We toiled up the right side-moraine. Soon reaching its top, we could overlook all the ground far to the S. and N. of the mountain-foot. A vast softly inclined plain with thousand upon thousand of great boulders sank away to the E., where it was merged in a level of alternate yellow sand and salt-white patches. Before the various valleys large moraines extended out relatively some distance. Such a moraine lay in front of our valley. The two side-moraines closed up together to form an almost novel dam, enclosing a small round lake hidden carefully away behind the walls. Further S., at the junction between débris and plain, lay a small regular cone-shaped mountain, that threw a comical shadow on to the plain in the last rays of sunshine.

A jagged mountain chain, rising dark and threatening against the red evening glow in the E., completed the rather bizarre picture in the background.

Had we dreamed that only at the foot of those distant peaks lay S. Bartolo we should most certainly have decided on a bivouac. As it was we were heartily thankful to find an Indian's hut. With difficulty we made the owner understand where we wanted to go, and then for hours and hours we dragged along our weary mules by the bridles over dreary stone wastes, through the beds of dried-up torrents, and over many a hill.

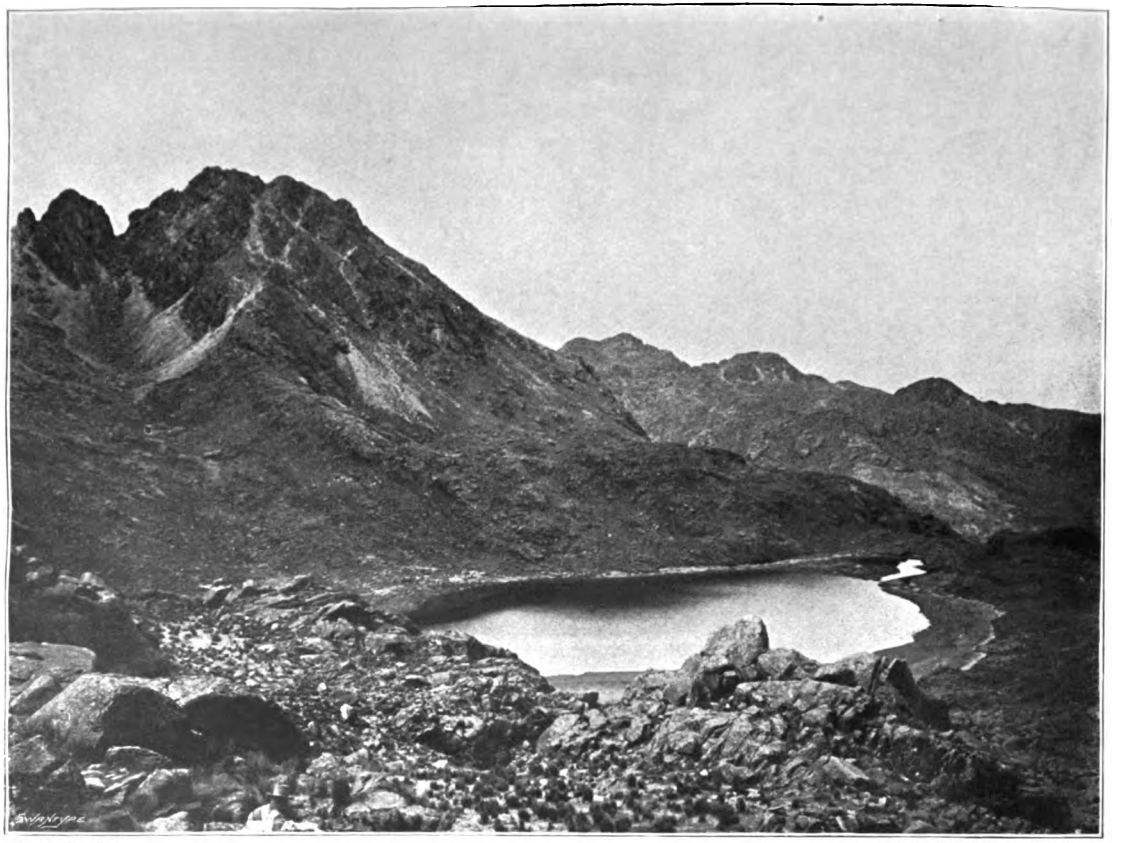
But here begins another chapter. The one concerning the Cordillera de Potosi was for the time being at an end. Other scenes and other neighbourhoods occupied our interests. I first remembered these mountains when drawing out the map at home, and keenly regretted not having devoted a short week to the study of that unknown, peaceful, self-contained world. That would have enabled me to give a geographical review instead of this cursory sketch.

