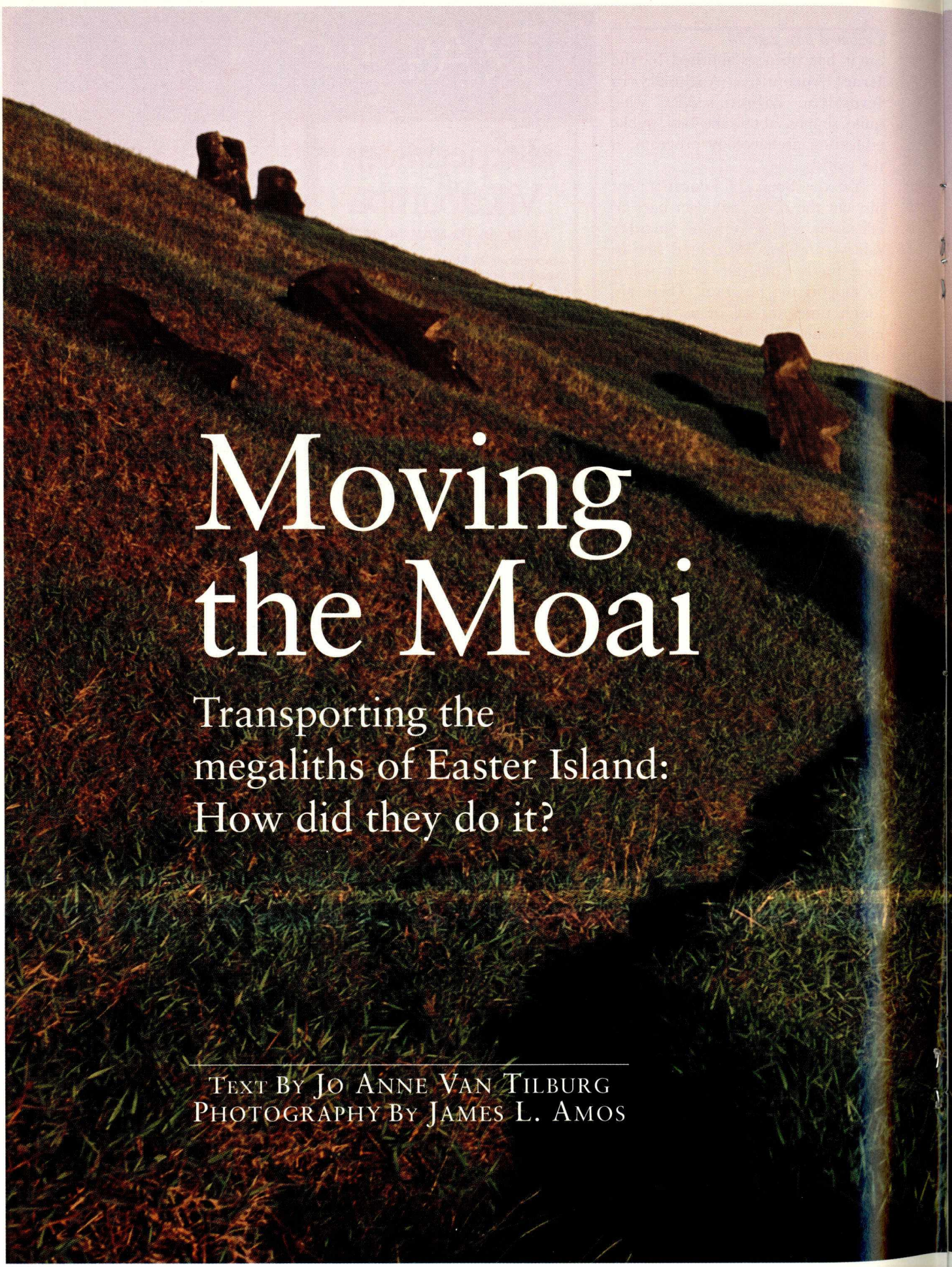
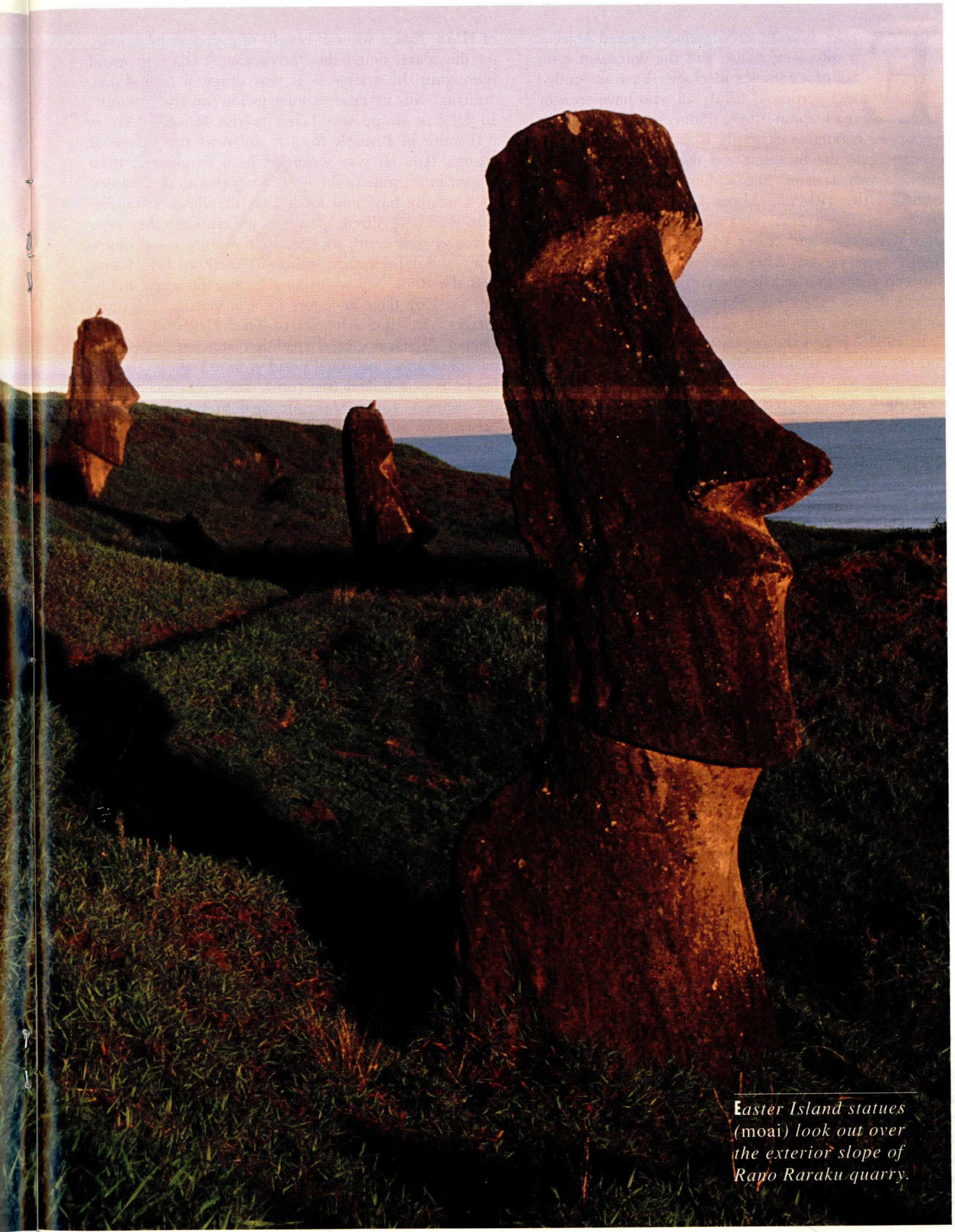


