

Eleusinian Mysteries, centaur, and things of that kind ; but we have not been able to find anything really definite as to their origin.

I might say that I was asked by the Government to report on the Bambudye society, and was able to satisfy our friends of the Administration as to the immoral practices, chants, etc. It is all too evident that they are foul. Our native is a strict exogamist, never marrying in his own village, but in the "kinyergele" of the Bambudye he gives way to the wildest promiscuity.

The PRESIDENT: We are very much obliged to Mr. Burton for the lecture which he has given and for his illustrations and, if I may so call them, the frills so unusual in lectures. In fact, I do not think that we have had so gifted a lecturer before us for a considerable time. But, quite seriously, what he has told us has shown not only that he has remarkable powers of representing the native, but also that he treats him with sympathy and puts an amount of diligence into studying him and his customs and practices—for instance, his drum-signalling—which are rare. Well, you have already, by your reaction to his lecture, amply assured him of the interest which you have felt in what he has said and the appreciation with which you have followed it.

THE STEREOGRAPHIC SURVEY OF THE SHAKSGAM

Major Kenneth Mason, M.C., R.E., Survey of India

*Read at the Afternoon Meeting of the Society, 9 May 1927. Map
following p. 416.*

AT the afternoon meeting of the Society, on 13 April 1922, Mr. Hinks remarked that he had not come across any example of a stereographic survey on a scale smaller than 1 : 20,000, except that of a small area in the Cumberland Lake district by Lieut. F. V. Thompson, R.E., in 1907, on a scale of 1 : 63,360. This occasion was my introduction to stereographic survey, for I assisted Thompson both with the photography and with the subsequent plotting on his machine. Later, in India, I persuaded the Surveyor-General to obtain a Thompson Stereo-plotter, and in 1913 I took pairs of photographs during the course of geodetic triangulation on the Pamirs, and plotted them in the Thompson instrument on my return.

In both these small-scale surveys it was difficult to convince practical surveyors of the utility of the method. Stereoscopic accommodation is obtained by novices in varying degrees, and full accommodation—I include rapidity and ease—only comes with practice. Those with eyes of equal power will find stereoscopy easier than those with a powerful master eye, and those whose eye muscles have been developed by practice will find stereoscopy a pleasure. The practical surveyor, who has been brought up solely to use the planetable, and who cannot easily fuse a stereoscopic image, has always been sceptical. Those who believed in the method were dismissed as extravagant enthusiasts by the sceptics.

The result of this attitude has been that we, in England, have fallen behindhand in the development of photographic survey methods.

Though Thompson's instrument was admittedly very imperfect, its invention was a great step forward, and in the first British patent specification for the Von Orel Stereo-Autograph, Messrs. Zeiss referred to Thompson's paper in the *Geographical Journal*, and acknowledged their indebtedness to the inventor. Several automatic plotting machines are now on the market, all designed on the Continent. They have been evolved primarily for large-scale and technical surveys. In England, where the Air Survey Committee functions, reports have been collected on these Autographs and Cartographs, but their suitability for air survey, as against ground survey, has been the main consideration. Nevertheless, owing to modifications and great advances in design, the base conditions for stereoscopic survey, which were, owing to their limitations, the main cause of criticism in the earlier models, have become far less exacting. Both Mr. Hinks and I felt that the application of the method to reconnaissance and exploration work deserved consideration and experiment; and from my first mention of a wish to try stereoscopic survey in the Shaksgam, I enlisted the enthusiastic co-operation of the Secretary.

On 18 January last year, at an afternoon meeting of the Society, Major Hutchison and Mr. Hinks read papers describing the Wild Photo-theodolite. This was the instrument which the Council purchased after exhaustive inquiries to ascertain which of the various models on the market was most up to date. This photo-theodolite the Council kindly lent to me for the experiments, together with its accessories. Chemicals, developing outfit, Imperial Special Process plates, etc., were purchased for the Survey of India by the good offices of the Society, and the whole outfit reached me at Simla early in March last year.

This field equipment is designed for use with the Wild Autograph, which has been specially constructed to plot the photographic pairs rapidly and accurately. I am not going to attempt to describe this machine. I could not do so intelligibly without one to show you, however much I tried. I understand it myself, thanks to Mr. Hinks and Mr. Hunziker, and a very good and concise description of it will be published in the *Journal* by the former, together with this paper. I will here only say that though it is most complicated to describe and difficult to explain geometrically, it is comparatively simple to operate, extraordinarily compact, and magnificently designed and constructed. How all the moving parts fail to foul one another during the plotting is a never-ending source of amazement to me.

Before commencing to describe my Shaksgam work, I will answer at once the various questions raised at that afternoon meeting last year, in order to avoid mixing them up with details later. I will not describe again the photo-theodolite, for I cannot improve on the published account.

The first point is the accuracy of the theodolite. At Simla, before

starting, I tested my readings against those of a second observer. We often read the same second, and were never as much as four seconds apart. But the illuminating prisms should not be moved during a round of angles. At the close of the expedition, I took three or four rounds of angles to well-defined points and obtained practically identical readings, which never differed by more than 2.5 seconds. On the expedition itself, my observed points were often very ill defined, and I got larger differences, through no fault of the instrument.

I did not care for the specular illumination of the circles, and in reading the vertical angles, I always reflected light into the prisms with white paper. Mr. Wild is now adding white matt surfaces for reflecting the light. He is also considering the provision of a rack and pinion to insert the prism for reading the vertical circle. These improvements have already been incorporated in the larger model of theodolite.

Some doubt was expressed whether the complicated system of lenses and prisms would stand rough usage in the field. Either the instrument did not have sufficient rough usage to damage it, or it was capable of withstanding it. The sponge rubber cases supplied by the Society were excellent, and did not deteriorate, though I had to re-set them with rubber solution twice during the expedition.

The optical system was unaffected by dust or moisture. But it was not a severe test for the latter, for Ladakh is excessively dry and we had no fog or dew.

I found the collimating level a great boon. It kept in perfect adjustment and saved much time during the observations. The diagonal prisms for reading high elevations were also quite convenient, once one became used to reading the micrometer reversed.

The experimental electrical illumination for night work was not altogether satisfactory, being added at the last minute. Mr. Wild has already improved it.

In the dry climate of Ladakh, the wood of the tripod shrunk in the sockets, both near the head and at the feet. This was easily remedied by tightening up with the socket keys. We had some very high winds to contend with; the tripod was rigid enough for observations, though for safety I had to dismantle the theodolite on more than one occasion. I found that if I used the theodolite in a high wind without the camera in its place, it was not quite steady.

Colonel Jack doubted the method of fixing the theodolite with two quick-motion screws to the tribrach stage. These screws worked quite satisfactorily in practice. I found the omission of sights a drawback; but Mr. Wild has told us that he is now fixing them to his latest patterns. The milled heads are perhaps too much alike, but this is a minor point, and it did not offend me.

The only really serious drawback I found to the instrument was the limitation in elevation to 42° . This was inconvenient at times, for at

most of my photo-stations I wanted a sun azimuth to assist the computation for resection, and this meant that I must observe the sun before 9 a.m. or after 4 p.m. in those latitudes. I admit that the sun is best for azimuth before or after these hours, but at high altitudes beggars can't be choosers.

There are two points about the camera which I will mention: The objective is amazingly good. The plate-carriers were not light-tight. I had to use the utmost care not to touch the face of the carriers, and though I covered them with a velvet hood, kindly made for me by Mrs. Hinks, both on taking them from their box and during exposure, light filtered in sometimes. Mr. Wild has now designed a new pattern, which was recently tested satisfactorily in Switzerland by being exposed to sunshine for two hours. But for still greater safety, even this new design should be dulled.

I think I have answered all the points raised at last year's meeting. The photo-theodolite emerges from these tests very satisfactorily. The few criticisms are really very superficial matters compared with the beautiful design and workmanship, and with the many solid advantages which this type of instrument has over the old, both for accuracy and rapidity. For convenience of transport and rapidity of work at camera stations, I prefer to have the camera and theodolite both mounted on one tripod, and not separately, as has been suggested; and I can best sum up my own feelings on the subject by saying that I hope I shall never have to observe with an old-pattern theodolite again.

This is all rather a digression from the Shaksgam. But I must still explain that at no period did I intend to make a *complete* map by stereoscopy. I knew that the difficulties of transport and uncertainties of travel would prevent the possibility of a proper reconnaissance for camera stations, and as the whole method was experimental for this class of work, I preferred to rely for my general map on the planetable of Khan Sahib Afraz Gul Khan, which could be controlled by my triangulation with the photo-theodolite. Also I had no technical assistant, other than the Khan Sahib, in survey or photography, though Captain Cave learned to use the instrument during the expedition and was most helpful when available.

