

GENERAL RE  
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Survey

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THE GOVERNMENT OF

DURING

1903-04.

PREPARED UNDER THE DIRECTION OF  
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OFFICIATING SURVEYOR GENERAL OF INDIA.



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## TRIGONOMETRICAL SURVEYS.

34. The programme of the triangulation party (No. 23) was to continue the Great Salween series southwards, but this was interfered with by the deputation of Captain Wood, R.E., to Nepal to investigate the identity of Mount Everest with a peak called Gaurisankar. When he returned in December, the season for observation in Burma was so far advanced that it was considered advisable to alter the programme and employ Captain Wood in observing geodetic azimuths at some of the longitude stations in India and Burma. The Provincial officers of the party were engaged during the field season in building stations for the Great Salween series extending as far south as latitude  $20^{\circ} 30'$ .

## SPECIAL OPERATIONS.

35. Captain Wood was employed at the commencement of the field season in identifying the Himalyan peaks seen from Kátmádu. By the time that he had completed this important work, it was too late for him to commence trigonometrical operations in Burma, and as no other officer was available, the principal triangulation of Burma was not continued. Work on the Great Salween series of principal triangulation will, however, be resumed as soon as opportunity offers, as it is required to determine the terrestrial position of the eastern boundary of Burma.

36. On finishing his work in Nepal, Captain Wood with No. 24 Party, proceeded to observe rigorous astronomical azimuths at longitude stations in India and Burma. These azimuthal observations are required for the determination, by means of Laplace's equation, of the errors accumulated in principal triangulation.

37. Captain Cowie in charge of No. 22 Party, extended the triangulation of the Great Arc of India northwards for a distance of 35 miles into the hills, and observed for latitude at stations in the heart of the Himalayas.

38. Pendulum observations were commenced this year with a new apparatus, and their progress is being watched with interest by European geodesists. The International Conference that met at Copenhagen in 1903, discussed the questions which were raised in the Survey of India Professional Paper No. 5 of 1901, concerning the deflections of gravity in northern and central India, and passed a resolution on the subject to the effect that the Indian plumb line determinations required to be supplemented by new observations of the pendulum, and that in no other way could the deformations of the geoid and the variations in the density of the earth's crust be definitely measured. After studying the use of the instrument at Potsdam, and observing with it at Kew and Greenwich, Major Lenox-Conyngham brought the new pendulum apparatus to India, and commenced determinations of the force of gravity in this country.

39. Tidal operations were continued by No. 25 Party, observations being recorded at 12 stations. The observatory at Okha in Cutch was opened during the year. Levelling operations were extended in Upper Burma.

40. Five detachments of No. 26 Party continued and extended the field work of the magnetic survey over different portions of the country. Four of the five base stations are now working, and it is hoped that Toungoo, the fifth, will be installed during 1905.

## GEOGRAPHICAL SURVEYS.

41. Under this head are included surveys and reconnaissances which are executed on the  $\frac{1}{2}$ -inch and smaller scales.

The survey detachment with the Aden Boundary Mission completed an area of 3,600 square miles on the  $\frac{1}{2}$ -inch scale, and 2,500 square miles on the  $\frac{1}{4}$ -inch scale. A narrative report of its work from the date of its commencement in 1901, will be found in the appendix.

The survey detachment with the Seistan Mission also completed about 15,000 square miles on the  $\frac{1}{4}$ -inch scale during the year 1904.

Another detachment accompanied the Tibet Mission, and completed an area of about 18,000 square miles of the country between British territory and Lha-sa. Captains Ryder and Wood, R.E., also returned from Gyang-tse via



Shi-ga-tse and Gartok to Simla and added another 40,000 square miles of geographic survey of much interest.

### HEAD-QUARTERS OFFICES, CALCUTTA.

42. The general direction of these offices remained under Colonel St. G. C. Gore, C.S.I., R.E., up to 23rd February 1904, and thereafter under Lieutenant-Colonel F. B. Longe, R.E. The Deputy Surveyor General's Office was also located, as usual, in Calcutta. The Surveyor General's Office was under Major J. M. Burn, R.E., up to 5th June 1904, and thereafter under Bt.-Lieutenant-Colonel T. F. B. Renny-Tailyour, R.E. The Drawing, Engraving and Map Record and Issue offices were under Major J. M. Fleming, up to 14th April 1904, when he proceeded on leave, and Major W. J. Bythell, R.E., took charge from the 3rd May 1904. The Photo-Litho Office was under Mr. T. A. Pope throughout the year. The Mathematical Instrument Office was under Major J. M. Burn, R.E., up to 5th June 1904, and thereafter under Bt.-Lt-Colonel T. F. B. Renny-Tailyour, R.E. Lieutenant C. M. Browne, D.S.O., R.E., remained attached to the Mathematical Instrument Office up to 31st July 1904.

43. *Drawing Office.*—The "General Section" has, as usual, been engaged throughout the year on the compilation and revision of the "general" maps, and the addition of new material to all standard sheets of which reprints and new editions are required. A large number of sheets received for publication from the various field parties have been scrutinized and prepared for press.

Ten "general" maps of India, on scales varying from  $\frac{1}{32}$  miles to  $\frac{1}{256}$  miles the inch, have been in progress during the year, of which 5 are new editions. Of these the new  $\frac{1}{32}$  and  $\frac{1}{64}$  mile maps have been delayed for a very considerable period, owing to the difficulty of obtaining the correct alignment of boundaries of the North-West Frontier Province from the local authorities. These boundaries can only be considered as approximate, as they are not from actual survey.

Sixteen sheets of  $\frac{1}{1,000,000}$  "map of India and adjacent countries" have been in hand during the year, and 13 of these are under publication.

Thirty maps of Provinces, chiefly on the scale of 16 miles = 1 inch, have been in progress during the year, of which those of Bengal, Madras and Bombay are new publications.

Forty-four "District" maps on the  $\frac{1}{4}$ -inch scale have been brought up to date or completed, 20 of which have been published.

Two hundred and thirty-six "standard sheets" on the scale of 1 inch = 1 mile have been in hand. Of these 97 have been published, (29 being new publications and 27 new editions). Forty-four more are under publication, 2 are of the Andamans, 14 of Bengal, (of which 4 have been drawn in this office), 28 of Bombay, 31 of Burma, 72 of Central India and Rájputána, 4 of the Central Provinces, 8 of Madras, 6 of the North-East Frontier, 2 of the Northern Trans-Frontier, 46 of the North-West Trans-Frontier, 1 of the Punjab, 6 of the South-East Frontier and 1 of South-West Asia. The remarks contained in last year's report concerning the difficulty of reconciling these separate surveys when compiling new standard sheets still hold good.

Twelve Burma "Forest" maps have been brought up to date and published.

Twenty-one "Administration Report" maps have been brought up to date and published, 2 are in hand and 3 under publication.

Four of the Burma "Degree sheets" on the scale of 1 inch = 4 miles have been in hand during the year, 1 has been published, 2 are under publication, and 1 is under compilation.

Eighteen "Index" maps on various scales have been brought up to date and published, 4 triangulation charts are in hand, 1 is under publication and 4 have been published.

A large number of plans of cities and cantonments, aggregating 76 sheets, all on large scales of survey, have been dealt with: of these 14 sheets are in hand, and the remainder have been brought up to date and published.

44. In the "Colouring Section," 2,523 sheets have been coloured during the year.



*Report on survey operations with the Tibet Frontier Commission by  
Captain C. H. D. Ryder, R.E.*

On 24th September 1903, I received orders at Bangalore to join the Tibet Frontier Commission at Kam-pa Dzong. Proceeding *via* Calcutta where I had to spend a few days collecting instruments and kit, I arrived at Siliguri, the railway base on the 3rd October and marched out the same afternoon to Sevoke, where the Tista leaves the hills. This was not the time of year to see the Tista valley at its best, very hot, raining every day and all day, the march up the valley was far from pleasant. The cart road, now open as far as Gang-tok, was then constantly blocked by landslips and very slippery. After Gang-tok was passed the views of the snows should have been magnificent, but the higher hills were veiled in clouds, all the more pleasant, therefore, was the marked change once the frontier pass, the Kangra La, was crossed; clouds were left behind, and during the two months I stayed at Kam-pa Dzong we had nothing but the finest weather with that wonderful clear atmosphere which every traveller in Tibet has remarked on.