Moving the Moai

Transporting the megaliths of Easter Island: How did they do it?

TEXT BY JO ANNE VAN TILBURG
PHOTOGRAPHY BY JAMES L. AMOS



Easter Island statues (moai) look out over the exterior slope of Rano Raraku quarry.

Easter Island's stone statues—sacred objects, emblems of status, and the dominant symbol of a complex ideology—have astounded and perplexed nearly all who have seen or read about them. Pioneering British ethnographer Katherine Scoresby Routledge was the first to investigate the meaning and function of the sculptures, known as *moai.* She and her husband William mounted the 1914–15 Mana Expedition to Easter Island, or Rapa Nui, and mapped Rano Raraku quarry, the volcanic crater where 95 percent of the statues were carved. They discovered and traced the unpaved roads that led from Rano Raraku to ceremonial platforms called *ahu.* Scattered along these roads were 45 statues, presumably abandoned "in transport."

In 1982 I joined the Instituto de Estudios, Universidad de Chile, in its archaeological survey of the island. During the past 12 years my Chilean colleagues and I have located, measured, photographed, drawn, and mapped 883 moai. This number includes visible quarry statues, those on ahu sites, many hidden in caves or partially buried, statues taken from the island to foreign museums, and 47 recorded as "in transport." In mapping Rano Raraku, the Chilean team located 397 of the total number of statues. With 80 percent of the island surveyed, it is possible that another 35–50 moai will be found.

Our goal was to produce a comprehensive description of moai form, style, context, and distribution. In the process we collected a massive amount of data about the political and ideological contexts of the statues. This information holds answers to many questions, not the least of which is how the moai were moved.

To answer this question, I first researched contemporary observations of large stone transport in many parts of the world. In Indonesia, huge gravestones weighing many tons are still hauled on sledges by as many as 150 men, women, and children pulling on attached ropes. In northeastern India, stones of two tons or more were moved over narrow trails as late as the 1940s. Other sources of information are the ethnographically documented cases of stone transport in Madagascar, Tonga, Micronesia, and the Marquesas Islands, and experimental archaeology projects at La Venta in Mexico, at the Giza Plateau in Egypt, and at Stonehenge and elsewhere in Great Britain. In virtually all cases, the stones were moved in a horizontal or, occasionally, lateral position on a sledge over rollers.

