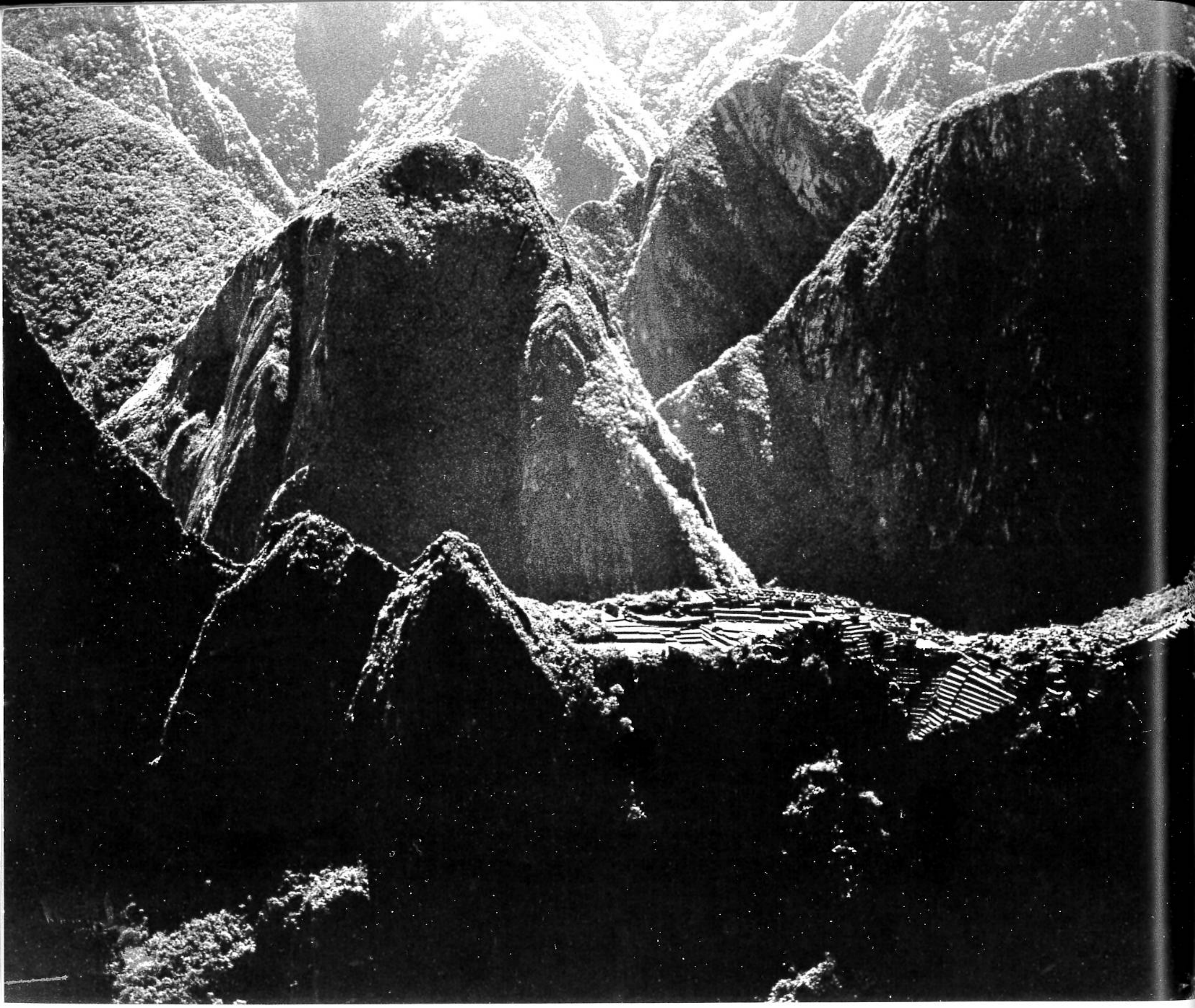


3.1 Machu Picchu among the peaks of the Andes, 1989. Photo by Marilyn Bridges.

III Machu Picchu Mysterious Royal Estate in the Cloud Forest

Lucy C. Salazar

Machu Picchu is probably the best known archaeological site in the western hemisphere, visited annually by hundreds of thousands of visitors, many of whom have traveled to Peru from Asia, Europe, and North America in order to see this magnificent Inca site buried deep in the cloud forest of the eastern Andean slopes. Machu Picchu has been described as one of the most mysterious places on earth, not only because of the otherworldly atmosphere of its white granite ruins, precipitous slopes, tangled forest, and dense mists, but also because of the many questions we have about it (Figure 3.1).

Why was it built on what seems to be an inconceivable location, a narrow ridge high above the heavily forested slopes of the Urubamba River? What led the Incas to invest large amounts of labor to build one of the most beautiful settlements known anywhere in the world in such a gorgeous landscape? Why was its spectacular mountaintop site unknown to the Spanish conquerors of the Incas? Who were its builders? What role did Machu Picchu play in Inca society (Figure 3.2)?

Since its rediscovery by Hiram Bingham on a cold morning of July 24, 1911 — its existence before this had been largely unknown to the world beyond local inhabitants — and despite the fact that thousands of visitors have journeyed to Machu Picchu, these mysteries remain unresolved. Travelers, Peruvian and foreign, continue to receive implausible and misleading information and perpetuate it. Bingham himself held and advanced many of these still current misconceptions, which, despite the evidence, have persisted for close to a century.

The ruins of Machu Picchu have inspired many myths, some of which are outgrowths of the limitations of Hiram Bingham's training and early-twentieth-century scholarship. The redoubtable leader of the Yale Peruvian Expedition was a professor of Latin American History at Yale, a geographer, explorer, and mountaineer, but he was not an archaeologist. His first journey to South America was across Venezuela and Colombia following the route of Simon Bolívar, the great South American emancipator (Bingham 1909). Bingham later began lecturing in South American history at Yale, his alma mater. Although he was highly intuitive, he was dependent on confusing and often inconsistent Spanish colonial narratives. He used these materials to draw a number of conclusions that archaeological research and other kinds of investigation contradict. His reliance on this one type of evidence and his lack of

3.2 Machu Picchu during the clearing of the forest, September 18, 1911. Photo by H. L. Tucker.

training in the other led Bingham to convince himself that what he had found was indeed what he had been seeking, the legendary Old Vilcabamba, or "Vilcabamba la Vieja," the citadel where Manco Inca, the last Inca king, rallied the resistance to the Spanish Conquest. But to this confirmation Bingham added a potentially incompatible interpretation: "Until further light can be traced on this fascinating problem it seems reasonable to conclude that at Machu Picchu we have the ruins of Tampu-tocco, the birthplace of the first Inca King, Manco Capac, and also the ruins of a sacred city, of the last Incas" (Bingham 1922: 339).

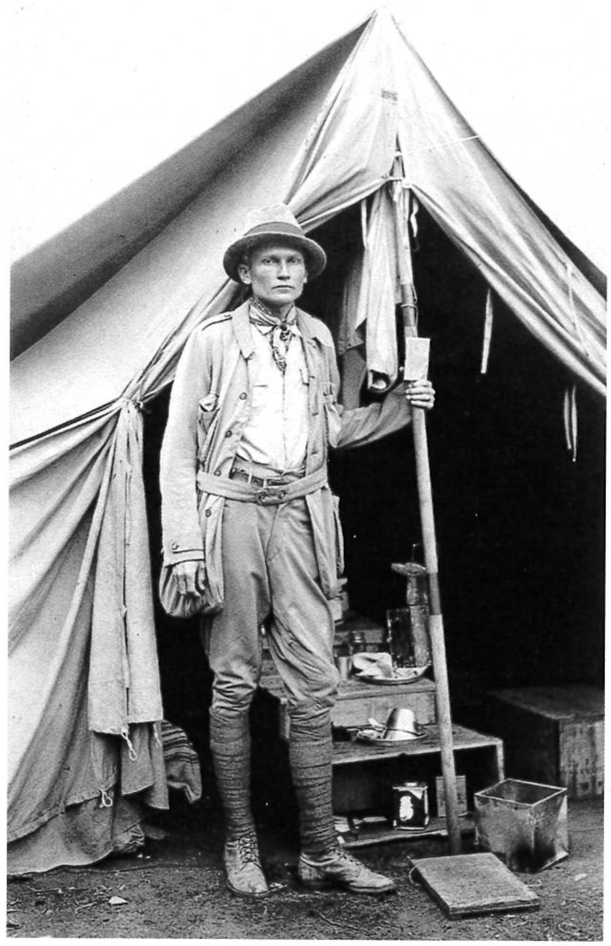
Because of the vagaries of history, Machu Picchu, whatever it may have been, remained in a near pristine state between its abandonment in the sixteenth century and its recovery in the early twentieth. Consequently the site offers the most complete example of classic Inca architecture and planning known to date. As a result of Bingham's three expeditions (the expeditions of 1912 and 1914–1915 were co-sponsored by Yale and the National Geographic Society), the Machu Picchu materials have offered opportunities for new studies, which in many cases have refuted Bingham's theories. Current studies of these materials continue to shed light on the settlement and administration of the Inca empire, the life of its elite and its retainers, and the nature of Inca society and culture.

More than ninety years after Bingham's first expedition, the mist is at last rising from Machu Picchu. While from the perspective of archaeological research this process is just beginning, the insights it has produced have already transformed our understanding of the site and the empire of which it was a part.

The Expedition

Hiram Bingham III was born in 1875 in Honolulu to a family of missionaries. He graduated from Yale in 1898 and returned to Hawai'i to serve as a pastor at the Palama Chapel. After marrying an heiress to the Tiffany fortune, Alfreda Mitchell, he traveled to Peru in 1909 and visited the great Inca ruins of Choqquequirau in the Apurimac Valley. Back in New Haven, in a letter to the editor of the *Yale Alumni Weekly* on March 10, 1911, Bingham suggested the possibility of developing fieldwork and exploration in the Andean region to improve the quality of teaching and instruction in Latin American history (Figure 3.3).

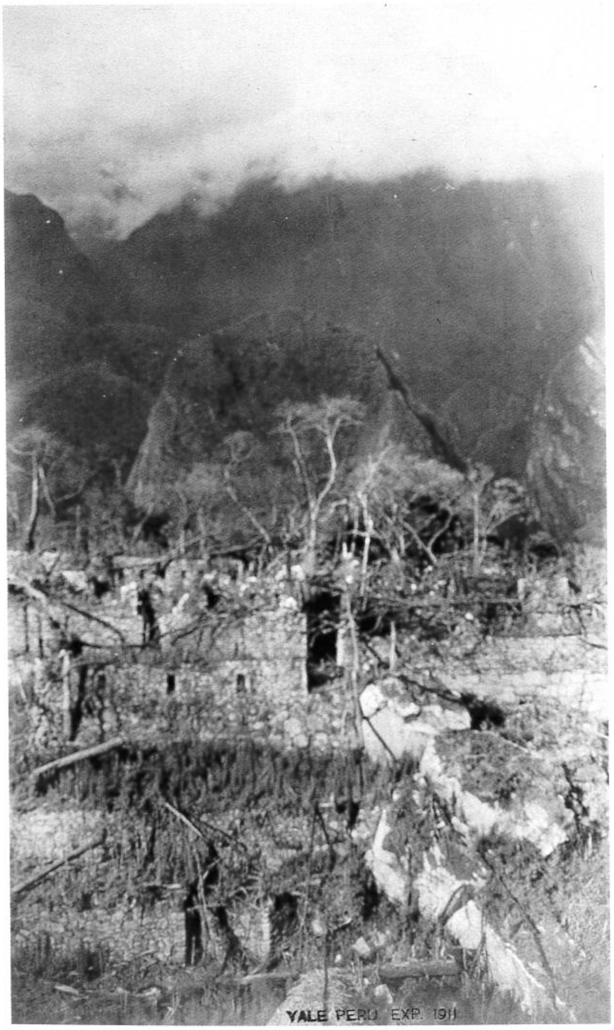
In 1911, with support primarily from Yale University and Yale alumni funds, Hiram Bingham organized an expedition with members from different academic backgrounds: Isaiah Bowman, assistant professor of geography at Yale; Dr. William Gage Erving, a physician specializing in orthopedic surgery; Harry Ward Foote, assistant professor of chemistry at Yale and an avocational naturalist; Kai Hendriksen, Danish topographer; Herman Tucker, mountain climber and assistant to Hendriksen; Paul Baxter Lanius, Yale undergraduate in the Sheffield Scientific School; Casimir Watkins, British naturalist; and Frank Hinkley, a Yale undergraduate assistant who was forced to leave the expedition only a few days into it after having an accident. Hiram Bingham personally selected the members and led the expedition to the Cuzco region in southern Peru, the capital of Tahuantinsuyu, as the great Inca Empire was called. He was looking for Vilcabamba, the neo-Inca capital on the forested eastern slopes of the Andes; from this city, descendants of the Inca emperors had opposed the Spanish conquerors for forty years. The Spaniards ultimately subdued the resistance and sacked Vilcabamba in 1572, and the area around it became depopulated. In fact, the city's location had remained lost to scholars. Bingham hoped to find old Vilcabamba by using sixteenth-century Spanish historical narratives (Bingham 1912, 1916b). Aided by a new road built in 1890 to facilitate the coca leaf and alcohol trade from the *haciendas* (large landed estates) Huadquiña, Maranura, and Santa Ana, Bingham followed the Urubamba River into an area particularly favored by the Inca royal family, and previously inaccessible to exploration.



3.3 Hiram Bingham at the main camp, September 1912. Photo by Ellwood C. Erdis.

On July 23, 1911, Melchor Arteaga, a local farmer at Mandor Pampa, told Bingham of Inca ruins high on a ridge over the river, hidden by secondary growth, and he wrote in his journal the names Maccu Picchu/Huayna Picchu (Figure 3.4). On the next day, Bingham, accompanied by Arteaga and the military escort assigned him by the Peruvian government, Sargent Carrasco, climbed 2,000 feet above the river. Exhausted, they arrived at the site and were welcomed by a group of residents who offered them sweet potatoes, called *cumara*, and gourds filled with cold water. Bingham described his discovery as:

> Two pleasant Indian farmers, Richarte and Alvarez, had chosen this Eagle's nest for their home. . . . The Indians said there were two paths to the outside world. Of one we already had the taste; the other, they said, was more difficult — a perilous path down the face of a rocky precipice on the other side of the ridge. . . . Without the slightest expectation of finding anything more interesting than the stone face terraces. . . . I entered the untouched forest beyond, and suddenly found myself in a maze of beautiful granite houses! . . . Under a carved rock the little boy showed me a cave beautifully lined with the finest cut stone. . . . To my astonishment I saw that this wall and its adjoining semicircular temple over the cave were as the finest stone work in the far-famed Temple of the Sun in Cuzco. (Bingham 1922: 317–321)



3.4 Machu Picchu, with the Cerro Putucusi in the background. Photo by H. L. Tucker.

Bingham returned the following year to clear and excavate the site.

Although the name Machu Picchu did not appear in any of the Spanish historical narratives with which Bingham was familiar, he nevertheless connected the site to the places described in them. He proposed — incorrectly, as it turns out — that Machu Picchu was the birthplace of the Incas, based on the link he perceived between an unusual three-windowed building at the site and the myth that the ancestors — the four Ayar brothers and their sisters — had emerged from three windows or caves in a mountain called Tampu Toco located in Pacaritambo, south of Cuzco (Bauer 1991; Bingham 1912: 326–331; Sarmiento 1944; Urton 1990). Eventually, Bingham also interpreted Machu Picchu as "Vilcabamba La Vieja" (Vilcabamba the Old), where according to Augustinian priest Father Antonio de la Calancha, a University of Idolatries was occupied mainly by cloistered women (*acllas*) devoted to the Inca religious cult of the sun (Bingham 1912: 334–338). Bingham's gifts as a popularizer of his own work had the unfortunate effect of establishing his errors as facts in the public consciousness. It was he who described Machu Picchu as a lost city, although, in fact, it was not a city — its population had been 750 at most — and it was not "lost" in any meaningful sense. Although Bingham's theories were often flawed, he was an exceptionally dedicated, intrepid, and, some might say, lucky explorer. In addition to the discovery of Machu Picchu, the same expedition of 1911 discovered the important archaeological sites of Vitcos and Espiritu Pampa (Bingham 1912).

Rediscovering Machu Picchu

Contrary to Bingham's speculations, Machu Picchu's origins appear to have been quite recent, perhaps some time in the 1450s or 1460s, preceding by less than a century Pizarro's conquest of the Incas' vast Andean Empire. The site's origins also appear to have been less spectacular than Bingham's grandiose theories would have it. In 1982, Richard Burger and I concluded on the

3.5 Panoramic view from the top of Mt. Machu Picchu showing the ruins on the ridge, and the Huayna Picchu hilltop in the center with the Urubamba River. Photo by Hiram Bingham, 1912.

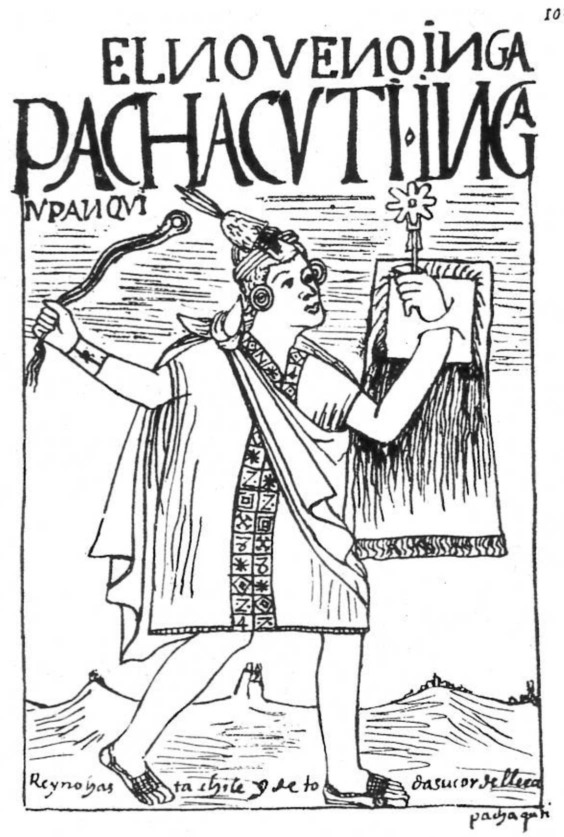
basis of the archaeological evidence that Machu Picchu, far from being the Inca birthplace, was merely one of a number of personal royal estates built by an Inca king in the remote countryside from the imperial capital, Cuzco.

In fact, ninety years of scholarship have radically transformed our understanding of the Inca Empire and of Machu Picchu's position in it. These studies have confirmed some of Bingham's intuitions and substantially refuted others. Machu Picchu can only be properly understood in the larger context of the Inca social, economic, and political structure (Figure 3.5).

Machu Picchu does not resemble any of the five types of settlement that account for 99 percent of the sites within Tahuantinsuyu, the empire between 1450 and 1532 AD, when the Incas held sway:

- It was only a tiny fraction of the size of Cuzco, the Inca capital, and lacked Cuzco's large temples and fortresses.
- Its form and size were not comparable to such Inca provincial administrative capitals as Huanuco Pampa, Hatun Xauxa, and Pumpu.
- Its location and strongly religious character — given the quality of stonework, the high-altitude setting, and the numerous shrines — set it apart from places like the administrative wayside stations, called *tambos*, the Incas had placed along their more than 30,000-mile road network.
- It was far too elaborate to have been either a rural village or one of the planned state agricultural sites on which the Incas forcibly settled alien ethnic communities as a development strategy.

- Its classic Inca architecture and the artifacts recovered from it show that Machu Picchu could not have been one of the non-Inca villages that paid tribute to the empire through their labor on public works, state lands, mines, and other projects.



3.6 The ninth Inca ruler, Pachacuti Inca Yupanqui, creator of Machu Picchu, as drawn by the native writer Felipe Guaman Poma.

Machu Picchu, however, does have features consistent with one special type of Inca settlement: the royal estate. These estates — there was a group of them in the empire — were defined as being outside the state administrative system and its support area, belonging instead to a specific Inca ruler and his descent group segment (see Chapter 4). These kin groups, called *panacas* (royal corporations or royal lineages), were each headed by an Inca king and supported in luxury by the lands and retainers acquired through conquest during that king's reign. This adulation continued after the king's death, because in his role as an ancestor he was part of court politics.

These royal retreats were associated with lands farmed for the panaca, the produce of which supported the centers and their visitors. There seem to have been many of these settlements in a number of areas, but the Urubamba Valley, to the north of Cuzco, was favored, perhaps because of its proximity to the capital and its warmer climate. Descriptions of the estate of the eleventh Inca ruler Huayna Capac, located in Yucay, upstream from Machu Picchu, tell of forests where exotic lowland plants and animals — such as deer, fish, chili peppers, coca, and peanuts — were kept for the emperor's pleasure (Farrington 1995; Niles 1988, 1999; Rowe 1987). According to the Spanish chroniclers, these centers were used as country estates for relaxation when the Inca ruler or his descendants traveled out of Cuzco. Hunting, entertaining other Inca nobles and foreign dignitaries, and other activities are mentioned.

