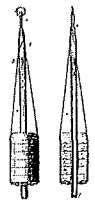
Pacific Islands and the Problem of Theorizing



The U.S. Exploring Expedition from Fieldwork to Publication

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"He strikes me as a very clever fellow," Charles Darwin wrote to Charles Lyell in December 1849. "I wish he was not quite so grand a generaliser."[1] There is some irony in finding these words written by Charles Darwin—a man whose geological publications had earned him criticism for his own tendency to generalize (i.e., to speculate, or theorize), and who had by this time filled hundreds of notebook pages with yet-unpublished theories of transmutation—and it is even more ironic to find them written to Charles Lyell, whose enthusiasm for theory-building had been pilloried and even caricatured by his geological rivals.[2] The target of Darwin's critique was James Dwight Dana, an American man of science four years his junior and the author of a new book Darwin was reading on the geological results of the U.S. Exploring Expedition (1838–1842; also known as the U.S. Ex. Ex.) to the Pacific. Dana was a generalizer with the ambition to match Darwin and Lyell, and he was shaping up to be a rival to Darwin in particular because he was working on two of the questions that had most animated the British naturalist during and after his own voyage around the world on HMS *Beagle* (1831–1836), namely the geological history of Pacific islands and the formation of coral reefs. When it came to those particular

questions, moreover, Dana could base his speculations upon a foundation of first-hand geological field work in the Pacific Ocean that vastly exceeded Darwin's experience there in both scope and duration. Such was his expertise in relevant zoological matters that he had also authored the U.S. Exploring Expedition report on zoophytes (coral-making organisms and anemones) prior to publishing his geological treatise.

The way in which the act of generalizing—theorizing—fused those two specialties of geology and marine-invertebrate zoology was the central issue in a public controversy that had enveloped Dana after the Exploring Expedition returned to the U.S.A. in 1842. At least that is the argument of the present essay. I focus on this conflict between the "clever fellow" Dana and his erstwhile companion on the Ex. Ex., Joseph Pitty Couthouy. Their quarrel has previously been characterized as a dispute over publishing priority, but I will argue that the basis for this disagreement was that each man, by developing a theory of coral reef formation, had muddied the boundary between the respective "departments" of science to which they had been assigned when the Ex. Ex. began in 1838. Specifically, Couthouy had been appointed the specialist in marine invertebrates and Dana was the expedition's geologist.

It is almost a truism that the rise of specialization in nineteenth-century science meant that no single individual could hope to master the range of topics and approaches that had once been grouped under the heading "natural history." The problem in the case of Couthouy and Dana, however, was not the incommensurability of different disciplines but rather the fact that each was competent and interested in the other's "department," with the two pursuing lines of investigation that led them to clash over the question of whether theorizing about coral reef formation was the departmental prerogative of zoology or geology.

Each man had been urged toward theorizing about coral reefs by the instructions they received upon being appointed to their respective positions on the expedition. The question of how coral reefs were formed had become a well-known question for naturalists, whose answers were potentially of great practical significance to navigators wanting to know where reefs were likely to be found and fearing that the growth of new reefs would introduce error into their maritime charts. Most puzzling of all reefs were those ring-shaped oceanic reefs now known as atolls, which encircled lagoons of shallow water but stood in ocean so deep as to be literally unfathomable by all but a handful of pioneering early-nineteenth century hydrographers.

Already by the beginning of the nineteenth century, no reader in a European or American library could encounter a description of a reef that did not incorporate some accounting of its origin. The term "coral reef" was itself

theory-laden, having come into use in various European languages around the end of the eighteenth century after Johann Reinhold Forster, naturalist on Cook's second voyage to the Pacific, became the first man of science to articulate the claim that such reefs were actually *built* by corals. After Forster, few voyagers sailed toward a coral reef without already knowing one or more theories of how it might have been formed. In the 1820s a pair of French naturalists, J.R. Quoy and J.P. Gaimard, argued on the basis of their experience in the Pacific that reef-building corals could only grow at depths within twenty or thirty feet of sea level. Here was a puzzle! How did corals that could only live in shallow water establish reefs that stood in the deepest parts of the ocean, and why did they grow to form a ring-like shape that left a lagoon in the center? Quoy and Gaimard themselves proposed a widely adopted idea that every atoll had formed atop a scarcely-submerged volcano crater (an explanation that I will refer to in this paper as the 'crater-rim theory'), Lyell, among others, endorsed this theory, and when preparations were being made for the Ex. Ex.'s departure this was the best available explanation for a phenomenon that Couthouy and Dana would both be charged to study.

It is difficult now to appreciate the degree of urgency that attended the search for clues to the formation of coral reefs in the decades around 1800. Many accounts suggested that coral reefs grew rapidly enough to choke the entrances to harbors, block channels, and even place barriers in the open sea. As a consequence, the British Admiralty began to instruct commanders of surveying vessels, Robert FitzRoy of the *Beagle* among them to investigate coral islands especially with a view to determining the laws that governed their growth. FitzRoy, for example, was ordered to carry out surveys that would test the "modern and very plausible" crater-rim theory. Before the voyage was over, however, FitzRoy's young companion Charles Darwin had rejected as "a monstrous hypothesis" this idea that each atoll was underlain at shallow depths by a volcano crater.[2b]

I have argued elsewhere that Darwin developed an innovative "amphibious" approach to natural history during the voyage as a consequence of his close attention to the work of the *Beagle*'s hydrographers, or maritime surveyors.[3] Their activities provided Darwin a means of "seeing" underwater that had not been exploited by other naturalists, as well as a novel method for collecting specimens from the sea floor. These specimens were the rocks and organisms (which is to say material for both Darwin's geological work and his zoological work) that adhered to the bottom of the sounding lead (pronounced "led") that hydrographers used to find depth. The hydrographers' techniques not only gave Darwin new ways to pursue his preexisting

interests in geology and in the study of zoophytes, but also to merge these interests by allowing him to make direct comparisons between the present-day sea floor and the sedimentary geological formations he found on land, which had been formed in the past on the floor of the sea. This in turn, I argue, made Darwin capable of perceiving the underwater features that led him to his own new explanation of coral reef formation, which became the topic of his first scientific treatise, the 1842 book *The Structure and Distribution of Coral Reefs*. Darwin's theory argued that ring-shaped coral reefs were the ultimate outcome of corals growing around the shoreline of sinking islands. As an island was submerged and eventually disappeared from view, the growth of corals upon this sinking foundation would allow the top of a fringing reef to keep pace with the level of the sea, eventually turning it into an atoll whose shape described the shoreline of the now-sunken island.

Couthouy and Dana each independently published theories of coral reef formation after they had returned home from the Exploring Expedition. Those theories were similar to one another and to Darwin's as well. The fact that Darwin's theory was a consequence of his novel approach to integrating the knowledge and practices from geology and marine zoology helps to illustrate why the similar theories published by Dana and Couthouy should have been difficult to attribute independently to either the geological or zoological departments of the expedition.

ESTABLISHING THE SCIENTIFIC "DEPARTMENTS" OF THE U.S. EXPLORING EXPEDITION

It is not surprising that an undertaking as costly as the U.S. Exploring Expedition was justified by a variety of ends. The dispatch of a naval squadron to explore the Pacific and Antarctic was conceived as an aid to commerce, aimed at protecting and expanding the interests of the American whalers and sealers who were already plying the Great Ocean. It was also a gesture meant to emulate and supersede the voyages of French and British scientific explorers such as Louis-Antoine de Bougainville and James Cook.[4] Both of these objectives were served by conducting surveys of islands that might be frequented by American vessels. The portion of this work that took place in the tropical Pacific was the most time-consuming task of the voyage, though it has often been overshadowed by the squadron's penetration into the Antarctic and the surveys of the Columbia River on the west coast of North America.[5] Warm Pacific waters were made treacherous by a profusion of low islands and coral reefs, and so the examination of coral formations was central to the mission. Anticipating the danger of navigating

these shores, as well as the possible hostility of their inhabitants, the commander of the expedition, Lieutenant Charles Wilkes, devised a "Method of Surveying the Coral Islands" that could be executed without landing.[6] The system exploited the multitude of vessels and officers that Wilkes had at his disposal and relied on the use of ships' guns to measure distance by sound. With observers in separate boats "occupying all the points of a trigonometric survey simultaneously," baselines would be established by sequential firing of guns, beginning with a ship standing off the island.[7] Vessels would then move systematically around the island in either direction until they met up again on the other side.

The Ex. Ex. was outfitted with a large corps of scientific specialists on the model of the French Baudin expedition (1800–1804) rather than with just one or two surgeon naturalists, gardeners, or philosophers-general, as had been the case on many of the more recent Pacific surveys, including those of Otto von Kotzebue and Frederick William Beechey.[8] Before the positions for men of science had been filled, the Secretary of the Navy Mahlon Dickerson wrote to the leaders of four of the nation's scientific institutions to request nominations for experts to join the expedition as well as advice on the topics to which the voyagers' attention should be directed.[9] A committee of the American Philosophical Society appointed to respond to Dickerson's request declined to nominate specific individuals, but instead produced a thirty-page statement of scientific objectives for the voyage. J.K. Paulding, who succeeded Dickerson as naval secretary in the Van Buren administration, transmitted this "learned and comprehensive Report" to Wilkes, declaring the scientific directions an official part of the commander's orders.[10]

In a move that helped to ensure that there would be friction between Couthouy and Dana, the APS instructions directed both the zoologists and the geologists of the voyage independently to tackle the question of coral island formation. This was not simple duplication of an order, however. The instructions revealed that it was possible, and indeed desirable, to approach the matter from distinct zoological and geological perspectives. The origin of coral islands could plausibly be examined by studying the conditions of coral growth or by seeking knowledge of submarine geology. I am aware of no previous voyage or expedition in which the study of coral reefs was formally divided between multiple specialists who were assigned different approaches to the same problem.[11] The APS zoology instructions, prepared by the Philadelphia naturalist Titian Peale (who, as it turned out, would himself serve as one of the expedition's several naturalists), sought a solution to the puzzle of reef formation in the habits of coral-forming animals. The zoologists were ordered "to dredge in deep as well as shallow water for the

numerous inhabitants of the ocean, and to ascertain as nearly as possible, the different depths at which those animals exist; the depths from which the various species of Zoophytes erect their fabrics and form Islands, many of which in after-times become the residence of Man; to ascertain the time requisite for the maturity of such; their food; and in fact to collect all the information which can be reasonably obtained of that race of animals, which though among the smallest, hold notwithstanding one of the most important places in the chain of created beings."[12]

Geologists, by contrast, according to the instructions written by the University of Pennsylvania's professor of geology and mineralogy H.D. Rogers, would approach the same problem by determining what lay beneath the corals. "The circular figure and deep water of the Coral Islands having given rise to the conjecture that these fabrics of the Zoophytes are based upon the craters of submarine volcanoes[,] the collection of any facts calculated to throw light upon this subject will form one of the interesting duties of the Geologists."[13] Such was the importance of understanding the submarine structure of coral reefs that the expedition was outfitted with well-drilling equipment that would enable a direct investigation of reef structure by boring down through a reef.

