MEMOIR

OF

ARNOLD GUYOT.

1807-1884.

BY

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BIOGRAPHICAL MEMOIR OF ARNOLD GUYOT.

It is a remarkable fact in the history of American science that, forty years since, the small Republic of Switzerland lost, and America gained, three scientists who became leading men of the country in their several departments—AGASSIZ, in Zoölogy, GUYOT, in Physical Geography, and LESQUEREUX in Paleontological Botany; Agassiz coming in 1846, Guyot and Lesquereux in 1848. A fourth, Mr. L. F. DE POURTALÈS, who accompanied Agassiz, also merits prominent mention; for he was "the pioneer of deep-sea dredging in America."* The Society of the Natural Sciences at Neuchâtel lost all four. As an American Academy of Sciences we cannot but rejoice in our gain; but we may also indulge at least in a passing regret for Neuchâtel, and recognize that in the life and death of Agassiz, Pourtalès, and Guyot we have common interests and sympathies.

My own acquaintance with Prof. Guyot commenced after his arrival in America, when half of his life was already passed. In preparing this sketch of our late colleague, I have therefore drawn largely from others, and chiefly from his family, and from a memorial address by Mr. Charles Faure, of Geneva, one of his pupils, which was published in 1884 by the Geographical Society of Geneva.†

Youth. Education in Switzerland and Germany, 1807 *to* 1835.—To obtain a clear insight into the character of Prof. Guyot, it is important to have in view, at the outset, the fact that the Guyot family, early in the sixteenth century, became protestants, through the preaching of the French reformer, Farel, the cotemporary of Luther; and also, the sequel to this fact, that at the revocation of the edict of Nantes, the Guyot family was one of the sixty that moved into the principality of Neuchâtel and Valangin from the valleys of Pragela and Queyraz in the high Alps of Dauphiny. Thus the race was one of earnestness and high purpose, of the kind

* A. Agassiz, Amer. Jour. Sci., 3d Ser., xx, 254, 1880.

† Vie et Travaux d'Arnold Guyot, 1807–1884, par Charles Faure, 72 pp. 8vo. Read before the Geographical Society of Geneva, April 25 and August 25, 1884.

and origin that contributed largely to the foundations of the American Republic.

Prof. Guyot's father, David Pierre, esteemed for his "prompt intelligence and perfect integrity," married, in 1796, Mademoiselle Constance Favarger, of Neuchâtel, "a lady of great personal beauty and rare nobility of character." Arnold Henri, one of twelve children, was born at Boudevilliers, on the 28th of September, 1807, and was named after the Swiss patriot of the fourteenth century, Arnold von Winkelried. About 1818 the family moved to Hauterive, three miles from Neuchâtel, where his father died the following year. From the house at Hauterive young Guyot had before him, to the southeastward, the whole chain of the Alps, from Mt. Blanc to Titlis; and his sensitive nature must have drawn inspiration from the glorious view—the same deep draughts that he attributed to young Agassiz, in his academic memoir of his friend, with reference to the same circumstance—the snowy Bernese Oberland, the Jungfrau, the Schreckhorn, the Finsteraarhorn, the Eigers, and other summits to Mt. Blanc, "looming up before his eyes in the view from his house." Such views are calculated to make physical geographers and geologists of active minds. Guyot early found pleasure in the collection of insects and plants, and evinced in this and other ways the impress that nature was making upon him.

Previous to the year 1818 and for a while after, Guyot was at school at La Chaux-de-Fonds, a noted village "at the foot of a narrow and savage gorge of the Jura," 3,070 feet above the sea. In 1821, then fourteen years of age, he entered the College of Neuchâtel, where he was a classmate of Leo Lesquereux, the botanist. "Guyot and I," says Lesquereux, "were, for some years, brothers in study, working in common, and often spending our vacations together, either at Guyot's home, at Hauterive, or with my parents at Fleurier; and I owe much in life to the good influences of this friendship." His studies were classical—Latin, Greek, and Philosophy—arranged for preparing a boy for the profession of the Law, Medicine, or Theology, with almost nothing to foster his love of nature.

In 1825, then eighteen, he left home to complete his education in Germany. After spending three months at Metzingen, near Stuttgart, in the study of the German language, he went to Carlsruhe where he became an inmate of the family of Mr. Braun, a man of wealth and scientific tastes, the father of the distinguished botanist and philosopher, Alexander Braun, the discoverer of phyllotaxis—terms of intimacy with the family on the part of several of his relatives having been of long standing. The family comprised also a younger son and two daughters. Agassiz was then a student at Heidelberg, along with young Alexander Braun and Carl Schimper, but he spent his summer vacations at the Carlsruhe mansion. A vacation soon came. "The arrival of the eldest son of the house," says Guyot, "already distinguished by his scientific publications, with his three university friends—Agassiz, Schimper, the gifted colaborer of Braun in the discovery of phyllotaxis, and Imhoff, of Bâle, the future author of one of the best Entomological Faunas of Switzerland and Southern Germany—was a stirring event, which threw new life into the quiet circle. After a short time devoted to a mutual acquaintance, every one began to work. The acquisition of knowledge was the rule of the day, and social enjoyment the sweet condiment to more solid food." "My remembrance," remarks Guyot, "of those few months of alternate work and play, attended by so much real progress, are among the most delightful of my younger days." "Add to these attractions the charm of the society of a few select and intimate friends, professors, clergymen, and artists, dropping in almost every evening, and you will easily understand how congenial, how fostering to all noble impulses, must have been the atmosphere of this family for the young and happy guests assembled under its hospitable roof." "Months were thus spent in constant and immediate intercourse with nature, the subjects of investigation changing with the advancing season. Botany and entomology had their turn," and "demonstrations of phyllotaxis," he says, "now reduced to definite formula by Braun and Schimper, and shown in various plant forms, but especially in pine-cones, were of absorbing interest. The whole plan of the present animal kingdom in its relations to the extinct paleontological forms was the theme of animated discussions." He adds, "It would be idle to attempt to determine the measure of mutual benefit derived by these young students of nature from their meeting under such favorable circumstances. It certainly was great, and we need no other proof of the strong impulse they all received from it than the new ardor with which each pursued and subsequently performed his life-work."*

*Guyot's Academic Memoir of Agassiz, pp. 9–12.

Guyot took in, equally with Agassiz, the newly-developed views in botany, embryology, and zoological classification that were the subjects of thought and discussion, and became profoundly impressed thereby, as his later work shows.

From Carlsruhe, Guyot went to Stuttgart and took the course at the gymnasium, where he made himself a proficient in the German language. Returning to Neuchâtel in 1827, and there quickened in his religious faith and feelings by the preaching of the Rev. Samuel Petit-pierre, his benevolent impulses under a sense of duty led him to turn from science to theology, and commence serious preparation for the ministry. In 1829, then 22 years of age, having this purpose still in view, he went to Berlin to attend the lectures of Schleiermacher, Neander, and Hengstenberg, and there remained for five years—1830 to 1835. In order to meet his expenses he accepted the invitation of Herr Müller, Privy Counsellor to the King of Prussia, to live with him and give his children the benefit of conversation in French. The position brought him into intercourse with the highest of Berlin society, and was in many ways of great benefit to him.

While pursuing theology in earnest, his hours of recreation found him making collections of the plants and shells of the country, and otherwise following his scientific leadings. Humboldt introduced him to the Berlin Botanical Garden, where the plants of the tropics were a source of special gratification and profit. Moreover, other courses of lectures attracted him, as those of Hegel, of Steffens on psychology and the philosophy of nature, Mitscherlich on chemistry, Hofmann on geology, Dove on physics and meteorology, and especially those of Carl Ritter, the eminent geographer, whose philosophical views were full of delight to his eager mind and touched a sympathetic cord. Under such influence he found his love for nature-science rapidly gaining possession of him; and, yielding finally to his mental demands and to his conscience, which would not permit him to enter the ministry with a divided purpose, he determined to drop theology and make science his chief pursuit.

Ritter, of all his Berlin teachers, made the profoundest impression on his course of thought; and his biographical sketch of him, presented to the American Geographical Society in 1860, four years after his death, exhibits the admiring affection of a pupil who was like Ritter in his profounder sentiments. A paragraph from the memoir will show the tenor of Ritter's geographical teaching and something of the mental affiliation between them. Guyot says (p. 48):

"Ritter, in the introduction to the 'Erdkunde,' declares that the fundamental idea which underlies all his work, and furnishes him a new principle for arranging the well-digested materials of the science of the globe, has its deep root in the domain of faith. This idea, he adds, was derived from an inward intuition, which gradually grew out of his life in nature and among men. It could not be, beforehand, sharply defined and limited, but would become fully manifested in the completion of the edifice itself. That noble edifice is now before us, and, unfinished though it be, it reveals the plan of the whole and allows us clearly to perceive that fundamental idea on which it rests. It is a strong faith that our globe, like the totality of creation, is a great organism, the work of an all-wise Divine Intelligence, an admirable structure, all the parts of which are purposely shaped and arranged and mutually dependent, and, like organs, fulfill, by the will of the Maker, specific functions which combine themselves into a common life. But for Ritter that organism of the globe comprises not nature only; it includes man, and, with man, the moral and intellectual life." "None before him perceived so clearly the hidden but strong ties which mutually bind man to nature—those close and fruitful relations between man and his dwelling place, between a continent and its inhabitants, between a country and the people which hold it as its share of the continent—those influences which stamp the races and nations each with a character of their own, never to be effaced during the long period of their existence." We have here ideas that took, in Guyot, a still larger expansion.