The fine Inca masonry, small size of the settlement, absence of features tied to the economic infrastructure, and other elements lead us to conclude, solely on the basis of archaeological evidence, that Machu Picchu was probably such a royal estate. This working hypothesis was confirmed by John Rowe's study of a 1568 document, written only thirty-six years after Pizarro's arrival, that mentions a site "Picchu," approximately where Machu Picchu is located today. The term *Machu*, that precedes *Picchu* means "old" and was used by locals to differentiate it from the hill at its northern extreme, called Huayna Picchu, which means "young." The entire area in which the site is located, according to Rowe, was apparently collectively called Picchu, or Pijchu (Rowe 1987: 14). These documents say that the lands in the bottom of the valley belonged to Inca Yupanqui (also known as Pachacuti Inca Yupanqui, the ninth ruler) and his panaca — Inaca Panaca Ayllo (Sarmiento de Gamboa 1944: 14). Although Machu Picchu is not mentioned per se, the documents imply that it would have fallen within Pachacuti's estate. Pachacuti Inca Yupanqui conquered this region in the course of his military campaign into the areas of Vitcos and Vilcabamba (Cobo 1979: 135–137). Under Pachacuti's leadership the Inca armies subjugated the Urubamba drainage in an effort to protect the Cuzco basin from a sneak attack by their principal adversaries, the Chancas. It is generally believed that Pachacuti conquered only the middle and lower Urubamba after his conquest of the Chancas, probably sometime in the 1450s. As a result of his military conquests he took the land along the river and built a series of royal estates (Figure 3.6).

Machu Picchu was the most spectacular commemoration of Pachacuti's war conquests. It had strategic importance for the neighboring highland groups. His other royal estates, Pisac and Ollantaytambo, were also constructed to glorify his military campaigns, but Machu Picchu was the symbol of his divine power, legitimacy, and authority. Rowe's hypothesis that Machu Picchu was founded by Pachacuti is consistent with our preliminary ceramic analysis, indicating the absence of Kilke, Lucre, and the other ceramic pottery styles immediately antecedent to the imperial Cuzco style of Inca pottery (Bauer 1999). The area had been only lightly settled before the Inca conquest, and it seems reasonable to suggest that Machu Picchu, built sometime between 1450 and 1470, had been in use for only some eighty years when Tahuantinsuyu crumbled and the site was abandoned.

The Royal Haven

A royal palace is a formal architectural symbol of the power of the ruler and his elite. It is also an example of a formal architecture created and maintained by the ruler. Studies of the structure and the functioning of the Machu Picchu household indicate that members of the Inca royalty and their retainers engaged in celebrations, diplomatic feasting, religious ceremonies and rituals, astronomical observations, and administrative affairs of the empire in Machu Picchu's warmer and more pleasant climate. The land around the retreat at Machu Picchu was terraced and farmed and otherwise made delightful to the rulers, their families, and visiting Inca nobility. In modern American terms Machu Picchu, as well as the other royal estates, served as a kind of Inca "Camp David," except that the estates did not pass to the king's successor upon his death.

The Inca ruler traveled through the empire with his court and his courtiers, which consisted of hundreds of retainers and advisors and thousands of troops. After the Inca's death, he was regarded as a living ancestor, and his body was embalmed and his mummy was cared for by hundreds of attendants. As during his lifetime, he was dressed in *cumpi* (fine textiles) — made of camelid fiber, gold, and feathers — and was carefully tended, fed, and given a daily change of clothing. Pachacuti, who established the restricted use of the vicuña wool for himself and his panaca (Garcilaso de la Vega 1958: 407), presumably wore garments woven of this remarkably fine fiber (Rowe 1977; Rowe and Rowe 1996; Salazar and Rousakis 2000). In the same spirit, Pachacuti may have been responsible for the creation of a symbolic system of geometric designs, called *tocapos*, depicted on the royal textiles. This distinctively imperial clothing illustrates how garments could communicate rapid and effective social information without the use of language. The most complex tocapos were used exclusively by the royal elite, and probably made by them, because of their secret symbols and meanings. These textiles embodied the power and authority of the Inca Empire. They were given by the Inca himself as the most valuable gifts, to the loyal members of Tahuantinsuyu.

What implications does the identification of Machu Picchu as a royal estate have for the interpretation of its archaeological remains? First, the general layout becomes comprehensible from a functional perspective. It would be expected that the site would have been used for part of each year, perhaps during May to September, when nightly frosts are common in Cuzco. During this period, the royal court and courtiers would have resided at the site along with a much larger number of retainers (*yanaconas*) to serve them. In addition to a permanent population of caretakers and servants who likely lived at the site throughout the year, specialized workers (*camayocs*) were brought by the Incas for their skilled craftsmanship. Some, from Peru's north coast, home of the Chimu, lived in the southwest section of the palace complex, near where the schist stone ritual paraphernalia was produced (Zapata 1983: 53–57).

Indeed, when we look at the layout of Machu Picchu, we can immediately identify a sector of high-status households in the northeast sector of the site. The residences utilized the classic architectural form, which the Incas referred to as *kancha*. These were composed of rectangular units arranged within a walled compound

3.7 Ingenuity Group. House 494, interior, from the southeast corner showing stone mortars cut into the boulders in the floor. Photo by Hiram Bingham, 1912.

around a central open-air patio, and various roofed buildings were used for sleeping, cooking, and household storage. Each kancha group typically had a single main entrance and would have been used by a single family group. Bingham identified fourteen groups of kanchas divided into two sectors: Upper (Hanan) and Lower (Hurin). Aware of this Inca custom, he referred to these groups as *ayllus* (kin groups).

As one might expect, each house group was unique in its room arrangement, decorations, and other features, just as each family differed in size, history, and status. Many of the kanchas of the Upper sector housed the elite, a message conveyed by the use of double-jamb entryways and walls of finely cut and polished stone. Many also incorporated household shrines. The masonry in these domestic constructions and other exquisite buildings used the locally available granite, but it is possible that stonework specialists (*pirca camayocs*) from the *altiplano* of Lake Titicaca may have participated in their construction. This possibility is consistent with the *altiplano* presence in Machu Picchu's burials (Salazar 1997a).

At Machu Picchu, three elite compounds on terraces to the east of the central plaza probably housed members of the Inca elite. Bingham labeled these compounds the Clan Groups, and he assigned names to them based on their distinctive characteristics, such as the Ingenuity Group and the Three-Doors Group (Figure 3.7). The three residential compounds are located adjacent to one another in the northeast sector of the site. Each is unique, and none conform to a simple kancha pattern such as that known from the elite housing at Ollantaytambo.

The three elite residential compounds are located on terraces overlooking Machu Picchu's central plaza. The largest and most southern of them, the Ingenuity Group and Private Garden Group, can be divided into four sections (Figure 3.8). The compound is surrounded by a perimetric wall, however, with only a single entrance on its southern wall. The imposing entry by way of a double-jambed doorway topped by a massive lintel immediately distinguishes this as a high-status compound. The back wall of a *huairona* (a three-sided room) has been placed to obstruct vision of the compound from the entrance, thereby enhancing privacy. Both the houses and the *huaironas* have numerous interior trapezoidal wall niches, up to eighteen in some of the larger buildings, alternating with cylindrical stone tenons. The sections of this compound are connected by narrow stone staircases, one of which is carved from a single block of bedrock. One notable feature of this large compound is the presence of two shrines focused on natural stone outcrops; another is the two unique circular mortars carved into the bedrock. Six windows in the western wall of the compound provide a view of the Temple of

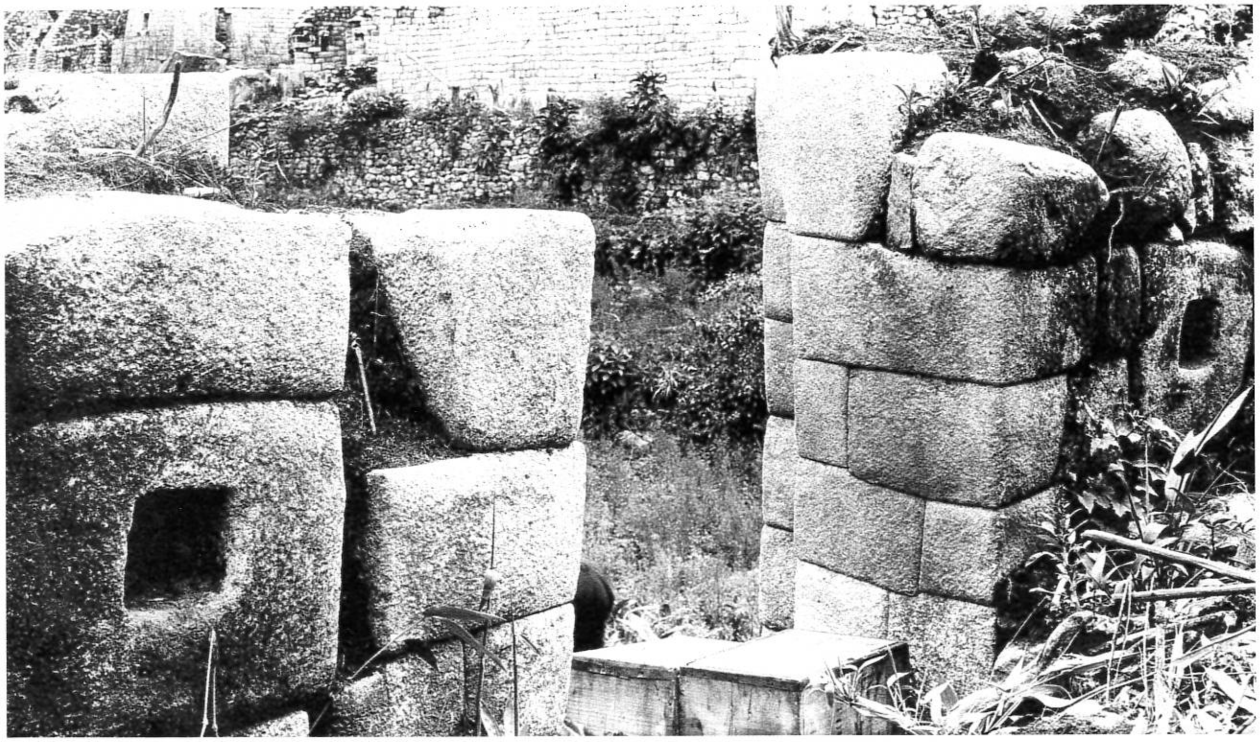
3.8 Ingenuity Group. General view, showing a high-gabled double house. Photo by Hiram Bingham, 1912.

the Sun (the Torreón) and the Temple of the Three Windows.

The adjacent compound, the Three-Door Group, covers an area of 111 by 170 feet. The entrance consists of three massive stone doorways, each of which has a double jamb with carved sockets with stone bar-holds. Its layout is basically three adjacent and interconnecting kanchas in which houses and huaironas surround a central patio on four sides. The few buildings with windows offer a view towards the eastern terraces and mountain landscape. The third and final elite compound at Machu Picchu, not named by Bingham but referred to as the Upper Group or *Conjunto Superior* (Buse 1978), has two sections. It has a single entry, which, like the others features the distinctive double jamb and carved stone bar-holds. The main entrance leads into a blind corridor, ensuring maximum privacy, while a secondary entrance provides access to the lower level of the compound. The most important section of this compound is a central patio flanked by huaironas and a roofed dwelling. The main dwelling measures 42 by 26 feet and has twenty large vertical niches (*hornacinas*).

The largest of the compounds, the Ingenuity Group, has eleven buildings that could have housed fifty or sixty elite residents. In contrast, the upper group probably held fewer than twenty people. It is unlikely that the three elite compounds held more than one hundred twenty members of the Inca nobility. The houses in these elite compounds average between 344 and 904 square feet, more than twice the size of the rustic dwellings outside the compounds that were occupied by the retainers. Many of the elite houses have finely fitted cut and polished stonework.

An unusual feature of these elite households is the bar-sockets that were carved in the entryway to each compound (Figure 3.9). These are believed to have been used to block entry to the compound, either symbolically by holding a cord or wood bar, or, literally, by supporting a massive wooden gate across the space (Bingham 1930: 76–79). Also, it is significant that behind each of these elite household compounds, outside the compound walls, there are rows of buildings lacking patio areas or any kancha-like arrangement. Such buildings at other Inca sites have been identified as resi-

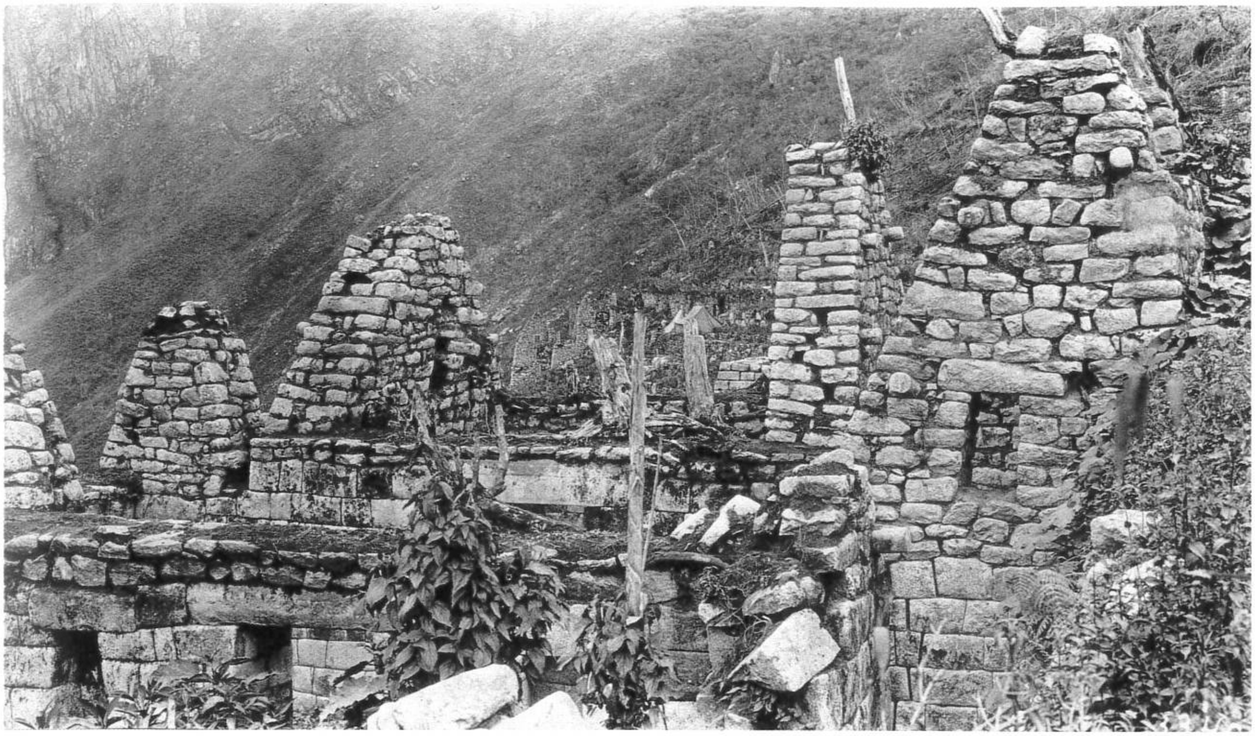


3.9 Gateway, interior, showing two bar sockets. Photo by Hiram Bingham, 1912.

dences of the yanaconas and camayocs (Niles 1987; Rowe 1982; Villanueva 1970: 139). The ethnohistoric evidence available indicates that one prerogative of an Inca panaca responsible for the conquest of new zones and populations was to have a number of individuals of the conquered group for its own service or to give these people to other panacas as a symbol of their newly acquired power. The rustic terrace buildings were probably occupied by these workers, associated with the adjacent households.

At most, 150 possible domestic dwellings have been identified within the site. Even if they were all residential in function and all were occupied, it is difficult to argue for a maximum population at any time in excess of 750 people within the "palace walls," and it is likely that the actual number was closer to 500 people, most of whom were yanaconas and camayocs. This number, of course, does not include the inhabitants of the land surrounding Machu Picchu whose agricultural fields probably provided much of the necessary food for the people living there. The terraces at Machu Picchu, which constituted only about 12 acres of agricultural land, could not provide a sufficient amount of food for the estimated population (Wright et al. 1997c: 47). Also, there is no evidence within the palace walls of houses for the farmers who tilled the terraces of Machu Picchu, nor did Bingham's excavations recover the diverse types of stone and metal tools used by this agricultural labor force.

Unlike the elite compounds, the residence of the emperor Sapa Inca (Unique Inca) is set apart physically in the southwest sector from all other domestic architecture. Above the complex to the west are broad terraces, and below it to the east is a small walled garden. Running along the north and south of the complex are deeply inset staircases leading to the plaza below. Thus, there was no housing adjacent to or even near the royal compound. This spatial isolation would have given the sovereign a degree of privacy absent from the elite compounds, perhaps a feature necessary to maintain the myth of divine kingship. Bingham appears to have been correct when he labeled it the King's Group (Figure 3.10).

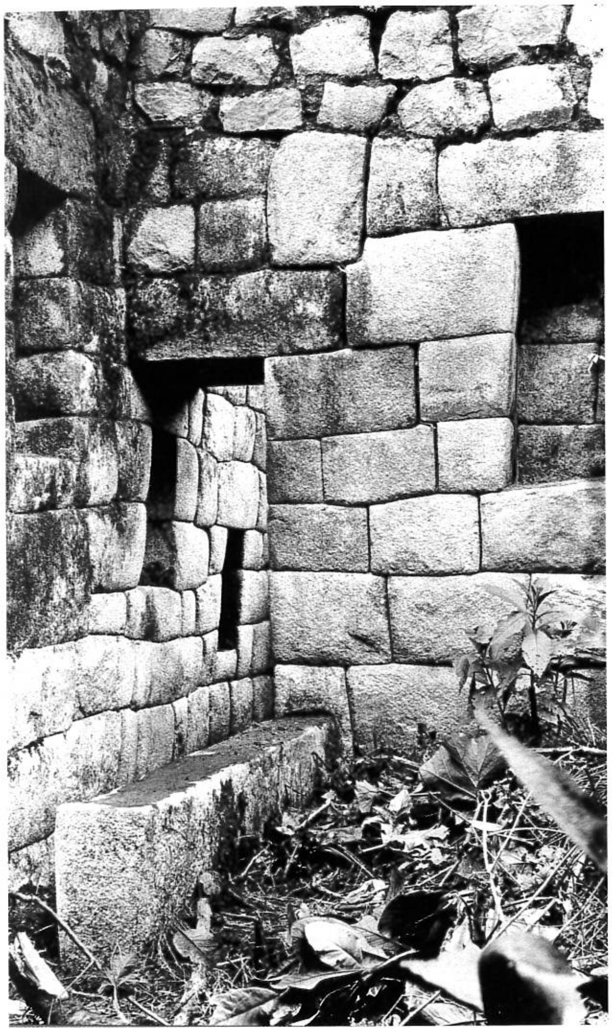


3.10 King's Group. General view from the northwest. Photo by Hiram Bingham.

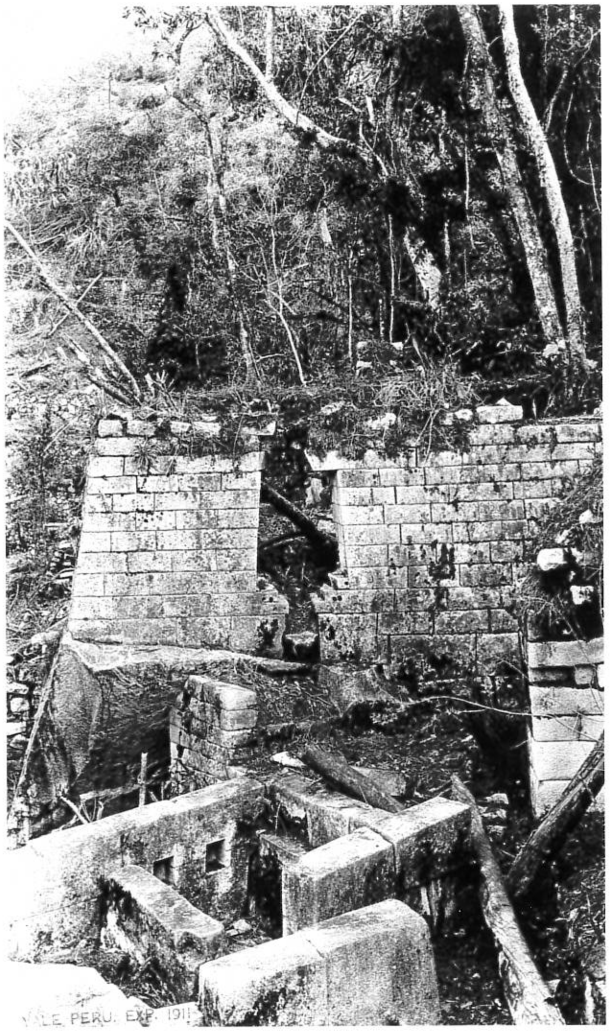
Significantly, this royal residential complex is adjacent to the Torreón. The dwelling of the sovereign is no larger than that of his elite relatives; in fact, the building in which he probably slept measures only 75 by 52 feet and the interior patio covers only 300 square feet (Figure 3.11). Entrance into the Inca ruler's complex, however, is more difficult than into the elite compounds. A large gateway is found in the compound's entryway, and another gateway limits access into the sector of the site in which the compound is located. The buildings in this royal complex also are set apart from the others by the care with which the white granite was selected for the walls, the superior quality of their fitted stonework, and the massive size of the stone lintels. Its lintels are twice the size of those used in the other residential compounds, and Bingham estimated their weight at three tons (Bingham 1930: 96).

