Photogravure

Survey of India Offices, Calcutta, 1924.

TOWA DZONG AND MONASTERY. (13,000 FEET), SOUTH TIBET.

RECORDS OF THE

SURVEY OF INDIA

Vol. XXI.

I. AIR-SURVEY IN THE IRRAWADDY DELTA 1923-24

BY MAJOR C. G. LEWIS R.E.

II. RECONNAISSANCE SURVEY IN BHUTAN AND SOUTH TIBET 1922

BY CAPTAIN H. R. C. MEADE I. A.

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ON THE

IRRAWADDY DELTA AIR SURVEY

by Major C. G. Lewis, R.E.

Survey of India

I. INTRODUCTION

1. *Proposals for the survey* of the Irrawaddy Delta forests from the air were first made just after the war by Mr. E. F. A. Hay, I.F.S., of the Forest Department in Burma. These proposals assumed concrete form in July 1923 with the conclusion of an agreement between Mr. R. C. Kemp (late Chief Inspector of Civil Air Craft to the Government of India) and the Government of Burma, by which the former contracted to carry out the air photography. The course of the negotiations between the departments concerned have been fully detailed by Mr. Blanford, Conservator of Forests, in his introduction to the Burma Forest Bulletin embodying the reports on the work. It is chiefly due to Lt.-Colonel C. P. Gunter, O.B.E., R.E., then Superintendent, Burma Circle and to Mr. H. W. A. Watson, I.F.S., Conservator, Working Plans Circle, that the final project was accepted by the Finance Committee of the Burma Government.

2. *The survey was undertaken* in the interests of the Burma Forest Department who have borne nearly the entire cost; its objects were :—

(a) To provide large scale topographical maps of the reserved forests of the Delta Forest Division.

(b) To prepare forest stock maps by the interpretation of the forest growth from the photographs.

3. *The air photography* and preparation of unrectified mosaics were carried out by Mr. R. C. Kemp, Aeronautical Engineer, in contract with the Government of Burma. (See Appendix).

The provision of ground control, the preparation of rectified mosaics, and the fair-mapping, were undertaken by No. 18 Party (Aero-Photo), Survey of India. (Major C. G. Lewis, R.E., in charge).

The stock maps are being compiled by the Burma Forest Department.

4. *The cost* of the air photography, amounting to 80 % of the total, was paid by the Forest Department.

The Surveyor General undertook to carry out the fixing of ground control and the fair-mapping at the expense of the Survey of India, as the survey would be available for the compilation of the Survey of India sheets on the one-inch and smaller scales. The cost of the construction of the mosaics has been debited to the Forest Department.

The cost-rates per square mile will be found in para. 56.

5. *The country under survey* consists of densely wooded alluvial plains, forming part of the coastal area of the Irrawaddy Delta. It is divided into six main areas by branches of the river, and each section is intersected by innumerable tidal creeks. The average height of the ground is not more than 2 feet above ordinary high tides, which flood parts of the area, while at high spring tides a very large proportion of the whole country is submerged. There is a considerable number of villages in the area, whose inhabitants are engaged for the most part in the fishing industry, and were it not for the reservation of the forests, the whole country would soon be cleared and given over to rice cultivation. Communications within the reserves are entirely by water; progress on land is most laborious, especially in the lower lying areas where the ground is covered by aerial roots which imprison the foot at every step. Except on the sea-face where there are sandy beaches, the banks of creeks which are covered at high water consist of soft mud, into which a man will sink sometimes waist deep. Banks which are above high water are usually firm.

A small detached portion of the area under survey, the Lebyauk Reserve, consists of low undulating hills from 40 to 150 feet high with only a small proportion of tidal country.

6. *Area surveyed.*—The original contract for air photography was for 1,000 square miles, of which 700 sq. miles were reserved forests. The non-reserved areas were included at the request of the Survey of India so as to leave no gaps.

On the completion of the photography of the greater part of this programme, the results were considered so satisfactory by the Forest and Survey departments, that a further considerable area comprising the Pyindayē Reserve was undertaken, although the latter had already been surveyed

on the 4-inch scale by the Land Records Department in 1918-19.

The total area photographed amounted to 1,440 sq. miles.

7. *No. 18 Party (Aero-Photo).*—This party, up till now engaged on the magnetic survey, was reconstituted on 1st October 1923 under its present designation for the purpose of co-operating with the Royal Air Force and other air agencies in carrying out air-photo surveys. Its first employment was the survey under report.

The personnel of the party for the field work consisted of Major C. G. Lewis, R.E., in charge; Mr. L. Williams, M.B.E., Class II Service; Mr. Muhammad Hasan, Upper Subordinate Service; one clerk, two computers and 32 *khalasis.*

8. *Boat Transport.*—The party arrived in Rangoon from Dehra Dūn on the 19th October and spent a fortnight at Monkey Point while arrangements for transport were being made. Considerable difficulty was experienced in obtaining a suitable launch, most of those available were either too big or too small. The "Moostary", a double decked paddle steamer, 115 feet long, was finally selected and hired for 3 months from a private owner at a cost of Rs. 2,500 a month, including the crew, but without fuel and engine room stores. Temporary canvas and batten cabins were fitted on the top deck. This boat provided living accommodation for the Officer in charge, Mr. Muhammad Hasan, with computers and *khalasis.* It was one of the few paddle steamers in Rangoon with independent paddles, the latter being a great advantage for negotiating the narrow winding creeks of the Delta. A small Government launch and houseboat were obtained on hire from the Forest Department for Mr. Williams and his men, but were not so convenient as the larger boat, as there was no living room for the *khalasís*; the latter had to go ashore for cooking and sleeping, and it was not always easy to find a camping ground.

In addition three motor boats were obtained from the Delta Division Forest Officer, who very kindly withdrew them from their normal work. Several sampans were purchased or hired for landing from the motor boats and for obtaining supplies and mail.

The party proceeded to the Delta early in November.

FIELD WORK

II. GROUND CONTROL

9. *Lack of information.*—During the summer of 1923, when the possible methods of fixing points in the area to be surveyed were under consideration, very little information as to the nature of the country was available. Officers with local knowledge had described the ground, but not having observed it from the point of view of survey requirements, were unable to clear up several essential points. During the rainy season a visit to the ground would have been of little use, even if there had been time to undertake it.

10. *Proposed Astronomical observations.*— Fixing points by wireless longitude and astronomical latitude was considered and some experiments were carried out in Mussoorie. The errors to which this method is liable, especially within such a comparatively small area, would have been very much greater than the poorest class of triangulation or traversing, and the idea was soon abandoned.

11. *Proposed use of existing triangulation.*—The Arakan Yoma range of hills lies to the west of the area, and it was thought that use could be made of the existing triangulation there (Burma Coast series) to fix points by intersection in what was said to be open cultivated country on the north and west fringes of the forest. With this object the 60-foot observation tower and 100-foot masts designed by Dr. de Graaff Hunter were brought over from Dehra Dūn.

12. *Triangulation impossible.*—It was found, however, on reaching the ground, that triangulation between the Yomas and the plains north or west of the main area was impossible owing to the height of the trees; the *kanazo* tree which forms the main stock in the Delta forests, attains a height approaching 150 feet, and the cultivated country contained belts of it which completely cut off any view of the hills to the west. The 100-foot masts were useless in such forests. An examination of the main river banks during the first few days of reconnaissance showed that, in many places and for considerable distances, trees overhang the water, touching its surface up to one chain from the bank. In such places no theodolite station could be prepared and it did not appear that triangulation up these rivers would be at all easy, if indeed possible.

In the meantime no better success had been met with in the detached Lebyauk Reserve. This reserve lies in a tangle of low rounded ridges all much the same height and covered with dense forest; triangulation was out of the question in the time available. The cultivated country north of the main area and surrounding the Lebyauk Reserve had been cadastrally surveyed about 40 years previously, but it was not known whether the traverses would prove sufficiently accurate to base fresh work on.

13. *Procedure adopted.*—At this stage, the prospects of successfully dealing with the task of fixing points seemed poor. It appeared probable that the only alternative would be that of traversing through dense forest, and this would not have been possible in one season with the small staff available. A visit to the coast, however, threw fresh light on the problem. It was found that the sea face consisted of broad sandy beaches where accurate traversing would be a simple matter, and that a portion of it for about 5 miles from the south-west corner of the area was visible from two of the southernmost stations of the coast triangulation series. Provided that triangulation could be carried up the main rivers, such river series could be connected by traverses along the sea face, and through the cultivated areas to the north of the reserves, and the area could thus be divided up into some 5 or 6 sections each enclosed by a circuit of fixed points.

This procedure was actually carried out and proved to be accurate and rapid.

The chart at the end of this report shows how the area was divided up by the main rivers. The largest circuit, enclosing about 350 sq. miles, was subdivided by means of a subtense traverse along one of the larger creeks. Further subdivision by this method would have been possible, but slow, and was not considered necessary.

14. To facilitate the river work, a triangular platform was designed with adjustable legs raising it up to 8 feet, also a tripod for the theodolite whose height was adjustable between 8 and 14 feet above the ground; the latter to stand inside the platform and independent from it. It was thought that this could be erected in water up to 6 or 7 feet deep and would overcome the difficulty of over-hanging trees. In practice, however, the platform was found diffi-

cult to manipulate from a boat, and a judicious selection of stations rendered its use unnecessary.

15. Some trouble was experienced in the initial triangles from the base Haingyi—Chauk-a-lat. The 16 mile ray from the latter station across the sea was interfered with by curvature, Chauk-a-lat being only 60 feet above M. S. L. To overcome this, station S F 3 had to be prepared about 20 feet above ground in a dead tree. The observing platform was built up from the ground and did not touch the tree at any point. Observing was done at low tide and at a time of high refraction, when the distant station was just visible above the horizon.

16. *Signals.*—Helios were used only for the two big triangles, thereafter the signals used were of a uniform pattern and consisted of white cloth (*mulmul*) stretched on a square frame and nailed diamond-wise on a pole. The size of the diamond varied from 1 ft. square to 3 ft. square according to the length of the ray and for the longer sides two diamonds were used, one below the other and facing at right angles so that one or other should always reflect the light. These signals could easily be seen up to 10 miles across water, provided the sun was in the right position. To ensure this it was usually arranged to observe from the east banks of rivers in the morning and from the west banks in the evening.

17. *Marks.*—The majority of the stations were either in shifting mud or on the edge of firm banks liable to be washed away, where no marks would have lasted longer than a season. The signal pole was used to mark the station and a wooden peg was driven alongside it in case the pole should be blown down. About 10 permanent mark stones, consisting of concrete posts were distributed through the area in the vicinity of villages, and were placed in the charge of the head-men. No attempt was made to preserve any of the other stations.

18. *Reconnaissance and observation.*—The Ywe and Kakayan rivers and the northern traverses were allotted to Mr. Williams and the remaining rivers and the sea-face traverses were undertaken by Major Lewis and Mr. Muhammad Hasan; the latter usually carried out the reconnaissance ahead, selecting sites for stations and clearing rays.