Down the long slope from the Kangra La and over the rolling downs near the village of Giri, the great snowy range gradually opened out, till on reaching Kam-pa Dzong, or at any rate from the hill above it, one continuous line of snows was visible stretching from Cho-mo-lha-ri to Mount Everest, a distance of some 150 miles. We were able to survey from this snowy range northwards to the Arun river—Tsang-po watershed; the Tibetans beyond sending men to watch us, but making no attempt to stop us surveying so long as we did not camp away from the mission post.

As regards the heights of peaks our results were of a negative nature. The highest point on the above named watershed was 20,100 feet; the two "very high snowy mountains" mentioned by Mr. Freshfield on page 362 of the R. G. S. Journal for March 1902 were disappointing, being only 21,200 feet in height. The fine snowy range apparently running north from Everest, but in reality running north, but some 30 miles east of Everest, has its highest summit at an elevation of 22,200 feet. In the photograph by Mr. Hayden (R. G. S. Journal, March 1904) it will be noticed that the northern side (*i.e.*, the right-hand one in the photograph) of Everest has a continuous slope which I estimated at 7,000 feet, and it is extremely unlikely that north of Everest and hidden by the nearer snowy range (on the right edge of the photograph), the peaks could again rise to a height anywhere approaching that of Everest. It is interesting here to note that Everest as viewed from Kam-pa Dzong, does not appear as the highest peak of a group, but as one massive summit standing by itself; nowhere could we hear of any local name for Everest although careful enquiries were made. The height of Kam-pa Dzong itself proved to be 15,200 feet, instead of 13,800 as on previous maps.

Fortunately, just as we had completed all possible surveying from Kam-pa Dzong, it was decided that the mission should retire and cross the Dzelap La into the Chumbi valley. We accordingly hurried across Sikkim, and caught up the main body of the mission and its escort at Chumbi. This valley is disappointing; it has always had a great reputation, but we found it to be only 200 or 300 yards wide, and not very rich. The houses at Rin-chen-gong are good, but this is due to the fact that the Tomos who inhabit the valley having a monopoly of the carrying trade from Phari Dzong down into Sikkim.

A short halt here enabled me to get the lower end of the valley surveyed, and detach Sub-surveyor Dalbir Rai, who followed the valley down to the plains and returned to Gnatong by the adjoining valley, thus completing a most useful piece of work including a hitherto unsurveyed portion of Bhutan.

The mission then moved up to Phari Dzong and over the Tang La (height 15,200 feet), a very easy pass, to Tū-na (height 14,800 feet). Here we spent the winter and except for some work in the Chumbi valley, surveying was nearly at a standstill; the Bhutan snowy range on the east, lower rounded hills on the west, and the Tibetan force at Gu-ru 6 miles north of us, limited our sphere of observation. The cold was intense, and a very unpleasant three months were spent before we again advanced. Numerous cases of pneumonia occurred, mostly fatal. Amongst them were two of my *khalásis*, but Sub-surveyor Hazrat Ali was fortunately one of the few that recovered. Towards the end of March Mr. Hayden, of the Geological Survey and I, with an escort of 20 rifles, made a short excursion across the plain to explore the Ling-shi La, a pass crossing the snowy range into Bhutan. Before, however, reaching this point we were met by a small Tibetan force and requested to return. In view of my knowledge that Colonel Younghusband was very anxious to avoid if possible a collision with the Tibetans, I decided to retire to Tū-na.

General Macdonald and the main force having arrived at Tū-na it was decided to make a preliminary advance to Gu-ru, where the Tibetans were encamped, and establish a post there. Our advance was opposed by the Tibetans who had divided their force, sending half to the east of the Bam Tso on the direct Lha-sa road. A short fight ensued in which the Tibetans suffered heavily. I left a surveyor with the post at Gu-ru, where he was able to do some work, while the main force returned that evening to Tū-na; on the 2nd April Captain Cowie, R.E. joined me, just in time for the advance to Gyang-tse which took place on the 4th April.



The Survey detachment was now constituted as follows:—

Captain C. H. D. Ryder, R.E., in charge.  
 Captain H. McC. Cowie, R. E.  
 Surveyor Sher Jang, Khan Bahadur.  
 Sub-surveyor Dalbir Rai.  
 Sub-surveyor Hazrat Ali.

Sher Jang remained in the Chumbi valley, the rest of the party accompanied the advance.

We camped on the 4th April at Gu-ru, and then marched round the shore of the Bam Tso to Chalu, and the following day did a short march down the narrow valley along which the stream flows connecting the Bam Tso with the Ka-la Tso. I ascended a point on the range between the two lakes from which a fine view of them was obtained. The Bam Tso has an area of about 25 square miles and the Ka-la Tso of about 15 square miles. Captain Cowie accompanied a mounted infantry patrol as far as Sa-ma-da; they found the village occupied by Tibetans, were heavily fired on, and returned to camp in the evening. Next day the 7th April, we had a level march to Mangtsa, where the open country ends. We could see Sa-ma-da down the narrow valley ahead of us, but the Tibetan force had retired.

There is no outlet to the Ka-la Tso, but there are obvious signs that in ancient times the water flowed out of the lake into the narrow gorge to Gyang-tse and the Tsang-po. About 8 miles from the lake in this direction a small stream rises from what is probably an underground flow from the lake, and flows in a broad and deep bed down the gorge.

From Mang-tsa the force marched to 3 miles short of Kang-mar, while Captain Cowie and I ascended the range to the east to a height of about 18,000 feet to try and get a view ahead; in this we were not successful, still higher hills on the north on both sides of the gorge blocking our view. The Tibetans were reported by the mounted infantry to be in force holding a wall across the valley at Kang-mar, but next day their position consisting of a strongly built wall, (which, however, could have been easily turned,) was found evacuated; next day they were located in a position holding a narrow gorge, known as the Red Idol gorge, with precipitous hills on either side, they were easily turned out of this by a direct attack and a long flanking climb on the part of the Gurkhas. We camped at Sapu that evening and marched on to the Gyang-tse plain the following day. On the 11th April, the Dzong or fort of Gyang-tse was surrendered by the Tibetans who seemed cowed by the defeats they had received; the mission was established in a village on the right bank of the Nyang Chu, where there is a bridge about 1,000 yards from the Dzong.

A force under Colonel Brander consisting of 2 companies 8th Gurkhas, 4 companies 32nd Pioneers, 2 7-prs., 2 machine guns, and 70 mounted infantry were left as escort, while the General and the main force retired to the Chumbi valley, leaving posts at Kang-mar, Ka-la Tso and other places on the line.

We now settled down to a peaceful existence, a bazaar was established outside the post and officers in small parties could wander about the plain shooting.

Captain Cowie and I were then able to start triangulation off a measured base, and with the help of three stations on the hills were able to complete all the work that was possible; but we were not then able to connect this triangulation with Kam-pa Dzong and the Great Trigonometrical peaks, but we fixed some peaks on the Ka-ro La range which afterwards proved invaluable in connecting the Lha-sa triangulation with this work.

Towards the end of the month a report came in that a force of Tibetans had collected on the Ka-ro La, 45 miles from Gyang-tse on the road to Lha-sa. A party, consisting of 50 men of the 32nd Pioneers and 30 mounted infantry under Lieutenant Hodgson, was sent out to verify this report. As this would afford an opportunity of getting in a good addition to our map, I decided to accompany the party with Captain Cowie and Mr. Haydon.

We reached Ra-lung, two long marches from Gyang-tse, on the 29th April, and the following day accompanied by the mounted infantry, rode up to the pass, about 2 miles beyond, where we saw the wall which the Tibetans had built. Lieutenant Hodgson took a few men forward to draw their fire and make them disclose their strength. In this he was successful and withdrawing his men without loss, although some Tibetans concealed on the hills above were rolling rocks down on them, we rode back to Ra-lung. I had intended taking the mounted infantry to Kang-mar in one long day's march, as it was important to have this route reconnoitred, but owing to the presence of the Tibetans in such force on the Ka-ro La, this was not now considered advisable, and we returned to Gyang-tse in two marches, arriving there on the 2nd May.

