Robert Hooke, Rudolf Erich Raspe, and the Concept of "Earthquakes"

By Albert V. Carozzi *

THE VARIOUS TYPES OF DISLOCATIONS in the earth's crust, particularly well displayed by sedimentary rocks, attracted the attention of many naturalists of the seventeenth and eighteenth centuries. Those who accurately described folded and tilted sedimentary beds, like Benoît de Maillet[1] and J. G. Lehmann,[2] interpreted them as the result of submarine deposition, layer after layer, over the irregularities of an indurated substratum, like coats of paint or plaster applied with a brush on an irregular wall. In the absence of any orogenic theory, this "plastering process" was the only rational explanation that could be offered for folded and tilted beds, although it neglected to take into account the fundamental observation of Nicolaus Steno (*Prodromus*, 1669) that water can only deposit horizontal beds even on an irregular substratum.

Within this concept of a static earth's crust in which deformed beds were considered as original depositional features, or in some local instances as the result of collapses into subterranean cavities, Robert Hooke's "Lectures and Discourses of Earthquakes and Subterraneous Eruptions"[3] appears as a revolutionary contribution. It was actually written in 1668—predating Steno's *Prodromus* by a year—but was published only as a posthumous work in 1705. In essence, Hooke's work introduced into structural geology the dynamic concept of vertical movements of the crust, upward and downward, explaining by means of a simple and spectacular hypothesis the origin of islands, continents, mountains and valleys within continents, and ocean basins.

Fundamental to all of Hooke's geological speculations was his conviction that the vast majority of fossils represent the remains of former marine organisms turned into stone. The principal object of his work, however, was to explain the manner in which fossils had been brought to the highest parts of the Alps, the Apennines, the Pyrenees, and to the interior of continents in general—their occurrence in such places being clear

* University of Illinois, Urbana. I am greatly indebted to my colleague George W. White for many helpful comments and for a critical reading of the manuscript.

[1] Benoît de Maillet, *Telliamed or Conversations between an Indian Philosopher and a French Missionary on the Diminution of the Sea*, trans. and ed. Albert V. Carozzi (Urbana: Univ. of Illinois Press, 1968).

[2] J. G. Lehmann, *Versuch einer Geschichte von Flötz-Gebürgen* (Berlin: Klüter, 1756).

[3] Robert Hooke, *The Posthumous Works of Robert Hooke Containing His Cutlerian Lectures and Other Discourses Read at the Meetings of the Illustrious Royal Society*, ed. Richard Waller and R. S. Secret (London: Smith & Walford, 1705). See esp. Ch. 5, pp. 279–450: "Lectures and Discourses of Earthquakes and Subterraneous Eruptions, explicating the Causes of the Rugged and Uneven Face of the Earth; and what Reason may be given for the frequent finding of Shells and other Sea and Land Petrified Substances scattered over the whole Terrestrial Superficies."

evidence that major changes in the distribution of land and sea had taken place since the creation.

Hooke attributed these important changes of the face of the earth essentially to the eruptions of some kind of subterranean fires or to *earthquakes*. It is fundamental to point out that Hooke used this word in the broad sense of any type of vertical displacement of the earth's crust, corresponding to the modern sense of diastrophic movements, not to the restricted sense of seismic disturbances. He considered that earthquakes could raise, lower, and disrupt the earth, even generate liquefactions, vitrifications, calcinations, and sublimations. Hooke demonstrated by numerous examples the universal character of this active principle of terrestrial change. He also combined it with his keen understanding of the climatic and local significance of fossils, attributing the extinction of certain fossil species to the effect of earthquakes destroying some species in certain places by raising or lowering the crust, while other species continued to live uninterruptedly elsewhere. Hooke's most remarkable contribution is the understanding that fossil mollusks deserve to be considered as historical documents, no less valuable than coins or manuscripts. However, he added, it would be very difficult, although not impossible, to unravel from them a *chronology* of the catastrophes and mutations which took place in the past.

