TABLE II.

Comparison between Standard Barometer (Newman's) and Portable Barometer (Barrow's), both reduced to 32° Fahr. and corrected for Capillary Action.

Date.	Standard Barometer.	Portable Barometer.	Difference.
Eaton Place:—			
July 1	29·797	29·808	+·011
,, 2	29·804	29·815	+·011
,, 2	29·866	29·880	·014
Aug. 6	29·722	29·730	·008
,, 7	28·821	29·833	·012
	..	..	+·011

TABLE III.

Comparison between Aneroid Barometer and Newman's Standard, reduced to 32° Fahr. and to Portable Barometer.

Date.	Standard Barometer.	Aneroid Barometer.	Diff. 1.	Diff. 2.
Eaton Place:—				
h. m.				
Oct. 20,	29·871	30·120	·249	·143
,, 21, 1 0 P.M.	29·957	30·186	·229	·123
,, 21, 10 0 ,,	30·086	30·306	·220	·114
,, 22, 10 0 ,,	29·842	30·062	·226	·120
,, 23, 3 0 ,,	29·161	29·408	·247	·141

VI.—*On the Adaptation of the Aneroid for the purposes of Surveying in India.* By George Buist, LL.D., F.R.S., Corresponding Member of the Royal Geographical Society of London. Communicated by Col. Sykes, F.R.S., F.R.G.S.

[Read February 24, 1851.]

One of the great desiderata with travellers is to be able to obtain an instrument for measuring elevations of moderate size, considerable portability, and immunity from injuries from the accidents apt to be encountered in journeying through new countries. Great degrees of nicety or exactitude are rarely attainable on a first visit, and are willingly dispensed with, in comparison to tolerable approximation, when only attainable by great risk, trouble, and delay. The mountain barometer can be made tolerably portable so far as size and weight are concerned; but in its strongest and most efficient form it is so extremely liable to accidents, so expensive and so difficult in India to have it repaired or replaced, that few travellers care to be encumbered with it at all. The mountain thermometer has done excellent barometric service in India, but it has seldom happened that instruments cut finer than fifths of a degree have been made use of; at moderate elevations one degree corresponds to 500 feet; so that even when degrees are cut to tenths, the smallest division will not indicate less than 50 feet. A good barometer, reading to hundredths, will indicate 10 feet. The mountain sympiesometer scarcely seems to have been made use of at all amongst us—wherefore, I know not: the instrument is quite as portable as the aneroid, and much less susceptible of injury than the mountain thermometer; it reads with almost the delicacy of a barometer, but is apt, on being long used in the country, to change its rate. Both the aneroid and sympiesometer in their best forms require to be frequently referred to a standard barometer. The mountain thermometer has this additional advantage over both—that, once rated, it runs little risk of going sensibly wrong: I say sensibly; for, by a late paper of Mr. Adie's, it appears that even thermometers alter very materially in their indications.* The mountain thermometer, portable as it is, is far from exempt from accidents, and, besides being liable to be broken, is easily injured by means of careless handling, and broken while being boiled; the air is apt to get entangled with the mercury,—an accident often occurring to such an extent as to occasion the risk or destruction of the instrument.† Under all

* Mr. John Adie, of Edinburgh, has published a very interesting article in the 'Philosophical Journal' for July, 1850, on the change which takes place in the standard points of thermometers (pp. 122–125). This appears sometimes to amount to no less than nine-tenths of a degree in a few months: this is equal to 450 feet in measurement, supposing we have scales cut to tenths, and no means of detecting or indicating the error. I do not think any aneroid or sympiesometer likely to go wrong to the extent of half an inch—nearly the equivalent of this, if they have been tolerably taken care of, and compared within a twelvemonth or so with a standard barometer; or, which is the same thing, rated from a point of known elevation—so that the general statement in the text must be taken with allowances after all that has been said in favour of mountain thermometers.

† The following description is given by Mr. Adie of the thermometers supplied by him to the Bombay Geographical Society; they are the most beautiful instruments I have ever seen:—

"The thermometers for the determination of altitudes by the boiling point of these circumstances, were the improvements of which the aneroid is obviously susceptible applied to it, it is likely that, all in all, it is

water are constructed as follows: A piece of tube is selected of perfectly equal calibre throughout its length; the section of the bore is round and fine, for the purpose of giving long degrees without having a very large bulb, which renders the carriage of such thermometers very dangerous for breakage. The bulb is made of glass cylinder-tube, which can be made more equal and stronger than a round blown bulb; and the proper size having been determined for each tube, the scales are determined by the following process: each tube with its finished bulb is weighed by a fine balance to 1-100th of a grain; they are then fitted with pure dry mercury, and regulated so that 62° shall have the same position as 212° is to have when the thermometer is finished.

"Temporary scales, divided into inch and decimal parts, are then fixed to each tube, and the point 32° obtained from melting ice, and 62° from a fine standard thermometer, and carefully read off on these temporary scales. This gives the length of 30° at these temperatures. But it is evident that this length would be greater than 30°, if we drive out a portion of the mercury to make 212° stand at the point where 62° stood when the scales were measured. This is corrected by carefully weighing the tubes before and after regulating them for 212°, and the proportion is stated. If the larger quantity of mercury give the length noted, the diminished quantity of mercury from regulation to 212° will give a diminished scale, which scale is the true or corrected one, to be divided on the thermometer; each degree is subdivided into fifth or tenth parts, and cut on the glass stem of the thermometer, or may be laid down on an attached scale.

