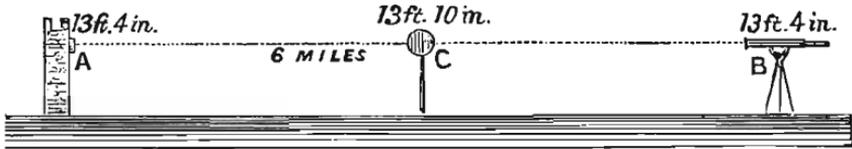


opposite to it is not seen, but only some other point minutely distant from it, but the distance of which is increased by the divergence caused by the lenses; and this divergence is what is called the "magnifying power." This is the source of those peculiarities which have been so very illogically considered to be proofs of the earth's rotundity. It is from this peculiarity that several gentlemen prematurely concluded that the water in the Bedford Canal was convex.

On the 5th of March, 1870, a party, consisting of Messrs. John Hampden, of Swindon, Wilts; Alfred Wallace, of London, William Carpenter, of Lewisham, M. W. B. Coulcher, of Downham Market, and J. H. Walsh, Editor of "The Field" newspaper, assembled on the northern bank of the "Old Bedford Canal," to repeat experiments similar to those described in figs. 2, 3, 4, and 5, on pages 11 to 14 of this work. But, from causes which need not be referred to here, they abandoned their original intentions, and substituted the following. On the western face of the Old Bedford Bridge, at Salter's Lode, a signal was placed at an elevation of 13 feet 4 inches above the water in the canal; at the distance of three miles a signal-post, with a disc 12 inches in diameter on the top, was so fixed that "the *centre* of the disc was 13 feet 4 inches above the water-line;" and at the distance of another three miles (or six miles altogether), on the eastern side of the Welney Bridge, another signal was placed, "3 inches above the top rail of the bridge, and 13 feet 4 inches above the water-line."* This arrangement is represented in the following diagram, fig. 94:—

* Reports by Messrs. Carpenter and Coulcher, published in "The Field" of March 26, 1870.

FIG. 94.



A, the signal on the Old Bedford Bridge ; B, the telescope on Welney Bridge ; and C, the central signal-post, three miles from each end. The object-glass of the telescope was $4\frac{1}{2}$ inches diameter ; hence the centre, or true eye-line, was $2\frac{1}{4}$ inches higher than the top of the signal B, and $3\frac{3}{4}$ inches *below* the top of the signal-disc at C. On directing the telescope, "with a power of 50," towards the signal A, the centre of which was $2\frac{1}{4}$ inches *below* the centre of the telescope, it was seen to be below it ; but the disc on the centre pole, the top of which was, *to begin with*, $3\frac{3}{4}$ inches *above* the centre, or line of sight, from the telescope, was seen to stand considerably *higher* than the signal A. From which, three of the gentlemen immediately, but most unwarrantably, concluded that the elevation of the disc in the field of view of the telescope was owing to a rise in the water of the canal, showing convexity ! whereas it was nothing more than simply the upward divergence (of that which was *already* $3\frac{3}{4}$ inches *above* the line of sight) produced by the magnifying power of the telescope, as shown in the experiment with the lens, on page 267, fig. 92.

Why did they omit to consider the fact that $3\frac{3}{4}$ inches ~~ex-~~cess of altitude would be made by a magnifying power of 50, to appear to stand considerably above the eye-line, and that a mere hair's breadth of dip—an amount which could not be detected—towards the distant signal would by magni-