Altitude Measurements by Mountaineers: Practical Experiences with the Watkin Aneroid.

By WILLIAM HUNTER WORKMAN, M.A., M.D., F.R.G.S.

AMONG the various mountain chains of the world the Himalayan, now comparatively little known, is likely to come more and more into favour with mountaineers, not only because it offers a more elevated and hence more attractive field for climbing endeavour than can elsewhere be found, but also because interesting problems connected with great altitudes can thus alone be solved.

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H. Hoek, photo *Swan Electric Engraving Co.,*

GLACIAL LAKE, CARI-CARI GROUP.

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The mountaineer of the future will undoubtedly add scientific training to his knowledge of mountain technicalities, and will be able to make investigations among the higher Himalayan regions which will prove to be of importance both to mountaineering and geographical science.

A condition essential to the value of such investigations is that the altitudes at which they are made should be properly determined. This subject has hitherto received from Himalayan travellers less attention than its importance demands.* Many statements as to altitudes attained have been made, which are wide of the mark, being based on estimates from readings of instruments of imperfect construction or not in condition to record pressures correctly; or from readings at the points specified only, without regard to other conditions essential to proper determination.

In the interest of science and of a spirit of fair play towards those who are labouring in the same field, where every extra hundred feet of altitude is gained at the expense of strenuous effort, one cannot be too careful to use every available means to fix the altitudes reached as correctly as possible.

To do this with an approximation to exactness with the means at the command of the mountaineer is, in many parts of the Himalaya, a difficult matter. Leaving the theodolite out of account, as unsuited to his use, he has to rely on the mercurial barometer, the hypsometer, or the aneroid, the readings of which can only give reliable results when compared with readings of similar instruments taken at the same time, or nearly the same time, at a convenient lower station, the height of which has been fixed. Such stations are rare in the Himalaya, and until more extensive scientific surveys have been made, aside from the peaks already fixed by the Indian Survey, the altitude of many others which may be attempted will have to be estimated by single readings uncompared with readings at a lower measured station, which estimates can, of course, only approximately represent the true altitudes.

Single readings of reliable instruments at different times at the same point may indicate for it altitudes differing from one another by 1,500 ft. or more, according as the pressure may be high or low. The highest of 252 consecutive readings

* It should be pointed out that this subject has been treated of from time to time by members of the Club, notably by such well known authorities as the late Mr. William Mathews and Mr. Edward Whymper.—EDITOR *A. J.*

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of the Government mercurial barometer at Skardo, taken for me during the summer of 1903, indicated for it, without comparison with readings at any lower station, an altitude of 7,268 ft., the lowest an altitude of 8,088 ft., a difference of 820 ft. Hence it is easy to see how, in the absence of a lower station, inaccuracies in estimating Himalayan heights may arise.

One person reaches a given high point at a time when the atmospheric pressure is low, and from the reading of his aneroid or hypsometer estimates its altitude at 20,000 ft. Another visits the same point when the pressure is high and estimates it at 18,500 ft. Neither gets the true altitude, which lies somewhere between the two estimates, but probably does not coincide with their average.

