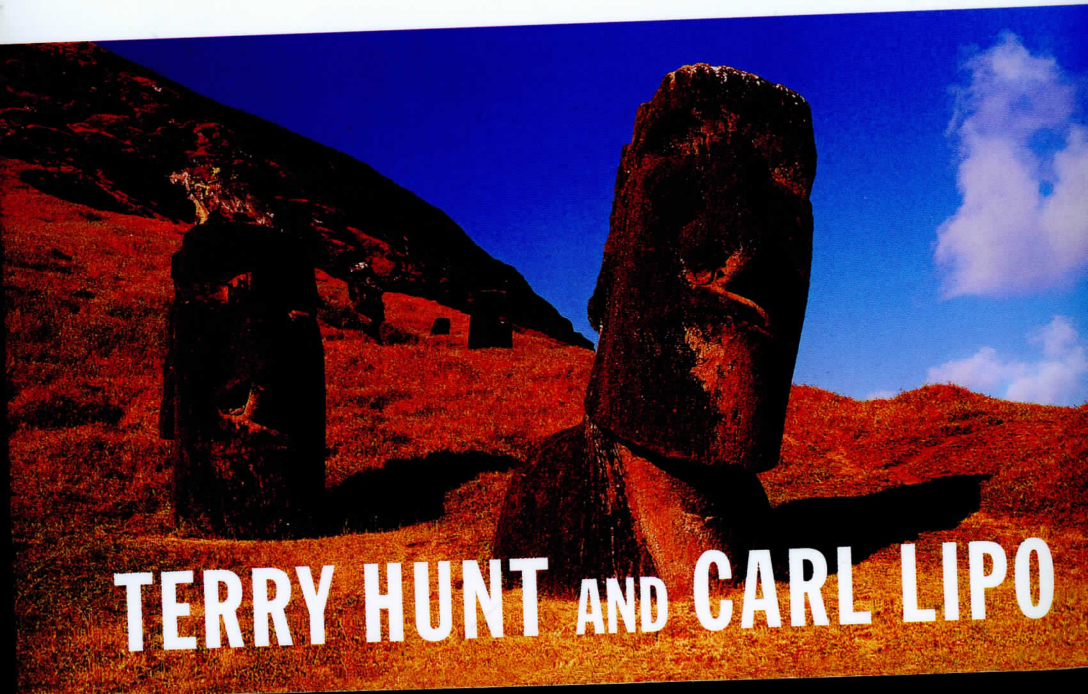
THE STATUES THAT WALKED

Unraveling the Mystery of Easter Island



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CHAPTER 3

Resilience

> We have seen that neither the position nor the fertility of Easter Island can account for its extraordinary outburst of memorial art. Yet difficulties to be met with often develop exceptional talent, and a hard environment has often bred a people of fine courage and capacity.
>
> —John Macmillan Brown,
> *The Riddle of the Pacific,* 1924

In 1774, Captain Cook was chagrined that Rapa Nui could provide so few provisions for resupplying his ships. He remarked, "there can be few places which afford less convenience for shipping than it does. There is no safe anchorage; no wood for fuel; nor any fresh water worth taking on board. Every thing must be raised by dint of labor, it cannot be supposed the inhabitants plant much more than is sufficient for them; and as they are but few in number, they cannot have much to spare to supply the wants of visitant strangers."[1] Cook limited his visit to the island to just three days.

All the early European visitors made such observations of the resources on the island, as all ports of call in the Pacific were important for resupply. Recall that Dutch captain Jacob Roggeveen noted during his 1722 visit that the land produced "bananas, potatoes, sugar-cane of remarkable thickness, and many other kinds of the fruits of the earth; although destitute of large trees and domestic animals, except poultry." The chief pilot of the Spanish fleet that arrived in 1770 reported that his men "saw no kind of wild nor domestic animal, excepting hens and some rats. The fields are uncultivated save some small plots of ground, in which they sow beds of *yuca*, yams, sweet potatoes, and several plantations of plantains and sugar-cane: but all very tasteless, as if from want of cultivation." Johann Forster, the naturalist on Cook's visit to the island in 1774, reported, "the whole number of plants growing upon [this island] does not exceed twenty species."[2]

It is clear that at the time of European contact, the array of food available on the island was quite limited, and the archaeological evidence shows that this was true well before the Europeans arrived. Botanists Catherine and Michel Orliac have conducted field and laboratory research designed over the last decade to determine the composition of plant species on the island in prehistory.[3] Through this laborious work, the Orliacs identified twenty taxa of woody plant species, including the Easter Island palm (*Jubaea chilensis*), bushes such as *Sophora toromiro,* and other types of shrubs and small trees. Their samples also contained food remains, and a collaborator of theirs, Erik Pearthree, identified a range of foods consistent with those noted by the early European visitors: sugarcane, taro, *ti* leaf (a leafy plant that is grown for its large, waxy leaves), sweet potato, and yams.

Excavations at Anakena Beach, the sands of which are particularly conducive to preserving bone, have revealed that the islanders also ate a mix of fish, birds, and animals that included dolphins, seals, sea turtles, fish, seabirds, land birds, chicken, and rats. We would expect to find this diet on the Pacific islands, but two key foods that we would also normally see are missing: the island apparently lacked both pigs and dogs. The Polynesians generally brought dogs and pigs, along with chicken and rats, when they set out to colonize other islands, as they were important sources of protein. We also found that most of the fish in our excavations were limited to those that inhabit the near shore waters; and these were limited since Rapa Nui lacked coral reefs so productive in other parts of Polynesia. So the diet on Rapa Nui was significantly less rich than on most of the other Pacific islands, and that was true right from the start of colonization.

The most abundant animal bones found in the excavations are those of the Polynesian rat. They composed roughly 60 percent of all the faunal remains that we collected in our own excavations. This lends credence to the belief that islanders brought rats with them as food. We know that elsewhere in Polynesia, rats were eaten, and there is also a reference to the Rapanui doing so in an account of a visit to the island by Georg Forster, the naturalist on Cook's expedition. He writes, "They also have rats, which, it seems, they eat; for I saw a man with some dead ones in his hand; and he seemed unwilling to part with them; giving me to understand they were for food."[4]

So we have relatively detailed accounting of the plant and animal resources available to the prehistoric Rapanui population and the composition of their diet. And given this fairly impoverished diet, what has long been puzzling was that the archaeological record seemed to contain no obvious evidence of large-scale prehistoric farming. Nowhere on the island can one find the remains of extensive terracing, for example, which might be expected, as we do find them on other islands with similar kinds of environments. On the northern part of the island of Hawaii, large prehistoric field systems are clearly visible,[5] and we know that these fields enabled the prehistoric (that is, AD 1400–1800) population to cultivate sweet potato, yams, taro, bananas, and other nonnative plants, a variety similar to that found on Rapa Nui. These prehistoric Hawaiian farmers also constructed an extensive series of low parallel earthen and stone walls that shielded their crops from the winds that blow vigorously over the slope of the island. Those walls also reduced the loss of water due to evaporation. In fact, based on studies of the effects of windbreaks on evaporation, we can say that they may have resulted in a 20–30 percent reduction.[6]

We wondered why the prehistoric farmers of Rapa Nui hadn't done the same. Given their prowess in transporting multi-ton statues across the island, it would seem that they were plenty

Figure 3.1. View of the Kohala field system showing an expanse of prehistoric agriculture on the northern part of the island of Hawaii.

capable of such engineering. Indeed, the early European explorers were struck by how little effort the islanders seemed to invest in such means of increasing cultivation. Numerous visitors made keen notes on the potential of the island based on the perspective of what Europeans would do. In his notes from his 1722 visit, Roggeveen wrote that "this place, as far as its rich soil and good climate are concerned, is such that it might be made into an earthly Paradise, if it were properly worked and cultivated; which is now only done in so far as the Inhabitants are obliged to for the maintenance of life."[7]

The Rapanui seemed to be underutilizing the island, and this was all the more perplexing given the enormous amount of effort they had apparently put into making their massive statues and stone platforms. This apparent contradiction was behind the conclusion that the islanders were living on the edge of survival in the aftermath of some past calamity. A culture that could produce such monumental works, the argument went, ought to have intensively managed field systems, and should have had concentrations of the population in villages, with land being reserved for cultivation and food production capable of supporting large populations. There seemed to be no other explanation: something very bad must have happened to these people.

It was this perception that led the French explorer La Pérouse—the next European explorer to arrive on the island after Captain Cook—to bring food supplies and new cultigens to the people of Rapa Nui. He set sail from France in 1785 on a round-the-world mission of exploration sponsored by King Louis XVI, with two ships, the *Astrolabe* and the *Boussole*. Arriving on Rapa Nui on April 9, 1786, he spent just a single day on the island, making observations and trading with the islanders, leaving them goats, sheep, pigs, and a wide array of plants, including cabbage, beets, maize, pumpkins, orange trees, lemon trees, and cotton.