When we left for Kashmir I was personally convinced that the photo-theodolite was admirably suited to the experiments and that these had every chance of being successful, provided the previous triangulation on which I depended was sufficiently accurate for resection work. This triangulation was far from geodetic. It consisted almost entirely of reconnaissance and exploration points, generally snow peaks unmarked in any way, and often fixed from small bases by different observers. The test therefore was a severe one.

I will make three groups of our experiments. The first includes a number of photographs taken within the area of the planetable survey,

in order to form a comparison between the two methods. The second comprises a number of photographs taken from stations at the edges of our planetable survey, in order to test the value of the method for long-distance reconnaissance survey. And the third is a small series of photographs taken on the line of march through Nubra in Ladakh, without any control points identified for certain, to test the limitations of the method for the revision of old maps.

In these tests the bases were of various lengths up to about 900 metres, the smaller ones being measured with the subtense bar provided with the outfit, the larger ones being computed after resecting each end. In only one instance was the camera axis normal to the base, and on one occasion it was inclined as much as 50° to the normal. The camera was tilted downwards on two occasions, and at times the axes were convergent. The base was never horizontal, as much as 100 metres difference being measured between the two ends of one base. Both cameras were used, the focal lengths being 165 and 250 millimetres.

The views were taken across valleys, up and down valleys, in close and in open country, in order to find out what conditions were best. Camera stations, or one of them, were generally resected by the photo-theodolite, but in one or two cases I had to fall back on planetable resections. On these latter occasions the base was very carefully measured by the subtense bar.

I will mention a few points about the field work. Though the Wild Autograph will deal with, and actually did deal with, minor errors in the field, great care should be taken to level the theodolite carefully and to record correctly the various elements of inclination, tilt, and convergence. The Autograph finds out any errors and will correct them, but time is lost when setting, if this has to be done. In the field there was some difficulty in getting suitable camera stations and bases, but this was chiefly due, though perhaps not entirely, to the high altitude and my own lack of experience.

It is essential to use first-class plates and to take great care with the photography. The Imperial Special Process Plates left nothing to be desired, and were in every way excellent. But however perfect the plates, I am convinced, from previous experience, that where definition is essential, as it is in long-distance micro-stereophotography, the development of the plates must take place in the field. I am certain that after exposure to light even the best emulsions tend to deteriorate if development is delayed. I personally developed all my negatives in the field by the tank method as soon after exposure as possible.

I now come to the actual plotting of the results. The Government of India placed me on deputation to Switzerland for one month with Lieut.-Colonel Sackville Hamilton of the Survey of India. Mr. Hinks was deputed by the Council of the Royal Geographical Society to join us and study the working of the Autograph. Before leaving for Switzer-

land, Mr. Hinks and I collected all our data in what we considered the most suitable form, the former kindly converting my spherical co-ordinates to rectangular.

There are at present five Wild Autographs in commission in Switzerland, two being at Dr. Helbling's Topographical Institute at Flums. Dr. Helbling very kindly allowed us the use of one of these for one month, and placed the services of Mr. Guido Hunziker, his chief engineer, at our disposal for that period. I wish here to acknowledge our very deep gratitude to these two gentlemen for all their courtesy and assistance. To enable us to plot our photographs, and at the same time to fulfil his own contracts, Dr. Helbling had to put double shifts on to his other Autograph—a practice which is always inconvenient and expensive. We also took up a lot of the time of Dr. Helbling and Mr. Hunziker, both of whom helped us in every possible way to master the intricacies of the instrument. The plotting itself was done by Mr. Hunziker and myself, taking turns at the Autograph.

We plotted three maps, one for each type of experiment. The accuracy test is on the scale of 1 : 50,000 ; the long-distance test is on a scale of 1 : 250,000 ; and the Nubra experiment 1 : 125,000.

I will now take each map separately. We selected the Kyagar glacier and neighbourhood for the first test, partly because we had more control points, and partly because we could combine more pairs of photographs, and therefore could test the junctions of pairs better. Here we had four camera stations, W₄, W₅, W₆, and W₇, on the ridge east of the Kyagar glacier, and on the bases W₅W₄, W₆W₄, W₆W₅, W₇W₅, and W₇W₆ we had five pairs of photographs taken with the small camera. My stations were resected from the Survey of India positions for Teram Kangri I., the Gasherbrums, and K₂, and one of my own less accurate points. The centre pair was controlled primarily on Teram Kangri I., and the adjacent pairs were set on points of detail derived from the first pair and checked on the trigonometrical control. The rest of the detail of these other pairs agreed most satisfactorily. On the left, Grant Peterkin's peak No. 27 coincided almost exactly with the Autograph position, and the height was correct within 20 feet. Colonel Wood's two points, 16¹ and 16², fell on the Karakoram crest-line, though, as they were not peaks but only points on the ridge, it is not possible to say whether they are absolutely exact. Teram Kangri III. agreed perfectly in the next pair to the right, and accurate positions of the other salient peaks of the range in the neighbourhood of these peaks have been obtained. These positions may be considered as trigonometrically correct. On the extreme right of the series of photographs there was a difference of about 50 metres on the ground at a distance of about 10 miles, between the position of a point plotted on this scale and series, and the position derived from another pair of photographs, taken with the large camera and set on K₂ and the Gasherbrums, between 30 and 42 miles away,

plotted on the scale of 1 : 250,000. This is only 0·2 millimetre on the latter scale.

In Mr. Hinks' description of the Autograph, he describes the various gears of the instrument, by which the different ranges of plotting are obtained. For this series we used the gears 1 : 1 for the distance and 3 : 1 for the foreground. One could of course only generalize the contouring of the Kyagar glacier. Mr. Hunziker and I spent a happy and interesting afternoon with the Autograph index traversing the glacier, and I am more than ever prepared to take off my hat to the first person who succeeds in crossing it on foot. The best chance appears to me to be between the glacier and the marble cliffs, but it would mean probably at least three days' hard work with the axe to cut a track for climbers, and one may even then be held up by lakes. The snout here is about 2 miles across. Further up the glacier there are too many lakes and crevasses, to say nothing of the great ice pinnacles themselves, to render any passage practicable in its present condition, unless the eastern moraine is followed. This last leads to the eastern of the two Karakoram spurs, and from here a crossing appears to be practicable to the western promontory without excessive difficulty. But from this point the big glacier from Teram Kangri is a decided obstacle and much crevassed, though the pinnacles here are not more than 20 feet high. The western moraine does not look difficult, but it certainly will be most exhausting. The western side glaciers form obstacles, but by keeping to the main moraine for some way, the ends of these side glaciers can be passed. I think the whole passage by this route would take four or five days of strenuous work, and I recommend any one desirous of crossing to study the photographs in the stereoscope first.