Guyot derived great profit also from the works and the friendship of Humboldt. His address at the Humboldt Commemoration of the American Geographical Society, in 1859, was a beautiful tribute to this model student of nature.*

The five years of study at the Berlin University terminated with an examination which brought him the degree of Doctor of Philosophy. His graduating thesis, written in Latin, as was then the rule, was on "The Natural Classification of Lakes."

To Paris, the Pyreness, Italy, etc., 1835 *to* 1839.—From Berlin,

*Journal of the American Geographical Society, vol. I, p. 242, October, 1859.

Guyot, in his 28th year—June of 1835—went to Paris to take charge of the education of the sons of Count de Pourtalès-Gorgier, and continued with the family four years. Letters of introduction from Humboldt led to much intercourse with Brongniart and other savants of the great city. For the summer he accompanied the family to Eaux Bonnes, in the Pyrenees. While there he made ascents of the higher peaks and took excursions in various directions—to the amphitheatre of Gavarnie, to the borders of Spain by the Pont d'Espagne and the pass beyond, to the valley of the Eaux Chaudes, etc.—in order to study the features and flora, and compare the mountains in these respects with the Alps. In the autumn he went with his pupils to Belgium, Holland, and the Rhine to study the characteristic features of these countries. The following year he visited Pisa, and there, besides enjoying the new scenes, made various barometrical measurements, determining the elevation of the Observatory at Florence and of other points.

Trip to the Glaciers in 1838.—In the spring of 1838 Agassiz found Guyot still at Paris. During the summer preceding Agassiz had startled the scientific world by his declarations as to a *Universal Glacial Era*, contained in a paper read before the Helvetic Society of Natural Sciences assembled at Neuchâtel. His work in 1837—prompted in 1836 by Charpentier's discoveries proving the fact of a former epoch of immense glaciers in Switzerland—had led him to the bold conclusion, and he was full of his new idea when he met his old companion. He urged Guyot, who hesitated at accepting his views without examination, to study the facts, and obtained the promise that he would visit the glaciers that summer.

In his memoir of Agassiz, Guyot states that his six weeks of investigation that season in the Central Alps (nearly two years before Agassiz commenced his investigations on the Glacier of the Aar) were fruitful beyond expectation. He says that, from the examination of the glaciers of the Aar, Rhone, Gries, Brenva, and others, he learned (1) the law of the moraines; (2) that of the more rapid flow of the center of the glacier than the sides; (3) that of the more rapid flow of the top than the bottom; (4) that of the laminated or ribboned structure ("blue bands"); and (5) that of the movement of the glacier by a gradual molecular displacement, instead of by a sliding of the ice-mass, as held by de Saussure.

The facts and conclusions were communicated to the Geological Society of France at a meeting at Porrentruy, in September, 1838.

The communication is mentioned in the Bulletin of the Society for that year,* but no report of it is given because the manuscript remained in his hands unfinished, in consequence of his protracted illness the winter following. The portion then finished (which was withheld from publication because, by special arrangement between them, Agassiz in 1840 entered upon the special study of the glaciers and Guyot on that of the Swiss erratic phenomena, for their separate parts of a general survey) has recently been printed in Volume XIII (1883) of the Bulletin of the Neuchâtel Society of Natural Sciences. In 1842 this manuscript was deposited, by motion of Agassiz, in the archives of the Neuchâtel Society, and in 1848 it was withdrawn by Guyot when he left for America. It is to be regretted that publication was not substituted in 1842 for burial. Its recent publication was made by the request of Guyot, early in 1883, from a certified copy of the original manuscript.

This paper gives the facts on which Guyot based his conclusions, and since these conclusions comprise some of the most important of the views now accepted relating to glacier motion and structure, and antedate the observations of Agassiz, Rendu, and Forbes, they have special interest.

The fact of *a less rapid movement of the bottom ice than the top, owing to friction,* he ascertained by the observation that in glaciers of steep descent, like the Rhone at its rapids, and the Gries, the transverse crevasses and the masses they cut off are at first vertical or nearly so; but below the rapids, where the slope is gentle and the crevasses become mostly closed, the masses are inclined with the pitch up stream, and this up-stream inclination is reduced at the termination of the glacier to a few degrees. The crevasses, although closing up below, are still traceable. He says the so-called layers are not strictly layers; but great numbers of cracks remain, which give to the mass the appearance of being made up of beds several yards thick, as may be seen in the glaciers of the Grindelwald valley, Aar, and others.

Further: To this pitch in the stratification at the lower extremity, the beds rising outward, Guyot attributes also the origin of the majestic ice-chambers, whence in most cases flow great streams, as that of the Rhone, of the Arveyron at the foot of the Mer de Glace, of the Lütschinen from the glaciers of Grindelwald.

* Volume IX, page 407.

The *more rapid movement of the centre than the sides* also was learned from the Rhone glacier and others of steep descent. The crevasses, at first transverse, were found to be arched in front below the rapids, and increasingly arched to the extremity, and the successive crevasse-lines were very nearly concentric with the semicircular outline of the extremity of the glacier. He gives a figure of the Rhone glacier as seen from the Maienwand in illustration, and other later glacialists have appealed to the same evidence of lateral friction.

The semicircular outline of the terminal moraine was found to be another result of the cause just mentioned; and so also the "eventail" arrangement of the several moraines immediately above the termination. The greater height and breadth of the central moraine is made a consequence of the greater velocity of the ice at the middle of the upper surface, more transportation taking place consequently in a given time.

Again: The conclusion that *the movement of the glacier was largely through molecular displacement* was supported by his observation that the ice, instead of breaking up and rising into an accumulation of masses on its passage by an isolated rock, or rocky islet, in its course, spread around and enveloped it without fracturing; and he refers to a fine example of this at the two isolated islets of rock in the midst of the great Brenva glacier, called the eyes of the glacier." The same thing is observed "at the Jardin du Talèfre, a true islet in the midst of a *mer de glace*, having a border of blocks of rock, or of a moraine, cast upon its sides by the march of the glacier, just like the coast dunes of an island in the ocean."

In view of such facts, Guyot observes: "If it is true that the different parts of a glacier move with different velocities; if the glacier adapts itself to the form of a valley and fills all depressions without ceasing to be continuous; if it can bend around an obstacle and closely enclose it without the fracturing of its mass, like a spreading liquid, we may affirm that the movements take place through a molecular displacement, and we must abandon, at least as the only cause, the idea of a slow sliding of the mass upon itself as incompatible with the phenomena presented.*

*In French his words of 1838 are: "On peut affirmer que ces mouvements ne peuvent avoir lieu qu' en vertu d' un déplacement moléculaire, et il faut abandonner, au moins comme cause unique, l' idée d' un glissement lent de la masse sur elle même, comme incompatible avec les phénomènes que presente la marche des glaciers."

The "blue bands" of the glacier were first described by Guyot. He called the structure stratification, and observed it in the ice of the summit of the glacier of Gries, at a height of about 7,500 feet. A peculiar furrowing of the surface of the ice, the furrows one or two inches broad, attracted his attention; and this result of weathering he found to have come from the unequal firmness of the layers constituting it, layers of a softer "snowy ice" alternating with those of firm bluish glassy ice. The stratification was found by him to extend over hundreds of square meters, and downward, on the sides of crevasses, twenty to thirty feet deep, or as far down as the eye could penetrate; and it was evident that "the layers of the two sides of a crevasse were once continuous, like the strata of the opposite sides of a transverse valley." He compared the stratification to that of certain coarsely schistose limestones.*

He remarks, in conclusion: "We should say that the layers were not annual layers, but rather a series made day by day from small successive snow-falls that were melted in part by the sun of the day, and covered each night by the thick frost-glazing which envelops all the snowy summits of the high Alps."†

He further observes that "these beds were evidently formed at a greater height and in a different position from that where observed." He adds, in closing his remarks on the subject: "Do the beds, at first horizontal, or at least parallel to the surface of the glacier, accomplish, during its movement, evolutions, as yet imperfectly understood, analogous to those before mentioned [that is, those occasioned by differences in velocity of the middle, sides, and bottom, owing to unequal friction]. This is a point which should have further examination, with observations as minute, numerous and universal as possible. Unfortunately a thick fog and threatening weather forced me to stop work before I had ascertained whether this structure was general for the whole mass of the glacier at that altitude, or whether restricted to that locality notwithstanding the proof of so large an extension of it."

*His words are: "Stratifié à la façon de certains calcaires grossièrement schisteux," and he explains it himself as implying a lamellar structure.

†In the original, the words are: "On aurait dit, non pas des couches annuelles, mais une série de couches plutôt journalières de neige tombée successivement par petites quantités, puis fondue en partie par le soleil de la journée, et couverte chaque nuit de cet épais verglas qui, au dessus de la région des glaces, recouvre toutes les sommités neigeuses des hautes Alpes."

