ARNOLD GUYOT AND HUMBOLDTIAN SCIENCE

In Mid Nineteenth-Century New England

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ABSTRACT

This article examines Arnold Guyot's (1807-1884) studies of the physical geography of New England within the concept of "Humboldtian science." After a brief explanation of that framework, it discusses Guyot's work on the Smithsonian Institution's meteorological project and his measurement of the heights of New England mountains and their written and cartographic display. Guyot is shown to be a full participant in and a leading practitioner of Humboldt's methods during his New England years.
Keywords: Alexander von Humboldt, Appalachian mountain system, Arnold Guyot, Joseph Henry, Smithsonian meteorological project.

Arnold Henri Guyot (1807-1884) is perhaps best remembered today as the author of *Earth and Man* (1849), a book based on the lectures he delivered early in 1849 in a hall of the Marlboro Chapel, the Lowell Institute's venue in central Boston. Guyot had been self-exiled from Switzerland in 1848 when the Grand Revolutionary Council of Geneva had invaded the nearby city of Neuchâtel and closed the Academy and College, where Guyot had been employed as Professor of Physical Geography and History since 1839 (Ferrell 1981; Koelsch 2008a, 2008c).

Guyot's teaching, as set forth in *Earth and Man*, in his lectures for teachers' institutes and normal schools in Massachusetts and New Jersey, and in much of his later series of elementary textbooks, both refined and extended the teaching ideas and methods he had learned from his primary mentor, Carl Ritter of the University of Berlin, under whom he had earned the Ph.D., *summa cum laude*, in 1835 (Koelsch 2008c). Guyot had not been enrolled at Berlin during the winter session of 1827-1828, when Alexander von Humboldt gave his famous course of lectures on physical geography at the university that served as the basis for his monumental five-volume work, *Cosmos*. Guyot did encounter him in the university's precincts, however. For instance, he found Humboldt in August Bockh's classroom, where they both heard lectures on philology and Greek archaeology. We know that Humboldt also attended Ritter's lectures at Berlin (Libbey 1884, 198; Sandys 1964, 3: 95-101; Wilson 2005, 37). Although Guyot was not a protégé of Humboldt to the same degree as his friend Louis Agassiz, during his stay in Berlin Guyot received a modest amount of Humboldt's interest and patronage. Guyot's dissertation at Berlin, dedicated to Humboldt and Ritter jointly, reflects his appreciation of both.

Most commentators on Guyot have stressed, sometimes to the point of exclusivity, his appropriation of Ritter's ideas on human-environment relations. Though Humboldt's ideas are not so obviously significant as Ritter's in Guyot's intellectual development, as Philip Wilson has shown it is evident in *Earth and Man* which, Wilson argues, is a selective synthesis of both (Wilson 2005). And in his own scientific work Guyot adopted Humboldt's interests and methods, particularly those in hypsometry and climatology, to a significant degree. At the American Geographical Society's Humboldt commemoration in 1859, Guyot pled for a continuation of Humboldt's scientific legacy in the New World, using "the careful methods that he taught us." Perhaps the relationship of the two in Guyot's mind was best expressed in the oft-quoted passage from his memorial address on Carl Ritter: "Humboldt furnishes the means; Ritter marks the goal" (Guyot 1859, 244; 1860, 63).

"Humboldtian Science" as Nineteenth-Century Practice

The term "Humboldtian science" was first used by the historian of exploration William Goetzmann to suggest a set of activities involving the patient accumulation of facts assembled in the hope that general laws would emerge (Goetzmann 1959, 18-19, 422, 423). The late Susan Faye Cannon, in an important book on early Victorian science, redefined the term as a practice that would eventually lead to laws through accurate measurement and the associated improvement of instrumentation, arguing for replacing the term "Baconian science" as a better description of nineteenth-century scientific practice. Cannon pointed out that not only did the latter term misrepresent Francis Bacon's own work, but that there was need for a new term that would identify more precisely the complex of interest and practices that, in its own time, was often called "physical geography" and which Humboldt had termed the "physics of the earth" (Cannon 1978, chap. 3).