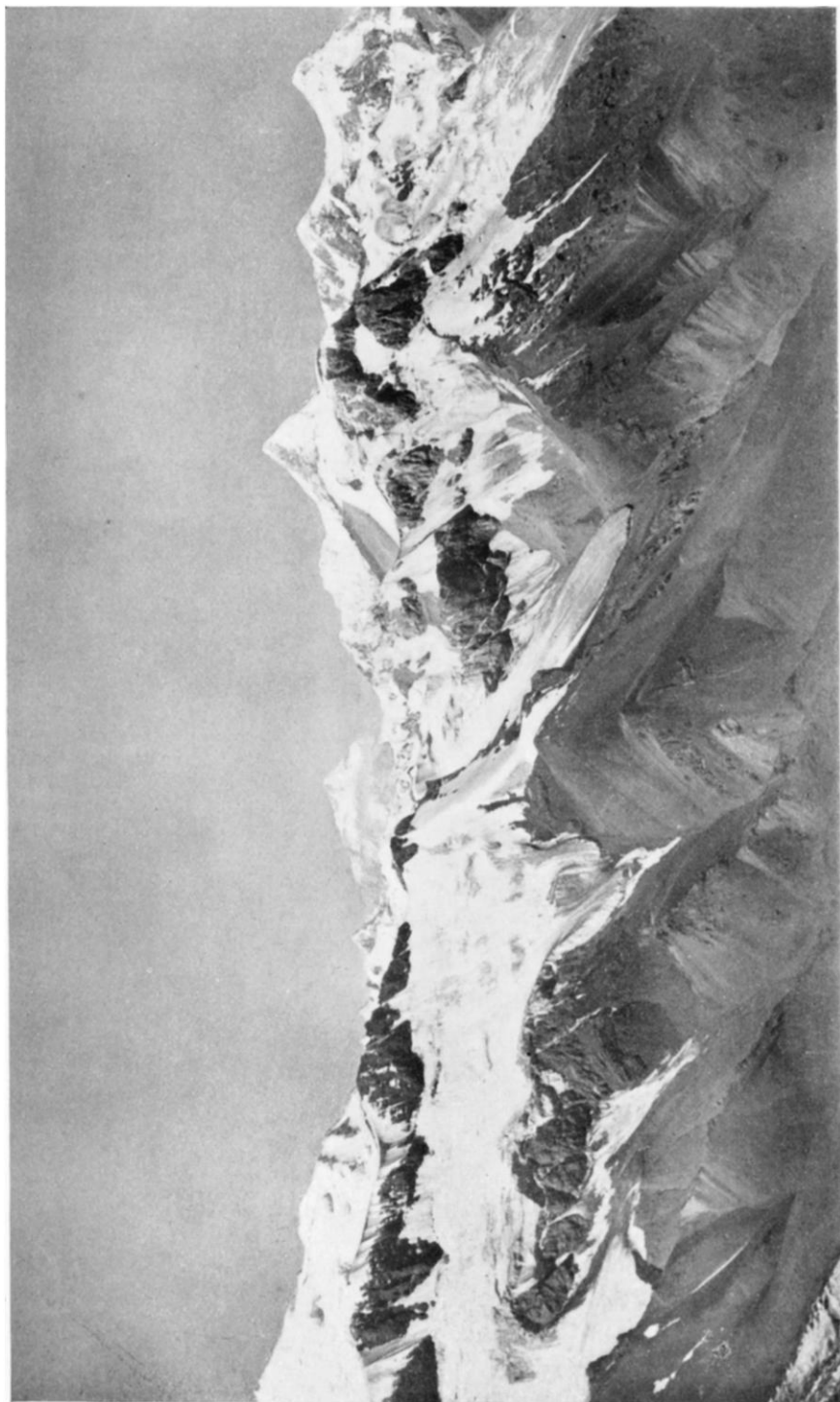
The Autograph came out very satisfactorily from this test. The second experiment deals with the distant plotting. The longest base I could get for photographing K_2 stereoscopically was about 900 metres. Even with a base of this length, Gasherbrum I. was almost lost behind the foreground of the left-hand view. K_2 is 42 miles away from here, "Broad Peak" 37, and Gasherbrum II. 33 miles. That is to say, neglecting the inclination of the camera axes to the normal, the ratios of base to distance were 1 : 84, 1 : 74, 1 : 66 for these peaks. With this base, 2935·5 feet, to be exact, with the large camera, and with a measured convergence, we were able to plot the detail and the 250-foot contours of K_2 and the nearer peaks without much difficulty.

Combining my right-hand photograph here with another at W5, *i.e.* using a shorter base, 1054·1 feet, the ratios were reduced to 1 : 210, 1 : 185, 1 : 165, while Gasherbrum I. appeared now with a ratio 1 : 150. Though it was still possible to plot the summit of K_2 within a quarter of a mile, it was no longer possible to plot the detail either here or in the neighbourhood of the "Broad Peak." As however more detail could now be combined stereoscopically near the Gasherbrums, an attempt

Gasherbrum I.,
26,470 Gasherbrum II., Broad Peak,
26,360 K₂,
28,250



*Across the Kyagar Glacier and down the Shaksgam Valley
From Station W4. Focal length 165 mm. Camera axis depressed 6 grades. Compare plate 4, 'G. J.', 69, p. 301, taken with focal
length 250 mm. axis horizontal*



Aghill Ranges and Gasherbrum I. from the Tatar La

was made to plot the contours also. It was found that they could only be plotted with extreme care, by joining up successive plotted points of the same height. I would therefore suggest that the ratio 1 : 165 is about the limiting effective ratio for the automatic plotting of detail.

In this series the heights of Gasherbrum I. and II. and of K_2 agreed within a few feet of the triangulated heights, after setting the Autograph height drum correctly for the Station heights and allowing for curvature and refraction. But Broad Peak appears in the Autograph to be only 26,400 feet in height, and not 27,132, as found by the Duke of the Abruzzi. If this peak had been at the edge of the plate, I would have given it the benefit of the doubt and assumed that either the instrument or I was at fault. But when controlled on both sides by such well-triangulated points as K_2 and the Gasherbrums for distance, direction, and height, an error of the Autograph is not possible. The height was checked at once by Mr. Hunziker, and we are convinced that this height, 26,400 feet, is correct within 50 feet, relative to K_2 .

The other points of interest in this series are these. We were able to plot some of the great northern spurs of the Karakoram Range that enclose the Urdok and Gasherbrum glaciers. Neither the naked eye, nor the planetable, nor the Canadian method of photogrammetry could have found any detail whatever of these ridges, or could have even discovered their existence. They are rock and snow ridges against a background of snow and rock, and nothing but stereoscopy could hope to separate them or recognize individual points. In the Autograph these ridges stand out in wonderful relief and are easily plottable, thanks to the excellence of the objective and of the plates. I do not think that any of us quite believed that the Autograph would pick out these details, and Mr. Wild himself was certainly more than sceptical until he saw the diapositives in his stereoscope.

In this series we have also determined the positions of the snouts of two more glaciers beyond the Kyagar, and have plotted the bed of the Shaksgam far below any point we could see with the naked eye or without the magnification afforded by the Autograph. This point cannot have been more than a short distance from the spot reached by Sir Francis Younghusband, and must have been easily visible to him.

From the photographs taken from the Tatar La, we were able to contour the northern faces of K_2 and Gasherbrum I., and to obtain additional information in their neighbourhood. The detail joined up quite satisfactorily with that plotted from the Kyagar stations.

Another pair of photographs of this small-scale series is interesting. It was taken down the Sa Lungpa gorge, and at the time we were unable to identify for certain the distant peaks. We called them collectively "the Gasherbrums," but did not know which summits were concerned. After plotting the detail from the Kyagar stations we were able to identify the peaks in the Sa Lungpa pair, simply because four peaks fell on the

plotted points and the heights agreed very well *inter se*. The three Gasherbrums concerned were II., III., IV. The Autograph was now controlled on these three peaks with the 1 : 1 gear ; the gears were changed to 3 : 1, and a good deal of extra detail was plotted along the peaks of the " Red Wall." We were, however, not able to trace the intricacies of the bottom of the Sa Lungpa gorges.

I must draw attention here to the correction necessary for refraction and curvature. The Autograph will not allow for this automatically. Mr. Hinks therefore worked out a curve for the necessary corrections, and Mr. Hunziker kindly converted this to a scale. This scale was used for the plotting of individual heights, and great accuracy was obtained with it. When setting the height drum for the plotting of contours, it was found quite accurate enough to divide the area into distance zones, each with a separate correction. With a little practice, this method of correction became quite rapid.

I will now turn to the last series. On my return through Nubra, the Khan Sahib's survey was closed at Panamik. We then marched towards Leh, and it occurred to me that I might improve the existing map by photography. The map is very much out of date, badly controlled by very few triangulated points, and the hills are very weakly and inadequately shown by hachures. I took four pairs of photographs on a long day's march near the Nubra-Shyok junction, noting only one doubtful triangulated point in all the four pairs and without being able to resect my camera stations. At each of these I observed a round of angles with the theodolite, including my base, the camera axis, the doubtful point, and other unknown points in the views. The result was quite satisfactory, and the Autograph map will on reduction fit over the existing map and greatly improve it.

I must admit that the success of all three experiments far surpassed my anticipations. I fully expected that with my very imperfect knowledge of the instruments before starting, something would go wrong. I made a certain number of mistakes through inexperience as it was, but the Autograph always found me out. On one occasion the camera trunnion was not correctly seated in its support. The error was made evident by a very bad " Vertical Parallax " in the Autograph. Mr. Hunziker worked out the various corrections for tilt, convergence, and base length, resetting the pair on its control points, and it was plotted quite satisfactorily.

I made one error in the identification of a control point. The Autograph immediately found me out, and the pair was plotted from controls obtained from its neighbour assisted by theodolite angles.