The theodolites used were 6-inch and 5-inch micrometers. These instruments were brought as it was thought

that astronomical latitudes might be required; they were unnecessarily accurate for the work actually carried out. Many of the stations were several feet below high water line in liquid mud into which the observer sank knee or even waist deep. At these stations wooden pegs up to 5 feet long were pushed into the mud for supporting the legs of the instrument, and cut branches or "duck-boards" supplied a footing for the observer. A closed round of angles could not be observed as any movement of the feet affected the position and level of the theodolite. It was thus necessary to read each angle separately, making the two readings required without shifting the feet. All three angles of every triangle (with a few exceptions) were measured, as in many cases the forward work depended on single triangles. The average triangular error was 14 seconds, which is satisfactory in view of the impossibility of accurate centring of either signal or instrument. The average difference in common sides was 0·7 feet per mile. The number of stations and intersected points fixed was 285 and 61 respectively. The length of sides varied between $\frac{1}{2}$ mile and 4 miles, the average being about 2 miles.

Azimuths were observed at intervals. The average error accumulated through the triangulation and traverses was about 45 seconds.

19. *Traversing.*—The lengths of legs along the sea-face varied between $\frac{1}{4}$ and 1 mile and were measured with a 500-foot or 100-foot steel tape and checked with a 66-foot chain; the longer tape was used for the legs or bases on which triangulation depended. For the traverse along the Chaunggyi Yegyaw a 10-foot subtense bar, extended to 18 feet, was used, and distances up to 90 chains were measured.

20. *The work was computed* on rectangular co-ordinates, the origin being that of the adjacent cadastral survey, viz. Lat. 16° 45′, Long. 94° 42′ 32·82″. Computations were kept abreast of observation so that the field charts could be kept correctly plotted; in this way the circuits could not be closed and adjusted before computing the co-ordinates, so the closing differences were distributed afterwards by Col. E.A. Tandy's method, taking the various circuits together as a whole.

21. *The average closing difference* in the 4 main circuits was 0·53 chain on the meridian and 0·56 chain on the perpendicular, the average length of a circuit being about

70 miles. This compares favourably with adjoining cadastral work, in which the closing differences in main circuits were frequently 2 to 3 chains.

22. *Junction with Cadastral Survey.*—The stations of the old cadastral survey were very difficult to find and to identify when found. Connections were made to 8 of these stations and differences varied between $+2{\cdot}3$ and $+6{\cdot}4$ chains on the meridian and $-1{\cdot}0$ and $+2{\cdot}7$ chains on the perpendicular. No attempt was made to adjust these differences, the new work being accepted after internal adjustment described in para 20.

23. *Points based on Cadastral Survey.*—In the Lebyauk Reserve, where triangulation was not feasible, 8 points were fixed, in pairs about one mile apart, in the four corners of the reserve, by means of traverses run from cadastral stations in the vicinity. Corrections were applied to the values of the latter to reduce them as nearly as possible to the terms of the new triangulation. The points fixed were forest reserve boundary pillars. In the same way several points were fixed on the east and west sides of the Kalayaik Block as the surrounding creeks were rather narrow for triangulation.

24. *Identification of points on the photos.*—Except in the Lebyauk Reserve, no attempt was made to mark fixed points artificially for identification on the photos, as this would have involved considerable delay and extensive clearing operations in heavy jungle. The vicinity of natural features such as corners of creek junctions, indentations in the banks, and large overhanging trees, facilitated the identification of the majority of the points. Had the photos been available on the ground, the recognition of points would have been considerably easier than was actually the case. It is very difficult to identify a point on a photograph from rough sketches, even with descriptions and measurement, especially as distinctive detail was exceptional. The identification some months later in recess quarters was thus very much a personal matter. Approximately two-thirds of the total number of points fixed were identified definitely, and of the remainder about half were redundant, being close to other points, and half were unplaced. The mere fact, however, that these unplaced points were along a river bank was of considerable value in locating the line of that bank. The eight fixed boundary pillars in Lebyauk were marked artifi-

cially; a circle of ground 24 feet in diameter, with the pillar as centre, was cleared of undergrowth and sprinkled with lime a week or two before photography. These marks showed clearly on the photos as a white dot with a darkish centre.

25. *The field work was completed* early in February and the party returned to Rangoon. Office room was obtained in one of the military buildings at Monkey Point and most of the party were accommodated in tents there.

26. During the field work all possible assistance was furnished by the Divisional Forest Officer, Mr. A. W. Moodie, O.B.E., who not only placed many of his staff at the disposal of the survey party, but himself accompanied the Officer in charge for several weeks during the preliminary reconnaissance, and made all arrangements for the collection of fuel for the launches and for the forwarding of mails and supplies.

III. AIR PHOTOGRAPHY

27. *Photography.*—Owing to delays in the settlement of the contract for this work, which was not finally decided upon until the end of July 1923, Mr. Kemp was not able to commence photography till February 1924. It was completed early in April. The best months of the year as regards calm weather and visibility are probably January and February. This late start enhanced the difficulty of steady flying owing to unfavourable atmospheric conditions, and the excellent average results obtained, in spite of adverse conditions, are very satisfactory.

The area was covered by means of vertical photographs. Oblique photos were tried but were of no value for mapping purposes, as the narrow creeks overhung by high forest only show up when viewed from overhead. For the same reason obliques could not be used for fixing extra points in the interior of circuits, as all points, except those in the immediate foreground, were hidden.

The total number of plates exposed was 3,795.

28. *The cameras* used were of the L. B. type; and these were probably the most suitable that were available. A larger plate in conjunction with a lens of longer focal length would have been an improvement, as this would have given a bigger scale without increasing the total number of photos. Such a camera was not obtainable at the time.

Its use would have increased the cost of photographic materials considerably.

29. *Scale of Photography.*—The "ceiling" of the seaplanes employed was 12,000 to 13,000 feet when fully loaded, but the climb above 10,000 feet was slow. Consequently it was necessary to use a 6-inch focal length lens to obtain the most economical scale for mapping. The average height maintained throughout was about 9,400 feet, resulting in a scale of about 3·4 inches to 1 mile. This scale was about the smallest compatible with the proper interpretation of detail.

30. "*Stripping.*"—The area was divided into sections bounded by main creeks and the "Stripping" over these sections was carried out systematically. Such gaps as were left were for the most part due to camera failures and not to faulty flying. Practically all gaps were covered at the first attempt. Coastal strips were taken covering the series of control points along the banks of main rivers and tying together the ends of cross strips. In the larger sections a central longitudinal strip at right angles to the cross strips was also taken. When the final mosaic was completed, it was found that there were two gaps in the whole area, one of 3 square miles in Lebyauk, and one of $\frac{1}{4}$ sq. mile in Pyindaye. These were both on the boundary of the forest and were due to the difficulty of locating the latter from the air.

31. *Tilt.*—The weather conditions resulted in a certain amount of tilt; excessive tilts were, however, exceptional, and were in many cases corrected by taking another photo immediately afterwards. Owing to the small number of fixed points, it is not possible to make an exact determination, but an examination was made of overlaps and of the errors in azimuth accumulated in strips. This investigation yielded the following approximate estimate of the percentage of different degrees of tilt:—

Under	1°		...	55 %
between	1° &	2°	...	35 %
,,	2° &	3°	...	7 %
,,	3° &	4°	...	$2\frac{2}{3}$ %
,,	4° &	5°	...	$\frac{1}{3}$ %
over 5°			...	one photo.

32. *Maintenance of scale.*—While variations in altitude occurred from day to day, the departure of individual photos from the mean scale of any one strip was very small.

The *maximum* difference of height (in one strip) from the mean, as disclosed by an examination of about 2,000 photos, was 200 feet. Differences exceeding about 50 feet were exceptional and occurred only in bumpy weather.

33. *The quality of the photographs* varied considerably. About one-half of the photos, taken under good conditions, could not have been improved upon; but during the latter part of the work, when the weather was hazy, some very poor photos resulted.

As regards topographical detail, however, this was of little consequence, as the detail consists almost solely of creeks, which showed up nearly as well as under better conditions of visibility. It was found that photos taken near midday gave the best results, as otherwise the minor creeks were obscured by shadows, this also suited the needs of stock mapping. Although it was at first thought that long shadows were desirable to facilitate the interpretation of forest growth, it was afterwards found that such shadows obscured more than they revealed.

OFFICE WORK

IV. PREPARATION OF THE MOSAICS

34. *The party remained in Rangoon* till the end of March whilst the air photography was being carried out. During this time the adjustment of the triangulation was completed, the mounting boards for the mosaics (mosaic-boards) were projected and plotted, and such photos as were received from Mr. Kemp were dealt with as described in para. 41. The Officer in charge was given a flight over the Delta in order to locate from the air certain fixed points whose identification on the photographs was in doubt. The office was moved on the 4th April to Maymyo.

35. *Dark room.*—An out-building (record room) of the Maymyo office was converted for photographic work and was divided into 3 rooms each about 7′ × 14′:—(a) enlarging and printing room, (b) plate-changing and developing room, (c) washing room; the last not being a dark room.

Each room was provided with an unlined wooden sink with water laid on.

36. *The enlarging lantern* was of the ordinary pattern for simple enlargement without rectification and had a lens

of 9-inch focal length. The plane of the copy-board was fixed at right angles to the optical axis of the lens, the board being movable along this axis for scaling. The final adjustment was made with a slow-motion screw. The enlarger was operated by daylight, and to obtain uniform lighting a moveable screen made of white cloth on a light frame 6 feet square, was erected outside, opposite the negative carrier. The screen was pivotted at its centre and had universal movement so as to reflect the maximum amount of light into the lantern. During the rainy season rapid variations in the light made the estimation of exposure difficult, and alternative lighting by acetylene was provided, (dissolved acetylene gas in cylinders), electricity not being available in Maymyo during the daytime.

The dark room work was carried out by two Indian photographic assistants without special qualifications, who were temporarily engaged.

37. *The copying camera* was set up in one of the drawing rooms. The plan board was fixed against an end wall, and the camera secured to a stand sliding on rails. Care was taken to ensure the optical axis being at right angles to the plan board. Lighting was from two side windows, front light being cut off by means of black curtains across the whole width of the room (see para. 49). The camera had a Dallmeyer lens, diameter $1\frac{5}{8}''$, of 12-inch focal length, and took up to $10'' \times 12''$ plates. Process plates $4\frac{3}{4}'' \times 6\frac{1}{2}''$ were used for copying.

38. *The scale* originally selected for the published maps was 4 inches to 1 mile, this being one of the normal scales for forest maps. It was soon recognised, however, that this scale was unduly large for the amount of topographical detail in the area under survey, and the reduction of the scale to 3-inch was approved. Both mosaics and fair sheets were prepared on the 3-inch scale

39. Two contact prints of each photo were supplied by Mr. Kemp. One set was pasted by strips on to narrow ribands of stiff brown paper, leaving the overlapping portions free; these *reference-strips* were put aside for reference in different stages of the work. The second set was used in the preparation of the mosaic as described in para 41.

