REPORTS FROM THE SCIENTIFIC EXPEDITION TO THE NORTH-WESTERN PROVINCES OF CHINA UNDER THE LEADERSHIP OF DR. SVEN HEDIN

— THE SINO-SWEDISH EXPEDITION —

PUBLICATION 6

II. Geodesy

1

LATITUDE AND LONGITUDE DETERMINATIONS

IN

EASTERN TURKISTAN AND NORTHERN TIBET DERIVED FROM ASTRONOMICAL OBSERVATIONS

BY

NILS AMBOLT

BOKFÖRLAGS AKTIEBOLAGET THULE · STOCKHOLM

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AND
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WITH 74 ILLUSTRATIONS, IN THE TEXT, TWO MAPS AND ONE TABLE IN POCKET AT END

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INTRODUCTORY NOTE

AS a prospective member of the Scientific Staff of my Expedition to Central Asia and Tibet 1927—1933, a young scholar of the University of Lund, Mr. NILS AMBOLT, was specially recommended to me by such prominent men as Professor CHARLIER, Professor CARLHEIM-GYLLENSKIÖLD, and others. During a short visit to Europe in the early summer of 1928, I first met Mr. AMBOLT at the Geodetical Institute of Potsdam, where he was completing a study of gravity determinations under the leadership of Geheime Regierungsrat Dr. E. KOHLSCHÜTTER. Both at that time and during the course of the expedition, Dr. KOHLSCHÜTTER and his staff encouraged and assisted AMBOLT in every way. Since his return from the expedition, AMBOLT has also on many occasions had the privilege of benefiting by their advice and assistance on a number of questions, particularly as regards gravity determinations on which subject a special volume of this series will be published later. Both Mr. AMBOLT and myself regard it as our first duty to express our sincere gratitude to Dr. KOHLSCHÜTTER and his staff for their keen interest and help in connection with our investigations in Asia.

Accompanied by Mr. AMBOLT, I returned to Central Asia via Russia and Siberia. From Semipalatinsk we continued to Chuguchak, where AMBOLT became seriously ill and had to stay some time. His field work, therefore, could not begin until 1929, and even then he was handicapped by disease and sickness.

During his travels in Central Asia and Tibet, Mr. AMBOLT arranged his work as far as possible in intimate collaboration with the geological and topographical researches of Dr. ERIK NORIN. Even when they did not travel together, they still followed a common plan.

Furthermore, during the entire period of his travels, AMBOLT carried out detailed meteorological observations. In this work, he was assisted by a young Russian, Mr. P. K. VOROTNIKOV from Chuguchak, who, on earlier occasions, had served as assistant to our surgeon, Dr. DAVID HUMMEL, and our Chief Meteorologist, Dr. WALDEMAR HAUDE. It was due to the assistance of VOROTNIKOV that AMBOLT was able to carry out a barometrical nivellement along the road from Toqsun to Khotan.

On occasions when the work of the expedition was limited to a certain region, both NORIN and AMBOLT organized as far as possible a fixed observation base, where the meteorological elements were read hour by hour.

When NORIN and AMBOLT continued their travels to the high regions, VOROTNIKOV, by reason of weak health, was unable to accompany them and had to return to Yarkend. After his excellent service in connection with our Expedition, the young Russian was worthy of a better fate than that which befell him. He was unfortunately shot during the political disturbances in Eastern Turkistan which began in 1931—1932.

In the region north of Bogdo-ula, Mr. AMBOLT collaborated in the autumn of 1930 with Dr. P. L. YUAN, who, as member of our staff, contributed considerably to our scientific accomplishments. Dr. YUAN was also of very great assistance to the whole Expedition politically and diplomatically, and for this reason sacrificed much valuable time that otherwise would have been available for scientific research.

From personal experience of several crossings of Northern Tibet, I know what it means to take a caravan through the Chang-tang, south of the head ranges of the Kun-lun. Despite the hardships and difficulties which he had to encounter in this region, AMBOLT pressed forward uninterruptedly and carried out his research programme to completion. When crossing Northern Tibet, he explored hitherto absolutely unknown country and thus also made new conquests on behalf of geographical science.

In 1914, an Expedition under Dr. FILIPPO DE FILIPPI succeeded in determining the exact coordinates of a few of the westernmost places in Eastern Turkistan. To these, Mr. AMBOLT has added 160 points, of which no less than 98 longitudes have been determined by the aid of wireless time signals.

SVEN HEDIN.

Stockholm, Sweden.
January 15, 1938.

PREFACE

This paper contains the results of the determinations of coordinates for 160 stations in Eastern Turkistan and Northern Tibet. The astronomical observations on which they are based were obtained during my work in 1929—1933 as a member of the Sino-Swedish Expedition to the North-Western Provinces of China, under the leadership of Dr. SVEN HEDIN.

When publishing this report I would like, first of all, to express my sincere gratitude to those who have in different ways, been the promotors of my work.

Above all, this gratitude is directed to Dr. SVEN HEDIN who not only has devoted his own life to the great but difficult purpose of exploring Central Asia but also has sacrificed the greater part of his fortune to make it possible for younger men to follow up the work begun by him. To Dr. SVEN HEDIN I owe deeply felt debt of gratitude for having received me as a member of his Expedition, for his generous assistance in many difficult and dangerous situations — thus, in spite of the extreme risk of infection, he nursed me through a period of very serious illness. Dr. D. HUMMEL helped to save my life on this occasion and I shall never forget his great medical skill, nor the manly tenderness he showed his patient.

I also use this opportunity to thank Miss ALMA HEDIN for all she has done for me during the years past.

Before I started my field-work I had the privilege of studying for 8 months in the "Geodätisches Institut", Potsdam. I am sincerely obliged to the then Director of this Institute Geh.-R. R. Prof. Dr. E. KOHLSCHÜTTER and his staff of collaborators and mechanicians for their valuable assistance and for the encouraging kindness they have showed me both at that time and on so many later occasions.

From the beginning of my work Dr. K. D. P. ROSÉN has shown a keen interest both in the practical details regarding instrumental equipment, and in the planning of the exploration work, and has also done his utmost to facilitate the working out of the results. For this I am deeply grateful.

The late Director of the Observatory of Lund Prof. Dr. C. V. L. CHARLIER is now beyond the reach of my thanks. Both he and the present Director Prof. Dr. K. LUNDMARK have followed my work with kind interest, and I have profited much

from their sound advice. I am glad to record here my great indebtedness to them both.

For years Prof. Dr. W. GYLLENBERG has been my teacher and a most sincere friend on whom I knew I could always rely for help and support. His advice have been manifold and valuable, and he has undertaken the tedious task of checking the calculations for my final list. My gratitude is deep and sincere.

Prof. Dr. A. HADDING has been kind enough to place at my disposal an excellent large working-room in the Geological Institute in Lund. For this generous kindness and for the interest he has shown my work, I am much indebted to him.

Dr. ERIK NORIN, my colleague in the field, has a considerable share in the results now published. From him I learnt how to travel. Our harmonious co-operation in the field has got a natural sequel in our co-operation at home. He has put his original maps at my full disposal, thus furnishing me with excellent material for the description of many of my stations in the field.

Fil. lic. FRIDA PALMÉR has kindly calculated the apparent positions of the stars which were not provided with a 10-day ephemeris, and I have also taken advantage of her accurate knowledge of the different fundamental catalogue systems when writing of the corrections to the systems FK3. I heartily thank Miss PALMÉR for all her amiable and skilled assistance.

To Dr. G. ALB. NILSSON I am under special obligation for the clever construction of a very light and easily transportable, but still effective, wireless receiving-set built by his brother Mr. N. NILSSON.

Dr. G. JARRING has revised the spelling of Turki and Mongol names, and his wife Fil. lic. AGNES JARRING has translated the Russian texts. Mr. F. BERGMAN, on the Staff of the "Östasiatiska Samlingarna" in Stockholm, has corrected the spelling of Chinese names. To these three friends I also express my sincere gratitude.

My Chinese colleague Prof. Dr. P. L. YUAN on many occasions kindly used his diplomatic talents to smooth my way, for which I tender him heart-felt thanks.

The Postal Commissioners in Urumchi Mr. J. McLORN and Mr. H. KIERKEGAARD and the SWEDISH MISSIONARIES in Yarkend and many other friends in Central Asia have rendered me most valuable assistance.

Two assistants, the Russian P. K. VOROTNIKOFF and the Mongol TOMES have through their honest diligence in many ways facilitated the collection of observations.

Since 1934, throughout the calculation-work I have had the fortune of having as an assistant Miss WANDA BERNSTRUP. She has proved an accurate calculator, quick at her work and with elegant and clear way of writing. She has been of invaluable aid to me.

The final re-drawings of most of the illustrations were kindly made by Mr. FRITZ JÖNSSON.

Besides to all those who have been the supporters of the Expedition as a whole my thanks are specially due to P. E. LINDAHLS STIPENDIEFOND, HIERTA-RETZIUS' FOND FÖR VETENSKAPLIG FORSKNING and KUNGL. FYSIOGRAFISKA SÄLLSKAPET for their generous help.

In reading the proofs my father Mr. ANDERS AMBOLT has given me highly appreciated help.

Finally, I thank my WIFE for untold help and support.

Lund, January, 1938.

NILS AMBOLT

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INTRODUCTION

The aim of the Sino-Swedish Expedition to the North-Western Provinces of China under the leadership of Dr. SVEN HEDIN was to make a scientific reconnaissance of Central Asia as comprehensive as possible. Central Asia has still vast areas, on the maps indicated: "Unexplored". In other parts, more or less systematic pioneer mapping has been carried out which, however, is often found to be lacking in accuracy. Usually this inaccuracy is a necessary consequence of the primitive methods generally used in pioneer exploration, but sometimes it is also due to ignorance or carelessness. Of fatal effect is, in many cases, the inaccuracy pertaining to the fundamental points fixed by astronomical observations or by triangulation, and upon which the topographic details of the maps are built.

Astronomical latitudes are easily fixed with a high degree of accuracy, but, until quite lately, the accurate determination of longitudes from astronomical observations has been impeded by very serious difficulties, hardly possible to eliminate. And so the explorers have often fixed their longitudes by itineraries only. New possibilities suddenly opened, when easily transportable wireless receiving sets for time signals became available, which made it possible to determine the astronomical longitude of a place with the same degree of accuracy as the astronomically fixed latitude. Dr. HEDIN, who well knew the necessity of fixing fundamental points in the vast regions of Central Asia which were to be the field of his Expeditions, entrusted me with this task.

At the time when I was to join the Expedition, the fieldwork had been carried on for about a year. The Expedition also had a wireless receiving set at its disposal. A receiving set at that time was rather an expensive matter, yet I insisted upon being allowed to bring along a set of my own. Dr. HEDIN granted this request with the same largeness of mind as he has always shown towards his assistants. Curiously enough, among the first news, I received, on entering Eastern Turkistan, was that the wireless set which the Expedition had brought along from the East and which had now arrived at the Urumchi headquarters, was confiscated by the authorities.

The severe, political disturbances in Eastern Turkistan which started in the years 1932—1933 prevented me from extending my survey as far east as I had hoped for.

However, some other members of the Expedition have also made astronomical observations which partly fill in the gap. These determinations are due to my collaborator Dr. E. NORIN, the Chinese Geodesist Mr. PARKER C. CHEN and the German Lieutenant (now Major) H. DETTMAN. Unfortunately they include but a few longitude determinations. It is my intention to treat these determinations in a later paper.

It is to be hoped that the longitude and the latitude determinations made by the German Explorer, Dr. W. FILCHNER during his last Expedition, which was equipped with a wireless set, will furnish some very valuable fundamental points along the route traversed by him.

Taken in order of time the field work carried out by me can be summed up in the following different journeys.

1. The Turfan excursion.
2. The Quruq-tagh journey in cooperation with Dr. NORIN.
3. The Bogdo excursion in cooperation with Prof. P. L. YUAN.
4. Urumchi-Aqsu.
5. Aqsu-Khotan, crossing Taklamakan.
6. The 1:st Qaranghu-tagh excursion.
7. Khotan—Yarkend.
8. Yarkend—Aq-sai-chin, over Kara-korum in cooperation with Dr. NORIN.
9. Aq-sai-chin—Qawaq in the Qara-qash valley and back.
10. Aq-sai-chin—Charchan, through Northern Tibet.
11. Charchan—Khotan.
12. The 2:nd Qaranghu-tagh excursion.
13. Khotan—Leh, over Lingzi-tang.

When the field-work was finished I started the compilation-work with the intention of preparing a publication, which would deal with all the material collected in the field, that is besides the astronomical data also geodetic, magnetic, topographic, gravitational and meteorological measurements. Experience soon proved that this plan had to be abandoned. It has caused a regrettable delay in the publishing of the results given in this paper.

Many of my astronomical determinations will be of far more importance when, later on, also the triangulations connecting them have been calculated. To defer the publication until these calculations are completed, would mean a delay, hardly justifiable as many of the points fixed and published here are of more general importance for map-drawers.

Comparing astronomical determinations of latitude and longitude in Central Asia with those obtained in civilized countries one must consider the difference in conditions under which the observations have been carried out.

Under normal "home"conditions there is no great difficulty in carrying any weight to a desired spot in the field. But in Central Asia all transportation is done by the aid of horses, camels, donkeys, yaaks or porters — on some few occasions by arabas (two-wheeled, springless carts). At home all field work is cancelled in winter. On an expedition, on the contrary, it is necessary to make the determinations without any regard to season, and very often there is only the night between two trying marches available for observations. With the typical, continental climate which prevails throughout Central Asia, one has to face severe cold in the winter season — especially so in Northern Tibet where the average height amounts to about 4800 m above sea level.

The extreme cold is as a rule accompanied by calm weather. Unfortunately temperatures about —10° Cels. and contemporaneous wind are far more common, and such a state of the weather is a much greater obstacle to observations, because of the penetrating power of the wind, than the severe cold with no wind. Such cold is not only inconvenient to the observer, it is dangerous for his fingers, and it has a menacing influence on his instruments. In addition, fuel is very scarce, or even lacking in those very districts where the most extreme cold is met with.

In certain provinces, lack of good will from the authorities is a common and unpleasant experience which adds to other difficulties.

The coordinates fixed by us have their greatest value firstly for the adjustment of the degree-net on maps of the regions traversed and explored. Secondly they are of interest from a geodetic point of view provided that the points measured are — or can be — connected through geodetic measurements by methods yielding an accuracy, which is greater than the differences possibly occurring between astronomical and geodetical coordinates. Of course, the astronomically fixed coordinates must also be of such accuracy, so that their errors do not conceal differences between the geodetic and astronomical work, eventually appearing.

On expeditions carried out into unexplored, or only little known, countries the astronomical observations as a rule have been made only in order to get the mentioned foundation for the maps. On such expeditions the maps are almost always based upon distances measured either by pacing or by the time used for covering the distance, and sometimes by cyclometer ("perambulator") giving a far greater degree of accuracy than the first mentioned methods. The angles are fixed by compass bearings. In such mapping work the errors may amount to about 2—10 %, depending upon the skill and carefulness of the observer and upon the terrain traversed. Counting with a distance covered daily of about 30 km, such errors correspond to errors of 600—3000 m in the relative position of two camps joined by the route, and then it is enough if the camps are fixed by a corresponding accuracy of 20″—100″. A greater accuracy in the mapping can be obtained by using, besides the cyclometer, a compass fixed on a tripod, or by using a planetable, or by triangulation. In the first two cases we may bring down the errors to about 1 %, through triangulation, even if *very rough* easily, to 0.01 %.

The first mentioned figure of 1 % corresponds to an accuracy desired of about 10″ in the astronomical determination of two consecutive camps. In order to fully utilize a triangulation, even if only very roughly, the astronomical determinations must be made with the utmost accuracy.

But the accuracy aimed at also depends on others factors. It must be kept in proportion to what it may cost, not only of money, but also of work and of risk. These factors are hard to estimate from one's writing-desk, but experience soon gives hints to what should be done, and what not.

There is another point, which is of importance in connection with the choice of accuracy, with which the determinations are to be made, namely the description of the fixed point. This description must be made in proportion to the accuracy of the work carried out at the point. Most of the Central Asiatic expeditions have sinned in this respect.

Sometimes it might be noticed, that the descriptions given by me which are usually in form of a map or connected with such a one, are too much detailed. If the mean error in a latitude for instance is about 1″ corresponding to a distance of 30 m, it may be considered superfluous to give a description of a caravansary, where the determination was made with a sketch-map 1 : 2000. However, just these sketches make it far more easy to locate the actual station, if it for some reason should be reoccupied.

Not all the places have such point descriptions. Especially in Chang-tang they are lacking. The reason is that in uninhabited regions a description must be connected with a map, in order to get a real value and in such regions which are surveyed, but where the maps have not yet been worked out, I consider it better to postpone the publishing of the descriptions until the maps are ready.

In many places the point which is determined, has been fixed by a so-called "obo", a cairn, as a rule built up of stones. Such an obo may be located at some distance from the measured point, but in that case the distance, and the direction to it, are measured.

Sometimes it may seem strange that I have not built up cairns. The reason is that such marking is often worthless, because of the well-known fact that the inhabitants are very suspicious of everything done by foreigners. The Turkis, for instance, are often afraid that a stone cairn built up on a mountain top may be, later on, taken as a pretext to state that this mountain belongs to the person who has built the cairn.

During the unsettled conditions now prevailing in Eastern Turkistan great changes in the settlements have often taken place. Towns and villages are burnt down. Still, I hope that the descriptions given in "Descriptions of stations" will make it possible to identify my points as both the road leading to, and from the place, and other details are given, which one ought to be able to recognize in spite of much destruction.

I. INSTRUMENTS

A. THEODOLITES

The FENNEL UNIVERSAL THEODOLITE is an ordinary old instrument with microscope reading for both circles.

An electrical bulb for illuminating the diaphragm, engraved on glass, was built in and a small rheostat for adjusting the intensity of the illumination was attached to the tripod. The "Fennel" was used for observations of corresponding altitudes. Thus the circles were never used but for pointing at the stars intended to be observed. When the temperature was low the instrument proved very difficult to handle, because of increasing friction. This did not depend upon error in lubrication but must at least partly have been caused by irregular contractions. Under normal conditions it was good. The diaphragm is illustrated in Fig. 2. The spirit level of the altitude circle was, when I received the instrument, fixed in its position by aid of gypsum. When the level value was determined it showed irregularities, which were

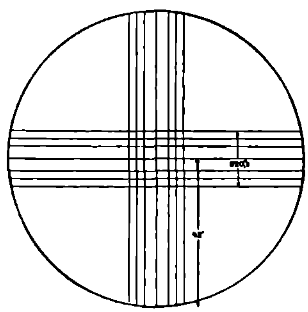

Fig. 2. The diaphragm of the Fennel Theodolite.

probably due to this gypsum. Therefore, I had the level attaching improved by Mr. MAX FECHNER, Geodätisches Institut, Potsdam, and the level value then became more constant and did not show any pronounced variation with temperature. After coming back from the field work, the value was again determined. No secular variation was discovered. The level value 8″.4 has been adopted for the computations. The distance between two division lines was 2.0 mm.

The Fennel Universal is a good instrument but it is heavy and not quickly fixed up for work. The packing was done so, that the tube with the vertical circle was taken out of its bearings and fixed by screws to a wooden plate. The lower part was fixed, also by screws, to a plate, in the bottom of the box. The whole box was then packed in another one, which originally was supplied with springs for the purpose to protect the instrument against bumps during the transport. A construction like this may be very practical in case of easy transportations but when the instrument must unavoidably be more or less roughly treated, the arrangement is evidently of little value. Therefore the inner box was provided with heavy felt-linings in order that the instrument should better endure heavy transports. None of the boxes could, however, prevent the horrible dust coming in — always a nuisance.

The Fennel Universal was used during the Turfan and the Quruq-tagh journeys. Later on, it was kept as a reserve instrument until Febr. 1932, when it was sent home from Yarkend by a trade caravan through the kind assistance of the Swedish missionaries. It arrived safely and is still in perfect condition, though because of its age, of course not up to date.

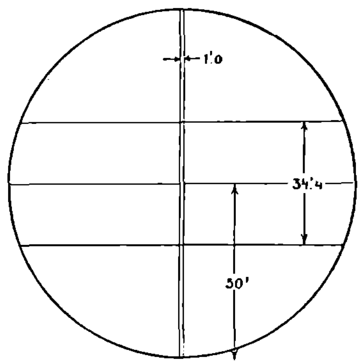

Fig. 4. The diaphragm of the Hildebrand Theodolite.

The HILDEBRAND THEODOLITE Nr. 64668 was of the ordinary "Einheits"-type. Since it is so well known there is no need to describe it in detail, but just a few remarks may be of interest. The diaphragm is seen in Fig. 4. The level connected with the vertical circle has a level-value of 31″.6 (according to the instrument certificate 30″.) and the distance between the division lines is 2.2 mm. It is to be deplored that the division is not carried entirely through. This is always a source of error which can give rise to displacements of a magnitude which, however, can be so small, that the errors cannot be discovered with certainty and corrected for. Every instrument of this type ought to have a more accurate level for the vertical circle — with a level-value of say 10″ — when intended to be used for astronomical work. Then the instrument's working effect would be far greater. Also, it would be an advantage to have some more horizontal wires inserted in the diaphragm.

The readings were done with verniers giving 1′ for the vertical circle and 0′.5

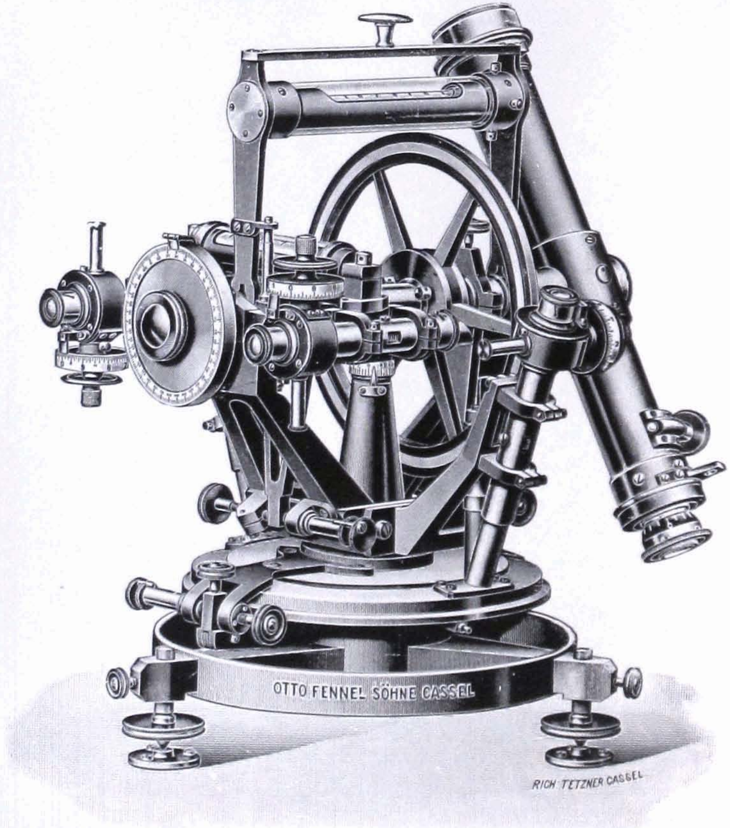

Fig. 1. The Fennel Universal Theodolite

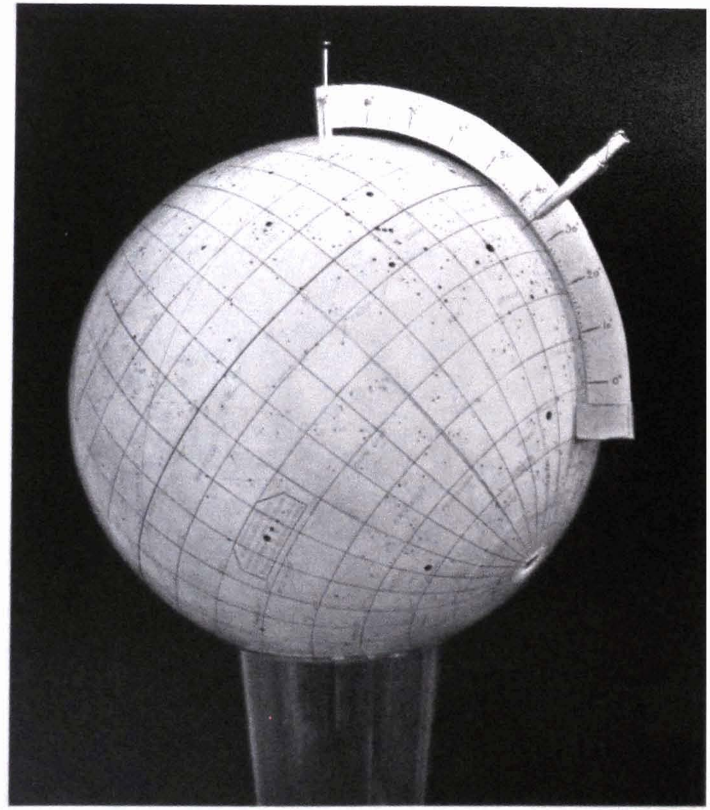

Fig. 12

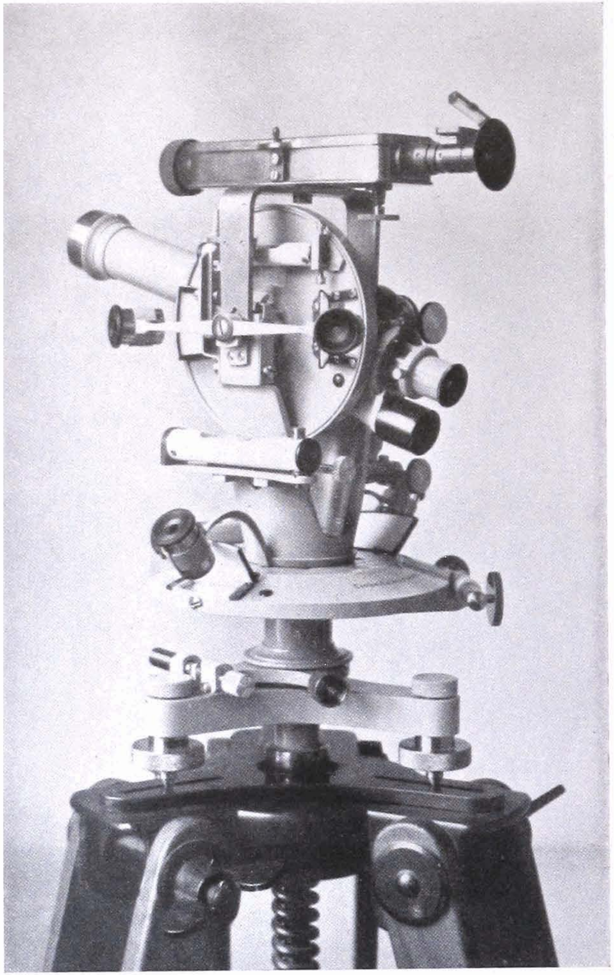

Fig. 3. The Hildebrand Theodolite

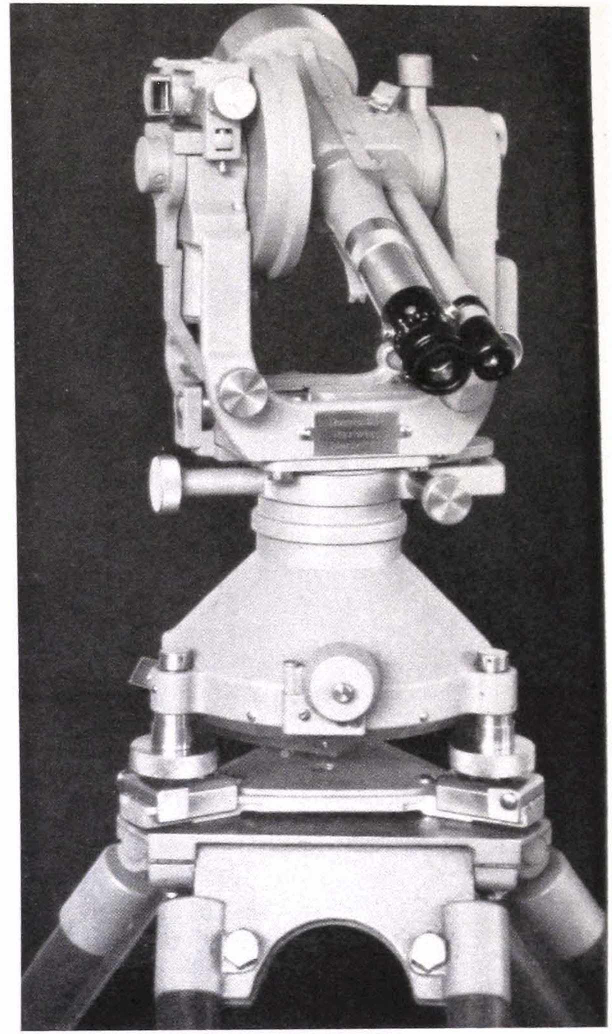

Fig. 5. The Wild Precision Theodolite

for the horizontal circle. It was possible to estimate about 10″ in azimuth and 15″ in altitude.

Twice the Hildebrand Theodolite met with accidents during the expedition. The first time was on March 31, 1932. The instrument, which in its wooden box was stored in a larger case together with some other instrument boxes, was transported on one side of a strong, calm horse, which unfortunately made a false step and fell down a precipice, 6 m deep. The outer case was badly damaged. The felt covering inside around the inner box softened the blow. Anyhow, the axle-journals slipped out of the bearings and when opened at once after the accident the instrument lay jammed. A careful examination did not reveal any damage. The second time during the transportation home, it was much worse. Probably the case which contained this instrument box was dropped. Anyhow, when unpacked, all the instruments in that case were hopelessly spoilt, and the Hildebrand Theodolite had to be sent to the factory in Freiburg to be repaired. When returned it was again in perfect order. During the whole course of the expedition this handy little instrument performed its services well.

The best instrument I possessed was the WILD PRECISION THEODOLITE Nr. 133. At the time when I left Sweden I was not yet quite conscious of the tremendous advantages this instrument had, its great accuracy and strong stability, its insensibility to rough transport, its small weight etc. But in field I soon learned to estimate it by its true value. Dr. NORIN possessed a small WILD UNIVERSAL and when we were cooperating in the Quruq-tagh mountains I almost every day had opportunity to compare the "Wild Universal" with the Hildebrand Einheitstheodolite. As a result of these comparisons I wrote Dr. SVEN HEDIN and asked him for the favour of sending me a Wild Precision Theodolite. Dr. HEDIN always did his utmost to provide us with instruments wanted — so even now. A Wild Precision Theodolite was purchased and by a special messenger taken to Novosibirsk. From there the German Consul General Mr. GROSSKOPF arranged a new messenger who brought it down to Bakhi on the border station towards Eastern Turkistan and by kindly assistance of the Soviet Consul General Mr. BOROVOI it was sent to Urumchi. There I had some caravan men awaiting to take it down to the southern part of the Quruq-tagh mountains where NORIN and I were working at that time. In Jigde-bulaq I received the instrument on March 11, 1930. Then it had been on the way for more than 2 months and for 5 weeks it had been transported on horseback, partly over very rough ground. I mention this long story of its transportation to make clear how wonderfully the instrument was protected by its metalbox and its outer case. It arrived in perfect order. The Wild Precision Theodolite is excellent for field work of the kind I was carrying out.

The "Wild", as it will be called below, is a modern instrument with glass circles and coincidence reading which eliminates eccentricity errors. After having read off, for instance, the horizontal scale through a tube close to the eyepiece, the vertical scale can be read through the same tube after turning a prism. From the same point, the altitude level can be adjusted to coincidence. Thus the observer can without altering his position:

1. Point the tube,
2. Adjust the altitude level to coincidence,
3. Read off both circles.

The method of reading off the circles is an unusual one but easily learnt, and experience shows that mistakes are seldom made. The scale value of the altitude level corresponds to 18″ for 2.2 mm. Since the direct reading of vertical angles is made to 0″.4, and 0″.04 can be estimated, this level value is not very well chosen. Generally it is adopted that a coincidence reading corresponds to an estimate of 1/20, that means about 1″, and thus I think that the proper scale value for this level should correspond to 4″ or less for the interval 2.2 mm if the full power of the instrument is to be used. Another arrangement would also contribute in the same direction, namely, if the coincidence of the level's two bubble-ends was read off through a magnifying glass instead of by the naked eye. In the instructions for handling the instrument attention is called to the fact that in order to obtain accurate results the coincidence screw must always be turned in the same direction when bringing about the coincidence. This is absolutely necessary. Neglecting that rule, accidental errors amounting to about 6″ may appear. But another thing is quite as necessary, namely, to turn the screw with which the level's bubble-ends are brought to coincide also in the same direction. If this rule is neglected, errors of about 5″ are likely to occur. This error would of course dicrease if a more accurate level was inserted, and probably in proportion to the exactness of the respective levels. If the level is gently tapped with a pencil the friction inside it will be eliminated and a more correct result obtained.

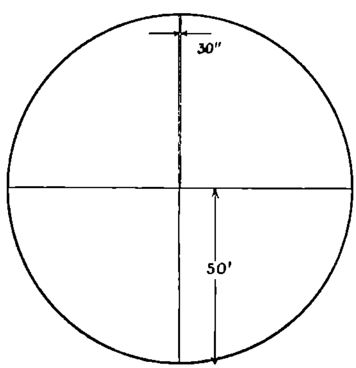

Fig. 6. The diaphragm of the Wild Theodolite.

The diaphragm is shown in Fig. 6. It proved suitable for geodetical purposes; for astronomical work it would have been an advantage to have some more horizontal lines.

In order to make it possible to adjust the instrument with more convenience and rapidity it ought to be provided with a box-level or still better, a cross-level — there is ample room for the fitting of one close to the plate-level. The division of the plate-level ought to be carried entirely through.

The illumination of the scales and the diaphragm is obtained through two electrical bulbs. It is important that the illumination when reading off the scales is fairly good — the mean error of a reading increases considerably when illumination grows poor. The small rheostat with which the intensity of the light could be varied was unsatisfactory. This little detail caused much trouble in the field. I also found the arrangements with the bulbs somewhat unsatisfactory. They often do not give uniform illumination of the scales which are moved to coincide. The arrangement and the position of the bulbs are shown in Fig. 7. Hence if the bulb is moved a little sideways, the illumination is essentially changed and will cause badly defined coincidences. If instead the bulb was fixed as in Fig. 8, a small change in its position would be of almost no effect for the illumination. And technically this arrangement could certainly be just as easily carried out.

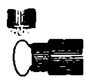
Fig. 7.


Fig. 8.

When speaking of the illumination of the scales, I take this opportunity to call attention to another fact of importance. When using the Wild instruments at daylight, it is necessary to use the electric illumination of the scales, if accurate determinations of angles are desired. Readings of the horizontal scale may differ by as much as 3″, if the illumination is changed.

The packing of the instrument was excellent. The metal box protected the theodolite wonderfully. On Aug. 24, 1932, up in Tibet, the theodolite was carried on one side of a horse which was led by the halter. On extremely rough ground on a hillside with big boulders the horse once turned over backwards and fell down with the theodolite under it. The cover received three ugly dents but the instrument itself was not hurt. I do not know any other instrument that could have passed through such an accident without almost hopeless damage.

The small key with which the closing screw of the metal box is turned was hard to handle when the temperature grew low. I therefore soldered a wing to it, to give better hold for the fingers.

The focussing of the tube is performed by means of an intermediate lens which is moved by turning a ring near the eyepiece. In my instrument this arrangement was not as it should be. When temperature was low — say under +5° Celsius — the ring could hardly be moved by the fingers, and for focussing, I was forced to use a pair of tongs — of course, this could only be done when the instrument was entirely free to move. Because of developments of triangulation nets, sides as small as about 50 m were very often measured. Therefore such adjustments were necessarily frequent — though performed with a great deal of anxiety.

The level of the altitude circle is adjusted by means of a screw which in my opinion is too small. Against the screw works a spring which ought to be stronger. Had this arrangement been better, the index error had probably been more stable.

Twice "Wild" has been under water. The first time was on Sept. 18, 1932, when the donkey which carried it, slipped on soft marshy ground. Though the instrument was quickly lifted out a little water had entered its metal box and the accident caused a lot of cleaning work, but no serious trouble. The second time it happened was when on June 25, 1933 the horse which this day carried it fell down in deep water. I was not told about this incident until the next morning and thus the instrument had spent the night with some water inside its box. Even now no serious damage was discovered, but on July 14, 1933 I observed that the diaphragm was distorted. I think this must have happened during the incident on June 25., or perhaps during the work when the instrument was cleaned the following day. The largest error that could enter the measurements from this obliquity amounts to 20″, but since the readings are always made near the centre of the diaphragm the probable error is only about 2″, and I think that the error in the worst cases cannot exceed 4″, which corresponds to a reading made 10′ from the centre. As soon as the error was discovered the instrument was readjusted.

Had this error remained for a longer time, it must have resulted in larger mean errors in the values of φ and λ. Since there appear no signs to that effect, it can be safely assumed that the distortion has existed during a very short time-interval only and cannot have badly influenced the main part of the observations.

The type of Wild Precision Theodolite used by me has later been replaced by a construction, considerably modernised, and improved. The axles are now of "kinematic design" which secures easy movements at any temperature, and increased accuracy. The illumination of the altitude circle has also been altered, and improved. For illuminating the diaphragm a mirror is arranged in the centre of the tube, so that it can be turned conveniently from the outside, and by this revolving, the intensity of the illumination is adjusted. Concerning the focussing, Mr. Wild says: "the inner screw-thread is in its shape and pitch so formed that even at a very low temperature, the focussing is easily and quickly performed". The latest designed instrument is furthermore packed into a cylindric case which is dust- and waterproof.

B. TRIPODS

Regarding the tripods there is a practical detail which in the hand-books is often overlooked. The tripods have legs made of some strong kind of wood and have metal fittings both at the upper part for fixing the instrument to the tripod and at the foot which is to be fixed in some way on the ground. The metal fittings are usually attached to the wood by an arrangement which makes it possible to have them tightened by means of a screw. This tightening is very important in regions like those I was travelling in. Because of the dryness of the air, the screws often had to be strained.

C. CHRONOMETERS AND CHRONOGRAPH

The box chronometers used all came from NARDIN, Le Locle, Switzerland. Nos. 2324 and 2396 were running sidereal time, 2531 mean time. They all had electrical contacts and could be arrested by aid of a golden spring which lifted up the balance. This spring was handled by means of a screw carried through the metal case. The chronometers 2324 and 2531 were always arrested when under transport. The same was the case with 2396 until May 6, 1931 from which date it was kept running also during the transport. This means an advantage for the work, but it implies a certain risk for the instrument. As I had two other chronometers to my disposal, I still deemed it justified to make this experiment, especially as the electrical contact of 2396 was at that time very bad and if it should be used for the more accurate time service at the Gravity determinations it had to be cleaned before.

It is of vital importance to have the chronometer connected with the wireless set for as short a time as possible, because the capacity self-induction arrangement to prevent sparks must be disconnected from the circuit, if the signals are to be heard at all, and thus the contact during the comparison is exposed to oxidation through sparks.

Here I shall not deal much with the condition and the run of the chronometers. This matter will appear in forthcoming papers treating the interpolated longitudes and the Gravity measurements.

By Nos. 2324 and 2396 the contact started at $^{s}.0$ and finished at $^{s}.5$, by 2531 the contact started at $^{s}.5$ and finished at $^{s}.0$. By 2324 and 2531 no contact was made for full

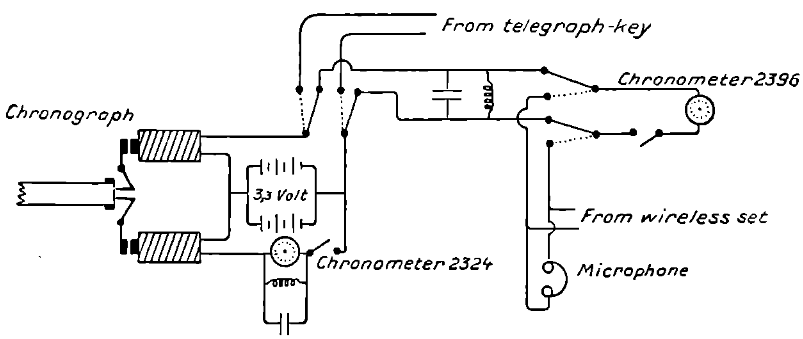

Fig. 9. Arrangement of electrical connections by chronographic registration of star observations and time comparison according to the HÄNNI-method.

minutes — these minute-markings made them especially suitable to work the chronograph. When the Hänni-method is used for recording timesignals it is a disadvantage to have such a minute-marking, if the chronometer is running mean time. It might happen that all the coincidences appear just at the full minutes and hence they cannot be utilized with very great accuracy.

I think a modern contact-chronometer of this type could be used even for very accurate time determinations instead of the pendulum clocks which as a rule are used. The contact chronometer is, of course, considerably easier to transport. The already mentioned arresting arrangement protects the instrument during transport extraordinarily well. And if the instrument is to be used for measurements which require the utmost accuracy it can easily be protected against temperature variations — in the field for instance by isolating the whole box well and placing the chronometer in a dug out hole in the ground.

All these three chronometers had the same arrangement to prevent the formation of sparks. It consisted of a self-induction of 3.2×10^{-4} Henry and a capacity of 1 MF both in series and fixed parallel to the breaking point of the chronometer. Though this arrangement was good, it could not prevent the contact from by and by working with less reliability. At last the contact had to be cleaned and readjusted. This was a difficult and riskful undertaking, but I performed this operation successfully on some occasions. It was then felt as a deficiency in the construction that the little platinum contact pin could not be *screwed* into its position. Had this been the case the adjustment could have been made far easier and with more accuracy.

The following pocket chronometers were used:

Kullberg 7759	Kullberg 7760
Ericsson 380	Löbner 346491
Strömgren and Olsen 598	Strömgren and Olsen 674

Further the Expedition possessed a number of ordinary watches. Regarding the description of their performances the same is valid as for the box chronometers.

When the Fennel Universal was used for the astronomical determinations a point chronograph from H. Wetzer in Pfronten, Germany, was used for recording the star-passages. It had a sounding spring as regulator and it served its purpose well. The paper fillet was read by aid of a celluloid reading scale of ordinary type.

D. WIRELESS SET

The wireless set was constructed by Dr. G. Alb. Nilsson, Lund, according to the scheme seen in Fig. 10. In desert regions it was combined with an aerial of about 100 m length and provided with as good connection to earth as could be found. Since the wireless always had to be handled in secrecy the servants were told that the aerial and the earth connections were used for measuring the difference in temperature

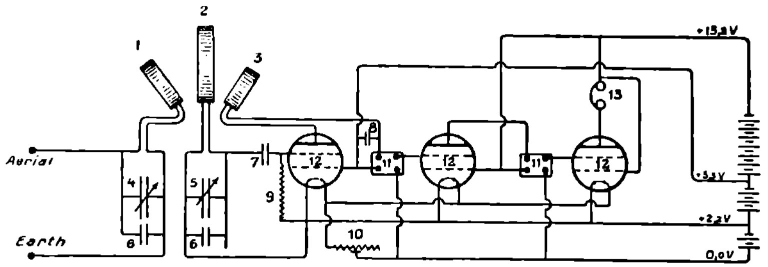

Fig. 10. The wireless receiving set constructed by Dr. G. ALB. NILSSON
1.Aerial coil, 750 turns. 2.Secondary circuit coil, 1250 turns. 3.Reaction coil 500 turns. 4.Aerial condenser. 5.Secondary circuit condenser. 6.Fixed condensers, each of 200 cm. 7.Grid condenser. 8.By-pass condenser. 9.Grid-leak. 10.Variable resistance for the plate current. 11.Intermediate circuit transformers, ratio ⅓. 12.Receiving valves of the double-grid type RE 072 D (TELEFUNKEN). 13.Microphone. 14.Accumulator-cells (NIFE) giving a tension of 1.1 Volt each.

Fig. 11.

between air and earth, or water. In populated districts an aerial of course could not be mounted; in these cases I instead used 500 m wire wound up to a coil of about 4 m diameter. This coil was attached to the roof of my tent and as earth served some metal cases connected with each other. In spite of these rather primitive arrangements I had as a rule, satisfactory reception. The valves were removed when the apparatus had to be transported.

A special advantage with this set was that no higher voltage than between 12 and 15 Volts was necessary for its working.

E. METEOROLOGICAL INSTRUMENTS

For measuring pressure PAULIN and BOHNE ANEROIDS were used, both in connection with FUESS BOILING-POINT HYPSOMETERS.

The setting and the reading of the PAULIN are more convenient and accurate if done by the aid of a magnifying glass. This affects the setting of the tendency pointer especially upon the accuracy of which the reading depends. And so, I think, it would be an additional improvement to cement a small lens to the covering glass, above the tendency pointer.

A few remarks about the hypsometer, too, may be justifiable here, because of its general importance for travellers. The FUESS apparatus, which was used by the HEDIN Expedition, is constructed by v. DANKELMAN and GRÜTZMACHER, and is an excellent instrument when correctly handled, according to instructions. In the latter there is, however, one point which ought to be added: it is necessary to take care that the bulb of the thermometer does not touch the tube-walls. Even if the apparatus is well levelled, it is not very easy to avoid such contact, or "sticking" to the tube-walls. Further, I think, the instrument could be improved by inserting a small ring, as shown in Fig. 11, into the tube so as to keep the thermometer-bulb free.

This ring with its three "teeth" is shaped, as shown in the figure, so as to prevent condensed water from pouring down on the bulb, and to lead it on towards the tube-walls instead.