But however well intentioned, his gesture was ill conceived. We now know that his scheme was destined for failure. Indeed, the animals were quickly consumed and the plants either failed to grow or quickly dwindled.[8] Were the islanders fools not to have made better use of them? No, the problem was that the island simply wasn't an environment suitable for sustaining the breeding of animals or cultivating such crops.

The landscape of Rapa Nui has little resemblance to the Dutch, English, Spanish, or French countrysides. The island is made from the weathered remains of ancient volcanic eruptions. Despite a somewhat tropical location, rainfall is seasonal but neither abundant nor predictable. While it is possible to attempt most forms of cultivation on the island, it is clear that few of them will be successful over the long run. The environment is so impoverished, in fact, that rather than seeing the islanders as environment destroyers, we would argue that they should be seen as ingenious environmental stewards. They might well have succumbed to the island's impoverishment of resources. That happened on other Pacific islands. Polynesians inhabited Pitcairn Island in prehistoric times. Yet when the mutineers from the *Bounty* arrived on the island in 1790, it was uninhabited. The same was true for scores of other islands across the Pacific, including remote Necker and Nihoa in Hawaii, Howland in the Phoenix Islands, and Washington, Fanning, and Christmas in the Northern Line Islands.[9]

Not all people on all islands managed to sustain their existence as those on Rapa Nui did. But how did they do so? If it wasn't by building terraces and protective walls, what were their methods?

Careful examination of the archaeological record provides the answers: they made good use of two techniques—the building of rock circles, known as *manavai,* and extensive rock-mulch gardening. Though both are well known from the archaeological record in other places around the world, the role they played on Rapa Nui was not well understood until discoveries in recent years revealed just how extensive the use of both was on the island.

Manavai are relatively small, usually circular, rock-wall enclosures.[10] Some of them stand six or more feet high while some are only one foot or so high, and others are underground. In some cases, the walls of *manavai* are constructed masonry-style, with rocks stacked and fitted atop each other in a single layer. In others, walls are constructed with well-defined parallel rows of boulders placed about three feet apart and with gravel fill set in between the rows. The walls might even be just piles of boulders. *Manavai* may be either singular structures or constructed in a honeycomb fashion. From accounts of their use elsewhere, we know that they facilitated growing crops like bananas, taro, and sugarcane, as well as paper mulberry, used to make bark cloth. Their enclosing walls protect plants from winds, minimizing dehydration, thus helping to optimize the use of available water. They continue to be used by some cultivators today and you can readily see the benefits: the portion of plants that are above the walls of the *manavai* are often brown and torn, while those below are green and healthy.

Manavai also allowed the soil within the walls to be enriched through the addition of household waste and garbage. Our excavations of a few *manavai* scattered along the northwest coast of Rapa Nui have shown soil that is relatively rich in burned material and organics relative to the surrounding earth. Inside the *manavai,* nutrient concentrations, particularly phosphorus and potassium,

Figure 3.2. A walled garden feature, or *manavai*.

are much higher than from soils measured outside the *manavai*. We found this pattern at all of the *manavai* we examined, with the concentrations often two or three times as great. This evidence is consistent with observations in 1786 by La Pérouse, who noted "the natives collect the grass and other vegetables, which they heap together and burn for the sake of ashes, as a manure."[11]

We wanted to determine, at least roughly, the number and distribution of *manavai* across the island, and to do so we were able to harness the power of high-resolution satellite images. While remote-sensing studies cannot replace ground-based investigations, they form an integral part of our research because they allow us to study the entire island through a single image and at relatively low cost. Satellite images are a great first step for documenting prehistoric landscapes, which fieldwork can then study in more detail.

One of our graduate students, Ileana Bradford, took on the project of mapping the location of *manavai* as part of her graduate research at California State University Long Beach. She used three sets of images collected in different years and during different seasons, because under different lighting conditions sometimes what had looked like *manavai* turned out not to be, and at others, some were revealed that weren't visible before. Her careful process provided us with a good overall estimate of their number. A total of 2,553 were identified, with most located within half a mile from the coast, and they are found over large areas of the island.

Of course, the number and distribution of stone enclosures that we observe today is only an estimate of what we might have found at any given point in prehistory. Many *manavai* still used today are likely prehistoric in origin. During our follow-up field surveys, we routinely found thriving banana, taro, and other plants growing in *manavai,* so today's islanders clearly understand how effective they are for cultivation. But we also know that some stone enclosures have been constructed or reconstructed recently, as illustrations of the prehistoric gardening practices for today's tourists.

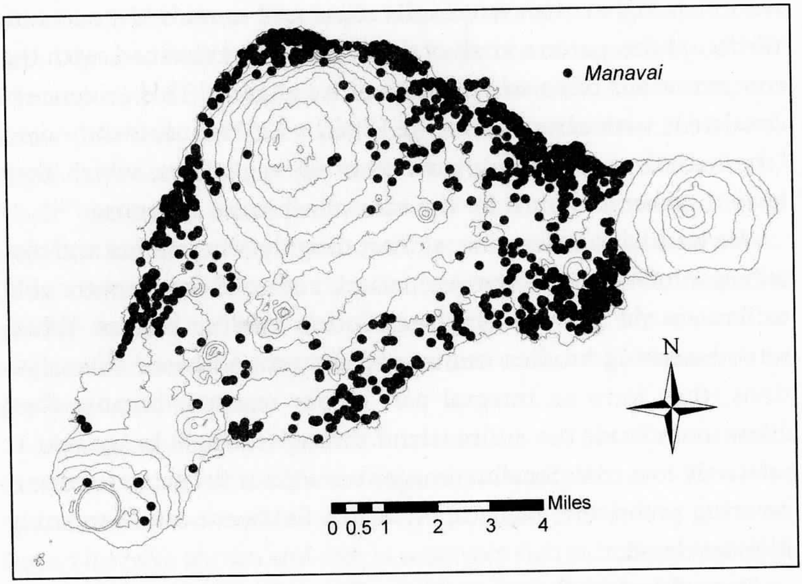

Figure 3.3. Distribution of circular stone enclosures (*manavai*) across Rapa Nui as identified on satellite images.

We would expect that the number would have grown over time, while at the same time, many *manavai* may have been destroyed to make way for other uses or refashioned into other structures. For example, we expect that some *manavai* were dismantled during the nineteenth and early twentieth centuries when so much of the island was converted into a sheep ranch. To control sheep grazing, ranchers constructed extensive stacked-stone structures known as *pirca* walls that stretched across the island, and we know that the *pirca* walls were formed from stones taken from nearby. Some of them undoubtedly came from *manavai,* as well as from other ancient structures. So the number and location of the enclosures, as we have mapped them, likely reflects some large, but not complete, remnant of what existed in prehistory. We expect there are fewer today than in the past because so much terrain is now taken over by the town of Hanga Roa, massive airport runway construction, modern farming, and extensive planting of eucalyptus trees.

Whatever the exact number of them was in earlier times, we could say that taken as a whole, they formed a substantial area for cultivation. The entire area enclosed by *manavai* today is roughly 6.4 square miles, more than 10 percent of the entire island's total surface. This total is even more impressive if one considers that a significant portion of the island consists of the crater lakes, as well as slopes on the shores of those lakes, which are too steep or too rocky for cultivation. With this understanding of the likely extent of *manavai* use, we can certainly conclude that they formed an integral part of ancient farming and that islanders understood very well their critical role in increasing crop yields.

There is an interesting question, though, about why we didn't find signs of *manavai* on various other parts of the island in addition to the shores of the lakes. The most notable area lacking them is the ancient volcano called Poike, at the easternmost part of the island. No stone enclosures are found on the broad slopes of the volcano. This might be explained by geological reasons, as the area lacked the number and size of stones necessary for making *manavai*. Of course, people could have transported rocks to the area, but apparently they didn't. We wondered whether another form of cultivation had been practiced there, but was of limited success.[12]

Early European accounts hint that other types of cultivation were in fact practiced on the island. La Pérouse in 1786, for example, mentions plantations of yams and potatoes as well as banana trees aligned in rows. The captain of the French expedition's sister ship *Astrolabe,* Paul Antoine Fleuriot de Langle, was sent by La Pérouse to explore inland areas of the island. On his trek past the crater at Rano Kau and toward the south coast, Fleuriot de Langle noted that "the cleared grounds have the form of a regular long square, but without any kind of enclosure."[13] Maps published with the written account of La Pérouse show areas on the western coast of the island covered with neatly delineated rectangular fields. A British botanist, Hugh Cuming, described similar cultivation features. During his visit to the island on the schooner *Discoverer* in November 1827, he found that "the Island is . . . extremely well cultivated the ground being laid out in square patches and those close to each other gives it a pretty appearance. Yams, Sweet potatoes, Plantains, Sugar Cane and Coco appear to be principally Cultivated."[14] These observations seem to confirm that the islanders had created cultivated gardens, even though little evidence of field systems has been described in archaeological survey reports.