Hooke does not appear to have had any clear idea about the causes of earthquakes and volcanoes, although he visualized a close relationship between the two phenomena; he considered them as the effects of "the general congregation of sulphureous subterraneous vapors." He thought it possible that the observed greater frequency of earthquakes and volcanoes on islands and along seacoasts might be due to the saline quality of seawater, causing subterranean fermentations with the sulphureous minerals located under the sea bottom. These fermentations would take fire and thus acquire enough force to uplift parts of the earth by earthquakes or to generate volcanoes while seeking an escape. The idea of the underground fermentation of sulphureous minerals certainly originated from the oxidation of pyrite, which does indeed cause the spontaneous combustion of coal seams at depth and of mine dumps at the surface.

Hooke conceived of the materials capable of producing conflagrations, eruptions, and earthquakes as somewhat similar to gunpowder. In describing deep-seated geological agents, Hooke apparently had not advanced further than the ancient and medievail writers. However, other aspects of his geological thinking, such as a remarkable grasp of the cyclic nature of events at the earth's surface and an understanding of unconformities, put him well ahead of his time and on the same level as Steno.[4]

Although implicitly accepting the Noachian Deluge, Hooke refuted it as a mechanism for depositing sedimentary beds and their enclosed fossils. He therefore felt compelled to present a diluvial theory of his own, becoming involved in many difficulties and contradictions which led him to a picture as extravagant as that reached by some of the diluvialists. In this way he became completely opposed to his earlier fundamental principles according to which he wanted to explain the former changes of the earth in *a more natural manner* than others had done. Possibly for this reason, as suggested by Charles Lyell,[5] his entire theory of earthquakes met with undeserved neglect.

[4] G. L. Davies, "Robert Hooke and His Conception of Earth-History," *Proceedings of the Geological Association*, 1964, *75*: 493–498.

[5] Charles Lyell, *Principles of Geology* (new ed., New York: Appleton, 1857), pp. 27–30.

Indeed, when Rudolf Erich Raspe,[6] the celebrated author of "Baron Munchausen's Marvellous Travels and Campaigns in Russia," had accepted in 1760 a modest clerical position in the Royal Library of Hanover, Hooke's contribution had essentially fallen into oblivion. The unusual combination of the intellectual impact of the Lisbon earthquake of 1755[7] and Raspe's activity as a library clerk made him "discover" Hooke's "Lectures and Discourses of Earthquakes." All through his life Raspe would be, as his friend J. G. von Herder called him, a "glücklicher Finder"—a fortunate finder.[8] He became rapidly convinced, after reading Hooke's system, that it was the best explanation, not only for volcanoes and earthquakes, but also for the origin of islands and continents. Therefore he decided that he would not only defend Hooke's theory, but give a new presentation of it by means of additionally proven data on new islands and mountains; in other words, he would present the work like Hooke would have written it had he lived in later times.

Although well versed in literature and the law, Raspe lacked what was considered appropriate geological training in the eighteenth century: attending a mining academy, such as Freiberg, or becoming the assistant of a famous naturalist, or taking fieldtrips to observe nature. It is certainly a mark of his genius that he nevertheless obtained notable success when he completed his bold project, published in 1763 under the title of *Specimen historiae naturalis globi terraquei. . . .*[9]

Specimen has usually been considered in later times as a rather conventional illustration of Hooke's "Lectures and Discourses of Earthquakes," and historians of geology, with the exception of Lyell, paid little attention to it.[10] However, a detailed analysis of *Specimen* reveals quite a different picture. The historical sections of the book are outstanding and testify to Raspe's classical erudition; those dealing with geology have obvious weaknesses, resulting from his lack of practical experience, but they also contain a number of original theoretical ideas in structural geology which are of great interest.