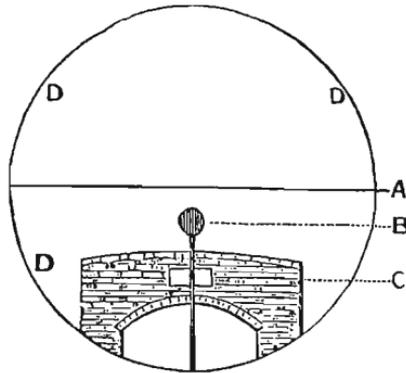
fyng, diverging, or dilating all above it, make it appear to be lifted up for several feet? Why did they not take care that the *top* of the centre disc was *in a line* with the telescope and the distant signal, A? Why, also, was the centre of the object glass fixed $2\frac{1}{4}$ inches *higher* than the centre of the object of observation at the other end? There was no difficulty in placing the *centre* of the telescope, the *top* of the middle disc, and the *centre* of the farthest signal mark, at the *same altitude*, and therefore in a straight line. For their own sakes as gentlemen, as well as for the sake of the cause they had undertaken to champion, it is unfortunate that they acted so unwisely; that they so foolishly laid themselves open to charges of unfairness in fixing the signals. Had they already seen enough to prove that the surface of the water was horizontal, and therefore instinctively felt a desire to do their best to delay as long as they could the day of general denunciation of their cherished doctrine of the earth's rotundity? Such questions are perfectly fair in relation to conduct so unjust and one-sided. It is evident that their anxiety to defend a doctrine which had been challenged by others overcame their desire for "truth without fear of consequences;" and they eagerly seized upon the veriest shadow of evidence to support themselves. In the whole history of invention, a more hasty, ill-conceived, illogical conclusion was never drawn; and it is well for civilisation that such procedure is almost universally denounced. It is scarcely possible to draw a favourable conclusion as to their motives in departing from their first intentions. Why did they not confine themselves to the repetition of

the experiments, an account of which I had long previously published to the world, and to test which the expedition was first arranged? That of sending out a boat for a distance of six miles, and watching its progress from a fixed point with a good telescope, would have completely satisfied them as to the true form of the surface of the water; and as no irregularity in altitudes of signals, nor peculiarities of instruments, could have influenced the result, all engaged must at once have submitted to the simple truth as developed by the simplest possible experiment. That men should cling to complication, and prefer it to simplicity of action, is difficult to understand, except on the principle, as it was said of old, "Some love darkness better than light." It is certain that many are ever ready to contend almost to death for their mere opinions, who have little or no regard for actual truth, however important in its bearings or sacred in its character.

These same gentlemen tried another experiment, from which they, quite as prematurely and illogically as before, drew the conclusion that the water was convex, and not horizontal.

"A 16-inch Troughton level, accurately adjusted, was placed in the same position and height above the water as the large achromatic telescope employed in the last experiment," when the signal-pole, three miles, and the signal-flag on the bridge, six miles, away, were seen as shown in the following diagram, fig. 95. A is the cross-hair, B the signal-disc, and C the signal-flag on the Old Bedford Bridge. The telescope, D, D, D, carrying the cross-hair A, is on the bridge at Welney, three miles obverse from B and six from C.

FIG. 95.



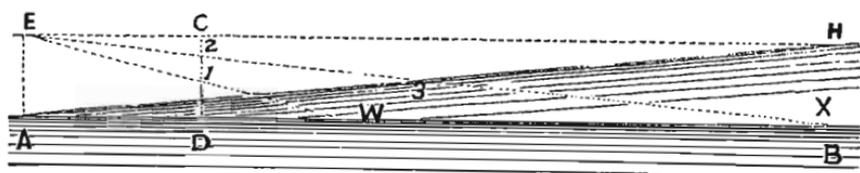
From the above observations, two of the experimenters at once concluded that the cross-hair in the line of sight was a tangent, and the water convex—the appearance of B, and C, resulting from the declination of the surface of the canal. It has been shown already that the best constructed levelling instruments necessarily produce, from the nature and arrangement of the lenses, a refraction or divergence of 1-1000th of a foot in a distance of 10 chains or 660 feet, so that the well-known and admitted refraction inseparable from the instruments employed, is fully sufficient to explain the position of the disc at B, and the flag at C, without demanding that the theory of the earth's rotundity is thereby corroborated. It is the duty of surveyors, and all who have an interest in this subject, to carefully study these peculiarities of levelling instruments, and not only to make themselves thoroughly acquainted with them, but to acknowledge their influence in every one of their operations. Should anyone have the slightest doubt of the effect of lenses in causing divergence of the line of sight, let him simply provide two

instruments of precisely the same construction, except that one shall have the lenses taken out. It will then be seen that the instrument with lenses will not read, upon a graduated staff, the same point as that without them. The latter will give the true reading; and the difference between this and the reading of the instrument with lenses, is the amount for which allowance must be made, otherwise the results, however extensive and important, must be fallacious.*

In connection with this part of the subject, it will be useful to explain what is the cause of the apparent rise of a plane or horizontal surface towards the axis of the eye.

