Bicentenary—1972

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1972 was the bicentenary of the first proposal for an enterprising and imaginative experiment—the use of a mountain to find the mass of the earth, suggested to the Royal Society by Nevil Maskelyne, the Astronomer Royal, in 1772. There had been an unsuccessful attempt by a French scientist, Bouguer, to use Chimborazo in the Andes for the purpose some years before, but arduous experimental conditions had led to inconclusive results. However, they did seem to indicate that the material at the centre of the globe was more dense than that at the surface, i.e., the earth was neither hollow nor filled with water as had been conjectured previously. Now wrote Maskelyne:

'If the attraction of gravity be exerted, as Sir Isaac Newton supposes, not only between the large bodies of the universe, but between the minutest particles of which these bodies are composed, or into which the mind can imagine them to be divided, acting universally according to that law by which the force which carries on the celestial motions is regulated; namely, that the accelerative force of each particle of matter, towards every other particle, decreases as the squares of the distances increase; it will necessarily follow, that every hill must, by its attraction, alter the direction of gravitation in heavy bodies in its neighbourhood, from what it would have been from the attraction of the earth alone, considered as bounded by a smooth and even surface. For, as the tendency of heavy bodies downwards, perpendicular to the earth's surface, is owing to the combined attraction of all the parts of the earth on it, so a neighbouring mountain ought, though in a far less degree, to attract the heavy body towards its centre of attraction, which cannot be placed far from the middle of the mountain. Hence the plumb-line of a quadrant, or any other astronomical instrument, must be deflected from its proper situation, by a small quantity towards the mountain; and the apparent altitudes of the stars, taken with the instrument, will be altered accordingly.

It will easily be acknowledged, that to find a sensible attraction of any hill, from undoubted experiment, would be a matter of no small curiosity, would greatly illustrate the general theory of gravity, and would make the universal gravitation of matter as it were palpable, to every person, and fit to convince those who will yield their assent to nothing but downright experiment. Nor would its uses end here, as it would serve to give us a better idea of the total mass of the earth, and the proportional density of the matter near the surface, compared with the mean density of the whole earth. The result of such an uncommon experiment, which I should hope would prove successful, would doubtless do honour to the nation where it was made, and the society which executed it.'

Two British hill areas were put forward initially as providing suitable conditions for the experiment—'Pendle-hill, Pennygant, Ingleborough and Whernside' on the Lancashire-Yorkshire border and 'Helwellin and Skidda' in Cumberland. However, in 1773 the Royal Society sent Charles Mason on a tour through the Highlands of Scotland 'taking notice of the principal hills in

England which lay on his route'. The above were rejected for various reasons, but in Perthshire he found: ' . . . a remarkable hill, of sufficient height, tolerably detached from other hills, and considerably larger from east to west than from north to south, called by the neighbouring inhabitants, Schehallion'. This was agreed as the site for the experiment. The necessary apparatus was available at the Royal Society, King George III provided the funds, Maskelyne was appointed to the task, and work began in 1774.

42 *Apparent difference in position of a star-transit viewed from north and south of a mountain* Sketch: P. Sharp

The method Maskelyne was proposing to use involved measuring the deflection of a plumb-line from the true vertical caused by the adjacent mass of the mountain. This was done by comparing observations of star transits across the meridian at stations north and south of the mountain, and thus obtaining the angle between the apparent verticals (zeniths) at the two stations. A portion of this effect is due to the curvature of the earth, the remainder results from the deflection of the plumb-line by the mountain (see figure).

Maskelyne arrived at the mountain on the last day of June 1774 and worked on, whenever the weather permitted, until 24 October, by which time he had made 337 observations on 43 different stars, taking every possible precaution to eliminate sources of error. In the meantime a careful survey of the mountain and its surroundings was being made by Reuben Barrow and William Menzies, and this was not finally completed until the following year.

The observed angle between the verticals was found to be 55 sec. the deflection due to the curvature of the earth obtained from the survey was 43 sec. giving a difference due to the mountain of 12 sec. The bulk of the mountain had to be computed from the survey figure before the final result could be obtained, and this work was carried out by William Hutton. If the density of the mountain had been the same as the earth, the measured deflection, after allowing for curvature, should have been 20·9 sec or $\frac{9}{5}$ times the observed amount. The earth, then, was $\frac{9}{5}$ times as dense as the mountain. The density of the mountain as measured on local rock samples was about 2·75 g/c^3, giving a density for the earth of 4·95 g/c^3 (i.e., confirming that the core is considerably more dense than the surface layers). (The present accepted average figure derived by a range of methods is 5·52 g/c^3.)

Increasing accuracy of measurement in later years enabled these earth-weighing experiments to be carried out inside the four walls of the laboratory. Advances in the knowledge of the inhomogeneity of the earth shook the premises on which this simple experiment was based. Nevertheless, the magnificence and scale of the concept leave us admiring still. Maskelyne and his associates have a secure place in the history of mountains.