NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA

BIOGRAPHICAL MEMOIRS
PART OF VOLUME IX

BIOGRAPHICAL MEMOIR

OF

JAMES DWIGHT DANA

1813-1895

BY

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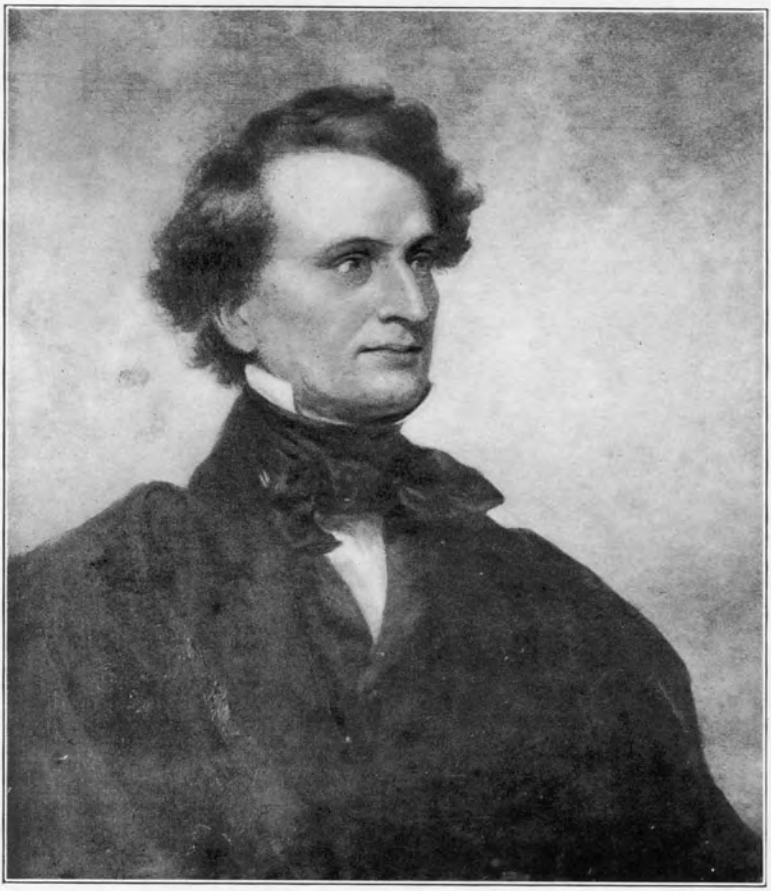
PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1919

CITY OF WASHINGTON
PUBLISHED BY THE NATIONAL ACADEMY OF SCIENCES
December, 1919



James W. Dana

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INTRODUCTION

If it appears strange that over twenty years should have elapsed since the death of the noted geologist, James Dwight Dana, before a biographical memoir of his life and work should be presented to the members of this Academy, this has been due to a variety of circumstances, which need not be dwelt upon here. If we have on the one hand the feeling that this should have been done before, on the other there is the advantage that from the time that has passed we are enabled to enlarge our perspective and to see in a clearer light the character of the man and the service which he rendered to American science. During this period, also, a life of Dana and various biographical notices, together with estimates of him as a teacher and as a scientist, have appeared, and this material has been freely used by the writer, upon whom has fallen the privilege of presenting a memoir to the Academy of one of its founders and most distinguished members.*

* The more important American biographical notices which have come to the attention of the writer are the following:

James Dwight Dana, by Edward S. Dana, Amer. Journ. Sci., vol. XLIX, pp. 1-28, 1895; with bibliography.

Memorial Address (James D. Dana and William D. Whitney), by Pres. Timothy Dwight, June 23, 1895.

James D. Dana as a Teacher of Geology, by O. C. Farrington, Journ. Geol., vol. III, p. 335, 1895.

James D. Dana as a Geologist, by H. S. Williams. *Ibid.*, p. 601.

James Dwight Dana, by C. E. Beecher, Amer. Geologist, vol XVII, 1896, pp. 1-16.

Memoir of James Dwight Dana, by Joseph Le Conte, Bull. Geol. Soc. Amer., vol. 7, 1896, pp. 461-479.

James Dwight Dana, by J. W. Powell, Science, new ser., vol. III, 1896, pp. 181-185.

A slender, erect figure of medium height; a well-shaped head, crowned with a mass of white hair; a thin, sensitive face with finely carved features, clean shaven, with a bronzed complexion; keen blue eyes and a kindly smile, touched with a trace of humor—such was the appearance of Professor Dana in the fall of 1881, as it impressed itself upon the memory of the writer, who, with other students, met him on a Saturday afternoon for a geological excursion in the environs of New Haven. He was then 68 years old, and still in the very crown of his active life. His alertness, vivacity, quickness of movement, and the general impression of physical energy and vigor which characterized him gave no hint of the many years during which he had struggled against disability. The effect he produced was immediate, and one could not meet him without recognizing at once that he was an extraordinary man, of superior intellect, capacity, and knowledge. The memory of Dana and that excursion as he conducted it is one of the most clearly cut impressions of the student days of the writer.

The last recollection is equally clear. Shortly before his death he brought to the writer's laboratory in Peabody Museum a fragment of rock from a ledge barely exposed in the lagoon of Clipperton Atoll which had been sent him by a naval officer. He believed it to be of volcanic nature, but desired an examination of it according to the latest petrographic methods. It proved to be a fragment of altered trachyte, and thus confirmed him in the view that it represented the final remnant left exposed of a subsiding volcanic island. It was, therefore, to him, almost at the very end of his life, another proof of the correctness of the theory that the Pacific atolls have been formed by the subsidence of oceanic islands—a matter which will be considered more in detail later. He was as full of keen

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Life of James Dwight Dana, by Daniel C. Gilman, 8°, pp. 409, 1899.

Dana the Man, by Wm. North Rice; Dana the Teacher, by E. O. Hovey; Dana the Geologist, by G. P. Merrill; Dana the Zoölogist, by John M. Clarke; addresses at the Dana Centenary of the Geological Society of America, Bull., vol. 24, 1913, pp. 55-69.

The Geology of James Dwight Dana, by Wm. North Rice, in Problems of American Geology, pp. 1-42, a series of lectures delivered at Yale University on the Silliman Foundation, December, 1913, commemorative of J. D. Dana, 8°, pp. 505, New Haven, 1915.

interest over this discovery as he might have been forty years earlier; one could see no abatement of this interest in his work to the very end of his life.

The writer offers these first and last recollections of Professor Dana because they may recall to those yet living who knew him, and who may chance to read this memoir, a similar vivid impression of his striking personality; to those who never knew him it would be difficult to convey in mere words the effect which he made upon the men of his generation. The writer cannot speak of this from any intimate personal knowledge of Professor Dana; when after student days his work in the university began, the latter lived a very retired life, and though busily engaged in work, was not often seen by the younger men, though always helpful and glad to see those who had occasion to consult him upon any problem, and he must, therefore, rely upon the testimony of others. For the purposes of this memoir the life of Dana must be considered from two standpoints: first, the account of his life; and, second, the consideration of his scientific work; one cannot, of course, treat of one without to some extent involving the other. It is natural to begin with his history.

EARLY LIFE

James Dwight Dana was born in Utica, N. Y., on the 12th of February, 1813. He was the eldest of a family of ten children. His father, James Dana, was a native of Massachusetts, a direct descendant of Richard Dana, the original immigrant and progenitor of the Dana family in New England. While the immediate derivation seems pretty clearly to be English, the ultimate origin of this stock is held by many to be Italian, partly on account of the nature of the name and partly because a family of Danas has long been existent in Italy, distinguished in intellectual fields and especially in scientific professions.

James Dana married Harriet Dwight, a daughter of Seth Dwight, of Williamsburg, Mass., and moved to Utica, N. Y., where he died, in 1860, at the age of 80. He was a successful man of business, engaged in mercantile pursuits.

Utica, at the time when the subject of this memoir was born, was a small, active town, which was passing beyond the fron-

tier stage and growing in size and importance. The history of the growth and development of the smaller American inland settlements from villages to towns and from towns to cities has been so often repeated that it is familiar to all and we may thus easily picture the conditions under which Dana grew to manhood. It is perhaps worth while to note how many famous Americans have developed under similar circumstances, and this is, perhaps, not difficult to understand when we reflect that these places have been built up successively by the most hardy, energetic, and industrious of our population. At such periods of development there has been nothing of the influence of inherited wealth on the one hand or of extreme poverty on the other. Achievement in some form or other is the result expected by the community in proportion as the opportunities are many. Having passed the frontier stage, the advantages of education in its simple forms are usually good and becoming better, and there is general insistence that they should be employed. When to this we add that Dana was reared in a home characterized by religious feeling, thrift, and common sense, in which, as he himself has said of his parents, "honesty, virtue, and industry seem almost to be our natural inheritance," it can be seen that the environment in his early years was a most favorable one, and we can understand why he himself was distinguished by those traits which he mentions.

It is reported of Dana that as a boy he was fond of collecting and bringing home natural objects. It may be that this shows the dawning of his instinct toward science; but we must not make too much of this, for it is a trait common to most boys and may well be due to the natural impulse toward acquisition. However this may be, we know that he came first under scientific instruction when, at the age of fourteen, he began to attend the Utica High School, then recently founded by Charles Bartlett, a graduate of Union College, who had studied the character of a number of educational institutions and had the breadth of view and foresight at that day to arrange for a teacher of natural sciences.

