Everest rejoins the Survey. He is deputed the task of running triangles westward over the Deccan plateau towards Poona and Bombay while Lambton moves towards Nagpur. However his work is cut short: Lambton dies on the field, on 20th January 1823, just 50 miles short of Nagpur.

Everest takes charge. Major changes take place in operations. Everest has worked out innovations in technique, using the improved quality of night air for making observations, employing specially designed lamps. Surveying can now proceed in the dry, healthier season, which means a longer stretch of eight months of fieldwork instead of a season of four wet months.

Everest, though again crippled by bouts of fever, doggedly moves northwards towards Agra, Lambton's northern goal. The country is thickly wooded and difficult. Everest is vanquished by the effort. Quite ill, he leaves for England at the end of 1825.

Everest's next five years in England are well spent. He studies instruments, tests the Colby Measuring Bars at Lord's Cricket Ground, purchases the most up-to-date apparatus. He analyses the methods used in the Ordnance Survey of Great Britain and interacts with leading scientists.

On his return to India in 1830, he puts all his plans into operation, taking the Great Arc survey to the highest standards of accuracy.

During Everest's five years of absence, the Survey staff has been employed to run longitudinal series, continuing eastwards from the northernmost point of the Great Arc to Calcutta. The work is done with difficulty over the flat plains of Bengal. Telegraph signalling towers are used and additional towers constructed.

Baselines:
Takalkhera
Sironj

To great heights of accuracy 1830 - 1843

Everest returns and takes office as Surveyor General and Superintendent of the Great Trigonometrical Survey. While at England Everest has managed to persuade the Government to extend its support to the Survey. A decision has been taken that no new topographical and geographical survey will be attempted without its trigonometrical framework.

At Calcutta, Everest establishes the necessary infrastructure to improve operations of the Great Arc. This includes hiring good technical support and setting up a workshop. Technical self-reliance is proclaimed. Everest completes the longitudinal series at Calcutta. And moves back to where he left off in 1830, to continue the Great Arc from Sironj. But there are now better instruments available. The Sironj baseline is remeasured with the new Colby compensation bar.

From Agra to Mathura and then on to Delhi…the progress of the Arc is rapid and full of military manoeuvres. To sight the triangles, the line of vision is cleared of impediments - trees, even dwellings are dispensed with. Towers and scaffoldings are constructed where no other solutions are available. At Delhi, the dense smoke-laden atmosphere is as problematic as the flatness of the surrounding Yamuna plains. Blue lights and heliotropes are used extensively for signalling to cut through the haze. Finally, the triangulation reaches Dehradun with Everest in a state of constant exertion and exhaustion.

The Arc is now getting to a state of completion. Finishing touches begin, connecting earlier series and checking out earlier measurements. This includes the entire triangulation southward to Bidar, covering the tracks of a full seven years of earlier field work. The operation involves enormous distances of marching and counter-marching over the country: about 2000 miles in all.

Another major experiment is conducted for the sake of accuracy. Simultaneous astronomical observations are taken at Kaliana and Kalianpur, two stations on the Great Arc separated by 398 miles. This involves formidable coordination and application. A great technical coup is the successful reconstruction of the astronomical instruments in the Great Arc workshop for the observations.

Secondary triangulations are carried out, following the rigid adherence to standards. By 1841, Everest's gridiron is complete. And Lambton's Great Arc has been measured, from Cape Comorin to Banog in the Himalayas.

George Everest sails off to England, passing on the office of Surveyor General to his trusted assistant Andrew Waugh.

Baselines:
Calcutta
Dehra Dun
Sironj
Bidar

Exploration and amalgamation 1843 - 1875

Under Andrew Waugh, a new phase begins, which bears out William Lambton's grand plan of a mesh extendable in any direction and to any distance: the mapping of the peaks of high altitude. Mirage-like, the snow peaks shimmer in the distance. Are they as high as they seem to be?

From Dehradun an east-west series of triangles is begun along the Nepalese border. A set of triangulation points are established from which 79 Himalayan peaks are observed. Each is identified by a roman numeral. In 1856, four years after the observations, it is announced that Peak XV is the highest mountain in the world, and will be known as Mount Everest, in honour of the earlier Surveyor General.

More mountains are to follow. The Karakorum range is explored by enthusiastic surveyor-mountaineers, the peaks of K1 and K2 are observed from the surrounding glaciers.

The Hindu Kush range of Kashmir is scaled and triangulated. The world mountaineering record is broken when the height of 22,300 ft (6,800 m) is climbed in the course of duty.

The exploration of Tibet, the roof of the world, is a natural corollary. Tibet is a politically sensitive region on which the Government needs basic information. The surveyors are trained to travel in disguise and take measurements with regulated footsteps and the most basic instruments. Enormous areas are covered by these valiant surveyors, who discover geographical features of completely unknown regions, including the North-West frontier between India and Afghanistan.

Among the most significant discoveries are the sources of the Ganga and the Brahmaputra.

Precision becomes an issue once again as discrepancies in heights brought out by triangulation from the sea level are noted. The regular measurement of mean sea level begins to be conducted through tidal observatories. Geodetic studies are next, as gravity and magnetic observations are carried out along the meridional arc, right from Kanya Kumari to the Himalayas, and observatories established.

The merging of strengths takes place: the three wings of the Survey, the Great Trigonometrical Survey, Revenue Surveys and Topographical Surveys, are joined to form the Survey of India.

Baselines:
Somnakhoda
Chach
Karachi
Vizagapatam
Bangalore
Comorin

Chronology of Events

1802 The fist baseline is measured near St Thomas' Mount Madras.

1803-1805 Warren assists Lambton, but leaves in 2 years to take over the Madras Observatory. Henry Kater joins the team, to leave in 1806.

1805 The peninsula is linked sea to sea - from Fort St George to Malabar coast.

"over a tract of country in many parts extremely difficult." Baseline is measured near Bangalore: the first section of the great meridional arc passes through Bangalore.

The longitude of the Madras Observatory is calculated at 80 deg 17' 21" E, becoming the reference for all surveys, and used in all maps till 1905.

1805-1806 Secondary triangulation is done along the flanks of the survey, as "all the positions on the sea coast, with several other points in the interior, are determined by the great triangles" Lambton sticks to the main triangles from Cuddalore to close on another baseline measured at Tanjore.

1806 Baseline is measured at Pachapaliyam, 135 miles west from Bangalore, near Coimbatore.
The triangulation moves from Coimbatore to Coorg "over these stupendous mountains"

1807 Lambton gets 4 assistants.

A new school of survey, the Madras Military Institution is founded. Lambton's triangles are broken down into smaller triangles by the surveyors, coordinates of the points computed and plotted on to plane table sections, showing details of topography.

1808 The great central arc is extended to Tanjore.

A major accident befalls the Great Theodolite which falls from a temple top at Tanjore. Lambton repairs it with the help of the ordnance establishment at Trichinopoly.

1807-1810 From Tanjore, secondary triangles are extended all over the area.

1809 Lambton is engaged in military operations against Travancore.

1810 Lambton works on his computations based at Pondicherry.
The results are published.

1811 New baseline is computed at Gooty.

1812 Lambton receives new values of the earth, which makes him recompute the whole of his great central arc up to Gooty. He returns to Adoni to continue with computations.

1813 Assistant De Penning starts triangulation down to the west coast, closing with a baseline measured near Honavar in 1814.

1814 Lambton asks for permission to visit the Nizam's dominions. By taking the arc to the 19th parallel on the Godavary will make it the largest that has ever been measured, exceeding by near two degrees the celebrated measurement made a few years ago by French Geometricians from Dunkirk to Barcelona."

The Great Arc is extended northwards into the Nizam's territories with the full approval of the Nizam.

1815 The Gooty - Bidar arc is closed by measuring a baseline at Bidar and taking astronomical observations at Damargida, 20 miles north-east.

Astronomical observations completed along the Arc of the same stars at the same season of the year are Punnae - Cape Comorin, Pachapalaiyam - Coimbatore, Doddagunta - Bangalore, Bommasundra - North Mysore, Namthabad - Gooty, Damargida - Bidar.

1817 De Penning takes the Arc across the Godavari river.

Voysey joins as surgeon and geologist. Voysey is to be Lambton's right hand, assisting in surveying functions apart from investigating the "disturbing force occasioned by diversity under the surface".

1818 The Survey progresses beyond the limits of Madras Presidency. It is transferred to the control of the central government and designated The Great Trigonometrical Survey of India. The support of the government is affirmed. Lambton is appointed Superintendent of the Survey.