Colonel Brander then decided to take out a force to turn the Tibetans out of their position on the Ka-ro La, as they were threatening our line of communications. On the 3rd May he accordingly started, Captain Cowie again accompanying, as I hoped he might be able to get the route from Ra-lung to Kang-mar done this time. They attacked the Tibetans on the 6th and drove them out of their position, but owing to our having in the meantime been attacked at Gyang-tse, Captain Cowie had to return with the force.

On the 4th, everything at Gyang-tse seemed peaceable, I had been out for a long day surveying on the hills to the south, and on my return heard of a report, originating from one of the patients in Captain Walton's civil hospital, that we were to be attacked next day. A small mounted infantry patrol went some miles down the Dong-tse road but



found nobody. The Tibetan force, however, was at Dong-tse itself, and leaving when the moon rose about 1 A.M., attacked us just after dawn. Their attack was a complete surprise, but once our men turned out, the Tibetans were easily driven off with heavy loss. If, however, the Tibetans had not given the alarm by shouting and firing their guns, we would have been in a rather awkward position. Another force of theirs had in the meantime occupied the Dzong, from whence they opened a heavy fire which to every one's surprise more than reached our post.

Colonel Brander's force returned on the 9th and as the Tibetans had been hard at work fortifying the Dzong, it was decided that it was impossible for us to attack it with success.

As it was obvious that surveying was out of the question, Captain Cowie and I volunteered for military duty and were appointed Assistant Field Engineer and Field Engineer, respectively, and were fully occupied in re-fortifying the post. The Tibetans never could make up their minds to really attack again, but most nights they used to make an attempt which usually ended in a lot of firing and nothing else. They, however, occupied a house only 450 yards from the post and opened a heavy fire from it. It was gallantly rushed by our men next morning and an outpost, called the Gurkha Post, was established there. The Tibetans also made a regular attempt to invest us by occupying the villages in our rear; they were driven out of several of these and on the 24th May re-inforcements arrived, consisting of 50 of the 32nd Pioneers and 80 Sappers under Captain Sheppard, R.E., and two other R. E. officers.

There being now plenty of R. E. Officers, Captain Cowie and I reverted to our legitimate duties. The Pa-la village which was threatening our post was captured on the 26th May, after a long day's fighting. Captain Cowie left on the 28th May to try and connect the triangulation round Gyang-tse with the Kam-pa Dzong and Sikkim work, but owing to constant cloudy weather he was unable to do so. I spent my time in computations, and in fortifying the Pa-la village, in charge of which I was placed, as I had volunteered to do any R. E. work under Captain Sheppard, R. E.

We thus passed a rather dull existence; the Tibetans made repeated night attacks on the two outposts, but their hearts always failed them; and though at first they were rather exciting and when the Dzong joined in, quite fine pyrotechnic displays, but towards the end they became monotonous. During this time Colonel Younghusband left for Chumbi, the post at Kang-mar being attacked as he was passing through, when the Tibetans were easily repulsed.

Towards the end of June the relief force under General Macdonald advanced from Chumbi. The day before reaching we heard that the Tibetans had occupied the Nye-ning monastery on the road. Colonel Brander, therefore, took out a small force on to the range overlooking the monastery and village from which one had a good view of the fight, which ended in the defeat of the Tibetans in spite of a stubborn resistance. General Macdonald then in a few days captured, first the Tse-chen monastery, which lay on a hill some 4 miles down the valley, and then, though delayed a few days by an insincere attempt on the part of the Tibetans to negotiate, the Dzong was captured on the 6th July, and we were at length free from the continual bombardment which lasted for two months.

Captain Cowie and Surveyor Sher Jang who had come up with the relief force, now rejoined me and on the 14th July we commenced our march to Lha-sa. Owing to the cloudy weather, rendering triangulation impossible, I thought it advisable, in case we could not afterwards connect Lha-sa and Gyang-tse by triangulation, to run a subtense bar traverse, this entailed Captain Cowie and I being on the road all day, starting with the advance guard and getting in in the evening. The weather too was very bad, heavy rain falling almost every day, effectually dispelling the prevailing notion that this part of Tibet is a rainless country.

The Ka-ro La (height 16,200 feet) was crossed on the 18th July, the bulk of the Tibetans holding the position bolting the night before from the wall in the valley, leaving their companions on the hills to their left to escape as best they could. They were easily driven out of their position by the 8th Gurkhas, who established a record in hill fighting at high altitudes, the Tibetan position reaching an elevation of 18,500 feet, and their retreat leading across the face of a glacier.

The next day the force moved to Nan-gar-tse Dzong in sight of the Yam-drok Tso lake. The snow peak marked in former maps in the centre of the promontary round which the Yam-drok Tso makes an almost complete circle, is a myth. No hill there has permanent snow, though as their height is about 17,000 feet, there doubtless is often snow lying there when there is none at Nan-gar-tse Dzong or on the shore of the lake (height 14,350 feet). After a day's halt we marched to Yar-sik where the original outlet of the lake obviously existed. We then marched for two more days along the shores of the lake, which all along this part is never more than 2 or 3 miles wide and very often less.

We crossed the Kam-pa La (height 15,400 feet) on the 24th, an easy ascent from the lake side, but a very long drop down to the Tsang-po. Owing to the low elevation 11,550 feet, and Sarat Chandra Das' description, I thought that the valley would have been well wooded, this, however, was not so the hills were quite bare and no trees grew wild, though round every village there were fine groves. We moved on 6 miles down the river to the place selected for the crossing, where the Tibetans had kindly left a large ferry boat on our side of the river.



The whole force had crossed on the 30th, a very laborious process only marred by the death of Major Bretherton, Chief Supply and Transport Officer, who was drowned by the upsetting of a Berthon boat raft. The valley here is broad and well cultivated, the river running in most places in several broad channels with sandy islands in between. It was about at its highest flood level soon after we had all crossed, with a very fast current deep, and about 140 yards in width.

On the 31st July we moved on, and after a few miles turned up the Kyi Chu, a well cultivated valley with a broad shallow river, resembling the Tsang-po valley on a slightly smaller scale. On the 2nd August we arrived at the To-long Chu, a large affluent of the Kyi Chu, and over which there is quite a good bridge. From here we were rewarded by our first sight of the Potala, the residence of the Dalai Lama, situated on a small isolated hill overlooking Lha-sa. Next day camp was moved to within a mile of the Potala; this was, however, only a temporary camp, and being swampy, another site was selected on drier ground north of the town, the mission being located in a very good house in pretty wooded grounds outside the town.

The weather was not favourable for surveying, rain fell constantly and heavy clouds lay on the surrounding hills, so after measuring a base, and observing a latitude and azimuth we confined ourselves to the survey of the town and suburbs of Lha-sa on the scale of 6 inches to the mile. This took some time, as we were at first not allowed to enter the town itself; but later on, having got in all the somewhat extensive groves, gardens, and summer residences outside the town, we were allowed to march through the streets with an escort. In order to avoid attracting attention, for this portion of the work we did not use a plane-table, but made a compass and pace traverse from one fixed point outside through to another fixed point on the other side. The inhabitants showed some curiosity but no hostility at our proceedings. The height of the plain above sea-level is 11,830 feet.

Captain Cowie left Lha-sa on the 29th August to return to Gyang-tse, to try and secure the connection in the triangulation between that town and the points I had fixed from Kam-pa Dzong. The weather now began to improve and I was able to go out with a small escort, firstly up the valley a day's march from whence I took mounted infantry up to the junction of the Pen-bo Chu with the main valley, just opposite the Garden monastery and some 30 miles from Lha-sa and secondly up the To-long Chu, a somewhat similar expedition.