The ring has a slit in order to make it elastic, and one is thus able to attach it to any part of the tube, by simply moving it by the aid of the thermometer.

The PAULIN instrument is especially worthy of praise and well suited to travellers. It could be improved by substituting another arrangement for the damping. The oil-damping was not satisfactory, firstly because the oil was of such a type that it grew stiff at low temperature, secondly, because the oil easily ran out of the little holder in which the damping mechanism moved. Because of this I removed the damping mechanism completely.

For boiling the hypsometers distilled water was always used. To prepare it I had a small copper still.

For measuring the temperature and moisture ordinary ASSMAN POCKET PSYCHROMETERS from FUESS in Berlin were used.

F. ACCUMULATORS AND BATTERIES

The electrical current necessary for many of the instruments was obtained from NIFE ACCUMULATORS which were charged by a generator turned by hand. This charging was rather hard work. However, it was as a rule easy to get people to do it and the apparatus was of comparatively small weight. A motor aggregate which many would prefer has its disadvantages too. Not only is it comparatively heavy, but what counts more, it may cause trouble with the authorities. Eastern Turkistan is still ruled under rather mediæval forms and an apparatus making so much noise may be dangerous there. Now as motorcars are growing more common it would perhaps be better. However, it is difficult to get fuel for motors too.

The turning mechanism for a hand-driven generator must not be too primitive. Mine caused much trouble, partly because of the sand which got into it so that the gear wore out too quickly, partly because the gear was not of sufficiently strong dimensions in itself.

Four kilograms of electrolyte (solid) was brought along in soldered tins of one kilogram each in order to make it possible to refill the cells when necessary.

Notwithstanding the fact that the cells were used for 5 years, often under extremely trying climatic conditions with temperature varying from about $+40°$ to $-40°$ Celsius and were all the time carried on the backs of horses or camels, sometimes from districts below sea level to mountain passes over 6000 m high, and were necessarily exposed to very rough treatment, sixteen of the eighteen cells were in perfect order when brought back home; one cell was spoiled through carelessness and one from unknown reason went out of function. This must be regarded as an extraordinarily good recommendation for the Nife battery.

As a reserve I had batteries which when used should at first be moistened.

G. STAR MAP

The stars observed were identified by aid of SCHURIG-GÖTZ' "Himmels-Atlas" (Leipzig 1923). The calculation of apparent places for the stars is tedious, and could in many cases be avoided, if one glancing at the star-map could see immediately which stars have, and which have not a 10-day ephemeris. If therefore, the stars having such 10-day ephemeris were marked on the map by a special sign, this would be an improvement. Another slight improvement would be to furnish the map with a small celluloid scale by the aid of which the coordinates of the stars could more easily, and somewhat more accurately, be estimated.

II. FIELD WORK

The following methods of observation have been used.

For latitude: 1. PEVZOFF's method.
2. Altitudes near the Meridian.

For time: 1. Corresponding Altitudes East and West.
2. Transit in the Vertical of Polaris.
3. Altitudes East and West.

Possessing a theodolite of the modern type, e. g. a Wild Theodolite, the best methods for travellers with experience of astronomical observations to determine latitudes and time are to use observations of Altitudes near the Meridian and Altitudes East and West. With an instrument of oldtype, PEVZOFF's method and corresponding Altitudes East and West are to be preferred. Transit in the Vertical of Polaris is always a good method especially as it easily gives a good first approximation of the clock correction.

The PEVZOFF method of determining latitudes is very convenient and fairly accurate. Northern and southern stars at the same side of the Meridian, are chosen for corresponding Altitudes so that their azimuthal distances from North and South, are approximately the same. If a pair of stars fulfills these conditions a small error in the knowledge of the clock correction is of negligible importance for calculating the latitude. Such pairs have been selected and listed by SELIVERSTOV in a very useful table. This table is not easy to obtain, but I had the privilege of borrowing a copy from Dr. KOHLSCHÜTTER, the Director of the Geodätisches Institut at Potsdam.

The SELIVERSTOV Tables have been calculated for the following conditions:

Altitude: 44° to 75°.
Azimuthal distance from the Meridian: 15° to 40°.
Time difference between the two starpassages: 5^m to 15^m.

From this Tables pairs were chosen. The altitude and azimuth of the stars were easily calculated from the Tables and used to point the instrument at the stars. The sidereal time for each star passing at the calculated altitude, can also be obtained from the Tables. During the observations, level readings were made as often as possible, and the transits of the stars were recorded electrically on the chronograph. For each star usually 4 readings of the two level-ends were obtained.

When space in time between the latitude pairs occurred, time-pairs were put in. Stars for these latter determinations were chosen arbitrarily. Of course, the ideal condition is that the stars have approximately the same declination, but if the latitude is well determined even large deviations from this ideal condition may be tolerated. For this kind of observation, it was necessary to have an assistant, who wrote down the level-readings and served the chronograph, which was kept in the tent together with the chronometers. During the first journey Mr. A. CARLSSON assisted me in these observations. During the Quruq-tagh journey I was assisted first by Dr. NORIN and later by the young Russian P. K. VOROTNIKOV.

Experience soon proved that the above mentioned method required too much time, and when the Wild Theodolite arrived, entirely different working methods were practised, so that only about half an hour or one hour was the time necessary for the astronomical observations. The scheme now used was the following, where:

RL means Reading tube Left. RE means Reading tube East.
RR means Reading tube Right. RW means Reading tube West.

Polaris	RL	Time.	Altitude.
Polaris	RR	Time.	Altitude.
Polaris }	Same Vertical RE	Time.	
1st Southern star }		Time.	
1st Southern star	RL	Time.	Altitude.
1st Southern star	RR	Time.	Altitude.
Polaris }	Same Vertical RW	Time.	
2nd Southern star }		Time.	
2nd Southern star	RR	Time.	Altitude.
2nd Southern star	RL	Time.	Altitude.

Later on the scheme was again changed and I used the following type:

Polaris	Each star was observed in RR and RL
Southern star	and by all eight observations
Eastern star	both time and altitude
Western star	were recorded.

The latter scheme I consider the very best. About half an hour was enough for the eight observations, and even if the temperature was very low, one could conveniently keep on for so short a time. Two native boys usually assisted. One was in charge of the box chronometer, the other of a kerosene lamp and the field book. The chronometer (as a rule nr. 2396) was held so near the observer that its beats could be heard. Through training, the boys developed a capacity of knowing exactly what I wanted at every moment, and that facilitated the observation work considerably. That the work is quickly done means also an advantage because the less time the chronometer is exposed to the cool air the better.

Meteorological data, of course, were always secured.

When a longitude was to be determined the star observations were connected with wireless time registrations. On march and with only one night at my disposal for the astronomical observations, I often had to be satisfied with the Rugby signals, which were received about midnight. With very good luck one could have the camp fixed, i. e. the tents put up, the instrument boxes unloaded and brought in and the wireless set unpacked and arranged for receiving so early that at about 6 o'clock in the evening the Nauen signals too could be received. With bad luck, one might have to wait untill 2 a.m. when the Bordeaux signals could be received. Reception was often so weak, that the slightest noise in the neighbourhood made it impossible to record the coincidences.

At places where gravity determinations were also made, the wireless signals were recorded according to the HÄNNI-method. By this very convenient method the scheme seen in Fig. 9 was used.

When the rhythmic signals started they were counted, naming the first signal 1. The switch A was closed. Then, if the signal was still heard besides the chronometer-beats, the switch was opened again. After about 10 seconds, I again tried with the switch and if the signals were *not* heard, the switch was kept closed, the counting going on continously. The number of the signal which first appeared was written down, say 35. The counting continues. The switch is opened. At 45, that is 10 seconds later, the chronometer is read off and this reading noted, say $17^h\ 56^m\ 41^s$. Counting to 60, the next signal is again called 1. If the counting has been accurately carried through the signal 2 will now be a long one and this is written down. The record looks for instance like this:

Number of minute	Number of coincidence signal	Corrected number of coinc. sign.	Chronometer time	Long signal	
				appeared at	ought to be at
1	35	35	$17^h\ 56^m\ 41^s$	2	2
2	48	48	$57^m\ 53^s$	3	3
5	13	14	$18^h\ 00^m\ 17^s$	5	6

Here it is seen that the long beat after the 5th minute appeared at 5. This of course must be due to a mistake in the counting, and to correct, the number 13 of the 5th minute coincidence must be changed to 14. Having made this correction, we form the differences between the numbers of coincidences. They are $1^m\ 13^s$ resp. $2^m\ 26^s$. The differences between the chronometer readings are $1^m\ 12^s$ resp. $2^m\ 24^s$

and these numbers are evidently in accordance with each other, since the wireless signals gain one second between each coincidence and between the two last coincidences there must have been one which has for some reason not been recorded. As a control, the chronometer time of the last signal was recorded, estimated to a tenth of a second. When the signals were clear and distinct one could often distinguish between different types of appearance of the signal. Thus by putting after the number of the coincidence one of the following notations (0), (¼), (½), (¾), or (1) this estimate was counted for. By 35 (0) is meant that the 35th signal was just heard, by 48 (1) is meant that the 48th signal was fully heard, that is that in reality the coincidence occurred by 47. I learned this kind of estimation from Prof. MÜHLIG in Potsdam. It may be of more theoretic interest here, since the exactness in the time determination by means of the wireless signals is already perfect for the purpose referred to here without this method. But, for the gravity determinations, it means an important improvement. The mean error in the comparison is for one single coincidence about $0.^s01$. As a rule 4 coincidences could be recorded.

When the signals were recorded only in order to determine a longitude, the comparison was simply obtained by picking out by ear the coincidences between the rhythmic signals and the chronometer beats. This handy method gives an accuracy of about $0.^s04$ from each coincidence. By this method coincidences were observed from both beats $.^s0$ and $.^s5$ of the chronometer.

When comparing the results obtained from beats $.^s0$ with those from $.^s5$ no systematic difference was found. Neither was there discovered any systematic difference between the results which were obtained from this method and those derived from comparisons according to the HÄNNI-method.

The reception was often so weak that the HÄNNI-method could not be practised. Even under such extremely bad conditions at least 4 coincidences could usually be directly recorded and thus an accuracy of about $0.^s02$ was still obtained in the comparison, quite satisfactory for the longitude determination. Of the signals recorded, Rugby GMT 18^t, which came about midnight, was best to be heard.

TABLE I. SIDEREAL TIME

Corrections to be added to chronometer-readings by recording rhythmic wireless signals to get the moment $0^m 0^s.000$.

Number of signal	Nauen and Bordeaux − Number of minute 1	2	3	4	5	Rugby + Number of minute 1	2	3	4	5
0		$1^m 58^s.356$	$2^m 57^s.534$	$3^m 56^s.712$	$4^m 55^s.890$		$4^m 2^s.630$	$3^m 3^s.452$	$2^m 4^s.274$	$1^m 5^s.096$
1	$1^m 0^s.164$	59.342	58.520	57.698	56.876	$5^m 0^s.821$	1.643	2.465	3.287	4.109
2	1.151	2 0.329	59.507	58.684	57.862	4 59.835	4 0.657	1.479	2.301	3.123
3	2.137	1.315	3 0.493	59.671	58.849	58.849	3 59.671	3 0.493	1.315	2.137
4	3.123	2.301	1.479	4 0.657	59.835	57.862	58.685	2 59.507	2 0.329	1.151
5	4.109	3.287	2.465	1.643	5 0.821	56.876	57.698	58.520	1 59.342	1 0.164
6	5.096	4.274	3.452	2.630	1.808	55.890	56.712	57.534	58.356	0 59.178
7	6.082	5.260	4.438	3.616	2.794	54.904	55.726	56.548	57.370	58.192
8	7.068	6.246	5.424	4.602	3.780	53.917	54.739	55.561	56.383	57.205
9	8.055	7.233	6.411	5.589	4.767	52.931	53.753	54.575	55.397	56.219
10	1 9.041	2 8.219	3 7.397	4 6.575	5 5.753	4 51.945	3 52.767	2 53.589	1 54.411	0 55.233
11	10.027	9.205	8.383	7.561	6.739	50 958	51.780	52.602	53.424	54.246
12	11.014	10.192	9.370	8.547	7.725	49.972	50.794	51.616	52.438	53.260
13	12.000	11.178	10.356	9.534	8.712	48.986	49.808	50.630	51.452	52.274
14	12.986	12.164	11.342	10.520	9.698	48.000	48.822	49.644	50.466	51.288
15	13.972	13.150	12.328	11.506	10.684	47.013	47.835	48.657	49.479	50.301
16	14.959	14.137	13.315	12.493	11.671	46.027	46.849	47.671	48.493	49.315
17	15.945	15.123	14.301	13.479	12.657	45.041	45.863	46.685	47.507	48.329
18	16.931	16.109	15.287	14.465	13.643	44.054	44.876	45.698	46.520	47.342
19	17.918	17.096	16.274	15.452	14.630	43.068	43.890	44.712	45.534	46.356
20	1 18.904	2 18.082	3 17.260	4 16.438	5 15.616	4 42.082	3 42.904	2 43.726	1 44.548	0 45.370
21	19.890	19.068	18.246	17.424	16.602	41.095	41.917	42.739	43.561	44.384
22	20.877	20.055	19.232	18.410	17.588	40.109	40.931	41.753	42.575	43.397
23	21.863	21.041	20.219	19.397	18.575	39.123	39.945	40.767	41.589	42.411
24	22,849	22.027	21.205	20.383	19.561	38.136	38.959	39.781	40.603	41.425
25	23.835	23.013	22.191	21.369	20.547	37.150	37.972	38.794	39.616	40.438
26	24.822	24.000	23.178	22.356	21.534	36.164	36.986	37.808	38.630	39.452
27	25.808	24.986	24.164	23.342	22.520	35.178	36.000	36.822	37.644	38.466
28	26.794	25.972	25.150	24.328	23.506	34.191	35.013	35.835	36.657	37.479
29	27.781	26.959	26.137	25.315	24.493	33.205	34.027	34.849	35.671	36.493
30	1 28.767	2 27.945	3 27.123	4 26.301	5 25.479	4 32.219	3 33.041	2 33.863	1 34.685	0 35.507
31	29.753	28.931	28.109	27.287	26.465	31.232	32.054	32.876	33.698	34.521
32	30.740	29.918	29.095	28.273	27.451	30.246	31.068	31.890	32.712	33.534
33	31.726	30.904	30.082	29.260	28.438	29.260	30.082	30.904	31.726	32.548
34	32.712	31.890	31.068	30.246	29.424	28.273	29.096	29.918	30.740	31.562
35	33.698	32.876	32.054	31.232	30.410	27.287	28.109	28.931	29.753	30.575
36	34.685	33.863	33.041	32.219	31.397	26.301	27.123	27.945	28.767	29 589
37	35.671	34.849	34.027	33.205	32.383	25.315	26.137	26.959	27.781	28.603
38	36.657	35.835	35.013	34.191	33.369	24.328	25.150	25.972	26.794	27.616
39	37.644	36.822	36 000	35.178	34.356	23.342	24.164	24.986	25.808	26.630
40	1 38.630	2 37.808	3 36.986	4 36.164	5 35.342	4 22.356	3 23.178	2 24.000	1 24.822	0 25.644
41	39.616	38.794	37.972	37.150	36.328	21.369	22.191	23.013	23.835	24.658
42	40.603	39.781	38.958	38.136	37.314	20.383	21.205	22.027	22.849	23.671
43	41.589	40.767	39.945	39.123	38.301	19.397	20.219	21.041	21.863	22.685
44	42.575	41.753	40.931	40.109	39.287	18.410	19.233	20.055	20.877	21.699
45	43.561	42.739	41.917	41.095	40.273	17.424	18.246	19.068	19.890	20.712
46	44.548	43.726	42.904	42.082	41.260	16.438	17.260	18.082	18.904	19.726
47	45.534	44.712	43.890	43.068	42.246	15.452	16.274	17.096	17.918	18.740
48	46.520	45.698	44.876	44.054	43.232	14.465	15.287	16.109	16.931	17.753
49	47.507	46.685	45.863	45.041	44.219	13.479	14.301	15.123	15.945	16.767
50	1 48.493	2 47.671	3 46.849	4 46.027	5 45.205	4 12.493	3 13.315	2 14.137	1 14.959	0 15.781
51	49.479	48.657	47.835	47.013	46.191	11.506	12.328	13.150	13.972	14.795
52	50.466	49.644	48.821	48.000	47.177	10.520	11.342	12.164	12.986	13.808
53	51.452	50.630	49.808	48.986	48.164	9.534	10.356	11.178	12.000	12.822
54	52.438	51.616	50.794	49.972	49.150	8.547	9.370	10.192	11.014	11.836
55	53.424	52.602	51.780	50.958	50.136	7.561	8.383	9.205	10.027	10.849
56	54.411	53.589	52.767	51.945	51.123	6.575	7.397	8.219	9.041	9.863
57	55.397	54.575	53.753	52.931	52.109	5.589	6.411	7.233	8.055	8.877
58	56.383	55.561	54.739	53.917	53.095	4.602	5.424	6.246	7.068	7.890
59	57.370	56.548	55.726	54.904	54.082	3.616	4.438	5.260	6.082	6.904
60	1 58 356	2 57.534	3 56.712	4 55.890	5 55.068	4 2.630	3 3.452	2 4.274	1 5.096	0 5.918
61					56.054					4.932
62					57.040					3.945
63					58.027					2.959
64					59.013					1.973
65					59.999					0.986
					6 0.986					0 0.000

Nauen and Bordeaux — Additional corrections to the absolute values for estimating $^1/_4$ $^1/_2$ $^3/_4$: $+^s.003$ $+^s.007$ $+^s.010$

Rugby — Additional corrections to the absolute values for estimating $^1/_4$ $^1/_2$ $^3/_4$: $-^s.003$ $-^s.007$ $-^s.010$

TABLE 2. MEAN TIME

Corrections to be added to chronometer-readings in recording rhythmic wireless signals to get the moment 0m 0s.000.

Number of signal	Bordeaux and Nauen − Number of minute 1	2	3	4	5	Rugby + Number of minute 1	2	3	4	5
0		1m58s.033	2m57s.049	3m56s.066	4m55s.082		4m1s.967	3m2s.951	2m3s.934	1m4s.918
1	1m0s.000	59.016	58.033	57.049	56.066	5m 0s.000	0.984	1.967	2.951	3.934
2	0.984	2 0.000	59.016	58.033	57.049	4 59.016	4 0.000	0.984	1.967	2.951
3	1.967	0.984	3 0.000	59.016	58.033	58.033	3 59.016	3 0.000	0.984	1.967
4	2.951	1.967	0.984	4 0.000	59.016	57.049	58.033	2 59.016	2 0.000	0.984
5	3.934	2.951	1.967	0.984	5 0.000	56.066	57.049	58.033	1 59.016	1 0.000
6	4.918	3.934	2.951	1.967	0.984	55.082	56.066	57.049	58.033	0 59.016
7	5.902	4.918	3.934	2.951	1.967	54.098	55.082	56.066	57.049	58.033
8	6.885	5.902	4.918	3.934	2.951	53.115	54.098	55.082	56.066	57.049
9	7.869	6.885	5.902	4.918	3.934	52.131	53.115	54.098	55.082	56.066
10	1 8.852	2 7.869	3 6.885	4 5.902	5 4.918	4 51.148	3 52.131	2 53.115	1 54.098	0 55.082
11	9.836	8.852	7.869	6.885	5.902	50.164	51.148	52.131	53.115	54.098
12	10.820	9.836	8.852	7.869	6.885	49.180	50.164	51.148	52.131	53.115
13	11.803	10.820	9.836	8.852	7.869	48.197	49.180	50.164	51.148	52.131
14	12.787	11.803	10.820	9.836	8.852	47.213	48.197	49.180	50.164	51.148
15	13.770	12.787	11.803	10.820	9.836	46.230	47.213	48.197	49.180	50.164
16	14.754	13.770	12.787	11.803	10.820	45.246	46.230	47.213	48.197	49.180
17	15.738	14.754	13.770	12.787	11.803	44.262	45.246	46.230	47.213	48.197
18	16.721	15.738	14.754	13.770	12.787	43.279	44.262	45.246	46.230	47.213
19	17.705	16.721	15.738	14.754	13.770	42.295	43.279	44.262	45.246	46.230
20	1 18.689	2 17.705	3 16.721	4 15.738	5 14.754	4 41.311	3 42.295	2 43.279	1 44.262	0 45.246
21	19.672	18.689	17.705	16.721	15.738	40.328	41.311	42.295	43.279	44.262
22	20.656	19.672	18.689	17.705	16.721	39.344	40.328	41.311	42.295	43.279
23	21.639	20.656	19.672	18.689	17.705	38.361	39.344	40.328	41.311	42.295
24	22.623	21.639	20.656	19.672	18.689	37.377	38.361	39.344	40.328	41.311
25	23.607	22.623	21.639	20.656	19.672	36.393	37.377	38.361	39.344	40.328
26	24.590	23.607	22.623	21.639	20.656	35.410	36.393	37.377	38.361	39.344
27	25.574	24.590	23.607	22.623	21.639	34.426	35.410	36.393	37.377	38.361
28	26.557	25.574	24.590	23.607	22.623	33.443	34.426	35.410	36.393	37.377
29	27.541	26.557	25.574	24.590	23.607	32.459	33.443	34.426	35.410	36.393
30	1 28.525	2 27.541	3 26.557	4 25.574	5 24.590	4 31.475	3 32.459	2 33.443	1 34.426	0 35.410
31	29.508	28.525	27.541	26.557	25.574	30.492	31.475	32.459	33.443	34.426
32	30.492	29.508	28.525	27.541	26.557	29.508	30.492	31.475	32.459	33.443
33	31.475	30.492	29.508	28.525	27.541	28.525	29.508	30.492	31.475	32.459
34	32.459	31.475	30.492	29.508	28.525	27.541	28.525	29.508	30.492	31.475
35	33.443	32.459	31.475	30.492	29.508	26.557	27.541	28.525	29.508	30.492
36	34.426	33.443	32.459	31.475	30.492	25.574	26.557	27.541	28.525	29.508
37	35.410	34.426	33.443	32.459	31.475	24.590	25.574	26.557	27.541	28.525
38	36.393	35.410	34.426	33.443	32.459	23.607	24.590	25.574	26.557	27.541
39	37.377	36.393	35.410	34.426	33.443	22.623	23.607	24.590	25.574	26.557
40	1 38.361	2 37.377	3 36.393	4 35.410	5 34.426	4 21.639	3 22.623	2 23.607	1 24.590	0 25.574
41	39.344	38.361	37.377	36.393	35.410	20.656	21.639	22.623	23.607	24.590
42	40.328	39.344	38.361	37.377	36.393	19.672	20.656	21.639	22.623	23.607
43	41.311	40.328	39.344	38.361	37.377	18.689	19.672	20.656	21.639	22.623
44	42.295	41.311	40.328	39.344	38.361	17.705	18.689	19.672	20.656	21.639
45	43.279	42.295	41.311	40.328	39.344	16.721	17.705	18.689	19.672	20.656
46	44.262	43.279	42.295	41.311	40.328	15.738	16.721	17.705	18.689	19.672
47	45.246	44.262	43.279	42.295	41.311	14.754	15.738	16.721	17.705	18.689
48	46.230	45.246	44.262	43.279	42.295	13.770	14.754	15.738	16.721	17.705
49	47.213	46.230	45.246	44.262	43.279	12.787	13.770	14.754	15.738	16.721
50	1 48.197	2 47.213	3 46.230	4 45.246	5 44.262	4 11.803	3 12.787	2 13.770	1 14.754	0 15.738
51	49.180	48.197	47.213	46.230	45.246	10.820	11.803	12.787	13.770	14.754
52	50.164	49.180	48.197	47.213	46.230	9.836	10.820	11.803	12.787	13.770
53	51.148	50.164	49.180	48.197	47.213	8.852	9.836	10.820	11.803	12.787
54	52.131	51.148	50.164	49.180	48.197	7.869	8.852	9.836	10.820	11.803
55	53.115	52.131	51.148	50.164	49.180	6.885	7.869	8.852	9.836	10.820
56	54.098	53.115	52.131	51.148	50.164	5.902	6.885	7.869	8.852	9.836
57	55.082	54.098	53.115	52.131	51.148	4.918	5.902	6.885	7.869	8.852
58	56.066	55.082	54.098	53.115	52.131	3.934	4.918	5.902	6.885	7.869
59	57.049	56.066	55.082	54.098	53.115	2.951	3.934	4.918	5.902	6.885
60	1 58.033	2 57.049	3 56.066	4 55.082	5 54.098	4 1.967	3 2.951	2 3.934	1 4.918	0 5.902
61					55.082					4.918
62					56.066					3.934
63					57.049					2.951
64					58.033					1.967
65					59.017					0.984
					6 0.000					0 0.000

Bordeaux and Nauen: Additional corrections to the absolute values for estimating

1/4	1/2	3/4
+.004	+.008	+.012

Rugby: Additional corrections to the absolute values for estimating

1/4	1/2	3/4
−.004	−.008	−.012

III. C O M P U T A T I O N S

Throughout the following symbols are used:

φ = Latitude.

λ = Longitude.

α = Right Ascension.

δ = Declination.

t = Hour Angle.

ϑ = Sidereal Time.

a = Azimuth.

h = Altitude (Height).

$0^h\ 0^m\ 0^s$ = Sidereal Time.

$0^t\ 0^m\ 0^s$ = Mean Time.

When the large material of observations collected and prepared in the present paper is treated for determining geographical positions one must pay attention to the difficult conditions under which the material is often collected. Mistakes in the recorded figures may be frequent but are mostly easily corrected. It also often happens that observations made during cloudy nights are referred to wrong stars. It must be considered of importance to do one's utmost to utilize such observations, which at first sight seem insufficient or worthless.

The initial formula for observations at corresponding altitudes is:

(1) $$\sin h = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos t.$$

Differentiation gives

$$\cos h\, dh = -\cos \varphi \cos \delta \sin t\, dt$$

or if it is remembered that

$$\cos h \sin a = \cos \delta \sin t$$

we arrive at

$$dh = - \sin a \cos \varphi \, dt$$

or

$$\sin a = - \frac{dh}{dt} \sec \varphi. \tag{2}$$

By means of this formula, the azimuth can be calculated if $\frac{dh}{dt}$ and φ are known. The latitude φ is always approximately known from the map, and if a star has two observations, $\frac{dh}{dt}$ can also be calculated, even if the two observations are made with different positions of the instrument-circles, provided the index error is known. (See KOHLSCHÜTTER: Ostafrikanische Pendelexpedition II p. 31.) The azimuth thus obtained is very rough, still it is of value. I used a star globe in order to identify the stars. The globe was kept in a circular holder and at a point corresponding to $\delta = \varphi$ for the place in question and α = the corrected sidereal time for the moment of observation, a needle was attached. This needle carries a paste-board quadrant with a scale showing 90° at the needle and graduated from degree to degree. Along this scale a small pointer is moved and can be fixed at an angle, which corresponds to the altitude of the star (Fig. 12). The accuracy is about half a degree. By aid of this simple apparatus and using the azimuth calculated many imperfect and incomplete observations could be corrected and utilized.

In some cases mistakes in the original figures were discovered by means of another method. Proceeding from the best known values of φ and Δu we calculate

1. The *time* of the observation, supposing the measured altitude angle is correctly recorded.
2. The *altitude angle,* supposing the time is correctly recorded.

Comparing the obtained numbers with the observed such errors as a false minute of time, miswriting, and erraneous readings of the scales have been discovered. Only very few observations were rejected as useless.

The treatment of the different kinds of observations here is given with examples. Successive approximations were always used. The calculations have been made by help of a *Facit* calculating machine.

A. LATITUDE

a. Pevzoff Latitude Pairs.

Our fundamental formula is

$$\sin \varphi \sin \delta_1 + \cos \varphi \cos \delta_1 \cos t_1 = \sin \varphi \sin \delta_2 + \cos \varphi \cos \delta_2 \cos t_2 \tag{3}$$

from which we obtain

$$\tan\varphi = \frac{\cos\delta_2 \cos t_2 - \cos\delta_1 \cos t_1}{\sin\delta_1 - \sin\delta_2} = S \cdot \frac{1}{\sin\delta_1 - \sin\delta_2}. \tag{4}$$

Since the hour angle in this formula only appears in the form of its cosines, we never need consider its sign.

The calculations for the pair in question are accomplished as follows.

Example: Camp 23. Mo-chia-khutuk. 1929. Dec. 21.

Instruments used: Fennel Universal.
Chronometer Nardin 2324.
Chronograph Wetzer.

Seliverstov 41° 30′ Pair Nr. 17

Assistant: Dr. E. NORIN.

Clock-corrections: $\Delta u = -5^m 02^s.2$

The altitude level has its zeropoint at the objective end.

Scale-value of the altitude-level 8″.4.

α Cephei	West	ω Piscium
$\alpha = 21^h 16^m 51^s.67$	$\frac{dt}{dh} = -\frac{1}{7.0}$	$\alpha = 23^h 55^m 42^s.11$
$\delta = +62° 17' 24''.8$		$\delta = +6° 28' 30''.1$

α Cephei				ω Piscium			
Recorded passages	Level readings	Sum of level readings and interpolated values	Correction to level-sum = 40.00	Recorded passages	Level readings	Sum of level readings and interpolated values	Correction to level-sum = 40.00
	7.3—32.9	40.20			7.7—32.0	39.70	
$1^h 25^m 48^s.2$		40.23	$-^s.14$	$1^h 36^m 39^s.4$		39.67	$+^s.20$
26 06 .45		40.30	— .18	58 .0		39.60	+ .24
24 .7		40.37	— .22	37 16 .2		39.53	+ .28
	7.4—33.0	40.40			7.6—31.9	39.50	
54 .7		40.50	— .30	46 .1		39.45	+ .33
	7.5—33.1	40.60			7.5—31.9	39.40	
27 25 .0		40.62	— .37	38 14 .4		39.43	+ .34
43 .8		40.65	— .39	36 .0		39.50	+ .30
28 01 .45		40.68	— .41	53 .3		39.57	+ .26
	7.6—33.1	40.70			7.6—32.0	39.60	

Remarks: Second star weak, difficult to observe, lense misted over, 5th and 6th passages poor.

Taking the first passage of the first star as an example, the time correction for the interpolated level-sum is obtained thus

$$-\frac{8.4}{7.0}\frac{(40.23-40.00)}{2}=-0^{s}.14.$$

When the correction Δu and the level correction are applied we obtain the true sidereal time of each passage, and from this the hour angle is derived.

Diaphragm line	First Star			Second Star		
	Sidereal Time	Hour Angle		Sidereal Time	Hour Angle	
1	$1^h20^m45^s.86$	$4^h\ 3^m\ 54^s.16$	$60°58'32''.4$	$1^h31^m37^s.40$	$1^h35^m55^s.33$	$23°58'50''.0$
2	21 04 .07	4 12 .37	61 3 05 .6	56 .04	36 13 .97	24 03 29 .6
3	22 .28	30 .58	7 38 .7	32 14 .29	32 .22	08 03 .3
4	52 .20	5 00 .50	15 07 .5	44 .23	37 02 .16	15 32 .4
5	22 22 .42	30 .72	22 40 .8	33 12 .55	30 .48	22 37 .2
6	41 .21	49 .51	27 22 .7	34 .10	52 .03	28 00 .5
7	58 .84	6 07 .14	31 47 .1	51 .36	38 09 .29	32 19 .4

$\delta_1 = +62°\ 17'\ 24''.7$ $\quad\cos\delta_1 + .464994$ $\quad\sin\delta_1 + .885314$ $\quad\sin\delta_1 - \sin\delta_2 = + .772543$

$\delta_2 = +\ 6\ 28\ 30.3$ $\quad\cos\delta_2 + .993621$ $\quad\sin\delta_2 + .112771$ $\quad\dfrac{1}{\sin\delta_1 - \sin\delta_2} = + 1.294426$

	Diaphragm Line						
	1	2	3	4	5	6	7
$\cos t_1$	.485181	.484022	.482863	.480957	.479029	.477829	.476702
$\cos t_2$	.913683	.913132	.912590	.911697	.910850	.910201	.909681
$\cos\delta_2\cos t_2$	.907855	.907307	.906769	.905881	.905040	.904395	.903878
$\cos\delta_1\cos t_1$	.225606	.225067	.224528	.223642	.222746	.222188	.221664
S	.682249	.682240	.682241	.682239	.682294	.682207	.682214
$\tan\varphi$	.883121	.883109	.883110	.883108	.883179	.883066	.883076
φ	$41°26'54''.3$	$41°26'52''.9$	$41°26'53''.0$	$41°26'52''.8$	$41°27'00''.9$	$41°26'47''.9$	$41°26'49''.1$

The numerical values of the trigonometric functions are taken from the tables by PETERS.[1]

1 Prof. Dr. J. PETERS: Sechsstellige Tafel der trigonometrischen Funktionen (Berlin 1929).

If we now take a look at the resulting values for φ, we see that two of them, the 5th and the 6th, deviate considerably from the other ones. But since the note under "Remarks" says that the 5th and 6th passages of the second star are poor, they are of course rejected. Hence it is evident that notes like this are of great value. The mean value of the remaining 5 determinations is

$$\varphi = 41^\circ\, 26'\, 52''.4 \pm 0''.8$$

b. Latitude from Observations of Polaris

From observed altitudes of Polaris the latitude is calculated according to the formula given in ALBRECHT: Formeln und Hilfstafeln IV Aufl. p. 52.

$$(5) \qquad \varphi = h - p \cos t + M \sin^2 t + N$$

where

$$p = \text{the polar-distance of Polaris}$$

$$M = \frac{1}{2} p^2 \sin 1'' \tan \varphi$$

$$N = \frac{1}{6} p^3 \sin^2 1'' (1 + 3 \tan^2 \varphi) \sin^2 t \cos t.$$

When the following designations are introduced

$$\frac{p^2}{p_0^2} = K_2 \qquad \frac{p^3}{p_0^3} = K_3$$

$$\frac{1}{2} p_0^2 \sin 1'' \tan \varphi = M_0$$

and

$$\frac{1}{6} p_0^3 \sin^2 1'' (1 + 3 \tan^2 \varphi) \sin^2 t \cos t = N_0$$

we have

$$M = K_2 M_0 \quad \text{and} \quad N = K_3 N_0$$

The values of K_2, K_3, M_0, and N_0 are tabulated (Tables 3, 4, and 5). Such tables are given in the above mentioned ALBRECHT'S, Hilfstafeln too, but they are now out of date. They were published in 1908 and p_0 was at that time chosen $= 4080''$ corresponding to $\delta_{\text{Polaris}} = 88^\circ 52' 00''$. For my tables I have chosen $p_0 = 3840''$ corresponding to $\delta_{\text{Polaris}} = 88^\circ 56' 00''$.

A new edition of ALBRECHT's Hilfstafeln is much to be desired. This new edition ought to take special regard to the development of calculation methods (use of ma-

TABLE 3

δ Polaris	p	K_2	K_3
88°55′ 0″	3900″	1.032	1.05
10	3890	.026	.04
20	80	.021	.03
30	70	.016	.02
40	60	.011	.02
50	50	.005	.01
88°56′ 0	3840	1.000	1.00
10	30	0.995	0.99
20	20	.990	.98
30	10	.984	.98
40	3800	.979	.97
50	3790	.974	.96
88°57′ 0	3780	0.969	0.95
10	70	.964	.95
20	60	.959	.94
30	50	.954	.93
40	40	.949	.92
50	30	.944	.92
88°58′ 0	3720	0.939	0.91
10	10	.933	.90
20	3700	.928	.89
30	3690	.923	.89
40	80	.918	.88
50	70	.913	.87
88°59′ 0	3660	0.909	0.87
10	50	.904	.86
20	40	.899	.85
30	30	.894	.84
40	20	.889	.84
50	10	.884	.83
89° 0′ 0	3600	0.879	0.82

TABLE 4

φ	M_0	φ	M_0
33° 0′	23″.21	39° 0′	28″.95
10	.36	10	29.12
20	.51	20	.29
30	.66	30	.46
40	.81	40	.64
50	.96	50	.82
34° 0	24.11	40° 0	29.99
10	.26	10	30.17
20	.41	20	.35
30	.57	30	.53
40	.72	40	.71
50	.87	50	.89
35° 0	25.03	41° 0	31.07
10	.19	10	.25
20	.34	20	.44
30	.50	30	.62
40	.65	40	.81
50	.81	50	32.00
36° 0	25.97	42° 0	32.18
10	26.13	10	.37
20	.29	20	.56
30	.45	30	.75
40	.61	40	.95
50	.77	50	33.14
37° 0	26.94	43° 0	33.33
10	27.10	10	.53
20	.26	20	.72
30	.43	30	.92
40	.59	40	34.12
50	.76	50	.32
38° 0	27.93	44° 0	34.52
10	28.09	10	.72
20	.26	20	.92
30	.43	30	35.13
40	.60	40	.33
50	.77	50	.54
39° 0	28.95	45° 0	35.74

chines instead of logarithms) as well as other improvements and discoveries during the past years. It is now almost impossible to come across a copy of the old tables.

The formula for φ given above yields results of an accuracy of at least 0.″1 and the computations are carried out accordingly. But, since the observations do not possess such a degree of accuracy no care is taken to get the decimals absolutely correct.

Example: Camp 237. B a i. 1931 April 9.

Wild Precision Theodolite. Polaris $\alpha = 1^h\ 35^m\ 54^s.3$

Chronometer Nardin 2396. $\delta = +\ 88°\ 56'\ 09''.0$

Barom. 663.7 mm. Therm. +2° Cels.

$p = 3831''.0$ $M_0 = +\ 31''.95$ $K_2 = 0.995$ $M = +\ 31''.80$

$N_0 = -\ 0''.1$ $K_3 = 0.99$ $N = -\ 0''.1$

TABLE 5

N_0 in units $1''.10^{-2}$ computed for $\delta_{Polaris} = +88° 56' 00''$ or $p_0 = 3840''$.

t (+)	t (−)	34°	35°	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°	t (−)	t (+)
0^h 0^m	12^h	0	0	0	0	0	0	0	0	0	0	0	0	12^h 0^m	24^h
10		0	0	0	0	0	0	0	0	0	0	0	0	50	
20		0	0	1	1	1	1	1	1	1	1	1	1	40	
30		1	1	1	1	1	1	1	1	1	1	2	2	30	
40		2	2	2	2	2	2	2	2	2	3	3	3	20	
50		2	2	3	3	3	3	3	3	3	4	4	4	10	
1 0	13	3	3	4	4	4	4	4	5	5	5	5	6	11 0	23
10		4	5	5	5	5	6	6	6	7	7	7	8	50	
20		6	6	6	6	7	7	7	8	8	9	9	10	40	
30		7	7	7	8	8	9	9	9	10	10	11	12	30	
40		8	9	9	9	10	10	11	11	12	13	13	14	20	
50		10	10	11	11	12	12	13	13	14	15	16	16	10	
2 0	14	11	12	12	13	13	14	15	15	16	17	18	19	10 0	22
10		13	13	14	14	15	16	16	17	18	19	20	21	50	
20		14	15	15	16	17	18	18	19	20	21	22	24	40	
30		15	16	17	17	18	19	20	21	22	23	24	26	30	
40		16	17	18	19	20	20	21	23	24	25	26	28	20	
50		18	18	19	20	21	22	23	24	25	27	28	30	10	
3 0	15	18	19	20	21	22	23	24	25	26	28	29	31	9 0	21
10		19	20	21	22	23	24	25	26	27	29	30	32	50	
20		19	20	21	22	23	24	26	27	28	30	31	33	40	
30		20	21	22	23	24	25	26	27	29	30	32	34	30	
40		20	21	22	23	24	25	26	27	29	30	32	34	20	
50		20	21	21	22	23	25	26	27	28	30	32	33	10	
4 0	16	19	20	21	22	23	24	26	27	28	30	31	33	8 0	20
10		19	20	20	21	22	23	25	26	27	29	30	32	50	
20		18	19	20	21	22	23	24	25	26	27	29	30	40	
30		17	18	18	19	20	21	22	23	24	26	27	28	30	
40		16	16	17	18	19	20	21	22	23	24	25	26	20	
50		14	15	15	16	17	18	19	20	21	22	23	24	10	
5 0	17	13	13	14	14	15	16	16	17	18	19	20	21	7 0	19
10		11	11	12	12	13	13	14	15	15	16	17	18	50	
20		9	9	10	10	10	11	12	12	13	13	14	15	40	
30		7	7	7	8	8	8	9	9	10	10	11	11	30	
40		4	5	5	5	5	6	6	6	7	7	7	8	20	
50		2	2	3	3	3	3	3	3	3	4	4	4	10	
6 0	18	0	0	0	0	0	0	0	0	0	0	0	0	6 0	18
+	−													−	+

	RR		RL	
Sidereal Time ϑ (corrected)	$12^h\ 15^m\ 01^s.5$		$12^h\ 18^m\ 59^s.5$	
Hour Angle $t = \vartheta - \alpha$	10 39 07.2		10 43 05.2	
Altitude		40° 47′ 57″.4		40° 48′ 44″.6
sin t	+.3456		+.3293	
$\sin^2 t$ — $M \sin^2 t$	+.1194	+ 3.8	+.1084	+ 3.4
cos t — N	−.93837	− 0.1	−.94421	− 0.1
$-p \cos t$	+ 3594″.9	+ 59 54.9	+ 3617″.3	+ 1 00 17.3
Refraction correction		− 1 00.3		− 1 00.2
Sum		+ 41 46 55.7		+ 41 48 05.0
Index correction		+ 34.4		− 34.4
φ		+ 41° 47′ 30″.1		+ 41° 47′ 30″.6
Mean value	$\varphi = + 41° 47′ 30″.4$			

The numerical values of sin t and cos t are taken from "Tavole Logaritmiche" page 384 etc., and $\sin^2 t$ is obtained from sin t using "BARLOW's Tables".

c. Latitude from Observations of Southern Stars

Instead of using development into series or auxiliary angles for the calculation, the following way was chosen. The initial formula:

$$\sin h = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos t$$

can be transformed into a form more convenient for the calculations.
Adding to the right hand side

$$\cos \varphi \cos \delta - \cos \varphi \cos \delta$$

we get

$$\sin h = \sin \varphi \sin \delta + \cos \varphi \cos \delta - \cos \varphi \cos \delta + \cos \varphi \cos \delta \cos t$$
$$= \cos (\varphi - \delta) + \cos \varphi \cos \delta (\cos t - 1),$$

or

$$\cos (\varphi - \delta) = \sin h + \cos \varphi \cos \delta (1 - \cos t). \quad (6)$$

From this formula $(\varphi - \delta)$ is calculated and then φ is obtained.

When the stars are observed near the meridian, $(1 - \cos t)$ is a small quantity and thus, when calculating $\cos \varphi \cos \delta (1 - \cos t)$, it is sufficient to use a value for φ that is only a first approximation. The larger the value for t is, the more accurate must be the value for φ. In my case I always had a good first approximation for φ available from observations of Polaris, and thus this method was rather convenient.

The index-error of the altitude circle is partly determined from pairs of this type and hence the correction for this error must be applied after the calculation of the pair is completed. In order to obtain an expression for the correction we differentiate Equation (6). Remembering that the term

$$\cos\varphi\cos\delta\,(1-\cos t)$$

must be regarded as a constant, we obtain

$$-d\varphi\sin(\varphi-\delta)=dh\cos h,$$

or

$$d\varphi=-dh\frac{\cos h}{\sin(\varphi-\delta)}=-dh\left[1+\frac{\cos h-\sin(\varphi-\delta)}{\sin(\varphi-\delta)}\right]. \tag{7}$$

The numerical values of cos h and sin $(\varphi-\delta)$ are calculated to four decimals. Substituting for dh the index-error, the calculated value of $d\varphi$ is the correction required.

Example: Camp 457. 1932 July 22.

Wild Precision Theodolite. $\varphi_1=+35°\,25'.7$
Chronometer Nardin 2396. λ Sagittarii: $\alpha = 18^h\,23^m\,50^s.2$
Barom. 423 mm. Therm. +8° Cels. $\delta=-25°27'\,45''.9$

	R L		R R	
Sidereal Time ϑ (corrected)	$17^h\,55^m\,08^s.6$		$17^h\,57^m\,33^s.6$	
Hour Angle $t=\vartheta-\alpha$	− 28 41 .6 =	− 7°10′24″.0	− 26 16 .6 =	− 6°34′ 09″.0
Altitude h		28 46 47 .0		28 46 48 .0
Refraction correction		− 58 .9		− 58 .9
1 − cos t (unit 10^{-7}) h_{corr}	78271	28 45 48 .1	65655	28 45 49 .1
cos φ	.81484			
cos δ cos φ cos δ	.90286	.73569		
(1 − cos t) cos φ cos δ		57583		48302
cos h sin h	.8766	.4811932	.8766	.4811975
sin $(\varphi-\delta)$ cos $(\varphi-\delta)$	.8734	.4869515	.8739	.4860277
cos h − sin $(\varphi-\delta)$ $\varphi-\delta$	.0032	60°51′34″.5	.0027	60°55′12″.6
δ		− 25 27 45 .9		− 25 27 45 .9
(φ)		+ 35 23 48 .6		+ 35 27 26 .7
Index corr.		+ 1 46 .9		− 1 46 .8
φ		+ 35 25 35 .5		+ 35 25 39 .9
Mean value		$\varphi=+35°\,25'\,37''.7$		

Cos φ, cos δ, and their product are calculated with the same number of actual figures as (1—cos t). In the calculations seven decimals have been used. The trigonometric values were taken from JORDAN's Opus Palatinum. If the calculations are restricted to six decimals, errors of about $0^s.2$ may occur — for the present case this degree of accuracy would have been sufficient.