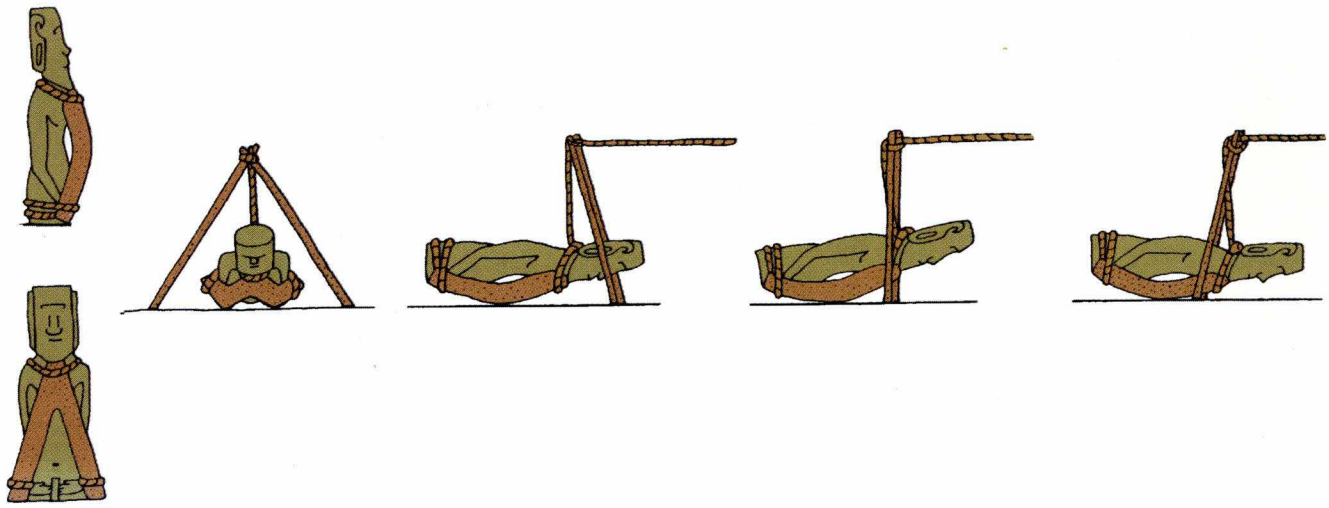
Next, I studied how eight Rapa Nui statues were collected by foreign museums. In 1886 U.S. Navy Paymaster William J. Thomson and the crew of the USS *Mohican* removed one that is now in the Smithsonian Institution. Islanders and draft animals hauled it two and one-half miles from an inland ahu to Anakena Bay, from which the *Mohican* sailed. The British Museum's statue, called Hoa Hakananai'a ("stolen or hidden friend"), was removed in 1868 from a stone house, then dragged by Rapa Nui people and crew members of HMS *Topaze,* without benefit of a sled. A missionary on the island noted the "precautions" taken to avoid damaging the statue as it was dragged face down, "tracing with its nose, a long furrow on the ground." In 1935 a statue was taken to the Musée d'Art et d'Histoire in Brussels from a site near the village of Hanga Roa. It was wrapped in a cargo net, then placed in a prone position on a wooden sledge, hauled to a nearby bay, and loaded on the Belgian training ship *Mercator.* Alfred Métraux, an ethnographer who witnessed the event, took the opportunity to ask questions about prehistoric transport methods. He found that the Rapa Nui were "unable to explain the methods used by their ancestors for transporting the stone images." In 1955 scientists of Thor Heyerdahl's Norwegian Archaeological Expedition attached a 13-foot-tall statue in a horizontal position to a Y-shaped sledge made from a forked tree trunk with cross pieces over the runners. Ropes were attached to the sledge, and between 75 and 180 people hauled it a few yards over flat ground.

Three additional methods of transportation have been suggested. American archaeologist William Mulloy, who directed the re-erection of statues on several restored sites, speculated that a 32-foot-tall, 89-ton statue called Paro could have been moved using a bipod of tree trunks about 30 feet tall. He believed the statue, suspended by ropes from the bipod, could have been inched forward by rocking it on its protruding belly. One or two of the larger statues lying along a transport road may have inspired Mulloy's fulcrum idea, but neither Paro nor the majority of the other larger-than-average statues have sufficient depth through the midsection to make the method feasible.

More recently, a crew directed by Thor Heyerdahl demonstrated that a 13-foot-tall moai could be inched forward in an upright position on completely flat terrain by tilting and rocking the statue back and forth while manipulating ropes attached to the statue's head and base, much as one would move a heavy piece of furniture. The statue they used, which now stands near Ahu Tongariki, was broken at the base during this operation.

Concrete replicas of moai, not particularly well designed or accurately proportioned, have been used in experiments similar to Heyerdahl's. American geologist Charles Love devised a variation on the upright, tilting method by attaching a pod—a small platform of short logs—to the base of his replica. Once upright on the pod, rollers were placed underneath and the replica was pulled forward over flat ground by attached ropes. This was an improvement over the tilting method, but spacing the rollers unevenly caused the replica to come crashing down.