Having done these two trips there only remained the Pen-bo La, the pass on the main road leading north and about 10 miles from Lha-sa. This was important for the triangulation, and I was lucky to do all that was necessary in a short spell of fine weather, which just coincided with the five days I spent in camp at the foot of the pass, climbing a hill of 18,000 feet elevation each day. From this range we were able to sketch in carefully the adjoining valley to the north, a broad well cultivated and thickly populated plain; and from three stations I was able to connect on with the peaks of the Ka-ro La range and also to fix many points north and eastwards, including some fine snow peaks south of the Tengri Nur, mentioned by Mr. Littledale, the highest of which was 23,250 feet in height, the highest we ever came across north of the Tsang-po. Two other snow peaks which I fixed are, I believe, those mentioned by M. Bonvalot and christened by him Mount Huc and Mount Gabet, but their heights were disappointing, the highest being 21,500 feet.

The treaty was formally signed at the Potala on the 7th September, and on the 23rd we left on our return march, re-crossing the Tsang-po ten miles above the point where we originally crossed, and then ascending the range between it and the Yam-drok Tso by the Do La, 16,000 feet, a long steep climb from the river. From this pass, the weather being clear, I had a fine view and was able to fix a station by observation to peaks on the Ka-ro La range and to two Bhutan peaks, already fixed from India, as well as to one of my stations on the hills north of Lha-sa. I had gone on ahead of the main force with an escort of 100 Gurkhas under Major Row. Next day we marched along the lake to Yar-sik, and ascended the range again, and observing from two more stations, the required connection between the triangulation done from Gyang-tse and that done at Lha-sa was secured.

At Yar-sik on the 30th September we met Captain Cowie, who though much hampered by the cloudy weather had effected a satisfactory connection between the Gyang-tse triangulation and the Kam-pa Dzong work, we here struck off the main route up the side valley, across a very low, in fact almost inappreciable watershed, and followed down the narrow valley known lower down as the Rong Chu, which flows into the Tsang-po. I have no doubt whatever that this is the old outlet of the Yam-drok Tso which now is land locked. Next day we left the valley, camping near the Nya-dong La, (height 16,000 feet) crossed the pass next day and so on to the plain above Ra-lung. This survey was useful in that it shewed the possibility of turning the Ka-ro La. Captain Cowie then made a round from Ra-lung into the Ni-ru valley down to Gob-shi and so to Gyang-tse, while I caught up the main force. I now made arrangements for Captain Cowie to complete the remaining work between Gyang-tse and Chumbi, on which he writes as follows:—

"On the 8th October with Sub-surveyor Hazrat Ali and a portion of the survey detachment I left Gyang-tse for Kang-mar, which was reached next day. Commencing a route survey from this village on the 10th, we struck off the



line of communications, marching eastwards through a narrow defile in the bare-rocky hills dividing the waters of the Nyang Chu and the Ni-ru Chu, as far as the Nilung La, which we crossed the same day, we followed the track which is part of the main road from Kang-mar to Ra-lung *via* the Wogya-la. After crossing this pass and descending into the open plain which receives the head waters of the Ni-ru Chu, we turned southwards, heading for the Bam Tso. Passing over the low rolling hills which intervened, we reached the lake on the 14th October, completing the survey of this locality and fixing the position of the Yu Tso, a lake lying at the foot of the snowfields of the big range, culminating further to the south-west in Cho-mo-lha-ri. On the 14th I got into communication with the head-quarter staff which had just reached Ka-la Tso, and, for the purpose of adding to the  $\frac{1}{2}$ -inch survey of the Kam-bu valley, obtained sanction to strike off the line of communications at Tū-na and crossing a pass some 12 miles west of the Tang La, to follow the course of the Kam-bu Chu, eventually rejoining the force at Chumbi.

Surveyor Sher Jang, who had accompanied the force from Gyang-tse as far as Ka-la Tso, joined me at Cha-lu on the 14th. On the 16th we left Tū-na, taking with us from there, a Tibetan who professed to know the hills to the east of Powhunri, and camped in a small valley below the pass.

On the evening of the 16th snow began to fall and by the 17th, and 18th, a severe blizzard had set in. We left camp on the 17th, in the midst of it, purposing to cross over into the Kham-bu valley, but were unable to reach even the pass. In consequence of mist and the thick driving snow it was impossible to see more than a few yards in any direction: we had no track to guide us and the snow was nowhere less than two feet deep. The difficulties of progressing were great and in addition, we, the guide included, lost our way. Though only a few of the party were frost-bitten, many had begun to suffer from snow blindness. Finding it impossible to proceed, with much trouble, we eventually got back on the 18th, to a point near our camping ground of the 16th. Next day, with over 50 per cent of the party incapable from snow blindness, we crossed the Tang-La and reached Pha-ri in the evening. On the 22nd, I reached Chumbi and reported to the General Officer Commanding (the telegraph line having been broken by the storm), who had sent out a search party for us from Chumbi.

The whole had recovered from snow blindness and the effects of exposure sufficiently to move on the 26th to Chumbi which we left on the 28th, and marching *via* the Nathu La and Gang-tok, reached Siliguri on the 5th November."

The survey results of the expedition are as follows:—

**Triangulation.**—An area of 45,000 square miles was completed connecting Lha-sa with India, all prominent peaks which were visible, with their heights, being fixed.

**Topography.**—An area of 17,000 square miles was surveyed on the scale of 4 miles to the inch, of which 3,000 square miles in the neighbourhood of the Chumbi valley, Gyang-tse and Lha-sa, were surveyed on the scale of 2 miles to the inch.

Route surveys on the scale of 1 inch to the mile were made of the road to Lha-sa.

Large scale plans were also made of the towns of Gyang-tse and Lha-sa.

Captain H. McC. Cowie, R.E., was of great assistance to me throughout, he is full of energy, and a very good draftsman.

Surveyor Sher Jang, Khan Bahadur, is a most careful and accurate plane-tableer, always turning out excellent work, at my request he was "mentioned in despatches."

Sub-surveyor Dalbir Rai did an excellent piece of work in Bhutan.

Sub-surveyor Hazrat Ali was with me throughout the expedition, he is an honest worker, and has improved greatly in his plane-tabling.

*Report on survey operations on the journey from Gyang-tse to Simla via Gar-tok by  
Captain C. H. D. RYDER, R.E.*

When the treaty was signed at Lha-sa on the 7th September 1904, it was decided that a party should proceed to Gar-tok to examine the place, as it was one of the trade marts which the Lha-sa Government had decided should be opened in Tibet. It was obvious that this would afford a great opportunity of adding to our geographical knowledge of the country; accordingly with the approval of the Surveyor General, a strong survey party accompanied the expedition. The ostensible object of the journey being a political outcome of the treaty, Captain Rawling of the Somersetshire Light Infantry, the officer deputed to open the trade mart, was placed in general control of the expedition with instructions to conform to my wishes in regard to survey matters. He was assisted by Lieutenant Bailey, 32nd Pioneers, whose knowledge of the Tibetan language proved very useful, the survey party consisting besides myself, of Captain H. Wood, R.E., and Sub-surveyor Ram Singh, R.S. Three military surveyors also accompanied us; one of these went sick and had to be sent back from Pin-dzo-ling, and very little use could be made of the other two owing to their limited knowledge of surveying, and to the fact that we were strong enough without them to carry on the work.



In making our arrangements for the journey, two considerations were paramount; firstly that we would be having a race against winter, with a possibility in the event of our being unable to get over the passes into India before the winter snows fell, the unpleasant prospect would have to be faced of having to winter at Gar-tok or some equally cold and inhospitable spot; secondly it was quite impossible to tell whether and to what extent, the Tibetans would assist us. Fighting had only lately ceased, the treaty had been signed barely a month previously, and there had been no opportunity of seeing whether the Tibetans would adhere to the treaty when our troops were withdrawn to India.

Our time for preparation was very short, every day's delay increasing the probability of our being snowed up. Captain Wood and Lieutenant Bailey arrived at Gyang-tse, which was to be our starting point, on the 30th September, while Captain Rawling and I only reached the same place on the 6th and 5th October, respectively.