I made an error in setting the camera at the right-hand station, so that the control points were shown in the Autograph nearly twice as far from the base centre as they should have been. My base length I knew was correct, for another pair taken with the large camera from it had

plotted well, and there was no vertical parallax. This indicated an error in convergence and not in tilt. An arbitrary convergence correction was applied to bring the control points correct, and the whole pair plotted perfectly and joined up well with the surrounding detail.

I will now mention two additional tests that we made with the Autograph. We found that if we intersected a distant point with each eye separately in the stereoscope, and then examined the point stereoscopically with both eyes together, the index appeared sometimes just behind and sometimes just in front of the point. This indicates that however much one tries to intersect an ill-defined point separately, as, for instance, by planetabling or by the Canadian method of intersections, one does not do so; whereas if one makes use of stereoscopic fusion, the simultaneity of the operation ensures exactness of identification, and therefore enables intersection at larger distances for short bases, with much less possibility of error.

The other test was this: We found that we were able to combine in the Autograph a photograph taken with the smaller camera (focal length 165 mm.), at the right-hand station and depressed 6 grades, with another photograph taken at a left-hand station with the large camera (focal length 250 mm.), with the axis horizontal. We obtained perfect stereoscopic accommodation. I may add that there was no combination of photographs that we put into the machine that we failed to plot.

The experiments bring out certain points about the field work that are probably well known to those who are using the method regularly, but which I had no means of knowing beforehand. The most ideal conditions for field work may be summed up as follows:

- (a) Stations should be higher than the ground surveyed.
- (b) Camera axes should be depressed, in order to prevent too much dead ground.
- (c) Camera axes should be inclined not more than 30° to the normal to the base, to get full advantage of the base length.
- (d) The ratio of base to distance should be if possible between 1 : 10 and 1 : 30; but it is still *quite easy* to plot, if these are extended 1 : 6 to 1 : 60; and it is still *possible*, if the ratio is decreased to 1 : 160.
- (e) Photographs taken across valleys are to be preferred to those taken up or down valleys. The former will have a more limited field of view, but will be far more complete than the latter, which will however be suitable if the method is only required for fixing additional control points.
- (f) For contouring the flat bottoms of valleys, stations should be sited as high as possible, and the camera tilted down as much as possible. If low stations only are available, details of roads, etc., are apt to be obscured by trees, and the tracing of contours also becomes less exact, owing to grazing rays of observation.

(g) It is important that shadows should not be too heavy, and they should be approximately the same in the right- and left-hand views. Otherwise stereoscopic relief is not easy. For the same reason, dense featureless snow slopes on the negative are difficult to plot where the sun blazes on them and obliterates detail. Where in nature dense white slopes are combined with heavy dark rocks, it might be advisable to take two pairs of photographs with different exposures.

The success of all these experiments exceeded our expectations. This is no doubt partly because of the climate and atmosphere of the Aghil ranges ; but there is no doubt that it is mainly due to the excellence of the design of both the field and the office apparatus. At the same time I cannot close my paper without saying that the accuracy of Colonel Montgomerie's triangulation of the great peaks seventy years ago enabled us to prove the value of this new method to-day.

Before the paper the CHAIRMAN (Colonel Sir CHARLES CLOSE) said : There are not very many more interesting developments in the survey world than that of stereophoto surveying. Major Mason, as we all know, has been out to the Shaksgam country and has there had a great opportunity, of which he has taken full advantage, to test this method, and he has recently been to Switzerland to make use of Wild's machine for the automatic plotting of his maps. He is now to tell us all about it, and I think that we shall all find that we have something to learn, and that the method is likely to be the starting-point of a new system of survey. With those few remarks I will ask Major Mason to read his paper.

Major Mason then read the paper printed above, and a discussion followed.

The CHAIRMAN : We are anxious to have a full discussion of this communication. I will ask Colonel Sackville Hamilton, who was in Switzerland with Major Mason, to speak first.

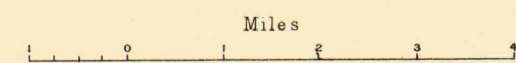
Lieut.-Col. SACKVILLE HAMILTON (Survey of India) : I am disappointed not to hear Mr. Hinks give his description of the instrument, as I had the good fortune to be with him in Switzerland. I can assure you the instrument is extraordinarily good. I went to Flums prepared to be sceptical, but I have been much converted so far as ground survey is concerned. The thing that struck me most was the fact that Major Mason was able to contour K_2 at a distance of 42 miles. That, he has admitted, is due first of all to the excellence of the Wild objectives and of the Imperial plates. But I think we ought also to pay a tribute to the accuracy which Major Mason himself must have brought to his work. Future users of the method must not think that they are going to be able to do photogrammetric survey at 40 miles' range, because they cannot. A great deal of the success achieved is due to the wonderful clearness of the atmosphere in the Karakoram, where Major Mason has been working. You cannot expect that in other places. Personally, I am of opinion that 10 to 12 miles is the most we may expect.

While we are on this subject I think it would be interesting to discuss costs. It ought to be realized that this method is a going concern in Switzerland. There are two firms, Dr. Helbling's at Flums and another at Berne, turning out work by this method. Dr. Helbling has work in South America on the



STEREOGRAPHIC SURVEY
of
NUBRA-SHYOK JUNCTION

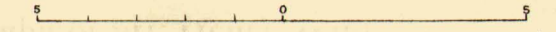
Mapped from two camera stations, I and II, with four pairs of photographs only, taken just off the line of march. No control points identified for certain. Scale 1/125,000. Contour interval 250 feet.



STEREOGRAPHIC SURVEY
of the
SHAKSGAM

Mapped from pairs of photographs taken from W4-W5, W4-W7, W10-W11 and W15-W16. Scale 1/250,000. Contour interval 500 feet.

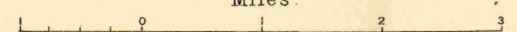
Miles.



STEREOGRAPHIC SURVEY
of the
KYAGAR GLACIER

Mapped from six pairs of photographs taken from four camera stations W4-W7 on one day. Scale 1/50,000. Contour interval 250 feet. Primary control Teram Kangri I. Reduced to 1/100,000 for publication.

Miles.