Colin Mackenzie is appointed Surveyor General of India.

George Everest joins as chief assistant.

Lambton, based at Hyderabad, is fully occupied with indoor work of computation,. He submits report of latitudes and longitudes of all points fixed since 1802 in a chart of 8 sheets.

Lambton obtains the mean value of 1:310 for the compression at the poles, and computes a table of lengths of a degree from the equator to the pole, from which the elements of all his trigonometrical stations are determined. Abstracts of results published and sent to societies in Calcutta, London and Paris. Lambton receives a valedictory letter from famous French geodesist De Lambre.

1819 The Arc is extended to Bidar, 70 miles north-west of Hyderabad.

Assistants Voysey, Olliver, Rossenrode and Everest carry out triangulations. Lambton writes to the Surveyor General about his plans to move northward "through the Deckan, and ultimately in a partial manner through Hindoostan" on a "correct geometrical basis"

Everest runs triangles between the Kistna and Godavari rivers. The entire party and Everest succumb to malaria in the jungles.

1820 A stricken Everest takes sick leave and goes to Cape of Good Hope to recuperate.

1821 The Nizam's territories have been covered. At the close of the Maratha war, the Arc is carried up to Berar. Voysey helps an ailing Lambton measure a base at Takarkhera and take astronomical fixes.

Lambton receives a report on the expansion of the chain standard with new values: he sets to work to readjust all his computations and values.

He produces his parameters for the figure of the earth.

1822 East India Company embarks on the compilation of a quarter inch Atlas of India. The job is entrusted to the great cartographer, John Walker, in London.

Everest returns from leave and is directed to move the triangles westwards towards Poona and Bombay. He discovers the remarkable increase in refraction of light after sunset and invents the vase light for night time surveying.

20th Jan 1823 Lambton dies on a march towards Nagpur, where he is proposing to base his operations for taking the Arc northward to Agra. He is laid to rest at Hinganghat. Lambton has completed the triangulation of 165,342 sq miles at a cost of 83837 pounds.

1823 Everest falls ill again on his way from Hyderabad, but carries on, taking the triangles across the across the Narbada river, through difficult forested river valleys north of Berar to Sironj. This is the northward extension as planned by Lambton.

De Penning and Voysey leave the survey. Everest now has only two trained assistants, Olliver and Rosenrode.

1824 Baseline at Sironj on parallel 24 deg. measured, just above the Tropic of Cancer

1825 Continuously ill, Everest sails home to England.

1825 -1830 Away from India, Everest examines his new theodolite design with Simms, visits Ireland to see the survey, visits Naples Observatory, begins calculations of the Arc with the help of computers from the Royal Observatory, orders compensating bars from Troughton & Simms, tests them at Lords Cricket Ground, promotes the case of the GTS with the Directors, publishes his accounts on the Great Arc, derives his first set of earth parameters…and is nominated Surveyor General of India.

1830 Everest reaches India. His return marks a triumphant new phase. The Great Trigonometrical Survey is now designated the master survey, leading all other district, revenue, topographical and military surveys.

New instruments of precision arrive with Everest: theodolites, astronomical circles, Colby compensation bars, reverberatory lamps and heliotropes for signals, and new methods of reduction.

1830-1832 Everest organises infrastructure from Calcutta: Henry Barrow is engaged as instrument maker; Mohsin Hussain is detained for emergency repairs in the field; eight field parties are planned, two for the Great Arc, and six to conduct secondary meridional triangulation; computers are hired.

1832 Longitudinal series connecting Sironj to Calcutta are completed by Olliver - a distance of 700 miles over the difficult terrain of Bundelkhand, Baghelkhand and Chota Nagpur. Reaching the Bengal plains, telegraph towers and specially constructed 75-foot masonry towers are used.

Calcutta baseline is measured with Colby's compensation bars.

1832-1833 Everest travels by boat on the Ganges from Calcutta to set up base in Mussoorie.

1833 Everest does a reconnaissance of the flat lands of the north, planning construction of towers and masts and scaffoldings

1832-1843 Meridional chains of triangles are carried northwards based on the longitudinal series connecting Sironj to Calcutta.

1833-1834 The survey moves from Agra to Delhi in dense smoke laden atmosphere, using ray tracing method. The difficulties are immense. Scaffoldings and towers are built to see over houses and trees. Trees are cut to free sight lines. Everest is assisted by Olliver and Radhanath Sickdhar. There is extensive use of blue lights and heliotropes.

1834 The triangulation reaches Dehradun with Everest in a state of constant exertion and exhaustion. Reaches Mussoorie in the rains and prepares for the season.

Everest observes the mountains, visiting Kedarnath, Nag Tibba and the Chaur. Preparations are made for measuring the baseline near Dehradun. Fifty comparisons are made between the compensation bars and the standard bar.

1835 Baseline is measured near Dehradun and connected to surrounding hill stations.

1836-1837 Triangles are taken southward to Sironj, near Gwalior. An observatory is established at Kaliana.

1837 Waugh carries the triangles over the Jumna plains.

Completing computations at Mussoorie, Everest reports a discrepancy of 3 feet between the length of the base measured at Sironj in 1824-5, and that computed from the triangles. It is not acceptable.

Everest complains to the Governor General Lord Auckland that he is doing the work of 6 people: "I have partially succeeded... in carrying on that duty formerly allotted to six persons... But the mental and the corporeal exertion has reduced me to the brink of the grave..."

1837-1838 Everest decides to re-observe the whole triangulation southward to Bidar, which includes the work of 1817-22 and his own work 1823-5. This involves enormous distances of marching and counter-marching: Capt Waugh travels about 2000 miles in the entire operation

1838 Mohsin Hussain finishes dividing the circles of the astronomical instruments, a job refused by Barrow.

1839 Simultaneous astronomical observations are conducted at Kaliana and Kalianpur for one month.

1840 The 18 inch theodolite is constructed by Mohsin Hussain

1841 New baseline is measured at Bidar, showing a difference of only 4 _ inches from the value derived from 85 triangles from Sironj, a distance of 425 miles.

Everest's work of continuing Lambton's Arc is complete: from Bidar to Banog in the Himalaya.

1843, 16th Dec Everest sails off on the Bentinck, Waugh succeeds him as Surveyor General.

1847-1849 For measuring principle triangles between Banog and Jammu, Du Vernet fixes position and height of approximately 50 snow peaks of Kangra and Chamba.

1849 Height of Everest is computed at 29002 feet by Head Computer Radha Nath Sickdhar at Calcutta.

1850 T G Montgomerie surveys Kashmir and carries the triangulation forward to Ladakh.

1852 Mulheran completes fixing the heights of snow peaks and survey of the great range towards Zanskar. A great achievement is the trigonometric linking of the upper Ganges with the Sutlej valley.

1855 The theory of isostasy is presented by J. Pratt, creating waves in the scientific community the world over.

1856 Thirty six new peaks are determined by Montgomerie at distances of 43 to 183 miles and heights varying from 7700 to 18000 feet.

The world's highest peak is finally brought to the world's notice as Mount Everest.

1858 The towering peak K2 is named Godwin Austin peak to honour another surveyor.

1861 George Everest is knighted by Queen Victoria in recognition of his work.

1865 Tibet, the roof of the world, is surveyed, by surveyors who travel incognito, using the most basic measurement devices.

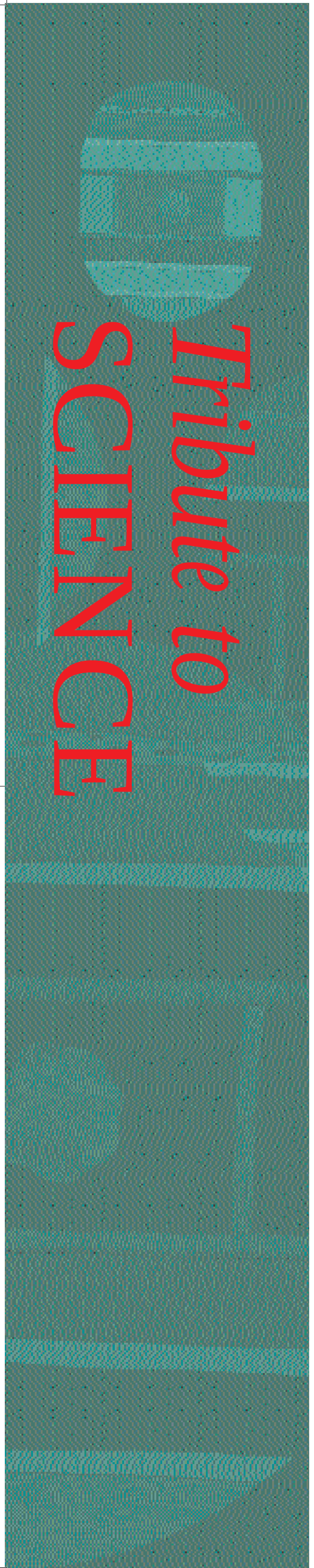
1865-1880 The Himalayas are explored extensively for over twenty five years.