The discussion of the origin of mountains and their relationships to ore deposits represents an important part of *Specimen.*[11] It discloses an obvious influence, although not specifically acknowledged, of the work of J. G. Lehmann published in 1756.[12] Raspe combines in a clever fashion some of the ideas of Lehmann with those of Hooke,

[6] For a detailed biography of Raspe and a complete list of his published works see J. Carswell, *The Prospector, being the life and times of Rudolf Erich Raspe (1737–1794)* (London: Cresset Press, 1950), and R. Hallo, *Rudolf Erich Raspe, ein Wegbereiter von deutscher Art und Kunst* (Stuttgart/Berlin: W. Kohlhammer, Göttinger Forschungen, Heft 5, 1934).

[7] T. D. Kendricks, *The Lisbon Earthquake* (Philadelphia: Lippincott, 1957).

[8] Carswell, *The Prospector*, p. 32.

[9] R. E. Raspe, *Specimen historiae naturalis globi terraquei, praecipue de novis e mari natis insulis, et ex his exactus descriptis et observatis ulterius confirmanda Hookiana telluris hypothesi, de origine montium et corporum petrefactorum* (Amsterdam/Leipzig: J. Schreuder and P. Mortier, 1763). An annotated English translation is being prepared with Mrs. Audrey N. Iversen under the title "An Introduction to the Natural History of the Terrestrial Sphere."

[10] Only Lyell seems to have appreciated the importance of Raspe's contribution, as shown by the following excerpt of one of his letters to Charles Hawkins, dated 25 Jan. 1830: "His views were decidedly far beyond those of his age and I was delighted to find that he coincided with me in his admiration of Hooke of whom I have always been a great votary for he appears not only to have preceeded our countrymen in many original views but even the Italians who in most things anticipated the theoretical truths and errors of other countries." (Hawkins Papers, West Sussex Record Office, Chichester, Sussex, courtesy of Mrs. Joan M. Eyles). See also *Principles of Geology*, pp. 42–43.

[11] Ch. I, "The Surface of the Terrestrial Sphere," Secs. 49–54.

[12] See n. 2 above.

and in so doing changes the original meaning of the fundamental term *Gang-Gebürge*, introduced by Lehmann into the geological literature. This situation requires some elaboration because of its far-reaching consequences on the geological terminology of the eighteenth century.

Lehmann defined three classes of mountains. The first class, or primitive mountains (*Uranfängliche Gebürge*), were those which are the largest and the highest in the world. They are also interpreted as the oldest, having been formed, at the time of the creation, by precipitation in strongly agitated waters. Their rocks consist of poorly defined, thick beds of rather uniform mineralogical composition, devoid of fossils and steeply dipping into the depths of the earth. Whenever these primitive mountains contain veins of mineral deposits they are called *Gang-Gebürge*. The veins did not develop at the time of formation of these mountains, but later, when the waters withdrew and the materials dried up and contracted, allowing the rising of vapors from the earth's interior. These primitive mountains remained exposed until the Mosaic Deluge. Its waters overtopped them and finally deposited around their lower slopes a series of well-bedded and fossiliferous deposits, dipping away from them at a low angle and even becoming horizontal. Lehmann called these deposits *Flötz-Gebürge*, or the second class of mountains.

Raspe uses the term *Gang-Gebürge* in a different and broader sense than Lehmann to describe the initial "rough and shapeless masses" of rocks forming the bottom of the ocean or the original surface of the earth, in general lying deeply buried and hidden beneath the bedded and fossiliferous sedimentary rocks. In other words, Raspe does not use the term for original primitive mountains, but more in the modern sense of "basement rocks," particularly when the latter have been uplifted by the forces of earthquakes into high mountains and appear as a core in the middle of these mountains. Under such conditions, and if the *Gang-Gebürge* are ore bearing, they are reached by the miners through their sedimentary cover, which apparently has, according to Raspe, little or no mineral deposits. His lithologic description of the *Gang-Gebürge* is similar to that of Lehmann. Massive igneous types are distinguished—"quartz, granite and porphyry, made of harder and more homogeneous stone, generally vitreous and devoid of fossils"—as well as rare bedded types apparently corresponding to metamorphic rocks, such as gneisses and mica-schists.[13] However, the term *Flötz-Gebürge* is never used (although Raspe described many sedimentary rocks), presumably because he did not believe in the reality of the Noachian Deluge.[14]