Machu Picchu was supplied with fresh springwater brought from a perennial spring on the north slope of the Machu Picchu mountain and a series of smaller springs along the way, and channeled to a stone-lined gravity canal from its source 2,456 feet to the south (Wright et al. 1997a: 838). Reaching the royal estate, it was channeled into a descending series of sixteen ritual fountains, the first of which is adjacent to the doorway of the royal compound. Thus, the water reached the Sapa Inca from the spring in its pure state, uncontaminated by prior usage (Figure 3.12). The highly elaborate fountain is unique at Machu Picchu in its unusual cut stone walls forming an enclosure that might have been used as a ceremonial bath. Like the other fountains at Machu Picchu, a cut stone channel delivers the springwater at the top of the fountain and a sharp-lipped rectangular fountain spout creates a falling jet of water into a small cut stone basin at the bottom of the enclosure (Wright et al. 1997a: 842). Rising 5 feet high, the walls of the fountain would have allowed the Inca ruler to take a ceremonial purification bath in absolute privacy, a concern referred to explicitly in the early chronicle of Pedro Pizarro (1978: 32).

While the Inca's quarters do not bespeak of a fondness for luxury, the exclusive garden and adjacent bath,



3.11 King's Group. House interior and entrance to toilet area. Photo by Hiram Bingham.



3.12 Fountains and Torreón before clearing. Photo by Hiram Bingham.

as well as the more private setting and the site's only private toilet arrangement, attest to the special comforts provided for the Inca ruler and roughly match the descriptions of royal dwellings in the Spanish chronicles. Pollen analysis of the soil of the Inca private garden and adjacent terraces has revealed that beans, corn, and potatoes were grown, perhaps along with some of the ninety species of orchids, found in the Machu Picchu Historic Reserve (Alfredo Valencia, personal communication). In designing the garden, the Incas may have been taken in consideration the gurgle of the running water of the fountains nearby for the relaxation of Inca Pachacuti, whose fondness for flowers has been recorded in the *cantares* or *haravec*, songs dedicated to the memory of the events of his life, and sung especially at the time of his death. Pedro Sarmiento de Gamboa (1944: 140) notes that at the time of his death, Pachacuti began to sing a cantar: "I was born as a lily in the garden, and like the lily I grew, as my age advanced / I became old and had to die, and so I withered and died." (*Nací como lirio en el jardín, y ansí fuí criado, y como vino mi edad, envejecí, / y como había de morir, así me sequé y morí.*).

Another distinctive architectural feature of the king's compound is a deep incised line grooved in the large lintel of the entrance (Figure 3.13); this kind of line appears also in the entrance of the main building of the Ingenuity Group, and this sort of visual signal has also been noted in one of the rooms of the Coricancha of Cuzco (Valencia and Gibaja 1992: 67). In 1980 a cave underneath the lintel was uncovered containing the remains of a woman (Valencia, personal communication). Other architectural details like friezes or wall murals and furnishings made of perishable materials have not survived. However, Bingham found remains of red paint on the stucco plastered walls of a house in the Ingenuity Group (Figure 3.14), and red bitumen-like paint were observed by the Spanish conquerors in the Inca residence at Cajamarca (Xérez 1968: 233).

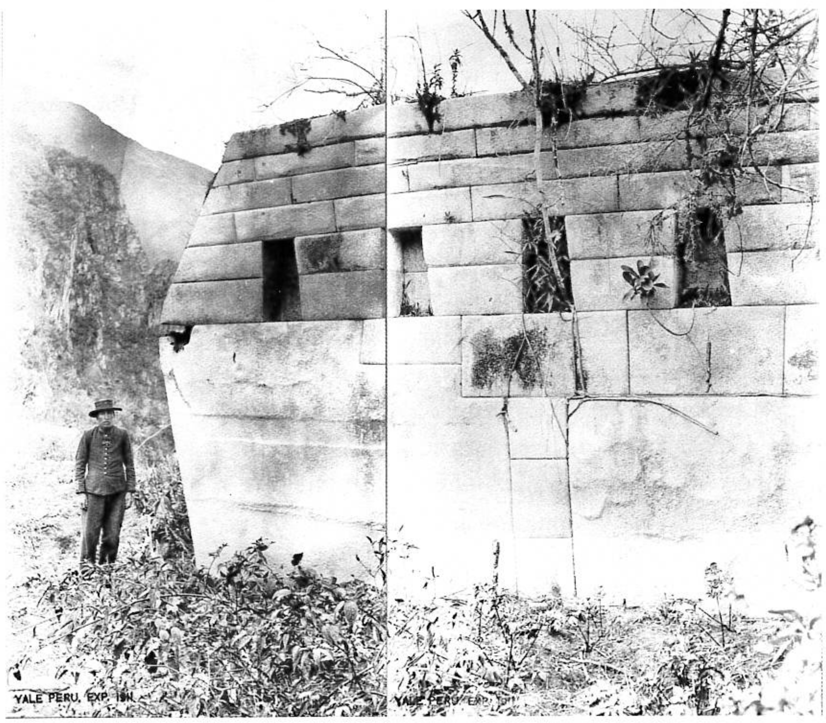
During the process of restoration in the King's Group, in the core of a wall, an offering of a guinea pig (*cuy*) was found pierced through by two shawl pins (*tupus*), one of gold and one of silver (Eusebio Mendoza, personal communication). This ritual offering is analogous to the offering made to commemorate the ritual burial of a wall that served as the foundation of a late terrace, where one such offering, a laminated gold bracelet, was found in pristine condition in the rubble of chipped stones (Elba Torres, personal communication).

Judging from the architectural evidence, besides the domestic architecture used by the elite and their retainers, the most common structures at Machu Picchu are those involved in the various religious rituals central to the royal court. The Incas, like most conquerors, claimed that their deities — the Sun and the Moon, among others — had instructed them to go forth and subdue all the nations to their north, south, east, and west. Their claim to legitimacy was closely tied to their ideology of being descended from the Sun and having special links to the cosmos and its manipulation. Inca rituals required a core of specialists and involved complex astronomical observations and carefully specified sequences of prayers and sacrifices. Pachacuti himself participated in the design and building of a new house for the worship of the Sun. After his visit to the shrine of Susurpuquiu, a natural spring (*pacarina*), a deity in the form of a man dressed in puma skins, serpents, ear spools, and a headdress in the form of the sun's rays, appeared through a crystal tablet or mirror and called him by his name saying he was his father, the Sun, and granted him the power and legitimacy of his divine kingship (Molina 1916; Sarmiento 1944; Betanzos 1987). In memory and celebration of this oracular event, which predicted his victory over the Chancas and his future conquests, Pachacuti rebuilt the Temple of the Sun in Cuzco, called the Coricancha. In this temple, a figure the size of a year-old child was made of solid gold during a month of fasting, sacrifices, and ceremonies. These rituals were carried out by the Inca ruler, himself a priest of the newly founded religion (Betanzos 1987). Some years later after the Chancas War, Pachacuti initiated new religious reforms as a way of organizing the dif-

3.13 Doorway with monolithic lintel in the King's Group. Also shown is Melquiades Richarte, the child who guided Bingham through the site. Photo by Hiram Bingham, 1911.

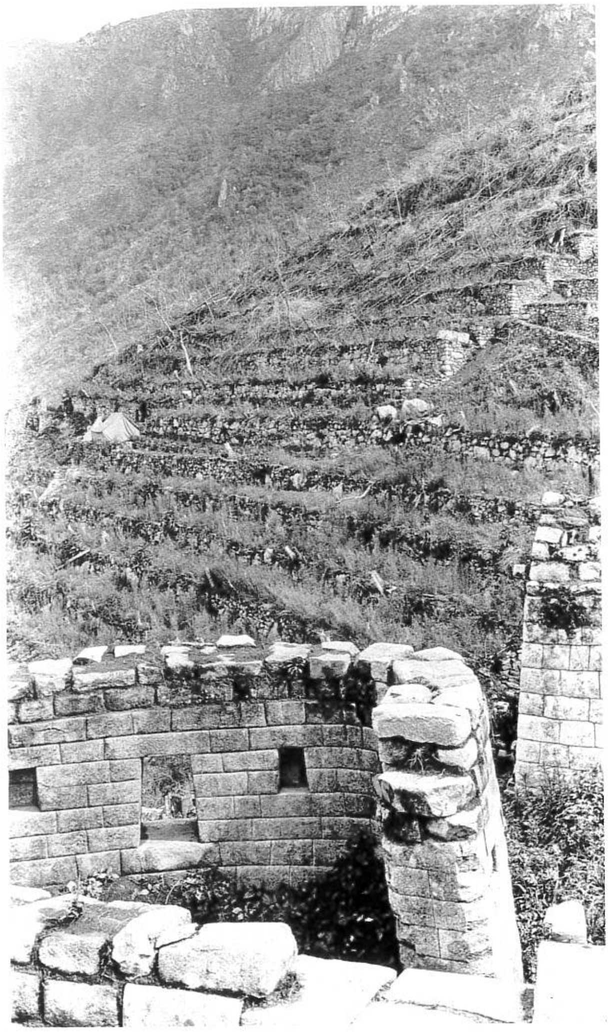
3.14 House in the Ingenuity Group, with red stucco showing in the windows on the left. Photo by Hiram Bingham.

3.15 Interior wall of the Main Temple. The stone block near Sergeant Carrasco is 10.2 feet wide, 8.0 feet high, and 2.8 feet thick. Photo by Hiram Bingham.



3.16 Intihuatana stone, from the southwest. Photo by Hiram Bingham.

3.17 View of the side of the Torreón after Bingham cleared it of vegetation. Photo by Hiram Bingham.



3.18 The Torreón with terraces and expedition tent in the background. Photo by Hiram Bingham.

ferent ethnic groups he was integrating under his imperial rule.

As Bingham (1930: 56–66) and others have observed, the entire upper section of Machu Picchu to the west of the main plaza is dedicated to an impressive set of structures or special features designed for ceremonial activities (Figure 3.15). These include the Main Temple, with its massive granite altar, and the Intihuatana, an elegant carved stone with a tall vertical shaft, that may have served to follow the movements of the Sun (Figure 3.16). Such early chroniclers as Cristóbal de Molina (1916), Juan de Betanzos (1987), and Polo de Ondegardo (1916) describe the Inca religious celebrations and refer to events of an astronomical nature such as the solstices or zenith passages dates, as well as events that involved celestial observations to determine crucial times, such as when to plant or to carry out sacrifices.

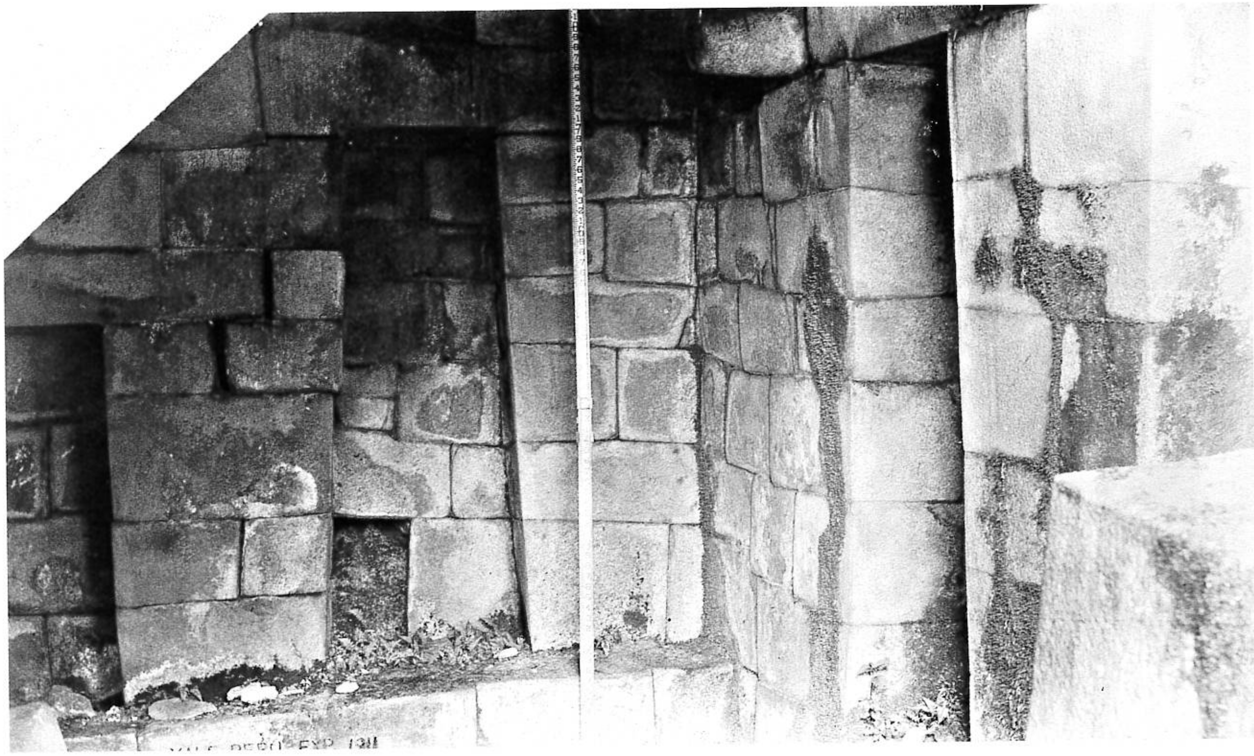
The Temple of the Sun, or the Torreón, as Bingham called this unique building, is a curved structure of carefully fitted masonry that encloses a carved rock outcrop in a form that resembles a feline, probably a puma. Pachacuti himself dressed for the wars with a puma skin over his head to show his ownership of this totemic ancestor. This mythical affinity reflects Pachacuti's superior spiritual status as a cultural hero (Helms 1998).

The Torreón has a clear view to the east (Figure 3.17). The two windows in this wall have symmetrical stone pegs projecting very close from the four corners. The Torreón's northeastern window is aligned to a declination of +21.6 degrees, providing an interesting similarity to the Coricancha (Dearborn and White 1982, 1983). Another special feature is the straight edge cut in the bedrock platform that points through the center of the window. Its orientation is precisely to the rising point of the sun on the June solstice. The solstitial alignment of the central stone is accurate to approximately 2 arc minutes, the best precision possible using the naked eye (Dearborn, Schreiber, and White 1987). But, to cast a shadow through the window and onto the stone for observations of the setting stone, they probably used a plumb bob that hung from a stick supported by the stone pegs; this or any other vertical object acted as a hand on a clock until the day of the solstice when the shadow could become parallel with the edge of the bedrock (Figure 3.18). Bingham found silver and bronze plumb bobs at the site (Bingham 1930: 184). Another instrument that could be used for casting a shadow is the plated bronze "mirror" (Bingham 1930: 182; Salazar 2001a). In addition, another window in the Torreón was used for the observation of the first morning rise of the constellation Pleiades (Dearborn and Schreiber 1986; Reinhard 1991; Urton 1982). It has been suggested that a similar astronomical observation was made at Pisac, also a royal estate of Pachacuti. A structure called Intimachay, located on the eastern side of Machu Picchu, or the Hurin, seems to have been created to monitor the sunrise on and around the December solstice (Dearborn, Schreiber, and White 1987). Also, the second win-

3.19 Rainbows are common over Machu Picchu. Photo by Sir Charles Chadwyck-Healey.

dow of the curved wall allowed visitors to view several constellations, such as the tail of Scorpio, called *Collca*, or Store House.

The Torreón and its associated features were a symbol of the Inca cosmological order as conceived by Pachacuti. I would like to argue that the form of the Torreón as seen from above corresponds to the Rainbow (*Kuychi*, "el arco del cielo"), one of the main deities of the Inca religion. It is relevant that the Coricancha in Cuzco housed a special shrine for the worship of the Rainbow. The Incas believed the rainbow originated from the Sun, and they displayed it as an emblem on their shields and coat of arms, a reference to the myth that they were descendants of the Sun. The rainbow was a celestial phenomenon that, like lightning, united the three spheres of the cosmos: the sky, the earth, and the underworld (Figure 3.19). Many investigators have assumed that the Torreón's curved wall symbolized the circular shape of the sun, but the form of the building is distinctively hemispherical, despite the ability of the Inca masons to create circular structures, such as the site of Ingapirca in Ecuador. On the colonial Inca ritual wooden vessels called *qeros*, the Sapa Inca is often shown beneath a rainbow — sometimes imagined as a two-headed

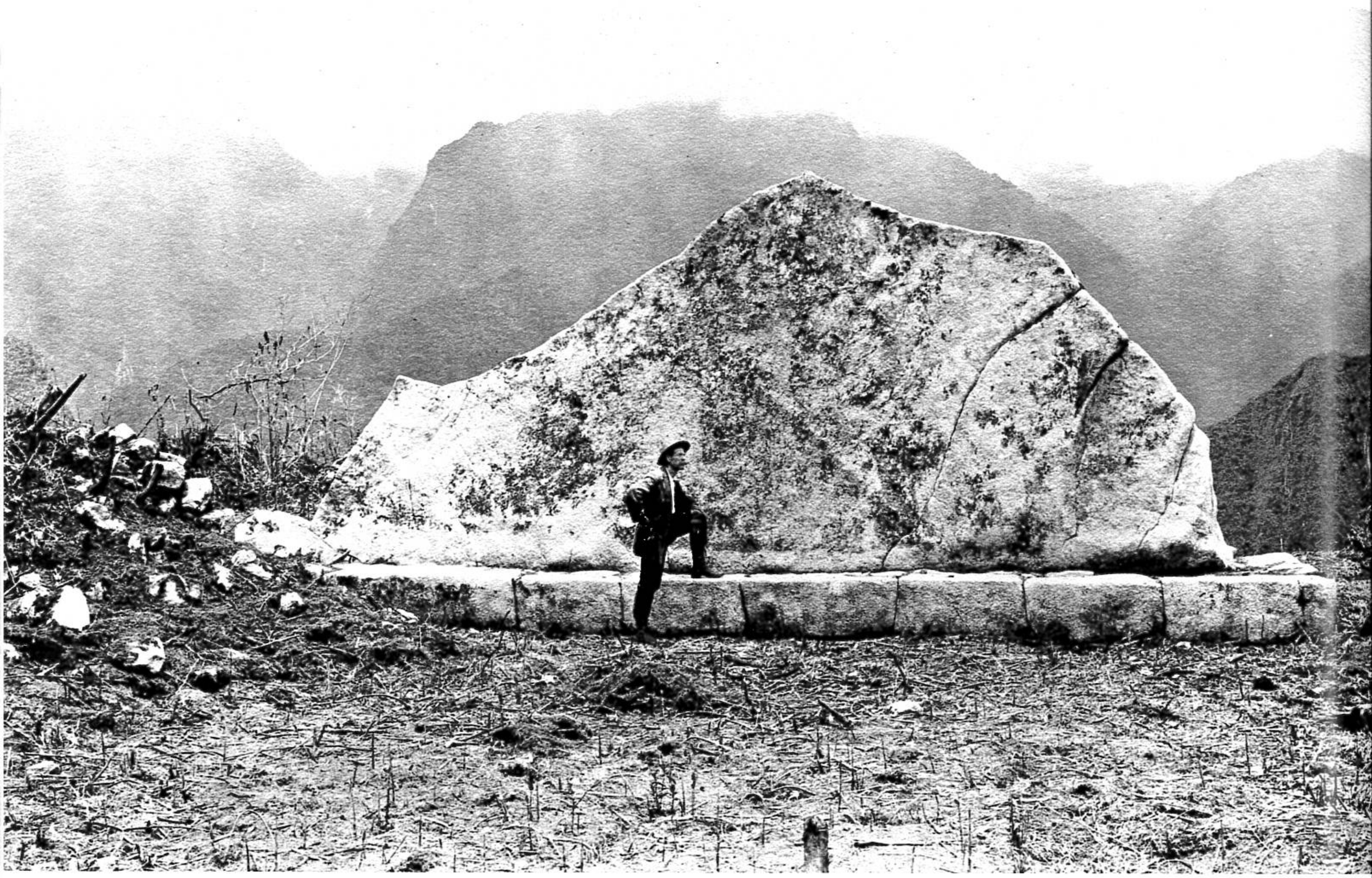


3.20 Cave with fine niches beneath the Torreón. Photo by Hiram Bingham.

3.21 Rock carved as a stairway beneath the Torreón. Photo by Hiram Bingham.

3.22 The emperor and queen worshipping such ancestral places as Tampu Toco. Drawing by Guaman Poma.

3.23 Shrine inside the Ingenuity Group. Photo by Hiram Bingham.



3.24 Ellwood C. Erdis in the rock outcrop shrine that resembles Mount Yanantin in the background. Photo by Hiram Bingham.