1866 Gravitational studies are carried out over the Great Arc by Basevi.

1871-1874 The source of the Ganga and the Brahmaputra are discovered and mapped.

1871-1872 Tidal observations are made at Tuticorin. These observations are reduced by simple harmonic motion to predict tides and calculate mean sea level.

1875 The three surveying branches - Trigonometrical, Topographical and Revenue are amalgamated to form the Survey of India.



"In each revolution of scientific thought new words are set to the old music, and that which has gone before is not destroyed but refocused."

A.S Eddington

1. Pythagoras (c 580 - c 500 BC): Greek mathematician and philosopher; propounded that the Earth was a globe revolving along with other planets around a central fire.

2. Aristotle (384 - 322 BC): Greek philosopher and scientist; author of several influential treatises on meteorology and astronomy.

3. Euclid (c 330 - c 260 BC): Greek mathematician; wrote a comprehensive treatise on plane and solid geometry along with a collection of geometrical theorems.

4. Hipparchus (c 190 - c 120 BC): Greek astronomer; devised a method of locating geographic positions by means of latitudes and longitudes.

5. Ptolemy (100 - 170): Egyptian astronomer and geographer; his Geography charted the then-known world and employed a system of longitude and latitude. Also advanced the study of trigonometry.

6. Eratosthenes (c 276 - 194): Greek geographer and mathematician; his map of the world was the first to contain lines of latitude and longitude. He also calculated the Earth's circumference.

7. Aryabhatta (476 - c 550): Indian astronomer and mathematician who held that the Earth rotates on its axis and gave correct explanations for eclipses of the Sun and the Moon.

8. Al-Khwarizmi (c 780 - c 850): Arab mathematician; wrote a treatise based on Ptolemy's Geography which is in the form of coordinate tables and there are several references to what may have been a world map.

9. Bhaskara (1114 - c 1160): Indian mathematician; the Siddanta Siromani contains tables of sines and other trigonometric relationships and even hints of the underlying ideas of calculus.

10. Nicolaus Copernicus (1473 - 1543): Polish astronomer; said the Sun was the centre of the solar system and the Earth, spinning on its axis once daily, revolved around it annually.

11. Galileo (1564 - 1642): Italian scientist; was the first to use a telescope to see sunspots, phases of Venus, lunar craters and the four main moons of Jupiter.

12. Johannes Kepler (1571 - 1630): German astronomer and natural philosopher; formulated the three laws of planetary motion known as Kepler's laws.

13. Isaac Newton (1642 - 1727): English physicist and mathematician; discovered the law of gravity, using which he calculated the masses of heavenly bodies and the oblateness of the Earth.

14. William Herschel (1738-1822) & Caroline Herschel (1750-1848): Brother & sister team of British astronomers; fashioning their own telescopes the duo made numerous celestial discoveries and catalogued thousands of stars.

15. Carl Ritter (1779 - 1859): German geographer; founder of modern geographical study who emphasized the influence of the physical environment on human activity.

16. Albert Einstein (1879 - 1955): German-American physicist; formulated the theories of relativity and introduced time as the fourth dimension.

17. Christian Doppler (1803-1853): Austrian physicist and mathematician; discoverer of the 'Doppler effect' that led to the finding of the 'red shift', proving of vital importance to astronomy.

18. Alfred Wegener (1880 - 1930): German meteorologist; advocated theory of continental drift, saying all the continents were once joined in one land mass called Pangaea.

19. Edwin Hubble (1889 - 1953): US astronomer; discovered the existence of other galaxies and that the universe is expanding.

20. Stephen Hawking (1942): British cosmologist; has made important contributions to (theories on) the origin of the universe.

The idea of INDIA

The idea of India grows, bright and exhilarating

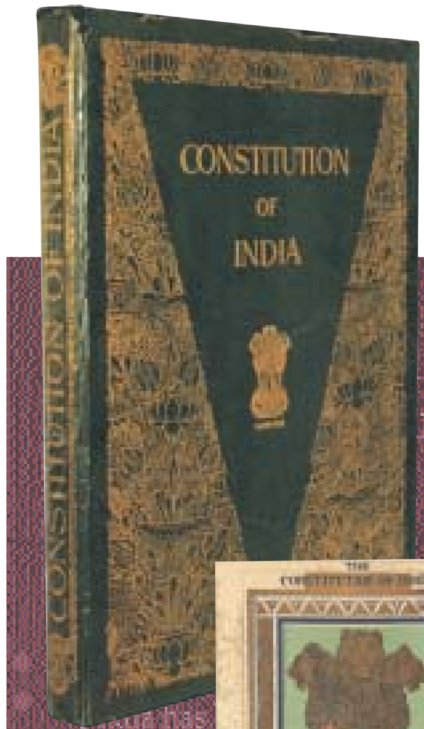
India has been re-defined. All its prominent features are in focus. The cities, the rivers, the mountains are seen in exact latitude and longitude.

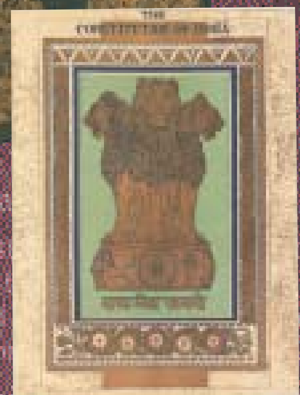
Virtually following the footsteps of the Great Arc, comes a great surge of nation-building development, as though the Great Arc has stimulated the nerve endings of the country, stroking out roads, canals, bridges, railway and telegraph lines.

What emerges is a triumphant and cohesive picture of India, unified east to west, north to south, a subcontinent completely in possession of itself.

The datum of the Everest ellipsoid is presented to the scientific world as the authoritative reference for this part of the world: the shape of the earth for the regions of India, Pakistan, Nepal, Myanmar, Sri Lanka, Bhutan and other South Asian countries.

Can there be a more accurate delineation of India? The re-measurement of earlier triangulations by Everest revealed only miniscule errors, a matter of a few inches. Today, the calibration of the Great Arc data with the World Geodetic System promises to pursue the quest for accuracy, with renewed dedication.





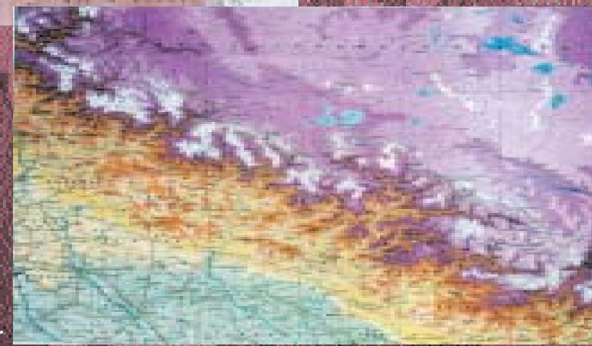
The Constitution of India
The Constitution of India was printed at the Survey of India's printing press in 1950. It was illustrated by Nandalal Bose, one of India's greatest artists.

Jawaharlal Nehru
First Prime Minister of independent India, he gave a major thrust to scientific developments in the country.

The first magnetic observatories were set up in 1902–03 in Madras and Dehradun with the network of observation stations steadily expanding all over the country.