Lehmann interpreted the strong tilting of the *Gang-Gebürge* as a primary feature expressing the mode of deposition, and their cracks and fissures as an effect of the drying up of the materials before the Deluge. Raspe, using a more dynamic approach and following Hooke's ideas, considered all these features as structural characters or mechanical results of pressure due to the uplifting of the *Gang-Gebürge* by the forces of earthquakes. He does not give any particular age for the filling of the veins by the action of subterranean waters, except to state that at one time the fissures had been open and were filled during the succession of time.[15]

The extent and attitude of sedimentary beds, their folding, tilting, and rupturing, and the associated systems of joints and fissures are described in a correct fashion. Again

[13] *Specimen*, Ch. I, Secs. 49 and 53.
[14] *Ibid.*, Ch. V, p. 185.
[15] *Ibid.*, Ch. I, Sec. 59.

following Hooke, Raspe interprets all these features as consequences of the pressures due to the uplifting forces of earthquakes.[16] This leads to his major contribution, given in Chapter IV of *Specimen*, entitled "Hooke's System," which consists of four mechanisms by means of which the generation of islands, continents, mountains within continents and at the bottom of the ocean is visualized. Raspe's fundamental premise is to consider the crystalline rocks forming the ocean bottom or the primitive surface of the earth as always overlain by a cover of sedimentary rocks. Then, expanding the dynamic concept of Hooke, he explains the observational facts by using the following four mechanisms:

1. A portion of the ocean floor consisting of the crystalline basement with its indurated sedimentary cover is pushed upward (Fig. 1) above sea level, generating an island or by extension a continent.[17]

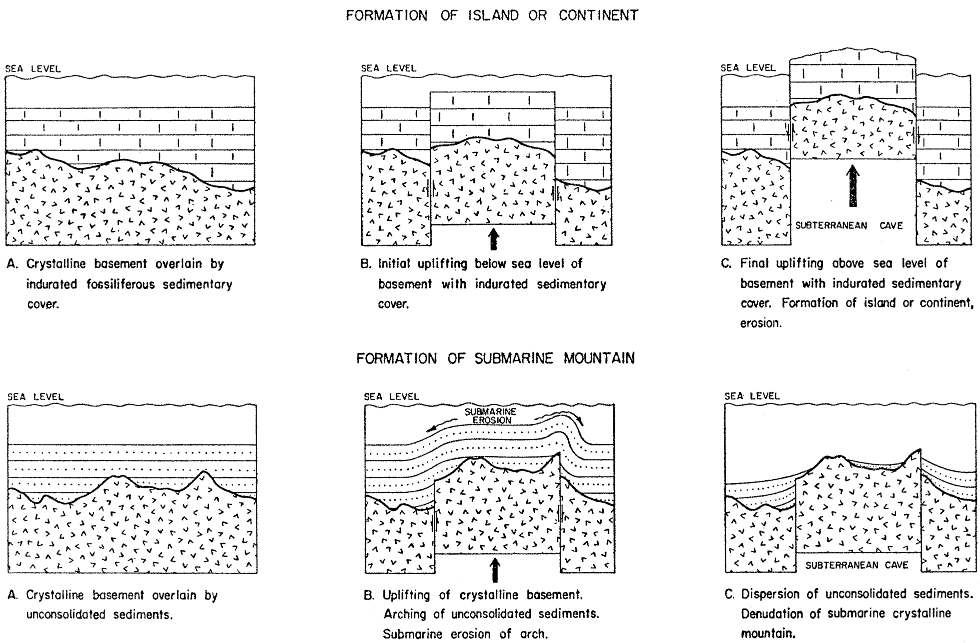

FIGURE 1. ***Theoretical diagrams illustrating the formation of an island or a continent and a submarine mountain according to Raspe.***

2. A portion of the ocean floor consisting only of the crystalline basement is pushed upward with its cover of unconsolidated sediments (Fig. 1). These are dispersed by submarine currents, and the crystalline rocks become exposed as submarine mountains.[18]

   After an island or a continent by extension has been pushed out of the ocean, further differential action by the force of earthquakes may generate mountains and intervening valleys or depressions by the following two processes:

[16] *Ibid.*, Secs. 9–29.