The first evidence for solving this apparent puzzle came in 1996, when then graduate student in archaeology Joan Wozniak conducted field research on the island's ancient cultivation. Her study area focused on a 0.3 by 0.6 mile portion of the northwestern coast of the island known as Te Niu. Carrying out a systematic survey, she walked across the landscape in a series of transects spaced every fifteen feet, recording all artifacts and architectural remains, as well as conducting small excavations. She found no obvious evidence of cultivation, encountering nothing but rock fields. But curiously, beneath the surface, buried in the soil, she found broken rocks, pits, and artifacts such as obsidian flakes. Thus, while the surface remains appeared to be just a carpet of cobbles and boulders, the subsurface demonstrated plenty of prehistoric activity.

This finding was perplexing at first, but then two different sources of inspiration led her to realize that these scatters of rocks were actually related to cultivation. First, while on Rapa Nui, Wozniak was shown by a local, Niko Haoa, how he protected taro that was growing in his gardens by placing rocks around the plant. Then, in reading the account written by the French explorer La Pérouse, she noted that on the west shore of the island he saw "large stones lying on the surface. These stones, which were found very troublesome in walking, are a real benefit to the soil, because they preserve the coolness and humidity of the earth, and in part supply the salutary shade of the trees, which the inhabitants have had the imprudence to cut down, no doubt at some very distant period."[15] The thought hit her in a flash: Could the rocky landscape of Rapa Nui actually represent a human-engineered landscape constructed for growing plants?

Though initially some of her professors dismissed the idea, she forged ahead in investigating it, and her subsequent excavations documented that the surface rocks and the soil underneath the rocks were both substantially modified by humans. Her analysis shows that prehistoric farmers must have placed the surface rocks there. Wozniak's geomorphology professor conceded that the composition of the soils underneath the surface rocks indicated that they must have been enriched by human intervention. Slowly others began to accept that she was on to something. It seemed that at Te Niu the islanders had practiced a technique known as lithic mulching.

The signs of lithic mulching have been found in excavations of ancient cultures all around the world. One well-known example is that of the ancient Hawaiians on the Kona Coast of the island of Hawaii. Here lithic mulching takes the form of great alignments of volcanic rock and large piles of stones in which a variety of crops were grown. Other locations with remains of lithic mulching include stone mounds in the Negev Desert of Israel, the pebble-mulched fields of Lanzhou, China, the ash fields of the Canary Islands, the rock mounds of prehistoric Hohokam in Arizona, and the pebble-mulched fields of prehistoric Anasazi in

New Mexico. Farmers in New York and New Jersey have also used lithic mulching as recently as the 1930s and 1940s. Farmers in northern Ohio as well as gardeners in New York City also practiced lithic mulching in the 1960s and 1970s.

Lithic mulching increases agricultural productivity in several ways. First, the surface rocks protect plants by generating more turbulent airflow over the garden surface. This results in a reduction of the highest daytime temperatures and an increase in the lowest nighttime temperatures, which produces a healthier growing environment for plants. In addition, the disrupted airflow limits the amount of wind that batters the foliage, similar to the protection offered by the walls of *manavai*. The placement of rocks, particularly broken, smaller ones, serves another essential function: it increases the productivity of the soil by exposing fresh, unweathered surfaces, thus releasing mineral nutrients held within the rock. By breaking down large rocks into small pieces, one can maximize the exposed surface area available for mineral leaching. Relative to a single large boulder, many fist-sized rocks of the same total volume have many times the amount of surface area. Often the rocks are placed not only on the surface, but also buried to directly introduce new sources of minerals into the soil.

Despite growing acceptance of the notion that the Rapanui had made use of the practice, there was continued skepticism because it suggested such a different understanding of the culture and history of the island. While Wozniak's research itself was widely accepted, many resisted the greater implications, since they directly upend the long-standing and oft-repeated belief that the rock-strewn landscape is unproductive, and was degraded as the result of the "imprudence of the ancestors," to quote La Pérouse. But over time, the idea began to take firm hold. The late Roger Green, a well-known Pacific archaeologist, began to wonder whether he had seen the same kinds of lithic mulch in areas where he had worked, such as in Hawaii. Archaeologists Chris Stevenson and Sonia Haoa found the same kind of patterns of surface rock and modified soils in excavations they conducted along the northeast coast of Rapa Nui.[16] The evidence began to grow.

We also found that the implications of her work took time to sink in. During the first several years of our fieldwork, we commonly commented to each other about the incredibly rocky terrain that makes up most of the island. Faced with guiding field school students on foot surveys across the landscape, we were always concerned with twisted ankles—injuries that are relatively minor in most places but worrisome on this remote island. The undeveloped land of Rapa Nui is literally a minefield of ankle-twisting rocks. Not only does the high density of rocks make the surface a hazard, but also the sizes of them seem almost designed to cause a tumble.

Throughout our surveys, we often cursed and pondered these swaths of billiard balls. Over time, however, we came to recognize that these dense patches of stone were located over a remarkable quantity of the island. We found them in flat areas, at the bottom of the slopes, on hill slopes, and in swales. We discussed this endlessly as we walked our survey transects and wondered what kind of geological or erosional process would result in this pattern. Are

Figure 3.4. Lithic mulch garden near Ahu Akahanga on the south coast of Rapa Nui.

Figure 3.5. Taro growing in lithic mulch, Te Niu area, on the northwest coast of Rapa Nui.

the rocks rolling down hills and accumulating after being exposed through erosion? No—there are no such rock exposures above the rock fields. Are the rock scatters caused by sheep that once covered the island by the tens of thousands? The explanation continued to elude us.

We had read Wozniak's work and we understood that she had identified features on the northwest coast that she called "rock gardens," but we had the impression that these must be fairly limited in size, gardens such as we think of them today, not vast expanses of stone. The mental leap we had to make was to see an entire landscape engineered, in a sense, as a garden.

A couple of bits of critical information came together to fully open our eyes to what we were seeing. First, other researchers began to find indications of these rock gardens in more and more locations across the island.[17] Eventually, German researchers Hans-Rudolf Bork, Andreas Mieth, and Bernd Tschochner calculated that stone gardening activity could be found across an area that spans almost one-half of the island's surface. Then, perhaps even more important, archaeologist Thegn Ladefoged with colleagues Chris Stevenson, Peter Vitousek, and Oliver Chadwick published a paper that showed that the island's soils had remarkably poor mineral content.[18] Based on chemical studies of sediment derived from the slopes of two of the island's volcanoes, Terevaka and Rano Aroi, where the most mineral-rich soil would be expected, they learned that phosphorus, which is important for plant growth, is uniformly low. Their work showed that unlike other volcanic islands in the Pacific, Rapa Nui has remarkably unproductive soils and, critically, that they have always been unproductive.

This point is essential to understanding the prehistory of Rapa Nui. While countless scholars have commented on the current poor condition of the environment, we now know that this situation was in existence long before the arrival of humans. Even when the island featured a palm forest, the soils were not particularly fertile.[19] While historic erosion from sheep ranching in the last century may have left the island with even less fertile soil, the contemporary environment is not much different from what prehistoric occupants faced in their struggle to grow crops.

The picture that had emerged provided an entirely new understanding of the prehistoric record. We had long assumed, as had many others, that Rapa Nui's volcanic origin bestowed it with reasonably productive soils. The largest constraint on agriculture on the island, we had assumed, was lack of reliable rainfall and flowing streams that could have been diverted for irrigation. But now it was becoming clear that Rapa Nui's soils had been fundamentally unproductive, and for a very long time. According to recent models[20] of the volcanic origins of the island, the bulk of Rano Kau on the southwest corner of the island was formed by eruptions that occurred between 450,000 and 940,000 years ago. Terevaka, to the north, and the source of much of the island's overall landmass, was volcanically active between 460,000 and 780,000 years ago. Overall, these volcanoes are old enough to have lost primarily mineral nutrients.[21]

Initially, the soil that is formed from freshly erupted volcanic ash and rock contains abundant minerals. Phosphorus and nitrogen, vital parts of photosynthesis—the conversion of solar energy to chemical energy—are abundant enough. Over time, however, the quotient of these nutrients declines with leaching from rainwater and use by plants. Consequently, while young volcanic islands are some of the most biologically productive places on earth, those with older volcanoes can be impoverished, even with adequate rainfall. In fact, abundant rainfall exacerbates the situation as mineral nutrients are flushed from the soil.

