Book Review and Essay: The Geology and Physical Geography of Robert Hooke (1635-1703)

**The Forgotten Genius: The Biography of Robert Hooke 1653-1703.**

**The Curious Life of Robert Hooke: The Man Who Measured London.**

Reviews and Short Biography of Hooke by
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Popular scientific biographies cannot be expected to make a complete exposition and assessment of their subject's work: such would require specialist treatment directed at a different audience. Assessing the scientific contributions of Robert Hooke (1635-1703) is notably difficult because he contributed significantly to the development of scientific knowledge in so many fields, and he was so prolific with ideas and suggestions that partisans of his genius can usually find something in his writing to confirm their faith. It is clear, for example, that the Newton specialist Richard Westfall (1969) brings considerably greater critical power to bear upon Hooke's physics than upon his geology. At the same time, Drake (1981, 1996) and Drake and Komar (1983) are almost uncritical champions of the view that Hooke, single-handedly and without credit, was the founder of modern geology.

As Curator of Experiments for the Royal Society (1662-1677), Secretary of the Royal Society (1677-1682), Gresham Professor of Geometry (1665-1703), and Cutlerian Lecturer in Mechanics (1664-1703), Robert Hooke contributed to developments in astronomy, biology, mechanics, meteorology, optics, and geology. His ideas in optics and celestial mechanics, although rarely worked through to a complete, conclusive mathematical demonstration (see Westfall 1969), prefigured Newton's mathematical and experimental triumphs, and he dogged Newton with claims of plagiarism; hence, ultimately, he became a victim, both in life and death, of Newton's wrath and almost boundless vindictiveness (see Espinassee1956, and Gleick 2003). While, earlier, Newton had graciously admitted the influence of others' ideas in his thinking about optics, including Hooke's, allowing that "If I have seen further, it is by standing on the shoulders of giants" (1676), later, concerning Hooke's claim to priority in universal gravitation and the inverse-square law, Newton wrote of Hooke as someone who "should have excused himself by reason of his inability," someone who "does nothing but pretend and grasp" -- "a man of strange and unsociable temper" (1686). Newton then: deleted a reference to "the Most Illustrious Hooke" from a draft of Book III of the "Principia" and added a prominent and glowing mention of Wren, Wallis, and Huygens (Gleick 2003, note 6, p.224); delayed publication of his "Opticks" (1704) until after Hooke's death "To avoid being engaged in disputes;" and, finally, on becoming President of the Royal Society, again after Hooke's death, is said to have destroyed the only portrait of Hooke believed to have existed (but see Jardine 2004, for a possible discovery).

Hooke's inventions and improvements were numerous and highly ingenious and included the iris diaphragm, the universal joint, the compound microscope, the wheel barometer, and the basic mechanism for the pocket watch (over which he had a patent dispute with Huygens). Hooke's version of the vacuum air pump was a wonder of its time and in his Oxford days (1657-1662) as Robert Boyle's assistant he had much to do with Boyle's formulation of his famous gas law. He was also appointed City Surveyor of London (1666-1676) following the Great Fire, in which capacity he laid out and oversaw the execution of the new street plan and contributed in the design of buildings, including some churches formerly attributed to Wren (Inwood 2003, pp.124-127): and it was Hooke who designed the Monument to the Great Fire. For all this, he is probably known to most
people only for "Hooke's Law;" namely, the restoring force due to a spring is proportional to the length that the spring is stretched provided the elastic limit is not exceeded.

As 2005 is the 300th anniversary of the publication of his Posthumous Works, which include his "Discourses of earthquakes and subterraneous eruptions," and since two popular biographies have been published so recently (Inwood 2003; Jardine 2004), this might be a good time to assess his contributions to geology and geomorphology.

The earliest modern biography of Hooke is Espinasse's (1956) fairly short topical review. Relatively little research and commentary on Hooke's geological work existed in 1956 (Lyell 1830; Geikie 1905; Rossiter 1935; Edwards 1936; Andrade 1950) and his "Lectures and discourses of earthquakes and subterraneous eruptions" was only republished in 1969 for the first time in over 100 years (Westfall 1969). Perhaps not surprisingly, Espinasse comments on Hooke's geology almost in the passing (pp.47,53,76-77). She devotes chapters to Hooke's Micrographia (1665) and the Cutlerian Lectures, but little to the Discourses before the Royal Society that contained the bulk of his geological thinking. She notes that, as in so many other matters, "Neglect also overtook Hooke's views on geology and evolution..." (p.76).

