
HINTS TO TRAVELLERS.

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HINTS TO TRAVELLERS.

(THIRD AND REVISED EDITION, DECEMBER, 1871.)

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and FRANCIS GALTON, Esq., F.R.S.

INTRODUCTION.

APPLICATIONS are frequently made by travellers to the Royal Geographical Society, for instructions by which they may make their labours useful to Geography.

The Council have always shown themselves disposed to pay considerable attention to such applications, when they proceed from persons who are zealously engaged in preparing themselves for arduous enterprises.

If a specific question be addressed to the Council on some particular instrument or point of equipment, they usually refer it to a Fellow of the Society, whose experience might enable him to afford a satisfactory answer. But a question of a more general nature, on the best instrumental outfit for an inexperienced traveller, is of such frequent occurrence, and demands so lengthened a reply, that the Council thought proper some years ago to appoint a Committee* for its full consideration. The Report of that Committee was printed in vol. xxiv. of the Journal of the Society, and was extensively circulated under the title of 'Hints to Travellers.' When this edition became exhausted, we were requested to take the opportunity of making a thorough revision of the work. This we did, and now that the second edition is out of print, we have again carefully

* This Committee consisted of Admiral FitzRoy and Lieut. Raper, R.N., and contained papers by Admirals Smyth and Beechey, Colonel Sykes, and Francis Galton, Esq.

revised the pamphlet. The present edition of the 'Hints to Travellers' will therefore form the answer of the Council, to whomsoever may request information, on the subject of which it treats.

The following remarks are to be understood as addressed to a person who, for the first time in his life, proposes to explore a wild country, and who asks, "What astronomical and mapping instruments, and other scientific outfit ought I to take with me? and what are the observations for latitude and longitude, on which I should chiefly rely?" To this end we give a list of instruments, books, and stationery, complete in itself, so that an intending traveller may order his outfit at once. He would then be satisfied that no object of real importance had been omitted, that he had bought nothing superfluous, and that the different items corresponded together in power and in their several uses.

Lists drawn up by different travellers of experience would undoubtedly vary, for there is considerable difference in their practice; but an explorer would never do wrong, who followed to the letter the list we are about to give. His danger lies in adopting scattered hints from many sources, and starting with instruments which, though severally good, are, when considered as a set, incongruous and incomplete; and, secondly, in trusting to the advice of observers who have little experience of the bush.

The outfit we recommend, based on the use of sextants and the mercurial horizon, would suit an explorer in any part of the world, who desired the means of bringing back as good geographical results as the earlier explorers of large tracts of land have ever yet succeeded in obtaining. And in this list, professedly compiled for an inexperienced observer, simple and well-known instruments alone find a place. We are very far indeed from thinking that makers of sextants have yet met all the wants of land travellers, but we *know* that good results may be obtained by such instruments as are to be bought from

any good optician. We therefore urge a young explorer to make *these* his mainstay; and if he takes other instruments, to do so more for the purpose of testing and reporting on their performances, than of relying in entire confidence upon them. Again, it is hazardous for a man hastily preparing himself for a journey, to order new apparatus from a maker; he cannot be sure that it will be well made or ready in time, and he may have to set sail in the possession of a strangely-shaped instrument—very delicate, difficult to pack—whose adjustments he has not had opportunity of mastering, and on which it is unlikely he will obtain information after his departure; whilst, if he determines on buying a sextant, and other well-known instruments, he may make his selection out of great numbers that are always to be found on sale, and practise himself in their use, under the tuition of the officers of the ship, during the whole of his voyage from England. It is therefore our object to give a list of instruments with which we advise a traveller of little experience to provide himself, and which will be found thoroughly adequate to do his work.

It should be borne in mind that travellers can seldom attain accuracy in their observations, perhaps hurriedly made, during a first exploration. Latitude within $\frac{1}{4}$ of a mile, and longitude within $\frac{1}{4}$ of a degree, is a somewhat better result than is usually obtained.

OUTFIT.

Examination of Instruments.—Let every Instrument be tested and its errors determined and tabulated at the Kew Observatory. This is done for a trifling fee. The following are some of the present charges, they have undergone occasional small changes:—Ordinary thermometers, 1s.; boiling-point thermometers, 2s. 6d.; ditto, very carefully, by the method of “calibration,” 5s.; marine and portable barometers, 10s.; prismatic compasses, 2s. 6d.; superior sextants, 5s.; Unifilar, dip circles, and other magnetic instruments are also verified. The carriage of the instruments to and from the Observatory to be paid. Address—“Superintendent of the Kew Observatory, Richmond, Surrey.” The establishment lies ten minutes’ walk from the *Richmond* railway station, and is reached through a farm-yard, leading into a large meadow. This observatory was established and conducted by the British Association, but is now maintained through a large donation, made by J. P. Gassiot, Esq., F.R.S., and is under the direction of a Committee appointed by the Royal

Society. Any persons ordering instruments from opticians may direct them to be previously forwarded to Kew for verification.

Packing.—It is difficult to give general rules, because the modes of transport vary materially in different countries. Inquiry should be made by the intending traveller at the Royal Geographical Society's rooms, as to what would be the best for him. The corners of all the instrument cases should be brass-bound; the fittings should be screwed, and not glued; and the boxes should be large enough to admit of the instruments being taken out and replaced with perfect ease. Instrument-makers are apt to attend overmuch to compactness, making as much as possible go into a small solid box, which can easily be put on a shelf; but this is not what a traveller wants. Bulk is rarely a difficulty to him, though weight is; and, above all, it is most important that he should be able to get at his instruments easily, even in the dark. Also a large light box suffers much less from an accidental concussion than a small and heavy one. Thermometers travel best when slipped into india-rubber tubes. A coil of such tubing will serve as a floor, to protect a case of delicate instruments from the effects of a jar. Horse-hair is of use to replace old packing, but it has first to be prepared by steeping in boiling water, twisting into a rope, and, after it is firmly set, chopping it into short pieces. The hairs retain their curvature and act as springs. Instruments travel excellently when packed in *loose*, *tumbled* cloths.

Sextant for regular work—

A sextant of 6-inch radius, light in weight, by a first-rate maker, divided on platinum, to ten minutes. It must have a moveable ground-glass screen in front of the reading-off lens, to tone down a glaring light. (As regards a level, attached to the arm, see 'Knorre's Method,' &c., p. 16.)

The handle must be large and convenient; the box large enough to hold the instrument with its index clamped to any part of the arc, and the place for the telescopes long enough to allow of their being put into the box when set at focus, with their tubes pulled out.

Stand, a stout tripod stand, such as is employed for photographic cameras of moderate size, fitted with a universal joint and a counterpoise. The use of this, when kneeling or sitting on a low stool, vastly increases the facility of making delicate lunar observations.

Sextant for detached expeditions, and for taking altitudes when the other sextant is in use for lunars—

A sextant of 3-inch radius, graduated to half-degrees, in a leather case, fitted to slip on to a leather belt, to be worn round the waist, when required.

Mercurial Horizon—

One of the usual construction. Its trough must not be less than $3\frac{1}{4}$ inches, inside length, and of the usual construction for filtering the mercury when it is poured in. The glass screen should fold, and be large enough to cover the trough without touching it. It must be by a first-rate maker, for inferior glass distorts the image. *Reserve*: one spare glass and an iron 3 or 4 ounce bottle of mercury.

One of Captain George's small horizons (*see* p. 19) to use on detached expeditions and occasional purposes.

Watch—

A good strong silver watch, not too heavy, with an open face and a second hand: it must wind up at the back. The hands should be black steel, long enough to cover the divisions. The divisions should be very clear and distinct. See that the second hand falls everywhere truly upon the divisions. *Reserve*: at least two other watches of the same character; these should be rolled up separately, each in a loosely-wrapped parcel of dry clothes, and they will never come to harm; they should be labelled, and rarely opened. The immediate envelope should be free from fluff or dirt. Covers of chamois leather should be washed before use. Half-a-dozen spare watch-glasses, fitting easily—two to each watch. Three spare watch-keys; one might be tied to the sextant-case, one wrapped up with each watch. See p. 23 for further particulars.

Compass—

A prismatic compass, graduated on aluminium, from 0° to 360° , with a shield of brass cut out here and there, to admit light, fixed over the glass. *Reserve*: one spare glass.

Two pocket compasses, from $1\frac{1}{2}$ to 2 inches in diameter. Their needles must carry cards graduated from 0° to 360° , and not twice over from 0° to 180° , in addition to the points. A line for True North, temporarily marked on the cards, in the position most appropriate to the magnetic variation at the country about to be visited, may be found convenient. These compasses should be light in weight, have plenty of depth, and be furnished with catches, to relieve the needle from its pivot when not used. The needles should work steadily and quickly: such as make long, slow oscillations are to be avoided. Cards, half black and half white, are recommended. (See p. 20 for further particulars.)

Lantern—

To be used with oil, and furnished with a large wick. See that there is abundant supply of air from air-holes in the *sides*; these are essential when the lantern is set upon the ground. Also that all the internal fittings can be removed and cleaned, and that they are solidly made, not merely soldered. It should be furnished with a reflector, to throw a clear light forwards and *downwards*. A good lantern is *most* important. A small ball of spare wick. Oil of the best quality: Wax tapers, for use on detached expeditions.

Thermometers—

Three short and stout boiling-point thermometers, and a small copper vessel, to fit into the top of the lantern, to boil the water in. (See p. 26.)

Three ordinary thermometers, which should be graduated from 10° or more below the freezing- to above the boiling-point.

Standard thermometers, at a charge of 1*l.* each, graduated at the Kew Observatory, may be obtained thence, on the application of any Fellow of the Royal Society, or Member of the British Association.

Aneroids—

Large pocket size ($2\frac{1}{4}$ inches across), capable of working without fracture over the highest mountain pass that is expected. Two are required, because simultaneous observations are important. Recollect that such observations, taken even at a great distance apart, are of value; because

the variation of the barometer, even in the latitude of England, in ordinary weather, hardly ever exceeds a quarter of an inch in a hundred miles. Aneroids are excellent for most differential observations, but unreliable for absolute ones. They are uncertain at high altitudes.

Mapping Instruments—

A small case of drawing instruments, containing, among other things, hair-compasses, beam-compasses, drawing-pen, and rectangular protractor.

Protractors: one circular, of metal, of 5 or 6 inches in diameter; one of horn, 5 inches, all graduated, like your compasses, from 0° to 360° .

A graduated ruler of 1 foot or more, in metal; 2 dozen artists' pins. Medium size measuring tape, say 12 yards; pocket ditto, 2 yards.

Memorandum.—We have designedly omitted from this list both *chronometers* and *mountain barometers*, on account of their proved difficulty of transport without injury, and the frequent disappointments they have caused, even to very careful travellers.

Stationery—

An artist's board, not less than 8 inches by 13, made of light, well-seasoned mahogany and what cabinet-makers call "framed," to rule and draw upon.

Plenty of good ordinary paper. Note-books (not "metallic," for prepared paper wants strength, and the leaves of such books are constantly torn out and lost; they are also damaged by wet). They should be all of one size, say 5 inches by $3\frac{1}{2}$, or larger. A leather pouch, secured to the waist-belt, having a flap buttoning easily over, to hold the note-book in use.

Two (or three) MS. books of strong ruled paper, foolscap size, each with a leather binding; the pages should be numbered, and journal observations, agreements, and everything else of value, written in them.

A sheet of blotting-paper cut up and put here and there in the ledgers.

Transparent cloth or paper. } For tracing.
Carbonised paper. }

Marquois's scales, for ruling parallel lines at definite intervals.

Blank maps, ruled for the latitudes and longitudes of the proposed route.

Plenty of brass pens and holders; also fine drawing-pens (steel crowquills) and holder. FH pencils; HB ditto.

Penknives. India-rubber cut up in bits.

Ink-powders of a kind that do not require vinegar. Red ink.

Paints for maps, viz., Indian ink, sepia, lake, cobalt, gamboge, oxgall, in a small tin case.

A dozen sable paint-brushes.

Materials for "squeezes," if travelling where inscriptions may have to be copied. (See p. 66.)

Books—

Raper's Navigation Tables; or, in default of these, either Inman's, or Norie's.

Weale's Tables are convenient from their compactness.

Shadwell's Cards of formulæ. (Potter, 31, Poultry, London. 2s. 6d.)

With the help of this little publication the traveller, who has any mathematical knowledge, will thoroughly understand what he is about, and he may dispense with the usual cumbrous navigation tables, confining himself to ordinary tables of logarithms. But we have recom-

mended that all travellers should be furnished with those navigation tables, because they afford at a single reference what otherwise requires additional trouble to obtain.

'Nautical Almanac' for current and future years, strongly bound. Three or four almanacs, such as that of Hannay and Dietrichsen. They give a vast deal of information, are useful to take on detached expeditions, also to cut tables out of.

Tables for barometers and boiling-point thermometers, to be procured at the instrument-maker's, or cut out from Guyot's elaborate meteorological tables, published by the Smithsonian Institution, New York.

Celestial Maps (uncoloured) pasted on calico (and learn how to use them). The best maps of the country you are going to visit, that are to be obtained. Admiralty Manual for the use of Travellers.

Mem.—Chauvenet's Astronomy (New York, 2 vols.) is one of the most complete and thorough of the mathematical works on geodesy and astronomical observations.

Additional Instruments, not necessary, but convenient.

Theodolites. (See p. 32.)

Telescope—

A large naval or deer-stalking telescope, for observing eclipses of Jupiter's satellites and occultations of small stars. It should not be less than 2 feet focus; it should have as large an object-glass as possible, astronomical eyepieces of from 45 to 60 magnifying power, and be fitted with a micrometer. (See p. 19.) The traveller should test it on the satellites, and be himself satisfied that he can see them perfectly well through it, before concluding the bargain. An ordinary telescope is wholly inadequate for that purpose. A clamp, with a universal joint and a cutting screw, to force into a log of wood, to support the telescope. The tripod stand already spoken of (*Seatant*) may easily be adapted to hold the clamp, but be sure that the telescope, when so arranged, can be pointed to stars directly above head, as well as to those nearer the horizon. A solid stand and easy movements are necessary to a powerful telescope, because slight tremors destroy its usefulness and the star or planet has to be watched and followed persistently, often in positions very inconvenient to the observer.

Plane table is very useful and almost essential for careful surveys of small tracts of country and for those topographical details which interest an antiquary. That by Lendy is one of the best, and its adjuncts are very complete. It would replace the artist's board mentioned above. The same tripod stand would serve for this that is used for other instruments.

Stop-watch, or pocket chronometer.

Pedometer.

Empty barometer tubes, and an iron bottle of mercury for filling them, to be used at a few important stations. (See p. 26.)

Pocket level (Abney's), with a mirror to show where the bubble is, when it is held to the eye. It serves as a clinometer, as well, for the measurement of slopes.

Maxima and minima thermometers. } For meteorological observations, see
Rain gauge. } p. 45.

Extracts from a Letter from JOHN KIRK, M.D., F.L.S., &c.

When Dr. Livingstone and I crossed the mountains and reached Lake Shirwa, our outfit was as follows: one 6-inch sextant, one mercurial horizon, one pocket chronometer, two prismatic compasses, one pocket compass, one field-glass, one aneroid barometer, two common thermometers, two boiling-point thermometers (the brass apparatus commonly supplied is quite superfluous), botanical paper, arsenical soap, one wide-mouthed bottle containing spirits of wine, pocket-lens, knives, note-books, water-colours, mathematical tables, nautical almanack, and wax candles.

The sextant and horizon were under the care of one man. They are on no account to be contained in the same box, partly from the danger of escape of mercury, but more especially to avoid the severe shock which so heavy a weight receives when placed on the ground, or should it happen to strike against a rock or tree; and these are contingencies to be expected. When carried, the limb should be very lightly clamped on the arc. We found no better plan when on the march than having the sextant and horizon fastened to opposite ends of a bamboo or stick, and carried over the shoulders of one of the porters. All the other instruments not carried by ourselves were packed among the other baggage. We read off the sextant by the help of the wax candles, which, from the stillness of the nights, we were able to use in the open air. On a short journey such an outfit is all that can be desired.

SEXTANT OBSERVATIONS.

The learner must recollect, that although the sextant, almanack, and logarithmic tables taken by land travellers are identical with those used at sea, yet the observations of the landsman and his whole method of ordinary work have quite a different character to those of the navigator. Therefore much will be found in works written for the use of navigators, which the landsman does not want, and, on the other hand, the problems he most requires are not those to which such works give most of their space. This is owing to several reasons, of which the following are the chief:—

1. A sailor is obliged to measure his altitudes from the sea horizon, which is rarely distinct in the night time, and therefore he mainly depends on the sun. The landsman is obliged to measure his altitudes from the mercurial horizon, and mainly observes stars; because the double meridian altitude of the sun is frequently out of the range of his sextant, and a mid-day halt may be inconvenient. The use of stars and the mercurial horizon introduces difficulty on the one hand, and great refinement on the other.

2. In an ordinary sea voyage, the accuracy required for the mapping of a country is of no use; neither could the sailor attain to such accuracy, if he wished it. First, because of the uncertainty of the effects of refraction upon the apparent position

of the sea horizon ; secondly, because the mercurial horizon gives a double altitude, and therefore double precision to the result ; so that a sextant of 3 inches radius on land has the efficacy of one of 6 inches at sea ; and, thirdly, because the unsteadiness of the ship interferes with the free use of the inverting telescope.

3. The sailor carries Greenwich time with him by means of his chronometers. A landsman cannot trust to chronometers. He must find Greenwich time by the independent means of lunars, satellites, occultations, or moon-culminations.

4. Positions in the open sea, that cannot be determined by astronomical observations, are roughly laid down by Course and estimated Distance from the last fixed station. On land, they can be laid down with great accuracy by triangulation.

5. The unsteadiness of the ship makes observation of the satellites, or of occultations of stars, an impossibility to sailors, while they are exceedingly easy and convenient to land travellers.

6. Magnetic variation has to be found constantly at sea, owing to the rapid change of position and the iron in the ships. On land but few, though careful, observations are required (avoiding magnetic rocks).

General Remarks on Observing.—Endeavour with much forethought to *balance* your observations. Whenever you have to take a star's altitude for time east, select and wait, if you have time to do so, for another star as nearly as may be of the same altitude west, and use the same telescope, horizon roof, &c. If a meridian altitude be taken north, choose another star of similar altitude, and take it south ; so also with lunars. In this way your observations will be in pairs, and the mean of each pair will tend to be independent of all constant instrumental and refraction errors ; and by comparing the means of these pairs, one with another, you will know your skill as an observer, and estimate with great certainty the accuracy that your results have reached. Never rest satisfied with your observations, unless you feel sure that you have gained means of ascertaining the limit beyond which you certainly are not wrong. Weight all your observations ; that is, when you write them down, put "good," "very good," "doubtful," &c., by their sides.

Nature of Observations :—

For Latitude—

1. The meridian altitude of the sun or stars is the simplest and safest. Altitudes of stars in pairs, N. and S. of the zenith, at or very near to the meridian, afford the perfection of accuracy.

It is to be understood that several altitudes should be read off, and time noted during the 5 or 10 minutes before and after the meridian passage.

2. The altitude of the Pole-star is a ready method in the northern hemisphere, but only available with an ordinary sextant and mercurial horizon between the N. lats. of about 15° and 60° . Nearer the Equator it is too low for the mercurial horizon, and nearer the Pole it is out of the range of the sextant.

3. By three altitudes of the sun or a star taken near the meridian, at *equal intervals of time*, and not necessarily restricted to the same side of the meridian. (*Chauvenet.*)*

4. When the sky is partly clouded, secure whatever stars you can surely identify, in case the meridian altitude should be lost. Almost any two stars, with the interval noted, are sufficient for the determination of the latitude, by the more or less troublesome calculations described in works on navigation. It is better to observe one or two additional stars as a check against mistake.

For Longitude by lunars, &c.—

Whenever you intend to observe for longitude, make a regular night of it; working hard and steadily, so as to accumulate a mass of observations, at a limited number of stations.

1. Lunar distances. No method is more serviceable than these.

They should be made in pairs, with stars E. and W. of moon, and nearly equidistant from it. Also the thermometer and barometer (or its equivalent, a thermometer in boiling water) should be noted, and the refraction corrected accordingly; because, if thermometric and barometric corrections be omitted, in observations made on a high and heated plateau, there will be serious errors in the results.

* Let a_1, a_2, a_3 be the three altitudes (it is better that none of them should be more than $\frac{1}{2}$ hour from the meridian); A the required meridian altitude; then if

$$q = \frac{[\frac{1}{2}(a_1 \smile a_3)]^2}{a_2 - \frac{1}{2}(a_1 + a_3)}, \quad q \text{ being expressed in seconds of arc, } A = a_2 + q.$$

The meridian altitude being thus determined, the latitude can be found in the usual manner. (This is a slight but convenient modification of Chauvenet's formula, by Admiral Shadwell.)

(*Example*)

$$\begin{array}{r} a_1 = 43^\circ 8' 20'' \qquad a_2 = 43^\circ 15' 30'' \qquad a_3 = 43^\circ 4' 0'' \\ \frac{1}{2}(a_1 + a_3) = 43 \quad 6 \quad 10 \\ a_2 - \frac{1}{2}(a_1 + a_3) = \quad 9 \quad 20 = 560'' \\ \frac{1}{2}(a_1 \smile a_3) = \quad 1 \quad 5 = 65'' \\ \text{hence } q = \frac{65^2}{560} = 8'', \text{ and } a_2 + q = 43^\circ 15' 38'' \end{array}$$

A complete pair of lunars, made wholly by one person, consists of the following observations, *in addition to those for latitude*. None of them may be omitted.

