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(*b*. Kingston-on-Soar, Derbyshire, England, 2 February 1793; *d*. Cambridge, England, 13 October 1866)

geology, mathematics.

The only son of a gentleman farmer, Hopkins had a desultory early education which included some practical farming in Norfolk. Later his father gave him a small estate near Bury St. Edmunds, but he found the task of management both uncongenial and unprofitable. After the death of his wife he sold the estate to pay off debts and to provide the means wherewith in 1822, at the age of thirty, he entered St. Peter's College (Peterhouse), Cambridge. Here he married again and his mathematical talent shone. He took the B.A. in 1827, placing as seventh wrangler, and then became a very successful private tutor of mathematics. Among his many pupils who attained high distinction were George Stokes, William Thomson (Lord Kelvin), P. G. Tait, Henry Fawcett, James Clerk Maxwell, and Isaac Todhunter. In the 1830's he was appointed a syndic for the building of the Fitzwilliam Museum.

Hopkins became intensely interested in geology about 1833, after excursions with Adam Sedgwick near Barmouth, in northern Wales. He decided that he would place the physical aspects of geology on a firmer basis, would free it from unverified ideas, and "support its theories upon clear mathematical demonstrations." [1] His mathematical models and propositions greatly impressed contemporary geologists, and in 1850 he was awarded the Wollaston Medal of the Geological Society of London for his application of mathematics to physics and geology. In 1851 and 1852 he was elected president of that society and in 1853 presided over the British Association for the Advancement of Science. He became a fellow of the Royal Society, and following his death the Cambridge University Philosophical Society founded in his honor a prize which was first awarded in 1867 and triennially thereafter.

The main written product of Hopkins' interest in pure mathematics is the two-volume *Elements of Trigonometry* (London, 1833–1847). His applications of mathematics to geology were expressed mainly in articles, the contents of which may be grouped under the following topics: crustal elevation and its effect on surface fracturing, the transport of erratic boulders, the nature of the earth's interior, and the causes of climatic change.

Hopkins attempted to explain dislocations or fractures at the earth's surface by estimating the effects of an elevatory force acting at every point beneath extensive portions of the earth's crust. From his consideration of the pressures exerted by explosive gases, vapors, and other subterranean forces upon the crust, he concluded that during crustal extension and fracturing there must originate in nearly all cases first a series of longitudinal parallel fractures and second, with continued uplift, a series of transverse dislocations at right angles to the first. This rectangular pattern of faults provided the fundamental directive lines during the elevation and formation of continents and of mountain systems. On this assumption Hopkins discussed the elevation and denudation of the English Weald and Lake District and of the Bas Boulonnais in northern France. In the Weald, a land of wide longitudinal vales at the foot of steep escarpments that are breached transversally by narrow river valleys, Hopkins concluded that the main vales and scarps were associated with longitudinal parallel fractures and that the transverse valleys were formed by dislocations at right angles to them. He admitted that he could not find true geological evidence of fracturing except perennial springs, which he assumed to be thrown out at faultlines. Today, as by the more perceptive geologists then, the Weald valleys and scarps are considered to be typical products of subaerial erosion and not of crustal fracturing.

Hopkins played an important and equally unfortunate part in the contemporary debate on the transport of erratic boulders. The aura of mathematical conclusiveness that surrounded his work caused his opinions to make a lasting impression and to be hailed as incontrovertible by his followers. At first he rejected glacial or ice transport as an explanation of the movement of erratic boulders, since it often involved "such obvious mechanical absurdities that the author considers it totally unworthy of the attention of the Society."[2] In his studies of the Lake District Hopkins postulated sudden upheavals during each of which a great mass of water, or "wave of translation," rushed down the rift valleys, rolling and sliding great boulders for long distances. The idea was welcomed by antiglacialists in Britain and by leading geologists in America, including H. D. Rogers, who in 1844 wrote:

It has been shown by Mr. Hopkins, of Cambridge, reasoning from the experimental deductions of Mr. Scott Russell upon the properties of waves, that "there is no difficulty in accounting for a current of twentyfive or thirty miles an hour, if we allow of paroxysmal elevation of from one hundred to two hundred feet," and he further proves that a current of twenty miles an hour ought to move a block of three hundred and twenty tons, and since the force of the current increases in the ratio of the square of the velocity, a very moderate addition to this speed is compatible with the transportation of the very largest erratics anywhere to be met with, either in America or Europe.[3]

Although Hopkins' idea was wrong when applied to the transport of glacial erratics—as he himself later half admitted—in presenting it he added detail which, when applied to hydraulic work, was to prove of great value and is today known as Gilbert's sixth-power law. Assuming, as Playfair had shown, that the force of a current increases in the ratio of the square of its velocity, Hopkins calculated that "if a certain current be just able to move a block of given weight and form, another current of double the velocity of the former would move a block of a similar form, whose weight should be to that of the former in the ratio of 2^6:1 *i.e*. of 64 to 1."[4]

Hopkins' theoretical investigations into the constitution of the interior of the earth made him "one of the most famous champions of the theory of the earth's rigidity."[5] Assuming that the earth was originally molten, he calculated from the varying effects of the sun's and moon's attraction (and especially of precession and nutation) that the solid crust of the earth had a thickness of at least one-quarter or one-fifth of its radius. This thickness, he concluded, virtually prohibited direct heat or matter transference from the molten interior to the earth's surface; and therefore volcanoes must draw their molten material from reservoirs of moderate size within the solid crust. The largely solid and rigid state of the earth was considered to be due to cooling and to great internal pressure, an opinion supported by the work of Poisson, Ampère, George H. Darwin, and Lord Kelvin. Indeed, it was on the advice of Kelvin that Hopkins in 1851 undertook at Manchester, with the help of Joule and Fairbairn, experiments that showed effectively that the fusion temperature of strata increased considerably with depth and pressure.