Inwood (2003) and Jardine (2004) are the first popular biographies in almost fifty years; both make interesting presentations out of Hooke's life. Jardine's book is the shorter of the two and perhaps the more entertaining, but Inwood's book, first published in Britain in 2002 under the title "The man who knew too much," is more comprehensive and fast-paced and is ultimately much the more satisfying of the two. Both authors devote much space to the politicking within the Royal Society and the various controversies over priority which embroiled Hooke all-too-frequently, but little to actually assessing the real value of his ideas. Jardine devotes nothing to his geological work, inserting reference to some of his observations on fossils only as part of an account of his up-bringing on the Isle of Wight, in southern England. Inwood provides brief accounts of Hooke's geological work at various stages of his life (pp.116-119, 347-348, 364-366). While making no attempt to assess their value, these accounts are roughly proportionate to everything else in his busy life and Inwood devotes an entire chapter to an important dispute in 1687 with the Oxford mathematician John Wallis over Hooke's disregard of Biblical chronology in his geological writing. Neither bibliographer mentions an earlier rancorous exchange in 1673 with Henry Oldenburg, the Secretary of the Royal Society, over Oldenburg having translated and published Steno's 1669 "Prodromus," which contained an argument concerning the organic origin of fossils and a theory of the Earth, something Hooke had first laid out in 1665 in his "Micrographia" and in detail in 1668 in an extended lecture ("discourse") before the Royal Society.

"Micrographia" (1665) contains a Preface in which Hooke lays out a scientific philosophy that is more or less hypothetico-deductive (Hooke commented further on this in his discourses of June 1667 - September 1668 and December-January of 1868-1687). The detailed observations contained in Micrographia were made possible by Hooke's design changes on the microscope (particularly illumination of the subject) and his great skill as an artist. The book was a sensation, but it contains much more than magnified observations of plants and animals, which alone should have secured his reputation. The book also contributes to: a chemical theory of combustion; a mechanical view of heat; the use of hair as a hygrometer; a theory of color and light; a design for a new thermometer; a theory linking respiration and combustion; a detailed description of plant cells ("cells" being his coinage); and a view of lunar craters as "bombardment holes." He also devoted a chapter to a careful comparison of fossilized wood and shells to living examples, and his observations lead him to conclude that fossils are true petrified organic remains and are not "form'd by some extraordinary Plastick virtue latent in the Earth it self" as was commonly believed at the time (p.110). He argued that "Nature does nothing in vain; it seems, I say, contrary to that great Wisdom of Nature, that these prettily shaped bodies should have all those curious Figures and contrivances... generated or wrought by a Plastick virtue, for no higher end then only to exhibit such a form" (p.112). He suggested that they came to be in their present locations "either by some Deluge, Inundation, Earthquake, or some-such means" (p.111) and recommended that a systematic collection and study be made of these phenomena (p.112).

Hooke elaborated greatly on these views in a series of lectures ("discourses") before the Royal Society between June 1667 and September 1668 (he added new arguments on several occasions over the next 32 years in what he saw as a failed attempt to persuade his colleagues in the Royal Society). He then believed that the Secretary of the Royal...
Society, Henry Oldenburg, who kept up correspondence with societies and individuals abroad (and who spent two months in 1667 in The Tower under suspicion of treason for "writing news to a virtuoso in France:" Winter 1916, p.197), had given away his ideas on fossils to Steno (Eyles 1958, p.174). To add to the injury, Oldenburg translated and published Steno's (1669) "Prodromus" between 1671 and 1673 before Hooke had a chance to publish his lectures from 1668 on the subject. Hooke was not placated by Oldenburg's Preface, in which he wrote: "Mr. Robert Hooke has... ready some Discourses upon this very argument [the organic origin of fossils], which, by reason of the many avocations he hath met with in the rebuilding of the City of London, and his attendance on the R. Society [Hooke was Curator and had to furnish three demonstrations per week to meetings], he hath not yet been able quite to finish for the press" (Winter 1968, p.111). In fact, Hooke never did finish these lectures for the press, and a final total of 27, dating from 1668 to 1700, were published posthumously in 1705; in the meantime, Oldenburg in his Preface quoted Boyle's unpublished opinions on the subject of minerals and fossils and so appeared to give him a share of the priority Hooke fully deserved.