This position was first occupied for three years by Fay Edgerton, a graduate of the Rensselaer Polytechnic Institute, who held classes in chemistry, mineralogy, botany, and geology.

There is testimony that he was an enthusiastic and inspiring teacher. Moreover, he had, happily, the all too rare custom of taking his students afield in pursuit of their nature studies. He made long collecting trips with them to particular localities for rocks and minerals. This, which would at once give dignity and standing to the pursuit of his natural instinct, could not fail to have a great influence upon a boy of Dana's tastes. It was here that he received his direct impulse toward science and his first training in the field in which he was to achieve success, as he himself recognized in after years.

Edgerton was succeeded in 1829 by Asa Gray, afterwards the famous botanist and professor at Harvard University, as teacher of natural sciences, and thus there began an acquaintance between him and Dana which ripened into an enduring friendship. Although this friendship was destined later to have a strong influence upon Dana's career, there is no evidence that during the year they were associated in the Bartlett Academy, before Dana went to college, he came directly under Gray's instruction.

In 1830 Dana entered the sophomore class in Yale College and took his degree of Bachelor of Arts in 1833. He was led to choose Yale, according to his statement, by the wide reputation as a teacher of science enjoyed at that time by the elder Benjamin Silliman. We must not conclude from this, however, that Dana had at this time any clear idea of embracing science as a profession, as we shall see later. The opportunities at that time for a scientific career were scanty, and most American naturalists were impelled into one rather by natural instincts and force of circumstances than by deliberate choice, and very commonly passed into one by way of training for the medical profession.

Although the curriculum of the American college was much simpler and less exacting then than now, the fact that Dana was able to enter the sophomore class at the age of 17 and graduate with a good standing in his class is a testimony to his ability and industry as a student. At that time the classics were the backbone of the college course, and the circumstances that Dana had had a rather weak preparation in ancient languages and entered his class a year late are the probable rea-

sons why he did not attain more marked distinction as a general scholar. He was, however, noted for his excellence in mathematics, for which, as we shall see, he had a predilection, and he devoted much time to science, especially to mineralogy and botany.

In his senior year in college we find Dana beginning to concern himself regarding his future career, and in a state of uncertainty which was not resolved until some years later. His love of natural science impelled him in a direction in which he saw no opening, and his father, a practical business man, with a large family dependent upon him, had no belief in the possibility of a successful and independent career in science. In those days an educated man perceived business, the ministry, law, medicine, and teaching open to him as fields of work. For business, law, and medicine Dana, in his letters home, which have been preserved, professed a strong disinclination; of the ministry there seems never to have been any question; and since from the time of his leaving college he must support himself, and did so, he naturally gravitated toward teaching, at which he had begun to earn his living when circumstances opened to him a great opportunity; whereupon he relinquished it until later, when he again assumed it as his vocation.

During his senior year Dana, backed by his friends, solicited from the Government the post of schoolmaster in the Navy. At that time the naval school at Annapolis (1845) had not been founded and it was the custom to furnish the naval vessels carrying midshipmen with teachers who should give suitable instruction to the future officers. Dana obtained the position of instructor in mathematics, was assigned to the *Delaware,* and, in August, 1833, sailed on a cruise to the Mediterranean. The voyage lasted nearly 16 months, and towards the close of 1834 he returned in the frigate *United States,* to which ship he had been transferred at Port Mahon. He visited Minorca and cities on the coast of France and Italy, made an ascent of Vesuvius, passed around Italy through the Straits of Messina, touched at some of the Greek islands, saw Athens, and spent some time at Smyrna.

It can be well imagined that a trip of this nature was not only a source of pleasure, but of great educational value to

a young man of Dana's character. He took full advantage of his opportunities and made a number of scientific notes and observations, including some on the geology of Minorca and in the vicinity of Smyrna. A letter of his, descriptive of the condition of Vesuvius as he saw the volcano in July, 1834, to Professor Silliman was published in the *American Journal of Science* and was his first scientific paper. He had leisure time on shipboard which he improved in reading and study. As an evidence of his industry and earnestness of purpose, we learn that he devoted many spare hours to working out problems in mathematical crystallography, in which he used measurements given by Phillips in his mineralogy, and in devising a new system of symbols for crystal planes. To most, and certainly to the great majority of those of us who have performed it, the calculation of crystal constants, however necessary and useful, is a very dry task, and it speaks volumes for Dana's caliber, that, as a youth of 21, amid the bustle of life aboard a naval vessel, he had the tenacity to pursue his favorite study of mineralogy in this way—the only one possible to him on a ship.

EARLY YEARS IN NEW HAVEN

After his return in December, 1834, his time for the next year or so was passed partly in New Haven and partly at his home in Utica. It was a period of anxious uncertainty to him, for as yet he saw no definite opening for a career which he wished to accept. He employed it usefully, however, in continuing his studies in chemistry and mineralogy. We find that he prepared several papers on the latter subject which were published; one of these, on the system of crystal symbols, thought out on his voyage. He also constructed a set of glass models of crystals for instructional purposes. He wrote an article on chemical nomenclature which he sent to Berzelius, the celebrated Swedish chemist, who replied with some kindly criticisms of certain features. It is of interest to note these early papers of Dana, because one sees from them that the orderly presentation, the organization of scientific facts and ideas into systematic form, which was so distinguishing a trait of his intellect, appeared at the very beginning of his career.

He also wrote part of a treatise on crystallography, intending it, as he said, for his own use, but in fact it became the beginning of his great work on mineralogy.

In 1836 Dana obtained the post of assistant to Professor Silliman, a place which had been previously held by the younger Silliman, Charles U. Shepard, Oliver P. Hubbard, and others, who afterwards pursued careers in science. He was pleased at the appointment, for the duties of the position, according to his statement, demanded only about three hours in the day and the remainder of his time he was free to devote to his studies and investigations. He now remained in New Haven for two years, during the first of which he acted as Silliman's assistant, and, probably incited in part by his friends, he continued his treatise on crystallography, added to it one on mineralogy, and thus prepared his first notable contribution to the literature of science, the *System of Mineralogy and Crystallography*. It is by this book (and its subsequent editions) that Dana's name is probably as well known as by any other of his works. We shall have occasion to consider it more in detail in another place, but it may be mentioned here that the manuscript was delivered to the printer in December, 1836, and the book appeared in May, 1837. For a young man not yet 24 years old to prepare the manuscript of a volume of 580 pages in an abstruse field, requiring constant verification of references and numerical constants, in a relatively short time is certainly a marked feat of executive industry. When it is added that the work is no mere compilation, but shows original philosophic conception in its treatment of various subjects, is without any signs of youth or immaturity, and was at once accorded a valued place in science in America and Europe, the work becomes still more remarkable. We must conclude that the material was already stored, in well thought out form, in Dana's mind, and needed for the most part only expression on the paper before him.

This important work at once gave Dana a well-merited standing among scientific men, although his acquirements had been already recognized by his friends and had led to a great opportunity for scientific research which now opened before him.

WILKES' EXPLORING EXPEDITION

About the beginning of the second quarter of the last century there began an agitation for the Government to send an exploring expedition into the Pacific, especially its southern portion. Other navies had already done this to the renown and credit of their governments in the geographical and other discoveries which they had made. Immense areas, however, still remained unexplored and it was felt that the United States, for its own sake in several ways, should join in this work. This movement was started by John N. Reynolds, of Ohio—a man of whom we know little, save that he was intensely interested in geographical exploration and anxious to promote it. He did not succeed at first in interesting the Government and on his own account made a voyage to the Pacific, traveled in Chile, and returned to the United States on an American naval vessel. On his return he began his agitation anew, induced various prominent men and societies to aid him, and finally Congress was moved to act and authorize the expedition when it became convinced that the exploration and surveys suggested would be of value to American commerce, and especially to the whaling industry.

The expedition was authorized in 1836, but two years passed before the necessary preliminaries could be settled and its organization completed. It was recognized from the beginning that the needs of science should be met by the inclusion of a staff of scientific observers. Dana had already, in August, 1836, been approached by Reynolds and offered a post on the staff, but at first declined. Afterward, urged by Asa Gray,* he reconsidered, offered himself as a candidate, and received his commission from the Navy Department in January, 1837. It was to take effect on July 4, 1838, and his salary was to be $2,500 a year and his subsistence while on active duty. One can easily imagine that, especially in those days, a position with such opportunities and pay to an energetic and ambitious young

* It is an interesting coincidence that Darwin, like Dana, owed his participation in a voyage of world discovery largely to the influence of a botanist, Professor John S. Henslow, of Cambridge University, who urged him to go, and brought him to the notice of Captain Fitzroy.

man of 24, dependent on his own exertions, was a most alluring one. It was the turning point in Dana's career.

He was named mineralogist to the expedition; but as the distinction between mineralogy and geology was then not clear as it is today, it was obviously intended by this that he should cover the field of geology, and under similar circumstances at the present time he would have been designated geologist. As we shall see later, he not only covered this subject, but took over a part of the field of zoölogy as well, partly because of the retirement of one of the staff who had undertaken this work. It was intended that Asa Gray should go as botanist and he had accepted the post. No doubt the thought of his companionship had had considerable influence in inducing Dana to reconsider his early refusal, and when Gray, led by the long delay and fine opportunities offered him at Harvard University, resigned his position it must have been a severe disappointment to Dana.