B. TIME

a. Corresponding Altitudes East and West.

Our initial relations are

$$\sin\varphi\sin\delta_1 + \cos\varphi\cos\delta_1\cos t_1 = \sin h_1 = x_1\,,$$
$$\sin\varphi\sin\delta_2 + \cos\varphi\cos\delta_2\cos t_2 = \sin h_2 = x_2$$

Differentiating these two equations we obtain

$$-\cos\varphi\cos\delta_1\sin t_1\,dt_1 = dx_1,$$
$$-\cos\varphi\cos\delta_2\sin t_2\,dt_2 = dx_2.$$

But since

$$dt_1 = dt_2 = \Delta u,$$

we get

$$\Delta u\,(\cos\varphi\cos\delta_2\sin t_2 - \cos\varphi\cos\delta_1\sin t_1) = dx_1 - dx_2.$$

Since the stars are observed at equal altitudes, we realize that if we use the true value Δu, we must have

$$x_1 + dx_1 = x_2 + dx_2,$$

or

$$dx_1 - dx_2 = x_2 - x_1,$$

and hence

$$\Delta u = \frac{x_2 - x_1}{\cos\varphi\cos\delta_2\sin t_2 - \cos\varphi\cos\delta_1\sin t_1}.$$

Counting Δu in seconds of time we eventually get

(8) $$\Delta u = \varkappa\,(x_2 - x_1),$$

where

(9) $$\varkappa = \frac{13751}{\cos\varphi\cos\delta_2\sin t_2 - \cos\varphi\cos\delta_1\sin t_1}.$$

The sign of $\varkappa$ in our observations must always agree with the sign of $\sin t_2$.

Of course, the formulas are valid only if the quantities dt_1 etc. are small. Therefore we first correct the observed values in the calculations, using an approximate value $\Delta_1 u$ for the clock correction.

For the time pairs, $\frac{dt}{dh}$ was empirically calculated from the time the stars used to cross the field of view. The distance between the two outermost lines of the diaphragm is $920''.5$. The correction for the level readings was made exactly in the same way as in the case of the PEVZOFF pairs.

Example: Camp 23. Mo-chia-khutuk. 1929 Dec. 20.

Fennel Universal Theodolite. West: α Pegasi: $\alpha = 23^h 01^m 15^s.12$

Chronometer Nardin 2324. $\delta = +14^\circ 49' 40''.8$

Chronograph Wetzer. East: γ Orionis: $\alpha = 5^h 21^m 23^s.02$

$\varphi = +41^\circ 26' 52''.8$ $\delta = +6^\circ 17' 22''.1$

The observed sidereal time is already corrected to approximately true sidereal time by adding $\Delta_1 u = -5^m 01^s.7$.

Corrections for the level-readings have also been applied.

STAR WEST			STAR EAST		
Sidereal Time	Hour Angle		Sidereal Time	Hour Angle	
$2^h 20^m 56^s.99$	$+3^h 19^m 41^s.87$	$+49^\circ 55' 28''.1$	$2^h 37^m 53^s.21$	$-2^h 43^m 29^s.81$	$-40^\circ 52' 27''.2$
21 08.92	53.80	58 27.0	40.28	42.74	55 41.1
20.39	20 05.27	+50 01 19.1	26.90	56.12	59 01.8
39.83	24.71	06 10.7	04.90	44 18.12	−41 04 31.8
59.32	44.20	11 3.0	36 41.82	41.20	10 18.0
22 10.91	55.79	13 56.9	29.17	53.85	13 27.8
22.60	21 07.48	16 52.2	16.92	45 06.10	16 31.5

$\sin\varphi$ +.661940	$\sin\delta_1$ +.255918		$\sin\delta_2$ +.109552
$\cos\varphi$ +.749557	$\cos\delta_1$ +.966698		$\cos\delta_2$ +.993981
$\cos\varphi\cos\delta_1$ +.724595	$\sin\varphi\sin\delta_1$ +.169402	$\cos\varphi\cos\delta_2$ +.745045	$\sin\varphi\sin\delta_2$ +.072517

$\cos t_1$	$\cos\varphi\cos\delta_1\cos t_1$	$\sin t_1$	$\cos t_2$	$\cos\varphi\cos\delta_2\cos t_2$	$\sin t_2$
+.643797	+.466492		+.756148	+.563364	
3133	6011		5532	2905	
2493	5547		4894	2430	
1409	4762	+.767	3844	1648	−.657
0322	3974		2740	0825	
.639674	3505		2134	0374	
9021	3031		1547	.559936	

x_1	x_2	$x_2 - x_1$	x	$\Delta_2 u$
.635894	.635881	−.000013		$+^s.17$
5413	5422	+. 9		−.12
4949	4947	−. 2		+.03
4164	4165	+. 1	−13200	−.01
3376	3342	−. 34		+.45
2907	2891	−. 16		+.21
2433	2453	+. 20		−.26

Mean value $\Delta_2 u = +0^s.07 \pm 0^s.09$

Result: $\Delta u = \Delta_1 u + \Delta_2 u = -5^m 01^s.63 \pm 0.09$

b. Transit in the Vertical of Polaris

For the computations the following formulas[1] were used (dashed symbols refer to Polaris, undashed to the Southern star).

$$(10) \qquad \Delta u = \alpha - \vartheta + \Delta \pm c \cdot k \qquad \begin{matrix} \text{RE} \\ \text{RW} \end{matrix}$$

where

$$\Delta = -\cot\delta' \sin(t' - t)(\tan\varphi - \tan\delta) \cdot 13751\,(1 + \mu),$$
$$\mu = \tan\delta \cot\delta' \cos(t' - t),$$

and

$$k = \sec\varphi \cdot \frac{\cos\frac{1}{2}(z' - z)}{\cos\frac{1}{2}(z' + z)}.$$

In the computations the collimation error — c — is at first neglected. Thus we get from two observations, one in RE and one in RW, two values for Δu, namely Δu_E and Δu_W, and have

$$(11) \qquad \begin{cases} \Delta u = \Delta u_E + c \cdot k, \\ \Delta u = \Delta u_W - c \cdot k. \end{cases}$$

In the expression for k we may put with sufficient accuracy

$$z' = 90^\circ - \varphi, \quad z_E = \varphi - \delta_E, \quad \text{and} \quad z_W = \varphi - \delta_W.$$

By doing so we get

$$k = \sec\varphi \cdot \frac{\cos\frac{1}{2}(90^\circ - 2\varphi + \delta)}{\cos\frac{1}{2}(90^\circ - \delta)}.$$

For convenience numerical values of k are tabulated in Table 6.

After having calculated Δu_E and Δu_W, we now get c from the relation

$$c = \frac{\Delta u_W - \Delta u_E}{k_E + k_W}.$$

With the obtained value for c we calculate Δu from one of the two relations (11). From the constancy from day to day of the of the collimation error c one gets an idea of the precision in the resulting values of Δu.

As already mentioned, the plate level of the "Wild" was not divided throughout. On repeated occasions I had trouble and confusion with the level-readings, and because of that I thought the best way to avoid such trouble in the future — and at

[1] Cf *Albrecht's* Hilfstafeln.

TABLE 6

$$k = \sec \varphi \cdot \frac{\cos \frac{1}{2}(90^\circ - 2\varphi + \delta)}{\cos \frac{1}{2}(90^\circ - \delta)}$$

δ \ φ	34°	36°	38°	40°	42°	44°	46°
−40°	2.819	2.871	2.926	2.983	3.045	3.110	3.180
−38	2.725	2.777	2.831	2.889	2.951	3.016	3.086
−36	2.637	2.689	2.744	2.802	2.863	2.928	2.998
−34	2.555	2.607	2.662	2.720	2.781	2.847	2.916
−32	2.479	2.531	2.585	2.643	2.705	2.770	2.840
−30	2.407	2.459	2.513	2.571	2.632	2.698	2.768
−28	2.339	2.391	2.445	2.503	2.565	2.630	2.700
−26	2.275	2.327	2.382	2.440	2.501	2.566	2.636
−24	2.214	2.266	2.321	2.379	2.440	2.506	2.576
−22	2.157	2.209	2.264	2.322	2.383	2.448	2.518
−20	2.103	2.155	2.209	2.267	2.328	2.394	2.464
−18	2.051	2.103	2.158	2.216	2.277	2.342	2.412
−16	2.001	2.054	2.108	2.166	2.227	2.293	2.363
−14	1.955	2.007	2.061	2.119	2.180	2.246	2.316
−12	1.909	1.961	2.016	2.074	2.135	2.201	2.270
−10	1.866	1.918	1.973	2.031	2.092	2.158	2.227
− 8	1.825	1.877	1.932	1.989	2.051	2.116	2.186
− 6	1.785	1.837	1.892	1.950	2.011	2.076	2.146
− 4	1.747	1.799	1.854	1.911	1.973	2.038	2.108
− 2	1.710	1.762	1.817	1.875	1.936	2.001	2.071
0	1.674	1.727	1.781	1.839	1.900	1.966	2.035
+ 2	1.640	1.692	1.747	1.805	1.866	1.932	2.001
+ 4	1.607	1.659	1.714	1.771	1.833	1.898	1.968
+ 6	1.575	1.627	1.682	1.739	1.801	1.866	1.936
+ 8	1.544	1.596	1.650	1.708	1.770	1.835	1.905
+10	1.514	1.566	1.620	1.678	1.739	1.805	1.875
+12	1.484	1.536	1.591	1.649	1.710	1.775	1.845
+14	1.456	1.508	1.563	1.620	1.682	1.747	1.817
+16	1.428	1.480	1.535	1.593	1.654	1.719	1.789
+18	1.401	1.453	1.508	1.566	1.627	1.692	1.762
+20	1.375	1.427	1.482	1.539	1.601	1.666	1.736
+22	1.349	1.401	1.456	1.514	1.575	1.640	1.710
+24	1.324	1.376	1.431	1.489	1.550	1.615	1.685
+26	1.299	1.352	1.406	1.464	1.525	1.591	1.660
+28	1.275	1.327	1.382	1.440	1.501	1.566	1.636
+30	1.252	1.304	1.359	1.416	1.478	1.543	1.613
+32	1.229	1.281	1.336	1.394	1.455	1.520	1.590
+34	1.206	1.258	1.313	1.371	1.432	1.498	1.567
+36	1.184	1.236	1.291	1.349	1.410	1.475	1.545
+38	1.162	1.214	1.269	1.327	1.388	1.453	1.523
+40	1.141	1.193	1.248	1.305	1.367	1.432	1.502
+42	1.122	1.172	1.226	1.284	1.345	1.411	1.481
+44	1.099	1.151	1.206	1.264	1.325	1.390	1.460
+46	1.078	1.131	1.185	1.243	1.304	1.370	1.440
+48	1.058	1.110	1.165	1.223	1.284	1.349	1.419
+50	1.038	1.090	1.145	1.203	1.264	1.330	1.399

the same time to simplify the observations — would be to adjust the theodolite so carefully that it should not be necessary to apply any level-correction at all. After the observations the exactness of the levelling was always checked. It is quite clear that this simplified procedure must mean a lack of accuracy — it would in fact have been far better to put a mark on the level, or on its fastening, to avoid confusion. The errors introduced are, however, of very little importance, since the method was used almost exclusively at places where longitudes are to be interpolated. And evidently the errors depending upon irregularities in the run of the chronometers are far greater than those which arise through deficiency in the nivellation of the theodolite.

In spite of the fact that I was aware of the lack of accuracy, I proposed this method without level-readings to Dr. NORIN, who did not possess a wireless set, for his time determinations. He determined latitudes from observations of Polaris and Southern stars near the meridian, and azimuths from observations of Polaris; for that reason a rough determination of time was satisfactory. And as he was not an astronomer by profession, I thought this method particularly suitable, because having observed the transit in the vertical of Polaris, he could immediately make an observation of the altitude of the Southern star used during the transit. Thus if a mistake was made in the identification of the star from the map, it could easily be discovered and corrected for. I have already completed the calculations of a great many of these observations, and have had opportunity to prove that the proposed simplified method was not out of place. Some might say that it would have been still better to instruct the observer to make the level-readings too. To this objection I would say that for a scientist, whose time is much occupied during fieldwork, and who has to make his astronomical observations in spare time, every facilitation in the observation work means an advantage. As already indicated, the observations referred to were arranged so that a small error in time was of no importance.

c. Altitudes East and West

Again we use the initial formula

$$\sin h = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos t,$$

which gives

$$\cos t = \frac{\sin h - \sin \varphi \sin \delta}{\cos \varphi \cos \delta}. \tag{12}$$

From this expression t is determined.

Through differentiation we get

$$dt = - dh \frac{\cos h}{15 \cos \varphi \cos \delta \sin t}, \tag{13}$$

from which formula the correction for the index-error of the altitude circle is calculated.

Example: Camp. 463. 1932 Aug. 11.

Wild Precision Theodolite. Star East: α Androm. $\alpha = 0^h\,04^m\,54^s.90$

Chronometer Nardin 2396. $\delta = +28^\circ\,43'\,07''.1$

$\varphi = 34^\circ\,43'\,42''.7$ Index error: $\begin{matrix}RR + \\ RL -\end{matrix}\ 2'\,10''.0$

$\sin\varphi = +.569689$ $\sin\delta = +.480509$ $\sin\varphi\sin\delta = +.273741$ $\cos\bar{h} = +.780$

$\cos\varphi = +.821860$ $\cos\delta = +.876990$ $\cos\varphi\cos\delta = +.720763$ $\sin\bar{t} = -.872$

	R L		R R		
h = Altitude (corr. for refraction)	38°31′13″.6		39°01′39″.7		$\bar{h} = +38°46'$
sin h	+.622794		+.629696		
sin h − sin φ sin δ	+.349053		+.355955		
cos t	+.484283		+.493859		
t	−61 02 04.2	− $4^h\,04^m\,08^s.28$	−60 24 19.8	− $4^h\,01^m\,37^s.32$	$\bar{t} = -60\ 43$
α		0 04 54.90		0 04 54.90	
$\vartheta = t + \alpha$		20 00 46.62		20 03 17.58	
ϑ obs.		19 51 59.6		19 54 51.8	
(Δu)		+ 8 47.02		+ 8 25.78	
Index. corr.		− 10.75		+ 10.75	
Δu		+ 8 36.27		+ 8 36.53	

In fact the above calculating scheme could have been made still simpler if Formula (12) was written the form

$$\cos t = (\sin h - \sin\varphi\sin\delta)\cdot\sec\varphi\sec\delta.$$

The reason why the index-error is not applied to the observed altitude is that it is partly determined from the difference between the observations here calculated. The definitive determination of this index-error will be treated below.

C. LONGITUDE

The calculation of the longitudes does not require much explanation. From the observations of star transits, the chronometer correction to local Sidereal Time is calculated, as shown above. The difference in time between Greenwich Sidereal Time which is determined, and calculated from the wireless signals, and the local sidereal time, gives directly the longitude desired. Some examples of the calculations follow. In fact the calculations have been performed with much individual consideration of which signals are in every particular case available for comparison, and of the uniformity of the rate of the chronometers.

For places where the reception of the time signals has failed, or where no time signals are registered, and where thus no wireless longitudes can be calculated, approximate longitudes are interpolated from the maps surveyed by Dr. NORIN and myself. In places where no topographic survey was carried out by us, other available maps were consulted. These interpolated longitudes are, of course, very rough. The reason why no longitudes are given as calculated from the interpolated time, derived from the transported chronometers is, as already indicated, that later papers are to deal with this problem in connection with the calculation of the triangulations, and the construction of our maps.

The Greenwich Sidereal Time for the moment of full hour at which the respective time-signals have been emitted, is calculated from the Sidereal Time given in Nautical Almanac 1929—1930 for Mean Noon and 1931 and onwards for the moment $0^h\ 0^m\ 0^s$. The quantities to be added are given in the following table:

Station	Approx. Local Mean Time	Greenwich Mean Time	Corrections to Greenwich Sidereal Time	
			1929—1930	1931
Bordeaux	2^t	20^t	$-16^h\ 02^m\ 37^s.70$	$-4^h\ 00^m\ 39^s.43$
Nauen	6	0	− 12 01 58 .28	
Bordeaux	14	8	− 4 00 39 .43	+ 8 01 18 .85
Rugby	16	10	− 2 00 19 .71	+ 10 01 38 .56
Nauen	18	12		+ 12 01 58 .28
Rugby	24	18	+ 6 00 59 .14	+ 18 02 57 .42

The emission of time signals does not occur at a moment corresponding to the exact full hour, but is affected by accidental errors which sometimes rise to unexpectedly large amounts. The exact moment of emission is taken from Bulletin Horaire. For the years 1929—1930 the tables giving "Heure demi-définitive", and their corrections "Amélioration de l'heure..." were used. For the years 1931—1933 the corrections to true time is received directly through the Tables VI "Heures définitives..." of the same publication.

In cases where the Nauen and Rugby time signals are for some reason, or other, not recorded in Bulletin Horaire, they are calculated by the aid of the corrections published in Beobachtungs Zirkular d. Astr. Nachrichten, respectively in Admiralty Notices to Mariners. These corrections are in such cases at first referred to the time system of Bulletin Horaire by the comparison of corresponding neighbouring corrections.

When these corrections are applied contemporaneously, the small correction for the time which the wireless signals require to reach the stations, is included. With sufficient accuracy this time is the same for all my stations and amounts to $\frac{1}{40}$ of a second.

When dealing with the calculation of the longitudes, I also take the opportunity to give an approximate idea of the travelling rates of the chronometers. Tables 7 and 8 give two series of comparisons for the chronometer Nardin 2396, obtained under quite different circumstances.

Table 7

Date	Signal	Gr. M. T.	Nardin 2396	λ'_{2396}
1932				
Febr. 6	Bordeaux	8^t	$22^h 13^m 45^s.18$	$-5^h 12^m 43^s.60$
	Rugby	10	0 14 04.85	43.56
	Nauen	12	2 14 24.55	[43.64]
				43.54
	Rugby	18	8 15 23.67	43.52
Febr. 7	Bordeaux	8	22 17 41.50	43.37
	Rugby	10	0 18 01.16	43.32
	Nauen	12	2 18 20.85	43.29
	Rugby	18	8 19 19.95	43.25
Febr. 8	Rugby	10	0 21 57.51	43.11
Febr. 10	Nauen	12	2 30 09.98	42.75

Table 8

Date	Signal	Gr. M. T.	Nardin 2396	λ'_{2396}
1932				
Sept. 3	Rugby	18^t	$22^h 47^m 39^s.51$	$-5^h 13^m 00^s.93$
9	"	"	23 11 18.83	00.96
15	"	"	23 34 58.16	04.87
19	"	"	23 50 44.37	07.35
22	"	"	0 02 34.03	09.15
27	"	"	0 22 16.80	13.74
29	"	"	0 30 09.91	14.70

The first series was observed in Yarkend. The chronometer was kept in a mud-hut, heated by a small stove of sheet-iron. Of course, such primitive heating cannot give a uniform temperature. Even if considerable differences are to be expected, it is still striking that the 3rd value $\lambda' = 5^h\ 12^m\ 43^s.64$ in Table 7 does not agree with the other ones. (The values are also represented in the diagram Fig. 13).

A careful examination of the observed data from which this exceptional figure was calculated did not reveal any mistake. The calculation also proved to be correct. But instead, it was discovered by comparing the values given in Bulletin Horaire and Beobachtungs Zirkular that one of these publications must have a printer's error as regards the figures given for the Nauen signal emitted at 12^t on 1932, Febr. 6. And as the value in Beobachtungs Zirkular agrees perfectly with the neighbouring values we have observed, it is stated that Bulletin Horaire is wrong. Therefore in its Vol. IV p. 364 1932, Febr. 6 DFY (Nauen) $12^h\ 6^m$ instead of 864, read 964. Thus, the value $43^s.64$ in Table 7 is given in brackets, the following line gives the correct figure 43.54.

The differences between a straight line joining the outermost points and a curve, which follows the values observed, never exceed $0^s.07$, the average deviation is $0.^s03$.

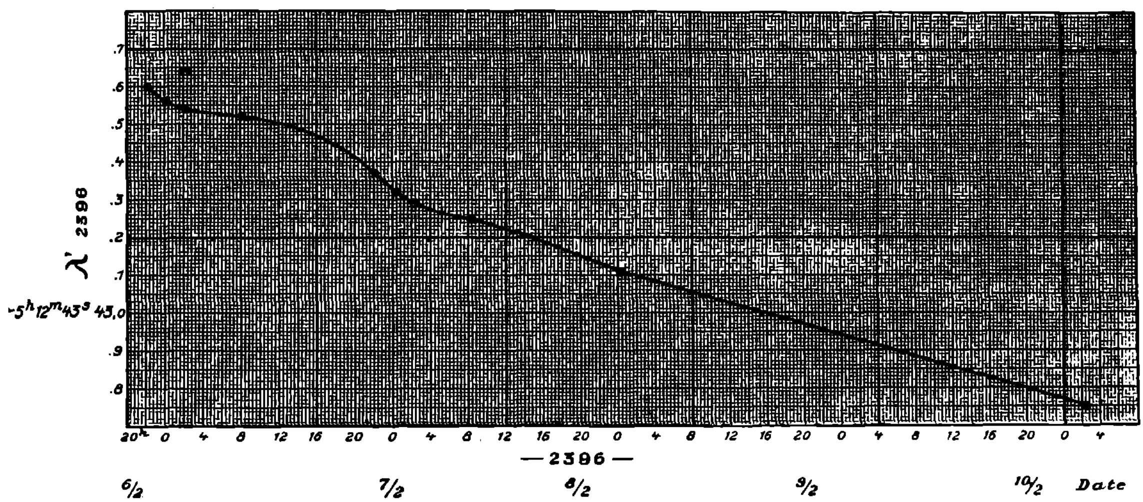

Fig. 13. Variation of λ'_{2396} in February 1932.

The series in Table 8, represented in Fig. 14, was obtained in September 1932. when I was travelling in Northern Tibet. Horses and donkeys were used for the transport, and the ground traversed was middle difficult, though the mean altitude was about 4800 m above sea-level. Our camp was pitched, and moved almost every day. From the diagram it is seen that there is a sudden leap in the travelling rate of the chronometer at the beginning of the month, but later on, the rate becomes fairly constant. The differences between a straight line joining the points representing Sept. 9, and Sept. 29, and the curve following the values observed is at maxi-

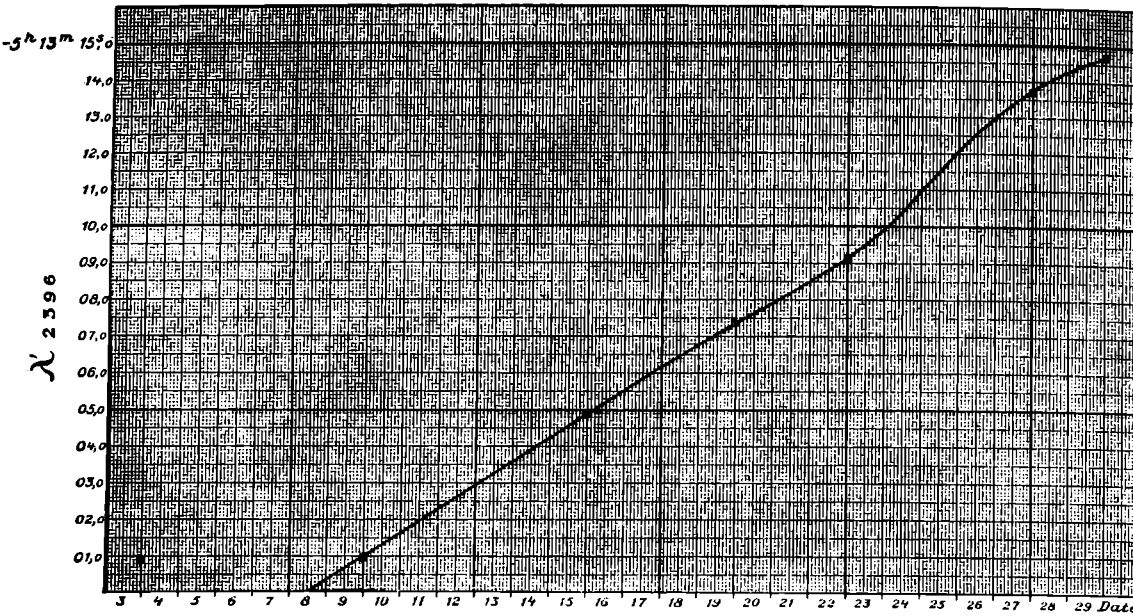

Fig. 14. Variation of λ'_{2396} during September 1932.

mum $1^s.0$, and upon an average $0^s.4$. In order to get figures directly comparable with those obtained in the first case, we divide these figures by 5, and obtain resp. $0^s.2$ and $0^s.08$. Hence in the second instance, the errors are about 3 times greater than in the first case, which means that the travelling rate of the chronometer, in the first instance, is about $3^2 = 9$ times more accurate than in the second.

In fact, the travelling rates of the Nardin chronometers were so reliable that the error in the records of Greenwich Time even at places where only one wireless comparison was obtained, is considerably smaller than the error which affects the determination of local time from star observations, provided the timeinterval between the wireless and the sidereal time determinations is not too long.

As numerical examples of the calculation of longitudes, we chose stations for which the time comparisons fall within the two series already discussed.

At Yarkend C. 309 the astronomical observations were made in the evening of Febr. 8, 1932. The chronometer used was Nardin 2324. The comparison between Nardin 2324, and Nardin 2396 which both are running sidereal time, was obtained by the aid of Nardin 2531 which runs mean time. The moment of coincidence for two chronometers running, one sidereal, and the other one mean time, is easily recorded, and all three chronometers concerned here were of such quality that no systematic errors occur between beats $^s.0$, and beats $^s.5$. Thus, we have one coincidence about every 3:rd minute. The following set of observations was obtained in the evening of Febr. 8.

Nardin 2531	Difference		Nardin 2396	Nardin 2324	Δ_{2324}
	Mean Time	Sidereal Time			
$19^t 37^m 57^s.00$			$4^h 00^m 27^s.00$		
	$1^m 32^s.00$	$1^m 32^s.25$			
39 29 .00			4 01 59 .25 comp.	$3^h 58^m 19^s.00$	$+ 3^m 40^s.25$
22 19 43 .00			6 42 39 .31 comp.	6 38 59 .00	+ 3 40 .31
	7 15 .00	7 16 .19			
26 58 .00			6 49 55 .50		

From the diagram in Fig. 13 we interpolate the values of λ'_{2396} corresponding to these two comparisons. From this λ'_{2396} we obtain λ'_{2324} by adding Δ_{2324}.

2396	2324	λ'_{2396}	λ'_{2324}
4^h 2^m	3^h 58^m	$- 5^h 12^m 43^s.08$	$- 5^h 09^m 02^s.83$
6 43	6 39	− 5 12 43 .06	− 5 09 02 .75

Between these two values of λ'_{2324} we interpolate the values valid for the moments at which the clock-corrections Δu_{2324} have been determined and finally obtain
$\lambda = \lambda'_{2324} - \Delta u_{2324}$.

2324	Δu_{2324}	λ'_{2324}	λ
5^h 22^m	$- 2^s.53$	$- 5^h 09^m 02^s.79$	$- 5^h 09^m 00^s.26$
5 51	− 2 .38	5 09 02 .77	.39
6 05	− 2 .47	5 09 02 .77	.30

Hence we obtain for C. 309:

$$\text{Mean value } \lambda = - \; 5^h 09^m 00^s.32 \pm 0^s.036$$
$$= - 77^\circ 15' 04''.8 \;\; \pm 0''.5.$$

At C. 484 the calculation is far simpler, as the same chronometer Nardin 2396 was used for the time determination from stars, and from wireless signals. The following values of the clock-correction Δu_{2396} were determined on Sept. 19:

Nardin 2396	Δu_{2396}
18^h 56^m	$+ 20^m 18^s.38$
59	+ 20 18 .07
19 02	+ 20 17 .90
04	+ 20 17 .50
Mean 19^h 00^m	$+ 20^m 17^s.96 \pm 0^s.16$

The linear interpolation between the values for λ'_{2396} obtained on Sept. 15, and on Sept. 19, (see Table 8), gives for $19^h 00^m$: $\lambda' = -5^h 13^m 07^s.23$, and the same value is obtained, if we instead extrapolate the value by the aid of corresponding values for Sept. 19, and Sept. 22. Hence the longitude is:

$$\lambda = \lambda'_{2396} - \Delta u_{2396} = -5^h 13^m 07^s.23 - 20^m 17^s.96$$
$$= -\ 5^h 33^m 25^s.19 \pm 0^s.16$$
$$= -83^\circ 21' 17''.9 \pm 2''.4$$

A note in the diary:: Breeze East and the temperature at which the observations were made (— 6°.2 Cels.), makes the mean error explainable.

For the determination on Sept. 9, at C. 479 interpolation between the values for Sept. 3, and Sept. 9, is *not* used, as it is evident that something has happened to the chronometer during these days, — though nothing is recorded in the diary. Extrapolating from Sept. 8 — Sept. 15, the probability to get the true value is far greater, and hence this method is used.

At this camp the following values of the clock-correction Δu_{2396} were determined:

Nardin 2396	Δu_{2396}
$18^h 32^m$	$+ 16^m 49^s.69$
34	.72
38	.99
40	.87
Mean $18^h 36^m$	Mean $+ 16^m 49^s.82 \pm 0^s.069$

For the value $18^h 36^m$ we get $\lambda'_{2396} = -5^h 13^m 00^s.84$

and hence:

$$\lambda = -\ 5^h 13^m 00^s.84 - 16^m 49^s.82 \pm 0^s.07$$
$$= -\ 5^h 29^m 50^s.66 \pm 0^s.07$$
$$= -82^\circ 27' 39''.9 \pm 1''.0.$$

D. INDEX-ERROR OF THE ALTITUDE CIRCLE

For the determinations, which depend on measured altitudes, it is of importance to determine the index-error — i — of the altitude circle. This determination was carried out as follows.

From the latitude determination derived from observations of Polaris we get:

RR
RL

$$i = \pm \frac{1}{2}(\varphi_{RL} - \varphi_{RR}).$$

From the latitude determination from southern stars we get:

$$\begin{matrix} \text{RR} \\ \text{RL} \end{matrix} \qquad i = \pm \frac{1}{2} (\varphi_{RR} - \varphi_{RL}),$$

and from stars observed for time determination we get one numerical value from each pair of observations. Differentiating our initial formula (1), and considering h and t as variable quantities, we find:

$$\cos h \, dh = - \cos \varphi \cos \delta \sin t \, dt,$$

or,

$$dh = - \frac{\cos \varphi \cos \delta \sin t}{\cos h} dt.$$

Let dt be equal to the difference $\Delta u_{RR} - \Delta u_{RL}$ obtained from a pair and expressed in seconds of time. Then we get:

$$\begin{matrix} \text{RR} \\ \text{RL} \end{matrix} \qquad i = \mp \frac{\cos \varphi \cos \delta \sin t}{\cos h} \frac{15}{2} [\Delta u_{RL} - \Delta u_{RR}].$$

Hence we get four values for i, whose mean is adopted for the derivation of the final results. I have always calculated the observations made in the different positions of the instrument, RR and RL, separately. This is of especial importance, because there is always a possibility that among the small number of observations available at the particular places, one for some reason may be poor. This is, of course, far more easily discovered, if the observations are treated separately, than in the case of a possible error already being partly smoothed out by forming a mean value with another observation. However, extremely few observations have been rejected for this reason.

It would have been advantageous if, in addition to each astronomical determination, yet another equation was given, determining the index-error from terrestrial observations. Such observations could easily have been made from almost every camp, and would have to a certain degree increased the value of the astronomical determinations.

E. REFRACTION

The refraction has been calculated by the aid of L. DE BALL: Refraktionstafeln, (Leipzig 1906) from the formula:

$$\log R = \log R_o + \log B + \log T.$$

The numeric values for log B, log T and log R_o, are taken from DE BALL's tables 1, 2, and 4, respectively. Table 1 is limited to pressures above 690 mm, and was therefore extended by an additional table going down to 390 mm. This table is published here, in a form suitable to be attached to DE BALL's tables (Table 9 in pocket, at the end of this paper).

It has not been considered necessary to pay any attention to the presence of moisture in the atmosphere, or to the altitude of the observer above sea-level, as the resulting corrections are insignificant, and also because the erratic effect caused by neglecting them, is fully compensated by the arrangement of making the star observations in opposite quarters.

Because of the peculiar geographical formation of the surface of the earth in Central Asia, and in consequense of the great diversity of the altitude of the territory which surrounds a station, one might expect that conspicuous anomalies in refraction could be discovered there. The Taklamakan desert, which has an average altitude of about 1200 m, is situated betweeen two mighty ranges of mountains, the T'ien-shan, and the K'un-lun. Along the border lines towards these two ranges there is a possibility that refraction anomalies might appear, due to the great difference in atmospheric conditions, which are likely to be found over two regions of such different characters. Over the desert the air is hot, and extremely dry, but over the mountains it is cold, and rather moist. Thus, it is conceivable that the refraction close to the T'ien-shan along its southern border line is greater for a star towards the north than a star towards the south. If we regard the northern border line of the K'un-lun range, on the other hand, we ought to expect the refraction to be greater for the southern stars. Hence, we must find, in the first case, a value of φ from observations of northern stars, which is greater than that derived from southern stars and in the second case a similar difference, as well. Now, one can say that in case of such differences occurring, they are simply due to the fact that the refraction value, which has been applied, is altogether too small.

In order to investigate this problem, the map in Fig. 15 has been prepared. For all stations where differences between determinations of latitude from observations of stars north and stars south could be calculated, they are plotted in that map. When $\varphi_N - \varphi_S$ is positive, it is marked by a line towards the north with its length corresponding to the amount of the difference. Differences $\Delta u_E - \Delta u_W$ are also given on a corresponding scale, and if positive the representing line is directed towards east. A glance at this figure shows that, as a rule, the lines $\varphi_N - \varphi_S$ along the boundaries in question, are all directed towards north. But as the lines representing the differences $\Delta u_E - \Delta u_W$ do not give preference to any special direction, we may conclude that the refraction is *not* to be corrected right through, but only for observations in the directions towards north—south.

It is impossible from the material collected by me to draw conclusions as to the real value of the corrections that ought to be applied for this anomaly. The problem must be more closely examined from a primary material containing many observations in different altitudes and azimuths. This material should include observations near zenith.

Anomalies of this type are likely to occur at all places where a corresponding topography exists, but in Central Asia such refraction deviations must be more

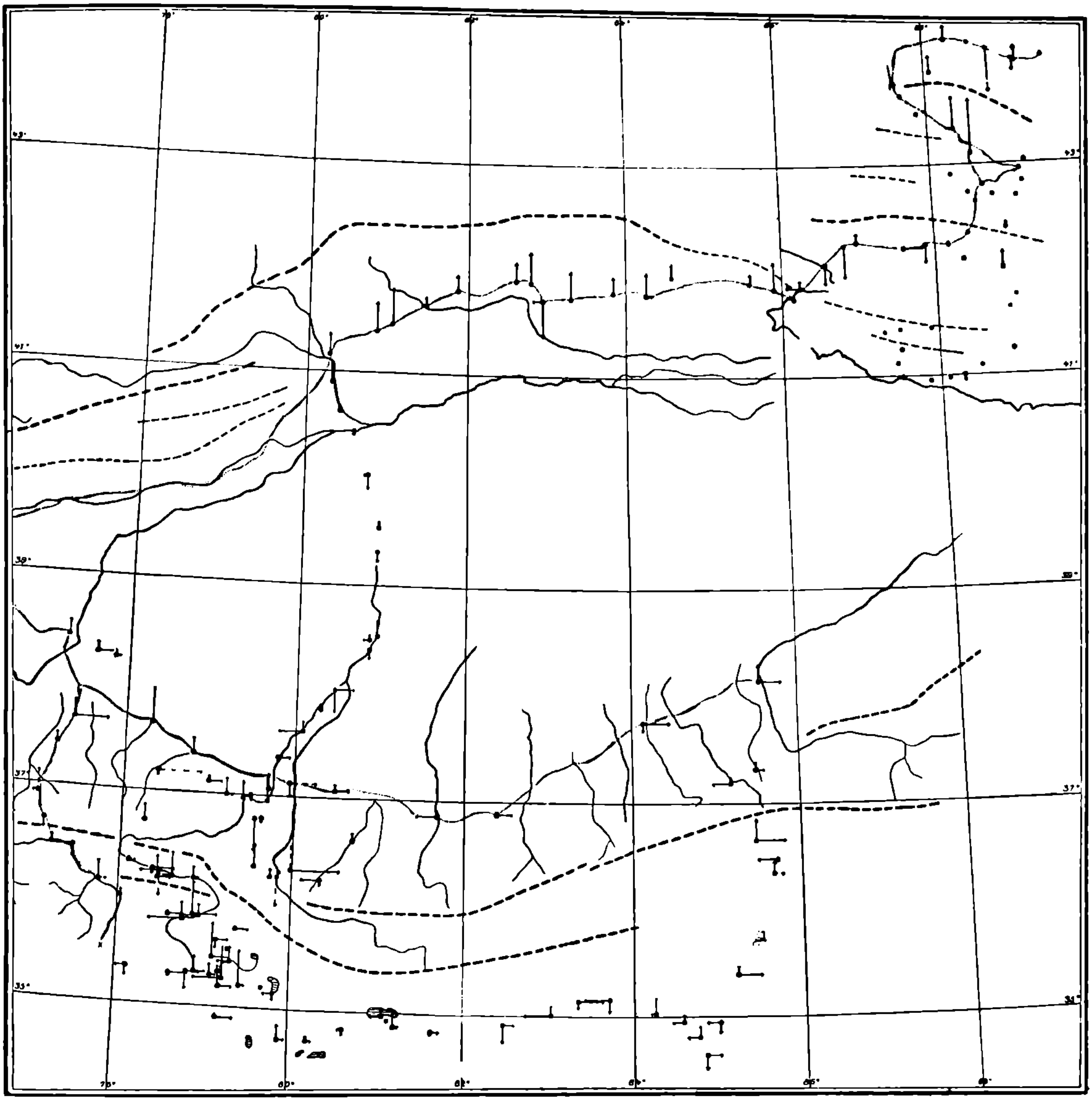

Fig. 15. Scale of the arrows: 1 mm = 1″.

pronounced than in most other parts of the earth, because of its peculiar geographical features, already mentioned.

It seems to me that a forthcoming Expedition should take up a comprehensive investigation of this interesting problem.

When we look back at the organization of the Expedition, it might now be considered a deficiency in the arrangements that the astronomical determinations have in some places been carried out according to methods which do not give any possibility of determining the refraction. Particularly regrettable is this deficiency, in regard to some places where the possibility of existing disturbances in the refraction might have been great, as for instance the three places situated in a row from north to south: Su-bashi, Turfan, and Qush-dong.

F. THE CORRECTIONS TO THE SYSTEM FK3

It is a general rule in natural science to express measured quantities in a number of figures which exceed the significative number by one, provided a mean error, denoting the degree of accuracy is not given. Therefore, it is so much more astonishing to see the great corrections according to the FK3 catalogue published in 1934 (a supplement to the Berliner Astronomisches Jahrbuch of 1936) that must be applied to the coordinates of stars as given in Berliner Jahrbuch.

American Ephemeris, Nautical Almanac, Almanaque Nautico de San Fernando, and Connaissance des Temps refer to the EICHELBERGER system, while the stars enumerated in the Berliner Astr. Jahrbuch form the system NFK. The stars coordinates in FK3 sometimes, and particularly for the stars of southern declinations, differ largely from those given in NFK; but when we compare the FK3 system with the EICHELBERGER system, the differences are of quite a modified order of magnitude, and fairly small. The FK3 system must for the present be considered as the most accurate, and so it ought to be recommended for works which are intended to produce results of the highest degree of accuracy.

The reason why the NFK is so very dissimilar to the FK3 and the EICHELBERGER systems is that AUWERS, when calculating this system, has used a number of older catalogues which have proved to be of a comparatively small accuracy, for instance the catalogues by BRADLEY and LALANDE.

The EICHELBERGER system, on the other hand, is based on few, but very accurate, star-catalogues.

When apparent places for the stars used by my observations were calculated, the FK3 corrections were not yet available, and thus I had to correct my calculations afterwards in order to refer my results to this system.

Of course, it would have been far easier to correct the positions of the stars before the computations. But even calculations already completed can be corrected without too much trouble.

The individual corrections of the stars have kindly been calculated by Miss PALMÉR. For 10-day stars belonging to Berliner Jahrbuch apparent places were taken from this almanac, and the individual corrections were simply taken from the "Dritter Fundamentalkatalog des Berliner Astronomischen Jahrbuchs, Reduktion des NFK auf den FK3 für 1925.0, 1934.5, 1935.5 und 1936.5, Katalog für 1950.0", which was published in 1934 as an appendix to Berliner Astronomisches Jahrbuch of 1936. For stars given in brackets in Berliner Astronomisches Jahrbuch, apparent places were calculated from Almanaque Nautico, and the corrections applied according to FK3 were obtained from:

$$\Delta\ App.\ place_{AN} = Mean\ place_{BJ} - Mean\ place_{AN} + \Delta_{FK3-NFK}.$$

For other stars no individual corrections were available. Their corrections were available. Their corrections were calculated by the aid of "Astronomical Papers Vol X, Part I" (Washington 1925), where the differences between the EICHELBERGER and the NFK systems are tabulated.

From the tables on pp. 152 and 153 (op. cit.) we get

$$\Delta\alpha_{NFK-Eich} = -[\Delta\alpha_\alpha + \Delta\alpha_\delta + (\Delta\mu_\alpha + \Delta\mu_\delta)\ (Ep. - 1925)]$$
$$\Delta\delta_{NFK-Eich} = -[\Delta\delta_\alpha + \Delta\delta_\delta + (\Delta\mu'_\alpha + \Delta\mu'_\delta)\ (Ep. - 1925)],$$

where $\Delta\mu_\alpha$ and $\Delta\mu_\delta$ are corrections to proper motion in α, and $\Delta\mu'_\alpha$ and $\Delta\mu'_\delta$ are corrections to proper motion in δ. (Since the tables are calculated so as to obtain the corrections to be applied to NFK in order to get EICHELBERGER, and since we desire the reverse corrections, we must change the sign for the total sums — hence the minus-sign before the big brackets.)

The corrections $\Delta\alpha_{FK3-NFK}$ and $\Delta\delta_{FK3-NFK}$ are taken from "Veröffentl. des Astr. Rechen Instituts zu Berlin Dahlem Nr. 54 pp. 84—87. Dritter Fundamentalkatalog des Berliner Astr. Jahrbuchs I Teil. Die AUWERS-Sterne für die Epochen 1925 und 1950." (1937).

When apparent places were first calculated for the stars observed by me, the positions were only in few cases taken from Berl. Jahrb. As the other catalogues used, are in fairly close accordance with FK3, the final corrections must be quite limited. In fact they are so small that it would perhaps not have been necessary to pay any attention to them. But because of the serious importance of this matter, and also because a correction to the system FK3 could conveniently be combined with a check of my calculations, I resolved to undertake the task involved by this changing of system.

The PEVZOFF latitude pairs have been corrected by a recalculation of the observation of the central line with corrected α and δ for the two stars.

In case no great difference appears between the first and the second result in the calculation of the same observations, the mean value of the seven transits is corrected according to this difference.

If an appreciable difference occurs, the first and the second calculations are checked in order to discover possible calculation errors. One single error of this kind has been found, due to a mistake in the interpolation of the apparent place of a star.

In order to get the corrections to those latitudes which are obtained through observations of Polaris, we differentiate equation (5). Disregarding the two last terms we find

$$d\varphi = -\cos t\, dp + p \sin t\, dt,$$

or, since

$$dp = -d\delta \text{ and } dt = -d\alpha,$$
$$d\varphi = \cos t\, d\delta - p \sin t\, d\alpha.$$

If $d\alpha$ is expressed in seconds of time we finally get

$$d\varphi = \cos t\, d\delta - \frac{p \sin t\, d\alpha}{13751}.$$

Assuming $p = 3840''$ we have

$$d\varphi = \cos t\, d\delta - 0''.3 \sin t\, d\alpha,$$

by the aid of which formula the proper corrections are calculated.

In case a southern star near the meridian has been observed for determination of latitude, the correction is simply $d\varphi = d\delta$.

For time determinations at corresponding altitudes the same method of reduction was used as for the PEVTSOV pairs — that is, recalculation of one of the transits.

For transits in the vertical of Polaris no corrections were applied for the change in the coordinates of Polaris, as they were of so small a magnitude, and the method used already implied larger errors. The change in declination of the clock star is of no importance, but the change in its rectascension $d\alpha$ has been taken into account and applied directly to Δu.