"When the thermometer is to be used the bulb must be carefully inspected, to see that there are no small detached globules of air attached to the interior of the bulb. Should such be found, they are to be removed by shaking in a larger globule from the contracted part of the bulb, and making it pass over the smaller globules, which it will take with it; it is then to be returned to the contracted part; and should any small portion of the mercury lodge in the tube it is to be joined to the column by heating the bulb till it rise to the small tube at the top of the thermometer, where the detached portions will unite.

"The best *method of using* these thermometers is to have the bulb and column of mercury up to the reading point brought to the boiling temperature: this is best done by a boiler provided with telescope slide-tubes, which can be regulated to any required length; or where such an apparatus is not at hand, the same length of column, as nearly as possible, should be kept out of the water. Professor J. D. Forbes ('Philosophical Transactions, Edinburgh,' vol. xv. p. 409) has, with great care, determined the difference of altitude due to a change of 1° in the boiling point of water, and found it to be 545·9 ft. for each degree of Fahrenheit. Thermometers used for this purpose should be frequently compared one with another, and their differences noted; or, where one only is used, the instrument should be noted as frequently as possible, both for the purpose of obtaining more perfect results from a mean of the observations, and for correcting small changes in the indication which go on in course of time.

"For security in carriage the thermometer is enclosed in a brass case, and supported at all points by woollen stuffing, and is removed from its case by screwing off the top and bottom, and pushing out the bulb, when the thermometer may be drawn out."—(For Tables and Directions see Appendix.)

Mr. Adie gives no directions for putting his mountain thermometer to rights when out of order. Having had some experience in this, I may mention the following as the result:—The air left purposely in the instrument is always apt to get interspersed betwixt portions of the mercury. When the detached portion is not very far up the tube—higher, say, than 200—then it may be brought back into the bulb by evaporation—a saline solution, ether, or ice. Should a considerable quantity of the quicksilver have got into the upper bulb, the first thing is to strike it by tapping to one side, to allow the air from below to pass it without obstruction; then boil the thermometer in a basin of strong brine; when at its highest, tap the upper bulb, and the mercury will fall back into the tube, and probably be driven one of the most convenient instruments the traveller can make use of within the limits to which it is trustworthy, whatever these may be. Mr. Adie considers them trustworthy to 28 inches only, or about 2000 feet in altitude, and did it suit within this it would be much; but it still remains to be seen whether it may not prove suitable to two or three times this elevation.

It appears to me that at home the value of the instrument has been greatly underrated, and it has been looked on, notwithstanding all the noise that has been made about it, as little better than a fair-weather glass, fit enough to take the place of the wheel-barometer, but fit for nothing more. Nothing, certainly, can be more ridiculous than the legends "set fair," "fair," "change," "rain," "much rain," and "stormy," with which instruments are encumbered, if they be meant for survey purposes. In the Deccan, or wherever throughout the fine weather the aneroid indicates a state of perpetual tempest—and the same is the case with all other localities of an elevation of 2000 feet—the legends are worse than perplexing and useless; they occupy space which might be valuably employed otherwise. The brass index, or register, may be expedient at home, where the instrument is used as a weather-glass only, and people are too slovenly or careless to write down their observations. Here it is an encumbrance, continually in the way, and liable to bring about the breaking of the glass. It ought to be at once discarded. The aneroid, as used at home, is cut from 27·5 to 31 inches, though it indicates 2500 feet: it ought to be cut all round the scale, or down to 23 inches at least. This will suit for Simla, or the summit of the Nilgherries.

The following description of the aneroid, taken from Dr. Purdie Thomson, will make what is about to be stated more clear than it otherwise might be to the general reader:—

"*The Aneroid Barometer.*—Since writing the preceding paragraph, the author has inspected * this new and beautiful instrument, invented by M. Vidi. It was described by Professor Lloyd to the British Association,† and reported to have stood the test of being placed under the receiver of an air-pump, when the indications corresponded with those of the mercurial gauge to less than 0·01 inch. The principle upon which the instrument depends is the pressure of

down by the air now above it. Allow the instrument to cool leisurely, and then cool the lower bulb as much as possible by any of the means already mentioned, when probably all will come right as before. Failing a bath of brine, use oil; but take great care in this case that the heat be not carried too far, so as to burst the tube. It is very probable that by expansion all the air may be made to pass above the mercury in the upper bulb, and the column become united without artificial cooling. On no account resort to a fire, charcoal, or a lamp, as you are almost sure to crack the bulb:—*experto crede.*

* At Mr. Abraham's, Lord Street, Liverpool. The price is 3*l.* It is 4¾ inches in diameter, and 1¾ inches thick. The scale is divided to 0·025 inch.

† At Swansea, in 1848.

the atmosphere upon a metallic chamber partially exhausted, and so constructed, that by a system of levers a motion is given to an index-hand which moves upon a dial.

"The principle of the vacuum-case was formerly applied by M. Conte * in Egypt, but from the faulty mode of constructing his instrument, it was rejected and neglected.