40. *Preparation of Rectified Mosaics by strips.*—The method employed in the preparation of the mosaics was similar to that already used in India and Mesopotamia. This

consists of reducing strips of original contact prints on to a negative that can be used in the enlarging lantern; these strips are then enlarged to the correct scale in the lantern and fitted together to form a mosaic. The length of the strips must be such that the ratio of enlargement is not so great as to cause loss of definition or to exceed the covering power of the lens. This ratio was fixed at about 5 times linear dimensions. This method is only suitable when the scale of compilation is equal to, or less than, that of the original photos; when it is larger the scaled prints will usually be obtained by direct enlargement from the original negatives.

41. *Reducing the strips.*—The second set of contact prints referred to in para. 39 were pinned in strips on to stout straw boards 24″ × 30″, termed *strip-boards.* In order to comply with the condition stated in the preceding para. these strips could not exceed 24″ in length, so were pinned parallel to the short side of the board. The original strips as photographed in the air, corresponding to the reference-strips, were in most cases considerably longer than 24″ and had to be subdivided into sections. The latter were selected as far as possible with reference to fixed points, though this was not essential as explained in para. 43. Each strip or section of a strip was independent of the next one on the strip-board, and was treated separately in the subsequent operation of enlarging to scale. The contact prints were carefully fitted by overlaps and where lateral tilt was apparent, causing error in azimuth, this was partially corrected by adjustment of the overlap. Ordinary pins were used for securing the prints. The detail on the prints was then inked up with Chinese white, as this showed up well against the flat dark tone of the forest; in cultivated areas, where the contrast was good, detail was not inked up at this stage.

On completion of several strip-boards, they were reduced on to half-plate negatives (termed *strip-negatives*), these being the largest plates the enlarger could take. The scale of the photos on these negatives was about 0·6 inch to 1 mile. Strip-boards were numbered serially in large figures, easily legible on the corresponding strip-negative. After development of the negative, the contact prints were unpinned from the strip-boards and filed.

42. *Mosaic-boards.*—The boards used for mounting the rectified mosaic (mosaic-boards) were photographic mounting boards obtained from the photographic trade in

Rangoon. They had the advantage of being large, 28″ × 44″, and having a surface of soft friable paper such that a print could easily be removed and repasted, a necessity which frequently arose during the preparation of the mosaics. They proved to be very uniform in response to atmospheric conditions of humidity. Durability and stiffness was provided by a double backing of linen and brown paper. 18 boards were required for the whole area. Adjoining boards were overlapped and not butt-joined. The rectangular grid and the points were plotted on the boards, with a margin of 1 to 1½ inches; the margins were overlapped and secured on the mounting table and the scaled photo strips pasted temporarily across the join. On completion of a common edge the prints were cut through along the grid line and pasted down on their respective boards.

The use of zinc sheets was considered, but though they had obvious advantages such as thinness and freedom from distortion, it was thought that these would be more than counterbalanced by the difficulty of removing photos once fixed.

43. *Scaling the strips.*—The series of fixed points formed closed perimeters round each section of the area; these followed well defined lines, viz. the banks of main creeks; and the taking of strips of photos following these lines and thus including all the perimeter points in a continuous strip, had been a simple matter for the flying man. This was of very great value in the preparation of the mosaic, as it was possible to lay down an accurately placed frame strip round each section. The strip-boards had been arranged with reference to the fixed points and the scaling of each portion of strip was carried out in the enlarger by means of lengths of paper marked with the distance between points as obtained from the plotted mosaic-boards. In cases where adjacent points were too far apart to be included in one strip on the strip-board, any two points of detail were selected for scaling, and their correct distance apart was obtained by calculation, after finding the ratio of reduction by measurements between corresponding fixed points on the reference-strip and on the mosaic-board. Errors in azimuth caused by tilt were corrected by cutting the scaled strips into sections and slewing each section through a small angle. Photos that were obviously tilted had been marked during pinning up and were made to bear a greater share of the azimuthal error. Sudden dis-

placements of detail caused by cutting and slewing were limited to 1 chain (about 0·04″) and the cuts were made so as to avoid detail as far as possible.

The perimeter strip having been laid down, the central longitudinal strip and certain selected cross strips were scaled using any convenient points of detail already in position in the perimeter strip and not necessarily fixed points. These were then fitted into position thus breaking up the enclosed area into a series of rectangles. The latter were last filled in; this was largely a matter of trial in order to disperse errors in lateral overlaps and keep them within the limits laid down in the preceding para. The prints were pasted temporarily in position in one or two places and on completion of a mosaic-board, the overlapping portions were cut away and the whole pasted down with butt-joints.

44. *As a means of testing the accuracy* of the mosaic, the line of control points along the Chaunggyi Yegyaw and on the Thaungdu River as far as the point where the latter turns south, was masked, and not made use of for scaling. A cross strip covering the majority of these points was then laid down and adjusted on the perimeter photos. The fixed points marked on the photos of this strip were then pricked through, and on lifting the strip and masking paper, it was found that the maximum error in position of any of the points was $1\frac{1}{2}$ chains (0·06″) at about the centre of the strip, which was 12 miles in length. This strip happened to be particularly free from tilt and changes of altitude; it is probable that elsewhere greater errors occur, but it is thought that the maximum error in position anywhere, with reference to the grid, should not exceed 5 chains.

45. *Interpretation of detail.*—On completion of pasting down, each board was carefully inked up in white, as the reproduction of the original inking did not always show up sufficiently well. The spherical graticule lines which were to appear on the map were ruled up, and the board was then examined for correctness of detail by two officers independently, against the reference-strips. The latter were kept in bundles corresponding with the boards of the mosaic. The interpretation of the photos presented some difficulty in the case of minor water courses. Creeks less than about 5 yards wide were usually obscured by trees and could only be followed for parts of their courses; wider creeks were often hidden but were usually given away by

the fact that a different class of tree generally grows on their banks. Most creeks meander, and even though partially concealed could be relied on to follow a regular curve. Any waterway over a chain in width was clear and conspicuous. Towards the edges of photos, small creeks running radially to the photo plumb-point were often visible while others were hidden by the displacement of the tree canopy.

46. *Pyindayē mosaic.*—The decision to photograph the Pyindayē Reserve was made after the party had left the field; it was therefore decided to base the mosaic on the existing 4-inch maps which had been surveyed by theodolite traverse. Some difficulty was experienced in adjusting the photos as the 4-inch survey had been carried out rapidly and was not of a high order of accuracy.

47. *The following registers and indexes* were kept up:—

(a) Register of original prints received from the air contractor.

(b) Particulars of each flight—A form giving the details of height, time, weather conditions, area covered, and blank negatives (if any) accompanied each batch of prints received from the air contractor.

(c) Register of strip-negatives, showing the serial number of the negative and the numbers of the individual photos contained in it.

(d) Index to strips. An index on the $\frac{1}{2}$-inch scale on which the outline of each strip is shown to scale, by a long rectangle, adjoining strips being in different colours. The numbers of the first and last photos of each strip are entered in the appropriate colour.

(e) Index showing the mosaic-boards and the fair sheets.

48. *Personnel and time taken in various operations.*— The preparation of the mosaic was commenced at the end of April and completed at the end of August. The following table shows the personnel employed and the time taken in the various operations.

	Description of work.	By whom carried out.	Total number of 6-hour men-days.
1	Pasting reference strips	Three Indian draftsmen	44*
2	Pinning and inking up strip-boards.	do. do.	120*
3	Scaling strips and fitting to mosaic.	Major Lewis and Mr. Muhammad Hasan	56†
4	Cutting and pasting down mosaic.	Mr. Muhammad Hasan	18
5	Inking up detail on mosaic.	One draftsman	20
6	Examination of detail against original contact prints.	Major Lewis and Mr. Muhammad Hasan	20

* These times are long owing to the men employed being untrained.
† Does not include dark room assistants.

49. *Photographic materials.*—The following table shows the amounts of the various photographic stores and chemicals used in the preparation of the rectified mosaics of an area of 100 square miles. It refers to all work done *subsequent* to the receipt of contact prints from Mr. Kemp.

Scale of original negatives :—3·4 inches to 1 mile.
Scale of mosaic :— ... 3 inches to 1 mile.
Number of air photos per 100 sq. miles :— 260

Photographic materials per 100 sq. miles of rectified mosaic.

Particulars.	Amount.
Process plates ($\frac{1}{2}$ plate size) for strip-negatives	7
Wellington Ward's "Enammo" bromide paper (in rolls 10 feet by 25 inches)	40 sq. feet.
Metol	$\frac{1}{4}$ oz.
Hydroquinone	$\frac{1}{2}$,,
Potassium bromide	$\frac{1}{4}$,,
Sodium carbonate (anhydrous) ...	4 ,,
Sodium sulphite. (...do...) ...	4 ,,
Potassium metabisulphite ...	1 ,,
Hypo	$1\frac{1}{2}$ lbs.

50. *Glossy vs. matt paper.*—Of the two copies of the first batch of contact prints received, one was printed on matt paper in order to avoid the difficulty of reflected light when copying. But even with the most suitable make of matt paper, a certain amount of detail is lost, whereas by

suitable lighting, glossy paper can be used without fear of loss of detail by reflected light. All front light is cut out and only side, top and bottom light used for copying (see para. 37).

For the mosaic, glossy paper is the most suitable. It does not take ink quite so well as matt, but has the great advantage that Indian ink, and ink prepared from water colour sticks, comes away at once with water and corrections are thus simplified. After the first batch of photos had been received, glossy paper was specified for both sets of prints.

V. FAIR-MAPPING

51. For purposes of fair-mapping, the area surveyed, except Lebyauk Reserve, was divided into 28 sheets covering 5 minutes of latitude and 10 minutes of longitude. Traces were made from the mosaic-boards by $2\frac{1}{2}$ minute squares, which were pasted on to a projection of each sheet. The latter were then sent to Calcutta for the preparation of blue prints on drawing paper on which the fair sheets were drawn. The scale of mapping was the same as that of the mosaics, viz., 3 inches to 1 mile, for reproduction. It should be possible to eliminate this intermediate tracing process. Bleaching out cannot be done satisfactorily after the mosaic has been prepared and if carried out before, the difficulties of fitting the scaled prints together correctly are greatly enhanced; moreover in the present case, all the detail on the photos was required for the compilation of the stock maps. Another method, suggested by Mr. Kemp, is that of staining the scaled strips to a blue colour so that only the inked up detail (in black) would be reproduced in photography; this appears to offer a good solution. It has the slight disadvantage that the mosaic boards would have to correspond with the fair sheets and would thus be rather small. Another disadvantage is that they could not be sent to Calcutta by post—a serious drawback in Burma.