These zoological and geological responsibilities were assigned, respectively, to Joseph Pitty Couthouy and James Dwight Dana. Initial plans for an even larger civilian scientific presence on the expedition's six ships were vetoed by Wilkes, who insisted that investigation of the physical and navigational sciences be the exclusive province of naval men.[14] Indeed, Wilkes owed his command of the Expedition in large part to the fact that his achievements and ambition in those areas outshone those of his fellow navy officers. During the voyage he took steps to add formal control of these scientific departments to his long list of personal duties.

Dana, who was twenty-five when the Expedition departed in 1838, had begun lobbying for the appointment as mineralogist and geologist two years earlier, fearing that a passive approach would leave him in a state of "disappointment."[15] However, as a protégé of one of the nation's foremost men of science, Yale's Benjamin Silliman, and having gained prior exposure to both the U.S. Navy and to European geology during his tenure as a shipboard mathematics instructor to midshipmen on the Mediterranean service, Dana was an excellent candidate for the scientific corps.[16] This experience, and his good fortune to be assigned to the expedition's second ship, the sloop of war *Peacock*, rather than to Wilkes's flagship *Vincennes*, helped him to evade the commander's hostility toward his civilian passengers much better than did his ill-fated colleague, Couthouy.

Had Joseph Couthouy remained with the expedition for its entire duration, this enigmatic figure might share with James Dana the distinction of having examined more Pacific coral reefs than any other naturalist in the age of sail. He was an erudite former merchant captain who riddled his journal with classical allusions and endlessly sought opportunities for his own advancement.[17] His business evidently took him to the Mediterranean and to the coral reefs of the Caribbean, for he had contributed specimens from both locations to the natural history cabinets of Boston. He pursued his scientific interests in home waters as well, helping to expand the marine catalogue of the Massachusetts zoological survey, and he had published a well-regarded taxonomic work on local molluscs and zoophytes. After appealing directly to President Andrew Jackson for a place on the expedition, he was appointed the squadron's conchologist and placed under Wilkes's supervision on the *Vincennes*.

Although there are many Exploring Expedition manuscripts extant we have only an odd assortment of those that belonged to Couthouy and Dana, and unfortunately for my purposes we have no contemporaneous sets of field notes that would allow us to compare directly how the two colleagues approached any given coral island. The single extant volume of Couthouy's journal spans only the first ten months of 1839, while Dana's journals from that early part of the voyage are missing (perhaps having been lost in the wreck of the *Peacock* at the mouth of the Columbia River in 1841).[18] The period covered by Couthouy's account comprised the beginning of the Expedition's first cruise across the tropical Pacific, a pass through the Low Archipelago, the Society Islands, and the Samoas on a track from South America to Australia. His journal gives the impression that at this stage he and Dana were sharing theoretical ideas (and disagreements) and cooperating well in building their respective collections of specimens.[19] In the following sections I will examine in turn first Couthouy's approach to studying coral reefs during these early months and then Dana's collecting, observing and theorizing during the expedition's second pass through the Pacific.

A ZOOLOGIST AT LARGE IN THE PACIFIC

Couthouy's journal entries indicate that he first approached the question of coral island formation from the zoological perspective instructed by Peale, meaning he paid careful attention to the depths at which reef-building corals could grow. When he was confined to a boat he peered down to examine corals that could be seen through the clear waters below, occasionally diving to obtain specimens and always observing the soundings if not making some

himself.[20] His primary work when he was able to get ashore lay in collecting marine invertebrates. He took his specimens into his cabin aboard the *Vincennes* to make sketches and descriptions of them; on more than one evening his sense of urgency saw him laboring "till near midnight merely taking rough notes of such things as cannot live until morning."[21] The squadron sighted dozens of coral islands during August and September 1839, and as Couthouy became more familiar with their general appearance he devoted an increasing proportion of his journal to comparisons between reefs. When he encountered Aurora Island [Makatea; also known varously as Metia and Mangaia] on 9 September 1839 he had a crucial experience that led him from investigations into the depth of coral growth to theorizing about the process of reef formation.

Aurora Island presented the appearance of an anomalous coral atoll which, rather than lying at the level of the sea, has emerged from the ocean. Couthouy described the island as "totally different from any of the islands previously seen . . . a perpendicular wall of coral conglomerate at least 300 feet high in some places rising directly from the sea with blue [i.e., very deep] water at a hundred yard's distance. [. . .] Half way or more up the cliff was an interrupted belt of excavations exactly similar to those at present worn away at the base of the cliffs by the action of the surf. The summit of the isle presented a broad plateau or table land somewhat lowest at the centre [. . .] the appearance of the island altogether being that of a coral reef raised up by some powerful agency to its present elevation."[22]

As the French naturalists Quoy and Gaimard had done at Timor the previous decade, Couthouy examined upraised coral in hopes of drawing general conclusions about the habits of living corals.[23] Unlike the English missionary to Polynesia John Williams, who had used Quoy and Gaimard's argument that reef-building corals could grow only within thirty feet of the surface to declare that such creatures could not have built tall islands like Aurora, Couthouy saw the height of continuous coral rock as evidence that the Frenchmen had simply got the depth limit wrong. Working on the assumption that Aurora's perpendicular wall had originally been formed by growing corals, Couthouy asserted that the island "proves conclusively that the calcareous Polypi construct their dwellings at [. . .] a depth much greater than it has been of late supposed they could exist." In his view, the island had been uplifted by two distinct events of elevation, each raising it by about 150 feet. In his journal he argued that "if the island has in this manner been elevated at two remote periods, it shews that the saxigenous Polypi construct their domiciles at a depth below the surface at least five times greater than that given by Quoy & Gaimard [for the coral genus *Astrea*] . . . ." As if he had

not previously realized that his observations of living corals had also long since contradicted the figure given by his French counterparts, Couthouy went on to note that "The estimate of Q & G. is certainly too low in regard to the number of feet at which Astreas are now found below the surface, as since our cruise among these islands I have myself frequently observed them in from 7 to 10 faths water [42–60 feet] in great abundance."[24]

Having used his observations of the island's geological structure to reason about the distribution and growth of coral animals, Couthouy's interests began to expand to encompass questions that he, like the authors of the scientific instructions to the expedition, considered to lie more properly within the realm of geology. Four weeks later at Rose Island in the Samoan Group, where there were "boulders of a very heavy cellular lava" scattered across the reef, he indulged for the first time in speculation about the foundation of a coral island. He considered the boulders to be "strong evidence that the base on which the corals here rest is a volcanic rock at no great distance below the surface, since it [i.e. the volcanic foundation] was not below the action of the surf, the only imaginable power that could have placed these boulders in their present situation."[25] The notion that this coral island might have a particularly shallow foundation seemed to call for a direct examination of the strata below, such as would have been possible if Wilkes had consented to employing the well-drilling machinery he had been issued for this very purpose. "A more eligible location for making some experiments by boring," Couthouy remarked, "for which we have the necessary apparatus in the Expedition, can hardly be expected to occur during the cruise."[26] There is no record of whether he made a direct appeal to Wilkes to allow for boring through the reef, but in any case the squadron departed the island the same day.[27]

Later that week, however, Couthouy was presented with another island that lured him into geological speculation. Aunuü was a steep-sided island that stood two hundred feet high with what appeared to be a crater in its center. He believed that "An examination of this island would be of much interest *in a geological point of view*."[28] What was extraordinary about it was the submarine topography on its flanks. "It is a singular fact," Couthouy reported in his journal, "that notwithstanding the abrupt manner in which this volcanic isle rises from the sea, there are soundings at 2 & ½ miles distant on a coral bottom distinctly visible." Although there was no hint of it at the water's surface, there was a submerged shelf of coral ringing the island. Couthouy's mind raced back to the reef-encircled islands of Tahiti and Eimeo, which the squadron had visited just two weeks earlier. He found that the coral shelf "had every appearance of being similar in nature to the

reefs surrounding the Society Islands, although centuries may elapse ere the labours of the Polypi shall raise it as near the surface as are those at the present day." If the comparison were apt, then it was possible that Aunuü was surrounded by a younger version of the reefs that encircled Tahiti and Eimeo at the surface, and this in turn might shed light on the relative ages of the high islands of the Pacific. "If this could be ascertained by a proper examination, to be the fact, would it not prove that the Polypi have been at work a much shorter period than at the Society & other barrier islands & by inference, that this group was elevated at a much later date?" Although he had noted the relevance of these thoughts for the department of geology, Couthouy was here getting right to the heart of his zoological instructions to determine the rate of corals' growth and the depths at which they grew.

Couthouy's attention to the conditions in which the reef forming corals were growing at the Pacific islands led him to conclude, however, that the very premise of this zoological instruction was misguided. That same day, in a private manuscript whose contents have otherwise been lost, Couthouy argued that it was temperature, and not merely depth, that limited the ability of zoophytes to form islands.[29] This idea, that water temperature might be the key to patterns of coral growth, proved central to the later tension between Couthouy and Dana.