"Upon comparison of indications made with the aneroid barometer —not corrected for the particular temperature—and a very perfect mercurial barometer, given by Mr. Dent, we find that from forty-nine observations made between the 6th January and 23rd February, 1848, the mean difference was 0·037 inch, the *aneroid* being in excess; and from sixty similar observations made with a standard barometer, during December, 1848, and between the 3rd and 31st January, 1849, the mean difference amounted to 0·026 inch, the *mercurial* being, in this case, in excess over the aneroid barometer. Combining these observations (109 in number) a mean difference amounting to 0·0025 inch is found to exist, the indications of the aneroid being in excess.† For general use the instrument is thus shown to be well suited; for the measurement of heights it is peculiarly adapted, from its portability and comparative strength; and for nautical purposes we know of no better instrument.

"Fig. 1 represents the external appearance of the aneroid barometer; Fig. 2, its internal arrangement, where the dial is supposed to be removed and the index hand retained; and Fig. 3, a perspective view of the same.‡

Fig. 1.

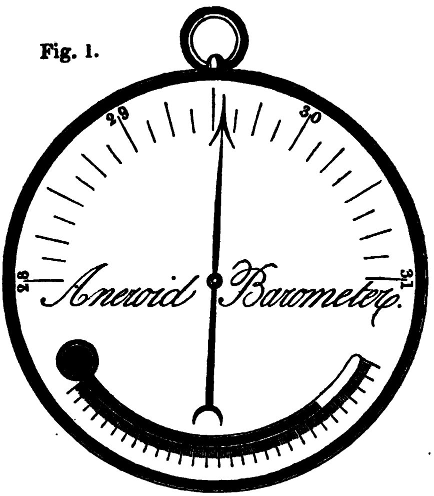
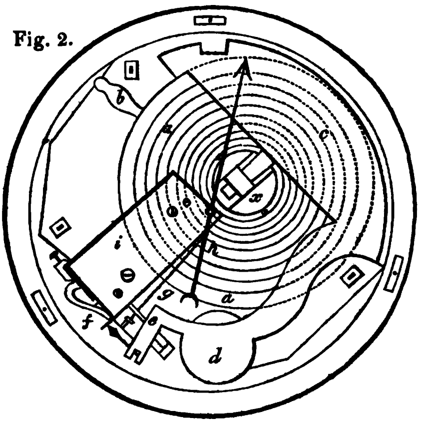


Fig. 2.



* Bulletin des Sciences. Floreal, An 6, p. 106.

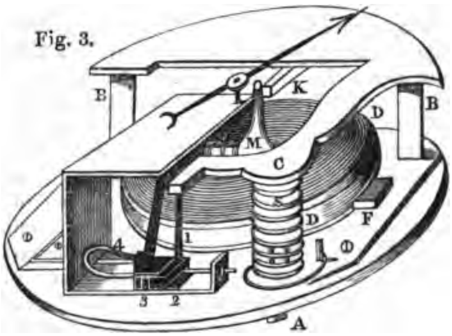
† The sum of all these observations gave 2139·722 inches for the aneroid, and 3239·44 inches for the mercurial barometer, the difference being 0·272 inch, which, divided by 109, = 0·00249.

‡ We beg to acknowledge the kindness of Mr. Dent in permitting casts to be taken of Figs. 3, 4, and 5, Aneroid Barometer.

"In Fig. 2, *a* is the metallic chamber or vacuum-vase, which receives the atmospheric impressions; it is corrugated in concentric circles, which increases its elasticity, and renders it more susceptible of atmospheric impressions; *b* is the tube, hermetically sealed, through which the air in *a* is exhausted. At the centre of *a* there is a solid cylindrical projection *x*, to the top of which the chief lever *c d e* is attached —this lever, which is of the second order, rests upon fixed pins, (r fulcra, placed vertically, and upon a spiral spring under *d*, but it is perfectly mobile. The extremity *e* of this lever is attached by a vertical rod and bow-shaped spring *f*, with another lever to which a watch-chain *g* is fastened, and extended to *h*, where it works upon a drum fixed to the axis of the index-hand, connected with a delicate spring at *h*,—the vertical motion is thus changed to a horizontal one, and the hand, which is attached to the metallic plate *i*, is thereby moved upon the dial. The movement originating in the vacuum-chamber is multiplied by these levers, so that a change in the corrugated surfaces, amounting to 1-220th of an inch, carries the point of the index-hand through a space of 3 inches on the dial.

"In Fig. 3 the vacuum-chamber is represented by D; the large lever by C, resting upon the fulcra B B and spiral spring S, and supporting the box D by the pin K. At the extremity of C is seen the vertical rod (1) connecting it with the levers (2 and 3) by the bow-

Fig. 3.



shaped spring (4). The square-headed screws *b e*, by screwing or unscrewing, admit an alteration in the distance of leverage, and thereby enable the index-hand to move over a space corresponding with the scale of a mercurial barometer. To the lever (3) is attached a light rod, terminating with the watch-chain, which is attached to the drum fastened to the axis. The handle is kept firmly fixed when not in motion, by a delicate flat spiral spring attached to the axis, acting against the force of the levers, and always in a state of tension. F is the exhausting tube: and A, at the back of the instrument, is a screw, which, upon being turned, alters the position of the index-hand, and thus enables the observer to adjust the aneroid to any mecurial barometer. The atmospheric pressure increasing on D will cause a slight depression of the corrugated surface to which K is attached, and a corresponding inclination of the lever C; but as this lever is resting upon unmoveable fulcra at B B, the motion will take place chiefly over the spiral spring S, the increased distance of the lever being as six to one. The metallic chamber being 2·5 inches in diameter, the pressure of the atmosphere should be about 73 lbs. upon the corrugated diaphragms, but owing to various causes it is not more than 44 lbs.