On receipt of the drawing blue-prints, the fair-drawing was proceeded with in the normal manner. The first sheet was begun at the end of July and it is expected that the last will be completed and submitted for publication by the end of December 1924.

52. *Verification of detail.*—Owing to the photograpy having been done so late in the season, it was not possible

to examine any of the photos on the ground, for verifying detail. This was not a serious matter as regards detail within reserve boundaries which consisted solely of creeks and areas of grass or scrub. Outside the reserves, the only items of topographical detail which should have been verified on the ground were:—(a) pagodas and *kyaungs;* (b) isolated buildings away from villages, often hidden by trees; (c) distinction between sand and mud areas on the foreshore; (d) high water line in areas of gently sloping beach where accretions are being formed. This verification will be carried out later when the area is taken up for 1-inch topographical survey.

53. *Mr. A. W. Moodie's survey.*—During 1922 and 1923, while the air survey was still being discussed, Mr. A. W. Moodie, O.B.E., I.F.S., then in charge of the Delta Forest Division, carried out a survey of the whole area, for the preparation of the working plan on which he was engaged. He covered each reserve with a grid formed by clearing lines through the forest, one mile apart in both directions; these lines were laid out by prismatic compass and involved an immense amount of labour. Chain traverses were run along all these lines and 4-inch maps were compiled from the data thus obtained. Considering that the forest staff were quite untrained in survey work, the resulting maps are wonderfully good, and reflect great credit on Mr. Moodie's enterprise in undertaking so arduous a task. These maps were of great use in the compilation of the air survey sheets, as they not only supplied information as to all the creek and place names within the reserves but also helped in establishing the existence of minor cross connections between main creeks, in cases where these were in doubt on the photos.

54. The fair-mapping of the *Lebyauk Reserve* was not put in hand, as it will be necessary to supplement the mosaic by a considerable amount of ground work before a map can be produced. Owing to the gentle nature of the slopes and to the overshadowing of streams by trees, it was impossible to follow even the general trend of valleys and hills, and the stereoscope was of no assistance. The tidal creeks and a few of the broader fresh water streams showed up well; and by using this detail as a basis without fixing any further points, the remainder of the detail and the contouring will be surveyed by plane-table traverse during topogra-

phical survey.

55. *Stock mapping.*—The mosaic-boards and reference-strips have been handed over to the Forest Department for the preparation of the stock maps. The rectified mosaics, being on the same scale as the maps, are proving of great assistance, as the limits of different classes of forest can be easily marked on them and subsequently transferred to the map.

VI. CONCLUSION

56. *The cost of the survey* was as follows:—

	Cost-rate per sq. mile.	
	Rs.	£.
(i) Photography—Mr. Kemp's contracts for 1,060 sq. miles —Rs. 2,75,000 and 380 sq. miles—Rs. 28,000.	210·4	14·03
(ii) Ground control—Rs. 39,327 for 1,060 sq. miles.	37·1	2·47
(iii) Preparation of mosaic.—Rs. 22,885 for 1,440 sq. miles.	15·9	1·06
(iv) Fair-mapping—Rs. 12,992 for 1,352 sq. miles. (Excludes Lebyauk Reserve).	10·3	0·69
Total	Rs. 273·7	£ 18·25

The cost of the photography is high, as this single project has had to bear the whole of the initial cost of Mr. Kemp's organisation.

57. *Results.*—It would be difficult to find a tract of country more suitable for survey by air photography, or more difficult to survey on the ground. Its advantages from the point of view of the former method are:— (a) it is flat;

(b) it is broken up into convenient sections by broad rivers; (c) each section contains conspicuous features in the form of creeks which assist the flying man in "stripping"; (d) a seaplane can alight anywhere in case of necessity; (e) there is practically no topographical detail of which the identification requires checking on the ground.

The difficulties of ground survey are obvious; hundreds of miles of theodolite traversing along the larger creeks would be required; where subtense methods are impossible, chaining through dense jungle must be resorted to. Plane-table traverse, done entirely from boats, would be used for the smaller creeks.

It was estimated that a ground survey by a party of normal strength (30 surveyors) would have taken 3 to 4 years and would have cost probably Rs. 500 per square mile. It would compare most unfavourably with air survey as regards accuracy of local detail and would scarcely be superior in accuracy of position.

The disadvantages of the air survey are:—(a) minor creeks up to 5 yards wide are frequently obscured by overhanging trees and cannot be traced throughout their full length; (b) it was seldom possible to photograph the coast line at low tide; consequently the low tide line and many sand banks covered at high water, were not surveyed; this was not of great importance as the sand banks are constantly shifting. The only modern survey of similar scale and extent carried out by the Survey of India in delta forests was that done by No. 6 Party in the *Sundarbans* of Bengal in 1905 to 1908; this survey took several seasons to traverse and detail survey; there were many casualties from wild animals and sickness, and a very large number of minor streams were never surveyed at all.

58. *The formation of accretions* is constantly taking place along the sea-face of the Delta: the successive coast lines are well shown up in the photos throughout the grass lands bordering the shore. There are sandy hooks in various stages of formation, while elsewhere, generally midway between the mouths of rivers, erosion is taking place, as is evidenced by the forests of dead trees standing out in the sea at high tide. Photography of the coast line at some future time will provide interesting data for the study of the formation ot accretions.

APPENDIX

SCHEDULE*

Mr. Kemp's Contract

Conditions to be fulfilled as regards the air photography for the Survey of India.

This contract is for the production of vertical and oblique photographs taken from aircraft suitable and necessary for the compilation of a 4 inches = 1 mile scale map of the area of the Irrawaddy Delta laid down in paragraph 3 under conditions described in the following paragraphs:—

1. The Survey of India will be responsible for the fixing of the trigonometrical points necessary to control the mosaic, the compilation of the mosaics, and the resultant maps on the scale of 4 inches = 1 mile.

2. The photography to be completed between the middle of December 1923 and the middle of March 1924.

3. The area to be covered, about 1,000 square miles, includes the forest reserves of Kyagan-Kwinbauk, Pyinalan, Kakayan and unreserved areas between the aforesaid forest reserves and the forest reserves of Labutkwe, Kalayeik, Kalayeik Extension, Nyinaung, Kadonkani, Myinmahla and Lebyauk of the Delta Forest Division. If considered advisable by the government the photography may be extended to cover the Pyindayē Forest Reserve, an area of about 300 square miles to be paid for at a rate not exceeding Rs. 120 per square mile of resultant mosaic, provided that by reasonable notice being given to the contractor the work on the extension can be undertaken in continuation of the former.

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* Note.—This schedule is an extract from Mr. Kemp's original contract with the Government of Burma. When this was drawn up it was realised that it would not be possible to verify completely the fulfilment of conditions Nos. 8 and 9 or to enforce them strictly. They were laid down as desiderata to be aimed at.

4. Both vertical and oblique photographs are to be submitted as required by the officer representing the Survey of India and the officer representing the Forest Department to enable the former to compile a forest map on the 4-inch = 1 mile scale and the latter to compile a stock map.

5. All land areas are to be covered by vertical photos including water channels of such width that both banks can be included on one photo. Small gaps not likely to contain important detail may be covered by "obliques" at the discretion of the Survey representative. Both banks of all water channels photographed must appear on one photo, so as to preclude the possibility of an overlap occurring in a water area only.

6. Size of negatives, lens, etc.—Negatives should be as large as 7-inch × 7-inch if possible, but the contractor may elect to perform the whole work either.—

(a) With a 7-inch × 7-inch negative in which case the lens should be 10-inch F. L. to be exposed at a height of not less than 12,000 feet, resultant scale being about 4·4 inches = 1 mile, area of ground covered 2·5 square miles; or

(b) With a 5-inch × 4-inch negative in which case the lens should be 6-inch F. L. or 8-inch F. L. to be exposed at a height of not less than 10,000 feet or 13,000 feet respectively, resultant scale being about 3·17 inches = 1 mile, area of ground covered 2 square miles. An 8-inch lens is preferable.

7. Overlaps both "forward" and "lateral" to be 30 per cent. (average), but not less than 20 per cent.

8. Departure from the mean height at which each series of overlaps is taken, not to exceed 1 per cent. (or 100 feet at 10,000 feet).

9. Tilt.—The photos are to be free from tilt due to the incorrect setting of the camera with respect to the trim of the machine in its flying position. The total tilt to be within 2° in the case of 75 per cent. of the photos and in no case to exceed 3°.

10. The quality of photos to be such that no difficulty is experienced in picking out all detail necessary for a 4-inch scale map.

11. Time of day of photography.—Photography should be carried out at about the same time each day, the actual hour to be determined by experiment in consultation with the Survey officer. Narrow channels should not be entirely obscured by cast shadows.

12. Re-photography when necessary.—Re-photography either by verticals or obliques to be carried out at the discretion of the Survey representative, if the first results are not satisfactory.

13. Supplementary photography.—Verticals on a scale larger or smaller than the normal to be taken to elucidate difficulties met with in the compilation of the rectified mosaic at the discretion of the Survey representative.

14. The negatives exposed for the purposes of this contract become the property of the Government of Burma

15. Copies of photos.—The contractor shall supply two prints of every vertical photograph taken (one on glossy and one on matt paper), one print of each oblique photo as well as two extra prints of such photos as the Survey representative may call for, for mapping purposes, and two prints of such photographs as the Forest Department may require, and a rough mosaic as compiled by Mr. Kemp's photographic officer.

16. The War Office Air Survey Committee should be consulted as regards the latest design of cameras and instruments required for flight control

NARRATIVE REPORT

OF THE

BHUTAN AND SOUTH TIBET SURVEY DETACHMENT 1922

by Captain H. R. C. Meade, I. A.
Survey of India

I. INTRODUCTION

BHUTAN DETACHMENT
Captain H. R. C. Meade, I.A.
Mr. Bansi Ram, Sub-Asstt. Supdt.
15 Khalassis.

1. *Objects of the expedition.*—In April 1922 Captain Meade and one surveyor were detailed to accompany Major F. M. Bailey, C.I.E., Political Officer in Sikkim, who was to travel through Bhutan and Tibet for the purpose of conferring the G.C.I.E. on His Highness Sir Ugyen Wangchuk, K.C.S.I., the Maharaja of Bhutan, and the Sanad of Maharaja on the Raja Traring near Gyantse, Tibet.

The Political Officer in Sikkim had asked for a survey officer to secure a good survey of the route followed through the centre of Bhutan from west to east, in order to "assist Bhutanese surveyors in their eventual survey of Bhutan and in selecting alignments for the future roads of the country". The work before the detachment was to fill as much as possible of the gap between Colonel Ryder's work of 1904-05, and the western edge of Major Morshead's exploration of 1913.