Aunuü turned out to be yet another of the many locations where Couthouy's ambitions were thwarted because the squadron sailed on too soon for his liking. Part of the problem was that Wilkes' method of surveying coral island coastlines was so intensive and speedy that it frequently left little time to actually study the islands. As Couthouy noted grimly after just a week in the Low Archipelago, "At present our opportunities are made entirely dependent on the amount of surveying that is necessary."[30] In the pages of his journal he recorded his infuriation with Wilkes for the commander's apparent disregard of the scientific men's desire to go ashore. On many occasions when Couthouy saw plenty of opportunity to land, the officers would make no boat available to the naturalists, or Wilkes, who was still angry about an episode in which Couthouy had delayed the ship while exploring the island of Clermont Tonnerre, would withhold permission for them to leave the ship until the day's surveying was almost finished, at which point he would allow them on shore for the final hour or two.[31]

Couthouy also felt that Wilkes was sabotaging his efforts even to carry out the most basic requirement of his zoological appointment, the collection and study of corals. Having stayed up late after taking a dozen specimens from inside the lagoon at the island of Raraka, he awoke the next morning to find that Wilkes had decided that the dying corals "endangered the health

of the crew by producing malaria" (even twenty years later Wilkes recalled it as "one of the most nausiating smells," an aroma that "tainted the Ship in every place and was exceedingly unwholesome"[32]), and the commander had made an order that "no specimens of coral, live shells, or anything else that may produce a bad smell will be taken below the spar deck, or into any of the rooms" of the *Vincennes*.[33] The order was disastrous for Couthouy because it precluded his evening shipboard work of describing and drawing, which in turn would seriously limit the number of specimens he would have time to treat. Wilkes later clarified that he expected Couthouy "to procure only one specimen of each species of coral which is to be as small as is consistent with the determination of its characters," which the conchologist considered "just the reverse of what has always been considered desirable in regard to specimens of this kind." As far as he was concerned, this was further evidence that this American expedition was not the truly scientific undertaking that its French and British predecessors had been, and he told Wilkes so. According to Couthouy's journal, the commander responded that he "did not care a d__n for what had been done in previous Expeditions."[34] This ugly episode was the beginning of the end of Couthouy's tenure with the squadron.[35]

It is not entirely clear what Dana may have been thinking about coral reef formation in the meantime. One certainty is that he had his own difficulties getting ashore despite being a degree removed from Wilkes by traveling aboard the *Peacock*. According to his subsequent publications on coral reefs, he complained of his limited chance to study Raraka, and admitted that he had never set foot upon Clermont Tonnerre or Rose Island, meaning that he missed two coral islands on the westward Pacific cruise that Couthouy had found instructive.[36] Dana remained vastly more tactful in his relations with Wilkes than Couthouy was, however, saving his comments about the scientific corps' "Naval servitude" at the coral islands for a private letter to Silliman.[37] According to reminiscences by both men, Dana and Couthouy had by this time developed a firm friendship and a mutual pleasure in collaborating.[38] They had camped together on an exhausting inland journey at Tahiti, and they willingly collected specimens for one another. Subsequent events suggest, however, that Couthouy had not revealed to Dana the extent of his speculations on the submarine foundations and relative ages of coral reefs.

ENCOUNTERING DARWIN'S THEORY?

A series of events soon conspired to shift both the opportunity and the responsibility for studying coral reefs entirely to Dana. The squadron arrived

at Sydney, New South Wales on 29 November 1839. Couthouy was in poor health, and Wilkes seized the chance to banish him to the Sandwich [Hawaiian] Islands to convalesce.[39] Meanwhile Dana's prospects were brightening. He was introduced to the Reverend W.B. Clarke, a recent graduate of Cambridge and former student of Adam Sedgwick's who had arrived in the colony earlier that year. While waiting for the other expeditionaries to return from an antarctic excursion, Dana joined Clarke on a series of extremely profitable inland geological rambles.[40]

At some point during this long southern summer, Dana learned that another of Sedgwick's former students, Charles Darwin, had recently offered a new explanation for the foundation of coral islands and barrier reefs.[41] While the exact extent and timing of his information about Darwin's work is unclear, Dana had already received Charles Lyell's 1838 *Elements of Geology* by mail at Valparaiso, Chile, the previous June.[42] Lyell there credited Darwin with demonstrating that "in those seas where circular coral islands abound, there is a slow and continued sinking of the submarine mountains on which these masses of coral are based."[43] Dana wrote years later that he had become aware of Darwin's theory in 1839 thanks to a short article in a Sydney newspaper, attesting that "a brief statement . . . of Mr. Darwin's theory with respect to the origin of the atoll and barrier forms of reefs . . . threw a flood of light over the subject."[44]

Judging by the notes he made during the voyage, however, Dana did not experience any epiphany about coral islands at Sydney. If anything, this newly considered evidence suggests that, unlike Couthouy, Dana had scarcely begun to puzzle over coral reef formation during the expedition's first traverse of the Pacific. Couthouy's journal would seem to suggest that, for his part, he either did not know Darwin's theory or did not consider it useful during the first Pacific cruise. Couthouy's own emerging ideas about the process of coral reef formation were based on his discovery that reef building corals could live at much greater depths than previously thought. By expanding his conception of how deeply corals could live, Couthouy was correspondingly reducing his need to answer the question to which Darwin's theory was an answer, namely the question of how shallow-water organisms could have established reefs in the middle of a deep ocean. Indeed Couthouy's comments about the relative ages of reefs seem to indicate that he imagined reefs to become established at some depth and grow upward, rather than commencing at near the surface as Darwin did.

In 1872 Dana recollected that he began to work with Darwin's theory in mind when he returned to the tropical Pacific after his stay in Australia.

> On reaching the Feejees, six months [after arriving at Sydney], in 1840, I found there similar facts [to those Darwin had invoked from the *Beagle* voyage] on a still grander scale and of more diversified character, so that I was afterward enabled to speak of his theory as established with more positiveness than he himself, in his philosophic caution, had been ready to adopt.[45]

This passage has been widely cited to suggest that Dana consciously worked to confirm Darwin's theory during the 1840 Pacific cruise. But the roughly scribbled field notes in his two extant Expedition notebooks from this period suggest, to the contrary, that Dana's newly active interest in coral reefs had little to do with the appearance of Darwin's theory and much to do with Couthouy's disappearance from the squadron.[46]

DANA'S SECOND PACIFIC CRUISE: INTEGRATING ZOOLOGY AND GEOLOGY

Dana's 1840 cruise in the Pacific is deservedly remembered as one of the most consequential periods of fieldwork ever undertaken by a geologist. He is most acclaimed for his insights into the history of the Hawaiian chain of islands, arguing convincingly that the islands were arranged in the linear archipelago from youngest to oldest and explaining how their rugged landscapes had been produced by subaerial, rather than marine, erosion. But this work formed just one part of a sustained investigation into a range of connected phenomena including the geology of island chains in general, the origin of coral reefs, and the formation and antiquity of oceans themselves. As David Igler has argued, Dana's undertaking yielded an unprecedented conception of the Pacific Ocean as a discrete geological entity.[47] One key feature of Dana's experience during this cruise, however, was that he had broadened his attention beyond the limits of his geological assignment to include as well the zoological questions and activities originally assigned to Couthouy.

After Couthouy left the squadron at Sydney, Dana entered his second cruise among the coral islands with the new additional responsibility of tending to Couthouy's zoological department. Thus, along with descriptions of the landscapes and lithology of the high islands of the Fijis, Dana's notebooks also contain evidence that he had inherited Couthouy's obsession with collecting corals and observing their conditions of growth. On the extensive reefs of Fiji Dana noted how the corals responded to differences in tide levels,

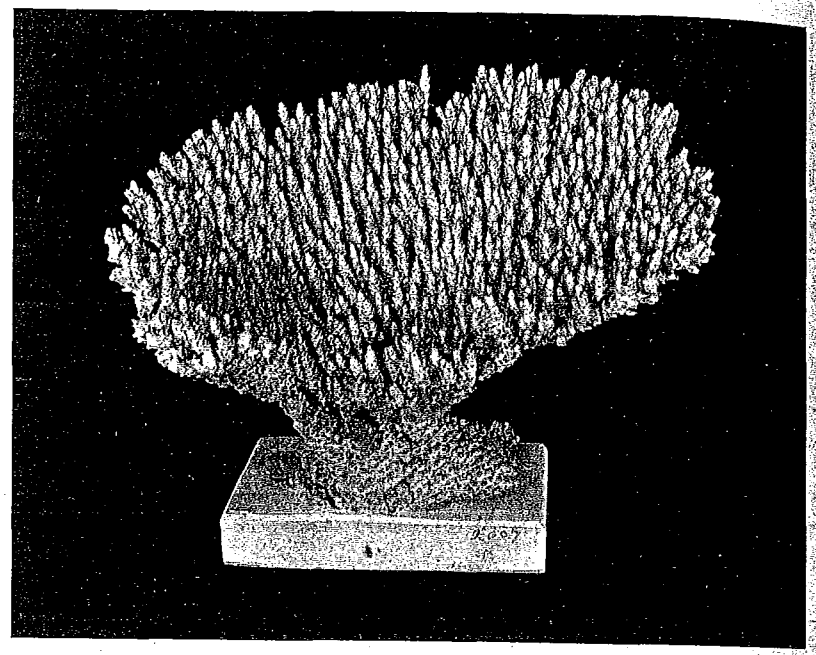

FIGURE 1 A coral specimen collected by James Dwight Dana in the Fiji Islands during the U.S. Exploring Expedition. Dana named the species *Madrepora spicifera*; it is now known as *Acropora spicifera*, Dana 1846. Peabody Museum YPM IZ 002007.CN.

he described the relative locations of various coral genera, and he identified "the species wh[ich] can grow in fresh[er] water than others."[48] Dana followed his own ship's officers' work with interest when the hydrographic survey yielded specimens or provided clues as to the depth at which the reef-builders were growing. Dana used methods including a "grapling iron" and a dredge to acquire a massive collection of Fiji corals; the Ex. Ex. specimen lists now held at the Smithsonian indicate that a single homebound shipment contained fifteen boxes of corals, most from the Fijis.[49] (See Figure 1)