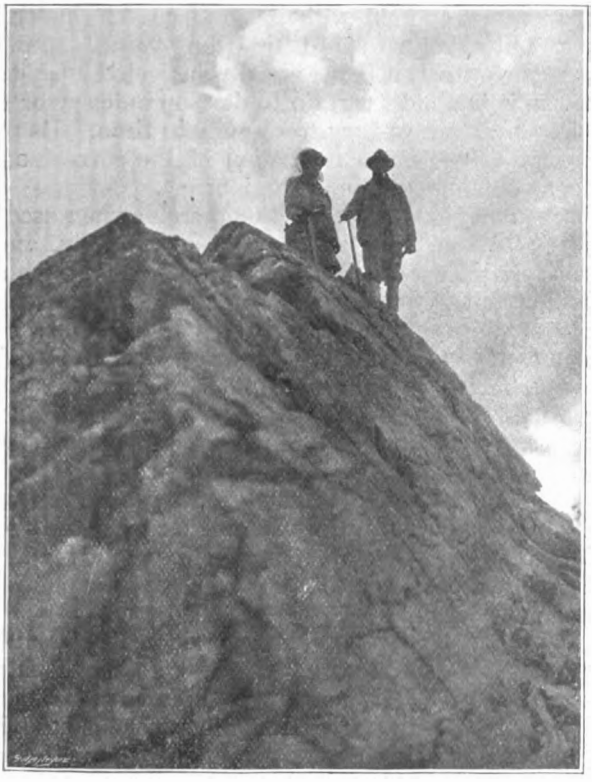
As regards the three instruments above mentioned, certain disadvantages possessed by each, which limit their field of usefulness, must be borne in mind. From the nature of its construction and its fragility the mercurial barometer is not adapted to the exigencies of mountain exploration. It is cumbersome and easily broken. Its more portable forms have not been brought to such perfection as to ensure the degree of accuracy, combined with simplicity of manipulation, which commends it to mountaineers in the trying circumstances in which they often find themselves. They are, therefore, forced to discard the mercurial barometer in favour of the hypsometer and aneroid, which possess the great advantage of portability.

The value of the hypsometer depends on the correct scaling of its thermometers. If these have been tested and found accurate, or their errors determined, there seems no reason why the hypsometer should not be as reliable as the mercurial barometer. It can be used at all camps and on mountains where there is no wind, or where shelter from the wind can be obtained. It cannot readily be used at points exposed to strong wind or deeply covered with soft snow, or where the nature of the ground is such as to afford no convenient resting-place, as on a sharp slope. Neither could any form of mercurial barometer well be employed under such conditions. With these exceptions the hypsometer is always ready for use without any tedious and often impossible manipulation, such as is necessary to the employment of the George barometer. Either absolute alcohol or rectified spirit should be used, especially at great altitudes, to ensure ready ignition and sufficient heat to boil the water quickly.

The aneroid, depending as it does on an exceedingly

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delicate mechanism, considerably more sensitive to jars than that of a watch, can scarcely be called, or expected to be, an instrument of precision under the conditions in which it is used by the explorer or the mountaineer. While a good aneroid, when at rest, will perform its work perhaps as well as a mercurial barometer, when carried about and subjected to the motion and jarring which it must receive on an expedition,



On the Summit of Mount Rachel (Basha Valley), 17,600 ft.*

it will develop index errors which render its readings unreliable. It makes no difference whether the jarring occurs at sea-level or at high altitudes; the result is the same in either case.

* Summit of Mount Rachel, 17,600 ft., Basha Valley. A knife edge, falls 1,500 ft. sheer on one side, and at one end only can the aneroid be used, and that only by a person entirely free from giddiness.—W. H. W.

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These index errors, in my experience, do not remain constant, but vary according to the kind and degree of motion brought to bear on the aneroid. They may be positive or negative, or may change from one to the other. I have seen them developed to more than an inch by rather severe jars, such as those caused by step-cutting, a jump, or a fall. A jar, which a pocket watch will stand with impunity, may suffice to permanently deflect the index of an aneroid.

Comparing an aneroid with a standard barometer before leaving and after return is of little if any value, as, under the rough usage to which it is necessarily subjected during distant expeditions, it is almost certain to develop index errors, which errors are as certain to vary from time to time. Its reading, therefore, on return is no indication of the correctness of its readings at different points of the journey.

In consequence of these errors the aneroid, when used alone, cannot be relied on to measure altitude properly, and is of comparatively little value for this purpose, as various reports of aneroid eccentricities testify.

Employed, however, in connection with a reliable barometer or hypsometer, by which its index errors can at any time be ascertained, it is a useful instrument and may render important and, apparently, quite reliable service where the hypsometer cannot be used. A moderate index error is of no great consequence, if one has the means of determining it. In spite of this an aneroid in good working order, if carefully carried, may register with considerable accuracy the difference of altitude between two points, its reading and the temperature being noted on leaving the lower point and on arrival at the upper one.