In the case of Rapa Nui, the volcanic soils are hundreds of thousands of years old and greatly depleted of their nutrients. The island, therefore, has been a poor place in which to make a living by farming since long before people arrived in AD 1200. Indeed, studies conducted by soil scientists Geertrui Louwagie and Roger Langohr confirm that water was not the main problem for the prehistoric farmers on the island, but rather, limited soil nutrients were. Using data for crop growth coupled with experiments of cultivation in four areas on Rapa Nui, Louwagie and Langohr demonstrated that only the addition of lithic mulching made soils rich enough to support even marginal conditions for plant growth.

This understanding was a revelation to us. The truth of cultivation on the island was that only the ingenuity of the islanders made it possible to produce a reliable food crop. One immediately obvious implication of lithic mulching as a central part of subsistence on Rapa Nui is that there must have been a staggering amount of labor invested in moving rocks. With an estimate of thirty square miles, the number of rocks that prehistoric islanders moved, broke, buried, and scattered on the surface is astronomical. Indeed, based on a study of lithic mulching at more than five hundred sites across Rapa Nui, Bork and his colleagues estimate that the total amount of stones weighed in excess of two million tons and individually numbered well over a billion. Given that many of the rock sources are nearby, but still a short distance away from the cultivation areas (about 150–200 feet), they estimate that the islanders traveled an aggregate of eight million miles over the duration of five hundred years of prehistoric cultivation.[22]

With this new understanding of the intensive work the islanders put into making cultivation possible on the island, we began to revisit the issue of the islanders' role in the fate of the *Jubaea* palm forest. The evidence was strong that it was a boom in the population of rats that had contributed significantly to the loss of forest. But we might ask, why didn't the islanders work to replenish the forest? If they were such dedicated stewards of their environment, this might have been expected. Indeed, while people probably did not engage in wholesale destruction of the forest, they did clear some forest.

Part of the answer comes from the fact that the *Jubaea* palms are slow growing. It takes several years for the tree to form a trunk and sixty years or more to produce seeds.[23] With rats consuming so many of the palm nuts, as the record suggests, few trees would regrow naturally. Even if the islanders had vigorously planted nuts in an attempt to replenish the forest, the palms would have taken multiple human generations to produce food. Meanwhile, rats would happily eat tender young palm seedlings as well as the nuts. As long as there were palms, there would be nuts, and rats to feed on them. Cultivating land on which the forest once stood meant a higher yield of food in Rapa Nui subsistence. As palms declined, more area became available for planting, and burned organic material from palms would have provided an important, albeit temporary, source of nutrients for crops. In this way, the decimation of the forest was by no means an ecological disaster, as least not as far as the human population was concerned.

This is the form of cultivation popularly known as slash-and-burn. Forms of it have been used in nearly every forested environment, including other Pacific islands, northern Europe, the Amazonian rain forest, Southeast Asia, and prehistoric North America. Also aptly called "shifting cultivation," the strategy typically requires populations to move from place to place, as the gain in soil productivity is temporary. When populations are able to move garden plots, slash-and-burn strategies can be sustained for long periods of time. Often groups follow a long-term rotation of land use, returning to areas only after trees and soil nutrients have regenerated.

On Rapa Nui, of course, neither expansion to new forested areas nor long-term rounds were possible within a short time, so shifting cultivation was only a temporary solution. Consequently, farmers soon switched to intensive use of *manavai* and lithic mulch.

Now let's revisit the question of why we find no *manavai* or rock mulch gardens on the slopes of Poike, the easternmost volcano on the island. Poike is distinct because unlike the slopes of the other two volcanoes, Rano Kau and Terevaka, its slopes contain almost no rock. Instead the slopes of Poike are covered with fine-grained soil from volcanic ash.

The lack of surface rock played a central role in traditional accounts of the conflict between two groups of islanders known as the Long Ears and Short Ears, said to have escalated out of control. Thor Heyerdahl, for example, writes:

> The long ears' last idea was to rid the whole of Easter Island of superfluous stone, so that all the earth could be cultivated. This work was begun on the Poike plateau, the easternmost part of the island, and the short ears had to carry every single loose stone to the edge of the cliff and fling it into the sea. This is why there is not a single loose stone on the grassy peninsula of Poike today, while the rest of the island is thickly covered with black and red scree and lava blocks.
>
> Now things were going too far for the short ears. They were tired of carrying stones for the long ears. They decided on war. The long ears fled from every other part of the island and established themselves at the easternmost end, on the cleared Poike peninsula.[24]

We would assert that this is a rather far-fetched tale. From the perspective of European farming, Poike would seem to be a superior location for growing crops, and according to that view of farming, rocks must be removed to make cultivation possible, especially with plowing. However, the volcano is ancient, even more so than

Terevaka, with the ash deposits that form its slopes produced by eruptions some 400,000 to almost 900,000 years ago. Perhaps even more than the rest of the island, the volcanic ash soil of Poike is heavily weathered and, as a result, is poor in mineral nutrients. These poor soils would pose a great challenge in producing any appreciable crop yield. Archaeological evidence shows that early colonists did cultivate the soils of Poike. But the evidence also indicates that these efforts at cultivation were soon abandoned.[25]

Using satellite images for our research, we were intrigued to find large swaths of parallel lines that showed up in our photos on the slopes of Poike. These lines are clearly visible in the images available on Google Earth. These parallel lines bear the unmistakable characteristics of crop furrows, marks made by the farmers to prepare soil for crops. We showed these marks to Sergio Rapu, a local archaeologist who earned a master's degree in anthropology at the University of Hawaii and served as the first native Rapanui governor of the island, and wondered whether this was previously unknown evidence of ancient farming. Sergio chuckled and immediately recognized the marks as an aborted attempt to grow corn on Poike just a decade or two ago. Despite the availability of industrial tools, the poor quality of the soil does not support crop growth.

So if the islanders wanted to cultivate the volcano's slopes, they would have needed to enrich the soil. Lithic mulching might have been a way to do so, which would, of course, have meant they would have brought rocks in to cover more of the surface, not have taken them away. But as we've seen, lithic mulching only marginally increases the quality of soil, and so it makes sense that the islanders would not have engaged in the practice at Poike.

We do see evidence of soil erosion on the volcano, and this has been cited as evidence for prehistoric environmental degradation. Indeed, it is clear that a palm forest once existed on Poike, and it is likely that it suffered the same fate as the forest elsewhere, being depleted both by rats and by the clearing of the land in initial attempts at cultivation. At first, burning the palms and other vegetation would have enriched the soil enough for crop growth, but soon after, cultivation was no longer feasible. No dramatic story of overexploitation or ecological collapse is needed to explain this outcome.

Our new understanding of the strategies used by the islanders to produce food in a sustainable fashion highlights the relationship of the human population to the environment of Rapa Nui. We now know that the island was never particularly productive, given the limited marine resources, the small number of introduced animals and cultigens, and the nutrient-poor volcanic soils.

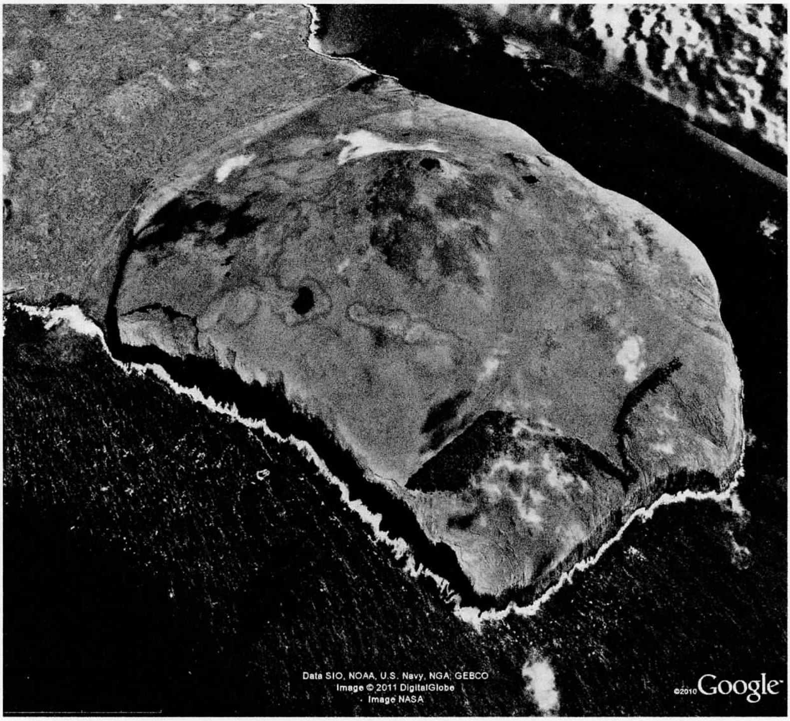

Figure 3.6. Google Earth perspective of the Poike Peninsula. The large scarred areas on the south and southeast margins of Poike are the result of historic erosion from sheep ranching. The lines along the eroded areas are eucalyptus trees planted in attempts to stem further erosion. These conservation efforts have not been particularly successful.