Guyot had some confidence in his conclusions, but he also felt, as he states, the importance of more detailed investigation in order to decide on their real value.

On the 1st of December, 1841, Guyot communicated the results of his observations of 1838, so far as relates to the "blue bands," at a meeting of the Neuchâtel Society of Natural Sciences, "reading some passages from his note written in 1838." This communication contains the additional fact that the layers of the stratification in the Gries glacier were inclined about 45°, were nearly transverse to the principal glazier, and appeared also to have sinuosities due to lateral compression.*

Agassiz, in his Système Glaciare (1847), cites from Guyot's manuscript (then deposited with the Neuchâtel Society) the part relating to the "blue bands" (the only part he ever cited), and in this citation there is a paragraph on the inclination or pitch of the layers, with Guyot's additional suggestion that the pitch of the layers looked as if a result of the advance of the surface portion over that below, a point already explained by him [by reference to friction at bottom].†

Guyot opens his account of the blue bands with the remark that, as he had seen them only on one occasion, he dares not hazard an explanation; but his later sentences show that he was inclined to regard them as a result of deposition, and to consider the varying inclinations in the layers as due to subsequent disturbing action—that is, to the irregularities of glacier movement, caused by friction and pressure under the varying conditions of the glacier valley as to form and size.

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* The report of the meeting of the Neuchâtel Society is contained in the Verhandlungen of the "Schweiz. Nat. Gesellschaft," Altdorf, 1842. The abstract of Guyot's communication there given (pp. 199–200) says: "La position de ces couches etait inclinée d'environ 45° dans le sens de la pente générale du glacier. Leur direction semblait presque transversale à celle du glacier principal, mais longitudinale à celle de son penchant méridional. Elle présentait quelquefois des sinuosités qui semblaient un effet de compression laterale."

† The cited paragraph in the Système Glaciaire (p. 209) is as follows: "La direction de ces couches coupait à angle droit la ligne de marche (de pente) du glacier, leur inclination déviait de 30° a 40° de la perpendiculaire vers la partie inférieure, comme si la pente superficielle gagnait de l'avance sur la partie inférieure ainsi que je l'ai décrit plus haut." The writer learns from Mrs. Arnold Guyot that this paragraph is a part of the original manuscript, and that it was by oversight that it was not sent to the Neuchâtel Society in 1883 with the rest.

Whether right or wrong in these suggestions as to the bands, Guyot's six weeks' work in the summer of 1838 was indeed fruitful. He had the satisfaction of seeing his conclusions for the most part confirmed by the facts collected by Agassiz, Forbes, and others, but not of receiving credit for his work and original conclusions, except on one point, and chiefly because of the want of proper publication.*

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* Rendu's "Théorie des Glaciers de la Savoie" was published in 1841 (Mem. Soc. Roy. Savoie, Chambéry, vol. X). Forbes's first letter from the Alps, announcing his discovery in August, 1841, of the "blue bands" in the Aar Glacier, was communicated to the Royal Society of Edinburgh December 6, 1841, and published in January in Jameson's N. Phil. J., vol. XXXII, 1842. Agassiz's first work on glaciers, "Etudes sur les Glaciers," was published in 1840. Neither of these publications mentions Guyot or his observations.

Guyot's communication of 1841, published in the Altdorf Verhandlungen, was drawn out by a discussion between Forbes and Agassiz relating to priority as to observations on the blue bands, and it was made just five days before Forbes's first letter was read in Edinburgh. Agassiz claimed credit for Guyot at the meeting in 1841, as a set-off against Forbes's claim, and again, in the N. Phil. Journ., XXXIII, 265, 1842. Forbes, in the following volume of that journal, XXXIV, 145, 1843, gives Guyot credit for original discovery as regards the "blue bands," and speaks of his corresponding with him on the subject; and he repeats the acknowledgment to the "ingenious professor of Neuchâtel," in his Travels through the Alps of Savoy, 1843 (first edition) and 1845 (second edition), page 28. Desor, in the same journal, XXXV, 308, 1843, in a paper on Agassiz's recent glacier researches, introduces a translation of Guyot's account of the banded structure, but cuts it short at the words "opposite sides of a transverse valley," leaving off the explanatory remarks which follow.

Tyndall, in his "Forms of Water" (1872, page 183), gives Guyot credit for priority; and he cites, both in this work and in his earlier "Glaciers of the Alps" (1856), a translation of Guyot's account, ending it a sentence short of Desor's citation, with the words "certain calcareous slates" in place of Guyot's "certain schistose limestones;" and on page 187 of "The Forms of Water," knowing only a part of what Guyot had written, he does him more than justice (admitting Tyndall's view to be established) in saying that he "threw out an exceedingly sagacious hint when he compared the veined structure to the cleavage of slate rocks," for the comparison in Guyot's paper implies rather stratification from deposition.

The first detailed comparison of the "blue bands" to slaty cleavage in structure, position, and origin appears to have been made by Prof. Henry D. Rogers at the Cambridge meeting of the American Association in 1849 (Proc. Am. Assoc , II, 181). But Rogers attributed the structure in both to conditions of temperature and not, like Tyndall, to pressure.

Having attended at Berlin the lectures of Dove on physics and meteorology and those of Ritter on physical geography, Guyot knew when he went to the mountains what to look for in case the glaciers were great flowing streams of ice, as had often been supposed; he knew that the flow of a stream is retarded along the sides and bottom by friction, and he naturally looked also for something in the encounter of the glacier with rocks answering to molecular displacement. Hence, in his six weeks of observations on the glaciers, he reached, without waste of time, good conclusions—the conclusions of a physical geographer. His investigation did not enable him to appreciate the interior fracturing that works along with molecular displacement in the flow of the ice, but his conclusion was still far in the right direction and decisive against the hypothesis he opposed. That he did not continue his study of the glaciers to thoroughly established results was owing to his yielding the subject afterward to Agassiz. Fidelity to his friend and his volunteered agreement curbed in and silenced him; and so his paper, excepting the paragraphs on the "blue bands," remained buried until after Agassiz's decease.

At Neufchâtel, Professor in the Academy, 1839 *to* 1848.—In 1839, at the age of thirty-two, Guyot left Paris and returned to his native town. He became at once an active member of the Society of the Natural Sciences (which had been initiated by Agassiz in 1832), and was made by the Society one of a committee—including also M. d' Osterwald and H. Ladame—for the organization of a system of meteorological observations in Switzerland and the selection of the best instruments for the purpose. On the establishment of the "Academy" at Neuchâtel, for the purpose of furnishing a university education to the graduates of the college or gymnasium, he was appointed to the chair of History and Physical Geography, and became a colleague of Agassiz. He hesitated about taking charge of the department of History, as this had not been one of his special lines of study; yet, once committed to it, he plunged into the subject with great earnestness. He says he groped on among the details for two years before he began to distinguish its grand periods, and the light as it broke in upon him caused so intense excitement that he was made ill.

Instruction was a great pleasure to him, because of his deep interest both in his subject and in his pupils. His two departments called out from him thirteen general and special courses of lectures.

With regard to the lectures, Mr. Faure says: "From the first, in spite of his apprehensions, he captivated his audience by his easy, elegant, sympathetic words, by the breadth of his views, and the abundance and happy arrangement of his facts. He had, each winter afterward, the pleasure of seeing men of cultivation of all classes in Neuchâtel pressing into the large hall of the college and listening to him with riveted attention." His pupil adds: "What zeal he inspired! what ardor for work! The fire with which he was filled passed to us. He was more than a professor; he was a devoted friend, a wise counsellor, associating himself with us and encouraging us in our work."

Guyot, besides lecturing and instructing, did all he could of outside work—meteorological, barometric, hydrographic, orographic, and glacialistic. The hydrographic work was the careful sounding of Lake Neuchâtel (in all 1,100 soundings) as the commencement of a study of the annual variation in the temperature of the waters of the Swiss lakes. His chief research—that on the distribution of the bowlders or erratics over Switzerland—occupied him, "single-handed, seven laborious summers, from 1840 to 1847," he allowing himself only, "at the end of his working season, the pleasure of a visit of a few days to the lively band of friends established on the Glacier of the Aar, in order to learn the results of their doings and communicate his own to them."* Switzerland in the ice period was his subject; and the sources of the bowlders and the courses of ice transportation were the chief inquiries. The investigation involved excursions on foot and careful examination of the whole range of the Swiss Alps, the slopes into Italy, the plains of Switzerland, and the mountains on the northern and western borders, including the Juras—in all an area of 190 by 310 miles—in order to trace the erratics to their high sources among the snowy summits, examine the rocks of all peaks, ridges, and valleys for comparison with those of the erratics, measure the heights along the lines and limits of the erratics from plain to mountain peak, and note all glacial markings. The task was accomplished with the greatest possible fidelity; "thousands of barometric measurements" were made in the course of it, and between 5,000 and 6,000 specimens were gathered in duplicate.

Thus, says Guyot:

"Eight erratic basins were recognized on the northern slope of the

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*Memoir of Agassiz, page 39.