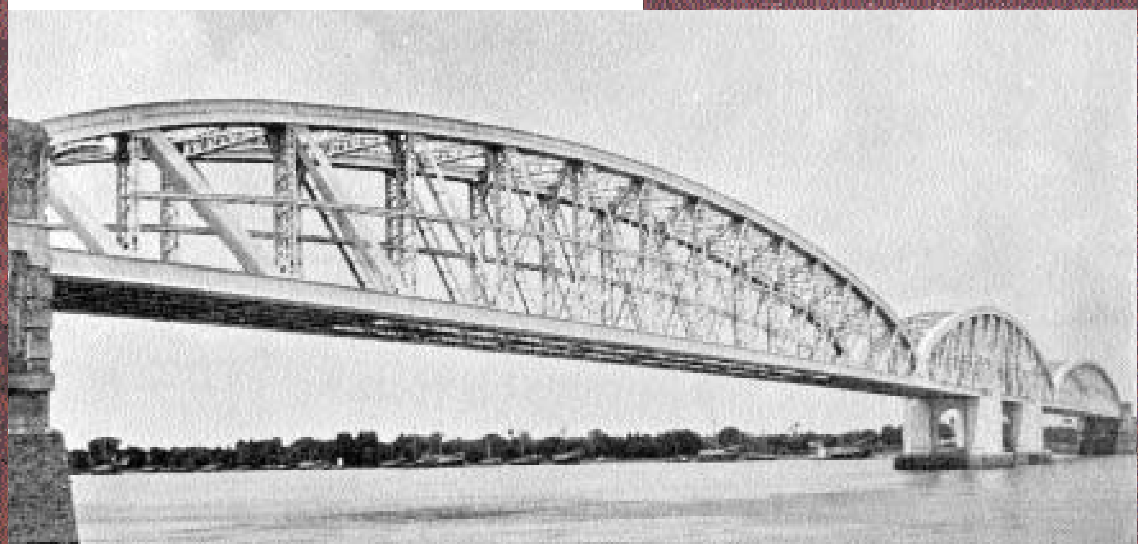
Map of provence of Bengal and Bihar

Built by Sir Bradford Leslie, the Jubilee Railway Bridge across the Hooghly River was another landmark in the country's development.

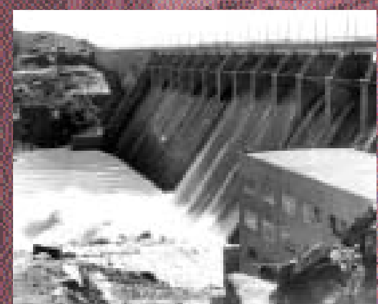


Map of Mansarovar

The Curzon Ganges Bridge was built to facilitate railway movement across the mighty river and is one of the early examples of infrastructure building by the British.



The Tilaiya Dam brings power and irrigation to rural areas.



The steam engine, pioneer of the Indian Railways.

Thermal station at Bokharo – among Nehru's 'temples of modern India'.

The Great Trigonometrical Survey, a remarkable scientific expedition in the history of mapping, succeeded in pulling India into the global scientific community.

At the completion of the Great Arc, we pause, step back for a moment to take a sweeping glance at the scientific environment of this period that had such a profound impact on our understanding of reality.

A New Way of Seeing

The period from the late-19th to early-20th century was a prolific one for discoveries and inventions in all areas of science. The great 'scientific spirit' pervaded every field of knowledge with the overwhelming desire to define all reality through rational measurement.

As discoveries, seemingly unrelated to mapping, began to dovetail like a huge jigsaw puzzle, they revealed limitations…that what the human eye sees is just a fraction of the electromagnetic spectrum; what the ear hears is just a fraction of the aural spectrum…

But this was an age of surging optimism. Rather than lamenting limitations, the human race revelled in the glory of science and marched forward with the invention of a new array of tools.

• Max Planc & Einstein revolutionized the world of physics
• Darwin brought out his highly controversial theory on the evolution of man
• Mendel's study of peas gave man the first inkling of the great spiral world of DNA and genetics
• Charles Babbage's concept of the computer/ calculator though conceived many years back was struggling to become a reality…

The music of the Universe

Till about 75 years ago, observation of the universe was limited by visible light. The discovery of electromagnetic radiation, in wavelengths ranging from gamma to radio, dramatically changed this view. It was as if the strains of a single instrument had been picked up by a philharmonic orchestra.

Everything in the universe gives off electromagnetic radiation of different wavelengths that are determined by the temperature of each individual body. This radiation contains photons that can be classified on the basis of their frequencies by a spectograph. The resultant 'signature' of the radiation is called the spectrum.

The spectrum of a star for instance, reveals its temperature, the velocity with which it is approaching or receding, its chemical composition, speed of rotation, size, mass as well as the amount of energy it puts out. Spectra, therefore, are invaluable to understanding the 'music' of the universe.

Seeing Sound

Sound is caused by small areas of high and low pressure that spread outward in a series of molecule collisions that rarefy and condense to form a wave. The collision profile determines the frequency of the wave. The human ear can catch only a fraction of the sound spectrum.

Sound cannot travel in a vacuum. Since the transmission of sound requires the collision of molecules, a medium, whether gas, liquid or solid is essential. When sound waves hit an object, they are either absorbed by the object or reflected back. Sonar interprets the frequency and strength of the reflection to plot size, density and distance of objects. The technique was first used in World War II to track submarines, it is used today in wide ranging areas - from medicine to ocean development.

Ever felt, THE EARTH MOVE

Every moment, even as you stand here reading this, the ground beneath your feet is moving - slowly, silently, relentlessly.

The Great Trigonometrical Survey of India gave rise to many important discoveries. One of them led to the understanding that the surface of the earth is much like a layer of skin that cools and congeals on the surface of a huge cauldron of boiling milk.

This skin breaks up into smaller sheets that are in constant motion due to the pressure of the boiling liquid below. Some fragments move away from one another and some collide. Sometimes new rifts form in them.

This is exactly how continental shelves on the surface of the earth behave, colliding or separating at these rifts or fault lines.

Many millions of years ago, all the landmasses that we call continents today, formed a single mass of land called Pangaea that slowly drifted apart. Scientists believe that these continents will continue inching their way to new permutations, creating fresh landmasses in an endless dance.

Tracking the shifting sands

The movement of the earth's surface is so painstakingly slow, that it is not evident even in several hundred human life-spans. It is visible only as a part of the lifespan of a planet. So, even as the ground below us is moving, we cannot feel it.

Seismic activity in India is related to the crush of the Indian peninsula plate northwards into the main plate of the Asian continent, and the breaking of the western continental margin. India has been divided in four major seismic zones. Of these four zones, the most active areas are to the north of the country falling directly below, or in line with, the Himalayas and in the western region of Gujarat.

Coming a long way from the days of triangulation, today the Survey of India is able to closely map even the minutest change over this vast land, on a real time basis.

With the help of differential GPS, it can now gauge movements that are even one billionth of a kilometre.

The Earth's shape revisited

The world is not exactly a mathematically precise sphere or even an ellipsoid, since its curvature varies at different parts of the globe. However to make calculations easier, while physically measuring distance it is important for us to have a standard against which we make our calculations.

The Great Trigonometrical Survey gave India a geodetic system specific to this part of the earth. Known as the Everest ellipsoid, it is based on the curvature that is particular to the Indian region stretching from the tip of the peninsula at the South to the mighty Himalayas at the North. In essence, the arc that covers the Indian region, coincides with an arc of the Everest Ellipsoid. All maps in India have been made and are maintained in accordance with this system.

While the Everest ellipsoid model is perfectly accurate in India, it becomes significantly inaccurate in the global context. So Indian maps are now being reviewed to match the World Geodetic System - WGS 84, which takes the centre of the earth as the centre of the Ellipsoid.

Taking Stock

Over the nearly 70 years of The Great Trigonometrical Survey a series of control points were established, some of the as far as 100 km from one another. These were essentially the sighting points which formed the vertices of the mesh of triangles cast over the entire country.

Today with the help of GPS and differential GPS the Survey of India has painstakingly verified the WGS-84 control points with GTS control points. It is now in the process of densifying these control points to distances as short as 10 km.

Earthquake Alert

The Kathiawar - Saurastra region is a severe seismic activity zone, among the most active in the world.

The region survived one of the most devastating earthquakes in January 2001. Since then it has experienced nearly 2,500 earthquake shocks of varying intensities.

Satellite pictures reveal this has caused new fault zones and the existing mainland fault has intensified.