Humboldtian science, as Cannon conceived it, "includes astronomy and the physics of the earth and the biology of the earth all viewed from a geographical standpoint, with the goal of discovering quantitative mathematical connections and relationships – 'laws,' if you prefer, although they may be charts or graphs" (Cannon 1978, 77). Cannon noted that Humboldt did not pretend to have invented all parts of this system. Improving the accuracy of portable instruments, for example, had been a concern of scientists long before Humboldt. But, she argued, Humboldt's contribution lay in "elevating the whole complex into the major concern of professional science for some forty years or so." Under this rubric she included the scientific pursuits of American scientists Alexander Dallas Bache, head of the Coast Survey; the physical geographer and oceanographer Matthew Fontaine Maury; Joseph Henry of the Smithsonian Institution; Harvard botanist Asa Gray, and other figures associated with scientific expeditions and state geological surveys (Cannon 1978, 74, 77).

"Humboldt's creed was measurement," Cannon asserted. All elements of the environment that varied geographically needed to have those variables precisely measured. These variables must also be related to one another in space and time, as well as to their local ecologies. Thus the distribution of plants must be related to variations in soil, degree of sunlight, latitude, altitude and other conditions of growth. Also, though Humboldt's ultimate aim was a search for governing laws of nature, he was quick to recognize that such laws could not be achieved in one man's lifetime, which bothered him no more than it did his nineteenth-century followers (Cannon

1978, 80, 87). In pointing out these characteristics of Humboldt's geographic approach to natural phenomena, Cannon fundamentally changed the ways we look at the scientific generation of his time.

Scholars writing subsequent to Cannon's seminal essay have used the concept to illuminate the work of Charles Darwin and other English-speaking scientists (see, e.g., Nicolson 1987; Home 1995). In a thought-provoking book linking literature and science, Laura Dassow Walls has contended that Henry David Thoreau was a Humboldtian as well (Walls 1995). Some, notably Humboldt scholar Michael Dettelbach, have attempted to extend the concept of Humboldtian science itself. Dettelbach has pointed out that Humboldt's view of the physical environment depended more upon complexity than upon a purely mechanistic approach. It depended on both "the greater the number of forces observed and accurately measured, and the greater the extent of the earth's surface such measurements covered..." Particularly important to Humboldt was meteorology, which with the aid of the isothermal lines he developed would show the influence of global forces acting locally; barometric measurement of altitudes and the construction of maps displaying variations in topography; and the geographical distribution of plants. Humboldt also recognized the importance of "an organized network of observers ...dispersed over large expanses of the earth's surface, using comparable instruments and standard protocols" (Dettelbach 1996, 291, 295-99). This approach was most notable in the cooperative research he stimulated on terrestrial magnetism (Cawood 1977), but is also marked in the Smithsonian network of meteorological observations, in which Guyot played a prominent role.

Cannon pointed out the contrast between Humboldtian science, "the accurate, measured study of widespread but interconnected real phenomena," and the restrictive framework of laboratory science. Humboldtian science depended upon a worldwide system of accurate observations of phenomena that could become part of the process of scientific generalization. By 1830, the year Guyot matriculated at Berlin, this was the arena of the scientific avant-garde (Cannon 1978, 105).

The Measurement of Atmospheric Phenomena

Soon after Guyot's arrival in the United States in September, 1848, he and Agassiz set off for Philadelphia to attend the inaugural meeting of the newly organized American Association for the Advancement of Science. Here Guyot met several prominent American scientists, was elected to membership, and spoke at length with the physicist Joseph Henry, formerly of the College of New Jersey and, in 1848, the first Secretary of the Smithsonian Institution. Henry had a long-standing interest in meteorology, and, in his days as a teacher at the Albany Academy, he had compiled the meteorological reports submitted by the various academies making weather observations in New York. The Regents of the University of the State of New York had required these reports since 1825, when they had furnished thermometers and wind gauges to each academy and required them to keep records of their observations (Coulson 1950, 29-30; Reingold 1973, 140; Moyer 1997, 124-25).