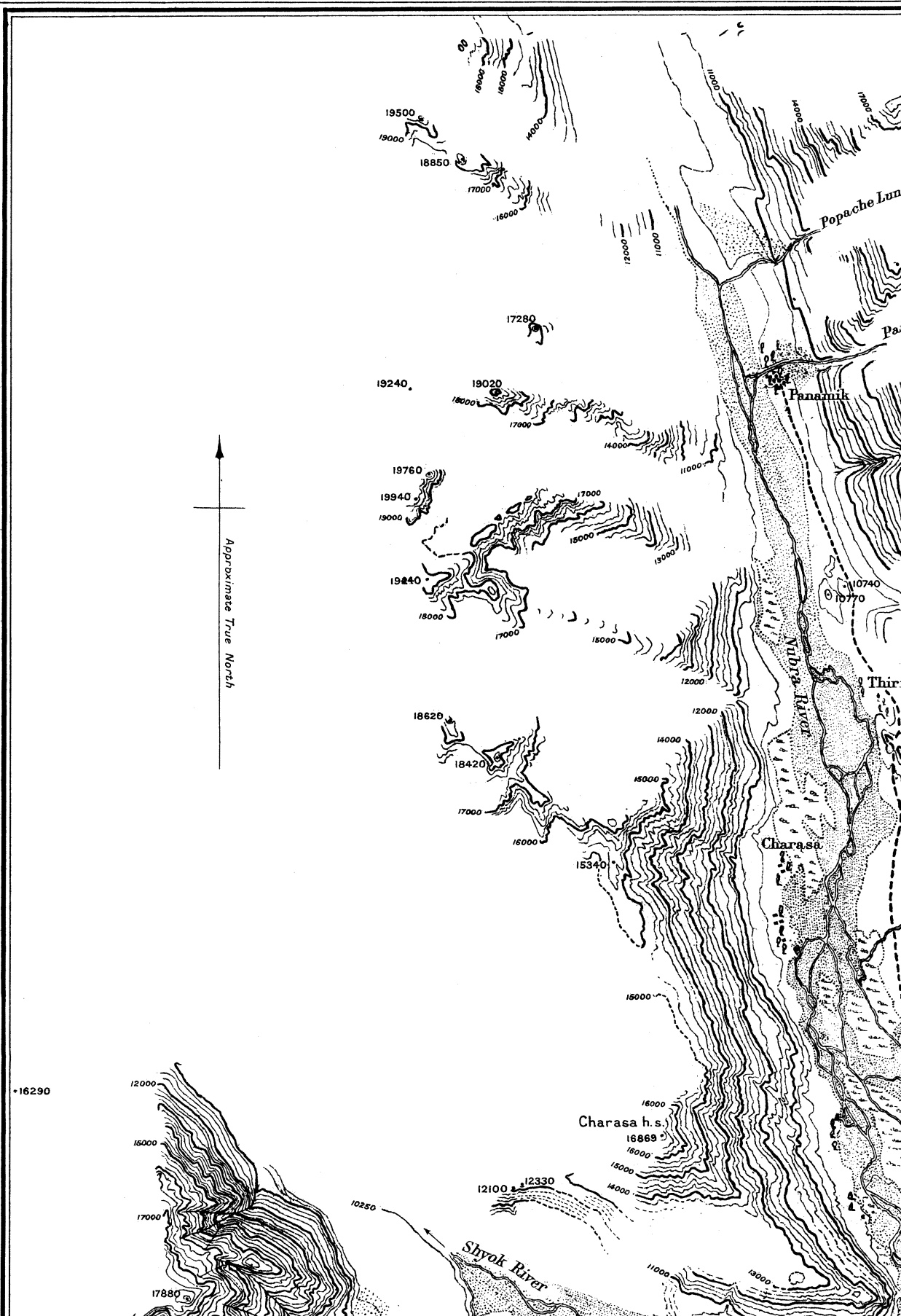
STEREOGRAPHIC SURVEY
OF THE
SHAKSGAM

with the Photo-Theodolite and
Autograph of Mr. Henry Wild

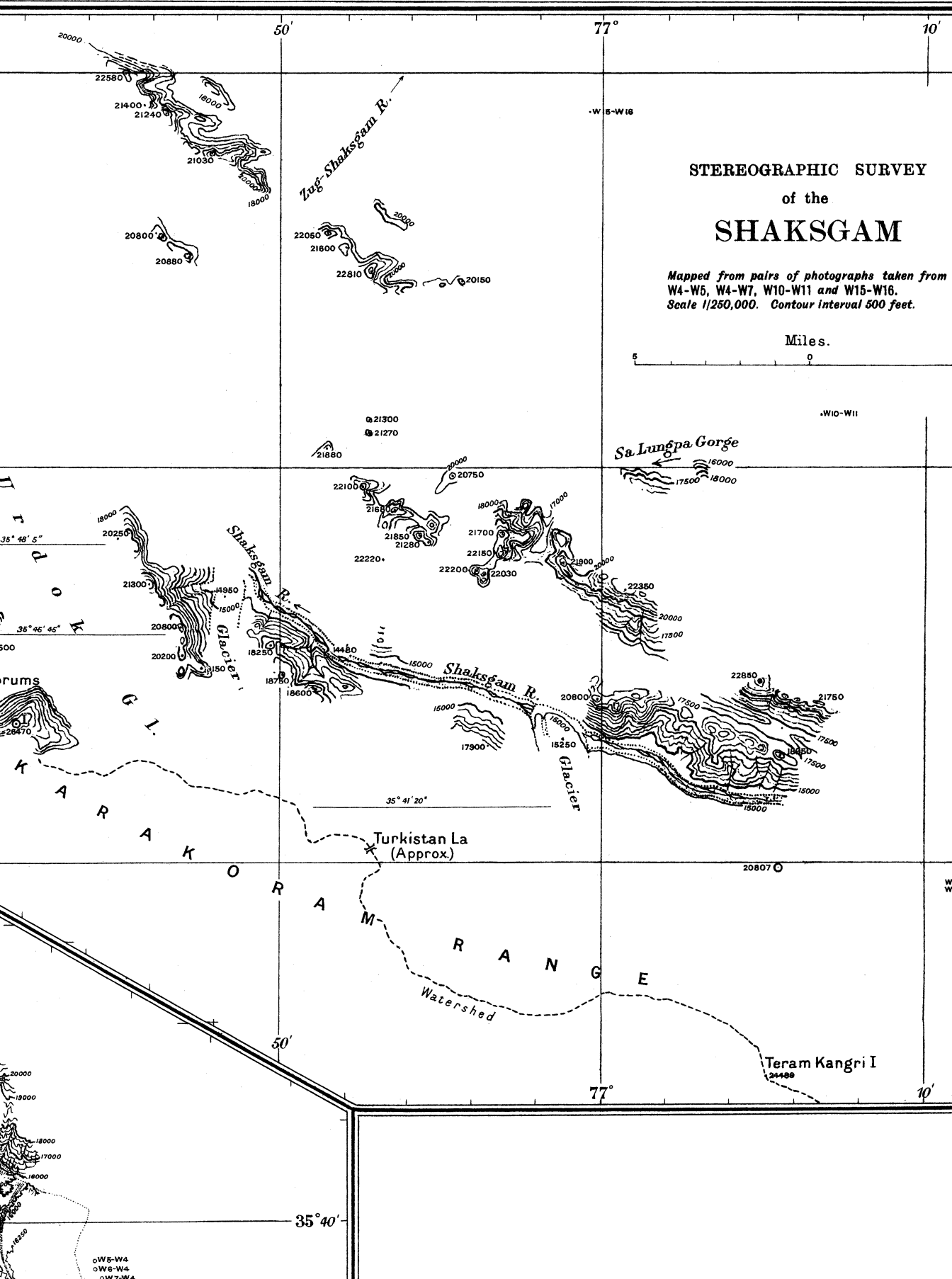
by

MAJOR KENNETH MASON, M.C., R.E.

Survey of India



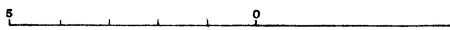




STEREOGRAPHIC SURVEY
of the
SHAKSGAM

Mapped from pairs of photographs taken from
W4-W6, W4-W7, W10-W11 and W15-W16.
Scale 1/250,000. Contour interval 500 feet.

Miles.



Zug-Shaksgam R.

Sa Lungpa Gorge

Shaksgam R.
Glacier

Shaksgam R.