An hour before beginning to observe, get everything in perfect order; see that the lamp is well trimmed, its air-holes free, and that it is filled with oil. Also rehearse the expected observations, that no hitch may occur after they have commenced. Then let the hand and eye have ample time to repose, and go on as follows:—

1. Read thermometer in air.
2. Adjust horizon-glass, if necessary.
3. Two pairs of observations for index error.
4. Three altitudes for time, star E.
5. Three altitudes for time, star W.
- A { 6. Five lunar distances, star E. of moon.
7. Five lunar distances, star W. of moon.
8. Three altitudes for time, star W.
9. Three altitudes for time, star E.
10. Two pair of observations for index error.
11. Read thermometer in air.
12. Read barometer (or its equivalent, as thermometer in boiling water).

The series A may be repeated over and over again, so long as the eye and hand can be surely depended on.

2. Occultations give the longitude with great accuracy, but those of stars of the fifth and higher magnitudes, which are easily seen with an ordinary telescope, very rarely occur. Stars of the sixth magnitude are given in the Nautical Almanack, and are less unfrequent; but it requires a good telescope, such as that mentioned page 11, to see them. With such an instrument, many stars not mentioned in the Almanack may be seen occulted under favourable circumstances,—that is, when the moon is not too bright, and when it is her dark limb which occults. A careful traveller should make it a point, when at any important station, to turn his telescope on to the moon, as soon as it is dark, to see if there be a probability of any such occurrence, for it is easy, after a little practice, to tell whether the moon is likely to sweep over any star visible within three or four hours of her position. Before your departure, or when you have leisure, calculate for yourself, or get some one to calculate for you, all the stars you could by any possibility see occulted. Shadwell's Tables for facilitating the approximate prediction of occultations and eclipses at any particular place (Bate, 21, Poultry) are very convenient for this purpose. Out of the list in the Nautical Almanack, perhaps

not one quarter are available,—the occultation occurring either when the star is below your horizon or in the daytime.

3. Jupiter's satellites occur somewhat more frequently than occultations. They give fair results, and are most convenient approximations to a traveller; for they require no calculation at all, except for local time.

Notes on Observing with a Sextant. By FRANCIS GALTON, F.R.S.

It may save trouble to others if I mention here the way which, after many trials, I adopted of observing with a sextant. During the daytime I made out a list of the stars that culminated at convenient hours, and their expected altitudes. I set my watch by sunset, if it was very wrong, and took care that the minute hand went in correspondence with the second hand; that is to say, that the minute hand was truly over a division when the second hand pointed 0 seconds. If they did not go together, I moved the minute hand till it was rightly set. Then I spread my rug north and south in an open spot of ground, trampling down the bushes and long grass round it. Next, when the time of observing approached, I lighted my lantern and set it on the ground in front of my rug; to this I brought all my instruments, and first spreading a small cloth to the right of the lantern, I set my horizon on it, filled it with mercury, and covered it with a glass. The cloth was to catch any mercury that might be spilled. I then propped up my watch to the left of the lantern, laid down my note-book, with the leaves tied open, and taking out my sextant, adjusted it to the expected altitude, and screwing on the telescope, which always was kept at my focus, I laid myself flat down on the rug. Then taking off the roof from the horizon, if there happened to be no wind, and turning the glare of the lantern away from my eyes, and upon the watch, I made an accurate contact of the star with its reflected image; then looking quickly round, I observed the watch. I now turned the lantern towards me, changed hands with the sextant, read off and wrote down, then turned the lantern back on the watch, and recommenced. For a meridian altitude I read off and wrote down about ten observations, both time and altitude, beginning a little before the star reached the meridian, and continuing after it had perceptibly sunk; it was thus easy to estimate the meridian altitude with accuracy. For greater refinement, in order to measure an important base-line, I occasionally protracted these altitudes, and drew a curved line through them with a free hand, to guide my judgment in estimating the meridian altitude. For lunars, I took time with my second sextant before beginning; also two or three times during the progress of the lunar, and finally at the close of all. I was thus very independent of the good going of my watch, for, by observing every half-hour, no watch that went at all could go far wrong.

KNORRE'S Method of bringing the Reflexion of a Star from the mirrors of the Sextant, into contact with the Reflexion of the Star in the Mercurial Horizon.

In the observation of the altitude of a star with the artificial horizon, it requires some practice to find the image of the star reflected from the sextant mirrors; and sometimes, when two bright stars stand near each other, there is danger of employing the reflected image of one of them for that of the other. A very simple method of avoiding this danger, by which the observa-

tion is also facilitated, has been suggested by Professor Knorre, of Russia. From very simple geometrical considerations it is readily shown that at the instant when the two images of the same star—one reflected from the artificial horizon, the other from the sextant mirrors—are in coincidence, the inclination of the index-glass to the horizon is equal to the inclination of the sight-line of the telescope to the horizon-glass, and is, therefore, a *constant angle*, which is the same for all stars. If, therefore, we attach a small spirit-level to the index-arm, so as to make with the index-glass an angle equal to this constant angle, the bubble of this level will play, when the two images of the star are in coincidence, in the middle of the field of view. With a sextant thus furnished, we begin by directing the sight-line towards the image in the mercury; we then move the index until the bubble plays, taking care not to lose the image in the mercury. The reflected image from the sextant mirrors will then be found in the field, or will be brought there by a slight vibratory motion of the instrument about the sight-line.

It is found most convenient to attach the level to the stem which carries the reading-glass, as it can then be arranged so as to revolve about an axis which stands at right angles to the plane of the sextant, and thus be easily adjusted. This adjustment is effected by bringing the two images of a known star, or of the sun, into coincidence; then, without changing the position of the instrument, revolving the level until the bubble plays. (*Extracted from Chauvenet.*)

Silvering Sextant Glasses—

(Extract from 'Nautical Surveying,' by Admiral Sir E. BELCHER, pp. 9, 10.)

The *requisites* are clean tinfoil and mercury (a hare's foot is handy)—lay the tinfoil which should exceed the surface of the glass by a quarter of an inch on each side, on a smooth surface (the back of a book), rub it out smooth with the finger, add a bubble of mercury, about the size of a small shot, which rub gently over the tinfoil until it spreads itself and shows a silvered surface, gently add sufficient mercury to cover the leaf so that its surface is fluid. Prepare a slip of paper the size of the tinfoil. Take the glass in the left hand, previously well cleaned, and the paper in the right. Brush the surface of the mercury gently to free it from dross. Lay the paper on the mercury, and the glass on it. Pressing gently on the glass, withdraw the paper. Turn the glass on its face, and leave it on an inclined plane to allow the mercury to flow off, which is accelerated by laying a strip of tinfoil as a conductor to its lower edge. The edges may, after twelve hours' rest, be removed. In twenty-four hours give it a coat of varnish made from spirits of wine and red sealing-wax. It may be as well to practise on small bits of common glass, which will soon prove the degree of perfection which the operator has attained.

Observations for Azimuth.—The true bearing of a heavenly body may be obtained by means of a sextant either from observations of altitude or from the apparent time. As the formula for obtaining the latter does not appear in many works on Navigation, it is given:—

Time.	Azimuth.	Month.	Day.	
H. M. S.	° ' "	° ' "		
		Co. Lat.		
		P. Dist.		
		Sum.	_____	
		Diff.	_____	
		½ Sum.	Cosec	Sec
		½ Diff.	Sine	Cosine
		½ Hor. >	Cotang	Cotang
		Arc 1 = Tang	_____	
Cor.		Arc 2.	Tang Arc 2	
	App. time		_____	
	Hor. <	⊖ true Az. (= Arc 2 - Arc 1.)		
	½	⊖ mag. Az.		
	½ hor. < in Arc.	Variation.	_____	

NOTE.—Arc 2 is of the same affection as the ½ polar disc. and Co. Lat. : when one is acute so is the other, and v. v.

Add arcs 1 and 2, when polar disc. is greater than Co. Latitude.
 Subtract " " " less " "

The angular distance between the Pole-star, which is only 1° from the Pole, and any object on the horizon, affords an approximate and simple method of obtaining the true bearing: the formula for the reduction of the oblique to the horizontal angle is—

Reduction of Angle.

* and obj.	Cosine
* Alt.	Secant
Red. Angle	Cosine _____

The bearing of the Pole-star at all times, or any other celestial object, when near the meridian, affords approximate means of obtaining, without calculation, the variation of the compass.

For Base Lines.—By Difference of Latitude—For base-lines the more rapid methods of attainment are alone suitable to explorers in wild countries. None of these measures is more accurate and speedy than that obtained by meridian altitudes of the same heavenly body (sun or star, not the moon) at different stations by the same observer with the same instruments. If the stations are on the true meridian, or nearly so, their difference of latitude is their distance; and if they are otherwise situated, their true bearing and their difference of latitude give the distance between them.

By Micrometer or Sextant, and Short Base. Should the traveller carry with him an astronomical telescope, it is advisable that it should be fitted with a micrometer for measuring small angles; care is, however, requisite in seeing that the board or object used for the base is accurately measured, and that it is at right angles to the line of sight. In the absence of the micrometer, the sextant will give a very fair approximation; the angle should, however, be measured both on and off the arc. Rochon's micrometer has been used with great effect in the geological survey of Canada.

ARTIFICIAL HORIZONS.

Mercurial Horizon.—Altitudes taken by its means are thoroughly reliable only when the reflexions have been observed from the uncovered mercury; for it is difficult to procure glass, large enough for the cover, which does not sensibly distort the reflexions. Glasses made by Mr. T. E. Butter, 4, Belvidere Crescent, Belvidere Road, Lambeth, have a high reputation. The errors introduced by the interposition of glass may be partly got rid of by reversing the cover between each pair of observations.

When observing for "equal altitudes," morning and evening, be sure that you have the same face of the cover opposite to you on both occasions. One of the faces of the cover should be marked for this purpose.

The trough should not be less than $3\frac{1}{4}$ inches inside length, because the convex border of the mercury is useless, and its surface is foreshortened to the observer.

Captain George's Horizon.—A very ingenious, small, and handy mercurial horizon has been contributed by Staff-Commander George, R.N., Curator of Maps at the Royal Geographical Society, and is made by Messrs. Gould and Porter, successors to Cary, optician, No. 181, Strand. It consists of a disc of glass floating on mercury, in a vessel which it nearly fits, and it has an arrangement (applicable also to the common mercurial trough) by which the mercury is introduced, ready filtered, from an attached reservoir, and afterwards withdrawn, in a manner that saves a great deal of trouble. The glass floats without touching the sides of the trough, and the whole of the mercury below it is serviceable. A very small trough on this principle gives as wide a field of view as a large trough used in the ordinary way. There is yet another advantage, in that the reflexion of the glass causes its under-surface to be optically raised; therefore the edges of the trough cut off proportionately

less of the field of view. Also, at very low altitudes, the reflexion from the upper surface of the glass, which may rise above the edges of the trough, becomes so bright as to materially reinforce, and even supersede, the reflexion from the mercury below. Hence very low altitudes may be observed with this instrument. It has, besides this, the great advantage of peculiar steadiness, both when people are walking near it and during wind.

As regards its accuracy, when the glass is of the best workmanship, the mercury pure, and its surface quite clean, the results leave nothing to be desired; but, unless these conditions are *scrupulously observed*, errors of five, or more, minutes in the double altitude, or of half that amount in the single altitude, may be easily introduced. For these reasons, and as the instrument is a new one, we have not recommended that a traveller should be wholly dependent on it; but we recommended that one should be taken for occasional use, especially for purposes of azimuth by the sun, to be taken on mountain-tops (see p. 21), for detached expeditions, where a heavier instrument would be a serious incumbrance, and for the determination of heights on hills whose altitudes are too low to come within the range of an ordinary mercurial trough. We recommend that its glasses be examined and approved before it is taken, and that it be used discreetly.*

Before introducing the mercury into the trough, cleanse the trough thoroughly from dust, which will otherwise rise to the surface of the mercury, and, when setting the glass afloat, take exactly the same precautions as in silvering sextant glasses (see p. 17), by putting paper or thin silk first on the mercury, and the glass upon that, and then carefully withdrawing the paper from under the glass.

COMPASSES.

Prismatic Compass.—The prismatic compass is one of a traveller's most useful instruments. Its graduations should be engraved on an aluminum ring, both on account of the clearness of the divisions and the lightness of the material. When using it, if you have no tripod, make a pile of stones and

* If the traveller should ever doubt the performance of one of these horizons, he may easily test its accuracy by means of any telescope mounted on a stand, and furnished with cross wires. He should direct the telescope down towards the mercury and intersect with the cross wires the reflexion of some clearly defined fixed point; then reverse or otherwise disturb the horizon, and, after it has again settled to rest, observe whether the cross wires continue to intersect the point. It is safer to select a point at some distance, else, if the level of the mercury be raised or lowered during the trial, the results would be vitiated.

lay the cover of the compass on the top, with its bottom upwards; this makes a smooth table for the azimuth compass itself to be moved about on. Be on guard against magnetic rocks; it may happen that the bare peaks of high hills, which are the best of places for observing from, and which a traveller often makes great sacrifices to reach, will be found so magnetic as to make compass observations worthless. A small sextant should always be taken up on these excursions. It is of little use in a wild country to devote much time to getting accurate bearings, as the landmarks themselves are rarely well defined: the main endeavour should be not to mistake one hill for another, to judiciously select good angles, and to carry on more than one independent scheme of triangulations at the same time, by comparison of which the accuracy of the whole may be tested. It is surprising how much work may be thrown away by want of judgment; and also how much may be done, with very little trouble, by a person who has acquired a good eye and memory of country.

It is, perhaps, hardly necessary to call attention to the fact, that in prismatic compass-cards the south pole of the magnet is necessarily placed under the 360° , and the north under the 180° , because in these instruments the reading is from the nearer edge of the card towards its centre, whereas in an ordinary compass the reading is from the centre of the card towards its outer edge. It follows from this that the same compass card cannot be used indifferently with or without a prism. Moreover the figures intended for use with a prism, have to be drawn not like ordinary figures, but like figures seen in a looking-glass, in order that the reflection in the prism may show them straight.

Pocket Compasses.—The patterns on these cards have been greatly improved of late years. Until recently it was scarcely possible to meet with a compass capable of being read in a dim twilight, which is just the time when it is of most importance to a traveller. Representations of three cards, each of which has its advocates, are given here. They are of the larger size, already recommended in "outfit," viz. 2 inches in diameter. Fig. 3, called the Rob Roy Canoe pattern, is decidedly less distinct in the twilight than the others, especially than Fig. 1, but some travellers have preferred it on account of the legibility of the N.E., S.E., &c.

The better cards are made either of tale covered with paper, or of mother-of-pearl. Both of these materials are heavy and their weight, of course, tends to injure the point on which they turn, especially if they happen to receive a jar when they are resting on the point, and also to make their oscillations sluggish. These disadvantages are, however, less serious than those

which attend the use of a common card, which warps with heat, and is spoiled by a wetting.*

A pocket compass suspended on gimbals practically comes to rest much more quickly than one that is held in the hand. This

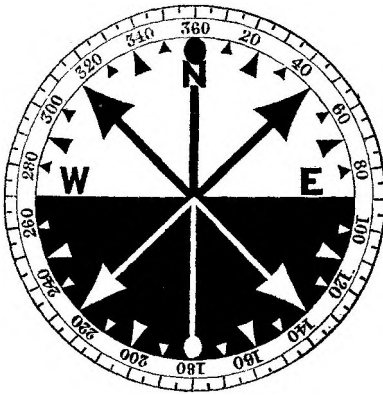


Fig. 1.

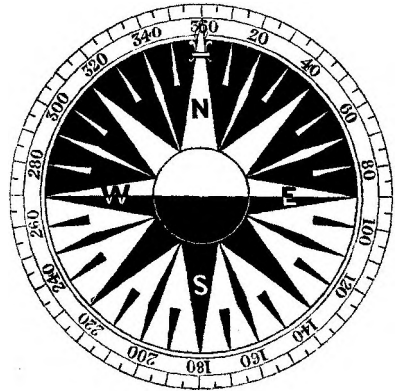


Fig. 2.

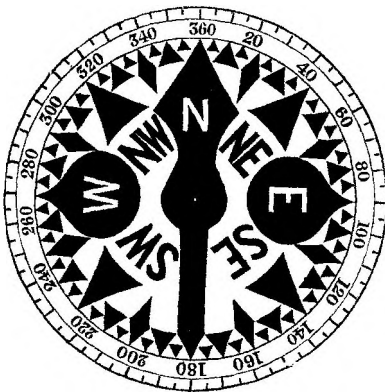
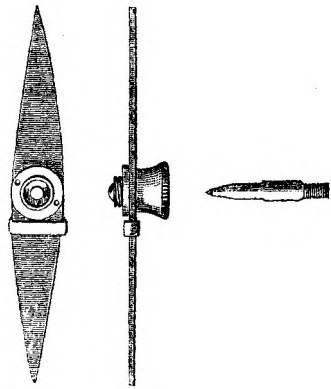


Fig. 3.



Plan, Section, and Pivot of Needle.

* A disc of aluminum foil, procurable at Johnson, Matthey, & Co., 77, Hatton Garden, London, is only one-ninth part the weight of a mother-of-pearl card of the same size. It seems equally good as regards durability, and it can be shaped and lettered in any desired manner by embossed stamps or by perforations. But I have not yet succeeded in fashioning it into a clearly legible card. Perhaps some instrument-maker may be more successful.

Mem.—To read a compass or a watch in the twilight, when it is a little too dark for unaided vision, use a *strong magnifying glass*. Its effect in giving distinctness is extraordinary.—F. GALTON.

advantage is specially noticeable when it is growing dark, and when consulted on the side of a hill, for in either case it is difficult to judge of horizontality. It is most important to a traveller, whose caravan is on the march, that he should lose very little time when he is consulting his compass.

WATCHES.

Mr. J. Brock, chronometer maker, 21, George Street, Portman Square, who has usually been applied to by the Council of the Royal Geographical Society, to furnish the watches given by them to various travellers, has furnished the following information at the instance of the authors of this pamphlet:—

The description of Watch most useful to a Traveller. By J. BROCK.

The description of watch I should recommend as suitable for a traveller, or anyone who requires a good timekeeper that will stand a certain amount of rough wear without getting out of order, is a 14 or 16 size, full-plate lever watch, with an *adjusted** compensation-balance and *tempered* balance-spring, cap over the works, sunk-seconds dial. Great care should be taken in marking the minutes upon the dial-plate, that they are exactly equal, or the traveller will have some difficulty to determine to which minute the seconds belong. The case should be of silver, without springs to open it, or hinges. The back that shuts over the part through which the key passes to wind up the watch, also the front that holds the glass, should snap tightly upon the other part of the watch-case. The glass should be of thick plate-glass, not less than one-eighth of an inch thick. The case, on account of the closeness of the fittings, will then be impervious to the dust, and would not easily allow water to get to the works.

A watch of this description cannot be sold for less than 1*l.*, if the works are of a quality necessary for good performance, and the various adjustments are properly attended to, and is the lowest standard of watch that any traveller ought to be satisfied with.

A chronometer will keep more regular time in different positions than the watch I have described, but in rough wear I consider it more likely to break down, as it certainly is not so strong in construction as the lever watch. An ordinary watchmaker, with care, could put the lever watch in order, but few are competent to repair a chronometer.

Watches of any construction will be more regular in their daily variation, if care is taken to keep them in the same position during each 24 hours; that is, when in the pocket, the same hour should always be uppermost; and they should be worn the same number of hours each day; and if laid down at night, let them be so every night.

No one can alter the regulator of a chronometer but a competent watchmaker, but anyone may be able to alter that of the lever watch. The chronometer is certainly the best instrument for anyone who requires a correct

* Many watches have compensation-balances applied to them which have never been tested in the least, and have only the appearance of being adjusted, without the result. An ordinary watch, if mechanically correct, will vary nearly one minute per day for every ten degrees' change of temperature—J. B.

timekeeper; and with the recent improvements, is quite suitable for the pocket, but not so good for general purposes and rough wear as the lever watch.

On Carrying Chronometers. By Admiral Sir GEORGE BACK, F.R.S.

It is impossible to avoid jolting pocket chronometers or watches when worn about the person.

On three Arctic (overland) expeditions, mine (frequently two chronometers) were suspended in cloth pockets, hung round the neck by a strong narrow silk ribbon, and kept in their places by two other ribbons tied round the waist; the whole was secured by the waistband of the trowsers, which was made with six holes (three on each side), to lace behind. A silk string, passed through eyelet-holes round the top of the pocket and tied, secured the chronometer in its place, and prevented wet and dirt from reaching it.

When travelling in summer, the chronometers were taken off at night and placed carefully in a hat, horizontally, or else in some blanket, under the upper part of the blankets forming the bed, where they were more out of the way of accidents; but in winter they were worn all night against the body, to protect them from the effects of the cold.

We (Franklin, Richardson, Kendall, &c.) never complained of finding "fluff," in the cloth pocket, and I do not know of an instance of the chronometers getting wet.

Franklin fell between two pieces of ice into the water, over-head, and sunk fully two feet, and the two chronometers were not injured.

I do not recommend "Macintosh" for the pockets. In cold, *freezing* weather, our Macintosh cloaks became stiff as planks; and in very sultry weather, portions of the caoutchouc oozed through. Common linen or washed chamois leather would do for lining.

On a Composition for keeping Watches or Compasses watertight.

By JAMES BROCK.

The method that I should recommend for preventing water from penetrating watch-cases, is the application of a preparation of beeswax and resin to the several parts where it is possible for the water to pass. The preparation I recommend should be composed of equal parts and well mixed. If it is for a very hot climate, the quantity of "resin" should be slightly increased. It may be kept prepared, and when wanted, a portion melted and applied to the several parts with a small brush or feather. If the watch is an ordinary *open-face*, with a *SNAP* bottom, the parts that should be attended to are—1st, the glass. Apply the preparation round it, and rub it in with the thumb, by which means it will be worked into any cavity. 2nd, open the glass and apply it round the part of the case upon which the glass shuts (be careful that you apply it to all the joints of the case), close the glass and squeeze it down tightly; what is squeezed out may be cleared away with the nail or a piece of wood. 3rd, open the back (where the watch is wound up) and apply the preparation in the same manner as just named. The case will require a little more force to open it, and the back should be attended to frequently. If the watch has a *hunting* (or double) case, or a *bottom that opens with a fly-spring*, the difficulty of keeping out the water is much increased, as there are so many openings into the case for the springs, &c. I should recommend that the springs be removed (which is easily done, as they are all screwed in), and that the holes through which they pass, also the *screw holes*, be stopped up with the preparation; also *remove the push-piece* from the pendant (this is done by taking out the screw, which passes through the bow), and stop up the hole from which it has been taken; but care should be used in doing so, as it is

essential that it should be stopped *below* the hole through which the screw of the bow passes. The bow may then be returned. The preparation should now be applied to the glass and the shutting parts, in the manner before described. The hunting cover will keep shut by nature of the preparation.