In his first report (1847) as Secretary of the Smithsonian, Henry had called for a national system of meteorological observations, particularly to assist the study of the origins and characteristics of storms. His consultant, the meteorologist Elias Loomis, recommended beginning by reorganizing the New York state system, equipping twenty academies with barometers and other instruments should they not have their own, and requiring reports of observations to the Smithsonian, following standardized instructions and reporting forms (Henry 1848; Coulson 1950, 195-96; Fleming 1990, chaps. 4, 5). Under these circumstances, the arrival of a scientist with extensive experience with barometric instruments, and who had previously set up a network of weather stations in Switzerland, must have seemed providential to the staunchly Presbyterian Henry. After the New York state legislature had approved and appropriated funding for the plan, Guyot was employed to order the instruments, plot the distribution of stations, and design registration forms and an instructional manual. Rejecting the instruments formerly employed in New York, Guyot had the New York instrument maker James Green manufacture a new cistern barometer reflecting the best current European standard, the Fortin, as modified by Ernst. Guyot and Green made further modifications in the interest of reliability and transportability. The result was the so-called "Smithsonian Barometer" (Middleton 1964, 345-48; 1969, 16-18; Fleming 1990, chap. 6).

Having divided the state into orographic regions in order to locate the best sites, Guyot spent November and December establishing seventeen stations along the storm track from Buffalo to New York City, teaching the observers the use of the new instruments, and determining barometrically the elevation of each station. He also placed barometers and wind-vanes in telegraph offices in the principal cities, thereby creating a record of pressure, wind direction, and other factors to be transmitted daily to the Smithsonian and to warn coastal cities of approaching storms. Armed with copies of his newly published pamphlet, *Directions for Meteorological Observations*, Guyot returned to New York in July 1850, revisiting the older stations and establishing twenty-one new ones, equipping a dozen of them with psychrometers to measure relative humidity.

Guyot's work in New York furnished him with an income, a model, and material for a series of scientific papers given to the American Association for the Advancement of Science and to the Boston-based American Academy of Arts and Sciences (hereinafter "Academy"), to which he had been elected in January 1849. To the latter group, in 1851, he used the opportunity of a tornado in Middlesex County to propose a new theory of tornado genesis. He also served on several Academy committees, including one advocating the metric system for barometric measurements (Academy 2: 236-37, 243-44, 269-70, 284-85, 289-91).

More importantly, Academy sponsorship helped Guyot and Henry persuade the Massachusetts legislature to establish a network of weather stations in that state similar to the one already launched in New York. At the Academy meeting of 6 February 1850, Guyot described his work in New York and moved the appointment of a committee to consider Massachusetts' cooperation in the Smithsonian network. Unsurprisingly, since Guyot chaired it, the committee reported favorably on the idea. The Academy then appointed another committee, chaired by the distinguished Harvard mathematician Benjamin Peirce, with Guyot and the influential Dr. Henry Ingersoll Bowditch as the other members, to petition the legislature for that purpose (Academy 2: 198-99, 220).

Ten days later, the trio formally petitioned the legislature to appropriate funds to purchase and install instruments at twelve to fifteen stations across Massachusetts. In addition to laying out the scientific justification, Peirce's committee argued the benefits of the scheme to commerce, agriculture, and public health, as well as to education, since under the plan the major academies, colleges, and normal schools would take part in making observations. Accompanying the proposal was a list of seventeen proposed stations (in Guyot's handwriting), together with a list of the equipment proposed for each. As he had done in New York, Guyot grouped the stations by physical region.