Our transport we organised as follows:—Twenty-six baggage ponies to give us a nucleus of our own, should the Tibetans make difficulties about providing us with animals; 17 riding ponies, it being important that, in view of long and continuous marching at a high elevation, as many men as possible should be mounted; 100 yaks were lent to us from one of the Transport Yak Corps to take us to Shi-ga-tse, but not to go beyond that town. From there onwards, however, the Tibetans invariably and without any demur provided us with whatever transport we required. Ponies, donkeys, mules, yaks and coolies at various times carried our baggage, and although it was difficult to supervise so large and mixed a caravan, no single article was lost during the whole time the journey lasted.

We took two months' supplies for all our men, with two months' extra of such things as ghi, goor, etc., which could not be obtained *en route*; while for the officers' mess we took four months stores. Meat we could rely on obtaining in abundance, and *tsamba* or parched barley flour, as long as we came across villages.

Our party was finally organised and ready to start on the 9th October as follows:—

Captain C. G. Rawling, Somersetshire Light Infantry.  
 Captain C. H. D. Ryder, R.E., Survey of India.  
 Captain H. Wood, R.E., do. do.  
 Lieut. F. M. Bailey, 32nd Pioneers.  
 Sub-surveyor Ram Singh, R. S.  
 Hospital Assistant Hira Singh.  
 3 Military surveyors.  
 5 Sepoys of the 8th Gurkha Rifles.  
 5 Survey *khalāsīs*.  
 7 Pony drivers.  
 2 Hindustani servants.  
 2 Tibetan servants.

Mahomed Isā, a Ladakhi, who acted as caravan leader, and last but not least, a very small Lhasa Blenheim spaniel who followed our fortunes throughout.

In order to have the advantage of the company of Captain O'Connor, who was remaining as trade agent at Gyang-tse, and who with two other officers was making a trip to Shi-ga-tse, we postponed our departure till the 10th.

Our first day's march took us to Dong-tse, the late head-quarters and supply depôt of the Tibetan army, which had attacked the mission and its escort for two long months at Gyang-tse, but here, like everywhere else, we were cordially received, mainly I fancy owing to our being accompanied by a Lha-sa official who had been deputed to escort us to Gar-tok, and also to our being supplied with a very strongly worded permit signed with the seals of the Lha-sa Government and of the three great Lha-sa monasteries, and directing all officials along the route to render every assistance.

Three more marches, following the valley of the Nyang-Chu, which is one of the richest and most prosperous valleys of Tibet, landed us at Shi-ga-tse on the 14th October. Here we spent several busy days with an army of tailors making warm clothing for ourselves and our men, lining all coats with lambskins, making fur caps and gloves, etc., till finally when fitted out we all presented an appearance akin to Arctic explorers. Our stay at Shi-ga-tse was not, however, all work. We paid a most interesting visit to the great Tra-shi Lhun-po monastery, where the monks received us most cordially, shewing us all over the place, and finally giving us refreshments of tea, cakes and dried fruits. This monastery is said to contain 4,000 monks, and although not so large as, is richer than, the great Lha-sa monasteries. The bulk of the buildings, the residences of the monks, were of the usual type, narrow paved roads with high houses on each side, dirty and not picturesque, but we all enjoyed the sight of the tombs of the five previous Tra-shi Lamas each a separate building with its golden roof, and highly ornamented interior, fitted with a wealth of turquoises, gold bowls, and rare old jade and cloisonné, the effect being somewhat marred by a foreground of small vessels holding lighted tapers, fed by very evil smelling butter. Bogle's description of his visit is very picturesque and accurate, the number of tombs has now, however, increased from three, as seen by him, to five as seen by us.

We were fortunate also in being received by the Tra-shi Lama, who, after holding an almost co-equal position to the Dalai Lama has now by the deposition of the latter, become the most important ecclesiastic in Tibet. He was living in his summer residence, a house outside the town to which, with Captain O'Connor as Political officer at our head, we pro-



ceeded. A little hitch occurred at the gateway, as an arch scoundrel Colonel Ma, who had been the Chinese official at Gyang-tse, when we were attacked, and had never given us warning nor even tried to protect the servants and property of his colleague Captain Parr, was also paying a visit. Captain O'Connor refused to enter the house while this individual was in it, and the latter had to be smuggled out by some back door; we were then shown up some steps and along dark passages till we arrived at the reception room, at the far end of which we could see the Tra-shi Lama seated cross-legged on cushions on a raised platform. He received us each with a bow and a smile which we returned and were shown to seats on one side of the room while the other side was filled with Tibetan officials and monks in either the ordinary maroon coloured clothes usually worn by monks, or in the yellow silk of the higher temporal officers. Tea, undrinkable as usual, was handed round, but on this occasion it had a certain glamour attached, due to its being served in enormous teapots of gold and silver. Dishes laden with sweetmeats and dried fruits were also brought in, and soon hurriedly removed and handed over to our followers.

While Captain O'Connor was exchanging civilities with the Tra-shi Lama we had time to think of the sudden change from a few months before, when the Tibetans, amongst whom was a strong contingent from this very place Shi-ga-tse, were attacking us at Gyang-tse, to the present moment, when we, a few unarmed officers were sitting in amity with our quondam enemies. The Tra-shi Lama himself is an interesting personality, sixth holder of the office, his face is one that would not pass unnoticed anywhere, still less in Tibet. He has clear cut features, high cheekbones, and a pale complexion; his quiet dignified manner made a lasting impression on us. His age is only about 23, and he seemed generally beloved and revered. During the whole of our visit a slight and pleasant smile never left his face. After silk scarves had been presented to us and our Tibetan followers had been blessed, we left, with the feeling, due partly to the personality of the Lama himself, partly to the room with its dim light, that we had been assisting at some religious ceremony.

We had commenced our survey at Dong-tse one march from Gyang-tse and as we wished to keep up triangulation, Captain Wood and I left Shi-ga-tse on the 17th October to do two short marches, the rest of the party leaving a day later and doing the two marches in one. Owing to bad weather, which gave us some rain and covered the surrounding hills with snow, we were unable to reach our hill, so decided to halt a day at Kang-jen Gom-pa, a most delightful camp in a grove of trees. This was the same storm which entailed such hardships on our force returning to India in the neighbourhood of Pha-ri Dzong; fortunately for us we were here at the lowest point of our journey, the height of Shi-ga-tse being 12,570 feet, and escaped with only slight inconvenience. By visiting three hills, one of which was over 18,500 feet elevation, and from two of which we had fine views of Mount Everest, Captain Wood was enabled to carry on the triangulation under very adverse circumstances. To climb one of these hills is itself a hard piece of work, to observe at the top in a bitter wind is one of the most physically painful operations I have ever experienced, and to do this in combination with a day's march, leads to a very long and hard day's work. Captain Wood carried this on for days and months with hardly any intermission, a feat which could only have been accomplished by an officer of his energy and determination.

Until we reached Pin-dzo-ling on the 22nd October the river had been a few miles to the north of our route, but from thence we followed the river more closely. Two more marches and we were at Lha-tse Dzong, a fort on a small rocky hill, very similar to those at Shi-ga-tse and Gyang-tse, surrounded on one side by the river, and on the others by a fair sized monastery and small town. The valley here widens out into a plain, cultivated in parts, barren elsewhere. At Lha-tse Dzong, we halted a day, which enabled Captain Wood and me to ascend a hill a few miles east of the town overlooking a broad bare valley which leads to the very famous Sa-kya monastery. We regretted that want of time, and the consideration that it was not advisable to divide into two parties until we had thoroughly tested the friendly disposition of the Tibetans, had prevented us from paying a visit to this monastery.

From Lha-tse however, the Tibetans having shewn no desire but to assist us in every way, we decided to separate; while Captain Wood and Lieutenant Bailey followed the main route which here crosses and leaves the river, Captain Rawling and I stuck to a route reported to lead along the south bank, as I did not wish, if possible, to omit any portion of the river from our survey.