These experiments were largely shots in the dark. I wanted to find a way to experiment with transport methods that didn't endanger a real statue and didn't depend on awkward and inexact replicas. It was also



DRAWING AFTER WILLIAM MULLOY, 1970

The *"bipod" transport method, suggested by William Mulloy in 1970, is overly complicated and now seen as largely unworkable.*

DRAWING AFTER P. PAVEL, 1990

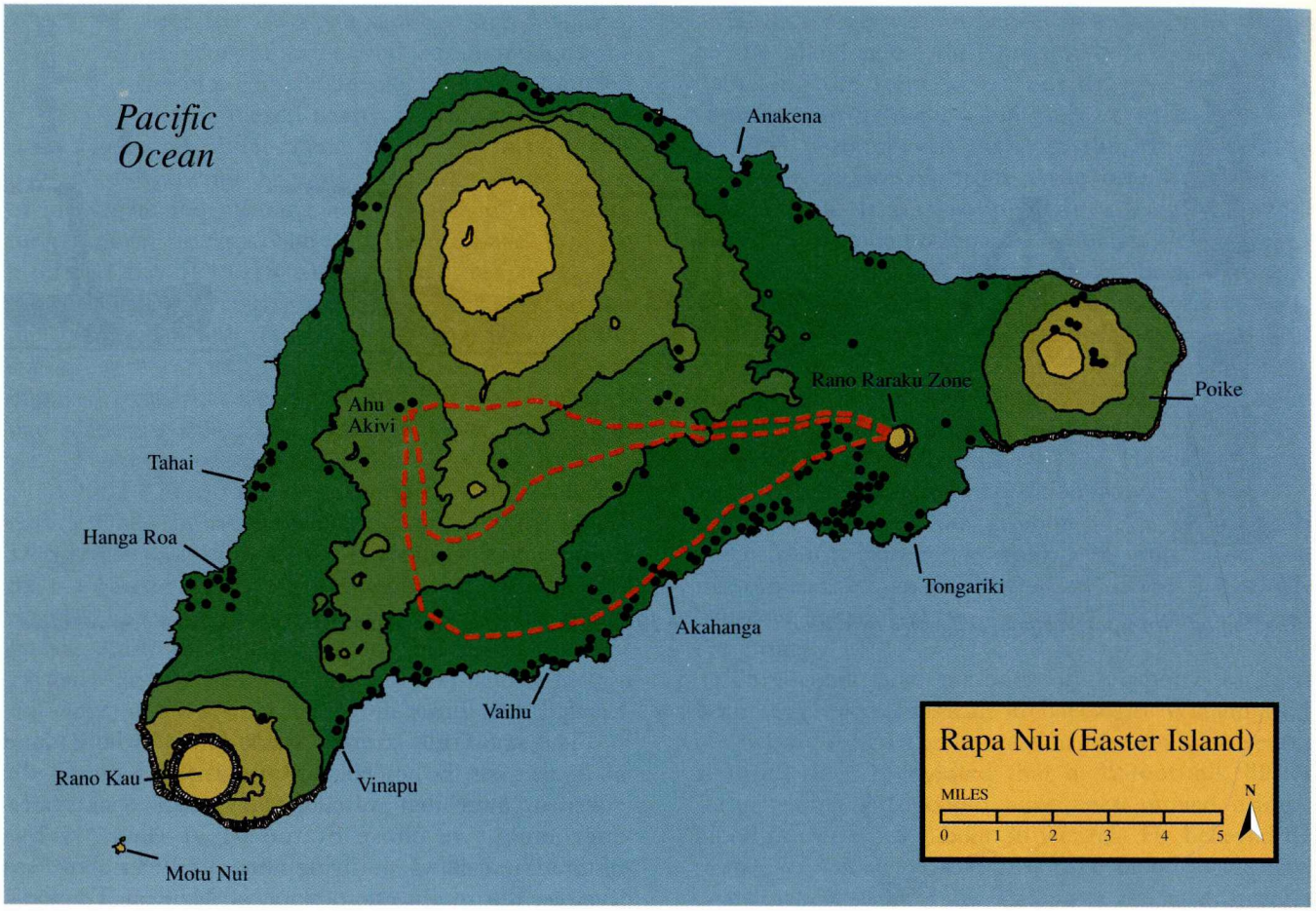
A *concrete replica moai was moved a few feet upright over flat ground by pulling, inclining, and turning the figure forward.*

important to conduct experiments that were controlled and replicable, and which could be generalized from one statue to many. The moai measurements we so painstakingly gathered over the years would be used to build a computer-simulated moai.

Of the statues inventoried thus far, 134 have ten crucial measurements that define body and head shapes and allow us to determine volume, weight, and center of gravity. All 134 are found on ahu or lying "in transport" between Rano Raraku and various ahu. Analyses of size, shape, weight, and proportionate relationships of head to body have allowed us to clarify statue forms.

The statistically average statue for the whole island is 14 feet, six inches tall and weighs 14 tons. Of the dozen or more that we could have used as our reference moai, we chose Statue 01 at Ahu Akivi, a restored and dated ahu lying about 460 feet above sea level on the southwestern slope of Maunga Terevaka. Statue 01 is 13 feet tall and weighs 14 tons. It is five feet wide at its base, almost five feet wide at its head, and has a total depth of three feet through the midpoint of the body. It has a total volume of 210 cubic feet, and its center of gravity is at four and one-half feet. Metric and photogrammetric data collected in 1991 allowed artist Gary Lloyd to sculpt a 1:10 scale model of Statue 01. A computer image of the model produced by laser scan was used to experiment with a variety of hypothetical transport methods.