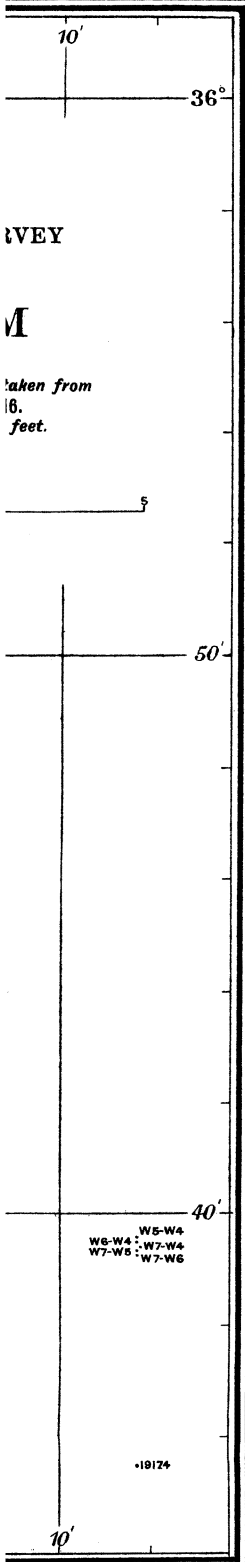
Glacier

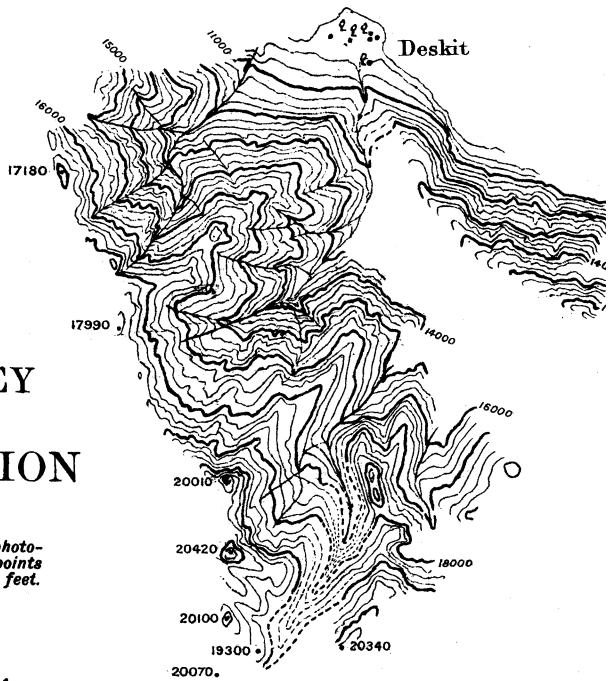
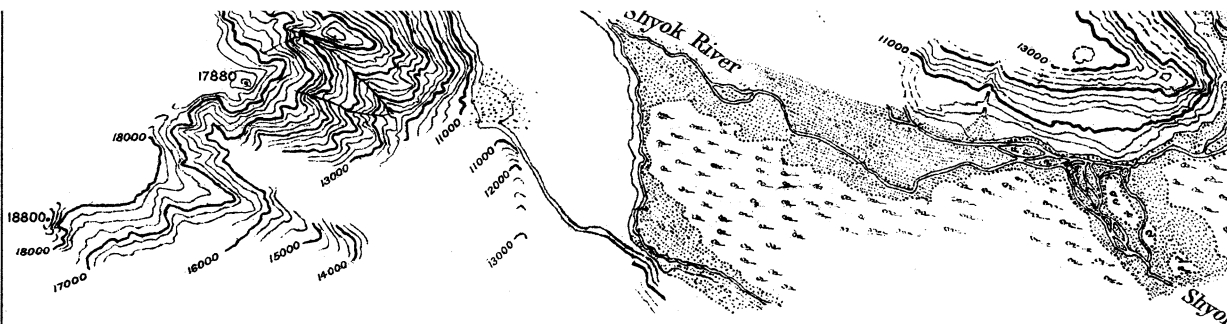
Turkistan La
(Approx.)

Watershed

Teram Kangri I
24498

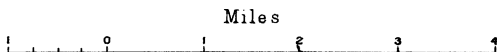
W5-W4
W6-W4
W7-W4

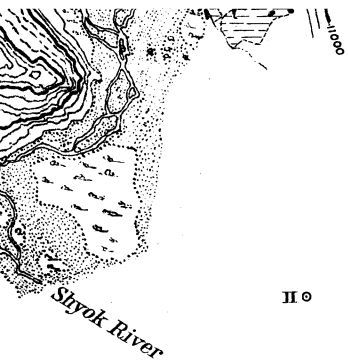




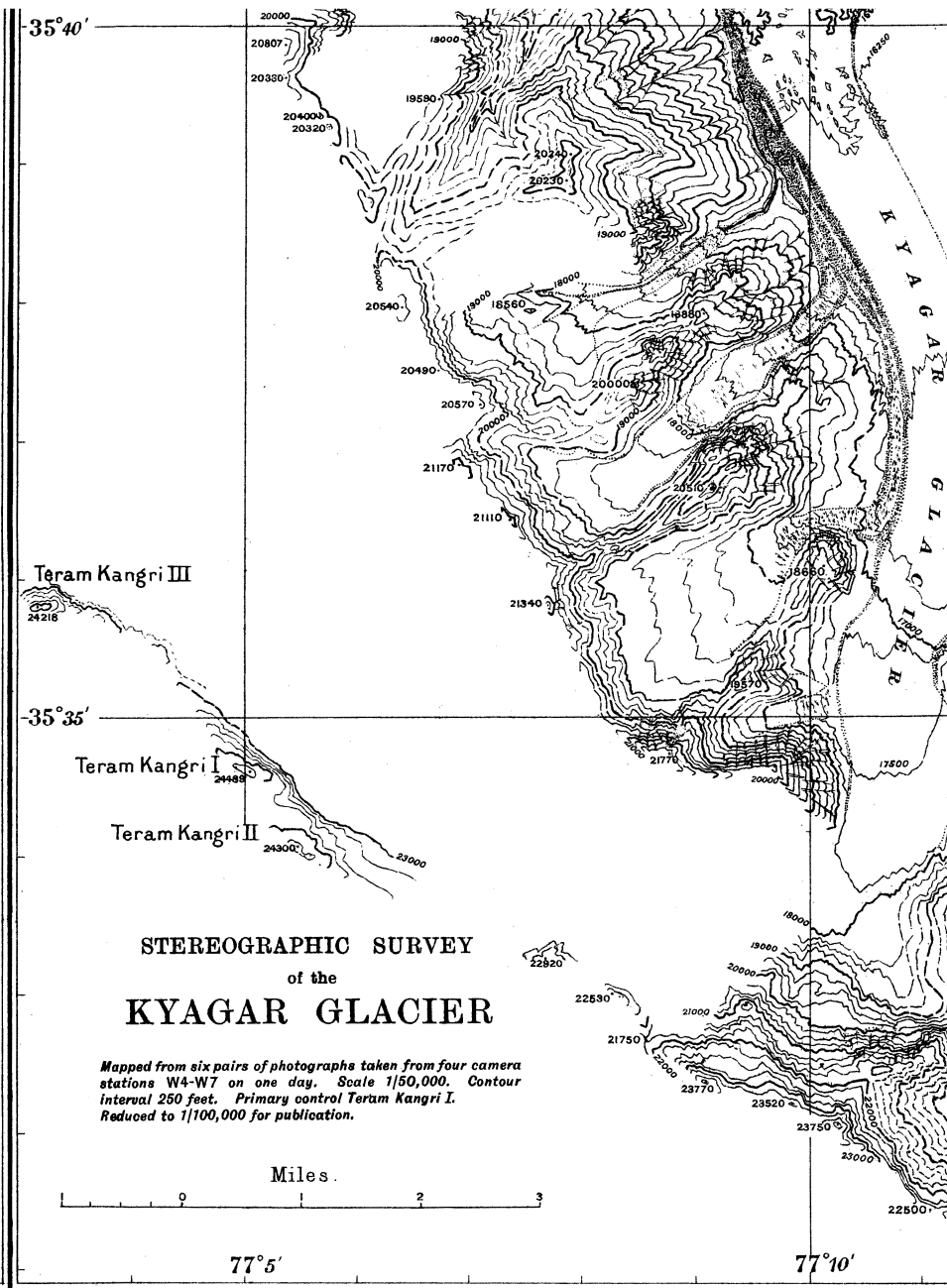
STEREOGRAPHIC SURVEY
of
NUBRA-SHYOK JUNCTION

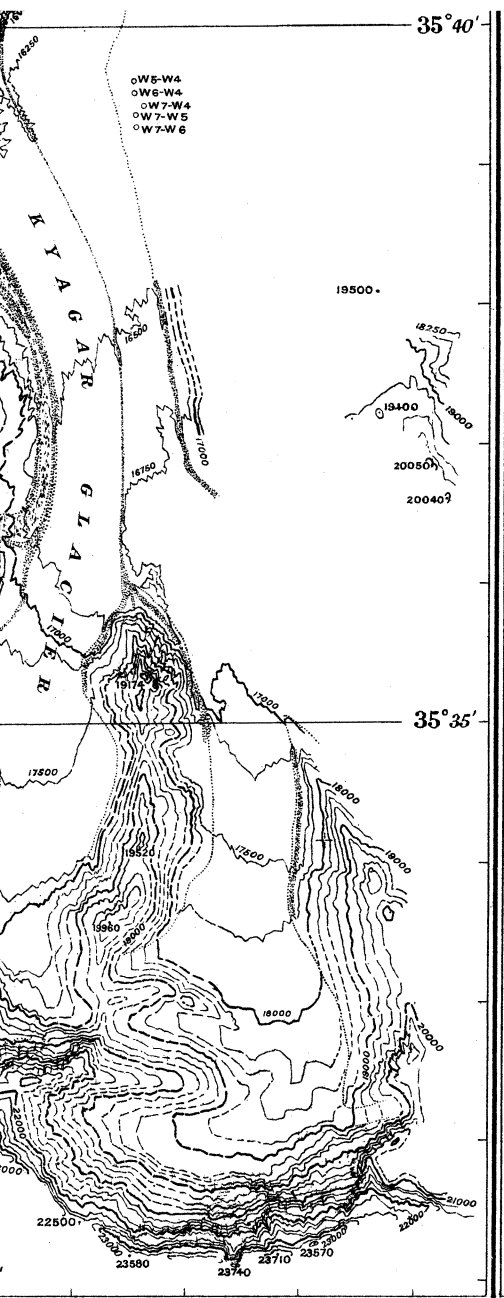
Mapped from two camera stations, I and II, with four pairs of photographs only, taken just off the line of march. No control points identified for certain. Scale 1/125,000. Contour interval 250 feet.





II O





STEREOGRAPHIC SURVEY

OF THE

SHAKSGAM

with the Photo-Theodolite and
Autograph of Mr. Henry Wild

by

MAJOR KENNETH MASON, M.C., R.I.