In order to obtain the corrections for stars observed East or West for time determinations, we consider Equation (1). Through differentiation we get

$$0 = \sin\varphi \cos\delta\, d\delta - \cos\varphi \cos t \sin\delta\, d\delta - \cos\varphi \cos\delta \sin t\, dt,$$

or if dt is expressed in seconds of time and $d\delta$ in seconds of arc,

$$dt = \left(\frac{\tan\varphi \operatorname{cosec} t}{15} - \frac{\tan\delta \operatorname{cotan} t}{15}\right) d\delta, \qquad \text{or} \qquad dt = (P + R)\, d\delta,$$

where $P = \frac{1}{15} \tan\varphi \operatorname{cosec} t$ and $R = -\frac{1}{15} \tan\delta \operatorname{cotan} t.$

Table 10 $P = \frac{1}{15} \tan \varphi \operatorname{cosec} t$

t \ φ	+35°	+37°	+39°	+41°	+43°	+45°
2h 0m	0.09	.10	.11	.12	.12	.13
30	.08	.08	.09	.10	.10	.11
3 0	.07	.07	.08	.08	.09	.09
30	.06	.06	.07	.07	.08	.08
4 0	.05	.06	.06	.07	.07	.08
5 0	.05	.05	.06	.06	.06	.07
6 0	.05	.05	.05	.06	.06	.07

Star East
$P -$

Star West
$P +$

Table 11 $R = -\frac{1}{15} \tan \delta \cot t$

t \ δ	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°
2h 0m	0.00	.01	.02	.03	.04	.05	.07	.08	.10	.12
5	.00	.01	.02	.03	.04	.05	.06	.08	.09	.11
10	.00	.01	.02	.03	.04	.05	.06	.07	.09	.10
20	.00	.01	.02	.03	.03	.04	.05	.07	.08	.10
40	.00	.01	.01	.02	.03	.04	.05	.06	.07	.08
3 0	.00	.01	.01	.02	.02	.03	.04	.05	.06	.07
30	.00	.00	.01	.01	.02	.02	.03	.04	.04	.05
4 0	.00	.00	.01	.01	.01	.02	.02	.03	.03	.04
30	.00	.00	.00	.01	.01	.01	.02	.02	.02	.03
5 0	.00	.00	.00	.00	.01	.01	.01	.01	.01	.02
30	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01
6 0	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Star East	
$\delta +$	$R +$
$\delta -$	$R -$

Star West	
$\delta +$	$R -$
$\delta -$	$R +$

Both these quantities are tabulated in Tables 10 and 11 for

Hour Angle	2^h	to	6^h
Latitude	$+35^\circ$	to	$+45^\circ$
Declination	0°	to	$\pm 45^\circ$

C. CORRECTIONS APPLIED TO THE COORDINATES OF DOUBLE STARS

As a rule close double stars were avoided as reference stars. In cases where such stars, nevertheless, have been observed, the position recorded of the double star corresponds to the average brightness of the pair. If the positions given in the ephemeris belong to one of the components due corrections to the medium were applied. These corrections are

$$\Delta\alpha_1^s = \frac{d}{k+1} \sin p \, \frac{\cos\delta}{15}$$

$$\Delta\delta_1'' = \frac{d}{k+1} \cos p$$

where

d = distance between the components in seconds of arc
p = position-angle from north, positive over east
δ = declination of the star
m_1 and m_2 = magnitudes of the two components
$\log k = -0.4\,(m_1 - m_2)$.

The most important corrections applied were those for ζ^1 Urs. Maj. $\Delta\alpha = +{}^s.18$ and $\Delta\delta = -2''.4$.

In the star list given in Berliner Jahrbuch some double stars are printed in a manner which may cause misunderstanding. For instance:

$$73\ \gamma\ \text{Androm.}\ \begin{matrix} 2.28 \\ 5.08 \end{matrix}\ \text{etc.}$$

The coordinates which follow, one should interpret as referring to the medium of the pair. But that is not the case. The coordinates are given for the *brightest* star. It would be far better to write γ^1 Androm. $2^m.28$ and put the magnitude $5^m.08$ for γ^2 in a foot-note together with its position angle and distance from γ^1, as do Nautical Almanac and also American Ephemeris.

Neither aberration, nor personal equation have been regarded as they are of a magnitude which is entirely concealed by the accidental errors. The same is valid for the variation of the Pole.

IV. LIST OF STATIONS

Longitudes printed in italics are determined by the aid of wireless signals. Longitudes given within [ ] are interpolated by the aid of itineraries. Mean errors within ( ) are estimated. All index-errors and collimation-errors refer do determinations made with the Wild Theodolite.

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error *i*	Collimation Error *c*
1*		URUMCHI	19. 3. 1929 6. 9. 1929 7. 9. 1929	43° 46′ 42″.2 ± 1″.0	4	*87° 36′ 12″.1 ± 1″.5*	2		
2*		TURFAN	16. 4. 1929	42° 56′ 37″.4 ± 1″.0	3	*89° 10′ 18″.* (± 3″.)	2		
3*		QUSH-DONG	25. 4. 1929 26. 4. 1929	42° 49′ 42″.4 ± 0″.2	3	[89° 12′]			
4*		SU-BASHI	4. 5. 1929 5. 5. 1929	43° 01′ 28″.1 ± 3″.3	2	*89° 15′ 08″.7 ± 2″.7*	3		
5*		DAVAN-CH'ENG I DAVAN-CH'ENG II	14. 5. 1929 30. 4. 1930	43° 20′ 53″.2 ± 3″.9 43° 20′ 01″.6 ± 2″.1	3 12	[88° 20′] [88° 21′		+ 14″.1	
6*	3		2. 10. 1929 3. 10. 1929	43° 29′ 01″.5 ± 0″.6	3	*87° 52′ 28″.6 ± 1″.0*	4		
7*	7	SHOR-BULAQ	11. 10. 1929	42° 54′ 10″. (± 3″.)	1	[88° 17′]			
8*	9	BURE-BULAQ	13. 10. 1929	42° 43′ 59″. ± 3″.	8	[88° 29′]			
9*	10	SU-BASHI	14. 10. 1929	42° 38′ 16″. (± 3″.)	9	[88° 35′]			
10*	12	ÜJME-DONG	16. 10. 1929	42° 20′ 35″. (± 3″.)	10	[88° 27′]			
11*	13	SHOR-BULAQ	19. 10. 1929	42° 05′ 54″.0 ± 2″.3	5	*88° 22′ 11″.9 ± 0″.6*	5		
12*	15	ARPISHME-BULAQ	8. 11. 1929 11. 4. 1930	42° 00′ 15″.3 ± 1″.2	4	*88° 52′ 38″.* (± 3″.)		+ 9″.3	
13*	23	MO-CHIA-KHUTUK	20. 12. 1929 21. 12. 1929 22. 12. 1929 1. 1. 1930	41° 26′ 52″.9 ± 0″.4	9	*87° 54′ 03″.1 ± 0″.9*	13		
14*	29	YUKKEN-GOL	23. 1. 1930	41° 26′ 24″. ± 15″.	2	[87° 30′]			
15*	32	SÖGET-BULAQ	4. 2. 1930	41° 24′ 42″.8 ± 1″.5	3	[87° 18′]			
16*	33	QURBANCHIQ	14. 2. 1930	41° 14′ 49″.2 ± 0″.8	7	*87° 30′ 27″.8 ± 0″.8*	4		

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error	Collimation Error c
17	34		19. 2. 1930	41° 07′ 00″. (± 10″.)	2	[87° 30′]			
18*	35	QURGHAN	20. 2. 1930 1. 3. 1930	40° 59′ 18″.7 ± 1″.1	2	*87° 30′ 35″. (± 3″.)*	2		
19*	35b	YING-P'AN	6. 3. 1930	40° 57′ 01″.8 ± 2″.9	2	*87° 51′ 31″.6 ± 2″.5*	3		
20	35c		8. 3. 1930	40° 58′ 17″.1 ± 1″.3	2	[88° 07′]			
21*	42	JIGDE-BULAQ	15. 3. 1930 18. 3. 1930	41° 00′ 14″.4 ± 1″.0	6	*88° 17′ 50″. (± 2″.)*	2	— 7″.5	
22	43		21. 3. 1930	41° 05′ 18″. (± 2″.)	2	[88° 31′]			
23*	44	GANSEN-TOGHRAQ-BULAQ	22. 3. 1930	41° 09′ 19″. (± 5″.)	1	[88° 49′]			
24*	45	NAN-CHAN-BULAQ	29. 3. 1930	41° 14′ 22″.7 ± 1″.9	4	*88° 56′ 29″.5 ± 1″.0*	5		
25	47 A	KHAGEN-BULAQ	7. 4. 1930	41° 37′ 53″. (± 6″.)	1	[88° 56′]			
26	48 A	YAM-BULAQ	8. 4. 1930	41° 44′ 53″. (± 3″.)	1	[89° 01′]			
27	52 A	ACHIQ-BULAQ	13. 4. 1930	42° 23′ 20″.7 ± 0″.8	8	[88° 57′]		+ 7″.9	
28*	53 A	BEJAN-TURA	15. 4. 1930	42° 41′ 03″.8 ± 1″.0	4	*89° 06′ 55″.9 ± 1″.8*	4		
29*	54 A	QAGHACHAQ	24. 4. 1930	42° 42′ 23″. (± 5″.)	2	[88° 48′]			
30	59 A	PAI-YANG-HO	29. 4. 1930	43° 12′ 14″. (± 2″.)	2	[88° 31′]			
31	63 A	CHI-CHI-TSAO	3. 5. 1930	43° 39′ 26″. (± 2″.)	4	[87° 41′]			
32	101		26. 7. 1930	43° 52′ 18″.6 ± 0″.4	4	[87° 40′]		+ 14″.3	
33	105	BOGDO	5. 8. 1930 24. 8. 1930	43° 53′ 22″.2 ± 1″.2	7	*88° 04′ 55″.8 ± 2″.9*	4	+ 41″.6	
34	107	T'U-TUN-TZE	4. 9. 1930	44° 12′ 02″.1 ± 0″.8	8	*88° 17′ 54″.2 ± 1″.8*	4	+ 34″.2	
35*	108	ERH-TAO-HO-TZE	6. 9. 1930	44° 10′ 30″. (± 5″.)	2	[88° 32′]		+ 38″.	
36*	109	WU-LIANG-MIAO	7. 9. 1930	44° 06′ 37″.3 ± 3″.8	4	[88° 49′]		+ 38″.8	

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error	Camp No. c
37*	110	P'O-CH'ENG-TZE	9. 9. 1930	44° 06′ 09″.1 ± 1″.1	4	[89° 06′]		+ 34″.5	
38*	112	KU-CH'ENG-TZE	12. 9. 1930	44° 01′ 36″.1 ± 0″.7	6	[89° 26′]		+ 33″.0	
39*	113	JIMASA	14. 9. 1930	44° 00′ 28″.3 ± 2″.2	6	[89° 04′]		+ 34″.7	
40*	206	HSIAO-TS'AO-HO	23. 2. 1931	43° 06′ 20″. (± 5″.)	4	[88° 33′]		+ 15″.1	+ 0s.44
41*	208	TOQSUN	26. 2. 1931	42° 47′ 45″. (± 5″.)	2	[88° 40′]		+ 32″.8	+ 0s.53
42*	211	QUMUSH	1. 3. 1931	42° 14′ 16″.9 ± 2″.5	4	[88° 11′]		+ 29″.1	+ 0s.74
43*	212	QARA-QIZIL	2. 3. 1931	42° 13′ 53″.1 ± 1″.7	4	[87° 53′]		+ 28″.5	+ 0s.69
44*	213	HSIN-CHING-TZE	3. 3. 1931	42° 13′ 14″. (± 3″.)	2	[87° 36′]		+ 29″.4	
45*	215	TAGHARCHI	5. 3. 1931	42° 15′ 44″.1 ± 3″.5	4	[86° 59′]		+ 30″.7	+ 1s.43
46*	216	OTUR-BULAQ	6. 3. 1931	42° 14′ 01″.0 ± 2″.7	4	[86° 49′]		+ 33″.8	+ 1s.20
47*	217	QARASHAHR	8. 3. 1931 9. 3. 1931	42° 03′ 22″.3 ± 1″.6	4	*86° 33′ 36″.* (± 3″.)	1	+ 30″.7	+ 1s.43 + 0s.66
48*	219	BASH-EGIN	19. 3. 1931	41° 50′ 03″.5 ± 0″.5	4	[86° 14′]		+ 30″.8	
49*	221	TIM	21. 3. 1931	41° 49′ 29″.0 ± 2″.2	4	[85° 54′]		+ 30″.5	+ 0s.47
50*	222	YANTAQ-KHUTUK	22. 3. 1931	41° 52′ 53″.0 ± 0″.7	4	[85° 35′]		+ 32″.4	+ 0s.48
51*	225	YANGI-HISSAR	25. 3. 1931	41° 56′ 37″.5 ± 1″.0	4	[84° 35′]		+ 34″.1	+ 0s.67
52*	226	BUGUR	26. 3. 1931 27. 3. 1931 28. 3. 1931	41° 46′ 21″.7 ± 1″.5	6	*84° 15′ 14″.* (± 3″.)	1	+ 36″.2	+ 0s.49
53*	228	AWAT (ABAD)	29. 3. 1931	41° 47′ 25″.3 ± 1″.0	5	[83° 50′]		+ 36″.1	+ 0s.46
54*	230	YAQA	31. 3. 1931	41° 43′ 48″.0 ± 2″.2	6	[83° 17′]		+ 37″.7	+ 0s.56
55*	231	KUCHAR	1. 4. 1931 2. 4. 1931	41° 42′ 35″.9 ± 3″.0	4	*82° 55′ 50″.9* (± 2″.0)	4	+ 34″.2	− 0s.09
56*	233	TOGHRAQ-DONG	5. 4. 1931	41° 52′ 39″.5 ± 2″.6	4	[82° 47′]		+ 34″.7	+ 0″.63

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error i	Collimation Error c
57*	234	YAO-TAN-TZU	6. 4. 1931	41° 53′ 15″.5 ± 1″.5	4	[82° 36′]		+ 39″.7	$+0^{s}.52$
58*	237	BAI	9. 4. 1931	41° 47′ 28″.6 ± 1″.3	4	[81° 52′]		+ 34″.4	$+0^{s}.44$
59*	239	QUSH-TAM	12. 4. 1931	41° 38′ 44″.8 ± 1″.0	4	[81° 28′]		+ 32″.7	$+0^{s}.50$
60*	241	TÜGE-KHANA	15. 4. 1931	41° 27′ 47″.1 ± 3″.0	4	[81° 04′]		+ 36″.0	$+0^{s}.42$
61*	242	QARA-YULGHUN	16. 4. 1931	41° 23′ 11″.5 ± 2″.2	5	[80° 51′]		+ 33″.8	$+0^{s}.52$
62*	244	AQSU, YANGI-SHAHR	19. 4. 1931 29. 4. 1931 4. 5. 1931	41° 09′ 39″.8 ± 1″.2	14	*80° 16′ 08″.* (± 3″.)	3	+ 37″.5 + 38″.7 + 34″.0	$+0^{s}.44$ $+0^{s}.36$ $+0^{s}.45$
63*	245	QUM-BASH	5. 5. 1931	40° 54′ 14″.1 ± 1″.6	4	[80° 18′]		+ 28″.5	$+1^{s}.01$
64	246	AWAT (ABAD)	6. 5. 1931	40° 38′ 08″.6 ± 1″.2	4	[80° 24′]		+ 34″.7	$+0^{s}.43$
65	247	YARKEND-DARYA	12. 5. 1931	40° 26′ 49″.6 ± 0″.9	8	*80° 34′ 53″.* (± 4″.)	1	+ 31″.8	$+0^{s}.85$
66	249		15. 5. 1931	40° 02′ 18″.5 ± 0″.9	6	[80° 49′]		+ 37″.3	
67	251	BORA-CHÜSHKAN- -BASHI	17. 5. 1931 18. 5. 1931	39° 32′ 13″.9 ± 1″.0	10	*80° 54′ 50″.* (± 3″.)	2	+ 36″.7	$+0^{s}.46$
68	252		22. 5. 1931	39° 18′ 38″.1 ± 0″.9	6	[80° 55′]		+ 36″.2	$+0^{s}.51$
69	255		29. 5. 1931	38° 31′ 22″.1 ± 1″.6	8	*80° 55′ 08″.* (± 3″.)	1	+ 42″.6	$+0^{s}.62$
70	256	MAZAR-TAGH	1. 6. 1931 2. 6. 1931	38° 29′ 07″.5 ± 1″.1	8	*80° 49′ 43″.0* ± 2″.2	2	+ 39″.1 + 41″.5	$+0^{s}.66$
71	257	SHOR-CHAQMA- -BASHI	8. 6. 1931	38° 23′ 39″.8 ± 0″.4	9	*80° 49′ 53″.0* ± 2″.1	2	+ 39″.9	$+0^{s}.71$
72	259		10. 6. 1931	38° 00′ 34″.2 ± 1″.8	4	[80° 26′]		+ 43″.7	
73	260	KALU	12. 6. 1931	37° 49′ 09″.7 ± 0″.8	8	*80° 16′ 20″.2* ± 1″.3	2	+ 46″.5	$+0^{s}.45$
74	261	CHINAR	15. 6. 1931	37° 36′ 52″.2 ± 1″.1	6	[80° 04′]		+ 51″.9	
75	262	ESKI	16. 6. 1931	37° 21′ 42″.2 ± 0″.9	6	[79° 46′]		+ 48″.4	$+0^{s}.53$
76*	263	KHOTAN	17. 6. 1931 6. 8. 1931 8. 8. 1931	37° 07′ 18″.3 ± 1″.3	9	*79° 55′ 58″.0* ± 2″.1	3	+ 59″.8 + 57″.8 + 63″.3	$+0^{s}.83$ $+0^{s}.86$

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error *i*	Collimation Error *c*
77	266	LANGHRU	29. 9. 1931	36° 56′ 34″.6 ± 1″.5	8	*79° 40′ 14″.5* ± 1″.2	2	+ 57″.0	$+0^{s}.76$
78	268	LOK-ÖGHIL	12. 10. 1931	36° 46′ 46″.7 ± 2″.6	4	*79° 32′ 22″.6* ± 1″.9	3	+ 60″.2	$+0^{s}.73$
79	269	ULUGH-ART-DAVAN	14. 10. 1931	36° 47′ 06″.9 ± 1″.9	4	*79° 37′ 07″.4* ± 2″.4	2	+ 66″.6	
80	272	BOSTANG-TOGHRAQ	31. 10. 1931	37° 00′ 00″.0 ± 0″.4	4	[79° 29′]		+ 58″.4	
81	273	ACHIQ-JILGA	1. 11. 1931	36° 57′ 52″.7 ± 1″.3	4	[79° 23′]		+ 62″.2	
82	274	JAFARNING-POTAI	2. 11. 1931	36° 59′ 46″.2 ± 1″.6	4	[79° 12′]		+ 55″.1	
83	275	DUWA	3. 11. 1931 12. 11. 1931	37° 06′ 34″.3 ± 0″.9	10	*78° 59′ 21″.6* ± 2″.9	4	+ 56″.2 + 54″.8	$+0^{s}.54$
84	277	TOZAQCHI	20. 11. 1931	37° 03′ 35″.9 ± 1″.1	4	*79° 41′ 16″.6* ± 1″.1	2	+ 57″.9	
85	282		27. 11. 1931 14. 12. 1931	36° 18′ 30″.8 ± 2″.8	2	[79° 58′]		+ 57″.1	
86	283	QARANGHU-TAGH	29. 11. 1931	36° 14′ 15″.1 ± 0″.8	4	*79° 44′ 14″.7* ± 0″.9	3	+ 56″.8	
87	285	NISSA	4. 12. 1931 6. 12. 1931	36° 20′ 01″.4 ± 1″.8	4	[79° 33′]		+ 54″.0	
88	294	HASHA	19. 12. 1931	36° 36′ 02″.3 ± 2″.3	7	*80° 40′ 50″.4* ± 4″.4	2	+ 55″.6	
89*	300	ZANGUYA	16. 1. 1932	37° 22′ 05″.2 ± 1″.2	4	*78° 47′ 23″.* (± 4″.)	1	+ 59″.9	
90*	302	GUMA	18. 1. 1932	37° 37′ 33″.0 ± 2″.9	4	[78° 18′]		+ 53″.7	
91	307	HANGETLIK	24. 1. 1932	38° 13′ 48″.7 ± 1″.4	4	*77° 49′ 01″.6* ± 0″.4	2	+ 53″.8	
92	308		25. 1. 1932	38° 15′ 59″.1 ± 0″.5	6	*77° 35′ 55″.6* ± 2″.2	2	+ 52″.8	
93*	309	YARKEND	8. 2. 1932	38° 24′ 34″.3 ± 1″.1	4	*77° 15′ 05″.1* ± 0″.6	3	+ 51″.2	$+1^{s}.14$
94	402	BESH-TEREK	25. 3. 1932	37° 38′ 33″.8 ± 1″.4	4	*77° 22′ 43″.4* ± 4″.9	2	+ 59″.9	
95	403	KÖK-YAR	27. 3. 1932	37° 24′ 08″.2 ± 2″.6	3	*77° 11′ 14″.* (± 3″.)	1	+ 57″.4	
96	407		31. 3. 1932	36° 55′ 08″.0 ± 2″.3	2	*76° 59′ 31″.0* ± 1″.0	3	+ 58″.7	

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Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error	Collimation Error c
97	409	GRUNJ-KARLIK	2. 4. 1932	36° 40′ 32″.0 ± 0″.8	4	77° 05′ 12″.8 ± 1″.8	2	+ 60″.8	
98	411	QULAN-ÖLDI	5. 4. 1932	36° 27′ 04″.5 ± 0″.9	4	77° 12′ 28″.6 ± 1″.0	3	+ 61″.2	+ 0s.85
99	412	LATE-YAY	6. 4. 1932	36° 26′ 10″.1 ± 1″.2	4	77° 26′ 10″.8 ± 3″.1	2	+ 64″.4	
100	414	KHAPALUNG	8. 4. 1932	36° 08′ 07″.6 ± 1″.4	4	77° 45′ 22″. (± 2″.)	3	+ 60″.4	
101	415	AQ-TAGH	10. 4. 1932	35° 59′ 54″.1 ± 0″.7	4	78° 01′ 25″.0 ± 4″.1	4	+ 58″.3	
102	420		15. 4. 1932	35° 20′ 10″.2 ± 2″.3	4	78° 07′ 21″.1 ± 2″.5	4	+ 59″.2	
103	422		18. 4. 1432	35° 17′ 32″.8 ± 0″.5	4	78° 37′ 12″.3 ± 1″.9	4	+ 57″.9	
104	424		20. 4. 1932	35° 18′ 33″.0 ± 2″.9	4	78° 49′ 01″.6 ± 1″.8	4	+ 56″.8	
105*	425		26. 4. 1932	35° 19′ 01″.7 ± 1″.5	4	78° 54′ 18″.1 ± 1″.8	4	+ 57″.1	
106	426		27. 4. 1032	35° 17′ 31″.7 ± 1″.4	4	79° 05′ 19″.5 ± 0″.6	4	+ 57″.6	
107	428		29. 4. 1932	35° 12′ 21″.4 ± 3″.1	4	79° 25′ 41″.1 ± 2″.4	4	+ 59″.0	
108*	430	AQ-SAI-CHIN	16. 5. 1932	35° 08′ 35″.4 ± 1″.4	4	79° 49′ 05″.0 ± 1″.0	4	+ 64″.3	
109	431		17. 5. 1932	35° 11′ 55″. (± 5″.)	2	[79° 41′]		(+ 57″.3)	
110	434		20. 5. 1932	35° 15′ 46″.7 ± 2″.7	4	79° 13′ 28″.2 ± 3″.4	4	+ 64″.0	
111	435		27. 5. 1932	35° 19′ 33″.1 ± 0″.7	4	79° 10′ 33″.2 ± 0″.7	4	+ 58″.4	
112	436		30. 5. 1932	35° 27′ 39″.4 ± 2″.8	4	79° 06′ 33″.6 ± 2″.2	4	+ 68″.6	
113	440		3. 6. 1932	35° 50′ 57″.7 ± 2″.8	4	78° 51′ 51″.6 ± 3″.9	4	+ 51″.4	
114	444	KENG-SHEWAR	15. 6. 1932	36° 12′ 01″.3 ± 1″.9	4	78° 36′ 30″.1 ± 0″.9	4	+ 62″.3	
115	445	QAWAQ	29. 6. 1932	36° 14′ 49″.1 ± 2″.8	2	78° 27′ 49″.8 ± 1″.5	5	+ 76″.9	
116	446	ASEM-KHAN-SESA	1. 7. 1932	36° 10′ 45″.2 ± 2″.2	4	78° 26′ 31″.3 ± 2″.1	4	+ 80″.4	

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error *i*	Collimation Error *c*
117	449	YANGI-YAYLAQ	6. 7. 1932	35° 50′ 34″.6 ± 0″.5	4	*78° 35′ 00″.0* ± 1″.6	4	+ 77″.1	
118	451		8. 7. 1932	35° 48′ 03″.3 ± 2″.2	4	*78° 44′ 36″.7* ± 3″.5	4	+ 85″.9	
119	452		9. 7. 1932	35° 50′ 04″.5 ± 1″.0	4	*78° 56′ 18″.9* ± 1″.8	4	+ 89″.1	
120	454		11. 7. 1932	35° 37′ 26″.8 ± 0″.9	4	*79° 08′ 47″.4* ± 1″.7	4	+ 85″.1	
121*	455		15. 7. 1932 22. 7. 1933	35° 44′ 00″.4 ± 1″.7	12	*79° 21′ 40″.6* ± 1″.6	8	+ 94″.1 + 71″.6	
122	457		22. 7. 1932	35° 25′ 39″.4 ± 1″.2	4	*79° 18′ 52″.6* ± 1″.2	4	+ 106″.5	
123	461		8. 8. 1932	34° 44′ 01″.3 ± 2″.2	4	*79° 53′ 05″.0* ± 1″.9	4	+ 120″.4	
124	463		11. 8. 1932	34° 43′ 42″.6 ± 1″.3	4	*80° 12′ 32″.1* ± 1″.9	4	+ 130″.0	
125	466		20. 8. 1932	34° 50′ 43″.4 ± 0″.7	6	*80° 36′ 51″.3* ± 1″.8	4	+ 125″.6	
126	469		27. 8. 1932	34° 58′ 40″.4 ± 1″.5	4	*81° 04′ 10″.5* ± 2″.5	4	+ 106″.3	
127	470		28. 8. 1932	34° 56′ 15″. (± 5″)	2	[81° 08′]		+ 104″.7	
128	471		30. 8. 1932	34° 52′ 21″.8 ± 1″.4	4	*81° 12′ 23″.5* ± 0″.7	4	+ 36″.7	
129	473		3. 9. 1932	34° 50′ 45″.0 ± 1″.8	4	*81° 38′ 13″.4* ± 1″.5	4	+ 44″.7	
130	479		9. 9. 1932	34° 55′ 06″.7 ± 1″.4	4	*82° 27′ 41″.1* ± 1″.1	4	+ 38″.3	
131	482		15. 9. 1932	35° 00′ 39″.2 ± 1″.1	4	*83° 01′ 16″.0* ± 2″.6	4	+ 43″.7	
132	484		19. 9. 1932	35° 08′ 46″.8 ± 1″.5	4	*83° 21′ 18″.3* ± 2″.4	4	+ 42″.3	
133	486		22. 9. 1932	35° 09′ 31″.8 ± 0″.9	4	*83° 42′ 52″.5* ± 2″.5	4	+ 47″.3	
134	491		27. 9. 1932	35° 01′ 39″.4 ± 1″.7	4	*84° 14′ 59″.1* ± 1″.5	4	+ 41″.4	
135	493		29. 9. 1932	34° 57′ 27″.4 ± 1″.4	4	*84° 34′ 32″.9* ± 1″.5	4	+ 45″.5	
136	495		2. 10. 1932	34° 48′ 43″.2 ± 0″.9	4	*84° 45′ 31″.3* ± 3″.0	4	−8′50″.2	

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error *i*	Collimation Error *c*
137	497		10. 10. 1932	34° 38′ 28″.2 ± 1″.1	4	*84° 50′ 15″.9* ± 2″.5	4	− 8′ 52″.1	
138	502		15. 10. 1932	34° 57′ 07″.8 ± 1″.0	4	*84° 59′ 25″.6* ± 1″.7	4	− 8′ 49″.7	
139	505		18. 10. 1932	35° 23′ 36″.8 ± 0″.8	6	*85° 18′ 34″.5* ± 2″.5	4	− 8′ 45″.7	
140	514		27. 10. 1932	36° 20′ 47″.2 ± 0″.9	4	*85° 39′ 41″.0* ± 0″.8	3	− 8′ 53″.1	
141	515		28. 10. 1932	36° 28′ 34″.7 ± 0″.6	2	*85° 42′ 09″.6* ± 2″.0	4	− 8′ 45″.2	
142	517		30. 10. 1932	36° 39′ 02″.7 ± 1″.7	4	*85° 27′ 15″.4* ± 3″.3	4	− 8′ 49″.2	
143	524	KÖNCHE-BULAQ	10. 11. 1932	37° 11′ 03″.2 ± 0″.7	4	*85° 10′ 14″.8* ± 1″.9	4	− 8′ 52″.1	
144	526	ACHAN	24. 11. 1932	37° 18′ 59″.1 ± 4″.1	4	*85° 28′ 03″.6* ± 2″.2	4	− 8′ 53″.6	
145*	528	CHARCHAN	31. 1. 1933 15. 3. 1933	38° 08′ 22″.8 ± 1″.6	8	*85° 31′ 56″.7* ± 1″.6	8	+ 10″.9 + 43″.8	
146	605	SHUDAN	8. 4. 1933	37° 45′ 30″.1 ± 2″.0	4	*84° 08′ 03″.* (± 4″.)	4	− 31″.7	
147*	611	OVRAZ	15. 4. 1933	36° 52′ 50″.5 ± 0″.3	3	*82° 22′ 22″.5* ± 1″.5	4	− 24″.1	
148*	613	KERIYA	23. 4. 1933	36° 51′ 27″.7 ± 0″.7	4	*81° 40′ 02″.7* ± 2″.1	4	− 16″.3	
149*	616	BESH-TOGHRAQ	29. 4. 1933	37° 03′ 46″.5 ± 1″.0	4	*80° 27′ 48″.* ± 5″.	4	− 12″.4	
150	625		21. 5. 1933	36° 14′ 12″. (± 5″.)	2	[79° 49′]		− 15″.5	
151	626	YES-TASH	23. 5. 1933	36° 17′ 23″. (± 6″.)	2	[79° 50′]		− 17″.9	
152	629	TAM-ÖGHIL	26. 5. 1933	36° 13′ 11″.4 ± 2″.0	4	[80° 19′]		− 19″.4	
153*	705		21. 6. 1933	37° 11′ 17″.6 ± 1″.3	4	[78° 23′]		−39′ 25″.8	
154	710	CHUQUR-ÖTEK	28. 6. 1933 29. 6. 1933	36° 42′ 57″.9 ± 2″.7	4	*78° 15′ 42″.6* ± 0″.4	4	+ 6″.3	
155	713	BALIQCHI (STEIN'S BILAKCHI	11. 7. 1933	36° 20′ 00″.6 ± 0″.9	4	*78° 06′ 04″.6* ± 1″.1	3	+ 30″.9	
156	714		15. 7. 1933	36° 16′ 02″.2 ± 0″.5	4	*78° 22′ 45″.6* ± 2″.3	4	+ 35″.1	

Reference No.	Camp No.	Place Names	Date of Observation	Latitude North	Number of Observations	Longitude E. of Gr.	Number of Observations	Index Error *i*	Collimation Error *c*
157	716		17. 7. 1933	36° 11′ 52″.8 ± 1″.2	4	*78° 51′ 29″.7* ± 1″.5	4	+ 42″.4	
158	720		24. 7. 1933	35° 32′ 36″.7 ± 0″.9	6	*79° 16′ 38″.4* ± 2″.1	4	+ 78″.9	
159	722		29. 7. 1933	35° 11′ 38″.4 ± 0″.7	4	*79° 11′ 23″.* (± 4″.)	4	+ 69″.2	
160	723		1. 8. 1933	34° 54′ 39″.9 ± 0″.7	4	*79° 10′ 17″.* (± 4″.)	4	+ 72″.4	

V. NOTE ON THE FORMING OF MEAN VALUES AND MEAN ERRORS

The final coordinates given in this list are mean values of the observations which have been formed according to the same principles as in the following example.

At Mo-chia-khutuk following determinations of φ were obtained by the method of PEVZOFF using the SELIVERSTOFF tables.

Table 12

SELIVERSTOFF 41°30′ Pair No.	Date		
	20. 12. 1929	21. 12. 1929	22. 12. 1929
17		41°26′52″.4 ± 0″.8	41°26′55″.9 ± 1″.1
27	41°26′51″.3 ± 0″.5	54 .9 ± 0 .5	53 .7 ± 0 .3
34			52 .5 ± 0 .2
37		51 .8 ± 0 .8	52 .6 ± 0 .3
46		51 .5 ± 0 .3	54 .4 ± 0 .3

Of these determinations one is rejected, namely pair 17 on the 22. 12. 1929:

$$41^\circ\ 26'\ 55''.9 \pm 1''.1.$$

The series from which this value was obtained, was the following:

59″.8 58″.2 56″.9 57″.1 52″.1 53″.9 52″.4.

The leap in this series of values makes it probable that the Fennel has been pushed during the observation. Judging from the mean of all the values for φ, the first 4 could have been rejected and the last 3 used. That may be considered a question of taste.

When forming the mean value of the remaining 9 values, I have done so, without giving them different weights. The fluctuation in the value certainly depends much upon irregularities in refraction conditions, and it is seen, that it is much more important to get many pairs, than tho detertermine each pair very accurately — a well-known fact.

The mean value of the remaining 9 determinations is

$$\varphi = 41^\circ\ 26'52''.8 \pm 0''.4$$

In the above "List of Stations" each PEVZOFF pair is counted as one observation.

As a rule the mean errors of the longitudes only depend on the determination of local time, because the Greenwich time is known practically exactly. But in some cases where only one wireless signal has been received the Greenwich time is known with a comparatively poor accuracy. In those cases the mean error has been estimated if no more observations were available from which it could be calculated. Later, if means are available, a full list of the original material of observations will be published and for each station will then also be given the calculated values from which the published mean values and their mean errors have been derived.

Extremely few observations have been excluded.

The mean errors have been calculated from the mean deviation by multiplying with $\sqrt{\frac{\pi}{2}}$.

VI. LIST OF THERMOMETER AND BAROMETER READINGS

Reference No.	Date	$T_{Cels.}$	B m/m Hg	Reference No.	Date	$T_{Cels.}$	B m/m Hg
1	1929 March 19	+ 5.°	700.	35	1930 Sept. 6	+12.9	709.4
	Sept. 6	+15.	700.	36	7	+11.5	707.0
	7	+15.	700.	37	9	+11.3	704.5
2	April 16	+15.	760.	38	12	+11.°	701.3
3	25	+17.	770.	39	14	+19.	695.0
	26	+17.	770.	40	1931 Febr. 23	− 4.5	712.1
4	May 4	+15.	735.	41	26	− 0.5	770.3
	5	+15.	735.	42	March 1	+ 1.0	684.6
5	14	+15.	675.	43	2	+ 0.3	641.4
	1930 April 30	+14.	673.	44	3	− 3.	653.
6	1929 Oct. 2	+ 5.	679.	45	5	+ 0.7	674.2
	3	+ 9.	679.	46	6	− 5.1	672.7
7	11	+ 8.	733.	47	8	+ 0.3	676.
8	13	+12.3	760.1		9	+ 4.	675.
9	14	+ 9.2	741.1	48	19	+13.2	676.
10	16	+ 6.2	637.5	49	21	+15.5	681.4
11	19	+ 6.	701.	50	22	+15.1	674.5
12	Nov. 8	+ 3.	707.	51	25	+ 3.8	684.5
	1930 April 11	+12.8	698.9	52	26	+ 7.0	681.3
13	1929 Dec. 20	−15.	604.		27	+ 5.	680.
	21	−17.	605.		28	+ 5.	680.
	22	−20.	605.	53	29	+10.8	678.
	1930 Jan. 1	−27.	605.	54	31	+12.	673.
14	23	−16.	618.5	55	April 1	+13.0	672.8
	24	−18.	618.		2	+13.8	673.4
15	Febr. 4	−13.	635.	56	5	+13.3	649.4
16	14	− 2.	659.	57	6	+16.	646.5
17	19	+ 3.7	678.1	58	9	+ 2.	663.7
18	20	− 3.	686.	59	12	+ 8.4	651.3
	March 1	0.	693.	60	15	+18.5	647.0
19	6	+ 5.	693.	61	16	+22.2	647.2
20	8	+ 3.	682.	62	19	+18.8	656.7
21	15	+ 9.3	662.5		29	+15.2	668.2
	18	+ 9.	663.		May 4	+11.7	674.3
22	21	+12.0	662.6	63	5	+ 9.5	676.7
23	22	+10.8	666.0	64	6	+10.0	674.7
24	29	+12.	668.	65	12	+19.8	670.3
25	April 7	+11.	646.	66	15	+19.0	666.0
26	8	+13.	668.	67	17	+20.	664.6
27	13	+11.	669.4		18	+22.	656.
28	15	+20.	775.	68	22	+21.0	663.1
29	24	+14.5	768.8	69	29	+17.	658.6
30	29	+11.	686.0	70	June 1	+20.	651.8
31	May 3	+15.	664.		2	+22.5	651.4
32	July 26	+25.0	687.	71	8	+20.1	661.7
33	Aug. 5	+12.	560.	72	10	+22.0	658.1
	24	+ 5.	560.	73	12	+19.1	652.2
34	Sept. 4	+ 7.	709.5	74	15	+20.1	650.9

Reference No.	Date	$T_{Cels.}$	B m/m Hg
75	1931 June 16	+20.0	645.1
76	17	+23.6	641.2
	Aug. 6	+24.0	638.6
	8	+26.3	638.9
77	Sept. 29	+18.	639.6
78	Oct. 12	+ 6.0	547.7
79	Oct. 14	+ 4.°	523.1
80	31	+ 7.	629.0
81	Nov. 1	+ 5.5	626.7
82	2	+ 4.1	593.2
83	3	+ 3.5	627.9
	12	− 0.5	622.9
84	20	− 2.	641.
85	27	− 7.0	546.7
	Dec. 14	−10.	544.5
86	Nov. 29	+ 2.0	550.0
87	Dec. 4	− 4.4	543.4
	6	− 2.5	544.2
88	19	− 8.4	604.8
89	1932 Jan. 16	− 7.	648.0
90	18	− 3.	650.2
91	24	− 9.	669.1
92	25	−10.	667.9
93	Febr. 8	− 1.6	660.6
94	March 25	+12.	625.0
95	27	+13.	601.0
96	31	+ 6.	547.0
97	April 2	+ 1.3	490.6
98	5	− 3.	474.7
99	6	− 2.	465.5
100	8	− 5.0	448.0
101	10	− 5.3	438.6
102	15	−11.	408.7
103	18	−10.	405.
104	20	− 9.	415.5
105	26	−10.	414.
106	27	−16.	406.6
107	29	−12.	414.2
108	May 16	− 8.0	424.4
109	17	− 5.3	424.2
110	20	− 4.0	417.3
111	27	− 6.0	413.5
112	30	− 3.	418.0
113	June 3	+ 2.5	444.5
114	15	+ 3.9	476.4
115	29	+ 4.	479.
116	July 1	+ 1.	440.

Reference No.	Date	$T_{Cels.}$	B m/m Hg
117	1932 July 6	+ 1.3	433.
118	8	+12.2	441.
119	9	+10.	448.
120	11	+ 4.°	412.
121	15	+ 7.	428.
	1933 July 22	+ 5.0	427.
122	1932 July 22	+ 8.	423.
123	Aug. 8	− 2.	395.
124	11	+ 8.	410.
125	20	+ 7.5	411.6
126	27	− 4.0	409.8
127	28	− 1.	406.8
128	30	+ 1.6	413.8
129	Sept. 3	+ 3.0	415.6
130	9	0.	400.
131	15	− 1.0	417.0
132	19	− 6.2	413.4
133	22	− 5.	412.0
134	27	− 3.5	416.7
135	29	− 2.1	416.4
136	Oct. 2	− 6.0	410.0
137	10	−13.	409.1
138	15	− 7.	413.
139	18	−13.5	415.2
140	27	−13.0	419.6
141	28	−14.0	424.7
142	30	−13.3	422.3
143	Nov. 10	− 7.5	530.6
144	24	−12.	540.4
145	1933 Jan. 31	− 9.2	659.2
	March 15	+ 9.7	657.2
146	April 8	+ 3.6	652.3
147	15	+ 9.0	628.8
148	23	+15.0	640.6
149	29	+17.0	648.4
150	May 21	+ 8.	513.
151	23	+ 1.0	481.0
152	26	+ 8.9	525.
153	June 21	+22.1	597.
154	29	+ 4.0	477.
155	July 11	+12.7	489.8
156	15	+15.0	483.
157	17	+ 9.5	473.
158	24	+ 2.4	417.
159	29	+ 5.2	412.
160	Aug. 1	+ 5.0	401.

VII. DESCRIPTIONS OF STATIONS

Most of the maps which are given in the figures accompanying this chapter are orientated according to Magnetic North which is indicated by an arrow with markings on one side only. Orientation according to Astronomical North is indicated by an arrow with markings on both sides.

If nothing else is stated broken lines indicate uncertainty. All directions given are reckoned from Magnetic North over East. Hatching is used to indicate built upon quarters.

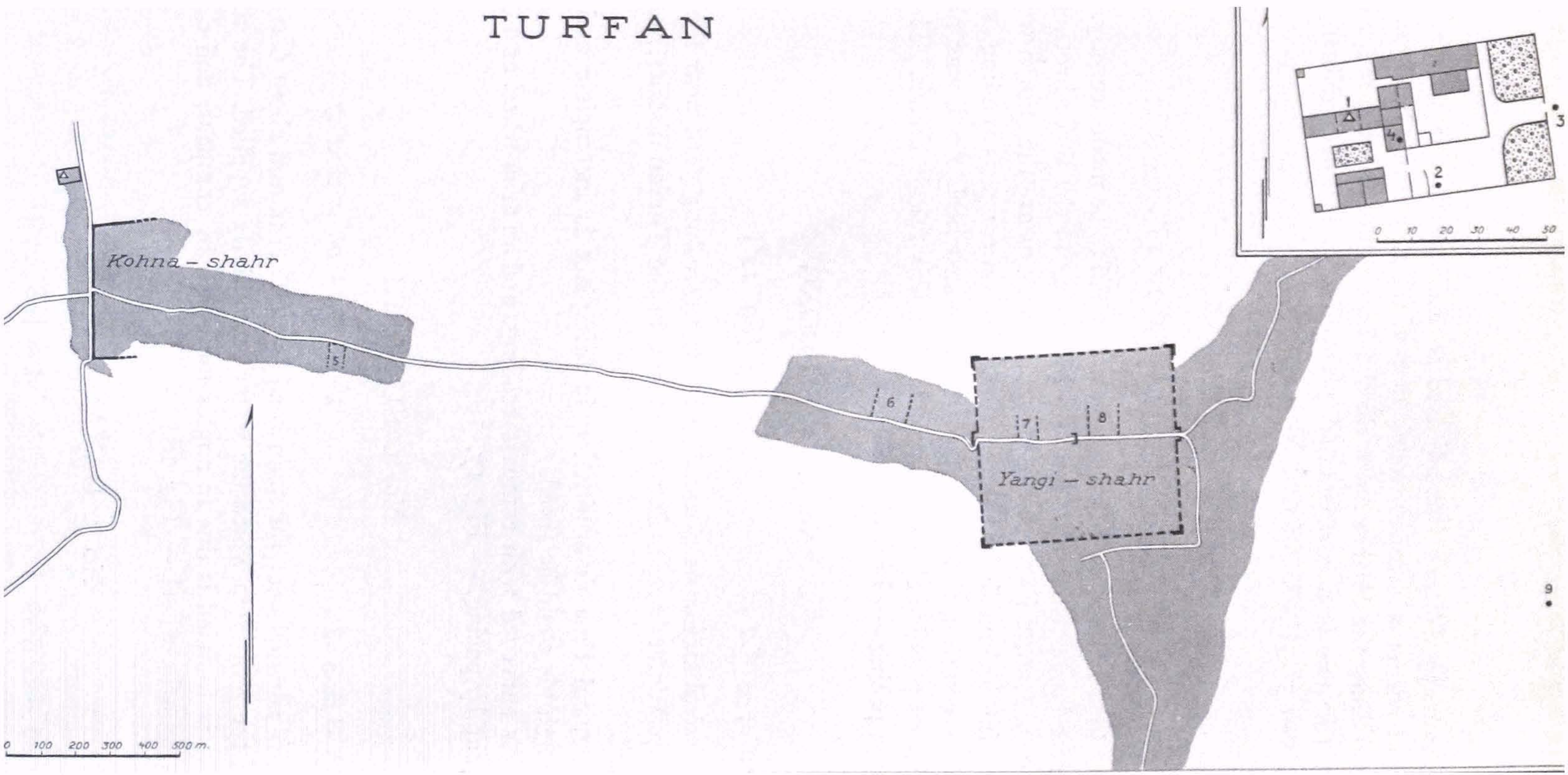
No. 1. URUMCHI

$\varphi = + 43° 46' 42''.2 \pm 1''.0$ $\lambda = 87° 36' 12''.1 \pm 1''.5$ E. of Gr.

The station is situated on the premises of the former Russian Asiatic Bank. The map of Urumchi which defines the place, is based on the following material. In the winter of 1930 I secretly made a map of the town with angles measured as rough compass-bearings, and distances by pacing. A little later Mr. H. Schart, a German civil-engineer and Government official, was ordered to make a map of the town. This new map which was made by official command is, of course, better. The angles are also in this case obtained by compass-readings, but the distances are measured by chain. Schart states that no checks have been secured. Our two maps correspond quite satisfactorily. In order to get my map accurate, I had made a triangulation from some small hills a few kilometers to the east of the town. From this triangulation the following points were fixed (see map in pocket at end):

1. Potai
2. Minaret
10. SW watch-tower of the large (inner) town wall
14. Western aerial mast
15. Central aerial mast
16. Eastern aerial mast
22. Magnetic station of the head-quarters of the Expedition on the roof of the demolished bank-building.