If these earthquakes continue to occur frequently as a result of new tectonic and mountain-building activities, in the next few thousand years the peninsula of Kutch-Bhuj and Kathiwar-Saurashtra could be cut off from the mainland of Gujarat to form separate islands,

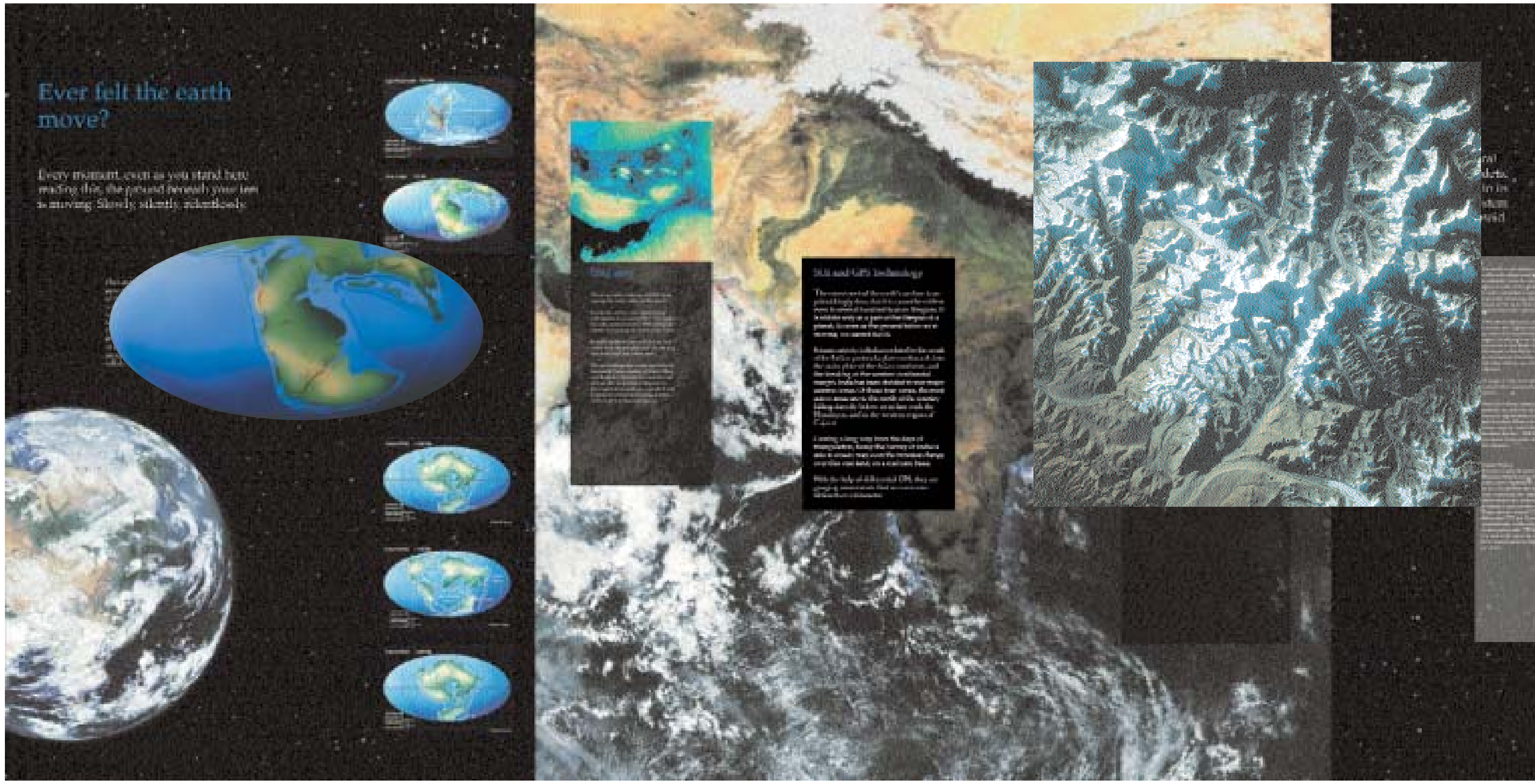
The Mighty Himalayas

Even during the days of the Great Trigonometrical Survey, mapping the Himalayas proved to be a most challenging task.

This awe-inspiring range of peaks that has held the fascination of the people of the subcontinent through the ages, inspiring myth and folklore, is in fact one of the youngest range of mountains in the world!

With the Indian plate pushing up against the main plate of the Asian continent, the Himalayas were formed due to an upward fold in the land where the two plates collided.

As the Indian plate continues to push northwards, these peaks are ever increasing in height. In fact, Mount Everest, the highest peak in the world, grows approximately two centimetres in height in a year.



Spaceship INDIA

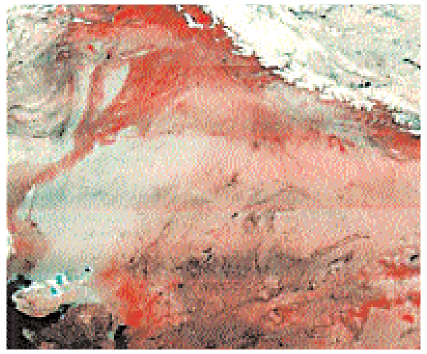
With remote sensing satellites came a storming of the frontiers of knowledge to the vast infinity of the universe. Looking back at earth it promoted a holistic understanding of the total earth system drawing attention to the impact of human-induced changes on the global environment. High quality Earth Observation (EO Data) beamed down from orbit meets a wide range of application services. It also facilitates total end-to-end solutions for sustainable development - the new mantra of a global world.