BAROMETERS AND THEIR SUBSTITUTES.

The travellers for whose use these remarks are prepared, being possessed of sextants or theodolites, would measure mountains by triangulation from a distance, which is at once by far the simplest and most accurate method of doing so. But they also require, for the purposes of physical geography, to ascertain the height of the country where they are travelling, above the sea-level; and whenever they have to observe lunars on elevated plateaux, a knowledge of the barometric correction for refraction is essential to them. For these latter purposes, explorers must have recourse to barometers, or to their more or less imperfect substitutes.

A single barometric observation made in regions where the barometer ranges, as with us, through two or more inches, even in ordinary weather, is unreliable to half that extent; that is, to more than 1000 feet, in calculating altitudes; but the mean of several observations taken at chance intervals, at repeated visits, and during ordinary weather, is not likely to be far amiss. In tropical regions the barometer is very much more steady than with us, and the heights deduced from the observations of travellers are proportionately more to be depended on.

If a second station can be established, for simultaneous observations, at 100 or even at 200 miles' distance, their relative heights can soon be determined with some accuracy by the barometer, because the meteorological waves are so vast, that there is seldom a difference, in ordinary weather, even in these latitudes, of a quarter of an inch (or say 250 feet of calculated altitude) between two stations 100 miles apart.

The readings of barometers and boiling-point thermometers, when they are erroneous, nearly always err in the direction of assigning too great elevations, for the barometer, when air or damp gets into the tube, is depressed, and the thermometer, when heated by imperfectly-boiling water, stands lower than it should.

The barometric instruments are,—

1. *Barometer*.—For reasons already given (p. 10), no description of portable barometers is inserted here; but it must be recollected that *empty* glass tubes can be carried without much risk, and that they can be filled with mercury when required, and be set up or used temporarily as barometers. The method of doing this is as follows:—

To fill a Glass Tube with Mercury for a temporary Barometer.

Take the ladle used for melting lead for bullets, and scour it bright with sand. Prop the tube at a slightly inclined angle on the forks of two sticks, planted in the ground, and rake embers of the camp-fire below it. Turn it till thoroughly warm—almost too hot to touch. Strain the mercury through paper twisted into a cone. Boil it in the ladle. Heat some more mercury in a cup, and let everything cool again. When cool enough to handle, set the tube on end, upon a cloth, to catch overflows of mercury. Fill the tube to overflowing. Put the finger firmly on the top and reverse the tube, plunging the end that is closed with the finger, into the cup of mercury. Then remove the finger gently. If, on inclining the tube, the mercury rises to the top with a sharp tap, it has been filled to the exclusion of all air, and it will do. All that now remains, is to measure with a rule from the top of the mercury in the tube, down to the top of that in the cup. It will be found convenient to have two marks scratched on each tube—the one an inch from its open end, and the other at 30 inches' interval from the one below. Then if the lowermost scratch be brought level with the surface of the mercury, the distance from the uppermost scratch has alone to be measured, and this can easily be done. It will also be convenient to arrange some simple gear to hold the tube upright, after it has been filled, as it may be desirable to keep the barometer in action after it has been made, and not merely to take a single reading, and then to empty the tube. A power of doing this becomes necessary in conducting simultaneous observations, as when a party is detached to take barometric heights in the neighbourhood. It would be easy to arrange fittings inside the box, in which the tubes are packed, for that purpose.

The operation of filling a tube should be practised at home in comfort, with a properly-made barometer for comparison, and plenty of mercury to fall back upon, before trusting oneself to the difficulties of the open field. If mercury is spilt on the ground, it may always be recovered by patience and skill, aided with a little digging, whenever the globules run down out of sight.

Probably the safest way of packing empty glass tubes would be to slip india-rubber bands over them to prevent their striking together, and to pack them among plenty of stuffing in a long light box, well protected by leather pads on the outside edges against concussion.

2. *Aneroid*.—An excellent instrument for giving moderate differences of elevation in neighbouring places, as in the process of laying down the contour lines of a country, but quite unreliable for absolute heights, because its index error is apt to change to any amount without the traveller being able to ascertain, much less to make a just allowance for, the change.

3. *Boiling-point Thermometers*.—These have the great merit of portability without risk, and of a pretty constant, but not absolutely constant, index error; consequently, they are largely used by travellers. Though the operation of boiling a thermometer is very simple in theory, it is very troublesome in practice over an ordinary camp fire. Colonel Grant, who had, together with Captain Speke, great experience in the manipulation of these instruments, speaks very highly of the effectiveness of the boiling apparatus which he took with him from the Geographical Society, and which was fitted into the bull's-eye lantern he used for reading off his sextant at night. The "shade"

was removed out of the lantern, and the boiling apparatus was put into its place. It was a copper cup, set in a jacket pierced with air-holes. An horizontal tube with a screw nozzle pierced the side both of the jacket and of the cup, and the thermometer was passed through this tube. The thermometer passed through a cork fixed into the middle of a screw which was screwed into the nozzle. It requires, however, very careful trimming of the lamp to obtain sufficient heat to boil the water thoroughly. We are, as yet, unable to recommend any compact apparatus fit to be used with a lamp fed with common oil, which shall act with certainty in the hands of an average traveller. It is essential to accuracy, and also to the steadiness of the mercury in the thermometer, that its bulb should not touch the boiling water, but be thoroughly enveloped in the steam which issues copiously from it.

Apparatus, to be used with spirits of wine, is made by Casella, 14, Hatton Garden. A small "Russian furnace" is by far the most powerful kind of spirit-lamp, and the best for out-of-door work; it consumes no more spirit than the common lamp.

A tin pot, with a sliding tin cylinder inside, with holes for escape of the steam, and which admits of being pegged at the desired height, suffices, when a common fire is the source of heat. The thermometer is passed through a cork which is pressed into a hole in the lid, which fits firmly (like the lid of a pill-box) on the top of the inside tin cylinder. The fire must be made of bright clear embers to avoid trouble with smoke, and the pot must be securely propped on stones or hung like a gipsy kettle, for fear of a fall and of destruction to the thermometer.

The thermometer should be observed after the water has been boiling freely, but not too tumultuously, for three or four minutes; and at least four or five readings should be taken, at half-minute intervals. Though pure water ought to be used, yet any water that is not very hard will suffice for a traveller's ordinary need.

Having obtained the boiling points, it remains to determine the value of the indication of barometric pressure from the following Tables, which are fairly approximate, and will serve in the absence of Guyot's collection or others. Supposing the thermometer to have been boiled at the foot and at the summit of a mountain, deduct the number in the column of "total altitude of feet" opposite the boiling point, as observed below, from the similar number corresponding to the boiling point above: this gives a roughly approximate height, which must be corrected for the temperature of the air between the two stations, in order to obtain a more nearly correct altitude. This correction is made by multiplying the nine hundredth part of

the altitude already obtained, by the difference between the sum of the temperatures at the two stations and 64° . This correction is *additive* when the sum of temperature exceeds 64° , otherwise it is subtractive. This latter is the case, when the mean temperature of the air at the two stations is below the freezing point :

Boiling point at summit of the hill	°	Feet.			
			204.2 =	4027	
„ „ its foot			208.7 =	1690	
Approximate height			2337		
Temp. of the air below ..	75°				
„ „ above ..	83				
Sum			158		
				64	
				94	
			Also	$\frac{2337}{900} = 2.6$	(nearly enough.)

For the correction, $94 \times 2.6 = 244$ (additive.)

Approximate height 2337

2581 feet, corrected altitude.

TABLE I.—To find the Barometric Pressure and Elevation corresponding to any observed Temperature of Boiling Water between 214° and 180° .

Boiling Point of Water.	Corresponding Height of Barometer.	Total Altitude in Feet from 30.00 in. or the Level of the Sea.	Value of each Degree in Feet of Altitude.	Proportional Part for One-tenth of a Degree.	Boiling Point of Water.	Corresponding Height of Barometer.	Total Altitude in Feet from 30.00 in. or the Level of the Sea.	Value of each Degree in Feet of Altitude.	Proportional Part for One-tenth of a Degree.
		Feet.	Feet.	Feet.			Feet.	Feet.	Feet.
214	31.19	-1013	..	..	196	21.71	8407	543	..
213	30.59	507	-504	..	195	21.26	8953	546	..
212	30.00	0	-507	..	194	20.82	9502	548	55
211	29.42	+ 509	+509	51	193	20.39	10053	551	..
210	28.85	1021	511	..	192	19.96	10606	553	..
209	28.29	1534	513	..	191	19.54	11161	556	..
208	27.73	2049	515	..	190	19.13	11719	558	56
207	27.18	2566	517	52	189	18.72	12280	560	..
206	26.64	3085	519	..	188	18.32	12843	563	..
205	26.11	3607	522	..	187	17.93	13408	565	57
204	25.59	4131	524	..	186	17.54	13977	569	..
203	25.08	4657	526	..	185	17.16	14548	572	58
202	24.58	5185	528	53	184	16.79	15124	575	..
201	24.08	5716	531	..	183	16.42	15702	578	..
200	23.59	6250	533	..	182	16.06	16284	581	..
199	23.11	6786	536	..	181	15.70	16869	584	..
198	22.64	7324	538	54	180	15.35	17455	587	59
197	22.17	7864	541	..					

When the boiling point at the upper station alone is observed, we have no option but to *assume* 30·00 inches, or a little less, as the average height of the barometer at the level of the sea. The altitude of the upper station is then at once approximately obtained by inspection of Table I.; correcting for assumed temperature of the air at the sea level. The serious inaccuracy to which the above assumption may lead, and its possible prevention by repeated observations at intervals extending over a considerable period, has already been pointed out.

The small but complete tables, next page, will be especially useful to those who carry a mountain barometer and are anxious to make accurate determinations, but are not furnished with larger tables. These are calculated by Loomis, and are extracted from Guyot's collection.

Part I. gives the altitude, subject to correction, for the temperature of the air, and for the other influences which are the subjects of Parts II. III. IV. and V.

Method of computation.—(1) Take from Part I. the two numbers corresponding to the two barometric heights; (2) from their difference subtract the correction found in Part II., with the difference between the thermometers that are attached to the barometers (*Mem.* this correction is not wanted for aneroids, for their works are mechanically compensated for temperature); (3) multiply the nine hundredth part of the value already obtained by the difference between the sum of the temperatures at the two stations and 64°. This correction is additive when the sum of the temperatures exceeds 64°, otherwise it is subtractive; (4) for further precision take corrections from Parts III. and IV., also from Part V., when the lower station is so high as to bring the case within the range of that table:—

<i>(Example)</i>	Upper Station.	Lower Station by Sea.
Thermometer in open air	70 ^o ·3	77 ^o ·5
Thermometer in barometer	70·3	77·5
Barometer	23·66	30·046
Latitude 21 ^o .		
Part I. gives	$\left\{ \begin{array}{l} \text{for } 30\cdot046 \text{ inches} \\ \text{for } 23\cdot66 \text{ inches} \end{array} \right.$	$\left\{ \begin{array}{l} 27,649\cdot7 \\ 21,406\cdot9 \end{array} \right.$
	Difference	6242·8
Part II. gives for 77 ^o ·5 - 70 ^o ·3 (=7 ^o ·2)	.. .. .	-16·9
	Approximate altitude	6225·9
$\frac{6225\cdot9}{900} + \left\{ 77^{\circ}\cdot5 + 70^{\circ}\cdot3 - 64 \right\} = 6918 \times 83\cdot8$		+ 579·7
	Nearly correct altitude	6805·6
Part III. gives for above altitude and latitude 21 ..		+ 13·3
Part IV. gives for above altitude		+ 19·3
Part V. is not used in this case		0·0
	Correct height above sea	6,888·2 feet.

PART I.

ARGUMENT, THE OBSERVED HEIGHT OF THE BAROMETER AT EITHER STATION.

Inches.	Feet.	Diff.	Inches.	Feet.	Diff.	Inches.	Feet.	Diff.	Inches.	Feet.	Diff.
11.0	1396.9	236.4	16.0	11186.3	162.8	21.0	18291.0	124.1	26.0	23871.0	100.3
11.1	1633.3	234.3	16.1	11349.9	161.8	21.1	18415.1	123.6	26.1	23971.3	99.9
11.2	1867.6	232.3	16.2	11510.9	160.8	21.2	18538.7	122.9	26.2	24071.2	99.5
11.3	2099.9	230.2	16.3	11671.7	159.8	21.3	18661.6	122.4	26.3	24170.7	99.1
11.4	2330.1	228.2	16.4	11831.5	158.8	21.4	18784.0	121.8	26.4	24269.8	98.8
11.5	2558.3	226.2	16.5	11990.3	157.9	21.5	18905.8	121.2	26.5	24368.6	98.4
11.6	2784.5	224.2	16.6	12148.2	156.9	21.6	19027.0	120.7	26.6	24467.0	98.1
11.7	3008.7	222.4	16.7	12305.1	155.9	21.7	19147.7	120.1	26.7	24565.1	97.6
11.8	3231.1	220.5	16.8	12461.0	154.1	21.8	19267.8	119.6	26.8	24662.7	97.3
11.9	3451.6	218.6	16.9	12616.1	153.3	21.9	19387.4	119.0	26.9	24760.0	97.0
12.0	3670.2	216.8	17.0	12770.2	152.3	22.0	19506.4	118.5	27.0	24857.0	96.6
12.1	3887.0	215.0	17.1	12923.5	151.5	22.1	19624.9	118.0	27.1	24953.6	96.2
12.2	4102.0	213.3	17.2	13075.8	150.6	22.2	19742.9	117.4	27.2	25049.8	95.9
12.3	4315.3	211.6	17.3	13227.3	149.7	22.3	19860.3	116.9	27.3	25145.7	95.5
12.4	4526.9	209.8	17.4	13377.9	148.9	22.4	19977.2	116.4	27.4	25241.2	95.2
12.5	4736.7	208.2	17.5	13527.6	148.0	22.5	20093.6	115.8	27.5	25336.4	94.8
12.6	4944.9	206.5	17.6	13676.5	147.2	22.6	20209.4	115.4	27.6	25431.2	94.5
12.7	5151.4	205.0	17.7	13824.5	146.3	22.7	20324.8	114.8	27.7	25525.7	94.2
12.8	5356.4	203.3	17.8	13971.7	145.6	22.8	20439.6	114.4	27.8	25619.9	93.8
12.9	5559.7	201.7	17.9	14118.0	145.6	22.9	20554.0	113.9	27.9	25713.7	93.4
13.0	5761.4	200.2	18.0	14263.6	144.7	23.0	20667.8	113.3	28.0	25807.1	93.2
13.1	5961.6	198.7	18.1	14408.3	144.0	23.1	20781.1	112.9	28.1	25900.3	92.8
13.2	6160.3	197.2	18.2	14552.3	143.1	23.2	20894.0	112.4	28.2	25993.1	92.5
13.3	6357.5	195.7	18.3	14695.4	142.4	23.3	21006.4	111.9	28.3	26085.6	92.1
13.4	6553.2	194.3	18.4	14837.8	141.6	23.4	21118.3	111.4	28.4	26177.7	91.9
13.5	6747.5	192.8	18.5	14979.4	140.9	23.5	21229.7	110.9	28.5	26269.6	91.5
13.6	6940.3	191.4	18.6	15120.3	140.0	23.6	21340.6	110.5	28.6	26361.1	91.2
13.7	7131.7	190.0	18.7	15260.3	139.4	23.7	21451.1	110.0	28.7	26452.3	90.9
13.8	7321.7	188.6	18.8	15399.7	138.7	23.8	21561.1	109.5	28.8	26543.2	90.5
13.9	7510.3	187.3	18.9	15538.3	137.9	23.9	21670.6	109.1	28.9	26633.7	90.3
14.0	7697.6	186.0	19.0	15676.2	137.1	24.0	21779.7	108.7	29.0	26724.0	89.9
14.1	7883.6	184.6	19.1	15813.3	136.5	24.1	21888.4	108.2	29.1	26813.9	89.6
14.2	8068.2	183.3	19.2	15949.8	135.7	24.2	21996.6	107.7	29.2	26903.5	89.3
14.3	8251.5	182.1	19.3	16085.5	135.0	24.3	22104.3	107.3	29.3	26992.8	89.1
14.4	8433.6	180.8	19.4	16220.5	134.3	24.4	22211.6	106.8	29.4	27081.9	88.7
14.5	8614.4	179.6	19.5	16354.8	133.7	24.5	22318.4	106.4	29.5	27170.6	88.4
14.6	8794.0	178.3	19.6	16488.8	132.9	24.6	22424.8	106.0	29.6	27259.0	88.1
14.7	8972.3	177.2	19.7	16621.5	132.3	24.7	22530.8	105.6	29.7	27347.1	87.8
14.8	9149.5	176.0	19.8	16753.7	131.6	24.8	22636.4	105.1	29.8	27434.9	87.6
14.9	9325.5	174.8	19.9	16885.3	131.0	24.9	22741.5	104.8	29.9	27522.5	87.2
15.0	9500.3	173.5	20.0	17016.3	130.3	25.0	22846.3	104.3	30.0	27609.7	86.9
15.1	9673.9	172.4	20.1	17146.6	129.7	25.1	22950.8	103.8	30.1	27696.6	86.7
15.2	9846.2	171.3	20.2	17276.3	129.0	25.2	23054.4	103.5	30.2	27783.3	86.4
15.3	10017.5	170.2	20.3	17405.3	128.4	25.3	23157.9	103.1	30.3	27869.7	86.0
15.4	10187.7	169.1	20.4	17533.7	127.7	25.4	23261.0	102.6	30.4	27955.7	85.8
15.5	10356.8	168.0	20.5	17661.4	127.2	25.5	23363.6	102.3	30.5	28041.5	85.6
15.6	10524.8	167.0	20.6	17788.6	126.5	25.6	23465.9	101.8	30.6	28127.1	85.2
15.7	10691.8	165.9	20.7	17915.1	125.9	25.7	23567.7	101.5	30.7	28212.3	85.0
15.8	10857.7	164.8	20.8	18041.1	125.3	25.8	23669.2	101.1	30.8	28297.3	84.7
15.9	11022.5	163.8	20.9	18166.3	124.7	25.9	23770.3	100.7	30.9	28382.0	84.4
16.0	11186.3		21.0	18291.0		26.0	23871.0		31.0	28466.4	

PART II.

CORRECTION DUE TO T—T', OR THE DIFFERENCE OF THE TEMPERATURES OF THE BAROMETERS AT THE TWO STATIONS.

This Correction is Negative when the Temperature at the Upper Station is lowest, and vice versâ.

T—T'.	Correction.	T—T'.	Correction.	T—T'.	Correction.	T—T'.	Correction.	T—T'.	Correction.	T—T'.	Correction.
Fah't.	Feet.	Fah't.	Feet.	Fah't.	Feet.	Fah't.	Feet.	Fah't.	Feet.	Fah't.	Feet.
1	2.3	14	32.8	27	63.2	40	93.6	53	124.1	66	154.5
2	4.7	15	35.1	28	65.5	41	96.0	54	126.4	67	156.8
3	7.0	16	37.5	29	67.9	42	98.3	55	128.7	68	159.2
4	9.4	17	39.8	30	70.2	43	100.7	56	131.1	69	161.5
5	11.7	18	42.1	31	72.6	44	103.0	57	133.4	70	163.9
6	14.0	19	44.5	32	74.9	45	105.3	58	135.8	71	166.2
7	16.4	20	46.8	33	77.3	46	107.7	59	138.1	72	168.6
8	18.7	21	49.2	34	79.6	47	110.0	60	140.4	73	170.9
9	21.1	22	51.5	35	81.9	48	112.4	61	142.8	74	173.3
10	23.4	23	53.8	36	84.3	49	114.7	62	145.1	75	175.6
11	25.8	24	56.2	37	86.6	50	117.0	63	147.5	76	177.9
12	28.1	25	58.5	38	89.0	51	119.4	64	149.8	77	180.3
13	30.4	26	60.9	39	91.3	52	121.7	65	152.2	78	182.6

PART III.

CORRECTION DUE TO THE CHANGE OF GRAVITY FROM THE LATITUDE OF 45° TO THE LATITUDE OF THE PLACE OF OBSERVATION.

Positive from Lat. 0° to 45°;
Negative from Lat. 45° to 90°.

Latitude.

PART IV.

CORRECTION FOR DECREASE OF GRAVITY ON A VERTICAL.
Always Positive.

PART V.

CORRECTION DUE TO THE HEIGHT OF THE LOWER STATION.

Always Positive.

Height of Barometer at Lower Station.