This delay, however, was a fortunate one for him; it enabled him to put his Mineralogy through the press and to prepare for publication several articles he had read before the Yale Natural History Society; to arrange his affairs and to attend meetings of the scientific staff, and generally in such ways as were necessary to qualify himself for the duties of his position.

The expedition finally sailed from Norfolk, Virginia, August 18, 1838, under command of Lieutenant (afterward Rear Admiral) Charles Wilkes, by whose name it was afterward generally known. It consisted of two sloops of war—the *Vincennes* and the *Peacock*—and several smaller vessels attached as supply ships and tenders. In addition to Dana, the scientific corps contained Charles Pickering, naturalist, who afterward attained considerable renown for his writings on the geographical distribution of men, plants, and animals; William D. Brackenridge and William Rich, botanists; Horatio E. Hale, ethnologist, and Joseph P. Couthouy, naturalist. There was added to these Titian R. Peale, of the famous Peale family of artists of Philadelphia, who prepared many of the plants for the scientific reports of the expedition. One should also include the naval officers who acted as geographers and surveyors, and there was an additional personnel of artists and assistants.

It is not our intention here to give any general account of the expedition, for this is a matter of history and well known, but merely to sketch the outline of that part of it which concerns the personal history of Dana.

He was assigned quarters on the *Peacock,* under the command of Lieutenant William L. Hudson, and Peale and Hale were his associates on board.

The squadron sailed first to Funchal, on the island of Madeira, and remained there a month. This gave Dana a good opportunity to study a dissected volcanic island; he had a number of such afterward. After a short visit to St. Iago, in the Cape Verdes, they proceeded to Rio Janeiro. The vessel and its supplies were found to be in poor condition and the fleet remained in Rio six weeks in order to refit. Dana was, as usual, industriously making everywhere good use of his time; on the voyage he was collecting, studying, and figuring oceanic crustacea, of which between the Cape Verdes and Rio he states he found 75 new species. Whenever opportunity afforded he made excursions ashore for geological observations and other studies and for collecting. From Rio the squadron sailed to Cape Horn, where it divided up for exploration. Dana was transferred to the store ship *Relief,* under Lieutenant Long, and it was intended that some weeks should be spent in study and exploration among the islands of the Magellan Straits. The bad weather and violent storms encountered, however, prevented this, and in one terrific gale the vessel, while anchored under Noir Island, for three days was in imminent danger of going ashore, with the certain loss of all on board, as one anchor after another gave way. Dana has left a thrilling account of this harrowing experience in a letter to a New Haven friend. Having lost all her anchors, the vessel could no longer remain in the Straits, and in order to refit sailed for Valparaiso, which was the general rendezvous of the fleet. They arrived there in April, 1839, and remained a number of weeks. Dana improved this opportunity, with the other naturalists, by making excursions in Chile, on which he made several mountain ascents to study the geology and to obtain views of the Andes.

From Valparaiso the expedition went to Callao, in Peru, where further inland excursions were made, and in July it

sailed for its essential task of exploration in the South Seas. The following month it arrived in the Low Archipelago, or Tuomata group. A number of islands were visited and the explorers proceeded to Tahiti, where some time was spent and surveys made. The Samoan group was next taken up and surveyed and mapped, the stay lasting until November 10, 1839, when the expedition sailed for Sydney, in New South Wales, where they arrived after three weeks. This portion of the voyage was Dana's introduction to the coral islands. Outside of the geology of volcanic masses as shown by many of the islands and their dissection by weathering, it must have been the coral reefs, with their richness of hitherto unknown and undescribed life, which chiefly occupied his time and attention, and we shall see later the results of these studies.

At Sydney a division of the work took place. The scientists, including Dana, were sent ashore, with orders to rendezvous later in New Zealand, while Wilkes with his vessels departed on his famous voyage in the Antarctic seas, when the great ice-barrier and the lands of the Antarctic continent were discovered. Meanwhile Dana made excursions in southern Australia, studying the country and its geology and collecting fossils, and after a couple of months proceeded in a sailing vessel, in which the corps of scientists found passage, to New Zealand, where they arrived February 24, 1840. While pursuing their researches and awaiting the arrival of Wilkes, they witnessed the acquisition of the islands by the British Government and the treaty-making with the native chiefs. When the vessels arrived from the southern voyage they went first to the Tonga Islands, then to the Fiji group, where they remained three months making surveys. In August, 1840, the squadron sailed for Hawaii, visiting several islands of the Phœnix group en route, and arrived at Honolulu on the 25th of September. Here, among other things, Dana had his great opportunity of studying volcanoes and volcanism in his visits to Mauna Loa, Kilauea, and other points. To confirm observations then made and to witness intervening changes, he revisited this region 47 years later, at the age of 74 years.

From Hawaii the *Peacock,* with Dana on board, returned (December 2, 1840) to Samoa for further work, visited the El-

lice group, then the Kingsmill, or Gilbert, Islands, went back to Honolulu, and from there to the mouth of the Columbia River. Attempting here to enter the river, the vessel was wrecked on the bar on the 18th of July, 1841, and after great peril all hands were saved, but their effects and much of the scientific results of their explorations were lost. They were rejoined here by Wilkes, who had been making surveys in Puget Sound; he remained in one vessel to survey the Columbia, while the *Vincennes* was sent to San Francisco. Meanwhile a party, under Lieutenant Emmons of the lost vessel, among whom was Dana, went overland to the same place. They ascended the Willamette, crossed the intervening ranges of the Cascade Mountains, passed by Mount Shasta, and descended the Sacramento River. This trip, an adventurous one for those days, must have offered the hardy explorers a great contrast with their recent work in the South Sea Islands. Although they had no idea of the remarkable activities that would begin less than ten years later, in the gold era of California, in those remote regions of Sacramento, it is interesting to observe that the geology of the country impressed Dana as being favorable for the finding of gold, and he so stated it in his report of the expedition.

The squadron reassembled at San Francisco, which at this time was a small village; a vessel, the *Oregon,* was bought to replace the lost *Peacock,* and at the end of October, 1841, it was ready to start on its homeward journey. By the way of Honolulu, where supplies were laid in, the expedition sailed toward the coast of Asia. Wilkes on the *Vincennes,* with Dana on board, proceeded to Manila; the other vessels went through the China Sea to Singapore. In the Philippines Dana had opportunity to make a short geological excursion. From here the vessel went to the Sulu Sea, where important surveys were made; then on to Singapore, whence the reunited squadron sailed for home by way of the Cape of Good Hope and the Island of St. Helena. The *Vincennes* reached New York Bay on June 10, 1842, and this important chapter in Dana's life was ended.

It must be clear to every one that in taking part in this expedition, especially at the time when it was made, Dana enjoyed an opportunity which comes to the lot of few naturalists. This

was recognized by Dana himself, as his letters show. It is one thing, however, to have opportunities and another thing to take advantage of them; that Dana fully employed his will appear in the sequel. It should, however, be stated in truth that much of his work on this voyage, as well as that of other members of the scientific staff, was done under disadvantageous circumstances. The importance of scientific work was not at that time accorded the recognition which it has since received, and the naval officers of the expedition, with little or no sympathy for or appreciation of any scientific work outside of the domains of geography, hydrography, and meteorology, in which they were interested, offered no coöperation, and not infrequently placed unnecessary hindrances in the way of the scientists to prevent them from carrying out their duties. Honor to whom honor is due. At the present time, in the minds of educated people, outside of those engaged in cartography, only two matters of interest which now seem of importance regarding this expedition survive—Wilkes' discoveries in the Antarctic seas and the results of Dana's scientific work. Let us be thankful that a different spirit regarding scientific men and their labor prevails at the present time.

THE REPORTS TO THE GOVERNMENT

On his return to the United States, in 1842, Dana established himself in Washington for the preparation and writing of his reports, and this labor occupied the larger part of his time for the next 13 years. He had been, as stated, appointed in the field of geology, but since during the voyage so much of the time was passed at sea and the opportunities for geological research were of necessity limited, he had worked largely in the domain of zoölogy, especially as the retirement of J. P. Couthouy, the naturalist, had caused this subject to devolve upon him, as previously mentioned. This is shown in a letter of his to Asa Gray, written in June, 1840, reviewing the results of his work on the trip to that date:

"In the geological line I shall be able to show you some long manuscripts; their other qualities I leave for you to judge of at a future day. Accompanying the manuscripts there are about

one hundred sketches of mountains, craters, basaltic causeways and caverns, faults and dikes, etc. My fossils, which include a large collection of the coral vegetation of Australia, were packed up without examination. Since arriving among the Fijis, I have taken hold of the corals and figured 175 species, with the animals of most of them. Among crustacea I have made collections and drawings, when geology was not requiring my time. My drawings are mostly confined to the smaller crustacea, and in all probability very few will turn out described species. I count up now 400 species, figured or painted, of which nearly 150 belong to the old class *Entomostraca.*"

After discussion of the subject, which lasted some time, it was finally decided by the authorities at Washington that Dana should assume the reports on corals and crustacea in addition to that on geology. He was compelled, however, in order to make the work on the corals complete, to add the coral-making animals and the allied forms, the sea-anemones and hydroids. This report on the Zoöphytes (Anthozoa) was the one first published; it appeared in 1846 and was a quarto volume of 741 pages, with a folio atlas of 61 plates. The colored drawings of the corals were made by Dana himself, as indicated in the previous paragraph. We shall refer to this volume later.