Survey of India

SHAKSGAM: Stereographic Survey
Mason

VEY

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Cordillera Railway, and has also contracted for work in Asia Minor for railway concessions. The machine is also doing other large-scale work, and remember for the present it is really a large-scale instrument. As regards costs, I discussed these with Dr. Helbling before I left Flums, but it is extremely difficult to give any accurate figures. It depends so much on the actual negatives, what detail is required, the area covered, and so on. The autograph costs in Switzerland £2800. When I asked Dr. Helbling as to rates for work which we ourselves might wish to send him, he told me that the use of the Autograph, including the pay of the two operators and overhead charges, would be 300 Swiss francs per day; that is, provided all the data be given to them already worked out in rectangular coordinates, heights in metres and angles in grades, and work can be commenced with the machine without increased labour for their computing staff. Given that, Dr. Helbling estimated in respect to ground survey only, assuming that the greater portion of each of the pairs of negatives contained useful detail which was required to be plotted, that in an eight-hour day they could plot five pairs per day on the scale of 1/20,000; four pairs on the scale of 1/50,000; three pairs on scales of 1/100,000 to 1/150,000; two on 1/200,000; and one pair on the scale of 1/250,000. That, of course, is a rough estimate: it might be more and it might be less.

The number of pairs of photographs given as being plotted in one eight-hour day is the maximum number for each particular scale that can be set and adjusted and fully exploited in the machine in that time. Nothing has so far been done with this Autograph on photographs taken from the air, but it is readily and easily adjustable to this interpretation.

Col. C. H. D. RYDER: I personally must honestly admit that I am a dreadful conservative. In connection with Col. Hamilton's remarks as to costs, what we really want to know is the cost of the instrument, of the intelligent and practical surveyor who is going to work it, the people who are going to make the result into maps; and then we have got to compare that with the cost of other methods. In India we all swear by the planetable. We have very cheap and good surveyors who do a lot of planetabling. There are of course, as one finds from an expedition to the Shaksgam, certain areas which it would be practically impossible to get at with a planetable. Nevertheless, I think that the planetable will remain supreme for the greater part of explorers' work; and that this sort of instrument or photography of some kind should really be looked on as a supplement to regular survey work, that is, as regards the photographic part. I was very glad to hear Major Mason say that the theodolite part of the instrument was first-class, and his certificate that he would sooner use that than any ordinary theodolite is a distinct recommendation in favour of the instrument as a theodolite. Major Mason is an enthusiast on the subject, and he has given us a very interesting description of the instrument. I know the method is in its infancy, but Mr. Hinks, Major Mason, and Col. Hamilton all went over to Switzerland and all spent a month either learning or improving their knowledge and working up a map. Well, those are three very able gentlemen, and one wonders whether, taking into account the amount of intelligence used and the value of their brains, we could attain equally good results with the ordinary old wooden planetable, except in those exceptional cases where you cannot get near the object.

Col. E. M. JACK (Ordnance Survey): Major Mason has answered a number of queries raised in regard to the photo-theodolite last year, but there is one point that was raised, I think at the discussion or afterwards, that he will perhaps give his opinion on, and that was the question whether it was really sound to

combine the theodolite with the camera in one mounting. I know that the opinion was expressed that it was unsound; that it was better to have the theodolite entirely separate from the camera. Major Mason has had a good deal of experience now, and I should rather gather that he has found no disadvantage. In the experiments that were carried out I think we have to remember, as Col. Hamilton said, that the atmosphere was extraordinarily clear and also that the whole of that country is, apparently, rock, snow, and ice. I wonder what the effect would be in a country where the atmosphere was less clear? Would there be merely a limitation of vision so that you could not work at such a great distance, or would there be any other effect? Also, what would be the result of attempting this method in country covered with forest? About the cost of the method, I think Col. Hamilton and Col. Ryder have both rather anticipated me. We of course must know more what the costs are, and we have got to come down to hard facts. We must know what would be the cost of this method per square mile as compared with other methods. Although this method is, for survey on small scales, in its infancy, I think surveyors while being conservative should at the same time be enterprising and entertain all possibilities. We have been shown quite clearly that there are most extraordinary possibilities in this method, and while at present I quite agree with Col. Ryder that it must be auxiliary to our old methods, we may find, of course, eventually that it will supplant the older methods, and I think we must be prepared to accept that. Otherwise I have only to say that it seems to me quite extraordinary that Major Mason has obtained the results he has with these very small bases; it is quite a remarkable thing. That he has such wonderful results is, I believe, partly due to the clearness of the atmosphere, but cannot be put down wholly to that. I should like to congratulate him very much on a most interesting paper which I have enjoyed immensely.

Mr. HOTINE (Geographical Section, General Staff): I have little to say beyond adding my thanks to Major Mason for his paper. I do not think there can be much doubt as to the value of the Wild Autograph in large or possibly medium scale photographic surveys from ground stations. It has also been designed to allow of its use for air photographs; but there it has yet to be proved. In dealing with air photographs, what Major Mason referred to as his mistakes are the rule rather than the exception, and it was illuminating to hear his remarks on the subject of trial and error setting in the few cases where he did make mistakes. Major Mason remarked that the rectification of his mistakes was helped on by the observation of what he called "height parallax." That is a literal translation from the German of a property known to us as "want of correspondence," and it is the only indication by which we can, without a dense ground control, rectify the "mistakes" occurring in air photographs. Unfortunately, the particular movements of the Wild machine are not entirely suitable for correspondence setting. So far only one machine has been designed which introduces movements suitable for this purpose, and that is not yet in the experimental stage.

Col. H. L. CROSTHWAIT: I am afraid I have not had any experience of this kind of surveying, but there are one or two points I should like to ask Major Mason. All the photographs he has shown us have been of mountainous country. It does not seem to me that you could apply this system to any but hilly ground. Col. Hamilton raised the question of cost. Has the cost rate per square mile been worked out? You might have a pair of photographs that had a great deal of ground in them; you might have a pair with a lot of

dead ground which would have to be gone over by the ordinary planetabbling methods in order to fill it up. Perhaps the system has not gone far enough to enable us to estimate what the cost per square mile would be on an average. I should like to congratulate Major Mason on his paper, which I think has been very interesting to all present.

Mr. HINKS : I have been described to-day as an enthusiast, and therefore you will allow me to express, without shame, my great enthusiasm for the results of the experiment that Major Mason has made. He has told you how we had been in correspondence for a long time before the Shaksgam expedition started. I was partly responsible for reporting to the Council upon the desirability of doing what Major Mason asked : " Can you, if you are going to make a contribution to my expedition, provide me with the instruments for stereo-survey ? " I think almost everybody who has heard the paper this afternoon will be very glad that the Council were able to do that, and will congratulate Major Mason upon the striking success of the experiment. Unfortunately, at present there is not in this country any machine that can deal with the stereoplotting of the beautiful pictures that Major Mason has taken, and therefore we had to arrange to work them up upon the Autograph. I was not at Flums for the whole month. I left England on April 6, and found Col. Hamilton and Major Mason well established at Ragaz, near by. They had kindly saved up one or two rather troublesome little problems to occupy me on my arrival, one of them being how we were going to correct these pictures at a distance of 60 or 70 kilometres for the curvature of the Earth and refraction. At a distance of 70 kilometres the correction to the measured height of K_2 referred to the base station ran up to something between 300 and 400 metres. A thousand feet had to be added to the measured height of K_2 to allow for the combined effect of refraction and curvature. One might have expected that there would be some difficulty in deciding upon the coefficient of refraction to be used. I think we made a happy and fortunate shot, for we were able to establish a table of corrections at this great distance which, as it proved, worked very well. The first time we tried it we determined the height of K_2 , which came out at the triangulated height within 1 metre ! Of course, that would not happen every time. It is what happened on that occasion, and it much cheered us up.

I never had a more difficult task set me than to write an intelligible description of the maze of complicated movements in the Autograph, to get the geometry of it all clear, and to show how the thing worked in all the various cases of inclined and convergent plates. The genius of Mr. Wild has succeeded in getting into a very compact space an instrument that will deal with all those various complications. I cannot think anybody would welcome an attempt to describe the mechanism this afternoon, especially the device of the double cam which is unique in Mr. Wild's instrument and is, as far as I know, understood by Mr. Wild himself and by nobody else. We have got some way towards understanding it, but when I tell you that the double-cam motion has to give motions to the plate which are comprehended in two trigonometrical expressions, one of which involves the square root of the product of a sine and a tangent, you will see that the mechanism of that motion requires a little care. I will not attempt to describe the instrument, but will ask those who are impatient to know about it to exercise their patience and wait until the description is published in the *Journal*.