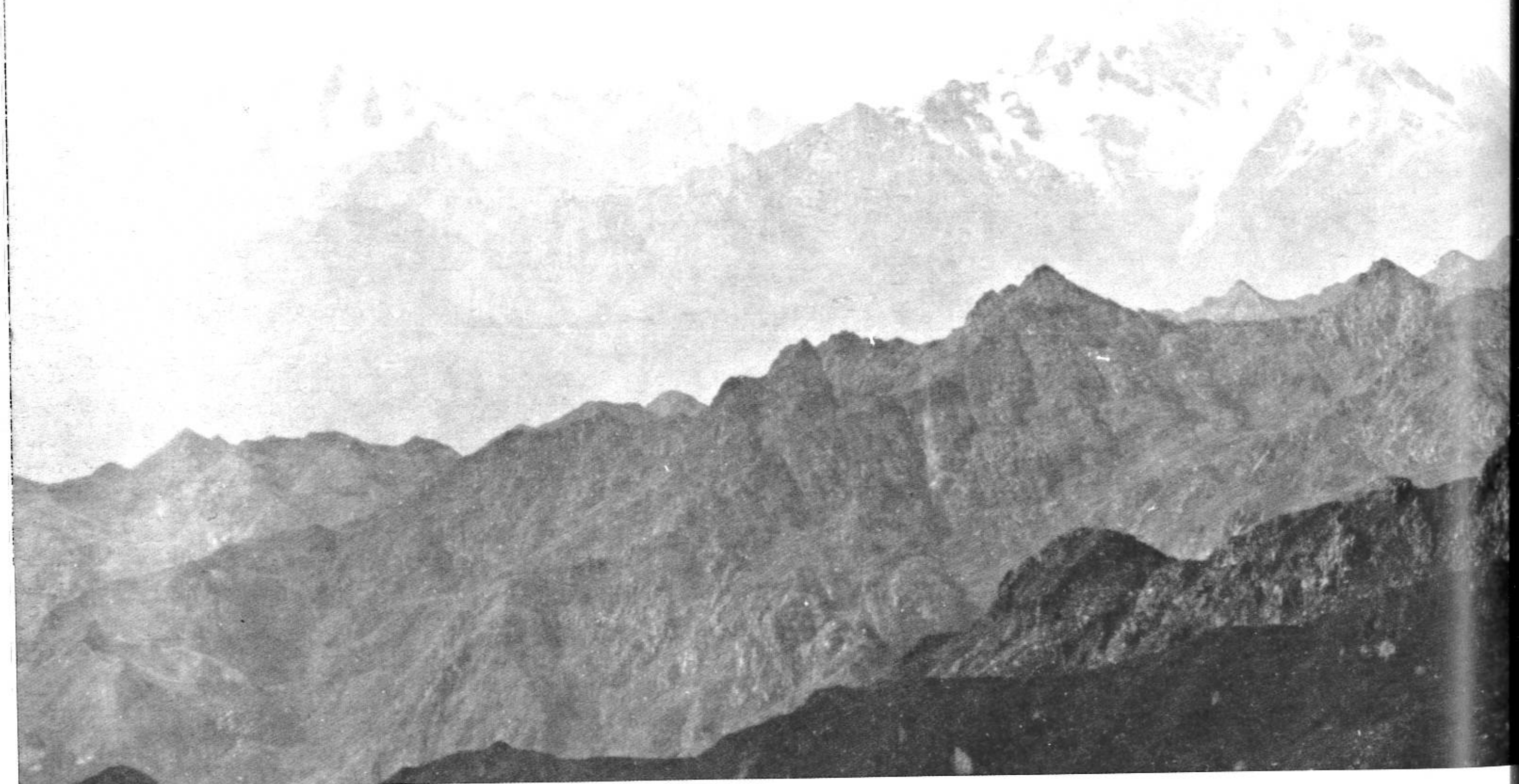
serpent (*amaru*) — because the rainbow was said to be the Inca's means of communicating with the Sun (Isbell 1978). The cave beneath the Torreón (Figure 3.20) conceptually corresponds to the underworld from which rivers and ancestors like the mythical Inca Manco Capac emerged from in Inca mythology (Figure 3.22). The carved stair in this chamber could have served as a small platform to support portable sacred images (Figure 3.21).

All these unusual architectural features at Machu Picchu, including the sixteen cut stone fountains, suggest the centrality of worship to the activities at Pachacuti's country palace. Similar features are well known from sites in Cuzco, where they were interpreted as reified elements from myth or history. Spanish chronicler Bernabé Cobo lists 328 shrines (*huacas*) in Cuzco's landscape, about 30 percent of which corresponded to natural stone formations (Cobo 1964). Significantly, the boulders and the rock outcrops all over Machu Picchu informed the planning of the buildings by the Inca architects and stonemasons. In a physical sense, they were probably a stabilizing feature, but at the same time these boulders were crucial elements in the animistic Inca religious philosophy (MacLean 1986: 72). The fine masonry platforms surrounding analogous features at Machu Picchu dispel any doubts that might exist concerning their ceremonial function (Figure 3.23). Moreover, religious features are not limited to the ceremonial sector. Natural stone outcrops that served as the focus of shrines occur on the eastern side of the site both within and adjacent to the principal areas of elite residence (Figure 3.24). But why should religious activity be so crucial to a country palace where hunting and other nonurban pleasures might be expected?

It is very significant that a large number of architectural structures, around thirty, were used for religious activities. This total is very high when compared to the remains of other royal estates, such as Chinchero, Huamanmarca, Pisac, and Callachaca (see Chapter 4). Pachacuti dedicated substantial amounts of skilled labor and prime real estate to these religious elements within the palace complex at Machu Picchu. It suggests that from the outset Pachacuti and his panaca may have played an exceptionally important role in the ceremonial life of the Cuzco elite. The claim by Inca Pachacuti and later rulers that a special relationship existed between the Inca royal lineages and the supernatural forces immanent in the landscape and the celestial sphere was so important that it had to be actively reaffirmed through daily ritual. It may be significant that one of Pachacuti's sons, Yamque Yupanqui Topa, was said to have devoted his life to Inca religious activities rather than political rulership. If a special link existed between Pachacuti's panaca and the Inca religious cult, it might help explain the presence of unusual ritual constructions like the Temple of Three Windows, whose architectural metaphorical reference to the Inca mythical origins is unparalleled at other royal estates (Figure 3.25). Encoded within Machu Picchu's architecture lies the structure of the Inca ideology upon which Pachacuti's legitimacy rested.

Inca sites were carefully located and landscaped into alignment with mountain peaks and constellations. From the summit of the Huayna Picchu, the magnificent peak of Salcantay is visible. It is the most prestigious snowcapped mountain in the Andes and regarded today, with its brother the Mount Asungate (20,905 feet above sea level), as the ancestors of all mountains and as deities to the people of Cuzco and Apurimac. Today Salcantay is considered a male deity invoked by male healers in rituals to cure illnesses, increase crop yields, and ensure livestock fertility (Reinhard 1991). Another snowcapped peak to the east of Machu Picchu visible from the Intihuatana is Mount Veronica (18,865 feet

3.25 Temple of Three Windows. Photo by Hiram Bingham.



3.26 Mount Salcantay and Mount Veronica. Photo by Hiram Bingham.

above sea level) to the east of Machu Picchu, which today is considered a female deity (*apu*) (Figure 3.26).

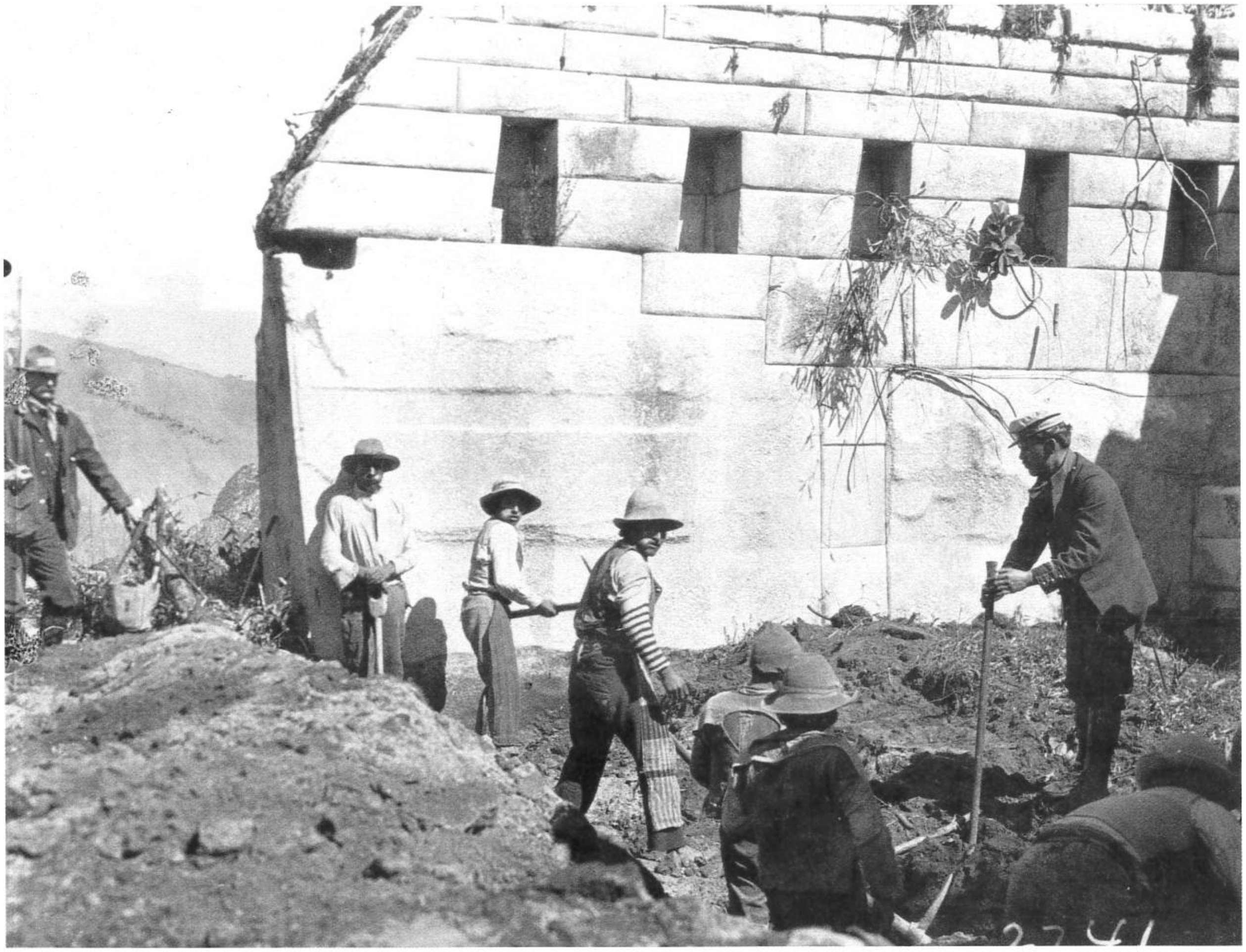
It is not surprising, then, that a royal estate such as Machu Picchu would feature numerous places for observing solar, lunar, and stellar activity (the windows of the Torreón), for making ritual offerings (the Principal Temple) (Figure 3.27), or for the temporary placement, worship, and sacrifices to their deities and ancestors (the cave beneath the Torreón). It is interesting, however, that in addition to such public areas of worship and ceremony on the upper northwest sector of the site, there are small shrines within each of the elite compounds, where more intimate family rituals could be carried out.

Demystifying Machu Picchu

Investigations of recent years have convincingly disproved Bingham's dual identifications of Machu Picchu as either the last Inca capital (i.e., Vilcabamba) or the

mythic Inca birthplace (i.e., Tampu Toco). But what about Bingham's rather passionate claim that the so-called Virgins of the Sun occupied Machu Picchu? This theory, not particularly consistent with his other two theories, derived primarily from George Eaton's conclusion that the skeletons recovered from the Machu Picchu burials in 1912 had almost all been women, with a few "effeminate men" (Eaton 1916).

These burials were discovered mainly in walled-up crevices beneath or adjacent to the large boulders strewn along the edges of the site. Bingham was familiar with the Inca custom of selecting young girls at the age of seven or so, and assigning them to a state-run female institution or *acllahuasi* (house of the chosen women) created by Pachacuti, where they were trained and educated to become priestesses, were sacrificial victims, or, in most cases, were kept as secondary wives of Inca emperors or to be distributed as a sign of favor to successful



3.27 Excavations at the Main Temple in 1912. Photo by Hiram Bingham.

generals, administrators, or allies. These houses, which the Spaniards compared to nunneries, were the focus of many Spanish accounts.

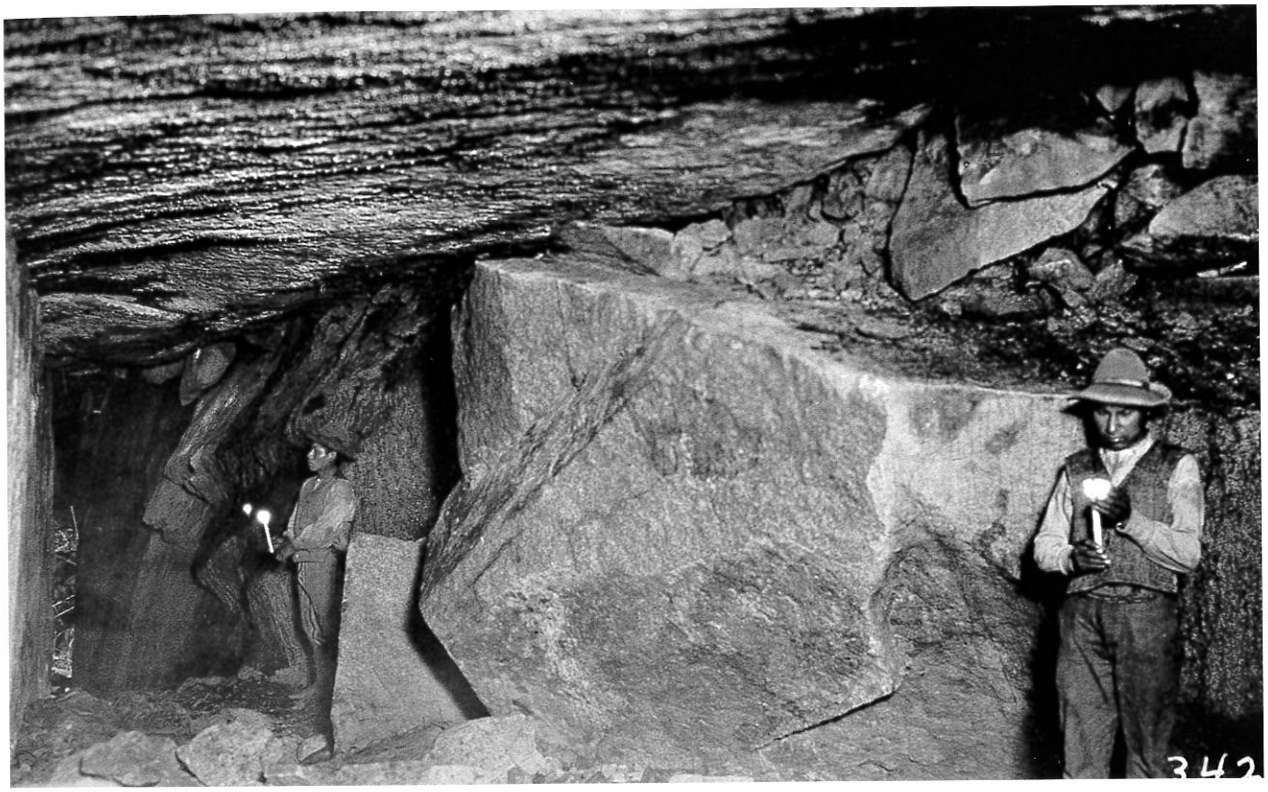
Understandably, Eaton's findings brought this group to Bingham's mind. At the site of Huanuco Pampa, Craig Morris found a distinctive structure of barrack-like form. It is a large compound with a single entrance that encloses a densely packed set of rooms. The excavation yielded high numbers of spindle whorls and shawl pins, artifacts associated primarily with the female sex (Morris and Thompson 1985). But no such architectural arrangement exists at Machu Picchu, nor did Bingham encounter large numbers of weaving implements or other artifacts related to females in any particular sector. How then can we explain Eaton's findings? Reanalysis of the skeletal materials has documented the presence of 174 individuals; the ratio of men to women was 1:1.5, rather than the asymmetric 1:4 Eaton calculated. The skeletal evidence also indicates that many of the adult women recovered had given birth, and there are skeletons of fetuses, infants, and young children (Verano 2003) (see Chapter 6). Bingham's theory of the Virgins of the Sun was an attempt to explain a nonexistent anomaly in the evidence.

Although the burials of men and women do shed light on life in Machu Picchu, royal estates were not the preferred burial grounds of the Inca elite. Inca royalty who died suddenly while visiting Machu Picchu would have been borne back on litters (as they had been brought there) for mummification and burial in Cuzco, the imperial capital. One would expect only retainers to be interred at a place like Machu Picchu, and this expectation accords well with the archaeological evidence. First, little energy was expended in preparation of the burial chambers, which, in most cases, was simply an unmodified natural space with a few rocks piled around the body to keep wild animals out. Second, most of the goods left with those found buried at Machu Picchu were modest at best. Because the dead were believed to use the items interred with them in their journey to the next world, even low-ranking officials — burials of the lowest Incan bureaucrats (*curaca pachaca*), who had charge of 100 taxpayers — were interred in the Ica Valley with precious metal cups, more than a dozen pieces of pottery, and other offerings (Menzel 1977: 97). In contrast, only a few modest offerings accompanied the bodies buried at Machu Picchu — rarely more than four to six pots, and even these typically were vessels that had been repaired during the life of the deceased. On burial goods alone we can infer that the majority of those buried at Machu Picchu were people of relatively low status.

Also, some of these skeletons bear the traces of broken bones and bad backs, which mark common laborers, such as retainers. The retainers — *yanaconas, mitimaes,* and *camayocs* — of the Inca elite are known to have been drawn from throughout the provinces. For example, the royal estate upstream from Machu Picchu at Yucay was said to have had retainers brought from Quito, Ecuador. The nonlocal origin and heterogeneity of the retainer population also fits well with the Machu Picchu burial sample. For example, several types of cranial deformation are represented, including types not typical of the Cuzco region. By far the most common ethnic groups represented in the Machu Picchu cemeteries are from the area surrounding Lake Titicaca (Collas, Lupaqas, Pacajes). There also significant numbers of Chimu from the north coast, Cañaris and Chachas from the northeastern mountains, and groups from the central coast. The number of burials of people from Cuzco appears to be small (Salazar 2001b).

Although the role of retainer was not prestigious within the vertical hierarchy of Inca society, documents from the sixteenth century mention that the Cañaris and Chachas were exempt from tribute and labor tax (*mita*) (Espinoza Soriano 1978; Villanueva 1971). At Machu Picchu, the mortuary treatment of the retainers suggests the multiple levels of individual identity and their real implications for daily life in a way not possible even through a close reading of Spanish historical narratives. At Machu Picchu some retainers were buried with pottery bearing the emblems of the Inca state: silver shawl pins, tweezers, and plated bronze mirrors (Salazar 2001). At the same time, these individuals retained their original ethnic identity, symbolized by the presence of pottery and other personal items made in the style of their homeland; the use of these ceramics was a public expression of their identity. Significantly, the burials of the retainers followed the Cuzco style of entombment rather than that of their homelands. This conformity suggests the degree of dominance of a retainer's native culture in the asymmetric world in which these people lived and died. Also, there is evidence that many of the Machu Picchu dead were regularly worshipped in their capacity as ancestors, and that the burial caves were the focus of post-inhumation visits. As expected, evidence also shows that ritual feasting involving food and drink was carried out around the entrance and periphery of the burial caves. The remains recovered there consisted mainly of animal bones, drinking vessels, and serving dishes (Figure 3.28). In Andean ideology, the mummified remains of ancestral dead (*mallquis*) were the object of great veneration because they provided for the continuation of life for their communities (Salomon 1996). The mallquis were considered the ultimate source of food, water, and agricultural land, and their burial places were located in natural or modified caves (*machays*). This belief system survived the Spanish Conquest. Mary Doyle, in her analysis of seventeenth- and eighteenth-century documents, encountered numerous descriptions of the performance of ceremonies at the entrances of machays honoring the dead with corn beer (*chicha*), llama blood, and guinea pigs (Doyle 1988).