TURFAN


Kohna - shahr
Yangi - shahr
5
6
7
8
9
1
2
3
4
0 10 20 30 40 50
0 100 200 300 400 500 m.

The map drawn by SCHART was adjusted to these seven triangulated points. In the lower right corner a detailed sketch map of the Expedition head-quarters is inserted which defines the station more closely. Like almost all the maps of stations which follow this one is also orientated according to magnetic North which for Urumchi is about 3° 51′ East of true North (1929).

No. 2. TURFAN

$\varphi = 42° 56' 37''.4 \pm 1''.0$ $\lambda = 89° 10' 18''.$ $(\pm 3''.)$

The station in Turfan where the observations had to be made secretly, is situated on the roof of a house within the premises belonging to the three brothers: ABDUL QADIR AQSAQAL, ABDUL FATAH and ABDUL SATAR, near the north-western corner of the Turfan Kohna-shahr. The map is based on compass readings and distances measured by counting the revolutions of an arba-wheel. As I was all the time guarded I had no possible chance of making but this rough sketch. The inserted map is based on pacing. — Fig. 16.

No. 3. QUSH-DONG

$\varphi = 42° 49' 42''.4 \pm 0''.2$ $\lambda = [89° 12']$

The astronomical station is situated in a large threshing yard near the hamlet as seen in the map. Water here, as in most places, in the Turfan-district, was received from a "karez".

The astronomical time determination in this place is incomplete and therefore no wireless longitude could be fixed.

The map was surveyed with compass readings and an arba-wheel as a cyclometer, the inserted map by pacing. — Fig. 17.

No. 4. SU-BASHI

$\varphi = 43° 01' 28''.1 \pm 3''.3$ $\lambda = 89° 15' 08''.7 \pm 2''.7$

The station is situated near the main road from Turfan and about 600 m straight south-west of the well from which the water was chiefly supplied. The survey upon which the map is founded is due to angles measured by compass, and distances by revolutions of an arba-wheel. — Fig. 18.

No. 5. DAVAN-CH'ENG

I $\varphi = 43° 20' 53''.2 \pm 3''.9$ $\lambda = [88° 20']$

II $\varphi = 43° 20' 01''.6 \pm 2''.1$ $\lambda = [88° 21']$

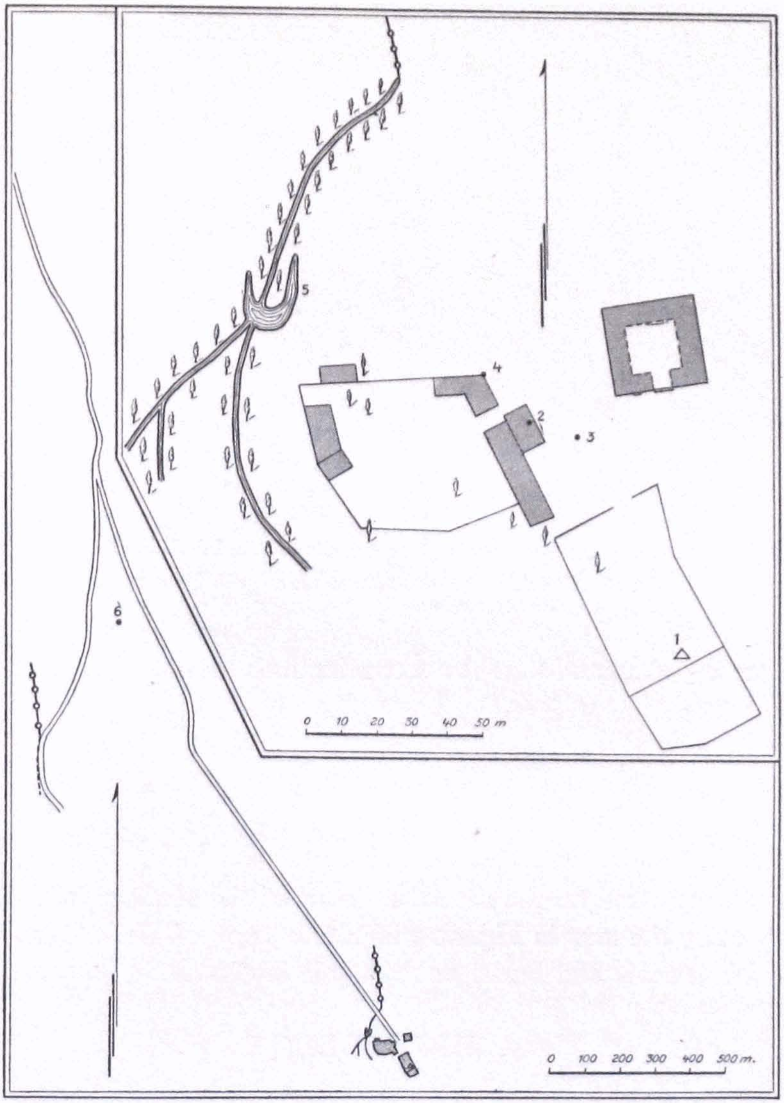


Fig. 17. Qush-dong. 1. Astr. station No. 3. 2. Gravity station. 3. Meteorol. station. 4. Route station. 5. Pond 6. Mazar.

In May 1929 one latitude was obtained in Davan-ch'eng at the point marked 1. in the map. A year later another latitude was fixed, however, not in the town proper but some 2.5 km towards the south-east. These two stations are connected by a route line which is constructed after a survey with compass-bearings and distances measured with a cyclometer. The route line has been checked by a triangulation and was found to be quite accurate. Estimating the magnetic declination to be 3°.5 E. of North, we measure from the map which represents the route line the distance in latitude between the two stations to be 1870 m corresponding to 60″.6. The distance as calculated from the two astronomical determinations is 51″.6. The mean error in

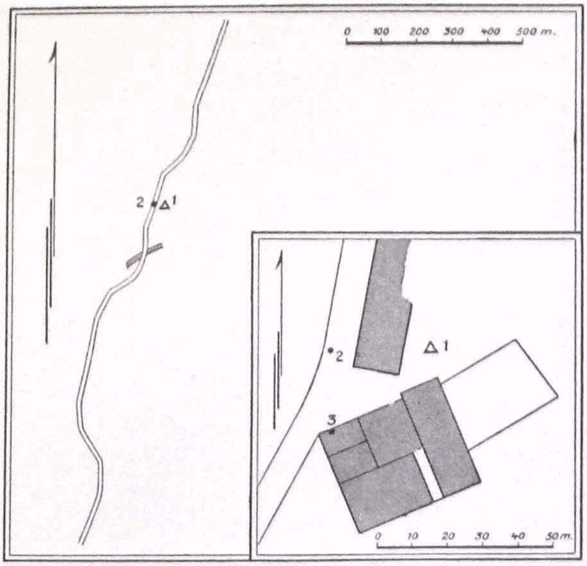


Fig. 18. Su-bashi. 1.Astr. station No.4. 2.Route station. 3.Gravity station.

this difference is $\pm 4''.4$, and thus the determinations agree, though not quite perfectly. — Fig. 19.

No. 6. Camp 3

$\varphi = 43^\circ\ 29'\ 01''.5 \pm 0''.6$ $\lambda = 87^\circ\ 52'\ 28''.6 \pm 1''.0$

The station is situated on the southern shore of the shallow lake of Ch'ai-o-p'u and is described by the map in Fig. 20 which is a copy of Dr. Norin's field map surveyed by plane-table and based on triangulation.

No. 7. SHOR-BULAQ Camp 7

$\varphi = 42^\circ\ 54'\ 10''\ (\pm 3''.)$ $\lambda = [88^\circ\ 17']$

The station is described by the map in Fig. 21 which is based on the field maps of Dr. Norin and myself, surveyed with a cyclometer respectively an arba-wheel as a cyclometer, and in both cases based on compass bearings. Close by, and east of the station, there was a small field of white, hard, salt-encrusted clay.

No. 8. BURE-BULAQ Camp 9

$\varphi = 43^\circ\ 43'\ 59''. \pm 3''.$ $\lambda = [88^\circ\ 29']$

This station is also described by the map in Fig. 21 (see No. 7. Shor-bulaq). The station is situated near the end of the cultivation.

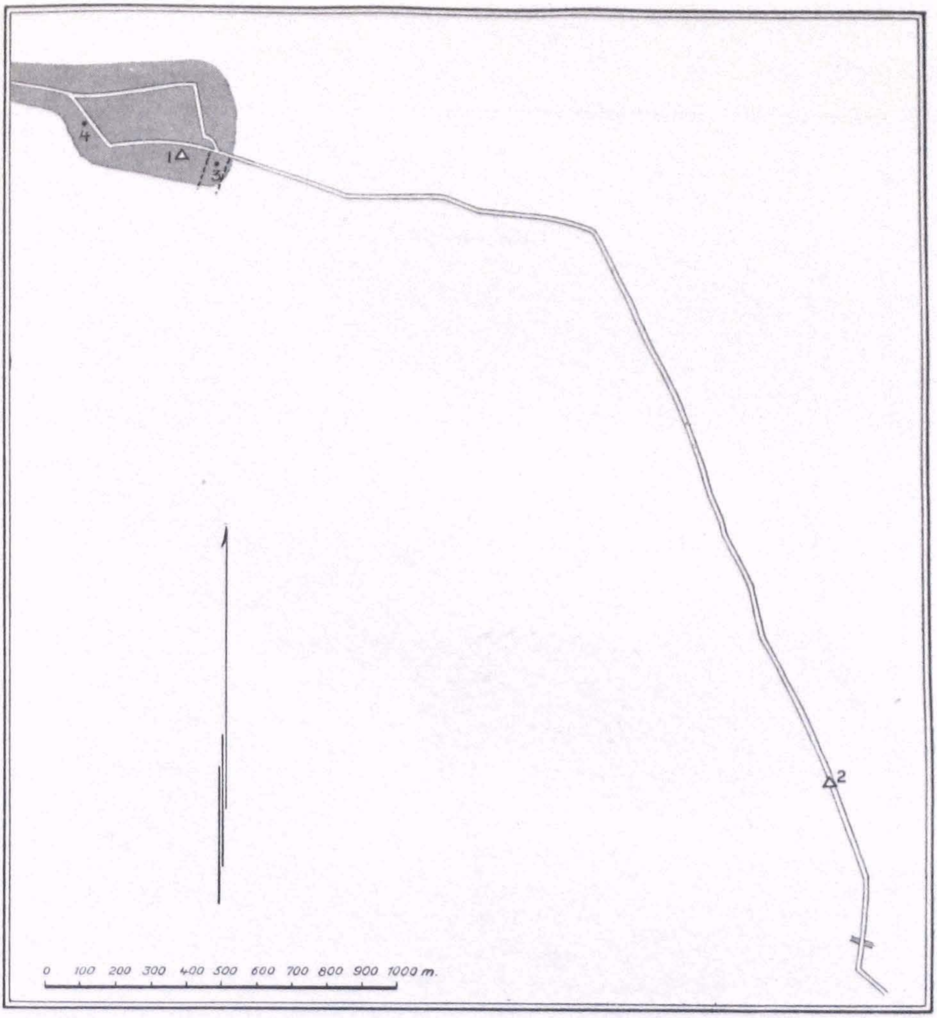


Fig. 19. Davan-ch'eng. 1. First astr. station No. 5. I. 2. Second astr. station No. 5. II. 3. Caranvansary. 4. Minaret.

No. 9. SU-BASHI Camp 10

$\varphi = 42° \; 38' \; 16''. \; (\pm 3''.)$ $\lambda = [88° \; 35']$

The station is situated in the inner court-yard of the caravansary and is described by the maps Fig. 21 and Fig. 22. Details regarding the map Fig. 21 are given in connection with No. 7, Shor-bulaq. For the other map the route line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured as compass bearings.

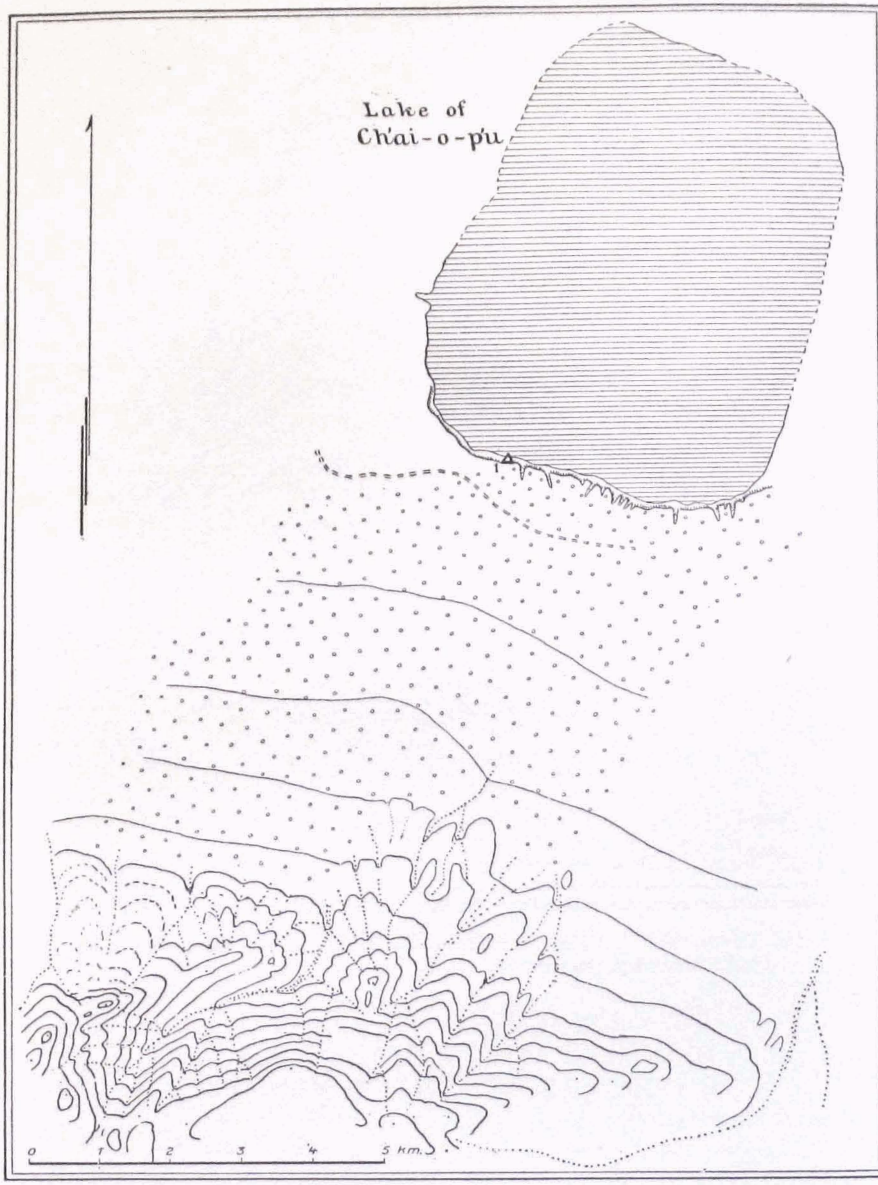


Fig. 20. Camp. 3. Interval of contours 50 m. 1.Astr. station No.6.

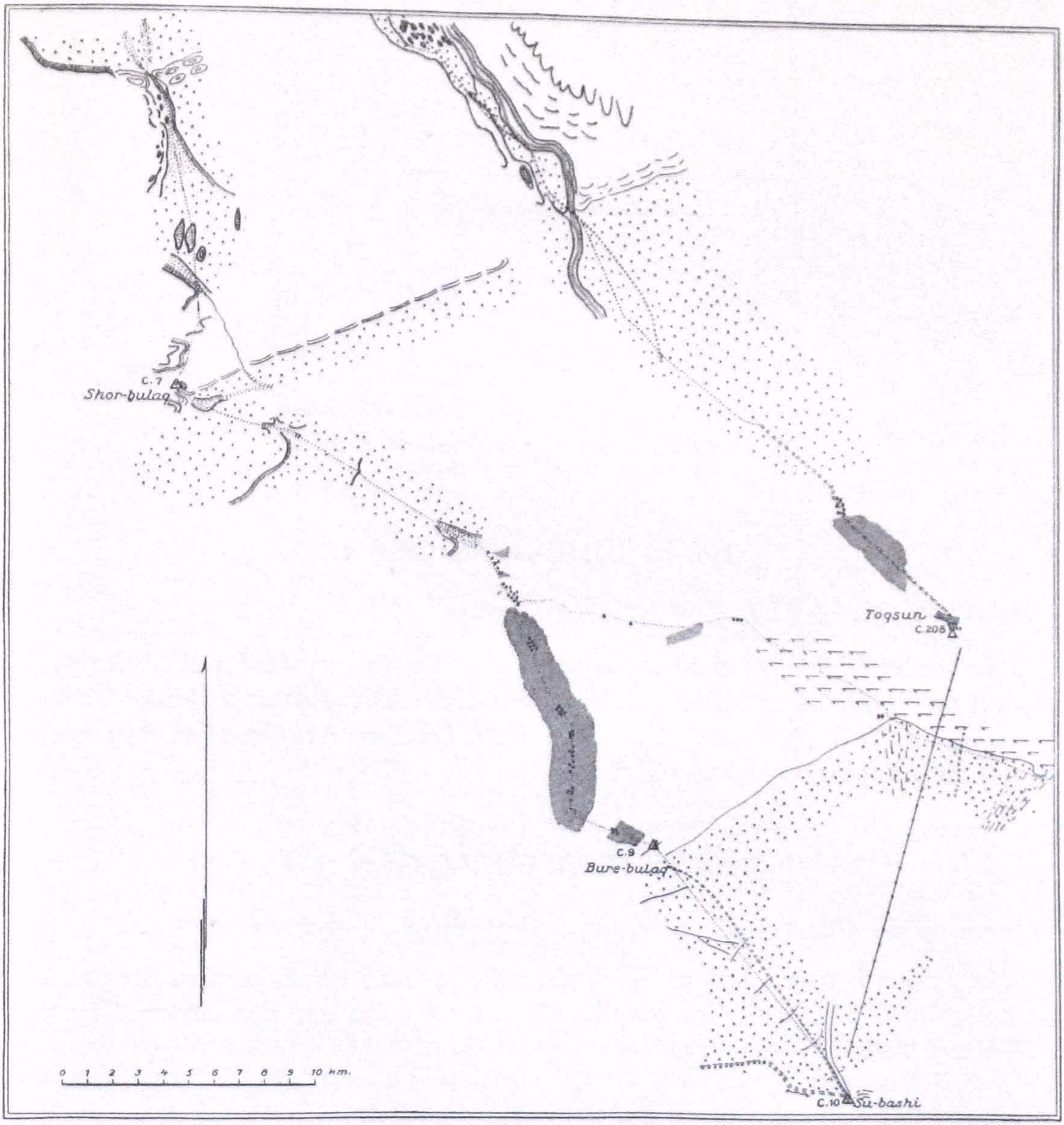

C.7
Shor-bulaq
Toqsun
C.208
C.9
Bure-bulaq
C.10
Su-bashi
0 1 2 3 4 5 6 7 8 9 10 km.

Fig. 21.

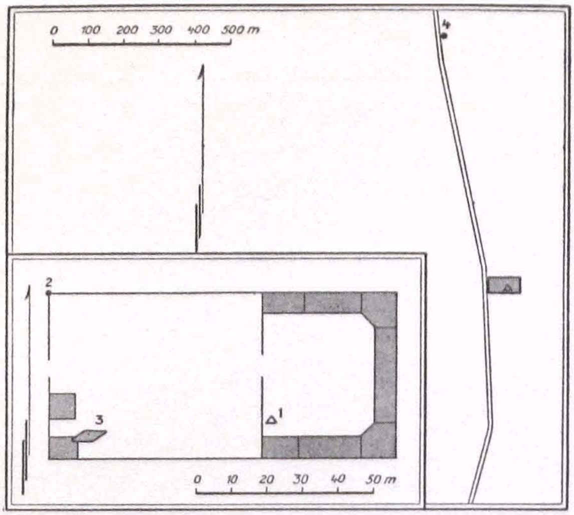


Fig. 22. Su-bashi. Camp 10. 1.Astr.station No.9. 2.Route station. 3.Potai. 4.Heap of stones.

No. 10. ÜJME-DONG Camp 12

$\varphi = 42^\circ\ 20'\ 35''.\ (\pm\ 3''.)$ $\lambda = [88^\circ\ 27']$

The station is situated close to the spring. At the time when I visited the place it was uninhabited. According to information from Dr. NORIN a shelter-hut has later on been built up close by. The route line is based on an arba-wheel as a cyclometer and compass bearings. — Fig. 23.

No. 11. SHOR-BULAQ Camp 13

$\varphi = 42^\circ\ 05'\ 54''.0 \pm 2''.3$ $\lambda = 88^\circ\ 22\ 11''.9 \pm 0''.6$

The station is situated 30 m SE of the well. The map which describes the stations is a copy of Dr. NORIN's field map based on a triangulation, and surveyed by the aid of a plane-table. — Fig. 24.

No. 12. ARPISHME-BULAQ Camp 15

$\varphi = 42^\circ\ 00'\ 15''.3 \pm 1''.2$ $\lambda = 88^\circ\ 52'\ 38''.\ (\pm\ 3'')$

The station is situated on a small hillock 200 m in the direction 74° from the little pond formed by the spring which is also marked in the map. This is a copy of Dr. NORIN's field map based on a triangulation, and surveyed by the aid of a plane-table. — Fig. 25.

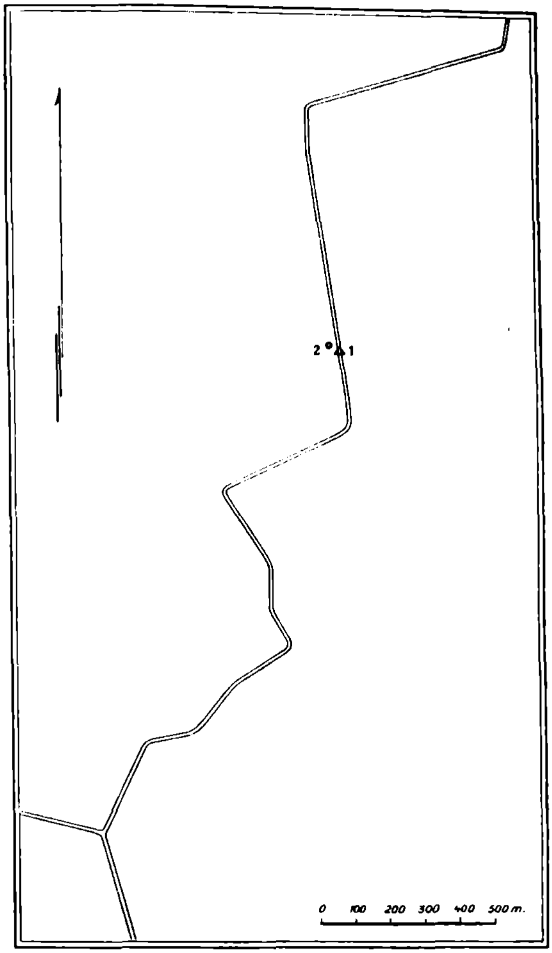


Fig. 23. Üjme-dong. Camp 12. 1.Astr. station No.10. 2.Well.

No. 13. MO-CHIA-KHUTUK Camp 23

$\varphi = 41^\circ\ 26'\ 52''.9 \pm 0''.4$ $\lambda = 87^\circ\ 54'\ 03''.1 \pm 0''.9$

The station is described by the map which is a copy of the topographical features as reproduced in Dr. NORIN's "Geological Map of Quruq-tagh" (Geology of Western Quruq tagh by ERIK NORIN, Stockholm 1937). This map is based on triangulated points, and plane-table survey. — Fig. 26.

No. 14. YUKKEN-GOL Camp 29

$\varphi = 41^\circ\ 26'\ 24''.\ (\pm\ 15''.)$ $\lambda = [87^\circ\ 30']$

The station is described by the map which is obtained in the same way as that of No. 13, Mo-chia-khutuk. — Fig. 27.

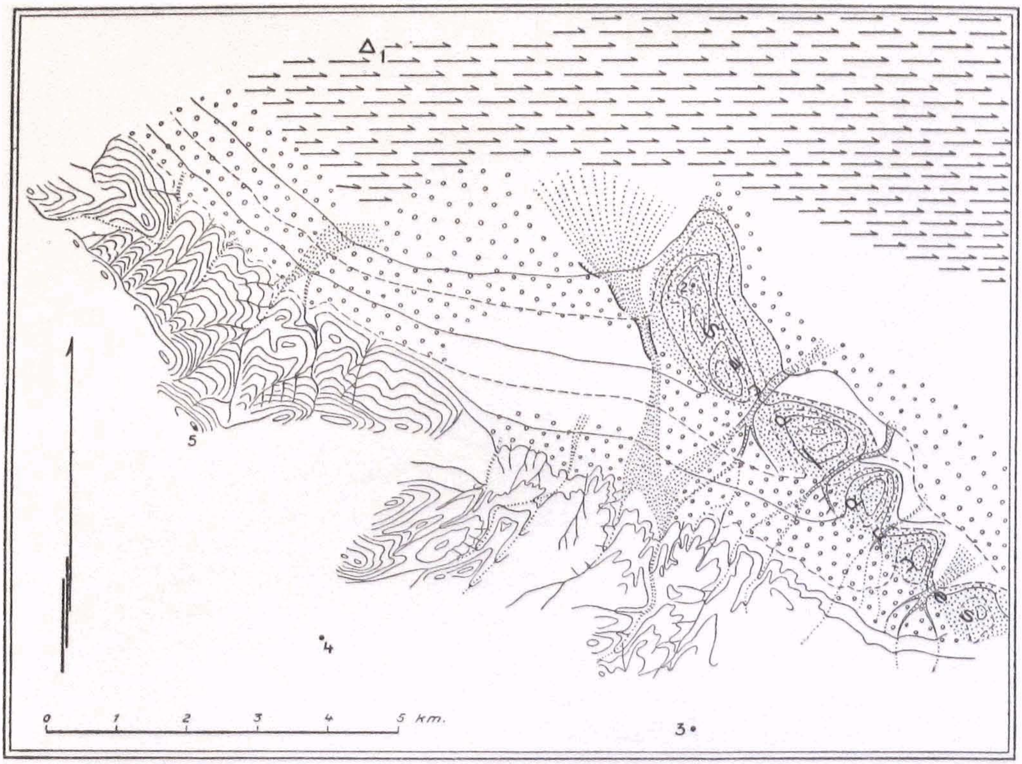


Fig 24. Shor-bulaq. Camp 13. Interval of contours 50 m (broken contours 25 m). 1. Astr. station No.11. 2, 3, 4 and 5. Triangulated peaks.

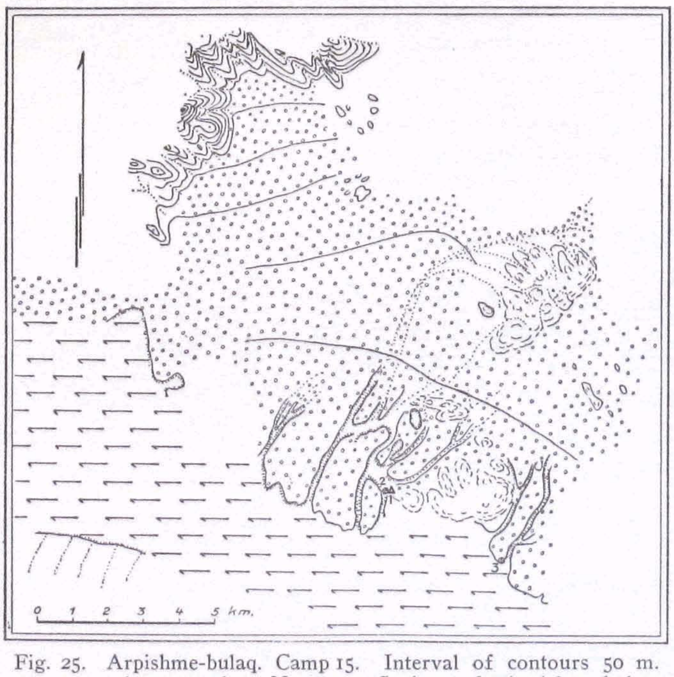


Fig. 25. Arpishme-bulaq. Camp 15. Interval of contours 50 m. 1.Astr. station No.12. 2.Spring of Arpishme-bulaq 3.Spring of Örkash-bulaq.

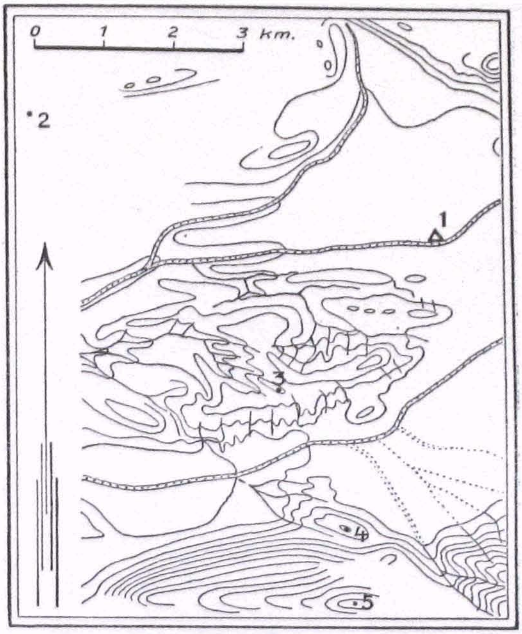


Fig. 26. Mo-chia-khutuk. Camp 23. 1.Astr. station No.13. 2, 3, 4 and 5. Triangulated peaks.

Fig. 27. Yukken-gol. Camp 29. Interval of contours 50 m. 1.Astr. station No.14. 2. and 3. Triangul. stations. 4. and 5.Ancient graves.

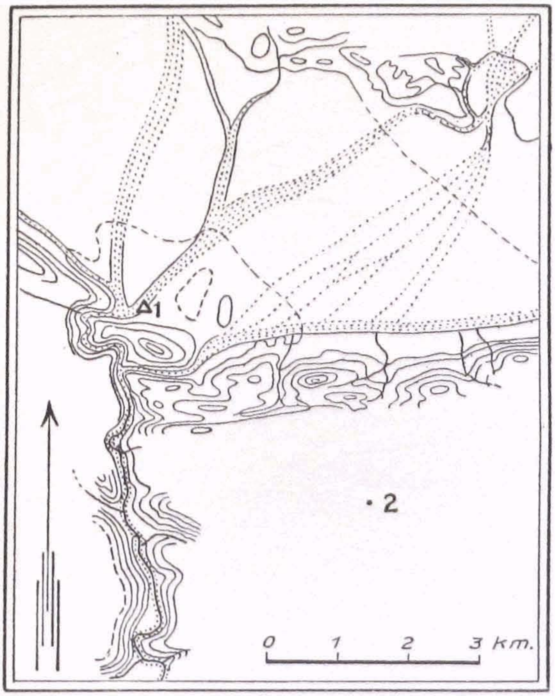


Fig. 28. Söget-bulaq. Camp 32. Interval of contours 50 m. 1. Astr. station No. 15. 2. Triangulated peak.

No. 15. SÖGET-BULAQ Camp 32

$\varphi = 41° 24' 42''.8 \pm 1''.5$ $\lambda = [87° 18']$

The station is described by the map which is of the same type as that of No. 13, Mo-chia-khutuk, with the exception of the Söget-bulaq valley running south from the station being surveyed only by compass bearings and a cyclometer. Thus the contour-lines there are less reliable. — Fig. 28.

No. 16. QURBANCHIQ Camp 33

$\varphi = 41° 14' 49''.2 \pm 0''.8$ $\lambda = 87° 30' 27''.8 \pm 0''.8$

The station is described by the map which is obtained in the same way as that of No. 13, Mo-chia-khutuk. The astronomical station is situated 15 m WSW of a 2 m high "obo" (stone-cairn). — Fig. 29.

No. 18. QURGHAN Camp 35

$\varphi = 40° 59' 18''.7 \pm 1''.1$ $\lambda = 87° 30' 35''. (\pm 3''.)$

The station is situated on the northern shore of the new river Qum-darya about

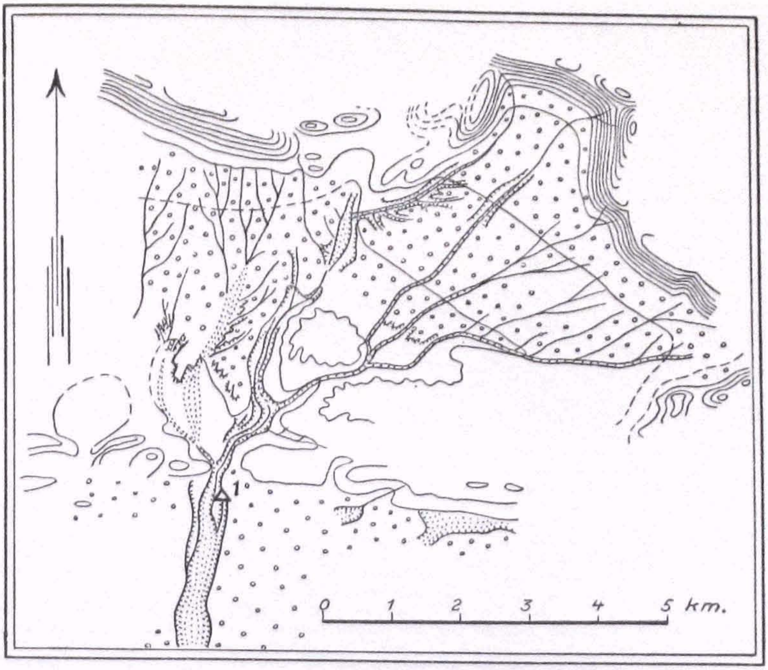


Fig. 29. Quarbanchiq. Camp 33. Interval of contours 50 m. 1. Astr. station No. 16.

4.5 km SSW of the Qurghan Potai. The map which describes the station is a copy of a map compiled by Dr. NORIN from the route-map of the river Qum-darya by Dr. SVEN HEDIN and Mr. P. C. CHEN, and from Dr. NORIN's and my route maps surveyed with compass and cyclometer. The relative position of the Qurghan Potai and the astronomic station is determined by triangulations. By comparing a map of the river which I worked out in 1930 to the map which has been elaborated in 1934 by Dr. HEDIN and Mr. CHEN, it is evident that the river does change its outlines very quickly — as so many of the Taklamakan rivers do. — Fig. 30.

No. 19. YING-P'AN Camp 35 b

$\varphi = 40° 57' 01''.8 \pm 2''.9$ $\lambda = 87° 51' 31''.6 \pm 2''.5$

The station is situated on the premises of the ruined Chinese rest-house. The map which describes the station is a copy of a map compiled by Dr. NORIN and based on the route maps drawn by Dr. SVEN HEDIN and Mr. P. C. CHEN as regards the river and our own route maps surveyed by compass bearings and a cyclometer as regards the northern part of the map. The inserted map of the rest-house was surveyed by pacing. — Fig. 31.

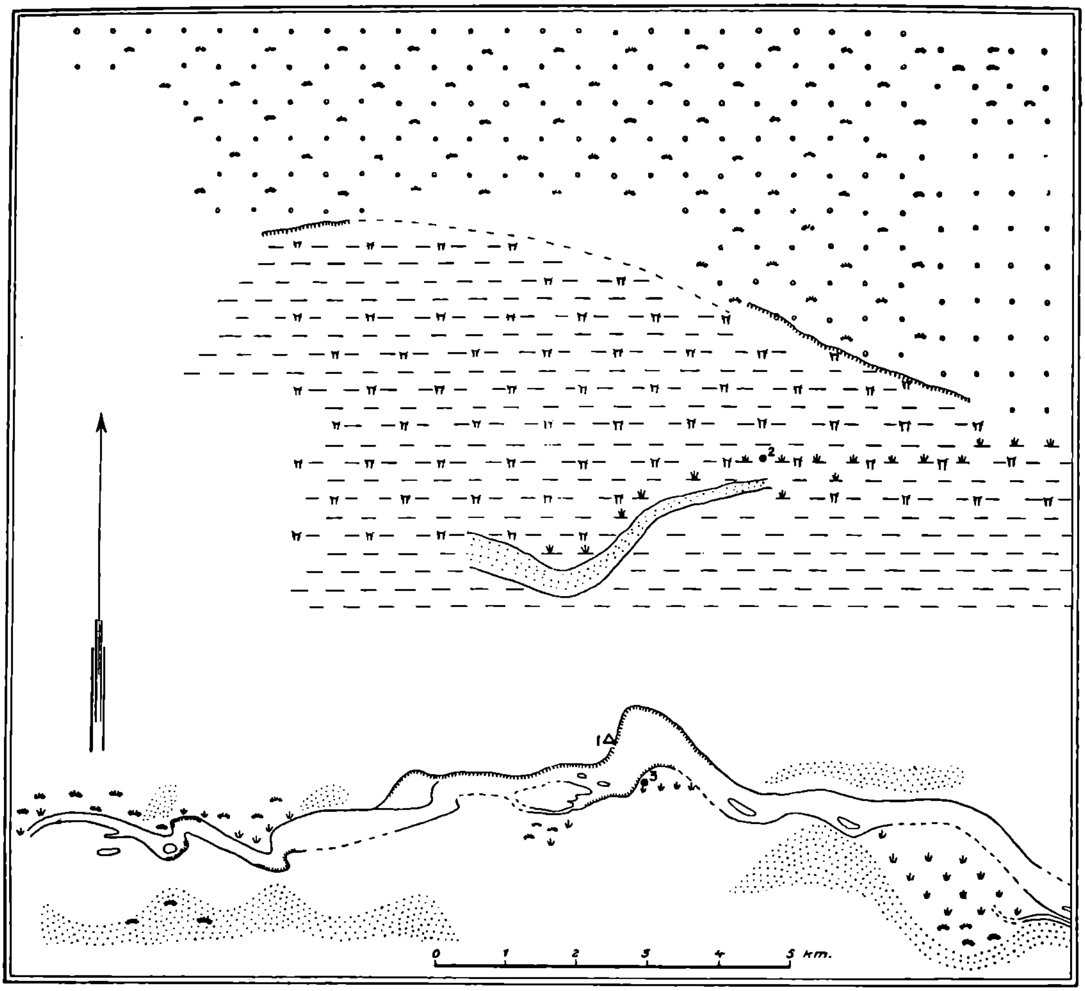


Fig. 30. Qurghan. Camp. 35. 1. Astr. station No. 18. 2. Quarghan Potai. 3. Dr. HEDIN's Camp 109 (1934).

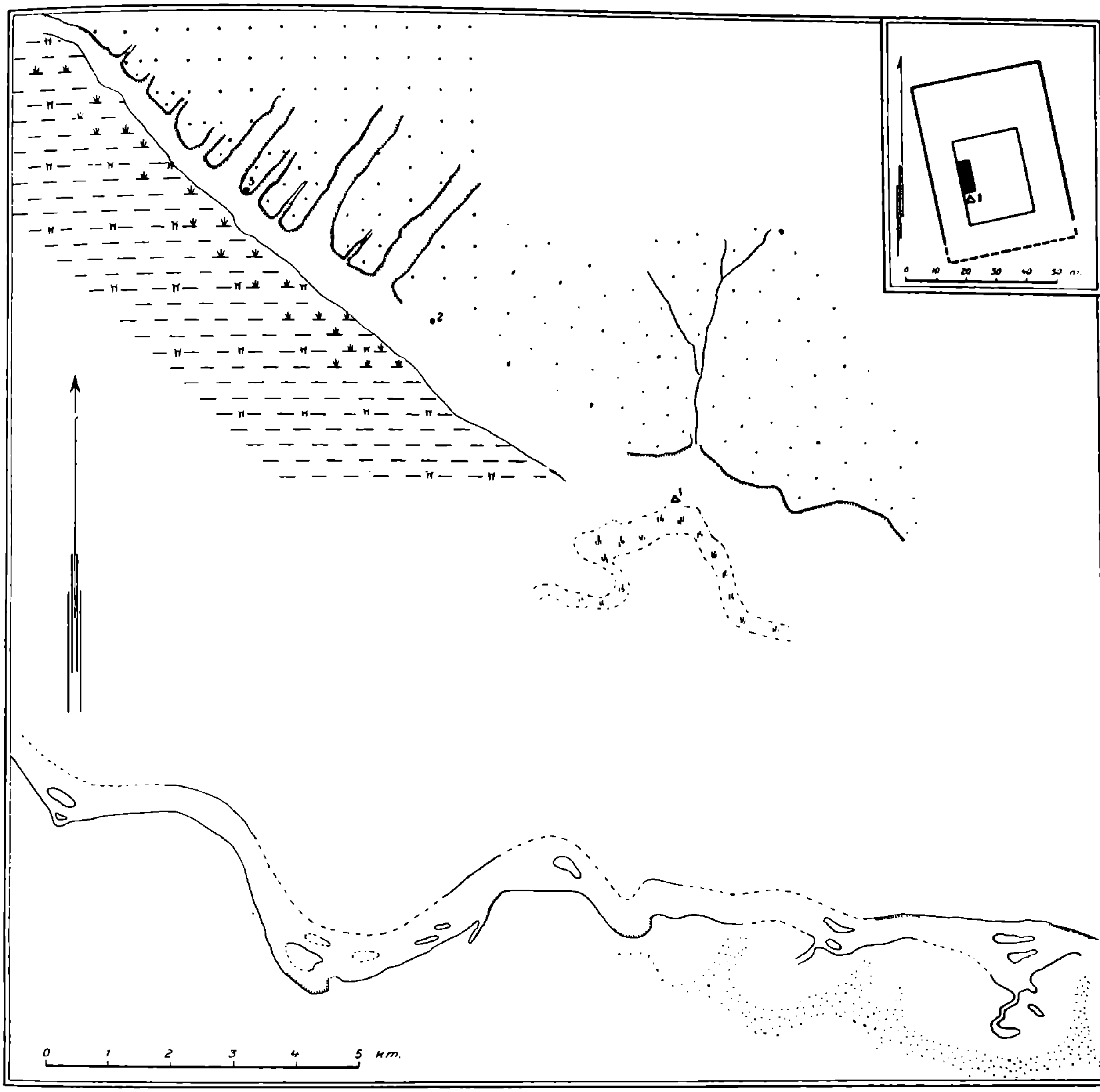


Fig. 31. Ying-p'an. Camp 35b. 1.Astr. station No.19. 2.Centre of the ruined shrines given in Sir AUREL STEIN's: "Innermost Asia. Vol.III." Plan 37. 3."Obo" of stems.

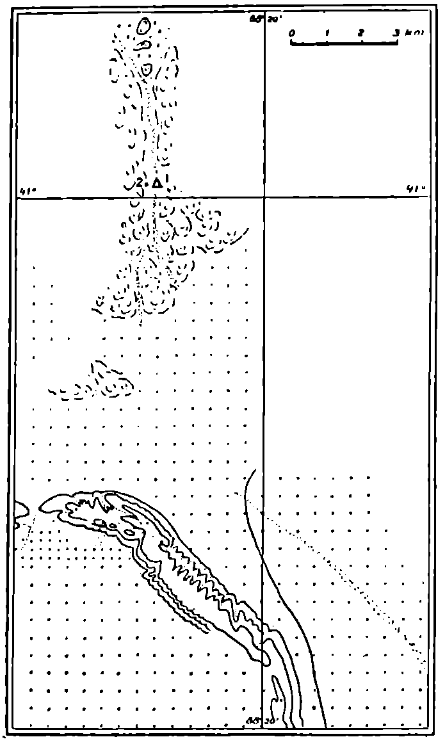


Fig. 32. Jigde-bulaq. Camp. 42. Interval of contours 50 m. 1. Astr. station No. 21. 2. Trigonom. station.

No. 21. JIGDE-BULAQ Camp 42

$\varphi = 41° 00' 14''.4 \pm 1''.0$ $\lambda = 88° 17' 50''. (\pm 2''.)$

The map which describes the station is a copy of Dr. NORIN's field map based on a triangulation, and surveyed by the aid of a plane-table. — Fig. 32.

No. 23. GANSEN-TOGHRAQ-BULAQ Camp 44

$\varphi = 41° 09' 19''. (\pm 5''.)$ $\lambda = [88° 49']$

The station is described by the map in Fig. 33 which is a copy of Dr. NORIN's field map, based on his and my route-lines with compass bearings and a cyclometer.

No. 24. NAN-CHAN-BULAQ Camp 45

$\varphi = 41° 14' 22''.7 \pm 1''.9$ $\lambda = 88° 56' 29''.5 \pm 1''.0$

This station is also described by the map in Fig. 33 (see No. 23). It will be more accurately defined later on in connection with forth-coming reports on the triangulations.