App. Alt.	Latitude.					45°	Feet.	Height of Barometer at Lower Station.								App. Alt.
	0°	10°	20°	30°	40°			16 in.	18 in.	20 in.	22 in.	24 in.	26 in.	28 in.		
	90°	80°	70°	60°	50°			Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.		
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1000	2.6	2.5	2.0	1.3	0.5	0	2.5	1.6	1.3	1.0	0.8	0.6	0.4	0.2	1000	
2000	5.3	5.0	4.1	2.6	0.9	0	5.2	3.1	2.5	2.0	1.5	1.1	0.7	0.3	2000	
3000	7.9	7.5	6.1	4.0	1.4	0	7.9	4.7	3.8	3.0	2.3	1.7	1.1	0.5	3000	
4000	10.6	10.0	8.1	5.3	1.8	0	10.8	6.3	5.1	4.0	3.1	2.2	1.4	0.7	4000	
5000	13.2	12.4	10.1	6.6	2.3	0	13.7	7.8	6.4	5.0	3.8	2.8	1.8	0.8	5000	
6000	15.9	14.9	12.2	7.9	2.8	0	16.7	9.4	7.6	6.0	4.6	3.3	2.1	1.0	6000	
7000	18.5	17.4	14.2	9.3	3.2	0	19.9	11.0	8.9	7.1	5.4	3.9	2.5	1.2	7000	
8000	21.2	19.9	16.2	10.6	3.7	0	23.1	12.5	10.2	8.1	6.2	4.4	2.8	1.3	8000	
9000	23.8	22.4	18.3	11.9	4.1	0	26.4	14.1	11.4	9.1	6.9	5.0	3.2	1.5	9000	
10000	26.5	24.9	20.3	13.2	4.6	0	29.8	15.7	12.7	10.1	7.7	5.5	3.5	1.7	10000	
11000	29.1	27.4	22.3	14.6	5.1	0	33.3	17.2	14.0	11.1	8.5	6.1	3.9	1.8	11000	
12000	31.8	29.9	24.4	15.9	5.5	0	36.9	18.8	15.3	12.1	9.2	6.6	4.2	2.0	12000	
13000	34.4	32.4	26.4	17.2	6.0	0	40.6	20.4	16.5	13.1	10.0	7.2	4.6	2.2	13000	
14000	37.1	34.9	28.4	18.5	6.4	0	44.4	21.9	17.8	14.1	10.8	7.7	4.9	2.3	14000	
15000	39.7	37.3	30.4	19.9	6.9	0	48.3	23.5	19.1	15.1	11.5	8.3	5.3	2.5	15000	
16000	42.4	39.8	32.5	21.2	7.4	0	52.3	25.1	20.3	16.1	12.3	8.8	5.6	2.7	16000	
17000	45.0	42.3	34.5	22.5	7.8	0	56.4	26.6	21.6	17.1	13.1	9.4	6.0	2.8	17000	
18000	47.7	44.8	36.5	23.8	8.3	0	60.5	28.2	22.9	18.1	13.8	9.9	6.3	3.0	18000	
19000	50.3	47.3	38.6	25.2	8.7	0	64.9	29.8	24.1	19.2	14.6	10.5	6.7	3.2	19000	
20000	53.0	49.8	40.6	26.5	9.2	0	69.2	31.3	25.4	20.2	15.4	11.0	7.0	3.3	20000	
21000	55.6	52.3	42.6	27.8	9.7	0	73.6	32.9	26.7	21.2	16.1	11.6	7.4	3.5	21000	
22000	58.3	54.8	44.7	29.1	10.1	0	78.2	34.5	28.0	22.2	16.9	12.1	7.7	3.7	22000	
23000	60.9	57.3	46.7	30.5	10.6	0	82.9	36.0	29.2	23.2	17.7	12.7	8.1	3.8	23000	
24000	63.6	59.8	48.7	31.8	11.0	0	87.6	37.6	30.5	24.2	18.5	13.2	8.4	4.0	24000	
25000	66.2	62.2	50.7	33.1	11.5	0	92.5	39.1	31.8	25.2	19.2	13.8	8.8	4.1	25000	

ON OBSERVATIONS WITH THEODOLITES OR ALTAZIMUTH INSTRUMENTS. By Colonel J. T. WALKER, R.E., F.R.S., Superintendent of the Great Trigonometrical Survey of India.

In the opening pages of these Hints, lists of instruments have been given which travellers of little experience are recommended to provide themselves with, and the sextant has been more particularly recommended, as the traveller will have opportunities of practising with it under the tuition of the officers of the ship which is conveying him to his destination. The suitability of this instrument for observations, both on land and sea, is thus a great advantage for any person who has not had an opportunity of learning the use of his instruments before starting on his expedition; and should he not have a sufficient knowledge of the methods of reducing the observations and calculating the results, he will find the simplest and easiest rules for his guidance in the several works on navigation, which are specially written for the reduction of observations with sextants by persons possessing little or no knowledge of the principles on which the rules are based. The inexperienced traveller can scarcely be expected to attain much accuracy in his observations and reductions, but should he explore unknown regions, he may be able to acquire valuable information, the immediate interest of which may be very considerable; but his work will necessarily be of a preliminary nature, and be liable to be largely corrected, or altogether superseded, by the operations of subsequent explorers.

But the extent of the regions of *terra incognita* in which inexperienced travellers can operate with the greatest advantage is constantly becoming more and more narrowed and diminished, and geographical science now-a-days frequently requires that the rough outlines which have hitherto sufficed for her purposes should not only be amplified and filled in, but rectified by more exact and reliable observations. The traveller must, in such cases, be provided with an instrument of greater capabilities than the sextant, and he should have thoroughly learnt the use of this instrument and the method of reducing the several kinds of observations which may be made with it before he commences operations. If he has no better instruments nor greater skill than his predecessors, his results may differ widely from theirs, but they will not be more worthy of confidence, and, while causing much perplexity and inconvenience to geographers, they will only exhibit with certainty the degree of uncertainty that is still attached to the problem under investigation.

An altazimuth instrument—or a theodolite possessing a complete vertical circle as well as a horizontal circle—is in many respects superior to a sextant. 1st, it measures horizontal angles directly, thus avoiding the labour of reducing oblique angles to the horizon; and a round of several angles can be measured with far less trouble than with the sextant. 2ndly, it measures small vertical angles of elevation or depression of objects which frequently could not be seen by reflection from a mercurial horizon for the measurement of the double angle by a sextant. 3rdly, its telescopic power is usually far higher than that of a sextant. 4thly, it may be so manipulated as to eliminate the effects—without in the first instance ascertaining the magnitudes—of certain constant instrumental errors, such as excentricity, collimation, and index errors. And 5thly, the influence of graduation errors may—when great accuracy is required—be reduced to a very considerable extent by systematic changes of the zero settings of the horizontal circle.

The disadvantages of the altazimuth instrument as compared with the sextant are its greater cost and bulk and weight; but in many instances these disadvantages will be more than counterbalanced by its superior capabilities.

Messrs. Troughton and Simms have favoured me with the following details regarding the cost, weight, and telescopic powers of these instruments as constructed by themselves:—

Instrument.	Weight of with Box.	Weight of Stand.	Price.	Telescopic Powers.	Readings of Verniers.	Details.
7-inch (radius) sextant Artificial horizon ..	lbs. 7 5 to 10	lbs.	£ s. d. 12 0 0	5 to 10	10"	*
4-inch (diameter) } transit theodolite }	13½	9	23 0 0	9 ,, 12	1'	Without transit axis level, and lamp.
5-inch ,, ,, ..	25	10	32 10 0	12 ,, 15	30"	With transit axis level, and lamp.
6-inch ,, ,, ..	31	12	40 0 0	12 ,, 18	20"	Do.

* The weight of a tripod stand, as described in "Outfit" (p. 8), would be additional.

The Messrs. Casella construct certain very light and cheap altazimuth instruments, with 3-inch circles, power 5, weight with box 4 lbs., weight of stand 3½ lbs. divided to 1', price under 20*l.*

For astronomical observations the sextant is decidedly preferable to very small altazimuth instruments, but the latter are to be preferred for the measurement of horizontal angles and small elevations or depressions.

The traveller must necessarily adapt his equipment to his requirements and the facilities he will possess for carrying his instruments about. He may find it convenient to employ

a sextant for astronomical, and a very small light altazimuth for terrestrial observations. But, whenever practicable, an altazimuth of moderate size, which may be used as a universal instrument, would undoubtedly be the most convenient and satisfactory.

The instrument which I would recommend for geographical explorations, as being well adapted for astronomical and for terrestrial observations, and not very bulky, is the 6-inch transit theodolite by Messrs. Troughton and Simms: several of these have been used in explorations connected with the operations of the Great Trigonometrical Survey of India, and have given great satisfaction, being sufficiently accurate for all desirable purposes, and not too heavy to be easily carried. These instruments are adapted for determinations of time and longitude by the method of zenith distances, and also by that of meridional transits; the former being best suited for the traveller when he can only devote a few hours to the operations, the latter when he is halting for a long time at one place: the two methods lead to strictly independent results, so that when both are employed they serve to check each other. The instrument is also well suited for latitude and azimuth observations; in fact it can be employed in any of the investigations which an explorer may have to undertake by means of astronomical observations. On the other hand, as an instrument for the measurement of terrestrial angles, whether horizontal or vertical, it is very valuable, and far superior to any sextant, not only being more conveniently manipulated, but possessing telescopic powers which permit of the detection and identification of objects that would often be sought for in vain with a sextant.

Trigonometrical operations are, as a rule, far simpler and more easily reduced, and lead to more accurate results than astronomical observations. A continuous triangulation, or a traverse with measured angles and distances, is necessarily impossible when the explorer has to pass through a country very rapidly; but he may frequently remain for several days at one place, and may then have opportunities of greatly extending the scope of his operations by executing a triangulation. Suppose him to be in view of a range of hills which he may not have an opportunity of exploring, distant say 50 to 100 miles; he may have already endeavoured on his line of march to fix points on the range by bearings, but from the absence of prominent landmarks has found a difficulty in identifying the points observed, and thinks he may have mistaken one hill for another in consequence of their changes in appearance as viewed from positions at some distance apart. If, during his

few days' halt, he can manage to do a little triangulation, he may fix the general outlines of the entire range relatively to his halting-place with very respectable accuracy. He has first to measure a base and determine by triangulation the positions of three stations lying in a direction nearly parallel to that of the range, and at distances of 2 to 5 miles apart; then at each of these stations he must measure the angles between the other stations and a series of points on the entire length of the range;* though no very prominent landmarks may be visible, still the telescope will show a number of objects—trees, masses of rock, and peculiarities of the ground—sufficiently clearly to permit of their being recognized at stations of observation which are so close to each other; and though the triangles will be very acute-angled, the angles may easily be measured with sufficient accuracy to give the distances of the points on the ranges from the stations of observation with a small percentage of error, whenever the marks are fairly identified; and as there will be two triangles to each point, and, therefore, double values of the side common to both triangles, any mistakes—whether of identity, or of reading, or calculation—will be at once shown up.

The 6-inch transit theodolites of the Indian Survey which have been used in military expeditions and explorations are specially provided with a pair of micrometers in the eyepiece of the telescope, for the purpose of measuring small angles, and more particularly those subtended by objects of known dimensions, by means of which the distance between the object and the observer is readily deduced. The system of micrometers is moveable through an angle of 90° , so as to permit of the measurement of either a horizontal or a vertical object. With the aid of this appliance, the instrument can be employed in carrying on a traverse without using any direct measuring apparatus, such as a chain or perambulator, the distances to the

* He should make a sketch of the outline of the range in his book of observations; and as he will probably be unable to ascertain the names of the hill summits at such a distance from them, and many of them may have no names, he had better number them in the order in which they are observed, and refer to them always by these numbers, until he can confidently replace a number by a name. Exaggerated sketches of the outlines of the objects intersected by the telescope are frequently of use to facilitate identification on proceeding to the next station.

The positions of places situated within or beyond the range of hills, which are invisible to the traveller, but are known to his native guides and assistants, may frequently be determined by making a native point the theodolite, as a gun, in the direction of the place, and state its distance beyond or on this side of the range. The guides will often be found to possess a remarkable knowledge of locality, and I have frequently known the independent pointings of different men towards distant invisible objects to coincide together very closely, as was shown by the readings of the azimuthal circle.

back and forward stations being determined by measuring the angles subtended by poles of known length, which are set up at the stations. In hilly and broken ground, in crossing rivers or other obstacles, and generally wherever a direct measurement is impracticable, this method of procedure is most convenient. It was adopted by Captain Carter, R.E., in his survey—with one of these instruments—of the line of country passed over by the British army in the Abyssinian expedition. Captain Carter carried a traverse from Adigerat to Magdala, a distance of nearly 300 miles, without any break of continuity, the daily rate of progress averaging 5 miles, and being occasionally as much as 8 miles. The difference of latitude between the origin and terminus as determined from these operations only differed by about a quarter of a mile from the value determined astronomically.

Whenever a halt occurred in the movements of the army, the instrument was used as a theodolite in triangulating to fix the positions of all hills and other prominent objects around the halting-place; it was also used for various astronomical observations.*

REMARKS ON THE MANIPULATION OF ALTAZIMUTH INSTRUMENTS.

Observations with these instruments should always be made in pairs, with the face of the vertical circle alternately to the right and left of the observer. Thus, supposing that in the first observation, or round of observations, the face of that circle is to the right of the observer, the telescope should be immediately afterwards moved through 180° in azimuth, and turned over in altitude, which will bring the face of the circle to the left of the observer, and then a second observation, or round of observations, should be taken; the mean of the two measures, face right and face left, will be free from collimation, index, and other instrumental errors.

In measuring horizontal angles between objects of nearly the same altitude, as landmarks not much above or below the

* These instruments being furnished with a pair of micrometers, which can be used either horizontally or vertically, are all the more valuable for astronomical observations; for the micrometers give two additional wires over which the stars may be observed, and these wires can be set at pleasure to any distance from the fixed wires in the diaphragm which may be best suited to the rate of movement of the star. For pairs of observations—face right and face left—no reductions to the centre wire are necessary; and thus greater accuracy is obtained with very slight additional trouble of observing, and still less of computing.

horizon, a change of face is not absolutely necessary, and may be dispensed with if the observer is hurried; but when such angles are measured between objects of very different altitudes—as a terrestrial referring mark and a star—and whenever altitudes are measured, whether of terrestrial or celestial objects, the observations should invariably be taken in both positions, alternately “face right” and “face left,” and the final result deduced from the mean, in order that the instrumental errors may be eliminated. There is no necessity to determine the magnitude of these errors, as in the sextant; in an instrument which has to travel far over bad ground the adjustments are liable to alter from time to time, but they are not likely to alter in the interval between two consecutive observations, and the errors arising therefrom will be eliminated in the mean of the pair.

In what follows regarding *astronomical* observations with these instruments, a complete observation will be understood to imply the mean of a pair of observations, one with face right, the other with face left, taken continuously without any considerable pause between them, the entire operation being considered as one observation.

DETERMINATIONS OF TIME, AZIMUTH, LATITUDE AND LONGITUDE, WITH A TRANSIT THEODOLITE.

The transit theodolite may be employed either as a transit instrument or as an altazimuthal instrument; it is adapted for all astronomical observations, excepting those of “lunar distances,” which can only be performed by a sextant or a reflecting circle, and occultations, which require larger telescopes.

Thus a description of each of the various kinds of observations which can be made with transit and altazimuth instruments, with full details of the methods to be employed in the corresponding reductions, would fill a volume, and be much more than is required for a book which merely purports to give hints to travellers. Those who wish to learn full particulars of each of the several methods of observation, and of the reductions, cannot do better than study Chauvenet’s ‘Spherical and Practical Astronomy,’ which is one of the most valuable works on the subject in the English language: it gives ample instructions for observations of all kinds, the rudest and most hurried, as well as the most refined and elaborate, and it supplies corresponding formulæ—approximate as well as rigorous—for the reduction of the observations.

As these Hints are merely intended to indicate the simplest and most expeditious methods by which a traveller who is able to carry a suitable altazimuthal instrument about with him can take the astronomical observations which are essentially necessary for his geographical explorations, they will be restricted to determinations of time, latitude and longitude, by the measurement of zenith distances, and of azimuths by horizontal angles; formulæ—some approximate but all sufficiently rigorous for the purpose, and adapted mostly from Chauvenet—will also be given, for the reduction of the observations.

Latitude Observations, the time being unknown.—The instrument being duly levelled and brought approximately into the meridian, set the telescope on any star—or on the sun—when approaching culmination, and follow it until the maximum altitude is reached; take the zenith-distance reading on the vertical circle, change face quickly, and make a second observation; the mean of the two will be a “complete observation” of zenith distance. Two or three pairs of observations may be taken to circumpolar stars, as their zenith distances will not alter sensibly during an interval of a quarter to half an hour; for other stars the observations should be restricted to one pair, and stars should not be observed when within 25° of the zenith. A single pair of observations with the $6''$ transit theodolite should give a determination within $20''$ of the truth; greater accuracy may be obtained by observing additional stars, more particularly when the stars are selected so as to form pairs of nearly equal distance from the zenith, north and south.

Latitude Observations, the time being known.—(1.) Observe the zenith distance of the Pole-star in any position, and reduce to the meridian by the tables in the ‘Nautical Almanac.’

(2.) Take circum-meridian observations of the zenith distance of any star, alternately face right and face left, and note the time of each observation; compute the reduction of the zenith distance at the time of observation to the distance on the meridian, and take the mean of the reduced results as the determination of the meridional zenith distance. Three or four pairs of observations may generally be made in succession to the same star; but the nearer the star is to the zenith the more accurately should the times be known—it is not desirable, therefore, to observe stars within 10° of the zenith. Here, too, pairs of north and south stars of nearly equal zenith distance will give the best results.

Time.—Take pairs of observations of the zenith distance of a star, noting the chronometer time of each, and adopt the mean of the times as the time corresponding to the mean zenith distance, with which, the latitude of the place, and the star’s declination, the star’s hour angle must be computed by either of the well-known formulæ: thus the local time and the chronometer error will be determined. For these observations stars are most favourably situated which are easterly or westerly, and not very near either to the horizon or to the meridian; and greatest accuracy is obtained when two stars are observed at nearly the same altitude, one to the east, the other to the west. With a pair of observations the chronometer error should be determined within 1 second when a $6''$ transit theodolite* is used.

* At a trial of one of these instruments for the Indian Survey, the results of six pairs of observations on east and west stars fell within an extreme range of 0.4 of a second of time; the stars were, however, observed on the wires of the two micrometers, as well as on the fixed wire of the diaphragm. (See footnote, page 36.)

Longitude.—Take pairs of observations of zenith distance on a star for the determination of the local time and chronometer error, then take other pairs of observations of zenith distance on the moon; in each instance adopt the mean of the chronometer times as that of the “complete observation” of zenith distance. Both moon and star should be easterly or westerly, and not very near either to the meridian or to the horizon. The operations should commence and close with star observations, in order that the chronometer rate may be duly ascertained and allowed for. Ten pairs of observations to the moon and six to stars ought not to occupy more than four hours, and they should give a very fair result, probably within 8 miles of the truth. The effect of instrumental errors will be materially reduced when the stars and the moon are on the same sides of the meridian and at nearly the same zenith distance; if time permits, observations should be taken both east and west of the meridian, and both before and after full moon.

Azimuth, time and latitude being unknown.—Observe the angles between a referring mark * and a star when the star is at the same altitude east and west of the meridian; several pairs of observations may be taken at consecutive altitudes, half with face right and half with face left. Or the angles may be measured between a referring mark and a circumpolar star at the times of its maximum elongations east and west. The mean of the two angles at opposite positions gives the angle between the star and the meridian, and thence the azimuth of the referring mark, without any calculations whatever. In the first case, however, an interval of several hours must be allowed to elapse between the observations east and west; and as twelve hours must necessarily elapse between the opposite elongations of a circumpolar star, few stars will ordinarily be visible at both elongations.

It may therefore be desirable to adopt a third and more expeditious method, as follows:—Measure the angles between the referring mark and *two* circumpolar stars at their respective elongations, selecting stars which are nearly in opposition or nearly in conjunction, and will attain their maximum elongations at nearly the same time, that the observations may be completed quickly; then with the observed value of the angle between the stars, and the given declinations of the stars, the azimuths of both may be readily computed, as shown at page 18.

Azimuths, latitude being known.—Observe the angle between the referring mark and a circumpolar star at maximum elongation, and compute the azimuth of the star. To stars near the pole two or three pairs of observations, face left and face right, may be taken before the star moves sensibly from the position of maximum elongation.

Azimuth, latitude and time being known.—Any star may be observed in any position, but the best results will be obtained when a circumpolar star is observed at a short distance from the elongation; the angle between the position of the star at the observation and at the elongation may be computed by the formulæ at page 18.

General Remarks.—The observed zenith distances should always be corrected for refraction; barometer and thermometer readings should, therefore,

* A good referring mark may be made of a cross with a hole of $\frac{1}{4}$ to $\frac{3}{8}$ an inch in diameter in the centre, to which observations can be taken by day and by night, being rendered visible at night by a bull's-eye lantern placed behind the hole and directed to the observer. The stem of the cross should be vertical, and driven firmly into the ground. The distance from the station of observation should be at least half a mile, and the station should be marked by a pin driven into the ground, over which the theodolite must be carefully centered whenever set up for horizontal observations.

be taken during the observations, for the better determination of the refraction. When no barometer is at hand, the height of the station of observation should be given, as deduced by the boiling point or otherwise, or even approximately estimated. It may be well to remember that in determining latitude errors of refraction may be eliminated by observing pairs of north and south stars of the same zenith distance.

FORMULÆ AND EXAMPLES.

Latitude by Circum-meridian Observations of a Star.

Let ϕ be the true latitude, ζ the true zenith distance on the meridian, ζ^o the observed zenith distance corrected for refraction, δ the declination of the star,* ϕ_0 an approximate value of ϕ , $= \delta \pm \zeta_0$, t the hour angle of the star.

$$\text{Put } A = \frac{\cos \phi_0 \cos \delta}{\sin \zeta_0} \text{ and } m = \frac{2}{\sin 1''} \sin^2 \frac{1}{2} t.$$

$$\text{Then } \zeta = \zeta_0 - Am, \text{ and } \phi = \delta \pm \zeta.$$

The values of m are tabulated in Chauvenet's 'Astronomy.'

Alternative forms of m , } $m = \text{cosec } 1'' \text{ versin } t.$
 adapted for various } $= .00055t^2$, when t is given in seconds of time.
 logarithmic tables. } $= 2t^2$ nearly, ,, ,, minutes ,,

Supposing n observations to be taken, then, since A is constant,

$$\zeta = \zeta_0 - A \frac{m_1 + m_2 + \dots + m_n}{n}.$$

Example.—CIRCUM-MERIDIAN OBSERVATIONS FOR LATITUDE TO β URSÆ MINORIS, NORTH OF THE ZENITH.