Alps—those of the Isère, the Arve, Rhone, Aar, Reuss, Limmat, Sentis, and Rhine; and four on the southern slope—that of the Adda, including Lake Como, of Lugano, of Ticino, including L. Maggiore, and that of the Val d'Aosta."

Moreover, a question left hitherto untouched—the distribution in each basin of the rocks special to it—was minutely examined, and the final results of all the laws observed in the arrangement of the erratic fragments were shown to be identical with the laws of the moraines. This identity, and the absolute continuity of the erratic phenomena from the heart of the Alps down the valleys and beyond to the Jura left no alternative but to admit the ancient existence of mighty glaciers as vast as the erratic regions themselves, and having a thickness of over 2,000 feet."

Brief notes on his work were published in the Bulletin of the Neuchâtel Society of the Natural Sciences for November, 1843, May and December, 1845, and January, 1847.*

Guyot reserved the complete report for the second volume of Agassiz's great work on glaciers. But, unfortunately, after the first volume by Agassiz appeared at Paris, in 1847, there came the revolution of 1848, which put an end to their plans.

The study of the geological structure of the Jura mountains, in which he worked out the system in the flexures of the strata and proved that it must have been produced by lateral pressure, was another of Guyot's labors soon after his return to Neuchâtel, although not reported on until 1849, at the Cambridge meeting of the American Association.†

Guyot had been teaching at Neuchâtel nine years when suddenly the "Academy" was suppressed by the Grand Revolutionary Council of Geneva of 1848. The 13th of June brought the tidings, and on the 30th the end came "without any indemnity to the professors." Letters from Agassiz urged him to come to America. Though reluctant to take the step because of the many ties of friendship and association that bound him to Switzerland, and especially on account of the family under his charge, consisting of his mother, then seventy years old, and two sisters, which he should have to leave behind, he had the decision of his mother, after her careful reading of Agassiz's

*The facts are well presented also, though briefly, in the second volume of D'Archiac's Histoire des Progrès de la Géologie, pp. 259–265.

†Proc. Amer. Assoc. II, 115, 1850.

letter, in favor of it,* and in the following August he left friends, home, and Europe.

In America. The Lowell Lectures at Boston. "Earth and Man." 1848, 1849.—Without English speech, with no plans ahead, and with more than forty years of his life behind, a crowd of apprehensions continued to haunt Guyot until he reached the American shores. Once landed in New York, he was soon after at Cambridge with his friend Agassiz; and from that time the calamity that had befallen him commenced to prove itself a blessing. It was for him, falling in with the "geographical march of history," and coming to the land and "people of the future," where no political or religious shackles were in the way of success, and where an audience as wide as the continent was ready for whatever he had to communicate.

In September, a fortnight after his arrival, Agassiz took Guyot to the meeting of the American Association at Philadelphia. At its close he made his first journey to the Alleghanies, spending a week in crossing the region in Pennsylvania to Bedford and Cumberland. On his return he stopped in Princeton to deliver a letter of introduction to Dr. Charles Hodge, and found there friends who later welcomed him as a colleague.

Returning to Cambridge, he was soon afterward invited by Mr. Lowell to deliver one of the winter courses of lectures at the Lowell Institute, and in January he resumed in Boston his academic work, taking for his subject *Comparative Physical Geography.* He spoke in French, almost without notes, to a large and appreciative audience, and from that time the Swiss professor had an American reputation. These lectures, written out after the delivery of each, were translated by Prof. Felton "with rare kindness and a disinterestedness still more rare," says Guyot,† and published under the title—now familiar—of "Earth and Man."

The views of Ritter, which had put life and humanity into geography, are used by the author as the basis of still wider generaliza-

* August 8th, 1848, the day of his departure from Neuchâtel, he writes: "Ma mère a été toujours si forte et si confiante qu' elle m'a soutenu jusqu' au dernier moment, mais son dernier sanglot, en me quittant, m'est allé au cœur: Oh! que Dieu me donne de la revoir et d'embellir ses derniers jours."

This desire was realized. In the autumn of 1849 he had the happiness of welcoming his mother, two sisters, and a niece to the new home which he had prepared for them in Cambridge.

† In the dedication of "Earth and Man" to Prof. Felton.

tions bearing on the earth and human history. Guyot first draws out in admirable style the distinctive physiographic features of the continents and seas, and then proceeds to consider the *physiology* of the continental forms, by which he meant the interactions of the continents in their own history, and in that of man as their tenant. Having finished the physiographic portraiture in the first seventy pages, he says: "We must now see these great organs in operation; we must see them in life, acting and reacting upon each other," that is, "their physiological phenomena."

In order to exhibit the "living" action between these "organs" in its true relations, he first explains the fundamental law of progress in all growth or development; then exhibits the application of the law to the earth in its genesis, and in its later progress through the ages, and finally draws out and puts into order the grander facts in the conditions of the earth connected with the development of man in his social, political and moral relations.

Guyot makes all historical progress a *development*, carried forward through the incessant action and reaction of differences or unlike conditions; he speaks of it as a gradual specialization of parts and functions, comparable to the progress in germ development and having the same general formula; as beginning in a homogeneous unit, which has real but unmarked differences of parts, advancing through various changes and individualizations, and ending in the complex "harmonic unit." He finds the law exemplified in the development of the earth after the nebular theory of La Place; in the slow progress of the earth's continents from the condition of scattered islands in a large shallow sea to that of united distinctively-featured lands; in the progress of the earth's life, as made known by geology; the progress in the development of the races of men, and in the origin of human societies. The three phases recognized in the process are that of undistinguishable parts, germ-like; that of diversification; that of unity, which "allows all differences, all individualities, to exist, but co-ordinates and subjects them to a superior aim." Further, the final product or "harmonic unit," be it an organic species, or a continent, or societies, or whatever condition, has its purpose fulfilled not in existing, but in preparing for and producing other development beyond.

As differentiation goes forward increasing differences, interactions become more energetic. The greater the variety of individualities and relations in a society of individuals the greater also is the sum of life, the more universal, more complete, and more elevated the development.

Further, besides the unfolding of life "in all its richness of kinds and forms by diversity, there is involved an exhibition of it in its utility, in its beauty, in its goodness, by harmony; and this also for the entire globe, collectively considered as a single individual." This last point was the special subject of the larger part of his lectures.

Here was development for all history. All was put under one formula, that which is expressed in embryonic development, and was illustrated by details sustaining the application of the law.

With regard to the geological succession of life, he had learned, from Agassiz's announcements in his "Poissons Fossiles" (the first volume, published in 1834), that the geological succession in species was analogous in many respects to embryonic succession,* and he had gathered other ideas from the philosophical thoughts of Goethe and Steffens, as well as Ritter; but in his special application of the principle to the earth's early and latter history, and to human progress, he went beyond his teachers.

In reply to an inquiry as to the originality of his views, he wrote me, December 6, 1856, as follows:

"The principle at the basis of development is at the bottom of all the modern philosophy of Germany, especially the philosophy of nature, but in what an abstract and indigestible form will be seen on opening any one of their uninviting volumes. Goethe, the poet and philosopher, has, in a more concrete and tangible form, the beautiful law that the more homogeneous the lower the organism, and the more diversified in its parts the higher the grade. Steffens, of Berlin, acted more directly on my mind, and from him I got a distinct view of the importance of the internal contrasts and differences as regards the process of life." * * * "All these notions of the law were taken, as was natural, from the organized being; I do not recollect to have seen it applied, as I have applied it, to inorganic nature; to astronomy; to geology—I mean to the growth of continents, and to the successive and increasing diversifications of the surface keeping pace with the wants of an increasing development of life; to Physical Geography, in which the law of *in-*

* Quoted by Guyot in his sketch of Agassiz, page 26.

ternal contrasts, as conditions of a more active life, plays so great a part. Hence the whole scheme of that part of Earth and Man. This law thus became for me the key for the appreciation and understanding and grouping of an immense number of phenomena both in Nature and History. My views of the human races and of universal history are, in great part, on the same base. So also the idea of the true sense of the first chapter of Genesis as a characteristic of the great organic epochs."

His recognition of the same principle in organic nature is expressed as follows in a letter of March 17, 1856, referring in the first paragraph to the view of Agassiz that the subkingdoms among animals and the grander divisions among plants represent so many plans of structure:

"But do we not too much forget that even structure is but a means—the expression of a mode or function of life, which mode or function is the idea of it, and in one sense its cause? If so, then structures only express various aspects and functions of life, animal or vegetable, and they are related and connected together as the various aspects, modes, and functions of organic life are with the essential idea of life itself.

"Now, life is essentially (I mean phenomenally) growth, development, movement from phase to phase, from birth to death, and it seems to me that I can find no principle which gives me a more clear, natural, and connected idea of the innumerable types and forms of vegetables and animals than to consider them as typical of so many phases of life, whether of growth, or mode of life, or function of life."