"Figs. 4 and 5 represent the vacuum-case, separated from the levers. The former shows the case before exhaustion; the latter after the air has been withdrawn. *a a a a* indicate the lapping over of the thin

Fig. 4.

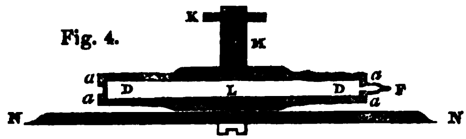
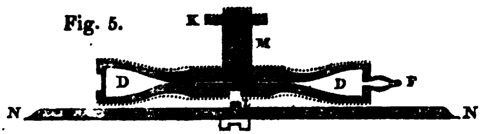


Fig. 5.



corrugated metallic diaphragms, where they are soldered to the rim; D is the vacuum-chamber, with F the exhausting tube; and L the screw part fixing D to the metallic plate N below. In Fig. 5 the vacuum-case is in a state of compression after being exhausted, and M represents the socket, which, being pulled by the pin K, places D in a state of tension. The dotted line marks the position of the diaphragms after the introduction of the gas, which effects compensation for changes in the capacity of the case by alterations of temperature. Without this gas the capacity of the case would be diminished by heat and increased by cold, but the changes in the elasticity of the gaseous fluid by varying temperatures effect compensation. In using the aneroid barometer for scientific purposes, a certain thermometrical correction is required. This is made by carefully noticing the indication of the instrument in the external atmosphere, then placing it before a fire till the thermometer indicates 100° F., and watching the change which has taken place. The variation of the hand, divided by the degrees of the thermometer, gives the quantity for each degree. The amount will be sometimes in excess, occasionally in defect."—Dr. D. P. Thomson's *Introduction to Meteorology*, pp. 447-452.

The following are the results of various comparisons betwixt the aneroid and barometer, made at different elevations, up to 2000 feet above the level of the sea; further than this I have not gone.

The survey-station at Neat's Tongue, between Trombay and Mehal, exactly 1000·6 feet above the mean level of the sea, as ascertained by theodolite, afforded a very suitable place for experiment, and the collection of instruments in possession of the Geographical Society offered a most convenient opportunity for determining the point. The beautiful standard barometers by Adie, 2, 3, and 5, were, with three aneroids, now selected for comparison. Barometer No. 4 was left at Balcairn, about 70 feet above the level of the sea, and No. 1 in the Geographical Society's rooms, 35 feet lower, for reference. The first observation was made at 5 P.M., about half-way up the hill, where barometer No. 4 stood at 29·600, temperature 84°; at Balcairn it had stood at 29·874 at 3 P.M., temperature 86°: it had thus fallen 0·274. The three aneroids stood as follows:—

	No. 3187.	No. 1942.	No. 1737.
Aneroid, 70 feet above sea	29·945	29·860	29·850
Neat's Tongue	29·626	29·552	29·560
Difference	·319	·308	·290

Mean ·306. There was no time to try more than one barometer here. On the top of the hill three barometers were made use of, exactly as at the survey-station; the cisterns were six inches above ground. The following is the result:—

	No. 2.	No. 3.	No. 5.
Barometers, at Balcairn, at 3 P.M.	29·882	29·849	29·874
Barometers, at Survey Station, at 6 P.M.	28·966	28·986	28·984
Difference	·916	·863	·890

Mean ·889. The temperature at Balcairn was 5° higher than that above. No correction for this was at this stage made.

Aneroids, as above	29·945	29·860	29·850
	28·900	28·888	28·950
Difference	1·045	·972	·900

Mean ·972. Difference from barometric mean ·083.

The following experiments were made at the level of the sea at half-tide, and at Balcairn on the summit of the rock close by:—

	No. 2.	No. 3.	No. 5.
Barometer, lower	29·936	29·914	29·926
Barometer, upper	·860	·836	·856
Difference	·076	·078	·070
Aneroid, lower	29·910	29·830	29·923
Aneroid, upper	·840	·770	·850
Difference	·070	·060	·073

The mean depression of the aneroids was thus ·067, that of the barometer was ·074; difference ·007—seven thousandth parts of an inch.

I took three instruments to Poona with me in the end of July. Two of these belonged to Messrs. Treacher, one to the Society, this last being sadly out of order; the cause of error was not observed at the time, it arose from the slackening of some of the screws, since tightened.

The results were the following:—the standard barometers employed were Nos. 1 and 2, two of the finest sent out by Mr. Adie; the way they kept together was admirable. The mountain sympiesometer referred to was a very elegant instrument procured for Colonel Campbell, whose indications were also very accurate, and in most perfect harmony with those of the other instruments. On comparing the instruments at Senree, about 70 feet above the level of the sea, they stood on the 22nd of July at 10 A.M. as under, the thermometer being 84°, the correction for temperature of the barometer here applied ·149. The standard at the observatory at this date was 29·667, the instrument being 32 feet above the level of the sea.

