KARAKORAM SURVEY, 1939: A NEW MAP

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Detailed accounts of E. E. Shipton’s 1939 expedition to the Karakoram have already appeared. The surveys carried out on the expedition were compiled during the winter of 1939-40 in the offices of the Survey of India at Dehra Dun, and were in course of being embodied into the standard quarter-inch sheets 42.P, 43.N, 42.L and 52.A when interrupted by more vital work for the armed forces. Nothing further could be done towards the publication of the map until the war was over, when arrangements were made for the return of the original plane-table sheets and records from India to the Royal Geographical Society. Several attempts have been made since then to have the map fair drawn and reproduced, but they failed through lack of funds. Not until a decade after completion of the field work has it become possible to bring the results of the Expedition’s work to a logical conclusion by the publication of the map. The necessary funds for this work have been subscribed by the Society, with a contribution from the Himalayan Committee.

The area covered by the map is one of considerable interest geographically, comprising as it does two of the longest glaciers outside polar regions and containing what is probably the greatest concentration of high peaks in the world. Before Shipton’s Expedition the only maps of the region were based on sketch surveys by Conway and, later, the Bullock-Workmans, which provided only a hesitant outline (often wildly in error) of this vastly complicated piece of terrain. Due to the political changes in India since the expedition took the field, it seems unlikely that an opportunity will occur again for many years for the employment in the Himalayas of a fully trained survey team on a private venture of this nature. Added to which, the recent developments in Sinkiang and the present uncertainty in Kashmir must necessarily give the map an added importance. The following notes are intended to fill in some of the technical details which could not be included in previous more general accounts of the expedition.

The Hispar Triangulation

While the methods used were not original, the scale of the country involved us in a number of problems the magnitude of which was not at first appreciated. Most of our troubles arose from the initial mistake of not adhering to Shipton’s original plan to begin the survey from a measured base on the Lukpe Lawo (“Snow Lake”) and thence extend a triangulation outwards which would be tied on to the few existing G.T.S. points in the area. The Survey of India, to whom we were much indebted for having lent us two experienced plane-tablers and for contributing generously to our funds, was anxious to establish if possible a connection between the G.T.S. stations in the Hunza valley, belonging to the Indo-Russian triangulation carried out by Mason in 1912-13, and the few isolated points in “Snow Lake” area such as peak 18/43M (“Ogre”) and peak 9/43M (“Ganchen”), which belonged to the much older Kashmir series carried out in 1855-60.

Had there been sufficient time, instruments and personnel available, the

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Survey of India plan would have been by far the most satisfactory way of tackling the job, but we had only one theodolite accurate enough for a triangulation of this order and one surveyor to use it. Moreover the majority of the triangulation stations lay between 6000 and 8000 feet above the valley floor. In addition the observations had to be computed fast enough to keep two plane-tablers busy. Although Shipton assisted me greatly both by his profound knowledge of the country and a remarkable gift for recognizing peaks from widely different angles, the difficulties in carrying an accurate network of triangles over a distance of 60 miles in such country in the space of a few weeks need no elaboration. To have completed the task satisfactorily in the time at our disposal, at least three observers and a computer must have been available.

To add to our troubles the weather was often unfavourable and we were many times held up for several days by mist, rain and dust avalanches. Water and fuel are scarce in the region, making camp sites hard to find and adding to the exertion of the climbs. Even in the best circumstances it took two days to complete a single station, while on occasions five days were taken up by one point.

As things turned out the time spent on the triangulation was disproportionate to the work of the Expedition as a whole. Much interesting exploratory work behind the south Hispar Wall and north of the Upper Biafo watershed had necessarily to be curtailed, nor were we able to make a detailed survey of the Alchori and Chogo Lungma glaciers which were included in our programme. Sadly enough, despite these sacrifices the primary object of establishing the connection between the Indo-Russian and Kashmir series, which had caused our change of plan, was never completed on account of an accident to the Wild theodolite.

Some confusion and delay was due to the Survey of India triangulation pamphlet 42.L, which gives a very misleading description of both the stations belonging to the Indo-Russian series in the Hunza valley which we had hoped to use as a base for the commencement of the survey. "Zangia Harar" is not, as described, "on the higher and more northern peak" of the hill of that name but is at least 50 feet below the top and 100 yards to the east. Still less is "Buru Harar" on the "highest accessible point of the ridge"; it is situated on a very inconspicuous spur in the Hunza valley 2000 feet below the summit of the ridge (climbed by us without difficulty) and was invisible even from a mile away to the west without the use of a helio. Misidentification of the latter station involved us in a great deal of trouble and delayed us by nearly a week. Finally we were obliged to abandon this station altogether and lay out a fresh base near Nagar, south of the Hispar river. The new base was later connected with Zangia Harar so that spherical co-ordinates could be computed. No reflection is cast on the Indo-Russian triangulation which was a fine piece of work carried out in extremely severe country. Nevertheless it seems a pity that, in a region where there existed little or no triangulation data, the stations were not selected on more conspicuous points that would have been of service to other surveyors.