2. *Previous Explorations.*—Hitherto this tract was known only by the route reports of past political officers and Indian explorers:—

(a) Mr. J. C. White's and Mr. C. A. Bell's official journeys from Chumbi to Bumtang. This is the main road across Bhutan and was again followed in 1922.

(b) Mr. J. C. White's journey from Dewangiri to Gyantse, up the Lhobrak river, then *via* the Ta La, Pomo Tso basin, Nelung and Kangmar (*vide* his special report No. 1680 dated 19th July 1906).

(c) Mr. C. A. Bell's journey from Buxar Duars to Hram-te *via* Trashicho Dzong and the Lingshi La.

(d) Rinzin Nimgyl's explorations of 1885-86, of Eastern Bhutan, and, *via* the Monlakarchung La, to Tse (Tibet), where imprisonment ended his labours, *vide* pages 372-375, volume VIII, Part II, "Records 1879-1892".

(e) Lama Ugyen Gyatso's 1883 exploration in Tibet, round the Pa-Dzo Tso and Yamdrok Tso lakes, and from Nangkartse, *via* Shabring and the Monda La,

down the Lhobrak River, *vide* pages 343-345 and 354-356, volume VIII, Part II, "Records, 1879-1892".

II. DESCRIPTION OF THE COUNTRY

3. *General.*—The main Himalayan divide in this area runs roughly east and west, and forms the political boundary between Tibet to the north and Sikkim, Bhutan and India to the south.

Nevertheless, the upper basin of the Amo Chu (which emerges in Bengal as the River Torsa), called the Chumbi or Tromo Valley, is Tibetan. It forms a wedge of Tibetan territory between Sikkim and Bhutan, but its southern boundary appears to be undemarcated.

The main trade-route between India and Tibet runs from Kalimpong into the Chumbi valley, and thence into Tibet proper over the Tang La (15,200 ft.), an extremely low col on the main divide, situated in longitude 89° 15′ between the Pauhunri group (23,180 ft.) in north Sikkim and the Chumolhari group (23,997 ft.) in north Bhutan.

Between the latter and the Lhobrak gorge in longitude 91° stretches an unbroken snow range averaging 20,000 feet or more.

4. *Bhutan.—Topography.*—Like the Amo Chu, the rivers and watersheds of Bhutan run roughly north and south, and in the route traversed in 1922 no fewer than 8 passes of between 11,000 and 15,000 ft. had to be crossed between Yatung (Chumbi) and Bumtang, the actual capital of Bhutan and the permanent residence of the Maharaja.

The valleys of Upper Bhutan, where we crossed them, average over 7,500 ft. and are flat, open, fertile and well-cultivated, with a very temperate climate. Even in mid-summer the only point on the journey, where a sun-hat was perhaps advisable for Europeans, was Wangdupotrang (4508 ft.). Here we crossed the Mo Chu by a fine pier-cantilever bridge, at a point where rock outcrops confine the river to a width of 80 yards. The Mo Chu is the largest river in Bhutan, and its basin drains the whole main snow range between Chumolhari and Kulhakangri and covers about a quarter of the whole area of Bhutan. In Assam it is called the San Kos River, and joins the Brahmaputra at Dhubri.

The hills of Bhutan, like those of Assam, are heavily wooded. But at this latitude (27° 30′) the passes are all on, or just below, the silver-fir and rhododendron line, and it is easy for the surveyor to get ideal stations, with extensive fields of view, above vegetation. Water, and in summer the weather, are the chief difficulties.

5. *Bhutan.—Inhabitants and resources.*—The Bhutanese, who look like Gurkhas without the pig-tail—both sexes wear their hair cropped—seem a sturdier race than the southern Tibetans.

Like the latter they are Buddhists, or rather Lama Devil-worshippers, and the numerous "Gompas" (monasteries), "Chortens" and "Chungur" or hydraulic prayer-wheels, labour-saving devices, are a feature of the country.

The Bhutanese language ("Drukpa") is a dialect of Tibetan, and the Sherpa khalasis, who talk Tibetan as well as Gurkhali, were understood everywhere, rendering interpreters unnecessary.

The Bhutanese are independent, industrious and prosperous, and their buildings (which are of stone with slab roofs), bridges, metal and cloth-work indicate a considerable degree of civilization.

The paths we travelled by were fit for pack-animals throughout, but had been specially graded and widened for the Political Officer's visit, and bridges repaired and new ones constructed.

The communications in South Bhutan are said to be very bad.

For survey parties, coolies are the normal transport, and yaks are only available near the passes into Tibet.

Rice is obtainable everywhere.

Dealings are normally with the "Trompons" or district officers, but an interpreter, duly authorised by one of the two Penlops to requisition transport, is imperative.

6. *South Tibet.—Topography.*—The Lhobrak River rises in Tibet on the north-western slopes of the northern Kulhakangri group (24,784 ft.) and, flowing east and then south round it, breaks through the snow range in longitude 91°, at a point just below its junction with the Kanang Chu. It finally enters Assam as the Manas.

East of the Lhobrak gorge, the snow range is much lower, averaging 18,000 feet or even less. The gorge itself is so narrow and deep that the main route cannot follow the

river at a comfortable level.

The Lhobrak basin, where we crossed it above the gorge, is an intermediate stage between the steep well-clothed hills of Bhutan and the rolling valleys of Tibet, and, Towa excepted, has the less inviting characteristics of each.

The Lhobrak basin is inhabited by Tibetans and is part of Tibet to below Lhakang Dzong. Here, as in Chumbi, the southern boundary is undemarcated.

After crossing the Uyu La, we reached the lake district of South Tibet, consisting of the Pomo, Yamdrok, Pa-Dzo, and Trigu lake basins. Of these, the Pomo Tso (16,200 feet) is probably the highest lake of that size in the world.

This area is markedly wetter and colder than the river valleys. Its main features are bare, rounded and everywhere rideable hills, rambling lakes, grassy plains and low divides.

It is inhabited by the "black tent" nomads ("Dokpas") who camp all the year round in yak hair tents, so closely woven as to be impervious to rain and snow, and tend enormous flocks, selling the wool.

The shores of the Yamdrok Tso are slightly less bleak than the rest of this area, and here the inhabitants are of much the same type as in the Lhobrak and Nyang Chu valleys. They live in solidly built "Dzongs" and villages, and are engaged largely in fishing.

7. *South Tibet.—Inhabitants and resources.*—Though too high to be as fertile as Bhutan, South Tibet never knows famine or drought. Its pasture is, as is well known, unsurpassed anywhere.

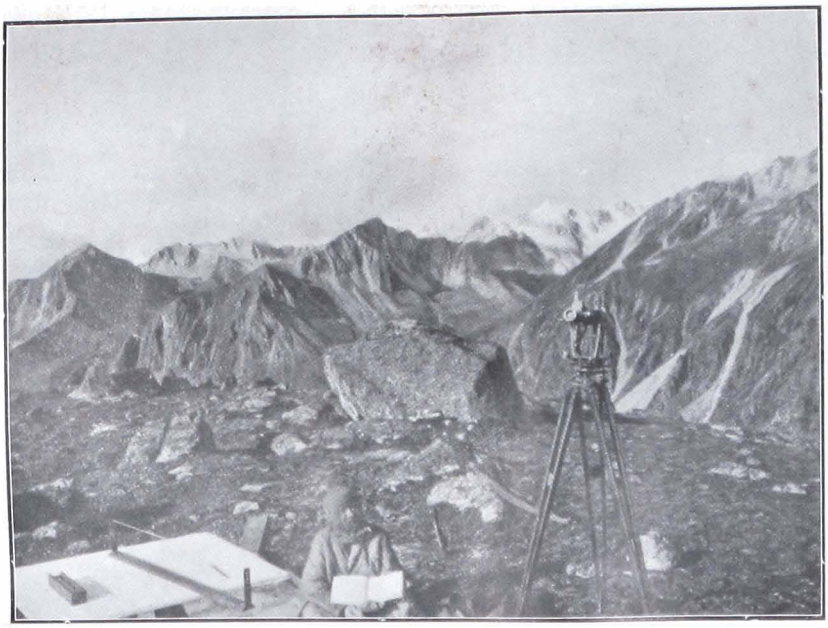
There are no trees except a few cultivated willows by the larger streams, and the geology of Tibet is still largely unexplored. Wood and iron for buildings, bridges etc., are imported from Bhutan and India, and yak dung is the only fuel.

Yak and donkey transport is cheap and plentiful.

In South Tibet, riding tats can always be hired locally by the day, and plane-table khalasis as well as plane-tablers should always be mounted.

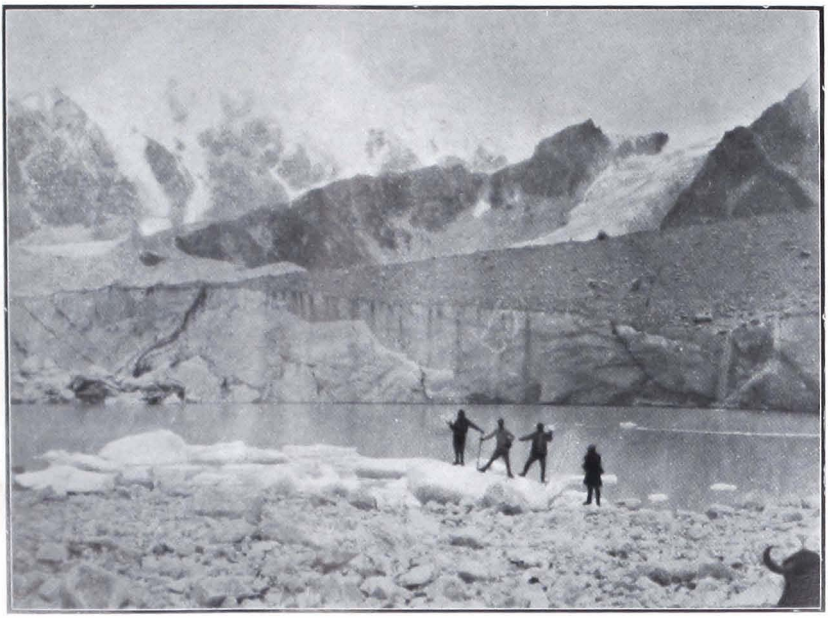
"Champa", or ground barley, can always be purchased locally, but forms a monotonous diet.

"Dzongpons" are the district officers of the administrative units, but their districts are so large and scattered that dealings are generally with village headmen, and a duly authorised representative should therefore accompany any detachment.