The Committee on Education, to whom the memorial was assigned, reported it favorably, and on 25 March, the Massachusetts legislature authorized the Governor to designate not more than twelve stations, one each to be located at the three colleges in the state (Harvard, Amherst, and Williams), and three of the others at the state normal schools at West Newton (now Framingham State College), Bridgewater, and Westfield. The legislature also authorized an appropriation from the state's School Fund of not more than $100 per station. Governor George Briggs did not designate the stations until January 1851, his list differing somewhat from Guyot's. He requested that the Smithsonian take charge of the project in cooperation with the Academy (Koelsch 1966, 76-78).

Henry again engaged Guyot to supervise the construction of the instruments, establish the stations, and train the observers. All instruments had been constructed and six stations were established by the end of 1851; four more began operations the following year. Outside the colleges and normal schools, however, Guyot had difficulty in recruiting willing observers, and on completion of the system in the fall of 1852, he recommended compensating them for their work. In that year he had also produced a set of meteorological tables that, subsequently revised and expanded to include physical tables, was to be reissued well into the twentieth century. But as J. R. Fleming has shown from his analysis of the original Smithsonian reports, observations at many Massachusetts stations were intermittent, short-lived, or both. Only six stations were still reporting as of March 1853 (Fleming 1990, 122). In April, 1854 the legislature authorized and the governor approved an annual payment of thirty dollars per year to each observer. In the same month another noted observer of nature, Henry Thoreau, noted in his journal that "It is remarkable how the American mind runs to statistics," citing among other evidence the meteorological observers in the then infant Smithsonian system (Entry for 17 April 1854, in Thoreau 1906, 6: 200; Koelsch 1966, chap. 2).

In his meteorological work in New York and Massachusetts, then, Guyot was doing more than simply establishing a proto-weather service, though he and Henry have often been justly praised as the precursors of the post-Civil War national weather system. Individual Americans had been making weather observations for many years (see, e.g., Brown 1940). But, as Mildred Berman has said of her subject, weather observer Dr. Edward Holyoke, "he distrusted fancy hypotheses" (Berman 1986, 238).

Guyot was doing something different from such earlier observers as Holyoke; he was applying Humboldtian principles to such problems. Humboldtian scientists were interested in gathering empirical data that would show variations over the earth's surface, selected in order to advance the process of developing the sciences through the testing of hypotheses, which would eventually develop into general theories or "laws." Guyot emphasized precise and up-to-date instrumentation, the creation of networks of observations to predict the weather and to establish, it was hoped, a "law of storms." In these, and in such other activity as trying to work out a general theory of tornado genesis, as well as in Guyot's placement of stations in relation to carefully measured altitudes and in the context of topographic regions, we can see examples of the methods Humboldt himself had practiced or advocated.

Guyot and New England Topography

As indicated earlier, another part of the Humboldtian practice was the precise measurement of variations in topography, especially the heights of mountains, and of accurate mapping of those measurements to display the variety of terrain over the earth's surface. In his Boston lectures of 1849, Guyot had credited Humboldt with being the first to recognize the importance of topographic mass, as revealed through his barometric measurements of altitude in Latin America. Guyot himself had devoted one lecture and part of another to the importance of relief (Guyot 1854, 54-55; Wright 1958, 10; Wright 1966, 140-41). He had a great deal of experience in barometric measurement of the heights of the Swiss Jura and other European mountain sites, ever since he took his first barometric observations from the Leaning Tower of Pisa in 1837 (Libbey 1884, 199-200). Soon after his arrival in the U.S., Guyot began assembling available data on the altitudes of the Appalachian mountain system. Confusion over place names and the errors suggested by comparison of widely varying published barometric measurements (in part because barometers used in the U.S. before his time were not often reliable) led Guyot to conclude that many new determinations were needed. Thanks to his work with Green in New York, he now had accurate instruments. Here, then, was a Humboldtian problem Guyot was uniquely equipped to study (Guyot 1861, 157-59, 163; Anstey 1960a).