Guyot endeavored to find the expression of the formula of development in the details of the systems of life, animal and vegetable, as exhibited in the progressive life of the globe as well as the existing species; and the preceding sentences in his letters were introductory to further explanations with regard to this system. His philosophical ideas were broad and deep enough to embrace the results of all discovery, although his illustrations manifested something of the limited knowledge of species and groups of thirty years since. In 1862 he delivered a course of lectures at the Smithsonian Institution on this subject, or "The Unity of Plan in the Systems of Life, as exhibited in the Characteristic Ideas and Mutual Relations of the great groups of the Vegetable and Animal Kingdoms;" but, although publication was desired by the Institution and urged by others, the manuscript was never ready. Full stenographic reports were made, which he never found time to revise.

It is interesting to note, in both Agassiz and Guyot, this full faith in a system of development as the best and truest expression of the order of succession in the progress of life, and, in Guyot, the application of the principle to all progress, while, at the same time, neither doubted the constancy of species or the necessity of divine acts for originating species and carrying forward the development. Agassiz declares, in his "Poissons Fossiles:" "More than 1,500 species of fossil fishes with which I have become acquainted say to me that the species do not pass gradually from one to the other, but appear and disappear suddenly, without direct relations with their predecessors." To each the system of progress was as orderly a system as that which evolutionists now recognize. The successional relations made known by paleontology were welcomed for the same reason as now: because they illustrated the true system of progress. The difference was not as to these relations, or the system of progress, but as to the means of carrying forward the development.

Guyot also gives a brief explanation of his views with regard to the *Geographical March of Human History*, and this is all he ever published of his historical course. In the expression "geographical march" he refers to the fact that human progress took place not by gradual elevation at one centre of civilization, but by successive transfers from one nation or centre to another. He points out and illustrates three stages in the progress:

First. The stage characteristic of the old Orient—that of *subjection;* subjection not only to the despotism of rulers and of society through castes, but also to that of Nature's forces through fear and superstition, and to the despotism of priests, exerted over both people and rulers through the superstitious element, and to priests and rulers conjoined, making the subjection complete. It was "the subjection of human liberty to the yoke of nature," "to the immutable, blind laws of necessity, which regulate the courses of the celestial bodies and the life of nature;" to the "inflexible, unloving, inexorable gods of the early East."

Secondly. The stage of growth in *individual* freedom, worked out in, and characterizing, Greece—a land "neighboring still the East," but admirably organized by its very features, by the combination within it of all the contrasts of the continent, for the development of individuality; a free people full of the energy of youth and the conscious strength of freemen, converting "the world of nature" into "that of the human soul," where "all the riches of poetry, of intellect, of reason, which are the heritage of the human mind, display themselves without obstacle and expand in the sun of liberty;" where "religion is a deification of the faculties and affections of man," where "the forces of nature, the trees of the forests, the mountains, the springs, and the rivers appear as objects of worship," "under the form of gods, of goddesses, and of nymphs, endowed with all the affections and subject to all the weaknesses of common mortals."

But, he says, the Empire of Alexander, and of individuality, and of fratricidal wars was not for the future. The Greek principle wanted the addition of association, "a principle determined by nature and not by voluntary agreement."

Third. The third stage was that of Rome, its centre a little farther toward the west, which through the spirit of *association* became the great empire and law-giver for the world. But selfish and corrupt, "one half of the men slaves to the other half," "exacting only one worship, that of the Emperor, who personifies the State," the Roman World, an aggregate of nations without a common faith, "perishes like the rest, of its own vices."

At that time, when the principle of association under human enactments was proving itself a failure, and despair was settling over the people, then, says Guyot, "the meek form of the Saviour appeared upon the scene of the world," to "recall man to the only living God," and "proclaim the equal worth of every human soul," "the unity and brotherhood of human kind." "It was upon this new basis that humanity, recommencing its task, goes on to build a new edifice." The task was not committed to the corrupt Roman; the Roman Empire broke before the Germans from the North, and the centre of civilization passed to the north of the Alps, and soon embraced all Europe. The new influences tended to harmonize the conflicting nationalties and bring about finally "a family of States so closely bound together that they are only members of the same body." And while liberty was thus gained for man, nature, as never before, opens herself to him and becomes his aid in all progress. Not only Europe, but, through her people, all the world receives the new light and commences to participate in the new progress.

But Europe and all the old nations, "through historical ties of every kind, ancient customs, acquired rights," encounter almost insurmountable difficulties in the way of adaptation to the exigencies of a new principle—that of "liberty, equality, and fraternity" rightly interpreted; and the carrying out of this work to reality demanded for its full development, as the law of history shows, that it should be transferred "to a new people;" transferred, as "the geographical march of civilization tells us, to a new continent, west of the Old World—to America;" a land wonderfully adapted to this purpose by the simplicity and unity of its features, by its great plains and rivers, and by its commanding position between the oceans.

He says, in conclusion, referring to the historic nations: "Asia, Europe, and North America are the three grand stages of humanity in its march through the ages. Asia is the cradle where man passed his infancy under the authority of law, and where he learned his dependence upon a sovereign master. Europe is the school where his youth was trained; where he waxed in strength and knowledge, grew to manhood, and learned at once his liberty and his moral responsibility. America is the theatre of his activity during the period of manhood, the land where he applies and practices all he has learned, brings into action all the forces he has acquired, and where he is still to learn that the entire development of his being and of his own happiness are only possible by willing obedience to the laws of his Maker."

When Carl Ritter received a copy of the work "Earth and Man" from his old pupil, he sent Guyot a letter of congratulations, with the strongly underscored word, *excellent,* thrice repeated; and more than once he wrote him that the whole conception carried out in the volume was a marked progress. He also told Guyot that he had made the volume his *vade mecum* on a long summer journey.

The work has passed through several editions in Great Britain, and has been translated into German and Swedish; and a translation into French, by Mr. Faure, will be published this year in Paris.

Guyot's views put the earth's genesis or development, as a sentence cited from him shows, under his general formula for historical progress; and although the subject is not dwelt upon in his Earth and Man, a brief statement of his argument and conclusions is, therefore, in place here.

The subject came under his consideration at Neuchâtel, in 1840, while preparing a lecture for his course in Physical Geography. Looking only to the suggestions of science, under which the so-called nebular theory had in his mind a place, he made out a scheme of the successive stages in the earth's development. After its completion it "flashed" upon him that the succession arrived at was just that of the cosmogonic record in Genesis, and this led later to a critical comparison of the two. Harmonizing the Bible and science was, hence, far from his original purpose.

The succession in the scheme so derived was (as I learned it from him) as follows:

First. The endowing of matter in space with forces, whence the beginning of its activity.

Second. The stage of specialization, or that of the subdividing of the original matter or nebula through the forces communicated, and thus the development of systems of spheres in space.

Third. The stage of the individualized worlds—the earth among them—and the commencing preparation of the earth for new developments pertaining to organic nature.

The events thus far are those of the inorganic part of the cosmogony.

In the organic period there was:

First. Life, manifested in the simpler kinds of plants. Next, animal or sentient life under simple forms—the Protozoans. These simple kinds of plants and animals represented the first or germ-like or homogeneous stage in the development of the system of life. He believed it to be probable that both existed before the close of Archæan time.

Second. The stage of specialization, or that of the development of plants and animals of higher and higher grade, under various types or subdivisions, based severally on different structural and physiological qualities.

Third. The stage of the synthetic or harmonic type. Among plants, that of the Dicotyledons, in which the different kinds of tissues in plants, and the stem, leaf, and flowers are for the first time harmoniously combined; and among animals, that of the Vertebrates, in which the nervous system has first its proper commanding position; and, lastly, among Mammals, that of Man, eminently the "harmonic unit" for the system of life, combining the highest of structural qualities and physiological characteristics under the most perfect harmonious development.

It is not surprising that after the conception of such a scheme he should have recognized a relation in it to the record in Genesis. Looking to this record, which announces the grand stages in a few brief sentences, he observed that the "fiat" of the first day, "Let light be," indicated, since light is a result of molecular action, the imparting of activity to matter as the first step in the development of the universe; that the dividing of the waters on the second day appeared to have its only befitting explanation in the subdividing or specialization of the primal nebula, as stated above; and that the fiat "Let the dry land appear," on the third day, indicated the defining of the earth and the preparation of it by the appearance of dry land for its new work. Thus he found the first three works in Genesis to correspond essentially with the first three in the scheme taught him by science. The following works, the creation (*a*) of plants, (*b*) of the Invertebrates and inferior Vertebrates, (*c*) of Mammals—the remaining Vertebrates, (*d*) of Man, have in the record the order of their first appearance as made known by science. It has to be admitted that doubt at present exists as to the earliest birds having preceded the Marsupial Mammals, but none as to their long preceding ordinary Mammals. Future discovery may place them before the Marsupials. Remains of birds are the rarest of fossil Vertebrates.

Guyot recognized also a still deeper concordance between Genesis and science, namely, that not only in the opening verses, but throughout the chapter, the idea of a system of development is taught. The fiat "Let light be" was the commencement of developments before the earth or other spheres had existence, not the creation of an entity. With regard to the earth, the first verse announces that it was formless, empty, waste, or, as the Septuagint translation describes it, "uncomposed and invisible." Then, on the third day, where the second mention comes in, the words are not Let the earth be, but "Let the dry land appear," implying that the specializing changes had gone forward eventuating in the earth and making it ready for further developments. The fiat creating plants was not Let plants be, but "Let the earth bring forth," which words imply development in some way; and a similar idea is to be derived from the fiats "Let the waters bring forth" for the Invertebrates and lower

Vertebrates on the fifth day, and "Let the earth bring forth" for Mammals on the sixth day.