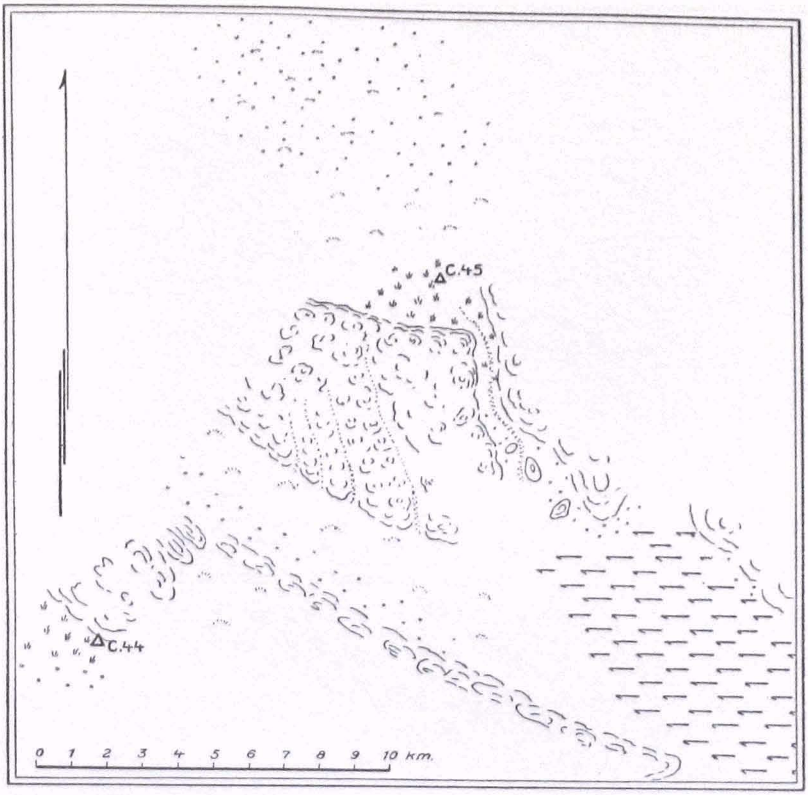


Fig. 33. Astr. station No.23 = Gansen-toghraq-bulaq. Camp 44.
Astr. station No.24 = Nan-chan-bulaq. Camp. 45.

No. 28. Well south of BEJAN-TURA Camp 53 A

$\varphi = 42° 41' 03''.8 \pm 1''.0$ $\lambda = 89° 06' 55''.9 \pm 1''.8$

The station is situated 10 m north of the well which is sunk near the point where the path crosses the terrace edge of the "sai", and about 3.5 km south of the "potai" or "tura" which is marked with the name Bejan-tura on Sir AUREL STEIN's map 1 : 500000. It is also described by the route map (compass — cyclometer) drawn by Dr. NORIN and myself and reproduced here. This map also includes the following station and as the ground traversed between these two places was quite even the map must be considered accurate. The haze almost constant in these regions prevented us from making a triangulation, greatly wished for. — Fig. 34.

No. 29. QAGHACHAQ Camp 54 A

$\varphi = 42° 42' 23''. (\pm 5''.)$ $\lambda = [88° 48']$

This station is also defined by the map in Fig. 34 (see No. 28).

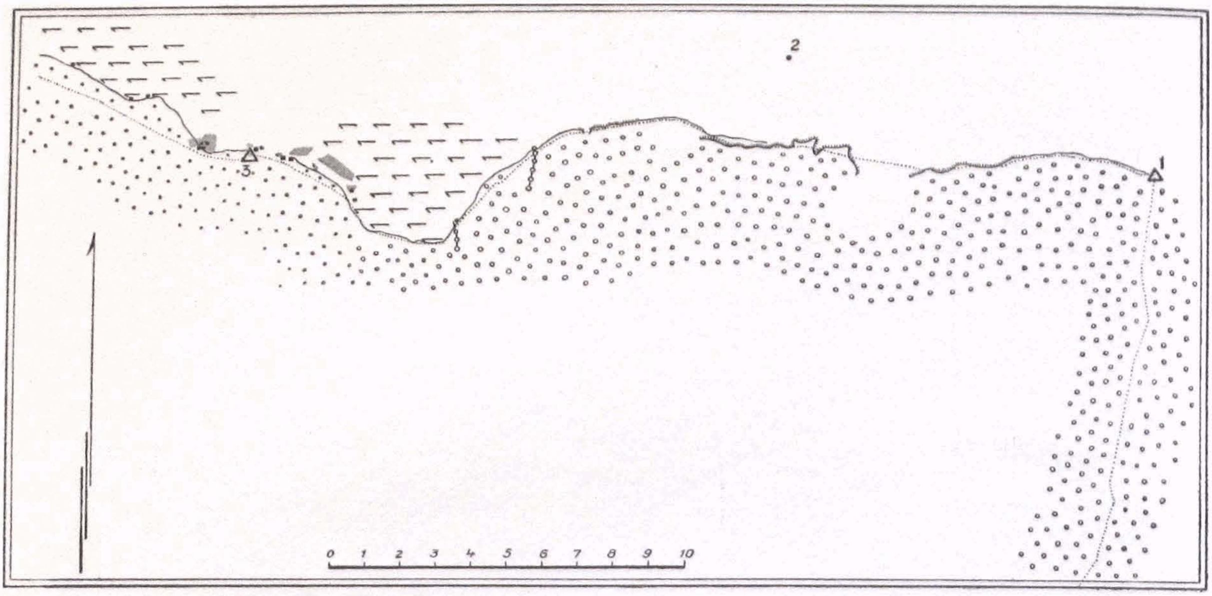


Fig. 34. 1.Astr. station No.28. south of Bejan-tura. 2.Potai. 3.Astr. station No. 29 at Qaghachaq.

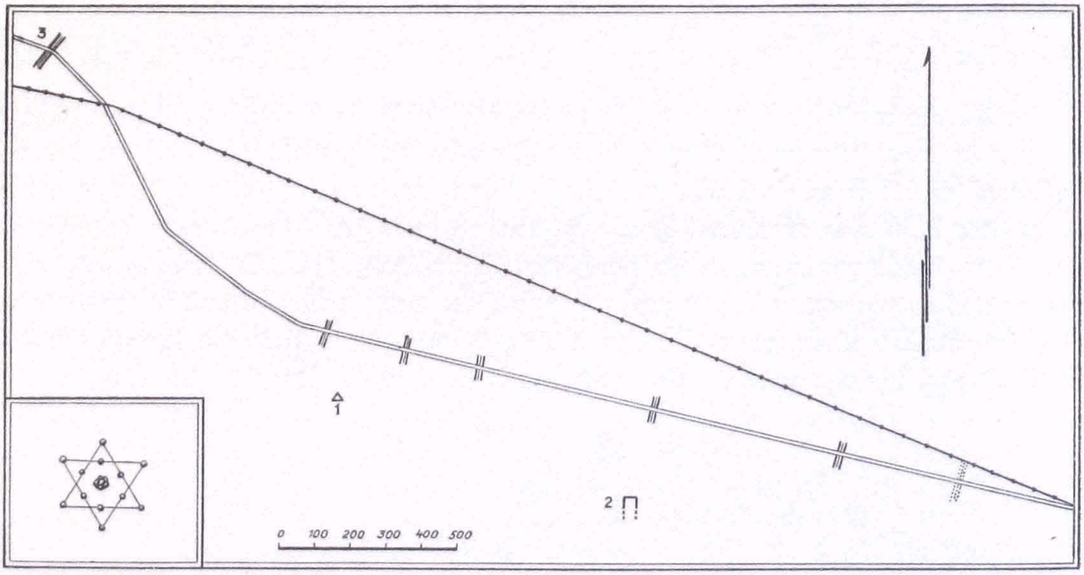


Fig. 35. Erh-tao-ho-tze. Camp. 108. 1.Astr. station No.35. 2.Temple ("Miao"), approximate position. 3.Deep river bed.

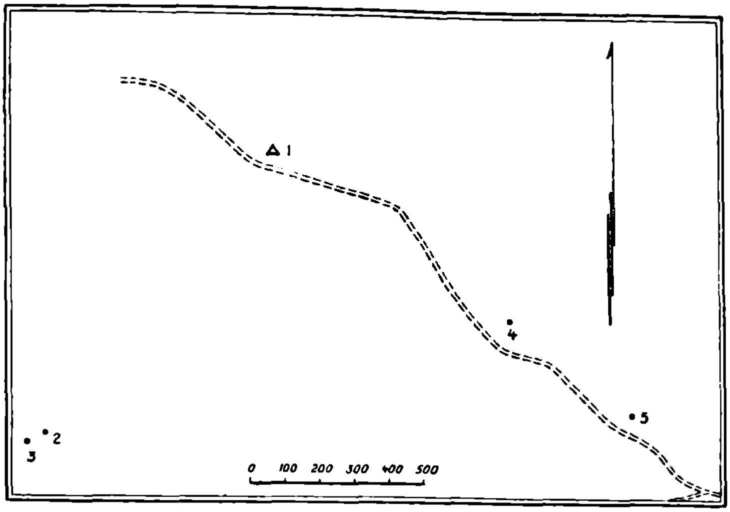


Fig. 36. Wu-liang-miao. Camp 109. 1.Astr. station No.36. 2.Triang. station. 3.Small "obo" (cairn). 4.Mazar. 5.Potai.

No. 35. ERH-TAO-HO-TZE Camp 108

$\varphi = 44° \; 10' \; 30''. \; (\pm 5''.)$ $\lambda = [88° \; 32']$

The station is situated about 175 m to the south of the road and is defined by the map in Fig. 35. The route line is based on an arba-wheel as a cyclometer, and compass bearings. The inserted map gives the configuration of a mark built up by small cairns at the place where the observation was made. The diameter of this mark is about 4 m.

No. 36. WU-LIANG-MIAO Camp 109

$\varphi = 44° \; 06' \; 37''.3 \pm 3''.8$ $\lambda = [88° \; 49']$

The station is situated about 1000 m NE of the monastery, Wu-liang-miao, and is defined in its position by the map in Fig. 36 which gives 4 other points as well, and which is based on a triangulation.

No. 37. P'O-CH'ENG-TZE Camp 110

$\varphi = 44° \; 06' \; 09''.1 \pm 1''.1$ $\lambda = [89° \; 06']$

The station is situated 207 m in the direction 299°.4 from the mark at the top of the large "Karaul" mound — 40 m by its base, 20 m high — which is shown to the left on Pl. 23. in Sir AUREL STEIN's Innnermost Asia. Vol. III. (Oxford 1928.)

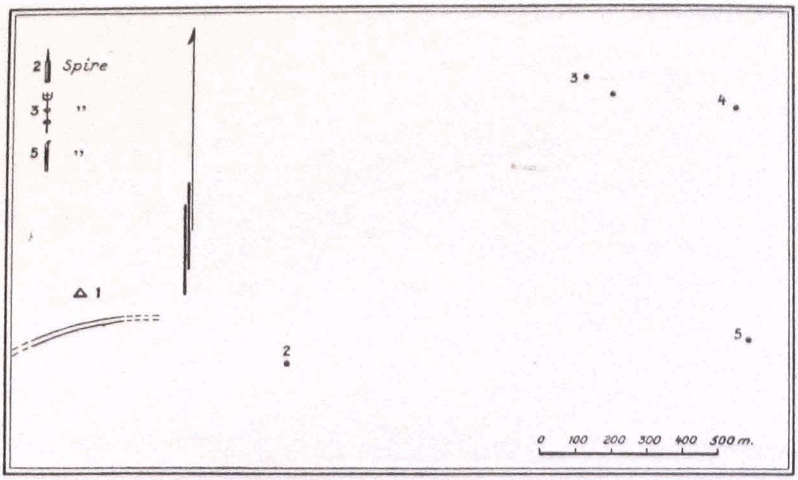


Fig. 37. Ku-ch'eng-tze. Camp 112. 1.Astr. station No.38. 4.Shansi Tower.

No. 38. KU-CH'ENG-TZE Camp 112

$\varphi = 44° 01' 36''.1 \pm 0''.7$ $\lambda = [89° 26']$

The station is situated to the east of the town and is defined in its position by a triangulation by which some prominent points of the town were determined. These points are given by the sketch in Fig. 37.

No. 39. JIMASA Camp 113

$\varphi = 44° 00' 28''.3 \pm 2''.2$ $\lambda = [89° 04']$

The station is situated about 1 km from the western gate of the city close by the main road and is defined by the map in Fig. 38 which is based on compass bearings, and distances by an arba-wheel as a cyclometer.

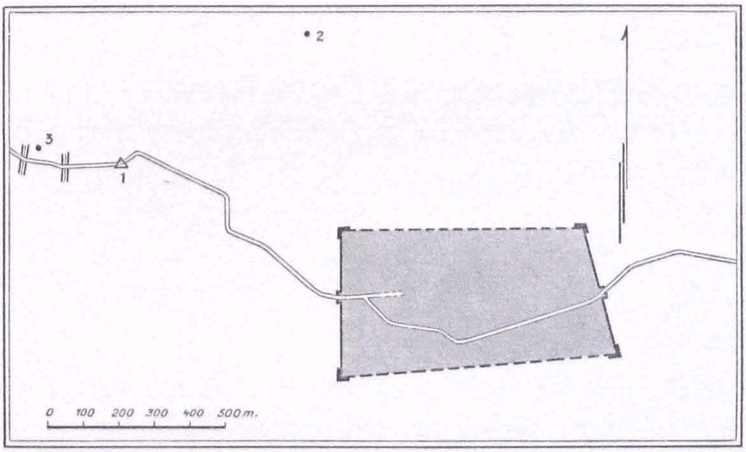


Fig. 38. Jimasa. Camp 113. 1.Astr. station No.39. 2.Potai. 3.Tower.

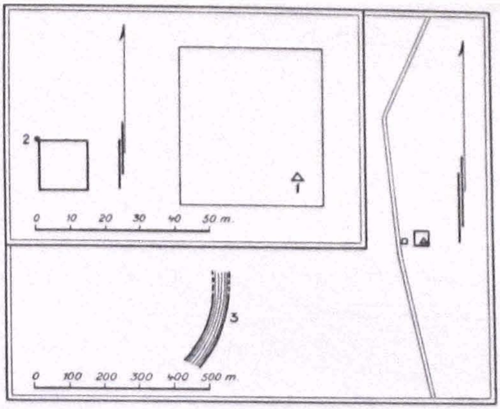


Fig. 39. Hsiao-ts'ao-ho. Camp 206. 1. Astr. station No. 40. 2. Route station. 3. Davan-ch'eng River.

No. 40. HSIAO-TS'AO-HO Camp 206

$\varphi = 43°\ 06'\ 20''.\ (\pm 5'')$ $\lambda = [88°\ 33']$

The station is situated within the premises of the caravansary in the south-western corner of its rather large yard, about 500 m east of the big Davan-ch'eng River. The route-line in Fig. 39 is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

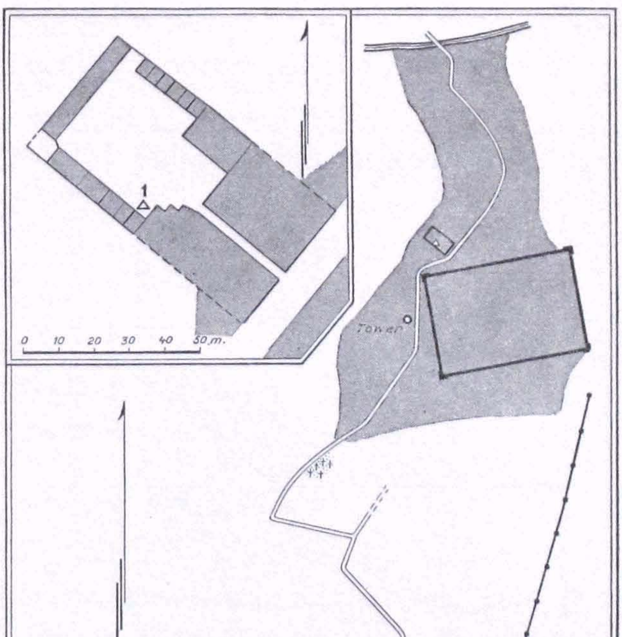


Fig. 40. Toqsun. Camp 208. 1. Astr. station No. 41.

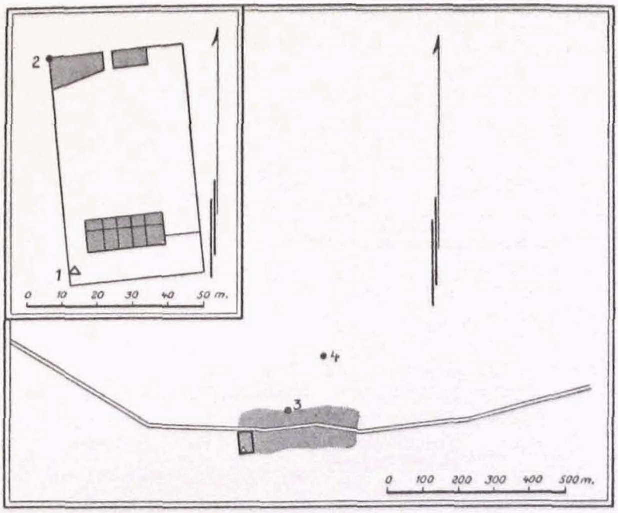


Fig. 41. Qumush. Camp. 211. 1.Astr. station No.42. 2.Route station. 3.Spring. 4.Mazar.

No. 41. TOQSUN Camp 208

$\varphi = 42° 47' 45''. (\pm 5''.)$ $\lambda = [88° 40']$

The station is situated in a caravansary, near the north-western corner of the town-wall as is shown on the map in Fig. 40. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass. The station is also seen on the map in Fig. 21 (Cf. No. 7).

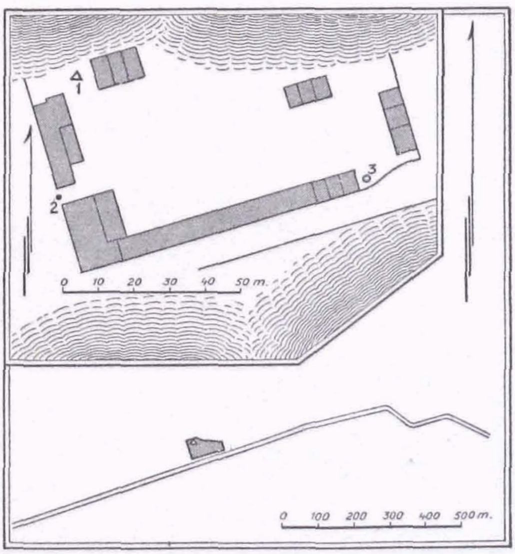


Fig. 42. Qara-quzil. Camp 212. 1.Astr. station No.43. 2.Route station. 3.Well.

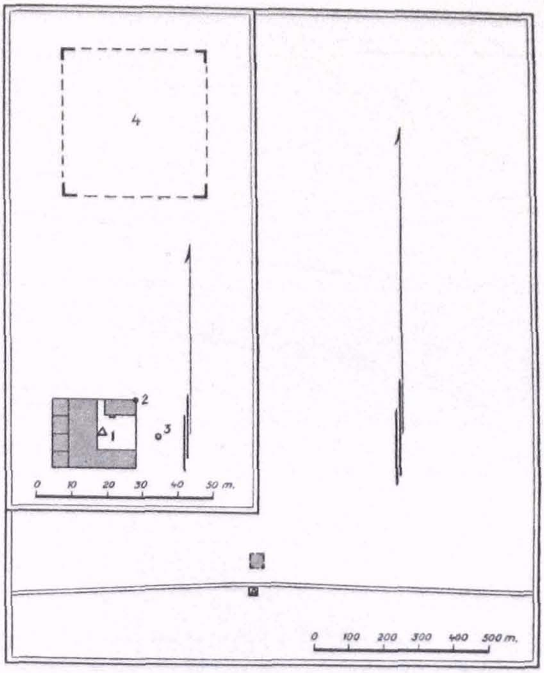


Fig. 43. Hsin-ching-tze. Camp 213. 1.Astr. station No.44. 2.Route station. 3.Well. 4.Old ruined caravansary.

No. 42. QUMUSH Camp 211

$\varphi = 42° 14' 16''.9 \pm 2''.5$ $\lambda = [88° 11']$

The station is situated in a very clean, newly built caravansary in the western part of the village as is seen on the map in Fig. 41. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 43. QARA-QIZIL Camp 212

$\varphi = 42° 13' 53''.1 \pm 1''.7$ $\lambda = [87° 53']$

The station is situated in the north-western corner of the caravansary as seen on the map in Fig. 42. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 44. HSIN-CHING-TZE Camp 213

$\varphi = 42° 13' 14''. (\pm 3''.)$ $\lambda = [87° 36']$

The station is situated on the premises of the newly built caravansary on the southern side of the road as seen on the map in Fig. 43. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

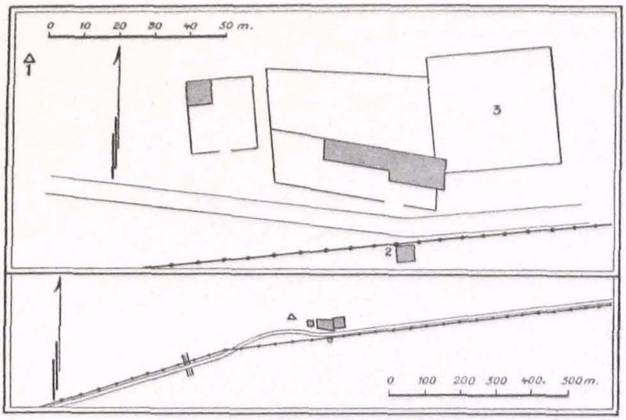


Fig. 44. Tagharchi. Camp 215. 1.Astr. station No.45. 2.Route station. 3.Threshing yard.

No. 45. TAGHARCHI Camp 215

$\varphi = 42^\circ\ 15'\ 44''.1 \pm 3''.5$ $\lambda = [86^\circ\ 59']$

The station is situated to the west of the hamlet as seen on the map in Fig. 44. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 46. OTUR-BULAQ Camp 216

$\varphi = 42^\circ\ 14'\ 01.''0 \pm 2''.7$ $\lambda = [86^\circ\ 49']$

The station is situated 50 m in the direction 210° from the bridge as seen on the map in Fig. 45. Survey by compass bearings and an arba-wheel as a cyclometer.

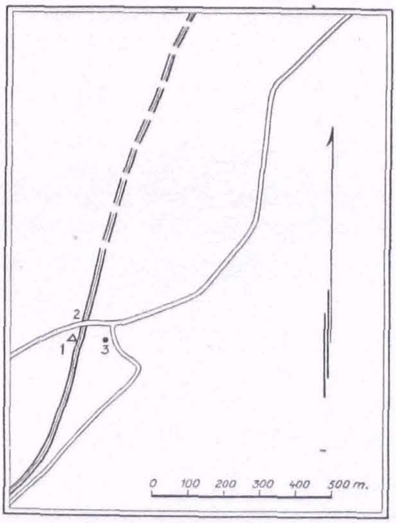


Fig. 45. Otur-bulaq. Camp. 216. 1.Astr. station No.46. 2.Bridge. 3.Ruin.

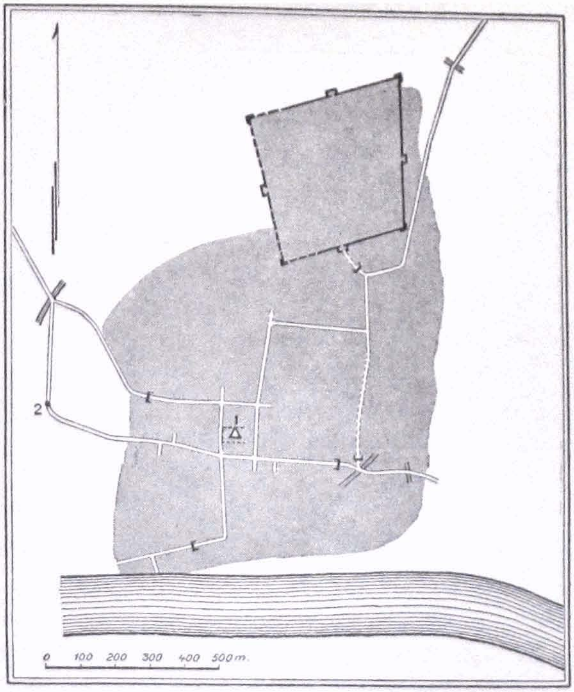


Fig. 46. Qarashahr. Camp. 217. 1.Astr. station No.47, first encampment. 2.Second encampment (route station).

No. 47. QARASHAHR Camp 217

$\varphi = 42^\circ\ 03'\ 22''.3 \pm 1''.6$ $\lambda = 86^\circ\ 33'\ 36''.\ (\pm\ 3''.)$

The station is situated 38 m in the direction 93° from the street-door of a caravansary which was for this province very comfortable and stylish. The main building had two storeys and its windows were provided with panes of glass instead of the usual paper. Before the new "yamen" inside the walled town was built, "Tao-tai" (governor of a province) used to live in this caravansary. The map in Fig. 46 of the town is surveyed with compass-bearings, and an arba-wheel as a cyclometer.

No. 48. BASH-EGIN Camp 219

$\varphi = 41^\circ\ 50'\ 03''.5 \pm 0''.5$ $\lambda = [86^\circ\ 14']$

The station is situated near Konche-darya on the premises of a caravansary as shown on the map in Fig. 47. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

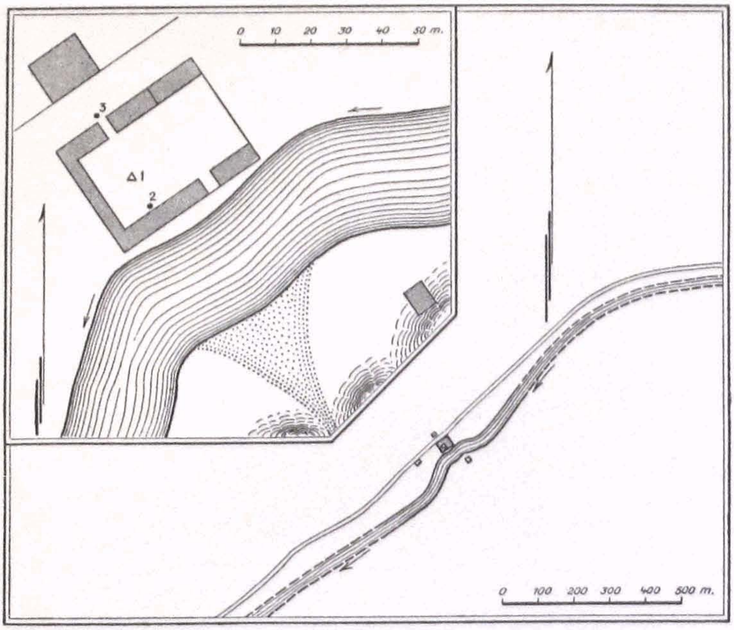


Fig. 47. Bash-egin. Camp 219. 1. Astr. station No. 48. 2. Magn. station. 3. Route station.

No. 49. TIM Camp 221

$\varphi = 41° \ 49' \ 29''.0 \pm 2''.2$ $\lambda = [85° \ 54']$

The station is situated on the premises of a caravansary not far from the large old potai, which is also shown on the map in Fig. 48. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

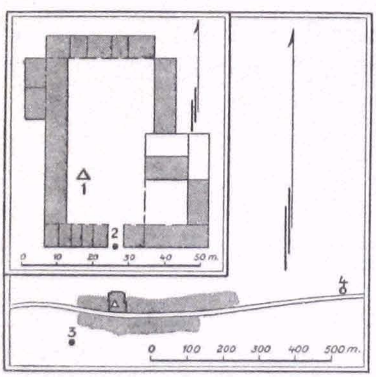


Fig. 48. Tim. Camp 221. 1. Astr. station No. 49. 2. Route station. 3. Potai. 4. Well

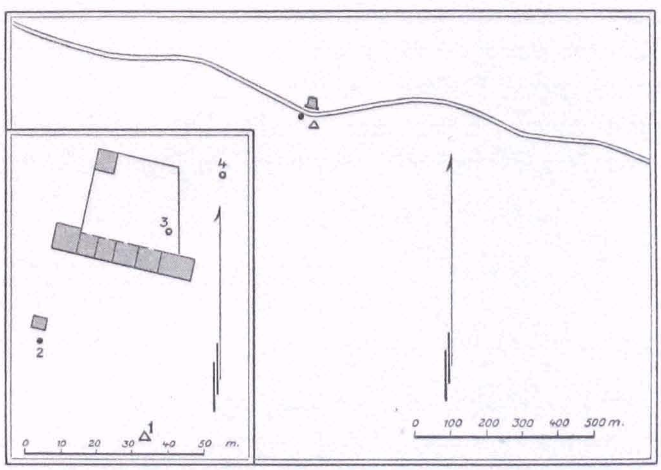


Fig. 49. Yantaq-khutuk. Camp 222. 1. Astr. station No. 50. 2. Route station. 3. Well. 4. Well.

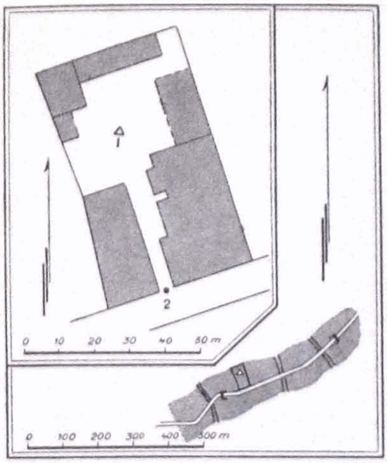


Fig. 50. Yangi-hissar. Camp 225. 1.Astr. station No.51. 2.Route station.

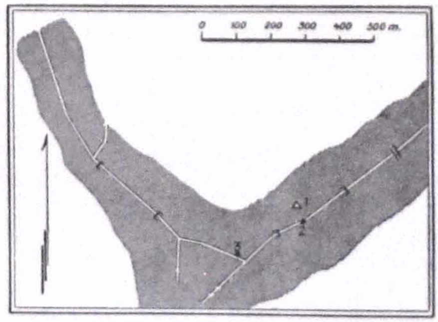


Fig. 51. Bugur. Camp 226. 1.Astr. station No. 54. 2.Route station. 3.Large temple.

No. 50. YANTAQ-KHUTUK Camp 222

$\varphi = 41^\circ\ 52'\ 53''.0 \pm 0''.7$ $\lambda = [85^\circ\ 35']$

The station is situated about 50 m south of the caravansary as seen on the map in Fig. 49. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 51. YANGI-HISSAR Camp 225

$\varphi = 41^\circ\ 56'\ 37''.5 \pm 1^\circ.0$ $\lambda = [84^\circ\ 35']$

The station is situated on the premises of a caravansary about 50 m east of the western village gate, as shown on the map in Fig. 50. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 52. BUGUR Camp 226

$\varphi = 41^\circ\ 46'\ 21''.7 \pm 1''.5$ $\lambda = 84^\circ\ 15'\ 14''.\ (\pm 3''.)$

The station is situated on the premises of a caravansary 45 m in the direction 338° from its street-door as shown on the map in Fig. 51 which is based on compass-bearings, and distances measured by an arba-wheel as a cyclometer.

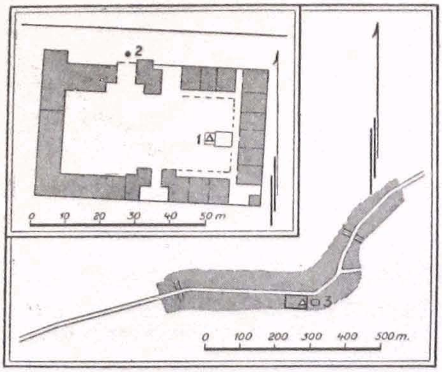


Fig. 52. Awat. Camp 228. 1.Astr. station No.53. 2.Route station. 3.Water-tank.

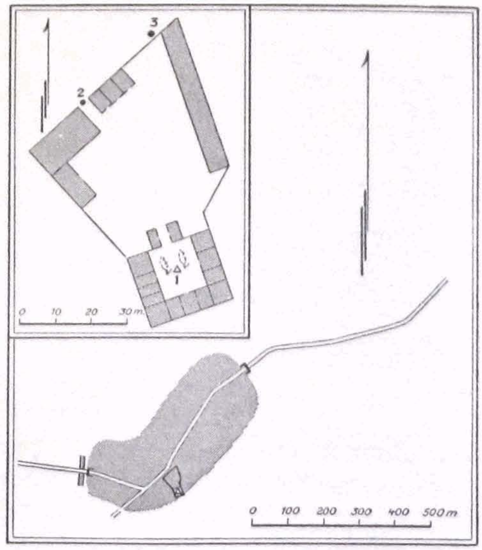


Fig. 53. Yaqa Camp 230. 1.Astr. station No.54. 2.Route station. 3.Stove for burning paper.

No. 53. AWAT Camp 228

$\varphi = 41° 47' 25''.3 \pm 1''.0$ $\lambda = [83° 50']$

The station is situated on a low clay-platform on the premises of a caravansary. Close by, and to the east of this caravansary there is a water-tank. The route-line in Fig. 52 is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 54. YAQA Camp 230

$\varphi = 41° 43' 48''.0 \pm 2''.2$ $\lambda = [83° 17']$

The station is situated between two poplars in the inner yard of a caravansary as seen on the map in Fig. 53. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 55. KUCHAR Camp 231

$\varphi = 41° 42' 35''.9 \pm 3''.0$ $\lambda = 82° 55' 50''.9\ (\pm 2''.0)$

The station is situated on the premises of a very clean caravansary where foreigners often stay. It is situated between two deep river-beds which, in the beginning of April, carried very little water. The map in Fig. 54 is based on distances of which some are measured by an arba-wheel as a cyclometer, some others by pacing. All angles are compass-bearings.

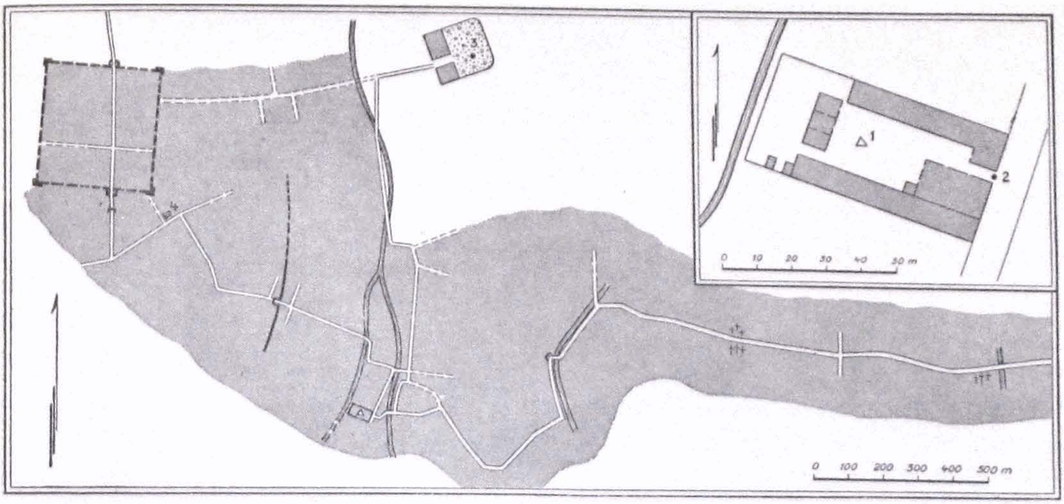


Fig. 54. Kuchar Camp 231. 1.Astr. station No. 55. 2.Route station. 3.Meteorol. main station. 4.Water-tank.

No. 56. TOGHRAQ-DONG Camp 233

$\varphi = 41^\circ\ 52'\ 39''.5 \pm 2''.6$ $\lambda = [88^\circ\ 47']$

The station is situated in the inner court-yard of a lonely, irregularly built caravansary as seen on the map in Fig. 55. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

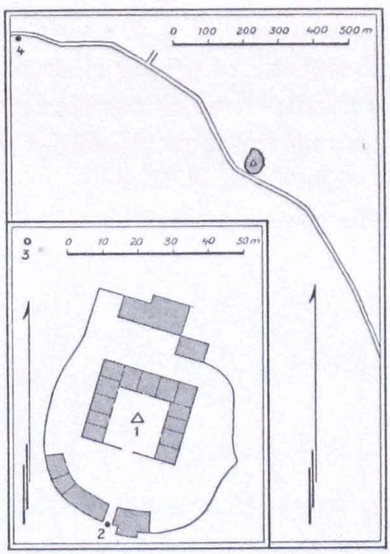


Fig. 55. Toghraq-dong Camp 233. 1.Astr. station No. 56. 2.Route station. 3.Well. 4."Obo" (cairn).

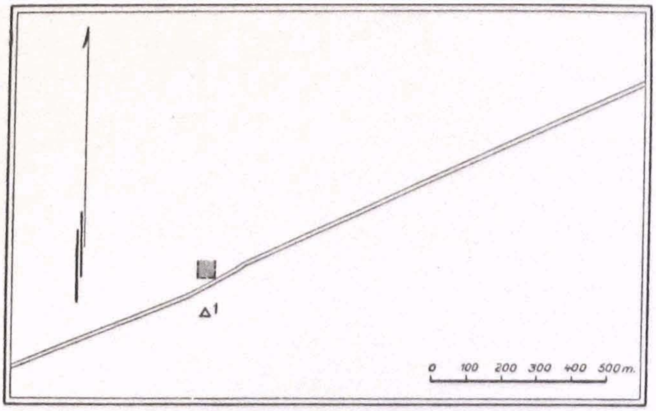


Fig. 56. Yao-tan-tzu Camp 234. 1.Astr. station No. 57.

No. 57. YAO-TAN-TZU Camp 234

$\varphi = 41^\circ\ 53'\ 15''.5 \pm 1''.5$ $\lambda = [82^\circ\ 36']$

The station is situated 100 m in direction 196° from the south-eastern corner of the house and is marked by an "obo". The route-line in Fig. 56 is measured by compass-bearings, and an arba-wheel as a cyclometer.

No. 58. BAI Camp 237

$\varphi = 41^\circ\ 47'\ 28''.6 \pm 1''.3$ $\lambda = [81^\circ\ 52']$

The station is situated just outside and to the east of the town on the premises of a caravansary on the western bank of the big river as seen on the map in Fig. 57. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

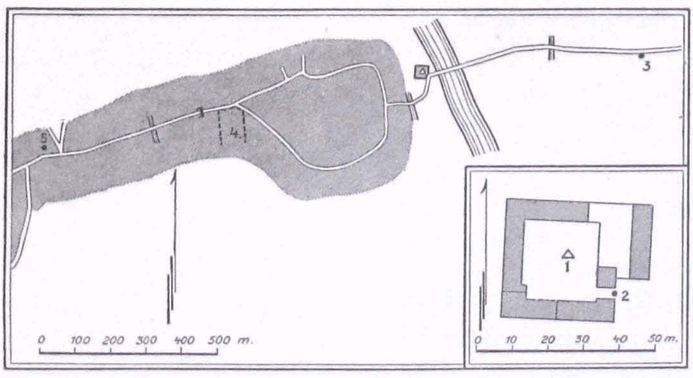


Fig. 57. Bai Camp 237. 1.Astr. station No. 58. 2.Route station. 3.Potai. 4.Yamen. 5.Stove for burning paper.

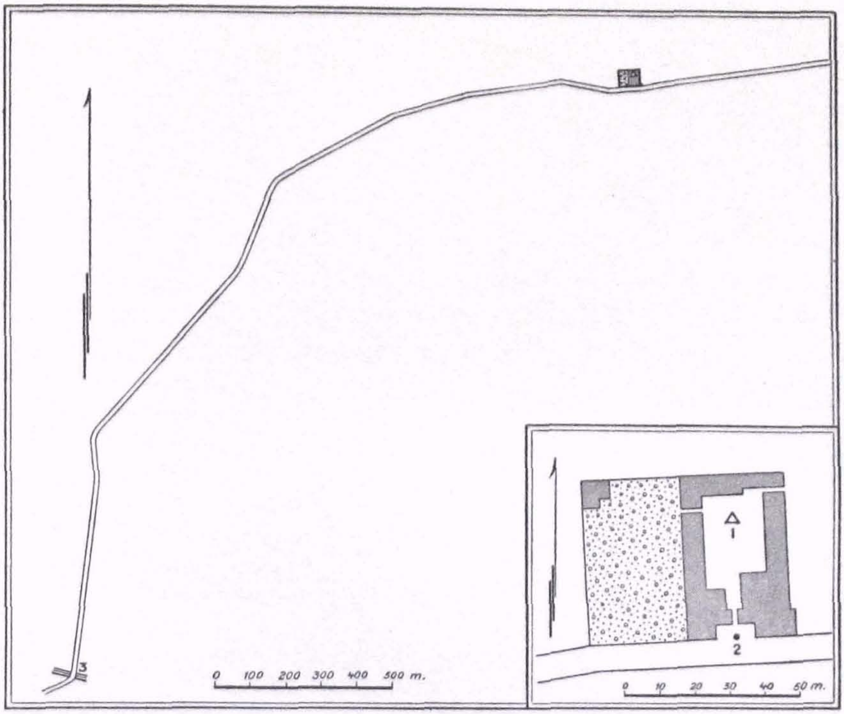


Fig. 58. Qush-tam Camp 239. 1.Astr. station No. 59. 2.Route station. 3.Bridge across the Muzart-darya.

No. 59. QUSH-TAM Camp 239

$\varphi = 41° 38' 44''.8 \pm 1''.0$ $\lambda = [81° 28']$

The station is situated on the premises of a farmer's house which lies on the northern side of the road, about 2300 m in direction 43° from the bridge across the Muzart-darya. The route-line in Fig. 58 is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 60. TÜGE-KHANA Camp 241

$\varphi = 41° 27' 47''.1 \pm 3''.0$ $\lambda = [81° 04']$

The station is situated 70 m in direction 222° from a small well which was very shallow and not good. We dug it out deeper and paved it. The astronomical station is marked by an "obo". The route-line given by the map in Fig. 59 is based on compass-bearings, and distances measured by an arba-wheel as a cyclometer.

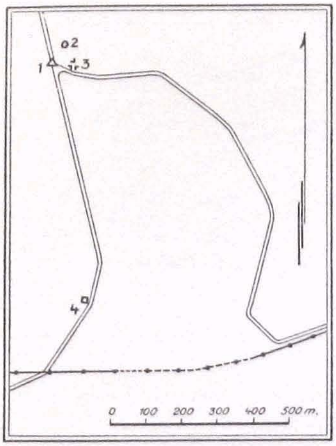


Fig. 59. Tüge-khana Camp 241.
1.Astr. station No. 60.
2.Well. 3.Ruin. 4.Potai.

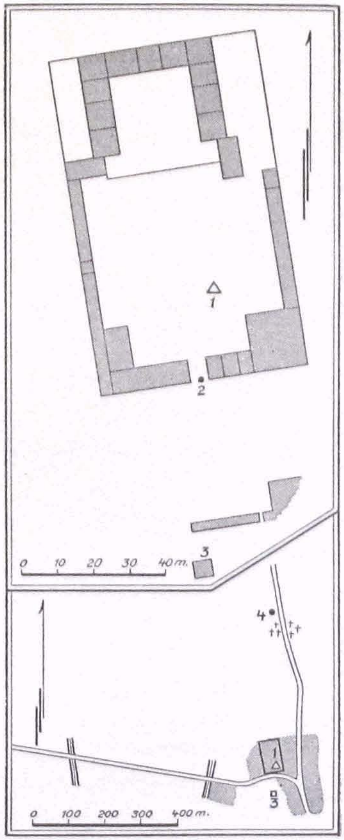


Fig. 60. Qara-yulghun Camp 242.
1.Astr. station No. 61.
2.Route station.
3.Potai. 4.Mazar.

No. 61. QARA-YULGHUN Camp 242

$\varphi = 41° 23' 11''.5 \pm 2''.2$ $\lambda = [80° 51']$

The station is situated on the premises of a caravansary as seen on the map in Fig. 60. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 62. AQSU, YANGI-SHAHR Camp 244

$\varphi = 41° 09' 39''.8 \pm 1''.2$ $\lambda = 80° 16' 08''. (\pm 3''.)$

The station is situated on the premises of a caravansary 31 m in the direction 304° from its street-door. The caravansary is situated near the centre of the walled part of the town as shown on the map in Fig. 61 which is surveyed by cyclometer and a compass.

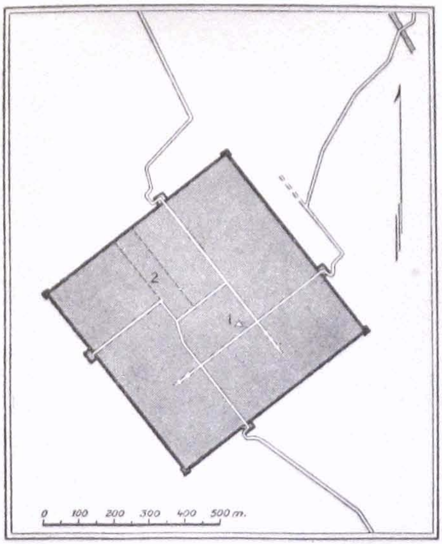


Fig. 61. Aqsu Camp 244. 1.Astr. station No. 62. 2.Tao-t'ai yamen.

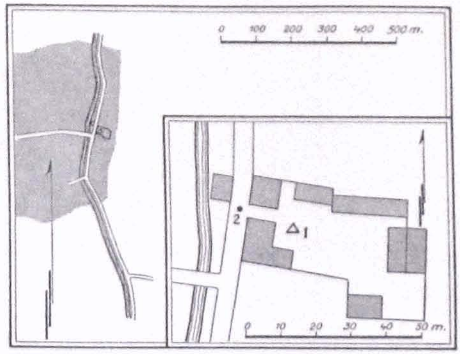


Fig. 62. Qum-bash Camp 245. 1.Astr. station No. 63. 2.Route station.

No. 63. QUM-BASH Camp 245

$\varphi = 40° 54' 14''.1 \pm 1''.6$ $\lambda = [80° 18']$

The station is situated on the premises of a caravansary close to the main road from Aqsu passing Qum-bash, on to Awat, as seen on the map in Fig. 62. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 76. KHOTAN Camp 263

$\varphi = 37° 07' 18''.3 \pm 1''.3$ $\lambda = 79° 55' 58''.0 \pm 2''.1$

In Khotan astronomical observations were obtained from two adjacent places within the premises of the caravansary belonging to the well-known British Aqsaqal, Badruddin Khan. The map in Fig. 63 is based on compass readings and pacing.