When Europeans entered the Pacific, the great double-hulled canoes for which Polynesia is now famous were few in number, seen mostly in Samoa, Tonga, and Fiji. Estimates of length vary, but 65 to 70 feet was typical. Canoe hulls from Fiji, Hawaii, and the Society Islands were hewn from massive hardwood tree trunks, weighed from 6 to 12 tons, and were between 108 and 118 feet long. Construction of such vessels was in the hands of master craftsmen with hereditary status and specialized knowledge. The work progressed in accordance with the availability of food. According to Fijian craftsmen, *"a tata tu i kete"* ("the chopping is in the belly"). Sometimes the canoes were built inland, where the best timber was available, and then hauled overland to a beach. In Fiji, the great war canoes are said to have been launched over the bodies of men, sacrificed to serve as rollers allowing the vessel to slide into the water. It is not unreasonable to speculate that moai were commissioned and paid for by Rapa Nui



MAP AND PATHWAY CALCULATIONS BY ZVI SHILLER AND SATISH SUNDAR

Rapa Nui *surface map based on a computer-generated image shows locations of statues and alternative transport paths from Rano Raraku quarry to Ahu Akivi. Path 1 (the optimal path of about six miles) is at top.*

chiefs in much the same way that canoes were built and paid for elsewhere.

We can presume that the Rapa Nui called upon generations of experience in marine exploration and canoe construction and that principles of the fulcrum, lever, forked lever, balance beam, pivot, and moving pivot would have been easily adapted to statue transportation. Ancient skills in the production of stone adzes and chisels, strong cordage, and boring and lashing techniques would have been utilized, as would methods for raising and securing masts using side, back, and fore stays. Fibers from the bark of the hau tree would have been twisted into long, strong ropes. Skilled master carvers would have employed a highly stylized design template, probably using knotted cords and charcoal to mark dimensions on the stone before a statue was roughed out.

We decided—based on Polynesian ethnographies, previous experimental archaeology projects in other megalithic societies, Rapa Nui terrain, and statue attributes—that a horizontal transport method was the most logical. The flat backs of the statues and lines of the shoulders were ideally shaped for such transport. Experiments with our scale model helped us to design a light and economical sledge. When transferred to our computer model, it consisted simply of two simulated, nonparallel wood beams 18 feet long and almost ten inches in diameter. These were placed under our computer reference statue so that they extended and met about three feet beyond the statue's head. The V-shaped alignment of the transport beams would help in pulling the sledge. The weight of the statue alone would hold the beams snugly in place. Fifteen to 20 "rollers" about ten inches in diameter were placed under the simulated beams. The statue was then "pulled" forward with ropes.

Of the 383 statues we have measured to date outside of Rano Raraku, 163 are lying face down, 122 are on their backs, and 31 are on their sides. Does the face down position of "in transport" statues mean they were being moved that way? Perhaps, although the experience of Hoa Hakananai'a being dragged with its nose "tracing a furrow in the ground" suggested to us that adjustments to our model would have to be made. To accommodate the face-down position, two crossbeams six and one-half feet long were required. One was placed at the neck to keep the nose and face clear of the ground, and the other, smaller one was placed at the base. Face-down or face-up, the stone experiences stress at the neck. In the face-up mode, a simple padding of vegetable material under the back of the neck solves the problem, but in the face-down position,

the stress is not completely relieved by padding. Some of the statues found "in transport" are broken at the neck, possibly from being transported face-down.

The most difficult aspect of moai transport was positioning and then erecting the statue on an ahu. The statues, whether they were in a face-up or face-down position on the sledge, were probably transported head-first. In the case of Ahu Akivi, statues could have approached the platform in either a face-up or face-down position and from either the front or the rear. Remaining on its transport sledge, the statue was aligned on the site with its base perpendicular to the platform. It was then pulled up a gently sloping earth ramp about three or four times the length of the statue. The base was raised about four feet and positioned on a flat pedestal on top of the platform. Using rocks, earth, rope stays, wedges, and levers, the statue would have been raised to an angle, where it was then guided slowly into place. At this point, the upright, tilting method would have been helpful in adjusting the statue's position on the flat pedestal. Any scars on the smoothly polished surface would have been abraded out with lumps of coral or pumice.

Some coastal ahu were built with high rear walls facing steep seaside cliffs. Moai were moved onto these platforms from the front. Houses and other structures were kept at a distance from the ahu, and the cleared, flat ground in front of the platforms provided ease of access. Earth ramps used in erecting statues were modified and beach cobble paving added to create platform extensions.