Over the long run, the islanders invested their energy in effective efforts to produce food in good times and bad given the resources available to them.

In light of this knowledge, we can readily see the unwarranted nature of claims for a prehistoric environmental catastrophe that turned a once-productive island into a barren landscape. If anything, the islanders contributed to an increase in the human carrying capacity of the island over time. We can also readily see that there is no reason to suspect that population sizes for the island ever greatly exceeded the numbers witnessed at the time of European contact in AD 1722. The first Europeans encountered a functional economic and social system shaped by five hundred years of experience of making a living on this modest island. The population of around three thousand recorded in 1722 reflects a sustainable size for the island, not one dramatically reduced through conflict and starvation.[26]

All of these findings suggest that rather than a case of abject failure, Rapa Nui is an unlikely story of success. Using the skills, knowledge, and materials available, and adapting them to meet the specific conditions, the islanders transformed Rapa Nui from an island covered in palm forest, with few resources for humans, into an island that could reliably, though marginally, sustain them over the long run.

Initially, the islanders practiced slash-and-burn cultivation, and as the forest declined, they created a series of *manavai* gardens while also laboriously turning the landscape into an engineered series of massive fields fertilized by broken volcanic rocks placed on the surface and in the ground. Little by little the island was transformed into an endless series of gardens. The story of Rapa Nui is one not of ecological suicide but of persistence and resilience in which the islanders employed innovative approaches and a willingness to invest massive amounts of labor.

Our understanding of the history of ecological management of Rapa Nui also contradicts, of course, the notion that the forest was depleted in large part for the purpose of building contraptions for transporting the massive statues. But if this wasn't the case, then the question of how the islanders did manage to move their statues becomes all the more puzzling. And if the islanders weren't the rapacious destroyers of their environment they have been depicted as, then we must revisit the notion that making and moving statues became a great burden to the island and its culture, contributing to its collapse. So let us now turn to this part of the Easter Island mystery.

CHAPTER 5

The Statues That Walked

They walked, and some fell by the way.
—Katherine Routledge,
The Mystery of Easter Island,
1919

The statue quarry of Rano Raraku, carved into the cliffside of the volcano's crater, is an amazing sight. Hundreds of *moai* stand proudly along the crater's slopes, with many others at the base of the quarry that seem to be waiting their turn for transport. Yet others are buried a good way into the ground, some all the way up to their heads. Congregated here in so many states and positions, they conjure up a vision of scores of artisans at work and an eerie sense that the latter have just left, planning to return tomorrow. It is easy to imagine that their work ceased in a single moment, as if, as with Pompeii, some catastrophe occurred. We were to find that the state of preservation of the quarry's remains is a treasure trove of clues about the greatest mystery regarding the *moai.*

The walls of the crater are formed by a relatively easily carved tuff born of an explosive eruption that left behind compressed particles of ash and basalt stones. To do their carving, the islanders used crude hand axes known as *toki,* made out of basalt much harder than the quarry's volcanic tuff. Hundreds of *toki* litter the surface, and the quarry walls are covered in the markings made

Figure 5.1. The *moai* quarry at Rano Raraku.

from them during carving, each mark an evocative vestige of a single swing of an axe.

We know that statue carving often started with the face, as numerous faces peer out from the cliffside—nose, eyes, and mouth—in the process of being shaped. Carvers continued, completing the ears, chin, and neck, and moved on from there to the arms and the rest of the body. Many of the statues left in progress are standing vertically, but some were being carved horizontally. All together, with so many partial faces and bodies projecting from it, the face of the Rano Raraku cliff looks like an M. C. Escher drawing, with statues interlocked and overlapping in complex patterns.

The many partially completed statues tell us that once the front of a statue was finished, the carvers removed material from the sides and underneath, working from both sides and moving in toward a final ridge of tuff along the whole length of the emerging statue, which formed a keel that held it fast to the bedrock. For those statues carved high up on the cliff, it's likely that rope was then fastened around the statue from above. The final ridge of tuff was then cut away, and the statue was lowered down the slope to the crater's base. Large carved holes in the bedrock near the crater's summit are likely evidence of giant palm logs fixed into the cliffside as part of massive pulleys used to maneuver at least some of the *moai*. For the statues carved on the lower slopes, it seems they were slid down, leaving grooves worn into the crater's surface.

Not all statues successfully completed this journey. Some cracked along the way and were abandoned. We know that the head of one of these, still found at the quarry, was refashioned into a much smaller statue. Many other statues were left either lying or standing on the steep slopes. There is also an array of statues standing upright at the base of the quarry, many of them deeply buried so that just their heads are exposed. Often referred to as heads, these were a mystery, and continue to confuse many observers, but excavations first by Katherine Routledge and then by Thor Heyerdahl revealed that these were in fact full statues

Figure 5.2. *Moai* at the base of quarry in upright position with carving on back complete.

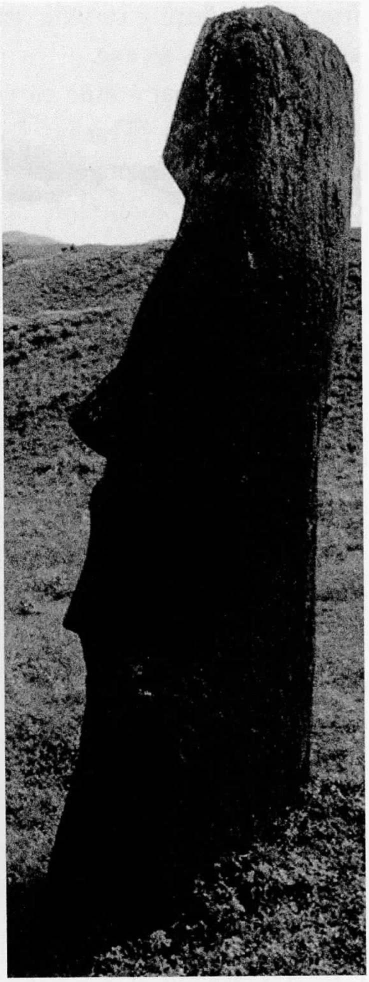

Figure 5.3. *Moai* at the base of quarry in upright position with incomplete back.

that ancient carvers had left standing in deep trenches once dug into the crater's lower slopes. The ancient trenches were either buried by the statue makers or filled in by sedimentation from centuries of erosion, leaving only the heads of the statues above the surface.

This suggests that by dragging and lowering the statues down the slope of the quarry, they were slid into the trenches, or sort of dropped gently into an upright position, where they could be erected easily to finish their carving. The outer edges of the quarry feature a series of these trenches, cut out perpendicularly from the slopes, filled with fragments and flakes of battered *toki*.

Figures 5.2 and 5.3 show statues located near each other on the bottom of the outer slope of the quarry. Each was carved from the upper slopes and lowered into trenches and left upright, but with the one on the left some additional carving had been done. The statue's head is thin and extended slightly forward. In addition, there are well-defined shoulders that are distinct from a somewhat "craned" neck. In contrast, the statue on the right has no neck or shoulders. Instead the long axis of the back is largely flat and continuous. This shape is a result of the long "keel" that once attached the statue to the bedrock from which it was shaped.

Once the statues were completed in terms of shape and balance, they were sent on a journey to their designated *ahu* along the roadways. As we have described, the *moai* roads are marked by a variety of constructed features—stone-lined curbs, leveled and flattened surfaces, cleared of stones—which must surely have played roles in moving the statues.

There has been much debate through the years about why so many statues were left at the quarry. Echoing Routledge and others, Jo Anne Van Tilburg claims that at least some were intended to remain at the quarry, never meant to be moved. In carefully studying all of the existing evidence, and making a series of our own observations and analyses, we found that the statues left at the quarry offer vital clues to answering the great outstanding question of just how the statues of Rapa Nui were moved.

Two basic notions about how they were transported have been proposed. One is that they were moved upright by an intricate method of rocking them that made them "walk." The other is that they were placed horizontally, in the prone or supine position, on a wood platform of one kind or another and pushed or pulled in some fashion. A fascinating set of experiments has been conducted in attempts to test these competing ideas.