[17] *Ibid.*, Ch. IV, Prop. XVIII.

[18] *Ibid.*, Props. XIX–XXI.

3. A portion of the crystalline basement with its indurated sedimentary cover is differentially pushed upward (Fig. 2, mechanism 1). The sedimentary cover partially shaken and broken is subsequently destroyed by erosion, exposing the crystalline rocks at the top of the mountain.[19]

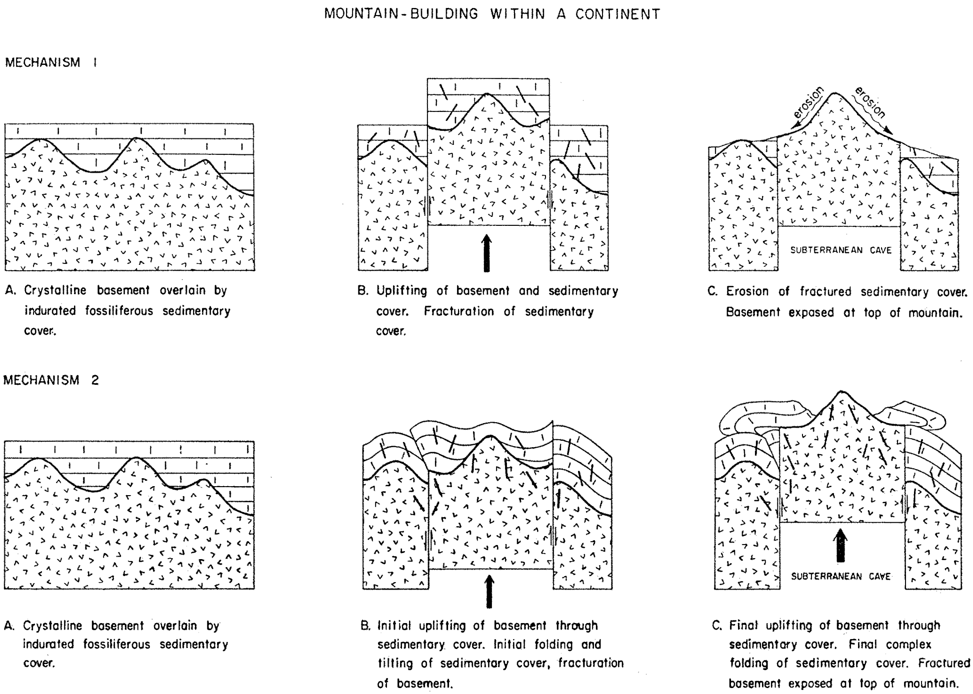

FIGURE 2. ***Theoretical diagrams illustrating two mechanisms of mountain building within a continent according to Raspe.***

4. A portion of the crystalline basement is differentially pushed upward *through* its indurated sedimentary cover (Fig. 2, mechanism 2), which becomes dislocated, tilted, and folded.[20] By means of this real mechanical intrusion, the crystalline rocks again reach the top of the mountains, displaying important networks of fractures and fissures. (Actually, this mechanism would lead to lateral overthrusting of the cover, which Raspe did not visualize, and the effect of erosion should also be considered.)

These four mechanisms necessarily involved in Raspe's mind the generation of subterranean or submarine caverns. Although uplifting has been discussed here for demonstration purposes, the sinking of adjacent areas, as well as alternating phases of uplifting and sinking, are part of the same process, all being different aspects of the effects of the subterranean force of earthquakes.