Accordingly, on the 26th we parted company, camping that night on opposite sides of the valley which now closed in, we kept to the river the following day, but on the 28th we had to leave it and for two marches followed up a side stream, the Chi Chu, running parallel to and only two or three miles distant from the Tsang-po, which we again rejoined on the 30th. On the 1st November, we could see that the river flowed between rocky hills with snow peaks on either side, compelling us to leave it. Making a wide detour to the south we marched up a side nullah, camping in bitter cold at nearly 16,000 feet, and crossing the Kura La, a very desolate pass, next day at an elevation of 17,900 feet, marching across the head of a plain, which forms the head waters of the Chi Chu, previously mentioned, we passed over an almost imperceptible watershed down a narrow stony valley to the village of Ka-jü. We had a magnificent view from a hill a few hundred feet above the pass of the main Himalayan range. Mount Everest stood up towering above the rest of the range in its neighbourhood, in one isolated peak a continuous drop of some 8,000 feet separating it from the rest of the range east and west of it. The village of Ka-jü (14,800 feet) lies



on the edge of the Su-tso-tang plain, which takes its name from an old ruined fort on a small eminence in its centre. It is here about five miles wide and we could see it trending away southwards and joining the Dingri maidan which lies north of Mount Everest. A day's halt here enabled me to cross this plain, from the hills on the western side of which I obtained an uninterrupted view of Mount Everest, no hills intervening. I was thus able to satisfactorily establish the fact, which I had suspected a year before at Kam-pa Dzong, that no peaks anywhere approaching the height of Everest exist to the north of it or anywhere in its neighbourhood; it stands alone in its magnificent solitude and is entirely disconnected from the mass to the west, of which peak XX (Gaurisankar) is the best known point, on the south-east of Everest but separated from it by a low gap lies Peak XIII (Makalu). We were here in the valley of the western branch of the Arun or Kosi river, but recrossing the watershed next day by the Sheru La 17,600 feet, we once more reached the banks of the Tsang-po on the 5th November. The scenery was now changing, trees we had said goodbye to some marches back, our last cultivation we passed that day, while the hills were becoming more open and the plains abounded in sand dunes. Brushwood was in places available for fuel, but we preferred argol or dried yak dung as it gave greater heat, and, if the fire was carefully looked after, less smoke. During the whole of this portion of the river journey, we had seen no four-footed game other than numerous hares and a few gazelle on the Su-tso-tang plain, but birds we saw and shot numbers of; Tibetan partridge, ram chikor, and Tibetan sand grouse giving us a welcome change in our otherwise monotonous fare of mutton.

On the 6th we crossed to the north bank of the river with the utmost difficulty, a crazy looking punt manned by lamas took us across in detachments, but owing to the masses of floating ice whirled down the river by the rapid current, the punt was repeatedly forced back, and only reached the opposite shore after floating down some 400 yards; the operation of hauling the boat up again to its original starting point against the ice being very hard work. On the 9th we arrived at Sa-ka Dzong a small village, and found that Captain Wood's party had reached there the day previous. We gave ourselves another day's halt here as there was a good deal of surveying to be done in the neighbourhood.

Captain Wood writes as follows regarding his journey:—

"Leaving Lha-tse on the 26th October we crossed the Tsang-po about half a mile below the town. A couple of boats had been collected by the Tibetans for ferrying across our kit and transport, but the process was very much shortened by the discovery of a ford about  $\frac{1}{4}$  mile up stream, by which the ponies were able to cross. After keeping to the north bank for about 10 miles, we turned up a side nullah, and camped at Sang-ge-lung village; following this nullah next day for a short distance, we crossed by an easy pass into a country, the drainage of which led into a succession of small lakes, whose surfaces were covered with geese and duck. On the largest of these the Ngap-ring Tso, a ta-sam or stage house is situated, which place we reached on the 27th, and hearing that no grain would be procurable until we reached Barkha on the Manasarowar lake, we bought all we could procure, but even this would only give our ponies a couple of pounds daily. The next day we passed Ralung the last place we saw cultivation. Every day now found us at a higher altitude as we were marching more or less along the watershed between the Tsang-po and its large tributary the Ra-ga Tsang-po. The valley of this latter stream is narrow, running almost due east and west, parallel to and about 30 miles to the north of the main river. Into this distance is crammed a tangled mass of hills whose crests average about 18,500 feet, with several peaks of about 22,000 feet covered with permanent snow. This part of our march was exceptionally unpleasant, as the wind on the hills never dropped by day below hurricane force, and camping at elevations up to 16,100 feet, the change in temperature from the comparatively warm valley of the Tsang-po, was most noticeable. The hills clothed with a coarse grass on their lower slopes, but quite bare above 17,000 feet, were as a rule easy to climb, and from the summits lovely views of the Himalayas were obtained. Makalu and Everest, both standing out as great isolated peaks, being particularly imposing. The ta-sams at which every four or five days we changed our yaks for fresh ones, were the only signs of habitations we encountered, and these as a rule consisted of tents with a mud hut or two. The marches were all long, and wearisome in their monotony, and owing to the narrowness of the valley, Ram Singh and I had to climb to the crests of the range every day, to carry on the survey, seldom getting into camp before sunset, and on one or two occasions not arriving before nine or ten at night. On the 5th November, we crossed the Ku La (16,700 feet), situated at the head waters of the Ra-ga Tsang-po, and by a steep descent dropped into the valley of a small stream draining into the Tsang-po. At that night's camp we received letters from Captain Ryder saying that he would arrive at Sa-Ka Dzong on the 9th. Passing under the snowy range of Cho-ur Dzong, whose peaks range up to 21,000 feet, we reached Sa-Ka Dzong on the 7th November."

During our halt at Sa-Ka Dzong, Captain Wood ascended a high peak to the north (19,300 feet), from which we had a fine view north, up the valley of the Charta Tsang-po, a tributary of the main river.

Sa-Ka Dzong (height 15,150 feet) has only a dozen or so houses, very dirty, the neighbourhood being like that of every Tibetan village, a dust and refuse heap. We left on the 11th November, again in two parties; this time Lieutenant Bailey accompanied me back to the river, while Captains Rawling and Wood followed the main route. That day



we forded the Char-ta Tsang-po, a fair sized affluent of the main river, and crossing some low hills, reached the Tsang-po on the 12th; which we crossed late on the same evening, it being necessary to do so then, as from my previous experience, I knew that the river would be nearly impassible in the morning from floating ice. We crossed in a small skin boat, our animals fording higher up. For several days we marched up stream in a broad valley covered with low sand dunes and stones, with a very small quantity of poor looking grass on which, however, kyang and gazelle seemed to thrive. The track followed by the Pandit Nain Singh, as he marched up from Nepal to Tra-dom in 1865, joined in on our left, but in these plains in Tibet, it is difficult to find any signs of a path, as every caravan meanders over the plain without keeping to any defined track.

We recrossed the river on the 16th, but now it was completely frozen over; a good track was made for the animals by throwing some earth down on the ice. That evening we reached Tra-dom, where we found the rest of the party had arrived on the 14th. The weather had taken a turn for the worse; low temperatures at night with cold winds in the day were the rule, but if the days were sunny, a little walking would soon make us warm; when the days were cloudy, however, there was nothing to counteract the cold, and a march was a most miserable performance.

Captain Wood writes:—"On leaving Sa-Ka Dzong our party kept down the valley till we reached the Char-ta Tsang-po, which we found no difficulty in crossing. The stream was at that time some 100 feet in width with a depth of two feet flowing in one channel, having just left a very deep narrow valley to emerge into a plain of about 3 miles in width. Striking up a small side nullah we followed it for 5 miles and camped at the foot of the La-lung La. On this pass we first saw signs of *ovis ammon*, and from the information we received, this appears to be the eastern limit of their habitat along the road we had traversed. The road for the next three days, if it can be called a road, was the worst we met with, and consisted of large broken rocks set in deep sand; and to make us even more uncomfortable, the weather changed to snow accompanied as usual by a howling gale of wind. Inhospitable as Tra-dom appeared to us when we first described it, we hurried on as fast as our ponies would take us, to get within the shelter of its single stone house, where we might warm our frozen limbs over a yak dung fire, and pity the remainder of our party who had still another two days to endure before they could hope to join us."

