EXCESSIVE CASES OF LATERAL REFRACTION

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Lateral, or horizontal refraction is quite frequently encountered in the angular measurement of triangulation systems, but its occurence is usually spasmodic and may usually be attributed to air currents or pockets on lines in proximity to buildings, mountain masses, *etc.* Two cases of consistent lateral refraction have occurred in Canada which permit the underlying causes in these cases to be investigated and, perhaps, explained.

An extended and persistent example of lateral refraction was met on the triangulation net of the St. Lawrence River and Gulf, the field work of which covered some 325 miles and extended over four seasons. In this net the lines along the river bank were so consistently " bent " *towards the river* that a practice had to be adopted of ending observations on these lines only when the results on at least two nights showed a satisfactory agreement. Lateral refraction affecting the observations by from 5 seconds to 15 seconds of arc was not at all uncommon, and it has been estimated that almost three times the amount of clear weather ordinarily necessary to secure the required program of observations was used to secure the required accuracy. Even with the precautions which were taken, the evidence shows a regular bending *towards the river* of the lines parallel to the river. This is evidenced by the error of closure of triangles, the sum of the three observed angles being less than the theoretical sum in the majority of cases.

From an illustration showing curved lines exaggerating the " bent " condition of the lines parallel to the river, it is obvious that the sums of the angles of all of the triangles of which the figures are composed would be less than they should be. The following table was compiled from the closure errors of the triangles used in the adjustment of this large net:

	Number	*Average error*
Triangles in which sum of angles was too small	42	—1.107"
Triangles in which sum of angles was too large	12	+0.700"

Had only accidental errors entered into the measurement of the angles of this net, approximately the same number of positive as negative closing errors would have been expected. The last column indicates that even where the sum of the angles was too large, the errors were probably reduced by the " bending " indicated above. This information may be stated in another way. In the adjustment of this net the large majority of the corrections to lines parallel to the river " unbent " these lines away from the river.

	Number	*Average correction*
Corrections which " unbent " lines away from river	54	0.450"
Corrections which produced opposite effect.	12	0.257"

This table indicates a great preponderance, both in number of bent lines and magnitude of the correction. In contrast to this tendency of the lines parallel to the river to bend towards the river, the adjustment gave to lines crossing the river 62 positive corrections averaging 0.343". and 61 negative corrections averaging 0.316". The errors on these lines are clearly of an accidental, rather than a constant, type.

A superficial explanation of the persistent occurrence of lateral refraction in this area is probably that the strata of air of different density frequently did not lie horizontal, as is generally assumed, but followed more or less closely the surface of the land. Lines along the hilly shore passed through strata which dipped towards the river, and the plane of the curved path of the ray of light, being perpendicular to the strata, was inclined towards the river. The light, hence, appeared above, and slightly to the river side of its true position instead of directly above, as would be the case were the strata of air horizontal. This theory accounts for the fact that on the lines across the river no evidence of horizontal refraction existed.

The season of 1925 provided further examples of the persistent occurence of this phenomenon and permitted the underlying causes in certain cases to be still further investigated. During the hot weather, in the course of the measurement of a precise traverse on the railway tracks along the Skeena River in British Columbia, aggravated cases of lateral refraction occurred. In this case the lines were " bent " *away from the river* and towards the hills, just the opposite to the effect in the St. Lawrence River area noted above.

The railway runs in a general east-and-west direction along the north bank of the river at the base of the cliffs many hundreds of feet high. The sun, therefore, shone on these cliffs during most of the day. Traverse courses were short, owing to the excessive curvature of the railway line, varying from 100 to 2,000 metres. An azimuth line connected stations about 5 miles apart, so that loops were formed which permitted the error of closure to be measured. Measurement of traverse angles made in strong sunlight consistently showed that the traverse lines were " bent " *towards the cliffs*, the angular error increasing with the length of the line. Re-observation of the angles at 65 traverse stations at night or on dull days disclosed errors of from three to five seconds on 100—to 200—metre lines and up to 20 seconds on lines near a mile in length. The sign of the error in all cases showed the lines to have been " bent " towards the cliffs.

The explanation advanced is that the air close to the cliffs became super-heated, much expanded and hence less dense than the air at equal elevations over the river. The layers of air of equal density or pressure therefore dipped as they approached the cliffs.

The refracted course of the rays of light passing through these layers of air of different density may have been tilted from a vertical even to a horizontal plane. Even in such cases the coefficient of refraction must have been from 0.2 to 0.5 to have produced the above effects, a very excessive figure.

The foregoing interpretation may be used to further explain the tilting of the air strata which was found in the St. Lawrence River area. The observations in this district were made on lights at night, when the land surface was cooling rapidly. This cooling would produce a contraction of the air with consequent greater density, and, as the land became cooler than the very large body of water, the strata of air of equal density would tilt upwards towards the hills and produce the lateral bending so consistently noted.

Under this theory it might have been anticipated that the above " bending " of the lines towards the St. Lawrence River would not have occurred had the lines been observed in the daytime. Indeed the effect might have been the reverse on hot days.

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