It should be noted that Steno had already published on the subject in 1667 (Garboe1958) and his polished geological observations and arguments are clearly his own work (see Eyles 1958). Hooke again returned to subject of priority in a discourse in July 1694 in which he castigated the Society for not publishing his work while, meantime, the Paris Academy had published a memoir in 1692 concerning "much the same with what I have formerly presented to this honorable society" (Waller 1705, p.448). Given the difficulty he was experiencing in getting his organic views accepted in London, Hooke wondered why what passed in Paris "for a good argument... may not also be a good argument here" (Waller 1705, p.448).

However Hooke may have underestimated his impact on English geological thinking beyond the Royal Society (see Ito 1988, for a review).

In arguing for an organic origin for fossils Hooke had to address the question as to why they often appeared to represent creatures that were no longer living. Not content simply to assert that perhaps they do still exist somewhere, yet to be discovered, he argued for evolution and extinction caused by environmental change as continents had changed their latitude: "there have been many other species of creatures in former ages, of which we can find none at present; and that 'tis not unlikely also but that there may be divers new kinds now, which have not been from the beginning" (Waller 1705, pp.291, 327, 435). Not surprisingly John Ray, the naturalist and natural theologian, regarded his own growing belief in the organic origin of fossils as fraught with dangers and "such a train of consequences as seem to shock the Scripture-History of the novity of the world" (Ray 1695, quoted in Davies 1969, p.17). Like Steno, Hooke also addressed their burial by deposition, the processes of fossilization, and the lithification of the enclosing rock (Waller 1705, pp.291, 294).

Hooke also had to account for the widespread distribution of fossils at all altitudes (also depths) and distances from the sea. In contrast to the proponents of the Deulge (e.g. Steno, Woodward), who at least accepted the organic origin of fossils, Hooke argued for the power of earthquakes and volcanoes to alter the distribution of land and sea, and believed that this had happened repeatedly: "nor are these changes only now -- but they have in all probability been of longstanding as the world" (Waller 1705, p.314). He had also placed sub-aerial processes alongside earthquakes as agents of surface change that tended to level out the effects of the latter, and so briefly outlined a rudimentary cyclic view of the continents (Waller 1705, pp.312-313). Later, for good measure ("to leave everyone to the freedom of his thoughts:" Waller 1705, p. 412), he also offered raising and lowering of crustal blocks as a mechanism for the "gathering of the waters" during Creation and for the Flood (Waller 1705, pp.412-415) although he believed that these were not the only occasions on which land and sea had exchanged places and neither did he think the Flood alone an adequate means to account for the distribution of fossils (Waller 1705, p.412). He speculated that earthquakes and volcanoes had perhaps been more frequent in the past, before Earth had "waxed old as animals and vegetables do... harder and fixt... [and] before the fuels... were much spent" (Waller 1705, p.325). Here Hooke echoes a common, directionalist religious view of the time.

In early 1687 Hooke outlined a coherent theory to account for repeated uplift and subsidence. He argued that Earth is oblate (again correctly foreshadowing Newton) and he conjectured that Earth is repeatedly subject to what today we term "true polar wander" (see movie animation at http://www.gps.caltech.edu/~devans/iitpw/science.html). He offered some possible mechanical and
astronomical tests of these ideas (Waller 1705, pp.345-362). Polar shift of an oblate Earth, he believed, would shift stresses within the planet's body and cause displacements of the "external" and "internal" parts of Earth. In addition, the greater equatorial depth of an oblate ocean would further contribute to submergence or emergence of land as latitudes shifted. Reference has been made above to the effects of latitude shift on evolution and extinction. Submergence would result in deposition and in preservation of animal remains (Waller 1705, pp.346-348).