One of our Watkin aneroids thus indicated a difference between two fixed points in the Alps of 3,500 ft., the measured difference being 3,509 ft.; again, a difference between two others of 1,875 ft., the measured difference being 1,880 ft. The small discrepancies here shown might be due to inability to read with absolute accuracy, owing to the closeness of the aneroid scale, or to a lack of coincidence in the position of the recording instruments, or to a slight change of atmospheric pressure during the ascent to the upper point.

An error from this last cause would be likely to occur during an ascent requiring several hours, but at great altitudes this might fairly be discarded. The result would be more accurate if, the index errors of the aneroids having been noted, simultaneous readings could be taken with an aneroid or hypsometer at the lower point.

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If, therefore, the altitude of a high camp be established by simultaneous readings of the hypsometer at the camp and instruments at a lower fixed station, and an ascent of a peak be made from that camp, in case the hypsometer could not be used at the summit of the peak, it would be legitimate to consider the altitude of the latter as being the height of the camp plus the difference shown by the aneroid readings, especially if its readings on return to camp corresponded to those taken before departure. Still more reliable would be the result obtained by comparing the aneroid readings at the summit, corrected for index errors with simultaneous readings at the camp or lower station.

Under a variety of conditions the aneroid, which can quickly be read anywhere, fulfils a purpose which no other instrument is capable of doing, and, as an adjunct of the hypsometer, is, under proper control, a valuable instrument. Independently of index errors it also serves a most useful purpose in determining changes in the weather. Two or more aneroids should therefore be included in the outfit of the mountain explorer.

On our expeditions among the Baltistan Himalayas in 1902–1903 we carried with us two hypsometers, each with two thermometers, two 3-in. three-circle Watkin aneroids scaled to 24,500 ft., one latest pattern 3-in. Watkin mountain aneroid scaled to 25,500 ft., and a 3-in. Hicks aneroid scaled to 18,000 ft., which naturally played no *rôle* above the limits of its scale.

The directions given with the Watkin mountain aneroid are to allow 1 min. to elapse after turning it into action and then read, the understanding being that at first its reading will be about ·1 in. too high, and that the index will fall in 1 min. to its proper position.

Before putting this instrument to practical use a large number of observations at elevations from sea-level to 5,200 ft. were made to determine the value of the apparatus for throwing it out of and into action—its distinctive feature. All four aneroids were set by a standard barometer, and kept under exactly the same conditions. The readings of the other three were used to check those of the one tested. It was found that, on putting the last out of action for periods varying from 10 min. to 24 hrs., and then restoring it, it showed plus index errors of from ·3 to ·7 in.

During the first minute the needle fell about ·1 in., as the maker stated it should; during the second minute about ·03 in., after which its movements became imperceptible to

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the unaided eye. Although it continued to fall a period of several hours was required, sometimes 12 to 18, to restore it to accord with the other aneroids. The result in all experiments was invariably the same, the length of time necessary for the index to assume its proper working position varying in general with the time it remained out of action. The aneroid was returned to the maker to be examined, but nothing amiss was discovered. At the present time, after four years of use, and having been recently cleaned and adjusted, it works in exactly the same manner.

As the aneroid was thus shown to be unavailable for immediate reading after being put into action, this feature of it was never used on expeditions, but it was employed, like any other aneroid, with the index always in action, in which condition it worked consistently, and gave about as good satisfaction as the three-circle aneroids, though the latter, having a more open scale, appeared more sensitive to changes of pressure.

During the summer of 1903, while we were delayed by a storm at a snow camp on the Hoh Lumba glacier, at an altitude of 15,000 ft., it was thrown out of action for 25 min. On being restored to action the index showed a plus error of ·6 in., which after 50 hrs. still stood at ·2 in., the control aneroids having meantime fallen ·1. Whether that error was ever reduced to zero our further movements prevented me from ascertaining.