The Nagar base was laid out by double extension from a Wild subtense bar. The Survey of India had offered us a Hunter "Short Base" before our departure (a more accurate apparatus than the subtense bar and ideally adapted for this type of work); regrettably we did not take it on account of the added weight.

The speed of progress prevented us from measuring all three angles of every triangle of the network. However, the work was computed as it progressed and a constant check maintained not merely on the stations but also on the intersected points which could be verified by the plane-tablers. The usual trouble

20,000 foot peaks bordering the Hispar glacier on the south
Plane tabling at 16,000 feet; Sosborne glacier

Triangulation station above the Hispar glacier
in exploratory triangulation of being unable to reconnoitre ahead necessitated a number of satellite stations, and corrections had to be made for these. Eight-foot cairns were built on all stations and proved sufficient for the longest ray (10 miles). A lime wash on the cairns would have been of great assistance in identification and would have added little weight to our loads. The stations were established in all cases on conspicuous points, mainly above 16,000 feet. Even without the cairns it should be possible for anyone to find most of them in the future from the description of the points, copies of which are held by the Survey of India, and by the Society's Map Room. We had neither the time nor the material to construct more permanent marks, but the cairns were strongly built and should last unless pulled down by local shepherds.

**Accident to the Wild theodolite**

After five weeks of intensive work the triangulation was within 10 miles of the Hispar pass. We were camped on the northern bank of the Hispar glacier below a hill that had been given the name "Dromedary Humps" on account of two small excrescences on the top. A spell of bad weather had just begun and the first day I was unable to observe owing to cloud; I went up a second time alone and set up the Wild on the southern of the two Humps, which consisted of an enormous pile of heterogeneous boulders. The uppermost rock, on which I was standing, must have weighed several tons and appeared securely lodged, but rain and thaw had undermined the stability of the pile and as I transferred my weight on to the outer edge of the boulder in order to level the instrument there was an ominous rumble beneath and the whole mass suddenly gave way. I was thrown downhill, the theodolite following closely behind. I escaped unhurt from the fall but the Wild received damage to its main axis and was out of action for the rest of the summer. The main object of the triangulation was thus brought to an untimely end. Fortunately we still had the small Zeiss TAL photo-theodolite reading to 1½ minutes which was used to supply the plane-tablers with control by a series of resections, making use of those points already established with the Wild T.2. before the accident, in addition to the G.T.S. points provided by the two Kanjut peaks (Pk 11/42P and Pk 12/42P) and the unnamed peak 18/43M.

**Plane-tabling**

Most of the detailed mapping was carried out by two Indian plane-tablers, Fazal Ellahi and Inayat Khan, lent by the Survey of India to assist the expedition during the summer programme. Fazal Ellahi had already fourteen years' experience in Himalayan mapping and it would have been difficult to find his equal for accuracy, speed and resourcefulness. His out-turn was quite remarkable and can be gauged from the fact that in the course of three months' work he surveyed in great detail a total area of approximately 600 square miles, much of it above the snow line at 14,000 feet, and including the entire area of the Lukpe Lawo ("Snow Lake"), the whole of the Biafo glacier and two-thirds of the Hispar. Inayat Khan although a younger and less experienced man also produced some excellent work. As he was unwell for the first few weeks, probably due to slow acclimatization, he was left to complete the lower third of the Hispar glacier, the Kunyang and Gharesa glaciers and some of the country around Nagar.

Both surveyors suffered to some extent in their work from an insufficiency of control points. Due to the accident with the Wild, Fazal Ellahi was obliged to work his survey of the Biafo glacier (an area of some 200 square miles) off not more than six triangulated points. For the greater part of the time the surveyors were left entirely to their own resources. Much of the work had necessarily
to go unchecked, but whenever examined it proved of an extremely high standard. Fazal Ellahi's clinometric heights of the Hispar pass and most other points in the Snow Lake area agreed almost exactly with my triangulated values. It was definitely established that the Bullock-Workman's estimates of peaks on the south Hispar Wall and in the vicinity of the Snow Lake were in error on the high side, by as much as 3000 feet in some cases.