Tra-dom did not tempt us to halt, it is a desolate spot, with a small monastery on the hill above, inhabited by only 3 or 4 monks; but from the hills to the north, we had a fine view of a snowy range reaching an elevation of 23,200 feet. We accordingly left the next day, and marching across the plain all day, camped amongst the hills on the far side. This plain is full of small ponds lying among sand dunes, and there was an unpleasant tributary or two to cross, the water frozen at the edge for four or five yards, then a drop of 3 feet into icy cold water full of floating ice, ending with a scramble out on the other side on to ice again. We now followed the river valley for a week or so, always in the same large plains, until we could see the watershed range ahead of us from the valleys of which innumerable streams issue to form the Tsang-po, the largest coming from a snowy range to the south-west. After enjoying some days of bright sunshine, the weather again took a turn for the worse, and we crossed the Ma-yum La, (height 16,900 feet) on the 26th November with a foot or two of snow on the ground. We had now finished with the Tsang-po, having surveyed it from Shi-ga-tse to its source. Our next point of interest was to be the lake region ahead of us. The day after crossing the Ma-yum La we camped on the northern shore of the Gūn-chu Tso, a lake 11 miles long by 2 or 3 miles broad, with an area of 22 square miles, completely frozen over, and having no outlet at all. Several *ovis Hodgsonii* (*ammon*) had been shot before reaching the Ma-yum La, and we now came on large herds of Tibetan antelope, of which we each shot several, and could have shot many more if we had wished, as they were very tame. Crossing several low passes and generally undulating ground we came in sight of the Manasarowar lake (Tibetan Tso Mo-bang) on the 30th November. The lake is neither impressive nor beautiful, like say, the Yam-drok Tso passed on the way to Lha-sa. It was not frozen over, except for 100 yards or so round the edge. The water was fresh, and our Surveyor Ram Singh, on account of its sanctity, bottled some and carried it back with him to his home in Dehra Dūn. Skirting the lake, we rode across the low hills which close in on the western side, to look for the outlet, which Moorcroft had not been able to find, which Strachey had found, and which Mr. Savage Landor had claimed to have discovered did not exist. We struck the channel a mile below the outlet, a small stream only partly frozen over, this we followed up and found that it did not flow from the lake but from a hot spring, at which we found and shot some mallard. We then followed up the dry nullah to the lake, and proved that Strachey was, as was to be expected quite correct. No water was flowing at this time of year, but the local Tibetans all agreed that for 4 months in each year there was a flow during the rainy season and the melting of the snows, *i.e.*, about from June to September. As a rise of about 2 feet in the level of the lake would cause water to flow down the channel, this appears quite worthy of belief. The length of the channel between the two lakes is about 3 miles. That day, the 2nd December, we reached a Tibetan stage house, and next day had a long days ride to try and discover an outlet for the second lake, the Rakas Tal or Tibetan La-gang-Tso. This lake is very dissimilar to Manasarowar in shape, and was entirely frozen over. The latter is about the same width 12 miles north and south as it is east and west, with



an area of 110 square miles; the former is a long narrow lake running north and south, some 16 miles long by 3 or 4 miles wide, with an area of about 55 square miles.

It is the sacred character of the Manasarowar lake rather than its size which has made it well known; its height above sea-level is 14,900 feet. We found an old stream bed issuing from the Rakas Tal, but every Tibetan we asked told the same story, that no water ever flowed along it now, but in days gone by, one man saying before the Sikh War, water did flow out of the lake and down this channel. We followed it down for some 6 miles along the plain, and could find none of the ordinary signs of water flowing down it, until we reached some low hills; here, evidently from the lie of the sand, water flowed at some time of the year and away from the lake. The lakes being now entirely disconnected at all times of the year from the Sutlej, the sources of that river must lie in the hills on either side of the valley and west of the lake region.

The Kailas snow peak was very prominent on the hills to the north, 21,800 feet in height. The strata forming the mountain are horizontal, which gives it a peculiar appearance; from the side we saw it, the top was quite inaccessible. There are several monasteries on the path which pilgrims follow in circumambulating the mountain. A very fine snow mass culminating in a peak over 25,000 in height, Me-mo or Gur-la Mandhata, lies to the south of the Manasarowar lake. A low watershed south-west of the lake leads to Purang or Taklakot.

Keeping to the north side of the broad open valley in which the Sutlej flows we arrived at another stage, Men-ze or Missar on 5th December. Here we divided sending our heavy baggage down with Ram Singh, as I wanted him to continue the survey of the Sutlej valley, while we went into Gar-tok. We were pleasantly surprised to find the Jer-ko La, the pass on the Sutlej-Indus watershed low and easy (height 16,200), and without difficulty reached Gar-tok (height 15,100 feet) on the 9th. This is the summer residence, Gar-yarsa. The two Gar-pons, the joint governors of western Tibet were residing at Ger-gunsa, the winter residence, some 30 miles down the valley, but had come up to receive us.

We only halted one day at Gar-tok, in that time we had seen more than enough of it; we were unanimous in looking on it as one of the most dreary inhabited places we had struck in our journey; a long broad plain, absolutely bare, with a dozen wretched hovels in the middle, constitutes, at this time of year, what is in summer the chief trading centre of western Tibet; but in the summer, traders are said to collect in large numbers, living in tents. The wind howled round the hut we were in continuously, and the weather looking threatening, we were not anxious to stay a minute longer than was necessary for Captain Rawling to settle up trade questions with the Gar-pons. Having now accomplished the main object of our journey, it only remained for us to get back into India as soon as possible. Fortune had favoured us so far but we had some high passes to cross. The first of these was the Ayi La, height 18,700 feet; two marches took us to the top of the pass, encountering a blizzard the second day. That evening we saw the only herd of wild yak we had come across in our journey. Crossing the pass next day was no easy matter, the ascent was gradual, but there was 2 feet of snow on the ground and a bitterly cold wind was blowing. It was with the utmost difficulty that, under some shelter from a rock, I took boiling point observations, and with a sigh of relief hurried down the other side. One of our chief obstacles was surmounted. It began snowing on the pass that evening so we had only just crossed in the nick of time, at Dun-kar (14,100 feet) where we camped that night we met cultivation for the first time, and it was a pleasant feeling, we were gradually coming to the end of high altitudes.

From here Captain Rawling and Lieutenant Bailey next day marched to Totling (Tibetan Tü-ling) on the Sutlej, where they met Ram Singh's party. Captain Wood and I halted a day at Dun-kar and marched next day to Ti-bu, where the whole party was once more united. We were now in the most intricate country I have ever seen, it must resemble the loess formation of Western China. The bottom of every nullah was some hundreds of feet below the general level of the valley, with their edges so cut and worn into fantastic shapes that it was difficult to believe that one was not looking on the ruins of old castles. There are also innumerable caves in which the inhabitants live.

On the 16th December at Kyi-ni-puk, we met Thakur Jai Cnand who had been sent up as our trade agent at Gar-tok; he brought with him some very welcome newspapers. I must own we none of us envied him his job for the winter.

Each day's march now consisted of climbing up out of a deep nullah and down again into the next. We crossed the Shi-ring La 16,400 feet on the 21st in deep snow with great difficulty, the descent on the western side being very bad going. Next day we camped at Tyak on the Sutlej, which had been flowing to the left of our route only a few miles distant, but invisible to us owing to its being at the bottom of a deep gorge. On the 23rd we marched to Shipki, crossing the river on the ice at an elevation of 9,300 feet. On Christmas Eve we surmounted our last obstacle, the Shipki La on the frontier, a climb of 5,000 feet mostly in snow and a drop of 6,000 feet on the other side, camping at Khab in British territory. From here we had 18 marches into Simla, finding bungalows at every stage, on and after 28th December, finally arriving at Simla on the 11th January.

I am indebted to Captain Rawling for the unfailing readiness with which he fell in with my proposals regarding the survey work, and for the excellent transport arrangements he made *en route*. Lieutenant Bailey's knowledge of the language was of the greatest assistance in obtaining for us the correct spelling of names and other information.



Captain Wood, as I have already mentioned, carried out the triangulation in a wonderful way. No one who has not experienced it knows the determination necessary to stay on a hill top in the bitter cold, and the pain involved in touching the screws of a theodolite.