Hopkins' theoretical studies on the motion of glaciers and on climatic change contained nothing new except their praiseworthy quantitative precision. For example, his deductions that the most probable cause of changes of climate during geological time was the influence of alterations in the various configurations of land and sea and in ocean currents were already held by Lyell and others, but none had hitherto expressed the details in precise mathematical terms. Thus, except in the popularization of quantification and in the broader field of geophysics, Hopkins' effect on contemporary geology was frequently retrogressive rather than progressive. He was often lacking in geological insight; and it is not entirely through misfortune that his valuable sixth-power law of hydraulic traction is usually attributed to G. K. Gilbert, who applied it firmly to river flow and not to mighty waves caused by paroxysmal uplifts of mountains.

NOTES

1. W. W. Smyth, in *Quarterly Journal of the Geological Society of London*, **23** (1867), xxx.

2. "On the Elevation and Denudation of the District of the Lakes of Cumberland and Westmoreland," p. 762.

3. Address to the Association of American Geologists and Naturalists, in *American Journal of Science*, **47** (1844), 244–245; see also R. J. Chorley, A. J. Dunn, and R. P. Beckinsale, *The History of the Study of Landforms*, I, 278.

4. *Op. cit*. (1842), pp. 764–765; (1849), p. 233.

5. K. A. von Zittel, *History of Geology and Palaeontology*, p. 178.

BIBLIOGRAPHY

I. Original Works. Hopkins' writings were published, often successively in enlarged form, mainly as articles in *Transactions of the Cambridge Philosophical Society, Proceedings* and *Quarterly Journal of the Geological Society of London, Philosophical Transactions of the Royal Society*, and *Report of the British Association for the Advancement of Science*. The most important are "Researches in Physical Geology," in *Transactions of the Cambridge Philosophical Society*, **6** (1838), 1–84, mainly on crustal elevation and fracturing; "Researches in Physical Geology," in *Philosophical Transactions of the Royal Society*, **129** (1839), 381–423; **130** (1840), 193–208; **132** (1842), 43–55, on precession and nutation and their probable effect on the nature of the earth's crust and interior—see also *Report of the British Association for the Advancement of Science* for 1847 (1848), pp. 33–92; and for 1853 (1854), pp. xli-lvii; "On the Geological Structure of the Wealden District and of the Bas Boulonnais," in *Proceedings of the Geological Society of London*, **3** (1841), 363–366; "On the Elevation and Denudation of the District of the Lakes of Cumberland and Westmoreland," *ibid*. (1842), pp. 757–766, repr. in full, with map, in *Quarterly Journal of the Geological Society of London*, **4** (1848), 70–98; "On the Motion of Glaciers," in *Transactions of the Cambridge Philosophical Society*, **8** (1849), 50-74, 159-169, which favors a rigid sliding, fracturing motion; "On the Transport of Erratic Blocks," *ibid.,* pp. 220-240; "Presidential Address," *in Quarterly Journal of the Geological Society of London,***8** (1852), xxi-lxxx, mainly on glacial drift and temperature changes; "On the Granitic Blocks of the South Highlands of Scotland," *ibid.,* pp. 20-30, which considers that striations on rocks are due to half-floating ice; "On the Causes Which May Have Produced Changes in the Earth's Superficial Temperature," *ibid.,* pp. 56-92, a detailed paper with a map of isotherms; and "Anniversary Address," *ibid.*, *9* (1853), xxii-xcii, which attacks Élie de Beaumont's ideas on pentagonal fracturing during crustal uplift and fracturing. See also "On the External Temperature of the Earth...," in *Monthly Notices of the Royal Astronomical Society,***17** (1856–1857), 190-195, which makes use of H. W. Dove's world isothermal map.

II. Secondary Literature. See R. E. Anderson, in *Dictionary of National Biography* XXVII (1891), 339-340; R. J. Chorley, A. J. Dunn, and R. P. Beckinsale, *The History of the Study of Landforms* I (London, 1964), *Passim,* with a portrait; J. W. Clark and T. M. Hughes, *Life and Letters of the Rev. Adam Sedgwick* II (Cambridge, 1890), 74, 154, 323; Henry Rogers Darwin, address to the Association of American Geologists and Naturalists, in *American Journal of Science*, **47** (1844), 244-245; W. W. Smyth, in *Quarterly Journal of the Geological Society of London,* **23** (1867), xxix-xxxii; *The Times* (London) (16 Oct. 1866), p. 4; and K. A. von Zittel, *History of Geology and Palaeontology,* M. M. Ogilvie-Gordon, trans. (London, 1901), pp. 168, 178, 303.

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