When Dana did engage with existing interpretations of coral reef formation, he appears to have done so not in order to confirm Darwin's theory, but rather with a view to disproving the earlier crater-rim theory that had been current when the voyage began. Evaluating this specific theory had been one of the tasks assigned specifically to the expedition's geologist in the instructions written by Henry Rogers. In the first of the two notebooks,

after a set of entries from the Fiji surveys of May and June 1840, Dana made a page of notes that he subsequently headed "Coral." It included the simple statement "Submarine volcanoes have not crater form—or lose it soon after eruption."[50] The relevance of this observation to "coral" was presumably that it undermined the main assumption of the crater-rim theory of coral island formation suggested by Quoy and Gaimard and popularized in the English language by Beechey and Lyell. If volcanoes that erupted underwater did not produce craters, then there would be no annular foundations for shallow-water corals to encrust and turn into ring-shaped reefs.[51]

Although the page of "Coral" notes is undated, the main entries were almost certainly written before 24 July, when Lieutenant Joseph Underwood was killed ashore on the island of Malolo in the aftermath of a failed bartering attempt. The notes refer to recent communication with Underwood and Passed Midshipman Blunt, who gave Dana information drawn from their earlier coral island surveys during the 1839 Pacific cruise. After noting their observations on the submarine topography of Clermont Tonnerre and Rose Island, Dana penned a query similar to the one that Couthouy had made, coincidentally the week the squadron had actually been at Rose Island, about the influence of temperature on coral growth. Dana's question was, "Does it not appear that the principle obstacle to large corals growing at great depths is owing to cold temperature—this is shown by not finding corals in cold latitudes."[52] Dana was proposing, in other words, that the depth limit of coral growth was merely a function of the fact that water temperature declined as the depth increased.

With questions about the effects of water temperature in mind, and having discarded the notion that submarine craters could underlie coral islands, Dana seized upon a new explanation for that familiar puzzle of how reefs constructed by shallow-water corals had become established in the deepest parts of the Pacific. "May not the temp[erature] of [the] seas [have] been warm when corals of coral islands first commenced to grow" he asked, "& will this account for the depth from which they are built up?" Dana did not record whether he was troubled by the origin of lagoons, which was the other question to which the crater-rim theory had provided an answer. Instead, in comments interlined with his promising new suggestions, he began to consider how he might strengthen his view. "What is the coldest temp[erature] of water in Lat[itude] 28° or 30°[?]" Speaking of the Australian barrier reef, where corals flourished so prolifically, he noted, "water flows from Equator along [East] Coast of N[ew] Holland. Coral stops at 23° or 24° [south latitude]." Finally, he underlined his hypothesis about the possibility that deep-standing reefs had been established when seas were

warmer and wrote an instruction to himself: "Examine Beechey's voyage for temperature of seas."[53]

Darwin's name appeared, finally, in Dana's next set of entries, which were headed "Miscellanea." But the topic was not Darwin's subsidence theory of coral formation; rather, Dana reflected on Darwin's claim that the elevation of the east coast of South America had produced the distinctive topography there. Dana's comment was that "Darwins theory of formation of the Pampas of La Plata—may not be correct—the action of sea on present coast produces just the reverse effect & a gradual elevation &c."[54] As reported by Charles Lyell in the book that Dana had acquired earlier in the voyage, Darwin had argued that the level plains of the Pampas were formed during gradual elevation of the continent.[55] Dana's perspective on the formation of the Fiji islands is revealed by his criticism of Darwin: he believed that the heavily dissected landscape at the Fijis was a product of the sea, and that a gradual elevation would further dissect it. "Submarine Islands of igneous origin when elevated rarely have distinct craters," he wrote, "they are intersected by deep vallies wh[ich] perhaps may have been in part excavated by the agitation of the water at the time of the eruption."[56] At this stage of the voyage, then, it would appear that Dana's perspective on the erosion of volcanic islands was almost diametrically opposed to the one for which he is now remembered. For at this moment, he was fixated on the islands' history of elevation as an explanation for their jagged valleys and uneven coastlines.

These were the views that Dana brought to the Sandwich Island of Oahu at the end of September 1840, where he discovered that the convalescing Couthouy had already been hard at work collecting widely across the archipelago. According to retrospective accounts by each man, the geologist and the zoologist exchanged specimens and notes during Dana's stay at Oahu. Dana's manuscript inventory of material sent home from the Sandwich Islands confirms that he received 474 geological "Specimens collected by Mr J.P. Couthouy," many of which came from islands that Dana never had the chance to visit.[57] Another of Dana's inventories shows Hawaiian specimens collected jointly by "J.P.C. & J.D.D.," which indicates that they also made field excursions together.[58] I have found no contemporary record of the content of their discussions at Oahu, however, and the retrospective accounts are all highly partisan and therefore highly suspect. Wilkes claimed in his autobiography that Couthouy attempted to resume control of the conchological department that Dana had been tending ever since Couthouy parted company with the expedition in Australia. According to Wilkes's often self-aggrandizing text, Couthouy "obtained possession of [the

conchological specimens, drawings, and notes] from Dana and made claim to them." Wilkes, who favoured Dana and detested Couthouy, instructed Couthouy to return the material to Dana and "issued an order . . . stat[ing] that [Couthouy] had nothing to do with them as he no longer belonged to the Expedition."[59] Couthouy claims to have surrendered the specimens willingly, and his journals and notebooks as well, and even at the height of the two naturalists' later enmity, Dana and Couthouy never referred to any open conflict, or even competition, between themselves at the Sandwich Islands. The composite picture painted by the two was of amiable cooperation, willing redistribution of specimens to the most appropriate recipient, and most intriguingly, the decision to collaborate in the preparation of a report on coral formations.

From each man's perspective, the decision to co-author a report on corals and reefs was justified because the subject could not be confined wholly within either zoology or geology. Dana claimed (when writing against Couthouy in 1844) that upon arriving in Oahu from the Fijis on 30 September 1840 he "la[id] before [Couthouy]" a manuscript of "over *seventy written pages*" and drawings of "more than one hundred species" of "coral animals," which the two spent nearly six hours reading together.[60] "After presenting him all my ideas and showing him the drawings," Dana attested, "I proposed . . . that we should unite our labors and bring out a report together on the whole subject of corals." He deemed it a reasonable course "in view of what I had done in this branch of science [i.e. the science of corals]--the zoological part of which belonged rightly to him, and the geological to me."[61] Couthouy (writing against Dana in 1844) concurred that "I [had] neglected no opportunity of making observations on the geological structure of reefs and islands for Mr. D[ana]'s information, and it was his knowledge of this which led to the proposition by him to publish on this subject jointly with me." He recalled that Dana had proposed authoring a joint report even earlier, "just prior to our parting in Sydney."[62]

It is easy to imagine why each man might have believed that he would profit from an agreement to publish together. As their notebooks reveal, each had by this time come up with exciting leaps of interpretation that might rightly be considered to belong *to the other's department*: Couthouy on the foundation of coral islands, and Dana on the factors limiting the growth of coral animals. According to their shared convention (and the instructions' stated protocol for the behaviour of the scientific corps), such insights should rightly be given over to the man to whose department they fell. If they authored a volume together, Dana and Couthouy would each be able to have their names attached to the first publication in which their

own ideas were presented. According to Dana, they spoke again on the topic after Couthouy had been permanently detached from the squadron. Notwithstanding Wilkes' apparent determination that Couthouy have nothing more to do with the expedition or its publications, the two remained committed to the plan. If indeed, as Dana claimed, "the importance [was] discussed of [Couthouy's] making observations in the West Indies, towards the joint report," they saw the conchologist's banishment as an opportunity to broaden the scope of their eventual collaboration. By both accounts, the men "parted when leaving the Sandwich Islands" with "peculiar intimacy" and "warm expressions of regard."[63]

Believing he had settled matters with Couthouy, Dana ventured back out into the Pacific inspired by a set of new ideas born of his two months in the Sandwich Islands. Having attended particularly closely to the chain's volcanic landscape, especially during fruitful visits to the crater of Diamond Hill [now Diamond Head] on Oahu and the active volcano of Kilauea on Hawaii, Dana became fascinated by the spatial distribution and relative ages of the Hawaiian islands. As a number of scholars have previously explained, after comparing the broad, intact dome of Kilauea with those of extinct volcanoes in various states of erosion, Dana concluded that the time since each volcano's last activity increased sequentially from the south-eastern end of the Hawaiian chain to the volcanic islands at its north-western extremity.[64] This had several implications for his broader efforts to interpret the geology of the Pacific. First, it led him to abandon the notion that the deep valleys characteristic of igneous high islands like the Societies and the Fijis were a product of marine erosion during their elevation.[65] Instead, he saw evidence at Kilauea and Mauna Loa that igneous islands could emerge from the sea without being intersected by the deep valleys he was accustomed to seeing, and hence to conclude that such features were the product of subaerial erosion, primarily by running water.

This in turn led Dana to an insight that has since been heralded as his greatest original contribution to an expanded Darwin-Dana subsidence theory of barrier reef and atoll formation.[66] Again contrary to the view he earlier recorded in the Fijis, he argued that the heavily embayed shorelines of islands like Tahiti could not be the product of a geological history in which the island's only motion relative to sea level had been elevation. Rather, such deep bays could only have been formed as a result of subsidence, which would allow ocean water to flood valleys that had already been formed and widened by subaerial erosion when the island stood higher. As Dana was later to argue, this interpretation offered independent evidence that many barrier-reef encircled islands had been sites of subsidence. If Dana made

this connection during the voyage, however, his surviving manuscripts do not reflect it.