Meanwhile, before this work appeared, he had published several short papers and also a new and enlarged edition of his *System of Mineralogy.*

In 1844 Dana returned to New Haven to live. He did not like Washington, where he was subjected to petty restrictions on the employment of his time, as if he were a clerk in an office. Washington at that time was a very different place from what it has since become—the scientific center of the country. There were no scientific institutions at that time, no museums, collections, laboratories, or libraries. As he wrote a friend: "It is perfectly absurd that I should be able to prepare my reports in a city where there are no books!" It was natural, then, that Dana, dissatisfied with the lack of facilities at Washington, should turn to New Haven, where they existed, where he had many friends and felt at home, and where, moreover, his fiancée, Miss Henrietta Silliman, daughter of his former instructor, the

elder Benjamin Silliman, lived. They were married on June 5, 1844, and New Haven then became his permanent home.

During the next ten years, until 1854, when the last of the reports on the Wilkes Exploring Expedition appeared, Dana was actively engaged in research and the finishing of these reports and in writing. A great number of shorter articles appeared from his pen, and a glance at his bibliography, appended to this memoir, shows that they were upon the most varied subjects: articles upon minerals, papers of a zoölogical nature, chiefly upon corals and crustacea, not alone descriptive, but bringing out broad principles of distribution and classification; many papers on geological subjects, also of a broad and general nature, such as the origin of continents, on coral islands, etc., and others on fossils. These were published mostly in the *American Journal of Science,* of which he became an associate editor in 1846. These shorter papers are to be regarded, however, as incidental to his chief works. In 1848 he brought out a *Manual of Mineralogy* (12°, 430 pp.), a shorter work than the *System,* intended for more popular use and for teaching purposes. The third edition of the *System of Mineralogy* appeared in 1850, a volume of 711 pages, and the fourth in 1854, 854 pages, in two volumes.

His report on the Zoöphytes of the Wilkes Expedition, a quarto volume of 741 pages and folio atlas of 61 plates, appeared in 1846, and the report on the Geology of the Expedition was published in 1849, a quarto volume of 756 pages, with folio atlas of 21 plates. The last report on the Crustacea appeared (1852-1854) in two volumes of 1,620 pages, collectively, with folio atlas of 96 plates. In these works, as previously indicated, the plates were largely prepared by Dana himself. In 1853 he published a short, popular treatise on "Coral Reefs and Islands."

These details are mentioned in order that one may judge during this period of Dana's activities and industry; it was probably the most productive period of his life. He received a modest stipend from the Government, and this with some private means permitted him to live quietly and devote himself to scientific work. In that day there was little opportunity for one to assume a career in pure science unless his own fortune

allowed him to do so. Dana, as he himself has stated, was fortunate in his opportunity, and, possessed at that period of good health and abounding energy, he was enabled to accomplish an enormous amount of work of the highest excellence, as indicated by what has been written above.

Before dismissing the subject of the Expedition reports, a word further in respect to them may be added here. I believe that those of us who have done scientific work for the Government and have furnished reports upon it have, without suspecting it, benefited in considerable measure by the education regarding such matters which Dana and his scientific colleagues of the Wilkes Expedition were compelled, as well as they could, to give to officials of executive departments of the Government. It goes, of course, without saying that where there is unbalanced enthusiasm and lack of judgment on one side and a too narrow exercise of red tape and interpretation of official precedent on the other, there is likely to be trouble; but we are not today hampered by constant directions as to how reports should be written, what should be included and what left out. Also, incredible as it may seem in this day of liberal publication and desire to diffuse knowledge as widely as possible, it was then felt in Congress that the value of the reports would be much enhanced by a very restricted publication of them. Thus of the report on corals 100 copies were to be printed for the Government and 75 for the publishing firm to sell, and strong objection was made to Dana's printing, at his own expense, 25 copies more for his own use! The idea was that the few great libraries and crowned heads, to whom official copies were to be sent by the Government, would value them much more if they knew they were receiving a *rara avis*. It is for this reason that these reports are so hard to obtain and are so difficult of access, and it would be a very grateful thing if a new edition in compact form, with photographic reproduction of the plates, of these classics in the literature of American science could be published for the benefit of scientific workers.

PROFESSORSHIP IN YALE COLLEGE

The finishing of the Expedition reports may be said to have closed a distinct chapter in Dana's life. Since his means did

not permit him to live a life wholly detached for scientific work, it became necessary while writing them to look forward to continuing his career along lines which would give him adequate support. It can hardly be imagined that this matter could have occasioned him any prolonged or deep anxiety. Although Dana was always very modest in his estimate of himself and his work, he had too much good sense not to know that by this time he was one of the best-known naturalists in the country, recognized everywhere in the world as one of the leading men of science, and that there must be institutions which would be only too glad to obtain his services. Harvard University had indeed already made tentatives in this direction. His friends, however, felt that Dana should be retained in New Haven and definitely connected with Yale College, and under the inspiration and assistance of the late Professor E. E. Salisbury, Oriental scholar and philologist, a fund for the endowment of the Silliman professorship of Natural History was established and he was invited to fill the chair.

This was in 1850; but Dana did not assume the duties of the post until February, 1856, when his inaugural lecture was delivered. He was then 43 years old, and from that time until 1890 he stood in close connection with the college and its aims and activities until ill health and advancing years made it necessary for him to retire; he was then, be it noted, in his 77th year! Of his work as a teacher and college officer we shall take occasion to say a word later.

BREAKDOWN IN HEALTH

Dana was now definitely fixed in his career; life stretched before him in lines of work in which he excelled and which he enjoyed. The tasks of his position in the college, editorial work, and the management of the *American Journal of Science*, the preparation of scientific books and papers, and the revision of his works already printed, together with research and field-work in his favorite subjects of geology and mineralogy, and the conducting of a considerable correspondence with scientific men at home and abroad—these filled his time and gave scope to his energies.

In the next year or two he produced a number of interesting and important shorter papers and a newly revised edition of his *Manual of Mineralogy;* but the hand of warning was already stretched out, and from incessant labor his health broke down, and in 1859 he was compelled to stop work and give himself a rest to recuperate.

In writing this memoir of Dana perhaps nothing has impressed me more than the enormous amount of work which he accomplished in the 10-year period between 1844 and 1854, when the last of the reports was completed and which I have indicated as the most productive portion of his life. One may see this from the facts so baldly stated in his bibliography. One finds that in this period he completed three quarto reports of 3,117 pages, two smaller books of 574 pages, and to the close of 1854 64 shorter articles aggregating 832 pages. In addition there were three revisions of the *System of Mineralogy,* involving each time much rewriting and inclusion of new matter, with a total of 2,205 pages. Some of the material of the shorter papers was included later in the larger works, but in total there are 6,728 pages of material prepared and seen through the press. Think of the proof-reading alone involved, to which that done for the Journal must be added! This was a tremendous task for one man to perform, and we do not need to look further to understand why Dana broke down from nervous exhaustion in 1859 and never fully recovered his normal health.

He went to Europe for a period of ten months for recuperation, but did not gain greatly from it, and some years afterward broke down again; several interruptions from illness also occurred, and during all the latter part of his life he was compelled to live under a very strict regimen of hours for work and for rest and sleep. He was obliged to give up social intercourse, with its pleasures and excitements, almost entirely and to live a very guarded and secluded life. This was a great deprivation to Dana himself and to his family, as he was naturally of a friendly social disposition and enjoyed meeting his friends and associates. His work at times for long periods had to be confined to one or two hours a day, perhaps to his classroom duties alone. Yet, in spite of these limitations and interruptions, during the thirty-odd remaining years of his life Dana

accomplished in sum total an enormous amount of work, as may be seen by reference to his bibliography. It was undoubtedly a real loss to American science that through overwork Dana lost his normal health while still a comparatively young man and was unable to take part in executive or public ways during the important years when the growth of science was so rapid and its organization and direction were being determined.

Through the medium of the *American Journal of Science* and his correspondence his influence was wide and constantly felt; but one can easily imagine what a help and stimulus he might have been if he could have played an active part in the organizations in which he was naturally interested, as, for instance, in the meetings and conducting of this Academy. President Gilman in his life of Dana gives letters to him from Agassiz and Darwin, both of whom were victims of ill health caused by overwork, warning him of its evils—warnings which none of the three regarded.

One result of Dana's breakdown was important in a scientific way and should be mentioned. He was compelled to live more or less in the open air and take active exercise. He began to take long walks, and in so doing the geology of the regions which came under his eye attracted him, and he was thus led into active field-work and a lively interest in the geology of southern New England and eastern New York State, upon which in ensuing years he made many researches and published a considerable number of important papers.