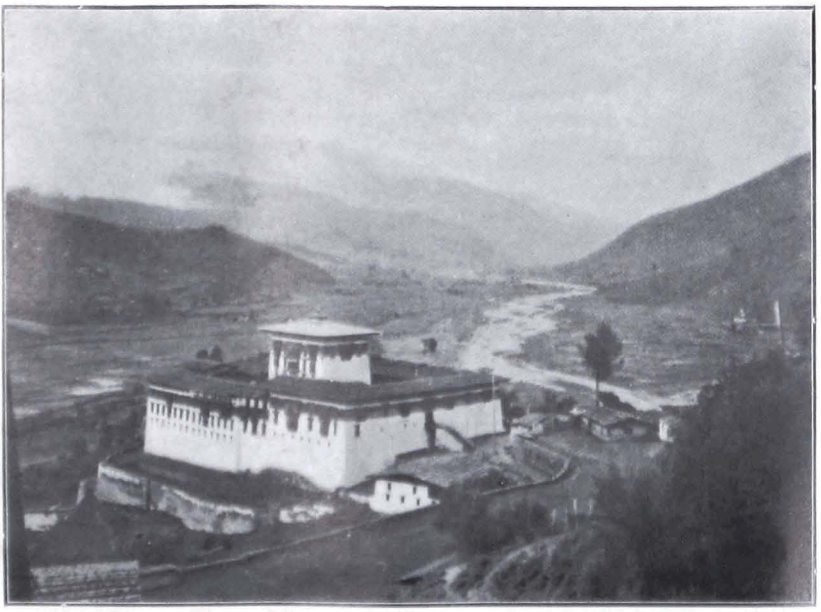


LAITSAWA HILL STATION, (16,167 FEET), NORTH BHUTĀN.

THE YAMDROK TSO FROM ABOVE RIUTRA, SOUTH TIBET.



MONLAKARCHUNG GLACIER, (16,200 FEET), SOURCE OF THE RIVER MANĀS. SOUTH TIBET.



PARO DZONG, WESTERN BHUTĀN.

8. *Geology.*—There was unfortunately no geologist in the party, but specimens were sent to Sir Henry Hayden in Central Tibet for analysis. Bhutan has plenty of lime, and South Tibet iron, but the only coal or graphite seen was near Towa in the Uyu Chu valley.

III. POLITICAL OFFICER'S JOURNEY

9. The social and political aspects of the journey have been dealt with fully in the Political Officer's official report and in a paper in the "Geographical Journal" of October 1924.

10. *Yatung to Bumtang.*—The Political Officer's party, which included the Hon'ble Mrs. Bailey, Lady Cozens-Hardy and Dr. Dyer, the Civil Surgeon at Gangtok, crossed Bhutan from Yatung to Bumtang (about 140 miles) in 17 marches of easy length, arriving on the 20th July.

The survey detachment double-marched 10 of these in order to save time for observing at the hill stations. This procedure was impracticable in Tibet owing to the length of the marches.

On arrival at Bumtang, the Bhutanese astrologers postponed the investiture ceremony, and we halted 10 days there.

11. *Bumtang to Monlakarchung.*—From Bumtang, the heavy baggage and surplus personnel were sent back to Gangtok. In view of the disappointing survey results up to this point, and in the hope of better weather, Mr. Bansi Ram also returned to Chumbi through Bhutan.

The remainder of the party marched up the Chamka Chu on the 1st August, and crossed the Monlakarchung La (17,442 ft.) into Tibet on the 7th, after camping the night before on the edge of a lake at the foot of the pass.

12. *Monlakarchung La Pass.*—The pass is a mere track 5 miles long over a glacier-covered col situated about 8 miles East of the Southern Kulhakangri group (24,740 ft.).

It is probably open only for 4 months in the year, and even then subject to blizzards. The glacier on the Bhutan side, where the track mounts it, slopes quite 45°, and the slope below ends in an ice-cliff. The gradient at the Tibetan end is much milder.

Yak transport is a necessity, ponies being led across.

The advance party all suffered from snow-blindness, but in the Political Officer's party those who had no snow-glasses

improvised, with yak hair and coloured silk, bandages over the eyes.

Mountain sickness was almost universal, and was probably due to hard exercise in the rarified atmosphere. As a preventive, apparently successful, some of the Sherpa khalasis plugged their ears.

13. *Longdo to Gyantse.*—From Longdo, the 1st camp in Tibet, till the Nyang Chu basin was entered over the Dap La (where the climate changes noticeably), very bad weather and low temperatures were the rule, and at the higher camps the thermometer fell to 35°F. at night. "Dzongpons", too, were very naturally anxious to expedite our progress, and invariably underestimated distances. Of the eight marches between Longdo and Talung, on five occasions the survey party got into camp after dark, and once (between Riutra and Talung) not till next morning.

From Longdo the route lay north to the south-east corner of the Yamdrok Tso and thence along its southern shore. All the rivers were in flood and unbridged, and several of them had to be forded after dark.

From Talung, the Political Officer's party passed into the Nyang Chu basin across the western end of that of the Pomo Tso, and reached Gyantse on the 27th August.

14. *Gyantse to Yatung.*—By this time some of the khalasis were considerably run down, and we halted 7 days at Gyantse.

The Political Officer's party returned to Yatung by the telegraph route, while the survey party re-visited the Pomo Tso basin via the Se La and reached Yatung on the 15th September by the Trari Chuma Chu valley and the Yu Tso, which is the shortest trade route between Lhasa and India, though the route via Gyantse is generally used.

At Yatung Mr. Bansi Ram rejoined the party.

15. *Route Reports.*—The Political officer made detailed route reports, and a very complete collection of birds, butterflies and plants, throughout the journey.

IV. SURVEY.—FIELD WORK

16. *Preliminary Arrangements.*—Captain Meade took over the equipment in Calcutta, and the khalasis at Gangtok, before the end of May.

The khalasis were Sherpas and a few Gurkhas recruited in Darjeeling.

For these conditions, Sherpas are the best possible personnel.

Owing to the death of the Maharani of Bhutan, the departure from Yatung (Chumbi) was postponed to the 20th June.

It was proposed to utilise the postponement in commencing a framework of single triangles direct from the triangulation stations on the Donkya range, but on the 2nd June Captain Meade met with an accident below the Natu La, and was incapacitated for a fortnight.

The plane-tabler also, who was originally detailed, could not join the detachment, and Sub-Assistant Superintendent Bansi Ram, detailed in his stead, only arrived at Yatung on the 18th June.

As explained below, the wretched weather and rapid marching would in any case have rendered systematic triangulation impossible.

The rapidity of the Political Officer's tour, the forecast of which was received in April 1922, the impossibility of returning to fill in gaps in the survey, and the imminence of the monsoon made it certain that a survey camera would be a valuable adjunct.

A survey camera was therefore applied for, but was, unfortunately, not available.

Under the circumtances, and on the advice of Major E.O. Wheeler, who has had much experience of photo-survey methods both in Canada and India, an *ordinary* $\frac{1}{4}$-plate Tropical Sanderson Camera was privately provided on the way through Calcutta.

This camera had a Goerz Dagor Anastigmat Lens of 125 mm. (4·921 inches) focal length, F. 6·8 maximum aperture, with a "Koilos" shutter, stopping down to F. 45.

The camera had a circular cup-level with a very insensitive bubble, which allowed (when tested afterwards) a dislevelment of 4 minutes in any direction before moving.

Neither camera nor tripod had levelling screws.

The camera was not fitted with collimation marks.

The only work done before taking the field was rough rectification of the level and parallelism of lens and plate.

A. Triangulation.

17. *Instruments.*—Captain Meade carried out the triangulation throughout, using a 6-inch Micrometer Theodolite, reading to 10 seconds of arc, single seconds being estimated by the observer.

A 3-inch Vernier Theodolite reading to 1 degree (single minutes being estimated from the vernier scale), was also carried but never used, and was sent back from Bumtang with Mr. Bansi Ram.

18. *Obstacles.--Rate of March.*—Reference has already been made to the accident which prevented triangulation from being commenced direct from the Donkya Range stations.

Four days of rain and snow on the first station, Kyu La, resulted only in a fixing by re-section. Thereafter the Political Officer found it politically inadvisable to leave the survey party to its own devices, and systematic triangulation was in consequence impracticable. The Bhutanese did not understand the object of camping in discomfort and bad weather, above water and fuel, and without visible results, and had the Political Officer waited for a systematic survey he would never have got through his programme. As it was, excluding the sixteen days in halts at Bumtang and Gyantse, 599 miles were covered in 72 days.

19. *Weather.*—The monsoon had broken, and the weather throughout was at its worst for survey purposes.

In Bhutan, out of 181 hours of daylight spent on hill stations, only 27 were available for triangulation, 23 before 8 A.M. and 4 in the evening.

On fine days after 8 A.M. the clouds, hitherto banked in the valleys, rose and reduced visibility to a few hundred yards for the day.

In Tibet, though clouds were high even on fine mornings, they drifted and uncovered peaks throughout the day, the whole of which was available. Visibility never fell below four or five miles.

The best time to triangulate in Bhutan is from mid-October onwards to March, and in Tibet October and from March till the monsoon arrives in June. Thus June to September would be a close season for both areas.

The original triangulation of Tibet in 1904-05 was carried out largely in winter, but the intense cold and shortage of water must be set off against the cloudless skies obtained.

20. *Obstacles to latitude and azimuth traverse.*—Owing to the bad weather experienced from the time of leaving Bhutan until the Yamdrok Lake was reached—a distance roughly of about 80 miles—no Trigonometrical points were visible and in consequence no azimuthal observations could be taken.

This portion of the map had therefore to be adjusted by occasional latitudes only.

For example, Peak No. 2/77L (24,740 ft.), the southern Kulhakangri, was not seen after leaving Bhutan, though actually visible from nearly all the hill stations visited in South Tibet.

21. *Output.*—But though triangulation was impracticable, every chance was taken of observing and obtaining resections. Occasionally the weather prevented even this.

Not a single observation was possible from Dhungajamso (13,672 ft.), fixed later as intersected point No. 29/78I, though 3 days were spent on it. This was most unfortunate, as it is probably the best and most central hill station in Bhutan.

And later, in spite of a very unsatisfactory resection at Laitsawa, and astronomical latitudes at Longdo, Tsoyu and Towa, the whole of the map between Kitipu h.s. and Sangtrongo h.s., where touch is regained with Colonel Ryder's 1904-05 triangulation, is in the air.

The following theodolite work was done.—

Hill stations at which observations were taken,...15
(of these one—Dhungajamso—was unfixed and 14 were fixed by resection).

Astronomical azimuths observed.....12

Astronomical latitudes..... 6
(2 of which were used with plane-table rays to obtain fixings).

Intersected points in sheets 78E and I, and 77L and P. .....32.

22. *Errors.*—The sources of error, due almost entirely to observing against time, have been given in detail in the angle-book.

There was no preliminary reconnaissance and only in one triangle (Chilai La, Bela La, and Pumo La h. s., which are intervisible) could the 3 angles have been observed. Bad weather prevented even this.

The only checks on accuracy therefore are the comparison of the computed with the astronomical azimuths. The latter were taken whenever possible.

On each hill station from which observations were taken a mark was set, surmounted by a cairn and, when obtainable, a pole or prayer-flag.