The second of Dana's Pacific notebooks demonstrates that his obsession during the first half of 1841 was to document the geographical orientation of individual islands and of island chains. During a brutally intensive surveying cruise that took the *Peacock* from Oahu back to the Samoas, and thence to a staggering number of low islands including those of the Ellice group, the Kingsmills, the Radack chain, and the Pescadores, before returning to Oahu on half-rations of water, Dana was enabled to compare a panoply of coral formations. Dana's opportunities to set foot on the islands were brief and infrequent, rarely exceeding two hours. Often his notes were based on observations taken from the deck as the ship skipped past islands that went unsurveyed. Revealing priorities that may have been dictated by the fact that he got short introductions to so many islands, Dana adopted a concise and consistent note-taking style focused on recording a handful of key variables for each locale.[67] Most important of these was the direction of what he called the "trend" or "longest axis" of an island or atoll. Throughout the notebook he underlined these facts: "trends NE & SW," for example, or "did not land[;] trends NNE & SSW."[68] In April 1841, referring to charts and to his own notes, he began writing entries that described the direction of entire island chains and compiling the trend of each island within them. His frequent result was to illustrate that the islands often "correspond[ed] closely in their direction" to that of the chains in which they lay.[69] The purpose of these efforts is not spelled out in the notebook. However, it seems clear that as the expedition moved painfully toward its merciful conclusion, Dana's objective after visiting Hawaii was to uncover the link between the causal agency that created individual islands and the one responsible for the geographical orientation of island groups.

COUTHOUY'S UNILATERAL DECISION TO PUBLISH

After his banishment by Wilkes, Couthouy made his way back to Boston. Meanwhile, the Exploring Expedition stretched into an unplanned fourth year. This was how it came to be that when the visiting British geologist Charles Lyell lectured in Boston on Darwin's new theory of coral reef formation in 1841, Couthouy was in the audience while his fellow New-Englander Dana was on the other side of the world.

Couthouy found the subsidence theory convincing, but he took issue with Lyell's second-hand descriptions of coral reefs. Upon learning that Darwin was planning to publish an entire book on the topic, Couthouy

resolved to publish his own views immediately despite the fact that his confiscated journals remained somewhere in the Pacific with Wilkes or Dana.[70] After managing nevertheless to recall in detail his experiences in the Pacific and to master a remarkable range of other data as well, Couthouy read a paper containing his "Remarks upon coral formations in the Pacific" to the Boston Society of Natural History on 15 December 1841. Even as he implicitly criticized the scantiness of Darwin's first-hand field study of coral islands, Couthouy claimed that his own months of experience examining low coral islands and reef-fringed high islands had impressed upon him "a conviction of the correctness of the theory here advanced by Mr. Darwin."[71]

Couthouy's paper was directed at what he considered to be an explicitly geological phenomenon, the form and origin of "the countless coral isles and reefs, which stud the equatorial seas, especially in the Pacific and Indian Oceans." The tone of the paper suggested that it was intended as a corrective for geologists, meaning Lyell in particular and Lyell as a proxy for the science as a whole. Couthouy reviewed the reasons why coral formations had long appealed to "the researches of the geologist," citing their relevance for understanding the earth's former climate, the origin of limestone and chalk formations, and the agency of small forces when allowed to act over immense time. The result of these geological researches had been "a variety of theories upon the mode in which such innumerable masses of coral have risen from the bottom of 'the vasty deep.'"[72] Of these he singled out the crater-rim theory for extended consideration and criticism because it had "obtain[ed] the sanction of some distinguished names among the geologists of Europe" (not least of whom was Lyell), and because Couthouy considered it to represent a misguided approach to the problem. Aside from the theory's shortcomings at explaining the form and distribution of coral islands (and Couthouy enumerated these problems enthusiastically), it was unsatisfactory in principle to have a theory that could account for only a single one of the several distinct forms of coral reef.[73] Couthouy's proposal to geologists invoked subsidence as a cause of the great thickness attained by many coral formations, and as a way to explain the relation between barrier reefs and atolls. But from this point of departure Couthouy suggested a new historical account of the formation of Pacific reefs that involved vertical movement of the sea floor in both directions. He argued that the low islands of the Pacific marked the location where a great equatorial land mass or group of islands had subsided in spurts interrupted by periods of quiescence. Evidence from Rose island and elsewhere indicated that the downward movement had ceased relatively recently, and had been followed by periods first of repose, and then of re-elevation.

Although Couthouy's first-hand experience of coral reefs was much more extensive than Darwin's, neither he nor Dana had spent as long at any single coral island as Darwin did in 1836 at South Keeling atoll in the Indian Ocean. Couthouy's account of coral reef forms differed from Darwin's as a consequence. Darwin, in the book manuscript that he was to finish the month after Couthouy read his paper, gave an extremely detailed account of Keeling and explained other reef forms as variants on this exemplary location. Couthouy, in his eighteen-page section on reef form and topography and coral zonation, on the other hand, described the general appearance of all the reefs he had seen and used different locations to illustrate separate features. On many points, including the means by which lagoons were conserved, the slow rate of coral growth, and the roles played in reef construction by different types of corals and calcareous algae, Couthouy and Darwin proved to be in complete and presumably independent agreement. On the other hand, while Couthouy claimed that he had "more than two years ago" come to "similar conclusions" to Darwin's on the origin of coral islands, he said that he had never "entertain[ed] [Darwin's] opinions respecting limited and definite areas of subsidence and elevation."[74]

Couthouy closed his paper by attending to the zoological question that had been his official assignment on the voyage, namely determining the factors that limited coral growth. As he had done in the notes written at Aunuü, he argued for the important role played by water temperature in dictating the abundance of reef-building corals, and proposed that Quoy and Gaimard had stated an erroneously shallow depth limit for coral growth because they had "not sufficiently taken into consideration the variations of temperature at small depths, produced by accidental causes."[75] He went on to argue further that water temperature was the main determinant of the global distribution of coral reefs. Unlike Darwin, who had sought in his 1837 coral paper to relate reef distribution to patterns of vertical crustal motion, Couthouy considered the placement of reefs to be intimately connected with the patterns of hot and cold water currents in the oceans. He called for a nationalized effort to gather temperature and depth data from a set of key locations including the coasts of Africa and Australia. He believed that a "connected series of observations . . . by direction of the Navy Department, and published in the form of tabular reports" would shed light not only on the question of reef distribution, but also on "questions relative to oceanic and (as connected with these,) atmospheric phenomena, our knowledge of which is yet in its infancy."[76]

While Couthouy was making public his views on coral reefs and his prescriptions for further research, James Dwight Dana was on the *Vincennes*,

a little over half way through the passage from San Francisco to Manila via yet another stop at the Sandwich Islands.

A PUBLIC DISPUTE OVER THE BOUNDARY BETWEEN ZOOLOGY AND GEOLOGY

Dana returned home along with the rest of the U.S. Exploring Expedition in June 1842 only to be met by an odd combination of public apathy about their achievements and scandal over the conduct of the voyage.[77] And just as the court-martial records involving Wilkes have been the source of spectacular insights into the practice of a scientific survey under naval discipline, there is much to learn about the practices and politics of natural history by studying the fracas that ensued when Dana learned that Couthouy had already published on coral formations.[78]

Dana sprang into action in April 1843 at the meeting of the Association of American Geologists and Naturalists in Albany, where he sought to establish himself above both Darwin and Couthouy as the foremost authority on coral reef formation. Choosing to identify himself as the voice of the expedition itself, he declared that Darwin's view on the role of subsidence in the formation of atolls "has been fully confirmed by the investigations of the Exploring Expedition," but he argued that Darwin had made mistakes in delineating "his regions of subsidence and elevation," and also in drawing "the conclusion that these changes are now in progress." And, as Couthouy had done, Dana emphasized how much more coral-reef field experience he had than Darwin, charging the British naturalist with making generalizations that had been "deduced without sufficient examination."[79]

Dana struck at Couthouy in open discussion of another of his papers, which asserted the refrigeration of the globe. He claimed that reef-building corals could not grow in low temperatures, and argued in consequence that because it is possible to find fossil corals well beyond the tropics then the ocean must have cooled during the tertiary period. Couthouy had argued to the same effect in his published article two years earlier, but Dana declared that his former colleague was "indebted [to Dana] for the views there advanced by him with regard to temperature limiting corals" and he corrected the temperature limit to 70°F (from 76°), which, according to the published abstract of the paper, was "the limit fixed upon by Mr. Dana when the views were communicated by him to Mr. Couthouy."[80] Dana reasserted his claim to priority in a formal paper as well, "On the temperature limiting the distribution of corals." After stating that he had "ascertain[ed] the influence of temperature on the growth of corals," which he now placed at

66° F., and claiming that this allowed him to explain the anomalous lack of coral reefs in the seas surrounding the tropical-but-cold Galapagos, and the equally anomalous presence of reefs at the extratropical-but-warm Bermudas, he insisted that

> in justice to myself I may state here, that this explanation, which was published some two years since by another, was originally derived from my manuscripts, which were laid open most confidingly for his perusal, while at the Sandwich Islands in 1840.[81]

Dana gave no critique of the substance of Couthouy's paper. By disputing only a single digit of Couthouy's sixty-six page essay, he tacitly indicated that the rest of its content was both accurate and plagiarized.