The trigonometrical station was upon the roof of the caravansary.

Great changes have taken place in the town since the survey of the map was done. A belt of closely built blocks 100—200 m broad on the eastern side of the eastern town-wall was burnt down and demolished during the recent war.

No. 89. ZANGUYA Camp 300

$\varphi = 37° 22' 05''.2 \pm 1''.2$ $\lambda = 78° 47' 23''. (\pm 4'')$

The station is situated on the premises of a caravansary as seen on the map in Fig. 64. The routeline is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

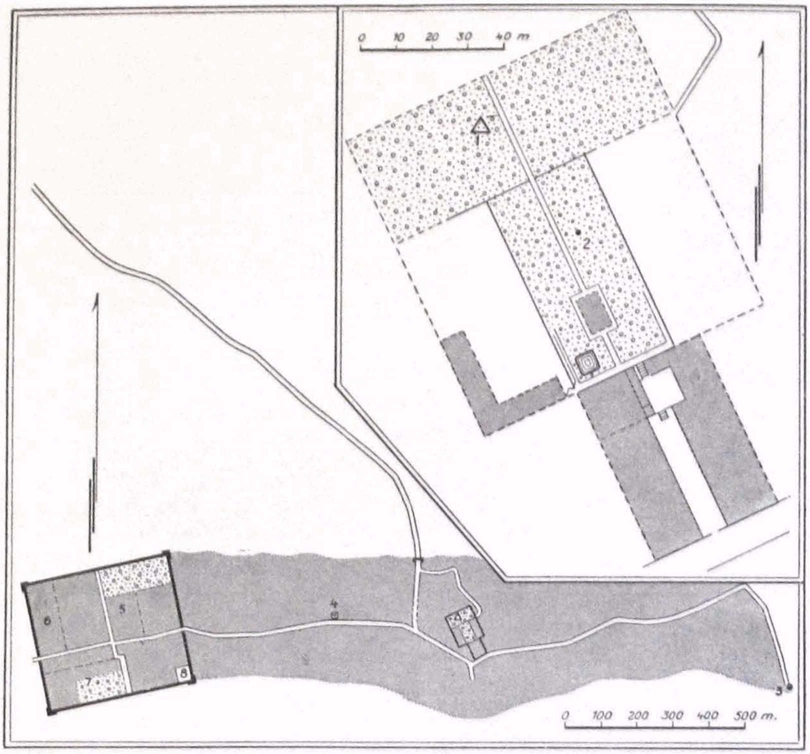


Fig. 63. Khotan Camp 263. 1.Astr. station No. 76. 2.Gravity station. 3.Potai. 4.Water-tank. 5.Tao-t'ai yamen. 6.Hsien-yang yamen. 7.T'ung-ling yamen. 8.Meteorol. station.

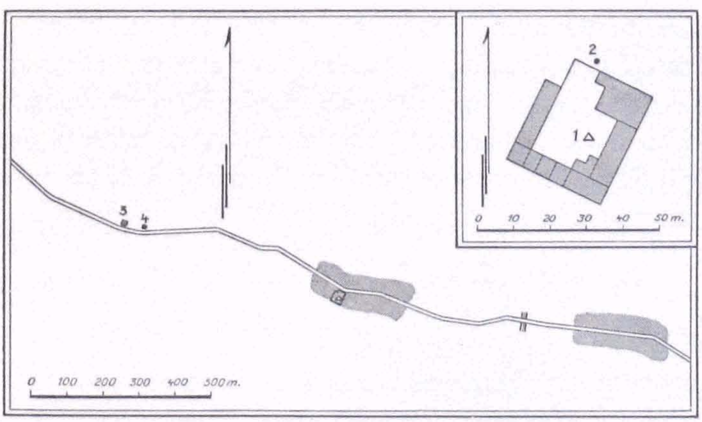


Fig. 64. Zanguya Camp 300. 1.Astr. station No. 89. 2.Route station. 3.Water-tank. 4.Temple.

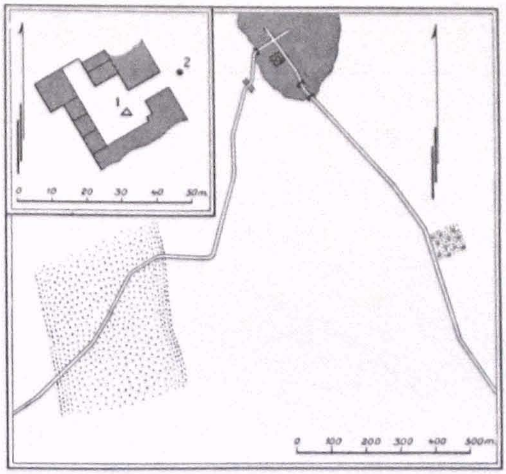


Fig. 65. Guma Camp 302. 1. Astr. station No. 90. 2. Route station.

No. 90. GUMA Camp 302

$\varphi = 37° 37' 33''.0 \pm 2''.9$ $\lambda = [78° 18']$

The station is situated on the premises of a caravansary near the road crossing, as seen on the map in Fig. 65. The route-line is based on an arba-wheel as a cyclometer, and the inserted map on paced distances. In both cases angles are measured by compass.

No. 93. YARKEND Camp 309

$\varphi = 38° 24' 34''.3 \pm 1''.1$ $\lambda = 77° 15' 05''.1 \pm 0''.6$

The station is situated 2 m in direction NNW from the sundial in the garden of the Swedish Mission and is shown by the map in Fig. 66. The inserted sketch map of the premises belonging to the Swedish Mission is taken from "På obanade stigar" by J. E. Lundahl (Stockholm 1917) with some additional information kindly given by Mr. Carl Persson of the Mission. The main features of the town-walls marked by dotted lines are taken from the sketch map, accompanying the report of the De Filippi expedition. The lines given in full are based on my own survey with compass and pacing.

No. 105. Camp 425

$\varphi = 35° 19' 01°.7 \pm 1''.5$ $\lambda = 78° 54' 18''.1 \pm 1''.8$

The station is defined by the map in Fig. 67 which is a copy of Dr. Norin's field map based on his survey with plane-table and cyclometer.

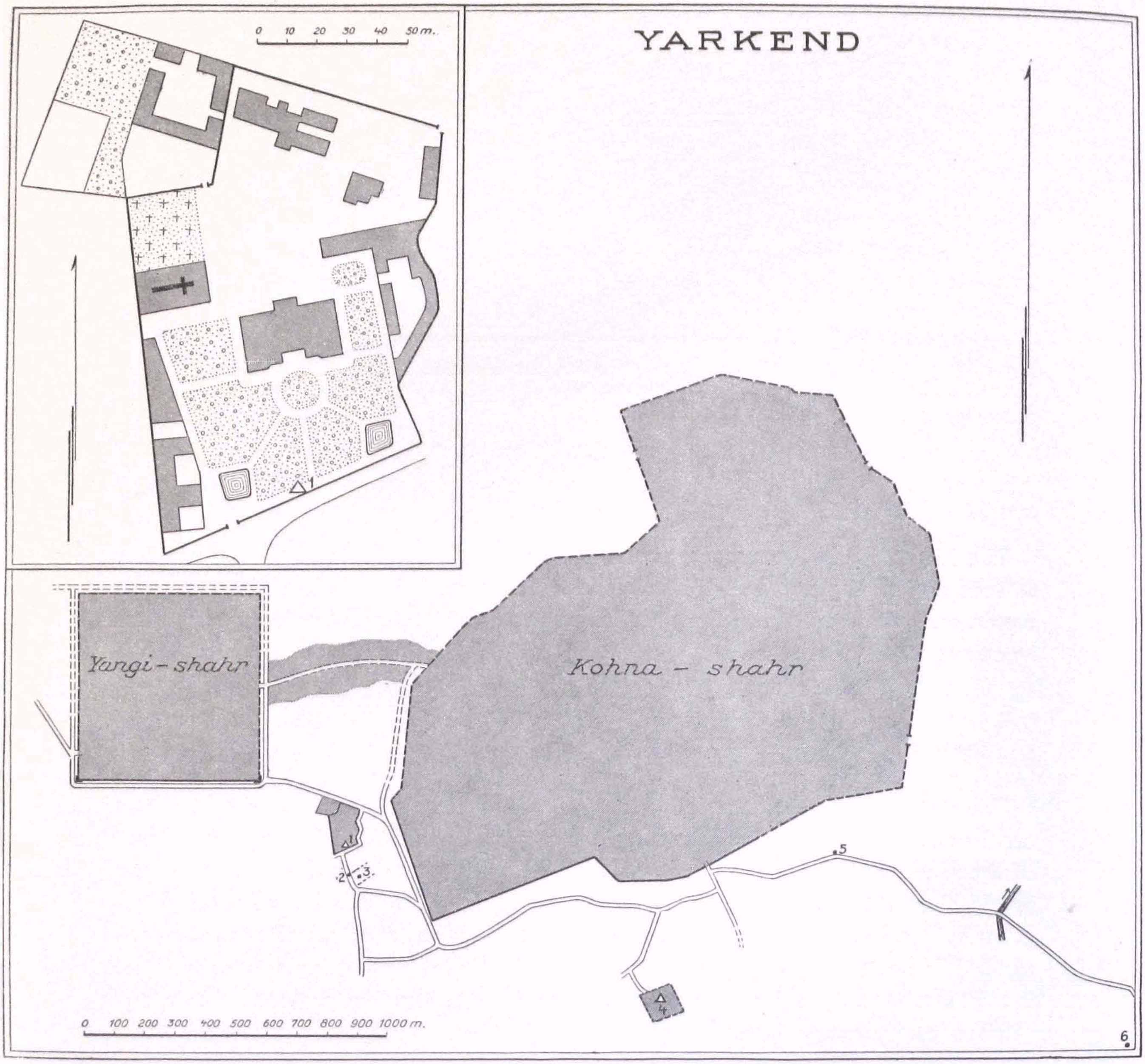


Fig. 66. Yarkend Camp 309. 1. Astr. station No. 93. 2. Route station. 3. Gravity station. 4. Astr. station of the De Filippi Expedition. 5. Tashlik-mazar. 6. Bai-döbe.

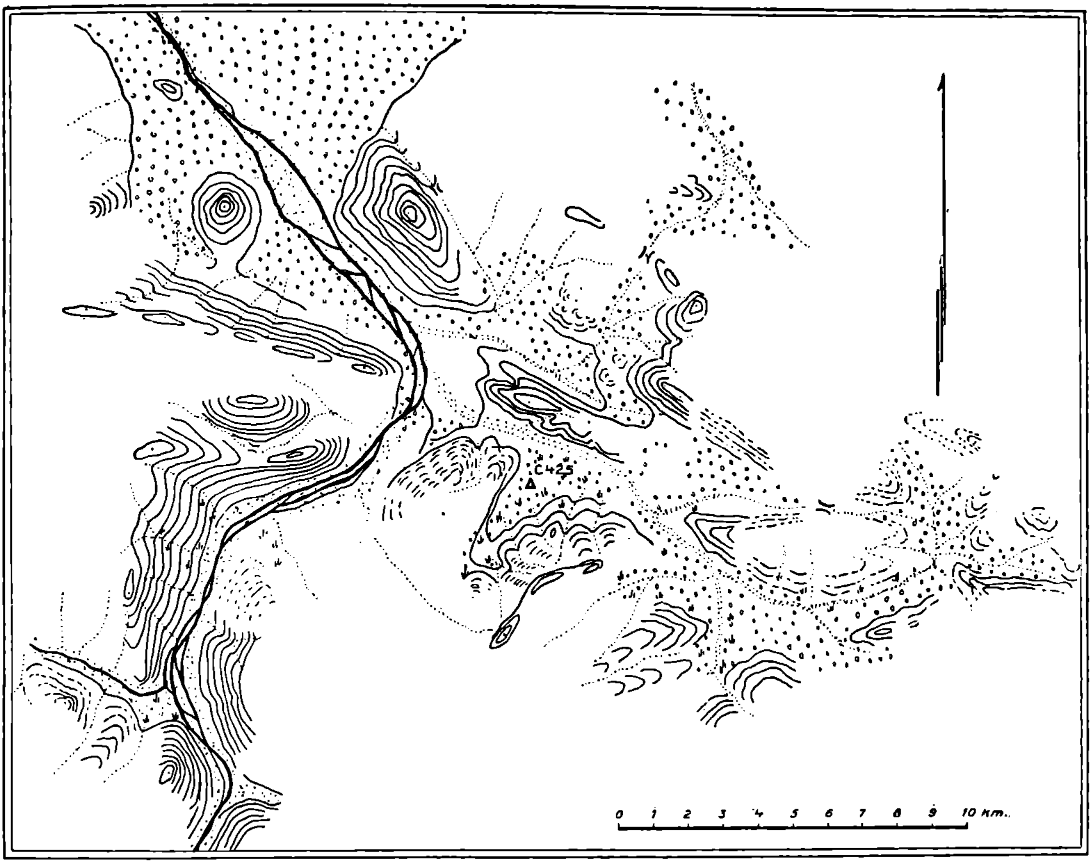


Fig. 67. Camp 425. Astr. station No. 105. Interval of contours 100 m.

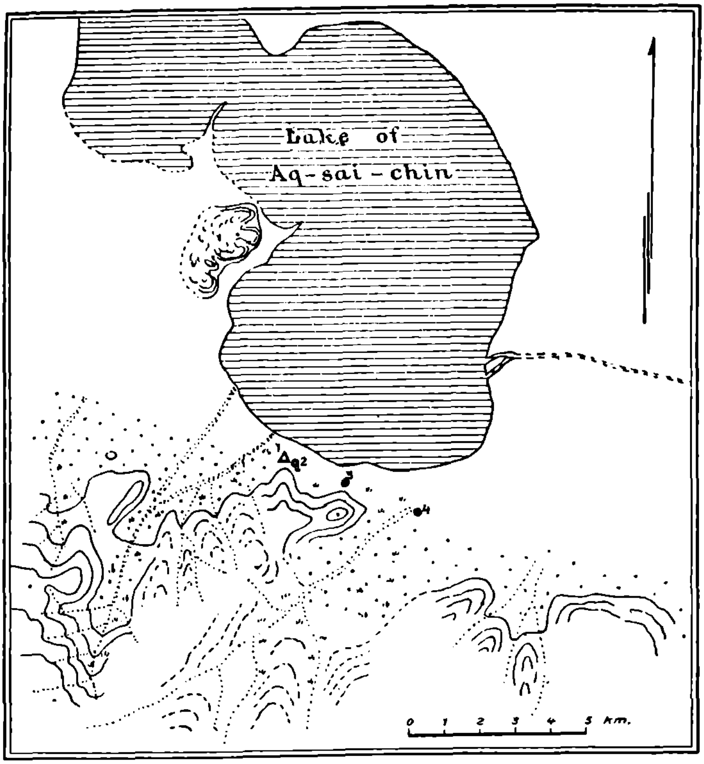


Fig. 68. Aqsai-chin Camp 430. Interval of contours 100 m. 1. Astr. station No. 108. 2, 3, and 4 Springs.

No. 108. AQ-SAI-CHIN Camp 430

$\varphi = 35° \, 08' \, 35''.4 \pm 1''.4$ $\lambda = 79° \, 49' \, 05''.0 \pm 1''.0$

The astronomical station is situated near the southern shore of Lake Aq-sai-chin and is described by the map in Fig. 68 which is a copy of Dr. NORIN's field map, surveyed by plane-table and based on triangulation. The big "obo" which has been built by some other traveller is situated 332 m in direction 182° from the astronomical station.*

[1] If Dr. TRINKLER had not because of his tragic death been prevented from working out his report himself (Geographische Forschungen im Westlichen Zentral-Asien und Karakorum-Himalaya von Dr. EMIL TRINKLER †. Berlin 1932) we certainly would have found in his map also the big stream which is the main feeder of Lake Aq-sai-chin, and which in July 1932 carried at least 30 m³ water pro second.

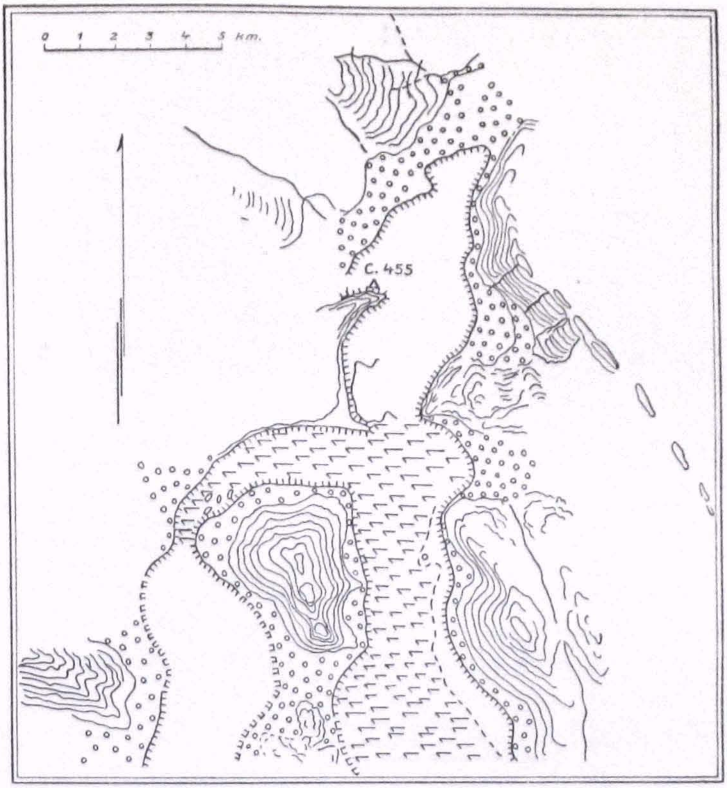


Fig. 69. Camp. 455. Astr. station No. 121. Interval of contours 100 m.

No. 121. Camp 455

$\varphi = 35° \, 44' \, 00''.4 \pm 1''.7$ $\lambda = 79° \, 21' \, 40''.6 \pm 1''.6$

The station is defined by the map in Fig. 69 which is a copy of Dr. NORIN's field map based on his survey with plane-table and cyclometer.

No. 145. CHARCHAN Camp 528

$\varphi = 38° \, 08' \, 22''.8 \pm 1''.6$ $\lambda = 85° \, 31' \, 56''.7 \pm 1''.6$

The station is situated on the premises of a caravansary as shown by the map in Fig. 70. The outline of the caravansary is only approximate (dotted lines!), but the astronomical station is accurately defined in its position with regard to the three points: 5, 6, and 7 on the map which are determined by a triangulation from a baseline east of the town. The details were surveyed by compass and pacing, and the resultant map has been adjusted to the triangulated points.

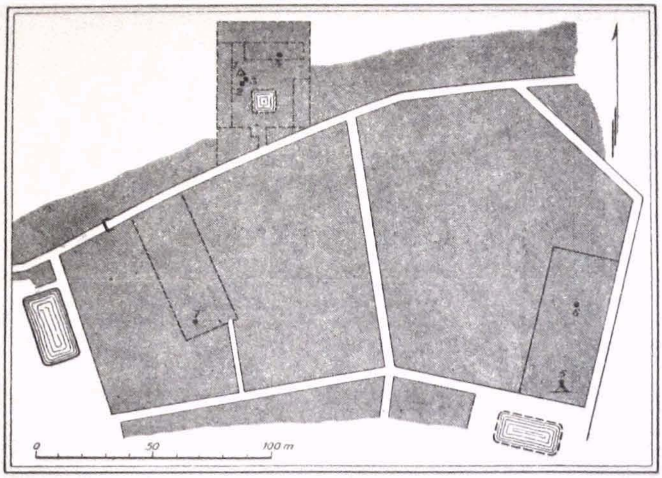


Fig. 70. Charchan Camp 528. 1.Astr. station No. 145. 2.Magn. station. 3.Meteorol. station. 4.Gravity station. 5.Triangle-shaped mark over the yamen. 6.Spire on the top of the yamen main-building. 7.Minaret.

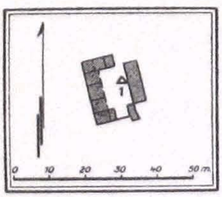


Fig. 71. Ovraz Camp 611. 1. Astr. station No.147.

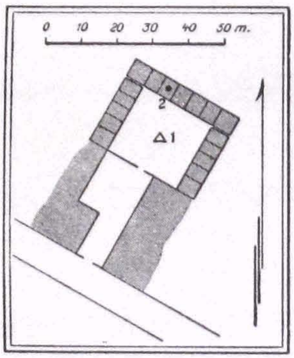


Fig. 72. Keriya Camp 613. 1.Astr. station No.148. 2.Gravity station.

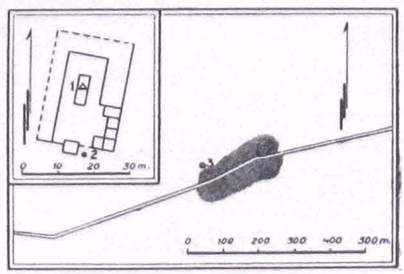


Fig. 73. Besh-toghraq Camp 616. 1.Astr. station No.149. 2.Route station. 3.Well. 4."Kuan-tien" (state caravansary).

No. 147. OVRAZ Camp 611

$\varphi = 36° \ 52' \ 50''.5 \pm 0''.3$ $\qquad$ $\lambda = 82° \ 22' \ 22''.5 \pm 1''.5$

The station is situated on the premises of the lonely little caravansary of which a sketch is given in Fig. 71.

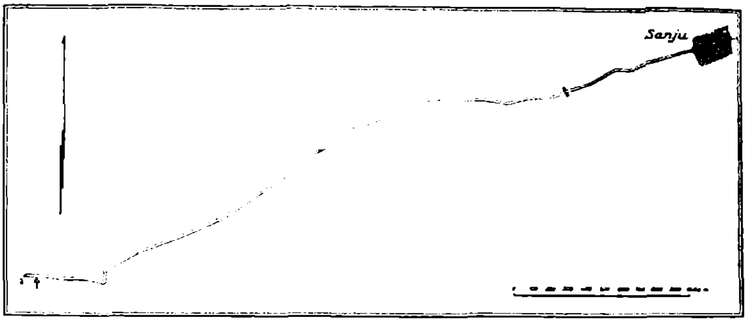


Fig. 74. Camp 705. 1.Astr. station No. 153. 2.Small temple. 3.Caravansary in the Sanju village.

No. 148. KERIYA Camp 613

$\varphi = 36^\circ\ 51'\ 27''.7 \pm 0''.7$ $\lambda = 81^\circ\ 40'\ 02''.7 \pm 2''.1$

When I arrived at Keriya where a revolution had just taken place, the political situation was still unsettled and, under such circumstances, it was inconvenient to try and work out a map.

The station is situated in the "Kuan-tien" (state-caravansary) near the centre of the town. A sketch of this caravansary is given in Fig. 72. Near the street-door there was a big Chinese triumphal arch.

No. 149. BESH-TOGHRAQ Camp 616

$\varphi = 37^\circ\ 03'\ 46''.5 \pm 1''.0$ $\lambda = 80^\circ\ 27'\ 48'' \pm 5''$

The station is situated in the eastern part of the village on a clay platform on the premises of a caravansary, as seen on the map in Fig. 73. The route-line is based on compass bearings and cyclometer readings, the inserted map on pacing.

No. 153. Camp 705

$\varphi = 37^\circ\ 11'\ 17''.6 \pm 1''.3$ $\lambda = [78^\circ\ 23']$

The station is situated about 4 km in direction WSW from the Sanju village and is defined by the map in Fig. 74 which is based on a survey with compass-bearings and a cyclometer.

VIII. HISTORICAL REMARKS

When discussing the earlier determinations of longitudes and latitudes which have been made in our regions, one must be sure that the determinations compared, are made at the same, or nearly, the same place. Or, before the comparison is made, corrections for location must be applied. Accurate observations can be compared only, if the quantities mentioned also are known with a considerable degree of accuracy. Thus if a determination is made with an accuracy of only about 2′, it is enough to add that it has been made in, for instance, Kashgar, Kohna-Shahr, but it is a pity if determinations, which have been made with an accuracy of, say, some seconds, are not provided with a description which clearly defines the point observed. Quite a number of explorers, as already mentioned, have sinned in this respect. Even if we have two determinations which are provided with good descriptions, it is by no means sure that the comparison between the data can be made, so as to enable us to form an opinion regarding which is to be preferred. The reason is that the maps, which are connecting the points, may be inaccurate. And if two maps exist and do not agree with each other, it is in many cases impossible to decide which of the two is right, and which is wrong. Thus the comparisons sometimes involve a good deal of subjective interpretation of the maps and the figures treated.

There is another detail to which I would like to draw attention. If a station has been astronomically determined and is fixed on a map by a sign, say a star or a triangle, then this sign ought to be fixed exactly at the point where the determination has been made. Above all it should be avoided to use two signs of about the same conspicuousness, where one, for instance, indicates an encampment, the other an anstronomical determination, and where the reader accordingly is in doubt which is the point to which the determination refers. This is, for instance, the case with some maps which are of the greatest interest for these regions, namely those constructed from material collected by Dr. Sven Hedin and Sir Aurel Stein.[1]

[1] As regards Sir Aurel Stein's maps I also react on the way in which the towns have been marked. They are in some cases marked by an outline which gives a slight idea of the shape of the town, in some, by a sign for a town-wall. For Kashgar, Kohna-shahr this sign is given, but is not orientated, and one is thus apt to believe that this means that the town has the shape of that sign, which however, is not at all the case. If a sign is used, it should always be orientated and if the shape of the respective towns are aimed at, the figure given must, of course, correspond to real facts, both regarding shape and size.

In the lists below the following markings have been used for the longitudes:

75° 18′ 16″	Value obtained by the aid of wireless signals,
75° 21′ 36″	Value otherwise absolutely fixed,
(75° 30′)	Value interpolated chronometrically,
[75° 32′]	Value interpolated by the aid of itineraries.

Amongst earlier determinations of geographical coordinates in the regions visited by me, I am at present going to deal with only such places which are inhabited or of special importance for the maps, and which are also found in my list of determinations. For the uninhabited regions in Northern Tibet, where for instance DEASY has determined many valuable points, a comparison must be postponed until our maps of these regions are constructed.

Before turning to the earlier determinations of coordinates, I wish to say a few words about the way in which some earlier values have been quoted by MERZBACHER in his work "Die Gebirgsgruppe Bogdo-Ola" (München in 1916). As this work is one of the better-known dealing with Eastern Turkistan, I think it is important to draw attention to the fact that MERZBACHER, who was a famous geographer, has made a number of mistakes on pages 5 and 6, where he gives the coordinates of Urumchi according to various travellers.

In the table below, I reproduce to the left the figures given by MERZBACHER and to the right, the true values given in the quoted works.

Coordinates of Urumchi according to

		Merzbacher	Resp. author.
PEVZOFF	φ	43° 47′ 22″	43° 44′.8
	λ	87 35 03	87° 35′.3
ROBOROVSKI	φ	43 47 22	43° 47′ 22″
	λ	87 36 00	(87 36 00)
CLEMENTI	φ	43 48 32	43 48 03.2
	λ	87 46 07	87 46 15.7
VAILLANT	φ	43 46 09	43° 46′.9
	λ	85 14 25[1]	85° 14′.25

ROBOROVSKI's longitude 87° 36′ 00″ is given in brackets and the text states that it is simply derived from PEVZOFF's value. Furthermore MERZBACHER says (p. 5) that PEVZOFF has described his points with mathematical accuracy, and better than ROBOROVSKI. As a matter of fact the contrary holds true.

Astronomical determinations have been made in Central Asia already in 1756—60. They were carried out by Jesuit Fathers and Chinese assistants at the request of CHI'EN LUNG. This foreseeing Chinese Emperor ordered three Jesuit Fathers:

[1] Longitude reckoned from Paris.

D'AROCHA, ESPINHA, and HALLERSTEIN, and four native, assisting astronomers to follow his armies which at that time marched towards that part of Central Asia, where I have now been working. What kind of instruments these gentlemen used is not known, but we know whole lists of places, which have been determined and we also know that of the coordinates given, only the latitudes have been fixed through astronomical observations. The longitudes, which are given as reckoned from Peking have been calculated from the itineraries joining the different stations.

In PETERMANN's Mitteilungen of 1880 these determinations have met with a criticism which is hardly justified. Prof. ALBERT HERRMANN has emphasized the extraordinarily great importance they have had. The degree-net of the "Manchu-map" has been constructed mainly by the aid of the coordinates given in these lists and this map represents a distinct improvement. The main geographical features of the country are laid down in it.

In the comparison list, Table 13, are given besides the values determined by the Jesuits and by me, in the colums headed "Reduced", values which have been derived

Table 13

Ambolt's Reference No.	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
		Ambolt	Reduced	Jesuits		Ambolt	Reduced	Jesuits	
	Chira......	1)36° 58'.6	37° 00'	36° 47'	+ 13'	1)80° 44'.2	80° 44	4) [81° 45]	—1° 01'
83	Duwa	37° 06' 34"	37 07	36 52	+ 15	*78° 59' 22'*	[79 00]	[79 21]	— 21
153	Sanju......	37 11 18	37 12	36 58	+ 14	[78 23]	[78 26]	[78 41]	— 15
76	Khotan	37 07 18	37 07	37 00	+ 07	*79 55 58*	79 56	[80 36]	— 40
148	Keriya.....	36 51 28	36 51	36 59	— 08	*81 40 03*	81 40	[83 03]	—1 23
95	Kök-yar ...	37 24 08	37 24	37 07	+ 17	*77 11 14*	77 11	[77 26]	— 15
	Qara-qash .	[37 16]	[37 16]	37 10	+ 06	[79 45]	[79 45]	[80 14]	— 29
93	Yarkend ...	38 24 34	38 25	38 19	+ 06	*77 15 05*	77 16	[76 18]	+ 58
	Kahsgar ...	2)39 28 20	39 28	39 25	+ 03	2)*75 59 06*	76 00	[74 03]	+1 57
	Airilghan ..	40 08.7	40 09	40 02	+ 07	88 20	88 20	[87 23]	+ 57
62	Aqsu	41 09 40	41 17	41 09	+ 08	*80 16 08*	80 15	[79 13]	+1 02
55	Kuchar	41 42 36	41 43	41 37	+ 06	*82 55 51*	82 56	[82 56]	00
58	Bai	41 47 29	41 47	41 41	+ 06	[81 52]	[81 52]	[81 16]	+ 36
	Sairam		[41 43]	41 41	+ 02		[82 17]	[81 48]	+ 29
52	Bugur	41 46 22	41 46	41 44	+ 02	*84 15 14*	84 15	[84 22]	— 07
	Qizil		[41 47]	41 45	+ 02		[82 28]	[82 03]	+ 25
	Korla	3)41 44 32	41 45	41 46	— 01	86 9.5	86 10	[86 32]	— 22
47	Qarashahr .	42 03 22	42 03	42 07	— 04	*86 33 36*	86 34	[87 11]	— 37
	Ushak-tal ..		[42 14]	42 16	— 02		[87 18]	[88 02]	— 44
	Ilanlik.....		[42 48]	42 56	— 08		[88 28]	[89 03]	— 35
2	Turfan	42 56 37	42 56	43 04	— 08	*89 10 18*	89 11	[89 43]	— 32
1	Urumchi...	43 46 42	43 49	43 27	+ 22	*87 36 12*	87 35	[88 31]	— 56
39	Jimasa.....	44 00 28	44 00	43 40	+ 20	[89 04]	[89 05]	[89 36]	— 31

1) From PEVZOFF
2) From the DE FILIPPI Exp.
3) From Sir AUREL STEIN
4) HERRMANN's value 32° 42' probably misprint, ought to be 34° 42'

from my coordinates and which are valid for the place, where the Jesuits have probably made their determinations. In some cases, where I have not had any determination and where it has been considered valuable still to obtain a comparison, I have used coordinates determined by the DE FILIPPI Expedition, or by PEVZOFF.

Most of the Jesuit values are taken from a paper by ALBERT HERRMANN: Die Westländer in der Chinesischen Kartographie, contained in Southern Tibet by SVEN HEDIN, Vol. VIII., some are taken from PETERMANN's Mitt. 1880, and one from PEVZOFF. All are reduced to the Greenwich Meridian.

The places where these early determinations have been made are not more closely defined, and it has therefore been necessary to reduce them to that place which *probably* corresponds to the place which is fixed by me. It is rather interesting to compare some of the values given in this list to those given in PETERMANN's Mitteilungen of 1880. The values given there are said to be the most up to date. The following table shows longitudes for four of the places mentioned. Three values are given for each place: the true, the value determined in 1756—60, and the value corresponding to PETERMANN's Mitteilungen of 1880. For the last two values the corrections are also given, and they show that the coordinates given by the Jesuit Fathers are *far* more accurate than the values given in PETERMANN's Mitteilungen of 1880.

Place Names	True	Jesuits 1756—60		PETERM. Mitt. 1880	
Urumchi	87° 35′	88° 31′	— 56′	88° 42′	— 1° 07′
Qarashahr	86 34	87 11	— 37	88 00	— 1 26
Korla	86 10	86 32	— 22	87 32	— 1 22
Turfan	89 11	89 43	— 32	91 35	— 2 24

PETERMANN's Mitteilungen has received a list of the old coordinates from the Jesuit Father BRUCKER, who had discovered them in some old letters. Father GAUBIL in one of these letters, written in 1758, says that the points are probably situated considerably further towards west. This opinion is quite right, but as late as in 1880 the knowledge of Inner Asia was so imperfect, that a publication of such fame and reliability as PETERMANN's Mitteilungen could publish an annihilating criticism saying "geographischen Werth haben somit diese Positionen der Portugiesischen Missionare nicht mehr". And modern determinations as already mentioned show, that the values supposed to be the best in 1880 are by *far* not so good as those from the years 1756—60.

HERMANN, ADOLPHE and ROBERT DE SCHLAGINTWEIT undertook a scientific mission to India and High Asia in the years 1854—58. They were very well equipped with instruments by the Indian Government. Five good theodolites which could be read to 10″—20″ were at their disposal. ADOLPHE travelled via Khotan to Yarkend and Kashgar, and has fixed the coordinates for these three places. No details of his observations are available, because he was decapitated, and his papers were lost.

ROBERT S. has therefore determined the position of these three important places from various itineraries. Of course, these values must be quite approximate. In fact, these latitudes and longitudes are less reliable than those obtained by the Jesuit Fathers 100 years earlier. But, unfortunately, even the coordinates which have been determined by the SCHLAGINTWEIT-brothers from astronomical observations, are probably less accurate, than might have been expected because of the excellent instruments they possessed.

HERMANN and ROBERT S. have determined the coordinates for "Suget" ($\varphi = 36°$ $10' 25''$, $\lambda = 77° 50' 05''$ E. of Gr.). This "Suget" is the same place as the station of "Suget Karaul" which has been fixed by the DE FILIPPI Expedition ($\varphi = 36° 20'$ $55''$, $\lambda = 78° 01' 36''$ E. of Gr.). Thus, the SCHLAGINTWEITS' value for φ is about 10′ too small. We must try and find an explanation of this marvellous discrepancy.

In the "Results of a scientific Mission to India and High Asia", by HERMANN, ADOLPHE and ROBERT DE SCHLAGINTWEIT (Leipzig and London in 1861) Part I p. 262 we find the following statement: "When descending the Karakorum pass on the evening of the 9th August, we were overtaken by the night before reaching our encampment at Δ Bullu. One of the horses carrying the theodolite fell down, and the level of the vertical circle was unfortunately broken. We had a spare level with us, which we connected with the vertical circle, but only with approximate accuracy. We thought at first that we had succeded in properly adjusting the vertical circle, but upon repeating our trials, we found, when taking the vertical angles of different peaks, that the adjustment was not sufficiently correct.

A few days later we succeeded in properly fixing the spare level. It then kept in perfect order, as is proved by our subsequent observations taken at Δ Suget."

A rough comparison of some of the SCHLAGINTWEITS' determinations, before the accident, proves them to be practically correct.

Thus, we may conclude that they have *not* been able to adjust the new level quite correctly — the 10′ difference in Suget Karaul must be due to a great index error. Furthermore it is clear that the SCHLAGINTWEITS made their observations only from one position of the instrument, otherwise the index error must have been eliminated. And further it is probable that they have taken observations for latitude

Table 14

Reference No. Ambolt	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
		Ambolt	Reduced	Schlagintweits		Ambolt	Reduced	Schlagintweits	
76	KHOTAN......	37°07′18″	37°07′	[36°50′]	+17′	*79°55′58″*	79°56′	[78°20′]	+1°36′
93	YARKEND	38 24 34	38 25	[38 10]	+15	*77 15 05*	77 16	[74 00]	+3 16
	KASHGAR.....	[1] 39 28 20	39 28	[39 15]	+13	[1] *75 59 06*	76 00	[71 50]	+4 10
	SUGET-KARAUL	[1] 36 20 55	36°20′55″	36°10′25″	+10′30″	[1] *78 01 36*	78°01′36″	(77°50′05″)	+0°11′31″

[1] According to the DE FILIPPI Expedition

Table 15

Reference No. Ambolt	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
		Ambolt	Reduced	Montgomerie		Ambolt	Reduced	Montgomerie	
93	YARKEND.....	38°24'34"	38°25'	[1] 38°20'	+ 5'	77°15'05"	77°16'	[1] [77°30'	—14'
76	KHOTAN......	37 07 18	37 07	[1] 37 37	—30	79 55 58	79 56	[1] [78 57]	+59
	KASHGAR.....	[3] 39 28 20	39 28	[1] 39 25	+ 3	[3] 75 59 06	76 00	[1] [75 21]	+39
				[2] 39 29	— 1			[2] [76 12]	—12

[1] From MAHOMED-I-HAMEED
[2] From MIRZA
[3] According to the DE FILIPPI Expedition

only at one side of zenith. If they had taken observations both north and south of zenith the index error would also have been eliminated, provided that in both cases the same position of the theodolite was used.

The SCHLAGINTWEITS determined the longitudes by the aid of chronometrically transported time. In the "Results" it is stated that the chronometers which they used, were very good. But a chronometrically extrapolated longitude must be hazardous — as proves the result — when the chronometers are carried along a route where extreme cold is met with.

It is a pity that R. SCHLAGINTWEIT wasted so much theoretically good work and careful calculations on this material. His ability as a calculator certainly was far greater than the three brothers' knowledge of how to deal with the instruments and how to arrange their observations most advantageously.

Captain T. G. MONTGOMERIE in 1862 organized measurements to be made of geographical coordinates for certain points in Eastern Turkistan. At that time it meant, indeed, a perilous enterprise for an European to travel in that country, but MONTGOMERIE thought that a native surveyor would be able to go there without meeting with too great difficulties. For this purpose he dispatched MAHOMED-I-HAMEED whom he had trained especially for the work. MAHOMED observed the latitude of Yarkend by the aid of a very small pocket sextant without any telescope — consequently the determination cannot be of any great accuracy — its mean error derived from 11 observations is $\pm$ 2'. The longitude was fixed from his itinerary.

In spite of such primitive methods this work was of great value and the results are more accurate than the results obtained by the SCHLAGINTWEIT brothers.

MAHOMED-I-HAMEED had to leave Yarkend because of the authorities being suspicious as to his doings. On his way back he died.

From the map, which MAHOMED-I-HAMEED had drawn, founded on information only, Captain MONTGOMERIE calculated the coordinates of Kashgar and Khotan. This explains the great error in latitude for Khotan. MONTGOMERIE's values were a first step onward after the work of the Jesuits and the coordinates of Yarkend were now fixed with errors amounting to but 5′ in latitude, and 12′ in longitude, results which must be said to be excellent.

MONTGOMERIE's idea that a fairly good value of the longitude of Yarkend might be calculated from Leh, situated nearly straight southwards from Yarkend, was quite a clever one. And MAHOMED-I-HAMEED had done his work well.

In 1868—69 MONTGOMERIE organized one more expedition to Eastern Turkistan, and this time one MIRZA was chosen as his surveyor. The list shows that MIRZA was as skilful as MAHOMED-I-HAMEED, and from the material he brought back, MONTGOMERIE calculated the longitude of Kashgar with remarkable accuracy.

In 1865 Mr. W. H. JOHNSON made an important journey to Khotan. When travelling he carried out a plane-table survey of the country traversed. This survey was based "on three previously-determined Trigonmetrical Stations on the Kiun Lun range" (Report on his Journey to Ilchi, the Capital of Khotan, in Chinese Tartary by W. H. JOHNSON. Journal of the Royal Geographical Society. Vol. 37. London 1867). JOHNSON did not attempt to take astronomical observations for longitude but determined the latitude of Khotan and Sanju by observations to the sun and the pole star. He states that the results derived from his observations, agree with those indepedently obtained by his plane-table. The latitude of Khotan is correct but for Sanju we must add 8′ to get the true value. JOHNSON's longitude determination were obtained by the aid of his plane-table which unfortunately has proved to be erroneous. A discussion of these longitudes thus is superfluous. The difficulties which are met with when carrying on a survey of that kind are obviously great. The identification of peaks viewed from different angles and with no markings is always apt to cause mistakes. But that his astronomical determination at Sanju must be corrected for with the mentioned great amount is difficult to explain. No details of his observations are given in his report.

Table 16

Reference No. Ambolt	Place Names	Latitude North according to			Correction
		Ambolt	Reduced	Johnson	
76	KHOTAN	37°07′18″	37°07′	37°07′	0′
153	SANJU	37 11 18	37 11.9	37°03′57″	+7.9

In 1868—69 G. J. W. HAYWARD travelled from Leh to Yarkend and Kashgar and, during his journey, he fixed some astronomical points by observations of the sun with a sextant. The longitudes were fixed from his itinerary. (Journal Royal Geogr. Soc. Vol. XL. in 1870, p. 33.)

From the list of comparisons, it is seen that his coordinates are not so accurate as one might have expected. But we must consider the circumstances under which

Table 17

Reference No. Ambolt	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
		Ambolt	Reduced	Hayward (H) and Shaw (S)		Ambolt	Reduced	Hayward (H) and Shaw (S)	
153	SANJU	37°11'18"	37 11'.9	H 37°15'20"	−3'.4	[78°23']	[78°26']	H 78°47'	−21'
93	YARKEND. ...	38 24 34	38 25	H 38 21 43	+3	77°15'05"	77 16	H 77 29	−13
93	YARKEND	38 24 34	38 25	S 38 24 41	0	77°15'05"	77 16	S 77°12'08"	+ 4

he made his journey, — every kind of survey-work was regarded with suspicion. An open display of instruments would, most decidedly, have implied unpleasant complications, if not absolute danger to life. HAYWARD says: "It was advisable even not to be seen writing too much, for suspicion of an Asiatic once aroused, it is hard to allay, and correspondence in his eyes is conspiracy." Only shortly after he had written these words, was he murdered.

Even if HAYWARD's astronomical determinations are not very accurate, they were still of value.

One year after HAYWARD's determination of the position of Yarkend a new position was obtained by Mr. ROBERT SHAW. He also used a sextant, and was able to work more freely. The coordinates given by him are already on a more modern standard. He was the first to make an absolute determination of the longitude of Yarkend.

The famous Russian explorer N. M. PRJEVALSKI during his four great journeys in 1870—73, in 1876—77, in 1879—80, and in 1883—85 determined, in all, 63 latitudes and 29 longitudes, the latter by the aid of portable chronometers. Most of his stations are situated to the east of my field, but at five places we have both made observations. (Izvestia. Imp. Russkoe Geograficheskoe Obshchestvo, 23, 1887, p. 361. St. Petersburg in 1888.)

At these five places PRJEVALSKI has only determined latitudes. It is difficult to obtain a real idea of their value as they are given without any descriptions. From the comparison with my values one should estimate the accuracy to be about ± 1'.

Table 18

Reference No. Ambolt	Reference No. Prjevalski	Place Names	Latitude North according to			Correction
			Ambolt	Reduced	Prjevalski	
145	9	CHARCHAN	38°08'23"	38°08'.4	38°09'.1	−0'.7
148	10	KERIYA	36 51 28	36 51.5	36 52.5	−1.0
76	12	KHOTAN......................	37 07 18	37 07.3	37 07.1	+0.2
70	14	MAZAR-TAGH	38 29 08	38 27.1	38 25.8	+1.3
62	16	AQSU	41 09 40	41 14.8	41 14.7	+0.1

When the FORSYTH Mission visited the south-western part of Eastern Turkistan in 1873 the Government of India appointed Capt. H. TROTTER of the Great Trigonometrical Survey of India together with three "Pundits" (native surveyors) to accompany the Mission. (Account of the survey operations in Eastern Turkistan, in 1873—74. By Captain H. TROTTER, R. E. Calcutta in 1875.)

Much valuable survey work has been made by them, and the coordinates determined from their astronomical observations with theodolite and sextants have long been utilized for map constructions. The longitudes have been calculated relatively to one absolute longitude fixed at Kashgar, Yangi-shahr from five days' observations of lunar zenith-distances. Unfortunately, we have no possibility to compare TROTTER's value for this important place with the up-to-date value which has been secured by the DE FILIPPI Expedition for Kashgar, Kohna-shahr. But the existing maps connecting the two towns differ greatly, and I have not been able to explain the discrepancies. From TROTTER's paper we calculate the mean error in the Kashgar longitude to be $\pm$ 1'.7. The maximum error of his result, I estimate to 1'.

The mean error in one single determination of latitude is 15" for the theodolite, and 30" for the sextants. The resulting latitudes have, as a rule, been calculated from a large number of observations, and have in such cases, of course, mean errors which are smaller in proportion to the square-root of this number. Thus, for some exceedingly carefully worked stations the final mean error amounts to only $\pm$ 3".