In the following diagram, fig. 96:—

FIG. 96.



Let A, B, represent a plane surface—say several miles over the sea, and E, an observer's eye. It is evident that on looking directly downwards, as from E to A, the real and the apparent position of the water-surface will be the same. But if a transparent screen or a plate of glass be erected at some distance from the eye, as at C, D, and the sight be directed over the water to the distance W, the line of sight will cut the screen C, D, at the point 1, and the surface of the water will appear at 3, equal to the altitude of 1. If the sight

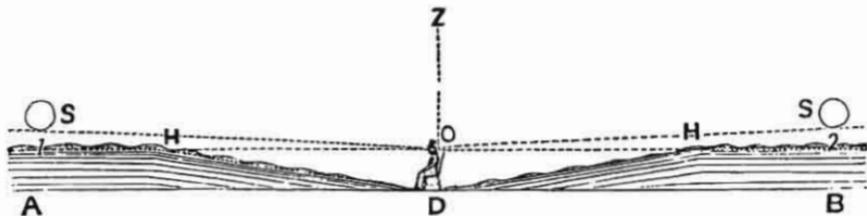
* The origin and consequences, pecuniary, legal, &c., of the two last-named experiments, may be known by reading several pamphlets written respectively by Mr. Hampden, Mr. Carpenter, and the author of this work, and the reports and subsequent correspondence in "The Field" newspaper.

is now directed to the point X, the line of sight, E, X, will cut the screen C, D, at the point 2, and the surface of the water will appear to be elevated to the point 4. It is evident, then, that the line of sight may be directed further and further over the water beyond X, and each further line of sight would cut the screen nearer to the line E, C, H, but could never become perfectly parallel with it. In the same way the surface of the water would appear nearer and nearer to the line E, H, at H, but could never come in actual contact with it: the angle H, E, X, becomes more and more acute as the distance increases; but, mathematically, the lines E, X, E, H, might be prolonged *ad infinitum*, the angle C, E, 2, infinitely acute, and the space H, 4, between the surface of the water and the line E, H, immeasurably small, but actual contact is mathematically impossible. Although there is always, at great distances, a minute space between the line of sight and the surface of the water at the horizon, still, for all practical purposes, and to the naked eye, there is no dip required.

The above remarks are made considering the water to be still, as if it were frozen; but as the water of the sea is always in a state of undulation, it is evident that a line of sight passing over a sea horizon cannot possibly continue mathematically parallel to the plane of the water, but must have a minute inclination upwards in the direction of the zenith. Hence it is that often, when the sun is setting over a stormy or heavily swelling sea, the phenomenon of sunset begins at a point on the horizon sensibly less than 90° from the zenith. The same phenomenon may be observed at sunrise, from any eminence over the sea in an easterly direction, as from the summit

of the Hill of Howth, and the rock called "Ireland's Eye," near Dublin, looking to the east over Liverpool Bay, in the direction of the coast of Lancashire. This is illustrated by diagram 97:—

FIG. 97.



A, D, B, represents the horizontal surface of the sea, and D 1, and D 2, the optical or apparent ascent of the water towards the eye-lines O 1, and O 2; O, D, the observer; Z, the zenith; H, H, the horizon; and S, S, the morning and evening sun. It is obvious from this diagram that if the water had a fixed character, as when frozen, the angle Z, O 1, or Z, O 2, would be one of 90° ; but on account of the waves and breakers at the horizon H, H, mounting half their altitudes above the lines O 1, and O 2, the line of sight meets the sun at S, which appears to rise or set on the elevated horizon H, the angle Z, O, S, being less than 90° .

This is evidently the cause of the sun setting and rising at sea, later when the water is calm, and earlier when it is greatly disturbed—a fact well known to observant sea-going travellers and residents on eastern or western shores. It is also the cause of the sun rising later and setting earlier than it would over a smooth plane of earth, or over absolutely still water, or than it ought to do mathematically for its known altitude.