Such a system of developments, which, after an initiating fiat, continued on their progress through the ages following, was not consistent with the idea that the days of Genesis were definite periods of time. It teaches that they simply mark the beginnings of new phases or new grand stages in the history of creation.

Guyot's critical eye further discovered that the two triads of days in the record—the first, the *inorganic*, including days one to three, the second, the *organic*, days four to six—have three parallel features which emphasize strongly this subdivision of the chapter, and indicate parallel stages in the developments: first, in each triad, the work of the first day was light; second, in each, the work of the last day comprised two great works; third, the second work of the last day in each triad was the introduction of an element that was to have its full development in the following era; in the first triad this element was life, plants being the second work, and life having its chief display in the succeeding era; in the second triad it was spiritual life, that of man, a planting of the moral world in the material, for the exaltation of the latter in aim and character.

Guyot thus shows that the old document is philosophical in its arrangement, true to the principles of development in history, and essentially true in the order of its announcements, and that the best explanation which science is now able to give on the great subject of cosmogony is also that which best explains, in all its details, the first chapter of Genesis and does it justice.

I have said that Guyot, while adopting the law of development and applying it to all history, still believed that true species came into existence only by divine act. In his later years, as his work on "Creation" shows, he was led to accept, though with some reservation, the doctrine of evolution through natural causes. He excepted man, and also the first of animal life; for in the case of both, while science speaks undecidedly, the record in Genesis teaches, by the use of *bara* for create, and by not using the word elsewhere subsequent to the first verse in the chapter, that actual creation was intended. He also held that there might be other exceptions; and he objected, moreover, on other grounds to the development of Man through nature alone. Still, as always with Guyot, God's will was the working force of nature, and secondary causes simply expressions of it.

Guyot's views on Genesis, although dating from 1840, and presented by him since that time in occasional courses of lectures, were not published in detail until the last year and hours of his life. With the publication of the volume his work and life ended.*

Educational Work. 1849 *to* 1884.—I pass now to Guyot's work in America. His lectures at Boston were "a brief epitome of his teaching in Neuchâtel,"† and they were, therefore, a part of European Guyot. He now becomes, though European in equipment, an American in his labors.

His lectures had made him known as a Geographer of the widest and most elevated kind. From Agassiz's home at Cambridge his acquaintance extended rapidly, and he was soon known also as a man of practical ideas with regard to school instruction in Geography and in other subjects. It was at once accepted from him that the starting point in geographical education should be nature and not books; that teachers should take their pupils to the hills and show them the valleys and streams and mountains, and aid them in tracing out the general features, so that they might make themselves geographers of the region about them and lay a foundation for broader geographical study; that the study of the geography of nature should precede that of man and political geography; that maps showing in strong lines the reliefs, or the mountains and plains, and then those showing the river systems and other natural features, should come before those of States and towns. The idea commended itself that each country should be presented to the mind of the pupil by such groupings of prominent features, inanimate and animate, as would, so far as possible, reproduce the reality of nature; and that waters, lands, and climates should not merely be described, but also displayed in their mutual interactions and relations, and in their interactions with the living tribes of the waters and land, that thereby the activities of the earth and their varied consequences might be understood, and also the influences thence arising that bear on man and human history.

These views he had learned from his teacher, Carl Ritter, and the latter in part directly from Pestalozzi. They were so obviously good that they spread rapidly. Guyot was soon under appointment from

* Creation, or the Biblical Cosmogony in the light of Modern Science. 136 pp., 8vo., Scribner's Sons, New York, 1884. A short article by him appeared in 1873 in the report of the 6th conference of the Evangelical Alliance, New York.

† Letter to the writer of February 4, 1881.

the Massachusetts Board of Education, lecturing on geography and methods of instruction to the Normal Schools and Teachers' Institute; and this engagement took him to all parts of the State and gave him each year, for the six years he held the position, aggregate audiences of 1,500 to 1,800 teachers. His friend Agassiz, moreover, was associated with him in the work, giving a like and equally strong impulse to studies in Natural History.

Guyot lived to see his methods of instruction become universal. He furthered this end by preparing, on his plan, between the years 1861 and 1875, a series of school geographies of different grades, six in number, ending in a school physical geography, and also a series of wall maps, physical, political, and classical, thirty in number, all of which passed into wide use.* These books forced the old books and atlases to change about or succumb, and they led, also, to many imitations among book makers.

His plan for the completion of the series in a general Treatise on Physical Geography, unfortunately, was never carried out. His failure is to be attributed in part to the difficulty he felt in putting his ideas down in English. He writes in 1882 to his Swiss friend, M. F. Godet:† "Que ne donnerais-je pas pour avoir la facilité d'écrire et de dicter! Mais cette malheureuse langue, qui n'est pas la mienne, est un obstacle toujours renaissant. La phrase m' entrave et me coûte dix fois plus que les idées." That Guyot understood the language well is evident from his memoirs of Ritter and Agassiz, and his tribute to Humboldt, as well as from his scientific papers.

Besides the geographical works already mentioned, Guyot was the author of the Treatise on Physical Geography in Johnson's Family Atlas of the World, and editor, with President Barnard, of Johnson's New Universal Encyclopedia, in which are several papers by him on geographical and other subjects. His school atlases and geographies received the Medal of Progress at the Vienna Exposition in 1873, and the Gold Medal, the highest honor awarded, at Paris in 1878.

In 1854 Guyot received an appointment to the professorship of Physical Geography and Geology at Princeton, then established for

* Guyot had a valuable aid in map-making in his nephew, Mr. E. Sandoz, who came to America with him, after having previously spent two years at Gotha with the geographer and publisher, Herr Petermann.

† Mr. Faure's biographical sketch, page 39.

him on an endowment from one who had learned to admire him as a Christian philospher, Mr. Daniel Price of Newark, New Jersey,* and in 1855 he removed with his family from Cambridge to Princeton, where he found his tastes, his social instincts, his desires to impart ideas as well as acquire them, all fully gratified. To the duties of his professorship he permitted himself to add other educational work, becoming and continuing for several years Lecturer on Physical Geography in the State Normal School at Trenton, and from 1861 to 1866 Lecturer Extraordinary in the Princeton Theological Seminary, on the Connection of Revealed Religion and Physical and Ethnological Science, and also giving courses of lectures for a time in the Union Theological Seminary, New York, and in connection with a university course in Columbia College, New York. At the Smithsonian Institution he delivered a course of five lectures in 1853 on the Harmonies of Nature and History, and in 1862 six lectures on the Unity of Plan in the System of Life, as mentioned on page 20.

Besides class instruction at Princeton, Guyot did important work for the college in the establishment of a museum. He found nothing there of the kind; but by effort at home and while on a trip to Europe, and with the aid of students inspired by him, and the generosity of friends, the museum became, under his care, rich both paleontologically and enthnographically, and in foreign as well as American specimens. It derives special interest, moreover, from possessing, through his gift, the 5,000 rock specimens collected in his study of the erratic phenomena of the Alps which he brought with him to the country. The specimens are so displayed in cases that, in connection with maps in the room, they teach "the extent, thickness, limits, and courses of the great ice-mass that once covered all Switzerland." Guyot, besides, found much gratification in the successful work of his pupils in Rocky Mountain exploration and the large additions to the collections thus secured. The memoir of Guyot by William Libbey, Jr., vice-director of the museum, speaks of the museum as the most substantial monument that Prof. Guyot has left behind him in Princeton.

Meteorological and Geographic Work, 1849 *to* 1881.—At the Philadelphia meeting of the American Association in 1848, where Guyot

* With the consent of Mr. Price, this chair was subsequently fully endowed by and named for Mr. John J. Blair, of New Jersey.

went with Agassiz soon after reaching the country, he met Prof. Henry, of the Smithsonian Institution, and this meeting was soon followed by the perfecting of plans for a national system of meteorological observations. Guyot was charged by Prof. Henry with the selection and ordering of the improved instruments that were required; and among his changes he rejected the old barometers in favor of the cistern barometer of Fortin as improved by Ernst and further improved in accordance with his own suggestion as regards safety of transportation, making what is now the Smithsonian barom, eter. He also prepared directions for meteorological observations which were published by the Institution as a pamphlet of forty pages in 1850, and a volume of meteorological and physical tables, which was printed and distributed in 1852. The latter very important work was afterward enlarged and became, in the edition of 1859, a volume of 634 pages, containing over 200 tables admirably arranged and adapted for the best meteorological and hypsometric work.* A letter of his to Prof. Henry in 1858 says that two-fifths of the pages of tables, representing 68,000 computed results, were wholly new and were prepared for the volume. He adds: "It is essentially a work of patience, in doing which the idea of saving much labor to others and facilitating scientific research is the only encouraging element."