Thor Heyerdahl and members of his Norwegian archaeological expedition in 1955–56 began this process of experimenting with making and moving *moai.* Heyerdahl directed 180 islanders to place a medium-sized *moai* on a sled made of a forked tree and drag it a short distance using two parallel ropes (depicted in Heyerdahl's book *Aku-Aku*). This awkward "experiment" was met with polite skepticism by islanders who insisted, simply, that their ancestors had made the *moai* "walk." That the statues were moved vertically, with some apparently abandoned in their upright positions along the way, is also supported by some historical observations. For example, members of Captain James Cook's crew describe taking shelter in the shade of a standing statue (not on an *ahu* platform) near Ahu Oroi along the south coast. This statue later fell, as we find it today.

William Mulloy, the young American archaeologist on that expedition, would continue work on the island, and he took the walking notion to heart, proposing a method of swinging a semi-upright *moai* suspended by its neck with ropes from a wooden bipod, a contraption like a tripod but with only two legs. No one ever tested Mulloy's theory by experiment, and indeed it would have proven difficult to move the statues that way, to say the least.

More progress was made by Czech engineer Pavel Pavel. He had studied Heyerdahl's experiment, including the film of 180 islanders arduously dragging a *moai* a short distance, and he thought there must have been a better way. He envisioned walking *moai* by a method that at first seemed impossible. Imaginatively, he made clay *moai* models in miniature and discovered that their center of gravity often occurred at about one-third of their height, making them stable, like a bowling pin. His next step was to try moving a full-size standing *moai.* Using the grounds of the technical secondary school in the medieval town of Strakonice in then-communist Czechoslovakia, Pavel fashioned a concrete *moai* about fourteen feet tall and weighing a respectable twelve tons.

In July 1982 in Strakonice, Pavel and sixteen men working in two groups put his ideas to the test with this massive concrete *moai*. With ropes one group pulled the upright statue to tilt it on edge, while at the same moment the second group pulled to twist it into its first "step." By careful coordination, rhythmic pulls and twists wiggled the massive stone statue forward in a walking motion. For obvious reasons, this approach was quickly dubbed the "refrigerator method." Pavel's experiment showed that a small number of people, working in careful unison, could readily move a multi-ton *moai*.

In 1986, Thor Heyerdahl invited Pavel to join the Kon-Tiki Museum expedition to Easter Island to try out his theory on an authentic stone statue. Pavel's team prudently started off with a small *moai* that had been displaced in modern times. Abandoned behind the village post office in Hanga Roa, this lonely *moai* measured just over eight feet and weighed between four to five tons. A team of only eight people, carefully orchestrating pulls and twists of ropes, walked this *moai* forward with relative ease. But perhaps this small statue was too easy. The next challenge came with a larger *moai* measuring twelve feet tall and weighing about nine tons. The *moai* was padded with reeds and tethered with ropes, and just sixteen people jerked, tilted, twisted, and rocked this upright giant with remarkable success. It was a truly exciting moment for the Rapanui and Europeans alike. Heyerdahl later described the scene:

> Pavel spoke no language known to any of us, but he was a genius in making his orders understood by gesture, waving his arms and feet. As the experiment started it was difficult to tilt the statue over on one edge, but as soon as the workers began jerking rather than pulling steadily, the procedure became much easier. When the two groups, with more practice, succeeded in finding the exact moments of coordinating the sideways and forward jerks,

> they worked together rhythmically, easily and without strain. In this manner the experimental image wriggled forward as if it were "walking." . . . At first we were scared stiff that the men with the top ropes would pull so hard that the giant would capsize, but Pavel reassured us that the design of the *moai* was so ingenious that the colossus would have to tilt almost sixty degrees before it would fall over. . . . We all felt a chill down our backs when we saw the sight that must have been so familiar to the early ancestors of the people around us . . . an estimated ten tons "walking" like a dog on a leash.[1]

From these experiments Pavel estimated that small crews of experienced movers could transport *moai* as much as six hundred feet a day.

An elder Rapanui man witnessing the experiment, Leonardo Haoa Pakomio, explained to Heyerdahl that they not only had a song for walking *moai,* but a specific word to describe their unique motion: *neke-neke. Neke-neke* translates as inching forward by moving the body with disabled legs, or no legs at all. Leonardo demonstrated the meaning of *neke-neke* by alternately pivoting on the balls and heels of his feet, rocking slightly, and keeping his knees stiff. Heyerdahl responded: "what other language in the world would have a special word for walking without legs?"[2]

Not everyone was convinced, though. Ferren MacIntyre, a scientist with a breadth of interests at the National University of Ireland, took a critical look at the theories and pointed out that anyone who has moved a refrigerator can appreciate the merits of Pavel's experiments. But, he suggested, Pavel's method would damage the base of the *moai,* not to mention that moving them standing meant that "the line between meta-stability and disaster is uncomfortably thin."[3] To solve potential stability problems, MacIntyre proposed adding a curved timber rocking foot and side rig. Like Pavel, this method suggests the feasibility of moving *moai* in an upright position with relative ease and employing only a small team of workers. However, this method has yet to be tested in transport experiments.

Charlie Love, who did so much research uncovering the roads, thought that Pavel's method worked fine, but he believed it would prove impractical for long-distance transport.[4] Love reasoned that transport had to be accomplished with little damage to the finished statue, and in his own experiment he and his team used timber and ropes to construct a "pod" attached to the base of the statue, making it possible to roll it upright over several logs. The logs or "rails" could be brought up from the rear and placed in the path of the moving giant. Using a twelve-foot-tall, eight-ton concrete *moai* replica on the cold windswept plains in his home state of Wyoming, Love and his team rumbled the statue 150 feet along timber rollers in just two minutes. The dramatic experiment was caught on film and featured in a television documentary in 2000. Whether Love's experiment captured a method actually used remains unknown. But this successful experiment did reinforce Pavel's finding that a relatively small group, well coordinated to be sure, could move a giant standing *moai* significant distances.

In contrast, statue researcher Jo Anne Van Tilburg offered a different theory. In her view, horizontal transport of the *moai* was a matter of the logic of the statues' design. Van Tilburg started with a small one-tenth scale model of what she considered a "statistically average *moai*," dubbed "Sam" from its acronym.[5] Sam was scanned to create a digital image for computer simulations. In the same research, Van Tilburg used a digitized map to find optimal paths for moving Sam across the island from the quarry at Rano Raraku to Ahu Akivi.[6]

She then molded a twelve-foot, ten-ton statue replica in concrete on Rapa Nui to employ in her experiments. She and her collaborators used a wooden transport sledge constructed of beams of modern eucalyptus trunks arranged in a semitriangular ("A-frame") form. The team placed the statue in a horizontal position onto the frame with a lift from a modern crane, either faceup or facedown. Like Love's method, the rails could be repositioned from rear to front as the massive stone payload rolled forward. Misalignments and jamming of the log rollers in the first experiment led the team to formulate a modified design modeled after a Polynesian "canoe ladder." This altered sledge had "sliders" lashed to the triangular frame supporting the statue, keeping it from going astray. As it turned out, sliding over longitudinal rails worked, but rolling did not. Van Tilburg and her large team of islanders pulled the sledge hundreds of feet over level ground, impeded only by the limitations of manpower and rock outcroppings blocking the path of travel. She showed that about forty people could pull a ten-ton statue this way with little trouble.

Van Tilburg's experiment was featured in a 2000 *Nova* television documentary about moving and erecting *moai.* To provide a critique of the experiment *Nova* invited Vince Lee, an American architect who had studied how massive stone blocks could have been moved into place for Inca constructions like those at Machu Picchu in Peru. Lee recognized that once the statues reached their destinations, the steep stone-constructed *ahu* platforms perched on cliffs above the sea, the pullers, who had to be out front, had nowhere to go in order to pull the statue all the way up the steep incline leading to the *ahu.* So Van Tilburg's theory quickly met with significant skepticism. Lee hypothesized that using levers could solve the problem. He designed a set of ladderlike frames, where one frame sits atop another and levers operated between them provide the leverage for efficient movement of the statue up to the *ahu.* These levered sleds could be maneuvered by a small team, with the slider pieces being continually leapfrogged ahead, which would allow them to move *moai* over a variety of slopes and terrain. The levered sleds could "turn on a dime" and move a heavy payload up an incline onto the *ahu* without anyone working on the seaward side. Despite some problems with Lee's admittedly impromptu solution on Rapa Nui, his team of twelve men levered a six-ton monolith about fifteen feet in an hour and a half, each man easily moving one thousand pounds of rock.