Barometers.		Mountain Sympiesometer.	Aneroids.		
1.	2.		5821.	5822.	2244.
29·676	29·662	29·750	29·765	29·790	29·780

The following were the readings of the instruments respectively at Poona at 10 A.M. on the 27th; the observatory standard had betwixt these two dates sunk from 29·667 to 29·187, or by 00·080:—

Temperature at Poona 76°, barometer corrected,

27·713	27·713	27·830	27·800	27·802	27·650

Difference betwixt Bombay and Poona—

1·963	1·949	1·920	1·965	1·988	2·130

The coincidences here betwixt the barometer and mountain sympiesometers, and Mr. Treacher's aneroids, are as close as may be.

These experiments were performed at Colonel Grant's, at the extreme end of the artillery lines; his house is pretty nearly on a level with the church, the top of the spire of which is set down in the trigonometrical survey at 2038 feet above the level of the sea; assuming the spire at 138, this will be 1900. Mr. Treacher's instruments were only cut to 27·5 inches, and that belonging to the Society, cut to 23, was unserviceable, so that the doubt expressed by Mr. Adie, as to whether or not aneroids are trustworthy below 28 inches for survey purposes, remains unsolved.*

I took our own aneroid to the top of Bapdieu Ghaut along with me; the following were the results:—but, as already stated, the instrument was unserviceable, so that no conclusion from its indications can in this case be drawn. The perfection of the mountain sympiesometer is very remarkable:

Bapdieu Ghaut, August 23.

	Barometer 1.	Sympiesometer.	Thermometer.
Poona, 7 A.M.	27·952 . .	28·05 . .	76
Bapdieu Ghaut, 9 A.M. .	26·747 . .	26·85 . .	74
	1·205	1·20	

The barometer is corrected for temperature to 32°.

Since these experiments were made, others have been concluded by Professor Patton, an extract from an account of which, lately read before the Geographical Society, is subjoined:—

"*Remarks on the Aneroid.*—Considerable discussion has of late arisen on the subject of the aneroid barometer, and great uncertainty still exists in reference to its utility. A letter from the eminent instrument-maker, Mr. Adie, read before a late meeting of this Society, has tended very much to increase previously existing doubts of its usefulness in ascertaining high altitudes, for which its portability and cheapness would have made it particularly suitable. This Society also having ordered a supply from England, it is of great importance not only to have those doubts set at rest, but also to have some means of testing their correctness, in order to inform purchasers of the limits within which they can be trusted. In order to do so, I obtained two aneroids, one belonging to Mr. Treacher, graduated to 27·5 inches, and one belonging to the Society, graduated to 23 inches, and subjected them to the following experiment. In the neck of a flask containing a small quantity of mercury, I inserted a small bent tube, and when the flask was inverted, the mercury of course stood at the same level in the flask and in the tube.

"The flask was properly supported on a small retort stand, and the aneroids were then placed under the receiver of an air-pump, and a few strokes given to the pump. When the air became a little rarified in the receiver, the elastic force of the air in the flask pressed down the mercury, and the degree of exhaustion was measured by the altitude to which the mercury rose in the tube. Therefore, neglecting for the present the diminution of the elastic force of the air in the flask, arising from the increase of volume, and neglecting also the change in the temperature under the receiver, the *rise* of mercury in the tube should be exactly equal to the *fall* indicated by the aneroid,

* On this point see Professor Patton's Observations at Mahabuleshwur, and also those of Colonel Yorke on the Puy de Dome, &c., in this No. of the Journal.—Ed.

and *vice versâ*. And this was the case in each of the experiments, as will be seen from the readings given below. The air was first pumped out, and the receiver not being perfectly air-tight, it re-entered gradually, and readings were taken at the same instant by myself and Mr. Ardaseer Framjee.

Treacher's Aneroid, No. 1.

Aneroid.	Height of Mercury in Tube.
Inches.	Inches.
27·5	2·55
28·0	2·25
28·5	1·55
29·0	1·05
29·5	0·55
30·05	0·00

Aneroid No. 2.

First Experiment.		Second Experiment.	
Aneroid.	Height of Mercury in Tube.	Aneroid.	Height of Mercury in Tube.
Inches.	Inches.	Inches.	Inches.
26·0	3·9	24·5	4·75
26·5	3·35	25·0	4·25
27·0	2·8	25·5	3·7
27·5	2·35	26·0	3·2
28·0	1·85	26·5	2·7
28·5	1·35	27·0	2·2
29·0	0·85	27·5	1·7
29·25	0·6	28·0	1·2
		28·25	1·975
		28·5	0·7
		28·75	0·425
		29·0	0·2
		29·7	0·5

"In the first experiment the aneroid rose 2·55 inches, and the mercury fell the same; in the second, the rise is 3·25 inches, and the fall 3·3; and in the third, the rise is 5·2 inches, and the fall 5·25 inches.