23. *Computations.*—The hill stations were resected from the Assam series of 1877-78 and Colonel Ryder's 1904-05 series. On reference, the Superintendent, Trigonometrical Survey, ruled that of the former none of the Bhutan-Tibet group were reliable, with the exception of Pk. 2/77 L (24,740 ft.). Accordingly they were not used, except at Laitsawa, where none others were available.

Peak 10 of Sheet 77L had been fixed in 1904-05 from Pede h.s. and Dola h.s., that is, from a 4-mile base 60 miles distant, and, with its height, had afterwards been rejected by Sir Sydney Burrard.

This is however the real Kulhakangri of the Tibetans, refixed as Pk. 19/77 L (24,784 ft.) of this series. With a characteristic satellite 22,600 feet high six miles north-west of it, it forms the Northern Kulhakangri group. Rising sheer and abrupt from a tangle of comparatively low hills, it is by its height and isolation easily the most prominent landmark in this part of South Tibet.

From Bhutan however it is hardly visible, being hidden by the mass of Peak 2/ 77L (24,740 feet), which lies 17 miles south-west of it. This the Bhutanese call Kulhakangri, though it is really only the southern group of that name.

This caused some confusion at the time.

B. Plane-Tabling

24. *Output.*—The results obtained by the detachment were:—

	Contours and form-lines Sq. miles.	Reconnaissance. Sq. miles.	
(A). Mr. Bansi Ram. Original Survey sheets 78 E and I.	1168	1480	2875 sq. miles
Revision in sheets 78 A and E.	207	20	
(B). Captain Meade. Original Survey sheets 77 K,L,O and P and 78 I.	1397	2544	6618 sq. miles
Revision in sheets 78 A and E, and 77 D, H, K and L.	2573	104	
	5345	4148	

Total	Original Survey.	6589	Total 9493 sq. miles on the $\frac{1}{4}$-inch scale.
	Revision ,,	2904	

The area shown by "contours and form-lines" is normal plane-tabling or photo survey from good fixings.

The area shown as "reconnaissance" is single-ray work, or plane-table sketches not based on triangulation.

25. *Mr. Bansi Ram's work* was $\frac{1}{4}$-inch planetabling based on the 1904-05 Tibet series and the Assam series, with good fixings throughout.

He worked on blue prints of the compilation of previous explorations (sheet 7 NE. trans-frontier), which proved relatively fairly accurate, though 3 to 5 miles out as a whole, not being based on triangulation.

At Bumtang, the triangulation hill stations visited up to that point were computed.

On Mr. Bansi Ram's return through Bhutan, by a route generally slightly north of the outward one, he was

able to planetable and contour accurately a good deal of western Bhutan adjoining Colonel Ryder's 1904-05 work, as well as the Chamka Chu and Gyetsa Chu valleys in Eastern Bhutan.

On his return journey he also mapped a good deal of the Mo Chu basin, which had been hitherto, owing to bad weather, almost entirely unsurveyed.

The most prominent snow peaks in the Mo Chu basin (two of which are over 23,000 ft.) were fixed from Mapi, Dhungajamso and Kitipu, but the upper Mo Chu and Mati Chu still remain practically unknown.

26. *Captain Meade's work* consists of:—Sketches by means of route traverses, prismatic compass work and photographs, and based partly on plane-table fixings, astronomical observations, and theodolite resections, compiled and adjusted in recess to the frame-work provided as described in IV A. above.

After Mr. Bansi Ram left the detachment at Bumtang, Captain Meade had to do the Plane-tabling as well as triangulation.

Under the circumstances, normal plane-tabling was not found to be feasible.

At every point observed from, as soon as visibility seemed most favourable, a round of photos was taken. The rest of the time saved from observing with the theodolite was spent in plane-table sketching, with a proper fixing if obtainable, otherwise on compass bearing, and in clinometer observation of possible photo-survey control points.

A prismatic compass time traverse was made along the valley from Kitipu to Laitsawa (three double marches), but the latter place was found to be comparatively shut in by higher ground southward, and the mapping of the upper Chamka Chu basin therefore consists of this traverse adjusted to the single-ray work from Kitipu and Laitsawa hill stations.

A rough fixing by astronomical latitude was obtained at Longdo, but from this point to Sangtrongo, where a proper fixing was obtained, the map is merely a sketch on compass bearings with a route traverse as far as the Uyu La, adjusted in recess to the fixings at Longdo and Sangtrongo, and the latitudes taken at Tsoyu and Towa.

A subtense bar was not taken, and it is almost certain that the rate of march would have precluded its use, either

for a subtense route traverse or for a base on which to build the reconnaissance.

On the other hand, a Barr and Stroud range-finder, as used by the 1913 Mishmi survey, would have been invaluable for a traverse of this portion of the route.

From Sangtrongo onwards all the stations were good fixings, by theodolite or plane-table re-sections from the 1904-05 triangulation.

The southern shore of the Yamdrok Tso is therefore comparatively accurate, though the sketching north east and east from Lhunbusho h.s. is on a single ray, and the work from Nyemalung plane-table fixing, owing to pouring rain, was done on a separate sheet, and transferred and adjusted by trace in recess.

The latter also applies to Pomotsongo and Se La stations, where, owing to the failure to recognise Kulhakangri as Pk. 10/77 (given without height), fixings were not obtained till afterwards.

Altogether in Captain Meade's work, out of 36 plane-table stations, 17 were unfixed at all by resection and had to be adjusted as described, 2 were latitudes only computed out afterwards, and 17 fixings, 3 of which were not obtained on the ground.

The least-known area of this part of south Tibet is the upper Lhobrak, by local reports a desolate and practically un-inhabited region.

There are two parallel snow-ranges south of the Pomo Tso, of which the northern, averaging nearly 20,000 feet, and extending from the Palu La to Peak 20/77 L, forms the lake's southern watershed. The southern and higher is the main Himalayan range forming the Bhutan-Tibet boundary. Between these ranges are the head-waters of the Trarichuma, Lhobrak and Konang rivers.

C. Photography

27. Before commencing the survey the principal point on the plate was found. The camera was levelled as far as possible, and three discs placed by theodolite in the same horizontal plane as the lens.

The line joining the discs was marked and cut in on the ground glass screen with the camera placed in its horizontal position, and again with the camera in its vertical position. The intersection of the 2 lines was taken as the principal

point, and this was found to be correct when checked accurately afterwards with a "Collimator".

The absence of levelling screws rendered it impossible to ensure absolute verticality of plate or to test the same.

In taking the panoramas 1-inch overlap was allowed at each edge, and no points on the outer 0·4 inch of plates were used. Each view was focussed on the ground glass screen, and the focal length so found was practically constant but shorter than the "infinity" focus marked by the makers (see para 30). The orient of each photo, *i.e.* the feature coinciding with the principal line on the ground glass screen, was noted in the angle book with the film or plate number.

Bearings and Angles of elevation or depression to 3 or more "control points", in each photo, were taken and entered in the angle book.

The average numbers of control-points *per photo* were :—

Trig points	1·6
Points to which bearings and vertical angles were found by planetable and clinometer	2·8

The level bubble was centred for each photo.

Panchromatic plates and film-packs were used. Owing to limitation of transport only one dozen plates were taken and no apparatus for developing etc., which was carried out in India.

Exposures were estimated with a "Watkins" Bee Meter but before the earliest prints were received from India there were several over-exposures.

In north Bhutan and Tibet, with the minimum stop (F. 45) and chromatic filter of density 4 times (K 4), which were invariably employed for landscapes, 5 seconds was the normal exposure for ordinary morning sunlight

117 Photos were taken for mapping purposes, of which 15 were failures (including one film-pack of 12 spoilt in developing).

They were taken from 17 stations, of which 11 were triangulated and 6 plane-table resections. The azimuths and vertical angles of the photo compilation control-points were taken by theodolite or by plane-table and clinometer.

V. SURVEY.—RECESS WORK

28. *General.*—On return from the field the khalasis

were discharged at Gangtok, equipment was returned to Calcutta, and Captain Meade and Mr. Bansi Ram returned to Shillong.

The triangulation computations and the compilation and adjustment of a reconnaissance map, for which the Political Officer in Sikkim had asked, were commenced in October as a preliminary to the photo-survey.

At the end of January 1923, Captain Meade joined No. 12 Party in the field and Mr. Bansi Ram was transferred to Burma.

29. *Compilation from Photos*—In the middle of April the photo enlargements were received from Dehra Dun, and the photo-survey compilation started.

The original negatives were 3·01″×4·06″ (though the long side varied in a few cases owing to the shutter of the dark slide not being fully drawn out) and were enlarged 2·47 times, so as to facilitate inking &c. and to bring the assumed focal length of the enlargement to 12″, for which length the Everest Photo "orient-finder" and "height-computer" had been constructed. Although it was assumed that all the Photos were on inclined plates, exact enlargements were made, and no attempt was made to rectify to a vertical plane during enlargement.

Enlargements on glossy paper, though not as good as matt for inking, are preferable as giving much clearer definition.

The horizon line, HH′ (*vide* fig. 1) of each photo was found by the vertical angles of not less than three control-points in the perspective. The principal point P of the

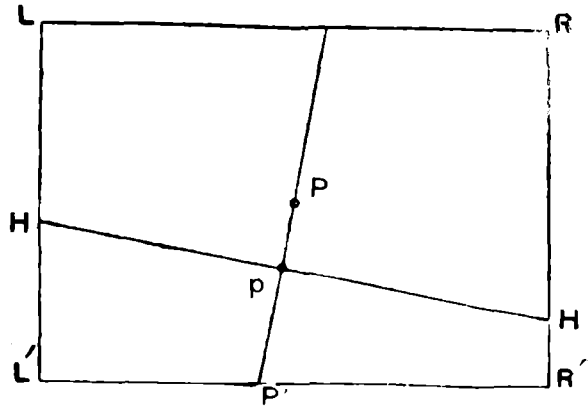


Fig 1

plate was found by measurement from the right top and bottom corners of the perspective, RR′, this side of the plate being unaffected by the incomplete withdrawal of the dark slide shutter. The line PP′, drawn perpendicular to HH′, was the principal line of the plate and p its intersection with the horizon line.

30. *Orienting the Photos.*—Constant focal length could not be assumed, and both focal length and orient were found for each photo separately with the "orient finder" (Fig. II), a celluloid plate on which are marked the horizon HH′, and distance lines Sp, with holes for pricking through their directions and that of the horizontal projection of the principal point, p.