After completing the triangulation, Russell and I crossed over from the Biafo into the deep-cut valley of the Sokha (old "Cornice") glacier, said by the Workman's to have no outlet. Here I was faced with an awkward problem. There were no fixed points whatever available, while only a week had been allotted for a very difficult and intricate area. Luckily we had with us the Wild telescopic alidade which I used to build up a graphical "triangulation" from an assumed base across the glacier. Azimuth I obtained from observations of Polaris at (or near) elongation. The plane-table was oriented correctly over a known station just before the computed time of elongation. The alidade was then moved until the vertical cross-hair of the telescope was on Polaris. True north was thus indicated by the edge of the sight rule, plus or minus a correction which could be obtained from the Nautical Almanack and laid off graphically on the board. Later I "tied on" to two points on the south Hispar Wall which enabled me to reduce the whole survey to a known scale and transfer relative form-lines to contours of known value. The method is not one that commends itself except as a last resort in the absence of any triangulated points; with an ordinary sight-rule it would have been impracticable.

Leaving the Sokha and Solu area, Russell and I travelled to Askole where we parted company. With one Sherpa and two local men I then began the survey of the Hoh Lungma and Sosbon glaciers from the south. Here my task was very much easier. From the summit of a high ridge west of the Hoh Lumba valley one overlooked the whole of the Sosbon and Hoh Lungma glacier systems. Peaks 12/42P, 18/43M, 9/43M, were all visible and the survey began with an accurate fix. Several other points that I had hoped to make use of for plane-table fixings proved either untrustworthy or non-existent. The Workman's 22,000-foot Peak "Meru," between the Hoh Lungma and Biafo glaciers, was mysteriously absent. Koser Kunge (35° 37' 10" N., 75° 39' 00" E.) was visible far to the south, but did not appear reliable either in height or position. Mango Gusor (Pk. 21/43M) was not visible. The survey was necessarily of a rapid nature but it may be fairly claimed that the glaciers and surrounding ridges are accurately placed. At each station a round of photographs was taken on 35 mm. film which cover nearly the whole area of the survey. With the help of these it has been possible to work up all the detail left out in the field.

Photographic survey

The Panmah, Choktoi and Nobande Sobeande glaciers were surveyed by Shipton, using the Zeiss TAL photo-theodolite, which had been obtained on loan from the makers. Later, at Dehra Dun, the photographs were plotted and the result is highly satisfactory; the method used, that of plane-tabling from single photographs, is one of the earliest forms of photo-surveying. It is ideal for use in high open country when time in the field is limited and personnel not highly trained. An account of the methods used is added as an appendix to this paper, and is based on our experiences with the Panmah survey. Save for a small area at the head of the Gharesa glacier, surveyed by Fountaine, and some pictures taken of the head of the Khurdopin, no other photo-survey was carried out. The programme of stereo-survey planned for the winter never materialized on account of the war.
APPENDIX

The single picture method of photographic mapping

The instrument used was the Zeiss TAL photo-theodolite, which is admirably designed for exploratory surveys of this type. The instrument in its case with all accessories and stand has a total weight of 14.4 lb. Horizontal and vertical angles are read in grads with a direct reading to one-tenth grad and an estimation to one-hundredth. In practice the horizontal angle was found to be accurate to within 1° minutes. For the sake of lightness we used film pack instead of plates, which worked satisfactorily. The size of the contact negative is 6.5 × 9 cm. The method employed was based on the combined use of the instrument both as a theodolite and as a photo plane-table, and is to be recommended wherever time in the field is more important than convenience in office compilation, and also in cases where stereoscopic photogrammetry is impracticable due to lack of trained personnel or insufficiency of time. The area mapped by this means covered the whole of the Panmah, Choktoi and Nobande Sobande glacier systems, an area of some 200 square miles, mostly lying between 13,000 and 24,000 feet. The whole of the field operations and photography were carried out by Shipton in the course of three weeks' work, the total number of stations occupied being approximately twenty. In the selection of these stations the following points were borne in mind:

The higher the station the less dead ground there is and the wider is the valley separation.

Pairs of stations were so placed as to obtain good intersections on the country mutually embraced by them.

Points in the area included by one station must be recognizable when seen from the second station. The surveyor (in this case, Shipton) must be constantly identifying himself with a plane-tabler faced with the problem of cutting in small points of detail he has observed from a previous station.

Whenever possible the stations were intervisible. On arrival at a station the first consideration was given to the photographs. These were taken near midday if possible, when shadows were absent. If however there was any danger of low cloud forming, the photography was carried out immediately on arrival and the pictures repeated again later if conditions improved. Horizontal and vertical angles were taken to as many prominent peaks as time permitted, including all points triangulated by Spender in 1937 and the old G.T.S. points.

The following records were kept:

(a) A list of all control points observed with a reference number and a description of each, and the station number from which they were observed.

(b) A list of all photographs taken at each station with their serial numbers, the angular interval of their principal planes and the displacement of the horizontal axis of the camera from its central position (equivalent to tilting the axes in other types of instrument).