Sub-surveyor Ram Singh is a first rate trans-frontier surveyor, and added one more to the list of expeditions on which he has done excellent work.

Hospital Assistant Hira Singh, not only doctored our party and brought us through without the loss of a man, but created an excellent effect by the care and patience he displayed in attending to the many Tibetans who came in to be treated.

The area surveyed with the plane-table comes to about 40,000 square miles, comprising the valley of the Tsang-po from Shi-ga-tse to its source, and the Manasarowar lake region, the doubtful points connected with which have been the subject of much discussion were satisfactorily decided. We completed the survey of the Sutlej river from its source to where it enters British territory, as well as the source of the Gar-tok branch of the Indus.

The triangulation, which is still under computation, was invaluable in correcting the plane-table work, and determining heights.

*An account of the Scientific work of the Survey of India, and a comparison of its progress with that of Foreign Surveys by Lieutenant-Colonel S. G. Burrara, F. R. S., R.E.*

The scientific work of the Survey of India consists of—

Principal Triangulation  
Levelling Operations  
Astronomical Operations  
Pendulum Operations  
Tidal Operations  
Magnetic Survey  
Solar Photography.

I beg that I may show in a few brief notes the uses and aims of the scientific work of the survey, but before doing so I wish to premise that no distinction can properly be drawn between scientific and practical work. Many operations conducted on scientific principles have immediate practical uses: they may in fact be likened to the exploitation of visible outcrops of coal. Others are more experimental, and may be likened to borings for invisible coal, believed to exist at certain depths. Others again are speculative, and may be likened to deeper borings, made to ascertain the strata in the crust, with the hope, that something valuable, perhaps coal or iron or gold, may turn up. But whether such operations are practical or experimental or speculative, they all have the same twofold purpose, *viz.*, the acquisition of information, and the rendering of that information useful. Almost all the the scientific operations of the Survey of India will be found to fall into the first category, and to possess immediate practical uses.

Before I enter into the details of the different scientific operations of the Survey of India, I may perhaps be allowed to refer briefly to the general question of the connection between science and surveys in modern times.

The primary object of a national survey is the making of maps, and all operations are subordinated to that end. It is for topographical purposes that a national survey measures its allotted portion of the earth's surface. If, however, these measurements be subsequently combined with astronomical determinations, the size and shape of the earth can be deduced, and a knowledge of this size and shape is essential to astronomers, geographers, geologists and meteorologists, all of whom look to surveys for information.

The great accuracy of modern astronomical observations for stellar and lunar parallax, and the difficulty, which mathematicians still experience in predicting exactly the places of the moon and the planets, are constantly necessitating more refined determinations of the figure of the earth, and astronomy is continually bringing pressure to bear upon surveys to lend her their aid,—for her celestial measurements must always emanate from a terrestrial base.

Man's first conception of the earth's figure was a plane: Greek philosophers thought it a sphere: Sir Isaac Newton showed that it must be a spheroid. Colonel Clarke, of the Ordnance Survey, contended that it was a triaxial ellipsoid. Modern Geodesy, after encountering great difficulties in testing in the field the theories of Newton and Clarke, has pronounced it a geoid. Astronomy now wishes us to tell her the dimensions of this geoid, and its departures from a spheroid.\*

In the days of Everest the figure of the earth was deduced from linear measurements, and the Great Arc of India was the only series of triangulation in India originally designed for a figural determination: all our other triangulation was intended and executed for the purpose of controlling topography. In 1858, Colonel Clarke showed that the figure and dimensions of the earth could be better deduced from measured areas than from measured arcs, and the whole triangulation of India became at once available for the discussion, provided it were subjected to astronomical tests.

A small portion only, however, of the earth's surface has so far been surveyed; and our present idea of the dimensions of our planet has been derived from wide generalisations. The total area of land and sea amounts to nearly 200 millions of square miles: the areas that have been surveyed do not aggregate 6 millions of square miles.

\* The geoid is the figure enclosed by the surface of the sea: this surface is that of a spheroid disfigured by protuberances and hollows.



The determination of the figure, and of the dimensions and of the specific gravity of the geoid is now in the hands of an International Geodetic Association, at whose conferences Professor George Darwin, F. R. S., represents Great Britain: India's co-operation is the more valued by the association, because she alone of the civilized nations possesses an equatorial area, and because she includes within her dominions the highest points of the earth's surface.

The amount of money spent annually by Europe and America on astronomical observations, runs into many millions sterling: humanity is striving to discover new facts concerning the myriads of distant bodies moving in space. As her development progresses, she grows ever more desirous too of investigating the one celestial body, which she can touch, and on which she finds herself travelling amongst the stars.

The difficulties, however, of studying even our own earth are great, because we are tied to its surface: our meteorologists cannot ascend into the atmosphere, our geologists cannot penetrate into the interior. We have learnt that the globe of rock, which constitutes our inter-planetary home, is the source of two great forces, gravity and magnetism; and a knowledge of the actions of these forces has become of importance to almost every branch of science. Their actions we have discovered are strangely dissimilar, and vary both with time and place.

The civilized nations are now making gravimetric and magnetic surveys of the earth, and are measuring the intensities, the directions and the pulsations of the terrestrial forces. India has been asked to bear her share, and to carry these operations over her own fraction of land-surface.

#### THE PRINCIPAL TRIANGULATION OF INDIA.

##### *Its Accuracy.*

The principal triangulation of India has been repeatedly attacked on the grounds that it is too accurate and too scientific for practical purposes. In 1800, in 1824, in 1850 and in 1886, attacks were made, but the Government after enquiry ordered its continuance. The present seems a good opportunity to take stock, to see what the triangulation has done for us and what it has cost us, and to consider by the light of modern requirements its accuracy and its errors.

The operations of a survey may be conveniently divided into, (1) the controlling framework, (2) the artistic superstructure. In discussing errors and accuracy it is advisable to keep these two divisions distinct, for whilst the controlling framework has to be guarded against cumulative errors, the artistic superstructure is only liable to accidental or local errors. The framework is constructed as follows:—

Foundation . . . . .	Principal Triangulation.
Plinth . . . . .	Secondary Triangulation.
Walls . . . . .	Tertiary Triangulation and Traversing.

Points fixed by tertiary triangulation or traverse should be sufficiently numerous to save the topographer from cumulative errors. Tertiary triangulation and traverses themselves, are liable only to accumulate errors over the short distances between secondary stations. In secondary triangulation the accumulation of error is confined to the distance which separates stations of the principal triangulation. In all survey operations, therefore, *after* the principal triangulation the accumulation of error is arrested: but what arrests the accumulation of error in the principal triangulation itself? The answer is that observations of a principal triangulation must be sufficiently accurate in themselves to avoid *embarrassing accumulations of error*.

We have been accustomed to state the error of triangulation in so many inches or so many feet per mile, and this custom has led laymen to believe, that the errors of principal triangulation are dispersed throughout its length. But the statement that an error has been found of 1 foot in a mile, is merely made to enable the merit of the triangulation to be gauged: in a length of 500 miles an error generated of a foot a mile is not dispersed, but is accumulated at the terminal. It follows, therefore, that the *requisite* precision of a principal triangulation must vary with the *distance* to be triangulated.\*

The following table shows the relative degrees of accuracy in the triangulations of different countries: the precision and length of the triangulation of Great Britain have been taken as the units.

Country.	Precision of triangulation.†	Length of triangulation.	Ratio of precision to length.
Russia . . . . .	2'0	3'3	0'6
India . . . . .	2'2	3'0	0'7
Great Britain . . . . .	1'0	1'0	1'0
Austria . . . . .	2'0	1'4	1'4
Italy . . . . .	2'0	1'25	1'6
Spain . . . . .	2'2	1'2	1'8
France (modern) . . . . .	3'0	1'2	2'5
Prussia (modern) . . . . .	3'6	1'4	2'6

\* The weight of triangulation varies inversely with its distance. The error of mean square increases with  $\sqrt{\text{distance}}$ , but in practice the terminal accumulation over a great length appears to be generally more due to systematic than to accidental errors.

† General Ferrero's report to the International Conference at Stuttgart in 1893.