Face.	Circle Readings. †			Mean Zenith Distances of Pairs of Observations.	Chronometer.	t in Minutes of Time.	t^2 .	Data.	
	°	'	''						
Left	Alt.	64	10	20	} H. M. S. (14 45 47	} 7.2	} 52	} R of Star .. H. M. S. 14 51 14	
Right	Z. D.	35	45	35					} 47 1	} 6.0	} 36	} Chron. Error + 1 46
Left	Alt.	64	10	50	} 48 55	} 4.1	} 17	} Chron. Time) 14 53 0 of Transit)	
Right	Z. D.	35	45	5					} 51 30	} 1.5	} 2
Left	Alt.	64	11	0	} 54 37	} 1.6	} 3	} $\delta \dots = 74 \ 46 \ 37$	
Right	Z. D.	35	45	8					} 56 22	} 3.4	} 12
Left	Alt.	64	10	40	} 57 43	} 4.7	} 22	} $\zeta_0 \dots = 35 \ 48 \ 5$	
Right	Z. D.	35	45	25					} 58 48	} 5.6	} 34
Left	Alt.	64	10	30	} 15 0 18	} 7.3	} 53	} $\phi_0 \dots = 38 \ 58 \ 32$	
Right	Z. D.	35	45	50					} 2 10	} 9.2	} 85
Mean				35 47 23	Mean			31.6	log cos ϕ_0 .. 9.8906
Refraction				+ 42					log cos δ .. 9.4192
				$\zeta_0 = 35 \ 48 \ 5$					log cosec ζ_0 .. 0.2330
				$- Am = \dots \dots$					$31.6 \times 2 = 63.2$.
				$\zeta = 35 \ 47 \ 43$					log A 9.5429
									log 63.2 .. 1.8007
									log Am 1.3436

For the above formula t should be less than 20 minutes, and ζ greater than 10° .

* When the sun is observed the declination corresponding to the mean of the times of observation should be used.

† The circle readings will be alternately altitudes and zenith distances \pm the index error of the instrument, which error is eliminated in the mean of a pair of observations.

Longitude by Lunar Zenith Distances.

The local time and the chronometer error having been determined from the star observations

Let ζ_0 = the observed zenith distance of the moon's limb.

Θ = the local sidereal time of the observation of ζ_0 .

L_1 = an assumed value of the longitude.

ΔL_1 = the required correction of L_1 .

L = the true longitude = $L_1 + \Delta L_1$.

ϕ = the latitude.

Find the Greenwich time corresponding to Θ and L_1 , for which take

δ = the moon's declination.

π = the moon's equatorial horizontal parallax. } from the

S = the moon's geocentric semi-diameter. } 'Naut. Alm.'

Let S_1 be the moon's apparent semi-diameter, and π_1 the corrected parallax;

then $S_1 = S + \Delta S$, and $\pi_1 = \pi + \Delta \pi$;

and the values of ΔS and $\Delta \pi$ may be interpolated from the tables below, which are abridged from Chauvenet.

Also put $\delta_1 = \delta + e^2 \pi_1 \sin \phi \cos \delta$, in which $\log e^2 = 7.8244$; and let r be the refraction for the apparent zen. dis. ζ_0 ;

and let $\zeta_2 = \zeta_0 + r + S_1$,

and $\zeta_1 = \zeta_2 - \pi_1 \sin \zeta_2$;

then the hour angle, t , is found from the equation

$$\sin^2 \frac{1}{2} t = \frac{\sin \frac{1}{2} [\zeta_1 + (\phi - \delta_1)] \sin \frac{1}{2} [\zeta_1 - (\phi - \delta_1)]}{\cos \phi \cos \delta_1}$$

after which the moon's right ascension, R , is found by the formula

$$R = \Theta - t.$$

The Greenwich mean time corresponding to the moon's R must be found from the 'Nautical Almanac'; with this and the local mean time a value of the longitude is determined, which, however, is approximate only, as t is computed with an approximate value of δ depending on the assumed longitude. Put L_2 for the approximate value of the longitude which is thus determined, and

Apparent Zen. Dis. of Moon.	Values of ΔS , always +.						Values of $\Delta \pi$, always +.			
	Horizontal Semi-diameter.						Latitude.	Equatorial Parallax.		
	14 30	15 0	15 30	16 0	16 30	17 0		53	57	61
0	13.7	14.6	15.6	16.7	17.7	18.8	0	0.0	0.0	0.0
10	13.5	14.4	15.4	16.4	17.5	18.6	10	0.3	0.3	0.4
20	12.9	13.8	14.7	15.7	16.7	17.7	20	1.2	1.3	1.4
30	11.8	12.7	13.5	14.4	15.4	16.3	30	2.7	2.9	3.1
40	10.5	11.2	12.0	12.8	13.6	14.4	40	4.4	4.7	5.1
50	8.8	9.4	10.1	10.7	11.4	12.1	50	6.2	6.7	7.2
60	6.9	7.3	7.9	8.4	8.9	9.5	60	8.0	8.6	9.2
70	4.7	5.1	5.4	5.8	6.1	6.5	70	9.4	10.1	10.8
80	2.4	2.6	2.8	3.0	3.2	3.4	80	10.3	11.1	11.9
90	0.1	0.1	0.1	0.1	0.2	0.2	90	10.6	11.4	12.2

put β = the increase of δ in a unit of time } at the Greenwich mean time
 and λ = " " \mathcal{R} " " } of the observation of the moon ;

$$\text{also let } a = \frac{\beta}{15\lambda} \left\{ \frac{\tan \phi}{\sin t} - \frac{\tan \delta}{\tan t} \right\};$$

$$\text{then } \Delta L_1 = \frac{L_2 - L_1}{1 + a}, \text{ and } L = L_1 + \Delta L_1.$$

These formulæ are demonstrated in Chauvenet, vol. i. pages 383 to 385; and when several observations have to be reduced, they entail less labour of computation than any other formula.

Example.—In latitude $\phi = 38^\circ 58' 53''$ and assumed longitude $L_1 = 5$ h. 6 m. west of Greenwich, on May 2nd, 1849, the moon being east of the meridian, the zenith distance of the moon's upper limb was observed to be $57^\circ 47' 28.5''$, when the local mean time was 5 h. 33 m. 21.6 s., and the local sidereal time $\Theta = 8$ h. 16 m. 14.61 s.

Approximate Greenwich mean time,
 10 h. 39 m. 21.6 s.

for which we find from the 'Naut. Alm.'

$$\begin{aligned} \delta &= + 3^\circ 47' 47.6'' \\ S &= 15 \quad 16.4 \\ \pi &= 56 \quad 3.1 \end{aligned}$$

and from the tables on page 22 we find

$$\begin{aligned} \Delta S &= + 8.1 \\ \Delta \pi &= + 4.4 \\ e^2 \pi_1 \sin \phi \left. \vphantom{\begin{matrix} \Delta S \\ \Delta \pi \end{matrix}} \right\} &= + 14.1 \\ \cos \delta & \end{aligned}$$

$$\zeta_0 = \overset{\circ}{57} \quad \overset{'}{47} \quad \overset{''}{28.5}$$

$$r = + 1 \quad 30.9$$

$$S_1 = + 15 \quad 24.5$$

$$\zeta_2 = 58 \quad 4 \quad 23.9$$

$$- \pi_1 \sin \zeta_2 = - 47 \quad 38.1$$

$$\zeta_1 = 57 \quad 16 \quad 45.8$$

$$\delta_1 = 3 \quad 48 \quad 1.7$$

With these values of δ_1 , ζ_1 , and ϕ we find—

$$t = \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ - 3 & 19 & 53.64; \end{matrix}$$

$$\text{but } \Theta = \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 8 & 16 & 14.61; \end{matrix}$$

$$\text{whence the computed } \mathcal{R} = \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 11 & 36 & 8.25. \end{matrix}$$

$$\left. \begin{array}{l} \text{The corresponding Greenwich mean time for this value} \\ \text{of the } \mathcal{R} \text{ is } \dots \dots \dots \end{array} \right\} \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 10 & 39 & 48.7 \end{matrix}$$

$$\text{The local mean time is } \dots \dots \dots \left. \vphantom{\begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 10 & 39 & 48.7 \end{matrix}} \right\} \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 5 & 33 & 21.6 \end{matrix}$$

$$\text{Whence the approx. long. } L_2 \text{ is } \dots \dots \dots \left. \vphantom{\begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 10 & 39 & 48.7 \end{matrix}} \right\} \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 5 & 6 & 27.1 \end{matrix}$$

$$\text{For the Greenwich mean time } \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 10 & 39 & 48.7 \end{matrix} \left\{ \begin{array}{l} \text{increase of } \mathcal{R} \text{ in } 1 = 2.014 = \lambda. \\ \text{'' } \delta \text{ '' } = 10''01 = \beta. \end{array} \right.$$

$$\text{Whence } a = - 0.3317; \text{ and since } L_2 - L_1 = + 27.1 \text{ s.},$$

$$\Delta L_1 = \overset{\text{S.}}{40.6}, \text{ and } L = \begin{matrix} \text{H.} & \text{M.} & \text{S.} \\ 5 & 6 & 40.6. \end{matrix}$$

Formulae for the reduction of Azimuth Observations.

(1.) When a star is observed at an elongation.

Let A be the azimuth, δ the declination, ϕ the latitude.

$$\text{Then } \sin A = \frac{\cos \delta.}{\cos \phi}.$$

(2.) When a star is observed at a short distance from the elongation.

Let t be the hour angle at the time of elongation,

$$\text{then } \cos t = \frac{\tan \phi}{\tan \delta}.$$

Let $d t$ be the difference between the hour angles at the times of elongation and of observation, and dA the corresponding difference of azimuth.

$$\text{then } \tan dA = -2 \sin^2 \frac{d t}{2} \sec \phi \cot \delta \operatorname{cosec} t;$$

whence if $d t$ is expressed in *minutes of time*, and κ is a constant,

$$\log \kappa \text{ being} = .29303 + \log \sec \phi + \log \cot \delta + \log \operatorname{cosec} t,$$

$$dA'' = -\kappa (d t)^2.$$

(3.) When two stars are observed at their elongations.

Let their azimuths be A_1 and A_2 , and their declinations δ_1 and δ_2 ,

$$\text{then } \sin A_1 = \frac{\cos \delta_1}{\cos \delta_2} \sin A_2.$$

The value of $A_1 + A_2$ or of $A_1 - A_2$ is given by the observations, $A_1 + A_2$ if the stars are at opposite elongations, $A_1 - A_2$ if they are at the same elongation. Suppose that we have

$$A_1 \pm A_2 = m,$$

$$\text{then } \cot A_1 = \cot m \pm \frac{\cos \delta_2}{\cos \delta_1} \operatorname{cosec} m,$$

$$\text{or } \cot A_2 = \cot m \pm \frac{\cos \delta_1}{\cos \delta_2} \operatorname{cosec} m.$$

ADJUSTMENTS OF THE "EVEREST THEODOLITE, IMPROVED, BY GROVER." (FURNISHED BY CAPTAIN PRATT, R.E.)

It is stated that this theodolite is likely to be adopted into the service of the Royal Engineers. It is therefore thought advisable to describe its adjustments. The instrument is made by Cooke and Sons, York.

1. *Correction for Parallax.*—Adjust the eyepiece to distinct vision of cross hairs, and correct for parallax by means of the object-glass screw.

2. *Making the Level of the Horizontal Limb parallel to that Limb.*—Clamp the tribrach* to axis, and unclamp the horizontal vernier-plate. Move the latter so that the horizontal limb's level may be over, or parallel to, two foot-screws. By means of these screws bring the bubble to the centre of level. Turn the vernier-plate round 180° , and correct the level's error half by

* Modern instruments are set on a tribrach, or 3-armed support, at the top of the stand, instead of being screwed on to the top of it. This is a great improvement in many ways.

the foot-screws and half by the level's capstan-headed screws. Turn the vernier-plate back to its original position; and if the bubble is not now exactly in the centre, correct as before. Repeat the process till accuracy is obtained.

3. *Levelling the Instrument*, i. e., *making its vertical axis truly vertical*.—Clamp the tribrach to axis, and unclamp the horizontal vernier-plate. Level the horizontal limb's level by the foot-screws. Turn the horizontal vernier-plate round 90° and re-level. This will make the vertical axis approximately vertical. Then bring the bubble of the vertical limb's level to the centre of bulb by the two antagonising screws at bottom of vertical vernier-plate. Turn round 180° ; and if the vertical limb's level is disturbed, correct half of the error by the foot-screws and half by the two antagonistic screws. Turn the horizontal plate 90° , and repeat the process till accuracy is obtained.

If the bubble of the level attached to the horizontal plate is now disturbed, bring it to centre of bulb by the capstan-headed screw, so as to make it an index of horizontality.

4. *Collimation*.

(a) *Vertical Collimation*.—Unclamp the vertical limb, and make its level horizontal by means of the antagonising screws. By means of the vertical limb's tangent-screw get the horizontal spider-line to cover some well-defined distant point. Read off the angle on the vertical verniers.

Reverse the instrument on its bearings, re-level, and re-intersect the same object. If now the vertical verniers read as at first, the vertical collimation is correct. If not, the mean of the readings is the true angular deviation from the horizontal. By means of the vertical limb's tangent-screw make the vertical verniers read this true deviation, and intersect the distant point by means of the antagonising screws.

This will disturb the level of the vertical limb. Restore its horizontality by means of the capstan-headed adjusting screws. The verniers should now read the same angle in both positions of the transit axis. If not, repeat the process till accuracy is obtained.

(b) *Horizontal Collimation*.—Intersect some well-defined distant point with the spider-lines. Reverse the instrument on its bearings. If there is any deviation from the intersection, correct half with the tangent-screw of the horizontal limb and half with the capstan-headed screws which move the diaphragm. Reverse the instrument on its bearings, and repeat similar corrections till accuracy is obtained.

**METEOROLOGICAL INSTRUCTIONS FOR THE USE OF
INEXPERIENCED OBSERVERS.**

(Extracted chiefly from a Circular issued by the Meteorological Society.)

The chief object of an inexperienced meteorological observer should be to obtain data whence an accurate table may be compiled, of the following character :—

Place.				
Lat.	Long.		Elev ⁿ .	
	Mean temp.	Monthly range.	Rain, &c.	Periodical winds.
Jan.				
Feb.				
Mar.				
April				
May				
June				
July				
Aug.				
Sept.				
Oct.				
Nov.				
Dec.				
Year				
No. of years' observation				
Hours and mode of observation ..				

The original observations should be carefully preserved, in order to give evidence of the sufficiency of the data whence the printed results have been obtained, and to afford opportunity of investigating such anomalies, as may at any future time call for inquiry.

The following instructions show the minimum of effort with which trustworthy results can be obtained. They are especially intended for residents. Travellers on the march must act up to the spirit of them, as nearly as they can.

OBSERVATIONS ON HEAT.

1. *To Expose Thermometers.*—The instruments must be placed in a carefully selected position, or all their results will be vitiated. Choose an airy place, where there is continuous, dense, and ample shade. There set up a box of not less than 2 feet in height, width, and depth. It must be constructed precisely on

the principle of an ordinary meat-safe; that is to say, it must be roofed (and better still, double roofed) from the rain, and have perforated sides, whether of gauze, trellis-work, or Venetian blinds, through which the air may pass with perfect freedom. It must be fixed on a stand or be suspended 4 feet above the ground. The thermometers should be hung on supports placed in the middle of the box, except where otherwise mentioned in the 1st method, § 3.

2. *Monthly Mean Temperatures.*—The average of the daily means, taken by one of the methods described in the next paragraph during an entire month, gives the monthly mean. If occasionally a day or a month be dropped, a gap must be left in the record, and no attempt be made to fill it.

3. *Daily Mean Temperatures.*

1st Method: This is the more accurate, but requires observations to be made *twice* in each day.

Procure a jar or box, of not less than 8 inches in length, width, and depth; fill it with dry sand, and set it in a properly exposed box (§ 1). Place a thermometer upright in the middle of the sand, with its bulb buried from 3 to 4 inches below its surface. Note its readings twice a day, at intervals of twelve hours, say at 9 A.M. and 9 P.M.; the mean of these readings may be accepted as the daily mean.

2nd Method: By observations made *once* in each day.

Hang a maximum and a minimum thermometer on supports, as described in § 1, and note their readings once daily, either in the morning or in the afternoon, and readjust the indexes. The mean of the maximum and minimum usually differs from the mean temperature of the day by less than half a degree; but occasionally (as at Barnaul in Central Asia) the difference exceeds $1\frac{1}{2}^{\circ}$. The liability to a constant error of this amount is too serious to be passed over without investigation, especially as the approximate correction due to each month can be readily ascertained by making occasional use of the 1st method as a standard of comparison. When the year's work is completed, it will be easy to estimate the corrections due to the several months, and to apply them to the monthly means obtained by this 2nd method.

4. *Monthly Range* is the difference between the lowest and highest readings during the month.

5. *Yearly Means*, whether of *temperature* or of *range*, are the averages of the monthly means.

“The enclosure of a maximum and minimum self-registering thermometer in a large cask of dry sand, which might be opened and read off twice a year, would also probably afford a very accurate mean result.”—*Sir John Herschel.*

RAIN, SNOW, AND DEW.

6. These must be measured by a Gauge, which should be placed on the ground or on a low stand in an exposed situation. The relation of the units of length and weight is such that the tenth of an inch of rain falling into a vessel whose mouth is a circular area of about two inches and nine-tenths in diameter (1.4467 inch radius) will weigh an ounce (Troy). Every medicine-chest contains a fluid ounce (Troy) measure; and, failing this, it will suffice to mark the space occupied in a small vessel by 480 drops of water, whose weight is one fluid ounce. A properly made rain-gauge and graduated measure is, however, preferable to any makeshift.

WIND.

7. Practised observers rarely use a weathercock, but watch the way the clouds (when any) are drifting. These are far steadier in their course than anything driven by the surface-currents of wind. For the requirement of the tabular statement now desired, it will be sufficient to note the prevalence of periodical weather.

PHOTOGRAPHY.

Photography for Travellers and Tourists. By DR. POLE, F.R.S.

[Reprinted, by permission, from 'Macmillan's Magazine' of 1862, and revised by the Author, 1871.]

Doubtless, the idea must often have occurred to almost every traveller, what an advantage it would be if he could himself take photographs, where he likes, of what he likes, when he likes, and how he likes. But such an idea must soon have been dismissed, from the supposed incompatibility of this with ordinary travelling arrangements. The usual notion of photographic operations comprehends a fearful array of dark rooms, huge instruments, chemical paraphernalia, water, and mess, which no sane person, out of the professional photographic guild, would think of burdening himself with on an ordinary journey, and which only a practised adept could use if he had them; and so the idea of a traveller's taking views for himself on his tour is generally dismissed at once as an impracticable chimera.

Now, it is the object of this article to show that such a view of the matter is a delusion, and that any traveller or tourist, gentleman, or lady, may, by about a quarter of an hour's learning, and with an amount of apparatus that would go into the gentleman's coat pocket, or the lady's reticule, put himself or herself into the desirable position we have named.

It is not our intention to write a treatise on photography; but we must state generally what the operations are, in order to make our explanations intelligible.

The process, then, of taking a photographic picture consists essentially of three main divisions, namely—1. Preparing the plate; 2. Taking the picture; and 3. Developing the image; and the most common and best known arrangement of these is as follows:—A glass plate of the proper size is coated with collodion, and made sensitive to light by dipping in a bath of a certain solution. It is then, *while it remains moist*, placed in the camera obscura, and exposed to the image formed by the lens; after which, *but still before the plate has had time to dry*, it is taken out, and treated with certain chemicals which have the property of developing the image so obtained. The plate is then what is called a “negative;” from which, after it has been secured by varnish, any number of impressions or “prints” may be taken at any time.

Now, it will be seen by the words we have printed in italics, that, according to this method of operation, the whole of the three parts of the process must be performed within a very short space of time; and, since the first and third require to be done in a place to which daylight cannot enter, a dark room, supplied with a somewhat extensive assortment of chemical apparatus, must be provided *close to the place* where the picture is taken. This method, from the necessity of the plate remaining moist, is called the *wet* process. It is always employed for portraits, and has the advantage not only of great beauty of finish, but of extreme sensitiveness, requiring only a few seconds' exposure in the camera.

The wet process was the first, and, we believe, for some time the only collodion process in use. But, in a happy moment, it occurred to somebody to inquire whether it was really indispensable that the plates should be kept *moist* during the whole operation; and it was found that, by certain modifications of the process of preparing them, they might be allowed to *dry*, and that some time might elapse between the preparation and the exposure, as well as between this and the development. The immense advantage this promised to landscape photography led to extensive investigation; and several processes have now been perfected which will secure this result. Plates may be prepared at any convenient time and place, and may be carried about for months, ready for use at a moment's notice; and, after the picture is taken, they may also be kept some time before development. The only price we pay for this advantage is the necessity for a little longer exposure in the camera; which, for landscapes, is of no moment at all.

The bearing of this discovery on our more immediate subject will be at once apparent, as it gets rid of the necessity of providing, on the journey, for the preparation and development, with all their cumbersome and troublesome apparatus, and limits what is necessary to the simple exposure, or taking of the picture. And another advantage of still more importance follows from this—namely, that the plates may be prepared and developed, not only in another place, but by another person. The knowledge, care, and skill required for photography, as well as the stains and all other disagreeables attending it, refer almost exclusively to the preparation and development; the exposure to take the view is an operation of the simplest kind, which anybody may learn in a few minutes, and which is attended with no trouble or inconvenience whatever.

Limiting, therefore, the traveller's operation to the taking of the picture, let us consider what this involves. The first question which affects materially the portability of the necessary apparatus, is the *size* of picture to be taken. We are accustomed to see very large and beautiful photographs of scenery and architecture; but these would be impracticable for the traveller, as the dimensions of the plate increase so materially every portion of the apparatus.