About a year later, Lee perfected his experiment in Colorado, where, using the sled and slider ladders, twenty-five volunteers moved a thirteen-ton block of marble across an equipment yard, up a 25 percent slope, and rotated this payload 90 degrees, all in about two hours. The experiment convincingly replicated the maneuvering that seemed necessary to place multi-ton *moai* atop monumental *ahu* platforms just above sea cliffs. Lee admits there is no direct evidence that this method was actually used, but he points out that no other system he imagined could achieve these results.[7]

Experiments are just that. They show plausible solutions and sometimes reveal the possible and impossible. But we must be careful not to overinterpret the significance of *moai*-moving replications. In any case, making sense of experiments and building the best explanations of what happened must take the actual archaeological evidence into consideration. This is what we set about doing.

Some debate and speculation still surrounds why so many statues were left along the roads. Our close examinations of these particular *moai* provide an answer. We can identify a number of attributes showing that the statues along the roadways reflect abandonment due to failure that occurred during transport. One reason we know this is that none of these statues has completed eye sockets, and we know that carvers waited until the statues had arrived at their *ahu* destinations before adding the eyes. In excavations at Anakena, archaeologist Sergio Rapu discovered that one of the last steps of completing a statue was inserting white coral eyes with pupils of black obsidian insets. The statues were "blind" as they moved along the roads, until reaching their place of final enshrinement, where emplacing their eyes brought these stone ancestors to life. A second clue that the statues were abandoned due to failed transport is their position: nearly all are aligned with the road's direction and heading away from the quarry. As monuments placed along roads as markers or guardians that had fallen over time, one might expect these fallen giants to be found in random positions, with some lying across or diagonal to the road.

We decided to study these *moai* left by the roads more closely, and our surveying of the ancient roads helped us here. When we had followed the ancient paths, we had documented over fifty statues that lay either on or directly adjacent to the roads. As we now examined multiple attributes of those statues along the roads, we couldn't help but notice that many of them had broken into two or more pieces. In most cases, the breaks occurred where you would expect them: along the thinnest—that is, the weakest—portions of the *moai*. We also noticed that some statue fragments, especially the heads, were separated sometimes by a few feet or more, indicating that when the statue broke, the force propelled the fragments forward or back. Katherine Routledge observed the same. She wrote about the *moai* along the roads, "some single figures are lying unbroken," but "others . . . proved to be so shattered that no amount of normal disintegration or shifting of soil could account for their condition—they had obviously fallen."[8] The statues falling from a vertical position seemed the only way to explain this pattern in the fragments.

Furthermore, we noted, as Routledge had observed long before us, that some *moai* found along ancient roadways lay on their backs and some on their faces. If they were moved horizontally on sledges, as Heyerdahl first proposed and Van Tilburg continues to assert, then the positions on the roads should reflect how they

Figure 5.4. A view of a statue that has fallen during transport.

were placed on such contraptions. Moved horizontally, we should expect to find *moai* either faceup or facedown in more or less random associations regardless of their location, the slope of the road, or other features. But this is not what we found. Instead we discovered that their positions either faceup or facedown seemed to depend on whether they had been moving up an incline or down one.

When statues were heading upslope we usually found them resting on their backs, and when heading downslope they were on their faces.[9] A quick statistical test shows that this association cannot be explained as random. This is more support for the argument that the statues were moved upright. Rocking a standing statue back and forth would naturally result in falling forward on the downslope and backward on the upslope. Close study of the data gave us some intriguing additional support for the argument that the statues were moved upright. We made note of two statues on the southern part of the island that had come to rest at perpendicular angles, that is, somewhere between standing and fallen. These *moai* are partially buried, one at the base with his head found well above the ground, the other almost completely buried in a nearly vertical position. We conjectured that these *moai* must have fallen in transport and were then brought to their positions by attempts to re-erect them by excavating a pit. The logic is that a fallen statue could be re-erected by digging a pit near the base, sliding him into it to reestablish a vertical position, and then walking him out along a ramp of earth from the excavation. In the two cases we observed, the ancient project was apparently never completed and time has allowed the earth to fill in the pit around the *moai*.

We reasoned we might find further important evidence for upright "walking" by examining the wear-and-tear on the abandoned statues, and as we inspected them, another consistent pattern became clear. Guided by Sergio Rapu, we noticed that many *moai* had suffered damage along the sides of their base. This damage took the form of concave scars emanating from their base, what archaeologists call conchoidal fracture, *conchoidal* meaning cone-shaped. Conchoidal fracture produces flakes in stone. Physics tells us that conchoidal fracture results from substantial pressure that forces flakes from a stone. The fracturing we found at the edges of the *moai* bases, from the bottom up, was precisely the damage that would come from the statues being rocked back and forth in a vertical position.

Looking at the statues themselves, their locations, breakage, and positions on slopes, confirmed to us that they had walked from the quarry. The first experiments by Heyerdahl, and more recent attempts by Van Tilburg and Lee, showed ways to move massive loads horizontally with varying success, but these methods do not fit what we find in the archaeological record itself. This leaves us with the vertical method of walking proposed by Pavel, or perhaps those tried by Love and Lee, using pods, sleds, or devices with levers. But the theories for pods, sleds, ladders, or other wooden contraptions raise another problem. The only large tree known from Rapa Nui is the palm, *Jubaea chilensis,* or a close relative. Palm trunks have a thin, dense, brittle kind of bark and a soft, fibrous interior. Palms employed in the heavy work of *moai* moving would certainly see the bark crack, leaving the soft interior to be crushed. For the same reason, palms did not provide suitable wood for making canoes. So, not only were the *moai* moved vertically, we argue, but that was done without the aid of a wooden device, just as Pavel had demonstrated.

After learning that the *moai* were moved vertically, and without wooden contraptions, we wondered if the statues themselves might tell us more about their transport. On one of our visits to the statue quarry at Rano Raraku with Sergio Rapu, we began to find more answers. When we asked him about how the statues had been moved, Sergio pointed to the overall shape of the *moai.* Notice, he said, how the statues have a large belly and wide bases in the quarry, but they've slimmed down at the *ahu.* Also, note how their bases are angled, making them seem to lean forward slightly. These features, he commented, were not shaped for some kind of ancient aesthetic. Instead the *moai* were carved this way to move them. The problem was not just carving a *moai,* but carving one that could be moved. Reshaping that was done to the statues once they were erected at the *ahu* obliterated some of this telltale evidence. "*Moai* liposuction" prepared them for permanent display. Looking closely, we recognized that the *moai* standing on *ahu* had narrower bases and smaller bellies than those still on the roads, giving them a more imposing athletic physique. Excavations of *ahu* have revealed the debris of volcanic tuff shaved off *moai* in their cosmetic makeovers, archaeologically confirming the timing and locations of the changes. The *moai*, Sergio explained with pride for his ancestors, were engineered to move.

Engineered to move. We immediately realized this made absolute sense. Statue carvers could fashion forms of any shape, size, or configuration. Nothing but imagination constrained their artistic license, nothing unless the statue was to be transported without falling on its way to the *ahu*. Talking with Sergio and then contemplating *moai* along the roads, we realized that that is where the statue's center of mass (often referred to as "center of gravity") proved critical. The center of mass for an object represents a point where the mass is evenly balanced in all directions. In a regular object such as a sphere, this point is usually in the center, and if we could rotate an object around its center of mass, it would spin freely in all directions, as some globes do. A low center of mass is helpful for making objects stable in motion: skiers squat low to make tight, sharp turns and engineers design race cars to have a low center of mass to improve handling.

Thinking back to the many statues we had measured along the ancient roadways, we could envision how changing the center of mass by altering the shape of a statue would affect its ability to be moved. It was basic physics. Consider an object shaped like a cone, with its narrow end pointed down to the ground. The center of mass will be near the top. As long as the center of mass is directly over the point touching the ground, the cone remains upright, but it's a tricky balancing act. Just a little push and the cone will topple over.

If you've ever tried to balance a soda bottle upside down, you can readily imagine the scenario. This relatively high placement of the center of mass would be highly beneficial, though, if the goal were to move the object. A small input of energy would result in a big effect.

In contrast, when the center of mass is low, an object becomes relatively stable. Think of a bowling pin, for example. It takes a lot of movement, and energy, to tilt a cone with the wide side at the bottom and make it fall over, and the wider the base, the farther one has to tilt the cone.

To evaluate the properties of the center of mass of the *moai,* we both measured and photographed a number of them. This work resulted in three-dimensional wire-frame representations of the statues.[10] The figure below shows the result for a statue that had fallen during transport.