Couthouy responded in the *American Journal of Science* (which was colloquially known as "Silliman's journal" after its founder and editor, Benjamin Silliman, who had been Dana's mentor at Yale) by asserting the independence of his ideas *and* of his scientific department. Couthouy argued that it was not only plausible that he could have determined the effect of temperature on coral growth independently of Dana, but that it was in fact his obligation and his right to do so as the executor of the zoological instructions. "It must be borne in mind," he told his fellow men of science, "that in the distribution of the various departments of natural history among the naturalists attached to the expedition, the corals were specially assigned to me. Their habits, growth, distribution and all else connected with their history, were consequently the objects of my particular attention."[82] What is more, Lyell's lecture in Boston had made Couthouy aware of the need to make his independently acquired views on reef formation public in advance of a forthcoming "elaborate work on [coral] distribution, &c." by Charles Darwin. Unlike Dana, Couthouy needled, "I deemed it highly probable that another person, observing the same facts as myself, might draw precisely the same inferences."[83]

In making these arguments Couthouy was expanding the grounds of debate beyond Dana's specific accusation of plagiarism.[84] Rather than merely asserting his independence from—if not priority over—Dana, he was invoking the sanctity of the scientific departments with which each man had been entrusted. The boundary between these departments was to be the most fiercely contested terrain in the next round of the battle, for in his reply Dana argued that if a department had been violated, it was his own. "Mr C[outhouy] claims in his vindication that the whole subject of corals was in his hands, much to my surprise, and no doubt to the surprise of all,

who know that the structure of coral islands is so far a *geological* question as to constitute an important chapter in all geological treatises. The point was considered so far settled at sea as never to have been mooted."[85] Dana neglected to mention that his original charge of plagiarism had not been in reference to the structure of coral islands, but to the growth of corals, which was almost as self-evidently a zoological question. Couthouy did not miss the opportunity to point this out, responding that *his* mandate had pertained "to living corals, to corals zoologically considered." Naturally this included "the influence of temperature upon their growth." As to Dana's charge of trespassing on geological turf, he protested that it had been precisely "for Mr. D[ana]'s information" that he had "neglected no opportunity of making observations on the geological structure of reefs and islands."[86]

As the dispute continued to smolder, Silliman and his son Benjamin, Jr., now co-editors of the *American Journal of Science*, had made the decision to print a special appendix to the 1844 volume in order to accommodate a paper each by Couthouy and Dana. In introducing the appendix the Sillimans (who, that same year, became father-in-law and brother-in-law to Dana when he married Henrietta Silliman) declared, "*science is no longer* the theme of discussion," and availed themselves of "the opportunity publicly to inform the parties interested, that this controversy will not again be permitted, under the covers of this Journal."[87]

The controversy was finally settled at the 1844 meeting of the American Association of Geologists and Naturalists, where Dana (in what Couthouy called a "manly acknowledgement") admitted that Couthouy had indeed devoted considerable, indpendent energy during the voyage to studying the effect of temperature on the growth of corals.[88] Dana's admission came after Couthouy presented him with his recently reclaimed notes from the expedition. For this reason it seems unlikely that Couthouy had shared this information with Dana during the voyage itself. It is conceivable that Couthouy never discussed the matter with Dana at Oahu because he considered it a purely zoological topic, though his explanation was that he had been utterly preoccupied at Oahu by the fact that Wilkes was on the verge of seizing his papers and detaching him from the expedition. For this very reason, and given that Dana was already the interim custodian of Couthouy's department, sharing his best work with Dana was probably Couthouy's last intention.

Couthouy may have won the battle to vindicate himself from the charge of plagiarism, but Dana prevailed in his covert war for Couthouy's department. Couthouy foresaw this in his talk at the 1844 meeting, where he took the opportunity of Dana's withdrawal to state what he considered

his original contributions to be. Couthouy claimed to have originated two "theories or principles" relating to corals: that their growth was limited by water temperature, regardless of depth, and that the absence of corals in certain areas was caused by cold currents. But Couthouy admitted that Dana had completed the expedition, and that for this reason it would be Dana, and not Couthouy, who would be in the position to judge the validity of these principles. "The time and opportunity for more extensive observation which were denied to me, it was the peculiar good fortune of Mr. Dana to enjoy . . . *His* is the rich harvest of facts, and their application in a wide field of observation."[89]

More importantly than finishing the voyage, Dana had remained in the good graces of Wilkes and the expedition's organizers. All of the expedition's specimens and drawings were government property, and it was Dana who received the commission to write not only the official volume on geology, but also the one on the zoophytes. He would have access to all of Couthouy's work as well as his own.

CONCLUSION: DIVISIONS OF SCIENTIFIC LABOR, FROM THE PACIFIC TO PUBLICATION

As the Sillimans noted, "science" as a body of knowledge may have ceased to be at issue in the disagreement between Couthouy and Dana. After all, the charge of plagiarism was germane because of their fundamental *agreement* as to the actual mode of coral reef formation. Science *as an activity*, on the other hand, remained the central theme of the dispute until the very end. According to both Couthouy and Dana, the root of their conflict lay in the other man's transgression of their agreed-upon division of scientific labor into zoological and geological departments. Seeing science as a set of activities or practices as well as a body of knowledge is particularly noteworthy here, because the scope for conflict between Couthouy and Dana depended upon precisely which scientific practice was at issue. In the collecting of specimens, for example, Couthouy and Dana had managed to coexist happily despite the fact that they both acknowledged collecting items that belonged to the other's department. In this activity the integrity of each department could be maintained very straightforwardly, because of the ease with which tangible specimens could be assigned a department and, if appropriate, exchanged. Sure enough, Couthouy and Dana had turned over specimens to one another according to the department they fit, and each considered this a mutually beneficial way to share the scientific labor of the voyage.

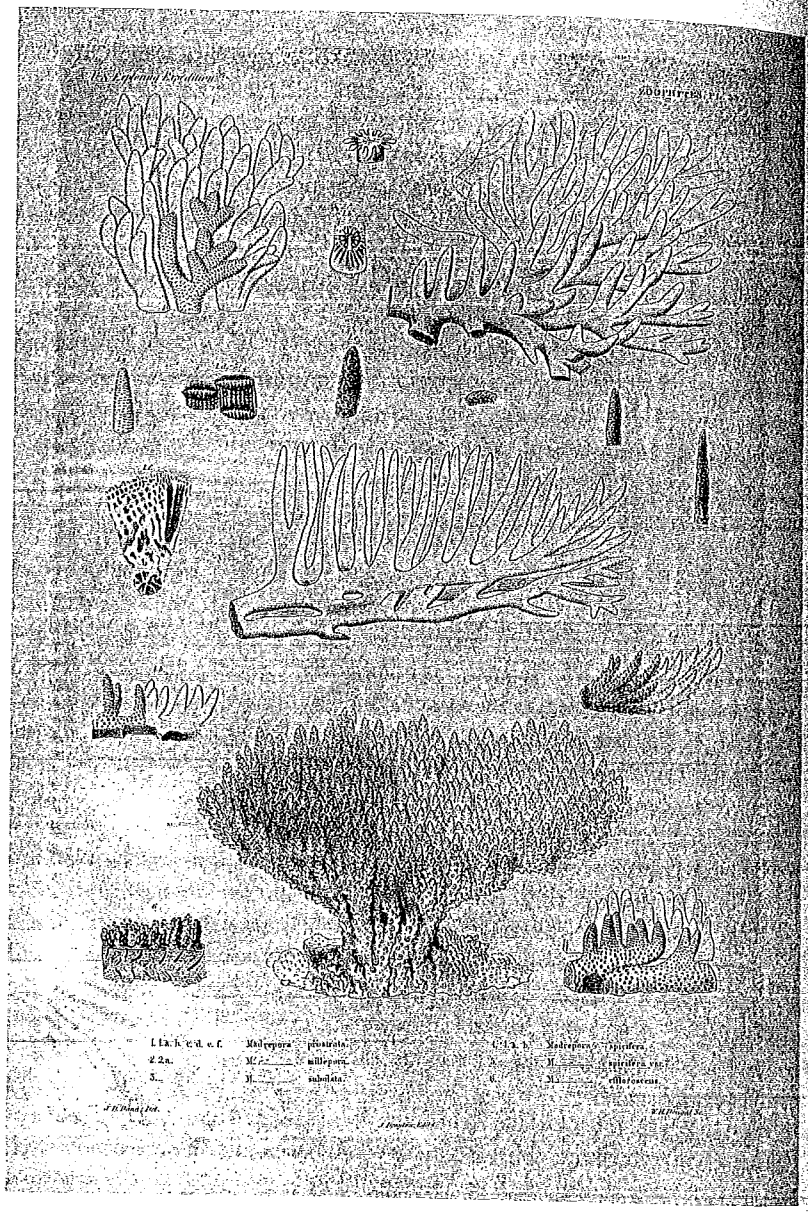

FIGURE 2 A plate from Dana's 1846 monograph on the zoophytes of the U.S. Exploring Expedition illustrating the previously pictured specimen of *Madrepora spicifera*.

What was at stake after the voyage was not simply the division of scientific labor among distinct departments or specializations, but also the division of scientific activity between study and publication. Dana had almost acknowledged as much in his final salvo in the dispute, seeming barely able to restrain himself from saying that he had offered at Oahu to make Couthouy his co-author precisely because he wanted access to, if not control over, the zoological as well as the geological publications to emerge from the voyage.[90] And after the expedition it was indeed Dana's work in producing the reports on geology and zoophytes that gained him the attention of Darwin, Lyell, and others. By the end of the 1840s, Dana could fairly consider himself the world's foremost authority on all scientific matters relating to Pacific corals and their formations. He had taken full advantage of the breadth of research topics allowed him by Couthouy's dismissal from the voyage, and of the breadth of experience presented by his extended cruises through the Pacific's richest coral zones, to acquire a familiarity with atolls and barrier reefs that dwarfed Darwin's first-hand knowledge. He had also taken advantage of the financial support grudgingly provided by the U.S. Congress for specialist work on the Ex. Ex. collections, which enabled him to devote the better part of a decade to full-time research and writing on zoological and geological topics. The intensity and duration of his labors startled his colleagues. What his coral reef theory lacked in originality by appearing after Darwin's was compensated by the weight and quality of evidence that Dana commanded.

This brings us back to Darwin's comment with which I began this essay, that he wished Dana were not so grand a generalizer. His words point our attention toward one final division of scientific labor that I wish to consider: the one between descriptive work and theorizing. The conflict between Couthouy and Dana emerged precisely at the point at which they transcended collecting in order to begin speculating, on the origin of coral reefs and on the reasons for their distribution. Whereas the former activity, as we have seen, yielded products that could easily be classified according to department, the act of answering theoretical questions was more difficult to govern because the work-products of theorizing could not be transferred with the same ease as specimens could be.

This problem was exacerbated in the present episode by the fact that coral reefs were a truly boundary-spanning phenomenon, simultaneously animal, vegetable, and mineral, and constituted at once by both fossil and living material. But it would be a mistake to assume that this issue could only have arisen in connection with coral reefs. At the level of explanatory work, or theory, there were many phenomena that brought the domains of

zoology and geology into overlapping contact. For the zoologists Georges Cuvier and Richard Owen, among others, considering paleontological evidence was central to answering questions of zoological theory. The geologist Charles Lyell, meanwhile, had devoted an entire volume of his *Principles of Geology* to the action of the organic world as it bore on geological theory, and coral reefs were the topic of just the final short chapter.