Differences of opinion and of taste may exist as to the degree of inconvenience it is worth while putting up with; but the writer of this paper, after considerable experience, has come to the conclusion that the smallest size in ordinary use—namely, the *stereoscopic* plate—is by far the most eligible one for travelling. The object is not to make large and valuable artistic pictures—that we must always leave to the professional man—but it is simply to preserve faithful representations; and this may be done as well on the small as on the large scale, and with infinitely less trouble. For, though the size is small, the delicacy of detail procurable with well-prepared plates, even in a large extent of view, is something marvellous, as may easily be seen in some of the magnificent stereoscopic views that are to be had in the shops; besides which, the stereoscopic effect gives an air of reality to the view which greatly enhances the value of the representation.

The camera for the double stereoscopic plate has been reduced, by ingenious contrivances, to a very portable size; but the writer has generally preferred to use a single plate of $3\frac{1}{4}$ by $2\frac{3}{4}$ inches, which is more handy and more easily manipulated. By taking two views of this size, and shifting the camera a few inches for the second one (for which purpose a simple contrivance may easily be introduced on the top of the stand), a stereoscopic picture will be obtained when prints from them are mounted side by side in the usual way. The camera for either the double or the single plate may be hung round the neck by a strap, and will be little inconvenience, while the stand will fold up into a straight stick, that may be carried in the hand. A stock of plates, enough for a day's work, may be carried in the pocket. The tourist can thus walk about without the slightest sense of incumbrance, and is prepared, at any moment, to take a view, either single or stereoscopic, of anything he sees—an operation which will occupy him from five to fifteen minutes, according to the light, and the time he may take to choose his position.

Considered as adding to the baggage of the traveller, these things are hardly worth mentioning—as, with the exception of the stand (which travels well in company with an umbrella), they will all lie snugly in a spare corner of a portmanteau. The stock of prepared plates will, of course, be regulated by the traveller's probable requirements during the time he is away.*

If the operator chooses to go to a little extra trouble, it is highly satisfactory to be able to *develop* the plates on the journey—which may conveniently be done in the evenings, at a hotel or lodging; and the apparatus for which adds very slightly to the bulk of the preparations. A small case of bottles, together with one or two small loose articles, are all the author takes with him. The development of a plate takes five or ten minutes, and is a process easily learnt; and the satisfaction of being able to see the same evening what one has been doing in the day is quite inducement enough to do it. But still, we repeat, this is not *necessary*, as the development may be left to another person and to another time.

We think we have shown how every traveller or tourist may be his own photographer, with much less trouble and difficulty than is generally supposed; and we must add that this is no untried plan. The writer of this article has been much in the habit of travelling; and, for years past, when he has gone on a journey, the little camera has been put into the portmanteau, as unassumingly and as regularly as the dressing-case. It has travelled in all sorts of countries, and has cast its eye on scenes which camera never looked at before; it has been a never-failing source of interesting occupation and amuse-

* Extract from letter by Rev. F. W. Holland: "I have found india-rubber bands most useful for packing negatives. A band slipped round each end of every alternate plate will keep them from contact, and they may thus be packed together without fear of injury."—ED.

ment, and has recorded its travels in hundreds of interesting views, some of much excellence, and very few otherwise than successful.

But it may be asked, Since the advantage and usefulness of this plan are so undeniable, how is it that we do not see it in more frequent use? Simply for the reason that the dealers in photographic apparatus have never yet had the enterprise to establish a manufacture and sale of dry prepared plates, in such a way as to insure their popularity.

The manufacture and sale of photographic apparatus and chemicals is now a very large branch of commerce; but many of the tradesmen who prosecute it appear to have a much more earnest view towards the profits of the business than to the advancement of the art—for, since the death of poor Mr. Archer (to whom we owe almost entirely the present state of photography, and who lost a fortune in its improvement), nearly every advance made has been by private individuals. We must not be misunderstood. There are many people who profess to sell dry plates, and these may often be found to possess many of the requisites they should have; but few can be depended on, and *none* combine all the qualities which are necessary to give the system the full benefit of its inestimable value. Some will not keep long enough before exposure; some will not keep at all after exposure; some fail in sensitiveness; some spoil soon after they are opened; to say nothing of the constant liability to stains, irregularities, blisters, and all sorts of troublesome and annoying defects, which not only spoil the operator's work, but—what is of more importance—destroy all reliance on his operations, and so discourage him from undertaking them. We are not sure whether some dealers may not be obtuse enough even to encourage defects, from the short-sighted notion of increasing the sale; but this we can say—that we know no maker who will guarantee the sincerity of his wish to make good plates, by consenting to allow for them if they turn out bad ones. If this state of things arose from imperfection in the art, we should not grumble, but could only urge improvement; but this is not so. It is well known that dry plates *can* be made,* satisfying all the conditions we have named, and which, with care and system in the manufacture, might be rendered thoroughly trustworthy. It is only the indolence or obstinacy of the trade that prevents their becoming regular articles of commerce.

We do not wish, however to discourage the traveller who may wish to adopt this admirable aid to his wanderings; for the object to be gained is so important that it is worth striving a little for. In the present state of the matter, he must either learn to prepare his own plates—which, after all, is no great exertion—or, if he buys them, he must at least learn to *develop* them, and must, at the same time, lay in with them a certain stock of patience and temper to meet disappointment; and we can assure him that, even at this price, he will find himself amply repaid. But we again urge that the case ought not to stand thus. The application of the dry processes to portable photography offers a boon almost inestimable to, but yet quite unappreciated by, the traveller and the tourist; and it only needs the zealous and earnest co-operation of the dealer, by so conducting the manufacture as to render it perfect and trustworthy, to raise this application into a branch of commerce of an extent, importance, and profit, little inferior to any in the trade.

* Extract from letter by Dr. Kirk: "The dry collodion process, which I believe will now supersede almost all others, had not made much progress when we went out; but in order to test it I took with me plates, prepared and sensitised in England in January, 1858, which, when tried at various times, continued to yield pictures up to August, 1863, having been kept sensitive all the interval at Teté on the Zambezi."—Ed.

On the same Subject. By the Rev. H. B. GEORGE, formerly Editor of the 'Alpine Journal.'

It would scarcely be possible for travellers, even if skilled in the art, to obtain many photographs on an expedition which went beyond the limits of civilization, unless trustworthy dry plates could be procured. With them there is nothing to hinder travellers from taking photographs anywhere, and all needful knowledge can be acquired in an hour. And inasmuch as pictures taken on very small plates can now be enlarged with considerable success, the bulk of plates which must be carried is too small to be any burden; the plates of the Liverpool Dry Plate Company (which may be trusted, so far as the writer's experience goes, very thoroughly) weigh about 1 lb. per dozen, each plate giving two pictures.

The best apparatus for a traveller's purposes is known as Edwards' miniature apparatus, and is manufactured by Messrs. Murray and Heath, of 69, Jermyn Street. (N.B. Lane, of Hatton Garden, has patented one called "Mulum in Parvo," which looks promising, but does not answer very well for rough work, and depending, as it does, entirely on Mackintosh cloth, is ill suited for hot climates. Messrs. Murray and Heath are introducing a new miniature camera, to take pictures 4 inches by 3 inches, instead of 2½ inches square, which packs very conveniently; but the writer has had as yet no opportunity of trying it. It is a question for each traveller whether the greater size of the pictures compensates for having to carry twice the weight of glass or for the loss of the possibility of taking stereoscopic pictures.) The camera is a cube of about 3½ inches, and the ordinary landscape lens fits inside it when packed up. This is better for rough work than any folding camera, which becomes useless if a fold cuts or wears through. The dark slide in which the plates are carried contains two plates back to back, on each of which two pictures can be taken. The writer's experience is, that two such slides, or eight pictures, are amply sufficient for a day's work, unless it is really devoted to photographing. A bit of black velvet to cover the camera is the only other thing necessary during the day. The store-box of plates, out of which the slides are filled at night, and into which the used plates are returned, will, of course, remain with the baggage. Pedestrians who are apt to quit their heavy baggage for several days at a time will find it convenient to have a small zinc box to hold about a dozen plates. Such a box, when full, weighs some 18 ounces, and, with the two dark slides, furnishes an ample provision of plates for several days. No other apparatus is absolutely necessary, except a stand for the camera; but it is highly desirable to take a second lens, with which pictures can be taken more rapidly. The ordinary Grubb lens, which requires an average of four minutes' exposure for dry plates, is best for landscapes, but useless for portraits, and not well adapted for buildings; a Ross lens should therefore be taken also in a separate case. Very possibly the Steinheil or some other lens may be found to answer all purposes sufficiently well. The writer speaks only from his own experience. A little plate with a curved groove along it will make it possible to take stereoscopic pictures with this camera; and it is convenient to use this for views which are of sufficient importance to make a second attempt worth while. The whole of the above apparatus weighs less than 5½ lbs., and can be packed in a leather case measuring 7½ in. by 7½ in. by 4 in.

The stand is of very great importance, especially to the pedestrian, and various plans may be adopted according to the nature of the expedition. One rule, however, holds good in all cases: do not have the camera to screw directly to the stand, but let it screw on to a saddle-shaped clamp, to fit across the head of the stand, secured there by a set screw. The little clamp takes up no appreciable space, and the risk of the screw being injured on a

journey is removed. The stand may be an ordinary wooden tripod, which serves as a rather cumbrous walking-pole; a better thing is a small tripod, which fits round and serves to steady a pole with a flat head, over which the clamp goes. Such a tripod may be used alone when convenient, and is very handy on mountain tops, &c., where the height of the camera above the ground does not signify. The writer has carried such a tripod on an ice-axe, and finds that it interferes scarcely at all with the facility of using the axe. It might be adapted to any pole carried for other purposes, provided only the pole can have a flat head, or the clamp is altered accordingly.

The dry plates will keep almost any time before exposure, and for months after it, so that travellers may bring their plates home for development. But any one starting on a long journey will do well to learn how to develop his own plates (an easy thing enough), and carry with him the necessary apparatus, which weighs very little. Thus he will be able to see how he has succeeded, and correct the times of exposure accordingly; besides, the plates, when once developed, are safe from injury through accidental exposure to light.

The worst enemy of the dry-plate photographer is dust. He should not only keep his camera most carefully clean, wiping the lenses very frequently but also gently brush the plates over with a camel's-hair pencil whenever they are moved into the dark slides and back into the store-boxes. The boxes should be fastened up very carefully, both to exclude light and dust, and also to prevent their being opened by servants or through any inadvertency. It is, of course, necessary to keep a register of the views taken, and the best mode of doing this is by marking on each plate a number corresponding to that in the traveller's journal. This may be written at the time of changing in pencil on the rough back of the plate, but when it comes to be developed must be scratched on the corner of the collodion film. The dark slides should be numbered also for convenience of reference. The record of views taken ought to note, besides the date and subject, the hour, length of exposure, and state of weather.

The rules for determining the right length of exposure are simple in outline, but cannot be reduced to a formula. The operator must decide on the exact time required in each case by his own instinct; but the general principle is, that the greater amount of light received on the lens the more rapidly will the picture be printed; that is to say, a distant view requires less time than a near object, and an object bright in itself or brightly illuminated less than a dark object. Moreover, the amount of light diminishes in proportion to the distance from midday, and to the amount of cloud in the sky. As a rule, the morning is better than the afternoon; it seems also that as one goes higher the time of exposure tends to diminish. When in doubt, it is well to expose a little more: for if a plate is under-exposed, the picture is not there; if it is over-exposed, the picture is there, though more or less burnt, and a little management in developing will correct much of this.

There is no avoiding the ever-present difficulty that near and far objects, foreground and background, require, for perfection, different exposures. All we can do is to assimilate them as nearly as possible. If there is a great distance to be taken, choose a brightly-illuminated foreground: on a mountain top, for instance, prefer snow to rocks. Disturb the snow a little, if possible, to break its uniform surface; but rocks will not print themselves distinctly till the distance is burned. Similarly, it is impossible to obtain a satisfactory photograph of what is to the eye most attractive—a distant view framed in the branches of some closely overhanging tree; one must be sacrificed to the other. The scale ranges from a minute and a half, on snow, under a bright sun, for a very distant view—such, for instance, as one from the summit of Mont Blanc—to five minutes, or occasionally even more, for a deep ravine on a dull day, or a dark object very near at hand.

The outfit for an explorer should be:—

Camera with Grubb lens, }
 Ross lens, in a case, } or some equivalent.

Extra lenses should be taken for safety on long expeditions.

4 dark slides. (See that they all work easily in the camera, and keep them as much sheltered from the sun as possible to prevent their warping. It is desirable to keep them wrapped up in black or yellow cloth or oil-silk.)

1 small zinc store-box, as above.

Wooden store-boxes, as many as may be required: those of the size usually made hold 36 plates or 72 pictures each.

Stand, according to circumstances.

2 or 3 clamps to fix camera on stand.

Plate for taking stereoscopic views.

Some black velvet, and plenty of india-rubber bands for holding the velvet over the camera.

HINTS ON THE PROJECTION OF ROUTES. By Staff-Commander C. GEORGE, R.N., Curator of Maps R.G.S.

For outdoor or field work the easiest method is by the plane projection, the data thus obtained being transferred to a Mercator's projection at the first halt or stopping station.

In the plane projection one equal length is assigned to all the degrees of latitude and longitude. It was first adopted on the erroneous supposition that the earth's surface is a plane. It is still the best for the traveller to use in his early attempts to project his journey, while the objects are still in sight. This projection is available as far as 20° on either side of the Equator;—beyond the parallel of 20°, and as far as 60°, Mercator's projection is preferable;—between 60° and the Pole, the distortion of both the plane and Mercator's projection is so apparent, that a polar or circular projection must be adopted.

Sheets of paper ruled into squares by strong lines and subdivided by finer ones, afford great assistance in map work.

For *outdoor* work, the scale of 1 inch to 1 mile is amply large enough to register every particular of one day's journey on a sheet 12 inches square:—the *indoor* or table-plan may be reduced to 10 miles to the inch, and plans for transmission home may be again reduced to 1 inch to 1 degree, when the larger plans cannot be sent.

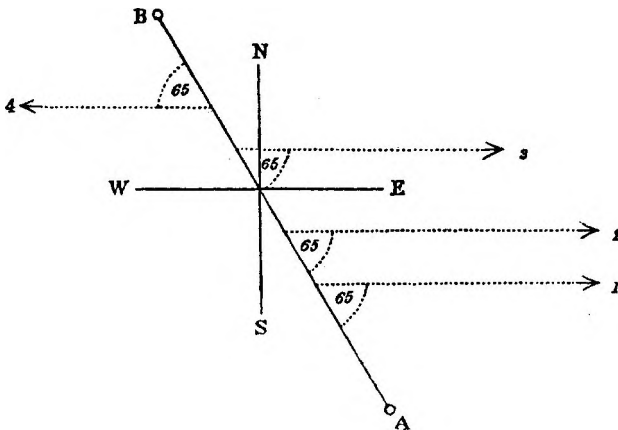
The chief point aimed at by the following directions is to draw more attention than has hitherto been given to the "*true bearing*" of objects, for the following reasons:—

- 1st. Any object whose true bearing is *east* or *west*, must be in the same **LATITUDE** as the place of the observer.
- 2nd. Any object whose true bearing is *north* or *south*, must be in the same **LONGITUDE** as the place of the observer.

While travelling in a northerly or southerly direction from a station whose latitude is known, and carefully noting the distance and direction travelled, it is only necessary to watch when objects come to the "true" east or west; and their latitude is obtained.

When travelling in an easterly or westerly direction from a fixed station, noting distance and direction, it is only necessary to watch when objects come to the true north or south, and their difference of longitude can be obtained, by using Table B, p. 62, from the station left.

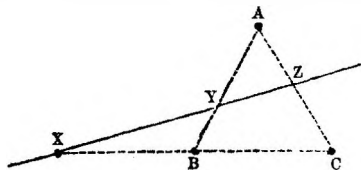
Thus, suppose a traveller passes from A, whose latitude is known, towards some distant hill, B; his route making an angle of 25° with the meridian. He sets his sextant to 65° ($65^\circ + 25^\circ = 90^\circ$), or to 115° ($180^\circ - 65^\circ$); then as the objects 1, 2, 3, and 4, successively come into contact with B or A, as the case may be, he ascertains with precision the moment when they are truly E. or W. of him; and so, knowing the distance he has travelled from A, he can readily calculate or protract their latitude.



When the traveller, as will frequently be the case, has to deviate from the line of route, his position can be determined by compass or true bearing of any object, and an angle to a second object. Or he may have recourse to transit observations; that is to say, whenever two fixed objects come in line, an angle to a third object will determine the position with great accuracy.

Observe, that in travelling along XYZ , the hills ABC can be mapped; for at X , or thereabouts, the bearing of B from C can be determined; at Y that of A from B ; and at Z that of A from C ; and so on for any number of hills. And it is very

important to recollect that it is not necessary to catch these lines of sight precisely; for by taking bearings twice, and the intermediate course approximately, there are sufficient data for



protracting out upon paper the required bearing. Thus, as soon as the peak of a distant hill is about to be occulted by the shoulder of a nearer one, a bearing should be taken; and again another one as soon as it has reappeared on the other side, and the intermediate course noted.

The advantage of this method of filling up a field-sketch will become more apparent as experience is gained. A third and accurate method of fixing the position is in general use among marine surveyors, but has hitherto been but little resorted to by land travellers, viz., by the angles subtended between three known objects. The instrument called the station-pointer is generally used for this purpose, but the position may also be found with a pair of compasses and a protractor, or, more simply, as follows, by means of a protractor and a sheet of tracing-paper. Draw a line through the centre of the paper; place the protractor on it near to the bottom of the sheet; lay off the right-hand angle to the right, and the left-hand angle to the left of the centre line; rule pencil-lines, radiating from the point over which the centre of the protractor has been placed, to the points that had been laid off; then place the paper on the plan or map, and move it about until the three lines coincide with the objects taken; prick through the points that lay beneath the centre of the protractor, and the observer's position is transferred to the plan. When possible, the centre object should be the nearest.

To Construct a Map on Mercator's Projection.

On a sheet of cartridge paper, 13 inches by 20, it is proposed to construct a map on Mercator's projection, on a scale of 10 miles to an inch equatorial—i. e. 6 inches to the degree of longitude.

$$\text{Limits of the Map } \left\{ \begin{array}{l} \text{Lat. } 31^{\circ} \text{ to } 33^{\circ} \text{ N.} \\ \text{Long. } 34^{\circ} \text{ to } 36^{\circ} \text{ E.} \end{array} \right.$$

Draw a base-line, find its centre, and erect a perpendicular to the top of the paper; the extremes of longitude 34° and 36°

added together and divided by 2, give 35° the central meridian, and which is represented by the perpendicular; on each side of it lay off 6 inches, and erect perpendiculars for the meridians 34 and 36; divide the base line into 10-mile divisions, and the part from $35^\circ 50'$ to $36^\circ 00'$ into miles for the latitude scale.

From Table A, take the following quantities:—

Lat. 31° to 32°	= $1^\circ 10'4$	=	the distance between parallels 31° and 32°
,, 32° to 33°	= $1^\circ 11'1$	,,	,, ,, 32° ,, 33°
	$2^\circ 21'5$	,,	,, ,, 31° ,, 33°

Having thus obtained the distances between the required parallels, divide the map into squares of 10 miles each way, and the map is ready for the projection of the route.

The following is to explain what has been said on the subject of "true bearing" and the traveller's route, also to exercise him in the use of his protracting instruments, in laying down his route and observations, &c., and to draw his attention to objects noticeable around him; the field of exploration is supposed to be Palestine, and by comparing his sketch, with a map of the same, he will at once see his proficiency. The following symbols have been used:—

\angle	's signifies angles.
\triangle	a station in the triangulation.
\odot	,, fixed by latitude.
\oplus	,, ,, longitude.
$\opl�$	,, ,, lat. and long.
\odot	,, ,, true bearing.
R. t.	,, ,, right tangent.
L. t.	,, ,, left ,,

The Field Book.

At No. 1 \triangle .

From a village on the bank of a river in lat. $31^\circ 00'$ N. and long. $35^\circ 17'$ E., proceeded to an elevated position No. 2, and camped; the route was N. 6. E. by compass, the variation being 6° westerly: distance 5 miles.

At No. 2 \triangle .

Early in the morning, when the sun was its own diameter above the horizon, measured with a sextant the angle between the northern limb of the sun and a distant high peak to the N.E.; the time being taken at the same moment, showed the watch to be about 5 min. slow.

With the azimuth compass several observations were made of N.E. peak; the needle being deflected after every observation, gave the mean reading of N. $36^\circ 40'$ E.; this object, of which the "true bearing" had been obtained, was, as is usually the case, then made "zero," and a round of sextant angles taken to conspicuous objects.

(A.)—TABLE TO CONSTRUCT MAPS ON MERCATOR'S PROJECTION.

	0	1	2	3	4	5	6	7	8	9
0		1 00	1 00.1	1 00.1	1 00.1	1 00.2	1 00.3	1 00.4	1 00.5	1 00.6
10	1 00.9	1 01	1 01.2	1 01.5	1 00.7	1 02	1 02.2	1 02.6	1 02.9	1 03.3
20	1 03.6	1 04.1	1 04.5	1 04.9	1 05.5	1 05.9	1 06.5	1 07	1 07.7	1 08.2
30	1 09	1 09.6	1 10.4	1 11.1	1 12	1 12.8	1 13.7	1 14.6	1 15.7	1 16
40	1 17.6	1 19	1 20.1	1 21.4	1 22.7	1 24.2	1 25.6	1 27.1	1 28.8	1 30.6
50	1 32.4	1 34.3	1 36.4	1 38.6	1 40.8	1 43.4	1 45.9	1 49	1 51.4	1 54.8
60	1 58.3	2 01.8	2 05.8	2 09.9	2 14.5	2 19.14	2 24.7	2 30.5	2 36.8	2 43.8
70	2 51.3	2 59.8	3 09.1	3 19.6	3 31.3	3 44.6	3 59.8	4 17.1	4 37.4	5 01.1
80	5 29.5	6 03	6 46.4	7 40.3	8 51.1	10 27.7	12 47.9	16 29.6	23 4.3	39 42.2

USE OF THE TABLE.