MANUAL OF GEOLOGY AND OTHER WORKS

In teaching his classes Dana had felt the lack of a suitable text-book, one especially adapted to the needs of American students, and recognizing that this want must be generally felt, and that such a book would have a broad field of usefulness, as soon as his health would permit him to do so, he commenced to prepare it, and in 1862 published the first edition of his *Manual of Geology*. Of the nature of this work and its successive editions we shall take occasion to speak later, and also of its influence on the development of geology in this country. It is sufficient to say here that it had a great and immediate

success, and that it is, perhaps, that one of Dana's works which has had the widest circulation and is the one by which in the popular mind he is best known. A smaller work, adapted to younger and less advanced classes and general reading, under the title of a *Text-book of Geology,* was issued shortly after, in 1864.

He then undertook the revision of the *System of Mineralogy* for a fifth edition, and the work was published in 1868. With each successive edition of this great work the task of revision, owing to the increase of knowledge in this field, had become proportionately greater, and the 14 intervening years since the fourth edition had been very fruitful ones in research. Dana had the aid of the late Professor George J. Brush in preparing part of the work and in proof-reading; but in spite of this the task was very great, especially as he added several improvements which entailed a most laborious search of the literature of the subject. It was the last edition prepared by Dana, the succeeding sixth one being carried out by his son, Edward S. Dana, and he again broke down in health after it was finished and for a time was compelled to suspend all work.

LATER YEARS

Meanwhile and in succeeding years Dana, as his health permitted, was steadily contributing shorter articles to the *American Journal of Science,* which were for the most part in the domain of geology. After his son, Edward S. Dana, began work in mineralogy we find only one more paper directly upon minerals published by him—in 1874. There were a few papers of a paleontological or biological character, and that he never lost his interest in the field of zoölogy is shown by the fact that his last original contribution to the *Journal,* which appeared in 1894, was on the derivation and homologies of some articulates. In the province of geology, however, these shorter papers of Dana, published in the last twenty years of his life, range over nearly the whole field and, touching upon the most varied topics, they indicate the breadth of his reading and interests and how firm a grasp he kept upon the progress of his favorite science in practically all of its development.

In 1880 he brought out a new edition of the *Manual of Geology,* but doing this overtaxed his strength; he was obliged for a time to relinquish class-room work, and in the next succeeding years his activities, beyond his college duties, were mainly confined to the preparation of the shorter geological articles and his field-work in Connecticut and eastern New York.

In 1887 his health seemed in great measure restored; he was much interested at this time in the nature and manifestations of volcanism, and he decided to revisit the Hawaiian Islands and see the changes which had occurred in the crater pit of Kilauea since his former view of it in 1840, when with the Wilkes Expedition. Nothing, perhaps, could illustrate better the unconquerable energy of Dana than that, in the 75th year of his age, he should undertake this long and in some parts difficult and fatiguing journey, where a number of times he made long trips on horseback, camped out at night, and made difficult ascents and descents. He was accompanied by his wife and younger daughter. It was the first long journey he had made since his visit to Europe in 1860—at which time he also revisited Vesuvius—and he withstood the incident fatigue remarkably well.

As the result of his observations in the Hawaiian Islands, Dana learned much, and in the succeeding two or three years he published a series of papers in the *American Journal of Science,* mostly on the history of the changes in the volcanic craters on Mauna Loa and giving his views on volcanic energy. This material, with added matter, and a chapter on the petrography of the Hawaiian lavas by Edward S. Dana, was recast into a work of 400 pages, entitled *Characteristics of Volcanoes,* which appeared in 1890, and at the time a second edition of the *Corals and Coral Islands* was published as a companion volume.

At this period his health again lapsed and he was compelled to relinquish his active college duties. For a time his classes were conducted by the late Professor Charles E. Beecher, until in 1892 the late Professor Henry S. Williams, afterwards of Cornell University, succeeded him in the Silliman professorship.

Dana was now (1892) in his 80th year; he stood like a Nestor in American science—full of years, of dignities, of honors, with the record of a life of wonderful accomplishment behind him; his health and strength were strictly limited. It would seem to most men as if the period of a well-earned repose had arrived. Not so Dana; an inextinguishable fire of energy and enthusiasm was his; he was one of those spirits which must die with the harness on, working to the last.

A number of short papers and a small volume on the local geology of the New Haven region came from his pen. The revision for a fourth edition of his *Manual of Geology* had been in preparation; this was now taken up and brought gradually, with some aid, joyfully given, from some of the younger workers in the science, to completion. It was an octavo volume of 1,057 pages; and when one considers that the work was practically rewritten, the vast amount of material it contains, and the study and familiarity of the literature it indicates, as well as the task of proof-reading, one cannot but be struck with wonder that a man of his age could have completed such an undertaking. It was his last notable achievement and he lived to see the completed volume in his hands.

His work on this book was finished in February, 1895. During the two months following he occupied himself in revising the texts of his elementary works on geology. His mind was as active and keen as ever, and he was still able to take considerable physical exercise. On April 13 he was about his regular occupations, cheerful as usual. In the evening he had a slight attack of trouble with the heart; the following evening, April 14, 1895, it recurred and he passed quickly and peacefully away. It was a most happy ending of a life of remarkable achievement, full of years and honor.

Professor Dana was survived by his wife (died January 3, 1907) and four children, two sons and two daughters, all of whom are still living.

PART II

REVIEW OF DANA'S SCIENTIFIC WORK

In the foregoing pages there has been given an account of the main features of Dana's life and the sequence of the production of his scientific work has been traced. It is now proper and fitting that these achievements should be considered and their importance in the structure of science and their influence in its development be pointed out.

Dana was one of the older school of naturalists; like Darwin, Agassiz, Wallace, and others, he began his career at a time when the domain of the natural sciences, as compared with its condition today, was limited and it was possible for men of their quality of mind to absorb, while still young, the facts and ideas necessary to appreciate its development in several different fields of knowledge, and to pursue research when desired in each of these fields. As time passed, with the volume of knowledge in each line continually increasing, specialization became more and more apparent and necessary; yet these men in great measure were still able to maintain their grasp of the progress in different branches, owing to their breadth of mind and industry in acquiring new facts and ideas as they appeared. Dana was especially distinguished in this way, and one may practically say that to the end of his life he followed the whole group of geological sciences, from mineralogy at one end to paleontology at the other, and from there on into the field of zoölogy. It seems impossible for men to do this today, for as the circle of knowledge ever increases, though the length of arc one can observe may remain the same, the number of degrees continually lessens. Although this in essence must be true, one cannot, however, be dogmatic in such an assertion, for even in this day there appear now and then men who may win distinction by their work in a group of sciences.

It seems safe to say, at least, that there is now no one man who can pronounce authoritatively and fully upon the value and bearing of all of Dana's work in science, and least of all does the writer of this memoir feel himself capable of doing so. We

must, therefore, be guided largely by the opinions of others, and, since there has appeared in the years that have intervened after his death a considerable volume of such opinion by those who are qualified to judge, it is now easier to form a just estimate. Also, we have additional evidence from the views of his contemporaries, expressed at one period or another during his lifetime.

Dana's influence upon the development of the lines of science in which he was interested was exerted in three directions, each of which must be considered: by his published works, by his editorship of the *American Journal of Science,* and by his services as a college officer. As the most important of these we shall first examine his original contributions to science, which must naturally be done under the three chief departments of Mineralogy, Geology, and Zoölogy, in which his activities were displayed.

IN MINERALOGY

Through the labors of Dana and those of his son, Edward S. Dana, who has carried forward his work, the family name has become indissolubly connected with this branch of science. The connection is indeed so intimate that it is possible in the future his name will be more popularly known for his services in this field than in any other, though such an estimate would not be a correct judgment of his greatest claim to distinction.

Dana's contributions to mineralogy, as the result of his own researches, are of a high order of merit—they are clean cut, accurate, and discriminating. They are upon the physical side of the science rather than the chemical, except as the latter is considered from theoretical viewpoints, and are largely crystallographic. This was natural, both from the mathematical bent of Dana's mind and the small opportunities for working in the chemical direction which presented themselves in his younger days. It is, perhaps, fortunate that no temptations to research offered themselves in chemical mineralogy, for this is relatively a narrower field, while the nature of his mind qualified him for work and success in a much broader one.

His chief service to mineralogy was not, however, the results of his investigations upon particular minerals, nor his expressed

views upon certain phases of the subject, however valuable these may be considered, but in the preparation of his great work, the *System of Mineralogy*. In this some of the most striking qualities of Dana's mind are revealed: his power of coördination and organization into orderly form of facts and ideas, his ability to grasp and retain a vast amount of material, and his unwearied industry that enabled him to bring a great task to quick completion. The feat he performed in writing the first edition has been previously alluded to. It was also not a mere compilation, for it contains new ideas in regard to crystallography and crystallogeny.

At first Dana was committed to a certain form of classification and to a Latin dual synonymy, similar to that employed in the biologic sciences. The growth of knowledge on the chemical side made this increasingly distasteful to him as its disadvantages became more apparent, and in the third edition he threw the whole plan overboard and adopted one, more fully developed in the fourth edition and since almost universally used, which is based largely on chemical principles. In his preface to this edition he makes a characteristic remark, which shows his openness of mind, that while he might seem to be fickle in discarding the Natural History plan after promising to use and support it, it was much worse to persist in error after the latter has been demonstrated.