Archaeological artifacts recovered from the graves and refuse argue against workers' involvement in agriculture, but the studies by Gordon and Rutledge (1987) indicate the production of tin bronze alloys at the site. Metalworking by-products, raw materials, and tools for creating metal artifacts provide strong evidence of an



3.28 Burial named the Gran Salon. Photo by Hiram Bingham.

unexpected component of daily life at Machu Picchu. Spanish chroniclers identified the ethnic groups in the tombs as having special metallurgical skills; many of them were brought to the royal estate because of this technical knowledge (Salazar 1997b). The identification of the Machu Picchu burials as basically belonging to specialized retainers helps to explain why Bingham failed to encounter large quantities of precious metal objects, because their inclusion would have been restricted largely to the elite.

The creation of highly valued craft items may have been part of an intentional strategy by Pachacuti's panaca to use these wealth objects in establishing or reinforcing alliances with other groups. The link between metallurgy and magical transformation has been observed cross-culturally and, in the Andes, the use of metals to represent supernatural forces is a feature not only of the Incas, but of many of their predecessors for over two millennia. And, in addition to this ideological dimension, metallurgy played a special role in the political economy of the Inca court.

Why Machu Picchu Was Perceived as "Lost"

Machu Picchu's location is indeed spectacular, and it was probably for this reason that it was selected for settlement. Whether or not it was couched in sacred geography or cosmological determinism, the Incas appreciated the aesthetic qualities of highland landscapes as much as or more than do modern-day archaeologists and travelers; their fascination with the site's location may have been based on the same features we find fascinating today.

Yet the choice of this spot had disadvantages as well as advantages. For example, it was located 60 miles from Cuzco in a lightly settled region; as such, it was particularly vulnerable to surprise attack from either rebellious highland groups like the Chancas or unconquered jungle groups downstream. With few prospects for reinforcements in the immediate area, the elite staying at Machu Picchu would have had to be concerned about security even during a short sojourn at the site.

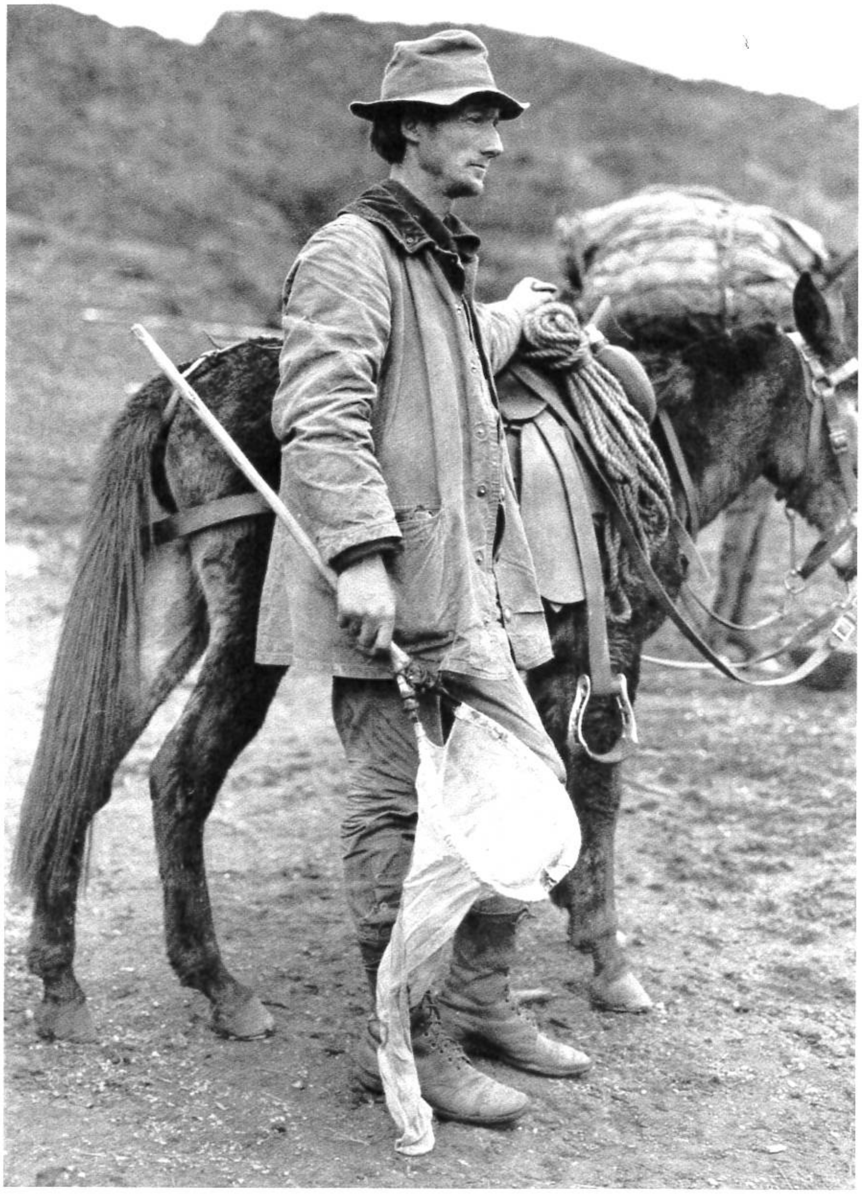
This concern is reflected in Machu Picchu's architecture. The building atop Huayna Picchu was positioned to enable detection of approaching armies far in advance of their arrival. The major road leading to Machu Picchu features a drawbridge spanning a chasm from which attendants could remove the requisite logs in case of a threat. The site itself is inaccessible from three sides because of the steep slopes; the fourth side is protected by a deep, dry moat, which has since been largely filled in by eroding soil. Beyond the stone-lined trench are two high stone walls. The single entrance into the inner city could have been lashed and defended even if the moat and the first wall were breached. As other scholars have noted, while Machu Picchu is not laid out as a military installation, it is undeniable that, in contrast to many Inca sites, special design features made the site defensible in case of attack.

As this discussion suggests, the relationship between the elite and the surrounding rural population may have been perceived as sensitive, a tension reflected in the way hospitality was provided to these groups. Inca rule was premised on the myth of royal generosity. Inca bureaucrats spent much of their time feasting the taxpayers at state centers, providing them with corn beer, coca leaves, alpaca meat, and music. Studies at Huanuco Pampa and other Inca administrative centers have demonstrated that the structures most commonly found around the main open plaza areas are long hallways (sometimes called *kallankas* by archaeologists) used for this ritual feasting. What distinguishes these as kallankas are their many doorways and the large numbers of broken serving vessels found surrounding them.

In Machu Picchu, such kallankas are not found in the plaza area. Instead, smaller versions of the kallankas are associated with each of the elite compounds, as if the royal families created facilities only to entertain one another, excluding the larger agricultural population that likely inhabited the countryside. There is, however, one large kallanka in the Machu Picchu complex, located outside of the city walls about 400 feet to the south above the agricultural terraces. Although small by Inca standards, this ten-door kallanka is twice the size of any inside the city; it would have been perfect for entertaining a large group of farmers without allowing them inside the town walls. In front of the kallanka is an open plaza space with a carved stone, probably used for religious rituals on these occasions.

The reason for Machu Picchu's abandonment, so mysterious to many visitors, is easy to understand. The site was never a self-sufficient center with an economic base. Its very existence was a luxury made possible by the surplus labor and goods at the disposal of the Inca elite. When Tahuantinsuyu was conquered, the socioeconomic system underlying it collapsed, and royal estates like Machu Picchu lost both its reason and the resources to continue to function. Some royal estates closer to Cuzco such as Ollantaytambo were transformed into simple rural villages and continued to survive into the seventeenth century as part of the emerging colonial economy. Others, like Machu Picchu, were too far from the main road system and urban markets to make continued utilization feasible; by the time the farmers finally abandoned the area, the Inca elite and their retainers had long since fled, taking with them whatever portable objects were of value.

The reason Machu Picchu is not mentioned in any of the early Spanish historical narratives of the conquerors is not particularly mysterious either. Historical records of that time were the work of Spanish writers who wrote mainly of those settlements perceived as being of special economic or military importance. Royal estates, of which Machu Picchu was but one of many, had little reason to attract their attention, particularly if it had been abandoned before large numbers of Spaniards had entered the region. Other impressive royal estates, such as Pisac, are similarly ignored by these chronicles, even though they were nearer to Cuzco and continued to be used in colonial times.



6.1 Naturalist and chemist Harry Foote, in search of insects. Photo by Hiram Bingham.

VI Scientific Insights into Daily Life at Machu Picchu

Richard L. Burger

For most of the twentieth century, our understanding of Machu Picchu was shaped by the ideas of Hiram Bingham III and the results of the expeditions he led. Bingham considered himself an explorer first and a historian second. He never had pretensions to being a scientist (A. Bingham 1989). Most early-twentieth-century archaeology had a strongly humanistic orientation, and Bingham's work was far from being exceptional in this regard. In thinking about the Incas, Bingham had a natural inclination to comb historical narratives for clues and, perhaps, draw upon his ethnographic observations among the Quechua-speaking farmers of the Urubamba drainage.

Almost a century has passed since Bingham's discoveries. In the United States, archaeological study of the Incas has become the domain of scholars trained in anthropology. As a consequence, the questions formulated and the techniques used to answer them have become strongly influenced by currents in the social and physical sciences. Over the past two decades, much progress has been made in archaeological analysis and it is now possible to ask and answer questions about Machu Picchu that would have seemed inconceivable to Bingham and his colleagues.

Beginning in 1983, the Yale Peabody Museum facilitated a series of new technical analyses by a variety of specialists in order to explore the scientific potential of the Bingham materials; other scientific studies were initiated independently at Machu Picchu itself. Questions focusing on diet, technology, and patterns of interaction have now been explored based on laboratory studies of the Machu Picchu collections recovered in 1912 and in the more recent field investigations. The findings of these studies give a much fuller and more accurate idea of the life of the people who lived at Machu Picchu. The purpose of this chapter is to provide a summary of these technical analyses and consider how they modify our understanding of daily life at the Inca royal estate at Machu Picchu.

Antecedents from the Yale Peruvian Expeditions

While not a scientist, or even an archaeologist, Hiram Bingham III was not a stranger to the idea of utilizing state-of-the-art scientific knowledge in order to shed light on Machu Picchu. As a historian focusing on modern Latin American development, Bingham had a detailed knowledge of the economic geography of South America. He had great respect for the technical knowledge necessary to evaluate and develop the natural resources in this continent and, in 1908, he was chosen as the youngest member of the United States delegation to the Pan-American Scientific Congress in Santiago, Chile. In organizing the Yale Peruvian Expeditions of 1911, 1912, and 1914–1915, Bingham put together teams of specialists from a wide range of fields. For example, the expedition of 1911, which resulted in the "scientific discovery" of Machu Picchu, included geographer Isaiah Bowman, chemist Harry Foote, and naturalist Casimir Watkins (Figure 6.1). The expedition of 1912, which focused on the excavation of Machu Picchu, included George Eaton, curator of osteology at the Yale Peabody Museum, and Herbert Gregory, a professor of geology at Yale. It would not be an exaggeration to characterize Bingham's archaeological projects as interdisciplinary investigations, and, in some respects, Bingham's historic expeditions foreshadowed an interdisciplinary archaeological approach that did not become popular in Peru until the 1970s, with projects such as Richard MacNeish's Ayacucho-Huanta Archaeological-Botanical Project.

The three Yale Peruvian Expeditions were interdisciplinary not only in staff composition but also in the discoveries they produced. Thus, the publications stemming from the expeditions included studies of the natural history of reptiles, amphibians, insects, mammals, land snails, and cacti, as well as the geography and geology of Cuzco, Andean terracing, and the physical anthropology of contemporary highland and lowland indigenous peoples (Bingham 1922). The biological investigators encountered numerous species never before documented. Most important from the perspective of this chapter, the specialists Bingham engaged used their expertise to analyze the archaeological materials from Machu Picchu with techniques that were sophisticated by the standards of their time. George Eaton (1916) produced an influential volume on the human skeletal material recovered in the Inca tombs at Machu Picchu, and Foote and Buell (1912) and Mathewson (1915) carried out chemical studies of the metal artifacts. These pioneering scientific analyses had a powerful impact on Bingham's interpretations, and they provide the antecedents for the research discussed here. Although these early analyses have now been partially superseded, when used critically they continue to provide insights and information of lasting value.

Curiously, the interdisciplinary character of the Yale Peruvian Expeditions has received little attention in studies of the history of archaeology. Most scholars have dwelled on the technical limitations of Bingham's archaeological training and practice. Bingham's conscious decision not to include professional archaeological personnel on the staff of the expeditions undermined his efforts and was responsible for some of the flawed interpretations that resulted. Nevertheless, the broad focus of Bingham's three expeditions is noteworthy, reflecting his distinctive vision of archaeology as part of a larger geographic endeavor. His involvement of first-class technicians was consistent with his pride in the technological prowess of the United States. The team that made up the 1912 Yale Peruvian Expedition stands in sharp contrast to that of other archaeological projects carried out in Peru in the early twentieth century by such investigators as Max Uhle, Julio C. Tello, Alfred Kroeber, and Luis Valcarcel. For these scholars, archaeological field research was a largely self-sufficient enterprise that might involve complementary historical research but did not require specialists from more scientific disciplines. The publications stemming from their research were limited to descriptions of excavations and artifacts, rarely involving technical studies of any kind. Thus, the scientific work described in the following sections can be seen as following the trail blazed by Bingham and the Yale Peruvian Expeditions.

Health and Diet at Machu Picchu

The archaeological site of Machu Picchu corresponds to a royal estate built by the emperor Pachacuti and controlled by his descendants (or *panaca*) roughly until the Spanish Conquest (Burger and Salazar-Burger 1993; Rowe 1990). The best-known portion of that estate is a finely constructed architectural complex that was created on the ridge crest between Machu Picchu Mountain and Huayna Picchu Mountain to serve as a country palace for the royal family, their guests, and their retainers. Although Bingham referred to it as a "lost city," probably no more than 750 people lived there at any given time. During the rainy season (November–April), the population probably dropped to only a few hundred people, most of whom were religious specialists and members of the support staff.

During the Yale Peruvian Expedition of 1912, over a hundred tombs were encountered, most of them hidden by the dense cloud forests of the site's eastern slopes. Concentrated in three clusters, these interments were usually placed within crevices beneath large granite boulders. In many cases, coarse walls were added to seal these simple tombs and protect them from animals and other intruders. The small number of grave goods, the modest quality and nature of these objects, and the variability of the skeletal materials indicate that these are the graves of Machu Picchu's retainers rather than interments of the members of the royal family or their guests (Burger and Salazar-Burger 1993; Salazar and Burger 2003; see also Chapter 3). Subsequent archaeological work at Machu Picchu has failed to uncover tombs that are significantly more elaborate than those found in 1912 (Valencia and Gibaja 1992). This mortuary pattern is not surprising, for if members of the Inca elite had died while residing at the country palace, they would have been transported to their principal residence in Cuzco rather than buried at Machu Picchu. Because the elite were transported on litters and because the journey to the capital took only three days, this option would not have presented serious obstacles.

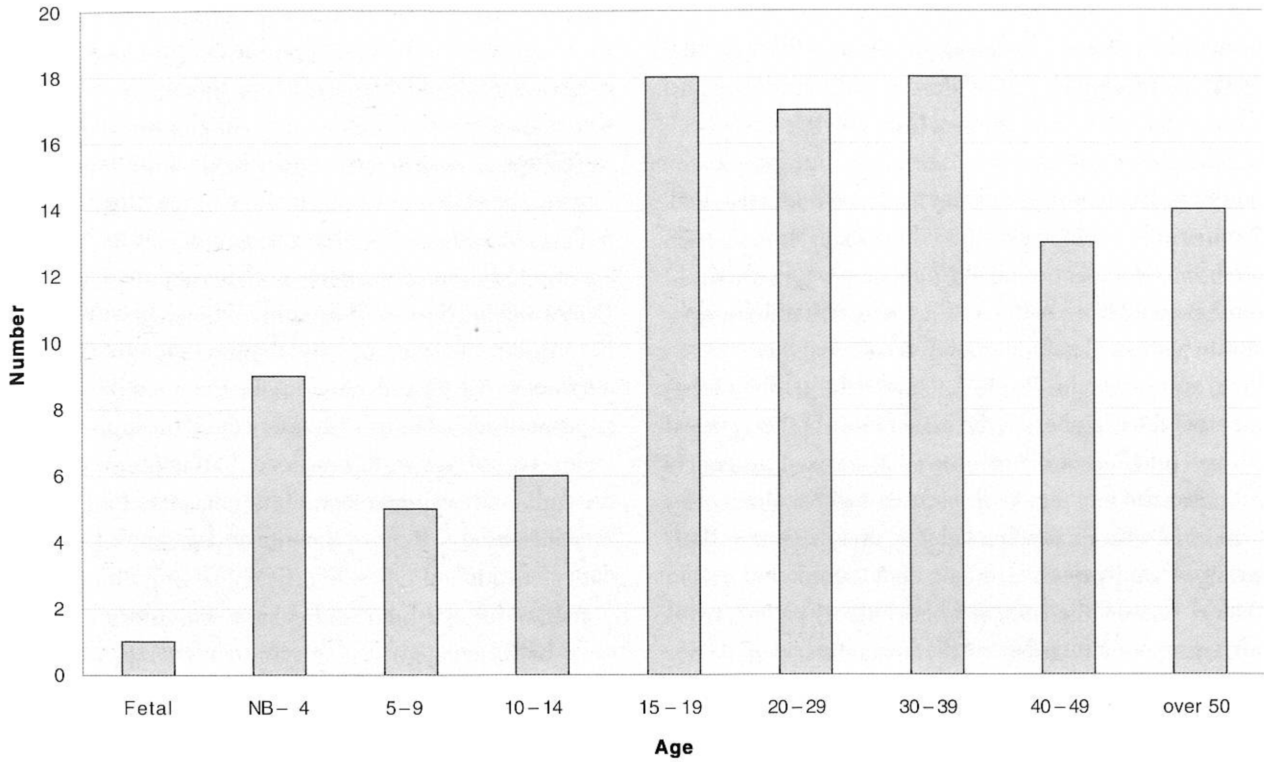
This background information is necessary to understand the significance and limitations of the recent analysis of the human skeletal materials recovered by the Yale Peruvian Expedition. This osteological analysis can illuminate many aspects of the lives (and deaths) of Machu Picchu's retainers, but it does not cast an equivalent light on the elite residents for whom the site was built. Because the Spanish chronicles devoted slight attention to the Incas' retainers and other staff, however, the information the osteological analyses provide is particularly welcome. It should be emphasized that the group of people buried at Machu Picchu was not homogeneous in status or ethnicity, as evidenced from the burials themselves. Despite this variability, however, it is first useful to consider the burial results as a group in order to obtain a general picture of what this population was like.

George Eaton, one of Bingham's colleagues at Yale, was the project osteologist on the 1912 expedition, and in 1916 he published a detailed study of the human remains that were recovered. Unfortunately, Eaton had not worked previously with skeletal materials from the Andes, and he was hampered by the lack of a large comparative sample of Peruvian skeletal remains that could be used as a baseline for his study. Bingham (1948) seized upon Eaton's main conclusion that the vast majority of the skeletons were female to support the hypothesis that Machu Picchu was occupied by the *aclla*, a group of cloistered women sometimes referred to as "Virgins of the Sun" or "Chosen Women." Because of Eaton's lack of experience and the limitations of the techniques he utilized as well as the incompatibility of a community of aclla with other aspects of the archaeological record, we were convinced that Eaton's sexing of the skeletons required reconsideration, as did his controversial claim that some of the individuals showed evidence of syphilis.

A definitive resolution of these and other issues was provided by a reanalysis of the entire osteological collection by John Verano, a physical anthropologist on the faculty of Tulane University. Verano has had more extensive experience working with osteological collections from archaeological sites in Peru than any other U.S. scholar in the field. He was enthusiastic about reexamining the Machu Picchu collection, one of the oldest and most complete osteological repositories of an Inca population, and was able to complete his initial observations while a visiting professor at Yale in the spring of 2000. In the detailed presentation of his findings, Verano (2003) concluded that a minimum of 174 individuals were represented in the Machu Picchu osteological sample. Contrary to Eaton's findings, a significant proportion of these individuals were males. In the new analysis, the ratio of females to males proves to be 1.46:1 rather than the 4:1 ratio cited in Eaton's work. The sex ratio documented by Verano is relatively balanced and does not suggest the need to posit the presence of a community of "Chosen Women" to explain it. The presence of children in the Machu Picchu sample, including newborns, and the osteological evidence that some of the women had given birth further undermines Bingham's "Virgins of the Sun" hypothesis.