We measured the center of mass along each of three spatial dimensions. Obviously, the center of gravity was located in the middle of the statue in terms of its width. This position is not surprising, since the statues are generally left/right symmetric, and if the center of gravity were not in the middle, the statues would tend to lean to the left or right. The height of the center of mass is

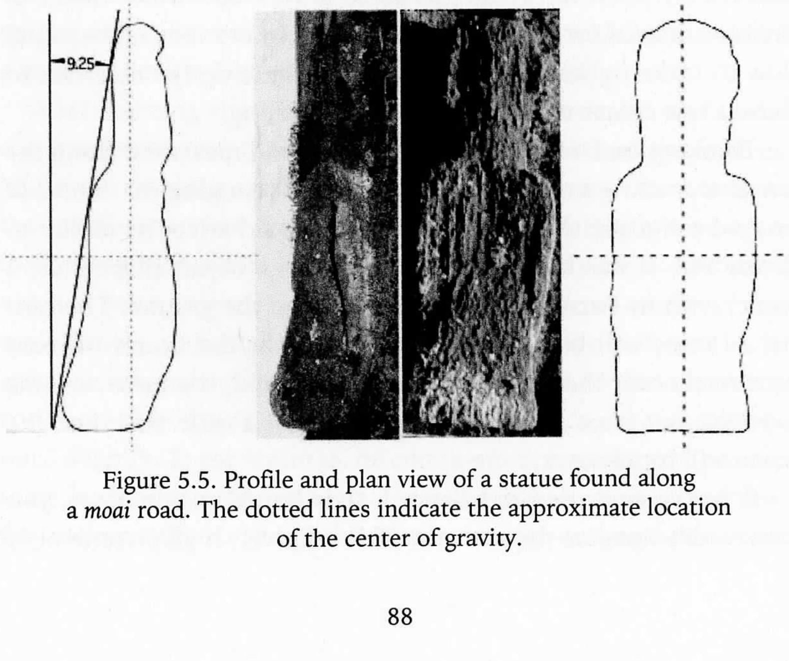

Figure 5.5. Profile and plan view of a statue found along a *moai* road. The dotted lines indicate the approximate location of the center of gravity.

also approximately in the center of the statue—midway between the base and the top of the head. But the center of mass in the depth dimension is remarkably forward relative to the base of the statue, just as Sergio had shown us. This was revelatory.

First, we cannot easily explain the peculiar location of the center of mass if the statues were transported horizontally. In fact, one would expect to find the center of mass toward the base, as this would facilitate raising the statue back up to its vertical orientation when placed on the *ahu*; it would effectively raise itself. There would also be no good reason for the center of mass to be located so close to the front.

On the other hand, this location of the center of mass makes a lot of sense for vertical transport through "walking." With the center of mass positioned at the front, rocking the statue back and forth is made relatively easy. This is similar to the physics of an inverse pendulum, which, unlike a regular pendulum, is turned upside down so the top swings back and forth from a fixed base. Both kinds of pendulums require very little energy to make them stay in motion for quite some time; they are very efficient at converting the energy we use to set them moving, and their own latent energy, called gravitational potential energy, into the kinetic energy of movement. As a pendulum swings, it travels an arc that spans from its highest point, when it has the most potential energy, through the bottom, when its velocity, and thus its kinetic energy, reaches a maximum, back to the level where it started when it very briefly slows to a stop. As the pendulum falls back down the other way, its potential energy is once again converted into kinetic energy, and the conversion is close to 100 percent.

The movement of an inverse pendulum also provides insight into the mechanics of our own walking. With each step you transform yourself into an inverted pendulum. When you pick up your leg to walk forward, you pivot on the foot that is placed on the ground. As you pivot, your center of mass—somewhere in the belly—follows the path of an arc. Your forward foot eventually hits the ground and your arc slows to a stop in that direction. At that point your kinetic energy is at a minimum—but your potential energy is at a maximum. As you fall forward into the next step, the stored potential energy is converted back into kinetic energy, and you accelerate again. This is the basic physics of walking. Moving large upright objects such as refrigerators and *moai* takes advantage of the same principle.

The forward and midlevel positioning of the center of gravity in the *moai* allowed them to be easily tipped back without falling over. The farther back a statue can be tipped, the farther the center of gravity can be swung forward. This maximizes the amount of potential energy as the statue is rocked and thus the farther forward it can be moved on each next swing. Of course, the center of gravity cannot be placed too far forward or the statue will easily fall facedown. With a margin of error provided, the position of the center of gravity almost—but not quite—to the forward edge is optimal for statue walking, but accidents were clearly to be expected. Once the statues were walking, the problem may have been stopping them.

Movement in this way also accounts for the shape of the statue bases, at least for the larger *moai*. The figure on page 91 shows the base of a statue that fell while being transported. The statue is lying facedown; its large belly is visible along the bottom edge. The shape of the base is related to how the statues were moved.

The front edge (toward the bottom of the photo) is strongly rounded, as that would be the portion of the base that would rotate while the statue was tilted. The back of the base is slightly rounded. The sides of the base, on the other hand, are relatively straight. This shape provided a long edge for initiating the tilting of the statue. The large surface area minimized the potential failure of the material caused by the weight of the statue. The curved front edge, however, reduced surface area and thus the friction as the statue rotated. Less friction meant easier moving, and less wear to the bottom of the *moai*.

Not all statues are shaped this way. Some have much wider bases, and others are more symmetric. Smaller statues, in particular, are quite variable. The taller and larger *moai*, however, are

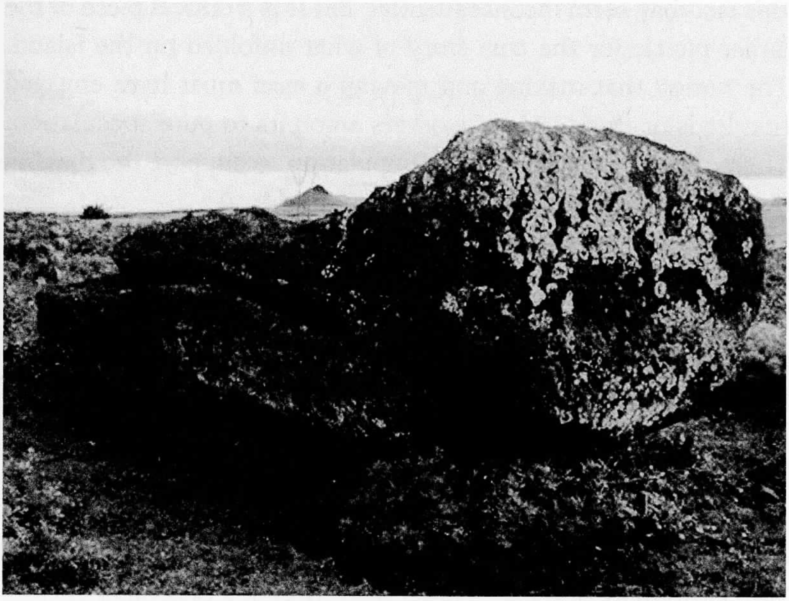

Figure 5.6. A view of the base of a *moai* fallen in transport along an ancient road.

more similar in shape and form to each other. And this makes perfect sense, since the larger the statue, the more important it would have been that the shape conform to the constraints dictated by transport. While a small statue might be moved regardless of its shape, the larger statues would have been a very different story. To those most skeptical we concede that it is possible that while the larger statues consistently have a form enabling vertical transport, they were nonetheless moved horizontally. However, we conclude that such a consistent center of mass that would have aided "walking" makes their horizontal transport most unlikely. Of course, the precise details of how the ancients moved the statues are still being teased out of the details of the archaeological record. But we believe it's clear that the archaeological facts, like the island folklore, tell us the *moai* "walked." They moved upright, traveling slowly and steadily over challenging terrain, propelled by teams of probably only fifteen to twenty people. Taken alone, this fact may seem inconsequential. But it is a critical piece of the larger puzzle for the true story of what unfolded on the island. The notion that making and moving a *moai* must have engaged hundreds or thousands of workers amounts to pure speculation. There was no need for a large population to support the making and moving of these monuments.

Walking the *moai* would have required cooperation, but not a powerful paramount chief overseeing a complex organization of conscripted carvers and pullers. The expediently constructed *moai* roads and the statues found along them reflect, we believe, the work of small-scale social groups. And walking the *moai* did not require vast amounts of timber for wooden sleds, rollers, or sliders. It was not a reckless mania for *moai* that exhausted the island's forest and tipped the ecological scales toward catastrophe. Solving the mystery of how the ancient islanders moved the *moai* pointed us to a dramatically different story for Rapa Nui, one that was written in stone and awaiting our best efforts to decipher it.