(c) Horizontal and vertical theodolite readings.

For convenience and to save space all three sets of recordings were kept in one small notebook.

On the return of the expedition to Dehra Dun, the compilation of the Panmah map was immediately begun and took, in all, three months to complete. The compilation and drawing of the map was carried out in the following stages:

1. Existing control. All existing triangulated points were first plotted on a sheet of backed or "rectostat" paper to a scale of half an inch to one mile.

1 Geogr. J. 91 (1938) 331.
2. **Kodatrace protractors.** A number of Kodatrace protractors were prepared of at least 5 inch radius. These were printed in ink on the glazed side of the Kodatrace, the circle being divided in degrees and tenths of a degree, every ten degree interval being numbered, so that when the protractor was viewed from the reverse (matt) side the numbers appeared the right way round and progressed in a clockwise direction from 0 to 360. There was one such protractor for each station, the number of which was marked in the corner.

3. **Resection of stations.** All observed angles from the stations were next set out on the matt side of their respective protractors, the number of each ray being marked against it on the outside of the circle. The resection of the stations then began. That station from which the greatest number of existing trig. points had been observed was taken first and, by sliding the protractor over the plot so that each of the trig. points lay on its respective ray, the resected position of the station was found graphically, pricked through, marked with a circle, and numbered on the plot. The remainder of the rays were then marked in pencil off the edge of the protractor on to the plot with their numbers. The principal lines of all photographs from the station were also transferred to the plot. In the same way the position of the second most favourable station was found and any common points between the two stations so far taken were intersected and used as additional control for fixing the third station, and so on until all the stations and new control had been plotted.

The stations were marked with small crosses in red ink and control points circled in black with their numbers in pencil. The heights of all points and stations were next computed and a height trace prepared. Everything on the plot was then erased leaving the stations, control points and principal lines of the photographs and any odd rays, the points of which had not been intersected. (These latter rays of course remained in pencil.)

4. **Photographic prints.** All prints were full plate enlargements (8½ x 6½ inches). Two prints were made from each negative, one matt and one glossy. Each enlargement was carefully checked to make sure there was a minimum of distortion in the print; especially with distant points, small errors of measurement on the print may amount to very large errors on the plot. As apparatus was not available to ensure that each print was enlarged by exactly the same amount, it was necessary to compute the principal distance for each individual picture. This was entered up in ink on the back of the print. The collimation axes were then drawn on the glossy copies only, using a fine pen or pricker.¹

¹ If \( f_1, h_1, v_1 \) are respectively the focal length of the camera, the horizontal distance between the collimation marks, and the vertical collimation distance referred to the pressure plate; while \( f_2, h_2 \) and \( v_2 \) are the corresponding values for the enlargement (\( f_2 \) is the principal distance in this case) then it is clear that:

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f_2 = \frac{f_1 \times h_2}{h_1} = \frac{f_1 \times v_2}{v_1}
\]
5. **Plotting of detail.** On the glazed side of a piece of Kodatrace a cross was then drawn (see figure) and a distance equal to $f_s$, the principal distance of the enlargement, was marked off along the tail of the cross. This was placed in position on the plot with $L$ on the station and $LP$ along the principal direction of the photograph as marked on the plot. The ray to any point $S$ on the photograph was next drawn by transferring the distance $x$ from photograph to Kodatrace, laying a straight edge along $LR$, and ticking the ray off on the plot sheet. At the same time the distance $LR$ was measured on the Kodatrace and $y$ on the print: these were entered up on a form ($y/LR$ is the tangent of the vertical angle to the point). Any control points that could be identified on the print were used to check the accuracy and the direction of the principal line, and also the presence of any distortion in the photography.

All photographs relating to a particular area were finally assembled and points of detail picked out and marked up with numbers in red ink on the matt copies. Glossy prints were used for measurement only and were not marked or defaced in any way except for inscribing the collimation axes. The drawing of the map then resolved itself into straightforward plane-tabling, in the drawing office instead of the field, and requires no further description.
HISPAR - BIAFO
(KARAKORA)
Surveyed by Members
Karakoram
A Deliberate plane-table surveys by Fazal Ellahi and Inayat Khan of the Survey of India, based on a triangulation by P.G. Mott.
B Plotted from photo-theodolite survey by E.E. Shipton.
C Rapid plane-table surveys by P.G. Mott.
LEGEND

Pack Tracks
Routes followed by expedition
Pass
Grazing Ground: Camping Ground
Traveller's Bungalow
Huts: permanent: temporary
Contours: Rocky slopes
Snow and Ice forms
1 glacier
2 moraine
3 crevasses
4 scree
5 perpetual snow

Triangulation Stations
Points fixed by theodolite
Other intersected points

To Arandu

To Chokpiong

To Ask