Plate I of *Specimen* (Fig. 3), unfortunately a rather crude sketch, provides nevertheless an interesting insight into Raspe's ideas about mountain building. Although this

[19] *Ibid.*, Prop. XXXIV.

[20] *Ibid.*

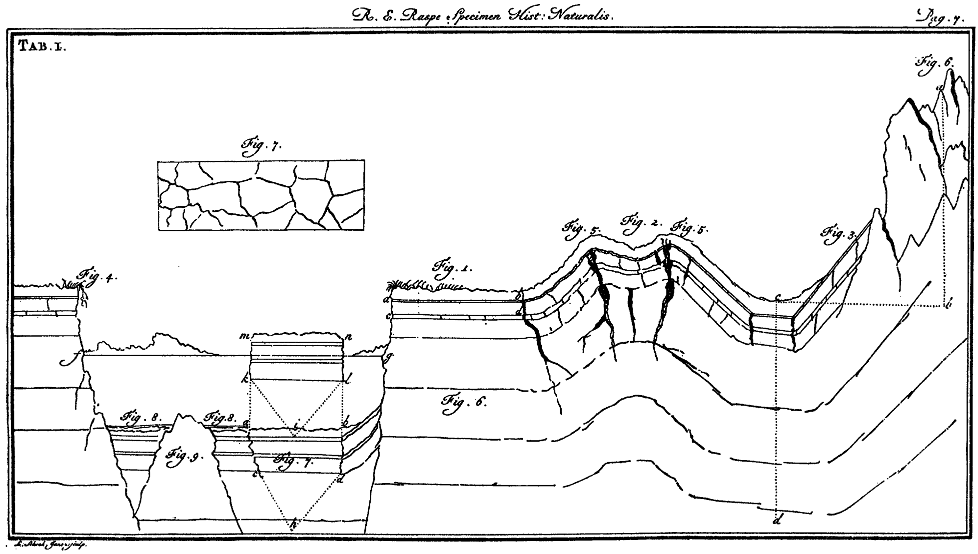

FIGURE 3. ***Reproduction of Plate I of Raspe's*** **Specimen historiae naturalis globi terraquei . . .** ***(1763).***

plate should not, in all fairness, be considered as the equivalent of a modern geological cross-section, it is a graphic synopsis of all the assumed effects of earthquakes. On the left half is a horizontal succession of beds dislocated by a subsided section which appears as a graben. On the left portion of its bottom is a granite submarine mountain (9), and from its right part an island is uplifted, creating a corresponding subterranean cavern (7). The center portion of the plate shows the same succession of beds concentrically folded into anticlines and synclines with radial V-shaped fractures, apparently mineralized. At the extreme right the "rough and shapeless masses" of crystalline rocks (6) display sharp peaks and appear indeed to have broken through the envelope of tilted bedded rocks with their joint system, a more detailed sketch of which is given in the upper left part of the plate.

In the history of the fundamental concepts of structural geology, the dynamic approach of Hooke and its detailed amplification by Raspe represent the first clear expression of the action of vertical movements in the shaping of the earth's crust. This process gradually gained acceptance and became, in the early part of the nineteenth century, the basis of the theory of the *cratères de soulèvement* advocated by Leopold von Buch (1825) and Alexander von Humboldt. Later, vertical movements were reduced to a secondary role, when the contraction theory was introduced by Léonce Élie de Beaumont (1829–1830). They were essentially dismissed in the latter part of the nineteenth century and early part of the twentieth century, when the geosynclinal theory (J. Hall, 1859, and J. D. Dana, 1873) and its related horizontal movements (overthrusts and *nappes* of E. Suess, 1875, and A. Heim, 1878) became the generally accepted process of mountain building. However, vertical movements have again been considered as an important mechanism in some recent orogenic hypotheses.[21]

[21] V. V. Beloussov, *Basic Problems in Geotectonics* (New York: McGraw-Hill, 1962).