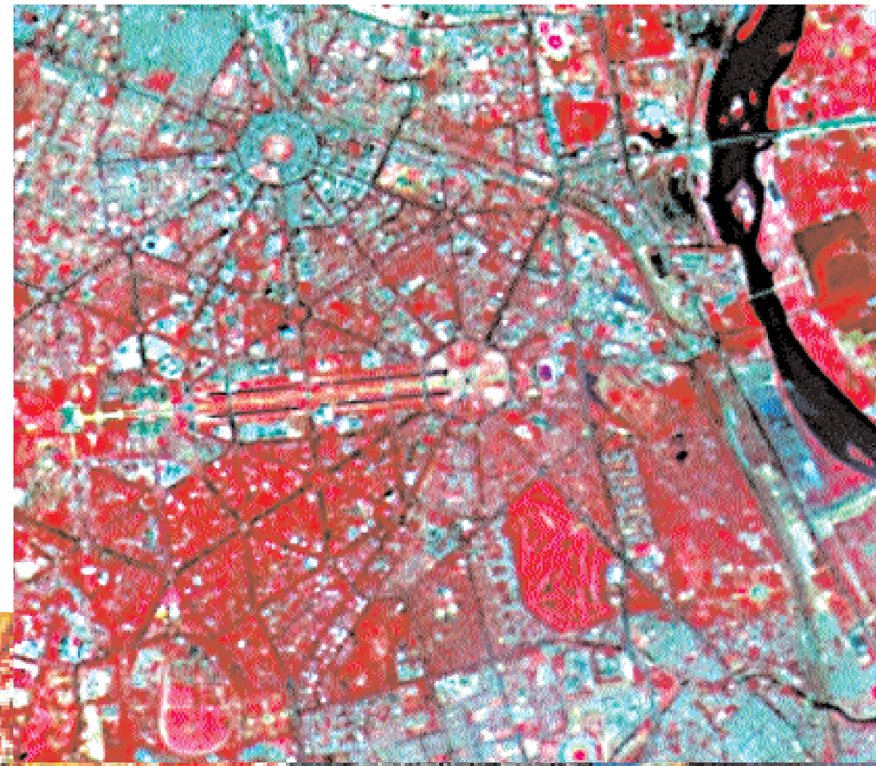
The Indian Point of View

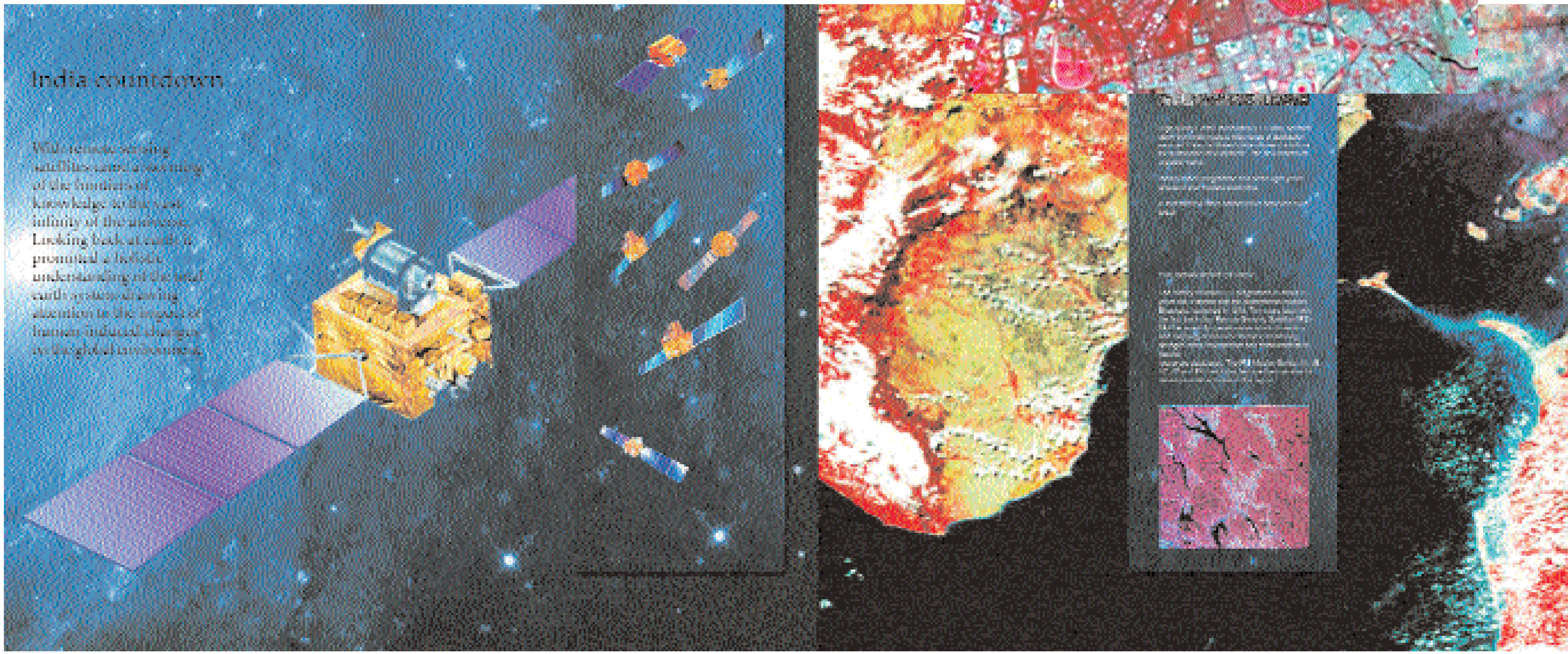
The history of Indian EO programme is about 25 years old. It started with the experimental satellite Bhaskara, launched in 1978. Ten years later, with the first the Indian Remote Sensing Satellite (IRS)-1A it became fully operational as a tool of inventory and mapping of resource themes; monitoring changes in the environment and establishment of natural resources databases. The IRS Mission Series, IA, 1B, 1C, 1D and P4, has today become the mainstay for developmental activities in the region.

Plotting Development

Reaching out to cartographers, map-makers, urban administrators and other decision-makers are precise, high-resolution images from Cartosats for multi dimensional applications. Data collected is available through the National Natural Resources Management System (NNRMS), to both private and government agenies. 13 ground stations - 3 in USA, 2 in Europe and one each in Eduador, Japan, Myanmar, Republic of Korea, Russia, Taiwan, Thailand and UAE take IRS data to international customers.







Brave new WORLD

Till the early 70s, maps created by the Survey of India contained a clutter of all information pertinent to a particular geographical area on one large sheet.

This common map was then accessed by all nodal agencies working in areas like forestry, defence applications, water resource management and geological research, irrespective of their specific requirement.

Any updating or change in these maps was a painstaking procedure involving pen and ink corrections.

The first step towards transforming this was the replacement of paper with a polyester-base that made it easier to preserve the original colour separations for longer periods.

From paper to digital

By the 80s, the Survey of India had succeeded in making a shift from paper to digital maps.

Using Digital Cartographic Databases (DCDB), it was able to create a database that stored information as separate layers linked to the base topographical map.

This allowed the printing of maps containing specific information, tailored to meet particular requirements.

The first digital mapping centres in India were set up for the Survey of India in Dehradun and Hyderabad, by Rolta.

But, this was just the beginning. From the digitisation of particular layers of information on a base map for theme-based prints to attaching every kind of information in the form of 'intelligent' data to the different layers on a map, the use of Geographical Information Systems has completely transformed the concept of mapping in India.

Facts about India

- 29 states, 6 Union Territories
- 3,287,590 sq. km of area
- 7,500 km long coastline
- 46 major rivers
- 14 principal languages and about 325 dialects
- 1,035,481,000 people

All in one geographical location … a single nation called India.

Information is empowerment, and to empower the people that form a nation they must be equipped with the knowledge of their environment.

From the hot sunny climes of Tamil Nadu to the harsh biting cold of the Himalayas, India has a richly diverse set of geographical conditions, which are in a constant state of flux under the influence of geological, climatic and man-made factors.

To minimize the wastage of vital resources there is pressing need for accurate information that can be updated on an almost instantaneous basis. Mapping various attributes of a location that are customised to particular needs … maps of the mind.

A map allows us to access different aspects of a particular geographical area in a single, consistent and accurate set of data

- makes this information accessible to readers who vary greatly in their map-reading skills
- uses a set of symbols, lines, and colours that minimise clutter and increases legibility

New maps of the mind

Combining the basic requirements of a map with our ability to instantaneously synthesise any kind of information with the help of digital technology, we are able to arrive at what some people call "new maps of the mind."

Virtual, thinking, living maps, called Geographical Information (GI) Systems that come into existence in answer to a specific need.

Whether we talk of the psychographics of the people living in an area, ground water levels, literacy levels of adults, or even the land use pattern of that area, we now have the ability to accurately represent all this information in multiple layers in a single map.

Helped hugely by GPS satellites, and remote sensing, GI Systems are capable of performing a range of tasks that is almost limitless.

From marketing a product, to storing of the details of every utility cable in a city or even modelling global change.

Bhavnagar, a small town in Gujarat, will soon be able to boast of geo-mobiles that carry on-location information about its intricate telecom network…

To curb poaching and preserve their natural environs of the endangered Asian elephant, elephant trails are being mapped and studied in the eastern state of Jharkhand…

The entire coast of India is being closely monitored after the mapping of human settlements has revealed an alarming relation between illegal construction and marine ecosystem erosion…

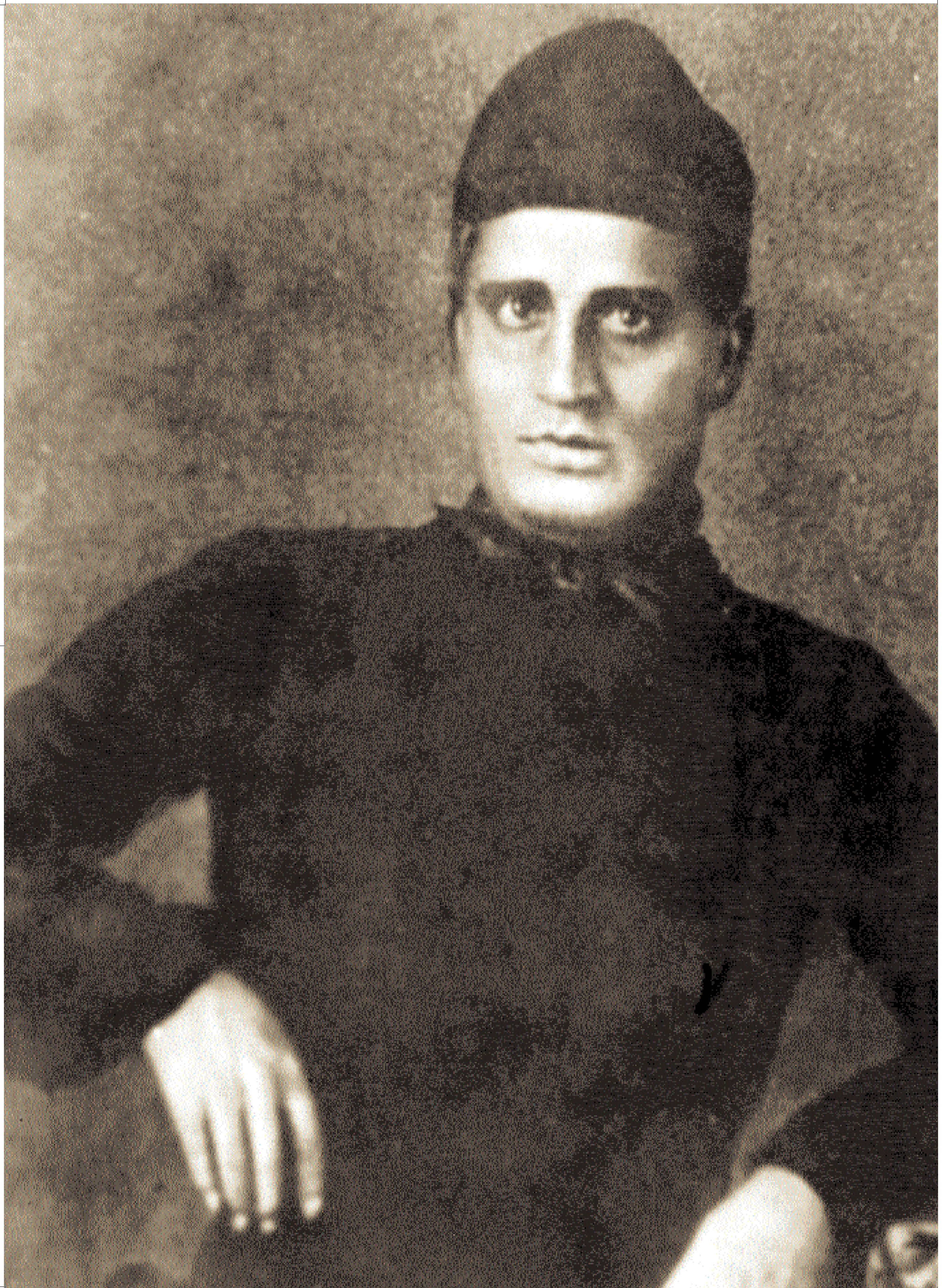
Farmers in Karnataka are able to precisely plan their crop for the entire year by mapping soil and water resource through the seasons…