His new theory of oblateness and repeated polar shift was ridiculed (so he thought) by an old Oxford acquaintance, the mathematician John Wallis who, in March 1687, wrote that Hooke caused the Earth to be "tossed and turned upside down ... and the top of the Alps become a sea only to enable us to give an account of some fish-shells found there" (Oldroyd 1989, p.212). Wallis declared that the Alps had never been under water "except in Noah's Flood" (Oldroyd 1989, p. 211) and that there were no historical (particularly Biblical) records of the kind of changes Hooke envisaged, either before or after the Flood. Wallis thought the idea that "the whole face of the Earth should have been ... many times all covered with water and dried again ... too extravagant for us to admit" and wondered "in what ages of the world ... should this have happened" (Oldroyd 1989, pp.211-212). Wallis himself subscribed to the view that fossils were simply mineral growths that resembled animal remains.

In response Hooke offered further possible observational tests of polar shift, but these proved impracticable or inconclusive (Oldroyd 1989, pp.221-225). He also vacillated somewhat on the question of repeated submersions: "as for my asserting it to have been so many times covered and dried as he [Wallis] alleges, this proceeds either from a falsity ... or a mistake of his information" (Oldroyd 1989, pp. 215). However, in a striking conjecture, Hooke declared that one day fossils themselves might be used "to raise a Chronology [a history] ... to state the intervals of the times wherein such catastrophes and mutations have happened" (Waller 1705, p.411). However, Hooke's conception of "chronology" is well within the then commonly accepted limits of Earth being no more than a few thousand years old; in fact, he suggests the Alps might well have been raised in the time since the Flood (Waller 1705, p.324).

In the absence of a conclusive demonstration of his ideas (something not unusual for Hooke) he then embarked on a series of remarkable lectures between late 1687 and late 1693, in which he examined recent accounts of earthquakes and volcanoes and in which he reinterpreted classical mythology as containing hidden knowledge of just such interchanges of land and sea as he had believed necessary to explain fossils. His obsession in this interpretive task makes his views appear increasingly catastrophist and linear as he loses sight of his overall theory of earthquakes. Lyell (1830 pp.31-35), who had expressed a very high opinion of Hooke as the first English geologist to argue cogently for the organic origin of fossils "in opposition to the prejudices of his age," believed that Hooke expended his scientific capital on this work and that "for this reason, perhaps, his whole theory of earthquakes met with very undeserved neglect" (p.35). Although his theory of polar shift lacked conclusive proof, at least it had not been "proposed dogmatically, but rather in the hope of promoting fresh inquiries and experiments" (p.33). Such was the impact of Wallis's criticism on the direction of Hooke's work that Young (1987) came to count Hooke among the "scriptural geologists."

But perhaps more than just Wallis's criticism was acting upon Hooke. In May 1689, Hooke insisted again that evolution and extinction had happened, and declared "yet I do not see how this doth in the least derogate from the power, Wisdom, and Providence of God, as is alleged, or that it doth any ways contradict any part of the Scripture ... I think quite the contrary inferences may, nay, must, and ought to be made" (Waller 1705, p.345). He continued, just as individuals grow and develop and die, "then why may there not be the same progression of the species from its first creation to its final termination?" (p.435). Here Hooke also referred to the commonly held theological view that the Earth itself was in dissolution. In July 1690 Hooke took further care to argue that his ideas were not blasphemous; specifically, his belief that not all land masses (such as the Americas) are accounted for in the Bible and his inquiries into the proximate physical causes of phenomena in general: "Divine Providence is not less conspicuous in every production we call natural" (Waller 1705, pp. 423-424). It is as if he felt on somewhat dangerous ground. Then, in June 1693, he seems to have realized that perhaps he might have gone too far in using classical (pagan) mythology as a source of knowledge and he carefully points out that "those who made this fable [he was discussing Phaeton] knew better things, and only made use of mythology to conceal their
knowledge from the vulgar" (Waller 1705, p.391 – see Rappaport, 1986, for dating of this lecture). It is possible that Hooke was here reacting to the fate of Thomas Burnet who was famous for "The Sacred Theory of the Earth" (Latin 1681-89, English 1684-90), and which Hooke's had read carefully. In 1692 Burnet published "Archaeologiae philosophicae sive doctrina antique de rerum originibus" which Hooke reported on to the Royal Society in December 1692 (see Ito 1988, footnote 39 p.302). In this book Burnet drew upon ancient myths concerning the creation of the world (as he had done in 1681), but he argued, further, that the Biblical account of the Fall was also an allegory. For his views Burnet was removed from his position as Clerk of the Closet in the Court of King William (Davies 1969, p.74).