Katherine Scoresby Routledge, noting the patterns of breakage on some "in transport" statues, first considered and then rejected the idea that they were being transported upright. Instead, she believed that most had stood erect in place to form a ceremonial road to Rano Raraku. Testing this hypothesis, archaeologist Arne Skjølsvold of the Kon-Tiki Museum conducted excavations of two "in transport" statues in 1986. One had a patterned arrangement of stone at the base, suggesting that it had supported the weight of the upright statue, and lending some credibility to Routledge's hypothesis. Her excavations in Rano Raraku quarry, and Skjølsvold's own in 1955, revealed human bone, stone bowls, and tools associated with some moai standing on the volcano's slopes. In 1774 Captain Cook's party sought the lunchtime shade of a standing statue that may be one lying "in transport" near Ahu Oroi. This huge moai is almost 30 feet tall, more than double the height of the statistical average. It has a notched base, which suggests that levers were used to help move it while in a horizontal position, but it is shattered in such a way that it appears to have fallen from an upright position. All of this evidence suggests that at least some upright statues in the quarry, and others that *appear* to be "in transport," may actually have been deliberately placed upright at their current non-ahu locations for use in ceremonial activity.

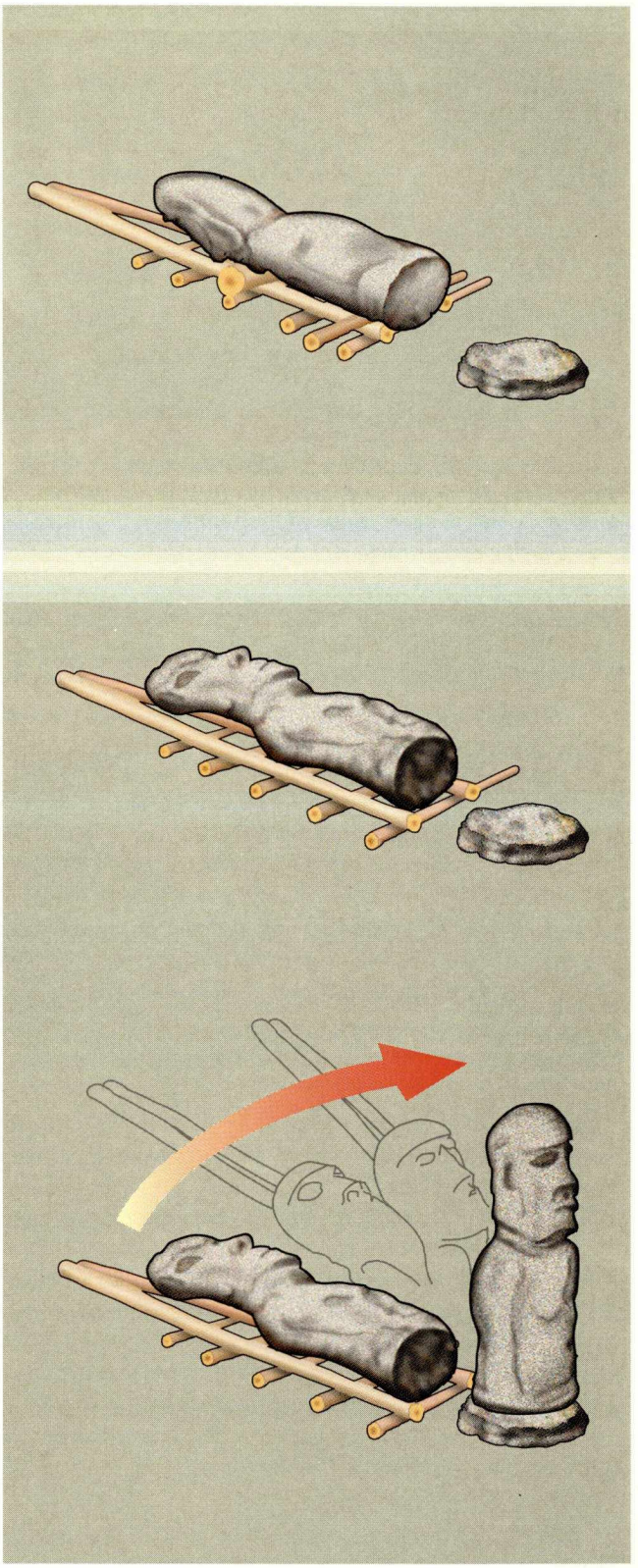


ILLUSTRATION BY JOE LEMONNIER BASED ON COMPUTER DRAFTING BY MIKE O'HARA WITH JO ANNE VAN TILBURG

Illustrations above were adapted from a three-dimensional 1:10 scale computer image of the Ahu Akivi Statue 01 "reference" moai: top, in a prone position on simulated transport sledge of two nonparallel beams; center, transported supine (the statue avoids damaging contact with the ground when the size of the rollers is increased or when cross pieces of different sizes are placed between the statue and its sledge); bottom, being erected on its ahu.

PHOTO WITH PERMISSION, MUSEO ANTROPOLOGICO R.P. SEBASTIAN ENGLERT

***S**tatues erected on ahu had carved eye sockets capable of holding eyepieces such as this white coral and red scoria one found during reconstruction of Ahu Naunau at Anakena.*

PHOTO WITH PERMISSION, MUSEO ANTROPOLOGICO R.P. SEBASTIAN ENGLERT

***R**apa Nui basalt fishhook frames the eye of a freshly speared fish, one of only about 140 species found in the island's waters.*

To test Routledge's idea of a ceremonial road further, we plotted the positions and orientations of moai lying along the main road from Rano Raraku to Rano Kau and the populous southeastern coast. The majority of statues either on their sides or face-down are lying with their heads oriented away from the quarry, while the heads of the face-up statues are toward the quarry. This means that nearly all of the statues, if standing upright, were looking southwest toward the massive bulk of the crater Rano Kau. There, from about A.D. 1450–1500 until well after contact with Europeans in 1722, the pan-island ceremonial center of Orongo flourished as the site of "birdman" rites. Predicated on the seasonal arrival of flocks of sooty terns and other birds following migratory schools of fish such as tuna, the birdman cult was a vital focus of Rapa Nui spiritual life. This cult emerged and evolved, in part, as a response to food resource scarcity and a changing sociopolitical environment. If Routledge's ceremonial road was, in fact, adorned with standing moai, the two spiritual centers of Rano Raraku and Rano Kau would have been visually linked in an extremely dramatic way.