Transport authorities have mapped and replanned the entire bus stop networks in the city to improve traffic conditions…

Lethal diseases such as cholera and tuberculosis are being mapped in relation to other geographical and social factors to facilitate a better understanding of public health policy…

The use of GIS is gaining ground in India as an aid to critical decisions making in hitherto unimagined time-frames.

It been a steady movement onwards from the first triangle of the mesh that eventually mapped the idea of India as one cohesive entity to a complex matrix of multi-layered information that can map the future…



CONTRIBUTION *of* INDIANS

IN THE MEASUREMENT OF THE GREAT INDIAN ARC OF THE MERIDIAN ON THE EARTH'S SURFACE ACCOMPANIED BY THE GREAT TRIGONOMETRICAL SURVEY

BRIGADIER KG BEHL (RETD)

When Major William Lambton started the measurement of the Great Indian Arc of the Meridian on the earth's surface, accompanied by the Great Trigonometrical Survey (GTS) on 10 April, 1802, Indians were employed in various subordinate ways in the work. Apart from doing menial household jobs, they were being used to carry instruments and equipment, to clear jungles and obstacles in the line of sight, to build hill stations and carry instruments and equipment to the hill tops, to send signals with flags, make measurements with chains and help in spreading baselines, etc. Minor artisans such as carpenters, blacksmiths, cobblers, etc, were employed for the day-to-day repair of equipment while others served as guides across forest or tribal areas and as security men to guard the camping areas. Those who learnt English were used for clerical work to maintain accounts and keep diaries of work or to act as munshis or writers to record tour details. In revenue surveys, educated Indians were being employed as sub-surveyors, also called native surveyors, required to help with the fieldwork. All the precision work of observation, on the other hand, was being done by British officers and their European retinue until 1830.

It was at that time that Major George Everest was appointed Surveyor General of India. Following in Colonel William Lambton's footsteps in triangulating the Great Arc, Everest was a creative and innovative genius. His introduction of compensation bars for measuring bases, heliotrope flashes and reverberatory lamps for signals for observation stations, method of ray tracing, erecting flag staffs, designing of survey towers, and so on, was unique but it required trained Indians to operate these. Though initially reluctant, he began to induct an increasing number of Indians as the work expanded and his faith in them grew, and in 1883, Lord William Bentinck, the Governor General, took the decision to promote the status of educated Indians in their service.

The measurements of the Arc of the Meridian and Great Trigonometrical Survey were spread over 1,600 miles in length along the meridian and, at places, 1,200 miles in latitude, in order to cover the entire country. This work took approximately fifty years to complete and is hailed as one of the most stupendous works in the history of science. It was also one of the most perilous tasks as it was carried out through practically all types of hostile terrain and conditions, including dense jungles, high and rugged hills, swollen rivers, floods, droughts, swamps and deserts, often infested with wild animals, dacoits, ferocious tribal people and a variety of snakes, leeches, mosquitoes and insects carrying fatal diseases. It was a time when there were no proper roads and the mode of transport was animal-driven carriages though most people travelled on foot carrying their baggage on their heads. Indians were employed to do the spadework in this great project and bore the brunt of attacks from animals and insects and the vagaries of weather and terrain, and like true soldiers in the ranks, they suffered the most in the process. It is no wonder that this complete operation of measurement of the Great Indian Arc cost more lives than most contemporary wars and most of those who laid down their lives for the cause were Indians.

George Everest was most impressed by two Indians, namely, Mohsin Hussain and Radhanath Sickdhar. Mohsin Hussain was taken from a jeweller's shop in Madras in 1824 and rose to become his leading instrument repairer and the company's Chief Mathematical Instrument Maker. Radhanath Sickdhar, who joined him in 1840 as Chief Computer, turned out to be a mathematical genius and was the first Indian to be employed in GTS work.

Syed Mir Mohsin Khas was born at Arcot, Madras, and his family was connected with the Nawab of Arcot. He was appointed in 1824 as instrument repairer at the Surveyor General's Office (SGO), Calcutta. On 3 October, 1836 he was promoted as Sub-Assistant and on 26 September, 1843, as Mathematical Instrument Maker. Everest found him particularly useful in petty repairs and adjustments to new instruments and base-line apparatus and also in the construction of old instruments. He had already learnt to take astronomical observations, and when promoting him as Sub-Assistant in 1836, Everest reported him as being:

"Peculiarly remarkable for his inventive talent, the facility with which he comprehends all mechanical arrangements, and the readiness with which he enters into all the new ideas of others." He later said that without the valuable aid rendered to him by Mohsin Khan, "it would have been utterly out of my power to carry into effect my various projects for the remodelment of the instruments, completion of the apparatus for comparing the chains, standard bars, remodeling of 18-inch theodolite and for having been able to introduce my reverberatory lamps into practical use."

Mohsin Khan's crowning triumph was the successful division of the horizontal circles of two astronomical instruments in 1839, which made them, it is said, even better than the originals.

Radhanath Sickdhar was born in October 1813 at Sikdarpara, Jorasanko, Calcutta. He was the son of Titu Ram Sickdhar, a Bengali Brahmin. He received an exceedingly good elementary education in mathematics at the Hindoo College, Calcutta. He joined as Computer in SGO on 20 December, 1831 and rose to become Chief Computer on 31 March, 1845. He never married. His knowledge of English was fundamental and despite this he eventually became thoroughly European in outlook. He became the right arm of George Everest and besides the work of computations was sometimes even allowed to make observations. He also computed the height of Mount Everest, which was declared the highest mountain in the world. He compiled the first edition of auxiliary tables of the Great Trigonometrical Survey in 1850. Elected member of the RAS in 1853, he retired on 15 March, 1862. Recipient of many awards, he trained many Indian computers who were employed to complete this pioneering work.

Everest, who was always on the move, recruited up-country carpenters, ironsmiths and fitters to assist him in his travelling workshop and most of them were put at Barrow's disposal at Kaliana for reconstructing faulty astronomical circles. One of these persons was Sub-Assistant Seid Mohsin, formerly designated as 'Native Artist', a person of natural genius and speed, and a practical turner and mechanic, as skilful as Barrow himself, except for that aspect of professional knowledge called 'trade secrets'. The second was Kusiali,a young man far above mediocrity who headed the native ironsmiths of the GTS establishment of artificers. The third was Ramdin, a subordinate, also above mediocrity. The fourth was Ramdheen, head carpenter of the Surveyor General's Office, who was trained in the workshop to be an able turner and workman in brass and iron. The fifth was Jewahir, a very able and expert turner, foreman and smith.

Colonel George Everest developed full faith in Indians and highly commended their hard work, dedication and devotion to duty, and their working conscientiously without supervision even under extremely hard climatic conditions.