One important part of Guyot's meteorological labors consisted in the selection and establishment of meteorological stations. With this object in view, he made in 1849 and 1850, under the direction of the Regents of the University of New York in conjunction with the Smithsonian Institution, a general orographic study of the State of New York in order to ascertain the best locations for such stations. Thirty-eight stations were then located by him at points widely distributed over the State; and, at the same time, patient, earnest Guyot took pains to instruct observers at the stations in the use of the meteorological instruments. Similar work was also done under like auspices in the State of Massachusetts. The report of the Regents of the University of New York for 1851 contains the topographical results of the exploration, giving an excellent sketch of the high plateaus and the larger valleys of the State.† The exploration in

* The volume of tables is No. 538 of the Smithsonian Publications. In 1862 it received from its author a further addition to its tables of 70 pages and in 1884 a new and enlarged edition, in preparation since 1879, was issued

† Reprinted in the American Journal of Science, 2d Ser., XIII, 272, 1852

1849 extended into the depth of winter, and his long journeys, in that inclement season, were often over unbroken roads and in the roughest of conveyances.

Thus Guyot went almost immediately to work in his favorite fields, laying the foundations not only for geographical education, but also for geographical investigation, and for a national system of meteorological observations and records. The national plan was not then inaugurated; but the work thus carried forward under the Smithsonian Institution was the initiator, in fact, of the United States Signal Service Bureau.

In the summer of 1861 Guyot had occasion to visit Europe, and he took advantage of the opportunity, observes Prof. Henry, "to determine, by his own observation, the relations of the standard barometers used by the Smithsonian Institution with the most important standards of the European observatories; and it is believed that these comparisons establish a correspondence of the European and American standards within the narrow limit of one or two thousandths of an inch."*

Besides the general survey of New York topography, Guyot carried forward, during his leisure weeks of the summer and autumn, a study of the altitudes and orography of the Appalachian Chain, or the mountain system of Eastern North America, in which work he had encouragement from appropriations by the Smithsonian Institution. He commenced, as early as 1849, a barometric exploration of the White Mountain system of New Hampshire, and continued his work at the North until he had spent five years over New Hampshire, the Green Mountains in Vermont, and the Adirondacks, and other parts of New York.

From these more northern portions of the Appalachian system he went to Virginia and North Carolina. In July of 1856 he measured barometrically twelve of the highest peaks of the Black Mountains in North Carolina, all of them higher than the White Mountains of New Hampshire. He was occupied with this southern part of the system from that time till late in the summer of 1860,

* Prof. Henry's Report to the Regents of the Smithsonian Institution for the year 1862. The observatories with which the comparisons were made were that of Kew, then under the direction of Stanley; that of Brussels, under Quetelet; that of Berlin, under Encke, and that of Geneva, under Plantamour, who had already compared the Geneva barometer with that of the Collège de France and that of the Observatory of Paris.

when his measured heights in that region of endless forests and great altitudes had increased in number until they exceeded 180; how much exceeded his paper does not say, as the altitudes determined in 1860 remain still unpublished. Besides these measurements, he made his survey complete by extending a net work of triangles over the area (nearly 150 miles in length), so fixing the positions of the peaks and ridges.

In a letter of October 3d, 1859, he writes, speaking of his work of that season in the Smoky Mountains, "the culminating range of North Carolina:" "My trip to the Smoky Mountains was a long and laborious one. Much rain, great distances, imperviable forests, delayed me two months. I camped out twenty nights, spending a night on every one of the highest summits, so as to have observations at the most favorable hours. The ridge of the Smoky Mountains I ran over from beginning to end, viz: to the great gap through which the Little Tennessee comes out of the mountains."

Having thus far finished his study of the mountain system, a new map of the whole Appalachian chain, made under his direction by his nephew, Mr. Sandoz, was published in 1860, in the July number of Petermann's "Mittheilungen." This map, with some emendations, was republished in 1861, in volume XXXI (Second Series) of the American Journal of Science, in illustration of an accompanying paper on the Appalachian system. This paper, after a brief history of his work, presents his results in an orographic description of the mountain region and an explanation of the laws which he had deduced, together with tables of more than 300 altitudes.

His "thousands of measurements" in the Alps had prepared him for accurate and thorough work here. As evidence of exactness, his barometric measurement of Mt. Washington in 1851 gave for the height 6,291 feet; the measurements by spirit-level made by N. A. Godwin, civil engineer, in 1852, gave 6,285 feet, and a similar leveling under the direction of the Coast Survey in 1853 gave 6,293 feet. So, again, the Black Dome of North Carolina, made 6,707 feet by him, was measured with a spirit-level by Major J. C. Turner, civil engineer, setting out from Guyot's point of departure, and the height made 6,711 feet.

There were still left unmeasured the heights of the Catskill Mountain range. In 1862 he went to work in this region, and continued it, as before, during his summer and autumn vacation months until the close of the summer of 1879, excepting the year 1871, when he took a trip to California for his health and some barometric work in the Rocky Mountains and the Coast Range. Gray's Peak, in Colorado, was one of the heights ascended and measured—an easy walk for *him*, said the young men of the party.

The Catskill region, a plateau of "piled-up strata owing its mountain forms chiefly to sculpturing waters," had its difficulties. Although so near New York and the Hudson river, and frequented each summer by thousands of tourists, it was to a large extent, especially over the southwestern part, an untracked wilderness of forests. In several cases his only chance for making his triangulation was by climbing to the tops of the highest trees, and then there was difficulty in identifying the distant, featureless, forest-buried summits. Moreover, many peaks had no names, and, again, the same name was often found to be used for two or three different peaks. He accomplished his work nevertheless, and when finished had gratifying proof of his great accuracy in spite of the difficulties. One point in the triangulation, the extreme western, was in common, as he afterward found, with that of the State survey of New York, under Mr. James T. Gardiner; and "in the position of this station," he says, writing August 12th, 1849, "we agree perfectly."

He discovered, by his explorations in the Catskills, nineteen summits that were higher than the highest previously known, three of them over 4,000 feet above tide-level. For the highest, called "Slide Mountain," he found the elevation 4,205 feet, while that of "High Peak," which had been thought the highest, proved to be only 3,664 feet.

This work closing so grandly Guyot's study of the Appalachian System—begun by him when he was 42 years of age—was finished in 1881 when 74. It was his "vacation" work. His memoir on the Catskills was published in 1880 in volume XIX (3d series) of the American Journal of Science, with two illustrating maps. The orographic structure of the range is described, its origin briefly and judiciously considered, and the heights given for over 200 points. A larger map (14 x 20 inches) was issued the year before as a pocket map. And thus his orographic labors have already contributed greatly to the convenience of tourists as well as to geographical science.

Guyot's first scientific work, fifty years since, and his last was mountain work. And I think I am safe in saying that no one before him, if any since, can claim to have made with the barometer more numerous and more accurate hypsometric measurements; his field books make the number of such measurements by him over twelve thousand. In all his explorations he manifested that unflagging energy and thoroughness which are required for accurate work. At the same time his acuteness of intellect and well-furnished mind, while demanding the fullest investigation for final results, led him quickly and surely in the path toward right conclusions, as was strikingly manifested in the outcome of those six weeks in 1838 over the glaciers. Besides these qualities of the careful and judicious observer his ever-searching mind, as shown by his comprehensive views on the earth, living nature, and man, was remarkable for its powers of philosophical analysis and generalization. The combination of the thorough student of facts in nature with the far-seeing student of principles and fundamental law has seldom been more complete, and we may therefore well describe him as in a remarkable degree—using his own language—"a harmonic unit."

The two friends from Switzerland, Guyot and Agassiz, were both needed by the country when they reached its shores. Each performed a work among us of great service to education as well as to science, and we owe them lasting gratitude. But their change of base in coming to America gave them a position for wider influence over the world, and American gratitude is not all that is due them.

In recognition of Guyot's services to science he was elected to honorary membership in several learned societies, among them the Geographical Society of London, and that of Paris; and since his decease a Geographical Society has been organized at Neuchâtel, this being, in the words of Prof. Louis Favre, "the finest monument that could be erected to the memory of a savant who had brought so much honor to his native land."

In 1867 Guyot married a daughter of the late Governor Haines, of New Jersey, a lady of intelligence and refinement, who made for him the happiest of homes; and his gentleness, consideration, and warmth of heart fitted him to contribute his share to that happiness.

Guyot's face and manner betokened deep and earnest thought rather than enthusiasm and quiet self-possession without self-assertion. A man of medium height, deep-set eyes, and spare figure, he looked as if made more for thinking than for acting, and yet his power of walking and climbing seems to have had no bounds, and scarcely failed him at all until after his three-score and ten had been passed. The greatest ascents gave his well-trained muscles no more fatigue than a walk in his garden; and pathless tangled forests for weeks in succession, with nights in the wild woods, were a source of great enjoyment. On the 29th of December, 1883, hardly six weeks before his decease, he wrote to the President of the Society of Natural Sciences of Neuchâtel, M. Coulon, after congratulating him on keeping up his walks to Chaumont, although then eighty years of age, "Even last year I could have told you of my seventy-six years and my ability still to climb our mountains, but unhappily it is not so now." *

His special weakness was a virtue in excess, an unobtrusiveness that disinclined him to assert himself, that made him too easily content with work without publication. Hence his results and original views often failed of recognition, and but one of his projected works of the higher series was ever completed. In a letter of November 15, 1858, in replying to one who had urged him to publish, he says: "And I am A. G., who thinks a good deal and delights in it, but is too easily satisfied with that selfish pleasure." Yet much of this reluctance was, as before said, owing to the hesitation of his critical mind in the use of the English language. Besides, he was ever waiting for more facts. And, too, he was overburdened, as he often said, with his educational labors. In accordance with his unassuming ways, de did not become a naturalized citizen of his adopted country until 1860, he feeling, rather than reasoning, that a foreigner should not hasten to intrude himself into political affairs.