In the fifth edition the theoretical matter was largely eliminated and the work devoted to the description of species. It was the most extensive examination and compendium of the literature that had then appeared, and one of its most valuable features is a complete study of the historical synonymy of mineral species. The amount of included matter, aided by rigid condensation, is enormous and the work the achievement of a colossal task.

It seems appropriate to add that the sixth edition of this great work was published 24 years later by Edward S. Dana; the included material is here more than one-half as great and an entire recalculation of the crystallographic constants was made, the text being in large part rewritten.

The influence of this work on the progress of the science of mineralogy, especially in this country, it is impossible to ade-

quately estimate. For 80 years it has been the indispensable manual of reference for all workers in the science and in related sciences and arts, as in chemistry, geology, mining, etc. Had Dana accomplished no work other than that which he did in mineralogy, we might yet justly feel that his career had been a notable one. His position in the science is much like that of Linnæus, who has been termed the father of systematic botany. Unlike Linnæus, he was able to change his system of classification to a natural one, and did so, achieving also in his science what de Jussieu and de Candolle did in botany.

Finally we must also recall the very useful text-book, the *Manual of Mineralogy,* which passed through many editions and was for years of service to teachers and students in this science.

IN GEOLOGY

Dana was naturally led into this field of science by the circumstances of his life, as has been shown in the foregoing pages. He was one of the earliest of our geologists with an official position, although, as noted, his title was that of mineralogist in the Wilkes Expedition. His preparation for actual field-work, as we should view it today, was scanty, but it was as good as could be had in that day. In addition to what was known of the subject itself, he had had training in chemistry, mineralogy, and mathematics, solid bases on which to build, and his studies in zoölogy were, of course, the foundation for his work on the historical side. He was not altogether devoid of actual field experience; for in his school and college courses he had had some advantages, and in his first voyage to the Mediterranean he had had opportunities to study volcanic islands and to see Vesuvius.

On a naval expedition, like that in which Dana took part, the occasions when detailed geological studies can be made are, naturally, not many. Long periods of time were passed at sea, other periods were spent surveying islands which presented no material but coral masses and sand; in others, volcanic rocks were present, but the dense growth of vegetation or the presence of hostile savages, or both, forbade observations, except such as could be made along the shores. Sometimes, as in the

Hawaiian Islands, longer excursions were made inland with great profit. His opportunities, however, we must remember, were not wholly confined to the smaller oceanic islands; for trips inland were made in Chile, Australia, New Zealand and in Oregon and California, though there were not many occasions on these for other than general observations on the nature of the country. In spite of these disadvantages, Dana collected a valuable amount of information, as may be seen by reference to his geological report, and the nature of his mind led him to attempt to classify the facts obtained and to endeavor to bring them into harmony with the general principles of geology as then known, and to deduce further generalizations from his studies.

As a result of his experiences on the Wilkes Expedition, Dana was led to take a special interest in the origin of coral islands and in volcanoes and volcanism. His devotion to mineralogy and its applications induced particular consideration of crystalline rocks and metamorphism, and the broader results of these studies are seen in his views of the development of the earth and its features as a whole. There is also to be considered his field-work in New England; but this will be treated later, and meanwhile the topics mentioned above may be discussed.

From his study of the coral islands and reefs in the South Seas, Dana was forced, like Darwin, to believe that the barrier reefs and atolls had been formed around islands, chiefly volcanic, by slow and profound subsidence of the ocean floor. Both observers reached this conclusion independently. Darwin antedated Dana in publication, but as the latter brought forward new facts in proof of the view and strongly supported it, the theory is commonly attributed to them unitedly. In later years the validity of this view as an explanation was attacked by Sir John Murray and Alexander Agassiz, who held that the peculiarities of coral reefs could be explained by conditions of growth of the reefs and that subsidence was not necessary. It may be pointed out that the two views are not exclusive, the one of the other, but that the reefs might be formed on either assumption, or by a combination of them. Rather recently other factors in the problem have been brought

forward, such as the changes in ocean levels induced by the storing on the land, and subsequent melting, of glacial ice-caps—a matter which in his day Dana could not have known the extent of or taken into account. It thus appears that the problem is much more complicated than was at first imagined, and it is probable that at the present time no single simple explanation could be advanced which would be universally accepted. Nevertheless, it still remains Dana's merit to have pointed out that the reefs are connected with changes of sea-level and, as so well urged by Professor William M. Davis, to have called attention to the facts of the topography of the islands, which indubitably prove that such changes have taken place. Valuable features of the theory will, therefore, persist, whether the view of profound oceanic subsidence is finally accepted or not.

Volcanism may be said to be that field of geology in which Dana began his work, his first published paper being one on Vesuvius. It was also the field in which he had some of his best opportunities while on the Wilkes Expedition. The interest thus excited early in life remained with him to the end, as shown by his second journey to Hawaii, in the 75th year of his age, and the subsequent issue of his volume on volcanoes. It is also shown by the fact that in the *Manual of Geology*, published in the last year of his life, the space allotted to this topic is much greater, relatively, than is usual in text-books on this science by others. His contributions in this field are of great importance and will remain permanently of value, for they are mainly original observations of facts, and his mind was too clear and sane to hazard, as some have done, a mass of speculations which later knowledge might completely disprove.

When Dana was nearly 60 years old, as his health demanded more exercise and life in the open air, he began his field-work on the highly crystalline rocks of western New England. His previous papers, books, and reviews show he had always had an interest in metamorphic rocks and metamorphism, into which he had been naturally led by his labors in mineralogy. These field studies Dana continued for many years, during which time he investigated and mapped many areas with the most labori-

ous detail. He recognized that if anything of value was to be obtained concerning the geology of the region it could only be done by the most painstaking of field study, and his course in this respect was in sharp contrast to much, perhaps most, of the previous work that had been done here, in which deductive reasoning and pure speculation had been at a maximum, while collection of facts by careful field-work and induction from them had been at a minimum. This was the first serious original work of Dana in what we should now call structural geology, the attempt to unravel the geological history of a particular region by a laborious collection of detailed observations.

One is led here to pause and wonder what would have been the history of American geology if the earlier workers in it could have started their labors in our west, in the region of the Rocky Mountains, for instance, instead of in the area of the northern Atlantic border, in New England, eastern New York and Pennsylvania, and eastern Canada. On the one hand, magnificent exposures; structural geology clearly displayed on a large and evident scale; stratigraphic series laid open to observation; every stage from intrusive to extrusive effects of volcanic energy bared by dissection, and other advantages every geologist will recognize. On the other hand, an enormously complicated series of problems, some of them still today baffling in spite of all our modern instruments and methods, subjected to vast erosion, largely masked by vegetation and heavy deposits of glacial drift. These earlier workers had no good topographical maps, none of our present developed methods of field-work, no help from the microscope, little or no resource in analytical chemistry, nor the innumerable aids which the development of all physical science and mathematics affords us today in testing conclusions. This should always be considered in making a just estimate of the work of Dana and others in this difficult region; the wonder should be, not that what we now consider are mistakes were made or erroneous conclusions were sometimes drawn, but that in spite of so many obstacles so much was accomplished.

The work of Dana in southwestern New England and eastern New York was very valuable; as a result of it a mass of misinformation and misconception was cleared away and the

problems clearly brought to view; a great mass of facts was collected and stored away. While some of his conclusions have been changed, others will permanently stand. Thus we must in large degree regard his work as fundamental, as the basis upon which the later structure of the geological history of the region is being built.

Also, we must not omit to mention that the other chief aspects of southern New England geology, its Triassic sandstones and their inclusion of trap masses and the results of the glacial invasion, attracted Dana's attention, and about them, also, he collected stores of data and published many papers embodying his conclusions. In reading his papers on the structure and history of the Triassic area, one cannot help wishing that he might have had the benefit of observing some of our western geology; much that seemed so difficult to him, with his clear mind, would have been so much easier and more comprehensible. His observations on the glacial geology and deposits will always remain a valuable chapter in the history of this phase of American geology.

The most valuable contributions which Dana has made to geologic science were not so much those which add to our knowledge of particular areas, but those broad generalizations which form some of the very bases upon which the science of today is founded. Some of these he set forth while he was still a young geologist, and it seems to the writer that he was naturally led into this line of thought by his observations on coral islands while on Wilkes' Expedition. To a mind which, like Dana's, had power to grasp a mass of details, to perceive the essential among them, and to deduce important principles therefrom, the sequence of thought seems to run irresistibly as follows: the coral islands denote subsidence of the ocean floor; such vast subsidence must condition uprising elsewhere, hence upon the continents; this may have been a continuous process, caused by the earth's contraction from cooling, hence the growth of the continents; such effects would produce lateral thrusts against the continental borders, which result in mountain-making; therefore mountains occur upon the continental borders. It seems as if we could almost see these successive steps and the viewpoints they opened out in

Dana's mind if we simply place before us the titles of the shorter geological papers he published in the years succeeding his return from the voyage, in their successive order:

Areas of subsidence in the Pacific, as indicated by the distribution of coral islands.

The origin of continents.

Geological results of the earth's contraction in consequence of cooling.

Origin of the grand outline features of the earth.

General view of the geological effects of the earth's cooling from a state of igneous fusion.