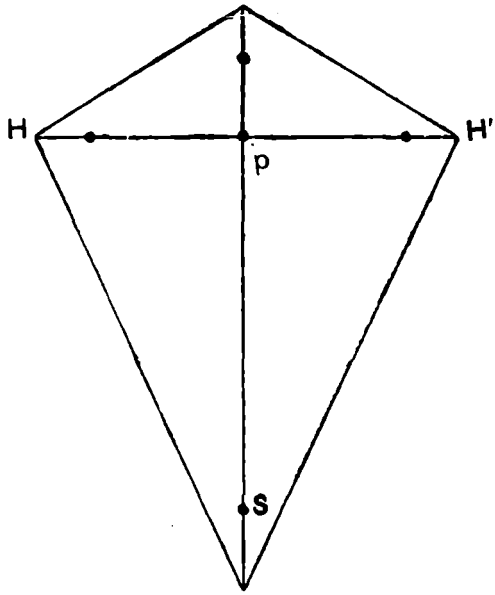


Fig II

On a projected piece of drawing paper (the "photo compilation plotting chart") all camera stations, trig. points, and photo-control points, or their azimuths from camera stations, were plotted.

The horizontal projections of not less than three control points were then taken from the photo and marked on line HH′ of the "orient-finder", and the orient finder was then moved about until the line pS, passed through the camera station (on the plotting chart) and the projections of the points on the line HH′ were each lying on the lines joining the camera station S, to the control points.

p and HH′ were then pricked through, and the distance of Sp is the focal length of the photo.

Thus the focal length Sp was found separately for each photo and averaged 11·726″ for all photos, as against 12″ assumed focal length (enlarged) of the lens.

31. *Plotting the survey.*—The compilation being by intersection only, prominent points were identified on the photos taken from not less than 2 stations, inked up and numbered consecutively. For easy reference, ink of different colours was used for different areas.

A strip of paper was then placed along the horizon line of each photo, and the horizontal projections of the principal point and all identified points taken.

This strip, placed on the orient horizon line (HH′ of fig. II) on the plotting chart, gave the azimuths of all points at the station S, and the points were then plotted by intersection of rays from 2 or more stations.

A perspectometer might have been used for drawing the lakes and adjacent plains in south Tibet, but a geometrical construction was used throughout.

32. *Heights*—Similarly the vertical projection of each point was taken off on the back of the strip, by aligning its edge to the principal line (Pp in Fig. I) of the photo.

Heights were then read off on the "Height Computer" (Fig. III).

This consists of an aluminium base AB, with three

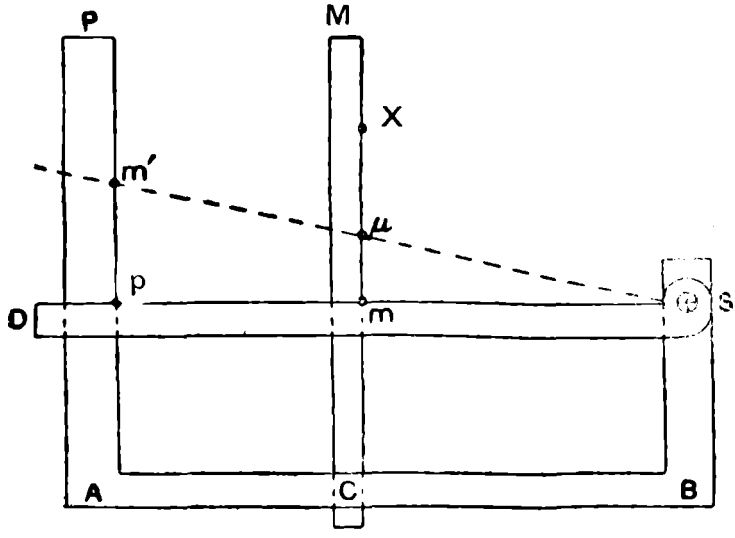


Fig III

vertical arms, two of which, SB and PA, were fixed 12″ (assumed focal length) apart, and the third, MC, fitted to slide along AB, always perpendicular to it. S had a glass diaphragm with cross-lines for placing S accurately over the station on the plotting chart, and was the pivot of a levered arm SD, on which, starting at S, was a scale in feet of corrections for curvature and refraction at the scale of the compilation ($\frac{1}{4}$″). MC also had a vertical scale of feet reading up and down from zero at m, S m p being parallel to AB.

In measuring heights, the "height computer" was so placed that S coincided with the station and Sp (parallel to AB) with the distance line of the orient on the plotting chart (Fig. II).

The height of any point X (*vide* fig. III) on the plotting chart was then read off as follows. Without moving the fixed frame, the edge MC was aligned to X. The correction for curvature and refraction was read off by aligning the arm SD on X.

The vertical strip was placed along PA, at distance S p (focal length) from S, p in PA being the horizontal projection of the principal point and SpP being a right angle. The edge SD is now aligned on m′, the vertical projection of X on the strip. Then μm on the scale MC shows the difference in height between the station and X without allowing for curvature and refraction.

The accordance of photo heights was as follows:—

	From 2 stations	*From 3 stations*
Agreeing within 125 feet (half a contour)	86	2
do. 250 feet	50	1
do. 375 feet	35	1
Over 375 feet difference	57*	10*

33. *Accuracy of the work*:—The camera was damaged at one of the last stations (RIUTRA) and was not tested till over 2 years after it had been used for survey purposes.

With the bubble central the max. forward inclination of the plate was found to be 0° 48′ and the backward inclination of the lens 0° 57′. Lateral inclination of lens to plate was 0° 1′ from left to right.

The error in azimuth due to this is a maximum for a point in the extreme top corner of the plate, and for a point on the edge of the plate at an elevation of 10° is ·0288 inches on the plate or 0° 7′ 2″.

* 17 of these were considered wrongly identified.

The error in vertical angle is a maximum for a similar point and amounts to ·0113 inches on the plate or 0° 2′ 53″ for a point on the edge of the plate at 10° elevation.

The error due to lateral inclination of the lens is imperceptible and only amounts to about 0° 0′ 6″.

34. *Conditions of the Photo Compilation.*—Although weather conditions were adverse, most of the area under survey was favourable to photo-survey, especially the bare rugged hills in the vicinity of the main snow-ranges.

The triangulation, on which the work was based, was mostly exploratory, and the stations and control-points fixed therefrom were not accurate enough for accurate photo-survey, even with a survey camera.

Moreover the speed of the journey rendered it impossible to increase the area and precision of the survey, as in plane tabling, by the multiplication of stations and views, and compelled recourse to a good deal of long ray work, the only material available. The maximum distance of the country mapped from the camera was 27 miles across the Pomo Tso and the adjoining plain, and the most acute intersection used was 11°.

Under the conditions of rapid marching and fleeting visibility encountered, the photographic material collected certainly increased the mapping outturn and provides a permanent record.

On the whole however, the use of *an ordinary camera with films* entails a more laborious, expensive and inaccurate compilation in recess than the use of a survey camera.

35. *Area Compiled from Photos.*—The method was used to map most of the lake district, as well as in the upper Trari Chuma Chu, Chamka Chu and Yutso basins.

The photo-survey was completed and Captain Meade rejoined No. 12 Party at the end of July. The permanent records and 4 sheets for fair-mapping were made over to No. 5 Drawing Office.

Besides the survey photos, a complete photographic record of the whole journey, local customs and the religious and monastic life of Bhutan and South Tibet was made, which is of ethnological interest.

Two hundred such photos were taken, and sets of these were presented by the Surveyor General to the Royal Geographical Society, the Alpine Club, the Dalai Lama and the Maharaja of Bhutan.

VI. GENERAL

36. *Cost of Survey.*—The field work, to the end of September 1922, cost Rs. 17,500/-. The recess work, up to the fair-mapping, including the salaries of the computing and compiling sections, cost Rs. 9,000 -. TOTAL. Rs. 26,500 -, giving a cost rate of Rs. 2·79 per square mile.

37. The Dalai Lama and the Maharaja of Bhutan have asked to see the maps, and a trace was presented to the latter in Bumtang. They appear to realise that topographical survey is a prelude to other forms of development. They welcome it if it is done openly, with their permission, and if the results are communicated to them.

38. Sincere thanks are due to the Political Officer for the excellent organisation of the tour and friendly relations with the inhabitants.

APPENDIX

Camp and Pass names	Heights	Camp and Pass names	Heights
Jalap La ...	14200	Wei-Tsang ...	13950
Natu La ...	14300	Tsogyu ...	15529
Yatung camp ...	9800	Monlakar Chung La ...	17442
Sharitang camp ...	11350	Longdo ...	14786
Kyu La ...	14151	Tse ...	12650
Ha La ...	13975	Tsoyu ...	14350
Damtang camp ...	10300	Pemaling Tso ...	14250
Ha Dzong camp ...	9100	Drum La ...	16660
Chi Lai La. ...	12420	Chu-Me ...	12850
Chang Na Na camp ...	9600	Towa ...	12550
Paro camp ...	7750	Uyu La ...	16150
Bela La camp ...	11650	Tso Chungsa ...	15600
Pyi Mi Tanka camp ...	8350	Ram La ...	15426
Tsa Li Ma Po camp ...	7700	Sungtrongo ...	14500
Do Kyong La ...	10400	Lhunbusho ...	14500
Lo Mi Tsawa camp ...	6700	Nyemalung ...	14500
Punaka camp ...	5169	Tepra ...	14550
Wang Du Potrang Dzong camp...	4508	Riutra ...	14550
Sam Ten Gang camp ...	7150	Talung ...	14650
Ritang Gompa camp ...	8175	Namoche ...	15200
Pele La ...	10950	Tug La ...	17072
Chen De Bi camp ...	8350	Pomo Tsongo ...	16350
Tsang ka camp ...	7600	Dap La ...	17088
Trong Sa Dzong camp ...	7225	Dapnang ...	15150
Yu to La ...	11210	Se La ...	17095
Gye Tsa camp ...	9800	Pomo Tso ...	16195
Kyi kyi La ...	11600	Pa-Dzo Tso ...	14500
Bumtang camp ...	9725	Yamdrok Tso ...	14500
Shapjetang ...	9860	Lingshi La ...	16118
Pangsang Sampa ...	10860	Tang La ...	15219
Tsampa ...	12450		

Passes not visited

Monda La	17200 ?—	Upper Lhobrak to Pomo Tso basin
Ta La	17300 ?—	ditto.
Koja La	17400 ?—	ditto.
Wagya La	17400 ?—	Upper Trarichuma Chu to Punaka, Bhutan
Yala	17200 ?—	Yu Tso basin to Punaka Bhutan
Palu La	17600 ?—	Upper Trarichuma Chu to Pomo Tso Basin.

Kala Tso
Yu Tso
Rham Tso
Drum La
24784 . KULAKANGRI
Ka-nang Chu
Monla Karchug La
24740 KANGRI
Thram-Te
23180 . PENHUNRI
Lingshe La
23997 . CHOMOLHARI
Tang La
Phari Dzong
Puna Ka Dzong
13672 . CHUNGKAJAMSO
Pele La
Kitipu h.s. ▲ 13553
Buntang
Yatung
Kyu La
Paro
Mangdu potrang Dzong
Mo Chu
Chamka Chu
Jelep La
GANGTOK
Mati Chu
Amo Chu
I N D I A
B H U T A N
15000
10000
5000
89° 0′
90° 0′
91° 0′
27° 0′