Before going on to deal with one or two points, I should like to associate myself with Major Mason in expressing our most sincere gratitude to Dr.

Helbling, who, in the midst of his very important and also very lucrative work for the railway companies, considerably disorganized his establishment in order, out of a real scientific interest, to make these experiments in survey upon a scale totally different from what he had ever worked on before. We are indebted equally to Mr. Hunziker, his chief engineer, as well, of course, as to Mr. Wild in the first instance.

I do not think that Major Mason, perhaps, quite sufficiently emphasized the fact that this was the first experiment made with these instruments upon geographical scales. They normally work upon the scale of $1/2,000$, and then make a combined reduced sheet upon the scale of $1/20,000$, as you see on the Argentine Railway surveys. Being geographers, we were not so much interested in scales of $1/2000$ or $1/20,000$, but in scales of something like $1/200,000$, and it is that work upon the small scales that has been so successfully accomplished though never tried before, so that the method is justified as a geographical and not a purely engineering method.

But one must not forget that there are certain things that geographers will want to be done upon those larger scales. When I first talked about the uses of this instrument I suggested that it would be extraordinarily interesting and important to survey very carefully certain areas that were liable to considerable denudation, such as Wastwater screes and Striding Edge on Helvellyn, and to establish now, correct within a few inches, a contoured map, so that it can be compared in one hundred years' time in order to see what has happened in the way of denudation. A similar question which could be most readily studied by the use of these machines would be to measure the changing volume of glaciers. It would be easy to contour glaciers, or to make a sort of integrator attached to the instrument and to measure the difference of volume from one year to another. An accurate estimate of the volumes of glaciers in India would be not only of scientific interest to India but, more important, of real, almost commercial interest, because it would indicate how fast the storage of water is changing.

We have heard a most interesting account from Col. Sackville Hamilton of an estimate of the costs, not of course in exactly the form in which a Surveyor-General would require to look at it. I take it—and this point Major Mason did not mention—that the Swiss Federal Topographical Survey having decided to re-survey the whole of Switzerland by this method shows that the costs are, at any rate, well within the power of such surveys to meet, and that they consider the expense well justified.

In particular reference to something Col. Ryder has said I would, with some strength, repudiate the suggestion that probably the amount of work represented in those three sheets was not worth the time of two senior officers of the Survey of India and one amateur enthusiast. It seemed to me a grossly unfair comparison. After all, when you are proposing to take up a new method it is presumably worth while for the Director of the Survey or some of his senior officers and advisers to devote a part of their time to studying the method in its inception and to discover whether or not it is worthy of adoption. The value of the time spent in preliminary experiments is surely not to be charged to the cost of the first results. But whether or not the method is economical for a regular survey I do not think matters to this Society. I would suggest that there are possibilities to geographers which are of inestimable value: the possibility of being able to secure material in rare circumstances in the course of a few days, such as on the expedition in the Shaksgam, to which you can devote as much labour as you like when the results have been success-

fully brought back to this country. Therefore any arguments as to whether it is worth while to adopt this method on the Ordnance Survey or the Survey of India for ordinary work has very little relevance in the case of us geographers, because the result you can obtain by seizing a rare opportunity may be quite inestimable. It would be undoubtedly expensive to introduce this machine into the country; but I believe the results Major Mason has shown you make you, or at any rate many of you, hope that some means may be found by which we shall be able to get the necessary number of thousands of pounds to establish one of the Wild Autographs here in the Society, and to undertake to work up plates contributed by geographical expeditions in distant parts of the world.

Major MASON: The first point is one which Col. Sackville Hamilton brought up. I quite agree with him that in a country where there are clouds and mist you cannot survey up to 40 miles. But there are many countries in the world where you do get a clear atmosphere, and then you can. In Switzerland they only plot up to about 15 or 16 miles, owing to the climate, which is really unsuitable. Nevertheless the Swiss topographical maps by the new method answer many points raised this afternoon. I did not mention them because I was speaking about the Shaksgam. The work in Switzerland brings out the advantages of having the camera and theodolite mounted together. The very small loss in accuracy is fully compensated by the great saving in time and transport. I had a second theodolite with me on the expedition. I left it behind at the *dépôt* to save transport, and found the Wild instrument ample.

Wooded country can be plotted on these small scales. But on large scales, say 1/2000, the height of the trees is a difficulty. For small-scale work you can make your index traverse among the trees, and estimate the bottoms with an inappreciable error. I had a simple example of it in the scrub country in Nubra. The question raised about accuracy of detail is answered well by comparison with the old and new Swiss surveys. If you look at the two displayed on the wall, you will see that one is accurate and the other inaccurate: at least, the two are certainly by no means the same. The Swiss Government were so astonished that they had a comparison made by their own surveyors on the ground. In every point of difference the Autograph map was correct, and the old planetable survey was wrong. And look how wrong it is! In some spots features are omitted and in some the contours are at right angles to their true direction.

Doubtless the new method has limitations: so has every method of survey. These limitations are fully recognized by those who are making it a commercial success. In Switzerland they do not attempt to make a complete map by this method alone. They take photographs and plot from these all the detail and contours that they can, economically. A few small gaps remain, actually 5 per cent. in the example shown. Then a planetabler, one man only, goes out and completes the map and fills in the gaps and names. This is more economical than surveying every gap by photography, and the planetabler now has a very good control for his small gaps. The combination is more economical and more accurate than planetabling alone.

One other point. Swiss maps are plotted on the 1/25,000 scale, and reduced to 1/50,000. This has been criticized as uneconomical. But if you think for a moment, it is not so. The Autograph operator works at the same pace, whatever the scale. But on a large scale the pencil moves faster and more regularly. It is like an efficient draftsman compared to a slow worker. With

the large scale, by the use of gears, one can plot nearer the base centre than on small scales. There are also other advantages which need not be mentioned.

Cost of course, in these hard times, must be taken into consideration. But surely it is no good paying any money at all for an incorrect map. I feel fairly confident that a survey department that neglects now to make maps as accurate as modern methods allow, will in a few years find its maps as out of date as the old caterpillar hachured maps are to-day.

The CHAIRMAN: I think most of those who have listened to this discussion and Major Mason's excellent lecture will have come to the conclusion that the method is here to stay. We may be rather slow at taking up a thing, but eventually we shall be as well equipped as other countries are now. It was not mentioned that there are several machines of different types. There are two Zeiss machines in Madrid at present working commercially, and when I was there a year ago they were making a map of Bilbao. I think most of those present are convinced that we have to study this method not only because it gives us the means of making surveys in positions where otherwise it might be impossible, but also because, ultimately, we shall get even more accurate surveys than we have now, and certainly done with greater facility. I was struck by Major Mason's account of the machine finding out if mistakes had been made. It rather reminds me of the story of Babbage's machine. It was said that his machine, when it wanted a logarithm, used to ring a bell. You put a logarithm in. If you put the right one in, everything went well; if you put in the wrong one, the machine ground away for some little time and then spat the logarithm out! However, seriously, we have had an excellent account by Major Mason of the fruits of an admirable expedition. I am sure the results are worthy of the expedition, and I do not think I can say more. In your name I thank Major Mason most heartily for his paper.

AN ATTEMPT TO DESCRIBE MR. WILD'S STEREO-PLOTTING MACHINE—THE AUTOGRAPH

Arthur R. Hinks, C.B.E., F.R.S., Sec. R.G.S.

Folding plate follows p. 416.

Introduction.

IN the discussion following Major Mason's paper on the Stereographic Survey of the Shaksgam I related briefly the circumstances in which the following paper was written. While Major Mason and Mr. Hunziker were plotting the Shaksgam plates on one of the Autographs established in the Vermessungs-Bureau of Dr. Helbling at Flums, it was my task to study and attempt to describe the theory and construction of the instrument, so far as is necessary for understanding the principles of Mr. Wild's solution. Mr. Wild himself has not as yet published any account of his machine; but its theory has been described in general terms by Mr. H. Härry in a useful collection of papers read at the meeting of the Schweizerischer Geometer-Verein at Zurich in May 1926 and published under the title: *Die Photogrammetrie und ihre Anwendung bei der Schweizerischen Grundbuchvermessung und bei der allgemeinen Landesvermessung* (Brugg, 1926). A rough translation of this paper,