In determining the ages of the Machu Picchu dead, Verano encountered a diverse population of infants,

Table 6.1 Machu Picchu Age Distribution



children, young adults, and elderly (Table 6.1). The burial population was dominated by adults (78 percent of the skeletons), with at least fourteen individuals who were over fifty years of age. The latter were old by the standards of the prehispanic world. Significantly, twenty individuals were under the age of fifteen, and one of the twenty was apparently a fetus. Given the underrepresentation of children's burials common in archaeological samples, the population of Machu Picchu appears to be a fairly normal one. Contrary to its traditional image, it in fact had its share of children playing at least along the margins of the settlement.

The stature of Machu Picchu's retainers was small by United States standards: men were an average of 5 feet 2 inches tall, and women averaged 4 feet 11 inches. None of the skeletons studied by Verano were over 5 feet 6 inches. It should be kept in mind, however, that studies of modern Quechua-speaking peoples in the Department of Cuzco found that the average height of an adult male was 5 feet 2.5 inches and an average female was 4 feet 9 inches tall (Stinson 1990, cited in Verano 2003). These contemporary highland farmers are remarkably close in height to those from Machu Picchu some five hundred years ago.

Judging from Verano's findings, the population at Machu Picchu was a fairly healthy one. Dental caries, however, were a common problem, which suggests the consumption of sticky, high-carbohydrate foods such as maize (corn). More severe pathologies, such as skull fractures of the kind produced by armed combat, are completely lacking at Machu Picchu (Verano 2003). This absence contrasts sharply to the findings at other late prehispanic sites in Cuzco. Similarly, osteological evidence of advanced arthritis and other markers of occupational stress was surprisingly limited. This suggests that the work load for retainers at Machu Picchu was reasonable, and somewhat less than the physical demands at other kinds of Inca sites. Although Verano failed to confirm Eaton's claims for syphilis, he did find evidence of tuberculosis and possible parasitic infections such as tapeworm. Nonetheless, the retainers appear to have enjoyed generally good health. This conclusion received independent support from the low frequency of growth disruptions in the formation of tooth enamel. The scarcity of hypoplasias similarly suggests that the retainers experienced few severe illnesses during their childhood.

It is reasonable to assume that the good health of the Machu Picchu retainers was based upon an adequate diet. Because little organic material has survived the heavy rains and temperature fluctuations at Machu Picchu, our understanding of their diet remains limited. Nevertheless, recent breakthroughs in the study of bone chemistry have provided some insights into what they were eating. The chemistry of human bone collagen reflects the foods consumed during an individual's lifetime, but it is often difficult to interpret these data because of similar results produced by different foods. In the Andes, however, maize is the only major food plant characterized by C4 photosynthesis. All the other dietary plants in prehispanic Peru utilized a C3 photosynthetic pathway (DeNiro and Hastorf 1985). C3 plants make 3-carbon molecules from atmospheric carbon dioxide, while C4 plants make 4-carbon in the first photosynthetic step. C3 plants discriminate against ^{13}C, the heavy carbon stable isotope, so that their delta ^{13}C ($\delta^{13}C$) values are lower (more negative) than those of C4 plants. The differences in the C3 and C4 pathways are mirrored in the contrasting carbon isotope ratios of these plants, which, in turn, shape the carbon isotope ratios of the bone collagen of animals that consume these plants as food. The ratio between the stable carbon isotopes (^{12}C and ^{13}C) is measured relative to a marine carbonate standard known as PDB, and the result is reported as a delta 13 value in parts per thousand (per mil). The carbonate standard has a high ^{13}C content, so the measurement of most living or formerly living things consequently yields negative numbers. The collagen of C3 plant eaters has $\delta^{13}C$ values of approximately -21.5 parts per thousand, or per mil, while animals that eat only C4 grasses have $\delta^{13}C$ collagen values of around -6.5 per mil. Some complicating factors existed such as contamination from the soil and confusion resulting from the chemical signature of marine foods, but it is possible to control for these variables. Thus, at least high in the Central Andes, it is feasible to use stable carbon isotope values of human bone to calculate the relative importance of maize in the diet. An earlier bone chemistry study of early pre-Inca cultures in the Peruvian highlands (2000–200 BC), for example, encountered $\delta^{13}C$ values of -18.7 per mil -19.0 per mil. Based on these figures, we have concluded that although corn was consumed, it was not a major staple crop, probably constituting less than 25 percent of the diet (Burger and Van der Merwe 1990).

The results of the Machu Picchu bone chemistry analyses provide a fascinating contrast to this earlier study. Bone samples from fifty-nine individuals of both sexes and different ages and cranial forms were analyzed in collaboration with Julia Lee-Thorp and Nikolaas van der Merwe at the Archaeometry Laboratory at the University of Cape Town. The carbon isotope figures ranged from -9.61 to -18.8 per mil, averaging -11.9 per mil (Burger, Lee-Thorp, and Van der Merwe 2003). The results indicate that most of the carbon in the bone collagen was derived from consuming C4 plants. Apparently, maize constituted the staple food for the retainers at Machu Picchu and, for most individuals, maize constituted 60 to 70 percent of the diet used to produce bone collagen. Although remarkably high, this figure probably underestimates the importance of maize in the total diet.

Although the importance of consuming corn beer (*chicha*) in Inca rituals has long been appreciated, the relative importance of maize in the diet has been the subject of debate. Potatoes and other high-altitude crops native to the Andes are better adapted to the mountain environments of Cuzco than maize, whose origin appears to have been in the lower and more tropical environments of Mexico (Pearsall 1994). In contemporary highland Peru, maize is viewed as a luxury to be consumed on holidays to break up the tedium of a diet dominated by tubers. Among the Inca, the elite associations of maize raised the possibility that even if it was the staple among the upper class, corn might be less important for the retainers serving the royal family and their guests than high-altitude foods such as potatoes, quinoa, and *chocho* (a lupine). One well-known Inca specialist, John Murra (1960), suggested that the prominent role of maize in Inca rituals reflected its special symbolic im-

6.2 Inca terraces at Machu Picchu where maize was grown along with other crops. Photo by Richard L. Burger.

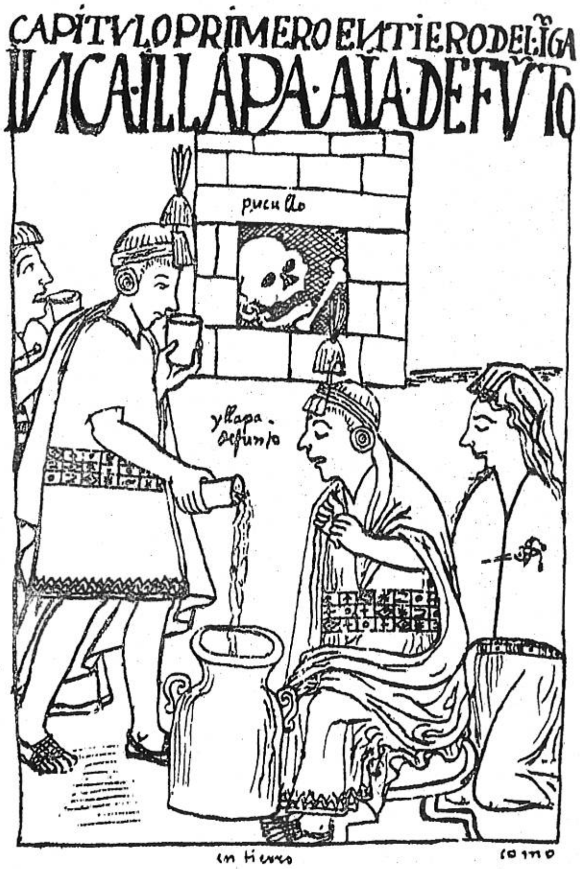
portance and its association with the state, rather than its importance in the daily diet. While Murra's argument is plausible, the large sample and the consistent results of the stable isotope analysis of human bone leaves little doubt not only that the servants and other staff at Machu Picchu had access to maize, but that it constituted the core of their daily diet.

When combined with beans, lupines, and other crops, maize is an extremely rich source of protein and other nutrients. The good health of Machu Picchu's retainers, both men and women, was to some degree the result of this imperial diet. Much to our surprise, in contrast to an earlier study of provincial Inca populations in the central highlands (Hastorf 1990; Hastorf and Johannessen 1993), there was no significant difference in maize consumption between Machu Picchu's male and female retainers. The equivalence of C_4 foods in their diet suggests that male and female retainers drank *chicha* and were involved in the activities associated with its consumption. The overall role of maize as the staple of Machu Picchu's population is consistent with Verano's (2003) documentation of numerous dental caries, which were probably the by-product of this maize-rich diet.

Judging from the carbon isotope study, plant foods other than maize constituted a small but significant proportion of the diet. Unfortunately, stable carbon isotope analysis does not shed light on their identity. One alternative source of relevant evidence comes from microscopic pollen that has been preserved since Inca times in the terraced fields on the eastern slopes of Machu Picchu. Pollen analysis is still rare in Central Andean archaeology, but it has become more common over the past two decades. Because the structure of pollen is largely inorganic, pollen does not decay the way most food remains do and, depending on the composition of the earth, it can remain intact, mixed with the soil for millennia despite heavy precipitation. During a study of the agricultural terracing on the slopes of Machu Picchu by Peruvian archaeologist Alfredo Valencia Zegarra and American hydrologist Ken Wright, soil samples were taken and pollen was successfully extracted (Figure 6.2). When these samples were analyzed, the results indicated that the crops planted there included potatoes and an unidentified legume as well as maize (see Chapter 5).

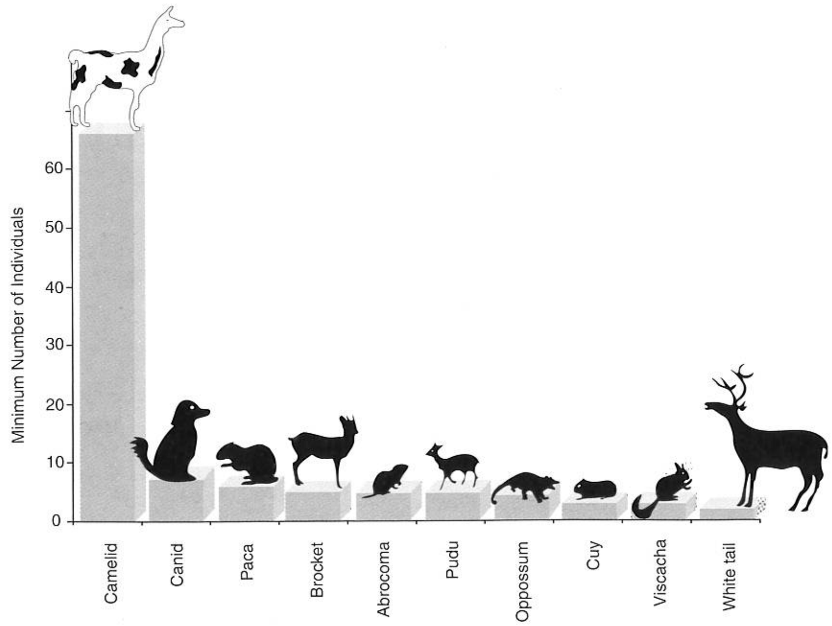
At Machu Picchu, meat would have been another source of protein and nutrients for the Inca elite and their staff, although early Spanish historical accounts indicate that meat was not the focus of Inca cuisine. According to the Spanish chroniclers, drinking, rather than eating, was the central feature of Inca foodways (Coe 1994). Nevertheless, the Incas did eat meat, and the abundant residue of animal bone at Inca and pre-Inca sites dispels any doubt about its presence in the diet. What animals were being eaten at Machu Picchu, given its unusual location in the cloud forest environment of the eastern Andean slopes? Bingham had little interest in this question, and his speculation on this subject was based on a small number of bones and local observations while at the site.

In contrast to the archaeology of Bingham's time, the analysis of faunal remains has become an important part of contemporary archaeology and analysis of animal bone has become an effective tool for studying diet and other cultural patterns. Bone is more resistant to the elements than plant material, but the animal bones encountered in the center of Machu Picchu were not kept by the 1912 Yale Peruvian Expedition. Fortunately, the animal bones that were recovered in or around the cave burials were carefully catalogued and preserved at the Peabody Museum of Natural History in New Haven. A few of these, like the rare remains of a paca (*Agouti thomasi*), were studied by Eaton (1916: 87–89) and others, and used to identify several previously unknown taxa and species native to the cloud forests around Machu Picchu. The Yale Peruvian Expedition paid much less attention to the more common animal remains that reflect the dietary habits of the residents of Machu Picchu.



6.3 Guaman Poma drawing of men and women drinking corn beer (*chicha*) at a funeral.

Beginning in 1994, zooarchaeologist George R. Miller initiated the first systematic analysis of the faunal remains from Machu Picchu. The sample consisted of 2,169 bone fragments, over a thousand of which could be identified at the family level or better. Because most of these came from the burial caves, Miller assumed they were the remains of food presented to the dead ancestors or consumed during graveside rituals. Such banquets for and with the dead were described by the Spanish chroniclers, and they continue to be a feature of traditional Andean ceremonial life (Figure 6.3). Although these faunal remains from the burial caves probably do not constitute an exact reflection of daily diet, they do suggest the range of animals that were eaten and their relative importance as food. According to Miller's analysis, by far the most abundant animal remains from the Machu Picchu burial caves were those of the do-



6.4 Relative abundance of animals recovered from the Machu Picchu burial caves. Courtesy of George Miller.

mesticated camelids (llama and alpaca). In terms of the total number of bones, they account for 88 percent of the remains. When these numbers are converted into the amount of meat they represent, camelids constituted over 90 percent of the remains. Miller (2003) believes that over 95 percent of the meat consumed at Machu Picchu came from alpaca or llama herds, or both (Figure 6.4).

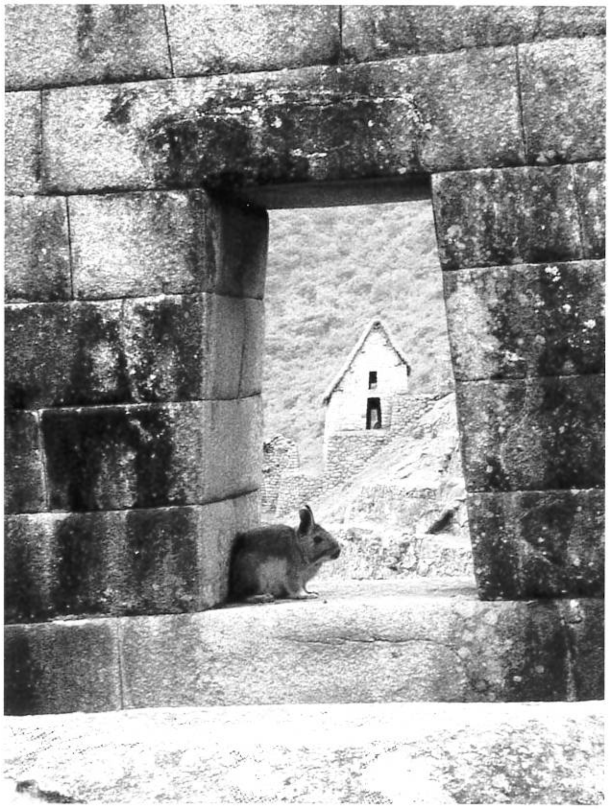
The natural habitat of both the llama and the alpaca is the high, open pastureland above 12,500 feet (3,800 meters) above sea level, known as *puna*, rather than the densely forested slopes below Machu Picchu between 6,600 and 8,000 feet (2,000 and 2,400 meters) above sea level. Some patches of high grassland are within a day's walk of Machu Picchu, and it is likely that llamas and alpacas would have been herded in these and more distant puna areas. Domesticated camelids were essential for transport and for wool production throughout the Inca Empire; one of the species, or both, would likely have been a common sight near Machu Picchu. Both llamas and alpacas were eaten in Inca times, although their role as a food source is traditionally thought to be secondary to their other economic functions.

At some point in the distant past, the llama and alpaca had a common wild ancestor. In fact, they can still interbreed and produce fertile offspring, although under normal circumstances such crossings are uncommon and avoided by both the herders and the animals themselves. From the perspective of archaeologists, an unfortunate result of this similarity is that it is extremely difficult to distinguish between the remains of llamas and alpacas on purely morphological grounds, particularly using archaeological samples. There is, however, a size differential between them; using biometrics, it is possible to determine with a fair degree of accuracy the kind or kinds of camelid represented.

In the case of the Machu Picchu sample, the camelids appear to have been mainly alpacas. Today, the alpaca is valued for its fine wool, as well as being prized as food. Alpacas are usually herded in the pasturelands above 14,000 feet above sea level so, at Machu Picchu, whose elevation is only 8,000 feet above sea level, alpacas are an exotic species brought from another, much higher ecozone. Some camelid remains are between modern alpacas and llamas in size. Miller believes these were a special variety of llama that may have been raised in Inca times and no longer exists in Peru. Based on his study of the skeletal elements represented in the Yale Peabody Collection, Miller concluded that the alpaca and llama remains represented were whole animals. Apparently, alpacas and small llamas were brought to Machu Picchu on the hoof to be slaughtered there and then prepared for funerary ceremonies. The sixty-six camelids identified among the Machu Picchu remains represent at least five tons of meat prepared during the funerary rituals of Machu Picchu's retainers.

Using the same skeletal remains, Miller was able to determine the age of the alpacas and llamas when they were slaughtered. This is of interest because young animals are more tender and less gamey than older animals, particularly when the latter have been herded year after year over vast distances. Of course, by slaughtering young animals, the Incas would lose the most productive years of wool production. This trade-off was appreciated early in Peruvian prehistory. In the Janabarriu Phase (400–200 BC) at Chavín de Huantar, for example, the elite consumed young camelids, while the less prosperous feasted on the tougher, older animals that were no longer suitable for other purposes (Miller and Burger 1995). At Machu Picchu, over a millennium later, none of the camelids recovered were under two years old, and 83 percent of them were over age three (Miller 2002). Thus, old alpacas and llamas appear to have been the meat offered as a final meal to dead retainers and their mourners at Machu Picchu. Perhaps these animals were herded for their wool and made available for slaughter and distribution to retainers only when their value as fiber producers had diminished. Alternatively, Miller suggests, a symbolic rationale could underlie the selection of older animals for sacrifice (a possibility discussed later in this chapter). It would be fascinating to analyze a sample of camelid bone from the daily refuse from the households or banqueting areas at Machu Picchu to see whether younger and more tender animals were being served. Such a study, unfortunately, must be left for the future.

The sixteenth-century Spanish accounts leave no doubt that hunting was one of the main activities the Inca royalty enjoyed while staying at their country palaces. The forested mountain slopes surrounding Machu Picchu would have provided an excellent setting for such activities, which has been confirmed by faunal analysis. Also, judging from the faunal remains, the royal retainers buried at Machu Picchu were allowed to consume some of the wild game that was bagged within the dense vegetation of the cloud forest (*ceja de selva*) below the royal palace. Among the bones Bingham's crew recovered is evidence of two types of deer (*Mazana americana* and *Pudu mephistopheles*). Both these species of deer are native to the cloud forest. It is significant that there is only an antler fragment of the white-tailed deer (*Odocoileus virginianus*) that are usually found at archaeological sites on the coast and highlands of Peru, and no examples of the *taruka* (*Hippocamelus antisensis*) that populate the high grasslands. Among the Machu Picchu remains are examples of the subtropical paca, or agouti (*Agouti paca*), which is a culinary delicacy of modern topical forest groups. In addition, the Inca retainers sometimes were able to capture the tasty rabbit-like viscachas (*Ligidium peruanum*), animals that still inhabit the rocky prominences surrounding the Machu Picchu ruins (Figure 6.5).



6.5 Viscacha at Machu Picchu, in 2001. Photo by George Miller.

These wild animals were complemented by the occasional opossum (*Didelphis albiventris*) and subtropical selva rodents, such as the *Abrocoma oblativa*, a distant relative of the chinchilla rat (Miller 2003). This evidence suggests a pattern of hunting in the lands immediately surrounding the royal palace.

The domesticated guinea pig (*Cavia porcellus*), or *cuy*, was valued as a delicacy by the Incas and their ancestors, probably because its meat and delicate taste offered a welcome break from the low-fat, high-carbohydrate diet that constituted the daily fare in the Andes. It is for this reason that the *cuy* remains a popular party food in the Peruvian highlands. At Machu Picchu, guinea pig teeth were found in two cave environments, thus confirming that its meat was consumed as part of funerary rituals. Given the small size of guinea pig bones, their vulnerability to the natural elements, and the absence of screening during the 1912 excavations, it is likely that cuyes, like viscachas, were underrepresented in the faunal sample recovered by the Yale Peruvian Expedition.