Geodesy means the investigation of the size, shape and structure of the earth. The main purpose of measuring the Great Arc of the Meridian was to define the spheroid. There are a number of activities, all ultimately utilitarian, which are required to be appropriately combined in order to get the exact shape of the geoid/spheroid based on the measurement of the Great Trigonometric Arc. In 1830 George Everest devised such a spheroid to fit in with the geoid over the Indian subcontinent. It was called the 'Everest Spheroid' - with its axis passing through Kalianpur as centre. (This is not only being used in India but is being used by Pakistan, Nepal, Myanamar, Sri Lanka, Bangladesh, Bhutan and other Southeast Asian countries.) This spheroid had some inherent weaknesses initially and corrections had to be applied to cater for the following forces in different fields: gravitational forces, magnetic forces, levelled heights, tidal predictions to determine sea level, astronomical observations to determine latitude and longitude. Observations were made in these fields by setting up observatories where Indians were employed along with others and suitable corrections applied to get the best fitting shape of the geoid. The process of geodetic triangulation carried out in India from 1802 to 1878 was adjusted in 1880 to the Everest Spheroid. Inherent weaknesses were discovered by JD Graff Hunter in 1916 and by Captain G Bamford in 1917 who pinpointed certain series as secondary, which were later taken up for upgradation and densification.

It is not possible to cover in this chapter all the works where Indians were employed, but I will point out some of the important series or areas and the Indians who made their mark here.

GRAVITATIONAL FORCES

In the study of the figure of the earth the effect of Himalayan masses to the plumb line was felt by Everest himself when he obtained pendulums of Henry Kater's inversible type from England (Kater was an assistant of Lambton, the inventor of Kater's pendulum and the prismatic compass.) In 1852 Captain A Pratt calculated the actual amount of attraction of the Himalayan masses and of deflection/deviation of the plum line at three stations of the Great Arc and thus propounded the Theory of Isostacy - a significant contribution made by India to world geophysical sciences. Though the actual pendulum observations were started in 1865 by Captain Basevi, the redefinition of Everest datum was realized in 1927 when the international spheroid was introduced and used for scientific purposes. Since then the demand for gravity and magnetic data has increased and the entire country has been covered with a mesh of gravity stations, 15 km apart. It provides valuable information regarding various gravity anomalies, gravity deflections and undulations. In these observations many Indians established Absolute Gravity Stations in India.

The contribution of BL Gulatee is held in high esteem amongst the scientific community. Gulatee determined the Gravimetric Geoid in the high

Himalayas and also corrected the height of Mount Everest. He also made a significant contribution to geophysical studies.

MAGNETIC OBSERVATIONS

Magnetic surveys were started in 1840 by Captain Boilean and the first determination of Dip, Declination and Horizontal Force, etc, was made in 1901 with instruments like the dip circle and conventional magnetometer. Magnetic observatories were also established in various parts of the country during 1902-4. Alibagh (Colaba) and the base line of five magnetic observatories was determined in 1920. Modern instruments were used from 1940 onwards with the advent of QHM, BMZ, vector magnetometers, etc. The Sabhawala observatory was commissioned in 1964 and continuously records observations with the latest instruments installed there. Magnetic instruments are calibrated here and are standardized at the Alibagh observatory. There are about 182 repeat stations spread over the entire country where observations are made at intervals of five years for the preparation of Epoch Charts.

LEVELLING OPERATIONS

Colonel Waugh initiated the plan of connecting trigonometric heights to levelled heights in 1856. Trigonometric heights had so far been determined by reciprocal observations of the vertical angles. Heights can be carried over long distances fairly accurately provided observations are taken at the time of minimum refraction but since the Indian triangulation was large it was considered necessary to check heights by levelling. The series was commenced in 1858 and by 1864 Karachi was connected with Calcutta - a level line of 2,200 miles - the staves were held vertically by Indians and readings taken by British officers. In many other series Indians were employed as second observers for simultaneous double levelling.

ASTRONOMICAL OBSERVATIONS

Astronomical observations of the azimuth for the control of direction were made at the start and close of every series of triangulation from Lambton's time; Everest introduced modifications for azimuth observations with circumpolar stars; this played a significant role in the determination of the astro-geodetic geoid and improvement of the triangulation network by being based on the Laplace azimuth.

Faith in Indians was further strengthened when, along with Dr Hunter, an Indian surveyor worked out the latitude of a place at Ujjain as 23 10' 24" N against the latitude 23 10' N. He was from the Ujjain astronomical observatory set up by the Jaipur maharaja Sawai Jai Singh II, one of five established by him in India. Employing Indians thus became extremely relevant, and the need to train technical persons for survey work in different fields, especially for precision geodetic surveys, was particularly felt

TIDAL PREDICTIONS TO DETERMINE DATUM

Captain AW Baird started systematic tidal observations in 1876 by installing self registering gauges all along the coast when the difference of three feet was noticed between Bombay and Madras sea levels. A number of Indians were employed for recording and reporting but Captain Baird spoke very highly of Dhondu Venayash in setting up tidal installations and inspecting the observations and also in training other Indian clerks. Baird was also very appreciative of Venayek Narayan as the most useful computer.

EXPLORATORY SURVEYS: CENTRAL ASIAN EXPLORERS

While recording the achievements of the outstanding men, both European and Indian, in the early work of the Survey of Indi, we must not forget the invaluable support they received from the accounts and experiences of travellers and adventurers in the

region. In 1832 Alexander Burnes travelled through Afghanistan and Turkestan, during which journey he took the assistance of two Indians, Mohammed Ali, an engineer from Bombay, and Mohan Lal, educated under the aegis of Charles Trevelyan. Mohan Lal was appointed as Write-writer on 18 December, 1831 from Delhi. He was a highly intelligent, lively young man who maintained a detailed diary of the journey through Kabul, Bukhara and Mashed, and the return through Herat, Kandahar and Peshawar. His fascinating journal was published at Calcutta in 1834, and gives a vivid account of Turkestan and its people.

TRANS-HIMALAYAN EXPLORERS

The first expedition in this region was undertaken by Muhamed-I-Hamed who travelled from Ladakh to Yarkand by the Karakoram Pass and fixed the latitude of Yarkand. He, however, died soon after his return. Although at that time Tibet was a mystic land closed to Europeans it was open to Indians.

Captain Montgomerie, the man in charge of the Kashmir survey, visualized the important role that Indians could play in charting that unknown country by travelling in the garb of tradesmen and mendicants. He engaged two brothers from one of the upper valleys of the Himalayas - Pandit Nain Singh and Pandit Kishen Singh. Both were trained in the use of the sextant, compass and hypsometer. From 1865 to 1892 they carried out a number of exploratory expeditions and blazed new trails in the art of clandestine surveys.

Nain Singh used a prayer wheel, which he kept rotating, as befitting a devout Buddhist, while on his way to Lhasa in 1865. His 1,200-mile journey from Kathmandu to Lhasa and from there to the Mansarover Lake and back is an outstanding record of exploration, revealing details of the southern trade route of Tibet and the Tsangpo's course of 600 miles. His last journey took place in 1873-5 from Leh to Lhasa and Assam to Calcutta, covering almost 1,324 miles, out of which 1,200 miles were virgin territory. His method of recording was to keep his observations on a particular day in the prayer wheel, covered with a lid to conceal it from others. It was an ingenious method and he took 31 observations for latitude 30 for boiling point (to determine height), and laid down 1,200 miles of route survey. These records make a fascinating study not only about unknown lands but about the life and customs of the people living there and, what is equally exciting, about how these travellers manoeuvred difficult situations.

Pandit Kishen Singh's first important journey was undertaken in 1872, when he made a route survey from Shigaste, north of the Tsangpo, round the shores of Tengri Nor and reached Lhasa from the north covering 320 miles and an area of 12,000 sq miles. In the process he explored one of the northern tributaries of the upper Brahmaputra. His second journey was through Tibet and Mongolia during 1878-82, where he spent four years and then suddenly reappeared from the confines of China. His exploratory work helped to solve geographical problems connected with the Irrawady and Brahmaputra rivers. He also discovered that the Tsangpo rises near Mansarover Lake and travelled 850 miles to Gyala Sidong. Among his many awards, Kishen Singh was decorated with the title of Rai Bahadur. He died in February 1921.

A number of other explorers were either trained by these two stalwarts or were otherwise commissioned to discover new territory, bringing back a lot of useful information on their return, namely, Kalyan Singh, Hari Ram, Kinthup, Lala, Nem Singh, Rinzin Namgayal, Ugyen Gyatso, Miza Shuja, Ata Mohammed, Abdul Subhan and others. It is not possible to give a detailed description of what they accomplished, but suffice it is to say that their exploratory work has added an immeasurable degree of support to the development and ongoing achievements of the Survey of India.

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