Hooke's continued his discourses on geology almost up to end of his life. There remains the question as to his influence in the English-speaking world: while some of his contemporaries were persuaded of his views on fossils (Ito 1988), his larger theory of earthquakes and the Earth had no followers, except possibly for Raspe (1763; Carozzi 1970). More immediately Woodward (1695), who had remained in the background while Hooke lived, came to the fore with his theory of Earth's dissolution during the Flood (see Davies 1969, pp.74-83, and Ito 1988).

Drake (1981, 1996) has argued that Hutton was greatly influenced by Hooke; certainly it appears that Hutton had Hooke in mind in dismissing the influence of axial shift and the power of earthquakes as a cause of major change (Hutton 1788, pp.222-223). Like Hooke, Hutton was not concerned with Creation and sought to understand nature in terms of natural events. Nevertheless, Hutton was more overtly religious (deistic) in his approach and focused first on denudation and the movement of material as part of a cycle that maintained Earth as a habitable place (see also Woodward 1695); Hutton had little to say about fossils, which he took to be organic. Most important, Hooke, while more free with history than many of his time, still did not think Earth more than a few thousand years old; Hutton, on the other hand, denied the Mosaic time scale and so freed geology from catastrophism. Hutton formulated a view of nature that he believed exhibited "wisdom, system and consistency" (p.304) operating over an "indefinite" time scale (p.301). Crucially, again unlike Hooke, Hutton was successful in actually demonstrating this system through the existence of unconformities. Hutton's system provided a workable framework for geology regardless of errors in the details (see the subtitle to Lyell's 1830 "Principles"), as was also the case with some of Steno's generalizations on strata.

In one of his last lectures, in 1694, frustrated at the prejudices he believed lay behind the lack of acceptance of his arguments for fossils, he returned to his first principles as a scientist: "one may easily believe that many changes may have happened on Earth of which we can have no written history . . . to me it seems very absurd to conclude that from the beginning things have continued in the same state we now find them, since we find every thing to change and vary in our remembrance; certainly 'tis a vain thing to make experiments and collect observations if, when we have them, we may not make use of them; if we must not believe our senses, if we may not judge of things by trials and sensible proofs, if we may not be allowed to take notice of and to make necessary consequentaries and corollaries, but must remain tied up to the opinions we have received from others and disbelieve every thing, tho' never so rational, if our received histories doth not confirm them . . . we should have no more to do but to learn what they have thought fit to leave us: but this is contrary to the Nullius in verba of this Society" [i.e. "Take no man's word for it:" the motto of the Royal Society] (Waller 1705, p.450).

Even if his work lost some of its focus in the 1680s, it cannot be denied that Hooke was the first scientific geologist in the English-speaking world, and herein lies his significance. Had he actually been able to test his views on polar wander and its effects on the Earth he would have found them to be erroneous; but that does not make him any less of a scientist or less worthy of our recognition.

End Notes
i Hooke's geological work can be read in various editions.
ii In general, facsimile reproductions of Waller's 1705 edition while authentic, are difficult to read (Westfall 1968; Brown 1971; Hooke 1978). Drake's (1996) edition of Hooke's "Lectures and discourses of earthquakes and subterraneous eruptions" has modern typeface and spelling, making it an easy read; it also contains an extensive biography and assessment of his work; however, this assessment
has its weaknesses – Drake is an unabashed Hooke "booster" and the commentary frequently repeats
misinterpretations and over-interpretations
contained in Drake (1981, 1983) and Drake and
The older facsimile editions all have excellent, brief
introductions. Westfall (1969) provides a realistic
assessment of Hooke's achievements and is well
worth reading although, as a Newton scholar,
Westfall is on his best ground when discussing
Hooke's physics; Brown (1971) summarizes each
lecture well; and Hooke (1978) reproduces, by way
of introduction, Rossiter's (1935) pioneering
geological essay. All the facsimile reproductions
contain Waller's (1705) original biography.

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