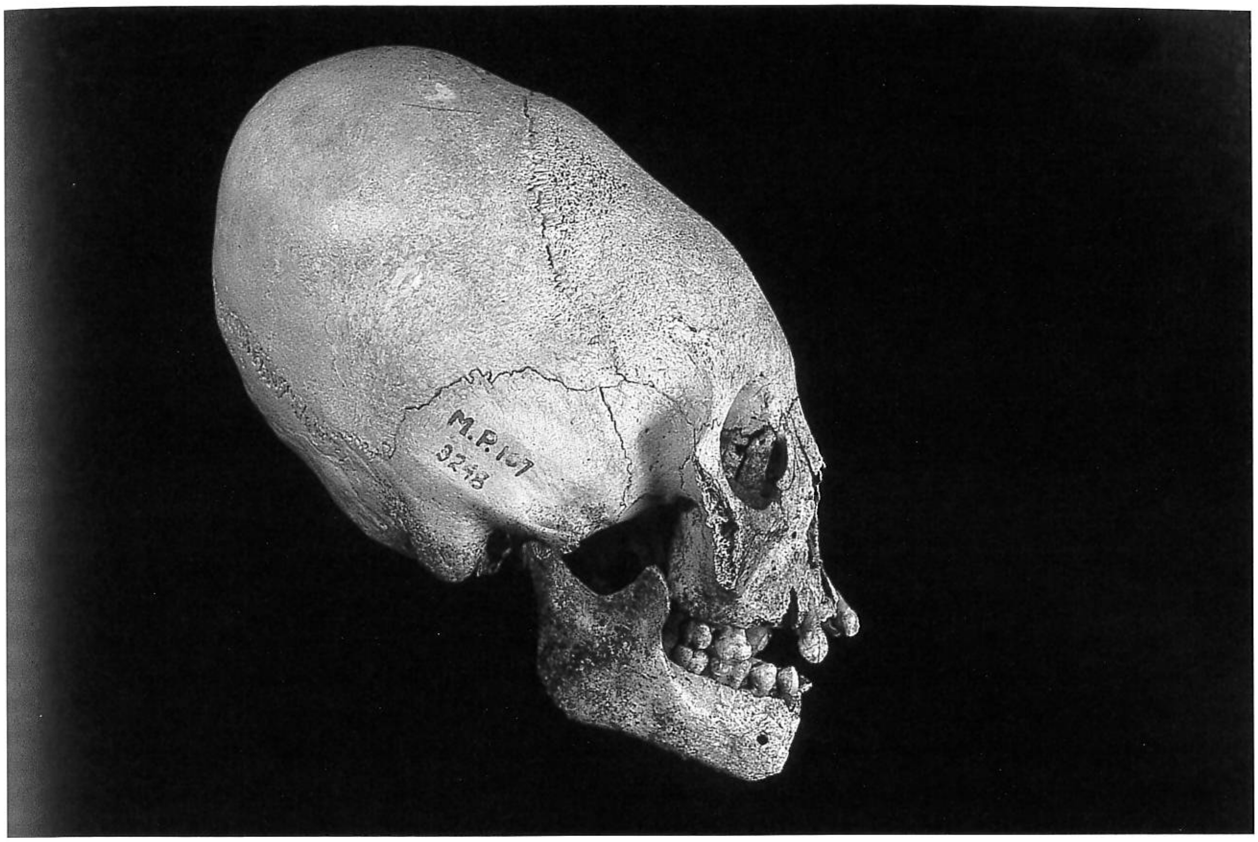
Some animals were probably kept at Machu Picchu as pets rather than as sources of food. The Spanish chroniclers indicate that tropical forest birds and monkeys were favorites of the Inca court. Although the archaeological evidence from Machu Picchu is silent on this, it offers an eloquent testament to the special relationship between the burial population at the site and their dogs. Six dogs were recovered from Machu Picchu's burials, and it is evident that these creatures served as companions to the dead, not as meals for the departed and their mourners. Miller (2003) reviewed the contexts in which dog remains were found; in all those instances where it is possible to determine the sex of the deceased, the tomb was always that of an older woman (Salazar 2001a). This conclusion, which draws upon excavation results, faunal analysis, and human osteology, illustrates the degree to which our understanding of Machu Picchu can be enriched by archaeology and laboratory analysis.

The Multi-Ethnic Character of Machu Picchu

Traditional characterizations of Machu Picchu have tended to focus on the Inca elite for whom the site was built and maintained. It is clear from the Spanish chronicles and the archaeological evidence that the Inca rulers drew upon their small ethnic group for imperial leadership. Consonant with this, the distinctive architecture of Machu Picchu embodies the cultural and social values of the ruling Inca ethnic group from the Cuzco Valley. Nevertheless, historic documents make it equally clear that retainers (*yanacona*) belonging to royal panacas were drawn from a wide range of ethnic groups that had been incorporated into Tahuantinsuyu by conquest or peaceful means. Because the great majority of the occupants of Pachacuti's royal estate at Machu Picchu were probably yanacona serving as support staff and craft specialists, it would be expected that the site population would have been a multiethnic mix reflecting the complex makeup of the empire, particularly those parts of it acquired by the military and political activities of Pachacuti (Chapter 3). On the basis of her analysis of grave goods, Lucy Salazar (1997a, 1997b) has argued that most of the individuals buried at the site came from areas outside of Cuzco. This conclusion, derived from a stylistic analysis of the ceramics that accompanied the dead, has received independent support from morphological and chemical research on the human osteological collections.

One of the most common ways of expressing ethnic identity in the prehispanic Andes was through cranial deformation. This was achieved through the binding of infants in cradle boards or with other devices while the skull was still relatively flexible. The result would have been visually conspicuous but would not have had an impact on the mental capacity of the individual. Such practices have a long history in the Andes and go back at least three millennia before the Inca (Burger 1992). Because cranial deformation was a function of culturally determined child-rearing practices, it is not surprising that specific kinds of cranial deformation were more common in some regions than others, and that a homogeneous population tended to favor a single kind of skull modification. In his 1916 monograph, Eaton identified the presence of different forms of cranial modification at Machu Picchu and plausibly attributed this to the mixed ethnic population in the burials.

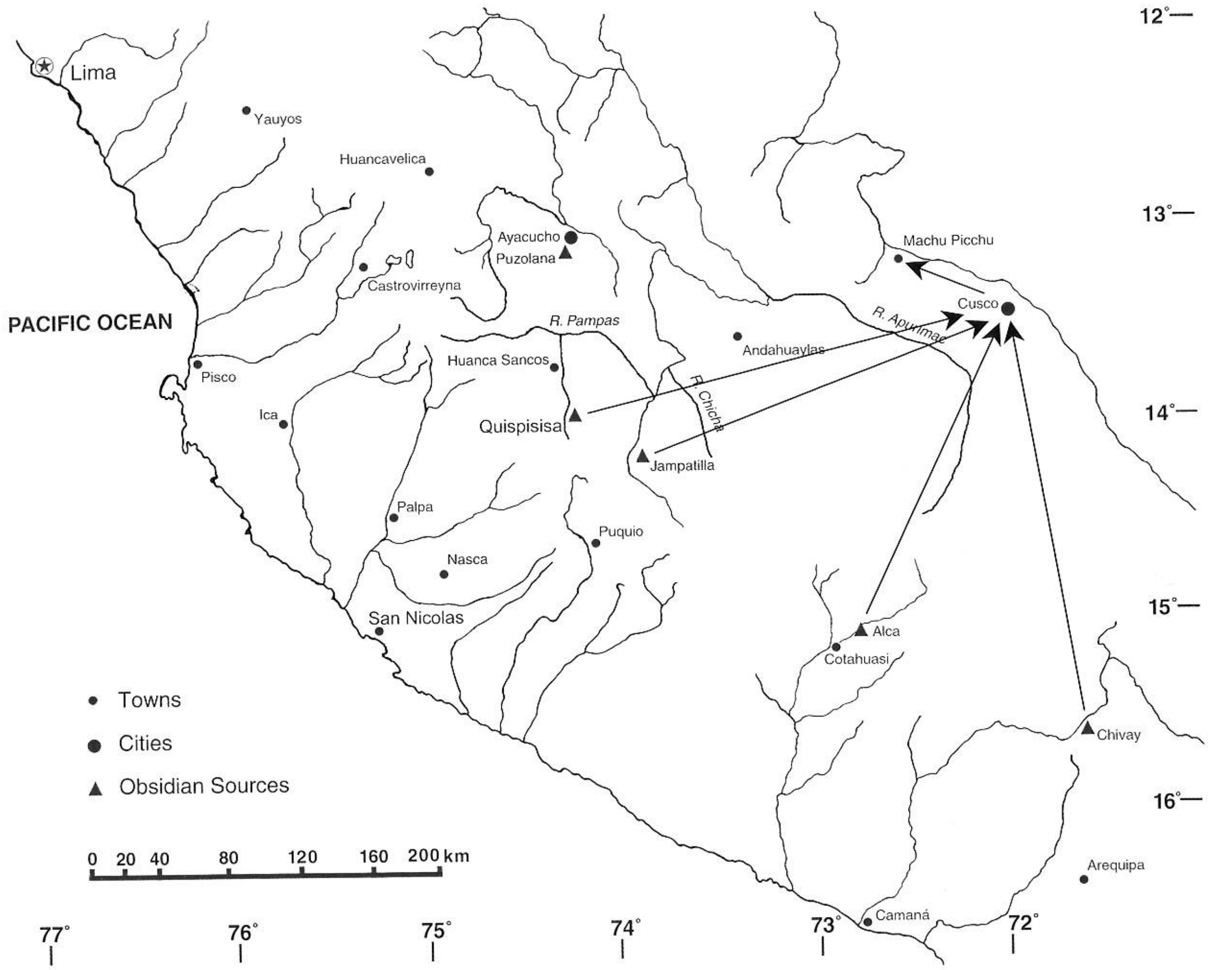
John Verano (2003) reexamined the presence of multiple types of cranial deformation at Machu Picchu by using more scientific procedures. He concluded that al-



6.6 Cranium from Machu Picchu illustrating annular deformation, which is associated with the highlands, especially the altiplano. Photo by John Verano.

though most skulls sufficiently intact for analysis were not deformed (55 percent), several types of cranial deformation were found (Figure 6.6). The most common type of deformation (23 percent) was annular or circumferential, a type of skull shaping linked to the wrapping of the head with cloth bands during infancy. This kind of deformation was imposed more commonly in the highlands than the coast, and it was particularly popular in the altiplano area of Lake Titicaca. The second kind of deformation, known as occipital flattening, occurs in some 22 percent of the samples. It is linked to the use of cradle boards and was associated with the ethnic groups from the central and north coast of Peru. Another analysis by Verano focusing on a statistical analysis of the facial portions of crania reveals that roughly half the Machu Picchu skulls can be classified as coastal. Many of these are similar to samples from the Jequetepeque Valley on Peru's northern coast, but others more closely resemble samples from Peru's central coast. Based on these two independent lines of evidence, Verano concluded that the burial population at Machu Picchu was ethnically heterogeneous.

A third line of evidence on population diversity is provided by an analysis of the bone chemistry of the Machu Picchu burials (Burger, Lee-Thorp, and Van der Merwe 2003). As already noted, the isotopic composition of collagen in human bones directly reflects diet, and archaeological studies have demonstrated that small villages show little variability in their bone chemistry, owing to their shared foodways. Because the isotopic composition of bones reflects the average diet of individuals over many years, it follows that if the individuals buried at Machu Picchu had been drawn from different ecological habitats, geographic regions, and cultural traditions



6.7 Location of sources of obsidian used at Machu Picchu. Drawing by Rosemary Volpe and Kim Zolvik.

there would be a significant degree of isotopic variability, and if it had been drawn from a single background (e.g., Incas from Cuzco), there would be relatively little variability. Two isotopes (C^{13} and N^{15}) analyzed for fifty-nine individuals suggest a highly diverse population. The $\delta^{13}C$ results range from −18.8 to −9.61 per mil, while the $\delta^{15}N$ results range from 6.05 to 12.79 per mil. When the $\delta^{13}C$ is plotted against $\delta^{15}N$, the values are not tightly clustered as one would expect for a homogeneous cultural group, which suggests dietary heterogeneity. This variability probably reflects differences in the dependence on maize as a staple and in the consumption of marine foods by those individuals coming from the coast.

In summary, judging from new osteological and chemical analyses, the population at Machu Picchu was a diverse one. At least in this respect, Machu Picchu had more in common with heterogeneous urban centers than with the small homogeneous villages of the Peruvian highlands chronicled by anthropologists. This conclusion reinforces the importance of considering Machu Picchu within the larger context of Tahuantinsuyu. Although some features of Machu Picchu can be understood in terms of local ecology and the mineral and other resources that attracted the Incas to the lower Urubamba, most features of the site relate to a much larger frame of reference.

Just as servants, metalworkers, masons, and other retainers were brought from the length and breadth of Tahuantinsuyu, so too were items utilized there. As discussed in the following section, sheets of pure tin were imported from the southern highlands of Bolivia to Machu Picchu for the creation of tin bronze objects. Likewise, a significant portion of the pottery, particularly that recovered in the tombs, also seems to have come from distant provinces (Salazar 2001b). In the latter case, a preliminary study using instrumental neutron activation has been carried out at the University of Missouri Research Reactor to determine the difference between locally produced and exotic ceramics based on the chemistry of their clay minerals. This study, while suggestive, has not yet yielded conclusive results because of the chemical variability of clays and the numerous clay deposits that were exploited in prehispanic times.

Success has been achieved, however, in a study of the obsidian artifacts that Bingham recovered in the center of Machu Picchu. Altogether, seven cutting tools made of obsidian glass were encountered by the 1912 expedition, but the lack of recent volcanic deposits around Machu Picchu left the origin of the raw material for these tools a mystery. Fortunately, obsidian deposits are extremely rare in the Central Andes, and recent laboratory research suggests that fewer than ten of them were intensively exploited in prehispanic times (Burger and Asaro 1979; Burger, Chavez, and Chavez 2000). Fieldworkers have successfully located most of these, and the sources of the three most important quarry areas have been documented (Figure 6.7).

In 2002, all seven obsidian tools from Machu Picchu were analyzed at the University of Missouri Research Reactor in collaboration with Mike Glascock, a specialist in the application of geochemistry to archaeology. A nondestructive x-ray fluorescence technique was utilized to study the trace element composition of the artifacts, all of which were visually similar. As expected, the majority of these (71 percent) proved to be made of obsidian from the Alca source located in the Cotahuasi Valley of central Arequipa. This massive deposit, which covers over 19 square miles, is found in the deepest canyon in the world at roughly 2 miles above sea level (Burger et al. 1998a, Justin Jennings, personal communication, 2002). It is located 140 miles southwest of Cuzco and, if procurement was direct, it would have taken about two weeks for it to have been transported over rugged terrain from the geological source to Machu Picchu. It is more likely that the obsidian tools were simply brought to the royal palace by the residents and visitors as part of their personal effects. Significantly, most people living in the Cuzco Valley depended on obsidian from the Alca source.

Much to our surprise, two of the tools did not come from the Alca source: one appears to come from the Quispisisa source and the other came from the Jampatilla source. Both these sources are located over 155 miles to the west of Machu Picchu in an area that now falls within the Department of Ayacucho. Throughout most of prehistory, the obsidian from these sources was not utilized by the residents of the Cuzco region. The Quispisisa source was the most important source for those living in what is now central and northern Peru (Burger and Glascock 2000), while the Jampatilla source was primarily of local importance for what is now southern Ayacucho and Apurimac (Burger et al. 1998c). In a comprehensive synthesis of obsidian procurement in Cuzco, the anomalous presence of Quispisisa obsidian and the single previously documented example of Jampatilla obsidian were shown to be correlated with the expansion of the Huari empire (Burger, Chavez, and Chavez 2000: 324–343). This probably resulted from the increased movement of individuals from more western areas into Cuzco for reasons of imperial administration and economy. A similar explanation can be offered to explain the presence of Quispisisa and Jampatilla obsidian at Machu Picchu, although, in this case, it would apply to the Inca rather than the Huari imperial expansion seven centuries earlier. The obsidian sourcing results suggest that visitors from other parts of the empire, particularly the central highlands of Peru, were present at Machu Picchu. An alternative hypothesis — that obsidian was being pooled through imperial taxation with the resulting admixture being redistributed to properties of the Inca state or its leaders — seems less likely, given the absence of clear documentary or archaeological evidence that the Inca state was intimately involved in the production or distribution of volcanic glass.

Craft Activity and Technological Innovation at Machu Picchu

During the dry season, daily life at Machu Picchu probably focused on the royal family and their needs. The public architecture that dominates the archaeological site continues to provide evidence of the public and private aspects of the activities required to maintain and entertain these individuals (see Chapter 3). While the nonelite residents of Machu Picchu who made up the majority of the site's occupants were primarily a support population for the elite, they also engaged in other productive activities. These mundane tasks were reflected in the artifacts recovered at Machu Picchu, and they received relatively little attention from Bingham. One can speculate that such activities may have increased in intensity during those months when the country palace was not being visited by the royal family. Among these secondary activities were textile production, as attested to by the presence of spindle whorls for spinning and bone tools for weaving (known as *wichuñas* in Quechua), and the production of stone objects, as documented by unfinished small stone carvings of locally available schist.

Metallurgy appears to have been especially important at Machu Picchu. The site is well situated for this activity because abundant fuel would have been available and its exposed setting would have favored the utilization of draft furnaces and other techniques harnessing natural wind. Some of the best evidence for the presence of metalworking at Machu Picchu comes from laboratory analyses carried out on the collections recovered by the 1912 Yale Peruvian Expedition. Of the approximately 170 metal artifacts recovered during the Machu Picchu excavations, 15 have been identified as metal stock, works in progress, and waste materials left over from metalworking. A detailed study of these pieces by Robert Gordon, a Yale professor specializing in the history of metallurgy, and his student John Rutledge has shed new light on the kinds of metalworking activities that were going on at Pachacuti's royal estate. Most were related to the creation of objects made from tin bronze, an alloy of copper linked with the Inca state.

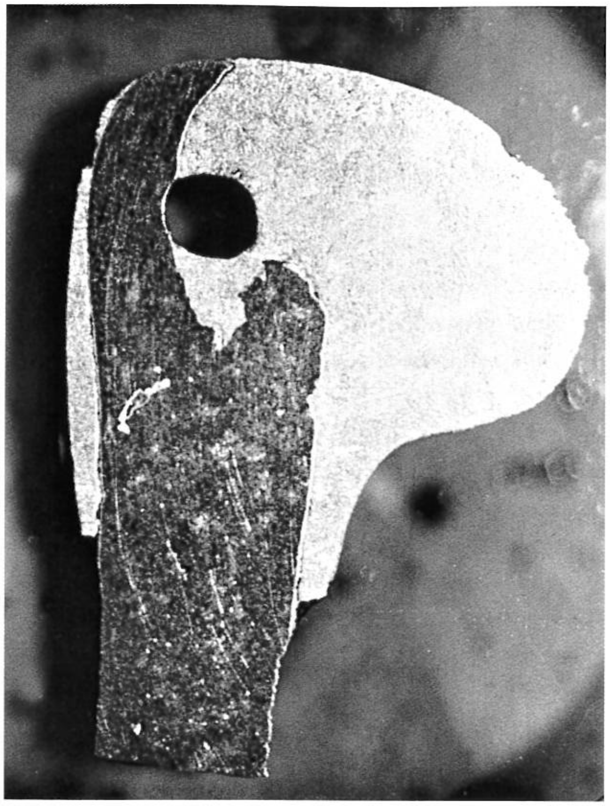
Tin is a rare metal in the Central Andes, and its closest source is the cassiterite deposits in the northern Bolivian highlands, hundreds of miles to the south of Machu Picchu. Although tin bronze was being produced south of Lake Titicaca by the end of the Middle Horizon (approximately 900 AD), it was not until the southern expansion of the Tahuantinsuyu in the fifteenth century AD that tin became available to Peruvian metallurgists and tin bronze finally appeared in the Cuzco region (Lechtman 1997). Tin bronze was disseminated throughout the Central Andes by Inca expansion, and tin bronze replaced or complemented the arsenic bronze alloys that had been produced in earlier times. It is likely that the Inca state controlled the production of tin and, by extension, that it dominated the production of tin bronze artifacts. Thus, the tin bronze objects that were created not only represented especially hard and durable products, but also symbolized the power of the Inca rulers in their composition. This link between the tin bronze objects and the Inca state was likewise reflected in their distinctive form, which drew from a limited array of shapes found throughout much of Tahuantinsuyu (Owen 1986).