There was, finally, a structural problem for Dana and Couthouy. The specialist sciences they had been charged to practice on the expedition had been created, in their Anglophone versions, precisely to put limits on the act of generalizing.[91] In geology and particularly in the science of zoology, as Sandra Herbert has pointed out, there was very little space to cast oneself as a theorist.[92] This was trouble for Couthouy especially, for there was no precedent for publishing a theory of coral reef formation *as a zoologist*. Dana could point to discussions of coral-reef structure "in all geological treatises," but even in that science generalizing could be a delicate matter. The irony of Darwin's jab at Dana pointed toward this tension: although many of Britain's most exalted naturalists personally considered the identification of laws and the establishment of theories to be the legitimate end of scientific inquiry, the actual deed of theorizing was often condemned as an affront to the responsible practice of natural history. No wonder, then, that Couthouy and Dana found it tricky to reserve generalizing on coral reefs as the exclusive domain of either man's department.

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ENDNOTES

1. Darwin to Charles Lyell [7? December 1849]. *Correspondence of Charles Darwin.*
2. Darwin's relationship with Lyell, and their respective attitudes toward the place of theorizing in natural history, are topics of my forthcoming book *Darwin's First Theory* (Chicago: University of Chicago Press, under revision). Martin Rudwick has written a great deal on Lyell's approach to theorizing and on the unenthusiastic response it received from rivals including Henry De la Beche. See, among other publications, Martin J. S. Rudwick, *Worlds before Adam: The Reconstruction of Geohistory in the Age of Reform* (Chicago: University of Chicago Press, 2008).

2b. From Beaufort's instructions to FitzRoy, reprinted in *Narrative of the Surveying Voyages of HMS Adventure and Beagle*, 3 vols. (London: H. Colburn, 1839), 2:38; Charles Darwin to Caroline Darwin, 29 Apr. 1836. Darwin Correspondence Project, "Letter no. 301," accessed on 15 June 2016,http://www.darwinproject.ac.uk/DCP-LETT-301."

3. The following material is drawn from Alistair Sponsel, "An Amphibious Being: How Maritime Surveying Reshaped Darwin's Approach to Natural History," *Isis* 107, no.2 (2016): 254-81.
4. William Ragan Stanton, *The Great United States Exploring Expedition of 1838–1842* (Berkeley: University of California Press, 1975), 1–40; Nathaniel Philbrick, *Sea of Glory: America's Voyage of Discovery: The U.S. Exploring Expedition, 1838–1842* (New York: Viking, 2003), 3–42; Herman J. Viola, "The Story of the U.S. Exploring Expedition," in *Magnificent Voyagers*, eds. Herman J. Viola and Carolyn Margolis (Washington: Smithsonian Institution Press, 1985), 9–23.
5. Mary Elizabeth Cooley, *The Exploring Expedition in the Pacific* (Lancaster, Pa.: Lancaster Press, Inc., 1940), 707–719; Ralph E. Ehrenberg, John A. Wolter, and Charles A. Burroughs, "Surveying and Charting the Pacific Basin," in *Magnificent Voyagers*, 164–87.
6. Charles Wilkes, *Hydrography* (Philadelphia: Printed by C. Sherman, 1861), 6–13; D. Graham Burnett, "Hydrographic Discipline among the Navigators: Charting an 'Empire of Science and Commerce' in the Nineteenth-Century Pacific," in *The Imperial Map*, ed. James Akerman (Chicago: University of Chicago Press, 2009), 184–259.
7. Wilkes, *Hydrography*, 6.
8. Kotzebue, a Baltic-German hydrographer in Russian service, commanded a pair of expeditions to the Pacific (1815–1818 and 1823–1826); the British naval officer and hydrographer Frederick William Beechey surveyed thirty-two coral islands during his 1825–1828 expedition to the Pacific.
9. Mahlon Dickerson to [Peter S. DuPonceau], 31 August 1836. Quoted in Edwin Grant Conklin, "Connection of the American Philosophical Society with Our First National Exploring Expedition," *Proceedings of the American Philosophical Society* 82, no. 5 (1940): 520. See also James Rehn, "Connection of the Academy of Natural Sciences of Philadelphia with Our First National Exploring Expedition," *Proceedings of the American Philosophical Society* 82, no. 5 (1940): 543–49; G.S. Bryan, "The Purpose, Equipment and Personnel of the Wilkes Expedition," *Proceedings of the American Philosophical Society* 82, no. 5 (1940): 551–60.
10. J.K. Paulding, "Instructions to the Commander." Quoted in Conklin, "Connection," 539.
11. Although the Frenchmen Quoy and Gaimard published jointly on coral reefs after their voyage on the *Uranie*, and the naturalists Eschscholtz and Chamisso produced separate statements on reef formation after their voyage

with Kotzebue, I have not seen any evidence of a formal division of labor within either pairing. The Yale professor Benjamin Silliman proposed the outlines of a similar arrangement in a letter to Jeremiah Reynolds of 30 May 1836. He cited "Coral animals" as a desideratum of "Zoology," and "Coral reef islands, above or under water" as a topic for "Geology, Mineralogy, &c," in describing "objects . . . deserving of especial notice in [a] voyage towards the South Pole." J. N. Reynolds, *Address, on the Subject of a Surveying and Exploring Expedition to the Pacific Ocean and South Seas* (New York: Harper & Brothers, 1836), 112–115.

12. Titian Peale, quoted in Conklin, "Connection," 530.
13. Henry D. Rogers, quoted in ibid., 533.
14. Stanton, *Exploring Expedition*, chap. 3.
15. See Dana to Asa Gray, December 1836. Harvard University Gray Herbarium Historic Letters File.
16. For Dana's biography, see Daniel Coit Gilman, *The Life of James Dwight Dana, Scientific Explorer, Mineralogist, Geologist, Zoologist, Professor in Yale University* (New York; London: Harper & Brothers, 1899); Daniel E. Appleman, "James Dwight Dana and Pacific Geology," in *Magnificent Voyagers*, 89–118; Michael Laurent Prendergast, "James Dwight Dana: the Life and Thought of an American Scientist" (Ph.D. dissertation, UCLA, 1978). On his coral reef work see David R. Stoddart, "'This Coral Episode': Darwin, Dana, and the Coral Reefs of the Pacific," in *Darwin's Laboratory: Evolutionary Theory and Natural History in the Pacific*, ed. Roy M. MacLeod and Philip F. Rehbock (Honolulu: University of Hawaii Press, 1994), 24–48.
17. One of Couthouy's Ex. Ex. journals is in the archives of the Boston Museum of Science. For biographical details see William H. Dall, "Some American Conchologists," *Proceedings of the Biological Society of Washington*, 4, 1888, 95–134; Stanton, *Exploring Expedition*, 48; Frederick M. Bayer, "The Invertebrates of the U.S. Exploring Expedition," in *Magnificent Voyagers*, 71–88.
18. The Couthouy journal that is held at the Boston Museum of Science (BMOS) is almost certainly a duplicate journal that he sent home to Boston from Sydney. It is neatly written and terminates abruptly with an entry written near "Opolu" on 29 October 1839, which corresponds with a description he gave of those "duplicate minutes of the most important of my observations from the time of our leaving the United States, to our arrival at Upolu in the Samoan group." Joseph Pitty Couthouy, "Reply to the Accusations of J.D. Dana, Geologist to the Exploring Expedition, Contained on Pp. 130 and 145 of Vol. XLV, Amer. Jour. Science and Arts," *American Journal of Science and Arts* 45, no. 2 (1843): 380.
19. See, e.g., Couthouy journal entries for 22 July and 31 August 1839. BMOS 22.
20. On diving for specimens and sounding, see Couthouy's journal entry for 25 August 1839 (at Wytoohee [Napuka] in the Disappointment Islands). BMOS 22. I argue for the significance of Darwin's attention to the soundings taken by the *Beagle*'s hydrographers in "An Amphibious Being: How Maritime Surveying Reshaped Darwin's Approach to Natural History."
21. Journal entry for 31 August 1839. BMOS 22.
22. Journal entry of 9 September 1839. BMOS 22. Dana later wrote that on approaching the island, he had supposed the cliffs to be basaltic (i.e., of volcanic

origin). James Dwight Dana, *On Coral Reefs and Islands* (New York: Putnam & Co, 1853), 35.