The ahu to which the "in transport" statues were theoretically being moved were not prepared to receive them. None had been cleared of broken sculpture, and their walls had not been strengthened to support the new statues, all of which are larger than average. The cumulative evidence suggests that, at about the time Orongo became important, the ahu were adapted to uses that did not require moai. Instead, the statues remained in Rano Raraku, where many were used in new ways. Taking everything as a whole, it appears to me that Routledge's ceremonial road is a very real possibility.

In our computer modeling we sought the optimal path the Rapa Nui would have taken to haul Statue 01 from Rano Raraku to Ahu Akivi. We invited Zvi Shiller and his engineering graduate students at the University of California at Los Angeles Robotics Lab to participate in this stage of our research. First, they digitized a topographic map of Rapa Nui to produce a three-dimensional map of the terrain. Using their computer programs and our statue data, they proposed three alternate routes.

Path 1 was the shortest, most direct route, requiring the least expenditure of energy. It ran westward and directly inland. Between 55 and 70 people would have been able to haul Statue 01 from Rano Raraku to Ahu Akivi along this route. A concerted pull on the hauling ropes would have moved the statue 14 feet. Taking into account pauses to adjust the statue, move the rollers, and tighten any lashings, the work could have been accomplished in five to seven days, calculated on the basis of a five-hour workday. Paths 2 and 3 were also viable, and neither required substantially more people to move the statue. However, Path 2 was longer and Path 3 the longest. Each demanded that laborers expend substantially more energy, thus requiring more food and water to get the job done.

The maximum force required to pull the statue in a horizontal position is two and one-half tons. In an upright position a 14-ton statue with a flat rectangular base requires two and one-third tons of force to tilt. Thus little energy is saved by tilting, although this transport method does not require wood. Pulling an upright statue on a "pod" over rollers requires nearly the same amount of wood as the horizontal method we designed. Manpower needs, however, are about half. The most obvious argument against upright transport is the Rapa Nui terrain. Our calculations show that an upright statue will fall often on a ten-degree slope and nearly all of the time on a 20-degree slope. Tilting an upright statue or pulling one on a "pod" of logs up or down even the gentlest slopes can be tricky and dangerous. Why would the Rapa Nui have resorted to such methods if, in fact, they even did? The only logical explanation would be a lack of wood and/or lack

of sufficient manpower. The statues at Ahu Akivi were erected sometime after A.D. 1400 and before the mid-1600s, when the simple, rectangular stone platform was renovated to hold seven statues. Was wood available on Rapa Nui then?

Swamps and lakes in the craters of Rano Raraku and Rano Kau, and on Maunga Terevaka, hold thousands of years of pollen, evidence of the island's history of vegetation and ecological change. Pollen was collected by several investigators, including the Norwegian Archaeological Expedition in 1955. In the early 1980s John Flenley of Massey University in New Zealand and his colleagues analyzed core samples collected on Rapa Nui. They found that the island was once lushly if not lavishly forested, and that a species of palm similar to the gigantic *Jubaea chilensis* was once present, along with other trees.

More recently, Chilean agronomist Gerardo Velasco discovered dozens of large, round holes in ancient, hardened lava flows along the island's coast. The holes are the "prints" left by the trunks of trees once entombed in lava. Close examination reveals patterned ridges in the stone, clearly made by the distinctive trunks of palms. Velasco has measured dozens of these holes, which average 18 inches in diameter. This size is a great deal smaller than that of *Jubaea chilensis*, suggesting that more than one type of palm may have existed on the island. Eighteen inches, however, is a perfect size for transport frames and rollers.

Deforestation took place on the island in various locales at different times, with Rano Raraku probably stripped of its trees by A.D. 1000. American archaeologist Chris Stevenson has found evidence of palms and other as yet unidentified trees at inland sites dating to

A*uthor, right, assisted by husband Johannes Van Tilburg, collects data for computer image of a statistically average moai.*

the 1400s and 1500s. It is safe to assume, therefore, that trees of appropriate dimensions were available for horizontal statue transport at about the time the Ahu Akivi statues were moved.

What about manpower? We used osteological data to calculate the stature of the prehistoric Rapa Nui man who would have transported and erected statues. Our Rapa Nui "reference man" was between the age of 18 and 30, in generally good health. He was five and one-half feet tall and weighed approximately 150 pounds. His daily nutritional requirement would have been 2,880 calories, of which he would have expended roughly 50 percent in energy. According to the ethnographer Alfred Métraux, the typical Rapa Nui family consisted of nine members. Data from western Polynesia clearly show an extended family could be expected to have 45 to 50 members. Virtually every member contributed some form of labor to the economic life of the whole. Conservatively, each extended family would have had eight males of appropriate age and vigor available to haul statues, meaning that between eight and nine extended families would have had to cooperate to move the average moai.