"This close coincidence is remarkable, and requires to be accounted for, and explained, because it would really indicate a considerable error in the aneroid, rather than prove its exactness. In the last experiment, the mercury in the tube fell 5·2 inches: the volume of the air in the flask was therefore lessened, and consequently its elastic force increased. This increase I ascertained by measuring the volume of the air in the flask, and the volume of 5·2 in. of the tube to be equal to a pressure of ·27 of an inch of mercury. The aneroid, therefore, instead of coinciding, should have differed by this amount from the reading of the tube; that is, the mercury should have fallen less than the aneroid by ·27 of an inch. But a little consideration of the circumstances of the case will account for the discrepancy, and prove that in this large range of 5·2 inches the aneroid differed by a less quantity than ·27 of an inch from the truth. The total fall of mercury in the tube should be diminished by the rise of the mercury in the flask, and this must have amounted to about 1-10th of an inch. The mercury used in the experiment was not pure, and should be corrected for temperature; and therefore the fall, which seems to represent a change of pressure of 5·25 inches, must be much less, and when the increased pressure in the flask is then added, the discrepancy will be inconsiderable. I have not been able to ascertain the amount of error due to these causes, nor to the change of temperature of the air in the receiver, but in future observations with more perfect apparatus I shall be able to do so. From these experiments I felt satisfied that the aneroid No. 2 would not differ from a mercurial barometer by more than 1-10th of an inch, if carried to a height of 6000 feet. Since these experiments were made, I have had an opportunity of taking it with me to Mahabuleshwur, and of comparing it with the sympiesometer, and the results given below show how accurately my anticipations have been fulfilled—at least, as far as 4500 feet. Dr. Buist's observations at Poona had already proved its correctness to the height of 2000 feet.

	Aneroid.	Sympiesometer.	Thermometer.	
Oct. 19.	29·8	29·56	90·0	12 o'clock at noon—level of sea.
„ 19.	27·725	29.5	8·5	3 ditto ditto.
„ 20.	29·85	29·65	83·6	9½ A.M., Mhar River.
„ 20.	29·155	28·93	85·5	5½ P.M.
„ 20.	25·79	25·54	68·5	9½ P.M., Monastery, Mahabuleshwur.

"The coincidence between the two instruments is seen to be very exact, the total fall of the aneroid being 4·01, and of the sympiesometer 4·02.

"The following are the readings of the aneroid and thermometer at different places between Mahabuleshwur and Poona:—

	Aneroid.	Thermometer.	
Oct. 21.	25·756	65·0	9½ A.M., Monastery, Mahabuleshwur.
„ 21.	25·9	68·0	4 P.M., top of Tai Ghaut.
„ 21.	27·175	72·0	5 P.M., bottom of ditto.
„ 22.	27·75	73·5	Top of Ghaut.
„ 22.	27·88	75·5	Bottom of ditto.
„ 22.	26·725	81·0	Top of Ghaut near Poona. 6 P.M.
„ 22.	27·87	80·0	Poona lines. 10 P.M.
„ 23.	27·77	81·5	Ditto 4½ P.M.
„ 23.	27·87	78·5	Ditto 10 A.M.

"A very slight examination of these observations will show how sensibly the aneroid is acted on by the smallest undulations of the ground, and it acts as freely at 25 inches as at 30.

"They make no pretence to great accuracy, because most of them were taken when the palkee in which I was carried was in actual motion, but this only proves more strongly the value of the instrument for general purposes.

"When the merits of the aneroid become known, and confidence is placed in its indications, it will probably supersede all other portable instruments for ascertaining the heights of mountains: I have therefore prepared the following table, which will enable any one who can multiply and divide to obtain altitudes with all the accuracy that is required for practical purposes. The formula used in the calculation is given by Poisson in the second volume of his 'Traité de Mécanique:'—

$$Z = 18393\ldots\left(1+\frac{2(t+t')}{1000}\right)\text{Log.}\frac{h}{h'}$$

where t and t' are the temperatures of the air in degree of the centigrade thermometer at the two places of observation, h and h' the length of the barometric columns, and Z the highest in metres.

Table to facilitate Calculations of Heights of Mountains.

32°	52416	47°	54163	62°	55901	77°	57658
33	52532	48	54280	63	56027	78	57774
34	52649	49	54396	64	56143	79	57890
35	52765	50	54512	65	56260	80	58007
36	52882	51	54629	66	56376	81	58124
37	52993	52	54745	67	56493	82	58240
38	53115	53	54862	68	56609	83	58356
39	53231	54	54979	69	56720	84	58472
40	53348	55	55095	70	56842	85	58539
41	53464	56	55211	71	56959	86	58706
42	53581	57	55328	72	57055	87	58823
43	53697	58	55444	73	57192	88	58939
44	53814	59	55561	74	57308	89	59055
45	53930	60	55677	75	57424	90	59172
46	54046	61	55794	76	57541	91	59288

"*Rule.*—Multiply the number in the table opposite to the mean of the temperatures of the two places in degrees of Fahrenheit, by the difference of the barometric heights, and divide by their sum. The quotient is the height in feet.

"*Example.*—On the 20th of October, 1850, the barometer stood at 29·85 in the Mhar river near the sea, the thermometer indicating 83·5; and at the Monastery Mahabuleshwur it fell to 25·79, and the thermometer to 68·5. Required the height. Here the mean temperature is 76°, opposite to which in the table is found 57541, which being multiplied by 4·06, the difference, and divided by 55·64, the sum of the barometric heights, gives 4198 feet, the height required.

Table of Heights found by the Aneroid.

	Feet.
Kenesoxe, above the level of the sea . . .	665
Mahabuleshwur, ditto	4198
Mount Charlotte, above Monastery	324
Mount Charlotte, above the level of the sea .	4524
Tai Ghaut	1862
Height of Ghaut, above Poona	1216
Poona, above the level of the sea	2025

"These heights, as far as I have been able to ascertain, coincide very nearly with the heights ascertained by other means. Indeed no single observation of the barometer at one of the places could be expected to give it more accurately.