The plan of development in the geological history of North America.

When his *Manual of Geology* was published, in 1862, and thereafter, this work in its successive editions served chiefly as the medium for expression of his general views on geology.

The estimate which we should place on Dana's influence on the development of geology as a science has been so nobly expressed by Joseph Le Conte in his commemorative address before the Geological Society of America* that we cannot do better than quote it here:

"As already said, the idea underlying all of Dana's geological work is that of the development of the earth as a unit. Before Dana, geology was doubtless in some sense a history—that is, a chronicle of interesting events; but with Dana it became much more, it became a philosophic history, a life history, a history of the evolution of the earth, and of the organic kingdom, in connection with one another.

"For the first time there was recognized a time-cosmos governed by law as the true field of geology, as the space-cosmos governed by law is the field of astronomy. Before Dana, geology was the study of a succession of formations; with Dana it was the study of a succession of eras, periods, epochs, during which geographic forms and organic forms were both developing toward a definite goal. The underlying idea of his geological work, I repeat, was the evolution of the earth as a whole. . . . But while he held firmly and expressed clearly this idea of the evolution of the whole earth through all time, yet he recognized the impossibility, in the present state of geological knowledge, of carrying it out in detail in every part of the earth. He therefore conceived the idea of taking one best known and simplest continent as a type. He regarded North America as such a type-continent

* Op. cit., page 41.

and its evolution as an epitome of geological history. . . . the idea has become the working theory, not only for American geologists, but for geologists everywhere. There can be no doubt that Dana's ideas and Dana's work, especially as systematically embodied in his *Manual,* constitute a distinct epoch in the history of geological science."

We may add here that this conception of the growth and evolution of a continent through geologic time naturally induces the view of the permanency of the earth's great features, of its continental masses and ocean basins—a conception of geologic thought of today which we owe to Dana. He was also one of the very first of the paleogeographers, as shown by the maps in the first edition of his Manual.

No review of Dana's work in geology would be complete without mention of the *Manual of Geology.* Of this work four editions, as stated, were issued, the last at the very close of his life. Like his *System of Mineralogy,* it served to display in geology his genius in classification and organization of masses of facts and ideas into a coherent and logical whole and for the expression of his philosophic thought. Generations of classes in American institutions have received their education in geology, and in considerable part in biology and philosophy, through the medium of this work. Its educational influence, therefore, has been very great and impossible to really estimate. As a text for beginners in college classes, the book, however, considered from the standpoint of student psychology, is a very tough crust for children's teeth. In time it was replaced in this function, in part, by Le Conte's *Elements of Geology,* which was better adapted to this purpose. The condensation is great and, especially in the last edition, the total amount of matter presented enormous, so that it has become rather a handbook of geology, especially of America—an indispensable work of reference. It is, perhaps, not too much to say that nearly all American workers, prominent in science today, have received much, and in many cases most, of their geological training by means of this book, and not a few have had no other instruction than that gained by their individual study of the work. Had Dana produced nothing but this volume he would yet have served this science as few others have done. His more elementary texts have also had a wide circulation and have greatly

helped in diffusing a popular knowledge of this subject; the *Text-book of Geology,* revised in recent years by Professor William North Rice, is still actively used.

IN ZOÖLOGY

Into this field of science Dana was impelled, so to speak, largely by the exigencies of the situation in the Wilkes Expedition. His preparation for zoölogical research from the standpoint of today must have been necessarily scanty, though we should not overlook the fact that some of his very earliest published papers were in the field of zoölogy, concerning spiders and crustaceans, in part in conjunction with others, and for which he drew the plates. This indicates he had made progress in zoölogical studies; he had also done some work in botany, but in the main he was obliged to educate himself in the field allotted him as he went on with his task. He thus became a trained specialist in a considerable part of the invertebrate field. As time passed his knowledge became wider and the preparation of his *Manual of Geology,* on the organic side, led him to obtain a firm grasp of practically the whole field of zoölogy in all its departments, especially with reference to its development and bearing on philosophic thought. He thus became one of the great naturalists of his day. His work at first was of a morphological nature, like other zoölogists of his time; but from the beginning one can see that he was never satisfied with the mere details of structure, and eventually he moved into much higher planes of thought.

In the writing and publishing of his first important work in this field, his report on the *Zoöphytes,* we see again displayed that organizing and philosophic turn of Dana's mind and his genius for classification. He was not content with a mere description of the species collected, but delved into the subject until he had clearly in mind all that was known upon these classes of animals and then proceeded to prepare a profound and philosophic treatment of them, involving a classification which is yet accepted essentially for corals. In doing this, as previously stated, he came in sharp conflict with the authorities at Washington, who wished him to confine himself to descrip-

tion of collected material alone; but, fortunately, Dana triumphed in the end and the volume was issued in the form he desired. The value of the publication, now one of the classics in the literature of zoölogy, was immediately recognized and gave Dana a standing as a naturalist of the first rank.

This was followed by his colossal work on the *Crustacea,* and to realize the effect produced by it upon his contemporaries we cannot do better, perhaps, than to quote what Darwin wrote to him about it in a letter given in Gilman's life of Dana:

"I have experienced such great interest in many parts and have found it so suggestive towards my *Cirrepedia* work that I cannot resist expressing my thanks and admiration. The geographical discussion struck me as eminently good. The size of the work and the necessary labor bestowed upon it are really surprising. Why, if you had done nothing else whatever, it would have been a *magnum opus* for life! Forgive my presuming to estimate your labors, but when I think that this work has followed your *Corals* and your *Geology,* I am really lost in astonishment at what you have done in mental labor. And then, beside the labor, so much originality in all your works!"

After this Dana's contributions to zoölogy were shorter papers, mostly of a philosophic character, and the development of his views in the *Manual.*

During his studies on the Crustacea he was led to notice that in any class of animals, in proportion as they rise higher in development, so much more does the structure become devoted to the service of the head, to the department of intelligence. He saw that in crustaceans in the higher forms more of the appendages were used for this purpose and less for mere locomotion. In Dana's mind, so naturally given to generalization, this idea appeared a fruitful discovery and its application seemed of increasing importance; eventually, under the term of *"cephalization,"* he brought out the principle of the dominance of the brain in determining the structure of the animal organism. This general principle, though not today with such a broad development and so wide an application as Dana conceived it, is yet important in biological and also in philosophic lines of thought and research, so that we should recognize what we owe to Dana for first clearly recognizing and stating it.

Dana was slow in accepting the theory of evolution in the

form stated by Darwin. Yet it is clear from his writings that not only was his mind moving along parallel lines, as indicated in part by what is stated above, but it was also accumulating facts and ideas that were carrying him toward that principle in its broader applications.

In the report on Crustacea, while he thinks that a species cannot be created by circumstances and physical forces, but must be the free act of a Divine Being, he yet remarks that "we may still believe the connection between the calling into existence of a species and the physical circumstances surrounding it to be as intimate nearly as cause and effect."

From this we may infer that the old idea that species suddenly appear by the fiat of a Creator, without regard to natural laws or conditions, no longer obtains in Dana's mind, but rather that the Divine Will manifests itself through the medium of natural means. He subsequently further defined this by stating, "a species . . . is based on a specific amount or condition of concentrated force defined in the act or law of creation";* but this referred to not only living organisms, but to inorganic compounds also.

If, however, we take this view, in connection with the recognition of the principle which has been mentioned above, we can appreciate how Dana had moved toward evolution without himself being aware of it. The principle of evolution is so universally accepted today and forms so fundamentally a part of our thinking, that it is difficult for us to realize a time when it formed no part of the mental outfit of science; we should do this, however, to appreciate how in some ways of thinking Dana was ahead of his time and how inevitable was his final acceptance of it.

Darwin's work on the origin of species appeared in 1859, but on account of ill health, as he himself states, Dana was unable to read it for several years. Gradually the conviction of the truth of this principle grew in his mind and, although he differed from others in some ways in regard to its application, he finally accepted it firmly, and in the last edition of his *Manual* he again affirms this belief. "Consequently, the law of nature,

* Amer. Journ. Sci., vol. xxiv, 1857, p. 307.

as regards kingdoms of life, is not permanence, but change, evolution."

Although Dana attained first rank as an active zoölogist comparatively early in life, as he also reached supremacy in mineralogy, he did not continue it as the chief field of his active thought. Both of these sciences, mineralogy and zoölogy, came eventually to have their chief interest to him in their bearing on his chosen field of mental activity—geology. And seeing from this how wide a range of knowledge his comprehensive mind possessed, it is easier to understand how he was able to approach this science from every point of view, from detailed work in any field to the broadest of philosophic generalizations, and to give to the whole a unity and cohesion it had not previously possessed. Of his contributions to science, on which in the future his fame will be found to chiefly rest, this, we believe, will have most distinction and importance.

THE AMERICAN JOURNAL OF SCIENCE

No statement of Dana's services to science, and to American science in particular, would be complete without mention of the part that he played in the editing and conducting of the *American Journal of Science,* which was for so long a time the only organ for scientific publication in this country, and which still remains, although the establishment of many journals in special fields of science and other foundations for scientific publishing have enabled it to restrict its field of activity, the means through which a large part of the scientific workers of the country naturally first make known the results of their labors.