Find in the Table the required parallel: the tens at the side, and the units at the top. At their intersection, will be found, in degrees and minutes, the distance of the required parallel from the next less degree; to be measured from the scale of longitude on the map in progress.

Given the parallel of 30°—required that of 31°.

30 at the side, and 1 at the top, intersects at 1° 09'6, the required distance of the two parallels.



Given the parallel of 31°—required that of 33°.

$$32^\circ = 1^\circ 10'4$$

$$33^\circ = 1^\circ 11'1$$

2° 21'5 the distance between the 31° and 33° parallel.

\angle 's and Observations.

Latitude by \odot 's N. and S. of zenith	31 ⁸ 5' 30" N.	
True bearing of N.E. peak	N. 30 40 E.	
Compass	N. 36 40 E.	ϕ
For height of Δ . Temp. of boiling-water 208 ⁶ . Aneroid 28 ¹⁶		
Temp. of air (in shade)	71 ⁰⁰	
N.E. peak, and r. t. of lake to the eastward	53 40	
" near point on opposite side of lake	22 00	
Two conical peaks in line and N.E. peak	30 40	
Village on the sea-coast	85 05	
Direction of this range	102 30	
L. t. of near range	110 30	
R. t.	30 40	

Remarks at this Δ . In the direction of N. 6 E. by compass were noticed two distant conical peaks in line, which at once determined the direction of route; it was also observed that the near range in the direction of the line of route was higher than No. 2 Δ , and on the way three streams would have to be crossed.




Proceeded onwards—

At No. 1 stream, \angle between conical peak and N.E. peak	31 ⁸ 10'
" No. 2	32 00
" No. 3	35 15
All these streams run eastward, towards the lake.	

Arrived at the foot of No. 3 Δ , encamped for the night; had travelled, by estimation, N. 6 E. 12 miles. Observed for lat.

At No. 3 Δ , top of Range.

The morning amplitude was not obtained, the sun being obscured by clouds; waited half an hour until the sun had risen 15°, and then obtained a set of azimuth observations.

Latitude by \odot 's N. and S. of zenith	31 ⁸ 14' N.	
True bearing of N.E. peak	N. 37 10 E.	
Compass bearing	N. 43 10 E.	
N.E. peak, and the low range of yesterday 125° 0' to 174 30		
" and r. t. of lake	88 00	
β point on opposite shore of lake	53 30	
" tongue point in lake stretching northward	23 30	
No. 1 village on sea-coast and N.E. peak	101 50	
No. 2	63 00	
Direction of this range	153 30	

Remarks.—This bearing (β) is east true, therefore the point on opposite side of lake is in the same lat. as Δ No. 3, and having been crossed by a true bearing from No. 2 Δ , it becomes a fixed point.

From this \angle was obtained a good view of the lake (see Sketch-book) for that portion to the southward of east; from thence it appeared to run northerly, somewhat parallel to the line of route, with a breadth of 8 or 10 miles, and numerous feeders running into it from both sides, and nearly at right angles to the coast-line of the lake. In the direction of the intended route-line there appeared a great number of streams, all of which will be fixed

by angle between the conical peaks in line and N.E. peak; the line of route was kept by measuring angle between the third Δ and the conical peaks, subtending \angle of 180° .

Travelled on for the next two days, crossed several streams and fixed them; they apparently rose on the high land to the westward, and all running towards the lake; made about 25 miles northing, and then arrived at the nearest of the two conical peaks that had been kept in line.

At No. 4 Δ South Conical Peak.

Lat. by \odot 's N. and S. of zenith	.. .. .	.. .. .	31 41 N. \odot
True bearing of N.E. peak	.. .. .	.. .. .	.. N.76 0 E. \odot
Compass	.. .. .	.. .. .	.. N.82 0 E.
For height of Δ . B. W.	208 ^o 30.	Aneroid	.. .. 28 ^o 00
Temp. of air	.. .. .	.. .. .	.. .. 67 ^o 00
North conical peak to N.E. peak	.. .. .	.. .. .	.. .. 76 ^o 00
No. 1 village on sea-coast and N.E. peak	.. .. .	.. .. .	.. .. 180 ^o 20
No. 2	.. .. .	.. .. .	.. .. 124 ^o 10
Large town to northward on the western slope of the			} 78 ^o 10
North conical peak and N.E. peak	.. .. .	.. .. .
Mouth of large river falling into northern end of lake,			} 4 ^o 10
and N.E. peak	.. .. .	.. .. .

Remarks.—This was the highest Δ yet visited. From it were seen several rivers running from the high range westward of the line of route towards the sea, therefore it is the dividing range between the lake and the sea.

Travelled on 6 miles to the northernmost of the two conical peaks, taking care to keep in line between the conical peaks, and when there make it a recruiting Δ , and visited the town on the western slope.

 \angle 's at No. 5 Δ North Conical Peak.

Lat. by \odot 's N. and S. of zenith	.. .. .	.. .. .	31 46 N. \odot
True bearing of N.E. peak	.. .. .	.. .. .	.. N.90 00 E. \odot
Compass	.. .. .	.. .. .	.. S.84 00 E.
For height of Δ . B. W.	207 ^o 00.	Aneroid	.. .. 27 ^o 18
Temp. of air	.. .. .	.. .. .	.. .. 69 ^o 00
A sharp peak and N.E. peak	.. .. .	.. .. .	.. .. 33 ^o 25
N.E. peak and No. 3	.. .. .	.. .. .	.. .. 90 ^o 00
Tangents of distant range running this way, and N.E. peak			} 95 ^o 30
A point on the sea-coast and N.E. peak	.. .. .	.. .. .		.. .. 102^{o}00
N.W. peak, and N.E. peak	.. .. .	.. .. .	.. .. 87 ^o 15
„ a sharp peak	.. .. .	.. .. .	.. .. 53 ^o 50

Remarks.—Finding by the true bearing that N.E. peak was in the same latitude as this Δ No. 5, the line of route was altered to go to N.E. peak.

At 10 miles' distance travelled, observed that the west shores of the lake were south true \odot .

At 16 miles travelled, arrived at the mouth of a river seen from No. 4 Δ running into the lake from the north.

Hints to Travellers. \angle 's at Mouth of River.

Eastern shores of the lake	South (true) \odot
No. 3 Δ , and last Δ No. 5	63°30'
Last Δ No. 5, and run of large river, running north	92°40'
Distant range to the n.w., runs to this Δ , \angle to	} 64°30'
No. 5 Δ	

Travelled on to the n.e. peak, or No. 6 Δ .

 \angle 's at No. 6 Δ N.E. Peak.

Distance travelled from No. 5 Δ , 24 miles east (true).

Lat. by \odot 's n. and s. of zenith	31° 46½' \ominus
True bearing of sharp peak to northward	n. 3 30 e.
Compass	n. 9 30 e.
For height of Δ . B.W. 211°00'. Aneroid	29°42'
Temp. of air	73°00'
No. 5 Δ and sharp peak	93°30'
No. 3 Δ and No. 5	52°50'
N.W. peak and sharp peak	24°50'
„ No. 5 Δ	68°40'

Proceeded northward to sharp peak No. 7 Δ ; travelled 17 miles, crossed several streams, apparently the feeders to the large river running northward, fixed them by angles subtended between No. 5 Δ and No. 6 Δ .

 \angle 's at No. 7 Δ Sharp Peak.

Lat. by \odot 's n. and s. of zenith	32° 03½' \ominus
True bearing of a peak n.w.	n. 30 30 w. \odot
Compass	n. 24 30 w.
For height of Δ . B.W. 202°00'. Aneroid	24°58'
Temp. of air	74°00'
N.W. peak, and flat-top mountain	49°20'
„ No. 6 Δ	145°35'
No. 5 Δ and n.w. peak	92°30'

Travelled on towards n.w. peak; at 15 miles came to the large river running to the south.

 \angle 's at Large River.

N.W. peak, and flat-top mountain	92° 20'
Flat top mountain, and No. 7 Δ	90° 40'

At the distance of 26 miles, observe that No. 7 to flat-top mountain measured 59° 30' \ominus .

At 30 miles' distance came to an elevated Δ , when the south end of a range to the westward measured 59° 30' to n.w. peak, this gave the lat. of that part of the range, and at 44 miles came to n.w. peak.

 \angle 's at No. 8 Δ , or N.W. Peak.

Lat. by \odot 's n. and s. of zenith	32° 42 n. \ominus
True bearing of flat-top mountain	s. 60 30 e. \odot
Compass	s. 55 0 e.

For height of Δ . B. W. 210°50	Aneroid	.. ..	29°00
Temp. of air	.. ..	.. ..	76°00
S. end of a lake to the east, and flat-top mountain	..	..	29°30
No. 5 Δ , and sharp peak No. 7 Δ	.. ..	.. ..	33°40
.. ..	.. ..	.. ..	24°05
No. 5 " and point on sea-coast	.. ..	.. ..	113°00
.. t's of near range	.. ..	.. ..	{ 100°50
			{ 26°30

Travelled east (true) towards the lake.

At 15 miles came to the lake, out of which flowed the large river going to the south. Height by B.W. = 213°25°.

Considering the large size of this river, and having already fixed the extreme and a midway Δ , decided upon returning southward and examine the river on the route back.

\angle 's at South side of Lake on West bank of River.*

No. 8 Δ and No. 7	.. ..	.. ..	99° 10'
No. 7 Δ and flat-top	.. ..	.. ..	32° 00'

\angle 's at large Affluent from the Eastward.

No. 8 Δ , and No. 7	.. ..	.. ..	118° 40'
No. 7 Δ ,, flat-top	.. ..	.. ..	39° 50'

\angle 's at large Affluent from the Westward.

Same objects	.. ..	.. ..	{ 146° 00'
			{ 58° 10'

\angle 's at large Affluent from the Eastward.

Same objects	.. ..	.. ..	{ 79° 00'
			{ 94° 30'

\angle 's at sharp Bend of River.

No. 7 Δ due east (true)	.. ..	.. ..	° \ominus'
No. 8 Δ , and No. 7 Δ	.. ..	.. ..	104° 10'
No. 7 Δ , and No. 6 Δ	.. ..	.. ..	67° 30'

Arrived at former Δ , river running into lake from the northward. Height by B.W. = 214°5°.

* These angles projected on a piece of *tracing-paper* will form a very good station-pointer, to determine this and the following Δ 's.

(B.)—GIVEN THE DEPARTURE, TO FIND THE DIFFERENCE OF LONGITUDE.

	0	1	2	3	4	5	6	7	8	9
0		1·0001	1·0006	1·0013	1·0026	1·0038	1·0055	1·0075	1·0098	1·0125
10	1·0154	1·0187	1·0224	1·0261	1·0306	1·0353	1·0403	1·0457	1·0514	1·0578
20	1·0642	1·0711	1·0785	1·0864	1·0946	1·1034	1·1126	1·1224	1·1326	1·1434
30	1·1547	1·1666	1·1792	1·1924	1·2062	1·2208	1·2361	1·2521	1·2690	1·2868
40	1·3054	1·3250	1·3456	1·3673	1·3902	1·4142	1·4395	1·4663	1·4945	1·5242
50	1·5557	1·5890	1·6242	1·6616	1·7013	1·7435	1·7883	1·8361	1·8871	1·9416
60	2·0000	2·0626	2·1301	2·2027	2·2812	2·3662	2·4586	2·5593	2·6695	2·7904
70	2·9238	3·0716	3·2361	3·4204	3·6280	3·8637	4·1337	4·4454	4·8097	5·2406
80	5·7587	6·3925	7·1856	8·2057	9·5664	11·475	14·334	19·108	28·653	57·307

USE OF THE TABLE.

Find in the Table the required parallel, the tens at the side and the units at the top: at their intersection will be found a quantity which, multiplied by the departure, gives the "diff. of longitude."

The departure from the meridian on the parallel of 34° was 25 miles—required the diff. of longitude.

$$25' \times 1.20 = 30' 00 \text{ the diff. of longitude.}$$

In the parallel of 60° the departure was 30 miles.

$$30' \times 2 = 60 \text{ miles, or 1 degree.}$$

In the parallel of 35° N. the route was N. 40 W., 37 miles' distance.

By Traverse Table, 40° course, $37 = 23.8 \times 1.22 = 29.03$, diff. of longitude.

TABLE FOR ROUGH TRIANGULATION WITHOUT THE USUAL INSTRUMENTS AND WITHOUT CALCULATION. By FRANCIS GALTON, F.R.S.

A traveller may ascertain the breadth of a river, or that of a valley, or the distance of any object on either side of his line of march, by taking about 60 additional paces and by making a single reference to the Table on the following page.

Suppose he is travelling from A to Z (Fig. I.), and wishes to learn the distance from A to C; and, it may be, also the angle A. Let him proceed as follows (referring now to Fig. II.).

1. Leave a mark at A. 2. Walk 10 paces towards Z, and make a mark, calling the place *m*. 3. Walk back to A. 4. Walk 10 paces towards C. 5. Walk to *m*, counting the paces to the nearest half-pace. (This gives the measurement of the line *a* (Fig. I.), which is the chord of the angle A, to radius 10.) 6. Walk 80 paces towards Z; make a mark, calling the place *B*; this completes 100 paces from A. 8. Walk 10 paces towards C. 9. Walk to *n*, counting the paces to the nearest half-pace. (This gives the line *b*, which is the chord of the angle B, to radius 10.)

Now enter the Table with *a* at the side and *b* at the top, and read off the distance A C, and the Angle A if also required.

If the Table be entered with *b* at the side and *a* at the top, it gives B C (and B).

Of course the units need not be paces: feet, furlongs, miles, hours' journey, or anything else will do, as well; and the units of A B need not be the same as those of *a* and *b*. Also any multiple or divisor of 100 for A B may be used, if the tabular number be similarly multiplied.

EXAMPLES.

<i>a</i> (in paces).	<i>b</i> (in paces).	A B.	A C.	Angle A.		B. C.	Angle B.	
				°	'		°	'
5	6½	100 paces	67 paces	28	58	53 paces	37	56
5	6½	50 miles	33½ miles	28	58	26½ miles	37	56
10½	7	100 paces	68 paces	63	22	92 paces	41	0
10½	7	1000 paces	680 paces	63	22	920 paces	41	0

Particular care must be taken to walk in a straight line from A to B. It will surprise most people, on looking back at their track, to see how curved it has been, and how far B *n* is from

TABLE for rough Triangulation without the usual Instruments and without Calculation. By FRANCIS GALTON, F. R.S.

	ANGLE.	5	6	7	8	9	10	11	12	13	14
		0 $\frac{1}{2}$	0 $\frac{1}{2}$	0 $\frac{1}{2}$	0 $\frac{1}{2}$	0 $\frac{1}{2}$	0 $\frac{1}{2}$	0 $\frac{1}{2}$	3 $\frac{1}{2}$	0 $\frac{1}{2}$	0 $\frac{1}{2}$
5 $0 \frac{1}{2}$	0	57 60	64 67	70 73	75 78	81 84	87 89	92 95	98 101	105 109	113 118
	28 58 31 56	55 59	62 65	69 72	74 78	81 84	87 90	93 96	100 103	107 112	116 122
6 $0 \frac{1}{2}$	34 56	54 57	61 64	68 71	74 77	80 84	87 90	94 97	101 105	110 115	120 126
	37 56	53 56	60 63	67 70	74 77	80 84	87 91	95 99	103 108	113 119	125 132
7 $0 \frac{1}{2}$	41 0	52 55	59 63	66 70	73 77	81 85	88 92	96 101	106 111	117 123	130 139
	44 4	51 55	58 62	66 70	73 77	81 85	89 94	98 103	109 114	121 128	136 146
8 $0 \frac{1}{2}$	47 10	50 54	58 62	66 70	74 78	82 86	91 95	101 106	112 118	126 134	144 156
	50 20	49 53	57 61	65 70	74 88	83 88	92 98	103 109	116 123	132 141	153
9 $0 \frac{1}{2}$	53 30	49 53	57 61	66 70	75 79	84 89	94 100	106 113	121 129	139 150	
	56 4	49 53	57 62	66 71	76 81	86 91	97 103	110 118	126 136	147	
10 $0 \frac{1}{2}$	60 0	48 53	57 62	67 72	77 82	88 94	100 107	115 123	133 145		
	63 22	48 53	58 63	68 73	78 84	90 97	104 112	120 130	141 154		
11 $0 \frac{1}{2}$	66 44	49 53	58 64	69 74	80 86	93 100	108 117	127 138			
	70 12	49 54	59 65	70 76	83 89	97 105	113 124	135 147			
12 $0 \frac{1}{2}$	73 46	50 55	60 66	72 79	85 93	101 110	120 131				
	77 22	50 55	62 68	75 81	89 98	106 117	128 141				
13 $0 \frac{1}{2}$	81 6	52 57	64 70	77 85	93 103	113 125	138 155				
	84 56	53 59	66 73	81 90	99 109	121 135	150				
14 $\frac{1}{2}$	88 52	55 62	69 77	85 95	106 118	132 148					
	92 56	57 65	73 81	91 102	114 129	145					
15 $0 \frac{1}{2}$	97 10	60 68	77 87	99 110	126 143						
	101 36	64 73	83 95	108 123	141						
16 $0 \frac{1}{2}$	106 16	60 79	90 105	121 140							
	111 12	76 88	103 120	141							

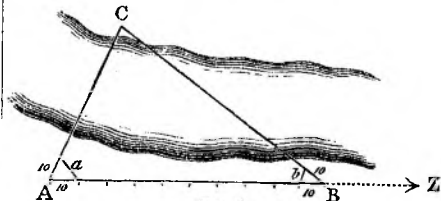


FIG. I.



FIG. II.

To find A C and angle A:—Enter with α at the side and b at the top.

To find B C and angle B:—Enter with b at the side and α at the top.

pointing truly towards A. It is always well to sight some distant object in a line with Z when walking towards it.

The triangle A B C must be so contrived that none of its angles are less than 30° , or the chords of the angles at A and B will not be found in the Table. These cases cease to give reliable results when the measurements are rudely made, and have therefore been omitted.

Should a traveller have no Tables by him, he can always *protract* his measurements to a scale on a sheet of paper, or even on the ground, and so solve his problem. If real accuracy be aimed at, it is clear that it may be obtained by careful measurements of the base and chords, combined with a rigorous calculation, as was first suggested by Sir George Everest, formerly Surveyor-General of India. (See 'Journ. R. Geog. Soc.,' 1860, p. 122.)

MEASUREMENT OF THE NUMBER OF CUBIC FEET OF WATER CONVEYED BY A RIVER IN EACH SECOND.

The data required are—the area of the river-section and the average velocity of the whole of the current. All that a traveller is likely to obtain, without special equipment, is the area of the river-section and the average velocity of the *surface* of the current, which is less than that of its entire body, owing to frictional retardation at the bottom.

To make the necessary measurements, choose a place where the river runs steadily in a straight and deep channel, and where a boat can be had. Prepare a few floats, of dry bushes with paper flags, and be assured they will act. Post an assistant on the river-bank, at a measured distance, of about half the estimated width of the river, down stream, in face of a well-marked object. Row across stream in a straight line, keeping two objects on a line in order to maintain your course. Sound at intervals from shore to shore, fixing your position on each occasion, by a sextant-angle between your starting-place and your assistant's station, and throw the floats overboard, signalling to your assistant when you do so, that he may note the interval that elapses before they severally arrive opposite to him. Take an angle from the opposite shore, to give the breadth of the river.

To make the calculation approximately, *protract* the section of the river on a paper ruled to scale in square feet, and count the number of squares in the area of the section. Multiply this by the number of feet between you and the assistant, and divide

by the number of seconds that the floats occupied, on an average, in reaching him.

Important rivers should always be measured above and below their confluence; for it settles the question of their relative sizes, and throws great light on the rainfall over their respective basins. The sectional area at the time of highest water, as shown by marks on the banks, and the slope of the bed ought also to be ascertained.

EXAMPLE.

DISTANCE FROM SHORE.	Start- ing- place.									Oppo- site Shore.	
Whence the boat started, mea- sured in feet }	0	90	160	240	330	420	500	600	700	780	
Depth at those distances mea- sured in feet. }	0	2	3½	4	4	5½	7	6½	3½	0	
Time required for float to drift opposite to assistant, mea- sured in seconds }	—	48	50	40	33	29	27	30	50	—	Ave- rage. 38·4

Distance of assistant, in feet, 150.

By protracting the data in the first two lines, on ruled paper as described above, it will be found that the area of the section is 3260 feet or thereabouts; this, multiplied into 150, gives 489,000 cubic feet of water as the contents of the river at any given moment between the line of soundings and the assistant. As this amount passes by in 38·4 seconds, the number of cubic feet per second is the former number divided by the latter, which gives 12,734.

It must be distinctly understood that this number is only roughly approximative, and that is excessive. However, with the above data, an engineer would be able to make a somewhat better calculation. In the meanwhile, the traveller might consider the flow of the river in question, to be between 10,000 and 13,000 feet per second.

PAPER SQUEEZES OF INSCRIPTIONS. By the Rev. F. W.
HOLLAND.

Some paper for "squeezes" should be taken, where inscriptions are likely to be met with. Many kinds of paper are suitable for this purpose, but that used by engravers is perhaps the best, since it combines a good substance and strength, with sufficient power of absorption. The process of taking squeezes is very simple. All dust or dirt should first be removed from the inscription with a rough brush. The paper should then be cut

to the requisite size, and laid upon it. With a soft close-haire brush, like a hat-brush, water should now be sprinkled upon the paper, and when thoroughly wetted, the brush should be used to press it into every portion of the inscription, so that a perfect impression may be taken. The paper should be left upon the inscription until thoroughly dry, and may then be rolled up without fear of spoiling the "squeeze." When the paper is thin, several sheets may be added, with the use of paste or rice-water, until sufficient substance be obtained. I have in this way taken excellent squeezes with merely whitey-brown paper. A store of paper, a few brushes, and a pair of large scissors for cutting the paper, are all the materials that are required.