Recently in London, by the kindness of Mr. J. Hicks, the maker, who placed at my disposal a new 4½-in. Watkin mountain aneroid, I was enabled to make some further observations, of which the following are typical:—Obs. 1: Aneroid put out of action for 5 min. On restoration index showed plus error of ·11 in. During first minute it fell ·02 in. It returned to normal position in 2 hrs. 45 min. Obs. 2: Out of action 1 hr.; when restored index error was plus ·15 in. During first minute index fell ·04 in. After 6 hrs. error of ·04 in. still existed. Obs. 3: Out of action 12 hrs. When restored index error was ·16 in. During first minute index fell ·03 in. At the end of 10 hrs. it agreed with that of control aneroid.*

From the above observations it is evident that neither of

* These results do not necessarily imply any lack of skill on the part of the maker, but rather illustrate the extreme difficulty of constructing of metal an instrument that shall work with the desired precision.—W. H. W.

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these aneroids could be relied upon to give correct readings immediately after being put into action, and that they would be useless if used in the prescribed manner by mountaineers, who have no time to wait for instruments to adjust themselves. The temporary shut-off index errors not only differ in the two instruments, but they are not constant in the same instrument under different conditions of time and altitude, which would have to be the case if any proper allowance were to be made for error from this cause. The observation at the glacial camp and others of similar nature, together with the fact that that aneroid has always shown a persistent tendency to plus error, lead me to suspect that the use of the shut-off may cause a permanent and accumulating plus error, although I have not been able to investigate this point sufficiently to assert it.

These are experiences with only two Watkin mountain aneroids; but, as these were made by a manufacturer of high reputation, and declared by him to be perfect in construction, and as the second was made four years later than the first, which latter bears a number well into the second hundred of its series, their distinctive feature, presumably, fairly represents the same feature of other similar instruments.

These results throw suspicion on the accuracy of readings taken in this manner with aneroids of this class, and suggest the desirability of further investigation of the working of this arrangement. Every possessor of a Watkin mountain aneroid can satisfy himself of its value, in case of his own instrument, by repeating these observations. A presumptive test can be readily made by setting the marker on the rim accurately with the index, after the aneroid has been a day or more in action turning it out of action for five minutes, and, on restoring it, observing how long a time is required for the index to coincide again with the marker.

On putting the aneroid into action for use I allow 48 hrs. to pass to permit it to adjust itself fully to existing conditions, and then test the index by barometer or hypsometer.

After starting on our expedition to Baltistan in 1902 the four aneroids, which when quiet had read well together, although handled with every care and subjected to the same conditions, so far as possible, developed different index errors, even when there was little change in altitude; and it was seldom that any three of them ever read alike. The extremes of difference sometimes amounted to ·5 inch. Altitude did not appear to influence the errors as checked by the

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hypsometer, and the aneroids averaged as well in this respect at 19,000 ft. and above as at 5,000 to 8,000 ft.

The two which proved most reliable often agreed in their readings or differed by only ·01 or ·02 inch. Both of these always showed plus errors above 17,000 ft., except on one occasion, when one of them had a slight minus error.

This last circumstance is of interest in connection with Mr. Whymper's observations on the loss of aneroids of an older type as compared with the mercurial barometer under diminished pressure, indicating possibly an improvement in construction.

Further observations with these two and a 3½-in. aneroid scaled to 25,500 ft., recently made for us, all of which when set and tested in the laboratory were found to correspond with the standard mercurial barometer throughout their whole range, showed a disagreement in the readings of all three after being carefully taken in a hand satchel at sea-level a few hours' journey from London. These facts, together with others of similar nature, lead me to the opinion that motion, if not the chief, is a very important factor in the causation of index errors, whatever may be found to be the effect of diminished pressure on instruments of recent construction.

The Beichgrat.

By THE EDITOR.

EVIL weather drove my friend W. C. Compton and myself, with our guides, Johann Stoller, of Kandersteg, a son-in-law of Compton's favourite guide, Abraham Müller, and Benjamin Pession, a brother of my trusty companion François Pession, of Valtournanche, to Belalp on August 28, 1905. We walked up from Naters on that rare delight last season a really fine morning. All things were at their best except the flowers, which had for the most part gone to sleep to prepare for next year's exhibition, except *Campanula barbata alba*, which would have been the bliss of solitude, but near to so frequented a track was adventuring itself to destruction. Shall I not then receive absolution from my readers when I admit that I plucked its flowers, lest haply they should be conveyed, roots and all, to an untimely sepulchre on the window-sill of some pseudo-philanthist's bedroom, or be exhibited in a purloined soup plate to the languid gaze of a bored *table d'hôte*? The weather, instead of bullying us, laid itself

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