From 30 July to 11 August 1849, Guyot and his nephew, the Gotha-trained cartographer Ernst Sandoz, who had accompanied his uncle to Massachusetts, made the first of what was to become a long series of summer expeditions to the New England mountains. In that brief period they made 204 hypsometric determinations. Between 1849 and 1852 Guyot and Sandoz ascertained the altitudes of 743 points in the White Mountains barometrically. In late August of 1857, Guyot's field party was the first to ascend that rugged peak, Mt. Carrigain. Guyot was then fifty years old and, as Laura and Guy Waterman have argued in their *Forest and Crag*, "it was a sensational climb for 1857." While establishing the Massachusetts stations, Guyot ascertained the elevations above sea level of 127 points, some barometrically and others by direct leveling from points previously established by railroad surveys or by the surveyors of the Massachusetts trigonometric survey of 1830, though he also accepted some of their earlier measurements (Guyot 1861; Chamberlain 1885, 138-39; Grant 1907; Waterman and Waterman 1989, 128, note a).

Guyot gradually extended his topographic surveys well beyond New England and, since almost all of his measurements were made by barometer, this meant he had to make these from the summit of each of the mountains he measured. Between 1862 and 1879 Guyot made numerous measurements in the Catskills, the last survey when he was approaching age seventy-two. He also measured heights in the Adirondacks, in the southern Appalachians, in the Rockies, and in California. His former student, Charles Faure, estimated that in Guyot's lifetime he had made 11,862 hypsometric observations. His friend James Dwight Dana, who evidently had access to Guyot's field notebooks, estimated that Guyot's lifetime total was "over twelve thousand." Writing in the 1930s, Myron Avery called him "the most thorough explorer who ever penetrated the Appalachian Mountain system," and characterized his knowledge of the Appalachian system as "such as has never been possessed by any other person…." (Dana 1886, 342; Waterman and Waterman 1989, 130).

Guyot climbed and measured such famed New England landmarks as the major peaks of the Presidential Range, as well as Mts. Moosilauke, Moriah, Whiteface, Chocorua, Monadnock, Greylock, Wachusett, and many others. He gave several papers to the American Association for the Advancement of Science on hypsometric topics, such as his "White Mountain Measurements" at the Montreal meetings of 1857 (noted in Thoreau's *Journal*; see entry for 24 August 1857, Thoreau 1906, 10:13). But he apparently published only two of his papers dealing with the New England mountains. One of these, in 1861, was a preliminary survey and map of the entire Appalachian mountain system. In that article, he discussed his methods and instruments and, as a good Humboldtian, he attempted to establish a topographic "law" of its variation in altitude and relief. The accompanying map, which Sandoz had drafted in the Gotha Geographical Institute under the direction of A. H. Petermann and which had been initially published in 1860 in Germany, contained an inset map of the White Mountains. In the other published paper, on New Hampshire's glacial erratics (a subject of his earlier research in Switzerland), he argued that the White Mountains had been a center for their dispersal, a view confirmed by modern geology (Guyot 1861; Anstey 1960b; Waterman and Waterman 1989, 130).

A third important and related paper, on the Catskills (Guyot 1880), also shows a strong Humboldtian methodological influence. Several peaks across the country named after Guyot, such as Mt. Guyot in the Twin Range of the White Mountains, testify to the contemporary importance of his measurements of altitude. In those cases where his measurements have been checked, they are often, though not invariably, close to those obtained in more recent and more technologically advanced surveys (Wright 1958, 10; 1966, 151; Waterman and Waterman 1989, 127). In all these activities – going where no scientist had gone before, greater precision in instrumental measurement, explanatory description of the previously unknown segments of the earth's surface, attempts to formulate "laws" of relief, and accurate mapping, Guyot proved himself a worthy representative of Humboldtian science in New England.