Under the title of the *American Journal of Science and Arts*—the last part of the name having been dropped in later years—it was founded in 1818 by the elder Benjamin Silliman. In 1838 the younger Silliman became associated with his father, and in 1846, on the beginning of the second series of 50 volumes, Dana was added to the staff. He remained in service almost to the day of his death, since the number which contains the obituary memoir of him by his son also contains several notices of scientific works prepared by him. The elder Silliman retired

in 1863, the younger in 1875, and was succeeded by Edward S. Dana, the present editor-in-chief. From 1850, until in the later years of his life he was relieved by his son, the chief burden of editing and conducting the magazine fell upon Dana. Any one who has performed this kind of work knows what a time-consuming and often thankless drudgery is involved in the endless correspondence, proof-reading, and other duties of editing a journal which, rain or shine, must appear, each number, at a stated period. But we must add to this that the *Journal* has never possessed any income beyond that afforded by the list of subscribers, and this income has never been more than sufficient to meet its expenses of publication. Consequently it has never been able to find a publisher who would assume it, and the financial responsibilities and risks have, perforce, been carried by the editors, who all these years, from the business point of view, have had only their labors for their pains. To consider only one aspect of it, it would seem to most that an enterprise of this nature would alone be sufficient to engage the time which could be spared from required duties, and it becomes a marvel how Dana, viewing also his physical condition for so many years, was able to carry this burden and yet accomplish what he did in other ways.

It was not, however, all of it mere drudgery without reward. By reason of the *Journal,* Dana kept constantly in touch in his correspondence with the best minds in the country, and this must have been in some measure an alleviation of the very retired life he was compelled to lead. It also afforded him a constant and ready means for the publication of his views on various topics, and by this and his notices of the work of others he was able to exert a wide influence upon scientific thought and work.

The maintenance of this journal, the cheerful giving of his time, thought, and labor to the service of others, and thus to science in general, is by no means the least of the benefits Dana conferred upon his own and succeeding generations and which should be held in grateful remembrance.

AS A TEACHER AND COLLEGE OFFICER

In considering Dana's career as a teacher, we must at the outset recall that he was already 43 years old when he held his first college exercise. It is not easy for a man at this age to begin an entirely new profession; forms of expression both in speaking and in writing have become more or less fixed and ways of viewing subjects and the approach to them hardened. It is one thing for years to have always been addressing and thinking on the plane of the most trained and advanced minds in the world and another thing to seek to set the imprint of knowledge on young and only partly formed mentalities. Teaching is in itself an art which can never be wholly reduced to a science; it is not sufficient to possess the requisite knowledge; one must also know how to impart it—a fact too often overlooked in the appointment of men to teaching positions. This art of imparting knowledge has to be slowly and patiently acquired; it is most easily learned in youth, and some have a greater talent for it than others; but, however great the talent, it must still be trained.

Thus we can see that in taking up college work as a profession Dana labored under certain disadvantages, but on the other hand he possessed undeniable qualifications for the work. Of great importance for a teacher, he had a most engaging and striking personality; he was a quick, eager, and incisive speaker; in addition to his great fund of knowledge, he had a wide experience of men and affairs, of travel and experience; he was full of enthusiasm; he lived a number of years under naval discipline, and in his youth, during his Mediterranean voyage, he had gained some experience in instruction.

Therefore, if we bear this in mind, and the great reputation he had already achieved, we can understand why from the beginning he produced a great effect upon his classes, and, although at first he had much to learn and no doubt often went far over his students' heads, he never failed to hold their interest and attention. At first he gave instruction in both mineralogy and geology, afterwards in the latter science alone. He also gave occasional lectures in other subjects which interested him and with which his studies had brought him into

close touch, such as evolution. A remarkable lecture which he sometimes gave was on coral islands; his enthusiasm, eloquence, and remarkable gift of vivid description never failed to carry his audience with him, and even into his later years to hear Professor Dana give this lecture was one of the events of a course in the university, as the writer can testify by personal experience.

Dana's contact with undergraduates in the earlier days of his teaching was not a close one; in his day geology was not an applied or technical science, as it has become today; it appealed in academic circles purely from the cultural standpoint, and the sciences were advancing slowly to importance in this last aspect. Thus, very fortunately for the rest of the world, he was not required to carry a heavy schedule of instructional work and could devote much of his time, when his health permitted, to other things, with results that have already been sufficiently indicated.

But the testimony of those who sat under him in these classes and which has been put on record is that he aroused great interest in his subject; that his standard of work and accomplishment was high; that the effect he made as a man and a teacher remained strongly imprinted in after life, and that young men obtained from him much more than was to be found between the covers of his text-book.

He was in the habit of giving occasional field excursions in the environs of New Haven to his college classes, in which others who were interested were invited to join. These were well attended and greatly enjoyed. The amount of strength and nervous energy he put into these, especially in getting about from place to place, was remarkable, and even the most athletic student found one of them no idle ramble in the country, but a real business affair, a tax on his mind and muscle. It was on one of these excursions, as mentioned at the beginning of this memoir, that the writer first came in contact with him, and the remembrance of it is as clearly cut as a cameo on its background.

In 1885, when elective studies began to be more extensively opened to undergraduates in the college, he offered a more advanced course in geology to seniors. This proved very suc-

cessful and he was able to continue it for a number of years. Occasionally Dana had more advanced students who worked under him, men who were taking up his science as their life pursuit. Some of these have risen to distinction, and at the time of his death they put on record their appreciation of him as an instructor and guide.* One point they all mention in common, and that was the openness of mind which Dana insisted they should bear toward the reception of scientific views and theories. As he was opposed to a dogmatic attitude himself and ready to be converted to a new view when in his judgment the facts indicated its correctness, so he desired his students to be of similar mind; he wished no authority in science to be recognized.

Although as a college officer Dana was not able to take a very active part in the management of routine affairs and the transaction of general business matters, he was, nevertheless, of great aid in various ways. His influence, from his commanding position as a scholar and scientist, was, naturally, great, and he always exerted it in the direction of progress and development, especially in the function of science in education. His encouragement of his younger associates in their work and the benefit of his advice, freely given, was of great value to the university.

The late Professor George J. Brush, the mineralogist, for so many years the director of the Sheffield Scientific School and leading spirit in its development, has a number of times spoken to the writer of the help afforded the institution, especially in its early days, by Professor Dana, in his advice and ready sympathy for its plans and aspirations. The late President Dwight, of Yale, in his noble memorial address upon Professors Dana and William D. Whitney, also gives a full appreciation of the service to the institution which the former afforded by his life and work, especially in his stimulation of the university ideals.† Others have spoken along similar lines.

When the University Museum became possible, through the munificence of George Peabody, he gave much time, thought, and advice to planning the building, and upon its completion,

* See articles cited, pp. 41 and 42.

† Op. cit., p. 41.

in 1876, he was active in the arrangement of its exhibits, especially in mineralogy. Thereafter it became in a large measure his home, and those yet living who knew him will always naturally associate him in their minds with his office and lecture-room in the edifice. It is this memory which causes one of the regrets at the necessary recent demolition of this building and the proposed erection of the museum upon another site.

CONCLUSION

Of the personal characteristics of Dana, of which it is appropriate to consider in a memoir of this nature, sufficient has been already said in the foregoing pages. It may, however, be added that he was very fond of music; he had some skill on the flute and guitar and composed a number of pieces; music was often a rest to him in his later years. He was naturally of a social disposition, and those who knew him in younger days have testified that he took pleasure in the gathering of friends and in intercourse with others, until his health demanded a strict limitation of such occasions. All his life he was a firm believer in the Christian faith and a constant attendant of the college church.

It is, perhaps, needless to say that in the course of his long life many honors were conferred upon Dana, but to make this record complete it may be mentioned that, among others, he received the honorary degree of Ph. D. from the University of Munich in 1872, of LL. D. from Amherst College in 1853, and from the universities of Harvard and Edinburgh in 1886. In 1872 the Geological Society of London conferred upon him the Wollaston medal in recognition of his work in Mineralogy and Geology; in 1877 the Royal Society of London awarded him the Copley medal for his Biological, Geological, and Mineralogical investigations, and in 1892 he received from the Boston Society of Natural History the Grand Walker prize of $1,000 for distinguished services in Natural History.

Of this Academy he was one of the original members and also a vice-president; but, unfortunately, his health did not permit him to take that active part in its meetings and management which his abilities and distinction would have naturally suggested. Of foreign academies he received membership in

a great number, among which may be mentioned those of St. Petersburg, Vienna, Berlin, Munich, Stockholm, and Budapest; Academy of Sciences in the Institute of France and the Royal Societies of London, Edinburgh, and Dublin. In this country academies or societies in Boston, New York, Philadelphia, and Washington honored him. He was president of the American Association for the Advancement of Science and delivered his presidential address at the Providence meeting in 1855. He was also president of the Geological Society of America in 1890. With all his honors, Dana was one of the most modest and unostentatious of men; he never expected them or spoke of them, even in his own family.

James Dwight Dana was one of the great naturalists, one of the greatest of geologists, and one of the leaders in the development of science on which our intellectual and material progress rests. We may have a just pride that our country produced him and that he was one of the founders of this Academy. May his memory ever serve us as an inspiration!

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