"Leslie's rule is very convenient, and sufficiently accurate; but the correction for the temperature of the air at the two places is often neglected in practice—and even in some scientific works the fact of a correction being required is not mentioned. But this correction cannot be omitted, because in the case of Mahabuleshwur it amounts to upwards of 400 feet. and in the case of Poona to about 180 feet. The results, however, are always too small, because in his investigation he was only anxious to obtain an approximation, and neglected systematically all but round numbers; and all the omissions tended to reduce the apparent height. Near the equator, the diminution of the force of gravity is another source of error, which still more diminishes the height deduced from the usual formula. I have therefore used, in the formation of the table given above, the number 52416, deduced from Poisson's formula, in preference to 52000 used by Leslie. Besides, the thermometer in general use being graduated according to Fahrenheit's scale, it is inconvenient to be obliged to convert the degrees into those of the centigrade. As some persons may prefer the use of his rule, I add it, with the example given above worked out:—

"*Leslie's Rule.*—As the sum of the mercurial columns is to their difference, so is the constant number 52000 feet to the approximate height. Correct the approximate elevation by shifting the decimal point three places back to the left, and multiply by twice the sum of the degrees of the detached thermometer: this product being now added, will give the true weight.

"Taking the former example, we have, 55·64 : 4·06 : : 52000 : 3793, the approximate height, and the correction is 3·798 ft. × 99·7 = 378, which gives for the true height 4171, differing from the former by 27 feet.

"Of the more minute daily variations, and the corrections, if any, that are to be applied, I hope to be able to have some account for the next meeting of the Society.

"21st Nov., 1850." "JOSEPH PATTON.

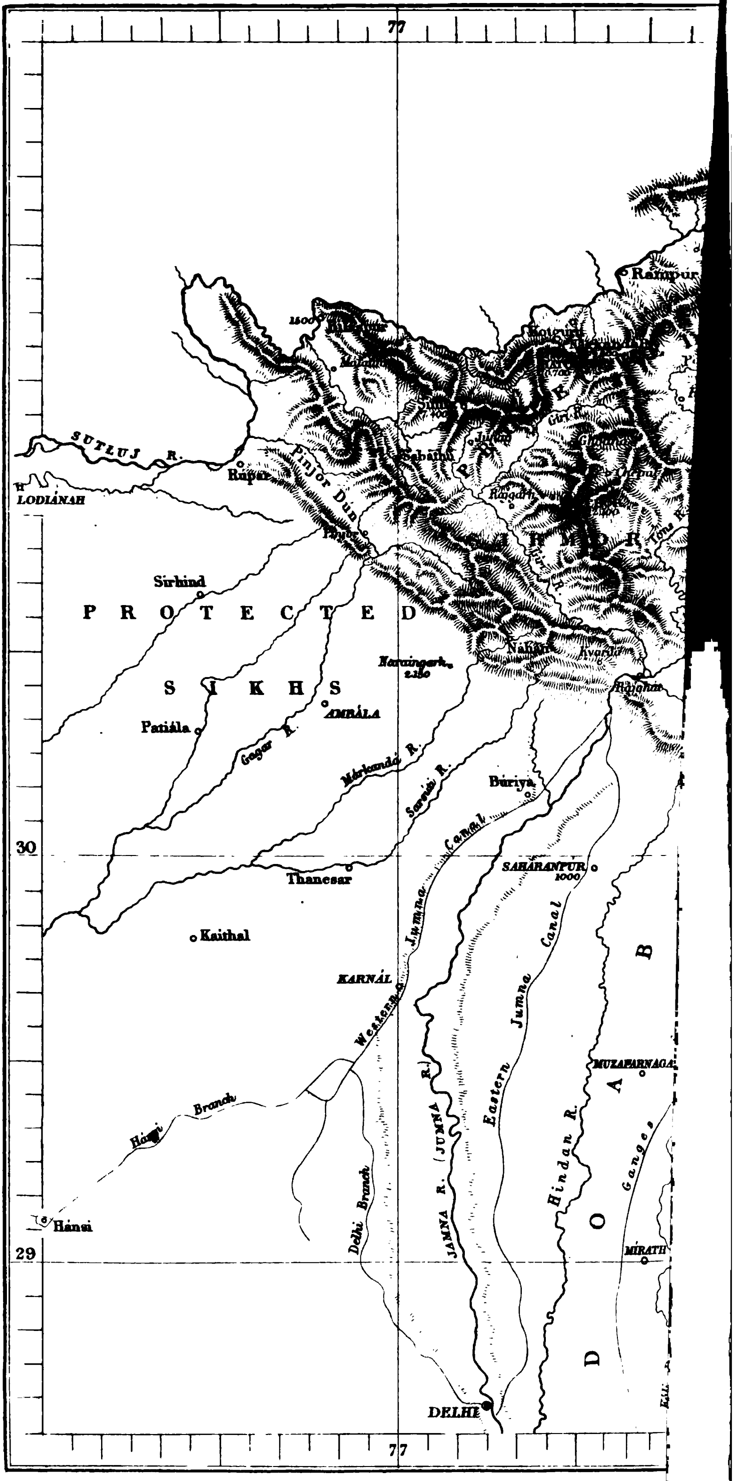
The dial plate, as we shall call it, is about four inches in diameter; the scale is engraven about half an inch in from the edge of the dial, it is by consequence nine inches in circumference, and when engraven all round is divided from 23 to 31, or over a space of eight inches, each space corresponding to a barometrical inch, being thus in reality 1·125 inches: this is divided into tenths, each tenth being subdivided into quarters, so that the instrument reads to 0·025; it may be extended to half this, or to 0·0125.