Capt. TROTTER has given no, or only, approximate descriptions of his stations. Very welcome exceptions represent the sketch-maps of Yarkend, Khotan, and Kashgar which are appended to his paper, and define the astronomical stations of Yarkend and Kashgar with an accuracy of $\pm$50 m. The Khotan station is defined as situated in "Shamal Bagh in nearly the same latitude as the centre of the city", which means an accuracy of about $\pm$ 100 m in latitude, and $\pm$ 400 m in longitude.

Table 19

Reference No. Ambolt	Reference No. Trotter	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
			Ambolt	Reduced	**Trotter**		**Ambolt**	Reduced	**Trotter**	
153	52	SANJU	37°11'18"	37°11'.9	37°11'17"	+0'.6				
93	57	YARKEND ..	38 24 34	38°24'53"	38 25 01	—0'08"	*77°15'05"*	77°14'47"	77°15'55"	—1'08"
95	69	KÖK-YAR ..	37 24 08	37 24.1	37 24 14	—0.1				
100	78	KHAPALUNG	36 08 08	36 08.1	36 08 34	—0.5				
101	79	AQ-TAGH ..	35 59 54	35 59.9	36 00 11	—0.3	*78 01 25*	78 01.4	78 03 20	—1.9
90	90	GUMA	37 37 33	37 37.5	37 37 31	0.0				
76	93	KHOTAN ...	37 07 18	37 07.4	37 07 36	—0.2	*79 55 58*	79 56.9	79 59 00	—2.1
148	99	KERIYA ...	36 51 28	36 51.5	36 51 26	+0.1				

Table 20

Reference No. Ambolt	Reference No. Grombchevski	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
			Ambolt	Reduced	**Grombchevski**		**Ambolt**	Reduced	**Grombchevski**	
153	28	SANJU.....	37°11′18″	37°10′.6	37°10′.7	—0′.1	[78°23′]	[78°22′]	(78 23′)	—1′
148	35	KERIYA ...	[1]06 52.2	36 52.2	36 51.6	+0.6				
95	39	KÖK-YAR ..	37 24 08	37 24.0	37 23.7	0.	*77 11 14*	77 11	(77 10)	+1
93	45	YARKEND..	38 24 34	38 24.0	38 23.3	+0.7				
	48	KASHGAR ..	[2]39 28 20	39 28.4	39 28.2	+0.2	[2]*75 59 06*	75 59	75 58	+1

[1] According to PEVZOFF
[2] According to the DE FILIPPI Expedition

B.L. GROMBCHEVSKI, another well-known Russian traveller, has provided us with two lists of coordinates containing together 67 stations from observations in the years 1888—90. (Izvestia, Imp. Russkoe Geograficheskoe Obshchestvo, 31, 1895, p. 381. St. Petersburg in 1895.)

GROMBCHEVSKI is the first traveller in these far-off regions who has added good descriptions of the stations to his list of coordinates. In some cases GROMBCHEVSKI and PEVZOFF have made observations at exactly the same place. GROMBCHEVSKI's descriptions of them are far more detailed than those by PEVZOFF and are therefore especially valuable. His astronomical observations are, however, not of the same high standard as those by PEVZOFF. In spite of that they are good. Their mean error is estimated to about $\pm 0'.2$.

Longitudes have been derived chronometrically, except for Kashgar, where GROMBCHEVSKI and SCHARNHORST together made an important absolute determination. The longitude obtained, 75° 58′ E. of Gr. seems to be fairly good.

The Russian travellers above mentioned have not published any details about their observations, or about their calculations. This may possibly be accounted for by the fact that the accuracy does not exceed 0′.2, still a few general remarks about instruments and methods used, would have been appreciated.

Among the earlier determinations which have been made in Central Asia, the very best originate from General PEVZOFF. They are published in Trudi Tibetskoi Ekspeditsii, 1889—90, Part I. (St. Petersburg in 1895). The observations were made with a portable transit instrument of the broken telescope type. The mean error for the resulting latitude coordinates is about 0″.7.

For four points absolute longitudes were determined from observations of occultations of stars by the moon. The mean error in these longitudes is about 1^s. One of these four points is Qarashahr, where I also have made a longitude determination.

The points, thus fixed, were used as the foundation for building up a net-work of stations, whose longitudes were determined chronometrically. In all, PEVZOFF gives a list of 34 stations. The internal mean error in longitude fluctuates from 0'.3 to 0'.7. In most cases this internal mean error corresponds to the real error of the determination. But great divergences are sometimes found. They do not appear for stations absolutely determined, but for such stations whose longitudes have been fixed by the aid of time transportation with chronometers. The great changes in temperature are likely to act in the same direction as the rate of many chronometers, and thus the chronometers may show values which give rather accordant longitudes when calculated, but which still do not correspond to the true value.

Below I reproduce a list of some of PEVZOFF's stations including the mean errors calculated from the material given in his report. These mean errors depend upon, and are calculated by the aid of the mean errors of the fundamental stations. From PEVZOFF's paper these errors can be derived, but very roughly.

Table 21

Reference No. Ambolt	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
		Ambolt	Reduced	Pevzoff		Ambolt	Reduced	Pevzoff	
93	YARKEND	38°24'34"	38°24'.1	38°24'.2	—0'.1	*77°15'05"*	77°13'.4	(77°15'.6)	—2'.2
76	KHOTAN.........	37 07 18	37 07.2	37 07.4	—0.2	*79 55 58*	79 57.2	(79 53.8)	+3.4
148	KERIYA	36 51 28		36 52.2		*81 40 03*	81 41	(81 40.8)	0.
144	ACHAN	37 18 59	37 19.0	37 19.2	—0.2	*85 28 04*	85 28.1	(85 24.8)	+3.3
145	CHARCHAN	38 08 23		38 09.4		*85 31 57*	85 32	(85 27.6)	+4.
47	QARASHAHR	42 03 22	42 03.0	42 03.0	0.0	*86 33 36*	86 34.7	86 35.1	0.
41	TOQSUN	42 47 45		42 46.9		[88 40]	[88 43]	(88 40.0)	+3.
1	URUMCHI	43 46 42	43 45.3	43 44.8	+0.5	*87 36 12*	87 35.5	(87 35.3)	+0.2

From the above list as well as from the mentioned small mean errors, it is evident that PEVZOFF's determinations are very accurate. Unfortunately, in the neighbourhood of Achan and Charchan his chronometers seem to have been exposed to great changes in temperature for which he has not been able to make any corrections. This fact has apparently affected the longitudes calculated, and made them less reliable than the others. Furthermore, it is deeply regrettable that PEVZOFF has not given more careful descriptions of his stations. Thus for instance, for Charchan he writes as follows: "The grove of Bostan-ambal-chüshkan close to the northern border of the village". From a comparison with the position determined by me, we see that his station was situated some 2 km towards the north from the centre of the village. But without this knowledge, I should have concluded that the station was situated near the same point, where I made my determination which is just on the border of the village proper and only a very short distance from the centre of the village.

The Russian Officer and topographer V. Y. ROBOROVSKI made his first astronomical determinations in our regions in 1890 as a member of the PEVZOFF Expedi-

Table 22

Reference No. Ambolt	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
		Ambolt	Reduced	Roborovski		Ambolt	Reduced	Roborovski	
145	CHARCHAN	38°08'23"		38°07'.6		*85°31'57"*	85°32'	85°23'.8	+ 0°08'.
41	TOQSUN	42 47 45		42°46'52"		[88 40]	[88 43]	[1][88°40' 21"]	+ 0 03.
1	URUMCHI	43 46 42	43°47'.4	43 47 22	0'.0	*87 36 12*	87 36.4	[1][87 36 00]	+ 0 00.4

[1] Longitude calculated from PEVZOFF's value.

tion. (Trudi Tibetskoi Ekspeditsii. Tome III p. 121. (St. Petersburg in 1892). Only a few years later in 1893—95 he himself was in charge of an expedition to Central Asia. During this expedition 29 stations were fixed. They are listed in "Trudi Ekspeditsii Imp. Russk. Geogr. Obshchestvo po Tsentralnoi Azii" by V. Y. ROBOROVSKI. (St. Petersburg in 1899) Tome 3 Part B p. 40. Only three points are common to us.

ROBOROVSKI's longitudes, all but one, have been obtained through chronometric interpolation, or even extrapolation from earlier determined fundamental points by the aid of pocket chronometers. Therefore their errors may be considerable.

Prof. HASSENSTEIN who constructed the maps accompanying Dr. SVEN HEDIN's report on his scientific results from his travels in 1894—97 (PETERMANNS Mitteilungen Ergänzungsband 28. 1900) says about ROBOROVSKI's and PEVZOFF's determinations of the position of Charchan that he cannot understand the great difference between the values. But, when regard is paid to the fact that the longitude has been determined chronometrically by both expeditions, the difference is quite reasonable.

The latitudes, which ROBOROVSKI has determined in 1890 have a mean error of 0'.2. Those determined in 1893—95 are more accurate, their mean error is about 0'.1.

ROBOROVSKI has, as already mentioned, described most of his stations very carefully. Unfortunately those stations, however, which we have in common have got no descriptions. Probably these descriptions have been omitted because these stations were also determined by PEVZOFF, and it is likely that ROBOROVSKI took it for granted that PEVZOFF had already made satisfactory descriptions of these places.

It is a striking fact that no descriptions have been given by the Russian travellers for some places of great importance. A possible explanation of this fact would be that maps over the places in question have been drawn, but have for some reasons been concealed. Such maps, of course, would give excellent descriptions.

In the years of 1891—94 DUTREUIL DE RHINS has fixed astronomically 86 latitudes, and 68 longitudes. (Mission Scientifique dans la Haute Asie 1890—95, Paris in 1898). They have been observed with a sextant, and are calculated by M. F. OLTRAMARE. Absolute longitudes have been determined from lunar altitudes and corresponding time determinations, but many longitudes have also been fixed chronometrically from Khotan which DUTREUIL DE RHINS used as his basis-station.

Table 23

Reference No. Ambolt	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
		Ambolt	Reduced	Dutreuil de Rhins		Ambolt	Reduced	Dutreuil de Rhins	
76	KHOTAN.......	37°07′18″	37°07′.3	37°07′00″	+ 0′.3	*79°55′58″*	79°56′.0	79°57′44″	− 1′.7
148	KERIYA 1	36 51 28	36°51′18″	36 51 14	+ 0′ 04″				
148	KERIYA 2	36 51 28	36 51 12	36 50 50	+ 0 22	*81 40 03*	81 39.0	81 41 29	− 2.5
153	SANJU.........	37 11 18	37 11.9	37 11 20	+ 0.6	[78 23]	[78 26]	78 17 59	+ 8.
149	BESH-TOGHRAQ	37 03 47	37 03.7	37 03 30	+ 0.2	*80 27 40*	80 27.7	80 30 29	− 2.8
144	ACHAN........	37 18 59	37 19.0	37 18 50	+ 0.2	*85 28 04*	85 28.1	85 24 29	+ 3.6
145	CHARCHAN	38 08 23	38 08 22	38 08 20	+ 0 02	*85 31 57*	85°31′53″	85 26 29	+ 5′ 24″

In the list, where the resulting coordinates are given on pp 287—289, OLTRAMARE gives two columns headed "Amplitude maximum de l'écart sur Khotan", and "Amplitude de l'écart sur Paris". These deviations give us an idea of the accuracy of the determinations, but I do not think that they are mean errors. If so, for the stations chronometrically fixed from Khotan, the "Amplitude de l'écart sur Paris" ought not to be calculated as the sum of this "Amplitude" for the Khotan station, and the "Amplitude sur Khotan", but instead as the square root of the quadratic sum of these two values. The latitudes are stated to be accurate within 10″.

No descriptions have been provided, but in the maps accompanying DUTREUIL DE RHINS' work, detailed sketches are given on a larger scale than the route map for some more important places, and these sketches form a kind of description. OLTRAMARE was well aware of the discrepancy in longitude for Khotan between the values from PEVZOFF's observations, and those made by DUTREUIL DE RHINS. And one cannot blame him for having given preference to the latter which depended upon an absolute determination. PEVZOFF's value was derived chronometrically. Still, as a matter of fact, PEZVOFF's value was far better.

Before Dr. SVEN HEDIN organized the Sino-Swedish Expedition in which I had the privilege to take part, he had already alone, without any scientific assistants, undertaken three important, and well-known, journeys of exploration to various parts of Central Asia.

During his first journey in 1894—97 Dr. HEDIN used a prismatic circle for astronomical observations, and by the aid of this instrument determined 17 latitudes the calculations of which were performed by Dr. K. D. P. ROSÉN. Their mean errors were found to be ± 10″. No observations for longitude were made during this journey. Of the latitudes only 7 have been published. (Petermanns Mitteilungen Ergänzungsband 28, 1900). For Khotan the value obtained was $\varphi = 37° \, 07' \, 20''$ which is in closest accordance with my result $\varphi = 37° \, 07' \, 18''$.

In 1899—1902 Dr. SVEN HEDIN added a list of 113 determined points. They have been calculated by Dr. K. G. OLSSON. (SVEN HEDIN. Scientific Results of a journey in Central Asia, 1899—1902. Vol. V. Part II. Les Observations astronomiques calculées et redigées par Dr. K. G. OLSSON. Stockholm 1907.)

Since 1889 Dr. SVEN HEDIN unfortunately suffers from *iritis*. This disease has deprived him of about 50 % of his normal eye-sight and, well aware of this fact, he refrained from making any determinations of absolute longitudes. Therefore Dr. OLSSON has interpolated chronometric longitudes from earlier determined points. As fundamental values for the longitudes of the stations in Eastern Turkistan Dr. OLSSON choose the longitudes fixed by PEVTSOV and ROBOROVSKI, a choise which has proved to be very wise.

The treatment of the material has been carried out with great care. Still Dr. OLSSON might have added to the already high value of his paper by giving also the mean errors of the resulting coordinates. The mean errors vary considerably — for one single determination I should put the mean error at ± 30″.

Of the stations determined during this expedition only two: Charchan and Ying-p'an occur in my list. During this journey Dr. SVEN HEDIN used the "Kleinste HILDEBRAND Universal" theodolite, which can be read to 30″ by verniers. Both the mutual concordance, of the observations, and the comparison with my values, indicate the results to be very good.

Table 24

Reference No. Ambolt	Reference No. Hedin	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
			Ambolt	Reduced	Hedin		Ambolt	Reduced	Hedin	
		KHOTAN	37°07′18″	37°07′18″	[1]37°07′20″	—0′02″				
145	24	CHARCHAN ...	38 08 23	38 08 19	[2]38 07 58	+0 21				
19	31	YING-P'AN	40 57 02	40 57 02	[2]40 57 14	—0 12	*87°51′32″*	87°51′32″	[2](87°48′57″)	+2′35″
105	67	Dr HEDIN'S Camp 296[4]..	35 19 02	35 17.3	[3]35 21	—4	*78 54 18*	78 57.7	[3](79 00)	—2
108	68	Dr HEDIN'S Camp 302 = = Camp 9 ..	35 08 35	35 08.6	[3]35 06 52	+1.7	*79 49 05*	79 49.1	[3](79 49 00)	+0.1

[1] Determined in 1896
[2] Determined in 1900
[3] Determined in 1908
[4] Dr. Hedin's latitude and longitude for Camp 296 were derived from an incomplete series of observations and are given as »approximate».

During the journey which Dr. SVEN HEDIN made in 1906—08 he had to simplify his methods of observation, on account of his declining eyesight, and therefore only the sun was made the object of observations. These observations were carried out by the aid of the same theodolite which was used in 1894—97, and were also calculated by Dr. K. G. OLSSON (Southern Tibet, Discoveries in former times compared with my own researches in 1906—1908 by SVEN HEDIN, Vol. VI Part II. Les Observations astronomiques calculées et redigées par Dr. K. G. OLSSON, Stockholm 1918). In spite of the difficulties offered by the material these calculations are excellent. As formerly, the longitudes are chronometrically determined. For only two stations from this journey of Dr. HEDIN's can a comparison with my values be obtained so far.

We see from the list above, that the coordinates fixed by Dr. SVEN HEDIN, diminish in accuracy year by year which may be due to the tragic fact that the weakness of his eyes has steadily increased. That he has had sufficient energy to carry on his astronomical observations in spite of this misfortune is worthy of great admiration. The coordinates obtained in 1906—08 were extremely valuable for our knowledge of the country he then traversed which was to a great extent unexplored.

In both his publications of Dr. HEDIN's astronomical observations Dr. OLSSON might have made matters more convenient for the reader by appending a list of the resulting coordinates.

In the years 1896—99 Capt. H. H. P. DEASY has made much valuable exploration work in Tibet and Chinese Turkistan. (In Tibet and Chinese Turkistan by Captain H. H. P. DEASY, London 1901).

His determinations of coordinates are mainly based upon triangulations, and it is likely that his work is of outstanding accuracy. A comparison with his work, however, must be postponed until our triangulations are calculated.

Outstanding as regards the exploration of Central Asia, is the extensive survey carried out mainly by Indian surveyors under the supervision of Sir AUREL STEIN. During three Expeditions in the years 1900—01, 1906—09, and 1913—15 large parts of Chinese Turkistan and Kansu were surveyed. As a result an atlas of 94 provisional sheets of maps to the scale of 1 : 253440 was published in 1912. The final maps comprising 47 sheets to the scale of 1 : 500000, and a "Memoir on maps" were published in 1923.

The fixed points of these maps depend largely upon observations of latitudes, complemented by triangulations in certain regions, by which the longitudes were calculated in relation to points fixed by earlier explorers. Probably owing to the difficulty of identifying peaks and the climatic obstacles encountered, these triangulations appear in many cases to be defective, and have, thus, incurred considerable discrepancies regarding the longitudes.

The triangulation covering Quruq-tagh, executed by LAL SINGH, is fixed in the degree-net by means of the longitude of Korla, as determined by CLEMENTI in 1907. This longitude has later proved to be erroneous.

In the same way CLEMENTI's deviating longitude for Aqsu has been used, which has caused serious distortion of that sheet. If the compilers had been aware of the great discrepancy between the longitude values of Urumchi, determined by PEVTSOV and CLEMENTI respectively, they might have avoided these erroneous longitudes.

Table 25

Reference No. Ambolt	Stein's Sheet No.	Place Names	Latitude North according to			Correction
			Ambolt	Reduced	Stein	
93	5	YARKEND	38°24′34″	38°23′.8	38°23′45″ 38 23 49	0′.0
95	6	KÖK-YAR	37 24 08	37 24	37 24 01	0.
79	9	ULUGH-ART-DAVAN	36 47 07	36 47	36 46 53	0.
77	9	LANGHRU	36 56 35	36 56	36 55 52	0.
76	9	KHOTAN	37 07 18	37 06.6	37 06 45	—0.2
70	13	MAZAR-TAGH	38 29 08	38 27.1	38 27 12	—0.1
152	14	TAM-ÖGHIL	36 13 11	36 13.2	36 13 41	—0.5
55	17	KUCHAR	41 42 36	41 43.1	41 42 58	+0.1
147	19	OVRAZ	36 52 51	36 52 51	36 53 12	—0′ 21″
145	22	CHARCHAN	38 08 23	38 08 22	38 08 21	+0 01
19	25	YING-P'AN	40 57 02	40 57 02	40 56 59	+0 03
11	28	SHOR-BULAQ	42 05 54	42 05 54	42 06 35	—0 41
2	28	TURFAN	42 56 37	42 56.0	42 55 39	+0.3
38	28	KU-CH'ENG-TZE	44 01 36	44 02.	44 02 03	0.

From STEIN's own plane-table traverses in 1908, the position of Aqsu was calculated to be $\lambda = 80° \; 4'$ E. of Gr. which is far better than CLEMENTI's value.

If STEIN had used, as the foundation for his map, the station determined by SVEN HEDIN at the inlet of the Aqsu-darya into the Tarim river, he would, in fact, have had his map approximately accurate in longitude.

However, it must be admitted that it is easy to make such statements now, when accurate values are available. At that time when the maps were constructed, a decision of the accuracy in the coordinates obtained by the various travellers, was very difficult.

It is a pity that almost no details are available about the latitudes determined by the members of STEIN's Expeditions. As a rule, the descriptions of the stations are also inadequate. Therefore, only a rough comparison of the data is possible. Thus I estimate the mean error of the latitudes to about 0.′2.

Finally I wish expressly to emphasize the importance of giving the mean error when presenting a measured, or calculated, position.

In the PELLIOT Missions in 1906—09 geographical coordinates were determined by Médecin-Major Dr. LOUIS VAILLANT. They were calculated by M. CLAUDE and are published in La Géographie, Tome 35, p. 494 (Paris in 1921). Absolute longitudes were determined for 14 places. In all, the coordinates for 47 stations were fixed. The latitudes are given to one tenth of a minute and seem to be accurate according to the same degree of accuracy. The longitudes are not so good as PEVZOFF's earlier

Table 26

Reference No. Ambolt	Reference No. Vaillant	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
			Ambolt	Reduced	Vaillant		Ambolt	Reduced	Vaillant	
	1	KASHGAR	[1]39°28'20"	39°28'.3	39 28'.5	− 0'.2	[1]*75°59'06"*	75°59'.1	76°00'.8	− 1'.7
58	4	BAI	41 47 29	41 47 .5	41 47 .4	+ 0 .1	[81 52]	[81 52]	81 56 .3	− 4 .
55	5	KUCHAR......	41 42 36	41 42 .5	41 42 .5	0 .0	*82 55 51*	82 55 .8	82 53 .6	+ 2 .2
52	10	BUGUR	41 46 22	41 46 .4	41 46 .2	+ 0 .2	*84 15 14*	84 15 .2	84 11 .1	+ 4 .1
51	11	YANGI-HISSAR .	41 56 38	41 56 .6	41 56 .5	+ 0 .1	[84 35]	[84 35]	84 31 .3	+ 4 .
47	14	QARASHAHR ..	42 03 22	42 03 .4	42 03 .5	− 0 .1	*86 33 36*	86 33 .6	86 30 .4	+ 3 .2
42	16	QUMUSH	42 14 17	42 14 .3	42 14 .2	+ 0 .1	[88 11]	[88 11]	88 04 .6	+ 6 .
1	18	URUMCHI	43 46 42	43 46 .7	43 46 .9	− 0 .2	*87 36 12*	87 36 .2	87 34 .4	+ 1 .8
2	19	TURFAN	42 56 37	42 56 .6	42 56 .6	0 .0	*89 10 18*	89 10 .3	89 02 .5	+ 7 .8

[1] According to the DE FILIPPI Expedition

determinations. Like many other travellers, VAILLANT neglected giving any descriptions of the stations fixed.

During his journey in 1907—08 from Kashgar to Kowloon Mr. CECIL CLEMENTI made astronomical observations every night, whenever the weather was favourable. From these observations he has calculated the latitudes of 141 stations and the longitudes of 139.

The instrument used was a CASELLA-theodolite. Readings could be estimated to 1", but the level value was only 32".

The determinations are published in "Summary of Geographical Observations taken during a Journey from Kashgar to Kowloon in 1907—08" by CECIL CLEMENTI, (Hongkong in 1911), and an extract of this paper is given in Geographical Journal Vol. XL 1912. The survey made by CLEMENTI show him to be an extremely diligent worker. The great number of observations mentioned were obtained during a journey which lasted for only 198 days.

From the "chain of chronometric meridian distances" which he has secured, the longitudes have been interpolated between the absolute values known. CLEMENTI himself has determined 9 of these absolute longitudes, but their accuracy is very inadequate, and therefore, almost all the longitudes published in his list are of no value, as given.

It is, however, likely that far more of value could have been extracted from CLEMENTI's material than he has himself provided us with. CLEMENTI is himself quite aware of, and states, this fact.

In the "General Remarks" on the computations he says: "I have been careful always to give sufficient data to enable anyone, equipped with a Nautical Almanac and the necessary text-books, to recompute each of my observations". In fact this

Table 27

Reference No. Ambolt	Reference No. Clementi	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
			Ambolt	Reduced	Clementi		Ambolt	Reduced	Clementi	
	1	KASHGAR	¹39°28′20″	39°28′20″	39°28′45″	−0′25″				
62	15	AQSU, YANGI-SHAHR.	41 09 40	41 09 31	41 07 57	+1 34	*80°16′08″*	80°16′08	(79°55′25″)	+20′43′
61	18	QARA-YULGHUN	41 23 12	41 23 12	41 23 22	−0 10	[80 51]	[80 51]	(80 39 51)	+11
58	21	BAI	41 47 29	41 47 26	41 46 59	+0 27	[81 52]	[81 52]	(81 58 22)	− 6
	22	QIZIL		[41 50]	41 49 15	+1		[82 25]	82 39 05	−14
56	23	TOGHRAQ-DONG	41 52 40	41 52 40	41 51 56	+0 44	[82 47]	[82 47]	(82 59 22)	−12
55	24	KUCHAR	41 42 36	41 43	41 43 49	−1	*82 55 51*	82 56	(83 07 56)	−12
54	26	YAKA	41 43 48	41 43 48	41 43 11	+0 37	[83 18]	[83 18]	(83 29 47)	−12
53	27	AWAT	41 47 25	41 47 29	41 47 06	+0 23	[83 50]	[83 50]	(83 58 48)	− 9
52	28	BUGUR	41 46 22	41 46 22	41 45 36	+0 46	*84 15 14*	84 15 14	(84 24 56)	− 9 42
51	29	YANGI-HISSAR . .	41 56 38	41 56 38	41 56 25	+0 13	[84 35]	[84 35]	(84 40 24)	− 5
47	35	QARASHAHR . . .	42 03 22	42 03 22	42 03 35	−0 13	*86 33 36*	86 33 36	(86 35 41)	− 2 05
	36	TAVILGHA		42 13	42 15 14	−2		[86 46]	86 51 19	− 5
43	38	QARA-QIZIL. . . .	42 13 53	42 13 53	42 14 02	−0 09	[87 53]	[87 53]	(87 51 50)	+ 1
42	39	QUMUSH.	42 14 17	42 14 17	42 13 30	+0 47	[88 11]	[88 11]	(88 13 22)	− 2
41	41	TOQSUN.	42 47 45	42 47 45	42 46 29	+1 16	[88 40]	[88 40]	(88 37 37)	+ 2
2	42	TURFAN	42 56 37	42 56.0	42 56 01	0.0	*89 10 18*	89 12.5	(89 06 03)	+ 6.4
1	47	URUMCHI	43 46 42	43 47.3	43 48 03	−0.8	*87 36 12*	87 36.0	87 46 16	−10.3

¹ According to the DE FILIPPI Expedition

is not the case. For such a recomputation one ought to have had the original values of every observation, not only the mean values.

From the comparison list we see that the latitudes sometimes also are affected with comparatively great errors. Therefore I hardly think that it would now be worth while undertaking a recomputation of CLEMENTI's values. It would involve a great deal of work and, probably, the resulting coordinates would still be affected with errors, of such a magnitude that the work could not be considered justifiable.

The DE FILIPPI Expedition has made the very best determinations of coordinates in Eastern Turkistan. The accuracy obtained is of the same order of magnitude for the latitudes and for the longitudes, the latter ones are determined by the aid of wireless time-signals. They are published in "Spedizione Italiana DE FILIPPI. Himàlaia Relaz. Scient. Ser. I.I." Bologna 1925. The Expedition was carried out in 1914.

For Yarkend and Kashgar which are of special interest to us, maps have been given which show the position of the stations. These maps unfortunately have not been provided with any scale, and nothing is said about their orientation. Prof. ABETTI in a letter to me deplores this fact, and states that the maps are on the scale of 1 : 25400, and the orientation is according to magnetic north. The maps

Table 28

Reference No. Ambolt	Place Names	Latitude North according to			Longitude E. of Gr. according to		
		Ambolt	Reduced	De Filippi	Ambolt	Reduced	De Filippi
93	YARKEND...	38°24'34".3±1".1	38°24'16".2	38°24'22".2±0".3	*77°15'05".1±0".6*	77°15'46".1	*77°15'46".0±0".6*

have been made secretly by Indian surveyors. Angles were taken as compass-readings, and distances paced. Of course, the maps therefore must be rather approximate. In Yarkend, where I have a station too, a comparison between our results can be made. The corrections for the difference in location between our resp. stations are obtained from my route connecting them with angles measured by compass, and distances by pacing. The errors in these corrections are estimated to be at the most 3″ in latitude and 4″ in longitude. From the list below it is seen that the agreement is somewhat lacking in latitude but very good in longitude.

In Kansu, Eastern Turkistan and Tibet only very few magnetic determinations have been made. It is the aim of the German Explorer Dr. W. FILCHNER to fill in this gap. Besides his magnetic observations, Dr. FILCHNER also has made elaborate topographical surveys, and determined astronomical coordinates. Of the 157 stations observed in 1926—1928 (Dr. FILCHNERS Geographische Ortsbestimmungen und Höhenmessungen in Zentralasien von E. PRZYBYLLOK und K. WALTER. Halle 1929) a comparison with my values can be obtained for Urumchi, Jimasa and Ku-ch'eng-tze.

It is at once seen from the Table that the longitudes are considerably erroneous. Dr. FILCHNER's values depend on mean values between longitudes obtained through the observation of lunar distances and chronometrically derived longitudes. The difference between the values mentioned for that part of Dr. FILCHNER's route which is of interest to us, amounts at most to 5′. The corrections in our table which are twice this value, show how unreliable such longitudes still are.

The latitudes are probably accurate to one minute of arc. Even if the observations are thus of no great accuracy, they are valuable. But one must react against the manner in which the stations are described. For instance, Dr. FILCHNER gives for his

Table 29

Reference No. Ambolt	Reference No. Filchner	Place Names	Latitude North according to			Correction	Longitude E. of Gr. according to			Correction
			Ambolt	Reduced	Filchner		Ambolt	Reduced	Filchner	
1	26	URUMCHI	43°46′42″	43°48′	43°48′	0′	*87°36′12″*	87°38′	(87°49′)	−11′
39	30	JIMASA	44 00 28	44 00	44 00	0	[89 07]	[89 09]	(89 18)	− 9
38	31	KU-CH'ENG-TZE	44 01 36	44 01	44 02	−1	[89 30]	[89 33]	(89 43)	−10

station No. 26 Ti-hua (Urumchi): Beobachtungsort im Garten der katholischen Mission und ferner östlich der Stadt in Ebene nördlich der Funkstation dicht bei Kanalbrücke, über die vom Nordosteck der Stadtmauer aus dem Weg nach Ku-tschöng führt. $\varphi = 43° 48'$ $\lambda = 87° 49'$ (p. 291 op. cit.)

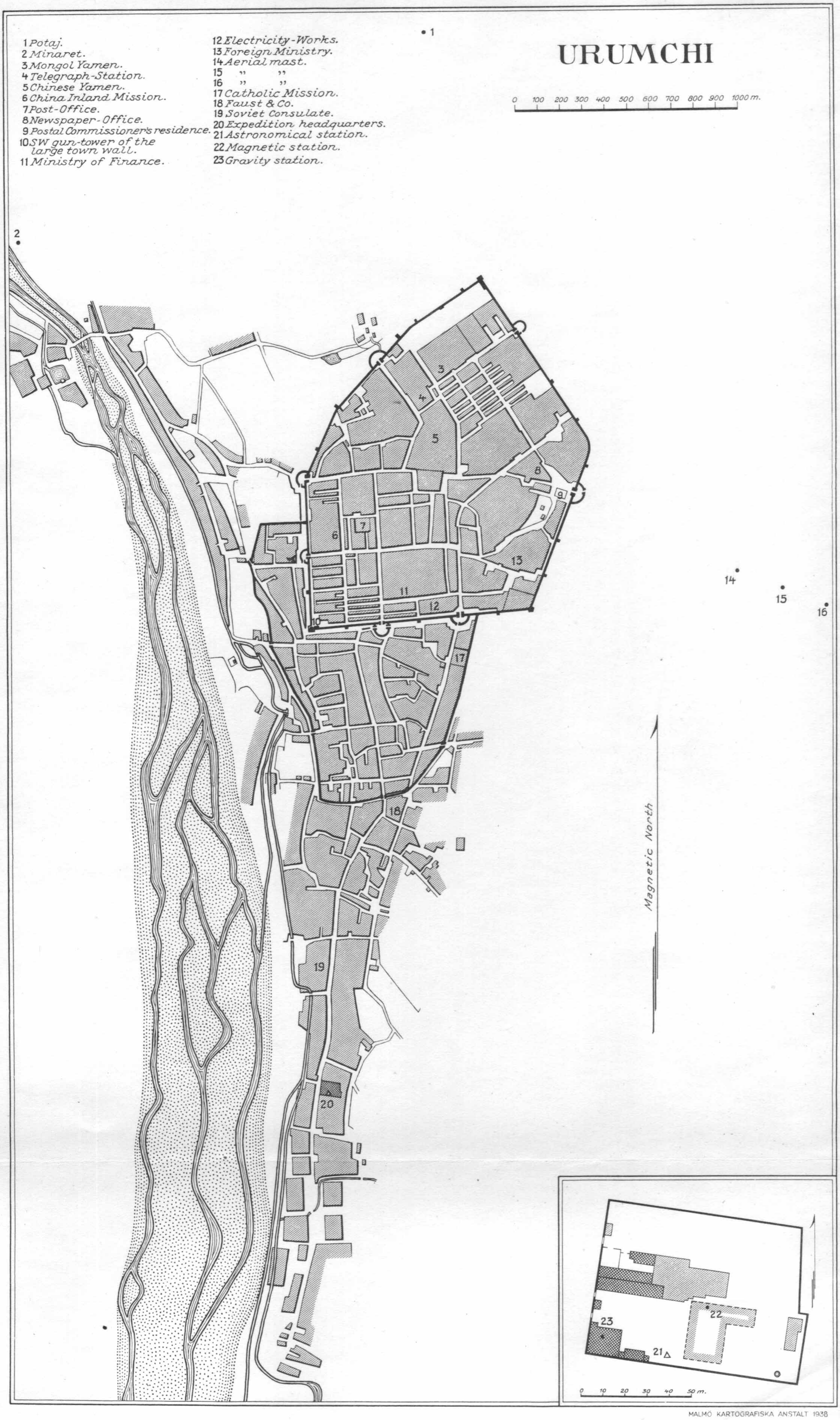
Thus observations have been obtained at two places — the distance between which is about 2 km — and coordinates are given only for one place.

PETERMANNS Mitteilungen Ergänzungsheft Nr. 215 contains a report by Dr. FILCHNER: Kartenwerk der Erdmagnetischen Forschungsexpedition nach Zentral-Asien 1926—28 (Gotha 1933). At the end of this paper there are "Orientierungsskizzen für die Stationspunkte (astronomisch-erdmagnetische Beobachtungspunkte)". When giving sketch maps, one ought to be very careful and, if an outline is uncertain, it should be marked by a broken line, for instance. Dr. FILCHNER's sketch No. 26 A of Urumchi is most inadequate, as is seen from a comparison with my map. It may enable a person to locate in the field Dr. FILCHNER's station — and certainly that is its main purpose, — but a geographer who tries to use such a sketch, when evaluating the astronomical determinations of coordinates, will be placed in an awkward position.

INDEX

ERRATA

Page 17 line 28 Bakhi	read Bakhti
„ 57 „ 13 Their corrections were available	to be omitted
„ 58 „ 22 Pevtsov	read Pevzoff
„ 61 „ 4 "do"	„ "to"
„ 62 column 9 "Index Error"	„ "Index Error i"
„ 63 „ „ „ „	„ „ „ „
„ 63 „ 10 "Camp. No."	„ "Collimation Error"
„ 63 Ref. No. 37 [89° 06′]	„ [89° 09′]
„ 63 „ „ 38 [89° 26′]	„ [89° 30′]
„ 63 „ „ 39 [89° 04′]	„ [89° 07′]
„ 63 „ „ 54 [83° 17′]	„ [83° 18′]
„ 78 No. 8. Bure-bulaq $\varphi = 43° 43' 59''$	„ $\varphi = 42° 43' 59''$
„ 94 line 3 "east".	„ "west"
„ 96 Fig. 42. "Qara-quzil"	„ "Qara-qizil"
„ 103 No. 56. Toghraq-dong λ = [88° 47′]	„ λ = [82° 47′]
„ 118 Table 13 "Kahsgar"	„ "Kashgar"
„ 125 „ 20 Keriya 06 52.2	„ 36 52.2
„ 134 line 7 "below"	„ "above"



MALMÖ KARTOGRAFISKA ANSTALT 1938

Table 9

Extension of DE BALLS Table for log B

mm	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
390	9.7103	104	105	106	107	108	109	110	111	113
391	114	115	116	117	118	119	120	121	123	124
392	125	126	127	128	129	130	131	133	134	135
393	136	137	138	139	140	141	143	144	145	146
394	147	148	149	150	151	152	154	155	156	157
395	158	159	160	161	162	163	165	166	167	168
396	169	170	171	172	173	174	175	177	178	179
397	180	181	182	183	184	185	186	188	189	190
398	191	192	193	194	195	196	197	198	200	201
399	202	203	204	205	206	207	208	209	210	211
400	9.7213	214	215	216	217	218	219	220	221	222
401	223	224	226	227	228	229	230	231	232	233
402	234	235	236	237	239	240	241	242	243	244
403	245	246	247	248	249	250	251	253	254	255
404	256	257	258	259	260	261	262	263	264	265
405	267	268	269	270	271	272	273	274	275	276
406	277	278	279	280	281	283	284	285	286	287
407	288	289	290	291	292	293	294	295	296	297
408	299	300	301	302	303	304	305	306	307	308
409	309	310	311	312	313	314	316	317	318	319
410	9.7320	321	322	323	324	325	326	327	328	329
411	330	331	332	334	335	336	337	338	339	340
412	341	342	343	344	345	346	347	348	349	350
413	351	353	354	355	356	357	358	359	360	361
414	362	363	364	365	366	367	368	369	370	371
415	372	373	375	376	377	378	379	380	381	382
416	383	384	385	386	387	388	389	390	391	392
417	393	394	395	396	397	399	400	401	402	403
418	404	405	406	407	408	409	410	411	412	413
419	414	415	416	417	418	419	420	421	422	423
420	9.7424	425	427	428	429	430	431	432	433	434
421	435	436	437	438	439	440	441	442	443	444
422	445	446	447	448	449	450	451	452	453	454
423	455	456	457	458	459	460	462	463	464	465
424	466	467	468	469	470	471	472	473	474	475
425	476	477	478	479	480	481	482	483	484	485
426	486	487	488	489	490	491	492	493	494	495
427	496	497	498	499	500	501	502	503	504	505
428	506	507	508	509	510	511	512	513	514	516
429	517	518	519	520	521	522	523	524	525	526
430	9.7527	528	529	530	531	532	533	534	535	536
431	537	538	539	540	541	542	543	544	545	546
432	547	548	549	550	551	552	553	554	455	556
433	557	558	559	560	561	562	563	564	565	566
434	567	568	569	570	571	572	573	574	575	576
435	577	578	579	580	581	582	583	584	585	586
436	587	588	589	590	591	592	593	594	595	596
437	597	598	599	600	601	602	603	604	605	606
438	607	608	609	610	611	612	613	614	615	616
439	617	618	619	620	621	622	623	624	625	625
440	9.7626	627	628	629	630	631	632	633	634	635

mm	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
440	9.7626	627	628	629	630	631	632	633	634	635
441	636	637	638	639	640	641	642	643	644	645
442	646	647	648	649	650	651	652	653	654	655
443	656	657	658	659	660	661	662	663	664	665
444	666	667	668	669	670	671	672	673	674	675
445	676	677	678	678	679	680	681	682	683	684
446	685	686	687	688	689	690	691	692	693	694
447	695	696	697	698	699	700	701	702	703	704
448	705	706	707	708	709	710	711	712	712	713
449	714	715	716	717	718	719	720	721	722	723
450	9.7724	725	726	727	728	729	730	731	732	733
451	734	735	736	737	738	739	739	740	741	742
452	743	744	745	746	747	748	749	750	751	752
453	753	754	755	756	757	758	759	760	761	762
454	763	763	764	765	766	767	768	769	770	771
455	772	773	774	775	776	777	778	779	780	781
456	782	783	784	784	785	786	787	788	789	790
457	791	792	793	794	795	796	797	798	799	800
458	801	802	803	803	804	805	806	807	808	809
459	810	811	812	813	814	815	816	817	818	819
460	9.7820	820	821	822	823	824	825	826	827	828
461	829	830	831	832	833	834	835	836	836	837
462	838	839	840	841	842	843	844	845	846	847
463	848	849	850	851	852	852	853	854	855	856
464	857	858	859	860	861	862	863	864	865	866
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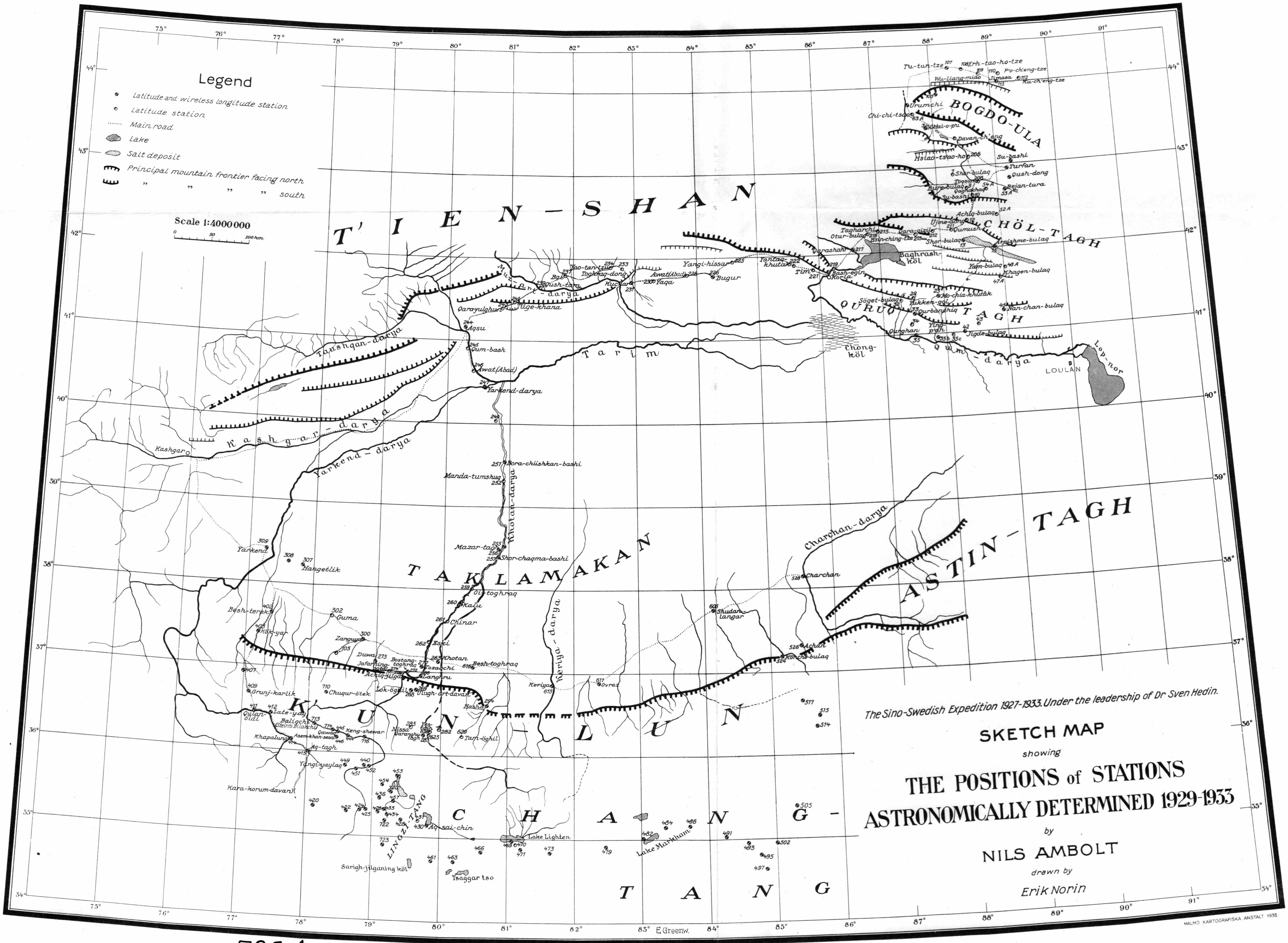
The Sino-Swedish Expedition 1927-1933. Under the leadership of Dr Sven Hedin.
SKETCH MAP
showing
THE POSITIONS of STATIONS
ASTRONOMICALLY DETERMINED 1929-1933
by
NILS AMBOLT
drawn by
Erik Norin
Legend
Latitude and wireless longitude station
Latitude station
Main road
Lake
Salt deposit
Principal mountain frontier facing north
" " " " south
Scale 1:4000000
T'IEN-SHAN
BOGDO-ULA
CHÖL-TAGH
QURUQ-TAGH
TAKLAMAKAN
ASTIN-TAGH
K'UN-LUN
CHANG-TANG
LINGZI-TANG
Tarim
Kashgar-darya
Yarkend-darya
Khotan-darya
Keriya-darya
Charchan-darya
Taushqan-darya
Muz-art-darya
Qum-darya
Lop-nor
LOULAN
Baghrash-köl
Chong-köl
Urumchi
Turfan
Qarashahr
Korla
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Yarkend
Khotan
Keriya
Charchan
Lake Lighten
Lake Markham
Aq-sai-chin
Tsaggar tso
Sarigh-jilganing köl
Kara-korum-davan
E. Greenw.
MALMÖ KARTOGRAFISKA ANSTALT 1938