23. On Quoy and Gaimard's work see Alistair Sponsel, "Coral Reef Formation and the Sciences of Earth, Life, and Sea, C. 1770–1952" (Ph.D. dissertation, Princeton University, 2009), 46–56.
24. Journal entry of 9 September 1839. BMOS 22.
25. Journal entry of 7 October 1839. BMOS 22.
26. Couthouy journal entry for 7 October 1839. BMOS 22, p. 289.
27. In the result of a baffling decision by Wilkes, the single occasion when the reef-boring apparatus was employed during the voyage was two years later (under Lieutenant Robert Johnson at Carlshoff Island [Aratika]) when neither Couthouy nor Dana was present. See Charles Wilkes, *Narrative of the United States Exploring Expedition. During the Years 1838, 1839, 1840, 1841, 1842* (Philadelphia: Lea and Blanchard, 1844), vols. 4, 286; Sponsel, "Coral Reef Formation," 279–280.
28. Journal entry of 11 October 1839. BMOS 22. Emphasis added.
29. Transcribed by Couthouy in "Remarks Explanatory of the Extent of His Views Relating to the Influence of Temperature on the Development of Corals, as Compared with Those Entertained by Jas. D. Dana, Esq.," in *Abstract of the Proceedings of the Fifth Session of the Association of American Geologists and Naturalists* (New York: Wiley & Putnam, 1844), 32.
30. Journal entry for 21 August 1839. BMOS 22.
31. See, for examples, the complaint in Journal entry for 21 August 1839. BMOS 22.
32. Wilkes, Charles. *Autobiography of Rear Admiral Charles Wilkes, U.S. Navy, 1798-1877*. (Washington: Naval History Division, Dept. of the Navy, 1978), 431.
33. Couthouy journal entry of 31 August 1839. BMOS 22. As Couthouy attests, "The words underlined here are so in the original." Wilkes reproduced the order in the appendix of *Narrative of the United States Exploring Expedition. During the Years 1838, 1839, 1840, 1841, 1842*, vol. 1.
34. Couthouy journal entry of 31 August 1839. BMOS 22.
35. There were several further conflicts between Wilkes and Couthouy in the final weeks of the Pacific cruise, notably over the custody of officers' collections and the privacy of Couthouy's notes. Couthouy's perspective is given full voice in his manuscript journal. Wilkes had his say in the *Narrative* and in his polemical and factually dubious *Autobiography*, all cited above. For a comparatively neutral account synthesized from these and other sources, see Stanton, *Exploring Expedition*, 116–147.
36. Dana, *On Coral Reefs and Islands*, 41, 45, 128.
37. Dana to Benjamin Silliman, 12 September 1839. Quoted in Stanton, *Exploring Expedition*, 137.
38. James D. Dana, "Reply to Mr. Couthouy's Vindication against the Charge of Plagiarism," *American Journal of Science and Arts* 46, no. 1 (1844): 129–36; Joseph Pitty Couthouy, "Review of and Strictures on Mr. Dana's Reply to Mr. Couthouy's Vindication against His Charge of Plagiarism," *American Journal of Science and Arts* Appendix to Vol 46, no. 2 (1844); James D. Dana, "Reply of J.D. Dana to Foregoing Article by Mr. Couthouy," *American Journal of Science and Arts* Appendix to 46, no. 2 (1844).

39. On Couthouy's illness, see Couthouy, "Reply to the Accusations," 380.
40. On the collaboration between Dana and Clarke, see Appleman, "James Dwight Dana and Pacific Geology," 95–98; Stoddart, "This Coral Episode': Darwin, Dana, and the Coral Reefs of the Pacific," 26–27.
41. James Dwight Dana, *Corals and Coral Islands* (New York: Dodd & Mead, 1872), 7.
42. Stoddart, "'This Coral Episode'", 26; David R. Stoddart, "Joseph Beete Jukes, the 'Cambridge Connection,' and the Theory of Reef Development in Australia in the 19th Century," *Earth Sciences History* 7 (1988): 101–102; Prendergast, "Dana," 165. For my fuller discussion of the means by which Dana might have learned of Darwin's theory see Sponsel, "Coral Reef Formation," 266–268.
43. Charles Lyell, *Elements of Geology* (London: John Murray, 1838), 402.
44. James D. Dana, *Corals and Coral Islands* (New York: Dodd & Mead, 1872), 7.
45. Dana, *Corals and Coral Islands*, 7.
46. Dana Family Papers, Sterling Library, Yale University (YUL). Box 10, folder 134. Microfilm reel 6, frames 388–466 and 467–513. (Dana's papers are viewable only on microfilm copies because of their fragile condition.)
47. David Igler, "On Coral Reefs, Volcanoes, Gods, and Patriotic Geology: Or, James Dwight Dana Assembles the Pacific Basin," *Pacific Historical Review* 79 (2010): 23–49.
48. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frames 409–411.
49. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, e.g., frame 410. Smithsonian Institution Archives (SIA) RU 7186, Box 2, Folder 6, "U.S. Exploring Expedition Annotated lists of specimens received from U.S. Exploring Expedition. 1839–1842."
50. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frame 461.
51. The development of Dana's views on submarine volcanoes is considered in more detail in Sponsel, "Coral Reef Formation."
52. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frames 461–462.
53. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frame 462.
54. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frame 462.
55. Lyell, *Elements of Geology*, 96. Although it is not certain that Dana was consulting this book as he pondered elevation, his notes on this page contain the term "metamorphic rock," recently coined by Lyell. Dana's queries on elevation included, "[Are there] No inclined strata on flanks of Andes? [Are] Metamorphic rocks of Andes easily distinguished from the true igneous?" Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frame 461.
56. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frame 461.
57. SIA RU 7186. Box 2, folder 3, "U.S. Exploring Expedition, Original Catalogue of Geological Specimens Collected at Sandwich Ids. By James D. Dana."
58. SIA RU 7186. Box 2, folder 5(D), "Original invoices and other official papers of the U.S. Exploring Expedition."
59. Wilkes, *Autobiography*, 480–81.
60. I have not found any such document among Dana's papers, but his "Oregon Notebook" of late 1841 contains a tally of his manuscripts which does include an entry for one called "Corals" that comprised "80 [pages] + 2 sketches." (YUL Dana Family Papers, Reel 6, frames 527–528.) This does not, of course, confirm that the coral manuscript really existed in late 1840 when Dana had last seen Couthouy. It should also be recalled that by the time Dana made landfall in Oregon, he had already lost manuscripts in the wreck of the *Peacock*.
61. Dana, "Reply to Couthouy's Vindication," 131.
62. Couthouy, "Strictures," 7.
63. Dana quoting Couthouy, in agreement. Dana, "Reply to Couthouy's Vindication," 130.
64. Notable contributions to the study of Dana's volcano work include Appleman, "James Dwight Dana and Pacific Geology"; J. Edward Hoffmeister, "James Dwight Dana's Studies of Volcanoes and of Coral Islands," *Proceedings of the American Philosophical Society* 82, no. 5 (1940): 721–32; Prendergast, "Dana."
65. Thus he never published this view held during the middle portion of the expedition, which is evidently why it has not been described by previous Dana scholars.
66. This achievement was celebrated first, and most vigorously, in William Morris Davis, *The Coral Reef Problem* (New York: American Geographical Society, 1928).
67. The style is well illustrated in Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frames 473–476.
68. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frame 475.
69. Dana Family Papers, YUL. Box 10, folder 134. Microfilm reel 6, frames 498–500.
70. On Lyell's lectures in the USA see Robert H. Dott, Jr., "Charles Lyell in America–his Lectures, Field Work and Mutual Influences 1841–1853," *Earth Sciences History* 15 (1996): 101–40; Leonard G. Wilson, ed., *Lyell in America: Transatlantic Geology 1841–1853* (Baltimore: Johns Hopkins University Press, 1998); Sponsel, *Darwin's First Theory*.
71. Joseph Pitty Couthouy, "Remarks upon Coral Formations in the Pacific; with Suggestions as to the Causes of Their Absence in the Same Parallels of Latitude on the Coast of South America," *Boston Journal of Natural History* 4 (1842): 76–77.
72. Ibid., 66–67.
73. Ibid., 72–76.
74. Ibid., 77.
75. Ibid., 74.
76. Ibid., 161–162.
77. The extensive court martial proceedings are described in the histories of the voyage cited above.
78. On the significance of alleged surveying errors in the proceedings, see Burnett, "Hydrographic Discipline."
79. James D. Dana, "On the Areas of Subsidence in the Pacific, as Indicated by the Distribution of Coral Islands," *American Journal of Science and Arts* 45, no. 1 (1843): 131.
80. "Abstract of the Proceedings of the Fourth Session of the Association of American Geologists and Naturalists," *American Journal of Science and Arts* 45, no. 1 (1843): 145.

81. James D. Dana, "On the Temperature Limiting the Distribution of Corals," *American Journal of Science and Arts* 45, no. 1 (1843): 130.
82. Couthouy, "Reply to the Accusations," 379.
83. Ibid., 381.
84. In the most detailed previous study of this episode, Michael Prendergast identified it as a priority dispute. Prendergast, "Dana," chap. 6.
85. Dana, "Reply to Couthouy's Vindication," 131. Original emphasis.
86. Couthouy, "Strictures," 7.
87. "Editorial Remark," *American Journal of Science and Arts,* Appendix to 46, no. 2 (1844).
88. James D. Dana, "Acknowledgement of J.D. Dana Relative to a Charge of Plagiarism," in *Abstract of the Proceedings of the Fifth Session of the Association of American Geologists and Naturalists* (New York: Wiley & Putnam, 1844), 30; Joseph Pitty Couthouy, "Acknowledgement of J.P. Couthouy Relative to a Charge of Plagiarism," in *Abstract of the Proceedings of the Fifth Session of the Association of American Geologists and Naturalists* (New York: Wiley & Putnam, 1844), 30.
89. Couthouy, "Remarks Explanatory . . . to the Influence of Temperature," 34–35.
90. Dana, "Reply of J.D. Dana to Foregoing Article by Mr. Couthouy," 11.
91. Whereas theorizing was a prime characteristic of German *Naturphilosophie* and Wernerian geognosy, and of the geological and zoological programs of Frenchmen such as de Luc, Cuvier, and Geoffroy Saint-Hilaire, the specialist sciences of zoology and geology had been established in Britain as explicitly anti-theoretical pursuits. The veneration for ostensibly descriptive science was meant to counteract the tradition of exuberant theorizing that characterized Continental natural history and earlier British "theories of the earth" by authors such as Thomas Burnet and William Whiston. The new generation of specialists sought to distinguish themselves alike from their speculative forebears and from contemporaries who grubbed in practical matters such as mining. Meanwhile, of course, Lyell, Darwin, and others did seek causal explanations as part of their work in geology and natural history, and their contemporaries John Herschel and William Whewell devoted themselves to giving accounts of how generalizing might responsibly be pursued (though Whewell claimed that geology had yet to advance to the stage when a "general system of geology" might be established). On geology see Martin J. S. Rudwick, "Charles Darwin in London: The Integration of Public and Private Science," *Isis* 73 (1982): 186–206; Rudwick, *Worlds before Adam*; James A. Secord, *Controversy in Victorian Geology: The Cambrian-Silurian Dispute* (Princeton: Princeton University Press, 1986). On zoology see Sandra Herbert, "The Place of Man in the Development of Darwin's Theory of Transmutation, Part II," *Journal of the History of Biology* 10 (1977): 155–227.
92. Herbert, "Place of Man, Part II."