The space betwixt the present scale and the extreme edge of the dial, half an inch in breadth all round, is occupied on the one side by the words stormy, much rain, rain, change, fair, and set fair—calculated in India only to mislead; these ought in all cases to be omitted, and the thermometer, which occupies the other side of the dial, should be sunk underneath it, so as not to interfere with the scale, or sweep of the index. The scale should be cut at the extreme outer edge of the dial plate; by this a fourth would be gained in space without altering the mechanism or form of the instrument. An inch will thus be represented by a space of 1·5 in length, instead of 1·125, and this may easily be subdivided into hundredth parts, capable of being estimated to half this, or to 0·005. Troughton's marine barometers, when meant to read without a vernier, arc cut to hundredths of an inch, each division being a third less than what I have recommended for the aneroid. As already stated, the brass index is a mere encumbrance, endangering the glass, and continually in the way; it ought at once to be abandoned. The steel index ought to be made much finer, and more delicate than at present, as fine, in fact, as the seconds hand of a watch: just now it occupies a space corresponding to about two-hundredths of an inch. Reducing its dimensions has another advantage besides improving the delicacy of the reading—it diminishes its mass and momentum, and so rids us of tremor and vibration when the instrument is moved about.

The improvements suggested are all too obvious to require to be more than mentioned; they can be carried out without in any way increasing the expense, size, or complexity of the instrument, and ought to be insisted on by all those ordering aneroids for surveying purposes, or for service of any sort in India.

Should Mr. Adie's surmise prove correct, and the aneroid at pressures under 28 inches cease, as at present cut, to harmonize with the barometer, it would be well, with an instrument so compact and convenient, to see whether a series of aneroids could not be so made as to serve in succession for any ordinary elevation; or whether the portions of the scale lower than those on the common aneroid might not be so altered as to afford the correct pressure. One instrument might serve for the first 2000 feet, a second when only marked up to 28 inches might carry us 2000 feet higher, and so on. The matter might be very easily determined under the receiver of an air-pump, without actual ascent, the barometric gauge, with a good scale, answering as well as the barometer itself.

The neatly glued, leather-covered, velvet-lined box, in which the aneroid is enclosed, is totally unsuited to India: a hot Deccan wind will warp, twist, and split it in pieces; a wet monsoon atmosphere dissolve all the glue, mould the stuffing, and rot both leather and velvet. To meet the risks of climate and rough usage, it ought to be provided with a strong brass, copper, or zinc box, of its own form, but some inch greater in diameter and


77
30
29
SUTLUJ R.
LODIANAH
Rupar
Pinjor Dun
Pinjor
Rampur
Kotgurh
Sabathu
Giri R.
Nahan
Sirhind
PROTECTED SIKHS
Naraingarh
2150
AMBALA
Patiála
Gagar R.
Markanda R.
Buriya
Thanesar
Kaithal
KARNAL
Western Jumna Canal
Hansi Branch
Hansi
Delhi Branch
JAMNA R. (JUMNA R.)
Eastern Jumna Canal
SAHARANPUR
1000
Hindan R.
DOAB
MUZAFARNAGA
Ganges
MIRATH
DELHI

so as to present half an inch of clear space all around. ...ght to be stuffed with hair, with scraps of cork, or with ...ubber, or fitted up with springs—fitted up in some such ... to diminish the risks of concussion or vibration. Were ...ole after this sewed round with soft leather, like the cover ...py-glass or powder-flask, and the instrument made to sling ...the shoulder, it would, I think, be so thoroughly protected ...educe the risk incurred to a mere trifle.

...he case of this, as in that of all the other instruments, it ...to be a maxim that weight with us is always a secondary ... to security; and that all the dangers likely to be encoun- ...should be provided against at home; and it should never be ...ten that nothing that will warp with heat, such as a thin ... of board, soften with any amount of damp combined with ...th, such as glue or gum, or attract insects, such as paste, ... thoroughly poisoned by corrosive sublimate, should be sent ...dia; and that as instrument-makers, or even good mechanics, ...hings almost unknown amongst us, that things apt to get out ...rder should be made as simple and as easy to take to pieces ...ossible.*

I.—*On the Physical Geography of the Provinces of Kumáon and Garhwál in the Himálaya Mountains, and of the adjoining parts of Tibet.* By R. Strachey, Esq., of the Bengal Engineers. Communicated by Sir Roderick I. Murchison.

[Read May 12, 1851.]

Although we are still almost entirely dependent upon Chinese geographers for our topographical knowledge of what has been called Central Asia, some small accessions to our stock of information are gradually being made which render it necessary for us to modify from time to time our preconceived ideas of the physical nature of this region, from which European travellers still continue to be most jealously excluded by the policy of the Chinese, who are everywhere paramount between Siberia and India.

The comparatively small elevation of the greater portion of this "terra incognita" was, I think, first pointed out by Humboldt, and we were taught by him, most correctly, that the high lands were confined to its more southern parts, which are commonly known to us under the name of Tibet.

This elevated region, to which it is that I now propose to direct your attention more particularly, extends through nearly 30° of

* See also the Paper by Lieut. Kay, R.N., Director of the Royal Observatory, Hobart Town, in the Journal of the Royal Society of Van Diemen's Land, p. 83, Jan. 1850.—Ed.