P*etroglyphs of the sacred* tangata manu *or birdman at Orongo, Rano Kau, may have had ritual functions similar to those of the* moai *standing on the slopes of Rano Raraku.*

We calculated an optimal daily diet for our Rapa Nui reference man. About 25–35 percent of the 2,880 calories would have been provided by fat. In order to replace the energy and body tissue he was expending in the work task, he would have needed 65–75 grams of protein and 15 grams of iron, in addition to calcium, phosphorous, carbohydrates, and various vitamins. To accomplish this each man would have had to consume either 200 grams of chicken or an equal amount of non-oily fish (preferably tuna or something similar) to gain 500–600 calories of protein. The remaining calories would have been supplied by sweet potatoes, sugar cane, and bananas, all important Rapa Nui crops with a high water content—a key factor in avoiding work fatigue. Water was also available in the crater lake of Rano Raraku and in the vicinity of Ahu Akivi.

To meet the food requirements of the laborers, a Rapa Nui chief (*ariki*) who commissioned an average statue and had it moved along Path 1 would have needed three to six acres per crop above and beyond the normal one-half acre required to feed each person. He would also have required a surplus of crops at least equal to what he was dispensing to pay for the fish or other protein. It is a conservative estimate that agricultural resources provided by 50 acres, or about double the extended family norm, were required to complete the Ahu Akivi transport task.

In the same way that Polynesian chiefs throughout the Pacific commissioned and paid for canoes, Rapa Nui chiefs called upon their communities to make and move statues. Work parties were formed of combined, co-resident family groups or cooperating extended family units at the behest of chiefs who exploited ties of kinship, shared religious beliefs, and personal status to marshall the resources of lineage lands and fishing grounds. Master craftspeople with extensive, formal, and institutionalized knowledge, training, talent, and skill directed work crews. Food, water, and timber were produced on lineage lands or traded for by chiefs, and appropriate ceremonies were conducted at all stages of the work. Polynesians distinguish between food needed for sustenance and feast food, and prodigious amounts of both were required for statue transport.

Transporting and raising seven statues at Ahu Akivi is typical of what a Rapa Nui chief could do, and is no small accomplishment. Transport methods used by Rapa Nui experts would logically have been those that were most efficient and of proven utility, and the horizontal method seems most appropriate. Adaptation to time, manpower, or resource shortages would have required flexibility and could have produced individual innovations.

The evidence throughout the Pacific is that limited island ecosystems with short food chains were dramatically transformed by humans. On Rapa Nui from about A.D. 1000, deforestation and agricultural land-use policies apparently caused serious soil erosion. Birds and eggs, once easily attainable foods, were signifi-

S*even statues of statistically average size and form were erected at Ahu Akivi sometime after* A.D. *1400 and before the mid-1600s. The ahu served as the destination site for the author's computer-simulated transport studies.*

cantly depleted and consequently more valuable. Natural disasters may have occurred that have not, as yet, been investigated. Rapa Nui cultural practices interacted with the island's marginal and isolated environment to precipitate a series of environmental problems, resource shortages, and probable social crises as yet not fully understood.

Not all Rapa Nui people experienced the same kind of problems at the same time, however. Polynesian people held their island homes in high regard, and chiefs were responsible for maintaining individual lineage land-use rights and managing resources. Some were more successful than others. There is direct archaeological evidence that many people tried to mitigate some of their environmental crises as they recognized and understood them. Practical innovations such as *manavai* (stone garden enclosures), which protected fragile plants from the wind, worked fairly well. The Rapa Nui also conceived the birdman cult and other dramatically new religious practices out of old ideas.

The moai were not abandoned, however. Instead of being transported to ahu, they were used in new ways. It appears that increasingly larger moai were erected on the slopes of Rano Raraku. This may reflect a general movement away from narrowly defined, ahu-based lineage concerns and toward more integrated, supralineage ideological practices concentrated on the two main sites of pan-island significance, Rano Raraku and Rano Kau. In the same time frame, however, and possibly less than 200 years before the 1722 arrival of Europeans, our simulated transport studies suggest that a typical Rapa Nui chief was still able to make and move an average-size statue.

The Rapa Nui courageously faced the open and empty sea when they founded and settled their tiny island. As they cleared and used the land and fished the surrounding ocean, they called upon their gods, their leaders, their families, and their own strengths. They interacted with their island environment in traditional ways. Their repertoire of coping skills was shaped by their heritage as Polynesians. European "discoverers" of Rapa Nui perceived the culture, with its fallen statues, as in a state of collapse. This is an ethnocentric Western interpretation rather than an archaeological one. As cultural outsiders, we can now see where the Rapa Nui went wrong. But because the course of Rapa Nui history was interrupted and redirected by the impact of Europeans, we will never know for certain just how successful they might have been in dealing with the environmental crises they faced. ■

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