Although indisposed to push himself, still, when in conversation with a man of like intelligence, he was sure to command eager attention, and, without other effort, to find places of honor and congenial work open to him. Within six months of his arrival in the country, a talk, in Philadelphia, with Prof. Henry gained for him the position of a virtual manager in the Meteorological Department of the Smithsonian Institution, and, by similar means, there came about his connection with the Massachusetts Board of Education. Through his wealth of ideas, not self-effort, he secured the several high positions occupied by him in the country.

Guyot was a man of devoted friendships. He manifested this

* Memorial sketch of A. Guyot by Prof. L. Favre, Vice-President, Bull. Soc. Sci. Nat. Neuchâtel, XIV, 327, 1884.

deeply in his tribute to his old teacher, Carl Ritter, and in that to his compatriot, Agassiz. There was no limit to his good-will. Children of his acquaintence knew this, and all who had the privilege of intercourse with him. On the 7th of November, 1864, he writes from Princeton, "I have bought the house in which I live, and my care has been to prepare and shape the garden for the next season according to my taste. A quiet green retreat to study and write, and good friends visiting me in it and filling it with the warm rays of affectionate friendship, is an ideal for which, if realized, I should heartily thank God."

Guyot was a fervently religious man, living as if ever in communion with his Heavenly Parent; a Christian, following closely in the footsteps of his Master. His search into nature's phenomena and laws was a search for divine truth and a divine purpose. His field-notes of 1850 contain the entry: "On n'est fort qu' avec la vérité, et ce que m' importe c' est de l' avoir de mon coté. Dieu sait que je la désire avant tout, et il me fera la grace de la reconnaitre." In his trip to Europe in 1861 he went as a delegate from the Presbyterian church of America to the convention of the Evangelical alliance which met that year in Geneva. He writes from Paris, under date of October 24th, just before his return, of his "great pleasure in attending, in that old stronghold of Protestant faith, the large and exceedingly interesting meeting," and in witnessing the "grand spectacle of so many sympathizing Christians from all quarters of Christendom uniting in the services with perfect freedom and unanimity." And then he shows his kindly nature in allusions to "the testimonies of love and true friendship" which had greeted him everywhere in his journey through Europe and the land of his youth, and in expressions of thankfulness "for those old affections" and those "deep sympathies which are destined, by their very nature, to outlive our mortal frames."

His Neuchâtel pupil, Mr. Faure, well observes: "He cared little for renown, but much for the study of nature and for the education of man." As fellow-students, we have special reason to admire in Guyot—as he wrote of Humboldt—"that ardent, devoted, disinterested love of nature which seemed, like a breath of life, to pervade all his acts; that deep feeling of reverence for truth so manifest in him which leaves no room for selfish motives in the pursuit of knowledge, and finds its highest reward in the possession of truth itself."

Arnold Guyot died at Princeton on the 8th of February, 1884. Funeral services were held in the church, where the officers and students of the college and other friends were gathered with the relatives of the deceased, and excellent memorial discourses were pronounced by Rev. Horace Hinsdale and Dr. James Murray, dean of the college. His remains lie buried in the Princeton Cemetery.

LIST OF THE WRITINGS OF PROF. ARNOLD GUYOT.

1835. Inaugural Dissertation, at Berlin, on the Natural Classification of Lakes. (In Latin.)

1835. Numerous contributions to the Encyclopédie du XIXéme Siècle, Paris. Among them the more extensive are on Germany, Physical Geography of Germany, and on the System of the Alps.

1838. On the Structure of Glaciers and the Laws of Glacier Motion. Read before the Geological Society of France in 1838, but not published until 1883.

1842. On the Ribboned Structure of the Glacier of Gries. From the paper of 1838. Read before the Soc. Sci. Nat. de Neuchâtel, December 1, 1841, and published in abstract in the Verhandl. d. Schweiz Nat. Gesellschaft, Altdorf, 1842, pp. 199, 200. Published in full, excepting the last part, in New Phil. J., Edinburgh, XXXV, 1843, in a paper on Agassiz's Glacial Researches, by Desor; also in Tyndall's Glaciers of the Alps (1856), and his Forms of Water (1872); also in full in Agassiz's Système Glaciare (1847).

1842. Observations on the Erratic Phenomena of Lower Switzerland and the Juras. Verhandl. d. Schweiz Nat. Ges., Altdorf, for July, 1842, pp. 132–145.

1843, '45, '47. Observations on the Erratic Phenomena of Switzerland. Bull. Soc. Sci. Nat., Neuchâtel, for November, 1843, May and December, 1845, and January, 1847.

1844. On the Law of the Formation and Distribution of Glacier Crevasses.

1847. Erratic Phenomena in the Alps: abstract in D'Archiac's Hist. Progr. Géol., Vol. II, pp. 259–265.

1849. Earth and Man, or Lectures on Comparative Physical Geography in its Relation to the History of Mankind. 310 pp. 8vo. Boston. Second edition in 1850.

1850. On the Upheaval of the Jura Mountains by Lateral Pressure. Proc. Amer. Assoc., II, 115. Read before the Association in August, 1849.

1850. Directions for Meteorological Observations. For the observers of the Smithsonian system of meteorological observations.

1852. Meteorological and Physical Tables. 212 pp. 8vo. Prepared for and published by the Smithsonian Institution. A second edition in 1859, 639 pp.; received an addition of 70 pages in 1862; a third edition in 1884, — pp.

1852. On the Topography of the State of New York. Rep. Regents Univ. New York for 1851, p. 232. Albany. Reprinted in Am. Jour. Sci., 2d Ser., XIII, 1852.

859. Address at the Humboldt Commemoration of the American Geological Society, in October, 1859. Jour. Amer. Geogr. and Statist. Soc., I, No. 8, 1859, pp. 242-245.

1860. Carl Ritter: an address to the American Geographical Society, February 16, 1860. Jour. Amer. Geogr. Soc., II, No. 1, 1860, pp.25-63.

1861. On the Physical Structure of the Appalachian System of Mountains, with a physical map of the system. Amer. Jour. Sci., 2d Ser., XXXI, 157.

1861. Altitudes in North Carolina and Georgia. Geol. Rep. North Carolina of 1861, and also of 1875.

1866-'75. A series of School Geographies, six volumes, including a Physical Geography. A series of wall maps, containing thirty maps.

1873. A Treatise on Physical Geography, Johnson's Family Atlas of the World.

1874. Cosmogony of the Bible, or the Biblical Account of Creation in the Light of Modern Science. Rep. of the Sixth Gen. Conference of the Evangelical Alliance, in New York, 1873.

1874-'77. Many articles in Johnson's Encyclopædia, of which Prof. Guyot was one of the editors-in-chief.

1875. Memoir of James Coffin. Read before the National Academy of Sciences.

1877'-78. Memoir of Louis Agassiz. Read before the National Academy of Sciences, October 23, 1877, and April, 1878. Published at Princeton. 50 pp. 8vo. April, 1883.

1879. Physical and Orographic Map of the Catskill Mountain Region; size, 14 x 20 inches.

1880. On the Physical Structure and Hypsometry of the Catskill Mountain Region, with two plates. Amer. Jour, Sci., 3d Ser., XIX, 429. Communicated to the National Academy of Sciences in part at sessions in 1875 and 1876.

1883. On the Existence in Both Hemispheres of a Dry Zone and its Cause. Amer. Jour. Sci., 3d Ser., XXVI, 161. Read before the National Academy of Sciences, November, 1882.

1884. Creation, or the Biblical Cosmogony in the Light of Modern Science. 136 pp. 12mo. New York.

PAPERS COMMUNICATED TO THE NATIONAL ACADEMY, BUT NOT DEPOSITED IN MANUSCRIPT.

August, 1864. At the meeting at New Haven. On the influence of the hour of the day on the results of barometric measurements of altitudes.

August, 1865. Northampton. On the probable cause of the Glacial Epoch of the Post-tertiary.

August, 1866. Northampton. On the influence of the hour of the day on the heights obtained by barometric measurements.

January, 1868. Washington. On the practical character of the usual thermometric scales, and a common substitute for them.

August, 1869. Northampton. On the law of distribution of volcanoes and its bearing on the theory of volcanic action.

April, 1873. Washington. On the altitude of Gray's and Torrey's Peaks, in Colorado; some questions connected with the determination of barometric altitudes in the interior of continents.

On the unity of the system of life in animals and the true principle of gradation in the various animal types.