Guyot left the region in 1855 to fulfill his duties as Professor of Geology and Physical Geography at the College of New Jersey (now Princeton University). In September 1857 he returned to New England to address the American Academy on New England's geographical features in relation to human settlement. Like much of Guyot's scholarly work, this manuscript memoir was never published. John Gorham Palfrey used it, however, as the source for his description of New England geography in the first volume of his *History of New England*, published two years later. Guyot also furnished hypsometric data, based on his own observations, for a map in that volume on "New England in 1620-1644." For the frontispiece to Palfrey's third volume, published in 1864, Guyot furnished the data for a more elaborate map, "New England in 1689," drafted by Sandoz (Academy 4: 5-6; Palfrey 1859, xvi, 9 note 1; 1864, vii; Anstey 1960b, 13).

Figure 1. Arnold Guyot's Map of New England in 1689 (Courtesy of Harvard University Map Library)

Conclusion

This article does not contend that Guyot alone introduced Humboldtian science to the U.S. American appreciation of Humboldt's scientific reputation dates to 1804, when, at the conclusion of his Latin American expedition, he was welcomed to Philadelphia and later entertained by Thomas Jefferson and others in Washington (Koelsch 2008b, 270-73). Explorers of the West, notably John C. Fremont, had attached Humboldt's name to numerous physical features; some seven mountains alone had been named for Humboldt by 1856. Several towns and counties also bore Humboldt's name. After the Humboldt centennial in 1869, German "Forty-Eighters" and others would name parks and erect statues in his memory (Belgum 2005; Mathewson and Sluyter, 2006). As Agassiz put it in his Humboldt centennial address in Boston, "Every schoolboy is familiar with his methods now, but he does not know that Humboldt is his teacher" (Agassiz 1869, 5).

Among the Harvard and other cutting-edge American scientists with whom Guyot came in contact after 1848, Humboldt and his methods were quite familiar. As Cannon pointed out, most of the major scientific researchers of the period were already practitioners of Humboldtian science, and several had participated in Humboldt's plan for an international network of observers of magnetism prior to Guyot's arrival. American publishers had issued editions of Humboldt's work in English translation since 1815, and Cambridge academics had reviewed these in scientific and general-interest journals. Indeed, by the 1850s, Humboldt had become such a celebrity that his opinions on American slavery, for example, were freely quoted, and Americans, including Harvard faculty and students, tried to include a visit to the aged scientist on their travels abroad. From 1847 onward, Humboldt's protégé Agassiz was ensconced in Harvard's new chair of Zoology and Geology, and indeed it was he who had encouraged Guyot to come to the United States (Koelsch 1966, 221-29; Koelsch 2008a; Wilson 2005).

Nevertheless, Guyot stands as a worthy example of Humboldtian science in New England. His meteorological and hypsometric work incorporated Humboldt's ideas and methods and served as an authentic demonstration of the merits of the approach. Guyot's insistence on accurate measurement and up-to-date instrumentation, his use of widespread scientific networks of observers of natural phenomena, his emphasis on the importance of topography and orographic regions, his use of precise forms of representation such as accurate mapping and naming, and his implicit contention that the study and the laboratory were inadequate as sites for studying the enormous and scientifically important variability of the earth's surface, all show his absorption of Humboldt's ideas.

Guyot's most widespread impact in the U.S. was probably his response to the need for new methods of and aids to instruction, an activity through which he made Ritter's name and ideas broadly familiar to American audiences (Koelsch 2008c). But it was not for nothing that Guyot placed Humboldt's portrait on the first page of his text on *Physical Geography*, published in 1873. In his successful attempts to develop the instruments and other materials for, and his active supervision of, the Smithsonian network of weather stations, and in his masterly program of measurement and exposition of the Appalachian mountain system in his New England years and beyond, Guyot was a significant figure among the American scientists of his time. Through his use of Humboldt's methods, Guyot made important contributions to the practice of Humboldtian science in America, and made it possible, through the observers and students he trained, for others to do so. In so doing, he accomplished what another New Englander, John K. Wright, would have described as transforming "*terrae incognitae*" into "*terrae cognitae*" (Wright 1947; 1966), fulfilling in New England a portion of Humboldt's dream of an earth made more intelligible by the progress of measurement and instrumentation.

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