The process of tin bronze production at Machu Picchu can be partially reconstructed on the basis of the metallurgical by-products studied by Rutledge and Gordon (1987). Judging from the fragments of pure tin and nearly pure copper sheet metal, the component metals for the bronze alloy were brought to Machu Picchu in almost pure form after initial processing closer to the geological deposits. Because no finished Inca objects of pure tin are known, it is reasonable to assume that tin from the irregular sheets found at Machu Picchu was designed to be mixed with copper. A close examination of the tin sheets reveals evidence that the tin was chipped away using metal chisels. At Machu Picchu, the bronze objects have a tin content of about 6.7 percent, a mixture that rarely varies more than a few percent. Several examples of tin and tin bronze "spills" confirm the assumption that bronze was actually being cast at Machu Picchu. One piece of metal recovered at the site was the result of molten tin being poured onto straw or some other organic surface, while two other pieces were the product of a tin bronze mix being spilled or poured onto a rock surface. Perhaps these "spills" were residuals that exceeded immediate needs or the volume of the crucible being utilized.

A subsequent stage of bronze production is attested to by fragments of work in process. Several bars of cast tin bronze have been forged by annealing and hammering but were never transformed into a finished tool or ornament. Another particularly memorable work in process is a partially completed tweezers whose blade has yet to be shaped. An analysis of its composition indicates an unusually high percentage of tin (9.7 percent), and Gordon suggests that this elevation in tin composition may have been intentional in order to ensure the hardness of the tweezer blades and the retention of spring action. In summary, there can be little doubt that tin bronze was being cast as stock and transformed into tools and decorative objects at Machu Picchu (Rutledge and Gordon 1987: 593).

Other artifacts found in 1912 at Machu Picchu indicate that artifacts of a silver copper alloy were also being produced. While these objects had a silver content of roughly only 14 percent, the surface enrichment process resulted in the even silver coloration of objects, such as the finger ring of hammered "silver" excavated at Machu Picchu. Heather Lechtman (1997) has argued that Inca metallurgy consisted basically of three components: copper, silver, and gold. As indicated by Gordon's recent studies, at least two of these were being manufactured at Machu Picchu.

Gordon's analysis of the Machu Picchu metal artifacts suggested much more than the existence of basic metalworking at the site. It provided new evidence for the innovative character of Inca metal technology, while at the same time indicating some of its limitations. The Incas, like many prehispanic cultures in the Americas, are frequently portrayed as technologically conservative. Of course, the rapid expansion of tin bronze throughout Tahuantinsuyu flies in the face of such a characterization. At Machu Picchu, a vivid example of metallurgical innovation, or, perhaps more accurately, experimentation, emerged from an analysis of a bronze ritual knife (*tumi*) with a llama head that Bingham recovered in cave burial 54 at Machu Picchu (Gordon and Rutledge 1984) (Figure 6.8). In his initial examination, Mathewson (1915) concluded that the *tumi*'s elaborate and distinctively colored handle had been cast onto the blade's stem from a high tin bronze alloy. Gordon's more recent study of the artifact showed that besides tin (9 percent), the metalworker had added an unprecedented quantity of bismuth (18 percent) to the mix. This is the first known use by the Incas of bismuth as an alloying element of bronze. After considering the alternatives, Gordon concluded that its inclusion was intentional. The advantages of a bismuth-rich tin bronze would have been to make a casting that adhered more effectively to the stem, and to produce a distinctively whiter color of bronze. Although this addition was a success in the case of the llama-handled *tumi*, the practice does not seem to have been extended to other objects at the site and may never have been adopted outside of Machu Picchu.



6.8 Analysis of this llama-headed ritual knife (*tumi*) from Machu Picchu yielded evidence of the addition of bismuth to the tin bronze alloy of the modeled handle, perhaps as a metallurgical experiment in casting technology. Photo by Robert Gordon.

Another kind of innovation suggested by the technical studies concerns the use of metal for tools at Machu Picchu. As Lechtman (1980) has observed, metals in the Central Andes were generally employed for ideological rather than mechanical ends. Consistent with this, it is widely accepted that the considerable engineering accomplishments of Inca builders were achieved with stone tools despite their knowledge of tin bronze and arsenic bronze. This was almost certainly true at Machu Picchu judging from the abundant stone cobbles with evidence of battering found in many portions of the site (Bingham 1930). Nevertheless, the presence of large bronze crowbars suggests that these metal tools may have been displacing wooden levers in late Inca times. When Gordon (1985) examined the surface marking and microstructural damage on the bronze crowbars and other tools from Machu Picchu, he concluded that masons had used some of them in producing the site's stonework. In his opinion, the kinds of postproduction stress and damage observable in these artifacts would have resulted only from working hard materials such as stone. This finding suggests that the Incas may have been in the process of moving away from a neolithic building technology at the time of the Spanish Conquest, and that their technology was far from static.

At the same time, Gordon observed that many of the newly identified metal masonry tools showed brittle fractures and other flaws resulting from sulphide inclusions and excessive porosity. The technical limitations of these tools contrast with the remarkable sophistication that characterizes other products of Inca metallurgy. If the fabrication of metal tools for masonry and other construction activities was a late innovation, it is possible that the Inca metalworkers still lacked the experience necessary to fine-tune the earlier metallurgical techniques that were appropriate for the production of jewelry or ritual objects but were not adequate for producing tools used in heavy-duty building activities. It is likely that with time, the Incas would have modified their alloys and casting processes to produce metals that were well suited for working stone and other hard materials.

Inca Science and the Construction of Machu Picchu

The remarkable beauty of Machu Picchu and the mystery concerning the reason for its creation and abandonment have overshadowed the investigation of basic questions concerning its construction and the technological knowledge underpinning its successful completion and maintenance. Such issues were touched upon by the 1912 Yale Peruvian Expedition, but only recently have scholars in the field begun to focus on issues such as the nature of Machu Picchu's hydraulic system, the character of the terracing along Machu Picchu's slopes, and the way in which the natural terrain at Machu Picchu was modified in order to support the construction of the royal palace complex. Drawing upon contemporary knowledge of engineering, Alfredo Valencia Zegarra and Kenneth Wright have pioneered technical studies of Inca engineering at Machu Picchu (Wright and Valencia Zegarra 2000). Their findings are so intriguing that a brief review of some of their conclusions is warranted in this overview of recent scientific advances in the understanding of Machu Picchu.

The picture that emerges from a study of Machu Picchu's hydraulic system is particularly compelling. Geological studies indicate that two principal faults, known as the Machu Picchu fault and the Huayna Picchu fault, transect the site; the saddle-like piece of flat land upon which the main Inca constructions were built is actually a block or graben wedged between the faults. The faults and the associated rock fractures increase the ability of precipitation to infiltrate this landscape, and this collected water in the subsoil becomes available at a spring located on the steep north slope above Machu Picchu (Wright, Witt, and Valencia Zegarra 1997b).

In Inca times, water from this perennial spring was carried 2,457 feet to Pachacuti's royal palace complex by way of a stone-lined canal. This water is remarkably pure, and its flow varies seasonally from 6 to 33 gallons per minute. The natural spring is a mere 60 feet above the central ridge-top settlement, so the creation of a gravity canal with the appropriate gradient to carry water required considerable skill and knowledge. The route and slope of the canal had to be determined before the design of Machu Picchu itself in order to ensure the availability of water to the elite and their retainers, and to avoid conflict between the canal's path and the elaborate architecture within the complex. Along most of the route, the grade of the Inca canal varies from 2.5–4.8 percent, but on the terraces adjacent to the center it is reduced to only 1 percent. To support the stone-lined canal and to maintain the appropriate gradient, a stone terrace 6–18 feet high was built. The well-fitted stone

6.9 Main canal carrying water from the natural spring to the palace complex at Machu Picchu. Photo by Richard L. Burger.

lining of Machu Picchu's canal would have minimized seepage and reduced maintenance requirements (Figure 6.9).

Once inside the palace complex, the canal fed a series of sixteen fountains, each of which was equipped with a sharp-edged fountain spout. These cut stone spouts created a jet of water that fell into each of the carved stone basins below. Such an arrangement would have been optimal for collecting water in ceramic jars. The water carried by the Machu Picchu canal system would have been adequate to meet the basic hydraulic needs of Machu Picchu's residents even during peak season (Wright, Kelly, and Valencia Zegarra 1997a; Wright and Valencia Zegarra 2000; Wright, Witt, and Valencia Zegarra 1997b). Nevertheless, the construction of an additional branch canal was under way at the time of the site's abandonment. Valencia Zegarra and Wright's recent research indicates that the Machu Picchu canal was built to meet the needs of the palace inhabitants and not to irrigate crops on the terraces adjacent to the site.

The terracing system at Machu Picchu, like the canal system, reflects considerable engineering know-how and was designed to support cultivation using the natural rainfall at Machu Picchu. Evidence from the Quelccaya ice cap (Thompson et al. 1986) suggests that rainfall early in the history of Machu Picchu (AD 1450–1500) may have averaged 72 inches, while during the site's later history (post-AD 1500), precipitation increased to 82 inches, which is slightly above the current level (Wright and Valencia Zegarra 2000: 50–51). Such levels of rainfall were more than sufficient to support the cultivation of maize and other crops (see Chapter 5).

Excavations of the Machu Picchu terraces show that they were carefully built with layers of different materials to ensure adequate drainage and soil fertility (Wright, Kelly, and Valencia Zegarra et al. 1997a). The constructed terraces typically began with a layer of large stones covered by a layer of medium gravel. Above this, the builders placed a layer of fine sand mixed with gravel. This was topped by a thick layer of topsoil probably brought from the valley floor and placed by hand behind the stone retaining wall on the top of the terraces. Basically, the Inca agricultural terracing system surrounding Machu Picchu constitutes a series of flat surfaces designed to create a human-made environment optimally suited to agricultural cultivation in this moist cloud forest environment. The stone retaining walls that supported the terraces commonly leaned inward by approximately 5 percent, thereby reinforcing the stability of these features. The fact that they have survived over five hundred years in this difficult terrain and climate is ample testament to the success of the engineering principles employed.

One final set of insights into the construction of Machu Picchu by Wright and Valencia Zegarra (2000: 36–46, 59–62) merits consideration. Improved geological understanding of the site indicates that the ridge-top encountered by the Inca at Machu Picchu would have

6.10 Gold bracelet, discovered at Machu Picchu in 1995 by archaeologist Elba Torres, buried deep within the construction fill of Machu Picchu's plaza. Photo by Kenneth R. Wright.

been an irregular surface, quite different from the flat, mesa-like configuration currently observed. If this were the case, much work would have been required to transform Machu Picchu into a landform that could sustain the elaborate architecture that fills the site's urban core. When excavators from the Instituto Nacional de Cultura penetrated the surface below one of Machu Picchu's plazas, they encountered a 3-foot layer of loose rock and stone chips. This unconsolidated fill was stabilized using construction walls unseen from the ground surface. In total, the excavations extended some 8 feet below the surface without reaching bedrock. This research suggests a massive investment in reshaping the site surface and providing it with drainage infrastructure. Wright estimates that this invisible subsurface construction constitutes roughly 60 percent of the effort invested in building Machu Picchu.

One unexpected discovery at this excavation of construction fill was made by Peruvian archaeologist Elba Torres. She found a gold bracelet that had been left as an offering before the placement of the thick stone fill layer (Wright and Valencia Zegarra 2000: 43). This bracelet, the only known example of a gold object from Machu Picchu, was taken to the Cusco Regional Museum for display (Figure 6.10). More important than the gold object is the new evidence on the massive and comprehensive modification of the ridge at Machu Picchu, which helps us understand why the site has remained intact for so long, resisting innumerable seasons of heavy rain, earthquakes, and other forces that could have led to the site's collapse and destruction. The sound subsurface foundations created by the Inca builders provided a level and well-drained surface that has successfully supported the heavy granite architecture and, more recently, accommodated the not inconsiderable flow of tourists (see Chapter 7).

Scientific Insights into Ritual Life at Machu Picchu

As illustrated in the foregoing sections, modern science has permitted many insights into the everyday world of Machu Picchu and its residents. It has also begun to provide us with a window on the less accessible, but equally important, realm of cosmology and religious rituals that was so central to life at Machu Picchu. Here we focus on three examples of recent advances in this area.

During Bingham's 1912 excavations, he encountered an anomalous cache of more than thirty obsidian pebbles near the main gateway into Machu Picchu. The origin and meaning of these small subangular objects was puzzling because of the absence of recent volcanic activity in the area and the uniqueness of the find. In an effort to make sense of the pebbles, Bingham (1930: 200) mentions the suggestion of a colleague at the Sheffield Scientific School that their source might be extraterrestrial, possibly the result of a meteorite shower. Fortunately, as already noted, much progress has been made over the past three decades in the chemical characterization of obsidian using such techniques as instrumental neutron activation and x-ray fluorescence. These procedures can be used to precisely characterize the trace element composition of obsidian artifacts like the Machu Picchu pebbles, and this data, in turn, can be employed to link the artifacts with the unique composition of the obsidian source from which they were obtained.

Research on the obsidian pebbles from Machu Picchu was initiated at the Lawrence Berkeley Laboratory and continued more recently at the University of Missouri Research Reactor. To date, four obsidian pebbles from the Gateway cache have been analyzed using x-ray fluorescence, and in all instances they have proved to come from the Chivay obsidian source in Arequipa's Colca Valley (Burger, Chavez, and Chavez 2000: 347; Glascock and Burger, unpublished data). This result was surprising because the Alca obsidian source is closer and more convenient to Cuzco populations and, by extension, to the residents of Machu Picchu. As already mentioned, none of the obsidian utilized in the making of tools used at Machu Picchu had been derived from the Chivay obsidian source.

Why, then, had the dozens of obsidian pebbles been carried some 250 miles to Machu Picchu from the high-altitude obsidian flow near the modern town of Chivay? In order to answer this question, it is important to recall that the obsidian pebbles from Machu Picchu are unmodified and show no evidence of having been used as tools. In fact, measuring less than an inch in diameter, the pebbles are too small to serve as raw material for cutting tools. Their placement together near a crucial location at the site, the main Gateway, further indicates that they were a ritual cache or offering. Such ceremonial offerings of precious or symbolically charged materials at special spots were common in Inca times and continue to be made in traditional highland communities.

But why would small obsidian pebbles have been selected, and why was volcanic glass from the Chivay source selected for the offering? A closer look at the pebbles and their source is necessary to begin considering this issue. Jay Ague, a geologist at Yale specializing in petrology, examined the pebbles and concluded that judging from their rounded facets, these small pieces of obsidian had been shaped by the eroding forces of water. Given the local geology, the obsidian pebbles had probably been collected from the banks of the Colca River at roughly 12,500 feet above sea level near the foot of the volcanic deposit in which the primary obsidian deposits are located, at over 15,700 feet above sea level. Because volcanic glass is brittle, it is quickly ground to dust by intense river action and, consequently, obsidian appears in the riverbed only immediately adjacent to the Chivay source (Burger et al. 1998b). Because only a short hike from the river (less than an hour) would have been required to procure large obsidian blocks over 1 foot on a side, it is reasonable to conclude that the selection of the small water-worn obsidian pebbles was intentional. Given this background, the simple explanation that the obsidian pebble cache was left by visitors from the Colca Canyon or some nearby area who journeyed to Machu Picchu and placed an offering of precious items from their region as they entered into the royal palace complex (Burger, Chavez, and Chavez 2000: 347) seems, at best, a partial answer to the question posed (Figure 6.11).

It is likely that a set of symbolic meanings lay behind the obsidian cache — meanings related to the special character of pebbles and the Chivay area itself. The Colca Canyon in general, and the Chivay area specifically, is one of the most actively volcanic zones in the Central Andes. In recent times, ash and smoke have risen from Mt. Sabancaya, a peak near Chivay. The Incas, like many of their highland ancestors, worshipped high mountains and considered them to be the source of supernatural forces (*apus*) and, consequently, they made offerings on or near important mountain peaks, including those near Chivay. In a related belief, the Incas viewed mountain peaks as sources of water and fertility (Reinhard 1985). Thus, it is possible that the obsidian pebbles left at Machu Picchu drew their multivalent symbolic force from their natural associations in the Colca Valley with high mountain peaks, the power of the underworld as manifested by active volcanoes, and the rushing water of the powerful river that shaped this group of unusual translucent stones.

A second example of the way in which scientific analysis may provide unexpected insights into ceremonial behavior is instructive because it illustrates how unexpected laboratory results may draw attention to previously ignored passages in the works of Spanish chroniclers, such as Bernabé Cobo, in order to make sense of the newly available findings. As mentioned earlier in this chapter, the faunal analysis of zooarchaeologist George Miller revealed that the most common animal offerings in the Machu Picchu graves were of elderly alpacas, almost always more than four years of age. This anomalous finding led Miller (2003) to return to the historical records, where he encountered references to Inca herds consisting exclusively of old or retired camelids (Cobo 1964). These animals were known as *aporucos*. He also found that these special animals, usually male, were required as offerings on particular ceremonial occasions. We do not know whether the symbolic links of aporucos to breeding, maleness, maturity, or some combination of these and other qualities led them to be considered desirable offerings at the graveside ceremonies at Machu Picchu, but their inclusion may have been result of Inca religious belief rather than simple socioeconomic considerations.

The third and final illustration of the way in which modern science has offered powerful new perspectives on ritual behavior shifts attention away from the laboratory to the new field research that has occurred since Bingham's time. It has long been known that the role of celestial observation was central to the ceremonial cycles and belief systems of the Incas and other cultures of the prehispanic world. Several of the architectural features, such as the Intihuatana (Hitching Post of the Sun) and Torreón (Temple of the Sun), were interpreted by Bingham and others as linked to the worship of the sun and its observation. There was, however, little consensus on exactly what was being observed by the Incas and what techniques were being employed to achieve these ends. In many early studies of archaeoastronomy, sweeping claims were made using Western notions of the sky and how it should be studied. These hypotheses, often untested or impossible to test, led to skepticism among many scholars about astronomical interpretations. Fortunately, recent research by ethnographers, archaeologists, and astronomers has made for a much clearer and more rigorous understanding of what astronomical patterns were being observed and how the Incas went about making those observations (Aveni 1981; Bauer and Dearborn 1995). From the perspective of archaeological practice, the introduction of powerful computing tools and more sophisticated surveying devices made it possible to assess the significance of the orientation of buildings or other features thought to be involved in Inca astronomical activities. As part of this intellectual renewal in archaeoastronomy, a field collaboration was initiated at Machu Picchu between astronomer Raymond White, astrophysicist David Dearborn, and archaeologist Katharina Schreiber. Their research during the 1980s demonstrated that the Incas at Machu Picchu made observations of the June and December solstices and other celestial phenomena (Dearborn and Schreiber 1986: 17) (see Chapter 3). In their work, a high degree of agreement was necessary between the observed orientations of observation points and the position where computer simulations determined the phenomenon in question should have occurred.

According to the Spanish chronicles, both the June and December solstices were major observances in the religious calendar of the Inca royalty. The June celebration, known as Inti Raymi, was a cause for pilgrimages to

6.11 Volcanic formations in the Chivay area of the Colca Valley along the western Andean slopes of Arequipa. River pebbles from the foot of this deposit were left as an offering near the Main Gateway at Machu Picchu. Photo by Richard L. Burger.

Cuzco and was celebrated throughout the empire. In fact, it continues to be widely celebrated today at archaeological sites in the Cuzco heartland (see Chapter 7). The December celebration, known as Capac Raymi, was of special importance to the Inca elite, marked by a feast that culminated on the day of the solstice with the initiation of noble boys into adulthood by piercing their ears, thus allowing them to wear ornamental ear spools that were the visual markers of the Inca elite (*orejones*). The findings at Machu Picchu are significant not only because they give us a clearer idea of how and where celestial observations were being made, subjects that are ambiguously alluded to in the historical documents, but also because they imply the presence of astronomically informed specialists among the populace at Machu Picchu. Also, the existence of observatories for both the

June and December solstices suggests that observations and associated rituals were being carried out at Machu Picchu throughout the year, including the rainy season when royal visits would have been unlikely.

The application of scientific techniques to better understand the archaeology of Machu Picchu is still in its infancy. Nevertheless, it has already yielded many exciting results. Each new finding raises additional questions that serve to stimulate research in the laboratory and in the field. These, in turn, force investigators to return to the ambiguous and often incomplete historical records with a new perspective and allow these materials to be used in a more critical and productive manner. The interplay between these multiple lines of evidence along with expertise drawn from many disciplines builds upon the seminal efforts of the 1912 Yale Peruvian Expedition and its groundbreaking interdisciplinary research.

While much of the mystery of Machu Picchu has been dispelled by recent breakthroughs, much remains to be learned. The work reported here represents the beginning of a long process of scientific rediscovery rather than its conclusion. One can only begin to imagine what new advances will be achieved in the next ninety years given the rapid pace of scientific developments and their incorporation into archaeological practice.