HINTS ON THE COLLECTION OF OBJECTS OF NATURAL HISTORY.
By H. W. BATES, Assistant Secretary R.G.S.

Travellers who intend devoting themselves specially to Natural History will generally possess all the requisite information beforehand. It is to those whose objects or duties are of another nature, or who, whilst on a purely geographical land-exploration, wish to know the readiest means of collecting, preserving, and safely transmitting specimens they collect that the following hints are addressed :—

Outfit.—Double-barrel guns, with spare nipples; and a few common guns to lend to native hunters—especially if going to the interior of Tropical America.

Fine powder in canisters, and fine shot (Nos. 8 and 11), must be taken from England: coarse powder and shot can be had in any part. A good supply of the best caps.

Arsenical soap, a few pounds in tin cases; brushes of different sizes.*

Two or three scalpels, scissors (including a pair of short-bladed ones), forceps of different sizes, for inserting cotton into the necks of birds' skins; needles and thread.

A few small traps, with which to capture small (mostly nocturnal) mammals.

Strong landing-net for water mollusks, &c. Two stout insect *sweeping-nets*.

* Most of the articles of a Naturalist's outfit can be obtained, at a few days' notice, of Mr. F. T. Higgins, Natural History Agent, 24, Bloomsbury-street, W.C.

Cylindrical tin box for collecting plants, with shoulder-strap.

A few dozens of small and strong broad-mouthed bottles; and a couple of corked pocket-boxes.

Insect-pins; a few ounces of each Nos. 5, 14, and 11.

Stone jars for reptiles and fishes in spirit; to fit four in in a box, with wooden partitions. If animals in spirit are to be collected largely, a supply of sheet-tin or zinc, with a pair of soldering-irons and a supply of soft solder, must be taken instead of stone jars. Cylindrical cases can be then made of any size required. By means of the soldering apparatus, also, empty powder-canisters and other tin vessels can be easily converted into receptacles for specimens.

A ream or two of botanical drying-paper, with boards of same size as the sheet, and leather straps.

A few gross of chip pill-boxes in nests.

A dozen corked store-boxes (about 14 inches by 11 inches, and $2\frac{1}{2}$ inches deep), fitted perpendicularly in a tin chest.

A few yards of india-rubber waterproof sheeting, as temporary covering to collections in wet weather, or in crossing rivers.

A set of carpenter's tools.

An outfit may be much lightened by having all the provisions and other consumable articles packed in square tin cases, and in boxes and jars of such forms as may render them available for containing specimens. If the traveller is going to the humid regions of the Indian Archipelago, South-eastern Asia, or Tropical America, where excessive moisture, mildew, and ants, are great enemies to the naturalist, he should add to his outfit two drying-cages; for everything that is not put at once into spirits is liable to be destroyed before it is dry enough to be stowed away in boxes. They may be made of light wood, so arranged as to take to pieces and put together again readily; one, for birds, should be about 2 feet 6 inches long by 1 foot 6 inches high and 1 foot broad; the other, for insects and other small specimens, may be about one-third less. They should have folding doors in front, having panels of perforated zinc, and the backs wholly of the latter material; the sides fitted with racks to hold six or eight plain shelves, which, in the smaller cage, should be covered with cork or any soft wood that may be obtained in tropical countries. A strong ring fixed in the top of the cage, with a cord having a hook attached at the end by which to hang it in an airy place, will keep the contained

specimens out of harm's way until they are quite dry, when they may be stowed away in close-fitting boxes. If this plan be not adopted, it will be almost impossible to preserve specimens in these countries.

Collecting.—The countries which are now the least known with regard to their Natural History, are New Guinea, and the large islands to the east of it, Northern Australia, the interior of Borneo, Thibet, and other parts of Central Asia, Equatorial Africa, and the eastern side of the Andes from east of Bogota to the south of Bolivia. In most of the better known countries the botany has been better investigated than the zoology, and in most countries there still remains much to be done in ascertaining the exact station, and the range, both vertical and horizontal, of known species. This leads us to one point, which cannot be too strongly insisted on, namely, that some means should be adopted by the traveller to record the exact locality of the specimens he collects. In the larger dried animals, this may be done by written tickets attached to the specimens; in pinned insects, a letter or number may be fixed on the pins of all specimens taken at one place and time—the mark to refer to a note-book. The initial letter, or first two or three letters of the locality, is perhaps the readiest plan; and when all the specimens taken at one place can be put into a separate box, one memorandum upon the box itself will be sufficient. Reptiles and fishes can have small parchment tickets attached to them before placing in spirits.

A traveller may be puzzled, in the midst of the profusion of animal and vegetable forms which he sees around him, to know what to secure and what to leave. Books can be of very little service to him on a journey, and he had better at once abandon all idea of encumbering himself with them. A few days' study at the principal museums before he starts on his voyage may teach him a great deal, and the cultivation of a habit of close observation and minute comparison of the specimens he obtains will teach him a great deal more. As a general rule, all species which he may meet with for the first time far in the interior, should be preferred to those common near the civilized parts. He should strive to obtain as much variety as possible, and not fill his boxes and jars with quantities of specimens of one or a few species. But, as some of the rarest and most interesting species have great resemblance to others which may be more common, he should avail himself of every opportunity of comparing the objects side by side. In most tropical countries the species found in open and semi-cultivated places are much less interesting than those inhabiting the interior of the forests, and it generally happens that the few

handsome kinds which attract the attention of the natives are species well known in European museums. In botany, a traveller, if obliged to restrict his collecting, might confine himself to those plants which are remarkable for their economical uses; always taking care to identify the flowers of the tree or shrub whose root, bark, leaves, wood, &c., are used by the natives, and preserving a few specimens of them. But, if he is the first to ascend any high mountain, he should make as general a collection of the flowering plants as possible, at the higher elevations. The same may be said of insects found on mountains, where they occur in great diversity—on the shady and cold sides rather than on the sunny slopes—under stones, and about the roots of herbage especially near springs, on shrubs and low trees, and so forth; for upon a knowledge of the plants and insects of mountain ranges depend many curious questions in the geographical distribution of forms over the earth. In reptiles, the smaller Batrachia (frogs, salamanders, &c.,) should not be neglected, especially the extremely numerous family of tree-frogs; lizards may be caught generally with the insect sweeping-net; the arboreal species seen out of reach may be brought down with a charge of dust-shot. Snakes should be taken without injuring the head, which is the most important part of the body; a cleft stick may be used in securing them by the neck, and on reaching camp they may be dropped into the jars of spirits. As large a collection as possible should be made of the smaller fishes of inland lakes and unexplored rivers; Dr. Gunther, of the British Museum, has authorized me to say that a traveller cannot fail to make a large number of interesting discoveries if he collects a few specimens of the species he meets with in the lakes and rivers of the interior of any country.

It can scarcely be expected that specimens of the larger animals can be brought away by a geographical expedition, although some species are still desiderata in the large museums of Europe. Additional specimens of all genera, of which there are numerous closely-allied species (*e.g.* rhinoceros, antelope, equus, &c.) would be very welcome for the better discrimination of the species. If only portions can be obtained, skulls are to be preferred. In humid tropical regions entire skins cannot be dried in time to prevent decay, and it is necessary to place them, rolled up in small compass, in spirits. The smaller mammals, of which there remain many to reward the explorer in almost all extra-European countries, may be skinned, dried, and packed in boxes in the same manner as birds. The smaller birds shot on an excursion should be carried to camp in the game-bag, folded in paper, the wounds, mouth, and anus

being first plugged with cotton. Powdered calcined gypsum will here be found very useful in absorbing blood from feathers, on account of the facility with which it can be afterwards cleared from the specimens. All plants, when gathered, are placed in the tin box which the traveller carries with him. Land and fresh-water shells may be carried home in a bag. All hard-bodied insects, such as beetles, ants, and so forth, should be placed, in collecting, in small bottles; each bottle having a piece of slightly-moistened rag placed within it, to prevent the insects from crowding and injuring each other. The hint previously given with regard to number of specimens must be repeated here. *Take as great a variety of species as possible.* The sweeping-net should be freely used (except in very wet weather) in sweeping and beating the herbage and lower trees. In collecting ants, it is necessary to open nests and secure the winged individuals of each species, which must be afterwards kept together with the wingless ones to secure the identification of the species. Bees and wasps may be caught in the net and then placed by means of small forceps in the collecting-bottle and afterwards killed in the same way as beetles and other hard-bodied insects. All soft-bodied insects should be killed on capture (by a slight pressure of the chest underneath the wings by thumb and finger) and then pinned in the pocket collecting-box. If the traveller has leisure and inclination for the pursuit, he may readily make a large and varied collection of these, and will do good service to science if he notes carefully the exact localities of his captures, altitude above the sea, nature of country, the sexes of the species (if detected), and information on habits. The delicate species should be handled very carefully and put away into the drying-cage immediately on return from an excursion. Spiders may be collected in bottles, and afterwards killed and pinned in the same way as other insects. Crustacea (shrimps, crawfish, &c.) in rivers and pools may be collected with the landing-net and afterwards well dried and pinned like hard-bodied insects except when they are large in size, when their bodies must be opened and emptied of their contents.

Preserving and Packing.—Previous to skinning a small mammal or bird, make a note of the colour of its eyes and soft parts, and, if time admits, of the dimensions of its trunk and limbs. It facilitates skinning of birds to break, before commencing, the first bone of the wings a short distance above the joint, which causes the members to lie open when the specimen is laid on its back on the skinning-board. The animal should be laid with its tail towards the right hand of the operator, and the incision made from the breast-bone nearly to the anus. A

blunt wooden style is useful in commencing the operation of separating the skin from the flesh. When the leg is reached, cut through the knee-joint and then clear the flesh from the shank as far as can be done, afterwards washing the bone slightly with arsenical soap, winding a thin strip of cotton round it and returning it to the skin. Repeat the process with the other leg, and then sever with the broad-bladed scissors the spine above the root of the tail. By carefully cutting into the flesh from above, the spine is finally severed without injuring the skin of the back, and it is then easy to continue the skinning up to the wings, when the bones are cut through at the place where they had previously been broken and the body finished as far as the commencement of the skull. A small piece of the skull is now cut away, together with the neck and body, and the brains and eyes scooped out, the inside washed with the soap, and clean cotton filled in, the eyes especially being made plump. In large-headed parrots, woodpeckers, and some other birds, the head cannot thus be cleaned; an incision has, therefore, to be made either on one side or on the back of the neck, through which the back of the skull can be thrust a little away and then cleaned, the incision being afterwards closed by two or three stitches. The bones then remaining in each wing must be cleaned, which must be done without loosening the quill-feathers. It is much better to take out the flesh by making an incision on the outside of the skin along the flesh on the inner side of the wing. The inside of the skin must now be washed with the soap, and a neck of cotton (not too thick) inserted by means of the long narrow forceps, taking care to fix the end well inside the skull and withdrawing the empty forceps without stretching the skin of the neck and thus distorting the shape of the bird. Skins need not be filled up with cotton or any other material, but laid, with the feathers smoothed down, on the boards of the drying-cage until they are ready to be packed in boxes. In very humid climates, like that of Tropical America, oxide of arsenic in powder is preferable to arsenical soap, on account of the skins drying quicker; but it cannot be recommended to the general traveller, owing to the danger attending its use.

In mammals the tail offers some difficulty to a beginner. To skin it, the root (after severing it from the spine) should be secured by a piece of strong twine, which should then be attached to a nail or beam; with two pieces of flat wood (one placed on each side of the naked root), held firmly by the hand and pulled downwards, the skin is made rapidly to give way generally to the tip. The tails of some animals, however, can be skinned only by incisions made down the middle from the

outside. The larger mammal skins may be inverted, and, after washing with the soap, dried in the sun : as before remarked, it is often necessary to roll them up and preserve in spirit.

The skins of small mammals and birds, after they are *quite* dry, may be packed in boxes, which must be previously well washed inside with arsenical soap, lined with paper and again covered with a coating of the soap and well dried in the sun. This is the very best means of securing the specimens from the attacks of noxious insects, which so often, to the great disgust of the traveller, destroy what he has taken so much pains to procure. Where wood is scarce, as in the interior of Africa, boxes may be made of the skins of antelopes or other large animals by stretching them, when newly stripped from the animal, over a square framework of sticks, and sewing up the edges ; after being dried in the sun they make excellent packing-cases.

With regard to reptiles and fishes, I cannot do better than quote the following remarks sent to me by Mr. Osbert Salvin, who collected these animals most successfully in Guatemala :—

“ Almost any spirit will answer for this purpose, its fitness consisting in the amount of alcohol contained in it. In all cases it is best to procure the strongest possible, being less bulky, and water can always be obtained to reduce the strength to the requisite amount. When the spirit sold retail by natives is not sufficiently strong, by visiting the distillery the traveller can often obtain the first runnings (the strongest) of the still, which will be stronger than he requires undiluted. The spirit used should be reduced to about proof, and the traveller should always be provided with an alcoholometer. If this is not at hand, a little practice will enable him to ascertain the strength of the spirit from the rapidity with which the bubbles break when rising to the surface of a small quantity shaken in a bottle. When the spirit has been used this test is of no value. When animals or fish are first immersed, it will be found that the spirit becomes rapidly weaker. Large specimens absorb the alcohol very speedily. The rapidity with which this absorption takes place should be carefully watched, and in warm climates the liquid tested at least every twelve hours, and fresh spirit added to restore it to its original strength. In colder climates it is not requisite to watch so closely, but practice will show what attention is necessary. It will be found that absorption of alcohol will be about proportionate to the rate of decomposition. Spirit should not be used too strong, as its effect is to contract the outer surface, and thus, closing the pores, prevent the alcohol from penetrating through to the inner parts of the specimen. *The principal point, then, is to*

watch that the strength of the spirit does not get below a certain point while the specimen is absorbing alcohol when first put in. It will be found that after two or three days the spirit retains its strength: when this is the case, the specimen will be perfectly preserved. Spirit should not be thrown away, no matter how often used, so long as the traveller has a reserve of sufficient strength to bring it back to its requisite strength.

“In selecting specimens for immersion, regard must be had to the means at the traveller’s disposal. Fish up to 9 inches long may be placed in spirit, with simply a slit cut to allow the spirit to enter to the entrails. With larger specimens, it is better to pass a long knife outside the ribs, so as to separate the muscles on each side of the vertebræ. It is also as well to remove as much food from the entrails as possible, taking care to leave all these in. The larger specimens can be skinned, leaving, however, the intestines in, and simply removing the flesh. Very large specimens preserved in this way absorb very little spirit. All half-digested food should be removed from snakes and animals. In spite of these precautions, specimens will often appear to be decomposing; but by more constant attention to re-strengthening the spirit, they will, in most cases, be preserved.

“A case (copper is the best), with a top that can be unscrewed and refixed easily, should always be carried as a receptacle. The opening should be large enough to allow the hand to be inserted; this is to hold freshly-caught specimens. When they have become preserved, they can all be removed and soldered up in tin or zinc boxes. Zinc is best, as it does not corrode so easily. The traveller will find it very convenient to take lessons in soldering, and so make his own boxes. If he takes them ready made, they had best be arranged so as to fit one into another before they are filled. When moving about, all specimens should be wrapped in calico or linen or other rags to prevent their rubbing one against the other. This should also be done to the specimens in the copper case when a move is necessary, as well as to those finally packed for transmission to Europe. These last should have all the interstices between the specimens filled in with cotton-wool or rags. If a leak should occur in a case, specimens thus packed will still be maintained moist and will keep some time without much injury. Proof spirit should be used when the specimens are finally packed, but it is not necessary that it should be fresh.”

Land and fresh-water shells, on reaching camp, should be placed in a basin of cold water to entice the animals out, and then, after draining off, killed by pouring boiling water over them. They may be cleared of flesh by means of a strong pin

or penknife. The operculum or mouthpiece of all shells which possess it should be preserved and placed inside the empty shell. Each shell, when dry, should be wrapped in a piece of paper and the collection packed in a box, well padded with cotton or other dry and elastic material.

The insects collected on an excursion should be attended to immediately on arrival in camp. When leisure and space are limited, all the hard-bodied ones may be put in bottles of spirit; and each bottle, when nearly full, should be filled up to the cork with a piece of rag, to prevent injury from shaking. Many species, however, become stained by spirit, and it is far better in dry countries, such as Africa, Australia, and Central Asia, to preserve all the hard-bodied ones in a dry state in pill-boxes. They are killed, whilst in the collecting-bottles, by plunging, for a few moments, the bottom half of the bottles in hot water. An hour afterwards the contents are shaken out over blotting-paper and put into pill-boxes—the bottom of the boxes being padded with cotton, over which is placed a circular piece of blotting-paper. The open pill-boxes should then be placed in the drying-cage for a day or two and then filled up with more cotton, the layer of insects being first covered by a circular piece of paper.* The soft-bodied specimens, which are brought home pinned, should be stuck in the drying-cage until they are dry, and then be pinned very close together in the store-boxes. The store-boxes, both bottom and sides, should each have inside a coating of arsenical soap before they are corked, and as they become filled, one by one, should be washed outside with the soap and pasted all over with paper. Camphor and other preservatives are of little or no use in tropical climates. In some countries where the traveller may wish to make a collection of the butterfly fauna, the best way is to preserve all the specimens in little paper envelopes. He should be careful not to press the insects too flat, simply killing them by pressure underneath the breast, folding their wings carefully backwards and slipping them each into its envelope. In very humid tropical countries, such as the river valleys of Tropical America and the islands of the Eastern Archipelago, the plan of stowing away even hard-bodied insects in pill-boxes does not answer, on account of the mould with which they soon become covered. There are, then, only two methods that can be adopted: one preserving them at once in spirits, the other pinning all those over a quarter of an inch long (running the pin through the right wing-case so as to come out beneath,

* The only preservative needed is a diluted wash of arsenical soap inside the pill-boxes, which, as in all other cases when soap is used, must be well dried afterwards, before the boxes are filled.

between the second and third pair of legs); and gumming those of smaller size on small sheets of card, cut of uniform size so as to fit perpendicularly in racked boxes, like those used to contain microscopical slides, but larger. The cards may be a few inches square, and each may hold several scores of specimens, very lightly gummed down a short distance apart. After the cards are filled they should be well dried, and the box containing them washed outside with arsenical soap and pasted over with paper. All the pinned specimens should be placed to dry for a few days in the drying-cage, and afterwards pinned very close together in the corked store-boxes.

Plants are dried by pressure, by means of the boards and straps, between sheets of botanical drying-paper—the paper requiring to be changed three or four times. When dry, the specimens may be placed between sheets of old newspapers, together with the notes the traveller may have made upon them, each placed upon the object to which it refers. Bundles of papers containing plants are not of difficult carriage; but they require to be guarded against wet, especially in fording rivers and in rainy weather, and should be wrapped in skins or india-rubber sheeting until they can be safely packed in wooden boxes and despatched to Europe. Seeds may be collected when quite ripe and preserved in small packets of botanical paper, with a number written on referring to preserved specimens of the flowers. Dry fruits and capsules should be collected when in countries not previously explored by botanists, if the traveller has means of identifying the species to which they belong.

Fossils.—The collection of fossils and minerals (except in the case of the discovery of new localities for valuable metals) is not to be recommended to the traveller, if he is not a Geologist. Fossils from an unexplored country are of little use unless the nature and order of superposition of the strata in which they are found can be at the same time investigated. In the cases, however, of recent alluvial strata, or the supposed beds of ancient lakes, or deposits in caves, or raised sea-beaches containing shells or bones of vertebrate animals, the traveller will do well to bring away specimens if a good opportunity offers. If the plan of the expedition includes the collection of fossil remains, the traveller will, of course, provide himself with a proper geological outfit and obtain the necessary instructions before leaving Europe.

All collections made in tropical countries should be sent to Europe with the least possible delay, as they soon become dete-

riorated or spoilt unless great care be bestowed upon them. Dry skins of animals and birds may be packed in wooden cases simply with sheets of paper to separate the skins. Shells and skulls should be provided with abundance of elastic padding, such as cotton. The boxes containing insects and crustacea should be placed in the middle of large boxes surrounded by an ample bed of hay or other light dry elastic material: if this last point be not carefully attended to, it will be doubtful whether such collections will sustain a voyage without much injury.

Travellers have excellent opportunities of observing the habits of animals in a state of nature, and these hints would be very deficient were not a few words said upon this subject. To know what to observe in the economy of animals is in itself an accomplishment which it would be unreasonable to expect the general traveller to possess, and without this he may bring home only insignificant details, contributing but little to our stock of knowledge. One general rule, however, may be kept always present to the mind, and this is, that anything concerning animals which bears upon the relations of species to their conditions of life is well worth observing and recording. Thus, it is important to note the various enemies which each species has to contend with, not only at one epoch in its life, but at every stage from birth to death, and at different seasons and in different localities. The way in which the existence of enemies limits the range of a species should also be noticed. The inorganic influences which inimically affect species, especially intermittently (such as the occurrence of disastrous seasons), and which are likely to operate in limiting their ranges, are also important subjects of inquiry. The migrations of animals, and especially any facts about the irruption of species into districts previously uninhabited by them, are well worth recording. The food of each species should be noticed, and if any change of customary food is observed, owing to the failure of the supply, it should be carefully recorded. The use in nature of any peculiar physical conformation of animals, the object of ornamentation, and so forth, should also be investigated whenever opportunity occurs. Any facts relating to the interbreeding in a state of nature of allied varieties, or the converse—that is, the antipathy to intercrossing of allied varieties—would be extremely interesting. In short, the traveller should bear in mind that facts having a philosophical bearing are much more important than mere anecdotes about animals.

To observe the actions of the larger animals, a telescope or opera-glass will be necessary, and the traveller should bear in mind, if a microscope is needed in his journey, that by unscrewing the tubes of the telescope, in which all the small glasses are contained, a compound microscope of considerable power is produced.
